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PARASITES OF SOME FREE-LIVING WILD ANIMALS AND FRESHWATER FISH SPECIES IN SOUTH AFRICA

by

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Submitted in fulfilment of the requirements for the degree of

DOCTOR OF VETERINARY SCIENCE

in the

DEPARTMENT OF VETERINARY TROPICAL DISEASES

FACULTY OF VETERINARY SCIENCE

UNIVERSITY OF PRETORIA

PRETORIA

2009

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J.D.F. Boomker
2009-05-28

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ACKNOWLEDGEMENTS

This research would not have been possible without the generous financial assistance of the National Research Foundation (NRF), who sponsored me during the early years, 1978 to 1995. The NRF also provided the funding for my stay in Paris, France during 1992.

The University of Pretoria and the Medical University of Southern Africa, now the Medunsa campus of the University of Limpopo, provided the necessary infrastructure and afforded me time to travel to the various nature reserves to collect the parasites.

I am indebted to the then South African National Parks, now known as SAN Parks, for placing the various hosts at my disposal, especially in the Kruger National Park (KNP). I am also most grateful for use of their facilities and their staff, who assisted me in any way they could. Mr. Johan Sithole and his men are thanked, especially the late Elvis, who scraped the mucosa off so many sets of intestines that he referred to himself as Dr. Ntambu, 'the doctor of the rope'. Messrs Cleve Cheney and the late Ben de Klerk are thanked for their hard work and for finding kudu when there were no kudu to be found. I spent many happy hours with Profs. Ivan Horak and Nick Kriek, and Drs. Dewald Keet and Roy Bengis collecting specimens from all over the KNP. To them my thanks for all the lessons taught and advice given. Dr. Valerius de Vos of the KNP went out of his way to assist me, firstly with the fish parasites and later with the wildlife parasites. Mr. Andre Potgieter always made sure that we had accommodation in the KNP and other nature reserves under the control of SAN Parks.

In the then Natal Parks Board parks, now known as Ezemvelo KZN Wildlife, Drr. Michael Keep and Jacques Flamand we always there to help where they could. To them and their staff I extend sincere thanks, not only for their assistance with collecting the parasites, but also for teaching me the basics of the Zulu language.

Finally but definitely not least, my thanks go to all the friends, family and numerous co-workers that made this research possible, especially Prof. Ivan Horak, Dr. Valerius de Vos, Dr. Kerstin Junker and the French researchers, Drr. Odile Bain, Marie-Claude Durette-Desset and Alain Chabaud.

It was also not possible to have collected all the helminths from the various animals myself, and I thank my technologists over the years, Mesdames Shirley Kingsley, Dalene Vermaak and Geraldine Smit, and Messers Nico Jonker, Dirk Booyse and Ryno Watermeyer, for their assistance that made these publications possible. They are co-authors on several of the papers that they have assisted with.

SUMMARY

This collection of papers comprises four sections. The first section deals with the helminth and arthropod parasites recovered from a variety of mammalian hosts, and consists of four chapters. The first chapter deals with the taxonomy of the parasites of mammalian hosts, where some 15 nematode species were either newly described, redescribed or descriptions amended, and the immature stages of an oestrid fly and the adults of two hippoboscid flies described. The second describes the seasonal occurrence of arthropod and helminth parasites recovered from approximately 1 380 antelope, scrub hares, warthogs and bushpigs. In the third chapter some miscellaneous natural and experimental findings of helminths in free-living hosts are presented, amongst others several new host-parasite associations and the proceedings of symposia, while the fourth chapter deals with the pathology of natural infections of impalas with *Cooperiodes hepaticae*, kudus with *Elaeophora sagitta* and buffaloes with *Parafilaria bassoni*.

The second section deals with the parasites of freshwater fishes. In the taxonomic part of this section, Chapter 1, one trematode genus is redescribed, and one new trematode species and 14 new nematode species described. In the second chapter, the seasonal occurrence of the helminth parasites of approximately 700 freshwater fish representing 14 species is presented.

The third part deals with the helminths of lizards, snakes and crocodiles, where a new *Paraspirura* species, a new *Madathamugadia* species and some 14 new species, subspecies and forms of subspecies of the oxyurid genera *Spauligodon*, *Skrjabinodon*, *Thelandros* and *Tachygonetria* were described. A comprehensive host-parasite list of snakes and lizards is included, as is an equally comprehensive host-parasite list of the pentastome parasites of crocodiles.

In the fourth part, two new *Tetrameres* species are described and the population dynamics of guineafowls and Swainson's spurfowl discussed. A complete list of the helminth parasites of guineafowls is listed, together with an extended host list of these parasites.

INTRODUCTION

My love affair with worms started in 1968 when, as a very low form of life, a "learner technician", I joined the then Department of Agriculture in the Section of Helminthology at the Onderstepoort Veterinary Research Institute. Dr. Anna Verster, under whom I was working, showed me where the worms were, that were sent from all over South Africa and that needed to be identified, and also told me where the books were to be found. Thus, after struggling with clearing agents, glass slides, books and articles for about two days, I was immensely proud of myself for finally managing to identify *Haemonchus contortus*, arguably the commonest parasitic worm in sheep in the world!

After qualifying as a veterinarian I started working in the Section of Pathology at the Veterinary Research Institute where I remained for three years. During this time I was tasked with necropsies of game animals and fish, and also investigated mortalities in these animals. This lead to a number of publications (Boomker, Coetzer & Scott, 1977; Boomker, Imes, Cameron, Naude & Schoonbee, 1977; Boomker & Henton, 1980) which I have not included here. I maintained my interest in worms and with a colleague described the occurrence of a giant liver fluke, *Fascioloides magna*, in the liver of a bovine imported from the United States of America (Boomker & Dale-Kuys, 1977).

In 1977 I joined the University of Pretoria as a lecturer. This is where I met Professor Ivan Horak, who was to play an important role in my life, not only as a friend but also as a mentor and co-worker. While I did a project in the Kruger National Park on the seasonal occurrence of helminth parasites in freshwater fishes, he did one on the seasonal occurrence of helminths of impalas and warthogs, and we assisted each other with our respective projects. When Prof. Horak went to take up the Directorship of the Tick Research Unit at Rhodes University, I took over the kudu parasite project from him – he did the ectoparasites and I did the internal parasites (Boomker, Horak & De Vos, 1989; Horak Boomker, Spickett & De Vos, 1992). Together we spent many happy hours "worming" and "ticking" in the hot climates of the eastern Transvaal (Mpumalanga) and Natal, and produced a number of papers on the parasites of wild animals that will not easily be equalled.

On one such an expedition I met Drs. Michael Keep and Jacques Flamand from the then Natal Parks Board, who invited me to do parasite surveys in the Natal Parks. A chance as good as that could not be declined or ignored and lead to several publications on a variety of antelope, with Prof. Horak again doing the ectoparasites. Thus, the seasonal occurrence of the helminths and ectoparasites of reedbuck (Horak, Keep, Flamand & Boomker, 1988; Boomker, Horak, Flamand & Keep, 1989), and nyala (Boomker, Horak & Flamand, 1991; Horak, Boomker & Flamand, 1995; Boomker, Booyse, Watermeyer, De Villiers, Horak & Flamand, 1996) were published, as were the parasite species composition and burdens of the rare red and blue duikers (Boomker, Booyse & Keep, 1991; Boomker, Horak & Flamand, 1991).

In 1984 I joined the newly created Faculty of Veterinary Science at the Medical University of Southern Africa (Medunsa), where I was appointed associate professor in Helminthology. Prof. Richard Reinecke, the then head of the Department of Parasitology at the University of Pretoria allowed me to take the material that I had collected over the years with me and to complete the data processing and reporting. The 15 years I spent at Medunsa were probably the most productive years of my life as far as publications are concerned.

Taxonomy and systematics have always fascinated me and I was fortunate enough to discover a number of helminth parasites new to science. Their descriptions gave me great satisfaction and I am pleased to have made a small contribution to the known biodiversity of this country. It also gave me the opportunity to immortalize some of my colleagues and friends by naming species after them! In 1992 I was invited to study newer trends in the approach to taxonomy and systematics under Professor Alain Chabaud at the Museum National d'Histoire Naturelle in Paris, France, where I also met Drs. Odile Bain, Marie-Claude Durette-Desset and Annie Petter. These specialists have taught me a great deal about the nematodes, and I was fortunate to be able to work and publish with them. I have described 13 new nematode species from mammals, and a trematode and 12 nematodes from fishes, either by myself or with mainly the French friends.

The postgraduate students that I supervised, especially the two German students (who sometimes referred to themselves as 'the germs'), did a sterling job on their respective topics. The parasites of reptiles have not been studied much and are highly specialized, to such an extent that for some of the genera there are forms of subspecies! These parasites belong mostly to the Order Oxyurida, which in South

Africa are poorly known. Dr. Stephan Hering-Hagenbeck studied the oxyurids of a variety of geckos and lizards and also described a number of new species (Hering-Hagenbeck & Boomker, 2000; Hering-Hagenbeck, Boomker, Petit, Killick-Kendrick & Bain, 2000; Hering-Hagenbeck, Petter & Boomker, 2000a, b).

Dr. Kerstin Junker chose to address the difficult and fascinating subject of the crocodile Pentastomida, all of whom have indirect life cycles. As adults they parasitize the lungs of crocodiles and the intermediate hosts are freshwater fishes. She succeeded in describing the life-cycle of *Sebekia wedli* (Junker, Boomker & Booyse, 1998), found and described the unknown males of *Alofia simpsoni* (Junker, Boomker & Bolton, 1999) and *Leiperia cincinnalis* (Junker, Boomker, Swanepoel & Taraschewski, 2000). She also described a new species of *Subtriquetra* from freshwater fishes, and the new genus and species, *Pelonia africana*, the first pentastomid to be described from a chelonian from Africa (Junker, Boomker & Booyse, 1998; Junker & Boomker, 2002).

During 1999 the Veterinary Faculty at Medunsa was closed and amalgamated with that of the University of Pretoria. At the time I joined the Department of Veterinary Tropical Diseases and in 2005 Dr. Junker was awarded a post-doctoral fellowship by the Claude Leon Foundation. Since much material had already been collected from guineafowls from the KNP and the Eastern Cape Province, she decided to address their parasites. She continued with the game-bird parasites when she was awarded a University of Pretoria post-doctoral fellowship. From this research emanated the descriptions of two new species of nematodes (Junker & Boomker, 2007; Junker, Davies, Jansen, Crowe & Boomker, 2008), and several publications dealing with the helminth population dynamics in gamebirds. This part of the study fascinated me, not only because of the numbers and species of helminths recovered, but also the diversity in the different age classes of birds.

SECTION 1

PARASITES

OF

FREE-LIVING MAMMALS

CHAPTER 1

Descriptions and re-descriptions

of

parasites of free-living mammals

Introduction

This chapter includes descriptions of new parasites of mammals as well as descriptions of larval stages in the life cycle of *Kirkioestrus* and a description of a *Lipoptena* species. Much of it is my work, and only those publications that have not been previously incorporated in one of my theses, are included here. Contributors were J.R. Palmieri (warthog filaria, for whom I collected material (Palmieri, Pletcher, De Vos & Boomker, 1985)), I.G. Horak (*Kirkioestrus*, for which I did the drawings and description (Horak, Boomker & De Vos, 1980)), E. Visagie (to whom I supplied material and edited the manuscript (Visagie, Horak & Boomker, 1992), R. Watermeyer (the *Setaria* species redescription, for which I supplied much of the material and funding, and edited the manuscript (Watermeyer, Boomker & Putterill, 2000, 2003, 2004) and J.R. Lichtenfels (description of *Haemonchus horaki*, material that I supplied after having previously published on the *Haemonchus* with the exceptionally long spicules (Boomker, Horak, Gibbons & De Vos, 1983; Lichtenfels, Pilitt, Gibbons & Boomker, 2001)). The paper on the *Molineus* of feral cats (Durette-Desset, Boomker & Malan, 2000) has been included here, because feral cats can be accepted as wild mammals!

This chapter has been arranged to group likes together, e.g. the descriptions of the trichostrongylids together, the *Setaria* species together and the miscellaneous ones together, and within the various groups, the articles are arranged chronologically.

ARTHROPODS (P 23)

HORAK, I.G., BOOMKER, J. & DE VOS, V., 1980. A description of the immature stages of *Kirkioestrus minutus* (Rodhain & Bequaert, 1915) (Diptera: Oestridae), and the life cycle and seasonal prevalence of this fly in blue wildebeest. *Onderstepoort Journal of Veterinary Research*, 47, 23 - 30.

VISAGIE, ELIZE J., HORAK, I.G. & BOOMKER, J., 1992. The louse fly *Lipoptena paradoxa* Newstead, 1907 (Diptera: Hippoboscidae): Description of its adult and puparium and biology in South Africa. *Onderstepoort Journal of Veterinary Research*, 59, 303 - 314.

TRICHOSTRONGYLID NEMATODES (P 45)

BOOMKER, J., 1977. A revision of the genus *Impalaia* Mönnig, 1924. *Onderstepoort Journal of Veterinary Research*, 44, 131 - 138.

BOOMKER, J., HORAK. I.G. & ALVES, REGINA, 1979. *Cooperia connochaeti* sp. nov. (Nematoda: Trichostrongylidae) from the blue wildebeest, *Connochaetes taurinus* (Burchell, 1823). *Onderstepoort Journal of Veterinary Research*, 46, 83 - 86.

BOOMKER, J., 1986. *Trichostrongylus auriculatus* n. sp. (Nematoda: Trichostrongylidae) from the steenbok *Raphicerus campestris* (Thunberg, 1811). *Onderstepoort Journal of Veterinary Research*, 53, 213 - 215.

BOOMKER, J. & DURETTE-DESSET, M.-C., 1997. Supplement to the description of *Longistrongylus thalae* (Troncy & Graber, 1973) Gibbons, 1981 (Nematoda: Ostertagiinae). *Systematic Parasitology*, 36, 69 - 73.

LICHTENFELS, J. RALPH, PILITT, PATRICIA L., GIBBONS, LYNDA M. & BOOMKER, JOOP D.F., 2001. *Haemonchus horak*i n. sp. (Nematoda: Trichostrongyloidea) from the grey rhebuck *Pelea capreolus* in South Africa. *Journal of Parasitology*, 87, 1095-1103.

BOOMKER, J. & DURETTE-DESSET, M.-C., 2003. Parasites of South African wildlife. XVII. *Ostertagia triquetra* n. sp. (Nematoda: Trichostrongylina) from the grey rhebuck, *Pelea capreolus* (Forster, 1790). *Onderstepoort Journal of Veterinary Research*, 70, 37 - 41.

BOOMKER, J. & TAYLOR, A., 2004. Parasites of South African wildlife. XVIII. *Cooperia pigachei* n. sp. (Nematoda: Cooperiidae) from the mountain reedbuck, *Redunca fulvofufula* (Afzelius, 1815). *Onderstepoort Journal of Veterinary Research*, 71, 171 – 174.

***SETARIA* SPECIES (P 85)**

WATERMEYER, R., BOOMKER, J. & PUTTERILL, J.F., 2000. Studies on the genus *Setaria* Viborg, 1795 in South Africa. I. *Setaria africana* (Yeh, 1959). *Onderstepoort Journal of Veterinary Research*, 67, 229-234.

WATERMEYER, R., BOOMKER, J. & PUTTERILL, J.F., 2003. Studies on the genus *Setaria* Viborg, 1795 in South Africa. II. *Setaria scalprum* (Von Linstow, 1908) and *Setaria saegeri* (Le Van Hoa, 1961). *Onderstepoort Journal of Veterinary Research*, 70, 7-13.

WATERMEYER, R., BOOMKER, J. & PUTTERILL, J.F., 2004. Studies on the genus *Setaria* Viborg, 1795 in South Africa. III. *Setaria thwaitei* Mönnig, 1933. *Onderstepoort Journal of Veterinary Research*, 71, 107-111.

MISCELLANEOUS HELMINTHS (P 103)

PALMIERI, J.R., PLETCHER, J.M., DE VOS, V. & BOOMKER, J., 1985. A new filarial nematode (Onchocercidae) from warthogs (*Phacochoerus aethiopicus*) of the Kruger National Park. *Journal of Helminthology*, 59, 241 - 245.

BOOMKER, J., 1990. Parasites of South African wildlife. V. Description of the males of *Oesophagostomum mocambiquei* Ortlepp, 1964 from warthogs, *Phacochoerus aethiopicus* (Pallas, 1766). *Onderstepoort Journal of Veterinary Research*, 57, 169 - 173.

BOOMKER, J., BAIN, O., CHABAUD, A.G. & KRIEK, N.P.J., 1995. *Stephanofilaria thelazioides* n. sp. (Nematoda: Filariidae) from a hippopotamus and its affinities with the species parasitic in the African black rhinoceros. *Systematic Parasitology*, 32, 205 - 210.

DURETTE-DESSET, MARIE-CLAUDE, BOOMKER, J. & MALAN, F.S., 2000. *Molineus cati* n. sp. (Nematoda, Trichostrongylina, Molineoidea), a parasite of feral cats, *Felis catus* linnaeus, 1758 in South Africa. *Onderstepoort Journal of Veterinary Research*, 67, 173-177.

ARTHROPODS

Onderstepoort J. vet. Res., 47, 23–30 (1980)

A DESCRIPTION OF THE IMMATURE STAGES OF *KIRKIOESTRUS MINUTUS* (RODHAIN & BEQUAERT, 1915) (DIPTERA: OESTRIDAE), AND THE LIFE CYCLE AND SEASONAL PREVALENCE OF THIS FLY IN BLUE WILDEBEEST

I. G. HORAK(1), J. BOOMKER(1) and V. DE VOS(2)

Abstract

HORAK, I. G., BOOMKER, J. & DE VOS, V., 1980. A description of the immature stages of *Kirkioestrus minutus* (Rodhain & Bequaert, 1915) (Diptera: Oestridae), and the life cycle and seasonal prevalence of this fly in blue wildebeest. *Onderstepoort Journal of Veterinary Research*, 47, 23–30 (1980)

Descriptions of the 1st, 2nd and 3rd instar larvae and the puparium of *Kirkioestrus minutus* are given. First instar larvae, which have not previously been described, can be distinguished from other oestrid larvae by the ventral spinulation of segments IV–XII and the spinulation of the anal protuberance.

Of 55 blue wildebeest examined in the Kruger National Park all but two 1-month-old and one 2-month-old animals were infested. First stage larvae are probably deposited in or on the nostrils and may develop within 30 days, initially in the nasal passages and then in the frontal sinuses to mature 3rd stage larvae. Development within the host appears to take longer during the cooler months of the year. Pupal periods vary from approximately 32 days in early or late summer to more than 50 days in winter.

Three of 6 blesbok examined at Badplaas in the eastern Transvaal were infested with 1st instar larvae only of *K. minutus* and it is suggested that blesbok may not be suitable hosts of this fly. Four black wildebeest in the Golden Gate National Park in the eastern Orange Free State were not infested.

Résumé

UNE DESCRIPTION DES STADES D'IMMATURITÉ DU KIRKIOESTRUS MINUTUS *(RODHAIN & BEQUAERT,* 1915) *(DIPTERA: OESTRIDAE), ET DU CYCLE DE VIE AVEC PRÉVALENCE SAISONNIÈRE DE CETTE MOUCHE CHEZ LE GNOU*

Des descriptions des 1er, 2d et 3me stades des larves et chrysalides du Kirkioestrus minutus (Rodhain & Bequaert, 1915) *sont données. Les larves de premier stade qui n'avaient pas été décrites antérieurement peuvent se distinguer des autres larves d'oestrides par la spinulation ventrale des segments IV–XII et par la spinulation de la protuberance anale. A la suite de l'examen de 55 gnous observés au Park National Kruger, tous les animaux, à l'exception de deux d'entr'eux, l'un agé de 1 mois et l'autre de 2 mois, se trouvaient infestés. Les larves du premier stade sont probablement déposées à l'intérieur ou sur les narines et peuvent se développer en 30 jours, initialement dans les passages nasaux et alors dans les sinus frontaux pour y mûrir en larves du 3me stade. Le développement à l'intérieur de l'hôte paraît prendre plus longtemps pendant les mois frais de l'années. Les périodes de chrysalide varient d'approximativement 32 jours au début ou à la fin de l'été jusqu'à 50 jours en hiver.*

Trois des blesboks examinés à Badplaas dans l'est du Transvaal étaient infestés avec des larves de K. minutus *du premier stade et il en est suggéré que le blesbok pourrait ne pas être un hôte adéquat pour cette mouche. Quatre gnous du Parc National Golden Gate dans l'est de l'Etat Libre d'Orange n'étaient pas infestés.*

Introduction

The larvae of *Kirkioestrus minutus* (Rodhain & Bequaert, 1915) are parasites of the nasal passages and para-nasal sinuses of the blue wildebeest (*Connochaetes taurinus*), korrigum (*Damaliscus korrigum*), common hartebeest (*Alcelaphus buselaphus*) and Lichtenstein's hartebeest (*Alcelaphus lichtensteini*) (Zumpt, 1965) and are also found in the tsessebe (*Damaliscus lunatus*) (Wetzel, 1970).

The 2nd and 3rd stage larvae and a female fly were described by Zumpt (1965), who stated that the 1st stage larva and life cycle were unknown and that few flies hatched from larvae that had been allowed to pupate. Wetzel (1970) mentioned that mature 3rd instar larvae are dark brown in colour, a feature not recorded by Zumpt (1965), and that the life cycle is probably similar to that of other Oestrinae in that the 1st stage larvae are laid around the nasal openings and in the eyes and migrate from there to the nasal and sinus cavities where they develop to 2nd and 3rd stage larvae. He also stated, without giving exact figures, that the pupal period lasted a month and that the life cycle is not seasonally influenced since 3rd stage larvae are present in February, March, July, October and December.

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(2) Department of Nature Conservation, National Parks Board, Private Bag X404, Skukuza 1350

Received 14 November 1979—Editor

In Zambia, Howard (1977) found that 8 out of 9 Lichtenstein's hartebeest harboured 24–34 3rd stage larvae of a *Kirkioestrus* species, and these he considered to be near *K. minutus*. As he was unable to identify the 1st and 2nd stage larvae specifically, he included these with the *Oestrus* spp. larvae, which were also present.

A survey conducted to determine the seasonal prevalence of the internal and external parasites of blue wildebeest in the Kruger National Park afforded an opportunity to study the oestrid flies parasitizing these animals. Nearly all the wildebeest examined were infested with *K. minutus*, and once the 1st stage larvae had been differentiated from those of other flies and the mature 3rd instar larvae had been allowed to pupate and flies to hatch, it became possible to describe the various developmental stages, the life history of the fly and its seasonal occurrence.

Materials and Methods

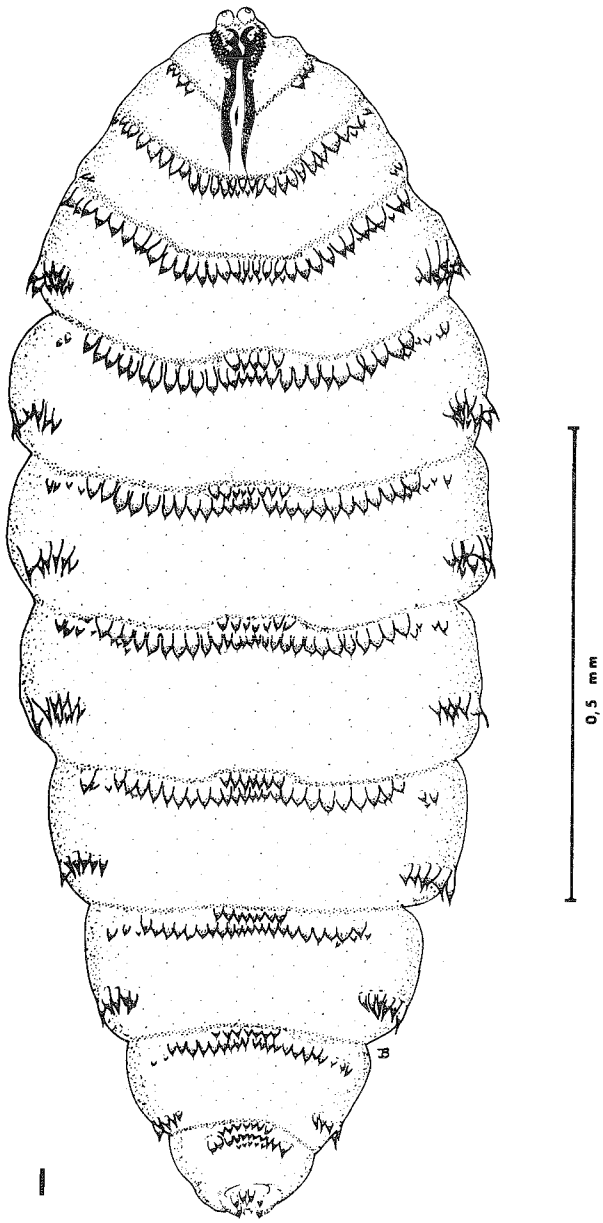
Each month from November 1977 to November 1978 at least 4 wildebeest were shot in the southern half of the Kruger National Park. The majority of wildebeest in the Park are born during December and an attempt was made each month to shoot 2 animals from the latest calf crop plus 2 from the previous year's crop. This culling procedure meant that animals ranging in age from 1–24 months were ultimately examined. Sometimes older animals were also shot.

As soon after death as possible the eyes of the animals were examined for oestrid larvae and the heads, severed from the carcasses, placed in plastic bags. The carcasses were eviscerated and the viscera placed in plastic bags and transported with the carcasses and heads to the laboratory at Skukuza.

The skin and ears were removed from each head, which was then divided sagittally by means of a bowsaw. All larvae present on the mucosa of the nasal septum, nasal passages and conchae were removed with fine-tipped forceps and placed in 70% ethyl alcohol. Thereafter the septum, conchae and half of the brain were removed for closer examination. The dura on the side from which the brain had been removed was stripped from the cranial cavity and placed in 70% alcohol. The sinus cavities were opened and all immature larvae removed and preserved in alcohol. The tracheae and the bronchial trees of the right lungs, the hearts and major blood vessels were opened and thoroughly washed. The washings were poured through sieves with 38μm apertures and the contents of the sieves were collected and preserved by adding 10% formaldehyde solution.

Whenever mature 3rd instar larvae were present in the sinus cavities, they were specifically identified under a stereoscopic microscope. The larvae of each species were placed separately in approximately 60 mm of vermiculite in glass bottles with nylon gauze tops and allowed to pupate. The flies hatched in these bottles, which were kept on a shelf in the necropsy room. This room had a single solid wall and three sides constructed of fine wire gauze on wooden supports. The bottles were examined daily and the dates of larval collection and fly emergence noted. Newly-emerged flies were left for approximately 2 h to expand and dry their wings and were then placed in 70% alcohol.

Six blesbok (*Damaliscus dorcas phillipsi*), shot at Badplaas in the eastern Transvaal, and 4 black wildebeest (*Connochaetes gnou*), shot in the Golden Gate National Park in the eastern Orange Free State, were examined in the same way.



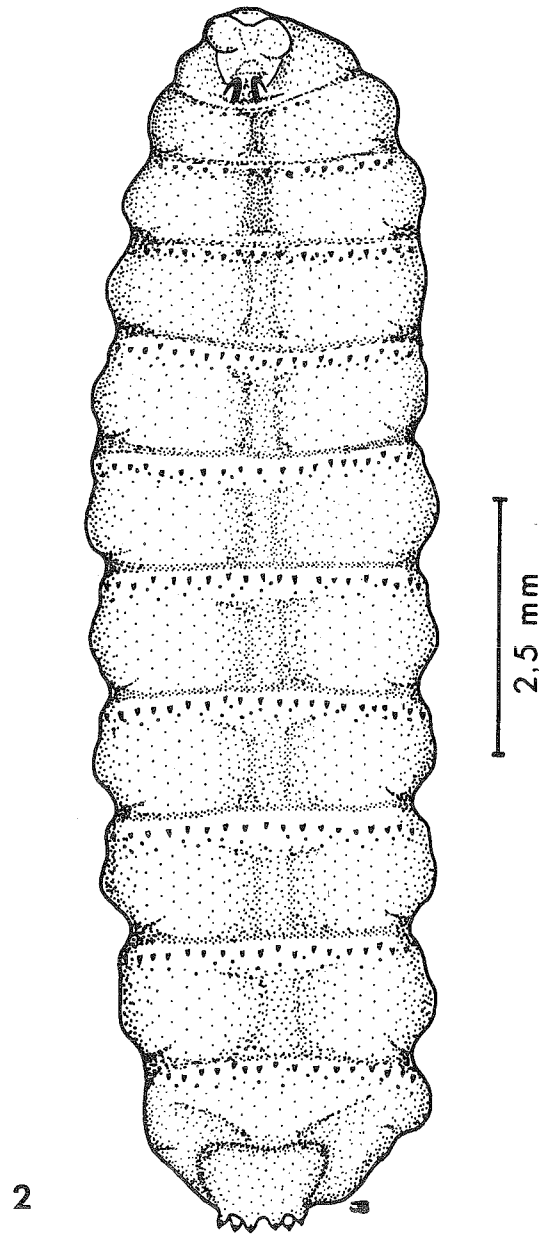
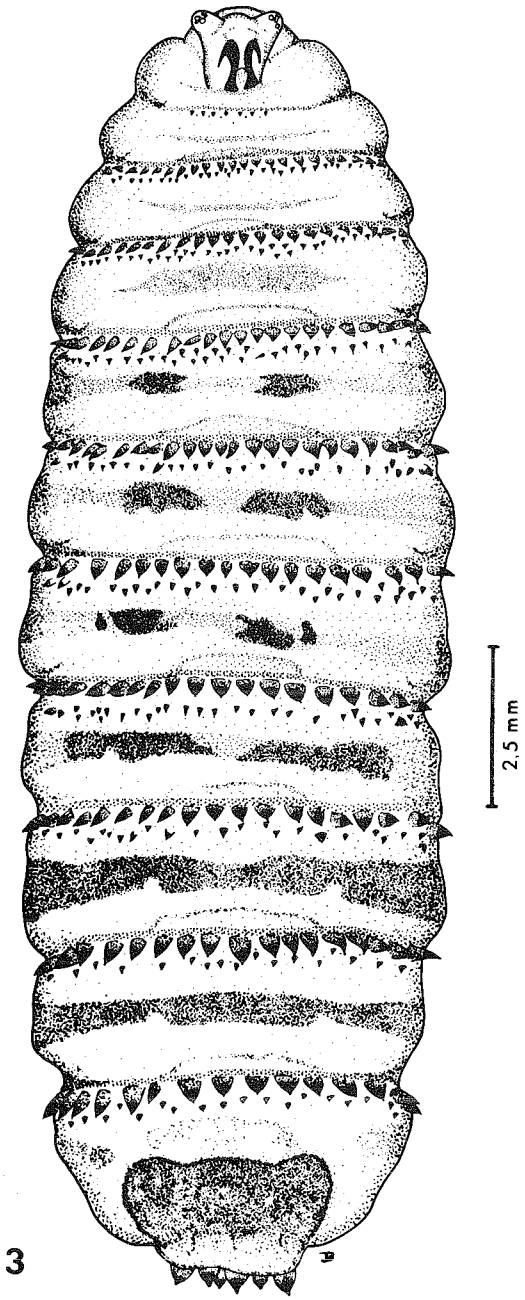


FIG. 1 First instar larva of *K. minutus*, ventral view
FIG. 2 Second instar larva of *K. minutus*, ventral view



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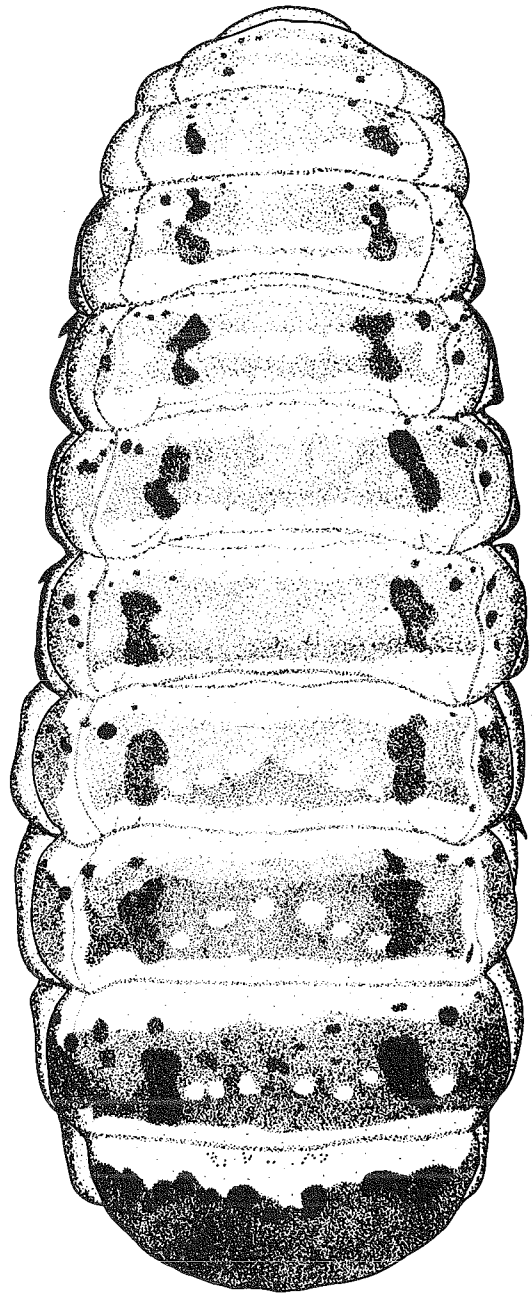

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FIG. 3 Third instar larva of *K. minutus*, ventral view
FIG. 4 Third instar larva of *K. minutus* dorsal view; scale as for Fig. 3

All the material collected was examined under a stereoscopic microscope for oestrid larvae which were identified according to species and stage of development. The body lengths of the larval stages of *K. minutus* were measured and these larvae and the pupal stage are illustrated and described below.

KIRKIOESTRUS MINUTUS (RODHAIN & BEQUAERT, 1915)

DESCRIPTION

The body lengths of the various larval stages are summarized in Table 1.

First instar larva (Fig. 1)

The semi-transparent, white 1st instar larva, which is broadly-rounded anteriorly widens progressively to the level of the 6th segment, then tapers gradually to a blunt point posteriorly. The antennal lobes each have one small pseudocellus. Ventrally, each of the segments IV–XII bears a band of large pointed spines, arranged in a short anterior row and a longer posterior row on its anterior border. Occasionally a short 3rd row of spines is present. The

TABLE 1 The ranges in length of the various larval stages of *K. minutus* recovered from blue wildebeest

Stage of development	Range in length (mm)	No. of larvae measured
1st stage larvae...	1,1– 4,8	111
2nd stage larvae..	3,1–13,4	106
2nd moult.....	10,5–13,9	22
3rd stage larvae..	10,1–28,0	142

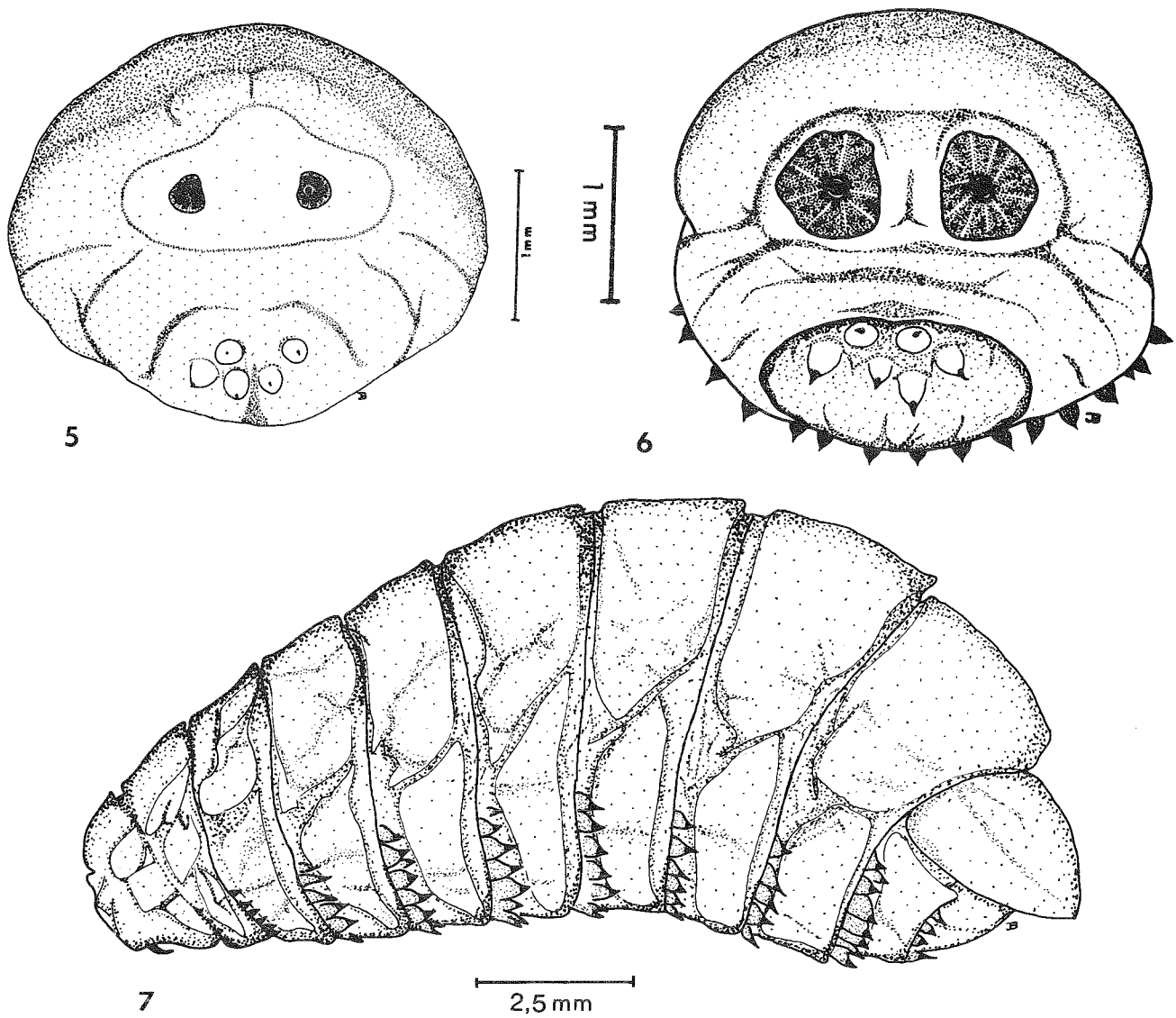

FIG. 5 Posterior end of 2nd instar of *K. minutus* larva, showing peritremes and spinulation
FIG. 6 Posterior end of 3rd instar larva of *K. minutus*, showing peritremes and spinulation
FIG. 7 Puparium of *K. minutus*, lateral view

posterior part of the 4th segment bears a few small spines lateroventrally, whereas segments V–XI bear a cluster of large spines in this position. The posterior spiracles lie in a shallow depression and are difficult to see. The anal protuberance bears about 7 small ventral and 2 large lateral pointed spines.

Second instar larva (Fig. 2, 5)

Larvae in the second instar (Fig. 2) are creamy-white in colour. The cephalic end is approximately as wide as the posterior end. The spinulation is the same as that of the 3rd instar larva and the latero-ventral spines present posteriorly on segments IV–XI of the 1st instar larva are absent. The peritremes are small, and the anal protuberance is armed with about 5–6 large spines (Fig. 5).

Third instar larva (Fig. 3, 4, 6)

The mature 3rd instar larva is yellow-brown in colour and slightly wider posteriorly than anteriorly (Fig. 3, 4). The antennal lobes each have 3 pseudocelli. Segments III–XII have dark brown patches laterally and segments IV–XI are each encircled by a dark brown band. The bands on the anterior segments are lighter in colour and narrower than those on the posterior segments. Ventrally, segment III bears only a short row of small spines, whereas segments IV–XII bear bands of spines anteriorly, each band consisting of an anterior row of large spines plus a posterior row of short spines. The posterior peritremes are fairly large and lie in a shallow depression. The dorsal margin of this depression is spineless, whereas the well-developed anal protuberance, which forms the ventral margin of the depression, bears approximately 6 large pointed spines (Fig. 6).

Pupa (Fig. 7)

The puparium is about 17 mm long, dark brown or black in colour, flat ventrally and markedly convex dorsally, and bears the spines of the unshed integument of the 3rd instar larva.

Life Cycle and Seasonal Prevalence in Blue Wildebeest

The burdens of *K. minutus* larvae recovered from 1–12-month-old wildebeest are summarized in Table 2.

TABLE 2 The numbers of *K. minutus* larvae recovered from 1- to 12-month-old blue wildebeest in the Kruger National Park

Date slaughtered	Age in months	Number and stage of development of *K. minutus* larvae recovered			
		1st	2nd	3rd	Total
1978					
16 January	1	0	0	0	0
16 January	1	0	0	0	0
14 February	2	0	0	0	0
14 February	2	0	1	0	1
13 March	3	0	0	1	1
13 March	3	0	1	1	2
3 April	4	0	1	11	12
3 April	4	0	5	8	13
17 April	4	20	1	13	34
17 April	4	0	11	6	17
8 May	5	0	14	11	25
8 May	5	0	8	5	13
5 June	6	4	21	53	78
5 June	6	68	1	0	69
3 July	7	0	8	29	37
3 July	7	0	11	47	58
7 August	8	0	6	15	21
7 August	8	0	6	25	31
11 September	9	0	6	89	95
11 September	9	0	3	6	9
16 October	10	0	22	51	73
16 October	10	0	17	88	105
15 November	11	0	17	86	103
15 November	11	0	7	138	145
1977					
15 November	11	0	2	30	32
16 November	11	0	0	33	33
13 December	12	7	1	31	39
14 December	12	0	0	8	8

TABLE 3 The mean numbers of *K. minutus* larvae recovered from blue wildebeest older than 3 months in the Kruger National Park

Month killed	No. of wildebeest examined	Mean number of *K. minutus* larvae recovered				
		1st	2nd	3rd	Total	1st and 2nd stage larvae as a % of the total
1977						
November	4	3,25	1,5	24,5	29,25	16,2
December	4	2,5	0,8	22,5	25,8	12,8
1978						
January	2	44,5	2,5	33,0	80,0	58,8
February	2	0,0	0,5	25,0	25,5	2,0
March	2	35,5	0,0	11,5	47,0	75,5
April	6	4,7	6,1	10,0	20,8	51,9
May	4	2,0	10,5	14,5	27,0	46,3
June	4	18,25	6,0	26,25	50,5	48,0
July	5	10,4	4,2	30,8	45,4	32,2
August	4	4,5	3,5	17,5	25,5	31,4
September	4	0,0	6,75	29,75	36,5	18,5
October	4	0,0	11,5	56,0	67,5	17,0
November	4	0,5	6,25	89,25	96,0	7,0

Except for the two 1-month-old animals and 1 of the 2-month-old animals, all the other wildebeest examined were infested. The 2-month-old and 3-month-old wildebeest shot during February and March 1978 harboured only 1 or 2 larvae. Thereafter larval burdens increased in number, reached a peak in the 6-month-old animals shot during June 1978, decreased slightly and then rose again to reach a major peak in the 11-month-old animals slaughtered during November 1978. The latter animals harboured considerably more larvae than the wildebeest of equal age killed the previous November.

Excluding the larval burdens of the animals 1–3 months of age, the mean monthly burdens of *K. minutus* larvae recovered from all the wildebeest examined are summarized in Table 3.

No 1st stage larvae were recovered during February, September or October 1978, while 2nd and 3rd stage larvae were present throughout the survey period. Except in November and December 1977 and February 1978, mature 3rd instar larvae were recovered in every month.

TABLE 4 The length of the pupal period of *K. minutus* in the Kruger National Park

Date larvae collected	No. collected	Date flies hatched	No. of flies hatched	Pupal period in days
1978				
16 Jan.	3	Failed to hatch	0	—
13 March	5	13 April (1), 14 April (3)	4	31–32
17 April	2	Failed to hatch	0	—
8 May	1	Failed to hatch	0	—
5 June	6	Failed to hatch	0	—
3 July	3	*25–30 August (1)	1	*53–58
7 August	7	20 September (2), 22 September (1)	3	44–46
11 Sept.	4	18 October (1)	1	37
16 Oct.	4	18 November (1), 19 November (1), 23 November (1)	3	33–38
15 Nov.	1	Failed to hatch	0	—

* The exact day on which the fly hatched was not recorded.
( ) =Brackets indicate number of flies hatched on a particular date.

TABLE 5 Oestrid larvae recovered from blesbok at Badplaas

Date blesbok killed	Number and stage of development of larvae recovered						
	K. minutus	*Gedoelstia* sp.			*O. macdonaldi*		
	1st	1st	2nd	3rd	1st	2nd	3rd
1978							
17 May	2	138	5	45	0	18	43
17 May	67	128	6	29	0	0	0
19 June	0	7	13	21	0	0	0
19 June	2	67	4	29	0	0	0
19 July	0	6	32	27	0	1	0
19 July	0	1	2	14	0	0	0

Although larval burdens varied considerably, larger proportions of the total burdens were in the 1st and 2nd stage of development from April–August than during September–December. The findings for January–March are difficult to assess as only 2 older animals were examined in each of these months. Large numbers of 1st stage larvae were present, however, during January and March.

First stage larvae were recovered from the nasal septa, ventral conchae and ventral and median nasal passages, 2nd and 3rd stage larvae from the frontal sinuses, and the nasal passages and conchae surrounding the sinus entrances. No *K. minutus* larvae were recovered from the eyes, brain surfaces, dura, hearts and major blood vessels, or lungs and tracheae.

A constant, although subjective observation, was that the mature 3rd instar larvae of *K. minutus* appeared sluggish when compared with similar larvae of the other oestrid species, namely, *Gedoelstia cristata, Gedoelstia hässleri, Oestrus aureoargentatus* and *Oestrus variolosus,* recovered from the wildebeest.

The dates of larval collection and fly emergence and the duration of the pupal periods are summarized in Table 4.

Few flies hatched in comparison with the total number of mature larvae collected. Pupal periods increased from 31–32 days for larvae collected during March 1978 to 53–58 days for the larva collected during July and subsequently decreased to 33–38 days for larvae collected during October.

The larval burdens of the blesbok shot at Badplaas are summarized in Table 5.

Three of the 6 blesbok were infested with 1st stage larvae of *K. minutus*, but harboured no 2nd or 3rd stage larvae of this species. Larvae of *Gedoelstia* sp. near *G. hässleri* in all 3 stages of larval development were present, however. Two animals were infested with *Oestrus macdonaldi*, 1 harbouring a 2nd stage larva and the other 2nd and 3rd stage larvae.

The 4 black wildebeest shot in the Golden Gate National Park harboured only larvae of *G. hässleri.*

Discussion

Larval identification

The 1st instar larva of *K. minutus* has to be differentiated from those of *Oestrus* spp. (*O. aureoargentatus* and *O. variolosus*) and *Gedoelstia* spp. (*G. cristata* and *G. hässleri*), which may also be found in the nasal passages of blue wildebeest (Zumpt, 1965). In *K. minutus* segments IV–XII each bear 2 rows of spines on their antero-ventral borders and the anal protuberance is armed with approximately 7 small ventral and 2 large lateral pointed spines. In *Oestrus* spp. the anterior borders of segments III–XII each bear 3–5 rows of ventral spines and the ventral aspect of the last segment has about 18–54 terminal hooklets arranged in 2 scallops (Basson, 1962; Zumpt, 1965; Nevill & Basson, 1966). In *Gedoelstia* spp. the antero-ventral borders of segments IV–XII each carry 3–4 rows of spines and the anal protuberance of segment XII is nude (Basson, 1962).

Life cycle

The recovery of 1st stage larvae from the nasal septa and passages of the wildebeest and not from the eyes, brain surfaces or dura implies that the life cycle is similar to that of *Oestrus ovis* in sheep, with the flies depositing larvae on or in the nostrils (Bedford, 1925; Capelle, 1966), and not like that of *Gedoelstia* spp., in which the larvae are deposited in the eyes and make their way to the brain and dura (Basson, 1966; Horak & Butt, 1977). The larvae may be deposited singly or in either small or large batches as indicated by the single larva recovered from the 2 and 3-month-old animals and the large numbers of 1st instar larvae recovered from older individuals.

Development of the 1st stage larvae takes place on the mucosa of the nasal passages and conchae and they grow from approximately 1,1 mm–4,8 mm during this process. The first moult probably occurs soon after this length has been reached but, since no larvae in the 1st ecdysis were recovered, this cannot be verified. This moult probably takes place on the median conchae as is the case with *O. ovis* (Cobbett & Mitchell, 1941; Horak, 1977). The newly emerged 2nd instar larvae, which may initially be shorter than larvae of the preceding stage, migrate to the frontal sinuses, where they grow to approximately 13,4 mm before commencing the 2nd ecdysis. During this moult the larvae also shrink slightly, as larvae at the commencement of the ecdysis usually exceeded 13,0 mm in length, while those at the point of emergence measured little more than 10,0 mm. Third stage larvae may grow to approximately 28,0 mm in length, but mature larvae considerably shorter than this were recovered. As the larvae mature their integument darkens to form bands around segments III–XII.

The total time taken for development in the host animal may be as short as 30 days. This period can be deduced from the fact that young wildebeest, shot during a particular month, often harboured considerably more 3rd stage larvae than the total larval burdens of animals shot during the previous month.

Mature 3rd instar larvae leave the host and pupate in the soil, pupal periods varying from approximately 32 days for larvae collected during October (early summer) and March (late summer) to more than 50 days for larvae collected during July (mid-winter). The pupal periods of the mature larvae collected during mid-summer would probably have been shorter than 30 days had they given rise to flies. The freed mature larvae or the pupae apparently required particular conditions for subsequent maximum eclosion of the flies. Only 12 flies hatched from a total of 36 mature larvae collected, while 29 of 37 *G. hässleri* larvae and 22 of 31 *O. aureoargentatus* larvae collected during the same period hatched. Zumpt (1965) commented on the small number of flies resulting from *K. minutus* larvae he had allowed to pupate. It is not clear from his description of the 3rd instar larvae whether he realized that these larvae are only mature once they exhibit dark circular bands, and he may have used immature 3rd stage larvae in his experiments.

Seasonal fluctuation

No clear seasonal fluctuations in the composition of the larval burdens were apparent, probably because the comparatively warm winter temperatures in the Kruger Park made development throughout the year possible. The increase in the proportion of 1st and 2nd stage larvae during the cooler months does indicate, however, a slower rate of development then, than in spring and summer. Similar observations have been made on the development of *O. ovis* in sheep (Cobbett & Mitchell, 1941; Rogers & Knapp, 1973; Horak, 1977).

A marked increase in infestation compared with the level of infestation during 1977 appeared imminent during the summer of 1978/79. Three out of the 4 animals shot during November 1978 harboured more than 100 larvae compared with the 25–33 larvae harboured by the 4 animals shot during the previous November. The reason for this increase cannot be deduced from the available data.

The pupal periods of *K. minutus* were generally similar to those of *G. cristata* and *O. aureoargentatus* larvae collected at the same time. However, *K. minutus* larvae collected during April–June failed to develop into flies, while the other 2 flies had pupal periods of approximately 70 days for larvae collected during May and June. The inability of *K. minutus* to develop to adulthood from mature larvae collected during this period is a finding apparently only applicable to the laboratory. The burdens of 1st instar larvae in wildebeest shot during July and August implied that mature larvae had successfully pupated in the field and flies hatched and deposited larvae during this time.

The seasonal fluctuations noted in the lengths of the pupal periods indicate that atmospheric temperature played an important role. Pupal periods were short during the warm months and considerably longer during the cooler months. Similar observations have been made for the pupal periods of *O. ovis* on the Transvaal Highveld (Horak, 1977). The shortest pupal period recorded for *K. minutus* in this study being 31 days compares favourably with the period of 1 month mentioned by Zumpt (1965) and Wetzel (1970), although they gave no exact figures nor the month in which the larvae had been collected.

Host specificity

Although a number of alcelaphine antelope have been listed as hosts of *K. minutus* (Zumpt, 1965; Wetzel, 1970), *K. minutus* had not previously been recovered from blesbok. The presence of 1st instar larvae only in blesbok at Badplaas suggests that these animals are not suitable hosts. Infestation in this area may have been maintained in tsessebe or in black wildebeest running in the same camp as the blesbok, although black wildebeest have not been described as hosts of this fly, nor did those in the Golden Gate National Park harbour its larvae.

ACKNOWLEDGEMENTS

We wish to thank Messrs P. C. Pieterse and B. de Klerk for their assistance with the necropsies of the wildebeest.

The Board of Curators of the National Parks Board kindly placed the blue and black wildebeest, and the Board of Public Resorts the blesbok, at our disposal.

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Onderstepoort J. vet. Res. 59, 303–314 (1992)

THE LOUSE FLY *LIPOPTENA PARADOXA* NEWSTEAD, 1907 (DIPTERA: HIPPOBOSCIDAE): DESCRIPTION OF ITS ADULT AND PUPARIUM AND BIOLOGY IN SOUTH AFRICA

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ABSTRACT

VISAGIE, ELIZE J., HORAK, I. G. & BOOMKER, J., 1992. The louse fly *Lipoptena paradoxa* Newstead, 1907 (Diptera: Hippoboscidae): description of its adult and puparium and biology in South Africa. *Onderstepoort Journal of Veterinary Research,* 59, 303–314 (1992)

Lipoptena paradoxa Newstead, 1907 is re-described using scanning electron microscopy and its puparium is described for the first time. The distribution of the fly is restricted to the eastern half of South Africa, generally at altitudes below 600 m. Its preferred hosts are all browsing antelope namely, bushbuck, nyalas, kudus and common duikers. The largest numbers of flies were present on kudus in the Kruger National Park from July or August to January and large numbers were recovered from these animals' tails from November to January. Considerably more female than male flies were collected.

INTRODUCTION

Conventional descriptions of the adults of the louse fly, *Lipoptena paradoxa* Newstead, 1907 (Diptera: Hippoboscidae) have been published in Newstead, Dutton & Todd (1907), and by Ferris (1930), Bequaert (1940; 1942), Tendeiro (1951) and Maa (1963; 1965; 1969). No descriptions based on scanning electron microscopic examination of the fly have been published nor has the puparium been described. There are a number of rather incomplete descriptions of the exterior of the puparia of various other hippoboscid flies (Ferris & Cole, 1922; Ferris, 1923; Schuurmans-Stekhoven, 1926; Bequaert, 1953; Maa, 1969; Theodor, 1975), while Baker (1990) has given a detailed description of the external features of the puparium of *Lipoptena mazamae* Rondani, 1878.

The distribution of *L. paradox* is confined to sub-Sharan Africa where it has been recorded from Ethiopia, Ghana, Kenya, Burundi, Uganda, Congo, Zaïre, Tanzania, Angola, Malawi, Zambia, Mozambique, Zimbabwe, Botswana and South Africa (Bequaert, 1942; Haeselbarth, Segerman & Zumpt, 1966; Maa, 1968; 1969; Hutson & Oldroyd, 1980). Within the Republic of South Africa it has been recorded in Transvaal, Natal and the Cape Province (Bedford, 1926; Maa, 1969; Boomker, Du Plessis & Boomker, 1983; Horak, Keep, Spickett & Boomker, 1989; Horak, Boomker, Spickett & De Vos, 1992).

The fly has been recovered from roan antelope (*Hippotragus equinus),* oribi *(Ourebia oribi),* grysbok *(Rhaphicerus melanotis),* common duiker *(Sylvicapra grimmia),* impala *(Aepyceros melampus),* bushbuck *(Tragelaphus scriptus),* lesser kudu *(Tragelaphus imberbis),* nyala *(Tragelaphus angasii),* kudu *(Tragelaphus strepsiceros),* eland *(Taurotragus oryx),* common reedbuck *(Redunca arundinum)* and waterbuck *(Kobus ellipsiprymnus)* (Bedford, 1926; Bequaert, 1940, 1942; Haeselbarth *et al.,* 1966; Maa, 1968; 1969; Boomker *et al.,* 1983; Horak *et al.,* 1989; 1992).

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Received 14 August 1992—Editor

L. paradoxa has an interesting life cycle in that the 3 larval instars develop *in utero* and the ensuing prepupa is deposited on the host animal. The prepupa falls to the ground and pupates. The imago that hatches is winged, but the wings break off once a host is found, the fly thus becoming confined to the host.

In this paper important taxonomic features of *L. paradoxa* are illustrated by means of scanning electron photomicrographs and the morphology of the puparium is described for the first time. The fly's geographic distribution and host-preference within the Republic of South Africa, which had hitherto been based on collections from individual animals, are now more clearly defined by surveys conducted in various regions on numerous hosts. The seasonal abundance of *L. paradoxa* on kudus in the Kruger National Park, eastern Transvaal Lowveld is discussed, as well as the ratio of male to female flies on these and other antelopes.

TAXONOMY

MATERIALS AND METHODS

Scanning electron microscopy (SEM)

Adult flies

Both fresh material and material stored in alcohol were used for SEM purposes. Dirt on specimens was removed with KOH or NaHpCl in an ultrasonic cleaner, or carefully brushed off with acetone before drying. Fresh specimens were frozen for 24 h or more, whereafter relevant structures were dissected out under a stereoscopic microscope and freeze-dried for 24 h. Specimens stored in alcohol were dehydrated in graded ethyl alcohol and completely desiccated in an oven at 35 °C. All specimens were stored in a desiccator until mounted on stubs using a chloroform-based adhesive. Small specimens were mounted with colourless nail varnish. Specimens were sputter-coated with gold and examined with an ISI 100 scanning electron microscope.

Puparia

Pupae were obtained from flies collected from immobilised bushbuck and kept in an incubator at 25 °C and 30 % RH until eclosion. The empty puparia were cut in half, mounted and sputter-coated as described for the adult flies.

Lipoptena paradoxa Newstead, 1907

Lipoptena paradoxa Newstead, 1907: 91;

Echestypus paradoxus Bruce, Hammerton & Bruce, 1911: 228;

Eschetypus paradoxus Curson, 1928: 182, laps cal.;

Echestypus parvipalpis Speiser, 1907: 3, 5; Falcoz, 1929: 52.

The institutions from which dry, or alcohol preserved, or slide-mounted specimens were obtained for study and comparison are listed below:

BMNH — British Museum (Natural History)
KGP — Kalahari Gemsbok National Park
KNP — Kruger National Park
NMSA — Natal Museum, South Africa
SAMC — South African Museum, Cape Town
SANC — South African National Collection of Insects
VRIO — Veterinary Research Institute, Onderstepoort
ZMHB — Museum für Naturkunde der Humboldt Universität zu Berlin

There are 2 syntype females. One of these is preserved in 70 % ethyl alchohol and the other is mounted under a coverslip on a glass slide. Information concerning these flies is given verbatim from the labels. Lines on the labels are separated by a slash (/), and different labels, from the top of the pin to the bottom, by a double slash (//).

Cotype: female; *Lipoptena paradoxa* / Newst. Type lot / On antelope / Kasongo / 28–1–05 Dutton & Todd // Kasongo / Congo Free State / 28–1–1905 / Drs Dutton & Todd / Recd. fr. R. Newstead // On antelope // *Lipoptena* / Co / type / paradoxa / Newstead // BMNH.

We hereby designate the alcohol preserved specimen as the lectotype and the other fly becomes a paralectotype.

Material examined

The material listed below was collected in South Africa by the authors and is deposited at the National Museum, Bloemfontein, Republic of South Africa.

115 specimens, Pafuri (23° 27′ S, 31° 19′ E), KNP, Transvaal (Tvl), ex kudu, 1981; 5 ♂, 5 ♀, Pafuri, KNP, ex bushbuck, 6 Oct. 1981; 5 ♂, 5 ♀, Pafuri, KNP, ex nyala, 6 Oct. 1981; 198 specimens, Satara (24° 23′ S, 31° 47′ E), KNP, ex kudu 8 Oct. 1982; 5 ♂, 5 ♀, Riekerts Laager (24° 30′ S, 28° 29′ E), Tvl, ex common duiker, 5 Nov. 1980; 1 ♂, 1 ♀, Skukuza (24° 58′ S, 31° 36′ E), KNP, ex kudu, 8 Jan. 1990; 1 ♂, 1 ♀, Skukuza (24° 58′ S, 31° 36′ E), KNP, ex kudu, 8 Jan. 1990; 1 ♂, 1 ♀, Skukuza, KNP, ex impala, 23 Apr. 1980; 1♀, Skukuza, KNP, ex lion, 14 Oct. 1986; 69 ♂, 94 ♀, Skukuza, KNP, ex bushbuck, 10 Jan. 1990; 13 ♂, 40 ♀, Skukuza, KNP, ex bushbuck, 6 Mar. 1990; 147 ♂, 282 ♀, Skukuza, KNP, ex bushbuck, 8 Mar. 1990; 166 ♂, 401 ♀, Skukuza, KNP, ex bushbuck, 4 Apr. 1990; 2 ♀, Kruger Gate (24° 59′ S, 31° 29′ E), KNP, ex cheetah, 3 July 1988; 2225 specimens, southern KNP (between 25° 06′–25° 21′ S and 31° 27′–31° 36′ E), ex kudu, 1981–1983; 1 ♂, 2 ♀, Mbyamiti (25° 15′ S, 31° 36′ E), KNP, ex impala, 21 Jan. 1981; 5 ♂, 5 ♀, Malelane (25° 28′ S, 31° 31′ E), KNP, ex kudu, 7 Dec. 1981; 5 ♂, 5 ♀, Umfolozi (between 28° 12′–28° 21′ S and 31° 42′–31° 59′ E), Natal, ex nyala, 18 Mar. 1983; 1 ♂, Charters Creek (28° 14′ S, 32° 25′ E), Natal, ex red duiker, 21 Mar. 1983; 5 ♂, 5 ♀, Charters Creek, Natal, ex bushbuck, 22 Mar. 1983; 5 ♂, 5 ♀, Weza State Forest (30° 35′ S, 29° 45′ E), Natal, ex bushbuck, April 1984; 5 ♂, 5 ♀, Andries Vosloo Kudu Reserve (33° 07′ S, 26° 40′ E), Cape Province, ex kudu, 21 Oct. 1985; 3 ♂, Southwell (33° 32′ S, 26° 41′ E), Cape Province, ex caracal, January 1986.

Material borrowed from other institutions:

1 ♀, Monze (16° 16′ S, 27° 29′ E), Northern Rhodesia (Zambia), ex bushbuck, 1959 (SAMC); 1 ♀, Chipangali (locality uncertain), Zambia, ex common duiker, 13 May 1963 (NMSA); 1 ♂, 4 ♀, Beira (19° 50′ S, 34° 52′ E), Mozambique, ex oribi, 15 Nov. 1941 (SAMC); 1 ♀, Pafuri, KNP, Tvl, ex nyala, date not given (VRIO); 1 ♂, 5 ♀, Nylsvley (24° 29′ S, 28° 42′ E), Tvl, ex kudu, 11 Sept. 1980 (VRIO); 11 ♂, 17 ♀, Skukuza, KNP, ex bushbuck, 15 Nov. 1982 (KNP); 10 ♂, 5 ♀, Skukuza, KNP, ex bushbuck, 18 Nov. 1982 (KNP); 1 ♂, Skukuza, KNP, ex impala, 2 June 1984 (KNP); 3 ♂, 5 ♀, Mbyamiti, KNP, ex kudu, 13 Aug. 1984 (KNP); 1 ♂, 4 ♀, Berg en Dal (25° 26′ S, 31° 26′ E), KNP, ex kudu, 31 Oct. 1986 (KNP); 2 ♂, 2 ♀, Barberton (25° 48′ S, 31° 03′ E), Tvl, host not given, 20 Aug. 1924 (SANC); 2 ♂, 1 ♀, Barberton, Tvl, ex bushbuck, 9 Oct. 1919 (SANC); 2 ♂, Ndumu (between 26° 50′–26° 56′ S and 32° 09′–32° 21′ E), Natal, host not given, 8 Oct. 1970 (VRIO); 7 specimens, Zululand (locality not supplied), host not given, 1922 (SANC); 1 ♂, Umfolozi, Natal, ex common duiker, 26 Oct. 1965 (NMSA); 1 ♀, Umfolozi, Natal, ex nyala, 26 Oct. 1965 (NMSA); 4 ♀, Bucklands* (locality uncertain), Cape Province, ex kudu, 21 Aug. 1976 (SAMC); 1 ♀, Bucklands (locality uncertain), Cape Province, ex kudu, 10 Oct. 1976 (SAMC); 2 ♀, Bucklands (locality uncertain), Cape Province, ex kudu, 29 Mar. 1977 (SAMC); 1 ♂, Bucklands (locality uncertain), Cape Province, ex kudu, 16 June 1977 (SAM); 6 ♀, Harvest Vale (locality uncertain), Cape Province, host not given, 3 May 1910 (SANC).

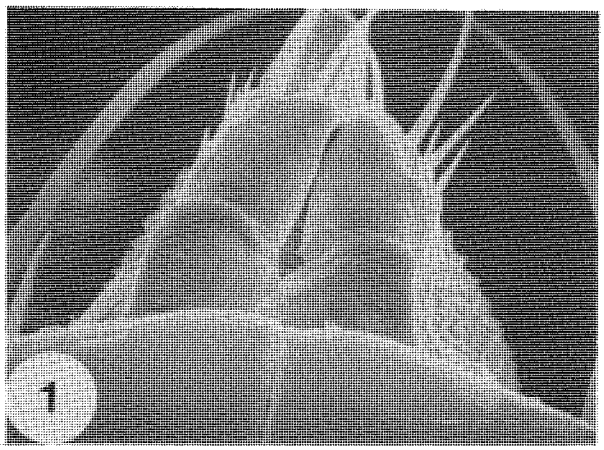
DESCRIPTION OF IMAGO

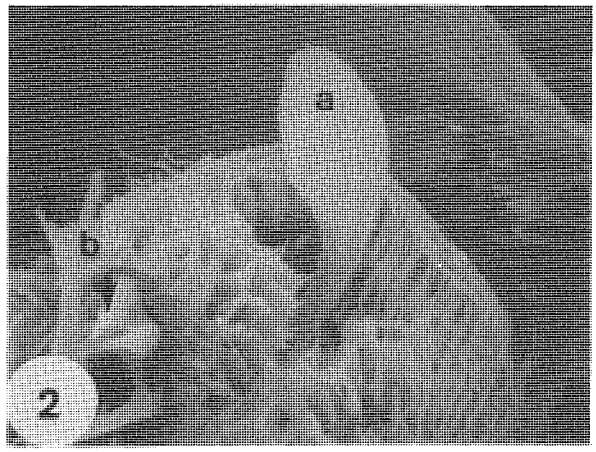
Female

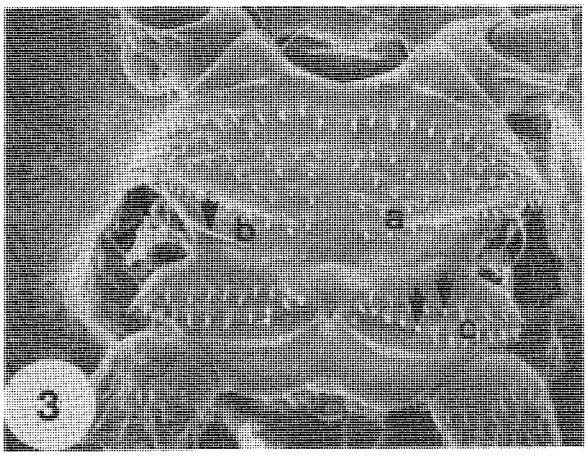
Length (head and thorax): 1,87–2,1 mm.

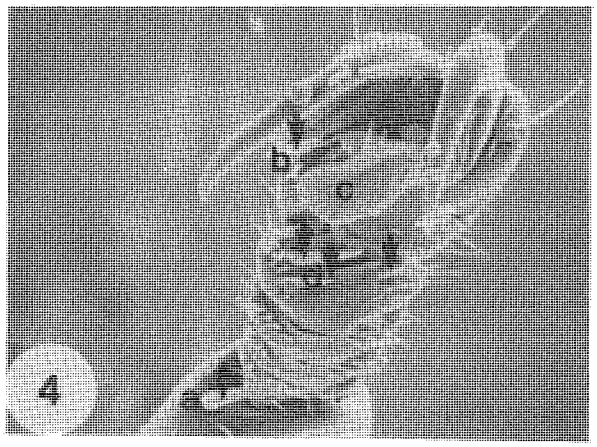
Head: width 1,0–1,1 mm, extended behind eyes; mediovertex 0,18–0,30 mm × 0,15–0,22 mm, nearly as long as or slightly longer than wide, about as long as frontoclypeus and slightly longer than postvertex (0,12–0,20 mm). Clypeus fused with frons, median longitudinal furrow rather short, ending in a circular pit; preptilinal area distinct but short; inner orbit

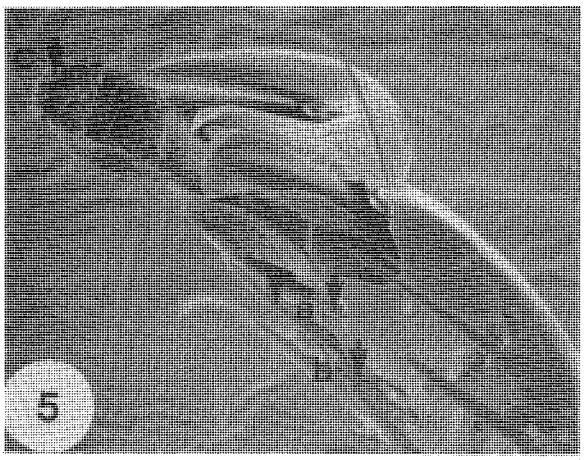
* This farm probably adjoins the Andries Vosloo Kudu Reserve from which some of our own material was collected











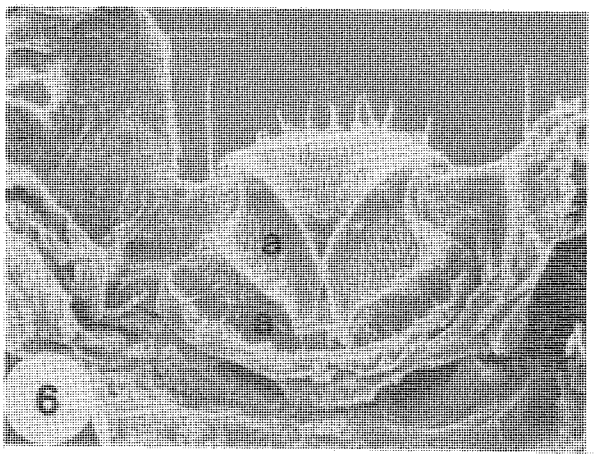
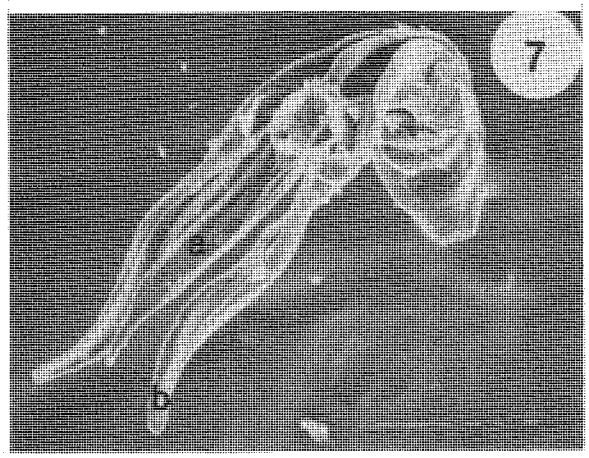
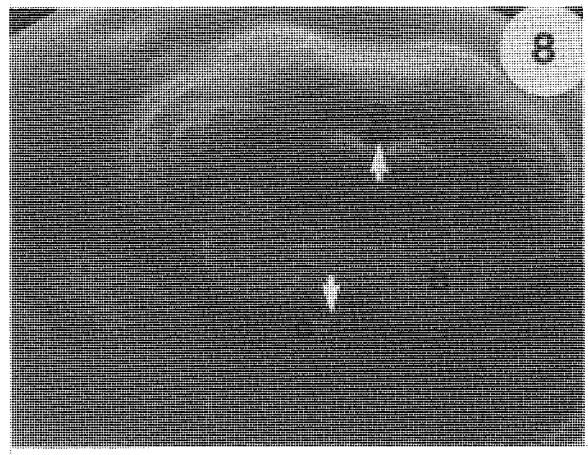


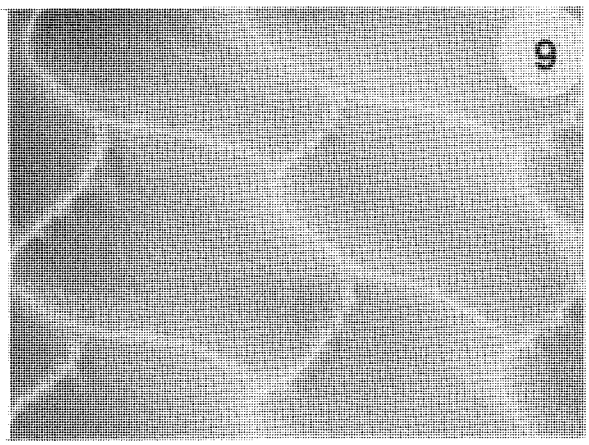
FIG. 1–6 *Lipoptena paradoxa* (female fly)

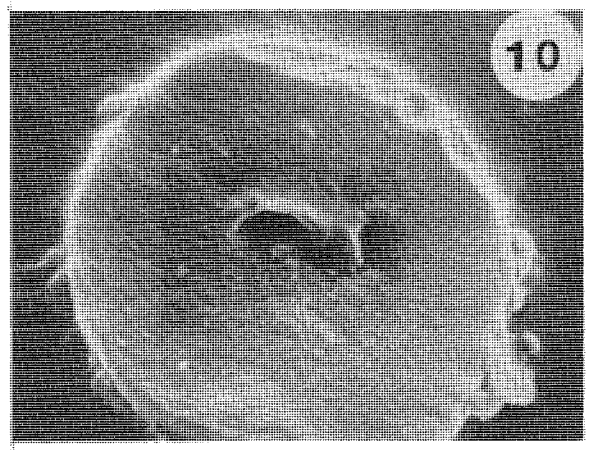
(1) Extended palpi with setae at the apex
(2) Tip of antenna with arista (a) and setae (b)
(3) Ventral view of the thorax showing the mesosternum with 4 or 5 rows of short spines (a) and 1 pair of posterolateral bristles (b). The metabasisternum has spines in 2 regular rows (c)
(4) First tibia with an apical spur (a), vestigial anterior pulvillus (b), well-developed posterior pulvillus (c), and the 4th and 5th tarsal segments with 1 large and 2 small spines (d)
(5) Third tarsus with 2 large plantar spines (a), a small ventral spine (b), and the long and well developed posterior pulvillus (c)
(6) Postgenital plate (a) after removal of the pregenital plate

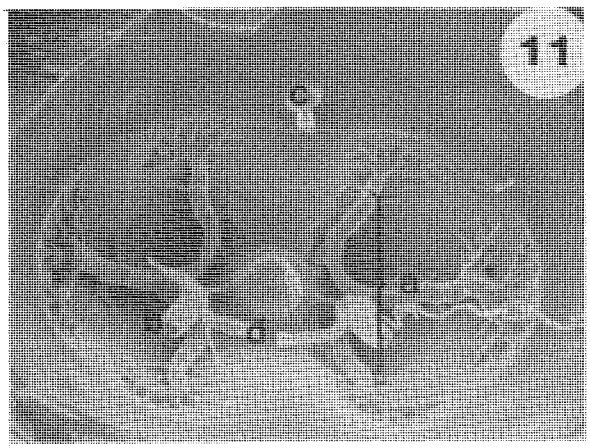
(Scale: — — — ——— 100 µm; — — ——— 10 µm; — ——— 0,1 µm)











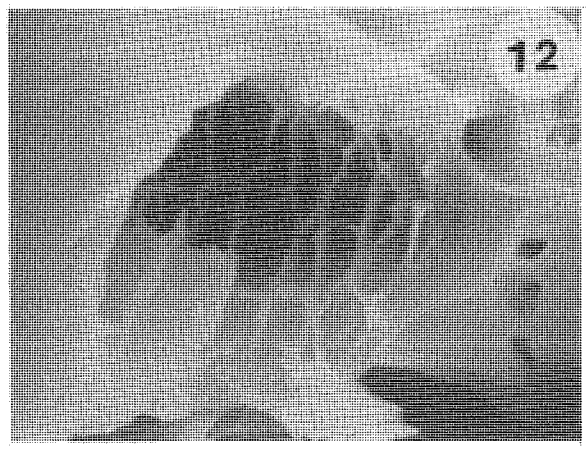


FIG. 7–12 *Lipoptena paradoxa*

(7) Male genitalia showing the aedeagus (a) and the parameres (b)
(8) Posterior end of the puparium with central depression and tracheal openings (a), spiracles (b) and the anal opening (c)
(9) Cuticular pattern between the spiracles on the puparium
(10) Spiracular pore on puparium with small central opening surrounded by a circular plate
(11) Interior of the posterior part of the puparium with 3 large tracheal branches on either side (a), each with smaller radiating branches. A large branch (b) with a smaller side branch (d) extends into the body. The apical pit is visible at (c)
(12) Supporting cuticular meshwork in a tracheal branch of the puparium

(Scale: — — — ——— 100 μm; — — ——— 10 μm; — ——— 0,1 μm)

0,15–0,20 mm, narrower than eye (0,28–0,32 mm), with 1 long vertical bristle; 2 short orbital bristles and 5 fine, very short orbital setae in an inner curved row. Anterior margin of frontoclypeus, between longitudinal furrow and apex of antennal pit, bearing 6 small setae; 5 short setae and 1 long bristle ventrally, next to palpi; 2 long bristles and 4 short setae below eye. Outer margin of eye bears a series of fine spines and a few scattered short fine setae are present on the postgena. A few setae on the gula at the concave margin of prosternal lobes. Postvertex short and very wide, flattened semi-elliptically. Rudimentary or vestigial palpi, only barely or not at all visible beyond anterior margin of frontoclypeus from above. However, SEM of a newly hatched fly shows extended palpi each with 7 setae on the apex (Fig. 1). Antennae short, sub-globular and recessed in antennal pits, which are surrounded by a continuous rim. Fig. 2 provides a more detailed picture of the antennal setae and arista.

Thorax: Prothorax: Pronotum transverse, anterior margin concave and posterior margin angularly convex. Promesonotal suture clearly visible.

Mesothrorax: median notal suture very faint, no intrascutal grooves; transverse mesonotal suture broadly interrupted medially; posthumeral suture well-demarcated. Large mesothoracic spiracle at posterolateral edge of humeral callosity. According to Bequaert (1942) mesonotal chaetotaxy of type specimen consists of 6 acrostichals in a curved row, some distance from the middle line. However, they are asymmetrically placed and may vary from 4 to 7 on either side. Three humerals and 2 laterocentrals close to notopleuron, and 2 rows each of 4 or 5 notopleurals, those of posterior row very long; usually 4 (rarely 3 or 5) scutellars in 2 pairs, inner pair very long; 3 or 4 postalar bristles, inner pair very long; 1 pair of very long posterior dorsocentral bristles; prosternal lobes with 2–3 ventral spines and 1 bristle on anterior inner margin. Mesosternum with a pair of long posterolateral bristles, and numerous relatively short spines, arranged more or less in 4–5 regular transverse rows, of which those of the 1st row are the largest.

Metathorax: Metabasisternum with 2 regular rows of spines, length and robustness similar to those of the last 3 rows on the mesosternum (Fig. 3).

Legs: Anterior coxa enlarged bearing oblique marginal row of setae dorsally, 1 of these very long; ventroposteriorly a row of 4 long setae; femora 1–3 with 3, 3 and 5 major dorsal bristles respectively; 1 anterior bristle on femora 1 and 3; tibiae 1–3 with 1, 2 and 3 apical spurs respectively (Fig. 4); tibia 3 with 3 major ventral bristles (plus a few minor ones), which are slightly longer but less robust than longest apical spur; tarsi 1–2 without ventral spines on segments 1–3, but with 1 major and 2 very small ventral spines on each of segments 4 and 5; tarsus 3 with 2, 1 and 1 small anterior spines on under-sides of segments 1–3 respectively, 2 major plantar spines and 1 minor ventral spine on each under-side of segments 4 and 5 (Fig. 5); anterior pulvilli of all legs vestigial, posterior pulvilli well-developed (Fig. 4); claws slightly asymmetrical.

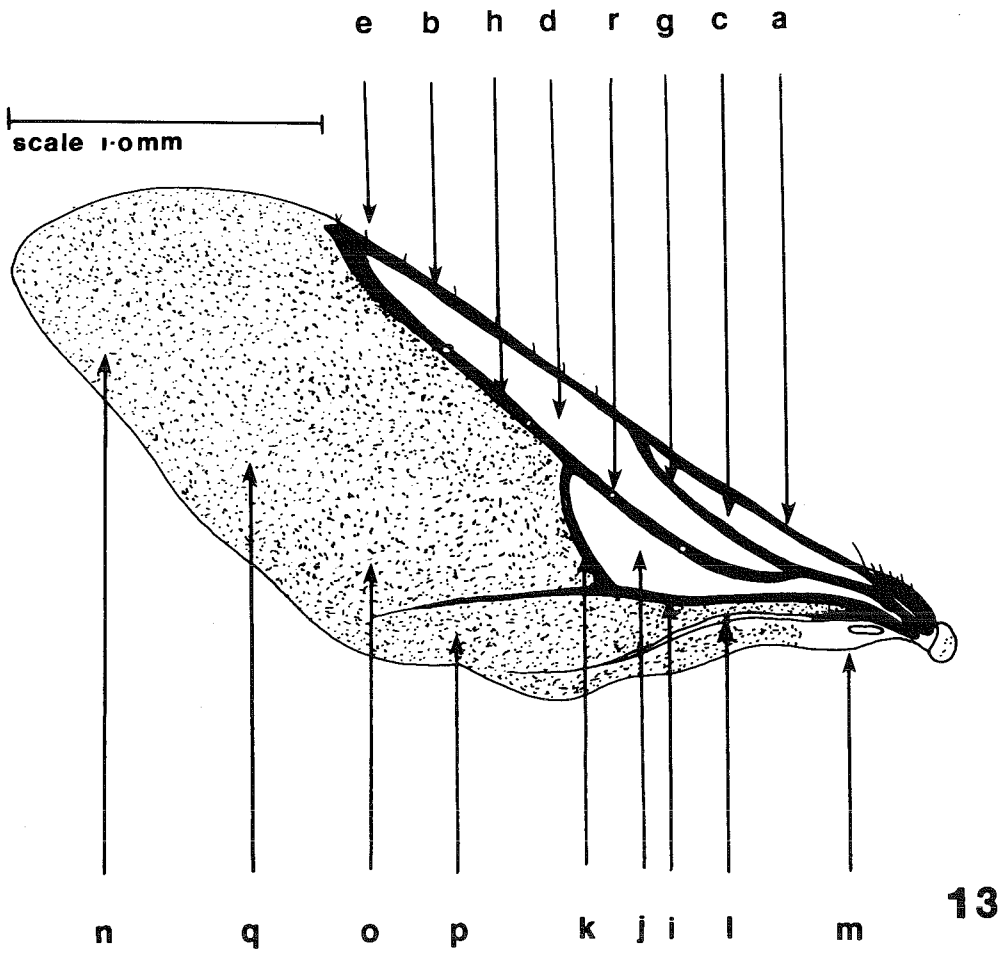
Wings: Length: 2,96 mm. Wing venation (Fig. 13) similar to that of *Lipoptena cervi* Linnaeus 1758 (Bequaert, 1940). Only 3 well-developed longitudinal veins are present, apparently the 1st (R1), 3rd (R4 & 5) and 5th (M_3 & C_2); the 6th (2nd An) is incomplete; other veins indicated by concave lines; only 1 cross-vein, between assumed 3rd and 5th longitudinals, and therefore, according to Bequaert (1940), probably a fusion of the anterior basal cross-vein (M_3), anterior cross-vein (r–m) and portion of 4th longitudinal vein (M_1 & M_2); the 3rd longitudinal ends in the tip of the costa at an acute angle without a knob-like swelling; costa thickened only at extreme base and between tips of 1st and 3rd longitudinals. Four sensoria on 3rd (R4+5) longitudinal vein. The thickened basal costa (CO1) has 1 long and a few short setae. Apical costa (CO2) has 8 setulae. Dorsal surface of basal cell and 2nd marginal cell free of microtrichia (Fig. 13). Microtrichia ventrally on basal cell and apical angle of 2nd marginal cell (between CO2 and R4+5) (Fig. 14); dorsal and ventral cells 3r, 1m and 2m as well as the axillary cell bear microtrichia. Alula rudimentary; no closed anal cell; haltere well-developed.

Abdomen: basal dorsal sclerotized pleurite I large, transverse, with a marginal row of long bristles and angular row of shorter setae on disc; pleurites II to V well demarcated and lightly sclerotized with a few uniformly spaced setae; 5 median tergal plates, all short and transverse, gradually increasing in size from 1st to 3rd, 4th smaller; 1st and 2nd bear a medially interupted transverse row of 4 to 6 setae; 3rd and 4th with 1 or 2 setae in each corner; 5th divided into 2 sclerites, each bearing 2 setae; remainder of dorsum usually extensively sclerotized, with traces of segmentation, and a few setae towards edges. Basal ventral sclerite broadly emarginate at apex, somewhat more shallowly than in other species, with broader lobes to the crescent; many sturdy setae along hind margin and a few on disc, 2 of the very long setae are placed near tip of each lobe; ventral portion of pleurites well-demarcated; abdominal spiracles small, more or less sclerotized, with fairly uniformly spaced setae arising from thickened bases, spiracles VI and VII almost enclosed in 4th and 5th tergal plates.

Genitalia: Median pregenital plate elongate, weakly sclerotized, with 3–5 setae in a transverse series on posterior margin, outer pair usually longer and more robust; lateral pre-genital plate entirely wanting; supra-anal plate with very fine and rather robust small setae. Fig. 6 illustrates post-genital plate after removal of pre-genital plate. Infra-anal plate with rather dense posterior setae, about as long as those on supra-anal plate and as stout as those on disc of abdominal venter.

Male

Length (head and thorax): 1,65–1,80 mm. Similar to ♀ in structure and chaetotaxy. Only 4 median tergal plates, corresponding to T1–4 of female, somewhat larger than in that sex, particularly the 1st and 2nd. Post-genital plate narrow with slightly broader anterior end (Maa, 1965). Parameres (Fig. 7) long, slender, straight, sharply pointed and punc-



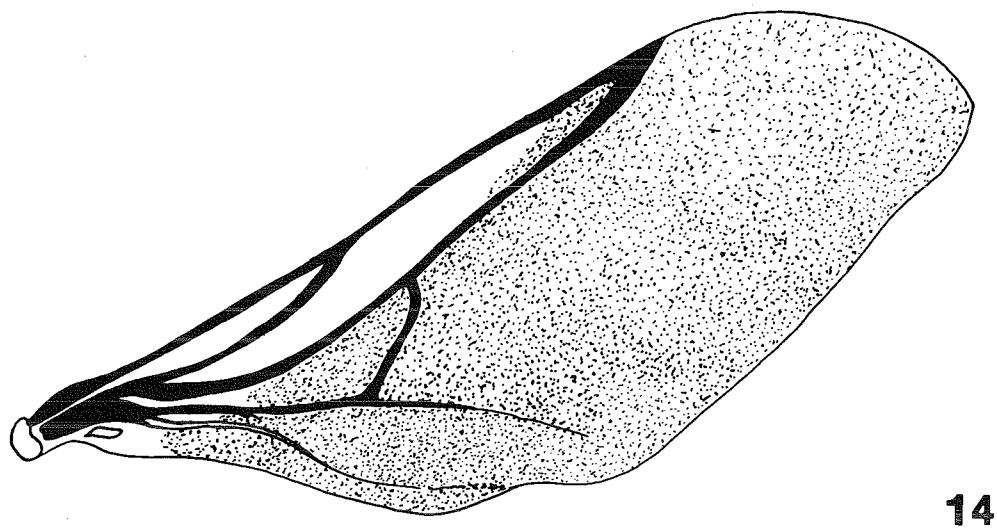


FIG. 13 and 14 *Lipoptena paradoxa*

(13) Wing (dorsal) venaton and distribution of microtrichia
(a) basicosta CO1; (b) apical costa CO2; (c) 1st marginal cell; (d) 2nd marginal cell; (e) setulae; (g) R1; (h) R4+5; (i) M3+C1; (j) 1 + 2nd basal cell; (k) M3 + r–m cross-vein; (l) 2nd An; (m) alula—rudimentary; (n) 3r cell; (o) 1m cell; (p) 2m cell;(q) microtrichia; (r) sensoria

(14) Distribution of microtrichia on ventral aspect of wing

tate; aedeagus narrow, sharply pointed cone of which the dorsolateral surfaces are covered with small setae.

DESCRIPTION OF PUPARIUM

The small, black, oval puparium of *L. paradoxa* is *ca* 2,2 mm long and *ca* 1,6 mm wide. Small anterior buccal opening with a slit-like extension. Circular seam of anterior cap, through which adult escapes, runs across and around surface of puparium, while the semicircular seam passes over the top to the sides and ends in circular seam.

The surface of the puparium is smooth and shiny with an indistinct polygonal pattern. The protruding posterior end of the puparium bears the tracheo-spiracular system. The spiracular pores radiate laterally from a central depression at the posterior end of the puparium, which contains 2 tracheal openings, and form 3 areas with a distinct pentagonal pattern on either side (Fig. 8 and 9). Each spiracular pore consists of a circular plate with a granular appearance and a small central opening (Fig. 10). Ventrally, just anterior to the posterior plate, there is a circular opening (the anus) with a raised cuticular rim described by Maa (1963, 1969) and Baker (1990) as the ventro-apical pit (Fig. 8). Three internal tracheal branches are attached to tracheal openings in the pupal wall on either side of the central depression (Fig. 11). These have shorter secondary branches extending to spiracular openings (Fig. 11) A larger tracheal branch with a smaller side branch extends into body of the pupa on either side (Fig. 11). Internal surface of trachea honeycombed with cuticular thickenings (Fig. 12).

DISCUSSION

Imago

Newstead in his original description of the fly, published in Newstead *et al.* (1907), noted the almost entire absence of external mouthparts, with the only indication of these organs being a minute truncated cone. Ferris (1930), however, stated that the palpi, while extremely small and in some individuals retracted into the head, are clearly recognisable and apparently constitute the cone mentioned above. In our studies, SEM of a newly hatched fly shows extended palpi attached to the head by a membranous structure giving the impression that the palpi are 2-segmented (Fig. 1).

No mention is made of the spines and bristles on the ventral aspect of the thorax by Newstead (Newstead *et al.*, 1907), but Ferris (1930) remarks that the thorax is ventrally beset with rows of tubercle-like setae. Maa (1965) describes the chaetotaxy of the ventral abdomen in greater detail and our findings add to his description.

Although Newstead did not describe the tarsus and claw of *L. paradoxa,* he has illustrated these structures, indicating a single pulvillus (Newstead *et al.*, 1907). Ferris (1930) has, however, illustrated the last tarsal segment as bearing 2 equal-sized pulvilli without commenting upon this in the text. Maa (1956) states that the anterior pulvilli are all vestigial, a finding with which we concur (Fig. 4).

No previous description of the wings of this fly has been published. We obtained newly hatched, winged specimens for this purpose from pupae incubated in the laboratory and based our nomenclature of the wing venation on that supplied by Bequaert (1940; 1942) and Maa (1963).

Puparium

The size and shape of the puparium of *L. paradoxa* is similar to that of *L. mazamae*. Baker (1990) gives a detailed description of the hexagonal pattern, with spherical cuticular extensions, which encircles the posterior end of the puparium of *L. mazamae*, but this is not mentioned in the case of the closely related *Lipoptena depressa* Say, 1823. This pattern does not occur in *L. paradoxa* (Fig. 9).

Baker (1990) also observed that the remainder of the puparial surface of *L. mazamae* has a polygonal pattern with distinct pits. The surface of the puparium of *L. paradoxa* is covered with a mesh of microscopic lines without pits. More research is needed to determine whether the differences in surface pattern and sculpturing are taxonomically important.

Anteriorly the ventral slit-like extension of the buccal opening of *L. paradoxa* is much larger and folded more deeply than that of *L. mazamae*. Posteriorly the number and arrangement of the spiracles also differ. We consider the large opening below the posterior end of the puparium (Fig. 11), which is referred to as the ventro-apical pit (Maa, 1963, 1969; Baker, 1990), to be the anal opening and it seems to be similar to that of *L. mazamae*. Details of the anal opening, and internal and external structure of the puparium of *L. paradoxa* are given in Fig. 8 and 11.

Previous descriptions of the tracheal branches of *Lipoptena* do not mention the 2 larger tracheal branches with 2 smaller side branches which extend forward into the body of the pupa (Fig. 11). The internal and external structure of the spiracular pores on the posterior end of the puparium also requires further investigation.

BIOLOGY

METHODS, RESULTS AND DISCUSSION

Geographic distribution

This was ascertained from the collection localities of specimens lent to us for taxonomic study and those we collected ourselves during surveys of ectoparasites of various hosts (Boomker *et al.*, 1983; Horak *et al.*,1989; 1992).

The geographic distribution of *L. paradoxa* within the Republic of South Africa is depicted in Fig. 15.

The fly is present in the eastern half of the country and then particularly in those regions where there are woodland, thickets or scrub of sufficient height to provide shelter for the hosts. It occurs at altitudes from a few metres to 2 000 m above sea level. Most collections, however, were made at altitudes below 600 m. The eastern regions of South Africa lie within the summer rainfall region of this country. With the possible exception of the south-western Cape

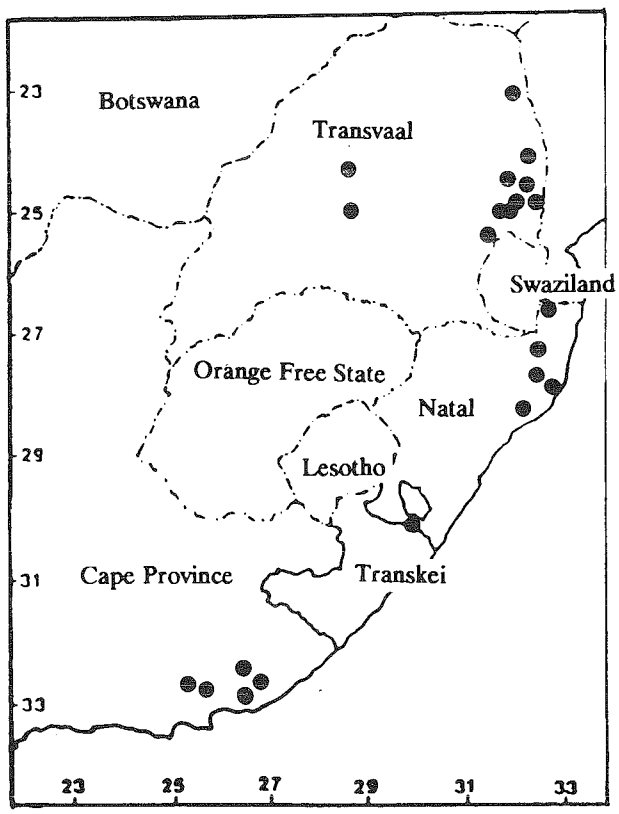


FIG. 15 The geographic distribution of *Lipoptena paradoxa* within the Republic of South Africa

TABLE 1 Birds and mammals examined for ectoparasites, including *Lipoptena paradoxa*, at various localities in South Africa within the distribution range of the fly. The preferred hosts of *L. paradoxa* are indicated in bold type

Species	Common name	Total No. examined
Birds		
Numida meleagris	Helmeted guineafowl	194
Mammals		
Lepus saxatilis	Scrub hare	312
Crocuta crocuta	Spotted hyaena	2
Acinonyx jubatus	Cheetah	2
Panthera pardus	Leopard	3
Panthera leo	Lion	5
Felis caracal	Caracal	22
Lycaon pictus	Wild dog	1
Canis adustus	Side-striped jackal	1
Equus burchelli	Burchell's zebra	33
Potamochoerus porcus	Bushpig	8
Phacochoerus aethiopicus	Warthog	68
Giraffa camelopardalis	Giraffe	2
Connochaetes taurinus	Blue wildebeest	47
Cephalophus natalensis	Red duiker	23
Sylvicapra grimmia	**Common duiker**	29
Aepyceros melampus	Impala	140
Capra hircus	Domestic goat (Angora)	48
Ovis aries	Domestic sheep (Dorper)	48
Bos sp.	Domestic cattle	46
Syncerus caffer	Buffalo	4
Tragelaphus strepsiceros	**Kudu**	133
Tragelaphus angasii	**Nyala**	9
Tragelaphus scriptus	**Bushbuck**	26
Taurotragus oryx	Eland	3
Redunca arundinum	Reedbuck	27

Province, which has a mediterranean climate, the eastern half of the country is moister than the west.

The preferred hosts of the fly all prefer savanna woodland or thickets and generally avoid open country (Smithers, 1983). Thus within its distribution range *L. paradoxa* is restricted to localities in which its preferred hosts occur and hence in which woodland or thickets predominate.

Hosts

Host preference was determined from animals we have examined within the distribution range of the fly during various surveys of ectoparasites, some of which have been published (Boomker *et al.*, 1983; Horak, Keep, Flamand & Boomker, 1988; Horak *et al.*, 1989; 1992). The species and numbers of animals examined are listed in Table 1.

Of all the species examined only those from which *L. paradoxa* was recovered are listed in Table 2. The regions in which these hosts were examined and the total numbers of flies collected are also given in this table.

Bushbuck, nyala, kudus and possibly common duikers are the preferred hosts. Twelve of the 16 common duikers examined in the central Transvaal were infested, but not 1 of the 13 seen in south-eastern Natal.

The preferred hosts are all browsers and consequently are found in or near woodland or thickets where browse is plentiful (Smithers, 1983). Although common duikers may be considered preferred hosts, where they and bushbuck were shot in the same habitat in the Weza State Forest, south-eastern Natal, not 1 of the 13 duikers was infested, while 6 of the 13 bushbuck were (Horak *et al.*, 1989; Table 2). All the bushbuck examined at other localities were infested and harboured considerably larger individual burdens than any of the animals shot in the Weza Forest.

All other animal species we found to be infested harboured very low individual burdens. Where fairly large numbers had been examined, as in the case of impala, red duikers and caracals only a small percentage of hosts was infested. We cannot comment on the host status of roan antelope, grysbok, oribi and waterbuck listed as hosts by Haeselbarth *et al.* (1966) and Maa (1969). We have either not examined these animals or have not examined them within the distribution range of the fly. Although Haeselbarth *et al.* (1966) list common reedbuck as a host not 1 of the 27 animals we examined was infested.

Study area for biology on kudus

This has been described by Boomker, Horak & De Vos (1989). In summary the site is situated in the southern part of the Kruger National Park between latitudes 25° 06′–25° 21′ S and longitudes 31° 27′–31° 36′ E and an altitudinal range from 200–350 m. The vegetation is classified as Lowveld (Acocks, 1988). The days are warm to very hot in summer and mild in winter and frost occurs occasionally. Rainfall varies form 600–700 mm per annum and usually falls in summer.

TABLE 2 Hosts in various regions of South Africa from which the authors have collected *Lipoptena paradoxa*

Host species	No. examined	No. infested	Total number of flies recovered
North-eastern Transvaal Lowveld			
Impala	4	0	0
Kudu	2	2	501
Nyala	2	2	314
Bushbuck	3	3	559
Eastern Transvaal Lowveld			
Cheetah	2	1	2
Lion	5	1	1
Impala	134	3	6
Kudu	97	96	5 082
Bushbuck	8	8	2 768
Eland	2	1	8
Central Transvaal			
Common duiker	16	12	277
North-eastern Natal			
Red duiker	23	1	2
Impala	2	0	0
Nyala	9	9	635
Bushbuck	2	2	564
South-eastern Natal			
Common duiker	13	0	0
Bushbuck	13	6	156
South-eastern Cape Province			
Caracal	22	1	3
Kudu	34	29	514
Eland	1	0	0

Survey animals

Each month from April 1981 to March 1983, 4 kudus were shot in the study area. At each occasion an attempt was made to obtain 1 adult male, 1 adult female, 1 young adult male and 1 juvenile or calf of either sex. The animals were aged according to the criteria described by Simpson (1971). Collections were made not less than 3 weeks or more than 5 weeks apart. A total of 96 kudus were shot but only 95 were examined as the material collected from 1 had been inadequately preserved. For statistical reasons, the animals were grouped, according to age, into calves, 0–12 months old (age group 1), juveniles, 13–24 months old (age group 2), young adults, 25–48 months old (age group 3) and prime or old adults, 49 months and older (age group 4) (Boomker *et al.*, 1989).

Four bushbuck were chemically immobilised in the Skukuza region of the KNP and live flies for pupal studies were collected from them.

Parasite recovery

The carcasses of the kudus were transported to the laboratory at Skukuza where they were processed for parasite recovery. The carcass of each animal was skinned and half the skin of the head and half the skin of the neck, body and upper legs, the whole skin of the tail, and 1 lower front leg and lower back leg with skin attached were placed separately in plastic bags. A tick-detaching agent [Triatix; Coopers SA (Pty) Ltd] was added to the skins in the bags and these were stored overnight. The following morning the skins were thoroughly scrubbed with brushes with 40 mm long steel bristles and washed. The tick-detaching agent remaining in the plastic bags and the material obtained from scrubbing and washing the skins were sieved over sieves with 0,15 mm apertures. The residues in the sieves were collected and preserved separately in 10 % formalin.

Representative samples of the material collected were examined under a stereoscopic microscope for the presence of lice, ticks and louse flies. The remainder of the material was examined macroscopically for adult ticks and louse flies. Only the data pertaining to the louse flies are reported here, those obtained for the lice and ticks have been published by Horak *et al.* (1992). The kudus were also examined for internal parasites and the findings published (Boomker *et al.*, 1989).

Observations on flies

The seasonal abundance of the flies on the kudus during the 2 years of the survey is illustrated in Fig. 16. The largest numbers of flies were present on the kudus from August 1981 to January 1982 and from July 1982 to January 1983. Large numbers of flies were recovered from the tails of the kudus from November to January during both years of the survey.

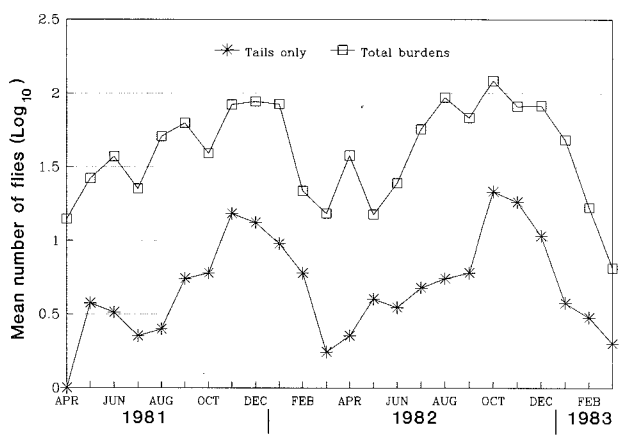


FIG. 16 The seasonal abundance of *Lipoptena paradoxa* on kudus in the southern region of the Kruger National Park

The pattern of abundance on the kudus could be due to the seasonal preference of the flies or the behaviour of the kudus. If it is due to the former, it would indicate that large numbers of flies hatched in mid-winter and early spring after prolonged pupal periods and infested the kudus. Since hippoboscid flies produce only a single mature 3rd instar larva at a time, with perhaps several days between successive larvae, it implies that each female fly would have to survive for several weeks or months to produce sufficient larvae to ensure the survival of the species. These flies and their offspring, which emerged after shorter pupal periods during summer,

would then be responsible for the 5 to 6 month period of peak abundance on the kudus.

If the pattern of abundance was caused by the behaviour of the kudus this would presuppose that kudus frequent habitat that is favourable for the survival of pupae from July or August to January. Such habitat would be dense riverine scrub and bush, the preferred habitat of bushbuck, or wooded slopes of hills and in valleys, where kudus tend to shelter during midday. The bushbuck immobilised during March and April 1990 and a bushbuck killed in a car accident in the Park during June 1982 (months of low *L. paradoxa* abundance on kudus), harboured considerably more flies than kudus, even during the periods of peak abundance on the latter animals. In addition 2 kudus shot during July 1980 in the Skukuza area, where the vegetation is much denser than in the study area, also harboured large numbers of louse flies (184 and 282). This seems to indicate that the pattern of abundance on kudus in the study area could be due to the antelopes' seasonal habitat choice within that region rather than the seasonal preference of the flies.

The large numbers of flies found on the tails of the kudus from November to January could be an attempt to escape grooming activities of the host during a period of peak abundance. Evans (1950) has described seasonal differences in the distribution of keds (*Melophagus ovinus*) in the fleece of various body regions of sheep. Amongst the preferred hosts of the louse flies, kudus have the shortest and sparsest hair cover. Especially during the warm summer months the bushy tails of kudus would afford protection for the flies against heat, firstly as cover against the sun and secondly, because of the long hair, an ideal means of moving away from the host's skin where the temperature would be fairly high.

The number of flies recovered from adult male and adult female kudus shot in the same months and from adult and juvenile animals also shot in the same months are compared in Table 3. Thus only data from animals that could be paired as to the months in which they were shot were used for comparison employing the paired Wilcoxon T-test.

TABLE 3 Differences in *Lipoptena paradoxa* burdens on paired age and sex groups of kudus shot in the Kruger National Park from April 1981 to March 1983

Kudu age	Kudu sex	Number of animals*	Mean number of flies	Signi-finance	Wilcoxon value	
					Calcu-lated	Table
Juveniles	Both sexes	14	78			
Adults	Males	14	62	P=0,10	19	22
Juveniles	Both sexes	13	86			
Adults	Females	13	31	P=0,04	17	18
Juveniles	Both sexes	15	78			
Adults	Both sexes	15	45	P=0,10	28	31
Adults	Males	15	63			
Adults	Females	15	26	P=0,01	11	16

* These animals could be paired with animals of different ages or sexes as both animals of each pair were shot during the same month

Adult male and juvenile kudus harboured significantly more flies than adult female kudus.

The smaller number of flies recovered from the adult female animals when compared with the adult males and the juveniles could be due to more efficient grooming by the females or to hormonal differences between the females and the other 2 groups of kudus. It could also be due to transference of flies from female animals to their calves, or as a result of differences in the resistance status of the various groups. If it was due to size one could expect males to harbour most flies, followed by females and then juveniles. There can, however, be many other reasons for these differences. In the case of ixodid tick infestation on domestic cattle, cows carry significantly fewer maturing females of *Boophilus microplus* than do male animals (Seifert, 1971). The 15 adult female kudus used for comparative purposes in the present study also carried significantly fewer nymphs and adults of the ixodid tick *Amblyomma hebraeum* and adults of *Boophilus decoloratus* than did the 15 adult male animals shot at the same time (Horak *et al.*, 1992). Similar differences were, however, not evident for the other tick species on the kudus.

The sex ratios of newly hatched flies, those collected from immobilised bushbuck, those collected from dead kudus, and those collected from common duikers by Boomker *et al.* (1983), are summarized in Table 4.

TABLE 4 The sex ratio of *Lipoptena paradoxa* hatching from pupae and recovered from bushbuck, kudus and common duikers in South Africa

Origin of flies	Number of animals examined	Number of male flies	Number of female flies	Sex ratio
Pupae	—	25	31	1:1,24
Immobilised bush-buck	4	395	817	1:2,07
Kudus	90*	853	1 253	1:1,47
Common duikers	16	103	173	1:1,68

* 96 kudu shot in total, flies for sex ratio determination only available from 90

The sex ratio of newly hatched flies was 1 male:1,24 females, on immobilised bushbuck it was 1:2,07 and on kudus and common duikers 1:1,47 and 1:1,68, respectively.

More females than males emerged from the pupae. A similar phenomenon has also been observed for *Hippobosca equina* (Hafez, Hilali & Fouda, 1977) and *Hippobosca longipennis* (Hafez & Hilali, 1978). In addition, the female flies probably also survive for longer on their hosts than do males if the findings for *H. equina* and *H. longipennis* are applicable (Hafez *et al.*, 1977; Hafez & Hilali, 1978). This would further accentuate the difference in the sex ratio. A single mating is apparently sufficient for the female to produce all her prepupae (Hafez *et al.*, 1977).

TABLE 5 The pupal period of *Lipoptena paradoxa* pupae incubated at various temperatures and relative humidities. The pupae were deposited by flies collected from bushbuck in the Kruger National Park

Pupal deposition date	Number of pupae incubated	Temperature (°C)	Relative humidity (%)	Number of adults emerged	Pupal period (days)
8 March 1990	11	25	30	1	32
8 March 1990	11	30	55	6	24
6 April 1990	47	25	30	23	23–28
6 April 1990	47	30	55	33	23–26

Observations on pupae

Flies captured on immobilised bushbuck were kept alive for as long as possible (1 or 2 days) without a blood-meal to allow them to produce fully developed larvae which became pupae. The pupae were placed in small glass tubes with gauze stoppers. These were suspended in plastic nets in long plastic jars which were half-filled with saturated solutions of $MgCl_2$ or glucose to produce humidities of 30 % and 55 % respectively.

To determine the effect of temperature on pupal duration, pupae were incubated at constant temperatures of 25° (30 % relative humidity) and of 30 °C (55 % relative humidity). The tubes were examined daily for adult emergence.

A total of 22 pupae were obtained within 24 h from 282 female flies collected from an immobilised bushbuck during March 1990. A total of 401 female flies collected from an immobilised bushbuck during April 1990 produced 94 pupae within 24 h. Approximately 1/4 of the latter flies thus produced prepupae within 24 h. This indicates that the period between the deposition of successive prepupa by individual flies may be as short as 4 days. Evans (1950) reports this period to be 7–8 days for *M. ovinus* and Hafez & Hilali (1978) found that for *H. longipennis* it could be 3–5 (mean 3,6) days during the warmer months and 3–8 (mean 6,4) days during the cooler months.

The numbers of flies that hatched from pupae after they had been incubated at various temperatures and relative humidities are summarized in Table 5.

There was considerable overlap in the pupal periods of the flies that hatched from those pupae kept at higher temperatures and humidities and of those kept at lower temperatures and humidities.

The greatest numbers of flies hatched during the daylight hours between 07:00 and 15:00. The newly emerged flies were very active and their wings expanded within a few minutes. However, some of the flies died just after emergence, while the wings of others failed to expand.

The pupal period of approximately 23–26 days recorded at 30 °C and 55 % RH corresponds fairly closely to the 20–26 days at 30 °C and 65 % RH recorded for *H. equina* by Hafez *et al.* (1977) and 19–23 days at 30 °C and 75 % RH for *H. longipennis* (Hafez & Hilali, 1978). The rate of emergence of adult *H. longipennis* from pupae was highest between 07:00 and 09:00, with few emerging at midday and none at night (Hafez & Hilali, 1978). Most of the *L. paradoxa* adults emerged in the early morning, but emergence continued till 15:00.

An attempt was made to ascertain the life-span and rate of reproduction of *L. paradoxa* by feeding newly emerged flies on a penned Cameroon goat. The flies were contained in a plastic tube with a gauze-covered lid at the 1 end and with the other end fixed tightly by means of glue and Elastoplast to the shaved neck of the goat.

The flies did not feed on the goat and all died.

Both *H. equina* and *H. longipennis* will feed successfully on guinea pigs and reproduce (Hafez *et al.*, 1977; Hafez & Hilali, 1978). As we were unable to get *L. paradoxa* to feed on the goat we consequently had to rely on pupae produced by flies collected from immobilised bushbuck for our studies on the life cycle.

The density of the vegetation frequented by the preferred host is probably essential for the survival of the pupae. The prepupae produced by the flies are not motile and rapidly darken and harden. In the field these prepupae would fall to the ground and the pupae would form on the soil surface, where they would be exposed to the elements. Hence, the dense type of vegetation preferred by the tragelaphine antelope is also the most suitable for the survival of the pupae.

ACKNOWLEDGEMENTS

We wish to thank the Faculty of Veterinary Science, University of Pretoria; Dr Errol Nevill, Veterinary Research Institute, Onderstepoort; Dr L. E. O. Braack, Kruger National Park; Dr Mervyn Mansell, National Collection of Insects, Pretoria; the Natal Museum, Pietermaritzburg; the South African Museum, Cape Town; and the State Museum, Windhoek, Namibia for making study material available. We are grateful to Mr A. M. Spickett and Miss Andrea van Niekerk of the Veterinary Research Institute, Onderstepoort for the statistical analysis and drawing of the graphs respectively. The senior author also expresses her thanks to Drs S. Louw and J. Irish, Mrs Annamé Wels and Miss Liz de Villiers of the National Museum, Bloemfontein. The Bloemfontein Municipal Zoo supplied the goat for the feeding experiments.

We also wish to thank Dr J. G. H. Londt of the Natal Museum for his critical review of the manuscript and many helpful suggestions.

This research was funded by the National Museum, Bloemfontein and the Foundation for Research Development.

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Printed by the Government Printer, Private Bag X85, Pretoria, 0001

TRICHOSTRONGYLID

NEMATODES

Onderstepoort J. vet. Res. 44 (3), 131–138 (1977)

A REVISION OF THE GENUS *IMPALAIA* MÖNNIG, 1924

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ABSTRACT

BOOMKER, J., 1977. A revision of the genus *Impalaia* Mönnig, 1924. *Onderstepoort Journal of Veterinary Research*. 44 (3), 131–138 (1977).

A revision of the genus *Impalaia* Mönnig, 1924 forms the subject of this report. Besides the type species, *Impalaia tuberculata* Mönnig, 1924, there are 2 valid species, viz., *I. nudicollis* Mönnig, 1931 and *I. okapiae* (Van den Berghe, 1937). *I. tuberculata longispiculata* (Wetzel & Fortmeyer, 1960), *I. somaliensis* (Crovieri, 1929) and *I. aegyptiaca* Soliman, 1956 are synonymous with *I. tuberculata*. *I. taurotragi* (Le Roux, 1936) appears to be an aberrant form of *I. nudicollis*. A parasite/host check-list is included.

Résumé

LA RÉVISION DU GENRE IMPALAIA *MÖNNIG*, 1924

Ce rapport a pour objet une révision du genre Impalaia *Mönnig*, 1924. *Outre l'espèce-type*, Impalaia tuberculata *Mönnig*, 1924, *il y a 2 espèces valides, soit* I. nudicollis *Mönnig*, 1931, *et* I. okapiae (*Van den Berghe*, 1937). I. tuberculata longispiculata (*Wetzel & Fortmeyer*, 1960), I. somaliensis (*Crovieri*, 1929) *et* I. aegyptiaca *Soliman*, 1956 *sont synonymes de* I. tuberculata. I. taurotragi (*Le Roux*, 1936) *semble être une forme irrégulière d'*I. nudicollis. *Une liste de contrôle des parasites et de leurs hôtes est jointe à cette révision.*

INTRODUCTION

In July 1970, a giraffe (*Giraffa camelopardalis* Linn., 1758) died in the National Zoological Gardens, Pretoria, Republic of South Africa. At autopsy the animal was found to be infested with *Cooperia punctata* (von Linstow, 1907), *Nematodirus spathiger* (Railliet, 1896), *Trichuris globulosa* (von Linstow, 1901) as well as with a number of specimens belonging to the genus *Impalaia*. In an attempt to identify these nematodes, type specimens of *Impalaia tuberculata* Mönnig, 1924, *I. nudicollis* Mönnig, 1931, *I. aegyptiaca* Soliman, 1956 and *I. taurotragi* (Le Roux, 1936), as well as specimens of *I. tuberculata* and *I. nudicollis* from different species of herbivores were examined. The range of variation of the different characters was determined and used to assess the validity of the various species.

DIAGNOSIS OF THE GENUS

Trichostrongylidae, Heligmosominae: The body is filiform and not spirally coiled. The cuticle bears about 14 longitudinal ridges which are supported by sclerotized rods. The cephalic region is inflated and bears 18–20 fine cross striations. The mouth is terminal and is surrounded by 3 small lips. The bursa is hoodshaped with an indistinct dorsal lobe. The arrangement of the bursal rays is typical for the genus. The vulva is located near the anus in the terminal tenth of the body. The female tail is knob-like and bears 3 subterminal papillae.

Redescription of **Impalaia tuberculata** *Mönnig*, 1924

Type host

Aepyceros melampus (Lichtenstein, 1812)—impala.

Other recorded hosts

Capra hircus Linn., 1758—domestic goat
Damaliscus dorcas dorcas (Pallas, 1766)—bontebok
Damaliscus dorcas phillipsi (Harper, 1939)—blesbok
Damaliscus lunatus (Burchell, 1823)—tsessebe
Giraffa camelopardalis (Linn., 1758)—giraffe
Hippotragus niger (Harris, 1838)—sable antelope
Raphicerus campestris (Thunberg, 1811)—steenbok
Raphicerus melanotis (Thunberg, 1811)—Cape grysbok
Redunca fulvorufula (Afzelius, 1815)—mountain reedbuck

Received 14 March 1977—Editor

Material examined

A. melampus—Type specimens (Onderstepoort Helminthological Collection, No. T 2010), 3 males, 6 females. Additional material: 15 males, 12 females, from 6 impala.
D. d. phillipsi—1 male and 2 females
D. lunatus—3 females
G. camelopardalis—5 males and 6 females
H. niger—5 males and 6 females
R. campestris—1 male and 1 female, both damaged anteriorly
R. fulvorufula—9 males and 9 females

Description

The principal measurements are listed in Table 1.

Male: The copulatory bursa has 2 large lateral lobes and an indistinct dorsal lobe (Fig. 1). The latero-ventral and ventro-ventral rays originate separately and both curve ventrally and anteriorly. The antero-lateral and medio-lateral rays run parallel for about one-half of their length. When they diverge, the antero-lateral ray curves anteriorly and the medio-lateral ray ventrally. The postero-lateral ray diverges from the medio-lateral ray at about one-fourth of its length and runs caudally and ventrally. The postero-lateral ray is the longest and the antero-lateral ray the shortest of the lateral rays. The length of the dorsal ray could not be determined in the type specimens. In the additional specimens from the type host, the 2 externo-dorsal rays arise at different levels from the dorsal ray, about one-fourth of its length from its origin. The right externo-dorsal ray is longer than the left one and shows a characteristic curvature near its end. Distally, the dorsal ray divides and each of the divisions redivides into laterally and caudally directed branches which give it a wide and squat appearance. The caudally directed branches each bear a small median protuberance. The lateral branches are longer than the caudally directed ones and end in small hooks that usually point anteriorly (Fig. 3).

The spicules are equal, slender, and end in fine points. Their proximal ends are clavate and do not show the hooks illustrated by Mönnig (1924) (Fig. 5a). The gubernaculum is boat-shaped and poorly sclerotized.

Female: The vulva is simple and slightly protruding and is situated in the caudal tenth of the body. The single ovijector consists of a muscular *pars ejaculatrix* which is separated from the *pars haustrix* by a well-

developed sphincter. There is a single uterus and one ovary. The tail is blunt and bears 3 subterminal papillae (Fig. 6a). Eggs are slightly elongated, thin-walled and contain a morula. Occassional eggs contain a larva.

Description of **Impalaia tuberculata longispiculata** (*Wetzel & Fortmeyer*, 1960)

Type host

Litocranius walleri (Brooke, 1878)—gerenuk

Other recorded hosts

Capra hircus (experimental)—domestic goat

Description

The principal measurements as recorded by Wetzel & Fortmeyer (1960) are listed in Table 1.

The following is an abridged version of the description given by Wetzel & Fortmeyer (1960):

Males: The copulatory bursa has the same structure and ray pattern as that of *I. tuberculata*. The almost symmetrical, long, thin externo-dorsal rays emerge from the dorsal ray about one-sixth of its length from its origin. Distally, the dorsal ray divides and redivides as in *I. tuberculata*. The spicules show greater variation in their lengths than those of *I. tuberculata* from the impala and are enclosed in a sheath for most of their length.

Females: The females conform to the description of *I. tuberculata* from the impala.

Redescription of **I. aegyptiaca** *Soliman*, 1956

Type host

Camelus dromedarius Linn., 1758—camel.

Material examined

Six paratype males and 10 paratype females.

Description

The principal measurements are listed in Table 1.

Males: The copulatory bursa has the same structure and ray pattern as that of *I. tuberculata*. The externo-dorsal rays arise from the dorsal ray at about one-seventh of its length from the base. The right externo-dorsal ray is longer than or equals the length of the left externo-dorsal ray. Distally, the dorsal ray divides and redivides as in *I. tuberculata*. A small protuberance on the caudally directed branch is present. The spicules are equal and slender. The gubernaculum is boat-shaped.

Females: The tail is blunt and bears 3 subterminal papillae. The vulva is a transverse slit. The single ovijector resembles that of *I. tuberculata*. Eggs are subspherical to elongate. The larger eggs contain larvae.

Description of **Impalaia somaliensis** (*Crovieri*, 1929) *Travassos*, 1937

Syn. **Anthostrongylus somaliensis** *Crovieri*, 1929

Host

Camelus dromedarius Linn., 1758—camel.

Description

The principal measurements recorded by Crovieri (1929) and cited by Travassos (1937) are listed in Table 1. The following is an abridged version of the description given by Travassos (1937).

Males: They are about 9 mm in length. Spicules are of uniform width in the middle and are dilated at the proximal end and acute and curving inwards at the distal end. The gubernaculum is 0,090 mm long.

Females: They are larger than the males. The posterior extremity is conical and ends in a very sharp point. The anus is at the base of the tail and the vulva is slightly in front of the anus. A prominent muscular vagina which divides into 2 uteri is present.

Description of **Impalaia okapiae** (*Van den Berghe*, 1937)

Syn. **Anthostrongylus okapiae** *Van den Berghe*, 1937

Type host

Okapia johnstoni (Sclater, 1901)—okapi.

Description

The principal measurements as recorded by Van den Berghe (1937) are listed in Table 4. The description is that given by Van den Berghe (1937).

Males: The dorsal lobe is separated from the 2 lateral lobes by a small ridge. The lateral lobes are asymmetrical, the left lobe and rays being larger than those on the right. The structure and disposition of the bursal rays are similar to those of *I. tuberculata*.

Females: According to Van den Berghe (1937), "the posterior extremity is enlarged at the height of the vulva and rings and terminates in a fine point. The vulva and the rings are closely approximated".

Redescription of **Impalaia nudicollis** *Mönnig*, 1931

Type host

Damaliscus dorcas phillipsi (Harper, 1939)—blesbok.

Other recorded hosts:

A. melampus—impala
Bos spp.—domestic cattle
C. dromedarius—camel
D. lunatus—tsessebe
Gazella thomsoni (Günther, 1884)—Thomson's gazelle
Kobus ellipsiprymnus (Ogilby, 1833)—waterbuck
O. aries—domestic sheep
R. campestris—steenbok
Sylvicapra grimmea (Linn., 1758)—grey duiker

Material examined

D. d. phillipsi—Type specimens (Onderstepoort Helminthological Collection, No. T 2030), males and females. Additional material: 4 males and 6 females from 3 blesbok.

O. aries—8 males and 6 females from experimental infestations, 14 and 30 days after infestation.

Taurotragus oryx (Pallas, 1776)—3 males and 3 females.

Description

The principal measurements are listed in Table 2.

Males: The bursa is fairly large, but markedly smaller than that of *I. tuberculata*, having 2 distinct lateral lobes and an indistinct dorsal lobe (Fig. 2). The origin and disposition of the lateral and ventral rays are identical with those of *I. tuberculata*. The dorsal ray does not have the characteristic bend of *I. tuberculata* but may be slightly curved and though the externo-dorsal rays are usually equal in number, they may differ slightly in length. They originate about one-fifth of the length of the dorsal ray from its base, at the same or slightly different levels. Distally, the

TABLE 4 Principal measurements of *I. okapiae* as given by Van den Berghe, 1937*

	♂	♀
Length (mm)	11,0	13,0
Width	247	330
Cephalic inflation length	53	—
Head width	—	—
Oesophagus length	478	462
Excretory pore	644	—
Spicule length	2,062	—
Gubernaculum length	170	—
Tail to anus	—	83
Anus to vulva	—	107
Vulva to tail	—	190
Ovijector	—	—
Eggs	—	82×65

* All measurements given in μm unless stated otherwise

dorsal ray divides and redivides immediately. The lateral branches are shorter than or equal to the median branches, which usually bear a protuberance (Fig. 4). In some specimens there is an additional small papilla immediately in front of the primary bifurcation. The spicules are slender, clavate, equal, and terminate in fine points. Proximally, they bear a small median process (Fig. 5b). The gubernaculum is boat-shaped.

Females: The tail is blunt and knob-like and bears 3 subterminal papillae (Fig. 6b). The vulva is a slightly protruding transverse slit situated in the caudal tenth of the body. The single ovijector consists of a muscular *pars ejaculatrix,* a well developed sphincter and a *pars haustrix*. The vagina is simple and muscular. There is a single uterus and one ovary. Eggs are slightly elongate.

Redescription of **Impalaia taurotragi** (*Le Roux,* 1936) *Travassos,* 1937.

Syn. **Minutostrongylus taurotragi** *Le Roux,* 1936

Type host

Taurotragus oryx (Pallas, 1776)—Cape eland

Material examined

The slightly damaged holotype male and the allotype female.

Description

These worms are the smallest in the genus.

The principal measurements are listed in Table 3.

The nerve ring is situated 136,8 μm from the anterior extremity in the female. The excretory pore could not be located in either specimen.

Male: The bursal rays resemble those of the genus. The dorsal ray is straight and very short. The externo-dorsal rays arise at the same height and the left externo-dorsal ray is a little shorter than the right. Distally, the dorsal ray divides and immediately redivides. The median branches each bear a small protuberance and are shorter than the lateral branches. The spicules are lightly sclerotized, equal, and terminate in fine points. The gubernaculum is boat-shaped.

Females: The tail is blunt and no papillae are present. The vulva is a slightly protruding transverse slit situated in the caudal tenth of the body. The single ovijector consists of a muscular *pars ejaculatrix,* a well-developed sphincter and a *pars haustrix*. The eggs are slightly elongate.

Discussion

The species in the genus *Impalaia* may be divided into (a) the *I. tuberculata* group, which includes *I. tuberculata, I. t. longispiculata, I. aegyptiaca, I. somaliensis* and *I. okapiae* and (b) the *I. nudicollis* group, which includes *I. nudicollis* and *I. taurotragi.*

The I. tuberculata *group*

All the species belonging to this group have a large copulatory bursa and a characteristic bend in the distal third of the dorsal ray. The tip of the dorsal ray spreads so that it is wider than long.

According to Mönnig (1924), the cervical region of *I. tuberculata* bears numerous irregularly arranged tubercles. Mönnig (1932), however, points out that these tubercles were artifacts and could not be used for specific identification. Daubney (1933) collected an *Impalaia* sp. from sheep in Kenya. The nematodes of this species did not have tubercles and were erroneously assigned to *I. nudicollis* instead of *I. tuberculata.* The measurements and illustrations given by Daubney (1933) are undoubtedly those of *I. tuberculata.* Wetzel & Fortmeyer (1960) described tubercles in the cervical region of *I. t. longispiculata.* The latter subspecies was based on specimens obtained from a goat which was infested with infective larvae derived from faecal cultures of gerenuk (Wetzel & Fortmeyer, 1960). Pande, Rai & Bhatia (1962) recovered an *Impalaia* sp. from a camel which they identified as *I. nudicollis.* They also provide a key for the genus *Impalaia* in which they erroneously use the presence of tubercles to differentiate between *I. tuberculata* and *I. nudicollis.*

It must be stressed that no tubercles were found in any of the specimens examined and their presence or absence cannot be used as a valid criterion for the separation of *I. tuberculata* and *I. nudicollis.*

Yeh (1956) identified nematodes from Thomson's gazelle as *I. nudicollis.* From the measurements he provides (Table 1), it is clear that these parasites are *I. tuberculata* and that they closely resemble *I. t. longispiculata* which differs from the type specimens only in the length of the spicules. The validity of *I. t. longispiculata* as a distinct subspecies is doubtful.

Pande *et al.,* (1962) compared *I. nudicollis* from the camel with those from Thomson's gazelle described by Yeh (1956). The parasites from the camel, however, cannot be assigned to any species as the measurements quoted in the text do not agree with those calculated from the illustrations.

I. aegyptiaca is the largest member of the genus. The excretory pore is situated 426–618 μm from the anterior extremity in the paratype males and 562–602 μm in the paratype females and not 3 800–4 200 μm as erroneously recorded by Soliman (1956). The shape and disposition of the bursal rays are identical with those of *I. tuberculata* type specimens. The length of the spicules is within the range of *I. tuberculata* as recorded by Yeh (1956) and Wetzel & Fortmeyer (1960).

Travassos (1937) stated that *I. somaliensis* differed from *I. tuberculata* in that it had a double uterus and larger spicules and eggs. The reference to the double uterus was evidently the result of an incorrect observation. The larger size of the spicules of *I. somaliensis* was not confirmed by a comparison with the figures of *I. tuberculata* as illustrated in Yorke & Mapleston (1926) (Travassos, 1937). Moreover, the size of the eggs is too variable to be considered a valid criterion for separating species.

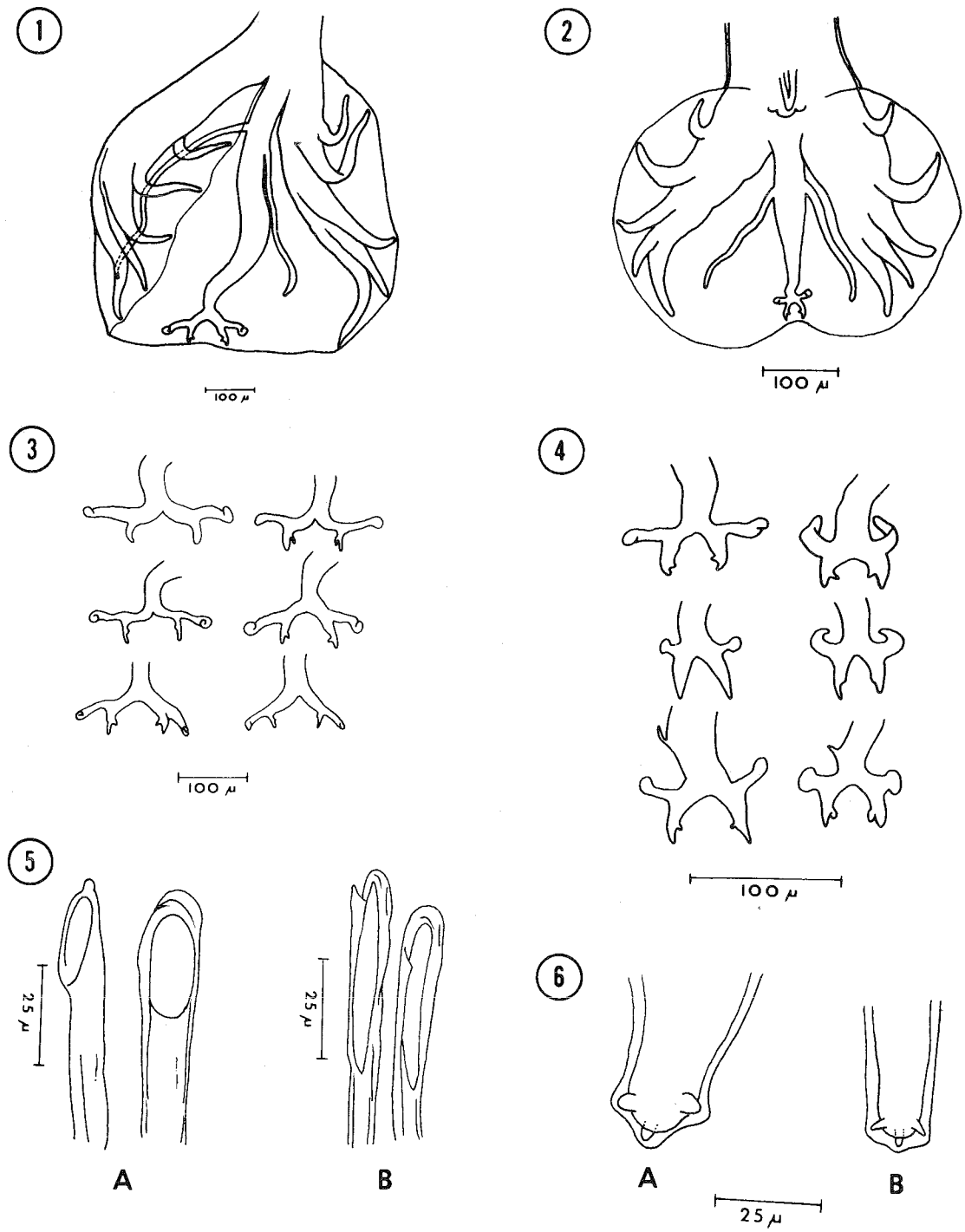

FIG. 1 Bursa of *I. tuberculata* from the type host, *A. melampus*. Ventral view
FIG. 2 Bursa of *I. nudicollis* from *T. oryx*. Dorsal view
FIG. 3 Variation in the tip of the dorsal ray of *I. tuberculata*. Top figures: from *C. dromedarius*; centre: from *R. fulvorufula*; bottom: from *A. melampus*
FIG. 4 Variation in the tip of the dorsal ray of *I. nudicollis*. Top figures: from *D. d. phillipsi*; centre and bottom: from *O. aries*
FIG. 5 Proximal end of spicules; (a) *I. tuberculata* from *A. melampus* (b) *I. nudicollis* from *D. d. phillipsi*
FIG. 6 Tail of female of (a) *I. tuberculata* from *A. melampus* (b) *I. nudicollis* from *D. d. phillipsi*

Both *I. aegyptiaca* and *I. somaliensis* are known only from the camel and have not been reported since their original description. *I. aegyptiaca* and *I. somaliensis* are considered synonyms of *I. tuberculata.*

Baer (1950) is of the opinion that *I. okapiae* and *I. somaliensis* should be retained as separate species as they differ from one another and from *I. tuberculata* in the length of the spicules and the size of the eggs. As no material of *I. okapiae* was available, the relationship of *I. okapiae* to the other members of the genus could not be determined.

I. tuberculata has been recorded from many species of antelope in Africa and the length of the spicules varies greatly in the different host animals. The spicules of *I. tuberculata* from the type host, the impala, are the shortest, while those from the reedbuck, giraffe, gerenuk, Thomson's gazelle, sable antelope and camel are longer. The specimens from the goat (Wetzel & Fortmeyer, 1960) showed a great variation in spicule length, viz., 838–1 202 μm. Such variation was also found in specimens from the Thomson's gazelle (Yeh, 1956) and may be due to the immune status of the host. This conclusion is supported by the findings of Keith (1967), who found that spicules of *Cooperia pectinata* (Ransom, 1907) were shorter in animals which had previously been exposed to the nematode. According to Keith (1967), the reduction in spicule length was due to a host reaction, stimulated by prior infestation and was not directly attributable to the presence of survivors of a previous infestation.

The I. nudicollis *group*

Mönnig (1931) experimentally infested sheep with infective larvae of *I. nudicollis* obtained from faecal cultures of a blesbok. The principal measurements of the parasites, recovered 14 and 30 days after infestation, are listed in Table 2.

Parasites from an eland, identified as *I. tuberculata* by Mönnig (1933), proved to be *I. nudicollis* upon re-examination and they are compared with *I. nudicollis* from blesbok in Table 2.

I. nudicollis may be differentiated from *I. tuberculata* by the smaller and shorter copulatory bursa, the straight dorsal ray and the narrow tip of the dorsal ray. The lateral branches of the tip of the dorsal ray of *I. nudicollis* are equal to or shorter than the median branches, whereas in *I. tuberculata* they are longer than the median branches and terminate in small hooks. The proximal ends of the spicules of *I. nudicollis* bear small median protuberances. Variations of the tip of the dorsal ray are illustrated in Fig. 4.

I. taurotragi males show characteristics of both *I. nudicollis* and *I. tuberculata.* The small size of the parasite, the copulatory bursa and the straight dorsal ray resemble those of *I. tuberculata* in that the lateral branches are longer than the median branches. Except for the smaller size, the females resemble those of *I. nudicollis.* Since *I. taurotragi* has not been recorded since its original finding and *I. nudicollis* has been recovered from the eland (Mönnig, 1933), *I. taurotragi* may possibly represent an aberrant form of *I. nudicollis.*

Conclusion

Specimens of *I. tuberculata* from different host species show great variation in the length of the spicules while the dorsal ray pattern remains constant. Those from the type host, the impala, have the shortest spicules (804–851 μm) and those from the sable antelope the longest (1 016–1 068 μm). The spicules of nematodes from the gerenuk (838–1 075 μm), the sheep (900–1 000 μm) and Thomson's gazelle (835–1 160 μm) fall between the two extremes. Since *I. t. longispiculata, I. aegyptiaca* and *I. somaliensis* have spicule lengths within the range of *I. tuberculata* from different hosts and have a similar dorsal ray pattern, they are considered synonymous with *I. tuberculata.*

I. nudicollis shows little variation in different host animals and *I. taurotragi* is possibly an aberrant form of *I. nudicollis.*

I. okapiae must be retained until further material becomes available, so that its status may be determined.

The parasites from the camel, described by Pande *et al.* (1962) need further study to verify their identity.

Revised host-parasite list for the genus Impalaia

1. *Impalaia tuberculata*

   Syn.:

   I. tuberculata longispiculata
   I. aegyptiaca
   I. somaliensis
   I. nudicollis from sheep (Daubney, 1933)
   I. nudicollis from *G. thomsoni* (Yeh, 1956)

   Host:

   Aepyceros melampus—Mönnig, 1924
   Capra hircus—Wetzel & Fortmeyer, 1960
   Camelus dromedarius—Crovieri, 1929; Soliman, 1956
   Damaliscus dorcas dorcas—Ortlepp, 1961
   D. dorcas phillipsi—Ortlepp, 1961
   D. lunatus—Ortlepp, 1961
   Gazella thomsoni—Yeh, 1956
   **Giraffa camelopardalis*—this paper
   **Hippotragus niger*—Verster, 1976 (personal communication)
   Litocranius walleri—Wetzel & Fortmeyer, 1960
   Ovis aries—Daubney, 1933
   Raphicerus campestris—Mönnig, 1931
   R. melanotus—Mönnig, 1931
   Redunca fulvorufula—Baker & Boomker, 1973

2. *Impalaia nudicollis*

   Syn.:

   I. tuberculata, from eland—Mönnig, 1933

   Host:

   Aepyceros melampus—Mönnig, 1933
   **Alcelaphus buselaphus*—this paper
   Camelus dromedarius—Round, 1962
   Damaliscus dorcas phillipsi—Mönnig, 1931
   D. lunatus—Mönnig, 1932
   Kobus ellipsiprymnus—Round, 1962
   Raphicerus campestris—Mönnig, 1933
   Taurotragus oryx—Mönnig, 1933

3. *Impalaia okapiae*

   Okapia johnstoni—Van den Berghe, 1937

4. *Impalaia taurotragi*

   Taurotragus oryx—Le Roux, 1936

* New host records

Acknowledgements

The author wishes to express his sincere gratitude to Mr S. Prudhoe of the British Museum (Natural History) for the loan of material, Drs Gertrud Theiler and Anna Verster for translations and valuable comments on the manuscript, and Mrs Deirdre Evans for technical assistance.

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TABLE 1 Comparison of primary measurements of *I. tuberculata* from different hosts*

Host	Synonym	Author		Length (mm)	Width	Cephalic inflation, length	Head width	Oesophagus length	Nerve ring from anterior extremity	Excretory pore from anterior extremity	Spicule length	Gubernaculum length	Bursa length	Externo-dorsal length Right	Externo-dorsal length Left	Dorsal length	Anus to tail	Anus to vulva	Vulva to tail	Ovijector	Eggs
A. melampus		Mönnig (2924)	♀	7,2–7,5	120	86–100	40–45	440	Just behind middle of oesophagus	—	600	—	—	—	—	—	40	60	100	—	60×32
			♂	18,5	120	86–100	40–45	440		—	—	—	—	—	—	—					
		Types, this paper	♂	7,0–8,0	103–129	81,4–92	25,9	440–445	240–307	—	850–858	74	—	—	—	—	51,8–59,2	185–188,7	240,5–244	—	—
		Additional material	♂	16,0–18,7	148	79,9–96	29,5	555–603	277	—	—	—	—	—	—	—					
			♂	7,5	122,1–148	96–114,7	25,9–29,6	425–477	266,4–300	499–569,5	804–851	81,4–92,5	562–737	384–684	284,9–351	415–576	44,4–66,6	136,9–203,5	181,3–270,1	407	55–66×26–44
			♂	15,5–16,9	137,9–192,4	103–129,5	29,6–37	451–499,5	285–314	495–529,1	—	—	—	—	—	—					
D. d. phillipsi			♂	4,2–6,3	140,6	85,1	33,3	362,6	—	403,3	950,9	92,5	737	473,3	351	603	51,8–59,2	143–159	194,8–218,2	358,4–362,6	62,9×37
			♀	10,7–12,6	166–185	122,1–125,8	33,3	410–444	240–278	481	—	—	—	—	—	—					
G. camelopardalis			♂	8,8–9,2	136–160	95–107	26	333–338	240–277	420–490	871–898	88,8–93,8	743–777	407–585	340–384	627–670	63	137–177	200–240	314–415	63–65×35–45
			♀	12,5–13,6	166–185	118–125	37	429–455	311–318	490–560	—	—	—	—	—	—					
H. niger			♂	7,1–9,5	142–172,8	98,4–156	31,2–36	417–494	211–261,8	537–600	1 016–1 168	84–112,8	684–807	420–484	330–367,2	607,5–704,5	52–72	136–172	188–224	408–589	60–76×28–55
			♀	13,1–15,6	161,5–192	108–121,8	33,6–38,4	454–532	228–319,2	603–607	—	—	—	—	—	—					
R. fulvorufula			♂	7,2–8,0	103–147,4	85,1–129,5	25,9–33,6	388,5–425	259–277,5	—	780–832	74–92,5	469–603	351–432,9	259–330	402–495	55,5–59,2	118,4–162,8	173,9–222	351–370	55,5–59,2×37–44,4
			♀	12,5–14,7	166,5–177	107,3–118,4	33,3–37	462,5–499,5	259–314,5	507,6–525,4	—	—	—	—	—	—					
C. dromedarius	*I. somaliensis*	Travassos (1937)	♂	9,0	163	—	—	—	—	—	1 080	90	—	—	—	—	—	—	—	—	80–90×50–54
			♀	14,0–17,0	—	—	—	—	—	—	—	—	—	—	—	—					
	I. aegyptiaca	Soliman (1956)	♂	8,5–11,5	130–160	—	32–38	380–520	320–330	3 800–4 200	1 300–1 600	82–100	—	—	—	600–700	—	—	—	—	65–73×37–41
			♀	15,0–21,0	140–170	—	34–36	460–620	320–370	3 800–4 200	—	—	—	—	—	—	52–68	114–192	182–260	400–600	
		Paratypes, this paper	♂	7,4–9,6	129,5–177,6	111–136,9	29,6–33,3	418–499,5	227–344	426,5–617,9	1 246–1 380	89–103,6	573,5–740	370–469,9	318,2–388	522–643	51,8–77,7	148–203,5	199,8–281,2	462–629	55,5–70,3×33,3–40,7
			♀	14,8–19,6	187,6–214,6	114,7–140,6	33,3–40,7	480–585	300–343	535–660	—	—	—	—	—	—					
L. walleri	*I. r. longispiculata*	Wetzel & Fortmeyer (1960)	♂	6,7–7,9	50–63 at oesophagus	—	—	300–365	207–246	391–437	838,1–1 202	79–104	—	—	—	—	—	—	—	—	63–79×41–46
			♀	12,5–16,1	52–69	—	—	316–382	206–246	418–478	—	—	—	—	—	—	38–49	—	139–224	—	
G. thomsoni	*I. nudicollis*	Yeh (1956)	♂	6,2–8,2	120–130	60–100	40–50	380–430	—	330–440	835–1 160	90–100	—	—	—	440	—	—	—	—	67–73×38–44
			♀	14,6–15,3	130–150	60–100	40–50	400–490	—	330–440	—	—	—	—	—	—	54–63	—	170–220	500–600	
O. aries	*I. nudicollis*	Daubney (1933)	♂	7,5–9,0	100	100–130	30	350–450	—	—	900–1 000	85	—	—	—	400–500	—	—	—	—	78×40
			♀	11,0–13,0	200	100–130	45	350–450	—	—	—	—	—	—	—	—	55–60	—	200	500–700	

* All measurements given in μm unless stated otherwise

TABLE 2 The principal measurements of *I. nudicollis* from different hosts*

Host	Author		Length (mm)	Width	Cephalic inflation, length	Head width	Oesophagus length	Nerve ring from anterior extremity	Excretory pore from anterior extremity	Spicule length	Gubernaculum length	Bursa length	Externo-dorsal length Right	Externo-dorsal length Left	Dorsal length	Anus to tail	Anus to vulva	Vulva to tail	Ovijector length	Eggs
D. d. phillipsi	Mönnig (1931)	♂	7,5–8,2	110–120	130–140	51	440–480	370–410	—	910–980	94–100	—	—	—	—	—	—	—	—	63–75×39–46
		♀	14,8–16,7	140–160	140–150	46–59	440–520	330–390	—	—	—	—	—	—	—	67–75	173–186	240–260	—	
	Types, this paper	♂	6,5–7,5	98–105	107–114	22,2–25,9	322–370	222–226	422	740–795	92,5	333–351	137–159	116–148	203–222	—	—	—	—	68×39
		♀	14,0–16,0	107–114	118–125	29,6	396–414	270–274	440	—	—	—	—	—	—	55,5–66,6	147,5–170,4	203–237	277–317	
	Additional material	♂	7,0–8,0	114,7–155,4	107–122	25,9	344,1–384	222–296	491	788–910	81,4–92,5	351–407	185–222	185–210	263,4–277	—	—	—	—	59,2–66,6×37–44,4
		♀	14,0–16,5	159,1–203,5	118–129	29,6–33,3	370–407	240–296	524	—	—	—	—	—	—	62,9–74	155–222	217–296	222–340	
O. aries																				
14 days in sheep		♂	6,3–7,0	111–136,9	99,1–107,3	22,2–25,9	351–403	185–240	370–440	871–951	81,4–96,2	333–370	166–210,9	185–222	222–296	—	—	—	—	59,2–62,9×33,3–37
		♀	12,5–13,7	148	111	33–37	407–410	259	462–484	—	—	—	—	—	—	74	185–222	259–296	296–370	
30 days in sheep		♂	6,0–6,7	100–133,6	100–114,7	25,9	314–340	240–259	388–462	777–832,5	85,1–92,5	296–333	166–185	166–177,6	240–259	—	—	—	—	55,5–59,2×37–40,7
		♀	10,8–12,9	125–137	111–118,4	29,6–33,3	370–384,5	240–259	425–458	—	—	—	—	—	—	111–122,5	129–148	240,5–259	222–259	
T. oryx		♂	6,3–7,0	118,4–140,6	48,1–62,9	25,9–29,6	333–370	215,7–227,8	388,5	743–802	81,4	296–333	170–185	155–166,5	222–258	—	—	—	—	55,5–59,2×40,7–48,7
		♀	12,5–14,0	122,1–136,9	92,5–99,9	25,9–29,6	395–447	203–258	402,8–528,4	—	—	—	—	—	—	62,9–66,6	159–177,1	222,4–243,7	259–296	

* All measurements are given in μm unless stated otherwise

TABLE 3 The principal measurements of *I. taurotragi**

Host	Author		Length (mm)	Width	Cephalic inflation, length	Head width	Oesophagus length	Nerve ring from anterior extremity	Excretory pore from anterior extremity	Spicule length	Gubernaculum length	Bursa length	Externo-dorsal length Right	Externo-dorsal length Left	Dorsal length	Anus to tail	Anus to vulva	Vulva to tail	Ovijector length	Eggs
T. oryx	Le Roux (1936)	♂	4,8	56	—	—	—	—	—	580	±60	—	—	—	40	—	—	—	—	—
		♀	6,1	88	—	18	645	—	165	—	—	—	—	—	—	52	126	178	—	78×35
	Holotype this paper	♂	3,1	46,8	—	—	—	—	—	554,4	57,6	92,2	64,8	57,6	39,6	—	—	—	—	—
	Allotype this paper	♀	4,85	93,6	32,4	14,4	637	136,8	—	—	—	—	—	—	—	54	111,6	165,6	342	61–68×36–39

* All measurements are given in μm unless stated otherwise

Onderstepoort J. vet. Res., 46, 83–86 (1979)

COOPERIA CONNOCHAETI SP. NOV. (NEMATODA, TRICHOSTRONGYLIDAE) FROM THE BLUE WILDEBEEST, *CONNOCHAETES TAURINUS* (BURCHELL, 1823)

J. BOOMKER(1), I. G. HORAK(1) and REGINA ALVES(2)

ABSTRACT

BOOMKER, J., HORAK, I. G. & ALVES, REGINA, 1979. *Cooperia connochaeti* sp. nov. (Nematoda, Trichostrongylidae) from the blue wildebeest, *Connochaetes taurinus* (Burchell, 1823). *Onderstepoort Journal of Veterinary Research*, 46, 83–86 (1979).

A new species of nematode, *Cooperia connochaeti*, was collected from cross-bred blue and black wildebeest at Krugersdorp (Transvaal), blue wildebeest *Connochaetes taurinus* (Burchell, 1823) from the Kruger National Park (Transvaal) and Lake Xhau (Botswana), as well as from impala *Aepyceros melampus* (Lichtenstein, 1812) at Malelane (Transvaal) and Pafuri (Kruger National Park).

These nematodes are smaller than *Cooperia pectinata* Ransom, 1907, and their spicules, which are bifid in the distal third, are shorter (145–166 μm) than those of *C. pectinata* (240–280 μm). In addition, the lateral branches of the dorsal ray of *C. connochaeti* are directed ventrally and slightly anteriorly, while those of *C. pectinata* are directed posteriorly.

Résumé

COOPERIA CONNOCHAETI *SP.NOV.* (*NEMATODA, TRICHOSTRONGYLIDAE*), *PARASITE DU GNOU BLEU* CONNOCHAETES TAURINUS (*BURCHELL*, 1823)

On a récolté une nouvelle espèce de nématode, Cooperia connochaeti, *chez des hybrides de gnous bleus et noirs à Krugersdorp (Transvaal), chez le gnou bleu* Connochaetes taurinus (*Burchell*, 1823) *au Parc National Kruger (Transvaal) et au lac Xhau (Botswana), ainsi que chez l'impala* Aepyceros melampus (*Lichtenstein*, 1812) *à Malelane (Transvaal) et à Pafuri (Parc National Kruger).*

Ces nématodes sont plus petits que Cooperia pectinata *Ransom*, 1907, *et leurs spicules, bifides au tiers distal, sont plus courts* (145–166 μm) *que ceux de* C. pectinata (240–280 μm). *En plus, les branches latérales de la raie dorsale de* C. connochaeti *sont dirigées ventralement et légèrement vers l'avant, tandis que celles de* C. pectinata *sont dirigées vers l'arrière.*

INTRODUCTION

During an anthelmintic test conducted in a private game park near Krugersdorp, Transvaal, nematodes of the genus *Cooperia* Ransom, 1907 were found in the small intestine of 17 of 18 cross-bred blue and black wildebeest (*Connochaetes taurinus* × *Connochaetes gnou*). Identical nematodes were found in 7 of 8 blue wildebeest, *Connochaetes taurinus* (Burchell, 1823), in the Kruger National Park and 1 of 7 from Lake Xhau, Botswana, as well as in impala, *Aepyceros melampus* (Lichtenstein, 1812), from Malelane, Transvaal and Pafuri, Kruger National Park.

The parasites were never present in vast numbers, 1 771 worms from a single animal at Krugersdorp and 1 256 from an animal in the Kruger National Park being the maximum numbers collected. With few exceptions they were the only nematodes present in the small intestine (Horak, unpublished data).

As these nematodes could not be assigned to any of the known species of *Cooperia*, they are described as *Cooperia connochaeti* sp. nov. The type host selected was *C. taurinus* from the Kruger National Park, since the wildebeest at Krugersdorp were hybrids.

DIAGNOSIS OF THE SPECIES

Trichostrongylidae, Trichostrongylinae: Anterior end with a cuticular dilatation, buccal capsule vestigeal; cervical papillae absent; 12–16 longitudinal ridges on body. Male with a symmetrical bursa; dorsal lobe distinct; spicules relatively short, thick and complex; gubernaculum absent. Female didelphic; vulva in posterior half of body; tail tapering to a more or less acute point.

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Received 11 January 1979—Editor

Description of Cooperia connochaeti *sp. nov.*

Type host

Connochaetes taurinus (Burchell, 1823) from the Kruger National Park.

Material examined

C. taurinus, Kruger National Park, type specimens (Onderstepoort Helminthological Collection, No. 2153), 12 males and 12 females.

C. taurinus, Lake Xhau, Botswana, 5 males, 5 females.

Connochaetes hybrids, Krugersdorp, Transvaal, 6 males, 6 females.

A. melampus, Malelane, Transvaal, 3 males, 4 females.

A. melampus, Pafuri, Transvaal, 6 males, 6 females.

Paratypes, 12 males and 12 females from blue wildebeest from the type locality, have been deposited in the Onderstepoort Helminthological Collection (No. 2154).

Description

The principal measurements are listed in Table 1.

Small worms of which the anterior end of the body is spirally coiled. The cuticle bears 12–14 longitudinal striations which begin approximately 100–135 μm from the anterior end and are supported by sclerotized rods. The supporting rods are larger and more strongly developed dorsally. There is a cephalic inflation which extends further dorsally than ventrally (Fig. 1). The measurements of the length of the cephalic inflation, as given in Table 1, are those of the longer dorsal portion.

TABLE 1 The principal measurements of *Cooperia connochaeti* sp. nov.*

Host locality	*C. taurinus* Kruger National Park (Type specimens)		*Connochaetes* hybrids Krugersdorp		*C. taurinus* Botswana	
	♂	♀	♂	♀	♂	♀
Length (mm)	4,4–5,1	5,9–7,1	5,0–5,8	6,2–7,9	4,4–5,1	5,1–7,2
Width	96,2–114,4	80,6–106,6	113–118	114,4–127,4	96,2–111,8	88,4–101,9
Head width	26–31,2	26–33,8	26–33,8	28,6–33,8	26–28,6	28,6–31,2
Cephalic inflation:						
Length	91–130	96,2–132,6	119,6–130	106–143	98,8–106,6	98,8–122,2
Width	28,6–46,8	44,1–57,2	39–49,4	44,2–49,4	36,4–39	36,4–39
Oesophagus	275,6–338	322,4–378,8	317–348,2	351–364	286–314	304–379
Nerve ring	208–260	221–293	205,4–273	241,8–273	208–221	218–241
Excretory pore	260–350	345–410	348,4–361,4	369–405,6	286–325	365–404,2
Bursa:						
Length closed	130–176,8	—	144,2–176	—	143–172,4	—
Width	117–169	—	175–185,4	—	143–166,4	—
Dorsal ray	91–109,2	—	91–104	—	104–130	—
Spicules	145–166,4	—	153–166,4	—	156–163,8	—
Tail to vulva	—	1 359,6–1 658,3	—	1 503,8–1 792,2	—	1 336–1 648
Tail to anus	—	123,6–169	—	144,4–164,8	—	130–176,8
Anus to vulva	—	1 190,6–1 534,7	—	1 339–1 647,8	—	1 159,2–1 518
Ovijector	—	309–473,8	—	364–416	—	391–432,6
Eggs:						
Length	—	56–72,8	—	65–72,8	—	54,6–70,8
Width	—	31,2–39	—	36,4–49,4	—	28,8–31,2

* All measurements given in μm unless stated otherwise

The mouth is surrounded by 3 small lips, each of which bears a small papilla. A pair of phasmids is also present (Fig. 1). The oesophagus has the usual cylindrical shape and is slightly thickened distally. The nerve ring is fairly distinct. The excretory pore may be situated either anterior to, at the end of, or posterior to the end of the oesophagus.

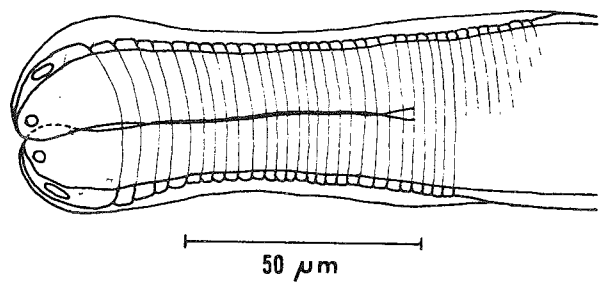

FIG. 1 Head, lateral view

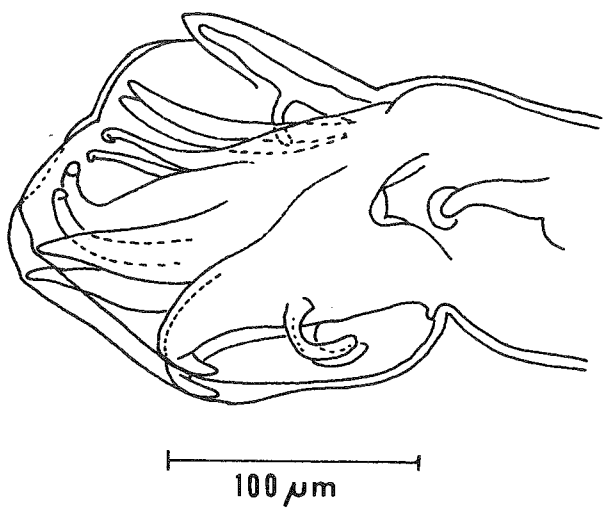

FIG. 2 Male bursa, lateral view

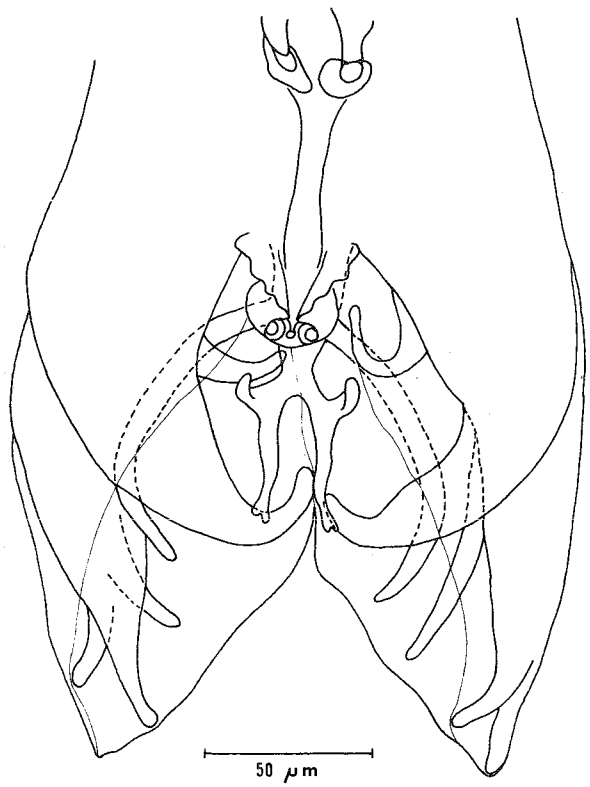

FIG. 3 Male bursa, ventral view

The males are 4,4–5,8 mm long. The bursa has the compact appearance of the genus, with 2 small lateral lobes from which the dorsal lobe is distinctly demarcated (Fig. 2). The ventro-ventral and latero-ventral rays are well separated, the latter being considerably larger than the former. Both rays curve anteriorly. Of the lateral rays, the antero-laterals are the largest, curve slightly inward and reach the margin of the bursa. The medio-lateral rays diverge from the antero-laterals and curve slightly inward and dorsally. The postero-lateral rays are slender and curve dorsally

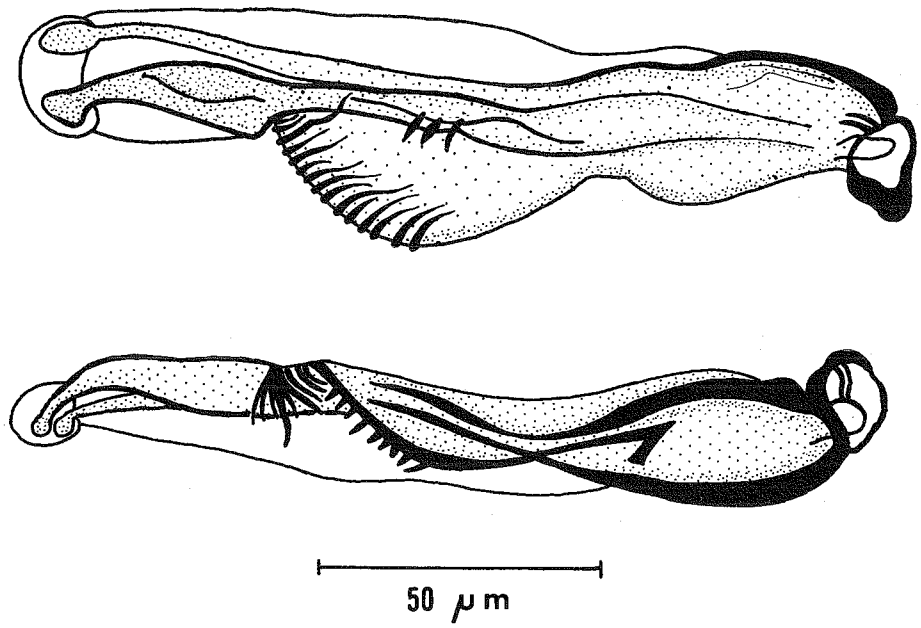

FIG. 4 Spicules; top lateral view, bottom ventral view

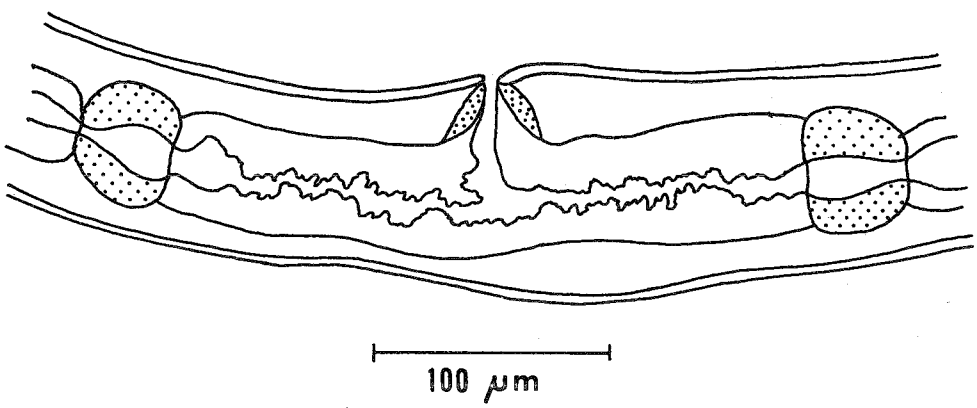

FIG. 5 Ovijector, lateral view

(Fig. 2). The dorsal ray is stout and the posterior third is divided into 2 branches. Ventrally directed branches arise posteriorly to the bifurcation of the main branch. The main branches, which together assume the typical lyre-shape of the genus, end in bifid tips, which are of equal thickness, but which may differ in length. The externo-dorsal rays arise from the middle of the main trunk of the dorsal ray. They are slender and have the characteristic shape of the genus (Fig. 3).

The spicules (Fig. 4) are equal and well sclerotized. The middle third of each has a pectinate expansion, followed by a depression into which the corrugations extend. The distal third of the spicule consists of 2 slender, slightly curved spurs, each terminating in a small, ovoid, non-sclerotized knob. Membranous alae are present. They extend from the pectinate expansion medially to enclose the 2 spurs of the spicules, and laterally to enclose the distal five sixths of the spicule. There is no gubernaculum.

The females are 5,0–7,9 mm long, and 80,6–127,4 µm wide across the vulva. The vulva is a slightly protruding transverse slit on the ventral aspect of the body, and is usually flanked by a pair of small lateral alae. The longitudinal striations are interrupted in the vulvar region, but are continuous dorsally. The ovijectors are well developed (Fig. 5). The tail is moderately long and ends acutely (Fig. 6). Eggs are ovoid to elongated.

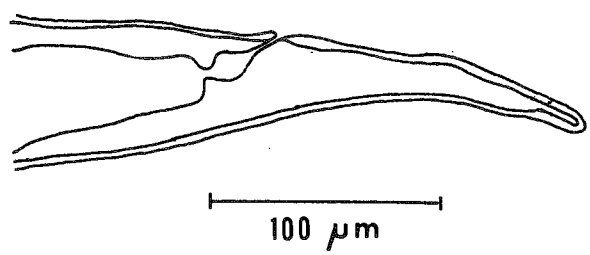

FIG. 6 Tail of female, lateral view

Discussion

The various *Cooperia* species may be divided into 2 groups. The first group, in which the lateral branches of the distal part of the dorsal ray arise anteriorly to, or at the bifurcation, includes *C. africana* Mönnig, 1933, *C. curticei* (Giles, 1892) Ransom, 1907, *C. minor*

Gutteres, 1947, *C. neitzi* Mönnig, 1933, *C. punctata* (von Linstow, 1907) Ransom, 1907, and *C. spatulata* Baylis, 1938.

In the second group the lateral branches of the distal part of the dorsal ray arise posteriorly to the bifurcation. The species included in this group are *C. borgesi* Gutteres, 1947, *C. fuelleborni* Hung, 1926, *C. hippotragusi* Gutteres, 1947, *C. hungi* Mönnig, 1931, *C. mcmasteri* Gordon, 1932, *C. oncophora* (Railliet, 1898) Ransom, 1907, *C. pectinata* Ransom, 1907, *C. reduncai* Gutteres, 1947, *C. verrucosa* Mönnig, 1933, *C. yoshidai* Mönnig, 1939, as well as *C. connochaeti*. The spicules of *C. connochaeti* resemble those of *C. pectinata* in shape but are smaller, (viz., 145–166 μm in *C. connochaeti* and 240–250 μm in *C. pectinata*) and are bifid in their distal third. The lateral branches of the dorsal ray of *C. connochaeti* are directed ventrally and slightly anteriorly, while those of *C. pectinata* are directed posteriorly.

Additional material from impala was examined and it was found that the measurements of these worms fall within the range given for the type specimens from the type host.

Acknowledgements

The authors wish to express their gratitude to the Board of Curators, National Parks Board, and the Krugersdorp Game Reserve and Pleasure Resort for placing the wildebeest and impala at their disposal, to Dr V. de Vos, National Parks Board, for assisting with the necropsies in the Kruger National Park, and to Dr I. Carmichael, Department of Helminthology, Veterinary Research Institute, for the loan of his material from Botswana.

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Onderstepoort J. vet. Res., 53, 213–215 (1986)

TRICHOSTRONGYLUS AURICULATUS N. SP. (NEMATODA: TRICHOSTRONGYLIDAE) FROM THE STEENBOK, *RAPHICERUS CAMPESTRIS* (THUNBERG, 1811)

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ABSTRACT

BOOMKER, J., 1986. *Trichostrongylus auriculatus* n. sp. (Nematoda: Trichostrongylidae) from the steenbok *Raphicerus campestris* (Thunberg, 1811). *Onderstepoort Journal of Veterinary Research*, 53, 213–215 (1986).

During a pilot survey of the parasites of some artiodactylids in the Kalahari Gemsbok National Park a new species of *Trichostrongylus* Looss, 1905 was recovered from the small intestine of a steenbok, *Raphicerus campestris* (Thunberg, 1811), a gemsbok, *Oryx gazella* (Linnaeus, 1758), and a red hartebeest, *Alcelaphus buselaphus* (Pallas, 1766). The male spicules were 0,120–0,148 mm long and an ear-shaped protuberance was present on the shaft of the left spicule. The presence of only a single protuberance is characteristic of the species.

INTRODUCTION

During a pilot survey of the parasites of some of the artiodactylids in the Kalahari Gemsbok National Park (KGNP), Cape Province, a new species of *Trichostrongylus* Looss, 1905 was recovered from the small intestine of a steenbok, *Raphicerus campestris* (Thunberg, 1811), a gemsbok, *Oryx gazella* (Linnaeus, 1758) and a red hartebeest, *Alcelaphus buselaphus* (Pallas, 1766). These worms were referred to as a *Trichostrongylus* species by Boomker, Horak & De Vos (1986) and are described here as *Trichostrongylus auriculatus* n. sp.

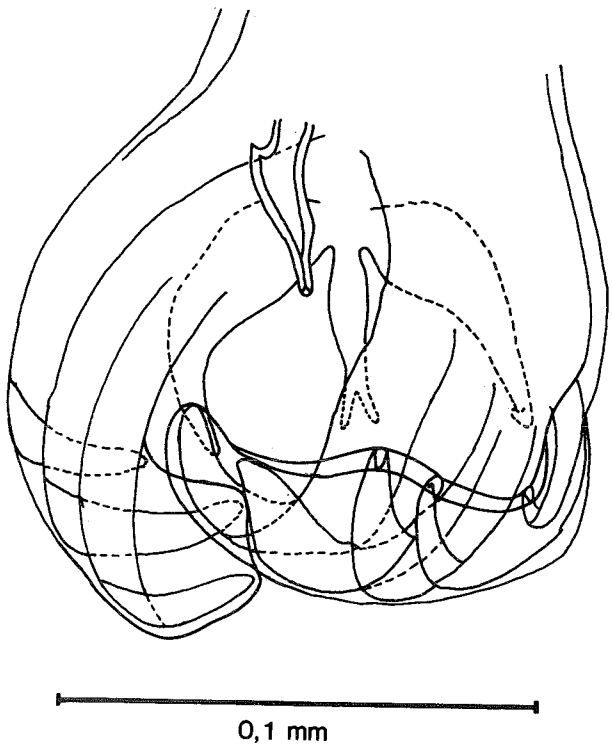

FIG. 1 Ventral view of the bursa of *Trichostrongylus auriculatus*

Only a few worms were recovered from each of the animals, the steenbok harbouring 60, the gemsbok 356 and the red hartebeest 50 male and female worms (Boomker *et al.*, 1986). The syntype specimens were selected from the steenbok, but paratypes were not selected because the worms from the other antelope were poorly preserved.

Received 30 June 1986—Editor

DIAGNOSIS OF THE GENUS

Trichostrongylidae: Trichostrongylinae: Small, slender worms with a small head and without a buccal capsule or cervical papillae; the excretory pore opens in a ventral notch slightly behind the nerve ring. The male bursa has large lateral lobes and a more or less distinct, symmetrical dorsal lobe; an accessory bursal membrane is absent and small prebursal papillae are present; the spicules are short and stout, ridged and variably sclerotized. A gubernaculum is present. Females are slightly larger than the males; the uteri are amphidelphic and the ovijector is situated in the posterior 1/3rd to 1/5th of the body; eggs are segmented when laid.

Description of *Trichostrongylus auriculatus* n. sp.

Type host

Raphicerus campestris (Thunberg, 1811) from the Kalahari Gemsbok National Park, Cape Province, Republic of South Africa.

Material examined

R. campestris from the type locality, syntype specimens (Onderstepoort Helminthological Collection, No. T2173), 5 male and 8 female worms.

O. gazella from the type locality, 5 males and 5 females.

A. buselaphus from the type locality, 2 male worms.

Paratype specimens were not selected because of the poor state of preservation of the worms from the gemsbok and the red hartebeest.

TABLE 1 The principal measurements (mm) of *Trichostrongylus auriculatus*

	Males	Females
Length	4,01 –4,99	4,20 –6,07
Width	0,084–0,104	0,084–0,100
Length of oesophagus	0,742–0,912	0,560–0,840
Distance of excretory pore form anterior end	0,140–0,156	0,140–0,156
Distance of prebursal papillae from posterior end	0,038–0,052	—
Length of left spicule	0,136–0,148	—
Length of right spicule	0,120–0,134	—
Length of gubernaculum	0,062–0,076	—
Combined length of ovijectors and sphincters	—	0,400–0,468
Distance of vulva from anus	—	0,844–1,208
Distance of anus from tip of tail	—	0,056–0,080
Distance of vulva from tip of tail	—	0,900–1,272
Eggs *(in utero)*, length	—	0,072–0,076
width	—	0,038–0,048

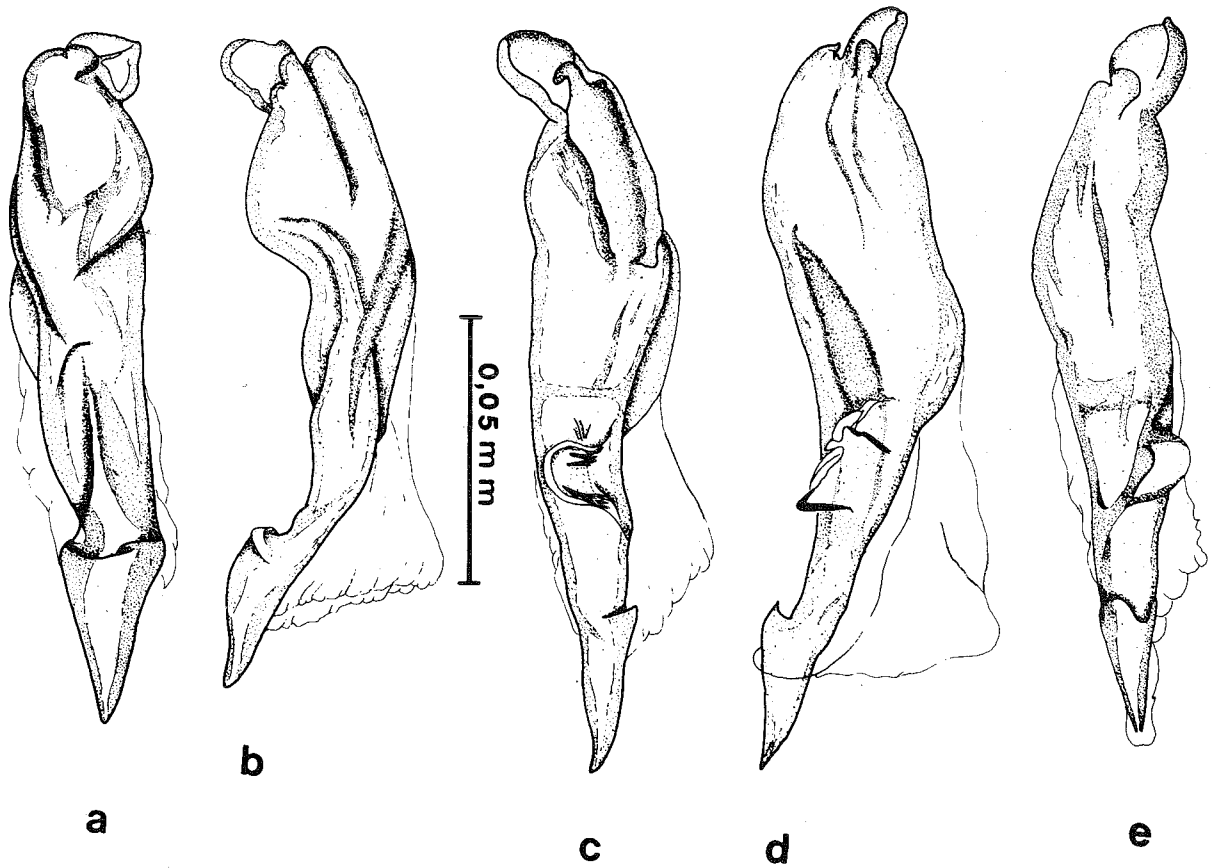

FIG. 2 Ventral (a) and lateral (b) views of the left spicule and dorsolateral (c), lateral (d) and ventrolateral (e) views of the right spicule of *Trichostrongylus auriculatus*

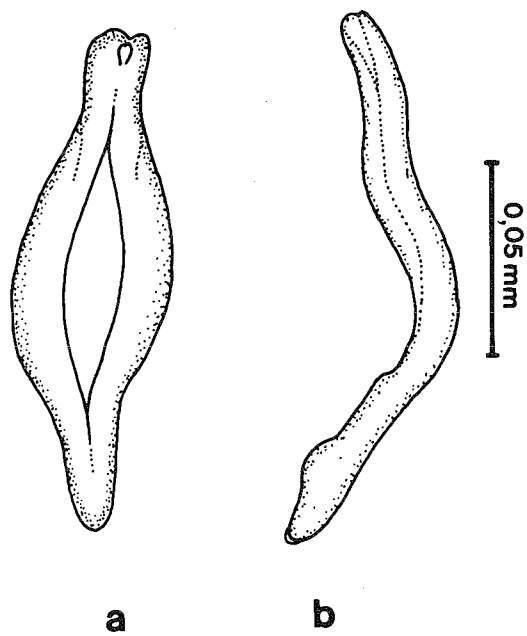

FIG. 3 The gubernaculum of *Trichostrongylus auriculatus* in (a) dorsal view and (b) ventral view

Description

The principal measurements are listed in Table 1.

Small worms that are often coiled; buccal capsule and cervical papillae absent; excretory pore opens in a ventrally situated notch slightly distal to the nerve ring; oesophagus cylindrical and only slightly distended distally.

The male bursa has the typical shape of those of other members of the genus (Fig. 1). There are 2 large lateral lobes and a more or less distinct dorsal lobe. The anteroventral rays are slender and curve anteriorly. The posteroventral rays are considerably thicker and curve laterally or only slightly anteriorly. The lateral rays diminish in size; the anterolateral curves anteriorly, the mediolateral curves laterally or slightly posteriorly and the posterolateral curves posteriorly. The externodorsal rays arise from the base of the dorsal ray and do not reach the bursal margin. The dorsal ray is short and slender and bifurcates at its distal end, each branch dividing in turn to form small digitate branches. Small prebursal papillae are present.

The spicules are subequal and complex; they appear to be longitudinally twisted and bear prominent ridges. The right spicule resembles that of *Trichostrongylus colubriformis* (Giles, 1892) Ransom, 1911 and has a fairly large body, a thinner shaft and a well-developed convex shoe (Fig. 2 a, b). The left spicule is longer and has a protuberance on the shaft which appears ear-shaped in dorsolateral or ventrolateral views, but angular in lateral view (Fig. 2 c–e). The protuberance consists of a sclerotized rim with 2 or 3 well-sclerotized rods that support the weakly sclerotized body. The shoe of this spicule is straight or only slightly concave. Well-developed membranous alae enclose the distal half of each spicule (Fig. 2). A weakly sclerotized, asymmetrically boat-shaped gubernaculum is present (Fig. 3 a). In lateral view, the gubernaculum is irregularly crescent-shaped and is slightly thickened distally (Fig. 3 b).

The females are slightly larger than the males and have the typical appearance of the genus. The vulva is situated approximately at the division of the anterior 2/3rds and the posterior 1/3rd of the body and vulvar lips are inconspicuous. The uteri are amphidelphic, and eggs are segmented when laid.

DISCUSSION

Although the spicules of *T. auriculatus* somewhat resemble those of *T. colubriformis*, the former nematodes are unique in that there is a protuberance on only 1 of the spicules. Another species that has prominent protuberances on the shafts of the spicules is *Trichostrongylus pietersi* Le Roux, 1932, where the protuberances have a different shape and occur on both spicules.

T. auriculatus seems to be limited to the arid areas of the country and has not been recovered from steenbok from the summer rainfall area (Boomker *et al.*, 1986).

ACKNOWLEDGEMENTS

I should like to thank the Board of Trustees, National Parks Board, for placing the animals at my disposal and Mr M. Knight of the Tick Research Unit, Rhodes University, Grahamstown for collecting the parasites.

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Systematic Parasitology **36:** 69–73, 1997.

Supplement to the description of *Longistrongylus thalae* (Troncy & Graber, 1973) Gibbons, 1981 (Nematoda: Ostertagiinae)

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Accepted for publication 22nd July, 1996

Abstract

Longistrongylus thalae (Troncy & Graber, 1973) Gibbons, 1981 is briefly re-described. The synlophe, the spicules and the apical cephalic structures, previously either inadequately or not figured, are illustrated. The authors concur with Gibbons (1981) that this nematode belongs to the genus *Longistrongylus* Le Roux, 1931, but consider the degree of asymmetry of the ovejector, as depicted by Troncy & Graber (1973), as not being representative of the species.

Introduction

Troncy & Graber (1973) originally described *Ostertagia thalae* from the abomasa of roan antelope *Hippotragus equinus* (Desmarest) and red hartebeest or kongoni *Alcelaphus buselaphus* (Pallas). Subsequently, Graber & Delavenay (1978) elevated the subgenus *Pseudomarshallagia*, created by Roetti (1941) for *Ostertagia (Pseudomarshallagia) elongata* Roetti, 1941, to full generic status and transferred *O. thalae* to *Pseudomarshallagia* in a new combination. Gibbons (1981) transferred *Pseudomarshallagia thalae* to the genus *Longistrongylus* Le Roux, 1931, because these genera had several characteristics in common. Durette-Desset (1989), however, retained the name *O. thalae*, and suggested that the species should be excluded from the Ostertagiinae and placed in the Graphidiinae, mainly because of the apparently asymmetrical uterus in the female.

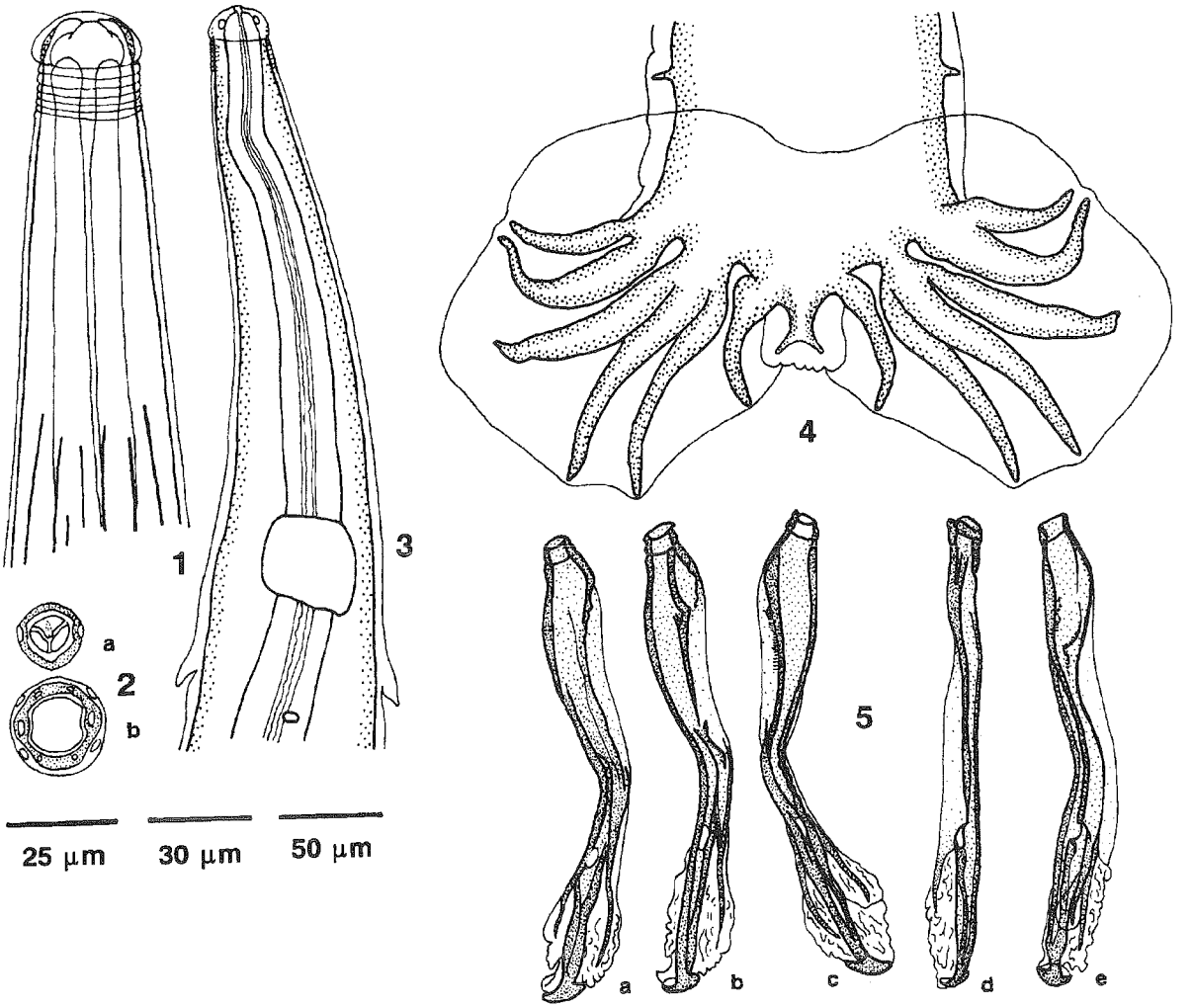
The purpose of this paper is to provide additional information on the species, as some of the illustrations provided by Troncy & Graber (1973) could be misleading.

Materials and methods

The specimens on which Troncy & Graber (1973) based their original description are in the collection of the Muséum National d'Histoire Naturelle (MNHN) and the following specimens were examined: 2 males, 2 females from *Alcelaphus buselaphus*, labelled *Bigalkenema thalae*, No. MNHN 43 MA; 1 male, 3 females from *Hippotragus equinus*, labelled *Ostertagia thalae*, No. MNHN 44 MA; holotype male, allotype female from *A. buselaphus*, labelled *Ostertagia thalae*, No. MNHN 45 MA; 6 males, 6 females from *A. buselaphus*, labelled *Ostertagia thalae*, No. MNHN 46 MA.

The nematodes were initially examined in water and, when deemed necessary, cleared in lactophenol. An *en face* preparation and cross-sections of the mid-body of male and female worms were made and studied in water and glycerine jelly, respectively. The cephalic synlophe was studied on nematodes mounted in phenol-alcohol. The spicules were dissected out of a male and examined in lactophenol. Measurements were made from drawings of the material, and all drawings were made with the aid of a Wild compound microscope and a drawing tube.

Measurements are given as those of the holotype or allotype, followed by those of the other specimens



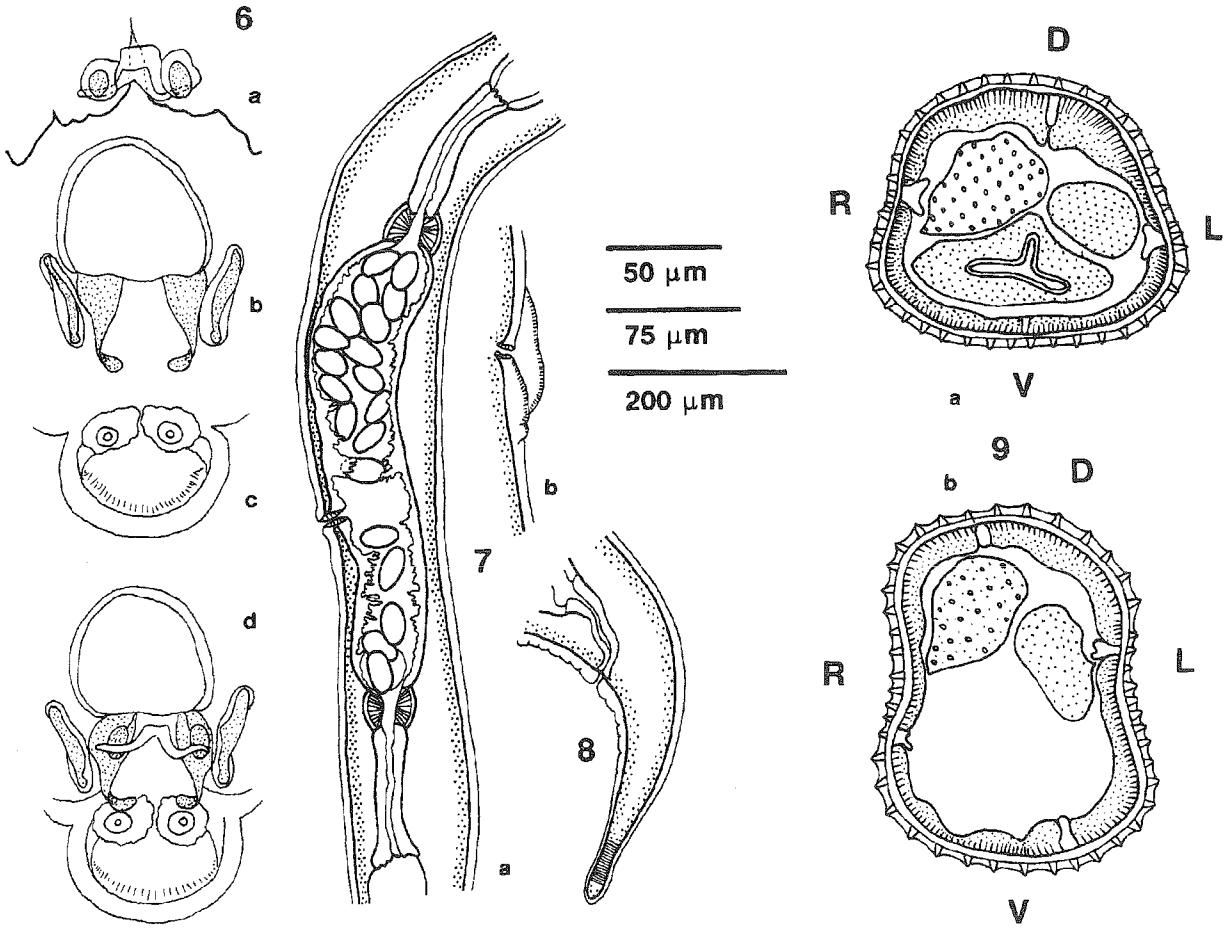
Figures 1–5. Longistrongylus thalae. 1. Dorsal view of the anterior end of a female showing the cross-striation in the cervical region and the beginning of the cuticular ridges. 2. A slightly deeper than *en face* view of a male, showing the proximal tip and opening of the dorsal oesophageal gland (a) and the apical structures on the head of a female (b). 3. Ventral view of the anterior end of a male. 4. Dorsal view of the bursa. 5. Interno-lateral, ventral and externo-lateral views (a–c) of the right, and ventral and dorsal views (d,e) of the left spicules. *Scale-bars*: 1,2,5, 25 μm; 3,4, 50 μm.

examined (in parentheses), and all measurements are given in micrometres (μm).

Longistrongylus thalae (Troncy & Graber, 1973) Gibbons, 1981

Description

Slender worms, with small cephalic vesicle. Fine cross-striations present on cuticle of the anterior region posterior to cephalic vesicle (Figures 1,3). Mouth round, without lips. Amphids comparatively large, 4 external labial and 4 cephalic papillae are visible (Figure 2b). Dorsal lobe of oesophagus immediately posterior to mouth exhibits proximal tip and opening of dorsal oesophageal gland (Figure 2a). Oesophagus clavate, indistinctly divided into muscular and glandular regions. Deirids prominent and situated laterally (Figure 3). Cervical synlophe consisting 3 parallel lateral ridges with adjacent parallel synlophe (Figure 10).



Figures 6–9. Longistrongylus thalae. 6. Genital cone; (a) ventral raylets and associated structures, dorsal view; (b) median, somewhat tubular, telamon, ventral view; (c) dorsal accessory bursal membrane with two papillae, representing rudimentary dorsal raylets, ventral view; (d) entire genital cone, ventral view. 7. Vulvar region of a female, showing the ovejector (a) and cuticular expansions at the vulva (b). 8. Lateral view of the female tail. 9. Transverse section through the mid-body of (a) a male and (b) a female. *Abbreviations*: D, dorsal; V, ventral; L, left; R, right; *Scale-bars*: 9, 25 µm; 6, 50 µm; 8, 75 µm; 7, 200 µm.

Males

Holotype male extensively damaged, so few anterior and posterior structures could be seen and measured. Body 7,905 (7,813–9,105) long, 157 (129–153) wide. Cephalic vesicle not measured in holotype; 10–15 long, 23–24 wide in other males. Cervical cross-striations could not be seen in holotype, but extend for 11–14 posterior to cephalic vesicle in other specimens. Muscular oesophagus 348 (278–376); glandular oesophagus 546 (557–613); total oesophageal length 894 (835–972); all measured from anterior extremity. Nerve-ring, deirids and excretory pore not seen in holotype, but 230–299, 286–355 and 261–327, respectively, in other specimens.

In hand-cut sections of mid-bodies of 4 males 44–51 (50, 51, 44, 50) cuticular ridges are present, the three in the lateral fields being slightly smaller than the rest. All ridges are perpendicular to body surface (Figure 9a).

Bursa with 2 well-developed lateral lobes and one small dorsal lobe which is crenulate posteriorly. Bursa of 2-1-2 type (Figure 4) and rays follow the description of Durette-Desset & Chabaud (1981).

Spicules equal or almost equal in length, well-sclerotised, curved in lateral view. Proximal part wider than distal part; latter consisting of stout main branch with rounded tip and 2 slender, pointed additional branches. Tip of each branch is enclosed in convoluted, transparent membranes (Figure 5a–e). Left spicule

209 (198–226); right spicule 205 (209–219). Gubernaculum absent.

Genital cone comparatively large and complex, contains lightly sclerotised elements; not seen in the holotype, 74–83 long and 40–43 wide in other males. The ventral raylets (papillae 0) paired and united at base (Figure 6a,d). Telamon present (Figure 6b,d); consists of lightly sclerotised structures which extend dorsally and caudally; latter forming incomplete loop through which spicules pass during extrusion. Accessory bursal membrane consists of membranous disc, on anterior end of which 2 ventrally directed papillae (papillae 7) occur (Figure 7c,d). Proconus not evident.

Females

Body 10,236 (9,532–10,963) long, 165 (150–181) wide. Cephalic vesicle 10 (11–14) long, 26 (24–27) wide. Cross-striations extend for 10 (12–16) posterior to cephalic vesicle. Muscular part of oesophagus 366 (342–367) long; glandular part 515 (512–553) long; combined length 881 (877–937). Nerve-ring not seen in allotype, situated 205–271 from anterior end in other females. Excretory pore and deirids 251 (238–317) and 289 (245–344) from anterior extremity, respectively.

Forty-two to 45 cuticular ridges present in mid-body (Figure 4b), arranged as described for males.

Vulva in posterior third of body, 1,414 (1,407–1,560) from anus and 1,616 (1,546–1,708) from caudal extremity. Small cuticular expansion may or may not occur in vulvar region (Figure 8a,b). Ovejector 898 (725–949) long, consisting of anterior infundibulum (167 (146–159)), anterior sphincter (38 (35–49)), anterior part of vestibule (289 (187–396)), posterior infundibulum (164 (104–167)), posterior sphincter (42 (35–49)) and posterior part of vestibule (198 (160–264)) (Figure 8a). There are 25 eggs in anterior branch of uterus of allotype, none in anterior infundibulum, 15 in anterior part of vestibule and 19 eggs in posterior branch of uterus, none in infundibulum and 19 in posterior part of vestibule. Eggs containing morula measure 52 × 28 (52–65 × 33–40). Tail bluntly pointed, 202 (125–156) long (Figure 9).

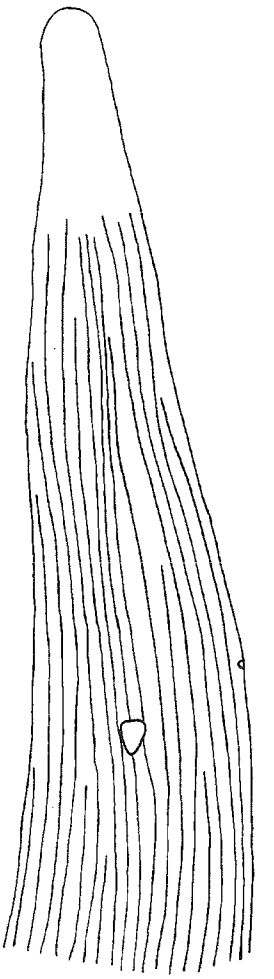


Figure 10. Longistrongylus thalae. Schematic representation in right lateral view of the anterior synlophe showing three parallel lateral ridges and adjacent parallel ridges.

Discussion

Except for the male spicules and the female ovejector, the original description and illustrations of *L. thalae* are precise. Troncy & Graber (1973) illustrated the ovejector as asymmetrical, with the posterior part bearing no eggs. While it is entirely possible that such a situation could occur, the majority of specimens we examined had eggs in both the anterior and posterior parts of the vestibule, although the posterior part tended to contain fewer eggs and was shorter than the anterior. The ovejector illustrated by Troncy & Graber (1973) should not be considered as representative, since only the anterior vestibulum contains eggs.

Troncy & Graber (1973) stated that there are between 30 and 50 longitudial ridges, and Gibbons (1981) that these are numerous, but neither author illustrated the synlophe. We found four males to have between 44 and 51 ridges, and two females 42 and 45 ridges, in the mid-body. This is unusual, as male trichostrongylid nematodes generally tend to have fewer

cuticular ridges than females. Although the females are longer than the males, there is little difference in their widths, and often the females are thinner than the males. The length of the oesophagus and the position of the deirids, nerve-rings and excretory pores in relation to the anterior ends also differ little between the sexes, and this may explain the similarity in the numbers of cuticular ridges. The anterior synlophe is closest to that of *Ostertagia mossi* Skrjabin, 1929, as illustrated by Hoberg, Lichtenfels & Pilitt (1993) and Lichtenfels & Hoberg (1993), and consists of three parallel lateral ridges with adjacent parallel synlophe.

We concur with Gibbons (1981) that *O. thalae (sensu stricto)* belongs to the genus *Longistrongylus*, and that it closely resembles *Longistrongylus banagiense* (Gibbons, 1972) Gibbons 1977. *L. thalae* may be distinguished from *L. banagiense* by its longer oesophagus and spicules, the presence of a telamon and by having more cuticular ridges in the synlophe of the mid-body.

Acknowledgements

This work was done at the Muséum National d'Histoire Naturelle, Paris, France, with a grant to the senior author from the Foundation for Research Development.

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J. Parasitol., 87(5), 2001, pp. 1095–1103

HAEMONCHUS HORAKI N. SP. (NEMATODA: TRICHOSTRONGYLOIDEA) FROM THE GREY RHEBUCK *PELEA CAPREOLUS* IN SOUTH AFRICA

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ABSTRACT: In the course of a revision of species of *Haemonchus* Cobb, 1898 (Nematoda), commonly referred to as large stomach worms and significant pathogens of ruminants, a new species was discovered in the grey rhebuck *Pelea capreolus,* and the bontebok *Damaliscus pygarthus,* in South Africa. The new species, *Haemonchus horaki,* was previously reported as a long-spicule form of *H. contortus* (Rudolphi, 1803) Ransom, 1911. The new species, compared with *H. contortus,* can be distinguished by significantly longer spicules (555–615 μm vs. 383–475 μm); a synlophe with fewer ridges (26 vs. 30 in the region of the posterior part of the esophagus) that extend more posteriorly (within 1 mm of the copulatory bursa in males and postvulvar in females, vs. 2/3 to 3/4 of prebursal and prevulvar lengths); and an asymmetrical dorsal lobe with a long dorsal ray divided for more than half of its length, forming 2 branches of unequal length (vs. a dorsal ray divided for less than half of its length and forming 2 equal branches in *H. contortus*).

Nematodes in *Haemonchus* Cobb, 1898, commonly referred to as large stomach worms, are significant pathogens of ruminants. They are among the most economically important parasites of cattle, sheep, and goats, causing significant production losses due to morbidity, mortality, cost of treatment, and suboptimal use of contaminated pastures (Gibbs and Herd, 1986). State-of-the-art descriptions, using the most sensitive characters for identification of species (the pattern of surface cuticular ridges, the synlophe), are available only for 3 species of *Haemonchus* that occur in North America. A phylogenetic classification of the 10 species of the genus is lacking. Modern descriptions of the remaining species and a predictive classification of the species of *Haemonchus* would greatly improve the diagnosis and prospects for controlling these nematode pathogens worldwide.

The synlophe (Desset, 1964) is the system of cuticular ridges distributed longitudinally on the surface of most nematodes in the Trichostrongyloidea. The synlophe has been used by Durette-Desset (1983) to classify genera and higher taxa of the Trichostrongyloidea. The number and pattern of ridges on the anterior half of the nematode also has been found to be the most sensitive and useful character for identifying species of many genera of Trichostrongyloidea (Lichtenfels, 1977, 1983; Measures and Anderson, 1983; Lichtenfels and Hoberg, 1993; Lichtenfels et al., 1994, 1997). In a revision of *Haemonchus,* Gibbons (1979) included midbody cross-sections of most species showing the number of ridges in that region of the body. Lichtenfels et al. (1986) have shown that the pattern of distribution of the ridges could be used to identify species of *Haemonchus.* Lichtenfels et al. (1994) found that *Haemonchus contortus* (Rudolphi, 1803) Ransom, 1911 has a synlophe of 30 ridges in the region of the posterior esophagus compared with 34 ridges in that region in both *H. placei* (Place, 1893) Ransom, 1911 and *H. similis* Travassos, 1914. Subsequently, Lichtenfels and Pilitt (2000) reported that a common synlophe pattern was found within several genera of the Haemonchinae, including *Ashworthius* Le Roux, 1930, *Mecistocirrus* Railliet & Henry, 1912, and *Haemonchus.* In addition, they identified specific areas of the pattern where variations among taxa were found. They suggested that differences among synlophe patterns would provide sensitive characters for evaluating or reevaluating the specific status of populations of large stomach worms, and that similarities among patterns would provide information for recognizing relationships among species and developing predictive classifications for these economically important nematode pathogens of ruminants.

A study of all available species of *Haemonchus* was undertaken to provide a further assessment of the synlophe and its usefulness for distinguishing among species and determining relationships within the genus. In the course of this study we discovered a new species of *Haemonchus.* The objective of the present paper is to present a description of the new species, previously reported (Horak et al., 1982; Boomker et al., 1983; Boomker and Horak, 1992) as a long-spicule form of *H. contortus.*

MATERIALS AND METHODS

Specimens measured included 2 lots each including 5 males and 5 females from 2 individual grey rhebuck *Pelea capreolus* (Forster, 1790) collected in the Bontebok National Park, Swellendam, Western Cape Province, South Africa, during December 1979 and the summer of 1990.

Nematodes were cleared in phenol–alcohol (80 parts melted phenol crystals and 20 parts absolute ethanol) for study in temporary wet mounts on glass microscope slides. Interference-contrast light microscopy was used to study the synlophe and other characters at a magnification of ×200–400. Some specimens were examined as temporary mounts in lactoglycerol to study the genital cone and bursa. A few specimens were dissected in Berlese's fluid, forming permanent mounts to study the spicules and gubernaculum. Cross-sections were studied as freehand cuts made with a cataract knife and mounted in glycerine jelly. Drawings of the synlophe patterns were prepared freehand. Drawings of characteristics of males were prepared with the aid of a camera lucida. Photomicrographs were obtained either with 35-mm cameras using Kodak T-max 100 black and white film or Kodak Ektachrome 100 or with a Jenoptik ProgRes 3012 digital camera. Selected images on film were digitized with a Nikon Cool Scan III. Photomicrographs were prepared for presentation in Microsoft Powerpoint. Measurements were made with a calibrated ocular micrometer. Nematode taxa above genus level follow the system of the *CIH Keys to Nematode Parasites of Vertebrates, No. 10* (Durette-Desset, 1983).

Terminology for the ridges of the synlophe follows Lichtenfels et al. (1994) and Lichtenfels and Pilitt (2000). Terminology for ovejectors follows Veglia (1915) in recognizing 3 parts of the ovejectors of

Received 11 December 2000; revised 6 April 2001; accepted 26 April 2001.

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Haemonchus. Veglia used the name pars haustrix for the long, slightly funnel-shaped part that communicates at its broad end with the uterus. The modern term for the pars haustrix is the universally adopted infundibulum (Chitwood and Chitwood, 1950). Veglia used the name pars ejectrix for the 2-part (sphincter and cylindrical or barrel-shaped part) second section of the ovejector of *H. contortus*. The proximal end (pars ejectrix 1), or sphincter, surrounds the distal end of the infundibulum. Both the sphincter and the cylindrical part (pars ejectrix 2) are covered with a thick layer of muscle with spiraling continuous fibers (Veglia, 1915) that clearly define it as a single structure demarcated at both ends (Fig. 26). Unfortunately, the only modern term used for the entire pars ejectrix is sphincter (Chitwood and Chitwood, 1950), and in some trichostrongyloid nematodes the cylindrical part (pars ejectrix 2) is reduced and the demarcation between the pars ejectrix and the vestibule is not distinct. This has led many workers to restrict the term sphincter to pars ejectrix 1, and to include pars ejectrix 2 with the vestibule, even in nematodes such as *Haemonchus* spp. in which the unity of pars ejectrix 1 and 2 and its separation from the vestibule is obvious. The muscular unpaired part of the ovejector that joins the anterior and posterior parts with the vagina was identified as a vestibule by Veglia (1915) and this term is universally accepted. The vestibule is clearly delimited from the cylindrical portion (= pars ejectrix 2) of the sphincter (sensu lato) in species of *Haemonchus*, but it is not in some other trichostrongyloids. We use the term infundibulum for pars haustrix, sphincter for both parts of pars ejectrix, and vestibule for the unpaired part as described by Veglia (1915).

DESCRIPTION

Haemonchus horaki n. sp.

(Figs. 1–26)

With characters of *Haemonchus*. Synlophe extends posteriorly over almost the entire body. Synlophe consists of 26 ridges through most of the length of the esophagus (Figs. 1–8). Ridges divided, for the purpose of discussion and comparison, into lateral fields of 4 on each side and dorsal and ventral fields of 9 roughly parallel ridges each. Ridges of the synlophe distinctly larger laterally than dorsally or ventrally (Figs. 7, 8). Ridges in the lateral field consist of 2 lateral ridges adjacent and parallel to the lateral line and 2 sublateral ridges, 1 dorsal and 1 ventral and parallel to the lateral ridges. One ventral ridge in line with excretory pore. Ridges of dorsal field arranged in similar pattern as those in ventral field. About 0.5 to 1.5 mm posterior to junction of esophagus and intestine, sublateral ridges on each side end, usually irregularly (Figs. 1–6) reducing number of ridges to 22 (Figs 2, 4, 5, and 8). About 10 to 16 mm posterior to ends of sublateral ridges (shorter distances in smaller males) lateral-most ridges of ventral and dorsal fields on each side end irregularly next to lateral ridges, reducing number of ridges to 18 (Fig. 6).

Male (on the basis of 10 specimens, 5 from each of 2 hosts): Body length 18.0–20.5 (19.2) mm. Esophagus length 1.51–1.71 (1.62) mm; 7.8–8.8 (8.5) % of body length. Anterior end to: nerve ring 315–380 (354); excretory pore 350–430 (388) (Fig. 11); cervical papillae 430–545 (484) (Fig. 10); subventral esophageal gland duct orifices (SVGO) 510–615 (564) (Fig. 11). Spicule length 555–615 (587); each with single lateral barb near distal tip (Figs. 13, 15, 20), right barb 45–60 (52) from tip, left barb 25–35 (32) from tip. Gubernaculum 300–335 (322) long (Figs. 17, 21), spindle-shaped in dorsal view, but with dorsal curve when viewed laterally (Fig. 17). Dorsal ray relatively long 235–260 (245), divided for more than half its length (Figs. 14, 18); slightly asymmetrical, right branch 140–200 (160) long, left branch 110–170 (135) long. Genital cone with single ventral "0" papilla (Figs 16, 19), paired lateral, rounded genital appendages (Figs. 13, 16, 19), and paired dorsal "7" papillae (Figs. 13, 16, 19). Synlophe ends distally within 1.0 mm of copulatory bursa.

Female (on the basis of 10 specimens, 5 from each of 2 hosts): Body length 21.2–31.1 (26.6) mm. Esophagus length 1.59–1.88 (1.75) mm, 5.9–7.5 (6.6) % of body length. Anterior end to: nerve ring 220–335 (290); excretory pore 240–385 (321); cervical papillae 300–480 (392); SVGO 475–600 (541). Vulva with protruding lips (Fig. 26), with or without knobs or vulval flap or lobe (Fig. 26); located posteriorly 82–87 (85) % of body length. Vagina length 140–235 (200). Ovejector (Figs. 25, 26) well-developed posteriorly and anteriorly, consisting of distinct parts (lengths): vestibule 215–265 (234); anterior sphincter 215–335 (252); anterior infundibulum 335–505 (438); posterior sphincter 198–410 (263); posterior infundibulum 215–515 (394). Eggs in uterus 75–85 (80) by 45–52 (48) (Fig. 23). Perivulval pore on surface of cuticle, dorsolaterally on each side in region of posterior infundibulum. Tail tapers gradually 450–670 (578) long (Fig. 24); phasmids dorsolaterally 127–235 (200) from tip. Synlophe ends posteriorly within 1.0 mm of anus.

Taxonomic summary

Type host: Grey rhebuck, *Pelea capreolus* (Forster, 1790) (Artiodactyla: Bovidae).

Site of infection: Abomasum.

Type locality: Bontebok National Park, Swellendam, Western Cape Province, Republic of South Africa (20°30′E, 34°03′S) (collected December 1979).

Prevalence and intensity: 11 of 25 *Pelea capreolus* infected; average 194 nematodes per host.

Specimens deposited: From type host and type locality: The National Collection of Animal Helminths, South Africa (holotype, no. T2182; allotype, no. T2183; paratypes, no. T2157, 14 males and 14 females and T2158, 5 males and 5 females; U.S. National Parasite Collection, Beltsville, Maryland 20705-2350, USA (paratypes, no. 70277); specimens from *Damaliscus pygarthus* from the type locality described by Boomker et al. (1983) have been lost.

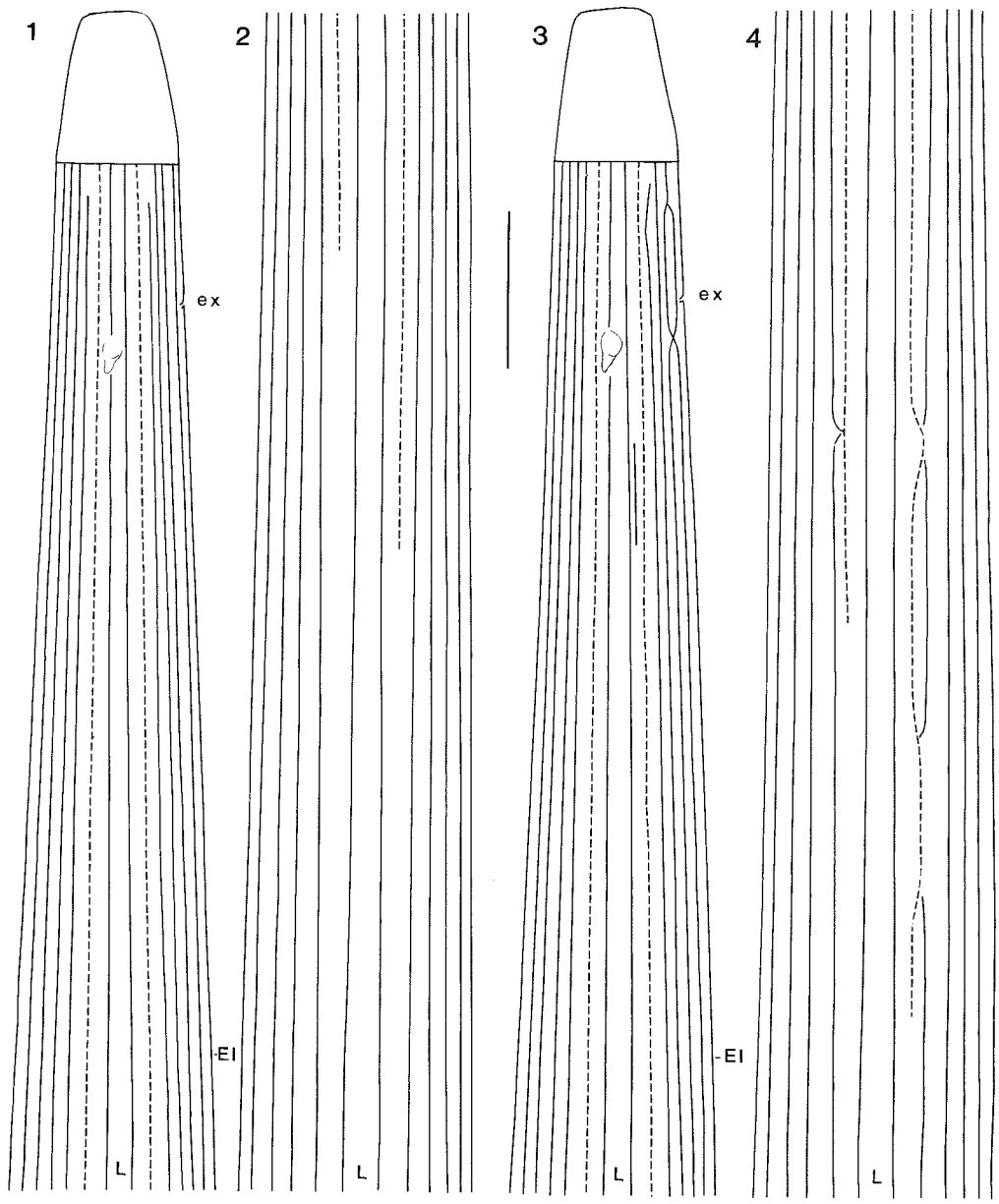
Etymology: The species is named in honor of Professor Ivan G. Horak, University of Pretoria, who first collected the nematode and recognized it as different from *H. contortus* because of its long spicules.

Diagnosis

The new species, *H. horaki*, is one of 5 species that have a synlophe of 30 or fewer ridges in the region of the posterior half of the esophagus that extends posteriorly over most of the body (J. R. Lichtenfels, pers. obs.). Included with *H. horaki* n. sp. in this group are *H. contortus, H. lawrenci* Sandground, 1933, *H. krugeri* Ortlepp, 1964, *H. dinniki* Sachs, Gibbons and Lweno, 1973. In only 3 species, *H. horaki, H. krugeri,* and *H. dinniki,* does the synlophe extend within 1 mm of the bursa in the males and postvulvarly to within 1 mm of the anus in the females. Among these 5 species, only *H. horaki* and *H. contortus* are significantly longer than 10 mm in length and have spicules significantly longer than 400 μm. The 3 remaining species, *H. lawrenci, H. krugeri,* and *H. dinniki,* are small, about 10 mm in length, with spicules under 400 μm in length or shorter. The new species can be distinguished further from *H. lawrenci, H. krugeri,* and *H. dinniki* by the symmetrical arrangement of the distal barbs on the spicules of those species. The new species can be separated further from *H. contortus* by its significantly longer spicules (555–615 in *H. horaki* and 383–475 in *H. contortus*) and its synlophe with fewer ridges (26 in the region of the posterior part of the esophagus in *H. horaki* and 30 in *H. contortus*) that extend more posteriorly (within 1 mm of the copulatory bursa in males and postvulvar in females of *H. horaki* compared with 2/3 to 3/4 of prebursal and prevulvar lengths in *H. contortus*). All the remaining species of *Haemonchus* have synlophes consisting of 34 or more ridges (Lichtenfels et al., 1994; J. R. Lichtenfels, pers. obs.). The ridges present in *H. contortus* but absent in *H. horaki* are the shorter of the paired sublateral ridges that begin near the level of the cervical papillae in *H. contortus* (dashed lines, Fig. 4 in Lichtenfels et al., 1994). The ridges present in *H. placei* (and all species with 34 or more ridges) but absent in both *H. horaki* and *H. contortus* are the subventral and subdorsal ridges that begin near the level of the middle of the esophagus in *H. placei* (dot-dash lines, Fig. 5 in Lichtenfels et al., 1994).

DISCUSSION

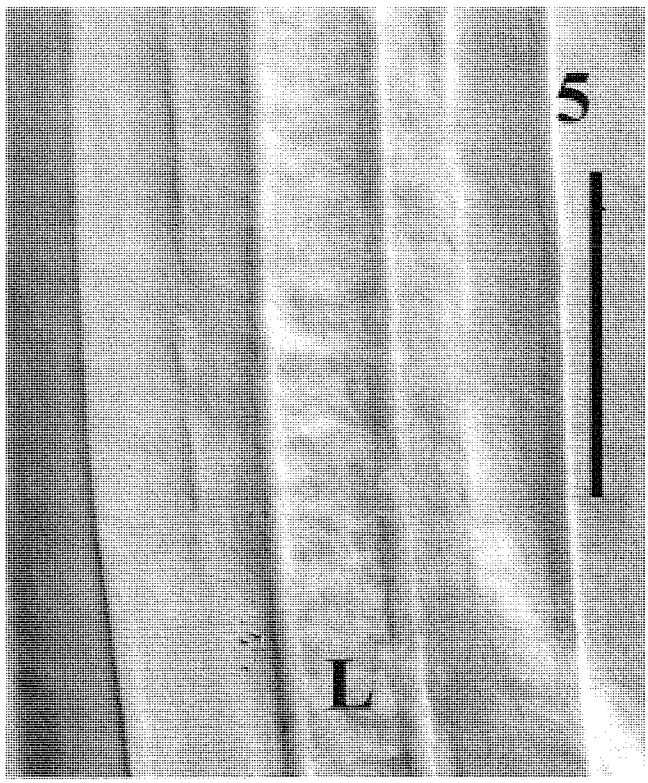
The long-spicule form of *H. contortus* described by Boomker et al. (1983) was recognized as unique initially because of its long spicules. However, because *H. placei* was considered by many (Gibbons, 1979) to be a synonym of *H. contortus,* there was a continuous range of spicule lengths for *H. contortus* of Gibbons (1979). After the discovery of synlophe differences (Lichtenfels et al., 1986; Lichtenfels et al., 1994) between *H.*

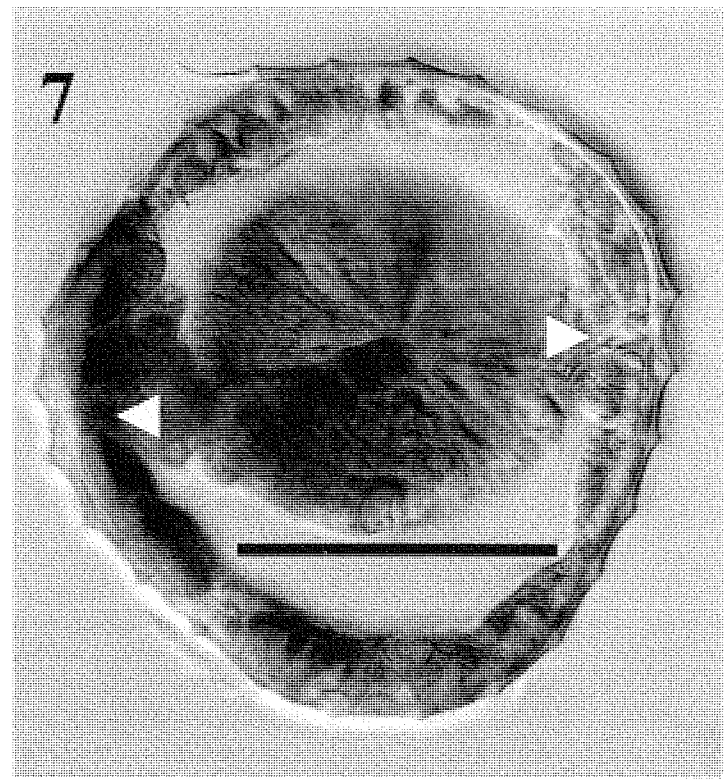


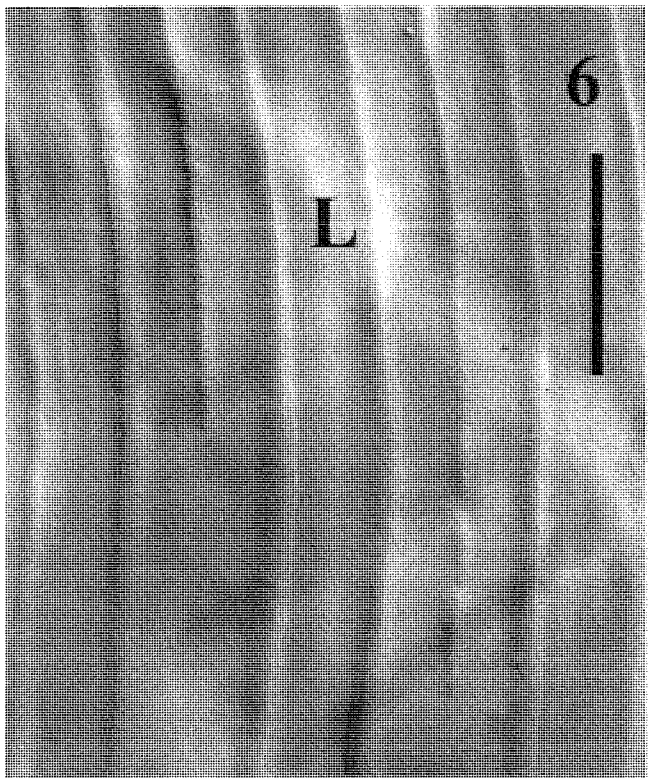
FIGURES 1–4. *Haemonchus horaki* n. sp., diagrammatic drawings of the synlophe, right lateral views (dashed lines = sublateral ridges; ex =excretory pore; EI = esophageal–intestinal junction; L = lateral). Scale bar 250 μm. **1.** Anterior end through region of the esophagus showing a typical pattern of 26 ridges. **2.** Postesophageal region (continuous with Figure 1) showing posterior ends of sublateral ridges of right side. Two additional sublateral ridges end on the left side. **3.** Anterior end through region of esophagus showing examples of variations in the synlophe that occur in this and related species. Note crossover and anastomosing of ridges near excretory pore and short extra ridge between lateral and sublateral ridges. **4.** Postesophageal region (continuous with previous figure) showing crossovers, anastomoses, and gaps in sublateral and adjacent ridges that occur in some specimens.

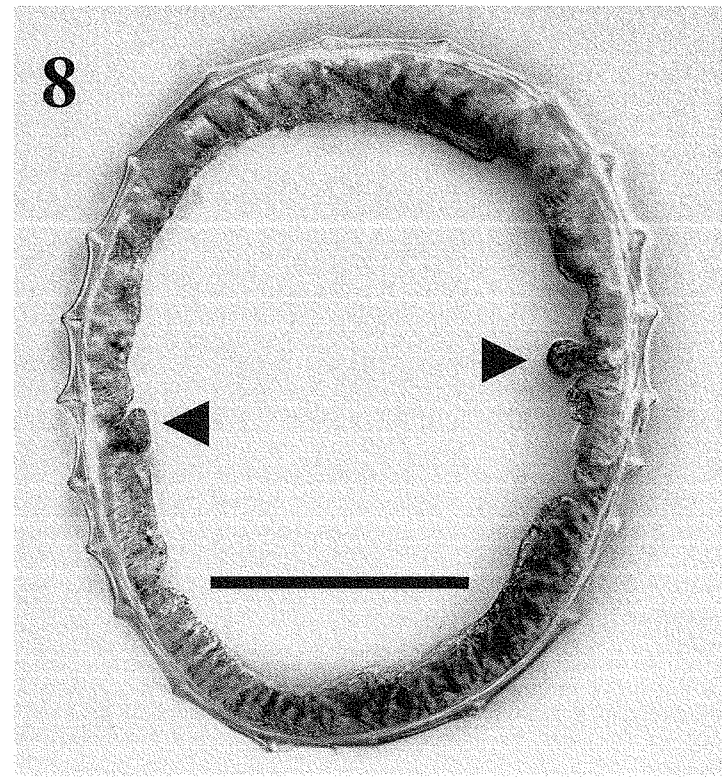
contortus and *H. placei,* the portion of the range of spicule lengths attributable to *H. placei* could be recognized (Lichtenfels et al., 1988). It then became increasingly apparent (Boomker and Horak, 1992) that the long-spicule form of *Haemonchus* reported by Boomker et al. (1983) was probably not *H. contortus.* The information on the synlophe provided by Lichtenfels et al. (1994) was sufficient to distinguish *H. horaki* from *H. placei,* which has 8 more ridges than the 26 of *H. horaki*, and those of *H. placei* are confined to the anterior half of the body in both sexes. Two additional species, *H. mitchelli* Le Roux, 1929 and *H. longistipes* Railliet and Henry, 1909, have long spicules that overlap the range of those of *H. horaki* sp. n. However, both *H. longistipes* and *H. mitchelli* have 34 or more ridges in synlophes confined to the anterior half of the body (J. R. Lichtenfels, pers. obs.).

The discovery that in some species of *Haemonchus* the synlophe extends for most of the length of the body, whereas in others it is confined to the anterior half, is paralleled by a similar discovery (E. P. Hoberg, pers. obs.) in an undescribed species of *Ashworthius.* Lichtenfels et al. (2000) have shown that the synlophe patterns among these genera and *Mecistocirrus* of the Haemonchinae are highly conserved, but variable regions

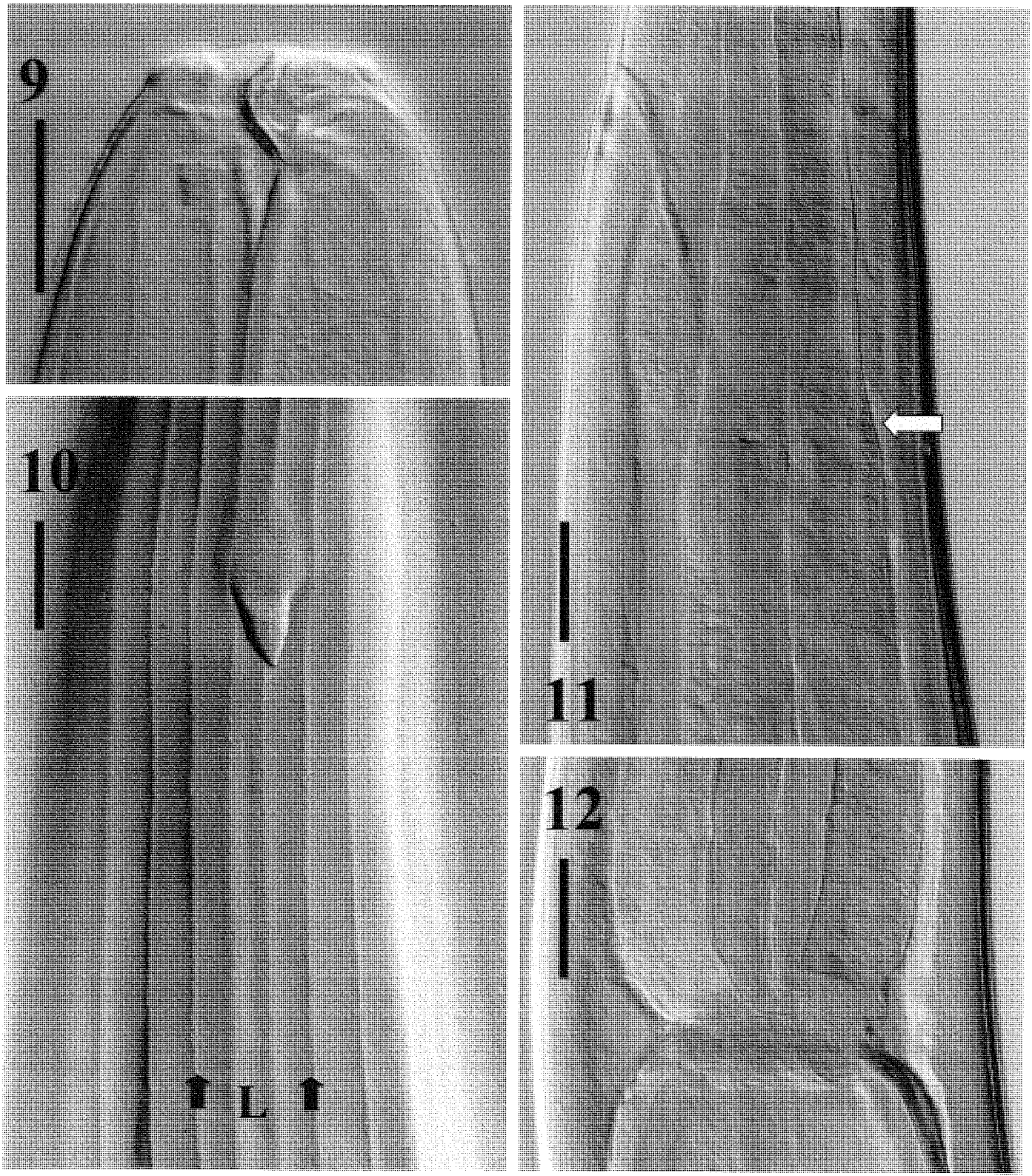




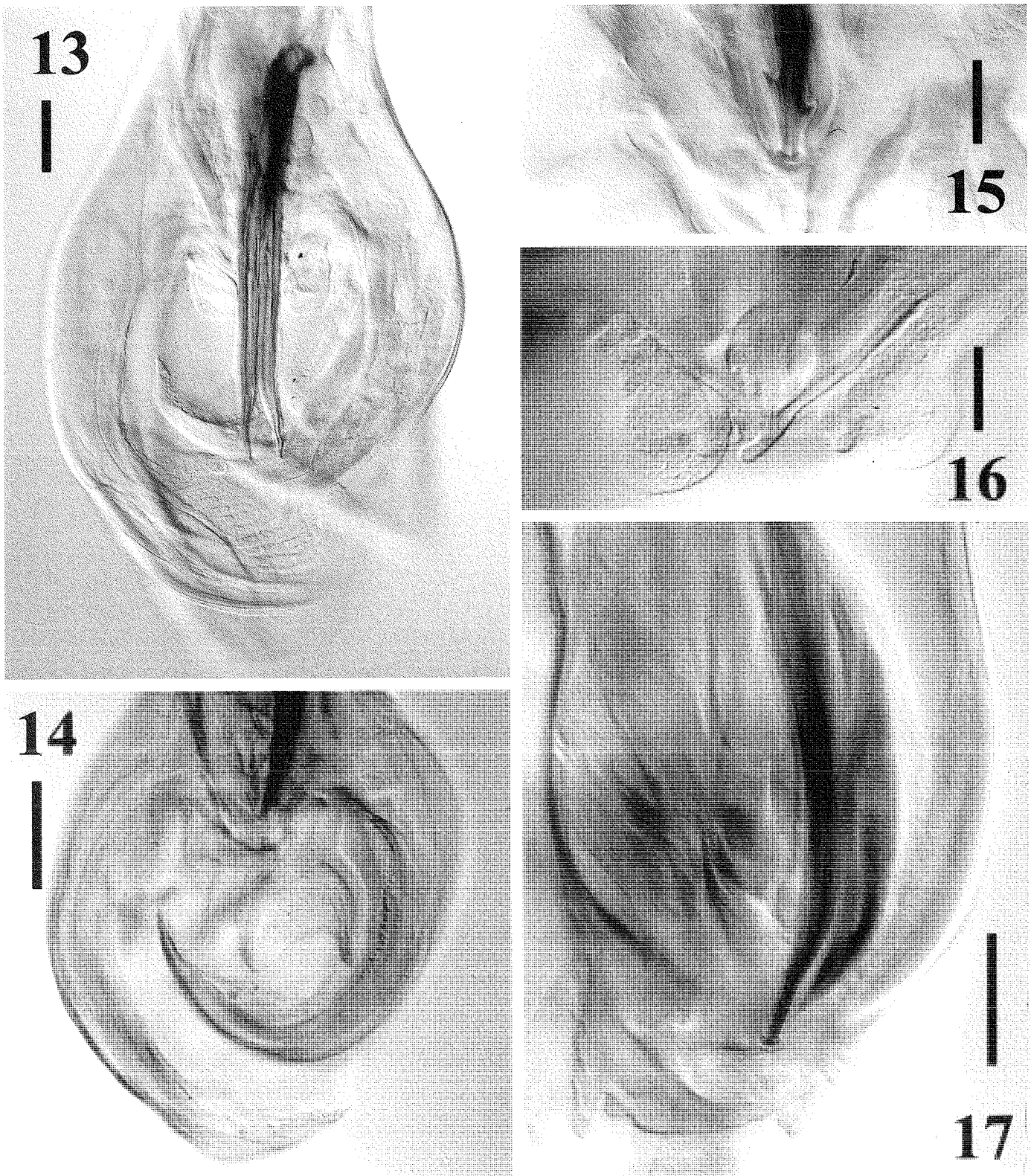




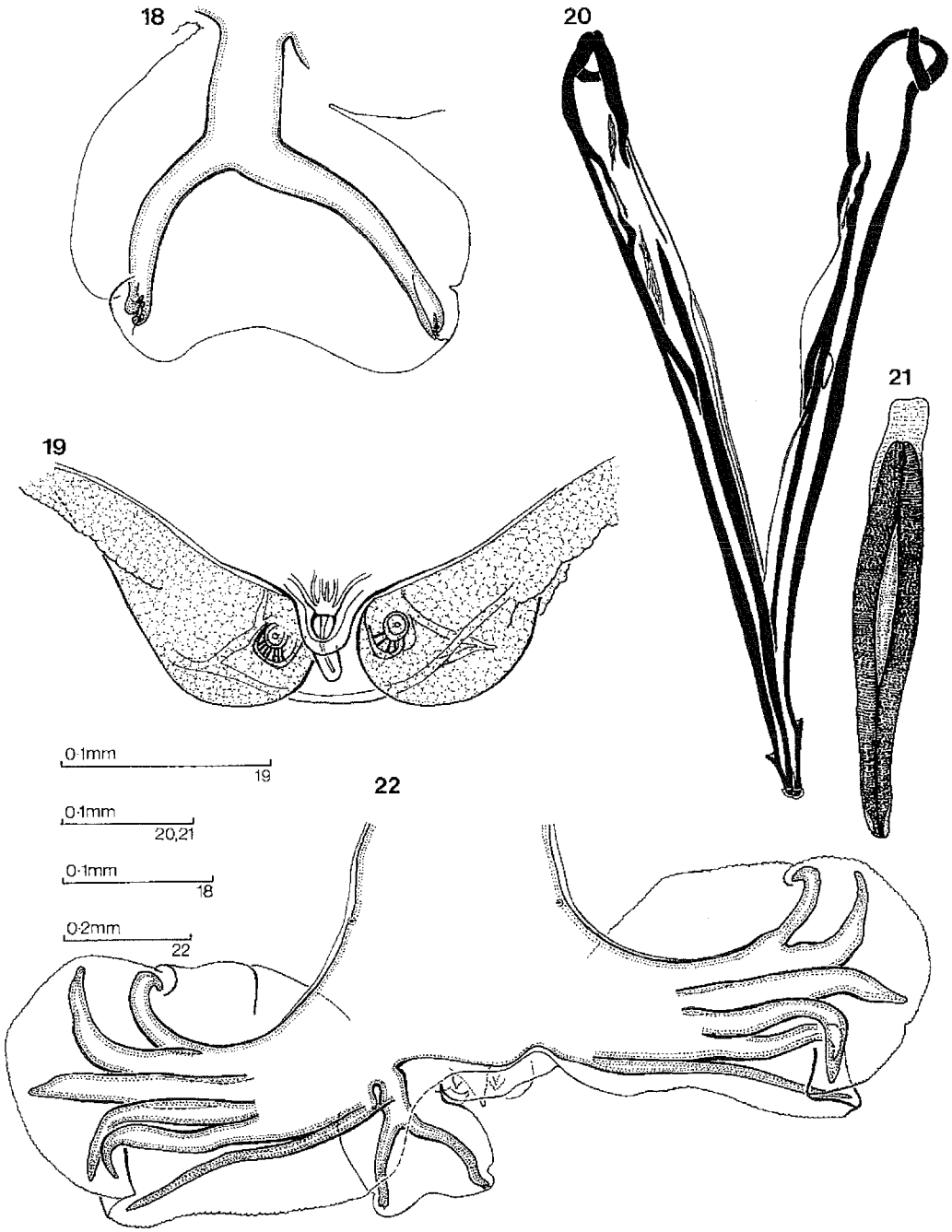
FIGURES 5–8. *Haemonchus horaki* n. sp., photomicrographs of characteristics of the synlophe. Scale bars 100 μm. **5.** Lateral synlophe, 3 mm from anterior end, showing posterior ends of sublateral ridges adjacent to lateral ridges (L = lateral). **6.** Posterior lateral synlophe, about 15 mm from anterior end, showing posterior ends of a pair of ridges adjacent to the lateral ridges (L = lateral). **7.** Cross-section through posterior portion of the esophagus of a male showing 26 cuticular ridges (arrowheads mark lateral). **8.** Cross-section at about midbody of a male showing 22 cuticular ridges (arrowheads mark lateral).



FIGURES 9–12. *Haemonchus horaki* n. sp., photomicrographs of head and esophageal region. **9.** Head, left lateral view showing large dorsal tooth. Scale bar 25 μm. **10.** Surface view of left lateral cervical papilla and synlophe (L = lateral; arrows mark sublateral ridges). Scale bar 50 μm. **11.** Excretory pore and esophagus, left lateral view, arrow at level at which ducts of subventral esophageal glands empty into lumen of esophagus and esophagus narrows anteriorly. Scale bar 50 μm. **12.** Esophageal–intestinal junction, right lateral view. Scale bar 50 μm.



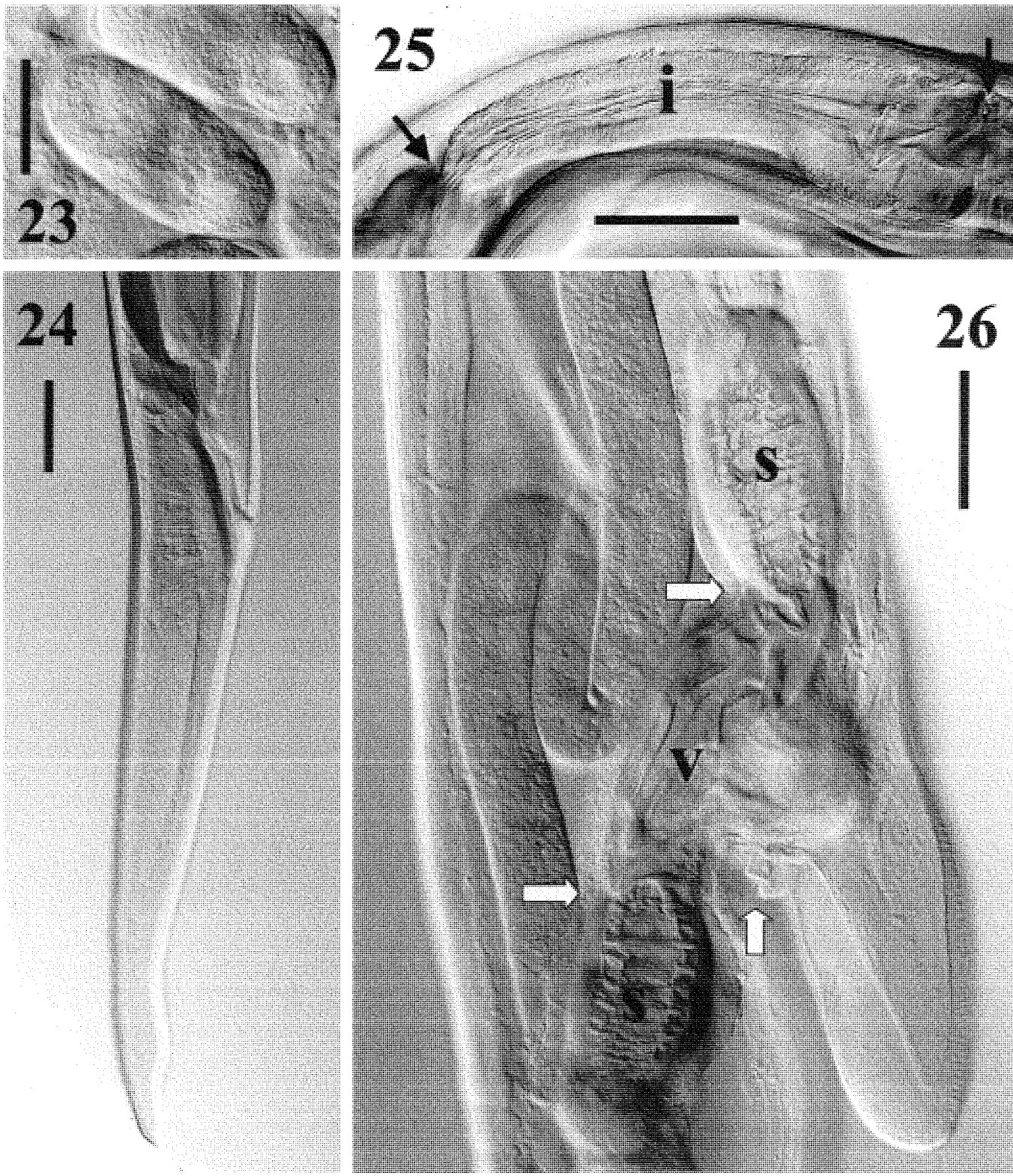
FIGURES 13–17. *Haemonchus horaki* n. sp., photomicrographs of male characteristics. **13.** Copulatory bursa and spicules, ventral view. Scale bar 100 μm. **14.** Dorsal ray of copulatory bursa, ventral view. Scale bar 100 μm. **15.** Distal tips of spicules, ventral view, showing barbs. Scale bar 50 μm. **16.** Genital cone, ventral view, showing single ventral "0" papilla, pair of dorsal "7" papillae, and lateral rounded genital appendages. Scale bar 50 μm. **17.** Genital cone, left lateral view, showing distal ends of spicules, gubernaculum, and papillae of genital cone. Scale bar 100 μm.



FIGURES 18–22. *Haemonchus horaki* n. sp., line drawings of male characteristics. **18.** Dorsal lobe and ray of copulatory bursa, ventral view. **19.** Genital cone, ventral view showing the ventral "0" papilla, lateral genital appendages, and the dorsal "7" papillae. **20.** Spicules dissected out of tissues, dorsal view. **21.** Gubernaculum dissected out of tissues, dorsoventral view. **22.** Copulatory bursa, dorsal view.

of the patterns were identified (Lichtenfels et al., 1994) among 3 species of *Haemonchus* and more recently among groups of species (J. R. Lichtenfels, pers. obs.) within *Haemonchus*. Thus, the preliminary data suggest that the synlophe has great potential also for understanding phylogenetic relationships within the Haemonchinae, although such studies and a key to the species of *Haemonchus* are beyond the scope of the present paper.

This nematode has been reported in 3 previous publications. Horak et al. (1982) reported *H. contortus* with exceptionally long spicules from *P. capreolus* and *D. pygarthus*, and Boomker et al. (1983) described this nematode from these hosts as *H. contortus*. In a later survey, Boomker and Horak (1992) found 11 of 25 *P. capreolus* to be infected with the long-spicule form of *H. contortus* and failed to find it in 16 *D. pygarthus*, the only other host from which this nematode had been reported (from a single animal). On the basis of these observations, Boomker and Horak (1992) suggested that the primary host of this nematode is *P. capreolus* and that *D. pygarthus* is not a normal host. Typical *H. contortus* occurs in other hosts such as *Redunca redunca* (Pallas, 1767)



FIGURES 23–26. *Haemonchus horaki* n. sp., photomicrographs of female characteristics. **23.** Uterine eggs. Scale bar 50 μm. **24.** Tail, right lateral view. Scale bar 100 μm. **25.** Anterior infundibulum (i) of ovejector. Arrows mark junctions, to the left with the anterior sphincter of the ovejector and to the right with the uterus. Scale bar 100 μm. **26.** Vulva (vertical arrow), vestibule (V), and sphincters of ovejector, right lateral view. (Horizontal arrows mark junctions of vestibule with sphincters.) Scale bar 100 μm.

in the same grazing area and must be considered to be sympatric with the new species.

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Parasites of South African wildlife. XVII. *Ostertagia triquetra* n. sp. (Nematoda: Trichostrongylina) from the grey rhebuck, *Pelea capreolus* (Forster, 1790)

J. BOOMKER[1] and M-C. DURETTE-DESSET[2]

ABSTRACT

BOOMKER, J. & DURETTE-DESSET, M-C. 2003. Parasites of South African wildlife. XVII. *Ostertagia triquetra* n. sp. (Nematoda: Trichostrongylina) from the grey rhebuck, *Pelea capreolus* (Forster, 1790). *Onderstepoort Journal of Veterinary Research*, 70:37–41

Re-examination of *Teladorsagia hamata* (Mönnig, 1932) Durette-Desset, 1989 reported from grey rhebuck, *Pelea capreolus* (Forster, 1790) proved it to be a new species of *Ostertagia* Ransom, 1907. The new species, for which the name *Ostertagia triquetra* n. sp. is proposed, differs from *Teladorsagia hamata* in the configuration of the bursal rays (2-1-2 in the former, 2-2-1 in the latter), and in that the interno-dorsal branch of the spicules bears a process that is triangular and convex in the new species, but concave and shaped like an ice-cream scoop in *Teladorsagia hamata*.

Ostertagia triquetra has so far been found only in grey rhebuck in the Eastern Cape Province while *Teladorsagia hamata* was recorded from springbok, *Antidorcas marsupialis* (Zimmerman, 1780) and gemsbok, *Oryx gazella* (Linnaeus, 1758) in the western part of the country.

Keywords: Nematoda, *Ostertagia triquetra*, *Pelea capreolus*

INTRODUCTION

Horak, De Vos & De Klerk (1982), Boomker (1990) and Boomker & Horak (1992) recorded *Teladorsagia hamata* (Mönnig, 1932) Durette-Desset, 1989 from grey rhebuck, *Pelea capreolus* (Forster, 1790) in the Bontebok National Park, Eastern Cape Province. Subsequent re-examination of the material, however, proved it to be a new species of *Ostertagia* Ransom, 1907. The new species, for which the name *Ostertagia triquetra* n. sp. is proposed, is described here and compared to *Teladorsagia hamata*, which it closely resembles as regards the principal measurements and the configuration of the spicules.

MATERIALS AND METHODS

Specimens were initially examined in water and, when necessary, cleared in lactophenol or phenol-alcohol. Temporary *en face* preparations and cross-sections of the mid-body of male and female specimens were made and mounted in lactophenol. The spicules were dissected out of several males and also examined in lactophenol. All drawings were made with a compound microscope and a drawing tube, and measurements were derived from these drawings. The nomenclature of the bursal rays used here is that of Durette-Desset & Chabaud (1981).

No specimens of *Teladorsagia hamata* were available for study and the measurements provided in Table 1 are those of Mönnig (1932).

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Accepted for publication 16 January 2003—Editor

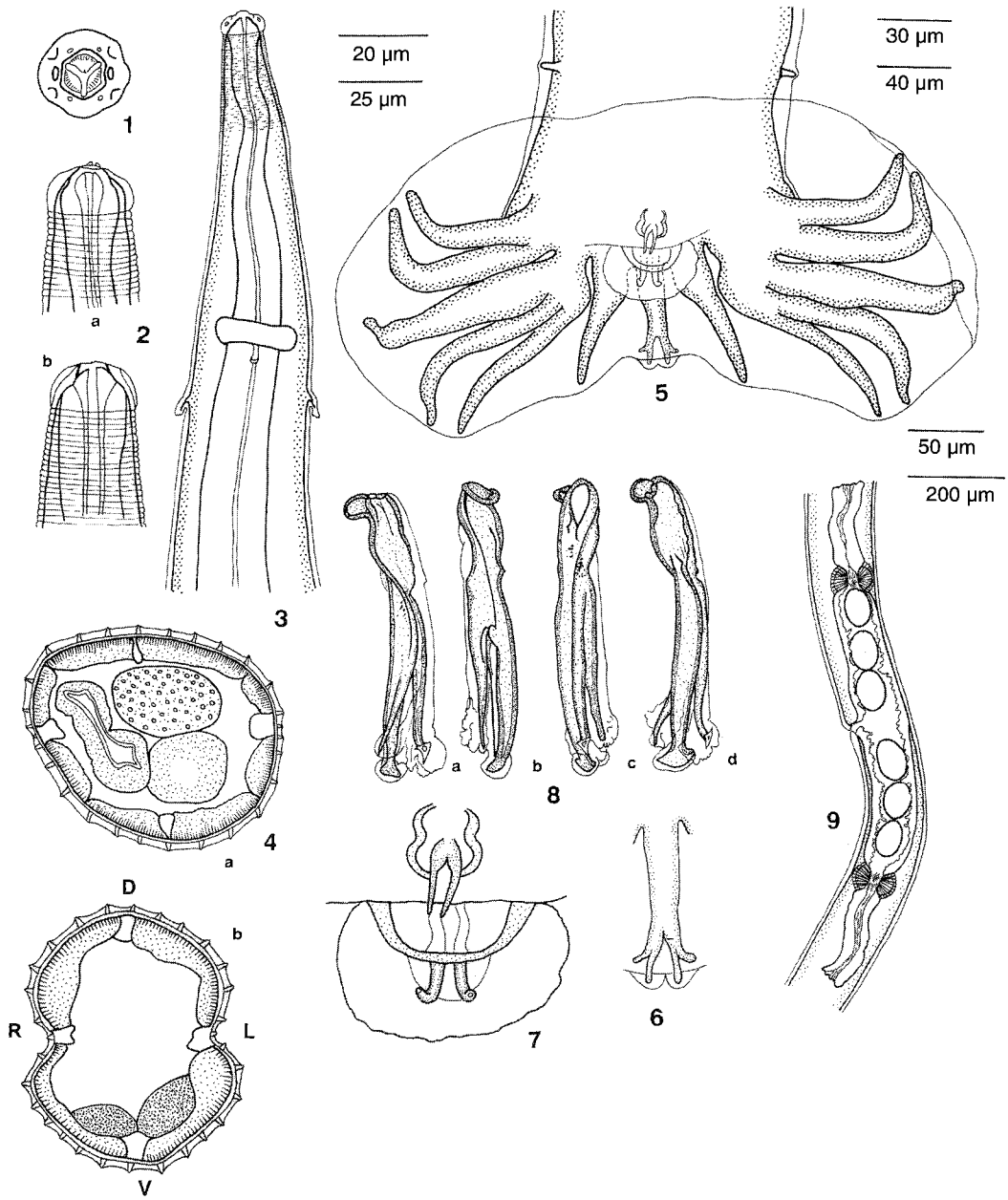

FIG. 1–9 ***Ostertagia triquetra*** **n. sp.**

FIG. 1 En face view of the head. Scale bar: 25 µm

FIG. 2 Ventral (a) and lateral (b) views of the head. Scale bar: 25 µm

FIG. 3 Dorsal view of the anterior part of a female. Scale bar: 50 µm

FIG. 4 Cross-section at mid-body of (a) a female and (b) a male; L—left, R—right, D—dorsal and V—ventral aspect of the body. Orientation of (a) is the same as that of (b). Scale bar: 30 µm

FIG. 5 Male bursa, ventral view. Scale bar: 40 µm

FIG. 6 Dorsal ray, showing the membranous extensions of the dorsal lobe. Scale bar: 25 µm

FIG. 7 Composite drawing of the genital cone and accessory bursal membrane, ventral view. Scale bar: 20 µm

FIG. 8 The right spicule in (a) ventromedian and (d) median views, showing the internoventral branch to the left and the internodorsal branch to the right in the latter figure. The ventral and dorsal aspect of the left spicule are illustrated in (b) and (c), respectively. Scale bar: 50 µm

FIG. 9 Left lateral view of the vulvar region and ovejector. Scale bar: 200 µm

DESCRIPTION OF *OSTERTAGIA TRIQUETRA* n. sp.

Synonymy

Ostertagia hamata sensu Horak, De Vos & De Klerk (1982), Boomker (1990) and Boomker & Horak (1992) *nec* Mönnig, 1932.

Type host

Pelea capreolus (Forster, 1790), from the Bontebok National Park, Swellendam, South Africa.

Material examined

Holotype male, allotype female, eight male and four female paratypes, all housed in the collection of the Muséum National d'Histoire Naturelle (MNHN), Paris, France, No. MNHN 431 MD; additional material from several grey rhebuck, 20 males and 20 females.

Etymology

The species name is derived from the Latin meaning 'triangular' *a propos* the triangular tip of the interno-dorsal branch of the spicules.

Description

The principal measurements are listed in Table 1.

Small nematodes with a small cephalic vesicle. The mouth is hexagonal and without lips. The dorsal lobe of the oesophagus immediately below the buccal ring appears tooth-like and has a small canal. Four external labial and four cephalic papillae are present, and the amphids are comparatively large (Fig. 1). The cephalic vesicle is followed by an area of fine transverse striations (Fig. 2). The oesophagus is indistinctly divided into an anterior muscular and a posterior glandular part, the division being slightly behind the nerve ring (Fig. 3). The excretory pore is near the laterally situated deirids. On cross-section at the mid-body, the males have 25–30 longitudinal cuticular ridges and the females 28–34, the lateral three or four of which appear smaller than the rest. In some male specimens the dorsolateral and ventrolateral ridges are slightly curved towards the dorsal and ventral aspects of the body, respectively, while the dorsal and ventral ridges are perpendicular to the body surface (Fig. 4A). The lateral synlophe is illustrated in Fig. 10.

MALES: The bursa has two large lateral lobes and a smaller dorsal lobe, which is indistinctly demarcated (Fig. 5). In some specimens the bursa is somewhat asymmetrical, the left lobe being slightly larger than the right one. The bursal rays have the 2-1-2 pattern. The pre-bursal papillae are large and easily visible; the tips of rays 2 and 3 are close to each other and both reach the bursal margin. Rays 4–6 have a common origin; ray 4 is thick, and its tip is some distance from rays 5 and 6 and also from the bursal margin; it curves toward rays two and three. Rays 5 and 6 become progressively thinner; they are close together with converging tips, the latter being near the bursal margin; both curve towards ray 8, which is relatively thick. The dorsal ray is short and bifurcates in the distal quarter, each branch in turn dividing into ray 9, which is small and papilla-like, and ray 10, which is undivided. The tip of ray 10 is enclosed in what appears to be membranous extensions of the dorsal lobe (Fig. 5 and 6). The genital cone is conspicuous and membranous, with fairly long ventral raylets. A large semicircular accessory bursal membrane with two slender dorsal raylets is present (Fig. 7).

The spicules are equal and well sclerotized. Each consists of a stout main "handle" and three branches. The externo-lateral branch bears ends in a shoe-like process and bears two branches of almost the same length. The shorter (interno-ventral) branch ends acutely, while the longer (interno-dorsal) branch is curved and bears a convex, triangular shoe. The tips of the two internal branches are covered by transparent membranes that extend cranially along the medial aspect of the spicules (Fig. 8). The 'ostertagiid' window is situated in the middle of the spicules. A lightly sclerotized gubernaculum, spoon-shaped in ventral view (Fig. 9), is present and it appears as if its rounded distal tip is fixed in or close to the cloacal opening.

FEMALES: The uterus is didelphic and situated in the posterior part of the body. The ovejector is slightly asymmetric in that the anterior part is often longer than the posterior part. The vulva is a slightly raised transverse slit and vulvar flaps are absent (Fig. 9). The tail is finely cross-striated and ends in an ovoid knob. The eggs are segmented when laid.

DISCUSSION

We consider the new species as belonging to the genus *Ostertagia* because the bursa is of the 2-1-2 type, the dorsal lobe and rays are reduced in length when compared to that of the genus *Marshallagia* Orloff, 1933, the tip of ray 4 curves towards rays 2 and 3, while rays 5 and 6 curve towards ray 8 and

TABLE 1 The principal measurements, in micrometres (µm), of *Ostertagia triquetra* n. sp. and *Teladorsagia hamata* (Mönnig, 1932)

Measurement	*Ostertagia triquetra* Males		*Ostertagia triquetra* Females		*Teladorsagia hamata* (After Mönnig 1932)	
	Holotype	Paratypes (n = 8)	Allotype	Paratypes (n = 4)	Males	Females
Length	8 159	7 847–9 197	10 490	10 420–11 275	6 600–7 850	8 090–11 020
Width	104	97–139	139	120–160	90–110	116
Length of cephalic vesicle	17	12–17	14	12–14	N	N
Width of cephalic vesicle	29	27–29	28	21–29	22–28	22–29
Extent of transverse striations behind head	70	64–80	65	52–64	N	N
Distance of deirids from anterior end	312	293–352	314	243–282	330–420	330–420
Distance of nerve ring from anterior end	249	216–279	233	191–213	240–290	240–290
Distance of excretory pore from anterior end	289	261–321	284	227–253	At deirids	At deirids
Length of muscular oesophagus	230	216–251	223	219–237	N	N
Length of glandular oesophagus	334	334–397	334	355–404	N	N
Total length of oesophagus	564	560–648	557	574–641	710–800	710–860
Ratio of oesoohagus length to body length	1:14.5	1:12.1–1:16.4	1:18.8	1:16.3–1:19.7	1:8.3–1:11.1	1:9.4–1:15.5
Length of left spicule	184	178–200	–	–	161–191	–
Length of right spicule	184	171–197	–	–	161–191	–
Length of gubernaculum	91	77–100	–	–	112	–
Length of tail	–	–	132	150–167	–	176–190
Distance of anus from vulva	–	–	1 680	1 686–1 928	–	1 130–1 584
Length of ovejector	–	–	1 069	951–1 055	–	150–230
Length of anterior infundibulum	–	–	219	180–215	–	N
Length of anterior sphincter	–	–	52	42–56	–	N
Length of anterior vestibulum	–	–	282	271–288	–	N
Length of posterior vestibulum	–	–	237	215–250	–	N
Length of posterior sphincter	–	–	42	42–49	–	N
Length of posterior infundibulum	–	–	237	194–229	–	N
Number of eggs, anterior part of uterus and ovejector	–	–	19	18	–	N
Number of eggs, posterior part of uterus and ovejector	–	–	18	13	–	N
Length of eggs	–	–	76	76–77	–	71
Width of eggs	–	–	44	44–46	–	39

– Not applicable
N Not given

the synlophe is of the *Ostertagia* type (Durette-Desset & Cabaret 1994). Furthermore, the spicules are ornamented and a gubernaculum is present. These characteristics conform to those given for the genus by Gibbons & Khalil (1982) and Durette-Desset (1989).

The males of *Ostertagia triquetra* can be differentiated from those of *Teladorsagia hamata* in the pattern of the bursal rays (2-1-2 in the former and 2-2-1 in the latter) and the tip of the interno-dorsal branch of the spicules, which is bent and has a convex, triangular process in the former species, while it is straight and concave, like a shallow ice-cream scoop, in the latter. Furthermore, the externodorsal rays of *Teladorsagia hamata* are longer than those of *Ostertagia triquetra*. The females of the two species closely resemble each other but can be separated on the synlophe and the larger size of *Ostertagia triquetra*. The oesophagus of *Teladorsagia hamata* is also longer than that of *Ostertagia triquetra* as indicated by the smaller ratio of the length of the oesophagus and the total body length.

In view of the morphological and host differences, we consider *Teladorsagia hamata sensu* Horak *et al.* (1982), Boomker (1990) and Boomker & Horak (1992) to be a distinct species for which the name *Ostertagia triquetra* n. sp. is proposed.

Horak (1981) and Boomker (1990) categorize the helminths of antelope into definitive, occasional, accidental and host-specific parasites. *Ostertagia triquetra* should be considered as a host-specific parasite, since it has been recorded only from *P. capreolus* and from this host only in the Bontebok National Park.

ACKNOWLEDGEMENTS

This study was done at the Muséum National d'Histoire Naturelle, Paris, France, with a study grant to the senior author from the Foundation of Research Development, now the National Foundation for Research.

The authors thank Professor A.G. Chabaud for his valued comments on the manuscript.

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Onderstepoort Journal of Veterinary Research, 71:171–174 (2004)

Parasites of South African wildlife. XVIII. *Cooperia pigachei* n. sp. (Nematoda: Cooperiidae) from the mountain reedbuck, *Redunca fulvorufula* (Afzelius, 1815)

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ABSTRACT

BOOMKER, J. & TAYLOR, W.A. 2004. Parasites of South Africa wildlife. XVIII. *Cooperia pigachei* n. sp. (Nematoda: Cooperiidae) from the mountain reedbuck, *Redunca fulvorufula* (Afzelius, 1815). *Onderstepoort Journal of Veterinary Research*, 71:171–174

A new species of *Cooperia*, for which the name *Cooperia pigachei* n. sp. is proposed, was recovered from a mountain reedbuck, *Redunca fulvorufula*, from the Sterkfontein Dam Nature Reserve, Free State Province, and is described and illustrated. It is close to *Cooperia neitzi* Mönnig, 1932 and the South African race of *Cooperia rotundispiculum* in having more than 14 longitudinal cuticular ridges and in that the lateral cervical synlophe is of the closed type. The new species differs from all the other species of the genus in that the lateral branches of the dorsal ray are large and T-shaped. The spicules are robust, over 0.3 mm long and have large, curved shoes on their tips.

Keywords: *Cooperia pigachei*, mountain reedbuck, Nematoda, *Redunca fulvorufula*

INTRODUCTION

During a study on the ecology of antelope in the Sterkfontein Dam Nature Reserve, Free State Province, the helminth parasites of a number of mountain reedbuck, *Redunca fulvorufula*, and grey rhebuck, *Pelea capreolus*, were collected. The area falls within the Grassland Biome, specifically the Moist Cool Highveld Grassland type (Bredenkamp & Van Rooyen 1996). Rainfall varies from 600 to 900 mm per year and occurs in summer. Temperatures vary from –11 °C to 38 °C, with an average of 17 °C. This is mountain grassland, with the typical cool, wet Drakensberg montane climate and severe frost. Occasional snow and frequent burning have major influences on the vegetation.

The mountain reedbuck from which the worms were recovered was a large adult female that was lactating but not pregnant, and, as determined from the kidney fat index, she was in reasonable condition. She was culled on the eastern side of the dam in the Park and was the only mountain reedbuck out of the 41 examined from which the new *Cooperia* species was recovered.

MATERIALS AND METHODS

Specimens were initially examined in water and when deemed necessary, cleared in lactophenol or phenol alcohol. Temporary cross-sections of the mid-body of a female specimen were made and mounted in lactophenol. All drawings (Fig. 1) were made with a compound microscope and a drawing tube, and measurements made from the drawings. Measurements are given as holotype/allotype fol-

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Accepted for publication 21 November 2003—Editor

lowed by the range of measurements of the paratypes (in parentheses). All are given in millimetres unless otherwise indicated.

The new species is placed in the family Cooperiidae, subfamily Cooperiinae according to the classification of Durette-Desset, Hugot, Darlu & Chabaud (1999).

RESULTS

Description

Males are 8.30 (8.23–8.93) long, and 0.202 (0.202–0.276) wide. The cephalic inflation is 0.143 (0.120–0.150) long and 0.051 (0.043–0.051) wide. The nerve ring was not seen in the holotype and was 0.253–0.332 from the anterior end in the paratype males. The excretory pore is 0.345 (0.366–0.406) and the minute deirids 0.363 (0.380–0.413) from the anterior end. The oesophagus is 0.552 (0.453–0.589) long.

The bursa has the typical appearance of the genus in that the short ray 2 is widely separated from the considerably longer ray 3. Rays 4 and 5 run parallel next to each other and have diverging tips, and the dorsal ray has a lyre-shaped appearance (Fig. 1A). The lateral branches of the dorsal ray arise at or just after the bifurcation of the main stem. These branches are unique within the genus in that they are quite robust and T-shaped (Fig. 1B). The spicules are virtually equal, the left one being 0.373 (0.340–0.396) long and the right one 0.368 (0.331–0.396). The tips of the spicules are large and enclosed in semi-transparent "shoes" (Fig. 1C). A gubernaculum is absent.

Females are 10.249 (8.353–11.249) long and 0.147 (0.120–0.207) wide. The cephalic inflation is 0.154 (0.076–0.161) long and 0.048 (0.041–0.083) wide. The nerve ring was not seen in the allotype but is situated 0.145–0.276 from the anterior end in the paratype females. The excretory pore and minute deirids are close together, 0.343 and 0.352 (0.251–0.465 and 0.265–0.478) from the anterior end, respectively. The oesophagus is 0.456 (0.336–0.465) long.

The vulva lies in the posterior third of the body, 7.698 (6.526–8.066) from the anterior end. Vulvar flaps are limited to the immediate vicinity of the vulva and are only slight expansions of the surrounding cuticular ridges of all individuals (Fig. 1D), except one, who has definitive flaps and several expanded cuticular ridges. The combined length of the opposed ovejectors, including the infundibula, sphincters and vestibule, is 1.370 (0.966–1.906). The tail is 0.159 (0.138–0.202) long. Eggs *in utero* measure 0.069–0.078 (0.074–0.097) long and 0.035–0.039 (0.037–0.055) wide.

On cross-section at the midbody, both the male and the female have seven dorsal and seven ventral ridges in addition to three lateral ridges on each side (Fig. 1D). The three lateral ridges are quite small. Ridges D1, D7, V1 and V7 are of similar size and slightly bigger than the lateral ones. The remaining dorsal and ventral ridges are large and more or less of equal size. All the ridges are perpendicular to the body surface.

In lateral view, the male cervical synlophe has 11 cuticular ridges (Fig. 1E) that are widely separated. The dorso- and ventro-lateral ridges (those bordering the minute lateral ridge) emerge close to each other a short distance behind the deirid. These then diverge slightly and run parallel over the length of the body. The lateral ridge starts a short distance behind the emergence of the dorso- and ventro-lateral ridges. Initially this field is hardly visible but soon becomes a distinct, solid band that runs for almost the entire length of the body. The lateral fields differ from the other fields in having a hyaline appearance and no ornamentation, whereas all the others have a tuberculated appearance brought about by underlying struts. As in many other species of the genus, the ridges extend from the base of the cervical inflation to the anterior part of the bursa in males and beyond the anus in females.

Type host

Mountain reedbuck, *Redunca fulvorufula* (Afzelius, 1815), from the Sterkfontein Dam Nature Reserve, (28°24'30 S; 28°58'25 E), eastern Free State Province, South Africa.

Material examined

Holotype male, allotype female, and four male and 13 female paratypes. The specimens have been deposited in the National Collection of Animal Helminths (formerly the Onderstepoort Helminthological Collection), Onderstepoort, access number T2185.

Etymology

The specific name is derived from the French for the long-toed, turned-up shoes, "pigaches", worn during the Middle Ages.

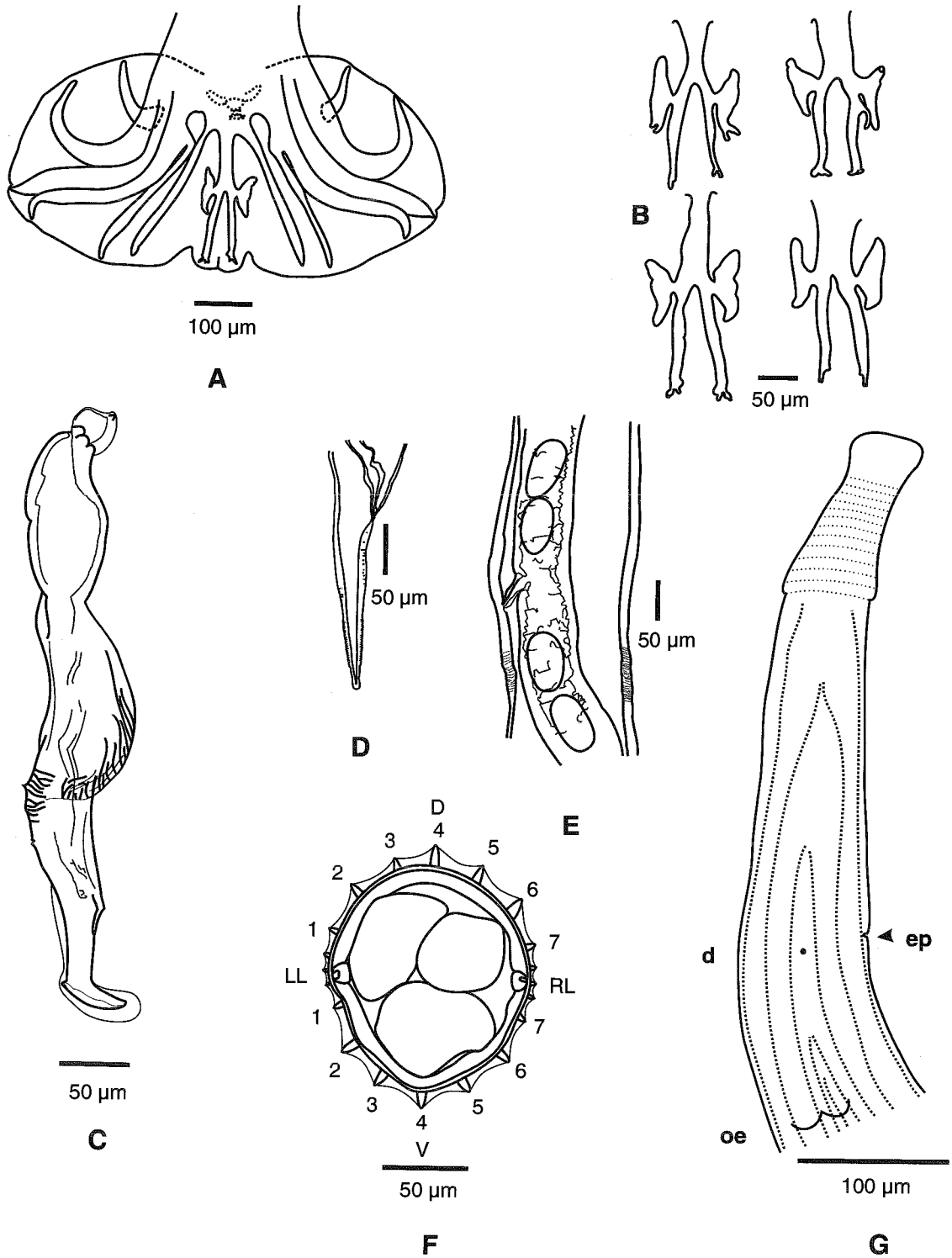

FIG. 1 *Cooperia pigachei*. A, dorsal view of the bursa; B, variations in the configuration of the dorsal ray; C, externo-lateral view of the right spicule; D, female tail, right lateral view; E, left lateral view of the vulval region of a female without flaps; F, schematic representation of a cross-section at mid-body of a female (D = dorsal, V = ventral, LL = left lateral and RL = right lateral); G, schematic representation of the lateral synlophe of a male (d = deirid, ep = excretory pore and oe = end of the oesophagus)

DISCUSSION

A large number of species of the genus *Cooperia* Ransom, 1907 occur in ruminants in Africa and these have been revised by Gibbons (1981). The majority of these species have 14 longitudinal cuticular ridges, five dorsal, five ventral, and two in each lateral field. Those with fewer ridges are *Cooperia chabaudi* Diaouré, 1964 that has 10 ridges and *Cooperia connochaeti* Boomker, Horak & Alves, 1979, that has 12 ridges of which the dorsal three are considerably smaller than the others. According to Gibbons (1981), *Cooperia neitzi* Mönnig, 1932 and *Cooperia verrucosa* Mönnig, 1932 have 19–20 ridges, 13 or 14 in the dorsal and ventral fields, and three in each lateral field. Hoberg, Lichtenfels & Pilitt (1993) state that at the midbody there are 20 ridges in male *C. neitzi* and 20–25 in females, and Boomker (1991) found *Cooperia rotundispiculum* to have 18–20 ridges. The male and female specimens examined in this study have 20 ridges, the arrangement of which is similar to that described for *C. neitzi*.

The cuticular inflations around the vulval area of the one specimen in which they were present are similar to that described by Hoberg *et al.* (1993) for *C. neitzi*. It is a prominent bilateral inflation, formed by hypertrophied ridges and reverts back to the pattern at midbody immediately following the posterior ovejector.

The cervical synlophe of *C. pigachei* is similar to that described for *C. neitzi*, *Cooperia punctata* and *Cooperia pectinata* (Lichtenfels 1977; Hoberg *et al.* 1993) in that it is of the converging or closed type. As is the case with *C. neitzi*, the minute lateral-most ridge of *C. pigachei* does not appear to be supported by struts, hence its hyaline appearance, while the remaining ridges are supported by struts giving them a striated or beaded appearance (Hoberg *et al.* 1993). From the illustrations provided by Hoberg *et al.* (1993) the lateral-most ridge of *C. neitzi* arises immediately posterior to the deirids, close to or at the junction of the oesophagus with the intestine, while the adjoining two (dorso- and ventro-lateral ridges) arise some distance in front of the deirid. In *C. pigachei* these three ridges arise quite a distance behind the deirids.

The configuration of the spicules of *C. pigachei* is near that of *Cooperia curticei* (Giles, 1892) Ransom, 1907, *Cooperia fuelleborni* Hung, 1926, *Cooperia hungi* (Mönnig, 1931) Mönnig, 1932, *Cooperia neitzi* Mönnig, 1932, *Cooperia pectinata* Ransom, 1907, *Cooperia rotundispiculum* Gibbons & Khalil, 1980 and the *Cooperia rotundispiculum* race described by Boomker (1991) in having large pectinate expansions more or less in the middle of each spicule. However, the new species differs from all of these by the presence of large curving "shoes" on the distal parts of the spicules. In addition, the dorsal ray is also unique among the *Cooperia* spp. in that it is the only species where the lateral branches of the dorsal ray are T-shaped.

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SETARIA SPECIES

Onderstepoort Journal of Veterinary Research, 67:229–234 (2000)

Studies on the genus *Setaria* Viborg, 1795 in South Africa. I. *Setaria africana* (Yeh, 1959)

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ABSTRACT

WATERMEYER, R., BOOMKER, J. & PUTTERILL, J.F. 2000. Studies on the genus *Setaria* Viborg, 1795 in South Africa. I. *Setaria africana* (Yeh, 1959). *Onderstepoort Journal of Veterinary Research*, 67:229–234

Setaria africana (Yeh, 1959) is represented by two subspecies, *Setaria africana africana* Troncy, Graber & Thal, 1976 from giant eland (*Taurotragus derbianus*) from the Central African Republic and Cameroon and *Setaria africana farchai* Troncy, Graber & Thal, 1976 from bushbuck (*Tragelaphus scriptus),* also from the Central African Republic. Material collected from nyala (*Tragelaphus angasii*), bushbuck and kudu (*Tragelaphus strepsiceros*) from several localities in the eastern region of South Africa was re-examined. Measurements of adult worms confirmed the differences between the two subspecies and scanning electron microscopy showed that the deirids of *S. africana africana* are single whereas those of *S. africana farchai* are double. *Setaria africana farchai* is recorded for the first time in South Africa.

Keywords: Helminth parasites, *Setaria africana, Setaria africana farchai,* South African wildlife

INTRODUCTION

The genus *Setaria* Viborg, 1795 is wide-spread and in Africa it occurs in equids, suids, hyracoids and ruminants (Round 1968). Yeh (1959) divided the genus *Setaria* into the genera *Setaria*, *Hyraconema* and *Artionema*, and described *Artionema africana* from, amongst others, nyala (*Tragelaphus angasii*) from KwaZulu-Natal. However, Nelson (1962) and Round (1968) did not accept this division. Ortlepp (1964) also rejected the genus *Artionema* and placed *Artionema hartwichi* Yeh, 1959 and *Artionema africana* Yeh, 1959 in the genus *Setaria.* Chabaud (1965) and Desset (1966) treated Yeh's (1959) divisions as subgenera while Anderson & Bain (1976) consider *Hyraconema* and *Artionema* as synonyms of *Setaria*.

During several surveys of the helminth parasites of South African wildlife, many specimens of the genus *Setaria* were collected from a variety of hosts, including kudu (*Tragelaphus strepsiceros*), nyala and bushbuck (*Tragelaphus scriptus*) (Boomker, Keep, Flamand & Horak 1984; Boomker, Horak & De Vos 1989; Boomker, Horak & Flamand 1991). *Setaria africana* was recovered from bushbuck, but the specimens from kudu and nyala were identified to the genus level only (Boomker *et al.* 1984, 1989, 1991). Ortlepp (1961) recorded the presence of *S. africana* in kudu and bushbuck and Troncy, Graber & Thal (1976) described *Setaria africana africana* and *Setaria africana farchai* from the abdominal cavities of the giant eland (*Taurotragus derbianus*) and bushbuck, respectively. The material from the South African hosts was re-examined, and the scanning electron microscopic appearance together with the measurements of the two subspecies of *S. africana* are presented here and compared with the findings of Yeh (1959) and Troncy *et al.* (1976).

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Accepted for publication 2 August 2000—Editor

MATERIALS AND METHODS

The specimens originated from the helminthological collection of one of us (JB), currently housed in the Department of Veterinary Tropical Diseases, University of Pretoria, and the following specimens were examined: one female from kudu, Pafuri, Kruger National Park (KNP); four males and 11 females from nyala in the Mkuzi Game Reserve, KwaZulu-Natal (KZN); two females from nyala in the Umfolozi Game Reserve, KZN; 22 males and 81 females from nyala in the Ndumu Game Reserve, KZN; one female from bushbuck from Pretoriuskop, KNP; three females from bushbuck in the Weza Forest Nature Reserve, KZN and one female from bushbuck at Charters Creek, KZN.

The nematodes were cleared in lactophenol and examined under a compound microscope with Nomarski's interference contrast lighting. Drawings were made with the aid of a drawing tube. Measurements were derived from the drawings and all are given in millimetres (mm). With the exception of the extensive collection from nyala, from which ten males and ten females were selected and measured, all the material was measured.

Specimens for scanning microscopy were dehydrated through graded ethyl alcohol and critically point dried from 100 % ethanol to liquid carbon dioxide. They were mounted on stubs and sputter-coated with gold. The examinations and photography were done with a Hitachi S-2500 scanning electron microscope operated at 8 kV.

RESULTS AND DISCUSSION

Of the 126 helminths examined, 121 proved to be *S. africana africana*. One female was recovered from kudu at Pafuri, four males and 11 females from nyala in the Mkuzi Game Reserve, two females from the same host in the Umfolozi Game Reserve and 22 males and 81 females from nyala in the Ndumu Game Reserve. These localities represent the northern part of the KNP and the northern game reserves of KZN. A total of five nematodes, one female from bushbuck at Pretoriuskop, KNP, three females from the same host in the Weza Forest and one female from bushbuck at Charters Creek, in the central part of KZN, proved to be *S. africana farchai*.

In Tables 1 and 2 the measurements of *S. africana africana* and *S. africana farchai* are compared with those made by Yeh (1959) and Troncy *et al.* (1976), respectively.

Desset (1966) found little difference between her *S. africana* material and that of Yeh (1959), and the measurements of the South African material also correspond well with those of Yeh (1959).

The majority of measurements of the South African *S. africana farchai* were similar to those recorded by Troncy *et al.* (1976). However, the cephalic elevations are larger and approach the measurements of those of *S. africana africana*. The oesophagus is also longer, the shortest measurements being well in excess of those given by Troncy *et al.* (1976). The caudal appendages are bigger and nearer the tail tip.

TABLE 1 Comparative measurements (in mm) of *Setaria africana africana*

Criterion	Males		Females		
	This paper	Yeh (1959)	This paper	This paper	Yeh (1959)
	Nyala (n = 10)		Kudu (n = 1)	Nyala (n = 10)	
Length	32,00–46,00	31,00–46,00	72,00	61,00–90,00	44,00–94,00
Width	0,320–0,380	0,270–0,350	0,690	0,490–0,650	0,500–0,700
Muscular oesophagus length	0,340–0,650	0,400–0,700	0,680	0,460–0,870	0,400–0,700
Glandular oesophagus length	4,790–6,450	3,500–6,200	7,620	5,920–8,470	4,500–8,400
Total oesophagus length	5,300–7,100	4,000–7,000	8,300	6,500– 9,100	5,000–9,000
Nerve ring from anterior end	0,170–0,250	0,200–0,270	0,240	0,200–0,280	0,200–0,300
Deirids from anterior end	0,270–0,490	0,320–0,650	0,440	0,420–0,630	0,400–0,500
Vulva distance from anterior end	–	–	0,540	0,450–0,620	0,400–0,600
Tail, length	0,160–0,240	0,160–0,180	0,358	0,350–0,610	0,400–0,600
Caudal appendages from tail tip	–	–	0,046	0,063–0,104	0,060–0,080
Caudal appendages length	–	–	0,015	0,011–0,017	0, 011
Right spicule, length	0,070–0,100	0,110–0,130	–	–	–
Left spicule shaft, length	0,170–0,200	0,170–0,190	–	–	–
Left spicule blade, length	0,070–0,090	0,080–0,110	–	–	–
Distance between cephalic elevations, lateral view	0,070–0,110	0,080–0,100	0,130	0,110–0,160	0,130–0,170
Distance between cephalic elevations, ventral view	0,020–0,030	#	0,050	0,030–0,040	0,050

– Not applicable
Measurements not given by author

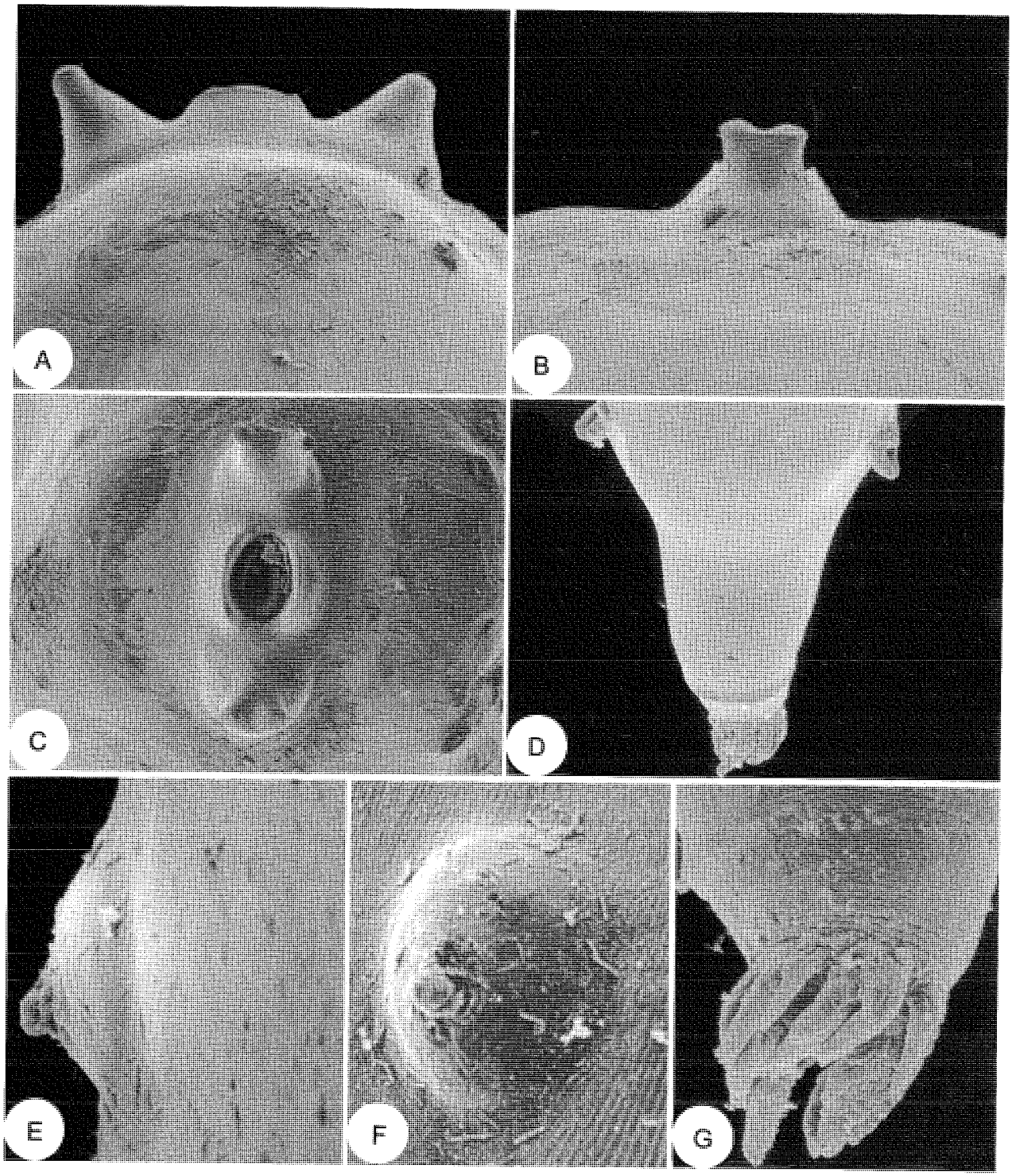

FIG. 1 *Setaria africana africana*

A Lateral view of cephalic elevations, x 600
B Ventral view of elevations, x 600
C *En face* view of elevations, x 500
D Ventral view of female tail, x 1000
E Lateral view of deirid, x 3000
F *En face* view of deirid, x 3000
G Terminal part of female tail, x 3000

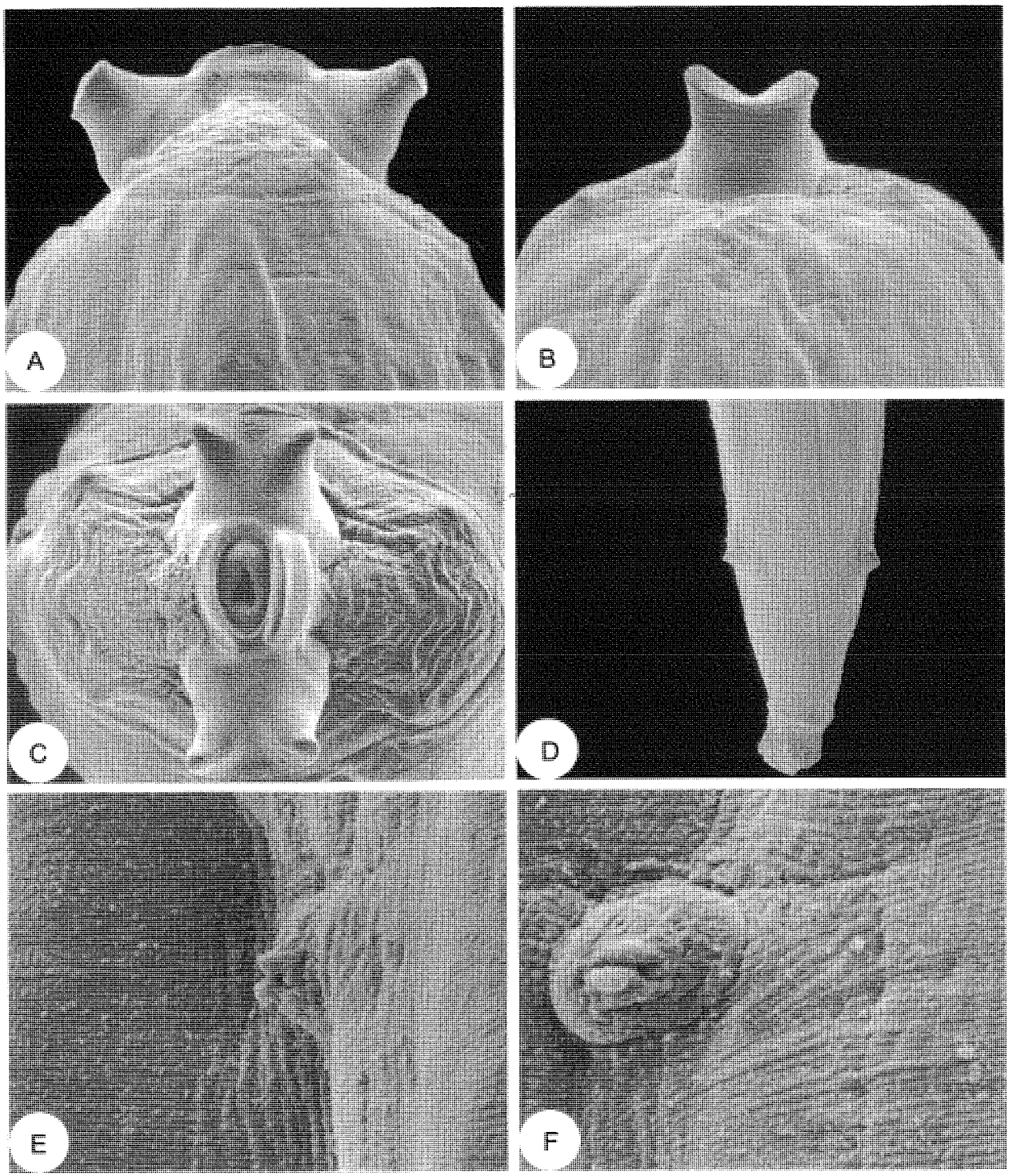

FIG. 2 *Setaria africana farchai*

A Lateral view of cephalic elevations, x 600
B Ventral view of elevations, x 600
C *En face* view of elevations, x 600
D Ventral view of female tail, x 1000
E Lateral view of deirid, x 3000
F *En face* view of deirid, x 3000

TABLE 2 Comparative measurements (in mm) of *Setaria africana farchai* females from bushbuck (*Tragelaphus scriptus*)

Criterion	Females		
	This paper		Troncy *et al.* (1976)
	Range	Mean	Range
Length	63,00–83,00	77,50	80,00
Width	0,350–0,630	0,510	0,600
Muscular oesophagus, length	0,400–0,970	0,750	0,660
Glandular oesophagus, length	5,330–7,420	6,130	4,440
Total oesophagus, length	6,300–7,820	6,880	5,100
Nerve ring from anterior end	0,220–0,290	0,270	0,260
Deirids from anterior end	0,400–0,550	0,490	0,560
Vulva from anterior end	0,460–0,580	0,530	0,570
Tail, length	0,320–0,670	0,510	0,630
Caudal appendages from tail tip	0,058–0,081	0,069	0,110
Length of right caudal appendage in ventral view	0,019	0,019	0,015*
Length of left caudal appendage in ventral view	0,017	0,017	0,008*
Distance between cephalic elevations, lateral view	0,097–0,173	0,134	0,104
Distance between cephalic elevations, ventral view	0,039–0,046	0,043	0,017

* Orientation of specimens not indicated

In addition, they are almost equal in length in the South African material whereas Troncy *et al.* (1976) found them to be unequal.

The scanning electron microscopical appearance of the two *S. africana* subspecies are presented in Fig. 1 and 2.

It is evident from the scanning electron micrographs that the description of Troncy *et al.* (1976) is accurate. However, they do not mention the deirids which in all specimens of *S. africana africana* examined are single and situated on a large promontory (Fig. 1E and 1F), whereas those of *S. africana farchai* are double and occur on a much smaller promontory (Fig. 2E and 2F). In addition, the peri-buccal crown of *S. africana africana* is more rectangular in shape than that of *S. africana farchai* which is spindle-shaped. The caudal extremities of female *S. africana africana* bear numerous rounded tubercles whereas those of *S. africana farchai* carry six to eight pointed tubercles.

Setaria africana was described from nyala but has also been recorded from bushbuck (Yeh 1959; Ortlepp 1961; Desset 1966; Roth & Dalchow 1967), kudu (Ortlepp 1961; Roth & Dalchow 1967) and giant eland (Sachs & Sachs 1968). Desset (1966) describes the deirids of *S. africana africana* from bushbuck as being single, but since the division is very difficult to see under a light microscope she might have examined *S. africana farchai*. The records of Ortlepp (1961) and of Roth & Dalchow (1967) from bushbuck could also be *S. africana farchai* but their records from kudu were in all probability *S. africana africana*. However, definitive conclusions cannot be made since the material of Desset (1966), Ortlepp (1961) and Roth & Dalchow (1967) was unavailable.

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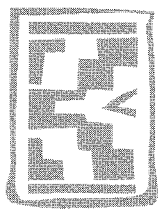

Studies on the genus *Setaria* Viborg, 1795 in South Africa. II. *Setaria scalprum* (Von Linstow, 1908) and *Setaria saegeri* (Le Van Hoa, 1961)

R. WATERMEYER[1], J. BOOMKER[1] and J.F. PUTTERIL[2]

ABSTRACT

WATERMEYER, R., BOOMKER, J. & PUTTERILL, J.F. 2003. Studies on the genus *Setaria* Viborg, 1795 in South Africa. II. *Setaria scalprum* (Von Linstow, 1908) and *Setaria saegeri* (Le Van Hoa, 1961). *Onderstepoort Journal of Veterinary Research*, 70:7–13

Setaria scalprum (Von Linstow, 1908) and *Setaria saegeri* (Le Van Hoa, 1961) are closely related filarid species that occur in the smaller antelope of Africa. Material previously collected from common duiker, *Sylvicapra grimmia,* steenbok, *Raphicerus campestris* and grysbok, *Raphicerus melanotis,* from several localities in the northern and eastern regions of South Africa was re-examined and measurements of adult worms were compared with those given in the original descriptions of the species. Scanning electron microscopy of the anterior and posterior regions of the female worms confirmed the validity of the two species. Differences in the postdeirid, ventral transverse bands and bosses on the cuticle of the male specimens were also observed. *Setaria saegeri* in common duiker and grysbok is a new parasite record for these hosts.

Keywords: Filarids, *Setaria saegeri*, *Setaria scalprum*, South African wildlife

INTRODUCTION

Various *Setaria* species have been recorded from wildlife in Africa, amongst which are *Setaria scalprum* (Von Linstow, 1908), described from steenbok, *Raphicerus campestris* and *Setaria saegeri* (Le Van Hoa, 1961) from common duiker, *Sylvicapra grimmia.* These two filarids are very similar and the possibility of misidentification of either species is possible, as stated by Le Van Hoa (1961) and Desset (1966). The description by Yeh (1959) of *S. scalprum* was, amongst others, from steenbok from Grahamstown, Eastern Cape Province, South Africa. *Setaria saegeri* has been recorded from common duiker in other parts of Africa, but no records of this species in South Africa could be found in the literature. Detailed scanning electron microscopic (SEM) studies on the morphological characteristics of *Setaria* species have been conducted by various workers, but mainly on species that occur in domesticated animals. There appears to be a paucity of information regarding SEM studies of *Setaria* spp. of wild animals of Africa.

During surveys of the helminth parasites of South African wildlife, specimens of the genus *Setaria* were collected from various artiodactylids, including common duiker (Boomker, Du Plessis & Boomker 1983; Boomker, Horak & De Vos 1986; Boomker, Keep & Horak 1987; Boomker, Horak & MacIvor 1989) and grysbok, *Raphicerus melanotis*, (Boomker *et al.* 1989). Ortlepp (1961) and Boomker *et al.* (1987, 1989) recorded *Setaria caelum* and *S. scalprum* from common duiker. Subsequent records of *Setaria* spp. from common duiker (Boomker *et al.*

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Accepted for publication 7 October 2002—Editor

1983, 1986) and grysbok (Boomker *et al.* 1989) were identified only to the genus level. The SEM appearance, together with the measurements of *S. scalprum* and *S. saegeri,* are presented here and compared with the findings of Yeh (1959), Le Van Hoa (1961), and Desset (1966).

MATERIALS AND METHODS

The specimens originated from the helminthological collection of one of us (J.B.), currently housed in the Department of Veterinary Tropical Diseases, University of Pretoria, as well as the National Collection of Animal Helminths (NCAH). The following specimens were examined: 25 females from common duiker from the Weza Forest Nature Reserve, KwaZulu-Natal (WFNR); three males from the same host from Uitenhage, Eastern Cape Province; one female from grysbok, from the latter locality; five males and 19 females from common duiker from the farm Riekerts Laager, Limpopo Province; ten females from common duiker from Malelane, Kruger National Park (KNP); one female from steenbok from Nwashitsumbe, KNP; five males and 28 females from steenbok from Stellenbosch, Western Cape Province; two males and ten females from common duiker from Ondangua, Namibia, NCAH No. S2246 and three females from common duiker from Ndumu Nature Reserve, KwaZulu-Natal, NCAH No. S2336.

The nematodes were cleared in lactophenol and examined under a compound microscope using differential interference illumination. Measurements were obtained from *camera lucida* drawings of the material, and are given in millimetres in Tables 1 and 2. Specimens for scanning electron microscopy, which had been preserved in 70 % ethanol, had a segment of the head and tail removed prior to further processing. Samples were re-hydrated to distilled water after which they were post-fixed in 4% glutaraldehyde and 1% osmium tetroxide. Specimens were dehydrated through graded ethanol and critical point dried from 100% ethanol to carbon dioxide. Each dried head and tail segment was individually mounted onto a conical brass SEM viewing stub and sputter coated with gold. Samples were viewed and micrographed using a Hitachi S-2500 scanning electron microscope operated at 8 kV.

RESULTS AND DISCUSSION

Of the 112 helminths examined, 65 out of 77 from common duiker from the different localities as well as the one nematode from grysbok from Uitenhage proved to be *S. saegeri.* The 12 specimens from common duiker from Ondangua, Namibia were not suitable for identification. The 34 helminths from steenbok from the KNP and Stellenbosch were identified as *S. scalprum.*

In Tables 1 and 2 the measurements of *S. scalprum* and *S. saegeri* are compared with those of Yeh (1959) and Le Van Hoa (1961), respectively.

Setaria scalprum from steenbok examined in this study generally corresponded closely to the description of Yeh (1959), except for being slightly smaller. The majority of measurements of the South African *S. saegeri* were similar to those recorded by Le Van Hoa (1961). However, the following differences were apparent: female specimens had a shorter oesophagus, the deirids were closer to the anterior end, and the tail was longer than that recorded by Le Van Hoa (1961). The scanning electron microscopical appearance of *S. scalprum* and *S. saegeri* are presented in Fig. 1 and 2.

It was evident that the two species are morphologically distinct, as recorded by Le Van Hoa (1961) and Desset (1966). In lateral view, the cephalic elevations of *S. scalprum* are short, stub-like projections whereas those of *S. saegeri* are prominent, long, tooth-like structures (Fig. 1A and 2A). In ventral view the elevations of *S. scalprum* have a wide base with the sides tapering down gradually towards the peribuccal crown whereas those of *S. saegeri* have a rounded base with the sides almost parallel (Fig. 1B and 2B). In apical view, the mouth opening of *S. scalprum* is round and is surrounded by a slightly raised peribuccal crown. The elevations are elongated in a dorsoventral plane. The mouth of *S. saegeri* is oval in shape and the elevations are smaller and rounded with diverging tips (Fig. 1C and 2C). Furthermore, the deirids of *S. scalprum* are single whereas those of *S. saegeri* are double (Fig. 1D, E and 2D, E) and the caudal appendages of *S. scalprum* are larger than those of *S. saegeri* (Fig. 1F and 2F). Yeh (1959) described the terminal button on the posterior extremity of *S. scalprum* females as a small knob, often ill-defined and Le Van Hoa (1961) only mentions the tail length of *S. saegeri.* Desset (1966) describes the terminal buttons of the two species as more or less tuberculated in *S. saegeri* and smooth in *S. scalprum* and her illustrations are the same as those of Le Van Hoa (1961). This is contradictory to our findings in that the terminal button of *S. scalprum* is bluntly rounded and bifid whereas that of *S. saegeri*

TABLE 1 The comparative measurements (in mm) of *Setaria scalprum* from steenbok, *Raphicerus campestris*

Criterion	Males			Females		
	This paper (n = 5)	Mean	Yeh (1959)	This paper (n = 6)	Mean	Yeh (1959)
Length	27.00–38.00	34.40	37.00	60.00–86.00	75.25	95.00
Width	0.299–0.345	0.328	0.270	0.377–0.519	0.471	0.670
Muscular oesophagus, length	0.230–0.446	0.369	0.380	0.391–0.480	0.421	0.420
Glandular oesophagus, length	2.880–4.400	3.415	3.540	3.980–4.809	4.386	4.700
Total oesophagus length	3.280–4.630	3.784	3.920	4.460–5.200	4.811	5.120
Nerve ring from anterior end	0.154–0.230	0.196	0.210	0.179–0.270	0.211	0.170
Deirids from anterior end	0.213–0.472	0.370	*	0.267–0.368	0.326	*
Vulva, distance from anterior end	–	–	–	0.184–0.370	0.283	0.290
Tail, length	0.110–0.143	0.130	0.120	0.276–0.368	0.328	0.420
Caudal appendages from tail tip	–	–	–	0.017–0.025	0.022	0.020
Caudal appendages, length	–	–	–	0.004–0.005	0.004	*
Right spicule, length	0.101–0.126	0.109	0.130	–	–	–
Left spicule shaft, length	0.133–0.179	0.159	0.140	–	–	–
Left spicule blade, length	0.055–0.103	0.077	0.100	–	–	–
Left spicule, total length	0.234–0.236	0.235	0.240	–	–	–
Distance between cephalic elevations, lateral view	0.033–0.040	0.037	*	0.031–0.050	0.041	*
Distance between cephalic elevations, ventral view	0.010–0.020	0.013	*	0.020	0.020	*

– Not applicable

* Measurements not given by author

TABLE 2 The comparative measurements (in mm) of *Setaria saegeri* from common duiker, *Sylvicapra grimmia*

Criterion	Males			Females			
	This paper		Le Van Hoa (1961)	This paper			Le Van Hoa (1961)
	Grey duiker (n = 5)		Grey duiker	Grysbok (n = 1)	Grey duiker (n = 19)		Grey duiker
	Range	Mean			Range	Mean	
Length	26.00–33.00	29.00	30.00	37.00	44.00–76.00	66.28	70.00
Width	0.300–0.370	0.330	0.230	0.390	0.360–0.560	0.470	0.470
Muscular oesophagus, length	0.280–0.500	0.410	0.370	0.510	0.280–0.590	0.470	0.480
Glandular oesophagus, length	2.600–5.180	4.210	4.700	5.150	4.570–5.660	5.230	6.120
Total oesophagus length	3.050–5.680	4.670	5.070	5.660	5.160–6.140	5.710	6.600
Nerve ring from anterior end	0.180–0.250	0.200	0.180	0.170	0.180–0.200	0.180	0.200
Deirids from anterior end	0.450–0.530	0.500	0.475	0.340	0.310–0.450	0.340	0.800
Vulva, distance from anterior end	–	–	–	0.250	0.230–0.350	0.280	0,300
Tail, length	0.120–0.140	0.120	0.140	0.320	0.300–0.480	0.380	0.230
Caudal appendages from tail tip	–	–	–	0.020	0.020–0.030	0.020	*
Caudal appendages, length	–	–	–	0.002	0.002–0.003	0.002	*
Right spicule, length	0.100–0.130	0.110	0.120	–	–	–	–
Left spicule shaft, length	0.188–0.207	0.197	*	–	–	–	–
Left spicule blade, length	0.062–0.064	0.063	*	–	–	–	–
Left spicule, total length	0.252–0.269	0.260	0.230	–	–	–	–
Distance between cephalic elevations, lateral view	0.030–0.040	0.030	*	0.040	0.040–0.050	0.040	*
Distance between cephalic elevations, ventral view	0.020	0.020	*	0.020	0.020	0.020	*

– Not applicable

* Measurements not given by author

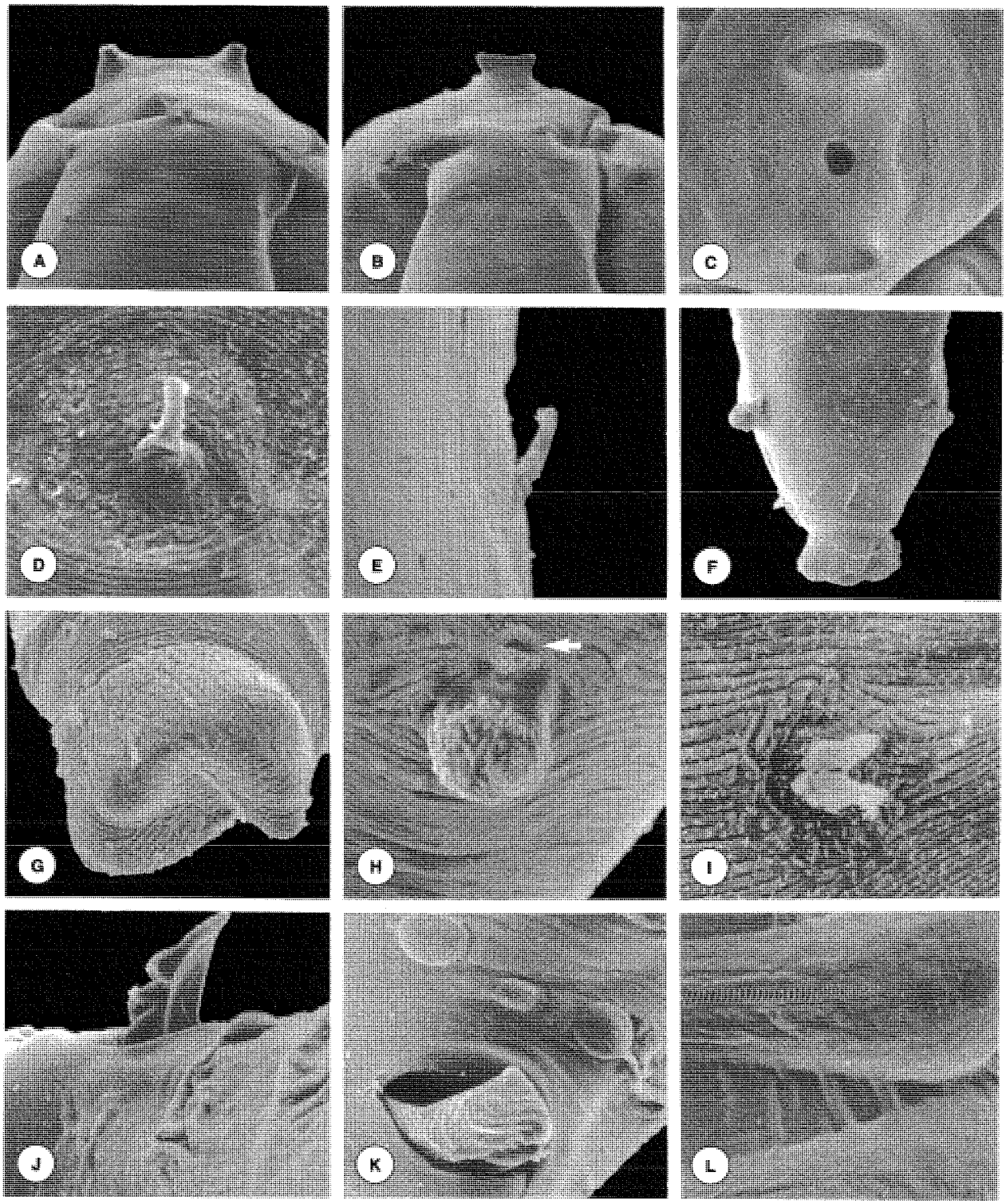

FIG. 1 *Setaria scalprum*

A. Lateral view of cephalic elevations, x 600. B. Ventral view of elevations, x 600. C. Apical view of elevations, x 600. D. Apical view of deirid, x 3 000. E. Lateral view of deirid, x 3 000 F. Ventral view of female tail, x 1 000. G. Terminal knob of female, x 4 000. H. Phasmidial pore of female (arrow), x 5 000 I. Postdeirid of male, x 5 000. J. Bosses on the cuticle, x 2 000. K. Male posterior end, x 2 000. L. Ventral transverse bands of male, x 1 500

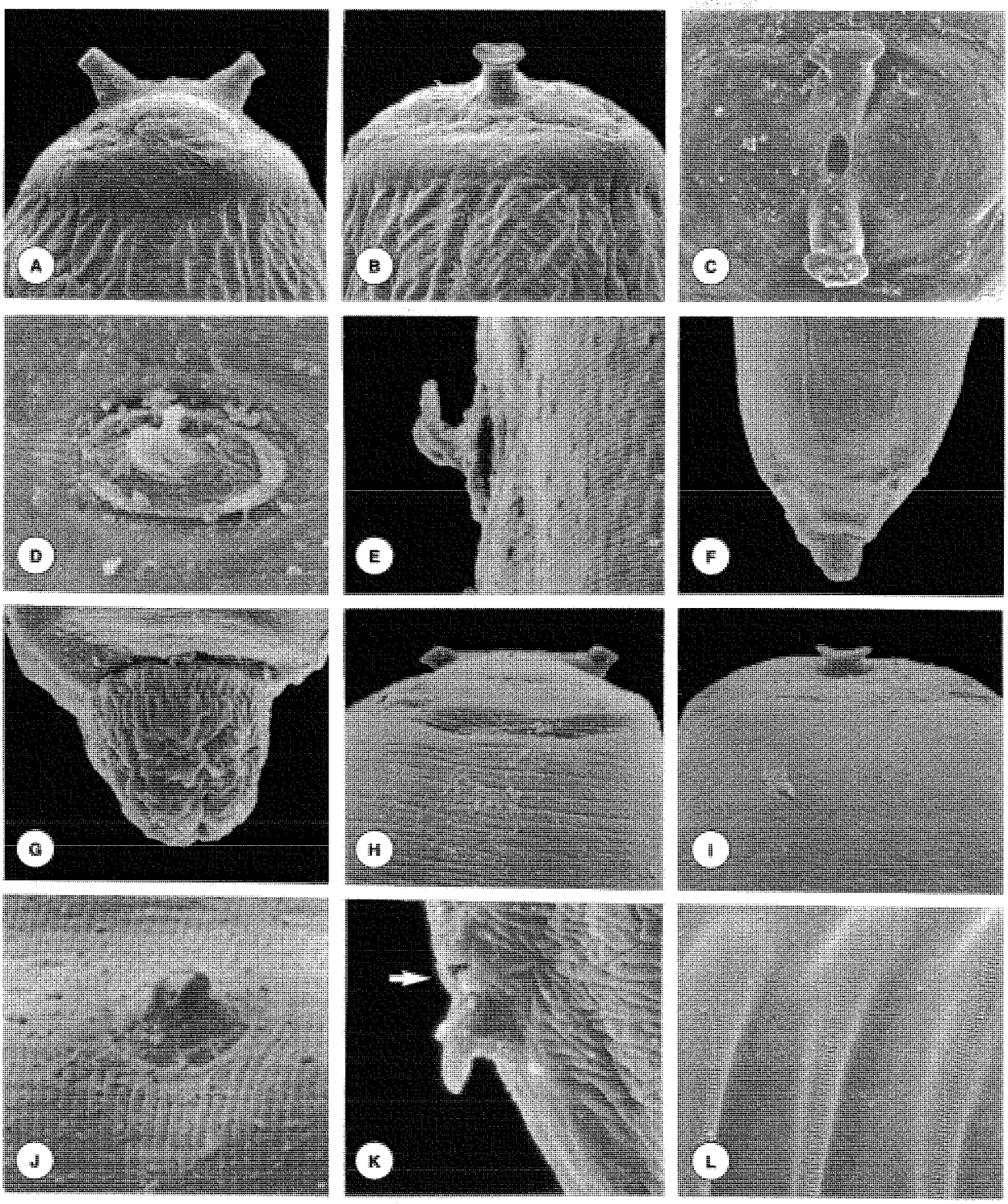

FIG. 2 *Setaria saegeri*

A. Lateral view of cephalic elevations, x 600. B. Ventral view of elevations, x 600. C. Apical view of elevations, x 600. D. Apical view of deirid, x 3 000. E. Lateral view of deirid, x 3 000. F. Ventral view of female tail, x 1 000. G. Terminal knob of female tail, x 4 000. H. Lateral view of cephalic elevations, x 600. Elevations are shortened due to shrinkage during SEM preparation. I. Ventral view of elevations, J. Postdeird of male, x 5 000. K. Caudal appendage of male with phasmidial pore (arrow), x 2 000. L. Ventral transverse bands of male, x 1 500

is thimble-shaped and rugose (Fig. 1G and 2G). The phasmidial pore, first visualized with the aid of scanning electron microscope by Shoho & Uni (1977), is situated on the upper side of the caudal appendages in both sexes and clearly visible in the female of *S. scalprum* and that of the male of *S. saegeri* (Fig. 1H and 2K). The postdeirid of the male *S. scalprum* is double and spine-like, the spines being of equal length, whereas that of *S. saegeri* is also double but shorter than that of *S. scalprum,* with spines of unequal length. (Fig. 1I and 2J). Small uniform bosses are present on the cuticle of *S. scalprum* males (Fig. 1J). The posterior end of a *S. scalprum* male with its protruding right spicule and a small sessile papilla just anterior to the cloaca and a pair of pre-cloacal papilla are illustrated in Fig. 1K. The ventral transverse bands on the cuticle of *S. scalprum* males appear larger with interconnecting ridges whereas in *S. saegeri* the bands are smaller and the ridges absent (Fig. 1L and 2L).

Shrinkage is one of the disadvantages of using SEM techniques and could lead to incorrect identification if not taken into consideration (Fig. 2H and 2I). Thus, light microscopy and scanning electron microscopy, used in conjunction are a useful combination for descriptions of nematodes.

Setaria saegeri was described from common duiker from the Congo but has also been recorded from the same host from Zimbabwe (Roth & Dalchow 1967), the Central African Republic and Cameroon (Troncy, Graber & Thal 1976). *Setaria scalprum* was described from steenbok but has also been found in impala, *Aepyceros melampus,* (Yeh 1959; Ortlepp 1961), common duiker (Desset 1966); Grants gazelle, *Gazella granti* (Yeh 1959), oribi, *Ourebia ourebi*, (Chabaud & Rousselot 1956; Yeh 1959; Ortlepp 1961; Desset 1966), red duiker, *Cephalophus natalensis,* (Boomker, Keep, Flamand & Horak 1984; Boomker, Horak & Flamand 1991). Boomker *et al.* (1989) recorded *S. scalprum* from common duiker that was, after re-examination, found to be *S. saegeri.* In 1961, Ortlepp recorded the presence of *S. caelum* in common duiker. The material was re-examined but due to severe shrinkage, the critical characteristics, such as cephalic elevations, deirids and posterior ends could not be clearly distinguished. Material collected from common duiker during 1963, by the same author and identified as *S. caelum* could be established as *S. saegeri* and the record of Boomker *et al.* (1987) of *S. caelum* from the same host was confirmed as *S. saegeri.*

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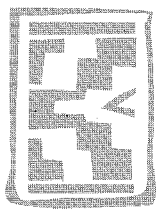

Studies on the genus *Setaria* Viborg, 1795 in South Africa. III. *Setaria thwaitei* Mönnig, 1933

R. WATERMEYER[1], J. BOOMKER[1] and J.F. PUTTERILL[2]

ABSTRACT

WATERMEYER, R., BOOMKER, J. & PUTTERILL, J.F. 2004. Studies on the genus *Setaria* Viborg, 1795 in South Africa. III. *Setaria thwaitei* Mönnig, 1933. *Onderstepoort Journal of Veterinary Research*, 71:107–111

Mönnig (1933) described *Setaria thwaitei* from a sable antelope, *Hippotragus niger,* the type host, as well as from roan antelope, *Hippotragus equinus,* and waterbuck, *Kobus ellipsiprymnus*. Yeh (1959) considered *Setaria thwaitei* to be synonym of *Setaria hornbyi*. Material collected from roan antelopes, sable antelopes and gemsbuck, *Oryx gazella,* from several localities in the north and south of South Africa, together with Mönnig's (1933) material, were re-examined. Measurements of the adult worms obtained in this study were compared with those in the original description of the species. Scanning electron microscopy of the anterior and posterior regions of the female worms confirmed *S. thwaitei* as a valid species.

Keywords: Nematodes, *Setaria thwaitei*, wildlife

INTRODUCTION

Mönnig (1933) created the species *Setaria thwaitei* for worms that were collected from the peritoneal cavity of a sable antelope, *Hippotragus niger,* from Limpopo Province, South Africa, but Yeh (1959) considered *S. thwaitei* conspecific with *Setaria hornbyi*. Since Mönnig's (1933) description of *S. thwaitei* only two records of this species are mentioned in the literature, namely those of Van den Berghe & Vuylsteke (1936) and Vuylsteke (1956) from roan antelopes, *Hippotragus equinus*, from the Congo and Angola respectively.

Material recovered from roan antelopes, sable antelopes and gemsbuck, *Oryx gazella,* from two nature reserves and three game farms as well as Mönnig's (1933) type specimens from a sable antelope, roan antelope and waterbuck, *Kobus ellipsiprymnus*, were re-examined. Specimens of *S. hornbyi* from gemsbuck, previously recovered by Ortlepp (1961) and Basson, Kruger, McCully & Van Niekerk (1966), was also re-examined. The scanning electron microscopic appearance, together with the measurements of *S. thwaitei* and *S. hornbyi* are presented here and compared with the Mönnig's (1933) findings.

MATERIAL AND METHODS

The specimens originated from the helminthological collection of the National Collection of Animal Helminths (NCAH) as well as those collected by one of us (JB), and are currently housed in the Department of Veterinary Tropical Diseases, Uni-

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Accepted for publication 3 November 2003—Editor

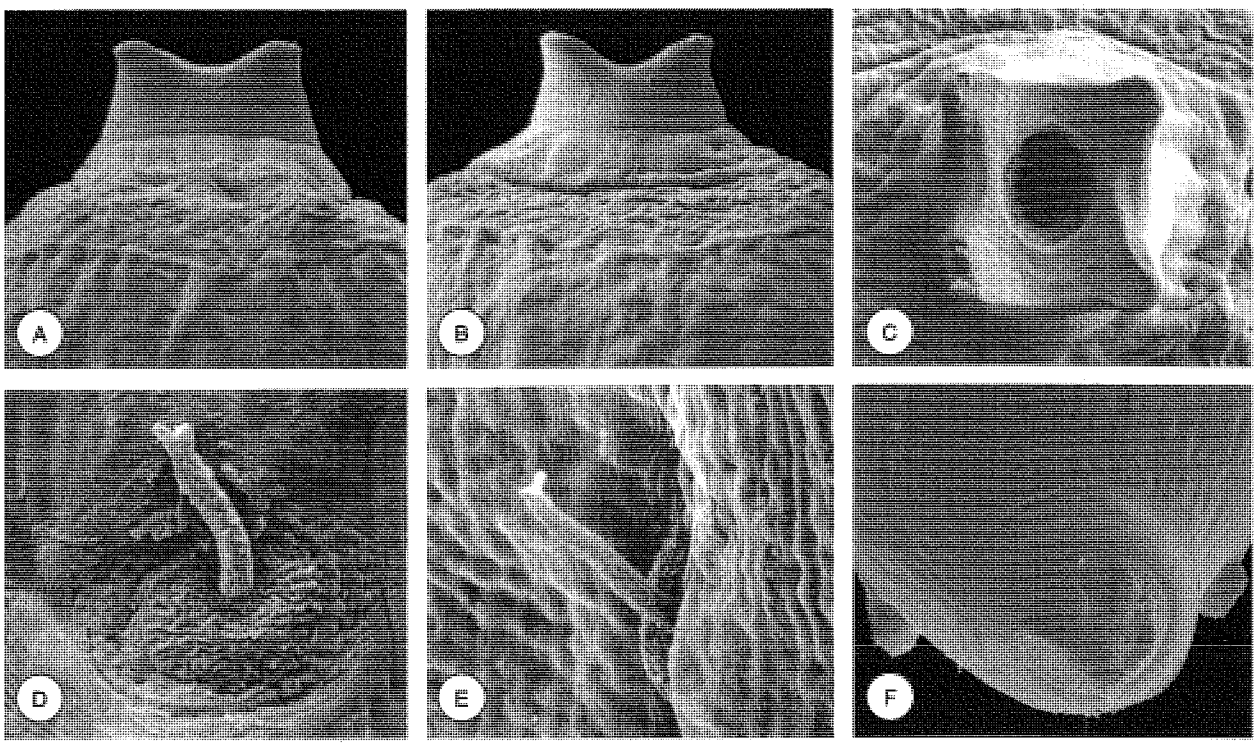

FIG. 1 *Setaria thwaitei*

(A) Lateral view of cephalic elevations, x 600; (B) ventral view of elevations, x 600; (C) apical view of elevations, x 600; (D) apical view of deirid, x 3 000; (E) lateral view of deirid, x 3 000; (F) terminal knob of female tail, x 1 500

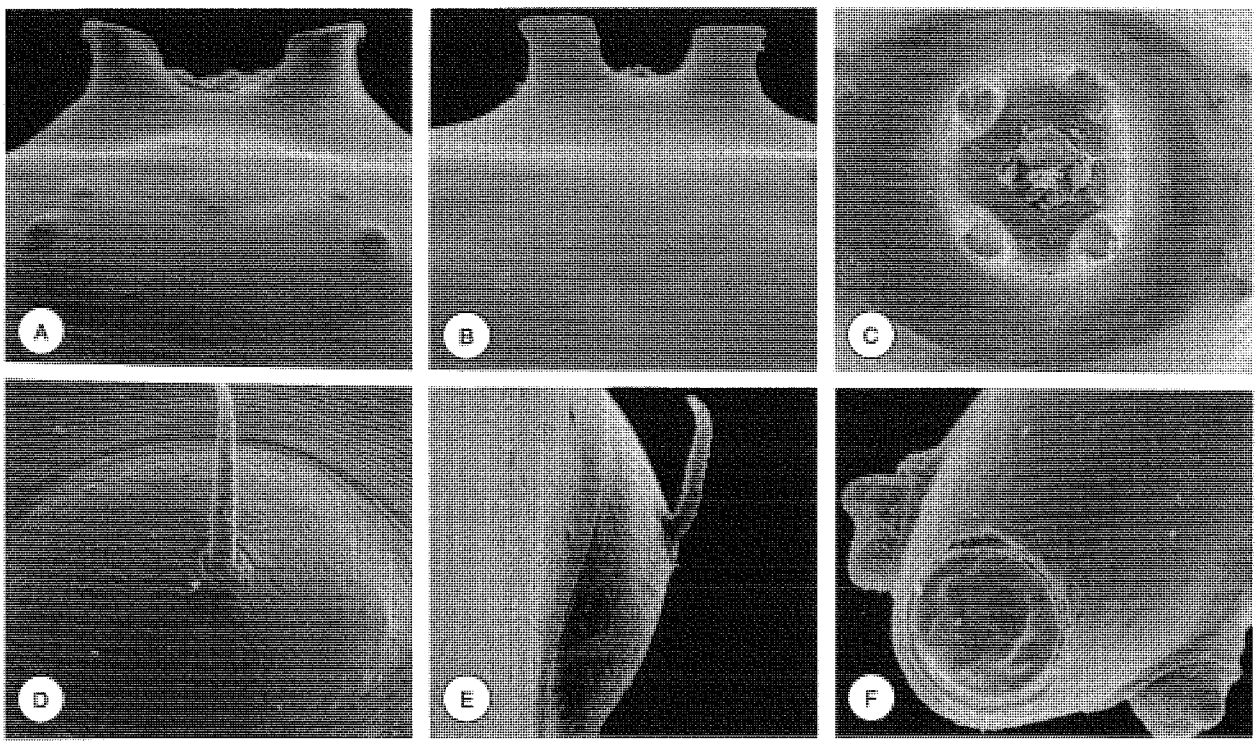

FIG. 2 *Setaria hornbyi*

(A) Lateral view of cephalic elevations, x 600; (B) ventral view of elevations, x 600; (C) apical view of elevations, x 600; (D) apical view of deirid, x 3 000; (E) lateral view of deirid, x 3 000; (F) terminal knob of female tail, x 1 500

TABLE 2 Comparative measurements (in mm) of the South African Setaria hornbyi and of *Setaria thwaitei*

Criterion	Males		Females	
	S. hornbyi	*S. thwaitei*	*S. hornbyi*	*S. thwaitei*
Length	83.00–87.00	63.00–82.00	157.00–212.00	115.00–321.00
Width	0.55–0.74	0.48–0.61	0.72–1.26	0.86–1.41
Muscular oesophagus, length	0.47–0.63	0.39–0.48	0.60–0.95	0.51–0.75
Glandular oesophagus, length	14.12–17.49	6.15–6.32	14.28–17.25	6.23–9.31
Total oesophagus length	14.59–18.12	5.30–6.80	15.00–18.12	6.77–10.06
Nerve ring from anterior end	0.25–0.31	0.28–0.29	0.30–0.37	0.26–0.51
Deirids from anterior end	0.55–0.73	0.62–0.71	0.63–0.92	0.54–0.77
Vulva, distance from anterior end	–	–	0.47–0.64	0.43–0.68
Tail, length	0.21–0.22	0.24–0.28	0.56–0.73	0.55–0.87
Caudal appendages from tail tip	–	–	0.05–0.08	0.04–0.09
Caudal appendages, length	–	–	0.017–0.019	0.016–0.034
Right spicule, length	0.18–0.20	0.17–0.21	–	–
Left spicule shaft, length	0.24–0.29	0.27–0.29	–	–
Left spicule blade, length	0.19–0.20	0.12–0.16	–	–
Left spicule sclerotized membrane	0.44–0.48	0.39–0.45	–	–
Distance between cephalic elevation, lateral view	0.11–0.13	0.06–0.07	0.11–0.13	0.07–0.09
Distance between cephalic elevation, ventral view	0.06	0.06–0.07	0.08–0.09	0.07–0.09

– Not applicable

Thwaite (1927) examined a large number of *Setaria* spp. from a variety of hosts. He concluded that there was considerable variation in the length of the specimens as well as in the "depth of the buccal ring and its protrusion in front of the head... even in worms from the same host". This could be because of the presence of more than one species of *Setaria*, in all probability both *S. hornbyi* and *S. thwaitei*. Yeh (1959) states: "Mönnig (1933), when he found the true *Artionema hornbyi* which Boulenger described, took the trouble to name it *Setaria thwaitei* new species with his only cited reference being Thwaite (1927)". This statement should be treated with reserve, since it appears that Boulenger (1921) described the "true" *S. hornbyi*, while Mönnig (1933) was quite correct in describing *S. thwaitei* as a separate new species.

Setaria thwaitei can be distinguished from *S. hornbyi* using several characteristic features. The cephalic elevations are distinct and the constriction at the level of the nerve ring, as described by Mönnig (1933), is much more prominent in *S. thwaitei*. Furthermore, *S. thwaitei* has a shorter oesophagus: body length ratio and the deirids have bifid tips. In view of these differences, we conclude that *S. thwaitei* is a separate and distinct species and it is herewith reinstated as such.

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A new filarial nematode (Onchocercidae) from warthogs (*Phacochoerus aethiopicus*) of the Kruger National Park

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ABSTRACT

Fifty-five warthogs [*Phacochoerus aethiopicus* (Suidae: Artiodactyla)] from the Kruger National Park, Republic of South Africa, were examined for parasites. Adult filarial nematodes were found in lymphatic vessels adjacent to peripheral and visceral lymph nodes, and microfilariae were found in lymph nodes and circulating blood. Both the adult parasite and the microfilaria are described. Specific identification is pending confirmation and recovery of intact adult specimens and microfilariae identical to those described herein.

MATERIALS AND METHODS

Fifty-five warthogs [*Phacochoerus aethiopicus* (Suidae: Artiodactyla)] were collected from the Kruger National Park, Republic of South Africa, and tissues from them examined at both the Onderstepoort Veterinary Research Institute and the Armed Forces Institute of Pathology. Nearly all warthogs over four months of age had some degree of eosinophilic lymphadenitis involving peripheral or visceral lymph nodes or both. 11 (30%) had microfilariae (mff) within affected nodes and two (4%) had mff as well as adult filariids located in lymphatic vessels adjacent to the nodes. Tissues containing worms were fixed in 10% buffered formalin, sectioned at 6 μm, and stained with haematoxylin and eosin and Movat's pentachrome stains. Microfilariae (mff) were preserved in 2·0% formalin (Knott's concentration technique) and stained with Mayer's haematoxylin and fast green. All measurements are in μm unless otherwise stated.

DESCRIPTION

(Filarioidea, Onchocercidae: Setariinae)

Material: Based upon 23 sections of lymph node with three adult male worms and four gravid female worms within dilated lymph vessels, 50 complete mff (Knott's concentration technique), and many partial mff found in tissue sections and in lymphatic and blood vessels. Voucher specimens (microfilariae and sectioned adults *in situ*) are deposited in the collections of the U.S.N.M. (77588 Helm. Coll. No.) National Parasite Collection, Beltsville, MD 20705, and the Armed Forces Institute of Pathology, Washington, D.C.

The investigators adhered to the principles described in "Guide for the Care and Use of Laboratory Animals" prepared by the Committee on Care and Use of Laboratory Animals of the Institute of Laboratory Animal Resources, National Research Council, DHEW Publication No. (NIH) 78-23, Revised 1978.
The opinions or assertions contained herein are the private views of the authors and are not to be construed as official or as reflecting the views of the Department of the Army, the Department of the Air Force, or the Department of Defense.

Host: *Phacochoerus aethiopicus*, Pallos 1766.

Habitat: Adults in efferent lymphatic vessels, microfilariae in circulating blood and lymph nodes.

Locality: Kruger National Park, Eastern Transvaal, Republic of South Africa.

Periodicity: Unknown.

Diagnosis: Onchocercidae (Leiper, 1911) (=Dipetalonematidae Wehr, 1935; =Setariidae Yorke and Maplestone, 1926).

Microfilaria: (N=20) (Fig. 1). Body slender and sheathed, with nuclei distinct when stained with Mayer's haematoxylin; 129 (118–136) by 3·8 (3·0–4·0) at level of first anterior nucleus, 3·8 (3·0–4·0) at nerve ring, 3·7 (3·0–4·0) at anal pore. Distance from anterior end to first nucleus, 2·9 (2·0–3·5); to nerve ring, 33·2 (32·5–35·0); to posterior *Innenkörper*, 56·1 (54·0–59·0); to anal pore, 87·4 (84·0–91·0); and to last nucleus in tail, 126·2 (114·0–130·5). Cephalic space short, slightly bulbous, and 2·8 (2·0–3·5) long by 3·9 (3·0–4·5) wide; ratio of cephalic L/W, 0·72 (0·67–0·88)/1. *Innenkörper*, 9·8 (8·0–11·0) long. Anal pore distinct, between *Innenkörper* and terminal body nuclei. R1 and R2-4 cells

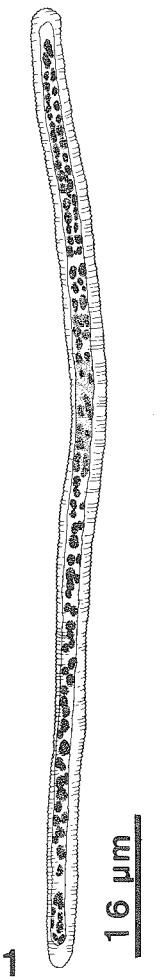

FIG. 1. Microfilaria of onchocercid nematode from the blood of the warthog *Phacochoerus aethiopicus*. (AFIP 83-7788).

not distinct when stained with Mayer's haematoxylin or Giemsa. First cephalic nucleus single (30%) or overlapping second (70%). Last nucleus, almost to tip of tail, 2·9 (1·5–3·5). Tail nuclei overlapping.

Adult worm (*male*): Body 65 (35–103) wide, 43–52 at level of oesophagus, 35–55 at level of spicules. Two dorso-lateral cuticularized curved areas in cephalic extremity. Lateral chords broad (approx. 20–25% of circumference), 3–6 on entering body-cavity. Somatic muscles well developed, 7–11 from cuticle to body-cavity. Oesophagus muscular, 22–25 wide with a triangular lumen. Cuticle thin (2·5–3·0) with fine, shallow longitudinal striations, approximately two per μm, and with pronounced bosses or papillae. Testis single, 20–29 wide; vas deferens 42–53 wide. Right and left spicules unequal in length; left, larger with a thin-walled tubular proximal portion (12 long × 7 wide), thick hyaline midsection (40 × 6) and a narrow, curved rod-like distal portion (12 × 4).

Adult worm (*female*): Anterior half of body 130–260 wide, posterior half 106–150 with two cuticularized curved areas in cephalic extremity. Lateral chords poorly developed. Somatic muscles poorly developed, protruding 1·0–2·5 into body-cavity. Cuticle (3·0–3·5) with fine, shallow longitudinal striations approximately two per μm, with pronounced bosses or papillae. Oesophagus as in male. Both uteri fill the body-cavity. Uteri with embryos, 46–52 by 60–72 wide; uteri with well developed mff, 62–72 × 82–103 wide. Mff *in utero* have a parallel or crystalline pattern (similar to cross section of rope).

Pathology: Affected lymph nodes were enlarged and multilobulated; accessory nodes were usually present and perinodal tissue was oedematous. Most nodes were mottled creamy-white and red-brown. On incision, clear to sanguinous fluid exuded and numerous cystic spaces measuring up to 2 mm in diameter were observed in the nodal parenchyma. Microscopically, changes in affected nodes included mild to marked infiltrations of eosinophils, plasmacytosis, lymphoid and reticular macrophage hyperplasia, the presence of multinucleated giant cells, haemorrhage and cystic dilatation of sinuses; these changes were most severe when mff were present. A segmental eosinophilic and proliferative inflammation was associated with the presence of intraluminal adult filariids in thin-walled vessels adjacent to affected nodes. The vessels were presumed to be lymphatics. A detailed description of the pathological changes in both lymph nodes and lymphatics is the subject of an additional report.

DISCUSSION

Reports of filariid nematodes infecting hosts of the family Suidae include the following: in Africa *Setaria congolensis* (=*S. bernardi*, *S. rodhaini*) has been reported from *Potomochoerus porcus*, *P. koiropotamus* and *Sus scrofa* in the Congo, Zimbabwe and Mozambique, *S. castroi* (=*S. shohoi*) from *Phacochoerus aethiopicus* and *Potomochoerus porcus* in Mozambique and Madagascar and *Suifilaria suis* in *Sus scrofa* in South Africa; in Asia a species of *Onchocerca*, namely, *O. dewittei* has been reported from *Sus scrofa jubatus*.

Reports of filariids in warthogs are rare. Neitz (1931, 1933) in a study of blood parasites of game in Zululand (South Africa) reported, without morphological description, 110-μm-long microfilariae in blood, spleen and gland (lymph?) smears from 5 of 56 warthogs. This number was later expanded to include another 7 of warthogs from the Umfolozi district. In 1963, Dr. H. H. Roth of the Department of Veterinary Services, Salisbury, Rhodesia, gave his collection of 20,000 nematodes from warthogs (*Phacochoerus aethiopicus*) to Dr. H. A. Kreis (Kreis, 1970), who reported two new filarial nematodes from the warthog. Kreis' description of the *Setaria* sp. is based upon one adult female, and that of *Papillosetaria phacochoeri* from one male worm.

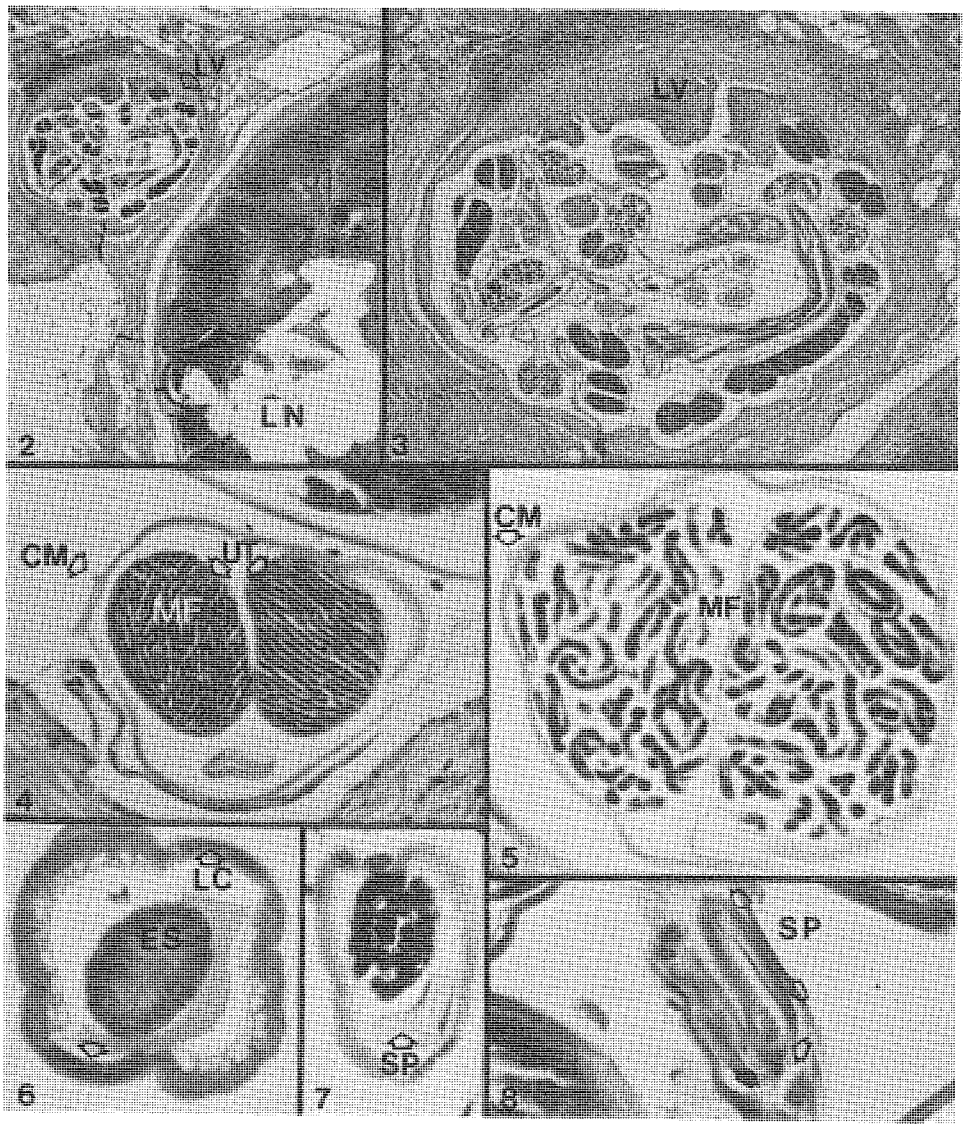

FIG. 2. Histological section of a lymph node (LN) with a dilated lymphatic vessel (LV) containing adult male and female onchocercid nematodes. (40 ×, AFIP 83-77900).

FIG. 3. Dilated lymphatic vessel (LV) in thickened and inflamed lymph node capsule. Note the sections of adult male and female onchocercid nematodes within. (160 ×, AFIP 83-7791).

FIGS. 4–5. Cross section of paired uteri (UT) of adult female onchocercid nematode. Uteri contain microfilariae (MF) in crystalline pattern. Note cuticular modification (CM) on outer body wall. (Fig. 4, 400 ×, AFIP 83–7795; Fig. 5, 630 ×, AFIP 83-7789).

FIG. 6. Cross section through the anterior portion of adult male onchocercid nematode demonstrating lateral chords (LC) and muscular oesophagus (ES). (630 ×, AFIP 83-7794).

FIG. 7. Cross section through the posterior portion of an adult male onchocercid nematode showing right and left spicules (SP) (630 ×, AFIP 83-7796).

FIG. 8. Longitudinal section through the right and left spicules (SP). Hollow arrows indicate the longer, curved right spicule, while arrow points out the shorter left spicule. (60 ×, AFIP 83-7792).

ORTLEPP (1964) examined nematodes from 30 warthogs and several bushpigs (*Potamochoerus porcus*) from Portuguese East Africa and Northern Rhodesia and recovered 21 female and 8 male worms (*Setaria congolensis* Railliet & Henry, 1911) from bushpigs, and a new species, *Setaria castroi*, from three warthogs and a single bushpig. No description is made of microfilariae of *Setaria* sp. in any of the above reports.

The microfilariae reported by NEITZ (1931) measured 110 μm; ours ranged from 118 to 136 μm. Adult filarial worms in the warthogs we examined had vulva in the anterior body, two lateral cuticularized expansions on the cephalic extremity, at least two cephalic tubercles, and markedly dissimilar spicules. We are confident that they represent a species within the Setariinae. ANDERSON & BAIN (1976) assign only two genera to this subfamily, *Setaria* and *Papillosetaria*. Our specimens lacked large cuticularized tubercles throughout the midbody, separating this parasite from the genus *Papillosetaria*. Our worms are probably the same or a closely related species to the *Setaria* sp. reported by KREIS (1970) or to *S. castroi* reported by ORTLEPP (1964). *Setaria* is not the only genus of filariid occurring in the family Suidae although the presence of sheathed mff would suggest the possible identity of the adults as *Setaria*.

There is no doubt that this nematode species belongs to the Filarioidea; however, we lacked intact adult specimens necessary for specific identification of this lymph-dwelling filarial nematode. Characteristics such as the precise location of the vulva, buccal structure and ornamentation, arrangement of caudal papillae, oesophageal structure, and body length were not available to us. There is a possibility that this is an accidental infection by a parasite not normally found in warthogs particularly in view of the site from which it was recovered. Although recorded in the cavity of some organs *Setaria* spp. are primarily parasites of the peritoneal cavity of their hosts. The parasites described in this paper are recovered from lymph vessels which is an atypical site for *Setaria*. At present we feel that it is advisable to leave the identification open to confirmation.

ACKNOWLEDGEMENTS

We thank Drs. Daniel H. Connor and Dean Gibson for the initial consultation report, the WHO Collaborating Center for Filarial Infection of Man, and the Armed Forces Institute of Pathology, Departments of Infectious and Parasitic Disease Pathology, and Veterinary Pathology, for support. We also thank Dr. Mark Eberhard of the Delta Regional Primate Center for taxonomic suggestions and direction. We thank the National Parks Board of Trustees, Republic of South Africa, for sanctioning the study of warthogs in the Kruger Park.

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Accepted 27th November, 1984.

Onderstepoort J. vet. Res., 57, 169–173 (1990)

PARASITES OF SOUTH AFRICAN WILDLIFE. V. A DESCRIPTION OF THE MALES OF *OESOPHAGOSTOMUM MOCAMBIQUEI* ORTLEPP, 1964 FROM WARTHOGS, *PHACOCHOERUS AETHIOPICUS* (PALLAS, 1766)

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ABSTRACT

BOOMKER, J., 1990. Parasites of South African wildlife. V. A description of the males of *Oesophagostomum mocambiquei* Ortlepp, 1964 from warthogs, *Phacochoerus aethiopicus* (Pallas, 1766). *Onderstepoort Journal of Veterinary Research*, 57, 169–173 (1990).

Oesophagostomum mocambiquei Ortlepp, 1964 was described from 9 females recovered from a warthog, *Phacochoerus aethiopicus* (Pallas, 1766), from northern Mozambique. Large numbers of *O. mocambiquei* were recovered during subsequent surveys of the parasites of warthogs from the Kruger National Park and the Hoedspruit Nature Reserve. The males, which have not yet been described, resemble those of *Oesophagostomum santosdiasi* Ortlepp, 1964 in the principal measurements. They can, however, be differentiated by the shape of the mouth capsule, which is round in *O. mocambiquei* and oval in *O. santosdiasi*.

A simplified key for the identification of the *Oesophagostomum* species that occur in warthogs in South Africa and Namibia is provided and the differences between them tabulated.

The names *Oesophagostomum moçambiquei* and *Oesophagostomum santos-diasi* are corrected to *O. mocambiquei* and *O. santosdiasi* respectively, since diacritic marks are not allowed under the Code of International Zoological Nomenclature.

INTRODUCTION

The species *Oesophagostomum mocambiquei* Ortlepp, 1964 was created for female worms recovered from the large intestines of warthogs, *Phacochoerus aethiopicus* (Pallas, 1766), from the northern parts of Mozambique and near Pilgrim's Rest in the eastern Transvaal (Ortlepp, 1964). The males of this species, however, have not yet been described.

Surveys of the parasites of warthogs have since been conducted in the Kruger National Park (KNP) (Horak, Boomker, De Vos & Potgieter, 1988) and the Hoedspruit Nature Reserve (HNR) (Boomker, Horak, Booyse & Meyer, unpublished data, 1989). Large numbers of male and female *O. mocambiquei* were recovered from the KNP and the HNR, and many of the worms were fixed *in copula*. As only *O. mocambiquei* and *Oesophagostomum mwanzae* Daubney, 1924 were present in the warthogs from the HNR, and in view of the distinct differences between the 2 species, the males found in association with female *O. mocambiquei* were considered to be the males of that species. They are described here and a simplified key for the identification of the *Oesophagostomum* spp. of warthogs in South Africa and Namibia is provided, and the differences between them tabulated.

MATERIALS AND METHODS

Large numbers of *O. mocambiquei* were recovered from the caecum and colon of warthogs shot in the HNR in the eastern Transvaal Lowveld. They were killed in hot saline and fixed in cold 10 % formalin. To clear them, worms were individually mounted in lactophenol and Berlese's medium, and they were measured with the aid of a calibrated ocular micrometer. Drawings were made with a camera lucida.

The specimens were prepared for scanning electron microscopy by rinsing in buffer and dehydrating in graded concentrations of ethyl alcohol. They were then critical point dried with carbon dioxide and mounted on stubs, followed by coating with a thin layer of carbon and sputter coating with gold. The examinations and photography were done with a Jeol 35C scanning electron microscope.

DESCRIPTION

Material examined

Six female worms from *Phacochoerus aethiopicus*, from the type locality (Onderstepoort Helminthological Collection, No. T 2141).

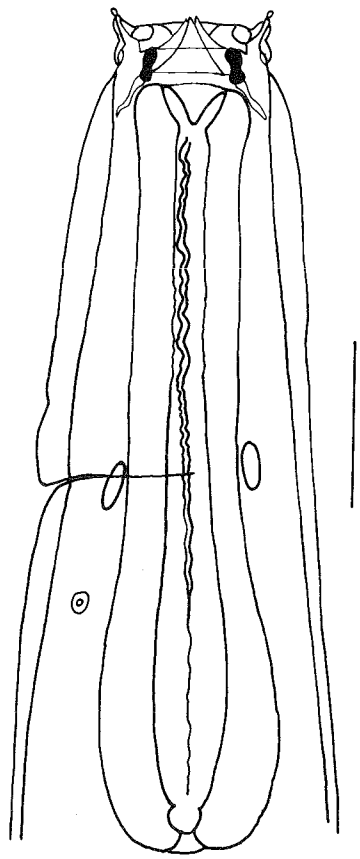

FIG. 1 Lateral view of the anterior end of a male *Oesophagostomum mocambiquei* (Bar length = 0,1 mm)

Received 10 May 1990—Editor

TABLE 1 The principal measurements (in mm) of *Oesophagostomum mocambiquei*

	Type specimens		This study	
	Ortlepp (1964)	This study	Males	Females
Length	17 – 20	13,18 – 17,92	12,30 – 15,82	16,26 – 19,88
Maximum width	0,350 – 0,420	0,580 – 0,800	0,408 – 0,552	0,560 – 0,760
Width of mouth collar	0,090 – 0,100	Damaged	0,080 – 0,092	0,088 – 0,104
Depth of buccal capsule	0,014 – 0,016	0,016 – 0,032	0,028 – 0,034	0,024 – 0,048
Width of buccal capsule	0,044 – 0,048	0,040 – 0,056	0,036 – 0,048	0,032 – 0,052
Thickness of buccal capsule wall	0,008	0,006 – 0,008	0,006 – 0,008	0,006 – 0,008
Distance of cervical groove from anterior end	0,220 – 0,227	0,220 – 0,280	0,180 – 0,252	0,160 – 0,296
Distance of cervical papillae from anterior end	0,300 – 0,330	0,384 – 0,402	0,260 – 0,424	0,280 – 0,412
Distance of nerve ring from anterior end	Just behind cervical groove	0,220 – 0,268	0,208 – 0,280	0,208 – 0,288
Length of oesophagus	0,420 – 0,500	0,464 – 0,536	0,424 – 0,556	0,484 – 0,564
Length of spicules	Not applicable		2,180 – 2,950	–
Length of gubernaculum	Not applicable		0,084 – 0,160	–
Length of vagina	0,650 – 0,750	0,664 – 0,720	–	0,728 – 0,952
Distance from tip of tail to anus	0,100 – 0,130	0,088 – 0,116	–	0,088 – 0,132
Distance from tip of tail to vulva	Not given	0,208 – 0,268	–	0,236 – 0,340
Distance between anus and vulva	0,130 – 0,150	0,120 – 0,160	–	0,140 – 0,212
Eggs *(in utero)*, length	0,080 – 0,090	0,080 – 0,092	–	0,080 – 0,100
width	0,047 – 0,048	0,048 – 0,068	–	0,040 – 0,056

TABLE 2 A summary of the differences between the species of *Oesophagostomum* that occur in warthogs in South Africa and Namibia

Species	Length (mm)	Shape of mouth capsule	Shape of oesophagus	Tail	Vagina (mm)	Spicules (mm)	Source
O. mocambiquei	12 – 20	Cylindrical	Club	Bent	0,73 – 0,95	2,18 – 2,95	This study
O. mpwapwae	13 – 15	Cylindrical	Club	Straight	2,1	3,10 – 3,80	Duthy, 1947; Ortlepp, 1964
O. mwanzae	13 – 20	Oval	Club, with 3 valves	Bent	0,35 – 0,50	1,87 – 2,20	Daubney, 1924; Ortlepp, 1964
O. roubaudi	17 – 23	Oval	Club	Bent	0,17 – 0,26	1,27 – 1,32	Daubney, 1926
O. santosdiasi	12 – 15	Oval	Club	Bent	0,70 – 1,0	2,40 – 2,70	Ortlepp, 1964
O. simpsoni	15 – 21	Oval	Short, thick sides almost parallel	Straight	0,10 – 0,15	1,20 – 1,30	Goodey, 1924 Ortlepp, 1964

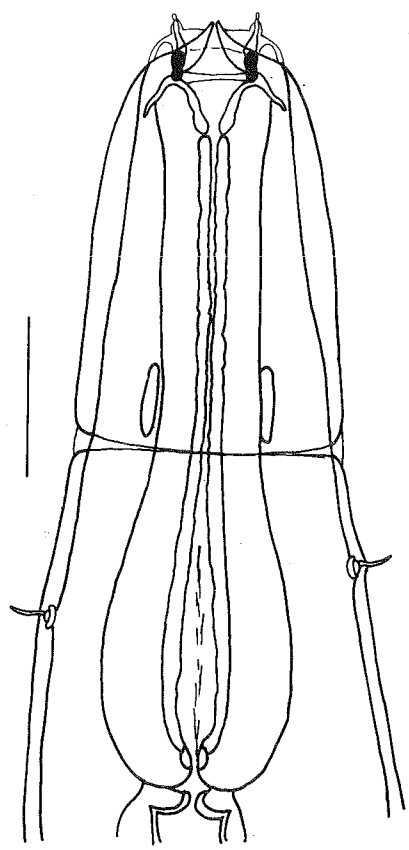

FIG. 2 Ventral view of the anterior end of a male *Oesophagostomum mocambiquei* (Bar length = 0,1 mm)

Sixteen male and 8 female worms from *P. aethiopicus* from the Hoedspruit Nature Reserve, eastern Transvaal (Onderstepoort Helminthological Collection, No. T 2180).

Twenty-four male and 16 female worms from 2 warthogs from the Hoedspruit Nature Reserve.

Additional material, consisting of numerous male and female worms from warthogs from the HNR, have been deposited with the Onderstepoort Helminthological Collection and the collection of the CAB International Institute of Parasitology, St. Albans, Herts, United Kingdom.

Description

As part of this study the type specimens were re-examined and their measurements, together with those of the male and female worms collected from the warthogs from HNR, are listed in Table 1.

Like the females, the males have a flattened mouth collar which is only slightly set off from the rest of the body. The circum-oral papillae are prominent (Fig. 1, 2 & 7a, b) and the amphids are raised slightly above the surface (Fig. 7a, b). The cervical swelling is small and is demarcated posteriorly by the cervical groove into which the excretory pore opens. The nerve ring is situated either just in front or just behind the cervical groove (Fig. 1 & 2). The cervical papillae are long and spike-like (Fig. 2, 7a) and lateral alae are absent. The buccal capsule is cylindrical (Fig. 7a & b). There are 6 triangular external leaf crown elements that extend obliquely forwards (Fig. 1, 2, 7a & b); an internal leaf crown is absent. An

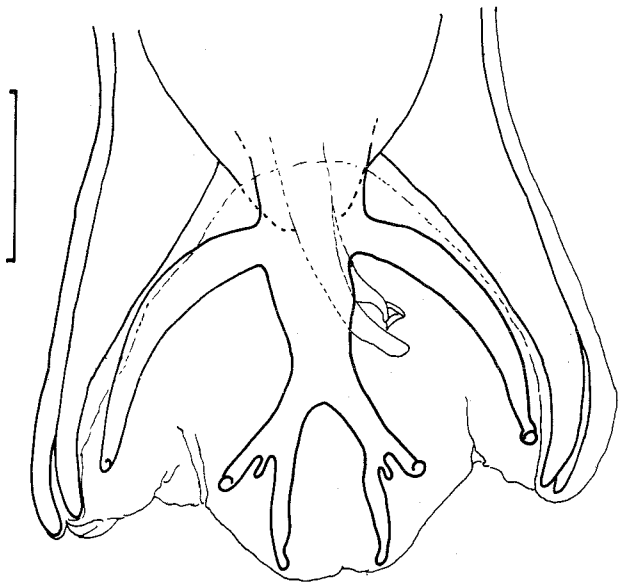

FIG. 3 Dorsal view of the partly opened bursa of *Oesophagostomum mocambiquei* (Bar length = 0,1 mm)

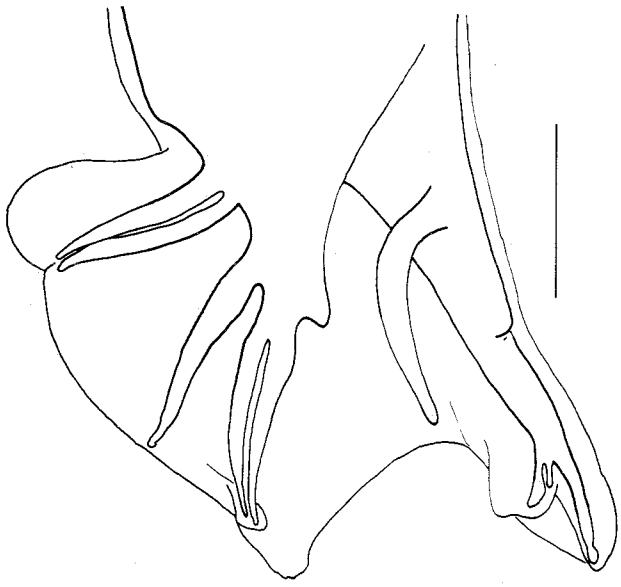

FIG. 4 Lateral view of one half of the bursa of *Oesophagostomum mocambiquei* (Bar length = 0,1 mm)

oesophageal funnel is present and the oesophagus is club-shaped (Fig. 1 & 2).

The bursa is rather small and compact. The dorsal lobe is longer than the ventral ones (Fig. 3 & 4). The ventral bursal rays are equally long and remain parallel for their entire length (Fig. 4). The anterolateral ray is widely separated from the mediolateral ray; the medio- and posterolateral rays run parallel and remain close to each other for their entire length. There is a distinct swelling on the posterior edge of the main trunk of the lateral rays, slightly cranial to the level of the origin of the posterolateral ray (Fig. 4). The externodorsal rays are of variable thickness, and curve posteriorly and ventrally (Fig. 4). The dorsal ray has a broad origin but tapers considerably before bifurcating, and each bifurcation is divided into lateral and medial branches (Fig. 3 & 5). A small papilla, which is sometimes hardly more than a small protuberance, may be present in a highly variable position between the lateral and

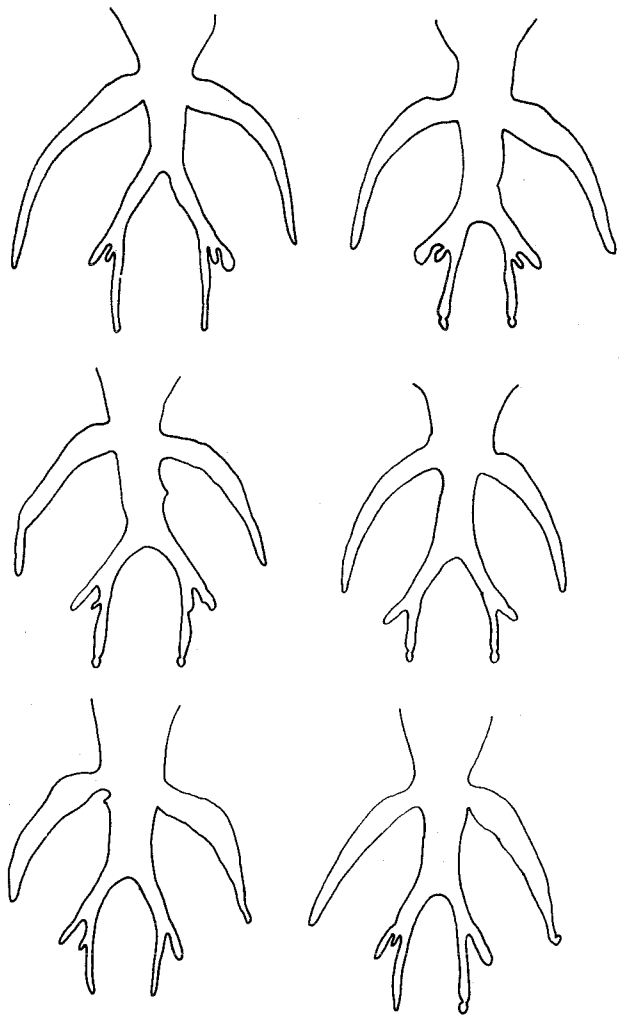

FIG. 5 Variations in the configuration of the dorsal ray of *Oesophagostomum mocambiquei* (Bar length = 0,1 mm)

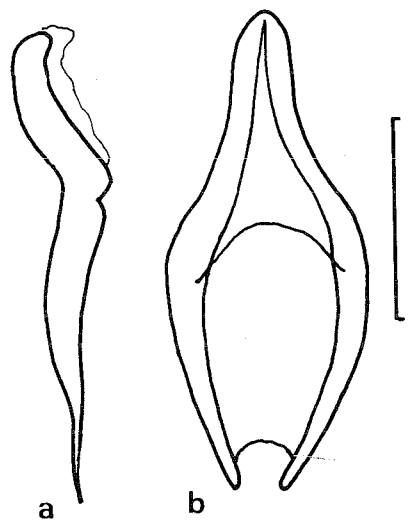

FIG. 6 The gubernaculum of *Oesophagostomum mocambiquei* in (a) lateral and (b) ventral views (Bar length = 0,05 mm)

medial branches, or it may be present on the dorsal ray (Fig. 5). In some males it is absent. In lateral view, the dorsal ray appears to consist of a thinner distal part that fits into a thicker proximal part; the junction of these parts is marked by a distinct crease (Fig. 4).

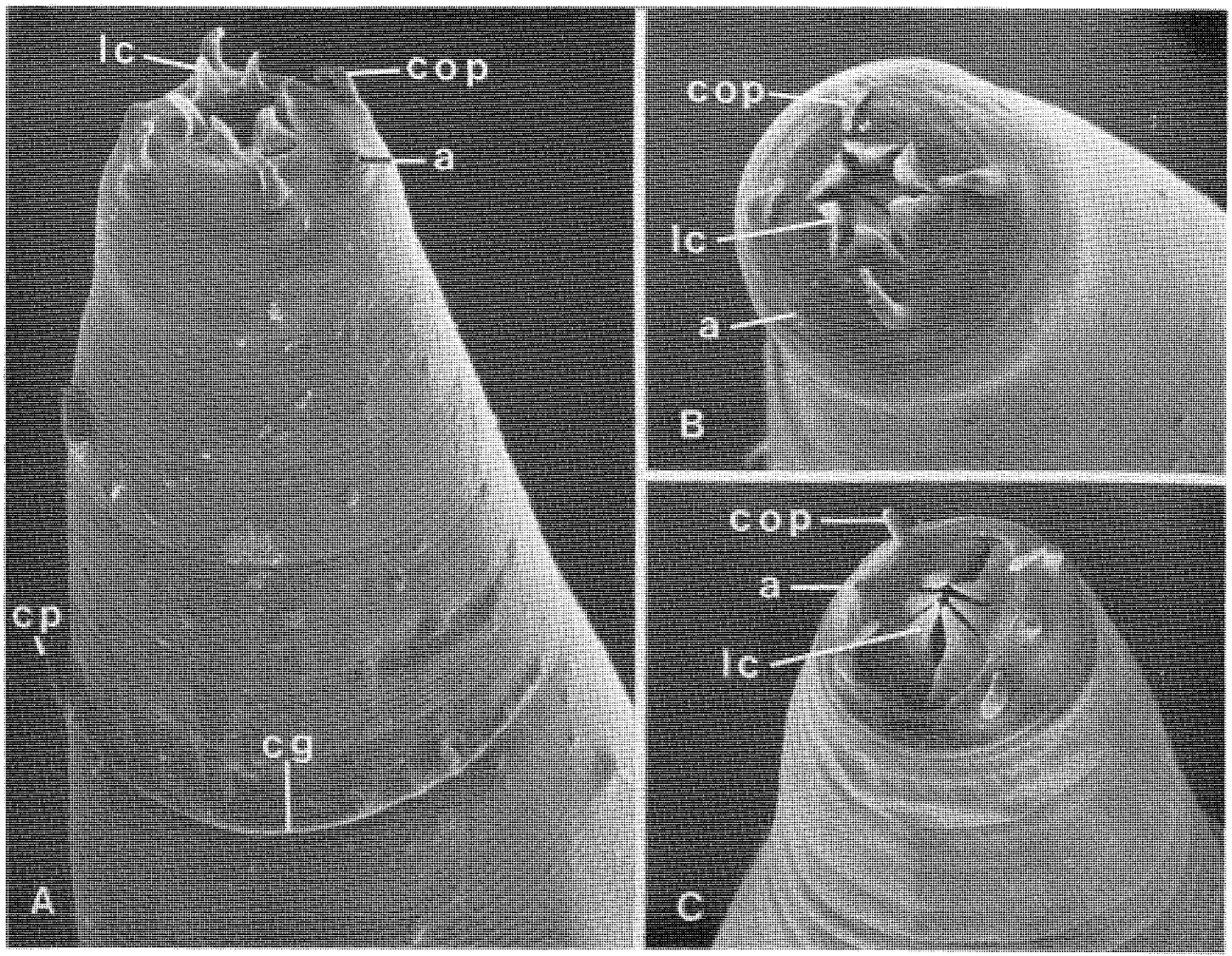

FIG. 7 (a) Ventral view of a male *Oesophagostomum mocambiquei*
(b) *En face* view of the head of a male *Oesophagostomum mocambiquei* showing the round mouth opening
(c) The head of a male *Oesophagostomum mwanzae*, showing the oval mouth opening

a = amphid
cg = cervical groove
lc = leaf crown
cp = cervical papillae
cop = circum-oral papillae

The spicules are long and slender and terminate in curved points that are enclosed in membranous alae. Transversely striated alae are present along their median margins. The gubernaculum is undulated in lateral view, but broadly diamond-shaped in dorsal or ventral views (Fig. 6). The genital cone is simple.

Apart from slight differences in the principal measurements of the type specimens, and thus the females of the species, Ortlepp's (1964) description is accurate.

For comparative purposes, the head of *O. mwanzae,* which has an oval buccal capsule, is illustrated in Fig. 7c.

Discussion

Ortlepp (1964) described 2 new *Oesophagostomum* species from warthogs as *O. moçambiquei* and *O. santos-diasi,* using the c-cedilla and a hyphen respectively. Horak *et al.* (1988) disregarded the c-cedilla in the species name *mocambiquei* but retained the hyphen in the name *santos-diasi.* Under the code of International Zoological Nomenclature, diacritic marks, including hyphens, are not allowed, and the species names are corrected here to *Oesophagostomum mocambiquei* and *Oesophagostomum santosdiasi.*

During this study it was found that the larger the total individual worm burden, the smaller the worms tended to be, and vice versa. This probably explains the differences in some of the measurements of the type specimens and those examined during this study. It also explains the rather wide range of the principal measurements of the worms examined during this study (Table 1).

No characteristic differences in the configuration of the bursa and its associated rays exist between the different *Oesophagostomum* spp. from warthogs. The protuberance on the median branch of the dorsal ray was illustrated and commented on by Daubney (1926) in *Oesophagostomum roubaudi* Daubney, 1926 and *O. mwanzae,* and is also present in *O. mocambiquei.*

O. mocambiquei closely resembles *O. santosdiasi* in the principal measurements. The most outstanding difference between the males of these two species is the shape of the buccal capsule, which is round in *O. mocambiquei* but oval in *O. santosdiasi,* similar to that of *O. mwanzae.*

Twelve *Oesophagostomum* spp. have so far been recovered from the large intestines of warthogs in Africa. They are *Oesophagostomum aethiopicum* Duthy, 1947, *Oesophagostomum eurycephalum*

Goodey, 1924, *Oesophagostomum farchai* Troncy, Graber & Thal, 1972, *Oesophagostomum goodeyi* Daubney, 1926, *O. mocambiquei, Oesophagostomum mpwapwae* Duthy, 1947, *O. mwanzae, Oesophagostomum oldi* Goodey, 1924, *O. roubaudi, O. santosdiasi, Oesophagostomum simpsoni* Goodey, 1924, and *Oesophagostomum yorkei* Thornton, 1924. There is, however, some doubt as to the correctness of the collection data, since Duthy (1947) reported that *O. mpwapwae, O. mwanzae, O. simpsoni* and *O. yorkei* were present in helminth collections from elephant, *Loxodonta africana,* and Goodey (1924) stated that *O. eurycephalum, O. mwanzae, O. oldi* and *O. simpsoni* were found in helminth collections from roan antelope, *Hippotragus equinus*. The fact that the records have been made cannot be ignored (Round, 1968) and they are therefore included in the list.

Of the worms listed above, only *O. mocambiquei, O. mwanzae, O. santosdiasi* and *O. simpsoni* have been found in warthogs in South Africa (Ortlepp, 1964; Horak *et al.*, 1988), while *O. mpwapwae, O. mwanzae* and *O. roubaudi* were recovered from warthogs from Namibia (Horak, Biggs, Hanssen & Hanssen, 1983). The differences between these 6 species are summarized in Table 2 and a simplified key for the identification of the *Oesophagostomum* spp. of warthogs in South Africa and Namibia is given below.

A simplified key to the *Oesophagostomum* spp. of warthogs in South Africa and Namibia.

Females

1. Tail bent dorsalwards 2
   Tail straight..... 5
2. Mouth capsule cylindrical ..... *O. mocambiquei*
   Mouth capsule oval..... 3
3. Oesophageal valves present ..... *O. mwanzae*
   Oesophageal valves absent 4
4. Vagina about 1 mm long..... *O. santosdiasi*
   Vagina not longer than 0,26 mm..... *O. roubaudi*
5. Mouth capsule cylindrical..... *O. mpwapwae*
   Mouth capsule oval..... *O. simpsoni*

Males

1. Mouth capsule oval..... 2
   Mouth capsule round..... 5
2. Oesophageal valves present ..... *O. mwanzae*
   Oesophageal valves absent 3
3. Spicules 2,4 to 2,7 mm long..... *O. santosdiasi*
   Spicules less than 1,5 mm long 4
4. Oesophagus short and wide with parallel sides
   ..... *O. simpsoni*
   Oesophagus club-shaped..... *O. roubaudi*
5. Spicules more than 3 mm long .... *O. mpwapwae*
   Spicules less than 3 mm long.... *O. mocambiquei*

ACKNOWLEDGEMENTS

I wish to thank the South African Defence Force for placing the warthogs at my disposal and Messrs P. Oosthuizen, D. Breytenbach, J. Botha and C. du Plessis for assistance. Mr H. J. Els provided the SEM photographs.

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Stephanofilaria thelazioides n. sp. (Nematoda: Filariidae) from a hippopotamus and its affinities with the species parasitic in the African black rhinoceros

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Accepted for publication 3rd October, 1994

Abstract

Stephanofilaria thelazioides n. sp. (Filarioidea: Filariidae: Stephanofilariinae) is described from a hippopotamus *Hippopotamus amphibius*. This nematode is close to *S. dinniki* Round, 1964, a parasite of the black rhinoceros *Diceros bicornis* in Africa, but differs from it in the number of cuticular spines surrounding the mouth, the arrangement of the cloacal papillae and the measurements of the spicules, gubernaculum and microfilariae. Species of the genus *Stephanofilaria* possess spines on the head which have been derived by modification of the sensory papillae. *S. thelazioides* is the most primitive species of the genus and has the least modified arrangement of these papillae, with six bifid internal labial spines, four bifid external labial spines and four cephalic papillae. The genus appears to have diversified in various mammals which have in common a thick skin, such as rhinoceroses, elephants, buffaloes and now the hippopotamus. It appears to have become adapted secondarily to domestic bovines, initially in Asia and subsequently in North America.

Introduction

During a recent drought in the Kruger National Park, it became necessary to cull a number of hippopotami in several rivers traversing the park. One of these animals had an ulcerated skin lesion of about 5 cm in diameter on the shoulder region. The lesion was excised, preserved in 10% buffered formalin and submitted to one of us (NPJK) for examination and diagnosis.

Histopathological examination revealed numerous nematodes embedded in a hyperplastic epidermis. Preliminary examination of the remainder of the lesion indicated that the worms belonged to the genus *Stephanofilaria* Ihle & Ihle–Landenberg, 1933, but they could not be assigned to any known species.

Materials and methods

Nematodes were dissected out of the lesion mentioned above using a stereoscopic microscope. Fourteen females, including the holotype, and two males, the allotype and a paratype, were recovered. In addition, the anterior and posterior ends of several females, as well as one anterior and two posterior ends of males, were found. All the specimens are housed in the collection of the Museum National d'Histoire Naturelle, Paris, number MNHN 122HS. Measurements were derived from *camera lucida* drawings.

Stephanofilaria thelazioides n. sp.

Type-host and locality: *Hippopotamus amphibius* Linnaeus, 1758, from the Kruger National Park, Republic of South Africa.

Description (Figs 1–3)

Cuticle without frills but transverse striations well-defined and large at level of mid-body (Fig. 2E). Head with projecting cuticular ring, hexagonal in apical view (Fig 1); external border of ring vertical; internal border gently sloping. Six small bifid cuticular internal labial spines on internal aspect of ring; further posterior are 4 cuticular external labial spines and, at their bases, 4 cephalic papillae. Amphids at level of external labial spines. Deirids bifid (Figs 2D, 3B), posterior to nerve-ring. Oral opening hexagonally-rounded; buccal cavity with thin wall. Oesophagus joining intestine immediately posterior to nerve-ring (Figs 2C, 3A).

Female. Lateral alae absent. Vulva near anterior end; vagina slender anteriorly; ovejector initially slightly dilated, then tubular (Figs 2B, C); opisthodelphic; ovaries and oviducts short. Tail almost straight or slightly curved ventrally, with rounded tip and subterminal phasmids (Fig 2H). Few microfilariae present in females examined; head slightly narrower than body; posterior end conical; sheath with same shape as microfilaria.

Male. Testes at mid-body; vas deferens runs anteriorly and reflexes near posterior extremity of oesophagus. *Area rugosa* with pattern of small beads packed close together, situated latero-ventrally (Figs 3D,E,G); at border of *area rugosa* bead-like pattern replaced by small longitudinal ridges (batonnets). Cuticle expanded in pre- and postcloacal regions, ventrally and laterally, forming caudal vesicle with lateral alae. Fifteen pairs of caudal papillae, arranged in 3 groups: one group of ventral ventro-lateral papillae comprising single precloacal papilla, one adanal pair, 2 strongly pedunculate postcloacal pairs and 2 subterminal pairs (Figs 3D, E); one group of 2 latero-ventral rows of pedunculate papillae, hind-most being at level of cloaca, the anterior-most 300 μm anterior to cloaca; and one group of 2 lateral rows of 3–4 pedunculate pairs in pre- and postcloacal regions (Fig 3F). Left spicule long and thin (Fig 3H) with shaft slightly longer than blade and spirally twisted distal tip (Fig 3I). Right spicule with shaft and blade only slightly differentiated; membranous alae present along blade; tip obtusely conical (Fig 3J). Gubernaculum lightly sclerotised.

Measurements (in micrometres unless otherwise stated)

Females. (Measurements are for holotype, with range in parentheses). Body 6.8 (6.3–6.8) mm long and 135 (135–180) wide; nerve-ring and deirids 110 (90–150) and 210 (140–275) respectively from anterior end; buccal capsule length 10 (10–11); oesophagus 150 (144–171) long; vulva 35 (22–35) from anterior end; vagina 220 (130–220) long; ovejector 280 long; tail 60 (50–60) long. Microfilariae expressed from ovejector 180 (160–195) long and 8 (8–10) wide.

Males. (Measurements are for allotype, with paratype fragments in parentheses). Body 3.2 (3.2) mm long, 80 (90) wide; length of buccal cavity 7 (7); nerve-ring and deirids 100 (80) and 160 (127) respectively, from anterior extremity; tail 30 (25, 25) long; left spicule 945 (880, 925) long with blade 500 (500, 475) long; right spicule 130 (120, 148) and gubernaculum 35 (25, 35) long.

Discussion

Sonin (1977) and Johnson (1987) revised the species of the genus *Stephanofilaria* and no new species have been added subsequently. Like Johnson (1987), we are of the opinion that *Stephanofilaria andamani* Sinha & Das, 1958 from the water buffalo *Bubalus bubali* in the Andaman islands and *Stephanofilaria srivastavi* Bhattacharjee, 1967 from the elephant *Elephas maximus* in India are *species inquirendae*, because "no taxonomic descriptions have been published in support of either name" (Johnson, 1987). Four species are currently recognised: *Stephanofilaria dedoesi* Ihle & Ihle–Landenberg, 1933 is a parasite of cattle, goats and water buffalo in Indonesia. Johnson (1987) considered *S. assamensis* Pandit, 1936 from India, *S. kaeli* Buckley, 1937 from Malaysia and *S. okinawaensis* Ueno & Chibana, 1977 from Japan (erroneously assigned to *S. rono* Kono, 1965 by Ivashkin, Shmytova & Koishibaev, 1971) as probable synonyms of *S. dedoesi*. All these species (or subspecies?, or synonyms?) have several features in common: cuticle with frills; head with a circle of internal labial spines, a circle of external labial spines and four cephalic papillae; female with the vulva at the level of the nerve-ring and a short conical tail; male with the left spicule 150–230 μm long, right spicule 40–50 μm long, gubernaculum present and lateral alae absent; and microfilariae 85–140 μm long with an elongate sheath.

Stephanofilaria zaheeri Singh, 1958 is also a parasite of cattle in Asia. Nevertheless, it may be distinct from *S. dedoesi* in that it has more internal and external

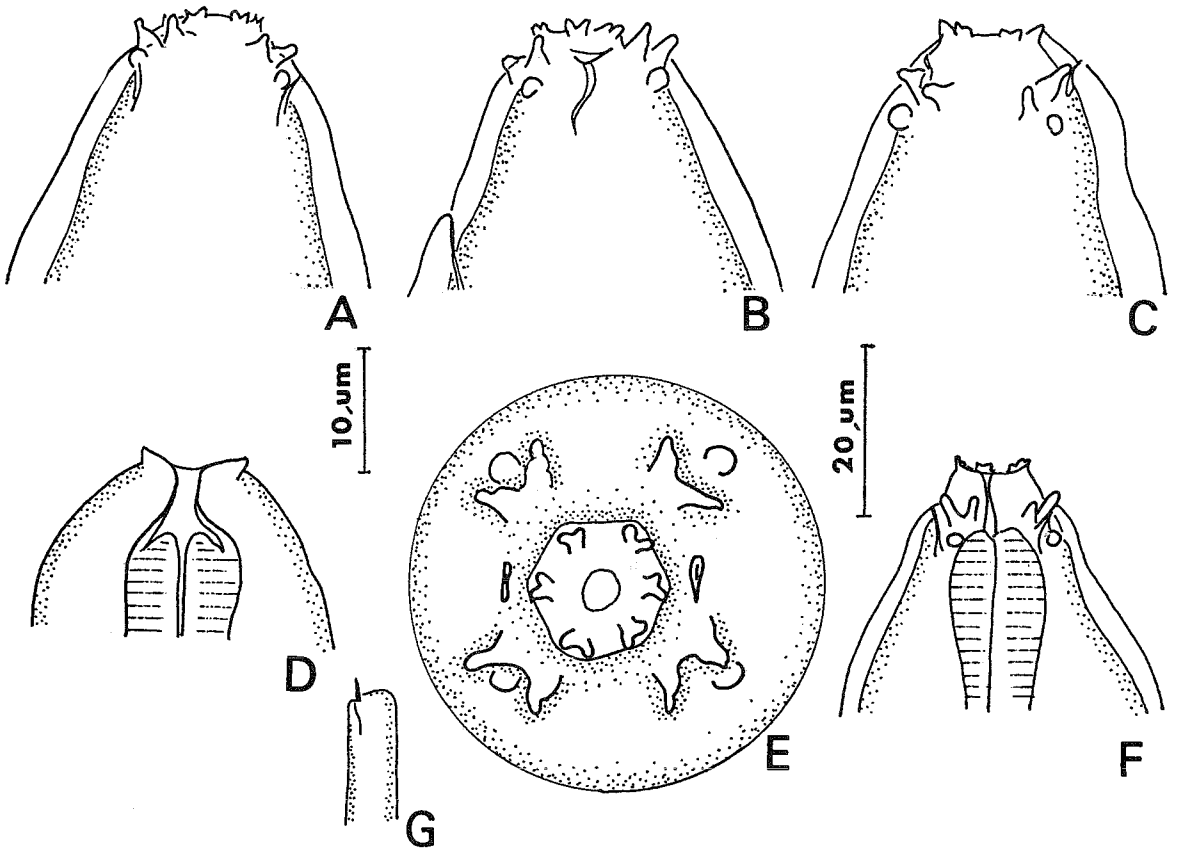

Fig. 1. Stephanofilaria thelazioides n. sp. Cephalic extremities of the female (A–E), the male (F) and the microfilaria (G). A, dorsal view; B, left lateral view; C, ventral view (since the head is slightly curved dorsally the internal labial papillae are more visible in A and the external labial papillae in C); D, longitudinal optical section, lateral view; E, apical view; F, lateral view; G, ventral view. *Scale-bars*: A,B,C,D,F, 20 µm; E,G, 10 µm.

labial spines (23–24 *vs* 15–18, and 28–32 *vs* 16–23). Singh (1958) stated that four external labial and four cephalic papillae are present, but these are difficult to see in such a small worm.

Stephanofilaria stilesi Chitwood, 1934 is a parasite of *Bos taurus* in the Nearctic region, but it has also been found in Russia. It differs from the previous species in the configuration of the cephalic structures, i.e. the extemal labial papillae are not transformed into cuticular spines (Anderson, 1968), there are five submedian cuticular spines (lateroventral according to Hibler, 1966), and frills on the cuticle of the body are absent. The microfilariae are also much smaller (40–60 µm long, 2–4 µm wide) and possess an ovoid sheath (Hibler, 1966).

Stephanofilaria dinniki Round, 1964 is a parasite of the black rhinoceros *Diceros bicornis* (Linnaeus, 1758) in East and South Africa. This species has no frills on the cuticle of the body. Round (1964) stated that the head bears a crown of 11–12 peribuccal spines (but illustrates 16), eight spines grouped in pairs slightly posteriorly and four cephalic papillae. This species also differs from the others in that the vulva is situated more anteriorly, the vagina is longer, the nerve-ring is further posterior, and the tail of the female is longer than wide and its tip is rounded; the spicules are also longer, the caudal alae are present and the cloacal papillae are pedunculate.

The last named species is the only one that bears close resemblance to our specimens. It was not possible to do comparative studies because the material from the rhinoceros had been lost. Nevertheless, the description of Round (1964) is precise and clearly shows the distinctive characteristics of the head, the caudal papillae and the dimensions of the spicules, gubernaculum and microfilariae. *S. dinniki* differs from our speci-

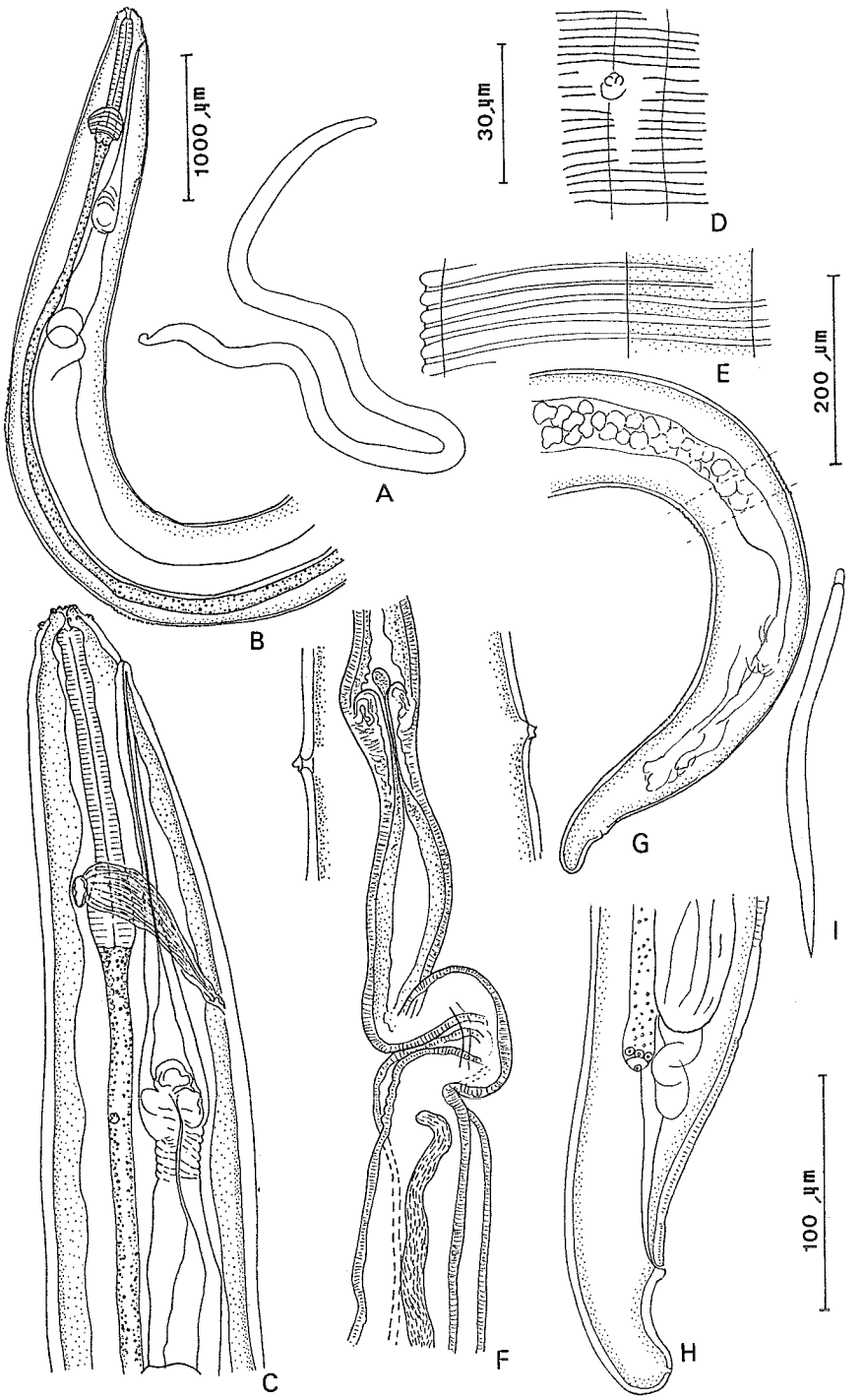

Fig. 2. Stephanofilaria thelazioides n. sp. Female. A, entire body; B, anterior region in right lateral view; C, anterior extremity in right lateral view showing the oesophagus and vagina; D, deirid; E, cuticular ornamentation; F, deirids and the division of the ovejector; G, posterior region; H, posterior extremity; I, microfilaria. *Scale-bars*: A, 1,000 µm; B,G, 200 µm; C,F,H, 100 µm; D,E,I, 30 µm.

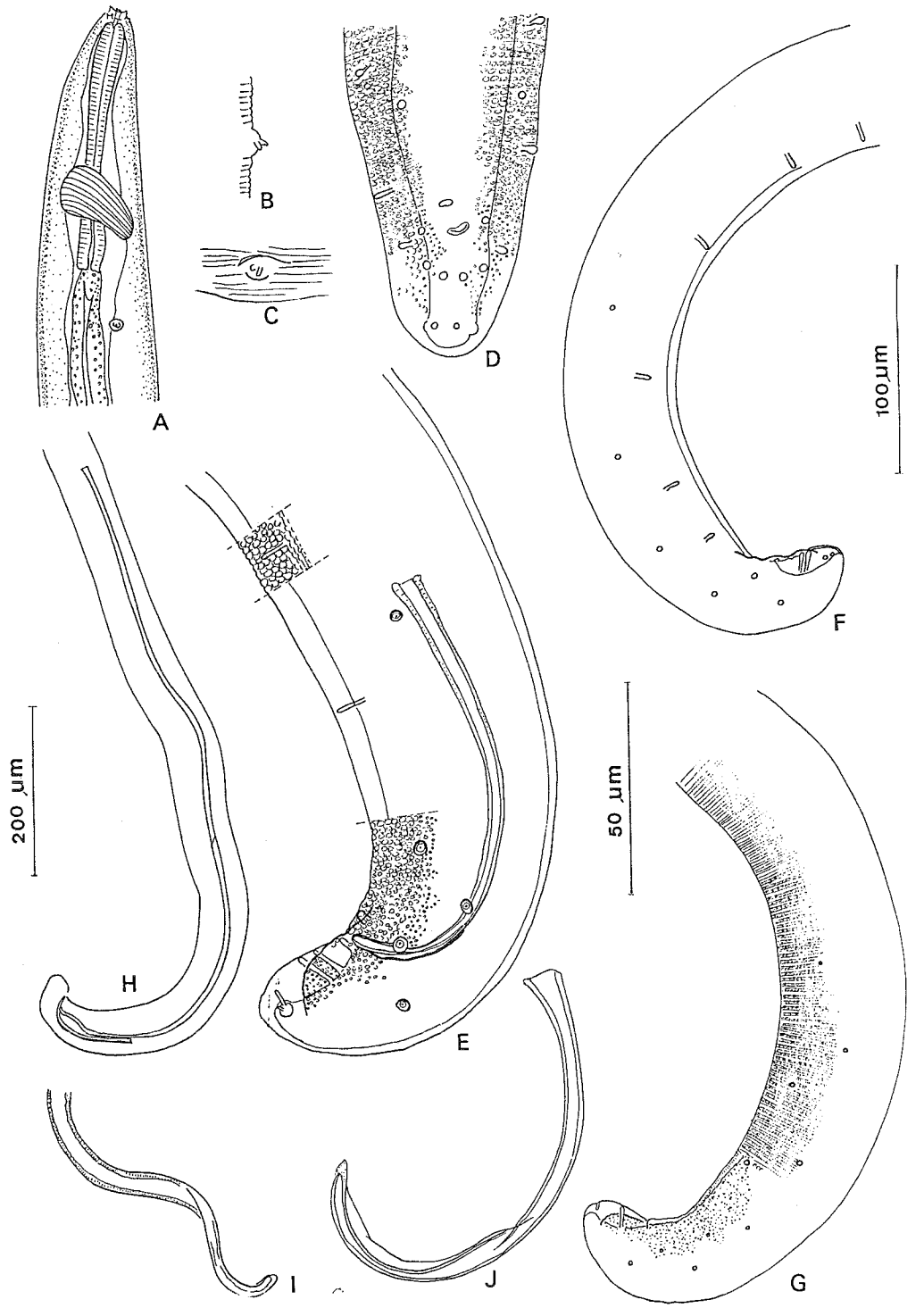

Fig. 3. *Stephanofilaria thelazioides* n. sp. Male. A, anterior extremity, right lateral view; B, deirid, median view; C, deirid, lateral view; D, posterior extremity, ventral view; E, posterior extremity, left lateral view, showing the right spicule and gubernaculum (the cuticular ornamentation is not drawn at mid-body); F, posterior extremity, right lateral view, showing the arrangement of the cloacal papillae; G, posterior extremity, left lateral view, showing the cuticular ornamentation; H, spicules; I, tip of the left spicule; J, right spicule. *Scale-bars*: H, 200 µm; A,D,F,G, 100 µm; B,C,E,I,J, 50 µm.

mens in the following respects: the head bears 12 (or 16?) internal labial spines arranged regularly, while our specimens have six distinct bifid spines; the three pairs of ventral postcloacal papillae are close together, while in our specimens one pair is adanal and two pairs are clearly more posterior; the left and right spicules and the gubernaculum are, respectively, 62–115, 530–750 and 11–14.5 μm long, while in our specimens they are 880–945, 120–148 and 25–35 μm in length; and the microfilariae are 120–150 μm long and have a cuticular cap, while in our specimens they are 180 μm long and without a cap.

In view of these differences, we consider the specimens from the hippopotamus to be a new species for which we propose the name *Stephanofilaria thelazioides* n. sp. The specific name refers to the affinities of *Stephanofilaria* with the genus *Thelazia* Bosc, 1819, previously established by Anderson (1957), Anderson & Bain (1976) and Bain (1981), which are especially apparent in the new species.

The different species of the genus *Stephanofilaria* can be classified phyletically. They have a cephalic ring which is already present in the larval stages (Hibler, 1966). The spines on the head, equally characteristic of the genus, are derived by modification of the sensory papillae, and these spines have become more modified as the species evolve. Several other characteristics give an indication of the degree of specialisation in each species: female and male tails that are shortened to a lesser or greater degree; caudal papillae which may or may not be numerous and have a lesser or greater tendency to accumulate in the cloacal region; and the considerable variation in the length of the spicules.

Based on the above, *S. thelazioides* from the hippopotamus appears to be the most primitive. *S. dinniki* from the rhinoceros is closely related, but the disposition of the spines on the head and the cloacal papillae are slightly more specialised. The species parasitising the domesticated Asiatic mammals (water buffalo, cattle, goats and elephants) are clearly more evolved, as is indicated by the multiplication of the internal labial and external labial spines and the shorter tail, as well as by the development of cuticular frills covering the body. *S. stilesi*, a parasite of cattle in North America, has the most advanced morphology in that the cuticular spines on the head are replaced by a small newly formed group of latero-ventral spines and in that the tail of the male is very short with the papillae arranged around the cloaca (Ivashkin, Timofeeva & Khromova, 1961).

Hippopotami, rhinoceroses, elephants and water buffaloes are mammals without obvious zoological affinities, but they have a thick skin in common. The evolution of the genus *Stephanofilaria* seems to be associated with this favourable biotope rather than with the phylogeny of the hosts. We assume that this genus is of African origin, was introduced into Asia and that its occurrence in cattle is recent.

Acknowledgements

We thank Dr Roy Bengis, State Veterinarian, Skukuza, Kruger National Park, for submitting the lesion in the skin of the hippopotamus, and Mme Roselyne Tcheprakoff, Muséum National d'Histoire Naturelle, for her technical assistance. Part of this study was made possible with a grant to the first author from the Foundation for Research Development.

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Onderstepoort Journal of Veterinary Research, 67:173–177 (2000)

Molineus cati n. sp. (Nematoda, Trichostrongylina, Molineoidea), a parasite of feral cats, *Felis catus* Linnaeus, 1758 in South Africa

MARIE-CLAUDE DURETTE-DESSET[1], J. BOOMKER[2] and F.S. MALAN[3]

ABSTRACT

DURETTE-DESSET, MARIE-CLAUDE, BOOMKER, J. & MALAN, F.S. 2000. *Molineus cati* sp. n. (Nematoda, Trichostrongylina, Molineoidea), a parasite of feral cats, *Felis catus* Linnaeus, 1758 in South Africa. *Onderstepoort Journal of Veterinary Research*, 67:173–177

A new species of the genus *Molineus* Cameron, 1923 was recovered from feral cats, *Felis catus* Linnaeus, 1758, in Mpumalanga Province, South Africa. Because of a caudal bursa with rays of the 2-1-2 type, but with the extremities of rays 4 nearer those of rays 3 than those of rays 5, the new species is closely related to seven Neotropical *Molineus* spp., four parasitic in Primates, two parasitic in Mustelidae and one a parasite of Procyonidae. Amongst these species, only *Molineus barbaris* Cameron, 1936, a parasite of *Tayra barbara* (Mustelidae) from Trinidad and *Molineus vexillarius* (Dunn, 1961), a parasite of *Tamarinus nigricollis* (Primates) from Peru have rays 4 longer than two-thirds the length of rays 3, like the new species. However, the new species is differentiated from the other two in that rays 9 arise at the level of the bifurcation of the dorsal ray and not after the division as is the case with *M. barbaris* and *M. vexillarius*.

Keywords: *Molineus cati*, Nematoda, Trichostrongylina, Molineoidea, *Felis catus*, Felidae, South Africa

INTRODUCTION

The genus *Molineus* was created by Cameron (1923) and redefined by Durette-Desset & Chabaud (1981b). It consists of 28 species, parasitic in Carnivora throughout the world (except Australia) and in Neotropical Primates. Three species were described in the Afrotropical region, two from Viverridae (Cameron 1927; Le Roux 1933) and one from Canidae (Troncy 1970). The new species represents the first record of a *Molineus* sp. of Felidae in this region. However, since it is a parasite of a domestic cat, *Felis catus* Linnaeus, 1758, it is not possible to determine whether it is a parasite of the Afrotropical region or was introduced from some other biogeographical region together with its host.

MATERIALS AND METHODS

During a survey of *Taenia* spp. in the vicinity of Middelburg, Mpumalanga Province (25°44'–25°47'S; 29°25'–29°30'E), a total of 22 feral domestic cats were caught and processed for worm recovery. Nematodes of the genus *Molineus* were encountered in the small intestine of four of these cats. The helminths were fixed and stored in 70% ethanol, studied in temporary wet mounts in water and, when necessary, cleared in lactophenol. Apical views and cross-sections were mounted and studied in lactophenol. Measurements are given in micrometers unless otherwise stated.

The nomenclature of taxa higher than the family-group is that of Durette-Desset & Chabaud (1993).

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Accepted for publication 12 June 2000—Editor

The synlophe was studied according to the method of Durette-Desset (1985), and the nomenclature used for the components of the caudal bursa is that of Durette-Desset & Chabaud (1981a).

DESCRIPTION

Type material

Holotype male, allotype female, number 187 MQa; three male and two female paratypes plus three posterior parts of female paratypes, number 187 MQb. All the specimens have been deposited in the Museum National d'Histoire Naturelle, Paris.

Type host

Felis catus Linnaeus, 1758 (Carnivora, Felidae).

Site

Small intestine.

Type locality

Middelburg, Mpumalanga Province (25°44'–25°47'S; 29°25'–29°30'E).

Etymology

The species is named after its host.

Description

Small nematodes, body not coiled. The nerve ring, excretory pore and deirids are situated at the same level, at mid-oesophagus (Fig.1I). A circular excretory groove, not surrounded by cuticular expansions, is present, as is an excretory sinus, 38 long (Fig. 1A and B).

Head

A cephalic vesicle is present. In apical view, the buccal opening is rounded and surrounded by two small amphids, six externo-lateral papillae and four cephalic papillae (Fig. 1D).

Synlophe

(Studied in one male and one female). In both sexes, the cuticle bears a varying number of uninterrupted ridges which appear posterior to the excretory groove (Fig. 1C) and disappear just anterior to the caudal bursa in male and at the caudal extremity in female (Fig. 1H). In the male, the number increases from 14 at the level of the oesophago-intestinal junction to 16 at mid-body (Fig. 1E), then to 28 in front of caudal bursa (Fig. 1F). In the female, the number increases from 21 at the oesophago-intestinal junction to 28 in the anterior third of body, then decreases to 16 at mid-body and increases again to 30 in the posterior third of body. Only the ventral ridges are interrupted in front of the vulva (Fig. 1G). Ridges are regularly spaced except those opposite the lateral fields, which are closer together and slightly smaller than the other. The smaller ridges continue for the entire length of the body of the male (Fig. 1E and F) but are present only at mid-body in female. Ridges are orientated perpendicularly to the body surface (Fig. 1E–H).

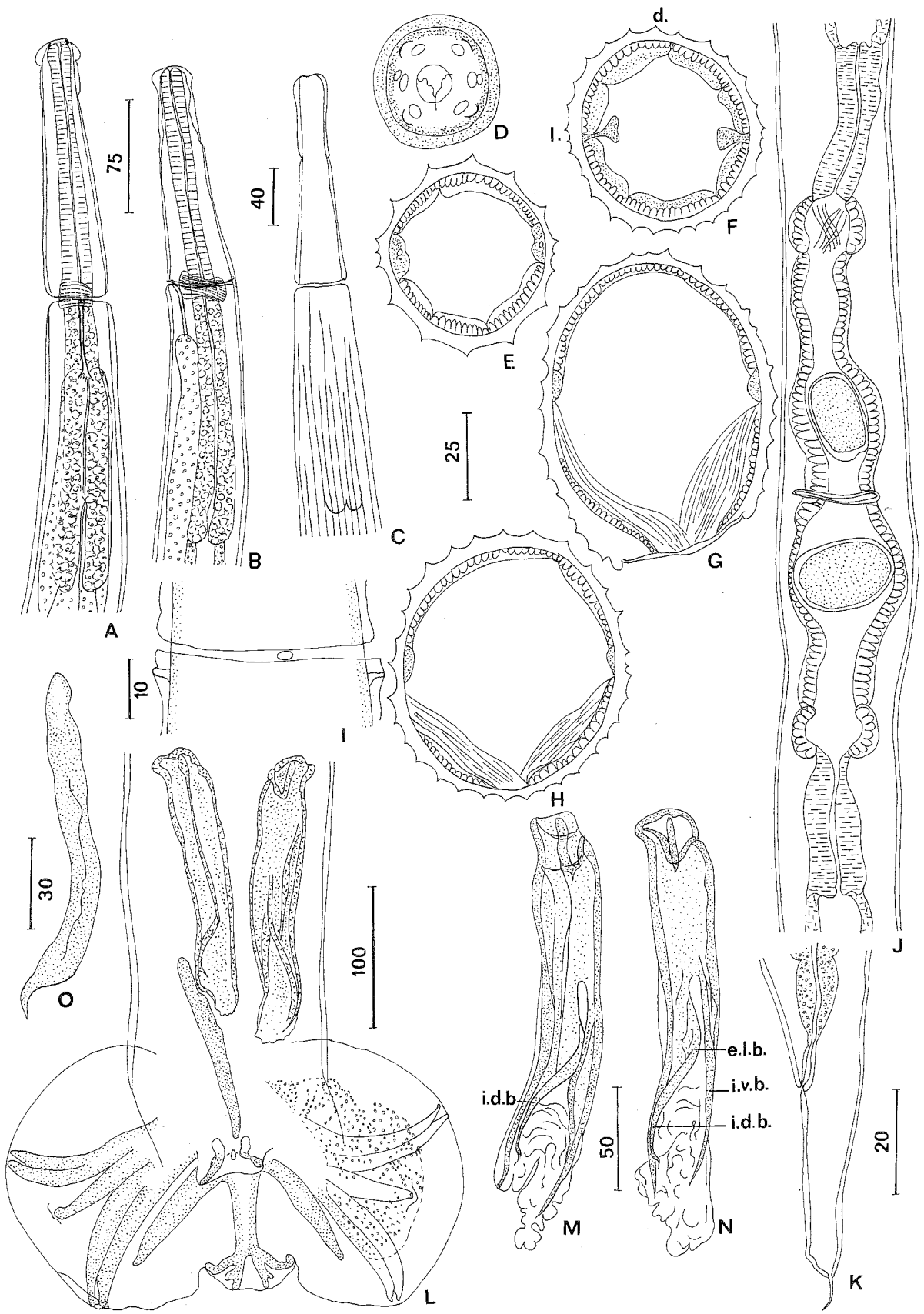
FIG. 1 *Molineus cati* n. sp.

A:	Female, anterior extremity, ventral view
B:	Holotype male, anterior extremity, left lateral view
C:	Male, anterior extremity, ventral view showing the appearance of the cuticular ridges
D:	Male, head, apical view
E–H:	Transversal sections of the body
E:	Male at mid-body
F:	Male, 400 µm above caudal bursa
G:	Female at vulva level
H:	Female, between vulva level and tail
I:	Female, detail of the excretory pore, the excretory groove and the deirids, ventral view
J:	Female, ovejector, ventral view
K:	Female tail, left lateral view
L:	Male, caudal bursa, ventral view. The spiny projections are illustrated only on the left lateral lobe
M, N:	Left spicule, dorsal and internal views
O:	Male gubernaculum, left lateral view

Note: The transversal sections are all orientated as indicated in Fig. 1F

Abbreviations: d, dorsal side; l, left side; e.l.b., externo-lateral branch; i.d.b., interno-dorsal branch; i.v.b., interno-ventral branch

Scale bars: A, B, J: 75 µm; C: 40 µm; D, O: 30 µm; E-H: 20 µm; I: 10 µm; K: 20 µm; L: 100 µm; M, N: 50 µm



Holotype male

The nematode is 5,1 mm long and 65 wide at mid-body. The cephalic vesicle is 55 long by 20 wide. The nerve ring, excretory pore and deirids are situated at 150, 150 and 155 from the apex, respectively, and the oesophagus is 335 long (Fig. 1B).

The caudal bursa is symmetrical and the bursal ray pattern is of type 2-1-2. Spiny projections occur on the lateral lobes (Fig. 1L). Rays 4 are short with their extremities nearer those of rays 3 than those of rays 5. Rays 8 are thick and arise from the basis of the dorsal ray, and are slightly shorter than the latter. The dorsal ray is divided into two branches at its distal extremity, each one in turn giving rise to three small branches; firstly, the external branches (rays 9), then the phasmids and rays 10 (internal branches).

The spicules are alate, 95 long, with the handle slightly shorter than blade. The blade is divided into two primary branches, the externo-lateral branch and the interno-ventral branch. The interno-dorsal branch arises from the externo-lateral branch and is smaller. All three the branches have sharp tips and are enveloped by a membrane (Fig. 1M and N). In ventral view the gubernaculum is rectangular in shape while in lateral view it is slightly curved (Fig. 1O).

The two paratype males are 4,6 and 4,8 mm long and 65, 60 wide at mid-body. The cephalic vesicle measures 50, 55 long by 20, 20 wide. The nerve ring, excretory pore and deirids are situated at the same level, 160, 160 and 165 from the apex, respectively. The oesophagus is 360, 355 long. The spicules are 105, 120 long and the gubernaculum is 75, 72 long in ventral view.

Allotype female

This female is 5,7 mm long and 65 wide at mid-body. A cephalic vesicle is present and measures 60 long by 20 wide. The nerve ring, excretory pore and deirids are situated at 165, 170, 175 from the apex, respectively. The oesophagus is 390 long. The uterus is didelphic and the vulva situated 1 100 from the caudal extremity, in the posterior sixth of the body. The *vagina vera* is 25 long and the vestibule 320 long. The anterior sphincter and infundibulum are 35 x 40 and 65 long, respectively, and the posterior sphincter and infundibulum 30 x 40 and 55 long, respectively (Fig. 1J). The anterior uterine branch is 960 long and contains 8 eggs while the posterior uterine branch is 500 long and contains 6 eggs. The eggs, in the morula stage, are 60 long by 45 wide. The tail is 60 long and the caudal spine is broken (seen only in 2 paratypes, 11 long) (Fig. 1K).

The two paratype females are 6,4 and 5,9 mm long and 80, 60 wide at mid-body. The cephalic vesicle is 65, 55 long by 23, 20 wide and the nerve ring is situated 180, 140 from the apex, the excretory pore 180, 140 and the deirids 185, 145, respectively. The oesophagus is 370, 360 long. Vulva is situated 1,1 and 1,2 mm from the caudal extremity. The vestibule is 305, 320 long. The anterior sphincter and infundibulum measure 45 x 48, 35 x 45 and 100, 70 long, respectively and the posterior sphincter and infundibulum 35 x 45, 30 X 40 and 90, 80 long, respectively. The anterior uterine branch is 800, 840 long and contains 12, 9 eggs while the posterior uterine branch 550, 580 long with 10, 4 eggs. Eggs in the morula stage measure 50, 58 long by 35, 40 wide. The tail is 60, 60 long and the caudal spine 11, 11 long.

DISCUSSION

The specimens from *Felis catus* belong to the genus *Molineus* Cameron, 1923 (Molineoidea), because of a synlophe with ridges orientated perpendicularly to the body surface and the pattern of the bursal rays. Rays 2 and 3 (ventral) are close together and run parallel as do rays 5 and 6 (lateral) and a short 4th ray is present. The spicules are short and thick, and the female is didelphic and her tail bears a spine.

Amongst the 28 species described, only seven species (four in Primates, two in Mustelidae and one in Procyonidae), all of Neotropical origin, share two common characters with the parasites of the cat, namely that the pattern of the caudal bursa is of type 2-1-2 (i.e. rays 4 arising from the common trunk at the same level as rays 2 and 3 on one side and rays 5 and 6 on the other) tending towards type 3-2 (i.e. extremities of rays 4 nearer those of rays 3 than those of rays 5) (Durette-Desset & Chabaud, 1981a). The second characteristic lies in the shape of the spicules, which have a blade that is divided into three branches of equal length.

Of these seven Neotropical species, five can be separated from the specimens of the cat by rays 4, which are shorter than two-thirds of the length of rays 3. Three species, *Molineus elegans* (Travassos, 1921), from *Saimiri sciurea* in Brazil, *Molineus midas* Durette-Desset & Corvione, 1998, from *Sanguinus midas* in French Guyana and *Molineus torulosus* (Molin, 1861) from *Cebus capucinus* in Brazil, occur in Primates, *Molineus nasuae* Lent et Freitas, 1938 occurs in *Nasua narica* (Procyonidae) in Brazil and *Molineus major* Cameron, 1936 in *Tayra barbara* (Mustelidae) from Trinidad. The parasites of the Primates and of *N. narica* are differentiated by the shape of the gubernaculum, of which the proximal part is adorned with a hook while the parasite of *T. barbara* is characterized by rays 8 being much shorter than the dorsal ray. In the remaining two species, *Molineus barbaris* Cameron, 1936 from *T. barbara* from Trinidad and *Molineus vexillarius* (Dunn, 1961) from *Tamarinus nigricollis* (Primates) in Peru, like in the

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specimens of *Felis*, rays 4 are longer than two-thirds the length of rays 3. However, *M. barbaris* and *M. vexillarius* can be differentiated from *M. cati* in that rays 9 arise on the dorsal ray after the division of the latter whereas rays 9 arises at the level of the division in the parasites of the cat.

The parasites of *Felis cati* belong to a new species for which we propose the name *Molineus cati* n. sp.

It is interesting to note *M. cati* is closely related to *Molineus* spp. of the Neotropical region rather than the Afrotropical species but, since *Molineus cati* was found in a domestic host, it is not possible to draw conclusions on the origin of the parasite.

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CHAPTER 2

Seasonal occurrence

of

parasites of free-living mammals

Introduction

The seasonal occurrence of parasites of wild mammals is presented and discussed here. Much of it is my own work, where I did the helminth identifications. Associates are E. Young (for whom I did the helminth identifications), M. Baker (where I also did the helminth identifications), U. Zieger (for whom I identified the helminths), K.J. Fellis and N.J. Negovetich (who used the data from the surveys of Boomker and Horak in the Kruger National Park, and whose manuscripts I edited), W.A. Taylor (for whom I identified the worms and was an advisor for his PhD thesis), M.B. Ellis (whose helminth identifications I confirmed or rejected, and extensively edited the manuscript), and then the numerous papers that I.G. Horak and I published as collaborators. He would often do the helminths, while I would check his identifications (!), or he would merely give me the helminths to identify, while I would give him the ectoparasites to identify from my own surveys.

These surveys gave extensive information on the fluctuation of helminth populations in the various species that they were done on. It emphasized the differences between the helminth intensities of browsers, grazers and intermediate feeders. It also provided information on the different helminth species in the various hosts. For example, *Haemonchus vegliai* is the main abomasal species in kudus, whereas *Haemonchus krugeri* and *Longistrongylus sabie* are the main ones in impalas. The publications are listed in chronological order.

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HELMINTH PARASITES

Onderstepoort J. vet. Res. 40 (2), 69–70 (1973)

HELMINTHS FROM THE MOUNTAIN REEDBUCK, *REDUNCA FULVORUFULA* (AFZELIUS, 1815)

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ABSTRACT

BAKER, MAUREEN K. & BOOMKER, J. Helminths from the mountain reedbuck, *Redunca fulvorufula* (Afzelius, 1815). *Onderstepoort J. vet. Res.* 40 (2), 69–70 (1973).

Helminth parasites recovered from the mountain reedbuck in the Loskop Dam Nature Reserve and the Mountain Zebra National Park are recorded. The following species are new host records: *Moniezia expansa, Cooperia hungi, C. oncophora, C. pectinata, C. yoshidai, Gongylonema* sp, *Haemonchus krugeri, Impalaia tuberculata, Nematodirus spathiger, Oesophagostomum columbianum, Skrjabinema* sp.

INTRODUCTION

Although the helminth fauna of many African antelopes is relatively well known (Ortlepp, 1961; Round, 1968), there is a dearth of data on the rarer species such as the mountain reedbuck, *Redunca fulvorufula* (Afzelius, 1815). Round (1968) lists six helminths from this antelope, viz. *Paramphistomum bothriophoron* (Braun, 1892), *Paramphistomum cervi* (Zeder, 1790), *Cysticercus tenuicollis* Rudolphi, 1810, *Haemonchus contortus* (Rudolphi, 1803), *Setaria boulengeri* Thwaite, 1927, and *Setaria hornbyi* Boulenger, 1921.

During 1969 and 1970 this antelope was the subject of an ecological study in the Loskop Dam Nature Reserve in the Transvaal. This necessitated the regular culling of a number of animals and special efforts were made to collect the helminths from them. During 1971 helminths were also recovered from mountain reedbuck in the Mountain Zebra National Park at Cradock, in the Cape Province.

MATERIALS AND METHODS

In the Loskop Dam Nature Reserve, helminths were recovered from the rumen, abdominal cavity and skeletal muscles of 42 reedbuck. Intestinal helminths were recovered from 11 of these animals, but it was possible to do total collections in four instances only.

In four reedbuck from the Mountain Zebra National Park the abdominal cavity and the intestinal tract were examined for helminths.

The descriptions of Ransom (1911), Mönnig (1931; 1932; 1939) and Travassos (1937) were used to identify the *Cooperia* spp.; Ransom (1911) and Ortlepp (1964) for *Haemonchus* spp.; Mönnig (1924) for the *Impalaia* sp.; Becklund & Walker (1967) for the *Nematodirus* sp.; Ransom (1911) for the *Oesophagostomum* sp. and Yeh (1959) for the *Setaria* sp.

RESULTS AND COMMENTS

The species of helminths recovered are listed in Table 1.

Conical flukes, *Paramphistomum* sp., were present in the rumen of 14 animals. Cysticerci were recovered from the skeletal muscles of 10 reedbuck. The rostellar hooks of these cysticerci resembled those of *Taenia crocutae* Mettrick & Beverley-Burton, 1961, in their number, size and shape (Verster, 1969).

Only one female of a *Gongylonema* sp. was recovered and it could not be identified specifically, nor could the five females and one severely damaged male of a *Skrjabinema* sp.

The apparent predominance of *S. boulengeri,* found in 42 of the 46 hosts, undoubtedly reflects the conditions under which the parasites were collected, i.e. in the field and often in poor light. Since *S. boulengeri* is a large nematode occurring in the abdominal cavity, it is more easily seen than the other smaller nematodes, particularly those inhabiting the intestine.

Cooperia spp. occurred in eight animals and were the predominant nematodes in the total collections from the small intestine. The small intestine of one animal contained 1 107 specimens representing the species *C. hungi, C. oncophora, C. pectinata* and *C. yoshidai.* In this animal *C. yoshidai* outnumbered the other *Cooperia* spp. in a ratio of six to one. A second animal harboured *C. hungi, C. oncophora* and *C. yoshidai,* while a third had *C. hungi* and *C. yoshidai.* In two instances, only females were present and a specific diagnosis was therefore impossible.

H. contortus was recovered from seven animals. One reedbuck was simultaneously infested with *H. krugeri* and *H. contortus* in a ratio of one to 25. Female *Haemonchus* spp. only were present in one animal examined in the Mountain Zebra National Park.

N. spathiger was present in all the animals examined in the Mountain Zebra National Park but did not occur in those from the Loskop Dam Nature Reserve. Its absence from the latter animals is not unexpected as it has not yet been recorded from the Transvaal. It is, however, of major importance in sheep in the Karoo (Viljoen, 1964; 1968).

TABLE 1 Helminths recovered from the mountain reedbuck

Parasite	No. of Animals Infested
Loskop Dam Nature Reserve	
Paramphistomum sp.	14
Cysticercus sp.	10
*Cooperia hungi** Mönnig, 1931	3
*Cooperia oncophora** (Railliet, 1898)	1
*Cooperia pectinata** Ransom, 1907	1
*Cooperia punctata** Linstow, 1907	1
*Cooperia yoshidai** Mönnig, 1939	4
Cooperia sp.	2
*Gongylonema** sp.	1
Haemonchus contortus (Rudolphi, 1803)	7
*Haemonchus krugeri** Ortlepp, 1964	1
*Impalaia tuberculata** Mönnig, 1923	3
*Oesophagostomum columbianum** Curtice, 1890	2
Setaria boulengeri Thwaite, 1927	38
*Skrjabinema** sp.	4
Mountain Zebra National Park	
*Moniezia expansa** (Rudolphi, 1810)	1
Haemonchus sp.	1
*Nematodirus spathiger** (Railliet, 1896)	4
Setaria boulengeri Thwaite, 1927	4

*New host record.

Received 8 May 1973 - Editor

Acknowledgements

The authors wish to express their sincere gratitude to Mr L. Irby of the Texas A & M University, U.S.A., who collected the parasites in the Loskop Dam Nature Reserve; Dr E. Young, State Veterinarian, Skukuza, who collected the parasites in the Mountain Zebra National Park and Dr Anna Verster, whose constant interest and valuable comments made this publication possible.

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Onderstepoort J. vet. Res., 51, 253–256 (1984)

THE HELMINTHS OF VARIOUS ANTELOPE SPECIES FROM NATAL

J. BOOMKER[1], M. E. KEEP[2], J. R. FLAMAND[3] and I. G. HORAK[4]

ABSTRACT

BOOMKER, J., KEEP, M. E., FLAMAND, J. R. & HORAK, I. G., 1984. The helminths of various antelope species from Natal. *Onderstepoort Journal of Veterinary Research*, 51, 253–256 (1984).

Helminth parasites were collected from 2 bushbuck, *Tragelaphus scriptus*, 2 red duiker, *Cephalophus natalensis*, 1 oribi, *Ourebia ourebi*, and 4 reedbuck, *Redunca arundinum*, that died or were culled in various parts of Natal. One trematode genus, 1 cestode genus and 12 nematode species were recovered. *Haemonchus contortus*, *Ostertagia harrisi*, *Trichostrongylus capricola*, *Trichostrongylus vitrinus*, *Cooperia rotundispiculum* and *Setaria scalprum* are new parasite records for the red duiker. *Trichostrongylus colubriformis* is a new parasite record for the oribi and *Longistrongylus schrenki*, *Trichostrongylus falculatus*, *Trichostrongylus colubriformis* and *Dictyocaulus viviparus* are recorded from the reedbuck for the first time. An unidentified paramphistome was also recovered from the reedbuck.

INTRODUCTION

The helminths of antelope occurring in and around the Natal game reserves have received little attention in the past. Such parasites as are known have been collected incidentally. The only records of the helminth burdens in bushbuck, *Tragelaphus scriptus*, oribi, *Ourebia ourebi*, common reedbuck, *Redunca arundinum*, and red duiker, *Cephalophus natalensis*, from this province of South Africa are provided by Le Roux (1930) and Keep (1983).

The habitat and food preferences of bushbuck and oribi in the Transvaal have been briefly described by Boomker, Horak & De Vos (1984). Both antelope are browsers, feeding on a large variety of plants.

The red duiker is a small antelope that is restricted to forested areas (Rautenbach, 1982). Very little is known about this animal, but Pienaar (1963) and Heinichen (1972) state that it is a delicate browser. Heinichen (1972) found it to be a nocturnal species, occurring singly or in pairs.

Reedbuck are medium-sized antelope that occur in well-grassed flatlands or rolling hills close to permanent water (Dorst & Dandelot, 1972; Rautenbach, 1982). Jungius (1971) and Venter (1979) discussed their ecology and food plant references and concluded that they are grazers, feeding for a large part on grasses unpalatable to other antelope.

The helminths recovered from these antelope are listed by Round (1968). Boomker *et al.* (1984) updated the list of parasites from bushbuck and oribi in the Transvaal, and Keep (1983) updated that of the helminths from the larger indigenous mammal species in Natal.

MATERIALS AND METHODS

Two male bushbuck and 2 red duiker males were shot in March 1983 at Charters Creek (28°14′S; 32°25′E) on the western shores of Lake St Lucia. Their gastro-intestinal parasites were collected as described by Reinecke (1973). The hearts, lungs and livers were processed for parasite recovery as described by Horak (1978a).

The parasites of a single male oribi, which died on a farm near Pietermaritzburg (29°58′S; 29°52′E) in September 1982, were collected.

Four male reedbuck were collected at different localities in Natal. Two were from near the Himeville Nature Reserve (29°44′S; 29°32′E) and were shot in August and December 1982 respectively. Another was obtained at Midmar Dam (29°30′S; 30°9′E) in October 1982, and the 4th was killed by a vehicle near Estcourt (28°58′S; 29°52′E) in December 1982.

The parasites of the rumen, the abomasal contents and digests, the small and large intestinal contents, the lungs and the abdominal cavity of 1 of the reedbuck from Himeville (No. 1) and the 1 from Midmar Dam (No. 2) were collected. Only the abomasal and small intestinal contents of the second animal from Himeville (No. 4) and the abomasal contents of the animal from Estcourt (No. 3) were available for examination. None of their hearts and livers were processed for parasites.

Separate aliquots representing 1/10th of the volume of the ingesta of the abomasum, small and large intestines of the 2 red duikers were examined for parasites. Two aliquots, each representing 1/50th of the volume of the gastro-intestinal ingesta of the bushbuck, were examined. Total parasite counts were made on the ruminal, abomasal and intestinal contents of each of the reedbuck and the oribi.

RESULTS

The helminths recovered from the bushbuck and the red duikers are listed in Table 1. Four nematode species and the larvae of a cestode were recovered from the bushbuck, and 6 nematode species from the red duikers. All the parasites found in the red duikers are new records for this antelope in South Africa.

The oribi harboured the following parasites: *Trichostrongylus falculatus*, 61 males; *Trichostrongylus colubriformis*, 6 males; *Trichostrongylus* spp., 52 females; *Cooperia yoshidai*, 9 males and 8 females. A total of 136 worms were recovered of which *T. colubriformis* represents a new parasite record.

The helminths from the reedbuck are listed in Table 2. One trematode genus and 8 nematode species were recovered, the paramphistome, *Longistrongylus schrenki*, *T. falculatus*, *T. colubriformis* and *Dictyocaulus viviparus being new parasite records*.

DISCUSSION

When compared with the numbers of species recovered and the size of the worm burdens of bushbuck from the Kruger National Park (KNP), as reported by Boomker *et al.* (1984), the 2 bushbuck from Charters Creek, Natal, had fewer species and smaller burdens. One possible explanation is that relatively few antelope species are found at Charters Creek, and that those that do occur there, such as greater kudu, nyala, bushbuck, red, blue and grey duikers, are almost exclusively browsers that usually carry few worms. *Ostertagia harrisi*, *Setaria africana* and *Taenia* spp. larvae were found in bushbuck from both localities, but *Gongylonema* sp. occurred in 1 bushbuck from Charters Creek only.

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Received 2 August 1984—Editor

TABLE 1 The helminth burdens of bushbuck and red duikers from Charters Creek, Lake St Lucia

Host, age and sex	*Haemonchus contortus*		*Ostertagia harrisi*			*Trichostrongylus* spp.	*Trichostrongylus capricola*	*Trichostrongylus vitrinus*	*Cooperia rotundispiculum*		*Paracooperia devossi*			*Gongylonema* sp.		*Setaria scalprum*	*Setaria africana*		*Taenia* spp. larvae	Total worm burden
	♀	♂	L_4	♀	♂	♀	♂	♂	♀	♂	L_4	♀	♂	♀	♂	♀	♀	♂		
Bushbuck:																				
Prime adult ♂	0	0	0	24	14	0	0	0	0	0	0	1	111	2	1	0	2	1	1	157
Old ♂	0	0	0	60	47	0	0	0	0	0	30	11	11	0	0	0	2	2	1	164
Red Duiker:																				
Young adult ♂	0	0	2	2	0	267	165	0	0	0	0	0	0	0	0	0	0	0	0	436
Old ♂	10	10	1	3	2	2 212	1 075	153	600	461	0	0	0	0	0	1	0	0	0	4 528

L_4 = 4th stage larvae

TABLE 2 The helminth burdens of common reedbuck from various localities in Natal

Date and locality	No.	Age and sex	Paramphistomes	*Haemonchus contortus*			*Longistrongylus schrenki*			*Cooperia yoshidai*			*Trichostrongylus* spp.	*Trichostrongylus falculatus*	*Trichostrongylus colubriformis*	*Dictyocaulus viviparus*			*Setaria* spp.	*Bunostomum* sp.	Total worm burden
			A	L_4	♀	♂	L_4	♀	♂	L_4	♀	♂	♀	♂	♂	L_4	♀	♂	♀	♀	
Himeville:																					
Aug 1982	1	Adult ♂	30	0	0	2	0	4	5	2	103	83	0	0	0	6	8	6	6	0	255
Dec 1982	4	Adult ♂	5	4	25	68	8	18	4	0	752	672	0	0	0	0	2	1	9	29	1 597
Midmar Dam:																					
Oct 1982	2*	Adult ♂	0	0	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Estcourt:																					
Dec 1982	3**	Subadult ♂	0	0	18	13	0	53	31	0	643	665	159	23	13	0	0	0	0	0	1 618

A = Adults
L_4 = 4th stage larvae
* = only abomasal parasites collected
** = only abomasal and small intestinal parasites collected

The finding of *Paracooperia devossi* in the Natal bushbuck supports the argument of Boomker & Kingsley (1984) that this parasite has only recently become a parasite of bushbuck. This parasite had not previously been found in any bushbuck from the various Natal game reserves (Keep, 1983), and so far it appears to be confined to the eastern parts of the country.

The helminths recovered from the red duikers are interesting. *Haemonchus contortus* is a cosmopolitan parasite of artiodactylids (Gibbons, 1979), and in South Africa it is usually associated with domestic animals or with antelope in contact with domestic animals (Boomker, unpublished data, 1981). Although currently there are no domestic ruminants at Charters Creek, they were there prior to its proclamation as part of the St Lucia Nature Reserve (Pringle, 1982), and their nematodes were possibly passed on to the antelope during that time.

The 2 *Trichostrongylus* spp. that were recovered were identified as *Trichostrongylus capricola* and *Trichostrongylus vitrinus,* although neither conforms exactly to its description as given by Ransom (1911) and Looss (1905). *T. capricola* from the red duikers had spicules 0,092–0,120 mm long as opposed to 0,130–0,149 mm recorded by Ransom (1911), and 0,114–0,149 mm recorded by Levine (1980). *T. vitrinus* had spicules 0,120–0,159 mm long as opposed to 0,160–0,170 mm given by Looss (1905) and 0,149–0,176 mm given by Levine (1980). The shorter spicule lengths may be due to the host's reaction stimulated by prior infestations, as described by Keith (1967), for *Cooperia pectinata.* Specimens from Europe of both *T. capricola* and *T. vitrinus* from sheep and goats were examined, and the length of their spicules found to be within the ranges given by Levine (1980). The membraneous alae surrounding the spicules, however, were not as well developed as those of the worms from the red duikers. Futhermore, Levine (1980) states that *T. capricola* occurs in the small intestine and abomasum of its hosts and *T. vitrinus* in the duodenum and rarely in the abomasum. Both species, however, occurred predominantly in the abomasa of the red duikers. *T. capricola* has not been recorded before from South African artiodactylids, either free-living or domesticated, but *T. vitrinus* has been found in sheep in the south-western Cape Province (Muller, 1968). Because both the dorsal ray and the spicules of the *Trichostrongylus* spp. from the red duiker were similar to those of *T. capricola* and *T. vitrinus,* they are identified as such, although closer scrutiny may prove them to be new species.

As yet, *O. harrisi* has been found only in bushbuck (Round, 1968; Boomker *et al.*, 1984), from which it was originally described (Le Roux, 1930). Its presence in the red duikers is probably due to the close association of these antelope and bushbuck at Charters Creek, as well as their similar habitat preferences.

The parasites of the oribi from Pietermaritzburg are somewhat similar to those of the oribi from the KNP (Boomker *et al.*, 1984). *Impalaia tuberculata, Cooperia fuelleborni* and *O. columbianum,* however, were not present in the Natal oribi and *T. instabilis* was replaced by *T. colubriformis.* From this and other surveys of the helminth parasites of antelope it appears that *I. tuberculata* and *T. instabilis* favour the drier parts of the country such as the Transvaal Bushveld and Lowveld.

Keep (1983) lists the helminths recovered from the reedbuck, but since no references to previous studies on their burdens in South Africa could be found, no comparisons could be made with the results of this investigation. *H. contortus, T. falculatus* and *T. colubriformis* are common parasites of ruminants, both domestic (Viljoen, 1964, 1969; Muller, 1968) and free-living (Horak, 1978a, b).

C. yoshidai was originally described from the reedbuck (Mönnig, 1939), but it has subsequently also been recorded from mountain reedbuck (Baker & Boomker, 1973), blesbok (Evans, 1978; Horak, Brown, Boomker, De Vos & Van Zyl, 1982; Keep, 1983) and oribi (Boomker *et al.*, 1984). *C. yoshidai* appears to be well adapted to all the hosts in which it has been found.

D. viviparus occurs on isolated farms (Reinecke, 1983) and was recovered only from the 2 reedbuck shot at Himeville. This village is situated in an area that forms part of the eastern watershed where the summers are moderate and the winters cold. The conditions are favourable for the survival of the free-living stages, which are sensitive to heat and desiccation, but are resistant to cold (Oakley, 1979).

Small numbers of *L. schrenki* were recovered from 3 out of the 4 reedbuck. It has not been reported from South African ruminants since its description (Ortlepp, 1939), and it appears to be a rare parasite.

ACKNOWLEDGEMENTS

We should like to thank the Director, Natal Parks Board, for placing the animals at our disposal and for providing the facilities to process them for parasite recovery. The assistance of Messrs Tony Tomkinson, warden, and Wynand Kanfer, a ranger at Charters Creek, and of Mrs Shirley Kingsley with the processing of the animals is gratefully acknowledged.

This study was partly funded by the Council for Scientific and Industrial Research and the University of Pretoria.

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Printed by the Government Printer, Private Bag X85, Pretoria, 0001

Onderstepoort J. vet. Res., 53, 93–102 (1986)

THE HELMINTH PARASITES OF VARIOUS ARTIODACTYLIDS FROM SOME SOUTH AFRICAN NATURE RESERVES

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ABSTRACT

BOOMKER, J., HORAK, I. G. and DE VOS, V., 1986. The helminth parasites of various artiodactylids from some South African nature reserves. *Onderstepoort Journal of Veterinary Research* 53, 93–102 (1986)

The helminth species composition and helminth burdens of 4 grey duikers, 12 bushbuck, 2 nyala, 2 giraffe, a steenbok, an oribi, a waterbuck and a tsessebe from the Kruger National Park (KNP); of a steenbok and a greater kudu from the farm Riekerts Laager, Transvaal; of a single blue duiker from the Tsitsikama Forest National Park, and of a blue wildebeest, a red hartebeest, a gemsbok and 2 springbok from the Kalahari Gemsbok National Park (KGNP) were collected, counted and identified

New parasite records are: *Agriostomum equidentatum* from the gemsbok, *Cooperia neitzi* from the bushbuck, *Cooperia* sp. from the gemsbok and the red hartebeest, *Cooperia yoshidai* from the waterbuck and the tsessebe, *Dictyocaulus viviparus* from the bushbuck, *Haemonchus bedfordi* from the waterbuck, *Haemonchus contortus* from the gemsbok, *Haemonchus krugeri* from the steenbok from the KNP, *Impalaia nudicollis* from the gemsbok and the red hartebeest, *Impalaia tuberculata* from the oribi and the waterbuck, *Impalaia* spp. from the kudu, *Longistrongylus meyeri* from the steenbok from Riekerts Laager and the gemsbok, *Longistrongylus sabie* from the steenbok from the KNP, *Longistrongylus schrenki* from the tsessebe, *Parabronema* sp. from the tsessebe and the red hartebeest, *Paracooperia serrata* from the gemsbok and the steenbok from the KGNP, *Pneumostrongylus calcaratus* from the bushbuck, *Strongyloides* sp. from the gemsbok, *Trichostrongylus* sp. from the gemsbok, the red hartebeest and the steenbok from the KGNP, *Trichostrongylus axei* from the blue duiker, *Trichostrongylus falculatus* from the bushbuck and the oribi, *Trichostrongylus instabilis* from the bushbuck, the steenbok from the KNP and the oribi and *Trichostrongylus thomasi* from the grey duikers and tsessebe.

Host specificity of the parasites was not marked and crossinfestation was common. This was not true for the giraffe, since none of the helminths of these animals were found in the antelope and vice versa.

INTRODUCTION

Many artiodactylids in game reserves die annually from accidents or diseases or are culled for research or other purposes not necessarily related to parasitological surveys. By collecting the internal parasites of such animals, valuable information on the species composition of their helminths and their helminth burdens can be obtained. This is particularly true in the case of rare species such as blue duiker, *Cephalophus monticola*, or species that are not well represented in a particular game reserve, such as nyala, *Tragelaphus angasi*, in the Kruger National Park (KNP).

The helminths recorded in this paper were recovered from 4 grey duikers, *Sylvicapra grimmia*, 1 blue duiker, *C. monticola*, 12 bushbuck, *Tragelaphus scriptus*, 2 nyala, *T. angasi*, 1 kudu, *Tragelaphus strepsiceros*, 2 giraffe, *Giraffa camelopardalis*, 3 steenbok, *Raphicerus campestris*, 1 oribi, *Ourebia ourebi*, 1 waterbuck, *Kobus ellipsiprymnus*, 1 tsessebe, *Damaliscus lunatus*, 1 red hartebeest, *Alcelaphus buselaphus*, 1 blue wildebeest, *Connochaetes taurinus*, 1 gemsbok, *Oryx gazella* and 2 springbok, *Antidorcas marsupialis*.

MATERIALS AND METHODS

Animals

The animals and the localities at which they were collected are listed in Table 1.

Collection of parasites

Apart from the blue duiker, only the formalinized gastro-intestinal tract of which was available, the gastro-intestinal parasites were collected in the field using the methods described by Reinecke (1973) and formalinized. The hearts, lungs and livers were processed as described by Horak (1978b) and were also formalinized. Since the parasites of the animals from the Kalahari Gemsbok National Park (KGNP) were collected in the field, where no waterbaths were available, digests, hearts and lungs were placed in the sun or near an open fire to reach the desired temperature.

One aliquot representing 1/10th of the volume of the ingesta was made separately for each of the abomasa, small and large intestines of the 4 grey duikers, the blue duiker, the steenbok, the springbok and the oribi, while 2 aliquots, each representing 1/50th of the volume of the ingesta were made for each of the remaining animals. All the aliquots and digests as well as the heart, lung and liver washings were examined microscopically.

In cases where more than one species of a genus was present, the males were identified specifically but not the females. The 4th stage larvae were identified to the generic level only.

RESULTS

The total numbers of helminths recovered from the gastro-intestinal tracts of the various animals are listed in Tables 2 and 3.

Grey duikers (Table 2)

Two cestode and 9 nematode species, were collected. *Trichostrongylus thomasi* is a new parasite record for these antelope.

Blue duiker (Table 2)

Trichostrongylus axei was the only helminth recovered and is a new record for the blue duiker.

Bushbuck (Table 2)

One cestode and 13 nematode species were recovered of which *Cooperia neitzi*, *Trichostrongylus instabilis*, *Trichostrongylus falculatus*, *Dictyocaulus viviparus* and *Pneumostrongylus calcaratus* are new parasite records for these antelope.

Nyala (Table 2)

Both the nyala were males; the younger one (No. 1) did not harbour any worms. The older male (No. 2) had

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Received 11 November 1985—Editor

TABLE 1 The collection data for the various artiodactylids examined during this study

Species	Number	Date	Locality
Grey duiker	4	Feb. 80–Jan. 81	Malelane, Kruger National Park; 25°28′S; 31°31′E
Blue duiker	1	Oct. 76	Tsitsikama Forest National Park, Cape Province; 33°54′–33°57′S; 23°51′–23°56′E
Nyala	2	Oct. 81	Pafuri, Kruger National Park; 22°26′S; 31°10′E
Bushbuck	3	Oct. 81	Pafuri, Kruger National Park; 22°26′S; 31°10′E
Bushbuck	9	Oct. 79–Nov. 82	Skukuza, Kruger National Park; 24°58′S; 31°35′E
Giraffe	2	July 80	Lower Sabie, Kruger National Park; 25°07′S; 31°50′E
Steenbok	1	Nov. 79	Riekerts Laager, Transvaal; 24°30′S; 28°29′E
Steenbok	1	Oct. 82	Malelane, Kruger National Park; 25°28′S; 31°31′E
Steenbok	1	Oct. 84	Kalahari Gemsbok National Park; Approx. 24°30′–25°47′S; 20°–20°52′E
Oribi	1	July 79	Pretoriuskop, Kruger National Park; 25°10′S; 31°16′E
Waterbuck	1	Feb. 83	Pretoriuskop, Kruger National Park; 25°10′S; 31°16′E
Tsessebe	1	June 83	Pretoriuskop, Kruger National Park; 25°10′S; 31°16′E
Kudu	1	Oct. 79	Riekerts Laager, Transvaal; 24°30′S; 28°29′E
Red Hartebeest	1	Oct. 84	Kalahari Gemsbok National Park; Approx. 24°30′–25°47′S; 20°–20°52′E
Blue Wildebeest	1	Oct. 84	Kalahari Gemsbok National Park; Approx. 24°30′–25°47′S; 20°–20°52′E
Springbok	2	Oct. 84	Kalahari Gemsbok National Park; Approx. 24°30′–25°47′S; 20°–20°52′E
Gemsbok	1	Oct. 84	Kalahari Gemsbok National Park; Approx. 24°30′–25°47′S; 20°–20°52′E

1561 worms, none of which could be identified specifically. The *Cooperia* sp. that was recovered is closely related to *Cooperia rotundispiculum* but was not identical with it.

Giraffe (Table 2)

Only 2 species of worms, *Parabronema skrjabini* and *Monodontella giraffae* were recovered and both are known to occur in giraffe.

Kudu (Table 2)

Of the worms recovered from this animal *T. instabilis* and the *Impalaia* sp. females are new parasite records.

Steenbok (Table 3)

The paramphistome and the nematodes *Longistrongylus meyeri, Longistrongylus sabie, Haemonchus krugeri,* and *T. instabilis* are new parasite records.

Oribi (Table 3)

T. instabilis, T. falculatus and *Impalaia tuberculata* are new parasite records for this antelope.

Waterbuck (Table 3)

Haemonchus bedfordi, Cooperia yoshidai and *I. tuberculata* are new nematode records for waterbuck.

Tsessebe (Table 3)

C. yoshidai, Longistrongylus schrenki, T. instabilis, and *T. thomasi* appear to be new parasite records for this antelope.

Gemsbok (Table 3)

The following helminths appear to be new parasite records: *Haemonchus contortus, L. meyeri, Paracooperia serrata, Impalaia nudicollis, Strongyloides* and *Agriostomum equidentatum.*

Blue wildebeest (Table 3)

The only worms recovered were *H. bedfordi,* which is a known parasite of blue wildebeest.

Springbok (Table 3)

All the worms recovered in this survey are known to occur in springbok.

Red hartebeest (Table 3)

I. nudicollis and the *Parabronema* sp. are new parasite records.

DISCUSSION

Grey duiker

The mean helminth burdens and the species composition of the helminths recovered from the duikers from the KNP show some similarity to those of the duikers from the central Transvaal (Boomker, Du Plessis & Boomker, 1983). The mean total worm burden of the duikers from the KNP was 704 worms and that of the duikers from the central Transvaal was 870 (Boomker *et al.,* 1983). Certain parasites such as *T. axei* and *C. pectinata* are frequently found in domestic animals, and were also present in the duikers from the central Transvaal. In the KNP they were replaced by parasites such as *T. thomasi, C. hungi* and *C. neitzi,* which are found almost exclusively in wild antelope. This is attributed to the relatively closed ecosystem in the KNP, where domestic ruminants are as a rule not found and the fact that the duikers from Riekerts Laager had contact with sheep, goats and cattle.

Blue duiker

The only parasite thus far recorded from the blue duiker in South Africa is *Moniezia expansa* (Gough, 1908). No record of nematodes from this antelope from South Africa could be found in the literature and *T. axei* is thus the first and only one recorded.

Bushbuck

The helminth parasites of bushbuck from South Africa have been recorded by Veglia (1919), Mönnig (1928, 1931, 1933), Le Roux (1929, 1930a, b) and Ortlepp (1961). Gibbons & Khalil (1980) and Boomker & Kingsley (1984) found *Paracooperia tragelaphi* and *P. devossi* in East and South African bushbuck respectively. The present paper adds 3 trichostrongylids and 2 lungworms to the existing list.

The *Trichostrongylus* spp. could have been acquired from any of the antelope present in the KNP, since both *T. instabilis* and *T. falculatus* are the species most frequently encountered in the small intestine (Horak & Boomker, 1983, unpublished data).

The name *T. instabilis* for a *Trichostrongylus* sp. resembling *T. colubriformis* but with a short hook and a markedly bent spicular shaft, is retained here for reasons given by Horak (1980) and Boomker *et al.,* (1983).

The occurrence of *T. falculatus* is somewhat of an enigma. In the semi-arid areas, such as the Karoo it is the dominant *Trichostrongylus* spp. during the cold and dry winter months (Viljoen, 1964, 1969). In the summer rainfall areas, such as the Transvaal Highveld the worms are present in small numbers in winter (Horak & Louw, 1977; Horak, 1978a). *T. colubriformis* is the dominant worm in the non-seasonal rainfall areas where the winters are mild and frost seldom occurs (Muller, 1968). In the KNP, which falls within the summer rainfall area, the winters are also mild and this probably accounts for the small numbers of *T. falculatus* recovered.

The members of the genus occur in larger numbers during the cooler months of the year (Reinecke, 1964,

1983) but *T. falculatus* in the semi-arid areas may increase markedly in spring if preceded by good rains (Viljoen, 1964, 1969). Horak (1978c), however, recovered the largest numbers of *T. falculatus* from cattle in the northern Transvaal during December (summer). Horak & Louw (1978) found worms of this genus to be abundant in cattle on the Transvaal Highveld during June while few worms occurred from July–September. The largest *Trichostrongylus* spp. burdens in cattle in the northern Transvaal were present during December, and very few worms were present from July–October (Horak, 1978c). From the present data it is apparent that *Trichostrongylus* spp. are more abundant in the bushbuck at Skukuza from June–October, a finding which is contrary to that of Horak (1978c) from an area that has a similar climate as the KNP.

C. neitzi is commonly encountered in antelope in the KNP (Boomker, 1983, unpublished data) and its presence in bushbuck is therefore to be expected. The *Cooperia* sp. from 1 of the bushbuck and 1 of the nyala shot at Pafuri and 1 bushbuck from Skukuza is very closely related to *C. rotundispiculum*. However, its spicules are shorter and it has 18–20 longitudinal cuticular ridges as opposed to the 14 present in *C. rotundispiculum* (Gibbons, Lynda M., 1983, personal communication).

O. harrisi has been described from bushbuck (Le Roux, 1930a) and has recently also been found in red duiker (*Cephalophus natalensis*) (Boomker, Keep & Flamand, 1984) and nyala from Natal game reserves (Boomker, 1983, unpublished data).

H. vegliai appears to be the most common *Haemonchus* sp. occurring in the browsing antelope and its presence in bushbuck is therefore not unexpected. It was also found in the grey duikers in this study and in those from the central Transvaal (Boomker *et al.*, 1983) and has been found in kudu, both from the central Transvaal and the KNP (Boomker, 1983, unpublished data).

P. devossi seems to be a recently acquired parasite of bushbuck in the KNP as was discussed by Boomker & Kingsley (1984).

C. sagittus is a common parasite of the tragelaphine antelope (Round, 1968) and has also been found in Cape buffalo *Syncerus caffer* (McCully, Van Niekerk & Basson, 1967), domestic cattle in the Transvaal (Boomker, 1979, unpublished data) and nyala from Natal (Keep, 1971).

D. viviparus was recovered from 2 animals, a young female from Pafuri and an adult male from Skukuza. Both these animals were debilitated and we assume that the infestation became established because of their enfeebled state. The epidemiology of this parasite is largely unknown. Isolated foci occur in the mist belt of the Drakensberg, both in Natal and Transvaal, and it is rife on irrigated pastures. No explanation for its occurrence in bushbuck in the KNP can be offered, and it must be assumed that the bushbuck are abnormal hosts, since only 5th stage worms were recovered.

P. calcaratus was originally described from an impala (Mönnig, 1932), and a single male was found in 1 of the bushbuck only. This animal was collected in November, 1982, during a severe drought in the KNP when as many as 1 000 impala and numerous bushbuck, kudu and warthog congregated daily on the irrigated lawns of the golf course in the staff village at Skukuza. This lungworm probably originated from an impala. It has spicules slightly shorter than those recorded by Mönnig (1932), which is an indication that the bushbuck is probably an abnormal host.

Nyala

Keep (1971) recorded some of the parasites of nyala from some of the Natal game reserves, but nothing is known about those from the KNP. No comments can be made on the parasites collected during this survey, since both the nematode genera that were recovered could not be identified specifically.

Giraffe

Fertile hydatid cysts have been recorded from a giraffe in an Australian zoo (Kelly, Boray & Dixon, 1968) and Sachs, Gibbons & Lweno (1973) found 3 *Haemonchus* spp. in East African giraffe. Pester & Laurence (1974) found *Moniezia expansa* and Shoho & Sachs (1975) *Setaria labiatopapillosa* and *Pseudofilaria giraffae* in East and South African giraffe.

Ivashkin (1956) experimentally infested larvae of the fly *Haematobia titilans* (= *Lyperosia titilans*) with 1st stage larvae of *Parabronema skrjabini* obtained from camels. He found encysted 2nd stage larvae of this nematode in the pupae of the flies and concluded that the infested flies had to be eaten by the final host for the life cycle to be completed. Various species of *Haematobia* are present in South Africa and they are considered to be almost permanent parasites, leaving their hosts only to lay eggs (Howell, Walker & Neville, 1978). It is not known, however, whether the South African species of *Haematobia* are the intermediate hosts of *P. skrjabini*.

M. giraffae is a parasite of the bile ducts of giraffe and, being a hookworm, it is assumed that infestation occurred percutaneously.

Kudu

Condy (1972) recorded the helminths of kudu in Zimbabwe. The worms recovered from the kudu from Riekerts Laager were similar to those of the steenbok and grey duikers from the same locality (Boomker *et al.*, 1983). The *Trichostrongylus* spp. recovered from the steenbok and grey duikers, however, were not present in the kudu.

Steenbok

Virtually the same worms as those occurring in grey duikers from Riekerts Laager were found in the steenbok from the same locality, the only addition being *L. meyeri* and the *Skrjabinema* spp. (Boomker *et al.*, 1983). These worms could have been acquired from any of the antelope present on the farm or from sheep and goats outside the confines of the farm (Boomker *et al.*, 1983).

Similar parasites were recovered from the steenbok from the KNP, the difference being the presence of *H. krugeri, L. sabie* and *T. instabilis*, and the absence of *T. axei* and *L. meyeri*.

The larger helminth burden of the steenbok from the KNP is ascribed to the drought experienced at the time, which resulted in its emaciated and weakened condition, and hence greater susceptibility to infestation.

In addition to the *Skrjabinema* spp., which were found in the steenbok from all the localities, the steenbok from the KGNP harboured only *P. serrata* and a *Trichostrongylus* species. *P. serrata* was described from a springbok (Mönnig, 1931), which is the commonest antelope in the KGNP, and the steenbok could easily have acquired this parasite from the springbok. The as yet unnamed *Trichostrongylus* sp. has spicules that are dissimilar in appearance. They are 120–134 and 136–148 μm long and an earshaped, sclerotized protuberance is present on the shaft of the longer one.

Oribi, waterbuck and tsessebe

Although the antelope were shot at exactly the same locality, the rhino camp near Pretoriuskop in the KNP, there are distinct differences, both in halminth burdens

TABLE 2 The helminth burdens of the browsing artiodactylids from various localties

Species	Locality and date	No.	Age	Sex	*Parabronema skrjabini*			*Monodontella giraffae*		*Haemonchus vegliai*			*Ostertagia harrisi*			*Trichostrongylus* spp.	*Trichostrongylus axei*	*Trichostrongylus falculatus*	*Trichostrongylus instabilis*	*Trichostrongylus thomasi*	*Cooperia* spp.			*Cooperia punctata*
					L4	♀	♂	♀	♂	L4	♀	♂	L4	♀	♂	♀	♂	♂	♂	♂	L4	♀	♂	♂
Grey Duiker	*Malelane*																							
	February '80	10	Prime adult	♂	—	—	—	—	—	0	0	10	—	—	—	33	0	0	0	20	0	130	0	—
	May '80	12	Old adult	♂♀	—	—	—	—	—	0	12	4	—	—	—	48	0	0	0	22	0	3	0	—
	May '80	13	Prime adult	♂♀	—	—	—	—	—	53	0	0	—	—	—	0	0	0	0	1	0	13	0	—
	January '81	17	Young adult	♂♀	—	—	—	—	—	2	10	10	—	—	—	0	0	0	0	0	0	0	0	—
Blue Duiker	*Tsitsikama*																							
	October '76	—	Not known		—	—	—	—	—	—	—	—	—	—	—	200	210	—	—	—	—	—	—	—
Bushbuck	*Pafuri*																							
	October '81	1	Prime adult	♂	—	—	—	—	—	0	197	191	0	0	0	0	0	0	0	0	0	0	0	0
	October '81	2	Old	♂♀	—	—	—	—	—	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	October '81	3	Young adult*	♀♂	—	—	—	—	—	0	0	0	0	0	0	0	0	0	0	0	50	1 457	1 426	0
	Skukuza																							
	October '79	4	Adult	♀♂	—	—	—	—	—	0	75	75	0	125	75	0	0	0	0	0	0	0	0	0
	October '79	5	Very old	♂♀	—	—	—	—	—	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	August '80	6	Yearling	♂♀	—	—	—	—	—	0	0	0	0	125	50	25	0	0	0	0	0	0	0	0
	October '80	7	2 years	♂♀	—	—	—	—	—	0	0	0	0	0	0	0	0	0	0	0	0	75	0	0
	June '82	8	Juvenile	♂♀	—	—	—	—	—	50	50	26	1	36	5	545	0	2	132	0	0	25	0	0
	June '82	9	Juvenile	♂♀	—	—	—	—	—	0	25	0	380	1 738	1 097	126	0	100	0	0	25	0	0	0
	November '82	10	Adult	♂♀	—	—	—	—	—	0	25	75	0	0	0	25	0	0	50	0	0	150	0	0
	November '82	11	Adult	♂♀	—	—	—	—	—	0	0	0	0	203	154	360	0	165	0	0	0	0	0	0
	November '82	12	Adult*	♂	—	—	—	—	—	0	57	55	0	81	97	0	0	0	0	0	0	125	75	0
Nyala	*Pafuri*																							
	October '81	1	Adult	♂	—	—	—	—	—	0	0	0	0	0	0	—	—	—	—	—	0	0	0	—
	October '81	2	Adult	♂	—	—	—	—	—	0	25	0	0	0	0	—	—	—	—	—	4	1 052	480	—
Giraffe	*Lower Sabie*																							
	July '80	1	Adult	♂	404	7 372	11 050	186	145	0	0	0	—	—	—	—	—	—	—	—	0	0	—	0
	July '80	2	Adult	♂	0	823	1 213	215	370	0	0	0	—	—	—	—	—	—	—	—	0	0	—	0
Kudu	*Riekerts Laager*																							
	October '79	—	Old	♂	—	—	—	—	—	0	69	41	—	—	—	90	0	0	20	0	0	262	0	71

— Not known to occur in this host

A Adult
L4 4th stage larvae
5th 5th stage
ND Not done

\+ Slight infestation
++ Moderate infestation
Epg Eggs per gram faeces
* Severely debilitated

TABLE 2 The helminth burdens of the browsing artiodactylids from various localties *(continued)*

Species	Locality and date	No.	Age	Sex	*Cooperia pectinata*	*Cooperia neitzi*	*Cooperia acutispiculum*	*Cooperia hungi*	*Impalaia* spp.		*Impalaia tuberculata*	*Paracooperia devossi*		*Oesophagostomum* spp.	*Gaigeria* spp.	*Longistrongylus* spp.	*Dictyocaulus viviparus*	*Pneumostrongylus calcaratus*	*Setaria* spp.	*Cordophilus sagittus*	Larvae of *Taenia* spp.	*Stilesia hepatica*	Total helminth burden	Epg
					♂	♂	♂	♂	L4	♀	♂	♀	♂	L4	♀	L4	5th	♂	A	A				
Grey Duiker	*Malelane*																							
	February '80	10	Prime adult	♂♀	0	30	50	0	0	490	340	—	—	10	0	0	—	—	1	—	0	+	1 114	100
	May '80	12	Old adult	♂♀	0	0	0	11	8	3	13	—	—	0	0	0	—	—	1	—	0	++	125	0
	May '80	13	Prime adult	♂♀	0	0	2	0	307	1	0	—	—	1	0	162	—	—	2	—	1	0	543	0
	January '81	17	Young adult	♂♀	0	0	0	0	388	282	352	—	—	0	0	0	—	—	0	—	8	0	1 052	300
Blue Duiker	*Tsitsikama*																							
	October '76	—	Not known		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	410	ND
Bushbuck	*Pafuri*																							
	October '81	1	Prime adult	♂	—	0	—	—	—	—	—	0	0	0	0	—	0	0	1	2	0	0	391	ND
	October '81	2	Old	♂♀	—	0	—	—	—	—	—	0	0	0	0	—	0	0	0	4	0	0	4	0
	October '81	3	Young adult*	♂♀	—	0	—	—	—	—	—	0	0	0	0	—	14	0	0	0	3	0	2 950	0
	Skukuza																							
	October '79	4	Adult	♀♂	—	0	—	—	—	—	—	0	0	0	0	—	0	0	0	0	0	0	350	ND
	October '79	5	Very old	♂♀	—	0	—	—	—	—	—	0	0	0	0	—	0	0	0	0	0	0	0	ND
	August '80	6	Yearling	♂♀	—	0	—	—	—	—	—	0	0	0	0	—	0	0	0	0	0	0	200	ND
	October '80	7	2 years	♂♀	—	25	—	—	—	—	—	0	0	0	0	—	0	0	0	0	0	0	100	ND
	June '82	8	Juvenile	♂♀	—	25	—	—	—	—	—	2	3	0	0	—	0	0	0	2	0	0	904	0
	June '82	9	Juvenile	♂♀	—	0	—	—	—	—	—	359	252	0	25	—	0	0	0	0	0	0	4 127	0
	November '82	10	Adult	♂♀	—	125	—	—	—	—	—	26	51	0	0	—	0	1	2	0	0	0	530	0
	November '82	11	Adult	♂♀	—	0	—	—	—	—	—	419	219	0	25	—	0	0	0	0	0	0	1 545	ND
	November '82	12	Adult*	♂	—	0	—	—	—	—	—	187	261	0	0	—	6	0	0	0	0	0	944	ND
Nyala	*Pafuri*																							
	October '81	1	Adult	♂	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0	0	0	—	0	0
	October '81	2	Adult	♂	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0	0	0	—	1 561	0
Giraffe	*Lower Sabie*																							
	July '80	1	Adult	♂	0	—	—	—	0	0	0	—	—	—	—	—	—	—	0	—	0	—	19 157	0
	July '80	2	Adult	♂	0	—	—	—	0	0	0	—	—	—	—	—	—	—	0	—	0	—	2 621	0
Kudu	*Riekerts Laager*																							
	October '79	—	Old	♂	20	0	0	0	0	10	0	0	0	0	0	—	—	—	0	0	0	—	583	ND

— Not known to occur in this host
A Adult
L4 4th stage larvae
5th 5th stage
ND Not done
\+ Slight infestation
++ Moderate infestation
Epg Eggs per gram faeces
* Severely debilitated

TABLE 3 The helminth burdens of grazing antelope and of grazing and browsing antelope from various localities

Species	Locality and date	Age	Sex	*Paramphistomes*	*Haemonchus* spp.		*Haemonchus bedfordi*	*Haemonchus contortus*	*Haemonchus krugeri*	*Trichostrongylus* spp.			*Trichostrongylus axei*	*Trichostrongylus falculatus*	*Trichostrongylus instabilis*	*Trichostrongylus thomasi*	*Longistrongylus* spp.		*Longistrongylus sabie*	*Longistrongylus schrenki*	*Longistrongylus meyeri*	*Cooperia*-like	*Cooperia* spp.		*Cooperia hungi*	*Cooperia yoshidai*
				A	L4	♀	♂	♂	♂	L4	♀	♂	♂	♂	♂	♂	L4	♀	♂	♂	♂	L4	♀	♂	♂	♂
Steenbok	*Malelane* October '82	Adult	♂	0	104	1 854	—	0	1 412	0	820	0	0	260	210	—	0	42	11	—	0	—	—	—	—
	Riekerts Laager November '79	Young adult	♂	121	0	0	—	0	0	78	342	0	50	250	0	—	5	22	0	—	2	—	—	—	—
	Kalahari October '84	Adult	♂	0	0	0	—	0	0	0	50	10	0	0	0	—	0	0	0	—	0	—	13	53	—	34
Oribi	*Pretoriuskop* July '79	Adult	♂	0	0	0	—	0	—	22	107	—	—	30	37	0	0	0		—	—	—		1 950	125	375
Waterbuck	*Pretoriuskop* February '83	Adult	♀	11	25	508	305	0	—	0	0	—	—	—	—	—	0	0	0	—	—	—	0	304	0	53
Tsessebe	*Pretoriuskop* February '83	Old	♀	0	0	123	0	260	—	0	10	—	—	—	1	4	0	3	2	—	—	—	0	6	—	—
Gemsbok	*Kalahari* October '84	Adult	♂	0	66	352	403	25	—	0	228	128	—	—	—	—	0	25	—	—	25	—	0	1	—	—
Blue wilde-beest	*Kalahari* October '84	Adult	♂	0	0	80	30	0	—	0	0	—	0	0	—	0	—	—	—	—	—	—	0	0	—	—
Springbok	*Kalahari* October '84	Young adult	♀	0	31	31	—	0	—	0	32	—	—	31	—	—	0	0	—	—	—	—	35	—	—	—
Red harte-beest	*Kalahari* October '84	Old	♂	—	0	426	250	0	—	0	25	25	—	—	—	—	—	—	—	—	—	—	0	1	1	—

— Not known to occur in this host
A Adult
L4 4th stage larvae
\+ Slight infestation
\+\+ Moderate infestation

TABLE 3 The helminth burdens of grazing antelope and of grazing and browsing antelope from various localities *(continued)*

Species	Locality and date	Age	Sex	*Cooperia fuelleborni*	*Cooperioides antidorci*		*Paracooperia serrata*		*Impalaia* spp.		*Impalaia nudicollis*	*Impalaia tuberculata*	*Parabronema* spp.		*Oesophagostomum columbianum*			*Skrjabinema* spp.	*Strongyloides* spp.	*Setaria* spp.	*Agriostomum equidentatum*			*Avitellina*	*Moniezia expansa*	*Stilesia hepatica*	Total helminth burden
				♂	♀	♂	♀	♂	L4	♀	♂	♂	♀	♂	L4	♀	♂	A	♀	♀	L4	♀	♂				
Steenbok	*Malelane* October '82	Adult	♂	—	—	—	0	0	0	688	0	357	—	—	0	0	0	20	—	0	—	—	—	0	0	++	5 778
	Riekerts Laager November '79	Young adult	♂	—	—	—	0	0	10	71	0	50	—	—	0	0	0	70	—	2	—	—	—	3	2	0	1 078
	Kalahari October '84	Adult	♂	—	—	—	60	80	0	0	0	0	—	—	0	0	0	9 080	—	0	—	—	—	0	0	0	9 280
Oribi	*Pretoriuskop* July '79	Adult	♂	15	—	—	—	—	0	97	0	61	—	—	0	1	4	—	—	3	—	—	—	0	—	0	477
Waterbuck	*Pretoriuskop* February '83	Adult	♀	525	—	—	—	—	0	150	0	75	—	—	8	0	25	—	—	0	—	—	—	—	0	+	4 082
Tsessebe	*Pretoriuskop* February '83	Old	♀	0	—	—	—	—	0	29	0	52	1	1	—	—	—	125	—	0	—	—	—	—	—	—	968
Gemsbok	*Kalahari* October '84	Adult	♂	—	—	—	905	943	457	832	530	—	—	—	0	0	0	—	650	0	1	250	50	0	0	—	5877
Blue wildebeest	*Kalahari* October '84	Adult	♂	—	—	—	—	—	—	—	—	—	—	—	0	0	0	—	0	—	0	0	0	0	0	0	110
Springbok	*Kalahari* October '84	Young adult	♀	—	93	49	131	96	0	30	41	0	—	—	0	0	0	—	0	—	0	30	0	—	0	—	630
	October '84	Young adult	♂	—	62	57	439	340	0	32	71	0	—	—	0	0	0	—	236	—	0	10	10	—	0	—	1 862
Red hartebeest	*Kalahari* October '84	Old	♂	—	—	—	—	—	0	527	251	—	87	182	0	0	0	—	0	—	—	—	—	—	0	0	1 774

— Not known to occur in this host
A Adult
L4 4th stage larvae
\+ Slight infestation
++ Moderate infestation

and composition. The only parasites found in all 3 animals were *I. tuberculata* and *C. yoshidai*. The latter was described from a reedbuck *Redunca arundinum* by Mönnig (1939), but has subsequently also been recovered from mountain reedbuck *Redunca fulvorufula* (Baker & Boomker, 1973), and blesbok (Evans, 1978; Horak, Brown, Boomker, De Vos & Van Zyl, 1982b), while the former is one of the commonest nematodes of antelope (Boomker, 1977; Gibbons, Durette-Desset & Daynes, 1977). Despite the fact that the antelope had similar feeding habits and shared the same habitat, only the host-specificity shown by the parasites can be offered to explain the differences in the helminth composition and burdens.

Longistrongylus thalae (syn. *Pseudomarshallagia thalae*) has been found in an oribi (Gibbons, 1981) and Bindernagel & Todd (1972) have recorded *Trichostrongylus* spp. from the same host.

Of the helminths listed as occurring in oribi (Round, 1968) only 3 are mentioned by Ortlepp (1961). They are *H. contortus* and *Onchocerca* sp., for which no localities were recorded, and *Setaria scalprum*, which was recorded from South Africa (Ortlepp, 1961). No comparisons can therefore be made and all the worms recovered in this study should be considered new parasite records for this antelope.

H. bedfordi has been recovered from sheep artificially infested with larvae obtained from the faeces of a waterbuck in the Johannesburg Zoological Gardens (Le Roux, 1930b). Its presence in naturally infested waterbuck is herewith confirmed.

No previous listing of the parasites of the tsessebe could be found in the literature and the results obtained in this study cannot be compared with those of other surveys.

Blue wildebeest

Horak, De Vos & Brown (1983) published the results of a survey of the parasite of blue wildebeest from the KNP. A small number of *H. bedfordi* only were recovered from the blue wildebeest from the KGNP. The same species were found in the animals from the KNP but because of insufficient data no comparisons could be made.

Springbok

Horak, Melzer & De Vos (1982a) listed the parasites they found in springbok from the western Transvaal and the western Cape Province and De Villiers, Liversidge & Reinecke (1985) those of springbok from a farm near Kimberley in the north-western Cape Province, respectively.

All the worms found in this survey are known parasites of springbok. Fewer species and lower burdens were, however, found in this survey than were found in the surveys conducted by Horak *et al.* (1982a) and De Villiers *et al.* (1985). This is ascribed to the extremely arid conditions in the KGNP.

Gemsbok and red hartebeest

Other than those published by Round (1968), no records of helminths of gemsbok and red hartebeest from South Africa exist in the literature. The gemsbok harboured a greater variety and a larger burden than the red hartebeest, which could be the result of different feeding habits.

General considerations

Of the above-mentioned animals, grey and blue duikers, bushbuck, nyala and kudu are almost exclusively browsers, feeding on the leaves, fruits and seeds of a large variety of woody plants and forbs (Dorst & Dandelot, 1972). Grass is seldom eaten by these antelope and then only when it is young and succulent or in the absence of browse (Hofmann, 1973). Giraffe are exclusively browsers feeding particularly on the shoots, leaves, flowers and pods of the leguminous trees, often to a height of 6 m above ground (Dorst & Dandelot, 1972). Steenbok, springbok and gemsbok are both grazers and browsers and will even dig for roots and tubers, while oribi, waterbuck, blue wildebeest, red hartebeest and tsessebe are grazers and will only occasionally feed on the leaves and shoots of dicotyledonaceous plants (Dorst & Dandelot, 1972).

When the mean helminth burdens of the antelope in this survey are compared, the following emerges: the 20 browsers harbour a mean of 887 worms, the 5 grazers 1 390,8 and the 6 mixed feeders, i.e. both grazing and browsing antelope, 4 063,5 worms. Giraffe are not included here because of their specialized feeding behaviour and because they are not antelope. We think that the feeding habits and the habitat preferences are responsible for these differences.

Grey duikers favour almost any kind of habitat with the exception of dense forests and deserts. The reason for their low helminth burdens have been commented on by Boomker *et al.* (1983).

Blue duiker are found exclusively in dense forest (Dorst & Dandelot, 1972) and, in the KNP, bushbuck and nyala favour the riverine or hillside forests and thick bush. Kudu are usually found in open savannah, but also occur in dense bush or light forest (Dorst & Dandelot, 1972). Within their chosen habitat the animals may roam considerably and are consequently subject to reinfestation with their own parasites to a limited extent only. Furthermore, apart from kudu and nyala, which occur in family groups, all the other antelope occur singly or in pairs, and are hence unlikely to contaminate their environment to any significant degree. It is usually only when animals are sick or injured that they stay in one place and become infested with their own parasites, with a resulting increase in helminth burdens. This was presumably the case with bushbuck No. 3, whose burden was considerably higher than the mean for the 3 bushbuck from Pafuri.

Bushbuck No. 9 had 4 102 worms, 3 215 of which were *D. harrisi*. This is the highest total worm burden for bushbuck from Skukuza. The bushbuck frequently visited the gardens of the residents of the staff village at Skukuza. Since these are watered regularly, favourable conditions for the survival of the infective larvae are probably created. Conversely, bushbuck No. 5, a very old male taken at the same locality, harboured no worms. This is possibly due to increased immunity after prolonged exposure. Michel (1963) found that resistance to the establishment of infestation developed in calves after prolonged exposure to *Ostertagia ostertagi*. It is possibly also true for *O. harrisi*, provided that the parasite elicits the same immune response as that evoked by *O. ostertagi*. Although the resistance to *O. ostertagi* differs markedly from that of *H. contortus* (=*H. placei*), a similar comparison could probably be made in the case of *H. vegliai* in bushbuck and *H. contortus* (=*H. placei*) in cattle (Fitzsimmons, 1969).

On the other hand, immunity is hardly likely to eliminate the entire worm burden and it is also quite possible that the burdens of browsing antelope are never large enough to elicit an immune response. In the latter case, bushbuck No. 5 may simply have lost whatever infestation it had and did not become reinfested.

Although giraffe are often found in herds (Dorst & Dandelot, 1972) their feeding habits are such that they will not easily become infested with the nematodes regu-

larly occurring in antelope. They could, however, acquire these helminths when grazing, though such acquisition occurs very seldom, if at all; for instance, during droughts when they are forced to graze to survive.

Steenbok, being both grazers and browsers, could conceivably become infested with the parasites of both groups of artiodactylids. However, the present limited data do not indicate this. Because steenbok often dig for roots and tubers, they could easily become infested with the anoplocephalid tapeworms that use oribatid mites as intermediate hosts. This appears to be the case in the steenbok from Riekerts Laager, but not in the animal from the KNP. In addition, *Stilesia hepatica* was found in the grey duikers from the KNP, and the tapeworm fragments found in the liver of the waterbuck are probably those of *S. hepatica*. This indicates that the grazers and the antelope that browse at ground level are the ones most likely to become infested with the anoplocephalid tapeworms.

An interesting finding is the occurrence of an unidentified *Parabronema* sp. in the waterbuck from the KNP and in the gemsbok and the red hartebeest from the KGNP. *Parabronema* spp. are known to occur in rhino and giraffe. The waterbuck was shot in the rhino camp, where a number of white rhino, *Ceratotherium simmum* are kept, but not giraffe. Neither giraffe nor rhino are present in the KGNP, and no explanation can be offered for the presence of the *Parabronema* sp. in these antelope.

From this study it appears that many of the helminths of antelope are not very host specific. This is borne out by the fact that *T. instabilis* occurred in bushbuck, the steenbok, the tsessebe and the oribi from the KNP. *T. falculatus* was recovered from bushbuck, the steenbok from the KNP and Riekerts Laager, and the oribi. *I. tuberculata* occurred in the steenbok from the KNP and Riekerts Laager, the oribi, the waterbuck and the tsessebe, while *I. nudicollis* occurred in the gemsbok, both the sprinbok and the red hartebeest from the KGNP. *C. yoshidai* occurred in the oribi, the waterbuck and the tsessebe, and *C. hungi* was found in the oribi and the waterbuck. A *Parabronema* sp. was found in the waterbuck, the gemsbok and the red hartebeest. The helminths from the giraffe, however, were not found in any of the antelope, nor were the worms of the antelope found in the giraffe.

It seems as if the antelope tolerate each other's helminths, an indication of a well-developed host-parasite relationship resulting from long-standing associations.

The fencing of game reserves and game parks limit the natural movements of animals and confine them to a limited space where they may easily become infested with each other's worms. It also appears from this and other studies (Horak, 1980; Boomker *et al.*, 1983) that antelope are better hosts for the parasites of domestic animals than domestic animals are for those of antelope.

ACKNOWLEDGEMENTS

We wish to express our gratitude to the Board of Curators, National Parks Board and Messrs M. Opperman and W. H. du Plessis for placing the animals at our disposal. Our thanks are also due to mesdames E. L. Visser and S. A. Kingsley and Messrs C. Cheney, B. D. de Klerk and N. H. Jonker for their technical assistance and assistance with the autopsies.

This project was funded by the University of Pretoria and the Council for Scientific and Industrial Research.

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Printed by the Government Printer, Private Bag X85, Pretoria, 0001

Onderstepoort J. vet. Res., 56, 51–57 (1989)

PARASITES OF SOUTH AFRICAN WILDLIFE. III. HELMINTHS OF COMMON REEDBUCK, *REDUNCA ARUNDINUM*, IN NATAL

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ABSTRACT

BOOMKER, J., HORAK, I. G., FLAMAND, J. R. B. & KEEP, M. E., 1989. Parasites of South African wildlife. III. Helminths of common reedbuck, *Redunca arundinum*, in Natal. *Onderstepoort Journal of Veterinary Research*, 56, 51–57 (1989)

Twenty-six common reedbuck, *Redunca arundinum*, were shot in pairs at monthly intervals for 13 consecutive months in the Himeville region of Natal. Ten nematode species, 2 cestodes and 1 trematode were recovered from these animals. *Cooperia yoshidai* was both the most numerous and most prevalent worm and peak burdens occurred during summer.

Thirty-one reedbuck, killed at different intervals in various localities within the St. Lucia Reserve, harboured between 4 and 11 nematode species, 1 cestode and 1 trematode. With the exception of 4 reedbuck shot during January 1987, in which *Haemonchus contortus* was the most abundant worm, *C. yoshidai* was again both the most abundant and most prevalent worm. Peak burdens of this nematode occurred during autumn to spring.

The helminths of 5 impala, *Aepyceros melampus*, also shot in the St. Lucia Reserve were examined. Some of the worm species of impala were also found in the reedbuck from the same locality and the helminths of the 2 antelope species are compared.

An amended list, which includes several new records of the parasites of common reedbuck in South Africa is provided.

INTRODUCTION

The ecology and habits of common reedbuck, *Redunca arundinum*, have briefly been discussed by Horak, Keep, Flamand & Boomker (1988).

The helminth parasites of reedbuck in Africa have been listed by Round (1968). The helminths of these antelope in the Republic of South Africa are given by Mönnig (1924, 1928, 1931, 1939), Ortlepp (1961), Round (1968), Keep (1983) and Boomker, Keep, Flamand & Horak (1984). The present paper provides an amended list of the helminth parasites of reedbuck in the Republic of South Africa.

Howard (1983) required freshly killed reedbuck for his detailed study of the species in Natal, and the opportunity was taken during the later stages of his project to collect the helminth parasites of 26 of the animals from the Himeville region. Permission was also obtained from the Natal Parks, Fish and Game Preservation Board to shoot 31 reedbuck and 5 impala, *Aepyceros melampus*, at different localities in the St Lucia Reserve. The helminths recovered from the reedbuck from the 2 localities and trends in their seasonal abundance are discussed in this paper, while the ectoparasites of the same animals have been recorded by Horak *et al.* (1988).

MATERIALS AND METHODS

The study areas

Both the study areas fall within the summer rainfall region, as illustrated by Reinecke (1983), and have been described by Horak *et al.* (1988).

The animals

Himeville

Two reedbuck, 1 adult and 1 sub-adult were shot each month for 13 consecutive months from May 1983 to May 1984. Their sexes depended on availability and 4 adult males, 9 adult females, 10 sub-adult males and 3 sub-adult females were collected.

The St. Lucia Reserve

One adult male, 1 adult female and 2 juvenile reedbuck of either sex were shot in the Eastern Shores Nature Reserve (ESNR) at 3-monthly intervals from March 1983 to April 1984. A further 2 reedbuck, 1 adult male and 1 adult female and 2 impala were shot in the St. Lucia Game Park during May 1984. Two male reedbuck were shot during August 1984 in an area in the ESNR where buffalo occur and 4 more reedbuck, an adult male, an adult female and 2 juveniles as well as 3 impala were shot at Charters Creek, which lies within the St. Lucia Reserve, during August 1984. Four more reedbuck were shot in the ESNR during January 1987 after a number of animals had been culled because of overpopulation.

Collection of parasites

The lungs, hearts and livers of all the antelope from Himeville were processed for worm recovery as described by Horak (1978) and the abomasa, the small intestines and the large intestines as described by Reinecke (1973).

As a water-bath was not available, the bottles containing the hearts, lungs, livers and digests of the reedbuck from the St. Lucia Reserve were placed in the sun, or, on cold or overcast days, near an open fire until the desired temperature of 40–43 °C was reached. They were then moved into the shade or away from the fire until the temperature dropped by 3–5 °C, whereafter they were shaken and returned to the sun or the fire. After sieving, the residues of the hearts, lungs and livers, as well as the digests were examined *in toto* under a stereoscopic microscope. One aliquot, representing 1/10th of the volume of the ingesta, was made separately for each of the abomasa, small intestines and large intestines and also examined under a stereoscopic microscope.

The adult worms were cleared in lactophenol and identified under a standard microscope with Nomarski's differential interference contrast illumination. The descriptions of the authors listed in Table 1 were used for the identification of the worms. This table also lists the worms recovered to date from common reedbuck in South Africa. In cases where more than 1 species of a genus was encountered, the males, but not the females, were identified specifically. Fourth stage larvae and trematodes were mostly identified only to generic level.

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Received 15 November 1988—Editor

TABLE 1 Amended list of the helminth parasites of common reedbuck in the Republic of South Africa with reference to the first record and the authors used to assist with the identification

Helminth species	First record	Identification
Trematodes		
Paramphistomum spp. Fischoeder, 1901	This paper	Eudardo, 1982
Cestodes		
Cysticercus sp. (*sic*)	Ortlepp, 1961	*
Moniezia benedeni Blanchard, 1891	This paper	Skrjabin & Spasski, 1963
Taenia hydatigena larvae	This paper	Verster, 1969
Nematodes		
Bunostomum cobi Maplestone, 1931	Ortlepp, 1961	*
Bunostomum trigonocephalum Railliet, 1902	Mönnig, 1928	*
Bunostomum sp.	Boomker *et al.*, 1984	†
Cooperia fuelleborni Hung, 1926	Ortlepp, 1961	*
Cooperia neitzi Mönnig, 1932	Ortlepp, 1961	*
Cooperia yoshidai Mönnig, 1939	Mönnig, 1939	Gibbons, 1981
Gaigeria sp. females	This paper	Ortlepp, 1937
Dictyocaulus viviparus Railliet & Henri, 1907	Boomker *et al.*, 1984	Yorke & Maplestone, 1926
Haemonchus contortus Cobb, 1898	Ortlepp, 1961	Gibbons, 1979
Haemonchus vegliai Le Roux, 1929	Ortlepp, 1961	*
Longistrongylus sabie Travassos, 1937	Ortlepp, 1961	*
Longistrongylus schrenki Ortlepp, 1939	Boomker *et al.*, 1984	Gibbons, 1977
Oesophagostomum columbianum Curtice, 1890	Mönnig, 1931	*
Ostertagia ostertagi Ransom, 1907	This paper	Ransom, 1911
Setaria bicoronata Railliet & Henri, 1911	This paper	Yeh, 1959
Setaria boulengeri Thwaite, 1927	Thwaite, 1927	*
Setaria hornbyi Boulenger, 1921	Mönnig, 1924	*
Setaria labiatopapillosa Railliet & Henri, 1911	Veglia, 1919	Yeh, 1959
Trichostrongylus colubriformis Ransom, 1911	Boomker *et al.*, 1984	†
Trichostrongylus falculatus Ransom, 1911	This paper	Ransom, 1911
Trichuris sp. females	This paper	Yorke & Maplestone, 1926

* = After Round (1968). Not found in this survey
† = Not found in this survey

TABLE 2 The helminths recovered from 26 common reedbuck from Himeville

Helminth species	Number of worms recovered			Number of animals infested
	Larvae	Adults	Total	
Paramphistomes	*	1 494	1 494	17
Moniezia benedeni	*	1	1	1
Taenia hydatigena	3	*	3	3
Cooperia yoshidai	317	37 969	38 286	22
Dictyocaulus viviparus	0	203	203	14
Gaigeria sp.	0	50	50	2
Haemonchus contortus	575	1 080	1 655	11
Longistrongylus schrenki	0	2 065	2 065	17
Ostertagia ostertagi	0	101	101	3
Setaria bicoronata	0	54	54	6
Setaria labiatopapillosa	0	1	1	1
Trichostrongylus falculatus	3	75	78	3
Trichuris sp. females	0	25	25	1
Mean nematode burden	34	1 601	1 635	—

* = Not found in reedbuck
— = Not applicable

RESULTS

Himeville

The helminths recovered from reedbuck from this region are listed in Table 2 and their seasonal abundance is graphically illustrated in Fig. 1.

Ten nematode species, 2 cestodes and 1 trematode were recovered. Of these, *Cooperia yoshidai* was both the most abundant and most prevalent nematode. One specimen of *Moniezia benedeni* was found in 1 of the animals and 3 others each harboured 1 larva of *Taenia hydatigena*. Paramphistomes were recovered from 17 animals.

The largest burden of 9 676 worms was recovered from an adult female shot during July 1983 and the smallest burden of 50 worms from a sub-adult male shot during May 1984. Only 1 animal, a sub-adult female shot during August 1983 did not harbour any worms.

The St. Lucia Reserve

The helminths recovered from the reedbuck shot in this reserve are listed in Table 3 and their seasonal abundance is illustrated in Fig. 2.

Nine nematode species, 1 cestode and 1 trematode were recovered from the 19 animals shot from March 1983 to April 1984 in the ESNR. The most abundant worm was *C. yoshidai* and the most prevalent worms were *Haemonchus contortus* and *Longistrongylus schrenki*.

The 4 reedbuck collected during January 1987 from the ESNR harboured only 4 nematodes species, of which

TABLE 3 The helminths recovered from common reedbuck from the St. Lucia Reserve

Helminth species	Number of worms recovered			Number of animals infested
	Larvae	Adults	Total	
Eastern Shores (19 animals)				
Paramphistomes	*	183	183	1
Moniezia benedeni	*	1	1	1
Cooperia yoshidai	4 422	59 114	63 536	16
Dictyocaulus viviparus	0	818	818	17
Gongylonema sp.	0	8	8	2
Haemonchus contortus	12 070	11 716	23 786	18
Longistrongylus schrenki	3 414	5 956	9 370	18
Oesophagostomum columbianum	1	51	52	3
Setaria bicoronata	0	194	194	14
Skrjabinema sp.	0	14 524	14 524	7
Trichuris sp. females	0	25	25	1
Mean nematode burden	1 048	4 863	5 911	
Eastern Shores, buffalo area (2 animals)				
Cooperia yoshidai	401	6 436	6 837	2
Dictyocaulus viviparus	0	311	311	2
Gongylonema sp.	0	7	7	1
Haemonchus contortus	1 803	700	2 503	2
Longistrongylus schrenki	502	1 055	1 557	2
Oesophagostomum sp. females	—	25	25	1
Setaria sp. females	—	6	6	1
Skrjabinema sp.	0	976	976	1
Mean nematode burden	1 353	4 758	6 111	
St. Lucia Game Park (2 animals)				
Cooperia hungi	†	101	101	1
Cooperia yoshidai	†	7 075	7 075	2
Cooperioides hepaticae	†	5	5	1
Cooperia-like	101	9 209	9 310	2
Dictyocaulus viviparus	0	293	293	2
Gongylonema sp.	0	1	1	1
Impalaia tuberculata	0	251	251	2
Longistrongylus schrenki	37	1 536	1 573	2
Oesophagostomum sp.	28	0	28	2
Setaria bicoronata	0	41	41	2
Skrjabinema sp.	0	11 156	11 156	2
Mean nematode burden	83	14 834	14 917	
Charters Creek (4 animals)				
Cooperia yoshidai	17 625	43 164	60 789	4
Dictyocaulus viviparus	0	278	278	4
Haemonchus contortus	1 167	2 330	3 497	4
Longistrongylus schrenki	0	333	333	3
Setaria sp. females	0	61	61	4
Skrjabinema spp.	0	10 650	10 650	1
Mean nematode burden	4 698	14 204	18 902	
Eastern Shores, January 1987 (4 animals)				
Cooperia yoshidai	10	64	74	2
Gaigeria sp. females	0	10	10	1
Haemonchus contortus	40	594	634	4
Longistrongylus schrenki	731	99	830	3
Mean nematode burden	195	192	387	

* = Not found in reedbuck
— = Not applicable
† = Larvae and females counted together as *Cooperia*-like

L. schrenki was the most abundant and *H. contortus* the most prevalent.

Eight nematode species were recovered from the 2 reedbuck from the buffalo area of the ESNR. *C. yoshidai* was the most abundant and together with *H. contortus*, *L. schrenki* and *Dictyocaulus viviparus*, occurred in both antelope.

Eleven nematode species, of which *Cooperia* spp. were the most abundant, were recovered from the reedbuck in the St. Lucia Game Park.

Only 6 nematode species were recovered from the antelope from Charters Creek. *C. yoshidai* was the most numerous and together with *D. viviparus*, *H. contortus* and a *Setaria* sp. occurred in all 4 animals.

The helminths recovered from the impala from the 2 localities are listed in Table 4.

Fifteen species of nematodes and 1 trematode were recovered from the impala from the St. Lucia Game Park. The *Cooperia* spp. together with the 2 *Coo-*

TABLE 4 The helminths recovered from impala from the St. Lucia Reserve

Helminth species	Number of worms recovered			Number of animals infested
	Larvae	Adults	Total	
St. Lucia Game Park (2 animals)				
Paramphistomes	*	1	1	1
Agriostomum sp. females	—	25	25	1
Cooperia fuelleborni	†	84	84	2
Cooperia hungi	†	204	204	2
Cooperia yoshidai	†	1 106	1 106	2
Cooperia spp. females	—	1 884	1 884	2
Cooperioides hamiltoni	†	236	236	2
Cooperioides hepaticae	†	85	85	2
Cooperia-like larvae	135	—	135	2
Dictyocaulus viviparus	0	18	18	1
Gaigeria pachyscelis	0	77	77	1
Haemonchus contortus	193	2 246	2 439	2
Impalaia tuberculata	82	1 795	1 877	2
Longistrongylus schrenki	0	290	290	2
Oesophagostomum sp.	104	50	154	2
Ostertagia sp.	0	153	153	2
Strongyloides papillosus	0	450	450	1
Trichostrongylus spp. females	—	75	75	1
Mean nematode burden	257	4 602	4 859	
Charters Creek (3 animals)				
Cooperioides hamiltoni	0	60	60	3
Haemonchus contortus	166	1 130	1 296	3
Longistrongylus schrenki	397	316	713	1
Trichostrongylus angistris	†	1	1	1
Trichostrongylus thomasi	†	119	119	3
Trichostrongylus instabilis	†	10	10	1
Trichostrongylus spp.	0	247	247	3
Mean nematode burden	187	628	815	

† = Larvae indistinguishable at species level and counted together
– = Not applicable
* = Not found in impala

perioides spp. were the most numerous, followed by *H. contortus*, and *Impalaia tuberculata*. Both antelope were infested with these nematodes.

Seven nematodes were recovered from the impala from Charters Creek. Of these, *H. contortus* was the most numerous, followed by *L. schrenki* and *Trichostrongylus* spp.

DISCUSSION

Himeville

D. viviparus is normally a definitive parasite of cattle and according to Reinecke (1983), it occurs particularly on irrigated pastures in isolated areas in the mist belt of the Drakensberg of Natal and the Transvaal, as well as in the western Cape Province. It has also been recovered from several antelope species, including reedbuck (Horak, De Vos & Brown, 1983; Boomker *et al.*, 1984). *D. viviparus* infestation seems to be common in the Himeville area. This is borne out by the fact that the 2 reedbuck previously examined for parasites (Boomker *et al.*, 1984) as well as 14 out of 26 antelope examined during this survey harboured this worm. A reedbuck from Midmar Dam and 1 from Estcourt, however, did not harbour these parasites (Boomker *et al.*, 1984). The free-living stages of this nematode are sensitive to heat and desiccation but are resistant to cold. Himeville falls within the mist belt of the Natal Drakensberg, where the winters are severe but the summers moderate. These environmental conditions appear to be favourable for the survival of the infective stages of this lungworm (Oakley, 1979; Reinecke, 1983; Boomker *et al.*, 1984).

H. contortus is a parasite of sheep, goats and cattle, but like *D. viviparus* has been recorded from many antelope species (Horak, 1981; Horak, Brown, Boomker, De Vos & Van Zyl, 1982; Horak, De Vos & De Klerk, 1982; Boomker, Du Plessis & Boomker, 1983; Horak *et al.*, 1983; Boomker *et al.*, 1984; Boomker, Horak & De Vos, 1986). According to the criteria set by Horak (1980, 1981), these helminths, together with *C. yoshidai*, and *Setaria bicoronata* could be considered definitive parasites of reedbuck. The occasional parasites seem to be the *Trichuris* spp., and the accidental parasites *O. ostertagi*, *Setaria labiatopapillosa* and *Trichostrongylus falculatus*.

Of a grand total of 44 166 helminths recovered from the 26 reedbuck, 38 286 were adult *C. yoshidai* and 4th stage *Cooperia* sp. larvae. Large numbers of *C. yoshidai* are to be expected in reedbuck since it is the type host (Mönnig, 1939), and trends in the seasonal abundance of the nematodes of reedbuck in the present survey seem to be due to *C. yoshidai* only.

The largest burden of 9 000 *C. yoshidai* was present in 1 of the animals shot during July 1983 (Fig. 1). The infective larvae of the *Cooperia* spp. are resistant to desiccation and to low temperatures (Reinecke, 1983) and can overwinter on irrigated pastures. Since reedbuck are known to utilize irrigated pastures in this area during winter (Howard, 1983), it is conceivable that the large burden in this animal was acquired from the pastures.

Smaller peaks of *C. yoshidai* were observed in reedbuck during October, November and December 1983 (Fig. 1) and we are of the opinion that these peaks reflect the true situation. This agrees with Hobbs (1961), who recorded peak egg counts due to *Cooperia* spp. in calves in Natal during spring and summer, and with Boomker, Keep & Horak (1987), who recovered peak numbers of a *Cooperia* sp. in bushbuck and grey duiker in the same province during these seasons.

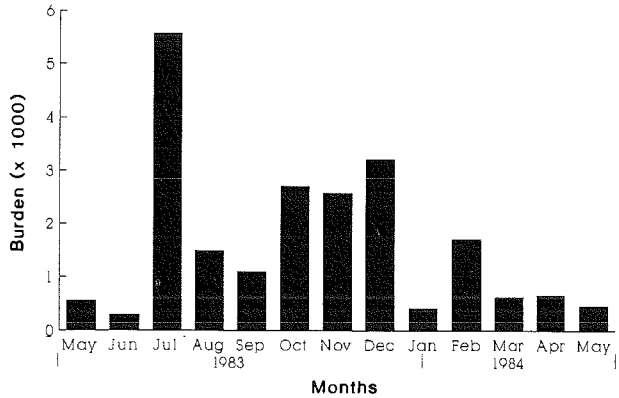

FIG. 1 The seasonal abundance of nematodes in common reedbuck in the Himeville region, Natal

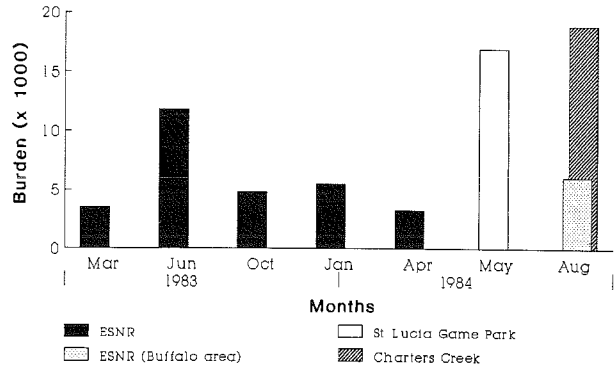

FIG. 2 The seasonal abundance of nematodes of common reedbuck in the St. Lucia Nature Reserve

Three reedbuck harboured only small numbers of *Ostertagia ostertagi*. This appears to be an accidental parasite of these animals and was probably acquired from cattle on the irrigated pastures.

Ortlepp (1939) described *L. schrenki* from a waterbuck, *Kobus ellipsiprymnus*, while Boomker *et al.* (1984) found small numbers of this parasite in reedbuck from Himeville and other regions of Natal. From the present data it appears to be fairly common in the province and should be considered a definitive parasite of reedbuck.

The mean total burden of 1 681 nematodes in the reedbuck is approximately the same as that found by Boomker *et al.* (1984) in reedbuck from other localities on the Natal midlands and should be considered the 'normal' mean burden in areas with a moderate climate.

The St. Lucia Reserve

Reedbuck

The definitive parasites of reedbuck from this locality are the same as those of reedbuck from Himeville. The occasional parasites are *Gongylonema* sp., *Skrjabinema* sp., *Trichuris* sp. and the *Oesophagostomum* spp., while the *Gaigeria* sp. and in the St. Lucia Game Park, *Cooperia hungi, Cooperioides hepaticae* and *Impalaia tuberculata* appear to be the accidental parasites.

Out of a grand total of 112 497 worms collected from the 19 animals from the ESNR, 63 533 (56,5 %) were *C. yoshidai* and their 4th stage larvae. In the ESNR (buffalo area) a total of 12 220 worms was recovered, of which 6 838 were *C. yoshidai* and their larvae. No trematodes or cestodes were recovered from the animals from the other localities within the St. Lucia Reserve. The reedbuck at Charters Creek harboured a total of 75 610 worms, of which 60 791 were *C. yoshidai* and their larvae. *C. yoshidai* constituted less than 50 % of the burdens of the reedbuck from the St. Lucia Game Park. Out of a total of 33 890 nematodes, 16 485 were *C. yoshidai* and 11 156 *Skrjabinema* sp.

The seasonal abundance of the helminths recovered from the reedbuck from the various localities within the St. Lucia Game Reserve are illustrated in Fig. 2.

The largest numbers of *C. yoshidai* in the antelope from the ESNR occurred in June 1983 and was due to one animal harbouring more than 10 000 worms. Large burdens of *C. yoshidai* also occurred in the reedbuck from the St. Lucia Game Park shot during May 1984 and in those from Charters Creek, shot in August 1984. From the present limited data it appears that *C. yoshidai* occurs in peak numbers during the cooler months of the year in reedbuck in the ESNR (May–August).

Despite the sensitivity of the free-living stages of *D. viviparus* to desiccation and heat, this nematode was present in the majority of the antelope in the St. Lucia Reserve, where the winters are mild and the summers hot, albeit in slightly smaller numbers than in the Himeville region with its severe winters and mild summers. This is in accordance with Reinecke's (1983) observation that the parasites are rife on irrigated pastures, to which the ESNR with its seasonally inundated grasslands and high rainfall could be likened.

There are 3 known species of *Skrjabinema* that parasitize the ruminants of this country. They are *Skrjabinema ovis, Skrjabinema africana* and *Skrjabinema alata* (Mönnig, 1932). As *S. africana* was described from 3 immature females and *S. alata* from 7 females only, we were unable to identify the *Skrjabinema* species found in this survey. These nematodes appear to be apathogenic, despite large numbers being present (11 081 in a reedbuck from the St. Lucia Game Park).

Trichuris sp., *Oesophagostomum columbianum*, and *I. tuberculata* are ubiquitous nematodes that have been recovered from a large variety of antelope (Round, 1968; Boomker, 1977; Gibbons, Durette-Desset & Daynes, 1977; Horak *et al.*, 1983).

C. hungi and *C. hepaticae* are nematodes that are primarily parasites of impala. Their presence in reedbuck in the St. Lucia Game Park is probably due to cross-infestation.

Impala

The 3 impala from Charters Creek harboured considerably fewer worms than the reedbuck. Presumably, this is because impala are mixed feeders, browsing frequently in between grazing periods, while reedbuck will only browse during winter or droughts, when grass is not readily available. We assume that reedbuck ingest more infective larvae on the grazing than do impala.

One of the impala from Charters Creek harboured a single male *Trichostrongylus angistris*, a nematode only recently described from the red duiker, *Cephalophus natalensis*, from this reserve (Boomker & Vermaak, 1986). The nematode has so far been recovered only from red duiker and its presence in impala is therefore a new record.

General considerations

The definitive parasites of reedbuck in Natal appear to be *C. yoshidai, D. viviparus, H. contortus, L. schrenki* and *Setaria* spp., all of which were recovered from antelope from the various localities. In the majority of cases, *C. yoshidai* was both the most abundant and the most

prevalent, with *D. viviparus*, *H. contortus* or *L. schrenki* occupying second, third or fourth place.

An interesting pattern as regards the total worm burdens from the different localities emerged from this study. The antelope from Himeville had the smallest mean burden, namely, 1 635 worms. We assume that the reedbuck population density in this region is such that the pasture does not become contaminated to any significant degree and that the regular treatment of the domestic stock with anthelmintics indirectly serves to limit the burdens in the antelope. Furthermore, the severe winters in the region cause many of the free-living stages to die.

The reedbuck from the ESNR and the area in the ESNR where buffalo occur had mean burdens of 5 911 and 6 111 worms respectively. The burdens are approximately 3,6–3,7 times that of the reedbuck from Himeville, indicating that the environmental conditions are more suitable for the survival of the free-living stages. It is also possible that because the population density of the reedbuck (0,46 per ha) is higher here than at Himeville, the environment is contaminated to a greater degree, ultimately leading to higher burdens.

The 4 reedbuck shot during January 1987 in the ESNR had a significantly lower total helminth burden, 387 as opposed to the approximately 6 011 worms in the antelope shot earlier. This may have been due to fewer infective larvae on the veld because of a smaller antelope population after some culling had taken place.

The antelope from the St. Lucia Game Park had a larger variety of worms and the mean burden was 14 917. This is approximately 9 times that of the reedbuck from Himeville and 2,5 times that of the antelope from the ESNR. The presence of worms such as *C. hungi*, *C. fuelleborni*, *C. hepaticae* and *I. tuberculata*, which are parasites of a number of other antelope species, including impala but excluding reedbuck, indicates that cross-infestation took place to a much greater degree than in the other localities. The Game Park is fenced and the population density of 0,86 reedbuck per ha is such that they, and presumably the other antelope species as well, are infested with each other's worms to a significant degree. It appears that host-specificity is largely absent in this park.

The lack of diversity in helminth species and the large mean burden in the reedbuck from Charters Creek is possibly the result of the few other grazing antelope that occur there as well as the high population density of 0,86 animals per ha. The reedbuck appear to be infested with their own host-specific worms and considering the mean burden of 18 902 worms, which is approximately 11,5 times that of the antelope from Himeville, considerable numbers of infective larvae must continually be present. Although the burden consists mainly of *C. yoshidai*, of which the pathogenicity is unknown, we are of the opinion that too many reedbuck are present and that some animals may have to be removed.

ACKNOWLEDGEMENTS

We thank the Director, Natal Parks, Game and Fish Preservation Board and the Director of Forestry, Directorate of Environmental Affairs, for placing the animals at our disposal. We also thank Dr P. C. Howard during whose project the antelope at Himeville were shot and who assisted with the collection of the parasites. Thanks are also due to the staff of the Natal Parks, Game and Fish Preservation Board, particularly those at Mission Rock and Charters Creek, for their assistance. Mr Dick Nash, Warden of the St. Lucia Reserve is thanked for supplying us with information about the reserve.

This project was partly funded by the Council for Scientific and Industrial Research.

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Parasites of South African wildlife. XIV. Helminths of nyalas (*Tragelaphus angasii*) in the Mkuzi Game Reserve, KwaZulu-Natal

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ABSTRACT

BOOMKER, J., BOOYSE, D.G., WATERMEYER, R., DE VILLIERS, I.L., HORAK, I.G. & FLAMAND, J.R.B. 1996. Parasites of South African wildlife. XIV. Helminths of nyalas (*Tragelaphus angasii*) in the Mkuzi Game Reserve, KwaZulu-Natal. *Onderstepoort Journal of Veterinary Research*, 63:265–271

The helminths of 58 nyalas (*Tragelaphus angasii*) culled in the Mkuzi Game Reserve, KwaZulu-Natal, during March 1991, and six culled during March 1994, were collected, identified and counted. Of these, an as yet undescribed *Camelostrongylus* sp., *Cooperia hungi*, an *Onchocerca* sp., *Strongyloides papillosus* and *Moniezia benedeni* are new parasite records.

The individual nematode burdens of the antelope examined during March 1991 varied from one to 2 327, and the total mean adult gastro-intestinal-nematode burden was 586. Those examined during March 1994 had burdens that varied from 322 to 1 778, with a mean of 854. The two *Camelostrongylus* spp. were the most prevalent nematodes in the nyalas culled during 1991, while the trematode *Cotylophoron jacksoni* was most prevalent in those culled during 1994. The most numerous nematode in nyala calves during 1991 was a *Cooperia rotundispiculum* race, while the two *Camelostrongylus* spp. were most numerous in the adult and sub-adult nyalas from both surveys.

No clear trends between rainfall and nematode burdens were evident, nor was there any correlation between faecal nematode egg counts and nematode burdens. Contrary to what was observed in an earlier survey, female nyalas had larger nematode burdens than the males.

Keywords: Helminths, nyala, parasites, *Tragelaphus angasii*, wildlife

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Accepted for publication 30 July 1996—Editor

INTRODUCTION

The internal parasites of nyalas (*Tragelaphus angasii*) were listed by Dixon (1964), Round (1968), Vincent, Hitchins, Bigalke & Bass (1968), Keep (1971), Boomker (1986), Boomker, Horak & De Vos (1986) and Boomker, Horak & Flamand (1991). The last-named authors reported on the helminths of 77 nyalas in four nature reserves in KwaZulu-Natal, including Mkuzi Game Reserve.

As part of the ongoing surveys of the helminth parasites of wild animals in South Africa, culling programmes of nyalas in the Mkuzi Game Reserve, northern KwaZulu-Natal, were attended during March

1991 and March 1994, and the helminth parasites of 58 and of six nyalas, respectively, collected. In this paper, the results of these collections are presented and compared with those of the previous survey conducted in this reserve. An amended host-parasite list is also provided.

MATERIALS AND METHODS

The geophysiology of the Mkuzi Game Reserve has been described by Boomker *et al.* (1991). In summary, the Reserve (27°33′–27°46′S; 32°07′–32°19′E, altitude 130–300 m), is approximately 25 091 ha in extent and situated in north-eastern KwaZulu-Natal. The vegetation of the higher altitudes is classified as Lowveld, while that of the lower altitudes consists of Coastal Forest and Thornveld (Acocks 1988). Rain falls mostly during summer, and summers are hot and often humid, while winters are mild. Frost seldom occurs.

A total of 58 nyalas, comprising 24 adults, 12 sub-adults and 22 calves, were shot during March 1991. The gastro-intestinal tracts (excluding the fore-stomachs) of 26 of these antelope were processed for helminth recovery, as described by Boomker, Horak & De Vos (1989) and the mucosae digested. Helminths were collected only from the abomasa and the proximal one-third of the small intestines of the remaining 32 antelope, and the respective mucosae digested. Neither the hearts, lungs nor livers of these antelope were examined for the presence of helminths.

Separate aliquots, each representing one-tenth of the volume of the ingesta of the abomasa, small intestines and large intestines, were made and examined under a stereoscopic microscope. The mucosal digests were examined *in toto*. All the worms were removed, identified and counted.

Faecal specimens were collected from the rectums of the antelope and duplicate faecal nematode egg counts were done, according to Reinecke's (1961) modification of the McMaster technique of Gordon & Whitlock (1939).

Three adult male and three adult female nyalas were processed for helminth recovery during March 1994, as described by Boomker *et al.* (1989). However, separate aliquots, representing only one-twentieth of the respective ingesta, were examined. The hearts and livers were not examined and the mucosae of the large intestines were not digested. Faecal specimens for nematode egg counts were not collected.

A number of the distomes recovered from the nyalas were dehydrated in graded ethyl alcohol and embedded in paraffin wax. Ventral and sagittal serial sections, 5 µm thick, were cut of the entire trematode, stained with Masson's trichrome stain (Bancroft & Stevens 1982) and mounted in Canada balsam.

Fragments of the cestode recovered from one of the nyalas examined during March 1991, were stained with aceto-alum-carmine stain. Gravid proglottides were compressed between two glass slides for better observation of the shape of the eggs.

All the helminths were identified under a standard microscope in accordance with the descriptions provided by the authors listed in Table 1.

RESULTS

The rainfall during the two months preceding and the month of parasite collection for the March 1983 as well as the 1991 and 1994 surveys, is presented in Fig. 1.

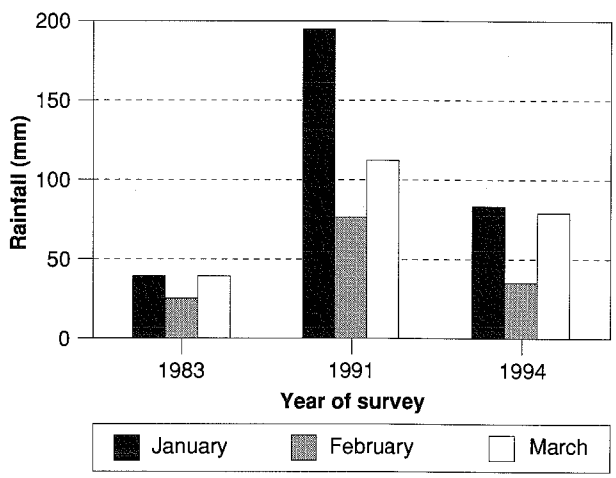

FIG. 1 Rainfall during the two months preceding and the month during which parasites were collected for each of the 1983, 1991 and 1994 surveys of the helminths of nyalas in Mkuzi Game Reserve

The *Camelostrongylus* spp. were the most numerous and accounted for 88,7% of the total adult nematode burden of the adult nyalas examined during March 1991. They were also the most prevalent, occurring in 23 out of the 24 antelope. *Paracooperia horaki* was next most numerous and prevalent (Table 2).

The sub-adult nyalas examined during March 1991 harboured three nematode genera, and seven identified to the species level. The *Camelostrongylus* spp. were the most numerous, accounting for 70 % of the adult nematode burden. They were also the most prevalent, occurring in all 12 antelope (Table 3).

Nyala calves examined during March 1991, harboured the largest variety of helminths. The two *Cooperia* spp. were the most numerous, and accounted for 47,7% of the total adult nematode burden, followed by the two *Camelostrongylus* spp. (31,4%) and *P. horaki* (10%). However, the *Camelostrongylus* spp. were the most prevalent, occurring in 20 out of the 22 antelope.

TABLE 1 Amended list of the helminth parasites of nyalas, *Tragelaphus angasii*, with reference to the first record and the authors of the descriptions used to assist with the identifications

Helminth species	First record	Identification
Trematodes		
Calicophoron calicophorum (Fischoeder, 1901) Näsmark, 1937	Ortlepp pers. comm [a]	-
Cotylophoron cotylophorum (Fischoeder, 1901) Stiles & Goldberger, 1910	Ortlepp pers. comm [a]	-
Cotylophoron jacksoni Näsmark, 1937	Dixon 1964	Eduardo 1985
Paramphistomum microbothrium (Fischoeder, 1901)	Dixon 1964	-
Schistosoma mattheei Veglia & Le Roux, 1929	Boomker *et al.* 1991	-
Cestodes		
Moniezia benedeni (Moniez, 1879) Blanchard, 1891	This paper	Taylor 1928
Taenia sp. larvae	Boomker *et al.* 1991	-
Thysaniezia sp.	Boomker *et al.* 1991	-
Nematodes		
Camelostrongylus harrisi (Le Roux, 1930) Durette-Desset, 1989	Vincent *et al.* 1968	Le Roux 1930
Camelostrongylus sp.	This paper	Boomker, unpublished data
Cooperia hungi Mönnig, 1931	This paper	Gibbons 1981
Cooperia rotundispiculum Khalil & Gibbons, 1980	Boomker 1991	Boomker 1991
Dictyocaulus viviparus (Bloch, 1782) Railliet & Henry, 1907	Keep 1971	-
Elaeophora sagittus (Von Linstow, 1907) Anderson & Bain, 1976	Ortlepp 1961	-
Gaigeria pachyscelis Railliet & Henry, 1910	Boomker *et al.* 1991	Levine 1980
Gongylonema verrucosum (Giles, 1982) Neumann, 1984	Vincent *et al.* 1968	-
Gongylonema sp.	Boomker *et al.* 1991	-
Haemonchus vegliai Le Roux,1929	Boomker *et al.* 1991	Gibbons 1979
Haemonchus sp.	Keep 1971	-
Impalaia tuberculata Mönnig, 1924	Boomker *et al.* 1991	Boomker 1977
Oesophagostomum sp.	Boomker *et al.* 1991	-
Onchocerca sp.	This paper	Anderson & Bain 1976
Paracooperia horaki Boomker, 1986	Boomker 1986	Boomker 1986
Setaria africana (Yeh, 1959) Ortlepp, 1961	Yeh 1959	Yeh 1959
Setaria labiatopapillosa (Perroncito, 1882) Railliet & Henry, 1911	Mönnig 1931	Yeh 1959
Setaria sp.	Boomker *et al.* 1991	Yeh 1959
Strongyloides papillosus (Wedl, 1856)	This paper	Ransom 1911
Teladorsagia trifurcata (Ransom, 1907)	Keep 1971	-
Trichostrongylus deflexus Boomker & Reinecke, 1989	Boomker *et al.* 1991	Boomker & Reinecke 1989
Trichostrongylus falculatus Ransom, 1911	Boomker *et al.* 1991	Ransom 1911

[a] As communicated to Round (1968)
- Not found in this survey

One trematode species, one nematode genus and three nematode species were recovered from the adult nyalas culled during March 1994. *Cotylophoron jacksoni* occurred in all six of the antelope, while the two *Camelostrongylus* spp. were the most numerous nematodes, comprising 91% of the total adult nematode burden. Together with *P. horaki*, the *Camelostrongylus* spp. were the most prevalent nematodes, each occurring in five antelope (Table 3).

The results of the faecal nematode egg counts are presented in Table 4.

The numbers of helminths collected during March 1983, and the 1991 and 1994 surveys are compared in Table 5. From this table it is clear that the 1991 survey yielded the largest variety of helminths.

DISCUSSION

Five new helminths can be added to the existing list of parasites of nyalas. These are the *Camelostrongylus* sp., *Cooperia hungi*, an *Onchocerca* sp., *Strongyloides papillosus* and *Moniezia benedeni*.

Camelostrongylus harrisi is a common parasite of nyalas and has been found in all the previous surveys (Boomker *et al.* 1986, 1991). The recent discovery of a new species is in line with the concept of major and minor species as observed between *Teladorsagia circumcincta* and *Teladorsagia trifurcata* of sheep (Lancaster & Hong 1981). *Camelostrongylus harrisi* would appear to be the major species in nyalas, because its numbers were 20–30% higher than

TABLE 2 Helminths recovered from 58 nyalas culled during March 1991

Helminth species	Number of helminths recovered			Number of animals infected
	Larvae	Adults	Total	
Adults (24 animals)				
Camelostrongylus harrisi	0	4 733	4 733	23
Camelostrongylus sp.	0	2 997	2 997	22
Cooperia hungi	0	20	20	1
Cooperia rotundispiculum	0	211	211	2
Cooperia females	0	73	73	3
Cooperia type larvae	390	–	390	2
Gaigeria pachyscelis	0	1	1	1
Ostertagia type larvae	84	–	84	5
Onchocerca sp.	–	1	1	1
Paracooperia horaki	0	679	679	16
Mean nematode burden	20	363	383	
Subadults (12 animals)				
Camelostrongylus harrisi	0	3 201	3 201	12
Camelostrongylus sp.	0	2 072	2 072	12
Cooperia hungi	0	869	869	2
Cooperia rotundispiculum	0	637	637	4
Cooperia type larvae	22	–	22	1
Haemonchus vegliai	0	36	36	3
Ostertagia type larvae	284	–	284	6
Paracooperia horaki	0	713	713	8
Setaria africana	0	3	3	3
Trichostrongylus deflexus	0	3	3	1
Mean nematode burden	25	628	653	
Calves (22 animals)				
Cotylophoron sp. immature	1	0	1	1
Moniezia benedeni	0	1	1	1
Camelostrongylus harrisi	0	3 749	3 749	20
Camelostrongylus sp.	0	1 821	1 821	20
Cooperia hungi	0	2 280	2 280	14
Cooperia rotundispiculum	0	6 169	6 169	14
Cooperia type larvae	1 395	–	1 395	7
Gaigeria pachyscelis	0	23	23	2
Haemonchus vegliai	0	460	460	9
Impalaia tuberculata	420	1 173	1 593	6
Ostertagia type larvae	50	–	50	4
Paracooperia horaki	0	1 774	1 774	19
Setaria sp.	0	1	1	1
Strongyloides papillosus	0	163	163	5
Trichostrongylus deflexus	0	11	11	1
Trichostrongylus falculatus	0	96	96	5
Trichostrongylus females	0	10	10	1
Mean nematode burden	85	806	891	

– Not applicable

those of the new species in all the surveys conducted. Together with a *Cooperia rotundispiculum* race and *P. horaki*, the two *Camelostrongylus* spp. were the definitive parasites of nyalas in the 1983 survey (Boomker *et al.* 1991). The 1991 and 1994 surveys confirm this observation.

Cooperia hungi is a common parasite of impalas, *Aepyceros melampus* (Horak 1978) and should be regarded as an accidental parasite of nyalas. The worms were found only in the 1991 survey, and then mostly in calves. The presence of *Strongyloides papillosus* only in calves, and then only in low numbers, suggests that this infestation may be milk-borne, as proposed for impalas (Horak 1978) and kudus (Boomker *et al.* 1989). Both the *Onchocerca* sp. and *Moniezia benedeni* can be regarded as accidental parasites.

TABLE 3 Helminths recovered from six adult nyalas culled during March 1994

Helminth sp.	No. of helminths recovered			No. of nyalas infected
	Larvae	Adults	Total	
Cotylophoron jacksoni	0	1 901	1 901	6
Camelostrongylus harrisi	0	3 019	3 019	5
Camelostrongylus sp.	0	1 649	1 649	5
Camelostrongylus females	–	20	20	1
Cooperia rotundispiculum	0	120	120	1
Paracooperia horaki	0	317	317	5
Mean nematode burden	0	854	854	

– Not applicable

TABLE 4 Total adult female nematode and total nematode burdens, and faecal nematode egg count of nyalas culled during March 1991

Female nyalas					Male nyalas				
Animal number and age	Total adult female nematode burden	Total nematode burden	Faecal nematode egg count (eggs/g)		Animal number and age	Total adult female nematode burden	Total nematode burden	Faecal nematode egg count (eggs/g)	
			Count 1	Count 2				Count 1	Count 2
Adults					Adults				
5	74	144	0	0	4	33	57	0	0
6	152	250	0	0	7	46	48	0	200
13	471	891	0	0	19	66	82	0	0
15	178	279	0	0	20	85	195	0	0
27	395	730	0	0	23	155	223	0	0
32	18	61	200	300	26	134	198	0	0
33	340	648	300	100	28	0	1	0	0
36	54	96	0	0	30	294	686	0	0
39	249	359	0	0	41	71	179	0	0
42	679	1 047	0	0	43	49	61	0	0
48	329	586	0	0	47	226	343	0	0
50	399	552	200	100					
55	524	891	0	0					
Mean	297	503	54	38	Mean	105	188	0	18
Subadults					Subadults				
31	50	136	0	0	10	242	444	0	0
38	691	1 143	200	100	17	33	44	0	0
44	704	1 129	0	0	29	572	1 083	200	200
45	270	782	0	0	37	239	392	0	0
54	350	774	0	100	51	191	337	0	0
					53	523	898	300	200
					56	299	369	0	0
Mean	413	793	40	40	Mean	300	510	71	57
Calves					Calves				
1	821	1 506	200	0	3	151	218	0	0
2	30	61	0	0	8	276	584	0	0
14	501	957	800	600	9	461	944	0	0
18	1 355	2 327	100	200	11	212	317	0	0
24	593	860	0	0	12	421	598	0	0
25	475	807	0	0	16	206	364	0	0
40	337	751	0	0	21	911	1 743	0	0
49	351	710	200	200	22	176	366	300	400
52	756	1 342	200	300	34	95	210	0	0
57	881	1 662	400	200	35	268	584	0	0
58	145	239	200	300	46	282	579	0	0
Mean	568	1 020	191	164	Mean	314	592	27	36

TABLE 5 Comparison of the results of the helminth surveys of nyalas conducted during March 1983, 1991 and 1994

Helminth species	Results of surveys conducted		
	1983 (n = 4)	1991 (n = 58)	1994 (n = 6)
Paramphistomes	3 432	1	1 901
Moniezia benedeni	–	1	–
Cooperia rotundispiculum	2 040	7 017	120
Cooperia hungi	–	3 169	–
Cooperia spp. females	–	73	–
Cooperia type larvae	0	1 807	–
Elaeophora sagittus	0	–	–
Gaigeria pachyscelis	1	24	–
Haemonchus vegliai	75	496	–
Haemonchus larvae	0	–	–
Impalaia tuberculata	0	1 173	–
Impalaia larvae	0	420	–
Camelostrongylus harrisi	15 331 [a]	11 683	3 019
Camelostrongylus sp.	112	6 890	1 649
Camelostrongylus females	–	–	20
Ostertagia type larvae	100	418	–
Onchocerca sp.	–	1	–
Paracooperia horaki	802	3 166	317
Setaria sp.	4	1	–
Setaria africana	–	3	–
Strongyloides papillosus	–	163	–
Trichostrongylus deflexus	–	14	–
Trichostrongylus falculatus	44	96	–
Trichostrongylus spp. females	–	10	–
Mean adult gastro-intestinal nematode burden	4 601	586	854

– Not found during that particular survey
[a] One animal harboured 13 293 *Camelostrongylus* spp. adults

Although good rain fell during January 1991, it did not appear to affect the mean adult nematode burden of the adult nyalas. It might, however, have affected the burdens in the younger animals, because in the subadults and calves they were 1,7 and 2,3 times, respectively, that of the adult nyalas. In the 1983 survey, male nyalas had larger burdens than the females (Boomker *et al.* 1991). However, in both the 1991 and 1994 surveys, the females had the larger burdens, but since only small numbers of helminths were involved, the differences are probably not significant.

It is clear that little correlation exists between the total female or total helminth burdens, and faecal nematode egg counts of nyalas. Similar results have been obtained for kudus in the Kruger National Park (Boomker *et al.* 1989), thereby indicating that faecal egg counts should not be used to determine the nematode population status of antelope in game reserves.

On comparing the results of the 1983, 1991 and 1994 surveys, it is apparent that the nyalas culled during 1983 had the largest mean burden, but this is owing to one of the antelope harbouring a large number of *Camelostrongylus harrisi*. If this animal is left out of the calculations, the mean adult nematode burden becomes 1 227, which is not much larger than the 854 of the 1994 survey. The nyalas culled during 1991 had the largest variety of helminths and the smallest burdens, while the six antelope culled during 1994 had the smallest variety of helminths and a mean burden intermediate to that of the other groups. This may have been brought about by climatic conditions or a slight overpopulation of nyalas during 1983. However, the magnitudes of the total burdens are insignificant, and when the species diversity is taken into account, they should in no way be detrimental to the antelope.

ACKNOWLEDGEMENTS

We wish to thank the Director of the Natal Parks Board for placing the animals at our disposal, and the staff of Mkuzi Game Reserve for their assistance.

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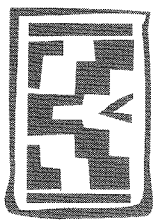

Parasites of South African wildlife. XV. Helminths of scrub hares, *Lepus saxatilis* in the Kruger National Park

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ABSTRACT

BOOMKER, J., HORAK, I.G. & BOOYSE, D.G. 1997. Parasites of South African wildlife. XV. Helminths of scrub hares, *Lepus saxatilis*, in the Kruger National Park. *Onderstepoort Journal of Veterinary Research*, 64:285—290

A total of 145 scrub hares from three localities in the Kruger National Park were examined for helminths: 124 at Skukuza, 15 at Shingwedzi, and three each at Pretoriuskop and Pafuri. *Trichostrongylus deflexus* was the most prevalent and most abundant nematode, and was collected from hares from all four localities. *Trichostrongylus falculatus* was present in three localities. *Trichostrongylus thomasi* and *Dermatoxys vlakhaasi* occurred only at Skukuza in 50 and 23 %, respectively, of the hares examined. The cestode *Mosgovoyia pectinata* and the nematode genus *Impalaia* were each recovered from three localities and *Cooperia hungi* from two. There was no apparent seasonal pattern of abundance of the worms, and the intensities of infection of male and female hares were similar. With the exception of *D. vlakhaasi,* all the helminths recovered in this study represent new records for scrub hares in South Africa.

Keywords: Helminths, *Lepus saxatilis*, parasites, scrub hares, wildlife

INTRODUCTION

Scrub hares, *Lepus saxatilis*, are widely distributed throughout Africa except in forested areas. In southern Africa they are absent from the western coastal desert and the eastern coastal forests as well as from the arid country bordering the Orange River (Skinner & Smithers 1990). They prefer savannah woodland or scrub where there is grass cover, but they do not occur on open grassland. They are common in agriculturally developed areas, especially those where crops are grown, and in derelict lands where there is bush regeneration. Scrub hares are mostly nocturnal and apparently sensitive to the weather, as they are not in evidence on cold nights. They are grazers, living on the leaves, stems and rhizomes of preferably green grass (Skinner & Smithers 1990).

The helminth parasites of hares have received little attention in this country. Ortlepp (1937, 1938b) described *Dermatoxys vlakhaasi* and *Inermicapsifer leporis*, from Cape hares, *Lepus capensis*, and Neitz (1965) lists *Coenurus serialis* collected from an unspecified hare by Ortlepp (1938a). This paper records the helminths collected from scrub hares at four localities in the Kruger National Park.

MATERIALS AND METHODS

Survey localities and animals

The hares examined in this survey are the same as those from which ectoparasites were collected at Shingwedzi, Pafuri and Pretoriuskop, and during the first two years of the ectoparasite survey at Skukuza (Horak, Spickett, Braack & Penzhorn 1993; Louw, Horak & Braack 1993). These authors also provide details on the vegetation types of the localities. The

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Accepted for publication 30 October 1997—Editor

particulars of the hares available to us and the localities at which they were collected are provided in Table 1.

All hares were processed for helminth recovery as described by Boomker, Horak & De Vos (1989), but digests of the mucosae of the stomach and intestines were not done. Female *Trichostrongylus* spp. were proportionally assigned to the males that occurred in each host. However, some hares harboured only female *Trichostrongylus* spp. and these have not been assigned to a species.

The ecological terms used here are in accordance with those of Margolis, Esch, Holmes, Kuris & Schad (1982) and the term 'average' is defined as the total number of parasites from all the hosts divided by the number of hosts in which the parasites are present.

RESULTS

Skukuza

The climatological data for Skukuza are graphically represented in Fig. 1. The average monthly intensities of the helminth infections are listed in Table 2 and the monthly fluctuations in the total *Trichostrongylus* spp. burdens are graphically illustrated in Fig. 2.

Six nematode species and one cestode species were collected from these hares. Of the nematodes *Trichostrongylus deflexus* (prevalence 96,8 %, range 40–9 563) was the commonest, followed by *Trichostrongylus thomasi* (prevalence 50,4 %, range 23–1 796), *Trichostrongylus falculatus* (prevalence 48,0 %, range 28–2 693), *Impalaia tuberculata* (prevalence 32,0 %, range 10–520) and *Dermatoxys vlakhaasi* (prevalence 23,3 %, range 1–120). Two hares each harboured 20 *Cooperia hungi*. One hare harboured 60 female *Trichostrongylus* spp. that could not be assigned to a species, one a single *Trichostrongylus* sp. larva, and another 20 *D. vlakhaasi* larvae. Three hares, one a juvenile female, the others two adult males, had no worms, while the range varied from 40–9 900 worms in the 121 (97,6 %) animals that were infected. The cestode *Mosgovoyia pectinata* was present in 22 hares (prevalence 17,7 %, range 1–17).

None of the helminths showed discernible seasonal trends, neither according to rainfall nor to minimum or maximum temperatures, and the intensities of infection between male and female hares, although very variable, were similar.

The prevalences of trichostrongylid nematodes in hares at Skukuza are compared in Table 3 with those in kudus, *Tragelaphus strepsiceros*, examined south and west of Skukuza from April 1981 to March 1983 (Boomker *et al.* 1989), and in impalas, *Aepyceros melampus* (Boomker, Horak & De Vos, unpublished data 980), and warthogs, *Phacochoerus africanus* (Horak, Boomker, De Vos & Potgieter 1988). The impalas and warthogs were examined from January 1980 to January 1981 and both species were shot in the same locality as the hares.

The scrub hares and impalas harboured five helminth species, and hares, kudus and warthogs harboured four species in common.

Pretoriuskop

Only *I. tuberculata* (prevalence 100 %, range 4–400), *T. deflexus* (prevalence 66 %, range 89–244), *T. falculatus* (prevalence 66 %, range 95–671) and *M. pectinata* (prevalence 66 %, range 1–14) were present in hares from this locality.

Shingwedzi

The average bimonthly burdens of the 15 hares from this locality are listed in Table 1. Four species of nematodes were collected, of which *I. tuberculata* (range 20–80) and *T. deflexus* (range 20–144) were both present in nine hares, *T. falculatus* in five, unidentified *Trichostrongylus* spp. females in two, and *C. hungi* in one. Fourteen hares harboured nematodes and a single animal two *M. pectinata*. No seasonal pattern of abundance was evident for either the individual nematode species or the entire worm burdens.

Pafuri

One of the three hares harboured 340 *T. deflexus* only, while no worms were present in the remaining two animals.

DISCUSSION

With the exception of *D. vlakhaasi*, all the helminths recovered in this study represent new parasite records for scrub hares in South Africa. *D. vlakhaasi* was originally described from a Cape hare by Ortlepp (1937) as *Heteroxinema vlakhaasi*. However, Quentin (1975) transferred this species to the genus *Dermatoxys*, a parasite exclusive to the Leporidae. Its presence in scrub hares is therefore to be expected and it should be regarded as a definitive parasite.

C. hungi is primarily a parasites of antelopes, in which it occurs commonly but in varying numbers, impala being the preferred hosts (Table 2). It was encountered in only one out of 41 warthogs examined in the Northern Province (Boomker, Horak, Booyse & Meyer 1991) and in none in the Kruger National Park (Horak *et al.* 1988). In view of its low prevalence and low intensity in the monogastric herbivores, including hares, it should be considered an accidental parasite in these animals.

I. tuberculata was originally described from an impala (Mönnig 1924). Subsequently it has been collected from a variety of antelopes (Boomker 1977, 1991) as well as from warthogs (Horak *et al.* 1988; Boomker *et al.* 1991). It was also recovered in very low numbers from all six red rock rabbits, *Pronolagus* sp., examined in Kenya by Fukumoto, Kamiya & Suzuki (1980) and should be considered a definitive parasite of hares and possibly rabbits. Its wide host spectrum indicates its tolerance of a variety of physiological environments.

Trichostrongylus spp. utilize a large variety of terrestrial vertebrates, notably birds and herbivorous mammals, as hosts. They seem to have evolved separately in domesticated and in wild animals, where different species occupy the same niches (Anderson 1992). For instance, *Trichostrongylus axei* is found in the abomasa of sheep, goats and cattle and the stomachs of domestic pigs and horses (Reinecke 1983), and *T. thomasi* in the abomasa of several wild ruminants (Boomker 1991) and the stomachs of warthogs (Horak *et al.* 1988; Boomker *et al.* 1991), zebras (Krecek, Malan, Reinecke & De Vos 1987) and now hares.

The presence of *Trichostrongylus* spp. in hares and rabbits is well known. Fukumoto *et al.* (1980) recorded *Trichostrongylus colubriformis* in 100 % *Pronolagus* sp. but the maximum number of worms collected from a single host was only 31, which is considerably fewer than the various *Trichostrongylus* spp. recovered from hares from all the localities in this study. Boag (1987) records the prevalence of *Trichostrongylus retortaeformis* in *L. capensis* and *Oryctolagus cuniculus* in Scotland as being 73,8 % and 80 %, respectively. The maximum number of worms he collected was 2 730 from a hare and 4 325 from a rabbit. Allgöwer (1992) found the same parasite in 92 % of *Lepus europaeus* in the upper Rhine Valley, Germany. These figures are reasonably similar to those for the hares from Skukuza.

In the Kruger National Park, scrub hares and impalas are the preferred hosts of *T. deflexus*, and warthogs

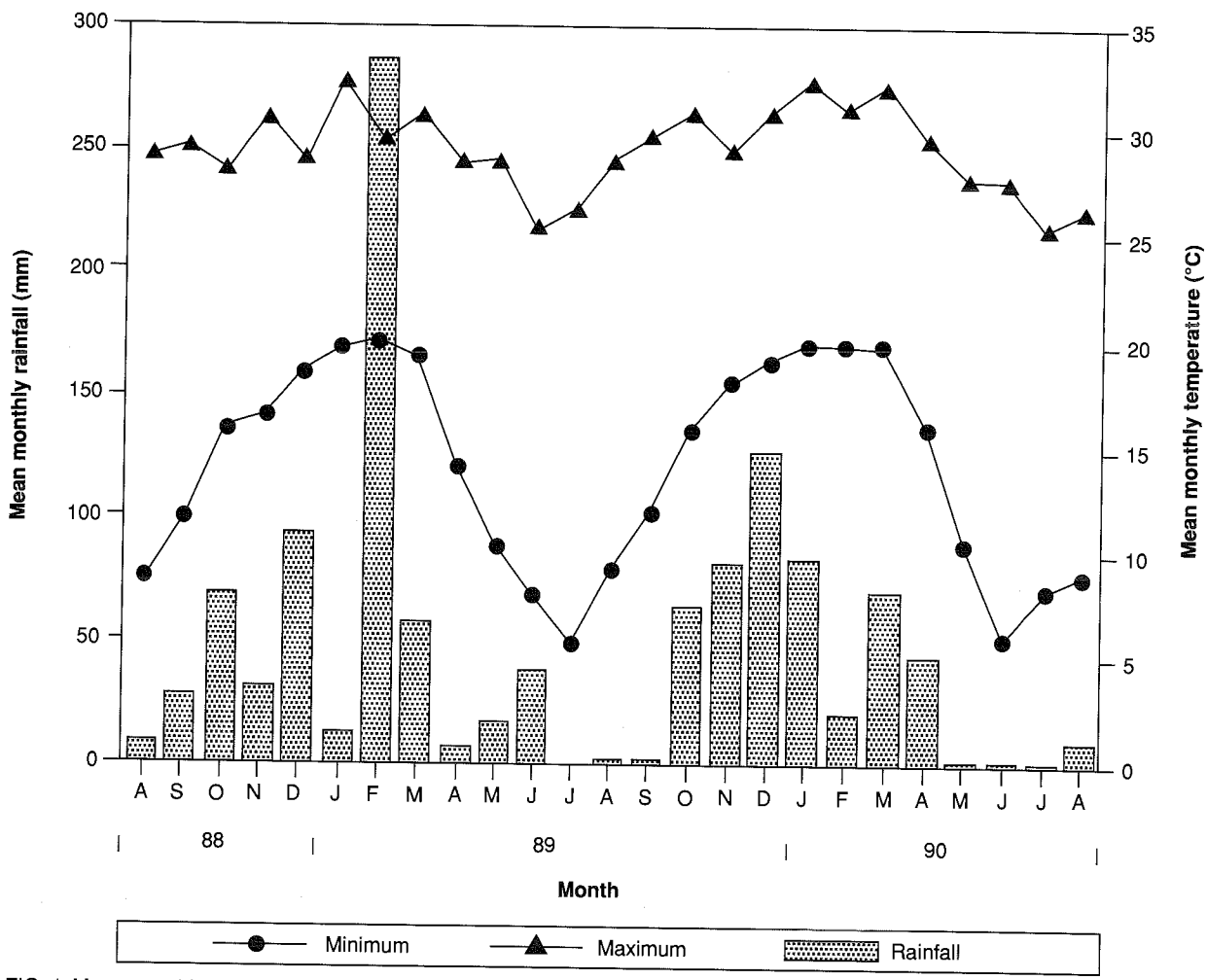

FIG. 1 Mean monthly rainfall, and mean monthly minimum and maximum temperatures measured at Skukuza for the period August 1988 to August 1990

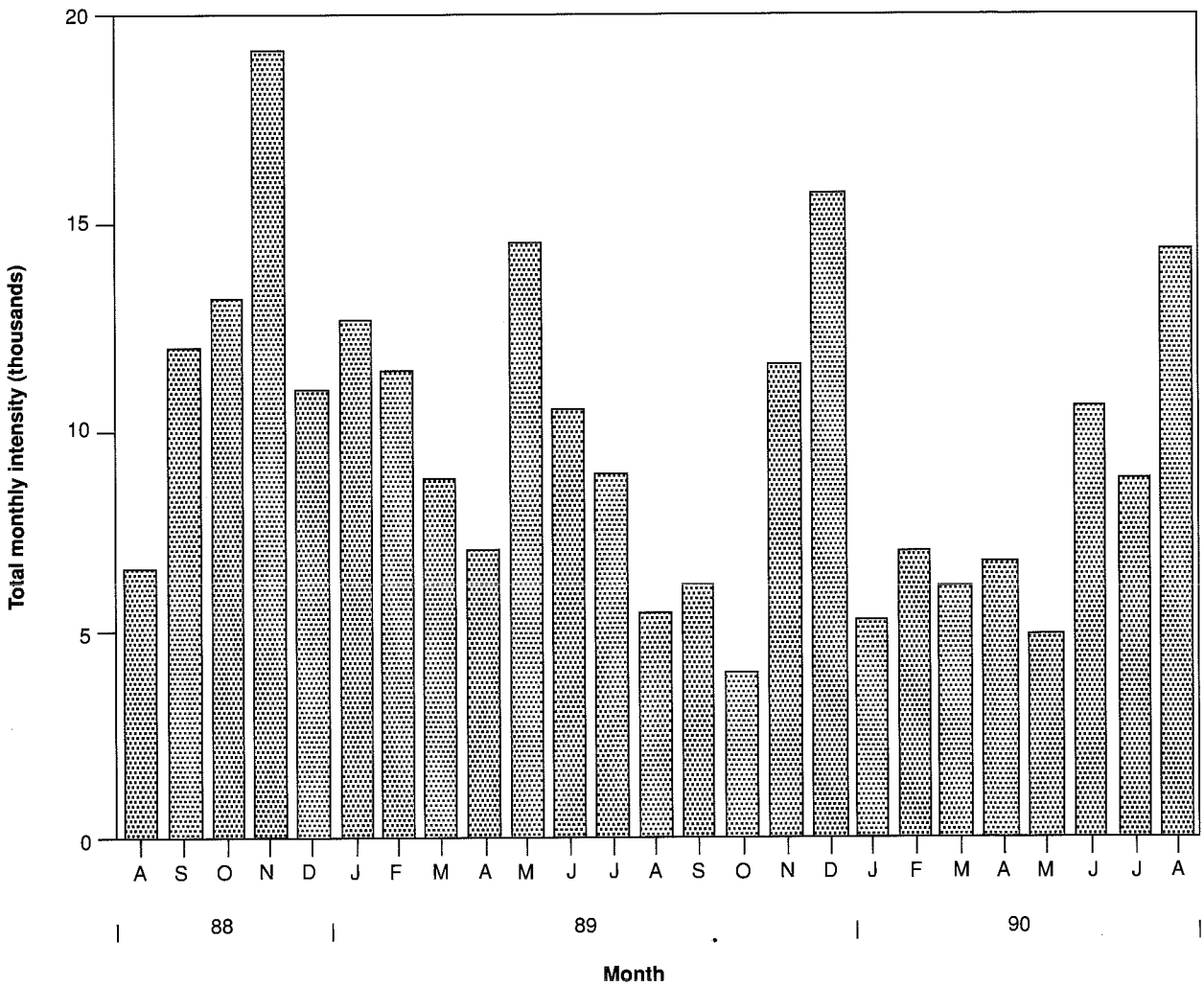

FIG. 2 Monthly fluctuations of the total *Trichostrongylus* spp. burdens of scrub hares at Skukuza during the period August 1988 to August 1990

TABLE 1 Collection data of scrub hares in the Kruger National Park

Locality	Grid reference	Section of Park	Frequency	Date collected	Ages and sex[b]				Number collected
					JF	SAF	AF	AM	
Skukuza	24°58′S,31°36′E	South	Five per month[a]	Aug 1988 – Aug 1990	2	–	35	87	124
Pretoriuskop	25°10′S,31°16′E	Sout-hwest	In one month	June 1989	–	–	2	1	3
Shingwedzi	23°07′S,31°26′E	North	Three bimonthly	Aug 1989 – Aug 1990	–	1	10	4	15
Pafuri	23°27′S,31°19′E	Far north-east	One per month	Feb 1990 – Apr 1990	–	1	2	–	3

[a] Excepting August 1988 when four were examined
[b] JF = Juvenile female; SAF = Sub-adult female; AF = Adult female; AM = Adult male

the preferred host of *T. thomasi*, while kudus appear to be poor hosts for *T. falculatus* and apparently do not harbour *T. thomasi* (Table 2). The high prevalence and incidence of *T. thomasi* in warthogs is surprising because it is considered a definitive parasite of wild ruminants. It now seems possible that the nematode is primarily a parasite of the monogastric herbivores and has secondarily adapted to ruminants.

The anoplocephalid tapeworm *M. pectinata* is a cosmopolitan parasite of the Lagomorpha and is the only one of the five species of the genus that occurs in

TABLE 2 The average monthly or bimonthly intensities of nematode infections of scrub hares, *Lepus saxatilis*, from Skukuza and Shingwedzi, Kruger National Park

Locality and month collected[a]	*Cooperia hungi*	*Impalaia tubercula*		*Trichostrongylus*				*Dermatoxys vlakhaasi*		Average monthly total nematode burden
		Adults	Larvae	*deflexus*	*falculatus*	*thomasi*	Females	Adults	Larvae	
Skukuza										
Aug. 1988: Males (3)	0	114	0	1 004	0	0	130	8	0	1 256
Females (1)	0	40	0	2 090	0	0	0	1	0	2 131
Sep. 1988: Males (5)	0	42	2	2 378	0	9	0	0	10	2 440
Oct. 1988: Males (3)	0	27	0	3 588	0	86	0	0	40	3 740
Females (2)	0	5	0	1 067	0	23	0	0	10	1 105
Nov. 1988: Males (3)	0	13	0	2 557	0	110	0	0	0	2 680
Females (2)	10	10	0	5 519	0	22	0	0	0	5 560
Dec. 1988: Males (2)	0	0	0	2 500	0	0	0	20	0	2 520
Females (3)	0	0	0	1 927	0	53	0	13	0	1 993
Jan. 1989: Males (2)	0	60	0	3 274	0	177	0	90	0	3 600
Females (3)	7	67	0	1 894	0	19	0	0	0	1 987
Feb. 1989: Males (5)	0	12	0	2 209	0	63	0	0	0	2 284
Mar. 1989: Males (4)	0	45	0	1 966	18	91	0	0	0	2 150
Females (1)	0	120	0	340	0	0	0	0	0	460
Apr. 1989: Males (3)	0	13	7	166	81	0	0	7	0	273
Females (2)	0	0	0	2 911	191	48	0	0	0	3 140
May 1989: Males (2)	0	0	0	1 682	1 402	97	0	10	0	3 191
Females (3)	0	7	0	2 432	168	106	0	0	0	2 713
Jun. 1989: Males (4)	0	0	0	2 101	318	81	0	0	0	2 500
Females (1)	0	0	0	175	245	0	0	0	0	420
Jul. 1989: Males (3)	0	0	0	1 883	348	16	0	7	0	2 253
Females (2)	0	0	0	703	206	152	0	0	0	1 061
Aug. 1989: Males (3)	0	20	0	1 265	131	17	20	0	0	1 453
Females (2)	0	10	0	529	0	72	0	0	0	610
Sep. 1989: Males (2)	0	0	0	1 805	59	306	0	10	0	2 180
Females (3)	0	20	0	563	29	8	0	7	0	627
Oct. 1989: Males (4)	0	5	0	793	163	30	0	5	0	995
Females (1)	0	0	0	0	0	0	0	0	0	0
Nov. 1989: Males (5)	0	116	0	2 010	226	64	0	4	0	2 420
Dec. 1989: Males (2)	0	0	0	2 431	626	124	0	0	0	3 180
Females (3)	0	93	0	2 426	634	33	0	0	0	3 186
Jan. 1990: Males (2)	0	0	0	486	18	37	0	0	0	540
Females (3)	0	27	0	1 232	153	15	0	0	0	1 427
Feb. 1990: Males (5)	0	0	0	965	267	186	0	0	0	1 388
Mar. 1990: Males (5)	0	52	0	1 173	0	47	0	8	0	1 280
Apr. 1990: Males (5)	0	8	0	1 126	89	122	0	0	0	1 344
May 1990: Males (3)	0	0	0	807	40	0	0	0	0	847
Females (2)	0	0	0	731	379	70	0	0	0	1 180
Jun. 1990: Males (5)	0	20	0	1 528	539	21	0	36	0	2 144
Jul. 1990: Males (3)	0	40	0	992	348	130	0	0	0	1 510
Females (2)	0	0	0	1 902	191	27	0	20	0	2 140
Aug. 1990: Males (4)	0	10	0	1 609	550	475	0	5	0	2 650
Females (1)	0	60	0	1 423	2 312	44	0	20	0	3 859
Shingwedzi										
Aug. 1989	0	80	0	110	60	0	0	0	0	250
Oct. 1989	0	33	0	63	47	0	60	0	0	203
Dec. 1989	0	40	0	102	36	0	60	0	0	238
Feb. 1990	40	40	0	70	0	0	0	0	0	150
Apr. 1990	0	40	0	20	0	0	0	0	0	60

[a] Figures in brackets indicate number of animals examined

TABLE 3 Comparison of the prevalence of the commonly shared trichostrongylid nematodes of scrub hares, warthogs, kudus and impalas

Host species	Helminth species and prevalence (%)				
	Cooperia hungi	*Impalaia tuberculata*	*Trichostrongylus*		
			deflexus	*falculatus*	*thomasi*
Scrub hares (*n* = 124)	1,6	32,3	96,8	48,4	50,8
Warthogs (*n* = 28)	–	3,6	14,3	3,6	75,0
Kudus (*n* = 96)	8,2	25,8	43,3	6,2	–
Impalas (*n* = 142)	87,3	72,5	86,6	24,6	57,0

Africa. It represents a new parasite record for scrub hares in this country.

ACKNOWLEDGEMENTS

We wish to thank the National Parks Board for placing the hares at our disposal, Dr L.E.O. Braack and Mr I. de Beer of the Parks Board, and Miss H. Heyne and Mr A.M. Spickett of the Onderstepoort Veterinary Institute, who assisted with the collection of the hares and the helminths. This study was funded by the Foundation for Research Development, the University of Pretoria, the Medical University of Southern Africa and the National Parks Board.

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Parasites of South African wildlife. XVI. Helminths of some antelope species from the Eastern and Western Cape Provinces

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ABSTRACT

BOOMKER, J., HORAK, I.G., WATERMEYER, R. & BOOYSE, D.G. 2000. Parasites of South African wildlife. XVI. Helminths of some antelope species from the Eastern and Western Cape Provinces. *Onderstepoort Journal of Veterinary Research,* 67:31–41

The numbers and species of helminths recovered from one black wildebeest, *Connochaetes gnou,* three eland, *Taurotragus oryx,* 18 mountain reedbuck, *Redunca fulvorufula,* one red hartebeest, *Alcelaphus buselaphus* and two springbok, *Antidorcas marsupialis*, in the Mountain Zebra National Park, Eastern Cape Province; two black wildebeest, two grey rhebuck, *Pelea capreolus,* two mountain reedbuck and four springbok in the Karoo National Park, Western Cape Province; two bontebok, *Damaliscus pygargus dorcas*, two eland, two gemsbok, *Oryx gazella* and two springbok in the West Coast National Park, Western Cape Province; and a single springbok on a farm near Bredasdorp, Western Cape Province, are recorded. Nematodes belonging to a total of 12 genera and 20 species were identified. A single cestode was also recovered. Sixteen new host associations are recorded for the nematodes and one for the cestode *Moniezia benedeni. Nematodirus spathiger* had the widest host spectrum and with the exception of black wildebeest, was collected from all the host species examined.

Keywords: Antelope, helminths, nature reserves, wildlife

INTRODUCTION

The helminths of a variety of antelope from the eastern part of South Africa, mainly the Kruger National Park and the KwaZulu-Natal Game Reserves, have been surveyed and the results documented (Horak, De Vos & Brown 1983; Boomker 1990). However, with the exception of those in grysbok, *Raphicerus melanotis,* common duikers, *Sylvicapra grimmia,* kudu, *Tragelaphus strepsiceros,* grey rhebuck, *Pelea capreolus* and bontebok, *Damaliscus pygargus dorcas,* few surveys have been conducted on the internal parasites of antelopes occurring in the Eastern and Western Cape Provinces (Boomker, Horak & MacIvor 1989c; Boomker, Horak & Knight 1991a; Boomker & Horak 1992).

During the late 1980s and early 1990s the opportunity arose to collect the helminths of antelope in three nature reserves and a commercial farm in these Provinces and the results are presented here.

MATERIALS AND METHODS

Survey localities

Mountain Zebra National Park

This park (32°10′–32°18′S; 25°24′–25°30′E; Alt. 1 200–1 975 m) lies near the town of Cradock in the northern part of the Eastern Cape Province and is approximately 6 536 ha in extent. The vegetation consists of Karroid *Merxmuelleria* Mountain Veld, replaced by Karoo on the higher slopes and Karroid Broken Veld in the northern section (Acocks 1988). Rainfall is low with 70 % falling during February and

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Accepted for publication 17 December 1999—Editor

March (Fourie 1983) and the area can be described as semi-arid. Summers are warm to hot and winters cold with frost occurring regularly. Snow sometimes falls on the higher parts (Penzhorn 1975).

The park contains blesbok, *Damaliscus pygargus phillipsi,* black wildebeest, *Connochaetes gnou,* eland, *Taurotragus oryx,* gemsbok, *Oryx gazella,* mountain reedbuck, *Redunca fulvorufula,* red hartebeest, *Alcelaphus buselaphus,* grey rhebuck, steenbok, *Raphicerus campestris,* klipspringer, *Oreotragus oreotragus,* springbok, *Antidorcas marsupialis* and Cape mountain zebra, *Equus zebra zebra.*

A single black wildebeest, three eland, one red hartebeest and two springbok were shot during the period March 1983 to February 1984. In addition, two mountain reedbuck were shot at approximately three-monthly intervals from November 1983 to December 1985, a total of 18 antelope.

Karoo National Park

The park (32°12′–32°20′S; 22°25′–22°39′E; Alt. 600–1 932 m) is situated near the town of Beaufort West in the north-western part of the Western Cape Province and comprises an area of 17 706 ha. The vegetation consists of typical Karroid Broken Veld, Karroid *Merxmuelleria* Mountain Veld replaced by Karoo and Central Lower Karoo vegetation types (Acocks 1988). Like the Mountain Zebra National Park, the area can be described as semi-arid. Summers are hot to very hot and winters cold, with frost occurring commonly. Snow sometimes falls on the higher reaches.

Two black wildebeest, two grey rhebuck, two mountain reedbuck and four springbok were shot in this reserve during February 1991.

West Coast National Park

This park (33°6′–33°10′S; 17°57′–18°2′E; Alt. 0–50 m) is situated on the west coast of the Western Cape Province, approximately 120 km north of Cape Town, and comprises an area of 24 779 ha. The vegetation consists of Strandveld and isolated patches of Coastal Fynbos (Acocks 1988). The park falls within the winter rainfall region where summers are moderate to hot, and winters cold and wet.

Two bontebok, two eland, two gemsbok and two springbok were shot here during February 1990.

The farm near Bredasdorp

A single springbok ewe was shot on a commercial farm situated approximately 30 km south-east of Bredasdorp, in the southern part of the Western Cape Province. The vegetation is classified as Coastal Fynbos and Coastal Renosterveld (Acocks 1988). In addition to springbok, eland and cattle are also present on the farm.

Collection and counting of parasites

The helminths of all these animals were collected, identified and counted as described by Boomker, Horak & De Vos (1989b). No digests of the abomasal and intestinal mucosae were done on the springbok from the farm near Bredasdorp.

RESULTS

For comparative purposes, the helminths are listed per locality and host rather than locality only. The helminths from eland from the Mountain Zebra and West Coast National Parks are listed in Table 1, those from mountain reedbuck from the Mountain Zebra and Karoo National Parks in Table 2 and those from springbok from all the localities in Table 3. Helminths from bontebok from the West Coast National Park are listed in Table 4 and those from gemsbok from the West Coast National Park in Table 5. Table 6 summarizes the host spectrum of the various helminths.

TABLE 1 The helminths recovered from eland in the Mountain Zebra and West Coast National Parks

Locality, number of hosts examined and helminth species	Number of helminths recovered			Prevalence %
	Larvae	Adults	Total	
Mountain Zebra National Park (*n* = 3)				
Haemonchus mitchelli	0	250	250	33,3
Nematodirus spathiger	0	1 750	1 750	33,3
Cooperia rotundispiculum race	0	4 750	4 750	33,3
Mean total burden	0	2 250	2 250	
West Coast National Park (*n* = 2)				
Bronchonema magna	0	0	6	50,0
Cooperia rotundispiculum race	0	35 603	35 603	100,0
Mean total burden	0	17 805	17 805	

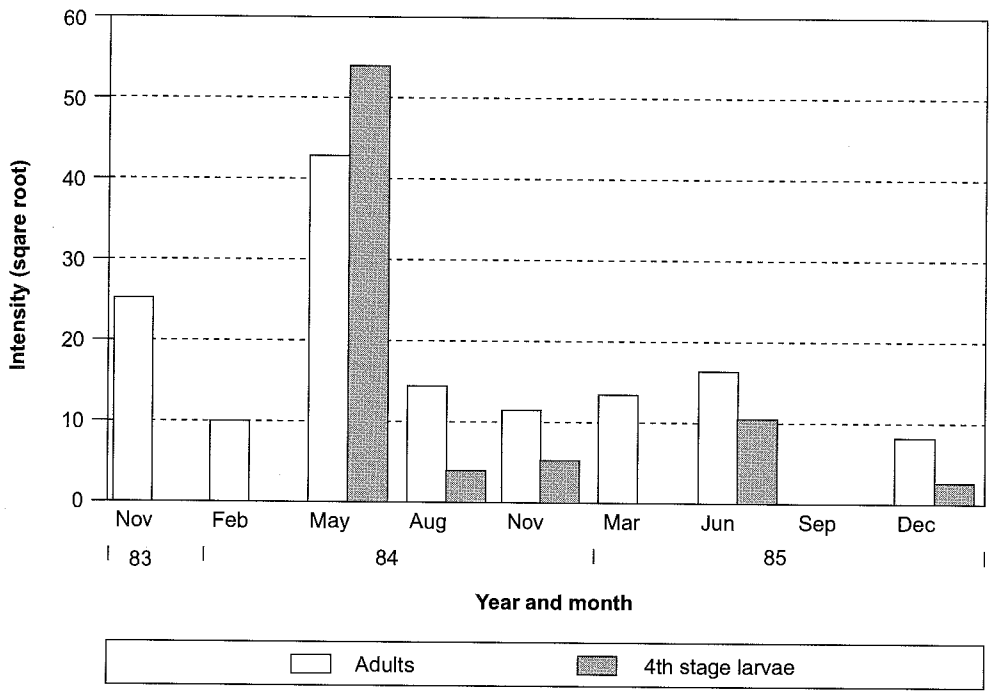

FIG. 1

Mean tri-monthly number of 4th stage and adult nematodes recovered from mountain reedbuck in the Mountain Zebra National Park. No helminths were recovered from the antelope shot during September 1985

TABLE 2 The helminths recovered from eland in the Mountain Zebra and Karoo National Parks

Locality, number of hosts examined and helminth species	Number of helminths recovered			Prevalence %
	Larvae	Adults	Total	
Mountain Zebra National Park (n = 18)				
Moniezia benedeni	[a]	2	2	5,5
Nematodirus spathiger	2 740	4 785	7 525	61,0
Ostertagia type females	–	1	1	5,5
Skrjabinema spp.	–	290	290	166,0
Trichostrongylus falculatus	0	20	20	5,5
Mean total nematode burden	152	283	435	
Karoo National Park (n = 2) No helminths were recovered	0	0	0	0

– Not applicable
[a] Do not occur in mountain reedbuck

Mountain Zebra National Park

The black wildebeest from this locality harboured a single *Taenia* sp. larva, one fourth stage *Haemonchus* sp. larva and 26 *Haemonchus* spp. females.

In eland the *Cooperia rotundispiculum* race was most numerous, accounting for 70 % of the adult nematode burden, followed by *Nematodirus spathiger* with 26 % (Table 1).

The red hartebeest harboured 1 725 *Nematodirus spathiger,* of which 325 were fourth stage larvae, as well as 100 *Trichostrongylus falculatus.* Both these nematodes are new parasite records for this host.

Four mountain reedbuck harboured no worms. The remaining 14 antelopes' burdens, including fourth stage larvae, varied from 1–7 600, the larger number occurring in a heavily pregnant female shot during May 1983. *Nematodirus spathiger* was present in 11 of the 14 mountain reedbuck that harboured worms, and was the only nematode species present in eight of the antelope. These nematodes accounted for 96 % of the number of adult nematodes present in these antelope (Table 2).

The seasonal distribution of the helminths recovered from mountain reedbuck during the November 1983 to December 1985 survey is graphically illustrated

TABLE 3 The helminths recovered from springbok in the Karoo, Mountain Zebra and West Coast National Parks, and on the farm near Bredasdorp

Locality, number of hosts examined and helminth species	Number of helminths recovered			Prevalence %
	Larvae	Adults	Total	
Mountain Zebra National Park ($n = 2$)				
Cooperioides antidorca	0	1 275	1 275	50
Haemonchus bedfordi	0	475	475	100
Longistrongylus albifrontis	0	89	89	50
Nematodirus spathiger	2 625	1 175	3 800	100
Ostertagia type females	–	25	25	50
Paracooperia serrata	0	1 175	1 175	50
Trichostrongylus falculatus	0	10 975	10 975	100
Mean total burden	1 313	7 595	8 908	
Karoo National Park ($n = 4$)				
Agriostomum equidentatum	0	40	40	25
Bronchonema magna	0	190	190	50
Cooperioides antidorca	0	30	30	25
Paracooperia serrata	0	145	145	75
Nematodirus spathiger	1 481	4 818	6 299	100
Trichostrongylus falculatus	0	996	996	100
Mean total burden	370	1 555	1 925	
West Coast National Park ($n = 2$)				
Bronchonema magna	0	58	58	100
Cooperia rotundispiculum race	0	160	160	50
Cooperioides antidorca	0	83	83	50
Longistrongylus curvispiculum	0	309	309	100
Longistrongylus namaquensis	0	298	298	100
Nematodirus spathiger	0	1 552	1 522	100
Paracooperia serrata	0	662	662	100
Trichostrongylus deflexus	0	905	905	100
Mean total burden	0	2 014	2 014	
The farm near Bredasdorp ($n = 1$)				
Bronchonema magna	–	30	30	100
Haemonchus bedfordi	[a]	60	60	100
Longistrongylus curvispiculum	[a]	3 880	3 880	100
Nematodirus spathiger	[a]	1 520	1 520	100
Ostertagia ostertagi	[a]	600	600	100
Trichostrongylus falculatus	[a]	120	120	100
Total burden	[a]	6 210	6 210	

– Not applicable
[a] Mucosal digests not done

in Fig. 1. With the exception of May 1984, when a peak burden of 1 875 nematodes was recorded, the tri-monthly mean burdens varied from 65–645 nematodes. No worms were recovered from the antelope examined during September 1985.

Trichostrongylus falculatus was the most numerous nematode in springbok, contributing 72% to the mean adult nematode burden, and together with *Cooperioides antidorca* (8%), *Nematodirus spathiger* (8%) and *Paracooperia serrata* (8%), accounted for 96% of the burden (Table 3).

Karoo National Park

Neither of the two black wildebeest nor the two mountain reedbuck examined in this park had any worms. One grey rhebuck harboured 50 *Nematodirus spathiger,* 20 of which were fourth stage larvae, while the other harboured only a single *Haemonchus bedfordi* male.

Nematodirus spathiger was the most numerous nematode in springbok, and contributed 77% to the mean total adult nematode burden, followed by *Trichostrongylus falculatus* with 16% (Table 3).

TABLE 4 The helminths recovered from two bontebok in the West Coast National Park

Helminth species	Number of helminths recovered			Prevalence %
	Larvae	Adults	Total	
Bronchonema magna	0	44	44	100
Cooperia rotundispiculum race	0	400	400	100
Haemonchus contortus	0	80	80	50
Longistrongylus curvispiculum	[a]	3 190	3 190	100
Longistrongylus namaquensis	[a]	170	170	50
Ostertagia type females	–	3 970	3 970	100
Ostertagia type larvae	5 483	–	–	100
Nematodirus spathiger	364	6 277	6 277	100
Teladorsagia circumcincta	[a]	335	335	100
Trichostrongylus axei	0	82	82	100
Trichostrongylus thomasi	0	230	230	100
Mean total burden	2 924	7 389	10 313	

[a] Larvae and females indistinguishable at species level and grouped together as *Ostertagia* type
– Not applicable

TABLE 5 The helminths recovered from two gemsbok in the West Coast National Park

Helminth species	Number of helminths recovered			Prevalence %
	Larvae	Adults	Total	
Bronchonema magna	0	10	10	100
Longistrongylus curvispiculum	0	101	101	50
Nematodirus spathiger	600	13 002	13 602	100
Ostertagia ostertagi	0	3 111	3 111	100
Trichostrongylus deflexus	0	345	345	50
Trichostrongylus falculatus	0	1 036	1 036	50
Trichostrongylus pietersei	0	1 781	1 781	100
Trichostrongylus rugatus	0	37 176	37 176	100
Trichostrongylus thomasi	0	219	219	50
Mean total burden	300	28 391	28 691	

West Coast National Park

The helminths collected from bontebok are listed in Table 4. The most abundant adult nematodes in this host were *Nematodirus spathiger,* which contributed 42 % to the mean total adult nematode burden, while the ostertagiid nematodes *Longistrongylus curvispiculum, Longistrongylus namaquensis, Teladorsagia circumcincta* and the *Ostertagia* type females together accounted for 52 %. The remaining nematodes occurred in small numbers.

The only gastro-intestinal nematode in eland from this park was *the Cooperia rotundispiculum* race, which occurred in large numbers (Table 1).

Trichostrongylus rugatus was the most numerous adult nematode in gemsbok (65 %) and together with *Nematodirus spathiger* (23 %), contributed 88 % of the mean total adult nematode population (Table 5).

Nematodirus spathiger accounted for 39 % of the adult nematodes in springbok, *Trichostrongylus deflexus* for 22 % and the remaining nematodes for 39 % (Table 3).

The farm near Bredasdorp

Longistrongylus curvispiculum accounted for 62 % of the adult nematode burden in the springbok, *Nematodirus spathiger* for 24 % and the remaining four nematode species for 14 % (Table 3).

DISCUSSION

Black wildebeest

Although a fairly common antelope species in the colder regions of the country, the helminths of black wildebeest have received little attention. Round (1968) recorded a trematode species, a larval *Taenia* sp. and five nematode species, Young, Zumpt, Boomker, Penzhorn & Erasmus (1973a) a *Haemonchus* sp. and an *Oesophagostomum* sp., and Horak

TABLE 6 The nematode species recovered per host species per locality

Helminth species	Mountain Zebra National Park					Karoo National Park					West Coast National Park			Farm		Number of host species infected
	Connochaetes gnou	*Taurotragus oryx*	*Redunca fulvorufula*	*Pelea capreolus*	*Alcelaphus buselaphus*	*Antidorcas marsupialis*	*Connochaetes gnou*	*Redunca fulvorufula*	*Pelea capreolus*	*Antidorcas marsupialis*	*Damaliscus pygargus dorcas*	*Oryx gazella*	*Taurotragus oryx*	*Antidorcas marsupialis*	*Antidorcas marsupialis*	
Agriostomum equidentatum	–	–	–	–	–	–	–	–	–	+	–	–	–	–	–	1
Bronchonema magna	–	–	–	–	–	–	–	–	–	+	+	+[a]	+[a]	+	+	4
Cooperia rotundispiculum	–	+	–	–	–	–	–	–	–	–	+[a]	–	+[a]	+[a]	–	3
Cooperioides antidorca	–	–	–	–	–	+	–	–	–	+	–	–	–	+	–	1
Haemonchus sp.	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1
Haemonchus bedfordi	–	–	–	–	–	+	–	–	+[a]	–	–	–	–	–	+	2
Haemonchus contortus	–	–	–	–	–	–	–	–	–	–	+	–	–	–	–	1
Haemonchus mitchelli	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	1
Longistrongylus albifrontis	–	–	–	–	–	+	–	–	–	–	–	–	–	–	–	1
Longistrongylus curvispiculum	–	–	–	–	–	–	–	–	–	–	+	+[a]	–	–	+	3
Longistrongylus namaquensis	–	–	–	–	–	–	–	–	–	–	+	–	–	+	–	2
Nematodirus spathiger	–	+[a]	+	–	+[a]	+	–	–	+	+	+	+	–	+	+	7
Ostertagia ostertagi	–	–	–	–	–	–	–	–	–	–	–	+[a]	–	–	+	2
Ostertagia type females	–	–	+	–	–	+	–	–	–	–	+	–	–	–	–	3
Paracooperia serrata	–	–	–	–	–	+	–	–	–	+	–	–	–	+	–	1
Skrjabinema sp.	–	–	+	–	–	–	–	–	–	–	–	–	–	–	–	1
Teladorsagia circumcincta	–	–	–	–	–	–	–	–	–	–	+	–	–	–	–	1
Trichostrongylus axei	–	–	–	–	–	–	–	–	–	–	+	–	–	–	–	1
Trichostrongylus deflexus	–	–	–	–	–	–	–	–	–	–	–	+[a]	–	+	–	2
Trichostrongylus falculatus	–	–	+[a]	–	+[a]	+	–	–	–	+	–	+	–	–	+	4
Trichostrongylus pietersei	–	–	–	–	–	–	–	–	–	–	–	+[a]	–	–	–	1
Trichostrongylus rugatus	–	–	–	–	–	–	–	–	–	–	–	+	–	–	–	1
Trichostrongylus thomasi	–	–	–	–	–	–	–	–	–	–	+	+[a]	–	–	–	2
Number of helminth species per host	1	3	4	0	2	7	0	0	2	6	10	9	2	8	6	

[a] New record

et al. (1983) *Haemonchus bedfordi, Oesophagostomum columbianum,* a *Trichuris* sp. and a *Thysaniezia* sp.

The single *Taenia* sp. larva recovered in the black wildebeest in the Mountain Zebra National Park could not be assigned to a species. Gough (1908) and Ortlepp (1961) recorded larval *Taenia hydatigena* in black wildebeest. Horak *et al.* (1983) did not find any larval cestodes in ten black wildebeest from a nature reserve in the Free State and another in Gauteng but found 34,5 % of 55 blue wildebeest, *Connochaetes taurinus,* in the Kruger National Park to be infected with the larval stages of *Taenia regis.*

The nematode burden of the black wildebeest examined in this survey is extremely low when compared with that recorded by Horak *et al.* (1983). This probably is a reflection of the adverse climatic conditions, namely hot summers and cold winters with little rainfall during either season, in both the Mountain Zebra and the Karoo National Parks. In addition, wildebeest's apparent resistance to parasite infections (Horak *et al.* 1983) may also have played a role.

Bontebok

The helminths of bontebok have thus far only been studied in the Bontebok National Park, and Boomker & Horak (1992) summarized the findings of several authors.

The only cestodes that have been recovered from these animals are *Moniezia expansa* (Boomker & Horak 1992) and a single *Taenia hydatigena* larva (Verster, Imes & Smit 1975). No cestodes were recovered from the two bontebok in the West Coast National Park.

We assume that a *Cooperia rotundispiculum* race, typical *Haemonchus contortus, Teladorsagia circumcincta* and *Trichostrongylus thomasi* were acquired from other antelope, especially springbok and eland or gemsbok, in the West Coast National Park since they did not occur in the Bontebok National Park. *Cooperia rotundispiculum* is a new parasite record for bontebok.

The mean adult nematode burden of bontebok surveyed in the Bontebok National Park during 1975, 1976 and 1979 was 6 787 (Horak, Brown, Boomker, De Vos & Van Zyl 1982b), while the mean adult nematode burden was 5 661 in the survey conducted during 1983–1984 (Boomker & Horak 1992). The bontebok from the West Coast National Park harboured a mean of 10 313 adult nematodes. We believe that the larger burden is due to the climatic conditions, the West Coast National Park being further in the winter rainfall region than the Bontebok Park, and the number of other host species present in this park.

Eland

Eland have also not to any significant degree been subject to parasite surveys in recent years. Round (1968) lists only one cestode and five nematode species from this host, and Mares, Amaral & Fachada (1984) two cestode genera and a nematode species from two eland in the former Republic of Transkei, now part of the Eastern Cape Province.

Nematodirus spathiger, Bronchonema magna and a race of *Cooperia rotundispiculum* constitute new parasite records for eland. *Bronchonema magna* was in all probability acquired from the springbok, which is the preferred host, while the other two species could have been acquired from any of the other antelopes present in the reserves.

Mares *et al.* (1984) do not record the actual numbers of nematodes recovered from the eland they examined and no other records of helminth burdens in eland could be found. The eland from the West Coast National Park harboured about eight times the mean number of nematodes of those in the Mountain Zebra National Park. We presume that these differences are largely due to the climate and stocking rates.

Grey rhebuck

As with the bontebok, the helminths of grey rhebuck have only been studied in the Bontebok National Park, and Boomker & Horak (1992) have summarized the findings of several authors.

Haemonchus bedfordi is a new parasite record for grey rhebuck and, as only one nematode was found in one of the antelope, it should be considered an accidental parasite.

The helminth burdens of these antelope in the Karoo National Park are insignificant and no comparison with the burdens of the antelope from the Bontebok National Park is possible.

Gemsbok

Although gemsbok are common in the more arid areas of South Africa, and are popular antelope with game farmers and hunters, few helminth surveys have been conducted on them. Round (1968) lists larval *Taenia hydatigena,* a cestode species and four nematode species as occurring in gemsbok in South Africa. Mares *et al.* (1984) list *Fasciola hepatica* and *Haemonchus contortus* from three antelope in the then Republic of Transkei. Gemsbok in the National Kalahari Gemsbok Park harboured *Agriostomum equidentatum, Haemonchus contortus, Longistrongylus meyeri, Paracooperia serrata, Impalaia nudicollis* and *Strongyloides* sp., all of which are parasites more commonly encountered in springbok (Boomker, Horak & De Vos 1986). Fourie, Vrahimis, Horak,

Terblanche & Kok (1991) recorded a cestode genus and the larvae of *Taenia* spp., as well as the larval stages of two nematode genera, the adults of four nematode genera and 13 nematode species from gemsbok introduced into the Willem Pretorius Nature Reserve in the Free State.

In the West Coast National Park, the gemsbok harboured a large variety of nematodes. Of these, *Nematodirus spathiger* and *Trichostrongylus rugatus* should be considered as definitive parasites, while *Ostertagia ostertagi, Trichostrongylus falculatus* and *Trichostrongylus pietersei* are occasional parasites. *Longistrongylus curvispiculum* and *Trichostrongylus deflexus* should be regarded as accidental parasites since they occurred in small numbers in only one of the gemsbok. New parasite records for gemsbok are *Bronchonema magna, Longistrongylus curvispiculum, Ostertagia ostertagi, Trichostrongylus deflexus, Trichostrongylus pietersei* and *Trichostrongylus thomasi.*

The gemsbok from the Kalahari National Gemsbok Park harboured 5 877 intestinal helminths (Boomker *et al.* 1986), those from the Willem Pretorius Nature Reserve a mean of 1 497 (Fourie *et al.* 1991) and those from the West Coast National Park a mean of 28 681 intestinal nematodes. We are of the opinion that the large burdens of the last named antelope are mainly due to climatic conditions and stocking rates.

Mountain reedbuck

The helminths of mountain reedbuck are also not well known despite this antelope's relative abundance in southern Africa.

Gough (1908) records a *Taenia* sp. larva, Veglia (1919) *Paramphistomum bothriophoron, Paramphistomum cervi* and *Haemonchus contortus,* Thwaite (1927) *Setaria boulengeri,* and Mönnig (1924) *Setaria hornbyi.* Ortlepp (1961) mentions only *Setaria boulengeri* and Baker & Boomker (1973) recovered ten nematode species, three nematode genera, *Paramphistomum* spp. (*sic*) and the larval stages of *Taenia* spp. from mountain reedbuck in the Loskop Dam Nature Reserve in the then Transvaal (now Mpumalanga). In addition, Baker & Boomker (1973) and Young *et al.* (1973a) found *Haemonchus* sp., *Nematodirus spathiger, Setaria boulengeri* and *Moniezia expansa* from these antelope in the Mountain Zebra National Park.

Moniezia benedeni and *Trichostrongylus falculatus* are new parasite records for mountain reedbuck.

Baker & Boomker (1973) recorded 1 107 nematodes from the small intestine of mountain reedbuck shot in the Loskop Dam Nature Reserve. Young *et al.* (1973a) did not record the numbers of helminths recovered from mountain reedbuck from the Mountain Zebra National Park but the mean adult nematode burden of the antelope from the same locality examined in this study was 283, which is negligible.

Comment: The identifications of *Paramphistomum* spp. in these antelope should be treated with reserve. According to Eduardo (1983), the genus *Paramphistomum* in Africa is limited to *Paramphistomum cephalophi,* from *Cephalophus nigrifrons* in Rwanda. *Paramphistomum bothriophoron* has been transferred to the genus *Calicophoron* (Eduardo 1983) while *Paramphistomum cervi* is in all probability a misidentification.

Red hartebeest

As with the gemsbok, red hartebeest are antelope that prefer the drier parts of the country. Few helminths have been recorded from these animals, and Ortlepp (1961) lists two trematode and five nematode species. Mares *et al.* (1984) added two cestode genera, three nematode genera and two nematode species, while Boomker *et al.* (1986) added *Impalaia nudicollis* and a *Parabronema* sp. to the list. *Nematodirus spathiger* and *Trichostrongylus falculatus* are new parasite records for these antelope.

Boomker *et al.* (1986) found 1 774 helminths in the red hartebeest from the Kalahari Gemsbok National Park, which is comparable to the 1 825 recorded from these antelope from the Mountain Zebra National Park.

Springbok

The helminths of springbok have been well documented by Ortlepp (1961), Round (1968), Young, Zumpt, Basson, Erasmus, Boyazoglu & Boomker (1973b), Horak, Meltzer & De Vos (1982a), De Vos (1982a), De Villiers, Liversidge & Reinecke (1985) and Boomker *et al.* (1986). A cestode genus, a cestode species and two larval cestodes, one trematode species, and 27 nematode species and four nematode genera have thus far been recovered.

De Villiers *et al.* (1985) recorded helminth burdens ranging from 2 954–12 224 in springbok from the Northern Cape Province. Horak *et al.* (1982a) found springbok in the Bontebok National Park to harbour 7 129–17 819 nematodes, those from Gauteng 2 563–11 585, and those from the Northwest Province 12 449–71 790. The numbers of fourth stage larvae often exceeded those of the adults nematodes. In the surveys conducted by De Villiers *et al.* (1985) and Horak *et al.* (1982), *Paracooperia serrata* was the most common nematode. The springbok from the Karoo and West Coast National Parks had insignificant numbers of this helminth and *Nematodirus spathiger* was the most commonly encountered parasite in both parks.

Ostertagia ostertagi from the antelope from the farm near Bredasdorp and *Cooperia rotundispiculum* from

the antelope in the West Coast National Park are new parasite records for springbok.

A summary of the host associations and the number of helminth species per host per locality are presented in Table 6. From this table it is apparent that bontebok in the West Coast National Park harboured the greatest number of nematode species (ten) followed by gemsbok (nine) and springbok (eight) at the same locality. Springbok in the Mountain Zebra National Park had seven species of nematodes and these antelope in the Karoo National Park and on the farm near Bredasdorp had six species. We believe that the number of antelope species in the West Coast National Park influenced the variety and the numbers of the helminths recovered from them.

Helminths

Although *Bronchonema magna* was originally described from blesbok, *Damaliscus pygargus phillipsi* by Mönnig (1932), it seems to be equally common in springbok (Ortlepp 1962) and bontebok (Verster *et al.* 1975; Horak *et al.* 1982b). However, it seems springbok are the preferred host of these nematodes and they tend to disappear from other antelope when springbok are removed from an area, as discussed by Boomker & Horak (1992). Since the nematodes occurred only in springbok in the Karoo National Park, but in all four the antelope species in the West Coast National Park, we believe that the presence of springbok in the West Coast National Park is undesirable.

Nematodirus spathiger is well-adapted to the semi-arid regions (Viljoen 1969). Since the infective third stage larvae occur within the egg and only hatch after good rain, massive infections are possible (Reinecke 1983). It appears to be a definitive parasite of all the hosts examined in this survey. As is evident from Table 5, gemsbok in the West Coast National Park seem to be especially good hosts.

Both *Trichostrongylus axei* and *Trichostronglylus thomasi* were recovered from the abomasum of both the bontebok in the West Coast National Park. The latter nematode represents a new parasite record for bontebok and usually fills the niche in antelope that *Trichostrongylus axei* occupies in domestic ruminants. Previous records of *T. thomasi* are from animals in the Kruger National Park and its surrounds, Mpumalanga (Horak *et al.* 1983; Boomker *et al.* 1989b), impala and red duiker in north-eastern KwaZulu-Natal (Boomker, Horak, Flamand & Keep 1989a; Boomker, Horak & Flamand 1991b), springbok near Lichtenburg, Northwest Province (Horak *et al.* 1982a) and kudu in the Etosha Game Reserve, Namibia (Boomker, Anthonissen & Horak 1988). All these localities are more than 1 000 km north of the West Coast National Park and it seems likely that this nematode was introduced into this park with one of the host species, probably gemsbok.

Trichostrongylus rugatus is a common parasite of domestic sheep and goats in the southern Eastern and Western Cape Province (Boomker *et al.* 1989c; Horak, Knight & Williams 1991; Reinecke, Kirkpatrick, Swart, Kriel & Frank 1987) and appears to be equally well adapted to gemsbok.

CONCLUSION

The danger of translocating antelope to small game reserves without prior anti-parasitic treatment has been pointed out by Horak (1980). Similarly, the translocation of antelope to climatic or vegetation regions where they normally did not occur can also be dangerous. We believe that a potentially hazardous situation exists in the West Coast National Park, where the climatic conditions appear to be favourable for the worms but cause stress especially in gemsbok and bontebok. For example, gemsbok in the Kalahari Gemsbok National Park harboured a total of 5 877 nematodes, including fourth stage larvae (Boomker *et al.* 1986), while those in the Free State harboured approximately 2 866 (Fourie *et al.* 1991). The mean burden of the antelope in the West Coast National Park was 28 691, which is 4,9–10 times as many worms.

A similar situation occurred in bontebok when they were kept near the town of Bredasdorp. They did not grow or reproduce well and harboured large numbers of parasites (Van der Walt & Ortlepp 1960). They were then moved to the current locality, near Swellendam, where their numbers increased and, presumably, their parasite loads declined.

As far as the helminths are concerned, a similar situation seems to develop in the West Coast National Park. Antelope in the Bontebok National Park harboured a mean of 1 722 adult trichostrongylids during the 1979 survey (Horak *et al.* 1982b) and 5 382 during the 1983/84 survey (Boomker & Horak 1992), *Nematodirus spathiger* being the most common nematode in both surveys. The mean number of adult helminths in the two bontebok in this survey was 7 389, the majority of which were ostertagiid nematodes of the genus *Longistrongylus.* The latter nematode genus is considered more pathogenic than *Nematodirus,* since they occur in the abomasum where they cause lesions similar to those of *Ostertagia* spp. and *Teladorsagia* spp. of cattle and sheep (Pletcher, Horak, De Vos & Boomker 1984). In addition, the forced association of antelope lends itself to cross infection. The occurrence of *Bronchonema* in gemsbok and eland can only be ascribed to the presence of springbok, while *Cooperia rotundispiculum* in springbok, eland and bontebok is the direct result of sharing pastures with eland. The *Cooperia* spp. are generally considered harmless in well-fed adult animals (Reinecke 1983), but *Bronchonema* may in time cause the death of some of the antelope.

ACKNOWLEDGEMENTS

We thank the Board of Trustees, South African National Parks, for making the antelope available to us, the staff of the various National Parks for their valued and excellent assistance with processing the animals and Mr Mick Dalton, owner of the farm near Bredasdorp for making the springbok available. This work was done with the partial financial assistance of the Foundation for Research Development (now the National Research Foundation).

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J. Parasitol., 91(4), 2005, pp. 863–870

HELMINTHS IN SYMPATRIC POPULATIONS OF MOUNTAIN REEDBUCK (*REDUNCA FULVORUFULA*) AND GRAY RHEBOK (*PELEA CAPREOLUS*) IN SOUTH AFRICA

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ABSTRACT: Helminths of mountain reedbuck (*Redunca fulvorufula fulvorufula*) and gray rhebok (*Pelea capreolus*) were investigated in South Africa between June 1999 and February 2002. Forty-one mountain reedbuck were culled at Sterkfontein Dam Nature Reserve over 8 different periods, and 25 mountain reedbuck were culled at Tussen die Riviere Nature Reserve over 3 different periods. A total of 17 kinds of helminths were found at the 2 sites, including 15 nematodes, 1 trematode, and 1 cestode. At Sterkfontein, the most prevalent and abundant species were *Cooperia yoshidai*, *Longistrongylus schrenki*, and *Haemonchus contortus*, with the latter 2 being more abundant during November/December than at other times of the year, probably because infective larvae increased on pasture at that time. No statistical differences were found in parasite loads between male and female mountain reedbuck. No correlation was found between fecal egg counts and adult worm counts or between parasite counts and body condition. At Tussen die Riviere, helminths in mountain reedbuck were less prevalent and abundant than at Sterkfontein. The most important species were *Nematodirus spathiger*, *Trichostrongylus falculatus*, and *Cooperia rotundispiculum*. Four gray rhebok died of natural causes at Sterkfontein, from which 5 kinds of helminths were recovered, including *C. yoshidai* and *Paracooperioides peleae*.

Southern mountain reedbuck (*Redunca fulvorufula fulvorufula*) and gray rhebok (*Pelea capreolus*) use rocky hillsides, steep grasslands, and mountain slopes that form marginal habitat for most other ungulate species in South Africa (Skinner and Smithers, 1990). In many areas, they are sympatric but maintain separate ecological niches in feeding and social habits. Mountain reedbucks are selective grazers and have social structures, including solitary and territorial males, unstable female herds with young, and bachelor groups (Irby, 1979; Dunbar and Roberts, 1992). Gray rhebok are browsers, feed mostly on forbs (Beukes, 1984; Ferreira and Bigalke, 1987), and form stable harem herds in which a dominant male permanently maintains a small group of females and young. Males without territories remain solitary (Esser, 1973; Ferreira and Bigalke, 1987).

The present study formed part of a wider project investigating factors influencing productivity in the 2 species. Mountain reedbuck have the potential to be cropped for meat production. They are fecund; produce good-quality, edible meat; and because they use marginal habitat, do not generally compete with other grazers (Irby, 1979; Skinner, 1980). Gray rhebok are less likely candidates for commercial meat production, because they are less common, are difficult to hunt, and are not favored for consumption (Skinner and Smithers, 1990). They are, however, highly marketable for trophy hunting.

Numerous fitness traits may be negatively affected by parasitic infections, including productivity (Wilson et al., 2002). The degree to which parasite effects translate into changes to host populations likely will depend on many factors, including dispersion of parasites among hosts, magnitude of parasite effects, and degree to which ages and sexes differ in parasitism (Schalk and Forbes, 1997).

The parasites of mountain reedbuck are not well known, despite the relative abundance of these antelopes in South Africa (Boomker et al., 2000). Baker and Boomker (1973) found 17 helminth species (14 nematodes, 2 cestodes, and 1 trematode) in mountain reedbuck at 2 sites within South Africa, but to our knowledge, no seasonal or gender differences have been investigated. The parasites of gray rhebok are even less well known (Boomker et al., 2000), with 12 nematode and 1 trematode species being found at a single site (Boomker et al., 1981; Horak et al., 1982).

The aim of the present study was to identify and quantify helminths of mountain reedbuck and gray rhebok as well as to investigate effects of season, host age, and host gender on the occurrence and numbers of parasites. Because helminths from both antelopes are poorly known, the present study provides additional helminthological data from new localities.

MATERIALS AND METHODS

Study sites

The present study was conducted at 2 Provincial Nature Reserves within the Free State Province of South Africa. Sterkfontein Dam Nature Reserve (hereafter Sterkfontein; 28°24′S, 29°02′E) has a total land area of 11,000 ha and an altitude varying between 1,700 and 2,350 m. It has a mild climate, with an average temperature of 17 C and average summer rainfall of 680 mm. Occasional snow and frequent burning have a major influence on the vegetation. Sterkfontein falls mainly within the Moist Cool Highveld Grassland (Bredenkamp and van Rooyen, 1996) and, in pristine condition, is dominated by the grass *Themeda triandra*.

Tussen die Riviere Nature Reserve (hereafter TdR; 30°30′S, 26°07′E) has an area of 22,000 ha, with an altitude varying between 1,200 and 1,500 m. Mean temperatures are 18 C, and annual summer rainfall averages 420 mm. The TdR falls in the Eastern Mixed Nama Karoo (Hoffman, 1996) and has a complex mix of grass- and shrub-dominated vegetation types.

Study animals

Culling schedules of mountain reedbuck differed between the 2 sites as a result of differing management programs. At Sterkfontein, 41 animals were culled over a 2-yr period. Eight separate culls were carried out at 3-mo intervals, with approximately 5 animals culled during each of the following months: March, June, September, and December 2000; May, August, and November 2001; and February 2002. In a typical culling period, 2 adult males, 2 adult females, and 1 juvenile of either sex were selected without knowledge of their age (aside from adult/juvenile status) and body condition. In addition to parasite extraction, the approximate age of each animal was estimated using body mass and dentition. Female reproductive condition also was established, and the body condition of each animal was determined using the kidney fat index (KFI), where KFI = (kidney fat wt/kidney wt)·100 (Riney, 1955).

Received 20 July 2004; revised 28 October 2004; accepted 1 November 2004.
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TABLE I. Prevalence and abundance of helminths recovered from 41 mountain reedbuck culled at Sterkfontein Dam Nature Reserve between March 2000 and February 2002.*

Nematode genera and some species	Prev. (%)	Site in host	Mean (n)	SD (n)	Range (n)
Calicophoron sp. (T)	5	Rum	6.1	27.8	0–150
Haemonchus sp. L4 (N)	32	Abo	21.4	61.9	0–350
Haemonchus contortus (N)	66	Abo	115.8	218.2	0–1,050
Longistrongylus sp. L4 (N)	44	Abo	72.9	135.0	0–470
Longistrongylus schrenki (N)‡	80	Abo	36.5	56.8	0–230
Longistrongylus namaquensis (N)‡	2	Abo	0.2	1.6	0–10
Ostertagia sp. (N)‡	2	Abo	0.2	1.6	0–10
Cooperia sp. L4 (N)	66	SI	312.3	682.3	0–4,050
Cooperia yoshidai (N)	98	SI	2,037.5	2,594.2	0–14,880
Cooperia pigachei (N)†	2	SI	3.7	23.4	0–150
Trichostrongylus falculatus (N)	12	SI	5.4	26.7	0–170
Trichostrongylus deflexus (N)‡	2	SI	0.2	1.6	0–10
Impalaia nudicollis (N)‡	2	SI	0.5	3.1	0–20
Paracooperioides peleae (N)‡	2	SI	0.2	1.6	0–10
Skrjabinema sp. (N)	39	LI	187.9	1,140.4	0–7,310
Moniezia sp. (C)	5	SI	0.1	2.0	0–10

* Prev., prevalence; SD, standard deviation; T, trematode; N, nematode; C, cestode; L4, fourth larval stage; Rum, rumen; Abo, abomasum; SI, small intestine; LI, large intestine.
† New species.
‡ New parasite record.

At TdR, 25 mountain reedbucks were culled over 3 separate time periods: December 1999, June 2000, and June 2001. Most of the animals were culled at night using spotlights and, therefore, were selected randomly. Approximate age, reproductive status, and KFI were determined.

Gray rhebok were not culled for meat production, and although they are occasionally used for trophy hunting, no systematic removal occurred during the present study. Therefore, parasite collection was only carried out from 4 animals that died naturally at Sterkfontein and, as a result, was only useful for limited helminth species identification.

Recovery of alimentary helminths

Rumens were opened and examined for paramphistomes. Parasites of the abomasa, small intestines, large intestines (including ceca), lungs, liver, and heart were collected as described by Horak (1978c). Aliquots representing one-tenth of the volume of each ingesta were collected for microscopic examination and stored in 70% ethanol. Species were identified using species descriptions (Boomker, 1977, 1991; Boomker et al., 1981; Gibbons, 1981; Boomker and Reinecke, 1989). Male nematodes were identified to the species level, and in most cases, females also could be identified to the species level by extrapolation. For cases in which male nematodes were not present, females were identified to the genus level only. Trematodes and cestodes were identified to the generic level only.

TABLE II. Prevalence and abundance of helminths recovered from 25 mountain reedbuck at Tussen die Riviere Nature Reserve between December 1999 and June 2001.*

Nematode genera some species	Prev. (%)	Site in host	Mean (n)	SD (n)	Range (n)
Calicophoron sp. (T)	4	Rum	2.0	12.5	0–80
Haemonchus contortus (N)	28	Abo	4.0	10.2	0–50
Longistrongylus albifrontis (N)	8	Abo	0.3	2.1	0–10
Nematodirus spathiger (N)	58	SI	15.1	22.5	0–100
Trichostrongylus falculatus (N)	31	SI	29.6	70.0	0–240
Cooperia rotundispiculum (N)†	31	SI	19.3	64.2	0–320
Cooperia yoshidai (N)	4	SI	0.4	2.0	0–10
Impalaia nudicollis (N)†	8	SI	1.7	6.0	0–30
Skrjabinema sp. (N)	4	LI	0.4	2.0	0–10
Setaria sp. (N)	4	Vis	0.1	0.2	0–1
Moniezia sp. (C)	4	SI	0.4	2.0	0–10

* Prev., prevalence; SD, standard deviation; T, trematode; N, nematode; C, cestode; Rum, rumen; Abo, abomasum; SI, small intestine; LI, large intestine; Vis, visceral cavity.
† New parasite record.

Fecal egg counts and larval culture

Feces were collected from 18 culled mountain reedbuck and from live gray rhebok at Sterkfontein. From the latter, feces were collected fresh off the ground twice a month from 5 animals between September 2001 and April 2002. Egg counts were carried out using the McMaster method (Reinecke, 1983) ("Eggs-Acto" McMaster egg counting chamber; Focal Point, Pretoria, South Africa; http://www.mcmaster.co.za), but no attempt was made to identify species. The remaining feces were used to culture larvae (Reinecke, 1983), which were harvested and counted after 10 and 14 days from each sample.

Statistical methods

Two-way ANOVAs were used to test for differences in parasite burdens in mountain reedbuck between genders and months. As with most parasite population data, the nematodes were strongly aggregated, so the data had to be $\log_{10}$ transformed. Because the occurrence of 1 species of nematode in the GIT was not dependent on or affected by the occurrence of another species, it was not of interest to test for differences between nematode species. Therefore, 3 separate 2-way ANOVAs were carried out for the 3 main nematode species. One-way ANOVA and Kruskal–Wallis ANOVA on ranks were used to test for differences in parasite loads of animals of different ages and females with varying degrees of pregnancy. Spearman rank-correlation coefficients were used to determine whether a correlation existed between the number of nematodes extracted and the KFI of each animal and to compare fecal egg counts with cultured larvae counts and adult worm counts.

RESULTS

Helminth species prevalence and abundance

Seventeen kinds of helminths, including 15 nematodes, 1 trematode, and 1 cestode, were recovered from mountain reedbuck at Sterkfontein and TdR (Tables I, II). At Sterkfontein, a

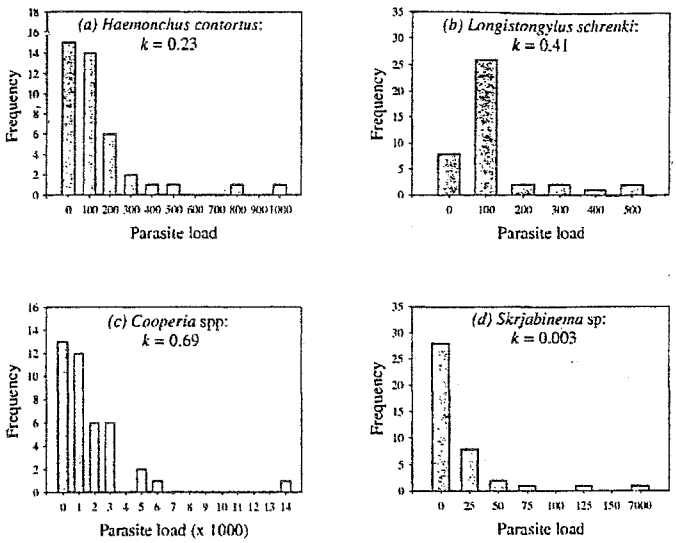

FIGURE 1. Observed frequency distributions of (a) *Haemonchus contortus*, (b) *Longistrongylus schrenki*, (c) *Cooperia* spp., and (d) *Skrjabinema* sp. found in 41 mountain reedbuck culled at Sterkfontein Dam Nature Reserve between March 2000 and February 2002. *k*, corrected moment estimate for aggregation.

new species of *Cooperia*, *Cooperia pigachei*, was found (Boomker and Taylor, 2004), and 6 new parasite records were established. At TdR, 2 new parasite records were established, and nematodes were less prevalent and abundant than at Sterkfontein.

Frequency distributions of nematodes at Sterkfontein

Figure 1 shows the frequency distributions of the 4 most common nematode species found in mountain reedbuck at Sterkfontein. All were highly aggregated. The degree of aggregation was tested using the corrected-moment estimate of *k* (Wilson et al., 2002):

$$k = (m^2 - s^2/n)/(s^2 - m)$$

where m = mean, s^2 = variance, and n = sample size.

Abomasum nematodes at Sterkfontein

Figure 2 shows seasonal variation in *Haemonchus contortus* and *Longistrongylus schrenki*. Differences between genders and between months (not seasons) in the numbers of *H. contortus* were tested for using a 2-way ANOVA. We found strong evidence for a difference in the number of parasites between months (ANOVA: $F = 5.352$, df = 7, $P < 0.001$), but we found no evidence for a difference between males and females (ANOVA: $F = 0.365$, df = 1, $P = 0.551$). Multiple pairwise comparisons using the Tukey test indicated that numbers of *H. contortus* were higher in December than in May, June, August, and September. We found marginal evidence for an interaction (ANOVA: $F = 2.044$, df = 7, $P = 0.089$). Males had more *H. contortus* than females in the autumn and winter, whereas females had more *H. contortus* than males in the spring and summer.

For *L. schrenki*, differences between genders and between months also were tested using a 2-way ANOVA. We found some evidence for a difference between months (ANOVA: $F = 2.464$, df = 7, $P = 0.045$), but we found no evidence for a difference between genders (ANOVA: $F = 0.025$, df = 1, $P = 0.875$) and no interaction (ANOVA: $F = 1.405$, df = 7, $P = 0.247$). Multiple pairwise comparisons using the Tukey test indicated that numbers of *L. schrenki* were higher in females in December than in February.

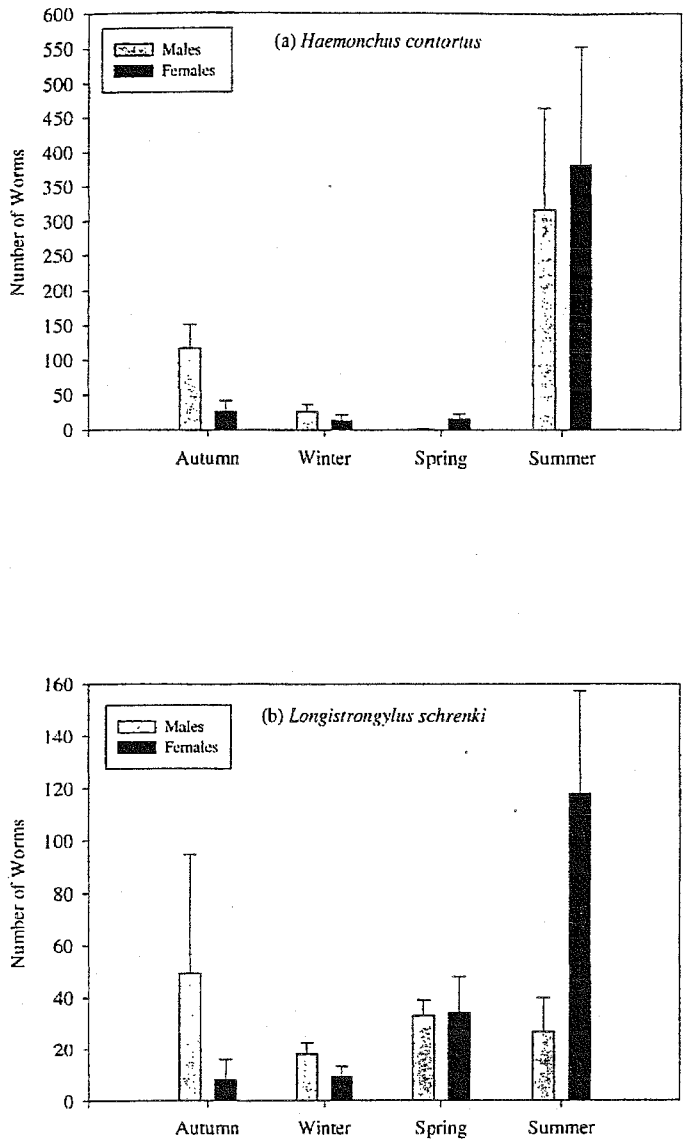

FIGURE 2. Seasonal variation in (a) *Haemonchus contortus* and (b) *Longistrongylus schrenki* in the abomasums of 20 male and 21 female mountain reedbuck at Sterkfontein Dam Nature Reserve. Numbers of animals per gender and per season varied between 4 and 6 (mean = 5). Error bars represent the standard error. Autumn, February/March; winter, May/June; spring, August/September; summer, November/December.

Small intestine nematodes at Sterkfontein

Seasonal variations in *Cooperia* spp. are shown in Figure 3. A 2-way ANOVA comparing variation in numbers of *Cooperia* spp. found no evidence for any differences between genders (ANOVA: $F = 0.050$, df = 1, $P = 0.825$) or between months (ANOVA: $F = 0.435$, df = 7, $P = 0.871$).

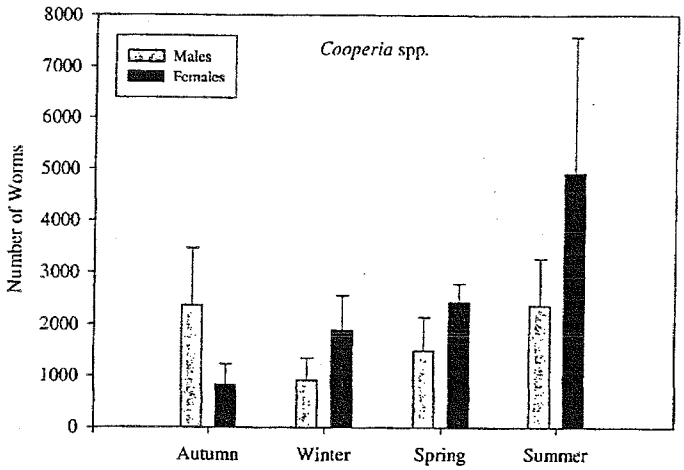

FIGURE 3. Seasonal variation in *Cooperia* spp. in the small intestines of 20 male and 21 female mountain reedbuck at Sterkfontein Dam Nature Reserve. Numbers of animals per gender per season varied between 4 and 6 (mean = 5). Error bars represent the standard error. Autumn, February/March; winter, May/June; spring, August/September; summer, November/December.

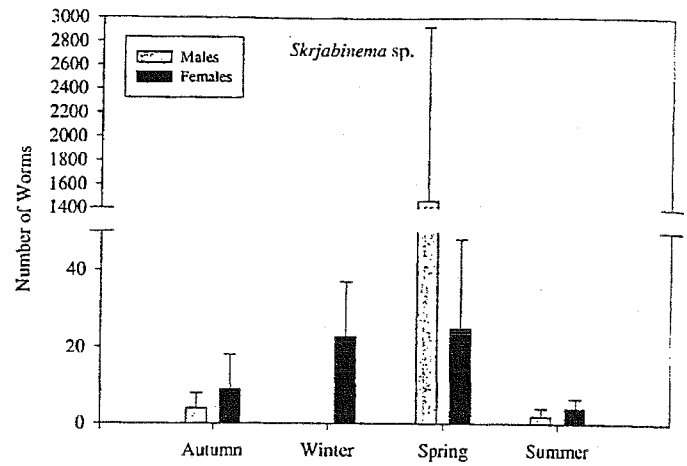

FIGURE 4. Seasonal variation in *Skrjabinema* sp. in the large intestines of 20 male and 21 female mountain reedbuck at Sterkfontein Dam Nature Reserve. Numbers of animals per gender per season varied between 4 and 6 (mean = 5). Error bars represent the standard error. Autumn, February/March; winter, May/June; spring, August/September; summer, November/December.

Large intestine nematodes at Sterkfontein

Skrjabinema sp. occurred at very low numbers in mountain reedbuck at Sterkfontein (Fig. 4). The relatively very large numbers of worms found in males during the spring compared to the other seasons resulted from the occurrence of a large number of worms in only 1 animal. No statistical analysis of differences between genders and between months was attempted.

Age differences

Analysis of the effect of age on parasite distributions in mountain reedbuck at Sterkfontein was limited, because only a small number of young and old animals were sampled. For mountain reedbuck, variation in abundance of *H. contortus* and *Cooperia* spp. were tested for in 3 different age classes. These included animals less than 25 kg (juveniles), animals between 25 and 30 kg (young adults), and animals greater than 30 kg (adults > 2.5 yr). Data for males and females were pooled, both because no statistical differences were found between them and because the sample size was too small to keep them separate. We found no evidence for any differences between the age groups for either *H. contortus* ($H = 1.695$, df = 2, $P = 0.429$) or *Cooperia* spp. ($H = 2.426$, df = 2, $P = 0.297$).

Host body condition

We determined the KFI for each culled mountain reedbuck at Sterkfontein and compared these values with the numbers of nematodes harbored by each animal in the abomasums, small intestines, and large intestines (Fig. 5). A Spearman rank-correlation coefficient found no evidence for a correlation between the numbers of parasites in either the abomasum or small intestine with KFI (abomasum: $r = -0.13$, $P = 0.435$; small intestine: $r = 0.03$, $P = 0.843$). The large intestine was not tested.

Nematodes and pregnancy

Variation in the number of nematodes found in females at varying stages of pregnancy was tested. Comparisons were made between nonpregnant females, pregnant females within the first half of gestation, pregnant females within the second half of gestation, and females that had recently given birth. Stage of pregnancy was estimated from fetal mass using the Hugget and Widdas (1951) formula.

We found evidence for a difference in the number of *H. contortus* between females at different times of pregnancy (ANOVA: $F = 5.11$, df = 3, $P = 0.011$), with females that had recently given birth having more worms than pregnant females within both the first and second halves of pregnancy. We found no evidence for a difference in the number of *Cooperia* spp.

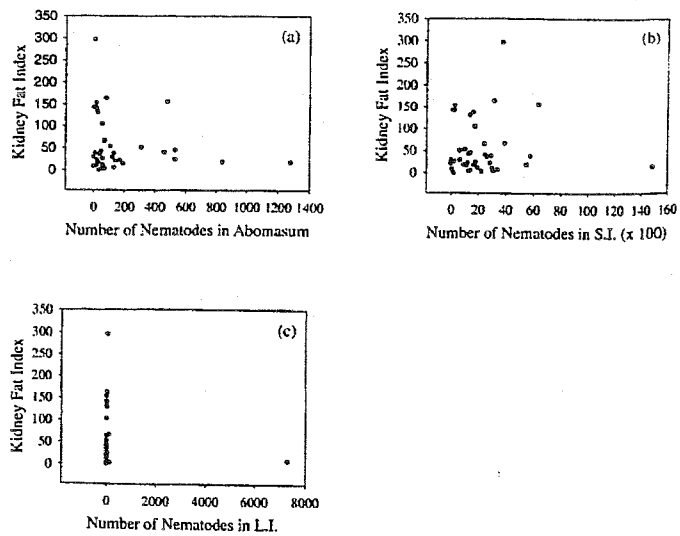

FIGURE 5. Scatter plots of kidney fat index against (a) number of nematodes in the abomasum, (b) number of nematodes in the small intestine, and (c) number of nematodes in the small intestine.

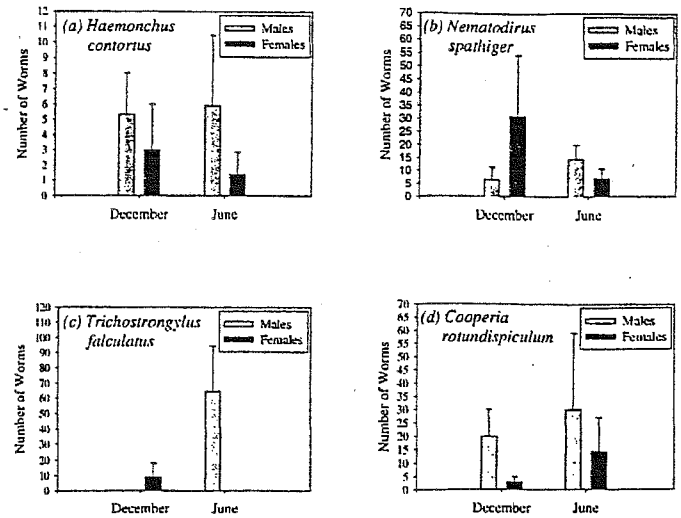

FIGURE 6. Seasonal variation in (a) *Haemonchus contortus*, (b) *Trichostrongylus falculatus*, (c) *Nematodirus spathiger*, and (d) *Cooperia rotundispiculum* in 14 male and 11 female mountain reedbuck at Tussen die Riviere Nature Reserve in 1 summer (December 1999) and 2 winter (June 2000 and June 2001) periods. Error bars represent the standard error.

between females at different times of pregnancy (ANOVA: $F = 0.780$, df = 3, $P = 0.522$).

Nematodes at TdR

Figure 6 shows the seasonal variation in numbers of the 4 most common species of nematode in mountain reedbuck at TdR between December 1999 and June 2001. Because of their low prevalence and abundance as well as the lack of any apparent pattern in variation between genders and seasons, we saw no reason to test the data statistically.

Nematodes of gray rhebok at Sterkfontein

Five nematode species were extracted from 4 gray rhebok that died at Sterkfontein during 2001 (Table III). Because of the small sample size, no gender or seasonal comparisons were attempted.

Fecal egg counts and larval culture

Fecal egg counts, larval culture counts, and adult worm counts in the GIT from 18 culled mountain reedbuck from Sterkfontein were compared using a Spearman rank-correlation coefficient. Egg counts were highly positively correlated with larval counts ($r_s = 0.952$, n = 18, $P < 0.001$), but we found no correlation between egg counts and adult worms ($r_s = -0.173$, n = 18, $P < 0.565$) or between larval counts and adult worms ($r_s = -0.211$, n = 18, $P < 0.409$).

Fecal egg counts and larval culture counts from gray rhebok were compared using a Spearman rank-correlation coefficient. We found a strong positive correlation between the 2 sampling techniques ($r_s = 0.747$, n = 57, $P < 0.001$). The average number of larvae cultured from 100 g of mountain reedbuck feces was 223,187, compared to 7,702 in gray rhebok.

TABLE III. Prevalence and abundance of nematodes recovered from 4 gray rhebok at Sterkfontein Dam Nature Reserve in 2001.*

Nematode species	Prev. (%)	Site in host	Mean (n)	SD (n)	Range (n)
Haemonchus contortus	50	Abo	32.5	42.7	0–90
Longistrongylus schrenki	25	Abo	15.0	30.0	0–60
Ostertagia sp.	75	Abo	168.8	243.3	0–520
Cooperia yashida†	100	SI	145.0	97.5	10–230
Paracooperioides peleae	50	SI	213.2	282.2	0–590

* Prev., prevalence; SD, standard deviation; Abo, abomasum; SI, small intestine.
† New parasite record.

DISCUSSION

Species prevalence and abundance

The number of helminths found in mountain reedbuck at Sterkfontein and TdR was the same as the number (n = 17) found at 2 other sites within South Africa (Baker and Boomker, 1973). However, 7 of the 14 nematode species found were new parasite records, emphasizing the fact that nematodes of mountain reedbuck are poorly known. Genera of helminths found at Loskop Dam Nature Reserve (Mpumalanga, South Africa) and Mountain Zebra National Park (Eastern Cape, South Africa), but not in the present study, were the nematodes *Gongylonema* sp. and *Oesophagostomum* sp.

Frequency distributions of nematodes

The nematode populations in mountain reedbuck at both Sterkfontein and TdR were highly aggregated, so the majority of the parasite population was concentrated into a minority of the host population. A relatively small number of individuals in the "tail" of the parasite distribution were then responsible for most parasite transmission (Wilson et al., 2002).

Heterogeneities in parasite loads occur in most natural populations (Shaw and Dobson, 1995; Wilson et al., 2002), and these could have a differential effect on host-species fitness and, ultimately, population dynamics. However, it is difficult to tell whether parasite loads, as in the most heavily infected individuals at Sterkfontein, were large enough to have a negative impact. Little information regarding the numbers of nematodes necessary to produce clinical disease in antelope is available (Boomker, 1990).

Pathogenesis caused by *H. contortus* is essentially an acute hemorrhagic anemia caused by the blood-sucking habits of the worms (Georgi and Georgi, 1990). At peak infection, naturally acquired populations of *H. contortus* may remove one-fifth of the circulating erythrocyte volume per day from lambs. Infections with as many as 500 worms, however, have been found to have little effect on the growth or wool production of sheep under conditions of satisfactory nutrition. In mountain reedbuck, the numbers of *H. contortus* needed for clinical signs of disease is unknown, but the mean of 116 worms per animal was probably negligible. The highest count was 1,050 worms in a young adult female, and this animal had a body condition similar to that of the rest of the animals culled at the same time.

Cooperia spp. usually play a secondary role in the pathogenesis of parasitic gastroenteritis of ruminants, but they may be the most numerous trichostrongyle present (Georgi and

Georgi, 1990). Although the number needed for clinical signs of disease is unknown, the average burden of 2,040 worms per animal would have been insignificant. The 15,000 worms found in 1 animal, however, might, in conjunction with other extenuating factors, result in some detrimental effects. This is speculative, because such effects have never been tested in wild antelope.

Possible causes of aggregation

Aggregation may be associated with heterogeneities in the host population, including host age, gender, body condition, behavior, and genetics (Wilson et al., 2002). It also may be associated with heterogeneities in the parasite population genetics or extrinsic factors, such as the spatial distribution of the parasites.

The most likely cause of heterogeneity in parasite loads (specifically, in *H. contortus*) was temporal variation in distributions of the parasite populations. Horak (1978a, 1978b, 1978c, 1978d, 1981) found that burdens of *H. contortus* in sheep, cattle, blesbok, and impala peaked between October and March at 4 sites in South Africa. Reinecke (1964, 1983) found that the abundance of *H. contortus* was positively correlated with ambient temperatures and rainfall. In summer rainfall areas, infective larvae on pasture increased after rains in excess of 15 ml per month and temperatures of greater than 17 C. Sheep acquired infection in November, and adult worms were dominant until February. At Sterkfontein, monthly rainfall only exceeded 15 ml after August, and at the time of the September 2000 and August 2001 culls, the rains had barely started. In addition, temperatures had not yet exceeded 17 C. Under this scenario, peak infections would have been expected only in the next culling periods (i.e., December 2000 and November 2001, respectively), and indeed, this was the case.

Host age could affect parasite distributions by a number of mechanisms, including parasite-induced host mortality and acquired immunity (Wilson et al., 2002). Although we found no evidence for a difference in parasite loads between animals of different ages, a thorough evaluation of age-associated heterogeneities was not possible in the present study because of the relatively small numbers of young and old animals sampled. Wilson et al. (2002) stated that sample sizes often decline with host age because of mortality, and if sampling effort is not directed at obtaining equal numbers of hosts in all age classes, then average parasite loads might appear to decline in old animals and parasite aggregation to decline with age, purely because of sampling biases.

Schalk and Forbes (1997) found that in 12 of 136 field studies on mammals, males exhibited a higher prevalence of parasites compared to females. In all 12 field studies, however, male biases were small (<5%). When meta-analyses were carried out using pooled data from these studies, including those that did not find male biases, males were still found to exhibit higher prevalences of parasites. Moore and Wilson (2002) found that the mean prevalence of infection was male-biased for helminths in mammals in general but not for Artiodactyla alone. Even if sex biases exist, determining the relative importance of the different mechanisms capable of generating them may prove to be extremely difficult, because many of the ecological and physiological factors covary (Wilson et al., 2002).

Intrinsic biological differences between host sexes could lead to 1 sex being more prone than the other to parasitic infections. Physiological, morphological, and behavioral differences between sexes could operate to create a slight but consistent sexual bias in infection levels. The present study, however, found no evidence of differences between males and females in parasite abundance.

Although no statistical differences were found between males and females in the present study, patterns of parasite loads were slightly different. Males had more worms than females between February and June, whereas females had more worms than males between August and December. One physiological aspect implicated in male-biased parasitism is that high testosterone levels can cause immunosuppression (Grossman, 1985). The main breeding season for mountain reedbuck was April/May, but if testosterone levels were higher at this time and males were immunosuppressed, then they should have had larger parasite loads. This, however, was not the case. The only nematode species that showed significant seasonal variation was *H. contortus*, and at Sterkfontein, males had their highest loads in December. Moreover, mountain reedbuck were considered to be nonseasonal (Irby, 1979), so significant peaks in testosterone secretion were unlikely to occur.

In females, evidence suggests that estrogens stimulate humoral and cell-mediated immunity (Schuurs and Verheul, 1990). In contrast, energetic costs of pregnancy and maternal care, plus the immunosuppressive effects of some hormones produced during parturition and lactation, may increase the susceptibility of females to parasites. Measuring immunocompetence is, however, fraught with difficulties (Wilson et al., 2002), because whether a simple relationship exists between immune function and disease susceptibility is unclear. Females at Sterkfontein had significantly more *H. contortus* in December than in May, June, August, and September, which is more consistent with the immunosuppression hypothesis during late pregnancy and parturition. Moreover, females that were lactating had significantly higher worm burdens than females that were still pregnant. Boomker (1990) found that the mean worm burden of lactating female kudu was more than double that of pregnant or quiescent females. The difference was ascribed to the stress associated with terminal pregnancy, parturition, lactation, and anxiety during the first few weeks of the newborn calf's life.

High parasite loads might decrease body condition, and this, in turn, will reduce resistance to parasitic infection. Body condition also is likely to affect the ability of hosts to compensate for damage inflicted by parasites, such as repairing tissues or replacing critical nutrients. At Sterkfontein, however, we found no correlation between numbers of parasites and body condition.

We are aware of few good examples of genetic variation in disease resistance in natural host populations, particularly in vertebrates. Even less research has been conducted on the importance of parasite heterogeneities. The effect of host or parasite genetics on parasitic infection rates was not within the scope of the present study.

Nematodes of TdR

No statistical tests were conducted on the parasite data from TdR; because prevalence and abundance of species were very

low, any patterns would have had no biological meaning. Nematode burdens at TdR were much lower than at Sterkfontein. This lower abundance may have resulted from lower densities of mountain reedbuck at TdR. Arneberg et al. (1998) showed that for strongylid nematodes of mammals, abundance may depend on host-population density, because as host densities increase, each parasite egg or larva enjoys an increased probability of contacting a host. Differences in habitat also may have played a role. At TdR, grasses were clumped, and numerous bare patches of earth occurred between tufts. In contrast, at Sterkfontein, percentage grass canopy cover was very high, allowing infective larval nematodes greater opportunity to attach themselves to grass clumps to be eaten by grazers, such as mountain reedbuck.

Nematodes of gray rhebok at Sterkfontein

Four studies of gray rhebok at Bontebok National Park (Boomker et al., 1981; Horak et al., 1982; Boomker, 1990; Boomker and Horak, 1992) recorded 12 kinds of nematode, compared to 5 found at Sterkfontein. Those of the present study were, however, recovered from only 4 animals. Although the sample size was small, gray rhebok at Sterkfontein had fewer helminths compared to mountain reedbuck at the same site but had more helminths compared to mountain reedbuck at TdR. All the gray rhebok sampled were adults, but their ages were unknown. Two of the 4 were in poor condition.

Fecal egg counts and larval culture

Egg counts and larval counts were highly correlated, but neither was correlated with the number of adult worms within the intestinal tracts of the animals. This latter result is in agreement with previous findings that indicate the relationship between indirect measures and actual worm burden is very complex (Shaw and Dobson, 1995) and that egg counts are not a reliable method for estimating the numbers of parasites within the GIT (Reinecke, 1983). Gray rhebok larval counts were lower than those for mountain reedbuck at Sterkfontein, but because of the lack of correlation between larval counts and adult worm counts, little consequence can be attributed to this.

ACKNOWLEDGMENTS

Thanks to Mark and Tracey Roods, Cedric Barbé, Nacelle Collins, Hector Dott, Dominic Moss, Francois Nieuwoudt, Colin Oliver, Marie Smith, Francois van den Berg, and Savvas Vrahimis. Also to Free State Department of Tourism, Environment, and Economic Affairs for allowing the present study and to the following organizations that provided funding: the Faculty of Veterinary Science, University of Pretoria; the South African National Research Foundation; the Blundell Memorial scholarship; and the Maberly Memorial scholarship.

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Onderstepoort Journal of Veterinary Research, 73:311–314 (2006)

RESEARCH COMMUNICATION

Helminth parasites of gemsbok (*Oryx gazella*) in the Klein Karoo

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ABSTRACT

ELLIS, M.B. & BOOMKER, J. 2006. Helminth parasites of gemsbok (*Oryx gazella*) in the Klein Karoo. *Onderstepoort Journal of Veterinary Research*, 73:311–314

The number and species of helminth parasites from three gemsbok (*Oryx gazella*) were recorded, and their faecal nematode egg counts and the level of pasture contamination determined. Six nematode genera were recovered and four species identified, of which *Trichostrongylus rugatus* was the most prevalent. Other nematode species recovered were *Cooperia* sp., *Agriostomum* sp., *Haemonchus contortus, Nematodirus spathiger* and *Ostertagia ostertagi.* None of the worms were present in all animals studied, and no new host associations were found. Cysticerci were recovered from the mesenteries of one gemsbok and a further two unidentifiable helminths were recovered from the abomasum and the kidney fat layer of another antelope.

Keywords: *Agriostomum*, *Cooperia*, cysticerci, *Haemonchus*, *Nematodirus*, *Oryx gazella*, *Ostertagia*

INTRODUCTION

Gemsbok, *Oryx gazella*, are large antelope of the tribe Hippotragini, along with the seven surviving species of the genera *Oryx*, *Addax* and *Hippotragus*. Members of this tribe are typically large, stocky animals with long, ridged horns, and within the genus *Oryx* these horns are straight. The genus *Oryx* occurs throughout Africa in semi-desert and desert areas, but *O. gazella* is found mainly in southern Africa. Gemsbok are grazers, generally feeding on coarse semi-arid grass, supplementing their diet with roots and tubers (Kingdon 1997). In areas with higher rainfall gemsbok can form nomadic herds of up to 50 individuals, but in more arid areas tend to be solitary or in much smaller, looser social groups. Whilst solitary males have been seen to defend territories (Estes 1991), nomadic tendencies and the patchiness of food, such as “fertile islands”, tends to restrict range establishment.

The helminths of these antelope have been listed by Round (1968). Boomker, Horak & De Vos (1986) added another five species and one genus of nematodes to the list and Boomker, Horak, Watermeyer & Booyse (2000) a further three nematode species.

This paper reports on the findings of an investigation of the parasites of gemsbok in Sanbona Wildlife Reserve in the Klein Karoo.

MATERIALS AND METHODS

Study site and animals

Sanbona Wildlife Reserve lies in the Western Cape Province approximately 200 km east of Cape Town (33°51’ S; 20°33’ E). The reserve is 54 000 ha in extent and is composed of Montagu Shale Rhenos-

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Accepted for publication 18 May 2006—Editor

terveld, transitional area North Langeberg Sandstone Fynbos and western Klein Karoo (R. Erasmus & K. Heunis, unpublished data 2004). The reserve is effectively split into two by the Warmwaterberg mountain range, resulting in a difference in the annual rainfall of 350 mm in the south and 200 mm in the north.

The first gemsbok were released onto the reserve in 1998 when it was still a Cape Wildlife Reserve. Sanbona, a private concern, acquired the reserve in 2002. A further 70 gemsbok were released in 2003 and the reserve currently holds 89 individuals. The antelope were captured in various localities throughout South Africa and it is possible that parasites not native to the Karoo have been introduced.

Three gemsbok were culled specifically for the helminth survey, and once thoroughly examined the carcasses were returned to the reserve to feed various carnivores in acclimatisation enclosures. Locations and details of culled animals are listed in Table 1. Mass and age were approximated by three workers and a consensus reached.

Pasture sampling

To check pasture larval contamination levels, ten plucks of foliage were taken every 10 m in a 10 m x 10 m grid to give a total of 100 sampling points and 1 000 plucks of vegetation. These were weighed and soaked overnight in warm water with 5 mℓ of detergent. Excess vegetation was then removed and the suspension allowed to sediment. The supernatant was gradually removed to leave a concentrated pellet of herbage and nematode larvae. These samples were re-suspended in a minimum of distilled water and larvae counted. Larval presence was recorded as the number of larvae per kg wet herbage.

Recovery of helminths

A full post-mortem examination was carried out on each individual, which involved the dissection of the heart, lungs, liver, and kidneys for determining the presence of helminths. A gross dissection of the masseter muscles was performed to locate metacestodes.

Carcasses that had to be transported for a long distance were opened and the organs ligated at appropriate locations to prevent mixing of gut contents or movement of parasites. The various parts of the intestinal tract were isolated as soon as possible after culling and opened down their length into separate containers with 5 ℓ physiological saline. The mucosa was stripped down its entire length between thumb and forefinger into the container and left to incubate at 37 °C with occasional stirring. After 3 h the mucosa was once again stripped into the container and the tissue discarded. The contents of the containers were made up to 5 ℓ with water, and two 250 mℓ sub-samples were taken and preserved with 10 mℓ formalin. The two sub-samples were combined and examined under a dissecting microscope for helminths. The helminths recovered were identified, coded and stored in formalin.

Faecal worm egg counts

Faeces were collected from the rectum of culled gemsbok to ensure correct identity of the specimen. A 4 g sample of faeces was added to 56 mℓ of saturated saline, thoroughly mixed with a glass rod and passed through a 100 µm sieve. The number of eggs per gram of faeces were then counted using a McMaster slide, and an average of three slides taken as the individual's faecal worm egg count.

Molecular bar-coding of unidentified samples

Bar-coding of the first 600 base pairs of the 18s (SSU) gene of nematodes was attempted as described by Blaxter, De Ley, Garey, Liu, Scheldeman, Vierstraete, Vanfleteren, Mackey, Dorris, Frisse, Vida & Thomas 1998; Dorris, De Ley & Blaxter 1999, and the first three divergent loops of the 28s (LSU) gene of the cysticerci (Littlewood, Curini-Galletti & Herniou 2000; Olson, Littlewood, Bray & Mariaux 2001). Cell digests were carried out according to the methods of Stanton, McNicol & Steele (1998), and PCR was performed as per the cited protocols.

RESULTS

Animal C had a much higher count and more diverse range of parasites than the other two study animals (Table 1). This included more than 20 cysticerci (2–10 cm) that were attached to the mesentery and two unidentifiable nematodes found in the abomasum and kidney fat layer. This was also the only individual that harboured *Cooperia* spp. in addition to the other identified nematode species. Unfortunately however it was not possible to identify the *Cooperia* spp. to species level.

Agriostomum sp. was the most numerous genus, but this is based on a single large infection in Animal C, biasing the count. *Trichostrongylus rugatus* was

TABLE 1 Collection data and helminths recovered from gemsbok in the Klein Karoo

Animal no.	A	B	C
Age	6 yr	6 yr	4 yr
Sex	Female	Female	Female
Mass (kg)	170	140	120
Helminths			
Agriostomum sp.	50	0	> 1 000
Cooperia sp.	0	0	50
Haemonchus contortus	10	0	70
Nematodirus spathiger	30	0	120
Ostertagia ostertagi	0	0	90
Trichostrongylus rugatus	90	30	80
Total no. of helminths	180	30	> 1 410
Faecal worm egg count	293	223	1508

the next most numerous and the most prevalent, and Animal B was infected with only this nematode.

At the site where Animal A was culled there were 1 550 larvae per kg wet herbage, where Animal B was culled there were 217 larvae and where Animal C was culled there were 1 444 larvae. Faecal worm egg counts were low in animals A and B (Table 1), which had low intensities of adult helminth despite the high larval counts on the herbage.

Attempts to identify the unknown nematodes from the abomasum and the body cavity using molecular techniques failed. This is most likely due to the effects on DNA of storage of these specimens in unbuffered formalin, leading to formalin-DNA-protein cross-linking which inhibits PCR amplification (Karlsen, Kalantari, Chitemerere, Johansson & Hagmar 1994; Schander & Halanych 2003).

DISCUSSION

A single gemsbok in the Kalahari Gemsbok National Park had a total of 5 877 nematodes (Boomker *et al.* 1986), two gemsbok from the Western Coast National Park (33°6'–33°10' S; 17°57'–18°2' E; Altitude 0–50 m) had an average of 28 391 worms (Boomker *et al.* 2000) and 24 antelope from the Free State had an average of 1 506 (Fourie, Vrahimis, Horak, Terblanche & Kok 1991). With the exception of Animal C, which was more heavily infected, the absolute number of parasites collected seem considerably lower in this study than in the two studies conducted by Boomker *et al.* (1986, 2000). It is possible that the overdispersion in Animal C is due to it having been captured at a site with high levels of *Agriostomum* and *Cooperia*, and on release at Sanbona was exposed to novel parasites leading to an increased infection rate.

The helminths of grey duiker in the same region were also investigated as part of this study. Their data are not included as only three cysticerci and one unidentified nematode were found in six individuals. The small numbers of parasites recovered are probably related to the nature of the Reserve and the drought that prevailed at the time.

Cooperia spp. are generally regarded as relatively harmless to well nourished and low stressed animals (Reinecke 1983), and the number recovered from Animal C is negligible. *Cooperia* spp. were not recovered from the gemsbok in the West Coast National Park. *Trichostrongylus rugatus* is primarily a parasite of the non-seasonal and summer rainfall areas (Reinecke 1983) but was the predominant nematode in gemsbok in the West Coast National Park, which is in the winter rainfall area (Boomker *et al.* 2000). Since the numbers of helminths recovered from the gemsbok in this study were small and that no signs disease or injury were noticed we conclude that the burdens were neglible.

Further studies using molecular techniques to identify helminths should be encouraged, but samples should be stored in ethanol or buffered formalin. However, there are problems associated with both options. Ethanol is an excellent preservative for DNA studies but can cause bloating and disruption of morphological characters, and buffered formalin, though better than unbuffered, still presents problems associated with DNA cross-linkage, which can reduce the effectiveness of amplification techniques.

ACKNOWLEDGEMENTS

We thank the staff of Sanbona Wildlife Reserve for making the antelope available to us and for their valuable assistance in the field, and Mr James Kitson for his assistance in processing the animals. This work was conducted with the financial assistance of the Weir Fund for Field Studies and the James Rennie Bequest.

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ARTHROPOD PARASITES

Onderstepoort J. vet. Res., 50, 221–228 (1983)

THE IXODID TICK BURDENS OF VARIOUS LARGE RUMINANT SPECIES IN SOUTH AFRICAN NATURE RESERVES

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ABSTRACT

HORAK, I. G., POTGIETER, F. T., WALKER, JANE B., DE VOS, V. & BOOMKER, J., 1983. The ixodid tick burdens of various large ruminant species in South African nature reserves. *Onderstepoort Journal of Veterinary Research*, 50, 221–228 (1983).

The ixodid tick burdens of eland (*Taurotragus oryx*), greater kudu (*Tragelaphus strepsiceros*), nyala (*Tragelaphus angasi*), bushbuck (*Tragelaphus scriptus*) and giraffe (*Giraffa camelopardalis*) in the Kruger National Park, Transvaal; of African buffalo (*Syncerus caffer*) and nyala in the Hluhluwe Game Reserve, Natal; and of gemsbok (*Oryx gazella*) in the Mountain Zebra National Park, an eland in the Thomas Baines Nature Reserve and an eland and greater kudu in the Andries Vosloo Kudu Reserve, eastern Cape Province, were determined.

The tick burdens of animals shot at the same time and locality are compared, and the attachment sites of some tick species on some of the hosts are given.

INTRODUCTION

During the past few years a number of surveys have been undertaken to determine the ixodid tick burdens of various wild ruminants in the Republic of South Africa. In this way the tick burdens of greater kudu (*Tragelaphus strepsiceros*); springbok (*Antidorcas marsupialis*); impala (*Aepyceros melampus*); blesbok (*Damaliscus dorcas phillipsi*); bontebok (*Damaliscus dorcas dorcas*), and vaal ribbok (*Pelea capreolus*) have been ascertained in different localities (Knight & Rechav, 1978; Horak, Meltzer & De Vos, 1982; Horak, 1982; Horak, Brown, Boomker, De Vos & Van Zyl, 1982; Horak, De Vos & De Klerk, 1982).

In this paper additional data are given on greater kudu, plus information on tick burdens of nyala (*Tragelaphus angasi*), bushbuck (*Tragelaphus scriptus*), eland (*Taurotragus oryx*), African buffalo (*Syncrus caffer*), giraffe (*Giraffa camelopardalis*) and gemsbok (*Oryx gazella*).

MATERIALS AND METHODS

The animals examined were either culled specifically for survey purposes or were shot or found dead because of injury or disease. The species of animals examined and the localities in which they were obtained are summarized in Table 1.

Ixodid ticks were recovered from these animals using the methods described by Horak *et al.* (1982). The skins of the nyala and buffalo from the Hluhluwe Game Reserve, however, were not immersed in a tick detaching agent but were transported in a weak solution of formalin in plastic bags to the laboratory at Onderstepoort. There they were scrubbed and washed in the same manner as the other skins.

Immature ticks and adult, unengorged *Boophilus decoloratus* were counted and identified by examining all the collected material, or representative samples of it, under a stereoscopic microscope. The representative samples were obtained by increasing the volume of the collected material to approximately 800 mℓ by the addition of water. The material was thoroughly mixed by rapidly pouring it from one container to another and then pouring exactly ½ of it into 1 of the containers. This ½ could be further divided after making it up to approximately 800 mℓ and following the same procedure as mentioned above. The usual size of the samples examined varied between ½ and ⅛ of the total, and an attempt was made to count and identify at least 300 immature ticks from each animal. The smallest samples examined were $^{1}/_{64}$th of the material form the skins of the buffaloes' necks, bodies and upper legs.

TABLE 1 Species of animals examined and localities in which they were obtained

Animals examined	Province	Locality	Co-ordinates	Altitude (m)	Vegetation as classified by Acocks (1975)
Eland	Transvaal (Kruger National Park)	Near Pretoriuskop	25°10′S; 31°16′E	600	Lowveld Sour Bushveld
Giraffe		Near Lower Sabie	25°07′S; 31°55′E	180	Lowveld
Greater kudu, bushbuck		Skukuza	24°58′S; 31°36′E	262	Lowveld
Greater kudu, bushbuck, nyala		Near Pafuri	23°27′S; 31°19′E	305	Mixed Bushveld
African buffalo, nyala	Natal	Hluhluwe Game Reserve	28°07′S; 32°03′E	150–450	Zululand Thornveld and Lowveld
Gemsbok	Cape Province	Mountain Zebra National Park	32°15′S; 24°41′E	1 200–1 957	Karroid *Merxmeullera* Mountain Veld replaced by Karoo
Eland		Thomas Baines Nature Reserve	33°23′S; 26°28′E	335–518	False Macchia, Eastern Province Thornveld and Valley Bushveld
Eland, greater kudu		Andries Vosloo Kudu Reserve	33°07′S; 26°40′E	300–450	Valley Bushveld

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Received 6 June 1983—Editor

TABLE 2 The ixodid tick burdens of eland, kudu, nyala, bushbuck and giraffe in the Kruger National Park

Host	Sex	Age	Date culled (C) or died (D)	Numbers of ixodid ticks recovered																							
				Amblyomma hebraeum				*Boophilus decoloratus*				*Rhipicephalus appendiculatus/ zambeziensis*	*Rhipicephalus appendiculatus*			*Rhipicephalus zambeziensis*			*Rhipicephalus evertsi evertsi*				*Rhipicephalus pravus* group	*Rhipicephalus kochi*			*Rhipicephalus simus*	
				L	N	♂	♀	L	N	♂	♀	L	N	♂	♀	N	♂	♀	L	N	♂	♀	L	N	♂	♀	♂	♀
Pretoriuskop																											
Eland*	F	Old	27 Sept 1979 (D)	4 128	1 704	744	153	384	96	144	0	112	352	0	0	16	0	0	64	0	9	0	0	0	0	0	1	0
Eland	M	6 weeks	1 Oct 1979 (C)	328	16	27	6	104	264	80	68 (4)	16	8	0	0	0	0	0	24	80	1	0	0	0	0	0	3	0
Skukuza																											
Bushbuck**	F	Adult	9 Oct 1979 (D)	5	12	2	0	23	31	3	1	9	0	0	0	105	0	0	0	0	1	0	0	0	0	0	0	0
Bushbuck***	M	Yearling	5 Aug 1980 (D)	51	22	4	2	268	114	51	23 (1)	472	3	0	0	604	0	0	8	1	0	0	0	0	0	0	0	0
Bushbuck	M	2 years	31 Oct 1980 (D)	58	79	0	0	162	75	9	0	4	0	1	1	94	1	1	4	6	0	0	0	0	0	0	0	0
Bushbuck****	M	6 months	14 June 1982 (D)	726	4	0	0	698	554	104	50	748	16	0	0	0	0	0	32	48	0	0	0	0	0	0	0	0
Bushbuck	F	Adult	11 Nov 1982 (D)	17	41	10	7	4 977	1 847	680	366 (21)	8	0	0	6	258	2	0	16	0	0	0	0	0	0	0	0	0
Bushbuck	M	Adult	15 Nov 1982 (D)	168	16	10	2	1 436	1 184	720	254 (4)	0	16	0	2	50	2	2	0	0	0	0	0	0	0	0	0	0
Bushbuck*****	F	Adult	17 Nov 1982 (D)	1 798	158	2	0	3 862	86	28	10	24	54	0	0	34	0	0	128	0	4	2	0	0	0	0	0	0
Bushbuck	M	Adult	18 Nov 1982 (D)	256	80	0	0	1 658	636	216	48	0	0	2	0	40	2	2	4	0	0	0	0	0	0	0	0	0
Kudu	M	Sub-adult	31 July 1980 (C)	16	2	0	0	64	0	18	12 (3)	368	16	0	0	96	0	0	8	16	1	0	0	0	0	0	0	0
Kudu	M	Adult	31 July 1980 (C)	80	144	10	3	112	128	144	34 (1)	752	112	0	1	240	1	1	0	0	2	0	0	0	0	0	0	0
Lower Sabie																											
Giraffe†	M	Adult	24 July 1980 (C)	624	272	585	167	2 208	1 600	464	132 (4)	1 376	592	0	0	0	0	0	448	48	2	2	0	0	0	0	0	0
Giraffe††	M	Adult	25 July 1980 (C)	128	160	360	112	192	320	256	137 (8)	80	32	0	0	0	0	0	0	0	10	2	0	0	0	0	2	0
Pafuri																											
Kudu	M	15–18 months	5 Oct 1981 (C)	218	78	4	2	981	1 092	253	156 (8)	0	232	0	0	0	0	0	16	0	4	0	136	48	20	7	0	0
Kudu	M	Adult	5 Oct 1981 (C)	161	56	2	0	643	896	424	102 (6)	0	150	0	0	0	0	0	24	4	0	2	64	66	14	12	0	0
Nyala	M	Adult	6 Oct 1981 (C)	56	4	3	0	32	14	16	10 (2)	28	249	0	0	24	0	0	0	0	0	0	250	308	42	34	0	0
Nyala	M	Adult	7 Oct 1981 (C)	0	12	0	0	121	105	85	30 (6)	24	300	0	0	12	0	0	0	0	0	0	280	200	29	26	0	0
Bushbuck	M	Adult	6 Oct 1981 (C)	8	76	0	0	48	8	4	0	69	148	0	0	44	0	0	1	0	0	0	236	112	34	54	0	0
Bushbuck	M	Old	8 Oct 1981 (C)	48	17	5	3	12	28	4	2 (2)	20	285	0	0	0	0	0	0	0	0	0	56	32	25	20	0	0
Bushbuck	F	Adult	8 Oct 1981 (C)	4	84	0	2	13	12	8	0	16	17	0	0	39	0	0	0	0	0	0	448	217	37	17	0	0

* *Haemaphysalis aciculifer* 2 ♂♂, ***Ixodes* sp. 6 nymphae, ****Ixodes* sp. 1 larva, 2 nymphae, *****Ixodes* sp. 28 larvae, ******Ixodes* sp. 16 larvae, ( ) = No. of ♀♀ *B. decoloratus* between 4,0 and 7,0 mm in lenght, † *Hyalomma truncatum* 6 ♂♂, †† *H. truncatum* 4 ♂♂, 4 ♀♀, L = Larvae, N = Nymphae

Maturing *B.decoloratus* females and adult ticks of other species where separated out by macroscopically examining the material *in toto* after the representative sample had been examined, and the ticks were identified and counted under the stereoscopic microscope.

The immature stages of the *Ixodes* spp. recovered were not specifically identified. No attempt was made to differentiate the larval stages of *Rhipicephalus appendiculatus, Rhipicephalus maculatus, Rhipicephalus muehlensi* and *Rhipiciphalus zambeziensis* when 2 or more of these species were present on the same host.

RESULTS

Kruger National Park

A total of 10 ixodid tick species were recovered from the animals examined in this park (Table 2). The adult eland and the giraffe harboured large numbers of adult *Amblyomma hebraeum*. At Skukuza, in the south of the park, nymphae of *R. zambeziensis* were more numerous than those of *R. appendiculatus*. At Pafuri, in the north, the converse was true. Larvae of the *Rhipicephalus pravus* group and nymphae and adults of *Rhipicephalus kochi* constituted a large proportion of the total tick burdens on all the animals at Pafuri. These ticks, however, were absent on all the animals from the localities in the south of the park. The kudu at Pafuri harboured considerably more *A. hebraeum* and *B. decoloratus* than the nyala or bushbuck shot during the same week from the same locality. These in turn harboured more *R. zambeziensis* and *R. kochi* and generally more *R. pravus* group larvae than the kudu.

Not only did the numbers of *B. decoloratus* harboured by the 3 antelope species at Pafuri differ considerably, but there was also a difference in the proportional distribution of this tick on the various hosts (Table 3).

TABLE 3 The proportional distribution of *Boophilus decoloratus* on kudu, nyala and bushbuck at Pafuri

Host	Mean No. of *B. decoloratus* recovered	Percentage of *B. decoloratus* recovered from			
		Head	Neck, body and upper legs	Lower legs and feet	Tail
Kudu	2 274	29,0	34,4	36,1	0,5
Nyala	207	14,5	4,9	79,9	0,7
Bushbuck	46	37,4	5,8	53,2	3,6

Approximately equal proportions of the *B. decoloratus* burden were recovered from the heads; the necks, bodies and upper legs; and lower legs and feet of the kudu. On both the nyala and bushbuck more than 50% of the ticks were recovered from the lower legs and feet and very few from the necks, bodies and upper legs.

Hluhluwe Game Reserve

Nine species of ixodid ticks were recovered from the buffalo and nyala shot in this reserve (Table 4). The buffalo were excellent hosts of all stages of development of *A. hebraeum*, the larvae of *Rhipicephalus* spp., the nymphae of *R. appendiculatus*, the nymphae and adults of *R. maculatus* and the adults of *Rhipicephalus simus*. The nyala were excellent hosts of the nymphae and adults of *R. muehlensi*, good hosts of the larvae of *Rhipicephalus* spp., and fair hosts of the nymphae of *R. appendiculatus* and *R. maculatus*. The majority of adult *A. hebraeum* and adult *R. maculatus* were recovered from the less hairy undersides of the buffalo, from the axilla to the escutcheon, while the majority of *R. meuhlensi* were recovered from the heads of the nyala.

Mountain Zebra National Park

Seven ixodid tick species were recovered from the gemsbok shot in this park (Table 5). Of these *Margaropus winthemi* and *Rhipicephalus glabroscutatum* were the most numerous.

Thomas Baines and Andries Vosloo Reserves

Nine ixodid tick species were recovered from the eland from the Thomas Baines Reserve, and 8 and 7 species from the eland and kudu, respectively, from the Andries Vosloo Reserve (Table 6).

The eland from the Thomas Baines Reserve haboured large numbers of all stages of development of *A. hebraeum, Haemaphysalis silacea* and *Rhipicephalus evertsi evertsi* plus larvae and adults of *R. appendiculatus*. The eland from the Andries Vosloo Reserve was heavily infested with larvae and adults of *A. hebraeum* and moderately infested with adult *R. appendiculatus* and *R. glabroscutatum*. The kudu, which had either died or been shot because of injury or exhaustion while being translocated, were moderately to heavily infested with all stages of development of *H. silacea* and the immature stages of *A. hebraeum, R. appendiculatus, R. evertsi evertsi* and *R. glabroscutatum*.

The proportional distributions of some of the ticks infesting the kudu are summarized in Table 7.

The larvae and nymphae of *A. hebraeum, H. silacea* and *R. glabroscutatum* and the *R. appendiculatus* larvae showed a preference for the lower legs and feet. The nymphae and adults of *R. appendiculatus* and larvae and nymphae of *R. evertsi evertsi* preferred the heads of the kudu. The largest proportion of male *H. silacea* were found on the neck, body and upper legs of the kudu, while the number of females found on the tail exceeded the total number of females attached elsewhere.

DISCUSSION

Several ticks had probably detached and left the skins of the animals that had died as a result of injury or disease before the carcasses of these animals could be brought to the laboratories and processed for tick recovery. This fact must be borne in mind when considering the tick burdens of these animals; they might have been considerably larger had it been possible to collect them immediately after the host's death.

The large number of dead bushbuck that were examined at Skukuza can be ascribed to the fact that these animals come into the staff village at night during the winter and spring months. Here they browse on the green garden shrubs and, if alarmed, may jump into a garden fence and break their necks. Others, dazzled by the bright headlights, are killed by cars.

With the exception of those of the buffaloes and the single eland from the Thomas Baines Reserve, none of the tick burdens harboured by the animals were particularly large. It is perhaps interesting to speculate what the total tick burdens of the buffaloes and the eland might have been had *B. decoloratus* also been present in large numbers in the Hluhluwe and Thomas Baines Reserves. The eland had a broken tooth and was emaciated, conditions which possibly made the animal more susceptible to infestation and accounted for its large tick burden. The buffaloes, however, were apparently all healthy.

The really large burdens of most developmental stages of the majority of tick species carried by the buffaloes suggest that, in those regions where these animals still occur, they must be regarded as amongst the most important hosts of ixodid ticks. This observation supports that of Dinnik, Walker, Barnett & Brocklesby (1963), who

TABLE 4 The ixodid tick burdens of buffalo and nyala in the Hluhluwe Game Reserve

Host	Sex	Age	Date slaughtered	Numbers of ixodid ticks recovered																					
				Amblyomma hebraeum				*Boophilus decoloratus*		*Haemaphysalis silacea*			*Rhipicephalus* spp.	*Rhipicephalus appendiculatus*			*Rhipicephalus maculatus*			*Rhipicephalus muehlensi*			*Rhipicephalus evertsi evertsi*			*Rhipicephalus simus*	
				L	N	♂	♀	L	♀	N	♂	♀	L	N	♂	♀	N	♂	♀	N	♂	♀	N	♂	♀	♂	♀
Buffalo	M	Sub-adult	6 Sept 1978	339	203	270	83	0	0	0	0	2	5 896	5 509	20	1	3 106	40	9	81	4	2	0	8	1	18	6
Buffalo	F	Adult	6 Sept 1978	148	405	323	49	0	0	0	1	0	5 220	6 221	0	0	1 933	31	27	0	14	18	0	12	10	39	20
Buffalo	F	Adult	7 Sept 1978	712	407	1 092	248	64	0	0	0	0	5 792	5 275	6	3	4 073	268	68	64	0	0	0	9	1	9	4
Buffalo	F	Adult	7 Sept 1978	220	228	347	167	0	0	0	0	0	9 704	5 552	12	9	6 376	284	120	1	0	0	1	7	1	4	13
Nyala*	M	Sub-adult	8 Sept 1978	40	34	5	0	24	16	8	1	0	3 552	1 672	0	1	152	3	4	312	206	72	0	1	0	0	0
Nyala**	M	Sub-adult	8 Sept 1978	192	26	2	0	0	0	0	2	2	2 232	856	0	0	872	0	0	2 000	369	218	0	0	0	0	0

* = *Ixodes pilosus* 1 ♂, 5 ♀♀

** = *Ixodes* sp. 16 larvae; *Ixodes* sp. 1 ♀ (probably *I. pilosus* but damaged)

L = Larvae

N = Nymphae

TABLE 5 The ixodid tick burdens of 2 gemsbok shot in the Mountain Zebra National Park

Age	Numbers of ixodid ticks recovered																	
	Amblyomma marmoreum	*Hyalomma truncatum*		*Hyalomma marginatum turanicum*		*Margaropus winthemi*			*Rhipicephalus* sp.	*Rhipicephalus* sp. (near *R. capensis*)		*Rhipicephalus evertsi evertsi*				*Rhipicephalus glabroscutatum*		
	N	♂	♀	♂	♀	N	♂	♀	L	♂	♀	L	N	♂	♀	N	♂	♀
Young adult	2	1	2	14	3	22	88	81	4	9	7	8	0	27	15	2	103	51
Adult	0	3	1	18	14	20	56	34	8	3	9	0	3	38	10	4	111	40

L = Larvae
N = Nymphae

remarked that buffalo in Uganda were so heavily infested with ticks that it was not possible to make total collections of these parasites. In contrast, Carmichael (1976) recovered only small burdens of adult ticks from 100 buffalo in Botswana. These animals had been immobilized in a foot-and-mouth disease investigation during which all visible ticks were collected. Carmichael (1976) attributed the small number of ticks partly to the fact that the collections were made towards the end of the seasonal long, dry period, and partly to the overall climate, which is sufficiently harsh to prevent the buildup of large numbers.

The composition of the burden of some tick species was undoubtedly related to the season during which the animals were slaughtered or had died. The majority of animals in the Kruger National Park and all the animals in the Hluhluwe Game Reserve were slaughtered or died during the months July–October (winter–spring) and generally carried fairly large numbers of nymphae of *R. appendiculatus*. This is the season in Southern Africa when nymphae of this tick reach peak numbers and few adults are present (Baker & Ducasse, 1967; Short & Norval, 1981 a, b,; Horak, 1982). Similarly, the large numbers of larvae of *R. appendiculatus* recovered from the eland and kudu during April and June, respectively, in the eastern Cape Province reflect the fact that these animals were examined in autumn and early winter, seasons when larvae of this tick reach peak numbers (Baker & Ducasse, 1967; Short & Norval, 1981 a, b; Horak, 1982.)

The recovery of large numbers of adult *A. hebraeum* from the eland, giraffe and buffalo in the Transvaal during winter and spring does not appear to be in accord with the findings of Norval (1977) and Knight & Rechav (1978) in the eastern Cape Province, or of Londt, Horak & De Villiers (1979) and Horak (1982) in the northern Transvaal. These authors all found adult *A. hebraeum* reached peak numbers during the summer months. In Natal, Baker & Ducasse (1967) recorded peak adult activity on cattle between September and January, a finding which more closely approximates to the present ones. It would, however, be necessary to examine eland, giraffe and buffalo at regular intervals throughout the year in the Kruger and Hluhluwe Parks to determine when the actual peaks in adult numbers occur and the number of ticks present at such times.

The very large numbers of adult *A. hebraeum* recovered from the eland, buffalo and giraffe, in comparison with the numbers collected from the somewhat smaller hosts such as kudu, nyala and bushbuck, suggest that the larger the host the more favourable it is for adult ticks of this species. The findings of Knight & Rechav (1978) support this contention in that, in a 13-month survey of the ticks of kudu in the eastern Cape Province, the greatest mean number of adult *A. hebraeum* they recovered from these animals was only 19. In a similar survey in the northern Transvaal, Horak (1982) recovered a mean of 80 adult *A. hebraeum* from cattle examined during February 1977, but impala from the same locality never harboured more than 1 adult tick of this species.

The *B. decoloratus* infestations encountered on animals in the Kruger National Park were never very large and, in general, adult ticks accounted for only a minor proportion of nearly every burden. However, a fairly high proportion of the adult females were over 4,0 mm in length, which probably indicates that they would engorge and detach within the next 24 h. In Australia, Wharton & Utech (1970) found that once the females of *Boophilus microplus* (which are somewhat larger than those of *B. decoloratus*) had reached a length of 4,5 mm they would complete their engorgement and drop within 24 h.

R. kochi has previously been recorded once only in South Africa, from an impala, also at Pafuri (Gertrud Theiler, unpublished data, 1964, as *Rhipicephalus neavei*). The numbers encountered in the present survey indicate that it must be regarded one of the major species of the Pafuri region.

Both host preference and host habitat probably played a role in the composition of the tick burdens of the buffalo and nyala in the Hluhluwe Game Reserve. The buffaloes generally prefer the savanna for grazing, while the nyala are found in the denser bush. From the findings in this survey it would appear that adult *A. hebraeum*, *R. evertsi evertsi*, *R. appendiculatus*, *R. maculatus* and *R. simus* prefer buffalo as hosts and that *R. muehlensi* prefers nyala. Adults of *Ixodes pilosus* were also found on nyala.

The Mountain Zebra National Park has a mean annual rainfall of only 398 mm, and the ticks recovered from the gemsbok there are mostly species associated with semi-arid conditions. *M. winthemi* is a 1-host tick which reaches peak numbers during the winter (Howell, Walker & Nevill, 1978), and the infestation may have been declining with the approach of summer. This might explain the absence of larvae and the relatively small numbers of nymphae recovered.

The numbers of ticks and tick species recovered from the gemsbok exceeded those recovered from blesbok slaughtered in the Mountain Zebra Park at the same time

TABLE 6 The ixodid tick burdens of eland and kudu in the eastern Cape Province

Host	Sex	Age	Date culled (C) or died (D)	Numbers of ixodid ticks recovered																							
				Amblyomma hebraeum				*Boophilus decoloratus*				*Haemaphysalis silacea*				*Ixodes* spp.		*Ixodes pilosus*		*Rhipicephalus appendiculatus*				*Rhipicephalus evertsi evertsi*				*Rhipicephalus glabroscutatum*			
				L	N	♂	♀	L	N	♂	♀	L	N	♂	♀	L	N	♂	♀	L	N	♂	♀	L	N	♂	♀	L	N	♂	♀
Thomas Baines Reserve																															
Eland*	M	Adult	29 April 82 (C)	6 352	320	1 443	189	16	48	13	4	3 600	432	881	264	304	80	4	10	4 760	40	1 185	222	992	144	127	18	0	0	0	0
Andries Vosloo Kudu Reserve																															
Eland**	M	Adult	4 March 83 (C)	1 159	52	1 195	134	0	0	0	0	331	32	179	24	0	0	0	2	94	0	205	165	152	40	49	6	880	156	198	164
Kudu	F	Adult	16 June 82 (D)	64	0	0	0	0	0	0	0	2 607	293	219	13	252	16	0	12	1 027	88	26	12	48	40	2	0	40	24	1	4
Kudu	M	Sub-adult	17 June 82 (C)	586	16	0	0	0	0	0	0	5 542	930	361	64	73	16	0	4	2 610	177	8	0	128	50	0	0	976	584	1	0
Kudu	F	Adult	17 June 82 (D)	625	52	0	0	0	0	0	0	1 497	226	83	13	0	0	0	0	2 341	376	46	10	321	80	0	0	5 846	1 296	6	1
Kudu	F	Adult	18 June 82 (D)	650	35	0	0	0	0	0	0	3 806	532	264	51	98	0	0	0	1 340	100	18	6	48	72	0	0	1 248	468	4	3
Kudu	M	Sub-adult	18 June 82 (D)	128	3	0	0	0	44	0	0	407	499	42	15	0	0	0	0	321	33	0	0	13	28	2	0	877	1 346	9	2

L = Larvae N = Nymphae

* Ixodes sp. 3 ♀♀; *Rhipicephalus* sp. (near *R. capensis*) 12 ♂♂, 1 ♀ and *Rhipicephalus simus* 20 ♂♂, 4 ♀♀

** *Hyalomma marginatum rufipes* 31 ♂♂, 6 ♀♀; *R. simus* 1 ♂, 1 ♀

TABLE 7 The proportional distribution of several tick species on 5 kudu in the Andries Vosloo Kudu Reserve

Tick species	Stage of development	Total No. recovered	Percentage recovered from			
			Head	Neck, body and upper legs	Lower legs and feet	Tail
Amblyomma hebraeum	Larvae	2 053	11,7	19,1	69,0	0,2
	Nymphae	106	15,1	5,7	76,4	2,8
Haemaphysalis silacea	Larvae	13 859	9,6	8,8	81,1	0,5
	Nymphae	2 480	6,1	7,4	85,8	0,7
	Male	969	1,2	39,2	35,5	24,1
	Female	156	1,3	34,6	0,6	63,5
Rhipicephalus appendiculatus	Larvae	7 639	22,7	21,6	55,0	0,7
	Nymphae	774	54,8	24,8	18,6	1,8
	Male	98	98,0	2,0	0,0	0,0
	Female	28	85,7	14,3	0,0	0,0
Rhipicephalus evertsi evertsi	Larvae	558	93,9	2,9	2,9	0,3
	Nymphae	270	90,4	6,7	2,9	0,0
Rhipicephalus glabroscutatum	Larvae	8 987	4,1	11,8	82,2	1,9
	Nymphae	3 718	1,5	7,7	88,9	1,9

(Horak *et al.*, 1982). The gemsbok appeared to be under some stress in this park, which may not be a natural habitat of these animals (Ansell, 1971), and were not thriving, factors which may have made them more susceptible to tick infestation, as has been found with cattle under stress infested with *B. microplus* (Utech, Seifert & Wharton, 1978).

During a 13-month long survey of ticks on kudu on farms adjoining the Andries Vosloo Kudu Reserve, Knight & Rechav (1978) shot 2 kudu during June 1976 and 2 during June 1977. These authors visually examined certain areas on these kudu and removed, counted and identified the ticks they found (Knight, personal communication, 1982). They recovered no immature or adult *R. glabroscutatum* or *R. evertsi evertsi* and few larvae of *A. hebraeum, H. silacea* and *R. appendiculatus* from these animals. It is possible that these ticks were not present, or were present only in small numbers, but it is more likely that the techniques they used were not as sensitive as those employed in the present survey. Their survey did indicate, however, that the larvae and nymphae of *H. silacea* and *R. appendiculatus* can reach peak numbers during June.

Because they had recovered no immature *R. glabroscutatum* from any of the kudu examined in their survey, Knight & Rechav (1978) stated: "This indicates that the immature stages feed on other hosts, possibly small mammals, as does *Rhipicephalus simus* Koch or, even on birds, as is the case with *Hyalomma marginatum rufipes* Koch." The present findings contradict this statement in that fairly large numbers of immature *R. glabroscutatum* were recovered from nearly every host that was infested with adults of this species.

Perhaps the most significant finding of the present investigation is that large numbers of ticks may be found on apparently healthy wild animals. These burdens will probably be even larger if the recovery techniques used in the present survey are further improved.

ACKNOWLEDGEMENTS

We wish to thank the National Parks Board for placing the animals in the Kruger National Park and the Mountain Zebra National Park at our disposal. The Natal Parks Board kindly made available the buffalo and nyala in the Hluhluwe Game Reserve, and the Cape Provincial Administration the eland and kudu in the Thomas Baines and Andries Vosloo Reserves.

The assistance of Messrs B. D. de Klerk, C. Cheney, M. M. Knight and E. J. Williams with processing the necropsies is gratefully acknowledged.

This research was funded by the University of Pretoria and the Council for Scientific and Industrial Research.

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Printed by and obtainable from the Goverment Printer, Private Bag X85, Pretoria, 0001

Onderstepoort J. vet. Res., 55, 19–22 (1988)

ARTHROPOD PARASITES OF COMMON REEDBUCK, *REDUNCA ARUNDINUM*, IN NATAL

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ABSTRACT

HORAK, I. G., KEEP, M. E., FLAMAND, J. R. B. & BOOMKER, J., 1988. Arthropod parasites of common reedbuck, *Redunca arundinum*, in Natal. *Onderstepoort Journal of Veterinary Research*, 55, 19–22 (1988)

Twenty-five common reedbuck, *Redunca arundinum*, from the Himeville region, 21 from the Eastern Shores Nature Reserve, 4 from the Charter's Creek Nature Reserve and 2 from the St Lucia Game Park, Natal were examined for arthropod parasites. The reedbuck from Himeville were infested with 4 ixodid tick species, those from the Eastern Shores with 7 species and those from Charter's Creek and St Lucia with 6 species. *Rhipicephalus evertsi evertsi* was the only tick common to the 4 localities.

The lice *Damalinia reduncae* and *Linognathus fahrenholzi* were present on the reedbuck from each locality.

In addition 3 red duiker, *Cephalophus natalensis*, and 2 bushbuck, *Tragelaphus scriptus*, from the Charter's Creek Nature Reserve plus 2 impala, *Aepyceros melampus*, from the St Lucia Game Park were examined for ixodid ticks. The red duiker were infested with 3 tick species and the bushbuck and impala with 4 each.

INTRODUCTION

Common reedbuck *(Redunca arundinum)* are medium-sized antelope, the adult males having a mass of about 80 kg and females 70 kg (Smithers, 1983). The southern subspecies *Redunca arundinum arundinum* occurs in southern Africa as far north as southern Angola and the Zambezi River (Howard, 1983), but because of their specialised habitat requirements their distribution within these limits is patchy and discontinuous. In South Africa they are found in the central parts of the Transvaal and are widespread in Natal below 2 100 m. They are also present in the Transkei and east of the Komgha District in the Cape Province (Smithers, 1983).

Reedbuck have 2 essential habitat requirements, namely cover in the form of long grass, reedbeds or rocks, and a water supply. They avoid woodland but will tolerate the occurrence of woody vegetation within their grassland habitat. They live in pairs or family parties and are territorial. They do not form herds. When food and water are readily available reedbuck are nocturnal, but they may become more active during daytime in winter. They are almost exclusively grazers although they may browse in winter when the nutritive value of the grasses is low. Thus they respond to favourable agricultural practices where pastures are artificially irrigated during the winter months. They can take advantage of this high quality grazing all the year round, which may result in abnormally high populations being present. They are not strictly seasonal breeders: a single young may be born at any time of the year, after a gestation period of about 7,5 months.

Howard (1983) required culled reedbuck for his extensive 3 year study of the species and the opportunity was taken during the latter part of this project to collect material for parasite investigation. Permission was also obtained to remove 27 reedbuck from the eastern and western shores of Lake St Lucia to investigate their parasites. The arthropod parasites recovered from these animals are discussed in this paper.

The ixodid ticks of common reedbuck from countries in Africa outside the Republic of South Africa are recorded by Theiler (1962) and Walker (1974), while those occurring in South Africa are listed by Theiler (1962) and Baker & Keep (1970). The lice infesting these animals are listed by Ledger (1980).

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Received 2 October 1987—Editor

MATERIALS AND METHODS

Study sites

Himeville

The animals examined were taken from 5 adjacent farms near Himeville (29° 43′ S; 29° 36′ E) in Natal. The area is situated between 1 550 and 2 000 m above sea level. The total rainfall for the 13 months during which the reedbuck were collected was 1 220 mm, most of which fell between October and March. The study site lies within the Highland Sourveld bioclimatic groups (Phillips, 1973). According to Acocks (1975) it supports forest and scrub forest, but very little of this now remains. The dominant vegetation type today is *Themeda-Apochaete* grassland; artificial, often irrigated, annual permanent pastures, and croplands of maize and Japanese radish. Natural woody plants are principally *Leucosidea* scrub along the waterways and a few patches of *Protea* savanna on hill slopes. Exotic species are mainly gums *(Eucalyptus* spp.), wattle *(Acacia* spp.) and pines *(Pinus* spp.).

In addition to common reedbuck other antelope species occurring in the area are eland, *Taurotragus oryx;* mountain reedbuck, *Redunca fulvorufula;* grey rhebok, *Pelea capreolus;* oribi, *Ourebia ourebi;* blesbok, *Damaliscus dorcas phillipsi,* and common duiker, *Sylvicapra grimmia*. As the area is primarily utilized for farming, cattle, sheep, and to a lesser extent horses, are the principal large mammals, nearly all of which are regularly dipped in acaricidal compounds, at least in the summer months.

St Lucia

Most of the animals (21) from this area came from the Eastern Shores Nature Reserve. For comparative purposes 2 were taken from the St Lucia Game Park and 4 from the Charter's Creek Nature Reserve of Lake St Lucia.

The Eastern Shores Reserve occupies an area of approximately 250 km^2 at the southern end of the Mozambique coastal plain, between 27° 51′ and 28° 25′ S latitude and 32° 20′ and 32° 40′ E longitude. The habitat favoured by reedbuck consists of low-lying, seasonally inundated grassland, within the Zululand Palm Veld subdivision of Coastal Thornveld and Coastal communities (Acocks, 1975).

TABLE 1 Arthropod parasites recovered from 25 reedbuck from the Himeville region of Natal

Arthropod species	Total numbers of arthropods recovered					Number of animals infested
Ixodid ticks	Larvae	Nymphae	Males	Females	Total	
Boophilus sp.	38	0	0	0	38	9
Ixodes sp.	110	8	0	2	120	9
Rhipicephalus evertsi evertsi	760	504	0	1	1 265	22
Rhipicephalus sp.	2	0	12	13	27	4
Total	910	512	12	16	1 450	
Lice	Nymphae		Adults		Total	
Damalinia reduncae	1 765		2 321		4 086	22
Linognathus fahrenholzi	136		320		456	14
Total	1 901		2 641		4 542	

TABLE 2 Arthropod parasites recovered from 21 reedbuck from the Eastern Shores Nature Reserve in Natal

Arthropod species	Total numbers of arthropods recovered					Number of animals infested
Ixodid ticks	Larvae	Nymphae	Males	Females	Total	
Amblyomma hebraeum	14	2	0	0	16	5
Amblyomma marmoreum	12	0	0	0	12	2
Boophilus decoloratus	250	4	4	0	258	10
Haempahysalis sp.	2	6	0	0	8	2
Rhipicephalus spp.	28	—	—	—	28	9
Rhipicephalus appendiculatus	—	6	4	0	10	5
Rhipicephalus muehlensi	—	6	2	0	8	4
Rhipicephalus evertsi evertsi	1 162	808	0	6	1 976	19
Total	1 468	832	10	6	2 316	
Lice	Nymphae		Adults		Total	
Damalinia reduncae	84		144		228	7
Linognathus fahrenholzi	16		10		26	4
Total	100		154		254	

TABLE 3 Arthropod parasites recovered from 6 reedbuck from the Charter's Creek Nature Reserve and the St Lucia Game Park

Arthropod species	Total numbers of arthropods recovered					Number of animals infested
Ixodid ticks	Larvae	Nymphae	Males	Females	Total	
Amblyomma hebraeum	34	0	0	0	34	1
Haemaphysalis sp.	46	6	0	0	52	2
Rhipicephalus spp.	7 400	—	—	—	7 400	6
Rhipicephalus appendiculatus	—	748	130	132	1 010	6
Rhipicephalus maculatus	—	252	0	0	252	4
Rhipicephalus muehlensi	—	84	2	0	86	3
Rhipicephalus evertsi evertsi	160	150	0	2	312	6
Total	7 640	1 240	132	134	9 146	
Lice	Nymphae		Adults		Total	
Damalinia reduncae	2		42		44	3
Linognathus fahrenholzi	32		8		40	1
Total	34		50		84	

The hottest month is February and the coolest July, and the total average rainfall is 1 109 mm. The wettest months are January to April and the driest July to September.

The population density of reedbuck on the Eastern Shores of Lake St Lucia (0,46 per ha) appears to be amongst the highest in Africa (Venter, 1979). Besides reedbuck, other major mammal species occurring in the Eastern Shores Reserve include hippopotamus *(Hippopotamus amphibius)*, numbering approximately 600; bushpig *(Potamochoerus porcus)*, and buffalo *(Syncerus caffer)*, numbering about 40 at the time of this study.

The St Lucia Game Park is an enclosed area at the southern end of the Eastern Shores Reserve containing, besides reedbuck, waterbuck *(Kobus ellipsiprymnus)*; blue wildebeest *(Connochaetes taurinus)*; impala *(Aepyceros melampus)*, and warthog *(Phacochoerus aethiopicus)*.

The Charter's Creek Nature Reserve lies immediately west of the Eastern Shores Reserve and consists of similar habitat to this reserve. Other mammals present there

TABLE 4 The tick burdens of red duiker, bushbuck and impala from the north-eastern regions of Natal

Date slaughtered	Numbers of ticks recovered																					
	Amblyomma hebraeum	*Boophilus decoloratus*				*Haemaphysalis physalis* spp.	*Haemaphysalis parmata*			*Haemaphysalis silacea*			*Rhipicephalus* spp.	*Rhipicephalus appendiculatus*			*Rhipicephalus muehlensi*			*Rhipicephalus evertsi evertsi*	
	L	L	N	M	F	L	N	M	F	N	M	F	L	N	M	F	N	M	F	L	N
Red duiker, Charter's Creek Nature Reserve																					
March 1983	16					104	48	64	8				256				64				
March 1983	8					8	40	8					272				88				
July 1984*							10	20	6				32				60	2			
Bushbuck, Charter's Creek Nature Reserve																					
March 1983						24	72	40	26	8	2	2	384				176	99	74	116	92
March 1983	56					120	32				6		1 760				368	114	76	48	28
Impala, St Lucia Game Park																					
May 1984		16	4	12	20								1 900	28	80	112	4	2			
May 1984**		36	30	18	16								1 664	16	4	6		2			

* *Amblyomma marmoreum* Larvae 2; *Rhipicephalus maculatus* Nymphae 8
** With the exception of this animal, which was a juvenile male, all the other antelope were adult males

L = Larvae
N = Nymphae
M = Males
F = Females

include bushbuck *(Tragelaphus scriptus);* nyala *(Tragelaphus angasii);* common duiker and steenbok *(Raphicerus campestris).* The reedbuck density there is much higher (0,86 per ha) than in the Eastern Shores Reserve.

Survey animals

At Himeville 2 reedbuck (1 adult and 1 subadult) were shot each month for 13 consecutive months from May 1983–May 1984. Two to 4 reedbuck were shot at 3–4 monthly intervals in the Eastern Shores Nature Reserve from March 1983–August 1984. Two reedbuck were shot in the St Lucia Game Park during May 1984 and 4 in the Charter's Creek region during August 1984.

In addition to the reedbuck, 3 red duiker, *Cephalophus natalensis,* and 2 bushbuck in the Charter's Creek region, and 2 impala in the St Lucia Game Park, were shot and examined for parasites.

Parasite recovery

Only 1 half of each animal was processed for arthropod recovery, otherwise the animals were treated as described by Horak, Meltzer & De Vos (1982). The tick burdens of these animals were determined as described by Horak, Potgieter, Walker, De Vos & Boomker (1983).

RESULTS

The parasite burdens of the 3 groups of reedbuck and of the red duiker, bushbuck and impala are summarized in Tables 1–4.

Twenty-five of the 26 reedbuck from Himeville were examined for ectoparasites. These animals harboured 4 ixodid tick species, of which *Rhipicephalus evertsi evertsi* was the most abundant and prevalent. With the exception of the 25 adult *Rhipicephalus* sp. from the lower legs and feet of the 2 animals examined during July 1983, only 3 adult ticks were recovered. The total tick burdens of the animals were also very low and no pattern of seasonal abundance could be determined.

Seven ixodid tick species were recovered from the reedbuck examined in the Eastern Shores Nature Reserve. *R. evertsi evertsi* was again the most abundant and most prevalent tick. Only 16 adult ticks were recovered and the total tick burdens of the reedbuck were low.

The reedbuck from the St Lucia Game Park and the Charter's Creek Nature Reserve were infested with 6 tick species. The total tick burdens of these animals were higher than those of the reedbuck from the other localities and they also harboured more adult ticks.

The lice *Damalinia reduncae* and *Linognathus fahrenholzi* were recovered from reedbuck examined at each of the study sites.

The red duiker were infested with 3 tick species, and the bushbuck and impala with 4 each.

DISCUSSION

In addition to the ticks we recovered from the reedbuck Baker & Keep (1970) list *Ixodes pilosus, Haemaphysalis aciculifer, Haemaphysalis silacea, Rhipicephalus pravus* and *Rhipicephalus simus* as being found on animals in Natal.

One of the reasons for determining the parasite burdens of the reedbuck in the Himeville district was to ascertain whether they served as a reservoir of ticks that could infest the domestic livestock utilizing the same pastures. The fact that fewer than 1 500 ticks in total

were recovered from the 25 reedbuck examined indicates that in this particular habitat they pose no threat to domestic animals.

The animals from the Eastern Shores Nature Reserve, although infested with a greater variety of tick species than those from Himeville, also harboured only small numbers of ticks of which very few were adult. This led us to believe that the reedbuck could be a tick resistant antelope species similar to the blue and black wildebeest (Horak, De Vos & Brown, 1983). It is, however, possible that the Himeville and Eastern Shores localities are situated in regions of low tick infestation and consequently the reedbuck from the St Lucia Game Park and Charter's Creek Nature Reserve, which we assumed to have higher tick populations, were examined. These animals harboured considerably larger numbers of ticks than the other reedbuck, which indicates that where reedbuck are found in regions of high tick abundance they are likely to carry fairly large numbers of these parasites. Although the reedbuck and impala were examined during the same month in the St Lucia Game Park, the reedbuck harboured no *B. decoloratus* while both the impala were infested. In respect of other species the tick burdens of these animals were similar.

The red duiker were shot at Charter's Creek during March 1983 and July 1984 and the bushbuck during March 1983. All these animals were infested with *Haemaphysalis parmata*, while the reedbuck shot at this locality during August 1984 were not infested. This difference could be due either to seasonal differences in the abundance of the ticks, or differences in host preference, or differences in the habitat preferences of the antelope. Theiler (1962) comments on this tick as follows, "A Central and West African tick of the Guinean region that ranges into the forested highlands of Eastern Africa". The only record for South Africa she gives is Durban, Natal where she felt it may have been a recent introduction. The recovery of *H. parmata* from the animals at Charter's Creek indicates either that it has spread there from the Durban region or that originally it was more wide-spread than Theiler (1962) thought. The bushbuck seems to be a favoured host of this tick because Theiler's (1945) description of this species is based on material collected from a bushbuck in Uganda.

ACKNOWLEDGEMENTS

We wish to thank the Natal Parks Board for placing the antelope at our disposal.

We are grateful to Mrs Valerie A. Horak for her able technical assistance and Dr Jane B. Walker who confirmed the identification of *H. parmata*. This research was funded by the Meat Board, the Council for Scientific and Industrial Research and Rhodes University.

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Printed by the Government Printer, Private Bag X85, Pretoria, 0001

Onderstepoort J. vet. Res., 56, 63–66 (1989)

PARASITES OF DOMESTIC AND WILD ANIMALS IN SOUTH AFRICA. XXIV. ARTHROPOD PARASITES OF BUSHBUCK AND COMMON DUIKER IN THE WEZA STATE FOREST, NATAL

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ABSTRACT

HORAK, I. G., KEEP, M. E., SPICKETT, A. M. & BOOMKER, J., 1989. Parasites of domestic and wild animals in South Africa. XXIV. Arthropod parasites of bushbuck and common duiker in the Weza State Forest, Natal. *Onderstepoort Journal of Veterinary Research*, 56, 63–66 (1989)

One bushbuck, *Tragelaphus scriptus*, and 1 common duiker, *Sylvicapra grimmia*, were shot each month from May 1983 to May 1984 in the Weza State Forest, Natal, i.e. a total of 13 animals of each species. The bushbuck were infested with 8 ixodid tick species, 2 louse species and a louse-fly species. The common duiker harboured 7 tick species and 2 louse species.

Ticks of the genus *Ixodes* were the most numerous and prevalent on both antelope species, but no pattern of seasonal abundance was evident. Although only small numbers were recovered, adult *Haemaphysalis aciculifer* were present from September to February, nymphs of *Rhipicephalus appendiculatus* from May to September, and adult *Rhipicephalus lunulatus* from December to March. The louse-fly, *Lipoptena paradoxa*, was recovered from some of the bushbuck from October to May.

INTRODUCTION

The distribution, habitats, habits and food preferences of bushbuck, *Tragelaphus scriptus*, and of common duiker, *Sylvicapra grimmia*, have been summarized and commented upon by Boomker, Keep & Horak (1987) and Boomker, Du Plessis & Boomker (1983) respectively.

The ixodid ticks of these animals in countries outside the Republic of South Africa have been recorded by Theiler (1962), Yeoman & Walker (1967) and Walker (1974). Those occurring in South Africa are listed by Theiler (1962) and Baker & Keep (1970), while Horak, Potgieter, Walker, De Vos & Boomker (1983) and Boomker *et al.* (1983) have determined the actual tick burdens of both species in the Transvaal.

The lice recovered from bushbuck and common duiker have been listed by Ledger (1980) and the flies by Haeselbarth, Segerman & Zumpt (1966). The louse and louse-fly burdens of common duiker have been determined by Boomker *et al.* (1983).

Allen-Rowlandson (1986) required freshly-killed bushbuck and common duiker for his study of these species within the Weza forestry areas of Natal. During the later part of his project, material for parasitological investigation was collected and the present paper records the arthropod parasite burdens of 13 animals of each species. The helminth burdens of these animals have been reported in a separate paper (Boomker *et al.*, 1987).

MATERIALS AND METHODS

Study site

The physiography of the Weza State Forest (30° 35′ S; 24° 45′ E), Alfred District of Natal, in which the animals were collected, has been described by Boomker *et al.* (1987).

Survey animals

One bushbuck and 1 common duiker were shot at night each month for 13 consecutive months from May 1983 to May 1984. Eleven adults and 2 sub-adults of each species were shot. These comprised 7 male and 6 female bushbuck and 8 male and 5 female duiker.

Parasite recovery

Immediately after slaughter the skins of the animals were processed for arthropod parasite recovery as described by Horak, Meltzer & De Vos (1982). The ectoparasite burdens of the animals were determined as described by Horak *et al.* (1983).

RESULTS

Bushbuck

The total numbers of arthropod parasites recovered from the 13 animals examined are summarized in Table 1.

The bushbuck were infested with 8 ixodid tick species, 2 louse species and a louse-fly species. Small numbers of adult *Haemaphysalis aciculifer* were recovered from each animal examined from September 1983 to February 1984. Ticks of the genus *Ixodes* were the most numerous and all animals were infested, but no pattern of seasonal abundance was evident. Three of the 5 antelope examined between December 1983 and April 1984 each harboured 2 adult *Rhipicephalus follis*, while the 3 animals examined between December and February were each infested with adult *Rhipicephalus lunulatus*. Six of the 8 antelope examined between October 1983 and May 1984 harboured the louse-fly *Lipoptena paradoxa*

Common Duiker

Table 2 summarizes the total numbers of arthropod parasites recovered from the 13 antelope examined.

The duiker harboured 7 ixodid tick species and 2 species of lice. The 3 animals examined between November 1983 and January 1984 were each infested with adult *H. aciculifer*. Although ticks of the genus *Ixodes* were the most numerous no pattern of seasonal abundance was evident. Each of the animals examined from May to September 1983 was infested with 2–4 nymphs of *Rhipicephalus appendiculatus*. Only the animal shot during March 1984 was infested with adult *R. lunulatus*.

DISCUSSION

Ixodid ticks

The bushbuck harboured more ticks of each species than did the duikers. In total they carried approximately 8 times more larvae, twice as many nymphs and 10 times

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Received 5 December 1988—Editor

TABLE 1 Arthropod parasites recovered from 13 bushbuck from the Weza State Forest, Natal

Arthropod species	Total numbers of arthropods recovered					Number of animals infested
Ixodid ticks	Larvae	Nymphs	♂♂	♀♀	Total	
Boophilus decoloratus	70	0	2	0	72	4
Haemaphysalis aciculifer	0	0	58	16	74	6
Ixodes spp.	42 502	4 568	—	—	47 070	13
Ixodes pilosus	—	—	212	978	1 190	13
Ixodes sp. (near *I. pilosus*)	—	—	64	930	994	12
Rhipicephalus appendiculatus	26	4	0	0	30	2
Rhipicephalus evertsi evertsi	788	120	0	0	908	9
Rhipicephalus follis	0	0	4	2	6	3
Rhipicephalus lunulatus	0	0	18	14	32	3
Total	43 386	4 692	358	1 940	50 376	
Lice	Nymphs		Adults		Total	
Damalinia natalensis	150		112		262	6
Linognathus panamensis	216		142		358	10
Total	382		258		640	
Flies	Adults				Total	
Lipoptena paradoxa	156				156	6

TABLE 2 Arthropod parasites recovered from 13 common duiker from the Weza State Forest, Natal

Arthropod species	Total numbers of arthropods recovered					Number of animals infested
Ixodid ticks	Larvae	Nymphs	♂♂	♀♀	Total	
Boophilus sp.	12	2	0	0	14	4
Haemaphysalis aciculifer	0	2	6	4	12	4
Ixodes spp.	5 370	2 140	—	—	7 510	13
Ixodes pilosus	—	—	21	124	145	12
Ixodes sp. (near *I. pilosus*)	—	—	15	58	73	10
Rhipicephalus appendiculatus	6	14	0	0	20	6
Rhipicephalus evertsi evertsi	92	20	0	0	112	9
Rhipicephalus lunulatus	0	0	2	0	2	1
Total	5 480	2 178	44	186	7 888	
Lice	Nymphs		Adults		Total	
Damalinia sp.	22		26		48	2
Linognathus breviceps-complex	30		50		80	8
Total	52		76		128	

more adults. MacLeod, Colbo, Madbouly & Mwanaumo (1977) have stated that the larger the host the more adult ticks it seems likely to carry. This is confirmed by the observations of Horak & Knight (1986) and Horak, Sheppey, Knight & Beuthin (1986). They determined the total tick burdens of various sympatric host species and found that, with some exceptions, the larger the animal species the better host it is, particularly for the adults.

Boophilus decoloratus

Horak *et al.* (1983) found that in habitats in which *B. decoloratus* abounds, such as the Kruger National Park, bushbuck are good hosts of this tick. The small number of ticks recovered from these animals in the present survey therefore probably indicates an unfavourable habitat. *B. decoloratus* prefers open grassland or savanna with an annual rainfall above 380 mm (Howell, Walker & Nevill, 1978), whereas the study area comprises mountain grassland (27 %), indigenous forest (19 %) and plantations of exotic trees (54 %) (Boomker *et al.*, 1987). The bushbuck and duiker examined in this study were shot in forested regions with variable grass cover depending upon the size of the trees. However, as only small numbers of *B. decoloratus* have been recovered from common duiker examined in a habitat suitable for the blue tick (Boomker *et al.*, 1983), duiker are in any event probably not good hosts for this species.

Haemaphysalis aciculifer

Hoogstraal & El Kammah (1972) have recorded bushbuck as a host of this tick in Uganda, Kenya and Tanzania and common duiker in Kenya. Walker (1974) also lists bushbuck and common duiker as hosts in Kenya. Its recovery from these animals in the Weza State Forest confirms the observation of Horak *et al.* (1986) that it has a wider distribution in South Africa than is given by Theiler (1962). Norval (1985) notes that the 7 collections made in Zimbabwe were all from animals in woodland or wooded grassland habitats on the high rainfall, highveld plateau. These collections, which consisted only of adults, were all made from November to January. In the south-western Cape Province Horak *et al.* (1986) recovered small numbers of adult ticks from grey rhebuck (*Pelea capreolus*) and bontebok (*Damaliscus dorcas dorcas*) from August to February. In the present survey adults were recovered from September to February.

Ixodes pilosus

We have assumed that the immature stages of this tick and those of the other *Ixodes* species recovered are indistinguishable, hence they are lumped under *Ixodes* spp. in the tables. *I. pilosus* is found in sourveld areas along the coast from Port Shepstone in Natal to Cape Town in the western Cape Province (Howell *et al.*, 1978). A total of 29 males and 102 females (a ratio of

1:3,5) were recovered by Norval (1974) from bushbuck and duiker in the eastern Cape Province. Horak, Jacot Guillarmod, Moolman & De Vos (1987) recovered 38 males and 130 females (a ratio of 1:3,4) from dogs and only 1 male and 39 females from caracals (*Felis caracal*) in the same region, while Horak *et al.* (1986) recovered 63 males and 205 females (a ratio of 1:3,3) from bontebok, grey rhebuck and scrub hares (*Lepus saxatilis*) in the south-western Cape Province. The animals from the Weza forest harboured a total of 233 males and 1 102 females (a ratio of 1:4,7). Norval (1974) suggests that these ratios indicate that mating may occur either on the host or on the ground.

Although no pattern of seasonal abundance was obvious in the present survey, Horak *et al.* (1986, 1987) found that in the south-western and eastern Cape Province the larvae peak in June and the nymphs in August, while the adults may peak from October to December or January to May. They suggested that only one life cycle was completed annually.

Ixodes sp.

These ticks resemble *I. pilosus*, but show definite palpal, coxal and setal differences and they probably represent a new species. One of us (A.M.S.) examined the *Ixodes* sp. collected from 2 blue duikers (*Cephalophus monticola*) during the National Tick Survey in Zimbabwe (Norval, Spickett & Clifford, 1987) and considers them to be identical to those collected in the present survey. No pattern of seasonal abundance is evident and the ratio of males to females is 1:12,5.

Rhipicephalus appendiculatus

Horak *et al.* (1983) and Boomker *et al.* (1983) recovered fair numbers of larvae and nymphs, but few adults, from bushbuck and common duiker examined in the Transvaal. None of those bushbuck were examined during late summer, the season of peak adult abundance, while some of the duiker were. The infestation at Weza was possibly maintained by cattle and goats which occasionally stray into the forest from surrounding farms (Boomker *et al.*, 1987). The period during which the nymphs were present (May–September) was slightly shorter than that of the peak nymphal abundance (April–October) observed by Knight & Rechav (1978) and Rechav (1982) on kudu (*Tragelaphus strepsiceros*), goats and cattle in the eastern Cape Province.

Rhipicephalus evertsi evertsi

Although no adult ticks were recovered this species was probably maintained by the mules and horses used as transport animals in the forest (Boomker *et al.*, 1987). Equids are the preferred hosts of this tick (Hoogstraal, 1956; Norval, 1981).

Rhipicephalus follis

The description of the male of *R. follis* by Theiler (1947) and the original illustrations by Dönitz (1910) were used to identify this species. The descriptions given under this name by Theiler & Robinson (1953) and the accompanying illustrations by D. Pringle are now thought to refer to another species. Theiler (1947) suggests that domestic stock are hosts of this tick. Although only very small numbers of adult ticks were recovered from the bushbuck these were present from December to April.

Rhipicephalus lunulatus

There has been considerable confusion in the past between this species and *Rhipicephalus tricuspis* (Walker, Keirans, Pegram & Clifford, 1988), but these authors have recently published redescriptions of both species, listed their host associations and illustrated their geographic distributions.

Norval & Tebele (1983) state that *R. lunulatus* is widely distributed in Zimbabwe in woodland or woodland/savanna habitats which receive 550–1 200 mm of rain per annum. Amongst the collections of adult ticks in that country, the majority of which were made from November to January, there is one from a common duiker. Colborne (1985) recovered adults from cattle in Zimbabwe from November to May. The preferred sites of attachment were the legs and tail. In the present study adult ticks were present from December to March and all but 2 were recovered from the lower legs of the bushbuck or duiker.

Lice

Both *Damalinia natalensis* and *Linognathus panamensis* are specific parasites of bushbuck (Ledger, 1980). The *Damalinia* sp. on the duiker could not be specifically identified, while the *Linognathus* sp. on this host belonged to the *Linognathus breviceps*-complex as discussed by Ferris (1932). Boomker *et al.* (1983) have recovered small numbers of *Damalinia lerouxi*, *L. breviceps* and *Linognathus zumpti zumpti* from common duikers in the central Transvaal. The lice burdens were never large on either of the antelope species and no patterns of seasonal abundance could be ascertained.

Flies

The louse-fly, *L. paradoxa*, has a wide host range among the antelope and many species that browse are infested (Haeselbarth *et al.*, 1966). Although some of the bushbuck in the present survey were infested none of the duikers were. This contrasts with the findings of Boomker *et al.* (1983), who recovered *L. paradoxa* from 12 of the 16 duikers they examined. In the present survey the flies were only recovered from October to May and then not from all the bushbuck examined during this period.

ACKNOWLEDGEMENTS

We wish to thank the Directorate of Forestry, Department of Environmental Affairs, for placing the animals at our disposal. We are also grateful to Dr T. S. Allen-Rowlandson, during whose project the animals were collected and who also assisted with the collection of parasites. The technical assistance of Mrs Valerie A. Horak is gratefully acknowledged. We are also indebted to Dr Jane B. Walker for confirming the identities of *R. follis* and *R. lunulatus* and for supplying the appropriate references and to Dr E. M. Nevill for confirming that of *L. paradoxa* and assisting with the identification of the lice.

This research was funded by the Council for Scientific and Industrial Research, the Meat Board and Rhodes University.

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Printed by the Government Printer, Private Bag X85, Pretoria, 0001

Onderstepoort J. vet. Res., 58, 281–284 (1991)

IXODID TICKS AND LICE INFESTING RED DUIKERS AND BUSHPIGS IN NORTH-EASTERN NATAL

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ABSTRACT

HORAK, I. G., BOOMKER, J. & FLAMAND, J. R. B., 1991. Ixodid ticks and lice infesting red duikers and bushpigs in north-eastern Natal. *Onderstepoort Journal of Veterinary Research,* 58, 281–284 (1991)

Eighteen red duikers, *Cephalophus natalensis,* from the Charters Creek Nature Reserve and 2 from Fanies Island Nature Reserve were processed for arthropod parasite recovery. They harboured 8 species of ixodid ticks and 2 lice species. All were infested with *Haemaphysalis parmata* and the nymphs of *Rhipicephalus muehlensi.*

Two bushpigs, *Potamochoerus porcus,* from the Ndumu Nature Reserve, 5 from the Eastern Shores Nature Reserve and 1 from Cape Vidal were examined for ectoparasites. They were infested with 8 ixodid tick species, of which *Rhipicephalus maculatus* was the most abundant, and with 1 louse species.

INTRODUCTION

Red duikers, *Cephalophus natalensis,* are small antelope that are limited to the thick scrub and evergreen forests of the eastern parts of Natal and a small area on the southern slopes of the Soutpansberg in the northern Transvaal (Smithers, 1983). They are considered rare and their status is precarious because of the rapid destruction of their natural habitat (Smithers, 1983). Very little is known about their ecology, but Pienaar (1963) and Heinichen (1972) state that they occur either singly or in temporary pairs, or a female may be accompanied by her offspring. These shy, secretive browsers are found near permanent surface water.

Bushpigs, *Potamochoerus porcus,* are chiefly nocturnal animals that occur in groups, or sounders, of up to 40 individuals. Sounders consist of a dominant board and sow, other sows, juveniles and piglets. They are usually associated with dense vegetation growth, such as forests, thickets, reed beds or heavy cover of tall grass. Like warthogs, bushpigs wallow in mud, probably as a means of temperature regulation and as protection against biting insects. They root in the same way as warthogs, generally making less use of hard ground. In areas where they are hunted, feeding will not commence before late at night but where they are afforded protection, they may be seen in the late afternoon and early morning. They consume a wide variety of plant matter, including fruits, *Acacia* pods and roots, and are known to be attracted to carrion (Smithers, 1983).

The ticks infesting red duikers and bushpigs have been listed by Theiler (1962) and Baker & Keep (1970) and the lice by Ledger (1980). Total tick collections have been made from 3 red duikers in the Charters Creek Nature Reserve (Horak, Keep, Flamand & Boomker, 1988). Two studies on the total numbers of arthropod parasites harboured by warthogs, *Phacochoerus aethiopicus,* have been conducted in southern Africa (Horak, Biggs, Hanssen & Hanssen, 1983; Horak, Boomker, De Vos & Potgieter, 1988), but no such work exists for bushpigs.

The present paper describes the total tick and lice burdens of red duikers and bushpigs examined in the north-eastern Natal nature reserves.

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Received 19 June 1991—Editor

MATERIALS AND METHODS

Survey localities

Charters Creek (28° 14′ S, 32° 25′ E, altitude 0–100 m) and Fanies Island (28° 07′ S, 32° 27′ E, altitude 0–100 m) are nature reserves situated on the western shores of Lake St Lucia. The Eastern Shores Nature Reserve (27° 51′–28° 25′ S, 32° 20′–32° 40′ E, altitude 0–30 m) occupies an area of approximately 250 km^2 at the southern end of the Mozambique coastal plain, between the Indian Ocean to the east and Lake St Lucia to the west. Cape Vidal (28° 08′ S, 32° 33′ E) is a camp situated on the sea shore in the Eastern Shores Nature Reserve, almost opposite Fanies Island.

All these localities form part of the greater St Lucia Nature Reserve, the vegetation of which is classified as the Zululand Palm Veld subdivision of Coastal Thornveld and Coastal communities (Acocks, 1988). The annual rainfall varies between 650 and 1 000 mm, most of which falls in summer. Summers are hot and humid and winters are mild. Frost seldom occurs.

Ndumu Game Reserve (26° 50′–26° 56′ S, 32° 09′–32° 21′ E, altitude 30–100 m) is situated in the extreme north of Natal and comprises an area approximately 11 000 ha in extent. It falls within the Lowveld subtype of Tropical Bush and Savannah (Acocks, 1988). The rainfall varies from 500 to 750 mm *per annum* and falls mostly in summer. Summers are hot and humid and winters are mild. Frost does not occur.

Survey animals

Eighteen red duikers were shot in the Charters Creek Nature Reserve and 2 in the Fanies Island Nature Reserve. Two bushpigs were shot in the Ndumu Nature Reserve, 5 in the Eastern Shores Nature Reserve and 1 at Cape Vidal.

Parasite recovery

The animals were all processed for ectoparasite recovery as described by Horak, Meltzer & De Vos (1982). All the material collected was examined under a stereoscopic microscope and the arthropods collected, identified and counted. The red duikers were also processed for the recovery of helminths and these have been recorded separately (Boomker, Horak & Flamand, 1991).

TABLE 1 Arthropod parasites recovered from 20 red duikers in 2 north-eastern Natal nature reserves

Arthropod species	Total number of arthropods recovered					Number of animals infested
Ixodid ticks	Larvae	Nymphs	Males	Females	Total	
Ambyomma marmoreum	38	8	0	0	46	11
Haemaphysalis leachi	2	0	0	0	2	1
Haemaphysalis parmata	1 388	608	476	116(10)	2 588	20
**Rhipicephalus* spp.	15 194	—	—	—	15 194	20
Rhipicephalus appendiculatus	—	2	2	0	4	2
Rhipicephalus maculatus	—	226	0	0	226	11
Rhipicephalus muehlensi	—	3 246	2	0	3 248	20
Rhipicephalus evertsi evertsi	42	22	0	0	64	2
Rhipicephalus sp. (near *R. oculatus*)	0	0	2	0	2	1
Lice		Nymphs		Adults	Total	
Damalinia sp.		894		398	1 292	9
Linognathus sp.		2 676		1 016	3 692	14

* Undifferentiated larvae of *R. appendiculatus, R. maculatus* and *R. muehlensi,* which are almost indistinguishable when partially engorged

( ) = Number of maturing female ticks that should detach within 24 h, i.e. idiosoma of *H. parmata* > 2,5 mm in length

TABLE 2 Arthropod parasites recovered from 8 bushpigs in 3 north-eastern Natal nature reserves

Arthropod species	Total number of arthropods recovered					Number of animals infested
Ixodid ticks	Larvae	Nymphs	Males	Females	Total	
Amblyomma hebraeum	2	2	6	2	12	3
Haemaphysalis parmata	6	2	0	0	8	1
Rhipicephalus appendiculatus	0	3	2	2	7	2
Rhipicephalus follis	0	0	2	12	14	1
Rhipicephalus maculatus	329	386	2 273	988(54)	3 976	8
Rhipicephalus muehlensi	0	43	0	2	45	3
Rhipicephalus simus	0	0	2	0	2	1
Rhipicephalus zumpti	0	0	81	58(8)	139	6
Lice		Nymphs		Adults	Total	
Haematopinus latus		186		114	300	4

( ) = Number of maturing female ticks that should detach within 24 h, i.e. idiosoma of *R. maculatus* and *R. zumpti* > 6,0 mm in length. The other female ticks had not yet reached this stage of maturation

RESULTS

Red duikers

The animals from the 2 reserves harboured the same parasite species in similar numbers and their burdens have been combined in Table 1.

The red duikers were infested with 8 ixodid tick species of which *Rhipicephalus* spp. larvae (*Rhipicephalus appendiculatus, Rhipicephalus maculatus* and *Rhipicephalus muehlensi*) were the most abundant and, together with all stages of development of *Haemaphysalis parmata* and the nymphs of *R. muehlensi* the most prevalent. No patterns of seasonal abundance could be established because the animals were not shot at regular intervals. Two lice species were also recovered.

Bushpigs

The parasite burdens of the bushpigs from the various localities have been combined and summarized in Table 2.

Eight species of ixodid ticks were recovered. Of these *R. maculatus* was the most abundant and prevalent. Four animals were infested with the louse *Haematopinus latus*.

DISCUSSION

The small size of red duikers and their habitat preference make them ideal hosts for the immature stages of many tick species. Their size also precludes them as hosts for adult ticks of many species as these appear to prefer larger animals (Horak, Potgieter, Walker, De Vos & Boomker, 1983). In contrast bushpigs, like warthogs, carry few immature ticks and are mainly infested by adults (Horak, Boomker, De Vos & Potgieter, 1988). This could be due to host preference or the thickness of their hides or their grooming habits or a combination of all 3 factors.

With the exception of *Amblyomma hebraeum, R. appendiculatus* and *Rhipicephalus simus*, the tick species recovered from the bushpigs differed from those recovered from warthogs in the eastern Transvaal Lowveld (Horak, Boomker, De Vos & Potgieter, 1988). This, however, is related to the geographic distributions of the ticks rather than host preference.

Amblyomma hebraeum: The immature stages of this tick have a particularly wide host range (Theiler, 1962; Horak, MacIvor, Petney & De Vos, 1987). Their virtual absence in the present survey and on common reedbuck, *Redunca arundinum,* examined in the same region (Horak, Keep, Flamand & Boomker, 1988) indicates that these reserves lie on the edge of this tick's distribution in this particular region.

Amblyomma marmoreum: The adults feed almost exclusively on tortoises, while the immature stages can be found on many host species (Theiler, 1962; Norval, 1975; Horak, MacIvor, Petney & De Vos, 1987). The small numbers on the red duikers are thus not unexpected.

Haemaphysalis parmata: The immature stages are not easily distinguishable from those of *Haemaphysalis silacea,* which also occurs in this region (Horak, Keep, Flamand & Boomker, 1988). Because we recovered the adults of only *H. parmata* in the present survey we have assigned the immature stages to this species as well.

Theiler (1962) states that *H. parmata* is a central and west African tick that ranges into the forested highlands of eastern Africa. She questions whether the only record for South Africa that she lists from Durban may not be due to a recent introduction. Horak, Keep, Flamand & Boomker (1988) surmised that it was more widespread than Theiler had thought and the present results confirm this. They felt that the bushbuck was a favoured host of this species, and red duikers must now also fall within this category.

Rhipicephalus appendiculatus: Very few ticks of this species were recovered from common reedbuck in the Eastern Shores Nature Reserves, but fairly large numbers were present on these animals in the Charters Creek Reserve (Horak, Keep, Flamand & Boomker, 1988). Their virtual absence on the red duikers and bushpigs in the present survey could be due either to host preference or to the very dense vegetation both species prefer as habitat.

Rhipicephalus follis: Although this tick is fairly widespread in the eastern half of the country (Horak, Keep, Spickett & Boomker, 1989; Horak, Fourie, Novellie & Williams, 1991), with the possible exception of eland, it is never encountered in large numbers (Horak *et al.*, 1991). Only 1 of the bushpigs was infested.

Rhipicephalus maculatus: Buffaloes appear to be the preferred hosts of all stages of development (Horak *et al.*, 1983). The immature stages may also be found on red duikers, nyala, *Tragelaphus angasi,* and bushpigs (Baker & Keep, 1970; Horak, Potgieter, Walker, De Vos & Boomker, 1983). Judging by the present findings, the latter animals are also excellent hosts of the adults.

Rhipicephalus muehlensi: Nyala are the preferred hosts of all stages of development (Horak, Potgieter, Walker, De Vos & Boomker, 1983). Red duikers, probably because they share the nyalas' habitat, may harbour large numbers of immatures. Even though bushpigs share the same habitat they harbour few specimens of this species.

Rhipicephalus simus prefers monogastric animals such as zebras, carnivores and warthogs (Horak, De Vos & De Klerk, 1984; Horak, Jacot Guillarmod, Moolman & De Vos, 1987; Horak, Boomker, De Vos & Potgieter, 1988). The small number recovered from only 1 of the bushpigs is probably more a reflection of the tick's geographic distribution than host preference.

Rhipicephalus zumpti: Baker & Keep (1970) have recorded this tick from black rhinoceros in Natal. According to them it is prevalent in Mozambique, but rare in Zululand. However, Clifford & Anastos (1962) have synonymized *R. zumpti* with *Rhipicephalus reichenowi*, which in turn has been synonymized with *Rhipicephalus planus* (Morel, 1980). Nevertheless it may yet prove to be a valid species. The presence of *R. zumpti* on 6 of the 8 bushpigs not only indicates that they are preferred hosts, but that the tick might not be rare in the north-eastern regions of Natal and Zululand.

No specific identifications of the lice on the red duikers were made. *Damalinia* species have not previously been recorded from this host (Ledger, 1980). The *Linognathus* species recovered seemed to belong to the *L. breviceps* group, but there is controversy concerning the identities of lice belonging to this group (Ledger, 1980). *Haematopinus latus,* recovered from the bushpigs, fairly closely resembles *Haematopinus phacochoeri* which parasitizes warthogs (Ledger, 1980).

ACKNOWLEDGEMENTS

We wish to thank the Natal Parks Board for placing the red duikers and bushpigs at our disposal and for supplying the staff and facilities for processing the animals for parasite recovery.

We are most grateful for the technical assistance of Mrs Santa Meyer, Miss Renade Bartlett and Mr E. J. Williams. Dr Jane B. Walker assisted with the identification of *R. zumpti* and also supplied the references concerning this species.

This research was funded by the Foundation for Research Development.

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Printed by the Government Printer, Private Bag X85, Pretoria, 0001

Onderstepoort J. vet. Res., 59, 253–257 (1992)

ARTHROPOD PARASITES OF SPRINGBOK, GEMSBOK, KUDUS, GIRAFFES AND BURCHELL'S AND HARTMANN'S ZEBRAS IN THE ETOSHA AND HARDAP NATURE RESERVES, NAMIBIA

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ABSTRACT

HORAK, I. G., ANTHONISSEN, M., KRECEK, R. C. & BOOMKER, J., 1992. Arthropod parasites of springbok, gemsbok, kudus, giraffes and Burchell's and Hartmann's zebras in the Etosha and Hardap Nature Reserves, Namibia. *Onderstepoort Journal of Veterinary Research*, 59, 253–257 (1992)

A total of 48 springbok, 48 gemsbok, 23 kudus and 6 giraffes were examined for ticks and lice, while 9 Burchell's zebras and 6 Hartmann's mountain zebras were examined only for ticks. Springbok and gemsbok were shot in both the Etosha National Park in the north and the Hardap Nature Reserve in the south of Namibia. All the other animals were shot in the Etosha National Park.

A total of 7 ixodid tick species and 8 lice species were recovered. The springbok carried few ticks. The adults of a *Rhipicephalus* sp. (near *R. oculatus*) were most numerous on the gemsbok, especially during November. The kudus were the only animals harbouring *Rhipicephalus zambeziensis.* Adult *Hyalomma truncatum,* followed by adult *Hyalomma marginatum rufipes,* were most abundant on the giraffes and adult *Rhipicephalus evertsi mimeticus* were commonest on the zebras.

INTRODUCTION

The ixodid ticks found in Namibia have been listed by Theiler (1962). Her records were compiled after the identification of ticks that had generally been collected by stock inspectors, veterinarians, zoologists and other interested parties. These did not represent total collections of ticks from the animals examined.

In recent times more thorough collections of ticks have been made by examining animals of a particular species at regular intervals for periods of at least 1 year. Warthogs (*Phacochoerus aethiopicus*), Hartmann's mountain zebras (*Equus zebra hartmannae*) and cattle have been examined in Namibia in this way and 9 ixodid tick species recovered (Horak, Biggs, Hanssen & Hanssen, 1983; Horak, Biggs & Reinecke, 1984; Biggs & Langenhoven, 1984). In a recent review of ticks occurring in southern Africa, Walker (1991) lists 30 species from Namibia.

A number of animals of various species were to be shot in the Etosha National Park and the Hardap Nature Reserve, Namibia, for reproductive and biological studies, while others were to be killed for helminth recovery. This presented the opportunity to obtain ticks also from these animals and collections were made from springbok (*Antidorcas marsupialis*), gemsbok (*Oryx gazella*), kudus (*Tragelaphus strepsiceros*), giraffes (*Giraffa camelopardalis angolensis*), Burchell's zebras (*Equus burchelli antiqorum*) and Hartmann's mountain zebras. This paper records the ixodid tick burdens of these animals, and the lice burdens of the springbok, gemsbok and kudus. The helminths from the zebras, kudus and giraffes have been reported elsewhere (Krecek, Reinecke & Malan, 1987; Boomker, Anthonissen & Horak, 1988; Krecek, Boomker, Penzhorn & Scheepers, 1990).

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Received 12 August 1992—Editor

MATERIALS AND METHODS

Study sites

The localities at which the animals were shot are summarized in Table 1.

Survey animals

Springbok and gemsbok were shot in the Hardap Nature Reserve at approximately 2-monthly intervals from May 1983 to June 1984. Springbok were also shot near Okaukuejo and gemsbok from near Otjovasandu in the Etosha National Park from June 1983 until April 1984 and February 1984 respectively. In addition 4 gemsbok were shot near Okaukuejo towards the end of April and beginning of May 1984. Kudus were shot at 2-monthly intervals near Namutoni, Etosha National Park, from June 1983 until April 1984. Nine Burchell's zebras and 6 Hartmann's mountain zebras were shot near Okaukuejo and Otjovasandu respectively in the Etosha National Park.

Two giraffes were shot near Okaukuejo in November 1985, 2 in March 1986 and 2 in July 1986. These months fall within the 3 seasons described for Etosha by Berry (1980); these are hot and wet (January to April); cold and dry (May to August), and hot and dry (September to December).

Parasite recovery

The springbok, gemsbok, kudus and giraffes were processed for ectoparasite recovery as described by Horak, Boomker, Spickett & De Vos (1992). Ticks were recovered from the zebras by making whole body searches; this meant that few immature ticks and no lice were collected. The ectoparasites from all the animals were identified and counted under a stereoscopic microscope.

TABLE 1 Localities at which various herbivores were shot in Namibia for the recovery of arthropod parasites

Locality	Co-ordinates	Vegetation type (Van der Merwe, 1983)
Otjovasandu, Etosha National Park	19° 15′ S, 14° 30′ E	Mopane savanna
Okaukuejo, Etosha National Park	19° 11′ S, 15° 55′ E	Mopane savanna
Namutoni, Etosha National Park	18° 49′ S, 16° 56′ E	Saline desert with dwarf shrub savanna fringe surrounded by Mopane savanna and Forest savanna and woodland
Hardap Nature Reserve	24° 30′ S, 17° 45′ E	Dwarf shrub savanna

TABLE 2 Ixodid ticks recovered from various wild herbivores in Namibia

Tick and host species	Locality	No. examined	No. infested	No. of ticks recovered				
				Larvae	Nymphs	Males	Females	Total
Hyalomma marginatum rufipes								
Gemsbok	Otjovasandu	18	1	0	0	1	0	1
	Okaukuejo	4	2	0	0	9	1	10
	Hardap	26	1	0	0	4	0	4
Giraffe	Okaukuejo	6	6	0	0	372	75	447
Burchell's zebra	Okaukuejo	9	3	0	0	8	1	9
Hartmann's mountain zebra	Otjovasandu	6	3	0	0	10	5	15
Hyalomma truncatum								
Gemsbok	Otjovasandu	18	5	0	0	6	1	7
	Okaukuejo	4	2	0	0	12	8	20
	Hardap	26	1	0	0	2	0	2
Giraffe	Okaukuejo	6	6	0	0	1550	584	2134
Burchell's zebra	Okaukuejo	9	1	0	0	2	0	2
Hartmann's mountain zebra	Otjovasandu	6	5	0	0	27	1	28
Rhipicephalus evertsi mimeticus								
Springbok	Okaukuejo	21	1	1	0	0	0	1
	Hardap	27	1	6	0	0	0	6
Gemsbok	Otjovasandu	18	2	0	3	2	0	5
Kudu	Namutoni	23	18	4835	1057	23	23	5938
Giraffe	Okaukuejo	6	5	0	0	14	5	19
Burchell's zebra	Okaukuejo	9	6	5	4	34	9	52
Hartmann's mountain zebra	Otjovasandu	6	5	13	9	46	13	81
Rhipicephalus longiceps								
Giraffe	Okaukuejo	6	1	0	0	1	0	1
Rhipicephalus turanicus								
Burchell's zebra	Okaukuejo	9	1	0	0	0	1	1
***Rhipicephalus sp.* (near *R. oculatus*)**								
Springbok	Hardap	27	4	0	0	3	1	4
Gemsbok	Otjovasandu	18	1	0	0	1	0	1
	Hardap	26	17	0	0	220	130	350
Kudu	Namutoni	23	6	0	0	10	4	14
Rhipicephalus zambeziensis								
Kudu	Namutoni	23	7	2	0	10	8	20

RESULTS AND DISCUSSION

Ixodid ticks

The tick species recovered, the hosts from which they were collected and the localities at which the hosts were examined are summarized in Table 2.

A total of 7 ixodid tick species were recovered. With the exception of the *Rhipicephalus* sp. (near *R. oculatus*), the Etosha National Park seemed to be a more favourable habitat for all species than the Hardap Nature Reserve. As noted in previous surveys, springbok had very low tick burdens (Horak, Meltzer & De Vos, 1982; De Villiers, Liversidge & Reinecke, 1985; Horak, Fourie, Novellie & Williams, 1991). Whether this was due to natural immunity, or host preference, or habitat preference, or behaviour of the antelope could not be determined in either this or the other surveys.

Hyalomma spp.

Both *Hyalomma marginatum rufipes* and *Hyalomma truncatum* prefer the drier western regions of southern Africa (Theiler, 1962; Howell, Walker & Nevill, 1978; Walker, 1991). Judging by the present results the Okaukuejo region of the Etosha National Park is a better habitat for *H. truncatum* than for *H. marginatum rufipes*. The preferred hosts of the adults are large animals such as cattle (Horak, 1982; Biggs & Langenhoven, 1984), horses (Horak, Biggs & Reinecke, 1984; Horak, Knight & De Vos, 1986), zebras and eland (Rechav, Zeederberg & Zeller, 1987; Horak *et al.*, 1991). The present results indicate that giraffes probably rank above all the other animals mentioned above as the host of choice. Each of the 6 giraffes examined harboured more than 200 adult *Hyalomma* and 1 of them more than 850 ticks.

Kudus are definitely not good hosts of adult *H. truncatum* (Horak *et al.*, 1992), while gemsbok should only be considered fair hosts of both species (Fourie, Vrahimis, Horak, Terblanche & Kok, 1991). Warthogs examined in the northern bushveld region of Namibia harboured more *H. truncatum* than *H. marginatum rufipes* (Horak *et al.*, 1983), while the converse was true for mountain zebras and horses examined in the central region west of Windhoek, and cattle examined east of Windhoek (Horak *et al.*, 1984; Biggs & Langenhoven, 1984). The preferred hosts of the immature stages of both species are scrub hares (Rechav *et al.*, 1987; Horak *et al.*, 1991; Horak & Fourie, 1991).

As only 2 giraffes were examined on each occasion, and then at 4-monthly intervals, it is virtually impossible to determine a pattern of seasonal abundance for these ticks. The total counts of *H. marginatum rufipes* were 206, 189 and 52, and those of *H. truncatum* 497, 602 and 1035, for both animals examined during November 1985 and March and July 1986 respectively.

Both these ticks have long mouthparts and these can cause considerable tissue damage, which may lead to secondary bacterial infection (Howell *et al.*, 1978). *H. marginatum rufipes* is a vector of *Anaplasma marginale*, the cause of gallsickness in cattle (Potgieter, 1981), and *H. truncatum* transmits a toxin causing sweating sickness in the latter animals (Howell *et al.*, 1978).

Rhipicephalus evertsi mimeticus

We are unable to differentiate the immature stages of this tick from those of *Rhipicephalus evertsi evertsi*. However, as the adults of only *R. evertsi mimeticus* were recovered we have assigned all the immatures to this subspecies. This tick prefers the arid regions of Namibia and western Botswana (Howell *et al.*, 1978).

In the case of *R. evertsi evertsi* equids are among the preferred hosts of all stages of development (Norval, 1981; Horak *et al.*, 1986). *R. evertsi mimeticus* appears also to favour these hosts (Horak *et al.*, 1984). The collection methods employed on the zebras in the present survey virtually precluded the recovery of immature ticks, which are found in the outer ear canals, and the numbers of adult ticks recovered were also small. Nevertheless their mean burdens of adult ticks were slightly higher than those of the other host species. The vast majority of the immature ticks recorded from the kudus at Namutoni were found on a single animal, which carried 4 172 larvae and 952 nymphs. Kudus are considered to be poor hosts of the closely related *R. evertsi evertsi* (Horak *et al.*, 1992).

No pattern of seasonal abundance was evident.

Rhipicephalus longiceps

Walker (1991) cites this as a rare tick found only in Namibia and Angola. It has been recovered from cattle, klipspringer and gemsbok (Walker, 1991), also from 3 of 37 warthogs examined in the northern bushveld of Namibia (Horak *et al.*, 1983). Its recovery from one of the giraffes appears to constitute a new host record.

Rhipicephalus turanicus

This tick has previously been recovered in the Etosha National Park and from Grootfontein in northern Namibia (Walker, 1991). Its adults have a very wide host range, and amongst the wild animals ostriches and zebras appear to carry the largest numbers (Pegram, Clifford, Walker & Keirans, 1987).

Rhipicephalus sp. (near *R. oculatus*)

The problems surrounding the species diagnosis of this tick and *Rhipicephalus oculatus sensu stricto* have been discussed by Walker (1991). She also records it as being widely distributed in Namibia, especially south of Windhoek, an observation confirmed by the present findings.

Walker (1991) lists the wild hosts as being mostly antelopes, particularly gemsbok and kudus. It has also been recorded (as *R. oculatus*) from 7 of 37 warthogs examined in the northern bushveld region of Namibia (Horak *et al.*, 1983). In the present survey gemsbok were more heavily infested than kudus, possibly owing to the more southerly locality at which they were examined. In a recent survey in South Africa, kudus just north of Grahamstown, in the eastern Cape Province, were more heavily infested than sheep, goats, cattle and scrub hares from the same locality (Horak & Knight, 1986).

No clear pattern of seasonal abundance could be seen on the eastern Cape kudus, but no ticks of this species were present on the animals examined during May and June (Horak *et al.*, 1992). The scrub hares from that particular locality, however, generally carried larger numbers of adult ticks during August and from November to April (Horak & Fourie, 1991). In the present survey the gemsbok in the Hardap Nature Reserve harboured the greatest numbers of ticks during November and February (Fig. 1). The largest numbers of ticks (a total of only 6 on 4 animals) were recorded on the kudus in the Etosha National Park during June and during August.

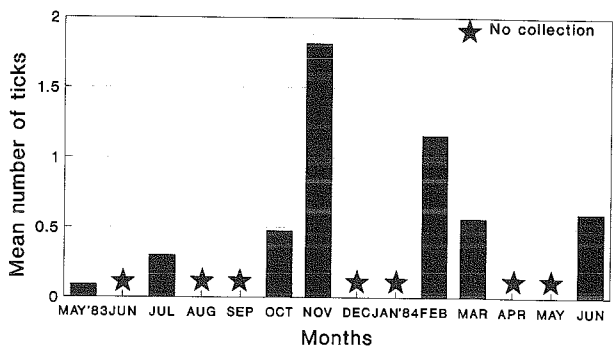

FIG. 1 The seasonal abundance of a *Rhipicephalus* sp. (near *R. oculatus*) on gemsbok in the Hardap Nature Reserve, Namibia [$\log_{10}(x + 1)$]

Rhipicephalus zambeziensis

This tick has been recorded in northern Namibia in the Kunene (Kaokoland) and the Otjozondjupa (Grootfontein) districts (Norval, Walker & Colborne, 1982). Namutoni, in the Etosha National Park, lies

between these 2 regions. *R. zambeziensis* infests a large variety of hosts, including carnivores, suids and bovids (Walker, 1991). Within its distribution range kudus appear to be amongst the preferred hosts of all stages of development (Horak *et al.*, 1992).

R. zambeziensis can transmit *Theileria parva parva* and *Theileria parva bovis,* the cause of East Coast fever and January disease respectively in cattle (Lawrence, Norval & Uilenberg, 1983). It also transmits *Theileria parva lawrencei* to buffaloes and cattle. In the former animals *T. parva lawrencei* is not pathogenic, but it produces the usually fatal Corridor disease in cattle.

Lice

The springbok harboured the greatest number of lice species, but the total burdens of individual animals were low (Table 3). No pattern of seasonal abundance was evident. De Villiers *et al.*, (1985) examined springbok near Kimberly in the Cape Province, South Africa, for parasites at fairly regular intervals for a period of 14 months. They recovered 6 lice species from these animals and the 4 major species all exhibited peak burdens during September.

TABLE 3 Lice recovered from springbok, gemsbok and kudus in Namibia

Host and lice species	Number of hosts examined	Number infested	Number of lice recovered		
			Nymphs	Adults	Total
Springbok					
Damalinia antidorcus	48	8	3	16	19
Linognathus antidorcitis	48	23	45	43	88
Linognathus armatus	48	1	0	11	11
Linognathus bedfordi	48	1	3	2	5
Linognathus euchore	48	15	35	40	75
Gemsbok					
Haematopinus oryx	48	3	38	5	43
Linognathus oryx	48	28	3567	737	4304
Kudu					
Linognathus taurotragus	23	17	582	311	893

Two lice species were recovered from the gemsbok, of which *Linognathus oryx* was the most abundant. The seasonal abundance of the latter species on the gemsbok is illustrated in Fig. 2.

Lice numbers started to increase sooner on the animals in the Hardap Reserve than on those in the Etosha Park. Peak numbers were recorded during November and December respectively (summer).

In contrast peak burdens of the louse *Linognathus taurotragus* were recorded in June (winter) on the kudus examined at Namutoni in the Etosha National Park (Fig. 3). No lice were recovered from the giraffes.

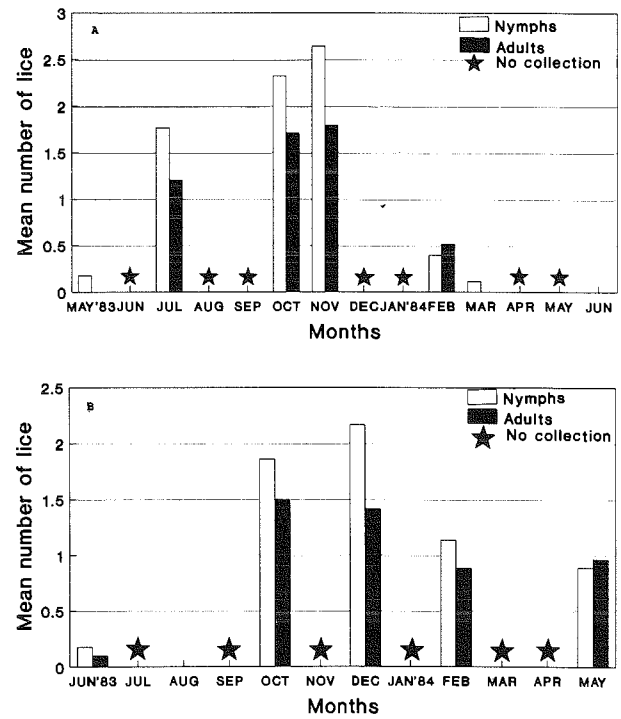

FIG. 2 The seasonal abundance of *Linognathus oryx* on gemsbok in Namibia [$\log_{10}$ (x + 1)]
A. in the Hardap Nature Reserve
B. in the Etosha National Park

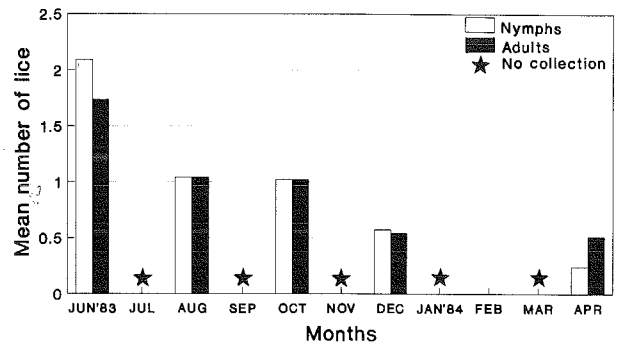

FIG. 3 The seasonal abundance of *Linognathus taurotragus* on kudus in the Etosha National Park, Namibia [$\log_{10}$ (x + 1)]

ACKNOWLEDGEMENTS

This study is part of the Wildlife Research Programme of the Faculty of Veterinary Science, University of Pretoria.

We would like to thank the Director, Department of Agriculture and Nature Conservation, for placing the animals at our disposal and Dr H. C. Biggs, Central Veterinary Laboratory, Windhoek for making the necessary arrangements, and the staff of the 2 nature reserves for their assistance with the necropsies. Messrs L. Scheepers and T. E. Krecek assisted with the parasite recoveries from the giraffes and Mrs Bonnie Roper, Prof. R. K. Reinecke and Dr F. S. Malan with those from the zebras. Mrs Santa Meyer collected the arthropod parasites from the processed material. Dr Jane B. Walker assisted

with the identification of *R. longiceps*. Miss Andrea van Niekerk drew the graphs.

This research was funded by the Foundation for Research Development and the University of Pretoria.

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PARASITES OF DOMESTIC AND WILD ANIMALS IN SOUTH AFRICA. XXX. ECTOPARASITES OF KUDUS IN THE EASTERN TRANSVAAL LOWVELD AND THE EASTERN CAPE PROVINCE

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ABSTRACT

HORAK, I. G., BOOMKER, J., SPICKETT, A. M. & DE VOS, V., 1992. Parasites of domestic and wild animals in South Africa. XXX. Ectoparasites of kudus in the eastern Transvaal Lowveld and the eastern Cape Province. *Onderstepoort Journal of Veterinary Research*, 59, 259–273 (1992)

Sets of four kudus were shot and examined for arthropod parasites at approximately monthly intervals from April 1981 to March 1983 in the southern part of the Kruger National Park, eastern Transvaal Lowveld. These animals harboured 10 ixodid tick species of which *Boophilus decoloratus* followed by *Amblyomma hebraeum* were the most abundant. The seasonal abundances of these ticks and of *Amblyomma marmoreum, Rhipicephalus appendiculatus, Rhipicephalus evertsi evertsi* and *Rhipicephalus zambeziensis* were determined. The kudus were also infested with 3 lice and 1 louse fly species, as well as the nymphs of a pentastomid.

Sixteen kudus were shot in the Andries Vosloo Kudu Reserve, eastern Cape Province and 9 on an adjacent farm. These animals were infested with 12 tick species. *A. hebraeum* followed by *Rhipicephalus glabroscutatum* were the most abundant on kudus in the reserve and *R. glabroscutatum* followed by *Haemaphysalis silacea* on the animals on the farm. The seasonal abundances of *A. hebraeum,A. marmoreum, H. silacea, R. appendiculatus, R. glabroscutatum* and a *Rhipicephalus* sp. (near *R. oculatus*) were determined on the kudus in the reserve. The kudus were also infested with 3 lice and 1 louse fly species. Two kudus examined in the Addo Elephant National Park were infested with 6 tick, 1 louse and 1 louse fly species.

INTRODUCTION

A number of surveys on the abundance of ectoparasites on a variety of host species have already been conducted in the eastern Transvaal Lowveld and the eastern Cape Province. Blue wildebeest, Burchell's zebras, warthogs and helmeted guineafowls have been examined in the Kruger National Park, eastern Transvaal Lowveld (Horak, De Vos & Brown, 1983; Horak, De Vos & De Klerk, 1984; Horak, Boomker, De Vos & Potgieter, 1988; Horak, Spickett, Braack & Williams, 1991). While kudus, cattle, Dorper sheep, Angora goats, scrub hares and helmeted guineafowls have been examined in the Andries Vosloo Kudu Reserve and/or on the adjacent farm "Bucklands", eastern Cape Province (Knight & Rechav, 1978; Rechav, 1982; Horak, Williams & Van Schalkwyk, 1991; Horak, Spickett, Braack & Williams, 1991; Horak, Knight & Williams, 1991; Horak & Fourie, 1991).

Several studies on the ixodid tick burdens of kudus, *Tragelaphus strepsiceros,* have been published. Knight & Rechav (1978) examined 25 animals from the farms "Bucklands" and "Ulster" and Horak, Potgieter, Walker, De Vos & Boomker (1983) 4 animals in the Kruger National Park and 5 from the Andries Vosloo Kudu Reserve. Horak & Knight (1986) and Petney & Horak (1987) also compared the burdens of some of the animals from the Andries Vosloo Kudu Reserve, included in the present paper, with those of kudus on the adjacent farm "Bucklands". These surveys all indicate that kudus are good hosts of several tick species and may become heavily infested, a fact also commented on by Lightfoot & Norval (1981) in Zimbabwe.

Kudus are large antelope that are widely distributed in southern and East Africa. They prefer light forest or dense bush (Ansell, 1971) and generally avoid open country (Dorst & Dandelot, 1972; Rautenbach, 1982). They usually live in small groups comprising adult cows and their offspring. Calves remain hidden for approximately the first 3 months of life and then join the cow groups (Novellie, 1983). Male animals leave the group when about 2 years old, while females stay with the group until fully mature (Novellie, 1983). Adult bulls form bachelor groups that join the cows during the breeding season (Novellie, 1983).

The present paper describes surveys on the abundance of ectoparasites of kudus shot in the Kruger National Park, eastern Transvaal Lowveld, in the Andries Vosloo Kudu Reserve and on the adjacent farm "Bucklands", and in the Addo Elephant National Park, eastern Cape Province. The kudus in these surveys were also examined for internal parasites and this has been reported elsewhere (Boomker, Horak & De Vos, 1989; Boomker, Horak & Knight, 1991).

MATERIALS AND METHODS

Parasite recovery

After the animals had been shot they were transported to the laboratories at Skukuza in the Kruger National Park or Grahamstown in the eastern Cape Province. There the carcass of each animal was skinned and half the skin of the head, half the skin of the body and upper legs, the whole skin of the tail as well as 1 lower front leg and 1 lower back leg with skin attached were placed separately in plastic bags. A tick-detaching agent[1] was added

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Received 15 July 1992—Editor

[1] Triatix: Coopers South Africa (Pty) Ltd

TABLE 1 Arthropod parasites of 95 kudus in the Kruger National Park

Arthropod species	Total number recovered					No. of kudus infested
Ixodid ticks	Larvae	Nymphs	Males	Females	Total	
Amblyomma hebraeum	67 216	9 801	659	291(9)	77 967	95
Amblyomma marmoreum	465	0	0	0	465	18
Boophilus decoloratus	161 815	107 711	35 959	18 140(360)	323 625	95
Haemaphysalis leachi/spinulosa	1	0	0	0	1	1
Hyalomma truncatum	0	0	30	6	36	16
Ixodes sp.	2	1	0	0	3	2
Rhipicephalus appendiculatus	11 915	3 208	3 062	1 721(31)	19 906	88
Rhipicephalus evertsi evertsi	9 015	940	167	63(2)	10 185	92
Rhipicephalus simus	0	0	6	9	15	5
Rhipicephalus zambeziensis	14 365	2 062	963	485(7)	17 875	91
Lice	Nymphs		Adults		Total	
Damalinia sp.	4 336		2 375		6 711	73
Haematopinus taurotragi	470		413		883	23
Linognathus taurotragus	4 782		2 781		7 563	43
Louse flies	Adults				Total	
Lipoptena paradoxa	4 616				4 616	94
Pentastomids	Nymphs				Total	
Linguatula nuttalli	667				667	60

( ) = Number of maturing females i.e. idiosoma of *A. hebraeum* >9,5 mm; *B. decoloratus* >4,0 mm; *R. appendiculatus* >5,0 mm; *R. evertsi evertsi* >6,0 mm; *R. zambeziensis* >5,0 mm. Females of the other tick species had not started to mature

to the skins in the bags which were tightly secured and stored overnight. The following morning the skins were thoroughly scrubbed with brushes with steel bristles and washed. The tick-detaching agent remaining in the plastic bags and the material obtained from scrubbing and washing the skins were sieved on sieves with 0,15 mm apertures. The residues in the sieves were collected, preserved in 10 % formalin and stored.

Pentastomid nymphs were recovered from the hearts, livers and lungs of the kudus, which had all been processed for helminth recovery (Boomker *et al.*, 1989).

Parasite counts

Representative samples of the material collected were examined under a stereoscopic microscope, and the parasites identified and counted. The remainder of the material was examined macroscopically for the presence of adult ticks and louse flies. These and the pentastomid nymphs recovered from the hearts, livers and lungs were counted and identified under a stereoscopic microscope. The data on the louse flies will be reported separately.

Surveys at Particular Localities

Kruger National Park (KNP)

Study site

This has been described in some detail by Boomker *et al.* (1989). In summary, it is located in the southern part of the park between latitude 25° 06′–25° 21′ S and longitude 31° 27′–31° 36′ E. The vegetation is classified as Lowveld (Acocks, 1988). The days are warm to hot in summer and mild in winter and frost occurs occasionally. Rainfall varies from 600–700 mm per annum and usually falls in summer.

Survey animals

Each month from April 1981 to March 1983, 4 kudus were shot in the study area. At each occasion an attempt was made to obtain 1 adult male, 1 adult female, 1 young or sub-adult male and 1 calf of either sex. The animals were aged according to Simpson (1971). For statistical reasons they have been grouped according to age into calves (0–12 months old), juveniles (13–24 months old), young adults (25–48 months old) and prime or old adults (49 months and older). A total of 96 kudus were shot, but only 95 were examined for ectoparasites as the material collected from 1 had not been adequately preserved.

Arthropod burdens

The total numbers of arthropod parasites recovered from the kudus shot in the survey area are summarized in Table 1.

The animals were infested with 10 ixodid tick species. *Boophilus decoloratus* and *A. hebraeum* were the most abundant and all kudus were infested. They were also infested with 3 lice and 1 louse fly species.

Seasonal abundance

The seasonal abundances of *A. hebraeum, Amblyomma marmoreum, B. decolaratus, Rhipicephalus appendiculatus, Rhipicephalus evertsi evertsi* and *Rhipicephalus zambeziensis* on the kudus are graphically illustrated in Fig. 1.

A. hebraeum exhibited no clear pattern of seasonal abundance, while the larvae of *A. marmoreum* were consistently present from March to July 1982 and during February and March 1983. Peak burdens of *B. decoloratus* were recorded in September and October 1981, and November and December

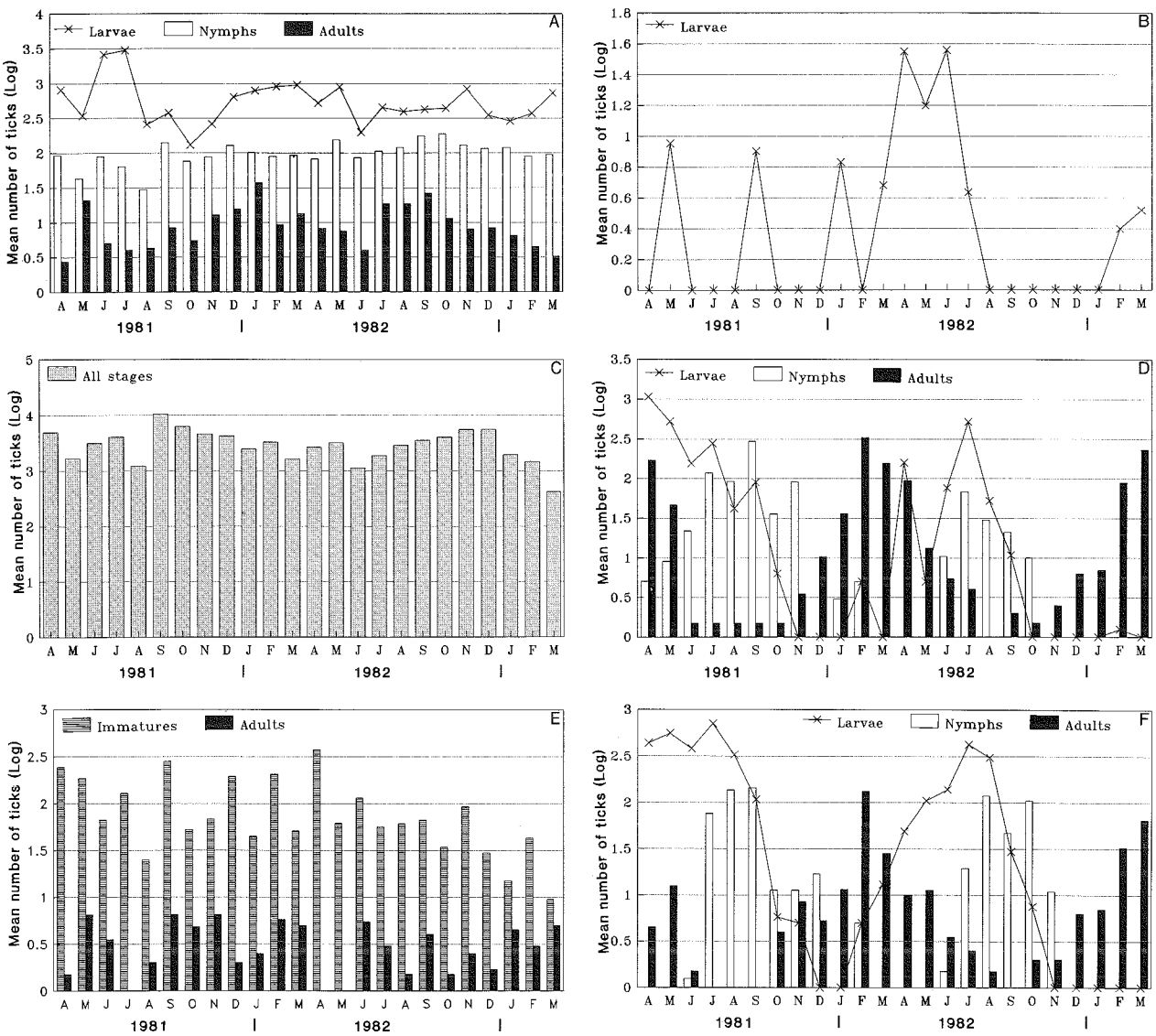

FIG. 1 The seasonal abundance of
A. *Amblyomma hebraeum*, B. *Amblyomma marmoreum*, C. *Boophilus decoloratus*, D. *Rhipicephalus appendiculatus*, E. *Rhipicephalus evertsi evertsi* and F. *Rhipicephalus zambeziensis* on kudus in the Kruger National Park

1982. The larvae of *R. appendiculatus* reached the largest numbers from April to July, the nymphs from July to September or November, and the adults during February to April. No clear pattern of seasonal abudance was evident for *R. evertsi evertsi.* Large numbers of larvae of *R. zambeziensis* were present from April to September, nymphs from July to September or October and adults during February and March.

Host sex-preferences

The host sex-preferences of *A. hebraeum* and *B. decoloratus* are summarized in Table 2.

Adult male kudus harboured significantly more nymphs, males and females of *A. hebraeum,* and more males and females of *B. decoloratus* than adult female animals. No such differences were noted for the other tick species or between adult animals and calves of 6 months or less of age.

Andries Vosloo Kudu Reserve (AVKR) and the farm "Bucklands"

Study site

The reserve (6 497 ha in extent) and the farm (5 480 ha), share an 11 km common boundary, and are situated in the eastern Cape Province around 33° 07 ′ S and 26° 40′ E with altitudes ranging from 335–538 m. The vegetation is classified as Valley Bushveld (Acocks, 1988). Rainfall is non-seasonal and the long-term mean annual total is 484 mm of which slightly more than 300 mm falls from October to March.

At the time of the survey the reserve contained approximately 450 kudus, 54 hartebeest, 140 eland and 100 buffaloes, and the farm approximately 300 kudus, 300 Dorper sheep, 4 000 Angora goats and 185 cattle. The domestic stock were regularly treated with an acaricide. Both properties harboured

TABLE 2 A comparison of the burdens of *Amblyomma hebraeum* and *Boophilus decoloratus* of 15 adult male and 15 adult female kudus shot in pairs during the same months and in the same locality, using a Wilcoxon matched-pairs signed-ranks test

Tick species	Developmental stage	Mean number of ticks recovered from adult kudus		Wilcoxon T value	Significance P =
		Male kudus	Female kudus		
Abmlyomma hebraeum	Nymphs	144,7	103,2	20,0	0,050
	Males	22,1	2,8	0,0	0,001
	Females	11,1	0,5	0,0	0,001
Boophilus decoloratus	Males	503,7	338,2	24,0	0,050
	Females	302,3	154,2	15,0	0,050

TABLE 3 Arthropod parasites of 16 kudus in the Andries Vosloo Kudu Reserve

Arthropod species	Total number recovered					No. of kudus infested
Ixodid ticks	Larvae	Nymphs	Males	Females	Total	
Amblyomma hebraeum	32 009	3 568	464	252(22)	36 293	16
Amblyomma marmoreum	2 112	0	0	0	2 112	11
Boophilus decoloratus	8	36	34	20	98	5
Haemaphysalis silacea	10 003	2 309	1 410	415(66)	14 137	16
Hyalomma marginatum rufipes	0	0	3	0	3	1
Hyalomma truncatum	0	0	2	0	2	1
Ixodes pilosus	0	14	2	12	28	4
Rhipicephalus appendiculatus	4 391	775	334	180(24)	5 680	16
Rhipicephalus evertsi evertsi	296	145	18	10	469	16
Rhipicephalus glabroscutatum	13 596	7 269	1 043	544(20)	22 452	16
Rhipicephalus sp. (near *R. oculatus*)	0	0	104	41(14)	145	13
Rhipicephalus simus	0	0	2	4	6	2
Lice	Nymphs		Adults		Total	
Haematopinus taurotragi	486		92		578	4
Linognathus taurotragus	1 895		784		2 679	16
Louse flies	Adults				Total	
Lipoptena paradoxa	108				108	13

( ) = Number of maturing females i.e. idiosoma of *A. hebraeum* >9,5 mm; *H. silacea* >5,0 mm; *R. appendiculatus* >5,0 mm; *R. glabroscutatum* >4,0 mm; *Rhipicephalus* sp. (near *R. oculatus*) >5,0 mm in length. Females of the other tick species had not started to mature

large numbers of small antelope, scrub hares and helmeted guineafowls.

Survey animals

Each month, from February 1985 to January 1986, and every 3 months thereafter, commencing March 1986 until December 1986, a single adult male kudu was shot on the reserve. With the exeption of June 1985 when 2 kudus were shot, 1 adult male kudu was shot on "Bucklands" every 3 months from March 1985 until December 1986. In this way 16 kudus on the reserve and 9 kudus on the farm where shot and examined.

Arthropod burdens

The total numbers of arthropod parasites recovered from kudus on the reserve and on the farm are summarized in Tables 3 and 4 respectively.

The kudus on the reserve were infested with 12 ixodid tick species of which *A. hebraeum* followed by *Rhipicephalus glabroscutatum* were the most abundant. The animals on the farm were infested with 9 tick species of which *R. glabroscutatum* followed by *Haemaphysalis silacea* were the most abundant. The kudus were infested with 3 lice and 1 louse fly species.

Seasonal abundance

The seasonal abundances of *A. hebraeum, A. marmoreum, H. silacea, R. appendiculatus, R. evertsi evertsi, R. glabroscutatum* and a *Rhipicephalus* sp. (near *R. oculatus*) on only those kudus which were shot from February 1985 to January 1986 in the reserve, are graphically represented in Fig. 2.

The largest numbers of larvae of *A. hebraeum* were present from March to May and during July 1985, nymphs during March, November and December and adults during December. Peak numbers of larvae of *A. marmoreum* were present during February, April and May 1985. The larvae of *H. silacea* reached peak numbers from February to August and during December 1985 and January 1986, the nymphs from May to August 1985 and the adults during August and October 1985. The larvae of *R. appendiculatus* reached the largest numbers from March to June, the nymphs from June to October and the adults from February to April 1985 and during January 1986. The immature stages of *R. evertsi evertsi* were at their lowest from August to November. Large numbers of immature *R. glabroscutatum,* a 2-host tick, were present from March to

TABLE 4 Arthropod parasites of 9 kudus on the farm "Bucklands", eastern Cape Province

Arthropod species	Total number recovered					No. of kudus infested
Ixodid ticks	Larvae	Nymphs	Males	Females	Total	
Amblyomma hebraeum	157	24	14	4	199	7
Amblyomma marmoreum	54	2	0	0	56	5
Boophilus decoloratus	43	34	21	4	102	3
Haemaphysalis silacea	1 994	783	410	112(16)	3 299	9
Hyalomma marginatum rufipes	0	0	2	0	2	1
Rhipicephalus appendiculatus	1 638	796	70	20	2 524	9
Rhipicephalus evertsi evertsi	92	130	20	1	243	8
Rhipicephalus glabroscutatum	11 460	5 980	580	236(16)	18 256	9
Rhipicephalus sp. (near *R. oculatus*)	0	0	30	13	43	6
Lice	Nymphs		Adults		Total	
Damalinia sp.	16		0		16	1
Haematopinus taurotragi	30		22		52	1
Linognathus taurotragus	1 344		525		1 869	9
Louse flies	Adults				Total	
Lipoptena paradoxa	68				68	7

( ) = Number of maturing females, i.e. idiosoma of *H. silacea* >5,0 mm; *R. glabroscutatum* >4,0 mm in length. Females of the other tick species had not started to mature

TABLE 5 The mean numbers of ticks recovered from kudus examined during the same months in the Andries Vosloo Kudu Reserve and on the farm "Bucklands"

Ixodid tick species	Mean numbers of ticks recovered					
	Kudus in Kudu Reserve			Kudus on "Bucklands"		
	Larvae	Nymphs	Adults	Larvae	Nymphs	Adults
Amblyomma hebraeum	3 188	325	66	17	3	2
Amblyomma marmoreum	119	0	0	6	0,2	0
Boophilus decoloratus	0	0	3	5	4	3
Haemaphysalis silacea	505	81	70	222	87	58
Hyalomma marginatum rufipes	0	0	0	0	0	0,2
Hyalomma truncatum	0	0	0,3	0	0	0
Ixodes pilosus	0	0	0,3	0	0	0
Rhipicephalus appendiculatus	489	63	20	182	88	10
Rhipicephalus evertsi evertsi	21	11	1	10	14	2
Rhipicephalus glabroscutatum	873	376	113	1 273	664	91
Rhipicephalus sp. (near *R. oculatus*)	0	0	8	0	0	5
Rhipicephalus simus	0	0	0,5	0	0	0

August and adults during February and from September to December 1985. The adults of the *Rhipicephalus* sp. (near *R. oculatus*) were present in all months except May and June.

The 9 kudus shot at 3-monthly intervals (2 during June 1985) on the farm "Bucklands" could be paired with 8 animals shot during the same months in the adjacent AVKR. The burdens of these animals are compared in Table 5.

With the exeption of the larvae, nymphs and males of *A. behraeum*, for which the differences were significant, such differences between the farm and the reserve were not evident for any of the other tick species.

Addo Elephant National Park

Study site

The park is located in the eastern Cape Province at 33 ° 30 ′ S; 25 ° 45′ E and the vegetation is described as Valley Bushveld (Acocks, 1988).

Survey animals

Two adult male kudus were shot in this reserve during April 1985.

Arthropod burdens

The kudus were infested with 6 ixodid tick species, 1 louse and 1 louse fly species (Table 6).

More than 90 % of the tick population on the kudus consisted of *A. hebraeum*.

DISCUSSION

General observations

Utech, Seifert & Wharton (1978) and Sutherst, Wharton, Cook, Sutherland & Bourne (1979) found that the calves of domestic cattle carried fewer *Boophilus microplus* than their dams. Although the kudu calves were not necessarily the offspring of the kudu females shot during the same months in the Kruger National Park, comparisons of the calves' tick burdens with those of the females were nevertheless made. It was possible to pair 16 calves aged

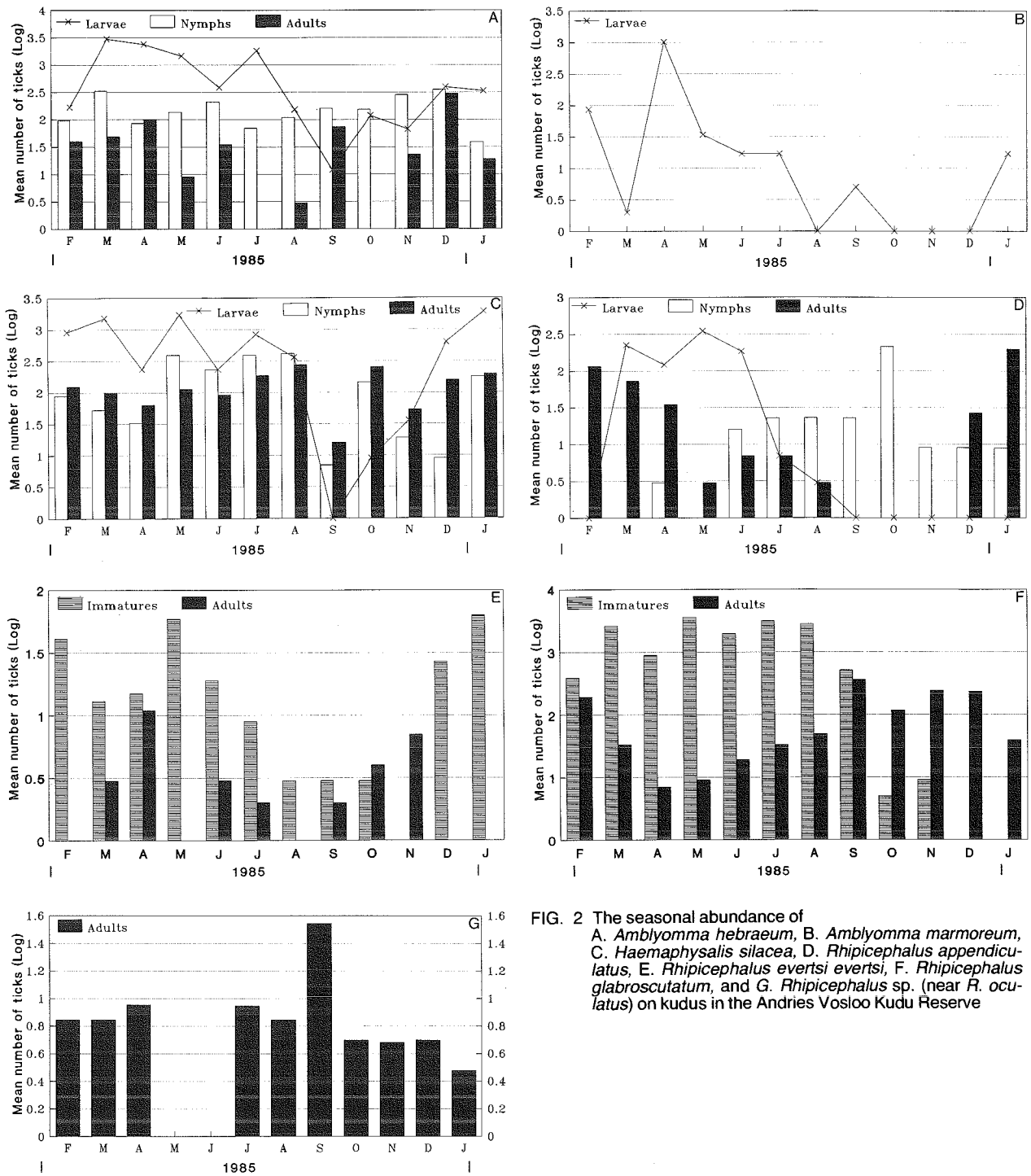

FIG. 2 The seasonal abundance of A. *Amblyomma hebraeum*, B. *Amblyomma marmoreum*, C. *Haemaphysalis silacea*, D. *Rhipicephalus appendiculatus*, E. *Rhipicephalus evertsi evertsi*, F. *Rhipicephalus glabroscutatum*, and G. *Rhipicephalus* sp. (near *R. oculatus*) on kudus in the Andries Vosloo Kudu Reserve

6 months or less with 16 adult females shot during the same months. No significant differences between the tick burdens of the calves and those of the cows were recorded. In fact, if one considers the size of the young calves compared with that of the cows, it would seem as if they are more prone to infestation than the cows.

Seifert (1971) recorded considerably more *B. microplus* on bulls than on domestic cows. He suggested that this strongly implies an influence of sex hormones on resistance. Our findings in the KNP show that adult male kudus carry significantly more nymphs (P=0,05), and males and females (P=0,001) of *A. hebraeum* and males and females (P=0,05) of *B. decoloratus* than do adult female animals. No such differences were recorded for any of the other tick species.

Horak, MacIvor, Petney & De Vos (1987) have suggested that the larger the host animal species the more likely it is to carry greater numbers of adult

TABLE 6 Arthropod parasites of 2 kudus in the Addo Elephant National Park

Arthropod species	Total number recovered					No. of kudus infested
Ixodid ticks	Larvae	Nymphs	Males	Females	Total	
Amblyomma hebraeum	14 957	1 165	30	10	16 162	2
Amblyomma marmoreum	17	0	0	0	17	2
Haemaphysalis silacea	985	125	119	44(4)	1 273	2
Hyalomma truncatum	0	0	1	0	1	1
Rhipicephalus evertsi evertsi	213	138	7	3	361	2
Rhipicephalus glabroscutatum	2	32	0	0	34	1
Lice	Nymphs		Adults		Total	
Linognathus taurotragus	22		6		28	1
Louse flies	Adults				Total	
Lipoptena paradoxa	11				11	2

( ) = Number of maturing females, i.e. idiosoma of *H. silacea* >5,0 mm in length. Females of the other tick species had not started to mature

A. hebraeum. The larger size of male kudus when compared to females may thus partially be responsible for the greater number of adult *A. hebraeum* carried by the former animals.

Kudus are good hosts of the immature stages of a large number of tick species (Horak & Knight, 1986; Tables 1 and 3). They are also good hosts of the adults of some species, such as *B. decoloratus, H. silacea, R. appendiculatus, R. glabroscutatum, R. zambeziensis* and a *Rhipicephalus* sp. (near *R. oculatus*). In addition adult male kudus must be considered good hosts of adult *A. hebraeum*.

Acaricidal treatment of the domestic livestock on "Bucklands" significantly affected the burdens only of *A. hebraeum* of kudus on the farm. This was probably due to the fact that cattle on the farm, which would have been good hosts for the adults of *A. hebraeum* as well as the other species, and the sheep and goats, which, with the exception of *R. glabroscutatum*, are generally poor hosts of the adults of most species, were all regularly treated with an acaricide and hence were poor hosts of all species. Thus, only the kudus, which, with the possible exception of the males, are not good hosts of adult *A. hebraeum*, but are good hosts of the adults of the other tick species, would have been largely responsible for maintaining the population of *A. hebraeum* on the farm. Petney & Horak (1987) state that the kudus clearly maintain a small but seemingly stable population of *A. hebraeum* on "Bucklands".

The eland and buffaloes on the reserve are very good hosts of adult *A. hebraeum* and individual animals may harbour more than 1 000 adult ticks (Horak, MacIvor, Petney & De Vos, 1987). They are also good hosts of the adults of the other tick species. These animals would largely be responsible for the large total burdens of *A. hebraeum* on the kudus on the reserve and they and the kudus themselves for the total burdens of the other tick species on the kudus.

The role kudus may play as reservoir hosts of ticks infesting cattle in mixed cattle and game ranching operations will depend on the population density of the former animals. As kudus are browsers (Owen-Smith, 1979; Novellie, 1983) their densities will be dependent upon the amount and quality of available browse. Thus in the Valley Bushveld of the eastern Cape Province where browse, particularly the spekboom *(Portulacaria afra)* is abundant, kudu density can be considerably higher than in the north-eastern Transvaal. Conventional stock fences do not serve as a barrier to kudus and consequently they could also disseminate ticks over considerable distances and several farms.

Both the tick reservoir status of kudus and their mobility could be advantageous to the stock farmer in that they could serve as a source of infected ticks on a cattle farm. This would help maintain immunity to diseases such as babesiosis *(Babesia bigemina)* and heartwater *(Cowdria ruminantium)* in cattle otherwise kept relatively tick-free by regular acaricidal treatment.

Amblyomma hebraeum

The 28 adult male kudus examined in the KNP harboured a mean of 1 003 larvae, 131 nymphs, 16 males and 8 females of this tick compared with 2 001, 223, 29 and 16, respectively, for the 16 males examined in the AVKR. The latter burdens were almost exactly double the former for each life stage as well as for the total. The larval:nymphal:adult ratio was virtually identical for male kudus on the 2 reserves being approximately 44:5:1.

This tick was introduced into the eastern Cape Province during the 1830's, probably on cattle from Zululand (Theiler, 1975; Provost & Bezuidenhout, 1987). The large numbers recovered from the kudus in this region confirm that it has become well established there. The fact that the kudus in the AVKR harboured nearly twice the burdens of those in the KNP does not, however, imply that the former habitat is more favourable than the latter; it is more a reflection of stocking density. The KNP is close to 2 M ha in extent and contains approximately 15 000 kudus, 400 eland, 30 000 buffaloes and 8 000 giraffes (all good hosts of adult *A. hebraeum*) resulting in an approximate stocking density of 1 of these animals per 37 ha. In the Kudu Reserve the approximate

stocking density for kudus, eland and buffaloes combined is 1 animal per 9,4 ha.

The immature stages of *A. hebraeum* have a wide host range (Theiler, 1962; Norval, 1974a). They utilize not only the same hosts as the adults, but a variety of small domestic and wild ruminants as well as scrub hares and helmeted guineafowls (Horak, MacIvor, Petney & De Vos, 1987). The higher stocking density in the AVKR is also reflected in the tick burdens of those hosts that harbour only immature stages; scrub hares had mean burdens of 46 larvae and 15 nymphs (Horak & Fourie, 1991) compared with 11 larvae and 11 nymphs on scrub hares in the KNP (Horak, Spickett & Braack, unpublished data). Helmeted guineafowls in the AVKR harboured 568 larvae and 26 nymphs, and those in the KNP 185 and 17 (Horak, Spickett, Braack & Williams, 1991). The hares, kudus and guineafowls in the AVKR were all examined at the same time, whereas in the KNP the hares and guineafowls were examined several years after the kudus.

If the number of immature ticks carried by female kudus and the smaller antelope as well as those harboured by scrub hares and guineafowls are taken into account the ratio of parasitic larvae and nymphs to adults will shift even further in favour of the immature stages.

The largest burden of adult ticks harboured by a single kudu was 72 males and 58 females recovered from a male shot in the KNP during January 1982 and 185 males and 119 females from a male shot in the AVKR during December 1985. The tick burdens of the 2 kudus examined in the Addo Elephant National Park indicate that burdens of *A. hebraeum* could possibly be even higher on kudus in this reserve than in either of the other reserves.

Despite only 1 animal being examined each month in the AVKR, larvae appeared to be more abundant during late summer and winter, nymphs during early summer and again in late summer and adults from early to late summer. This pattern of seasonal abundance corresponds to that observed by Knight & Rechav (1978) on kudus and by Rechav (1982) on cattle examined in the same locality, and is probably regulated by climate. In the KNP, where temperatures are higher than those in the eastern Cape Province, no clear pattern of seasonal abundance was evident and the tick's life cycle appeared to continue uninterrupted throughout the year.

Amblyomma marmoreum

Tortoises are the preferred hosts for all parasitic stages of this tick (Theiler, 1962; Norval, 1975b; Dower, Petney & Horak, 1988). Helmeted guineafowls, scrub hares, caracal, kudus, eland and cattle are all good hosts of the larvae if the numbers recovered and percentage of hosts infested are taken into account (Horak, MacIvor, Petney & De Vos, 1987; Horak & Fourie, 1991). With the possible exception of guineafowls, none of these animals are good hosts of the nymphs.

The large total number of larvae recovered from the kudus in the AVKR compared with those on "Bucklands" and in the KNP is due to 2 animals. One of these harboured 1 008 and the other 865 larvae.

The period of peak larval abundance (January to July) on kudus in the AVKR was longer than that on animals in the KNP (April to June). The seasonal abundance of larvae on helmeted guineafowls in the AVKR was similar to that on the kudus at the same locality, while that on guineafowls in the KNP extended from February or March to July or August (Horak, Spickett, Braack & Williams, 1991). The only nymphs recovered were from a kudu examined on "Bucklands" during December 1986.

Boophilus decoloratus

This was by far the most abundant tick on the kudus in the KNP, a finding also applicable to blue wildebeest and Burchell's zebras examined in this park (Horak, De Vos & Brown, 1983; Horak *et al.*, 1984). Drag-sampling of 32 of the 35 vegetation zones in the KNP during March 1988 indicated that *A. hebraeum* was the dominant species (Spickett, Horak, Braack & Van Ark, 1991), but this may well have been due to the month in which the samples were collected. Monthly drag-sampling of 2 vegetation zones near the study site over a period of 3 years, from 1988 to 1991, indicated that *R. zambeziensis* followed by *B. decoloratus* were most abundant in the zone north of the study site and *A. hebraeum* followed by *R. appendiculatus* and then *B. decoloratus* in the zone east of the study site (Horak, Spickett & Braack, unpublished data). Although it is possible that *B. decoloratus* was the dominant tick on the vegetation within the study area this seems unlikely in the light of the drag-sampling data from the 2 zones.

Two possible reasons for the large numbers of *B. decoloratus* on the kudus are, firstly that this is a 1-host tick, spending approximately 21 days on an animal in order to complete its parasitic life cycle (Londt & Spickett, 1976). Thus *B. decoloratus* recovered at slaughter represent ticks acquired during the previous 3 weeks compared with the multi-host tick species in which each stage, with the possible exception of males, spends approximately only 7 days on the host. Secondly the loss between the developmental stages, which do not each have to seek a new host in the case of a 1-host tick, is considerably less than that encountered with multi-host ticks. Furthermore kudus must be accepted as one of the preferred hosts of *B. decoloratus.* In the present study they harboured mean total burdens of 3 407 ticks of this species compared with 548 on blue wildebeest and 1 827 on Burchell's zebras examined in the KNP during earlier studies (Horak, De Vos & Brown, 1983; Horak *et al.*, 1984).

The overall ratio of larvae to nymphs to adults is 3,0:2,0:1,0 and this implies a good translation to adulthood without too much loss during the developmental stages and further confirms that kudus are one of the preferred hosts of *B. decoloratus.* On blue wildebeest and Burchell's zebras examined in the KNP during earlier studies these ratios were 8,9:1,7:1,0 and 3,0:1,1:1,0 respectively, indicating that wildebeest are poor hosts and zebras good hosts (Horak, De Vos & Brown, 1983; Horak *et al.*, 1984).

The ratios of males to females on the 3 host species were 1,98:1,00; 1,35:1,00 and 2,07:1,00 for the kudus, wildebeest and zebras, respectively. The most logical explanations for this disparity seem to be firstly, that because of the larger size of the females they are more easily rubbed or groomed off by the host and secondly, that the males remain attached for longer than the females. This differs markedly from the findings of Davey & Cooksey (1988) for *B. microplus* and *Boophilus annulatus* on artificially infested cattle. They recovered fewer males than females and recorded ratios of 1,00:1,36 and 1,00:1,35 males to females for the 2 tick species. They ascribed these differences to a selective mortality of males at some point in their development resulting in more females reaching the adult stage.

If one accepts that the kudus in the KNP acquired infestation on a daily basis and that female *B. decoloratus* spend 6 days on the animals, of which the last day is spent engorging before detaching (Londt & Spickett, 1976), then approximately 1/6 of all females should be engorging. This would imply that there should have been a total of 3 023 engorging females compared with the 360 actually recovered. This small number could be due to acquired resistance in the kudus as noted in the case of *Bos indicus* cross breeds of cattle and *B. microplus* (Sutherst, Maywald, Bourne, Sutherland & Stegeman, 1988). In cattle this resistance is only fully evident at approximately 2 years of age, but was already effective in the kudu calves. The small number could also be due to the fact that the kudus were usually shot after 08:00 h whereas many of the engorged females may have detached earlier.

It is probable that red-billed oxpeckers, which are commonly found on kudus in the KNP, also played a role in reducing the numbers of engorging female *B. decoloratus.* This tick is one of the preferred foods of these birds (Bezuidenhout & Stutterheim, 1980). Blue wildebeest and Burchell's zebras examined in the KNP also harboured small numbers of engorging female *B. decoloratus* compared to the total burdens of ticks of this species (Horak, De Vos & Brown, 1983; Horak *et al.,* 1984).

The peaks of abundance recorded for *B. decoloratus* on the kudus during September and October 1981 and November and December 1982 correspond to the peaks recorded during October 1978 on blue wildebeest and September 1979 and 1980 and December 1980 on Burchell's zebras in the KNP. These peaks, which occurred in spring or early summer, could be due to synchronous hatching of large numbers of larvae from eggs that had overwintered (Robertson, 1981; Spickett & Heyne, 1990). The spring rise could also possibly be coupled to a decrease in host resistance resulting from poor nutrition during the preceding winter and early spring months (Sutherst *et al.,* 1979).

Baker & Ducasse (1967) recovered peak numbers of *B. decoloratus* from calves in Natal from November to June. With the exception of 1 year when large numbers of ticks were present during November and December, Robertson (1981) recovered most *B. decoloratus* from cattle on a coastal property in the eastern Cape Province from February to June during a 4 year survey. Spickett, De Klerk, Enslin & Scholtz (1989) recorded peaks in the activity of *B. decoloratus* on cattle in the south-eastern Transvaal during February, July, October and December. In Natal Baker, Ducasse, Sutherst & Maywald (1989) recorded peak activity on cattle during spring and autumn. Rechav & Kostrzewski (1991) found peaks of activity in March/April, July, September/October, and December/January on cattle in the northern Transvaal. Horak, Williams & Van Schalkwyk (1991) recovered most *B. decoloratus* from Merino sheep during July and November in the eastern Orange Free State and in the eastern Cape Province. It would thus appear that in South Africa *B. decoloratus* may be encountered in peak numbers during any or all seasons. Nevertheless, spring and late summer seem to be the most preferred times.

The inland Valley Bushveld regions of the eastern Cape Province are not a suitable habitat for the free-living stages of *B. decoloratus.* Very few were recovered from the kudus in the AVKR and on "Bucklands" and none on the kudus from the Addo Park. Knight & Rechav (1978) also recovered only a few *B. decoloratus* from the kudus they examined on "Bucklands" and its environs.

In the KNP 21,3 % of all *B. decoloratus* were attached to the lower legs and feet of the kudus, 13,9 % to the heads and ears, 63,4 % to the necks, bodies and upper legs and 1,4 % to the tails. Only 10,9 % of the population of female ticks was attached to the legs and lower feet compared with 24,9 % of the males, indicating a selective loss of the larger female life stage from this attachment site.

Furthermore only 4,4 % of all engorging females were recovered from the lower legs and feet while 81,1 % and 6,1 % were recovered from the necks, bodies and upper legs and from the tails, respectively. This indicates that the lower legs and feet were particularly unfavourable for the completion of the female life cycle whereas the tails seemed to afford most protection for these large ticks. On Burchell's zebras examined in the park at an earlier occasion 8,0 % of *B. decoloratus* were attached to the lower legs and feet, 8,9 % to the heads and ears and 83,1 % to the necks, bodies, upper, legs and tails (Horak *et al.,* 1984).

Haemaphysalis silacea

According to Howell, Walker & Nevill (1978) this tick is found in well-wooded ravines and river valleys in the eastern Cape Province and in Natal. Hence its presence on kudus in the Valley Bushveld vegetation of the AVKR, "Bucklands" and Addo Elephant National Park. It has a wide host range including kudus, eland, sheep, goats, cattle and helmeted guineafowls (Knight & Rechav, 1978; Horak, Potgieter, Walker, De Vos & Boomker, 1983; Horak & Knight, 1986).

In the present survey 27,8 % of all males and 59,5 % of all females were found attached on the tails of the kudus in the AVKR. In addition 84,8 % of all the engorging female ticks were recovered from the tails. This need not necessarily imply that the tail

is a preferred site of attachment for female ticks of this species, but rather that the long hair on the tail affords greater protection against grooming for this larger life stage and particularly for those that are engorging.

As only 1 kudu was examined at each occasion the pattern of seasonal abundance on these animals is not reliable. It would, however, appear as if the life cycle continues throughout the year. Combining the findings of this study with those of Norval (1975a), Knight & Rechav (1978), Rechav (1982) and Horak, Williams & Van Schalkwyk (1991), larvae are most numerous from summer to early winter, nymphs from autumn to spring and adults in spring and in late summer.

Hyalomma spp.

The distribution of *Hyalomma marginatum rufipes* includes the Valley Bushveld regions of the eastern Cape Province, while that of *Hyalomma truncatum* includes the latter region as well as the KNP (Howell *et al.*, 1978). Scrub hares are the preferred hosts of the immature stages of both these ticks (Horak & MacIvor, 1987; Rechav, Zeederberg & Zeller, 1987; Horak & Fourie, 1991). Using the number of ticks recovered from scrub hares as criterion the Valley Bushveld is not a good habitat for the 2 *Hyalomma* spp. (Horak & MacIvor, 1987; Horak & Fourie, 1991), whereas the KNP is a good habitat for *H. truncatum* (Horak, Spickett & Braack, unpublished data). The small number of adult ticks recovered from the kudus in the KNP is therefore evidence that these animals are not good hosts of this tick. The preferred hosts of the adults are eland and zebras and probably giraffes (Rechav *et al.*, 1987; Horak, Fourie, Novellie & Williams, 1991). The small numbers of the 2 *Hyalomma* spp. on the kudus in the eastern Cape Province are a reflection both of the unsuitability of the habitat and the host species.

Adult *H. truncatum* were generally recovered from the kudus in the KNP during any month from January to July. In the AVKR and on "Bucklands" *Hyalomma* spp. were recovered in March, April and during June.

Ixodes pilosus

In the Cape Province this tick is generally confined to the Sourveld coastal regions (Howell *et al.*, 1978). Its presence on the animals in the AVKR probably reflects its most northern distribution at this particular point. The preponderance of parasitic females over males is typical for this species (Norval, 1974b; Horak, Sheppey, Knight & Beuthin, 1986), in which mating probably takes place off the host.

Rhipicephalus appendiculatus

The KNP, AVKR and "Bucklands" all lie within the geographic distribution of this tick as described by Howell *et al.* (1978). The Addo Elephant National Park is situated to the west of the southern limits of this distribution and no *R. appendiculatus* were recovered from the kudus examined in this park.

The adults appear to prefer large bovids such as cattle, eland and buffaloes but kudus, sable antelopes and impala are also good hosts (Norval, Walker & Colborne, 1982; Horak, Potgieter, Walker, De Vos & Boomker, 1983). The immature stages can also be recovered in large numbers from these hosts, but may be encountered in similar large numbers on Burchell's zebras and on a variety of smaller animals such as sheep, goats, small antelope and scrub hares (Norval *et al.*, 1982; Horak *et al.*, 1984; Horak & Knight, 1986).

The taxonomic differences between *R. appendiculatus* and *R. zambeziensis* have only fairly recently been described (Walker, Norval & Corwin, 1981). We have always been able to distinguish between the nymphs of the 2 species and did so for each of the separate skin regions examined. The larvae and adults, however, were only differentiated once the ticks for each kudu had been pooled and hence no preferred sites of attachment for these stages can be identified. In the KNP 21,8 % of nymphs of *R. appendiculatus* were recovered from the lower legs and feet, 53,1 % from the heads and ears and 25,1 % from the necks, upper legs, bodies and tails of the kudus. These figures were 27,4 %, 50,1 % and 22,5 % respectively for the animals in the AVKR. Baker & Ducasse (1967) recovered 58,0 % of nymphs from the heads and ears of live-sampled cattle in Natal and 16,6 % from their legs and feet. In Uganda Kaiser, Sutherst & Bourne (1982) recovered 24 % of nymphs from the head and ears of live-sampled cattle and 20 % from around the hooves.

The overall ratio of larvae to nymphs to adults of 2,49:0,67:1,00 on kudus in the KNP and 8,54:1,51:1,00 in the AVKR compared with the 16:4:1 we consider closer to the normal population distribution for a 3-host tick, can have various explanations. Firstly, the recovery of the immature stages by the scrubbing method employed may not be as effective as for the larger adults. Secondly, smaller antelope species and scrub hares may carry substantial numbers of immatures with few or no adults (Horak, 1982; Boomker, Du Plessis & Boomker, 1983; Horak & Knight, 1986). Large numbers of *Rhipicephalus* spp. nymphs and probably also larvae, may selectively be removed by oxpeckers (Bezuidenhout & Stutterheim, 1980). Baker & Ducasse (1967) recorded ratios of 4,10 larvae to 2,87 nymphs to 1,00 adults on live-sampled cattle in Natal.

The ratio of males to females of 1,78:1,00 on kudus in the KNP and 1,86:1,00 in the AVKR compares favourably with that of 1,84:1,00 and 1,88:1,00 recorded by Londt, Horak & De Villiers (1979) and Horak (1982) on cattle in the northern Transvaal and of 1,99:1,00 found by Kaiser *et al.* (1982) on cattle in Uganda. The latter authors recorded a ratio of 1,84:1,00 only 7 days after the hosts had been picked clean of ticks and suggested that further experiments to explain this phenomenon were necessary. Bezuidenhout & Stutterheim (1980) found that oxpeckers consume nearly twice as many female *Rhipicephalus* spp. as they do males.

If one assumes that female *R. appendiculatus* spend approximately 7 days on their hosts

(Minshull, 1982), that these hosts are constantly exposed to infestation during periods of peak seasonal abundance of the ticks, and that the female ticks engorge during the last 24 h of their attachment, then approximately 1/7 (14,3 %) of the female ticks should be maturing. On the kudus in the KNP only 1,8 % were maturing, whereas this figure was 13,3 % for the animals in the AVKR. Minshull (1982) found that most engorged females of *R. appendiculatus* detached from artificially infested cattle between 06:00 and 08:00 h. As most of the kudus in the KNP were shot after 08:00 h many engorged female ticks could already have detached. The same argument does not apply to the animals in the AVKR, which were also shot after 08:00 h and yet harboured a large proportion of maturing females. Oxpeckers, which as mentioned previously, prefer female *Rhipicephalus* spp. ticks to males, may also be responsible for the small number of maturing ticks in the KNP. These birds were not present in the AVKR.

The seasonal abundance of the adults and nymphs in the 2 reserves was reasonably similar. In the AVKR increased numbers of larvae were recovered 1 month earlier than in the KNP, whereas peak larval activity extended for 1 month longer in the latter reserve. In general terms larvae were active from late summer to winter or spring, nymphs from winter to spring and adults from mid-summer to autumn. This pattern of abundance corresponds to that observed on cattle in Natal by Baker & Ducasse (1967), in the northern Transvaal by Horak (1982) and in the eastern Cape Province by Rechav (1982).

Short & Norval (1981) state that the pattern of seasonal abundance is chiefly dependent on the activity period of the adults and that this is regulated by the combined influences of humidity, temperature and daylength. Unfortunately too few animals were examined in each of the reserves to determine accurately the periods of activity of the adults. If, however, tick counts from cattle slaughtered at monthly intervals over a 2 year period on "Bucklands" at the same time as the kudus in the AVKR (Horak, unpublished data), are added to the latter data it would appear as if peak adult activity extends from December to February in this region of the eastern Cape Province. This corresponds exactly with that recorded by Rechav (1981) in this area. Taking the mean values for the 2 year study in the KNP into account peak adult activity occurred from February to May in this park.

Rhipicephalus evertsi evertsi

Although this tick has a very widespread distribution in South Africa (Howell *et al.*, 1978), it never occurs in very large numbers except on zebras and eland (Horak *et al.*, 1984; Horak, Fourie, Novellie & Williams, 1991). If the burdens of the kudus in the KNP are compared with those of Burchell's zebras examined a few years previously in the same park (Horak *et al.*, 1984) it is obvious that kudus are not a preferred host of *R. evertsi evertsi*. The mean burdens of the zebras comprised 606 larvae, 259 nymphs and 76 adults compared with 95 larvae, 10 nymphs and 2 adults on the kudus. In addition, it would appear as if kudus do not, or cannot, harbour many nymphs of this 2-host tick, of which the immature stages occur in the ear canal. This could affect the successful translation of larvae to nymphs when many larvae are present. In the KNP mean burdens of 95 larvae translated into only 10 nymphs compared with mean burdens of 16 larvae on kudus in the AVKR and "Bucklands" combined, translating into 11 nymphs. The largest number of nymphs recovered from a kudu was 72, compared with 626 from an eland and 1 944 from a zebra (Horak, unpublished data).

Combining the total numbers of adult *R. evertsi evertsi* recovered from all the kudus examined in the present surveys, the ratio of males to females is 2,75:1,00. The marked preponderence of males is probably because more males than females may be recovered from animals even within 1 week of them having been picked clean of ticks, and that males may remain on the host for longer than females and thus their numbers accumulate (Kaiser *et al.*, 1982).

No clear pattern of seasonal abundance was evident. The fact that both adults and immatures may be present throughout the year indicates that more than 1 life cycle can be completed annually and that development is continuous in the regions in which the present surveys were conducted. This corresponds to the observations made by Matson & Norval (1977) on cattle in Zimbabwe, Horak, Williams & Van Schalkwyk (1991) on sheep in the Orange Free State and in the eastern Cape Province, Horak *et al.* (1984) and Horak, Fourie, Novellie & Williams (1991) on Burchell's zebras in the KNP as well as on Cape mountain zebras and eland in the Karoo respectively.

Rhipicephalus glabroscutatum

The geographic distribution of this tick has been described by MacIvor (1985). It is largely confined to the eastern Cape Province where it inhabits non-coastal areas of low rainfall characterized by Karoo and Karoid vegetation, with isolated pockets extending into the western Cape Province. Its original hosts were probably the antelope inhabiting these regions and more particularly eland, kudus, mountain reedbuck and common duikers (MacIvor, 1985; Horak & Knight, 1986; MacIvor & Horak, 1987; Horak, Fourie, Novellie & Williams, 1991) and probably also bushbuck. Scrub hares may harbour the immature stages only (Horak & Knight, 1986; Horak & Fourie, 1991). With the introduction of domestic stock into these regions *R. glabroscutatum* now also infests goats, sheep and cattle (MacIvor & Horak, 1984, 1987; MacIvor, 1985; Horak & Knight, 1986; Horak, Williams & Van Schalkwyk, 1991).

According to MacIvor (1985) the preferred site of attachment is the legs and feet. In the present survey 83,9 % of all immature ticks and 95,7 % of all adults were recovered from the lower legs and feet of the kudus in the AVKR and on "Bucklands". MacIvor & Horak (1987) state that while goats may frequently harbour large numbers of adult ticks between their hooves none where found between the hooves of the antelope they examined on one of the farms on which they worked. They suggested

that this difference might be due to the structure of the hooves with the concave axial corium of the goat hoof resulting in a space in the interdigital region which could be exploited by ticks, while the straight axial corium of the antelopes' hooves limited this space.

The seasonal abundance of *R. glabroscutatum* on a variety of host species has been determined in the eastern Cape Province (Knight & Rechav, 1978; MacIvor & Horak, 1984, 1987; Horak, Williams & Van Schalkwyk, 1991; Horak, Knight & Williams, 1991; Horak & Fourie, 1991), the Karoo (Horak, Fourie, Novellie & Williams, 1991) and the south-western Cape Province (Horak, Sheppey, Knight & Beuthin, 1986). In all these regions the greatest numbers of immature ticks were recovered from March to August and of adults from September to January or February. It is probable that only 1 generation is completed annually (MacIvor, 1985).

Rhipicephalus sp. (near *R. oculatus)*

The taxonomic problems that exist between this tick and *Rhipicephalus oculatus* have been discussed by Walker (1991). Its geographic distribution has also been briefly addressed by Walker (1991). It is fairly common in certain Valley Bushveld regions of the eastern Cape Province, where the adults may be found on scrub hares, kudus, cattle, sheep and goats (Horak & Knight, 1986).

In the present study 10,6 % of the ticks were recovered from the heads and ears of the kudus, 80,8 % from the necks, bodies and upper legs, and equal proportions from the lower legs plus feet and from the tails. May and June appear to be the only months in which no adult ticks are present. This pattern of seasonal abundance was confirmed on scrub hares, sheep, goats and cattle examined in the AVKR or on "Bucklands" at the same time as the kudus (Horak, unpublished data).

Rhipicephalus simus

Although this tick has a widespread distribution, mainly in the eastern regions of South Africa (Howell *et al.*, 1978), it is seldom encountered in large numbers. The preferred hosts of the adults are large monogastric animals such as zebras, warthogs, large wild carnivores and dogs, but they also occur on cattle (Howell *et al.*, 1978; Horak *et al.*, 1984; Horak, Jacot Guillarmod, Moolman & De Vos, 1987; Horak *et al.*, 1988).

In the KNP a total of 15 adults were recovered from the 95 kudus examined, while 33 Burchell's zebras, 7 large carnivores and 51 warthogs examined in the park harboured totals of 381, 669 and 560 adults respectively (Horak *et al.*, 1984; Horak Jacot Guillarmod, Moolman & De Vos, 1987; Horak *et al.*, 1988). The 25 kudus shot in the AVKR and on "Bucklands" harboured a total of only 6 adults while 46 cattle examined on "Bucklands" at the same time harboured 48 adults (Horak, unpublished data). It is thus obvious that kudus are not good hosts of adult *R. simus*. The immature stages prefer rodents (Norval & Mason, 1981).

Twelve of the 15 ticks recovered from the kudus in the KNP and all 6 ticks from the kudus in the AVKR were collected from the lower legs and feet of the animals. Too few ticks were present to determine any pattern of seasonal abundance.

Rhipicephalus zambeziensis

This tick has only fairly recently been described and its morphology compared with that of *R. appendiculatus* (Walker *et al.*, 1981). Its ecology and that of *R. appendiculatus,* with particular emphasis on Zimbabwe, have also been described (Norval *et al.*, 1982). In South Africa *R. zambeziensis* has to date only been found in the Transvaal and more particularly on farms in the west of the province as well as in the northern and southern regions of the KNP in the east of the province (Norval *et al.*, 1982). This distribution falls entirely within that of *R. appendiculatus* as illustrated by Howell *et al.* (1978). However, more recent data from the KNP indicate that there are areas of overlap as well as regions in which one or the other tick occurs almost exclusively (Horak, Spickett & Braack, unpublished data). The study site from which the kudus in the KNP were collected lies within such a region of overlap. To the east and west of this site there are zones within the KNP in which *R. appeı diculatus* occurs almost exclusively and to the north a zone in which *R. zambeziensis* occurs virtually exclusively (Horak, Spickett & Braack, unpublished data).

Although large carnivores, warthogs, bushpigs and equids can be infested, the preferred hosts of *R. zambeziensis* seem to be impala, bushbuck, nyalas, kudus, eland and probably cattle and buffaloes (Norval *et al.*, 1982; Walker, 1991). In the present study 91 of the 95 kudus were infested. Two of the 4 kudus that were not infested were examined during November and 1 during December, both months of generally low abundance for all stages of development (Fig. 1). The total numbers of *R. appendiculatus* and *R. zambeziensis* recovered from the kudus suggest that the zone in which they were examined is equally favourable for both tick species.

As mentioned earlier for *R. appendiculatus*, we can unfortunately also only give the preferred sites of attachment for the nymphal stage of *R. zambeziensis.* Of these 81,4 % were attached to the lower legs and feet, 9,2 % to the head and ears, 8,6 % to the neck, body and upper legs and 0,8 % to the tail. Thus the nymphs of *R. appendiculatus* prefer the heads and ears and those of *R. zambeziensis* the lower legs and feet of kudus.

The ratio of larvae to nymphs to adults of 9,92:1,42:1,00 indicates that the kudus are good hosts of larvae, while many nymphs possibly fed on other host species. The total numbers of larvae of *R. appendiculatus* and *R. zambeziensis* recovered from the kudus were reasonably similar but fewer nymphs and adults of *R. zambeziensis* were recovered. This suggests that kudus may be less favoured as hosts of these stages than for those of *R. appendiculatus.*

The ratio of male to female *R. zambeziensis* of 1,99:1,00 is comparable to that of *R. appendiculatus* on the same animals. As in the case of the latter tick, few maturing females were recovered.

According to Norval *et al.* (1982) the seasonal abundances of these 2 ticks are similar in Zimbabwe. The present results confirm this finding and the periods of seasonal activity are almost identical; larvae exhibiting peak abundance in autumn and winter, nymphs during winter and spring and adults in late summer.

Lice

Damalinia sp. have not previously been recovered from kudus, while *Haematopinus taurotragi* and *Linognathus taurotragus,* which were both originally described from eland, have (Ledger, 1980). The lice infestations were always light and no pattern of seasonal abundance or host age-preference or host sex-preference could be determined.

Flies

The majority of kudus at each survey locality were infested with the louse fly *Lipoptena paradoxa.* The seasonal abundance of this fly on the kudus and other aspects of its biology will be reported separately.

Pentastomid nymphs

In earlier surveys Horak, De Vos & Brown (1983) and Horak *et al.* (1988) recovered the nymphs of *Linguatula nuttalli* from 12 (21,8 %) of 55 blue wildebeest and 18 (35,3 %) of 51 warthogs examined in the KNP. Kudus would appear to be more susceptible to infection as 60 (63,2 %) of the 95 animals examined in the park were infected. Lions are the final host of this parasite.

ACKNOWLEDGEMENTS

This study is part of the Wildlife Research Programme of the Faculty of Veterinary Science, University of Pretoria.

We wish to express our thanks to the National Parks Board of Trustees, who placed the kudus in the Kruger National Park and Addo Elephant National Park at our disposal. The Division of Nature Conservation of the Cape Provincial Administration and Mr W. A. Phillips made the animals in the Andries Vosloo Kudu Reserve and on the farm "Bucklands" respectively, available to us.

We are most appreciative of the assistance of Messrs B. D. de Klerk, C. Cheney, P. D. Burdett and M. M. Knight with the necropsies and Mesdames Gail Walter and Shelley Beuthin and Mr E. J. Williams with the parasite recoveries. Miss Andrea van Niekerk drew the graphs. Dr Jane Walker confirmed the identity of the *Rhipicephalus* sp. (near *R. oculatus*).

This research was funded by the National Parks Board, the Cape Provincial Administration, Pretoria University, the South African Nature Foundation, the Meat Board and the Council for Scientific and Industrial Research.

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Onderstepoort Journal of Veterinary Research, 62:171–179 (1995)

Parasites of domestic and wild animals in South Africa. XXXIV. Arthropod parasites of nyalas in north-eastern KwaZulu-Natal

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ABSTRACT

HORAK, I.G., BOOMKER, J. & FLAMAND, J.R.B. 1995. Parasites of domestic and wild animals in South Africa. XXXIV. Arthropod parasites of nyalas in north-eastern KwaZulu-Natal. *Onderstepoort Journal of Veterinary Research*, 62:171–179

Seventy-three nyalas (*Tragelaphus angasii*) in the Umfolozi, Mkuzi and Ndumu Game Reserves in north-eastern KwaZulu-Natal were examined for arthropod parasites during 1983 and 1984. In addition, six animals were examined during 1994. Ten ixodid tick species, two louse species and a louse fly species were recovered. The nyalas were good hosts of all stages of development of *Boophilus decoloratus, Rhipicephalus appendiculatus* and *Rhipicephalus muehlensi* and the immature stages of *Amblyomma hebraeum* and *Rhipicephalus maculatus*.

Adult male animals harboured more adult ticks, biting lice and louse flies than did adult females.

B. decoloratus was generally most abundant from October to May. The larvae of *R. appendiculatus* peaked from April to October, nymphs from July to October and adults, on adult male nyalas, from February to May. Larvae of *R. maculatus* were most abundant from May to July and nymphs from June to October. The immature stages of *A. hebraeum* and all stages of *R. muehlensi* were present throughout the year.

Keywords: Arthropod parasites, nyalas, north-eastern KwaZulu-Natal, *Tragelaphus angasii*

INTRODUCTION

Several surveys of ixodid ticks infesting domestic and wild animals in KwaZulu-Natal, have already been conducted. Baker & Ducasse (1967) and Baker, Ducasse, Sutherst & Maywald (1989) examined cattle, and Baker & Ducasse (1968), goats. Buffaloes *(Syncerus caffer)*, nyalas *(Tragelaphus angasii)*, common reedbuck *(Redunca arundinum)*, impalas *(Aepyceros melampus)*, bushbuck *(Tragelaphus scriptus)*, common duikers *(Sylvicapra grimmia)*, red duikers *(Cephalophus natalensis)*, bushpigs *(Potamochoerus larvatus)* and scrub hares *(Lepus saxatilis)* were examined by Horak, Potgieter, Walker, De Vos & Boomker (1983), Horak, Keep, Flamand & Boomker (1988), Horak, Keep, Spickett & Boomker (1989), Horak, Boomker & Flamand (1991a) and Horak, Spickett, Braack, Penzhorn, Bagnall & Uys (1995). Baker & Keep (1970) published a checklist of ticks infesting the larger wild animals in KwaZulu-Natal game reserves, while Keep (1971) produced such a list specifically for nyalas.

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Accepted for publication 25 July 1995—Editor

Nyalas in the north-eastern KwaZulu-Natal game reserves had to be culled during the late 1970s and early 1980s because their numbers exceeded the carrying capacity of the land. Culling or relocation has subsequently continued at irregular intervals. In conjunction with this activity, parasites were collected from some of the culled animals and Boomker, Horak & Flamand (1991) reported on the helminths recovered. They also summarized the available data on the morphometrics, feeding and behaviour of nyalas and briefly described the physiography of the Umfolozi, Mkuzi and Ndumu Game Reserves.

According to Smithers (1983), male nyalas are considerably taller and heavier than females. Adult males are horned and slatey-grey to dark brown in colour with a few white, vertical stripes on the body. They have a dorsal crest of long hair from the back of the head to the base of the tail and a heavy fringe of long hair on the under-parts of the neck and along the middle line of the chest and belly. Females are hornless, bright chestnut in colour and have up to 18 white, vertical stripes on their bodies. Nyalas are predominantly browsers and have a restricted habitat in that they are usually found in thickets in dry savanna woodland or riverine woodland (Smithers 1983).

The present paper records the ectoparasite burdens of nyalas culled in the Umfolozi, Mkuzi and Ndumu Game Reserves in north-eastern KwaZulu-Natal.

MATERIALS AND METHODS

Study areas and animals

Umfolozi

The Umfolozi Game Reserve (28°12´–28°21´S; 31°42´–31°59´E) comprises about 47753 ha of hilly country, 130–600 m above sea level. Two vegetation types are recognized, namely Zululand Thornveld along the slopes and crests of the hills and Lowveld in the valleys (Acocks 1988). Both browse and grazing are plentiful. Annual rainfall is 500–750 mm and falls mainly in summer. Summers are hot and winters cool to mild, and frost seldom occurs.

An attempt was made to obtain one adult male, one adult female and one juvenile nyala of either sex at monthly intervals from March 1983 to April 1984, but neither the population sample nor the monthly collection was always possible. Forty nyalas were examined, of which 14 were adult males, 15 adult females, four juvenile males and seven juvenile females. No animals were examined during September or November 1983.

Mkuzi

The Mkuzi Game Reserve, which is approximately 25091 ha in extent, is situated in the so-called Maputaland (27°33´–27°46´S; 32°07´–32°19´E; altitude 130–300 m), and extends from the eastern foothills of the Lebombo mountain range, eastwards into the Makatini flats. The vegetation of the higher areas is classified as Lowveld, while that at lower altitudes consists of the Zululand Palm Veld subdivision of Coastal Forest and Thornveld (Acocks 1988). Rain falls mostly in summer with a variation of 500–750 mm. Summers are hot and often humid and winters are mild. Frost seldom occurs.

Nineteen nyalas were shot from March 1983 to May 1984. Of these, six were adult males, five adult females, five juvenile males and three juvenile females. In addition to these animals three adult male and three adult female nyalas were examined during March 1994.

Ndumu

The Ndumu Game Reserve (26°50´–26°56´S; 32°09´–32°21´E; altitude 30–100 m) comprises approximately 11000 ha. It is situated in the extreme north of KwaZulu-Natal and shares a common boundary in the north with southern Mozambique. Ndumu falls within the Lowveld subtype of Tropical Bush and Savannah (Acocks 1988). Rainfall varies from 500 to 750 mm per annum and falls mostly in summer. Summers are hot and humid and winters are mild; frost does not occur.

Fourteen nyalas, five adult males, three adult and one old female, one juvenile male and four juvenile females, were shot in this reserve from April 1983 to May 1984.

Collection and counting of parasites

The arthropod parasites of the nyalas were collected, identified and counted as described by Horak, Boomker, Spickett & De Vos (1992) for kudus. The numbers of engorging female ticks were determined only on the six animals examined in Mkuzi during March 1994.

RESULTS

Umfolozi

The ectoparasites collected from animals examined in the Umfolozi Game Reserve are summarized in Table 1.

The nyalas were infested with ten ixodid tick species of which *Rhipicephalus muehlensi*, followed by *Rhipicephalus appendiculatus*, were the most abundant. Every animal was infested with these ticks and with *Boophilus decoloratus*. The nyalas also harboured two louse species and a louse fly.

The seasonal abundances of these ticks and of the immature stages of *Rhipicephalus maculatus* are graphically illustrated in Fig. 1.

The largest numbers of *B. decoloratus* were collected during April and May 1983 and from October 1983 to February 1984. Larvae of *R. appendiculatus* were most abundant from April to October, nymphs from July to October and adults on adult male nyalas during the months of February to May. Larvae of *R. maculatus* were most abundant from May to July and nymphs, from June to October. No clear pattern of seasonal abundance was evident for *R. muehlensi*.

Comment: Observations on the seasonal abundances of all stages of development of *B. decoloratus* and of *R. muehlensi* and the immature stages of *R. appendiculatus* and *R. maculatus* are compromised by the fact that no nyalas were examined during September and November 1983.

Mkuzi

The arthropod burdens of animals examined in this reserve during 1983/1984 and during 1994 are summarized in Tables 2 and 3, respectively.

Eight ixodid tick species were recovered from the first set of nyalas and seven from the second set. Animals examined during the months of October to March generally harboured substantial numbers of *B. decoloratus*, while those examined during May, June and July had very small burdens. The seasonal abundances of *R. appendiculatus* and *R. maculatus* appeared to be similar to those recorded on the nyalas examined in the Umfolozi Game Reserve. *R. muehlensi*, which comprised more than 75% of the

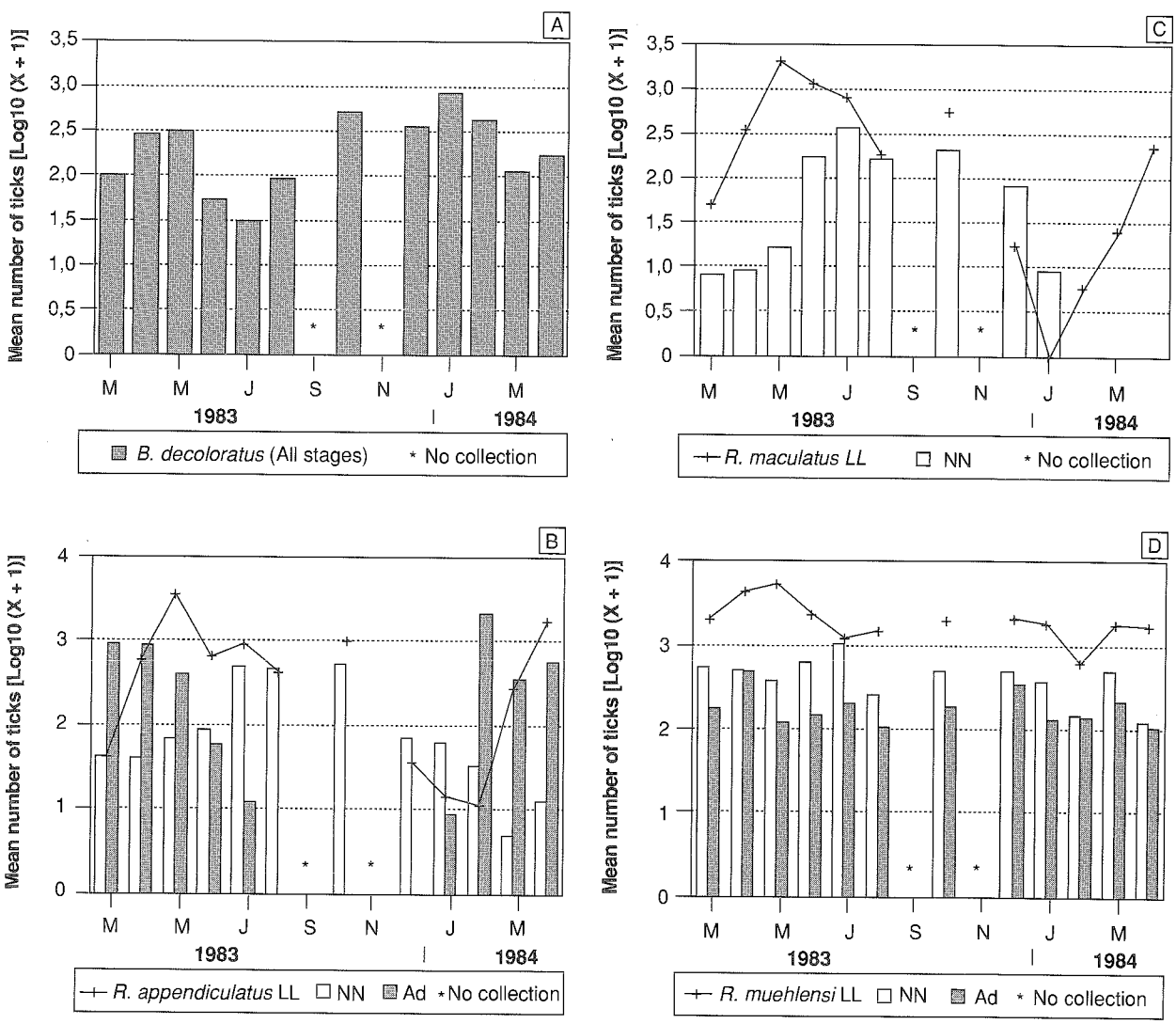

FIG. 1 The seasonal abundance of A. *Boophilus decoloratus*
B. *Rhipicephalus appendiculatus*, (adults only on male animals)
C. *Rhipicephalus maculatus*
D. *Rhipicephalus muehlensi* on nyalas in the Umfolozi Game Reserve

ticks collected from both groups of animals, was present in large numbers throughout the survey.

Most of the nyalas were infested with *Linognathus angasi* and all, with *Lipoptena paradoxa.*

Ndumu

The numbers of arthropods collected from nyalas in this reserve are summarized in Table 4.

The animals were infested with eight ixodid tick species, two species of louse and a louse fly species. *R. muehlensi* was the most abundant and prevalent tick, while considerably fewer *R. appendiculatus* than *R. maculatus* were recovered. The approximately 4-month intervals at which animals were examined, precluded determination of seasonal abundance.

Host sex preference

Twenty-one adult male and 21 adult female nyalas were shot in pairs at the same times and at the same localities during the 1983/1984 survey period. In addition, three adult male and three adult female animals were shot in the Mkuzi Game Reserve on 9–10 March 1994. The parasite burdens of the male and female nyalas were compared by means of the Mann-Whitney *U*-test for non-parametrically distributed data. The mean burdens of the major parasites on these 48 animals are summarized in Table 5.

Adult male nyalas harboured significantly more ($P \leq 0,05$) nymphs of *Amblyomma hebraeum,* males and females of *B. decoloratus, R. appendiculatus* and *R. muehlensi*, males of *R. maculatus,* nymphs and adults of the *Damalinia* sp. and adults of *L. paradoxa* than did adult female nyalas.

Locality preferences

The mean parasite burdens of nyalas examined in each of the reserves during 1983 and 1984 are summarized in Table 6.

Umfolozi was a good habitat for *A. hebraeum*, the only habitat in which *Haemaphysalis silacea* was present, and the only habitat of the three which was more suitable for *R. appendiculatus* than for *R. maculatus*. Mkuzi was a good habitat for *A. hebraeum, B. decoloratus, R. maculatus* and *R. muehlensi*. With the exceptions of *R. muehlensi,* for which it appeared to be the best of the three habitats, and of *R. maculatus*, Ndumu was the least favourable habitat for nearly all tick species. It must, however, be remembered that the animals were not examined in each of the reserves at the same times.

DISCUSSION

Hunters in KwaZulu-Natal often comment on the large numbers of ticks encountered on nyalas. The present findings confirm this observation, particularly as trophy hunters invariably shoot adult male animals and the head and cape (skin of the neck) of the animal are regarded as the trophy. *R. appendiculatus* and *R. muehlensi* prefer the ears, heads and upper necks of male nyalas as attachment sites and are

TABLE 1 Arthropod parasites of 40 nyalas examined in the Umfolozi Game Reserve during 1983/1984

Arthropod species	Total numbers recovered					No. of nyalas infested
Ixodid ticks	Larvae	Nymphs	Males	Females	Total	
Amblyomma hebraeum	16 296	3 030	66	22	19 414	39
Amblyomma spp.	56	0	0	0	56	1
Boophilus decoloratus	4 611	3 225	1 526	1 063	10 425	40
Haemaphysalis aciculifer	0	0	0	2	2	1
Haemaphysalis silacea	571	152	47	60	830	16
Ixodes sp. (near *I. pilosus*)	598	8	14	16	636	11
Rhipicephalus appendiculatus	32 343	7 352	3 160	2 580	45 435	40
Rhipicephalus evertsi evertsi	644	0	10	4	658	15
Rhipicephalus maculatus	20 674	4 183	6	64	24 927	35
Rhipicephalus muehlensi	92 024	19 724	4 662	2 940	119 350	40
Lice	Nymphs		Adults		Total	
Damalinia sp.	2 134		1 269		3 403	13
Linognathus angasi	5 132		2 792		7 924	36
Louse flies	Males		Females		Total	
Lipoptena paradoxa	1 032		1 304		2 360[a]	38

[a] Including pieces of flies whose sex could not be determined

consequently present on those parts of the animal which will ultimately become the trophy. In addition, adults of the latter tick are present throughout the year so that large numbers of ticks are always present on and around the heads of nyalas.

Horak *et al.* (1992) noted that adult male kudus carried significantly more nymphal and adult *A. hebraeum* and adult *B. decoloratus* than did adult females. A similar finding for *L. paradoxa* on kudus was reported by Visagie, Horak & Boomker (1992). These authors postulated that body size, grooming or hormonal influences could be responsible for these differences. If it is assumed that adult male and female nyalas utilize the same habitat, the reasons for the lower tick, louse and louse fly burdens on the females justify further investigation.

Amblyomma spp.

Horak, MacIvor, Petney & De Vos (1987) observed that the larger the host species the greater the likeli-

TABLE 2 Arthropod parasites of 19 nyalas examined in the Mkuzi Game Reserve during 1983/1984

Arthropod species	Total numbers recovered					No. of nyalas infested
Ixodid ticks	Larvae	Nymphs	Males	Females	Total	
Amblyomma hebraeum	7 169	916	28	4	8 117	19
Amblyomma spp.	1 271	0	0	0	1 271	7
Boophilus decoloratus	6 882	1 966	492	214	9 554	18
Ixodes sp. (near *I. pilosus*)	32	0	0	0	32	1
Rhipicephalus appendiculatus	4 650	348	775	645	6 418	18
Rhipicephalus evertsi evertsi	112	8	2	0	122	4
Rhipicephalus maculatus	12 499	1 488	56	58	14 101	19
Rhipicephalus muehlensi	105 491	17 856	7 409	5 238	135 994	19
Lice	Nymphs		Adults		Total	
Damalinia sp.	112		104		216	4
Linognathus angasi	1 492		562		2 054	17
Louse flies	Males		Females		Total	
Lipoptena paradoxa	354		414		798[a]	19

[a] Including pieces of flies whose sex could not be determined

TABLE 3 Arthropod parasites of six nyalas examined in the Mkuzi Game Reserve during March 1994

Arthropod species	Total numbers recovered					No. of nyalas infested
Ixodid ticks	Larvae	Nymphs	Males	Females	Total	
Amblyomma hebraeum	2 620	274	24	4	2 922	6
Amblyomma spp.	81	0	0	0	81	2
Boophilus decoloratus	1 785	375	160	146 (16)	2 466	6
Rhipicephalus appendiculatus	8	0	975	535 (22)	1 518	6
Rhipicephalus evertsi evertsi	48	0	11	2	61	5
Rhipicephalus maculatus	220	19	14	14	267	6
Rhipicephalus muehlensi	30 880	4 351	3 235	2 092 (190)	40 558	6
Lice	Nymphs		Adults		Total	
Damalinia sp.	222		55		277	3
Linognathus angasi	639		232		871	6
Louse flies	Males		Females		Total	
Lipoptena paradoxa	295		403		704[a]	6

( ) = Number of engorging female ticks, i.e. idiosoma of *B. decoloratus* and *R. muehlensi* > 4,0 mm and *R. appendiculatus* > 5,0 mm in length
[a] = Including pieces of six flies whose sex could not be determined

TABLE 4 Arthropod parasites of 14 nyalas examined in the Ndumu Game Reserve during 1983/1984

Arthropod species	Total numbers recovered					No. of nyalas infested
Ixodid ticks	Larvae	Nymphs	Males	Females	Total	
Amblyomma hebraeum	224	190	0	0	414	9
Amblyomma spp.	48	0	0	0	48	2
Boophilus decoloratus	388	164	66	36	654	10
Ixodes sp. (near *I. pilosus*)	48	32	2	0	82	3
Rhipicephalus appendiculatus	2 888	196	234	176	3 494	12
Rhipicephalus evertsi evertsi	32	0	0	0	32	1
Rhipicephalus maculatus	10 000	734	86	56	10 876	13
Rhipicephalus muehlensi	93 764	17 724	6 370	4 176	122 034	14
Lice	Nymphs		Adults		Total	
Damalinia sp.	24		48		72	2
Linognathus angasi	1 968		616		2 584	12
Louse flies	Males		Females		Total	
Lipoptena paradoxa	368		452		822[a]	12

[a] Including pieces of two flies whose sex could not be determined

hood that it would harbour large numbers of adult *A. hebraeum*. From a subsequent study it would appear as if kudus lie on the border between the really large and the smaller wild-host species (Horak *et al.* 1992). Male kudus may harbour fairly substantial numbers of adult *A. hebraeum,* while females seldom carry more than two or three ticks. Although both the Umfolozi and Mkuzi Game Reserves are located in habitats favourable for *A. hebraeum*, not all animals were infested with adults, and the largest burden of adult *A. hebraeum* comprised only 22 ticks, which incidently were recovered from an adult female nyala. This indicates that nyalas fall within the group of smaller host species, i.e. they are good hosts of the immature stages but not of adult *A. hebraeum.*

The absence of a pattern of seasonal abundance can be ascribed to the year-round warm climate of the reserves, similar to that encountered in the Kruger National Park, where all stages of *A. hebraeum* were present on kudus throughout the year (Horak *et al.* 1992).

Both *Amblyomma marmoreum* and *Amblyomma nuttalli,* whose adults prefer to feed on tortoises, are present in KwaZulu-Natal (Walker 1991). We are unable to differentiate between the immature stages of these ticks and have therefore allocated specimens resembling them, merely to *Amblyomma* spp. Most of these ticks were collected from nyalas in the Mkuzi Game Reserve and were present mainly during March.

Boophilus decoloratus

Substantial numbers of this tick have been recorded on cattle at lower altitudes in southern KwaZulu-Natal (Baker & Ducasse 1967; Baker *et al.* 1989). Although Baker & Keep (1970) list it as occurring on numerous wild animals, including nyalas, in this province, quantitative studies by Horak *et al.* (1983, 1988, 1989, 1991a) indicate that it is present only in small numbers on wild animals in those regions where the latter authors conducted their studies. In the present survey, however, nyalas in the Mkuzi Game Reserve harboured fairly large numbers of *B. decoloratus*. The overall ratio of larvae to nymphs to adults of 3,7:1,5:1,0, calculated from all the nyalas examined, is not unlike that found on kudus in the Eastern Transvaal (3,0:2,0:1,0) and implies a good translation of larvae and nymphs to adulthood (Horak *et al.* 1992). With the exception of two localities at which tick numbers increased in spring, Baker *et al.* (1989) recorded the largest burdens of *B. decoloratus* on cattle from mid to late summer or autumn. In this survey, the largest burdens were present on nyalas examined in months falling within the period October to May (spring to autumn).

Haemaphysalis spp.

Baker & Keep (1970) recorded *H. aciculifer* on common duikers, common reedbuck and bushbuck in the Umfolozi/Hluhluwe Game Reserve complex, and Horak *et al.* (1989) collected this tick from common duikers and bushbuck in the Weza State Forest, southern KwaZulu-Natal. Although *H. aciculifer* is widely distributed, it is never encountered in very large numbers (Walker 1991). It was collected from only one nyala in this study.

H. silacea has been recorded on animals in the Umfolozi/Hluhluwe Game Reserve complex and in the

TABLE 5 A comparison of the parasite burdens of 24 male and 24 female nyalas examined at the same localities in north-eastern KwaZulu-Natal at the same times

Developmental stage	Male nyalas		Female nyalas		Significance $P \leq 0,05$
	Mean burden (range)	No. of nyalas infested	Mean burden (range)	No. of nyalas infested	
Ixodid ticks					
Amblyomma hebraeum					
Larvae	503,5 (0–1 866)	21	282,3 (0–1 135)	21	–
Nymphs	114,0 (0–368)	21	41,5 (0–160)	20	0,020
Males	2,7 (0–10)	14	1,9 (0–20)	7	–
Females	0,8 (0–4)	8	0,5 (0–10)	2	–
Boophilus decoloratus					
Larvae	186,6 (0–1 157)	19	124,2 (0–464)	21	–
Nymphs	106,3 (0–596)	17	57,1 (0–256)	18	–
Males	61,4 (0–504)	20	18,9 (0–128)	14	0,030
Females	43,3 (0–344)	22	9,7 (0–76)	15	0,005
Rhipicephalus appendiculatus					
Larvae	517,3 (0–3 746)	18	605,5 (0–5 421)	17	–
Nymphs	144,1 (0–912)	14	88,3 (0–560)	15	–
Males	194,2 (0–1 232)	17	4,9 (0–30)	10	0,002
Females	150,4 (0–1 030)	16	2,5 (0–20)	10	0,005
Rhipicephalus maculatus					
Larvae	419,3 (0–3 276)	20	480,2 (0–1 929)	18	–
Nymphs	92,5 (0–448)	17	82,7 (0–448)	18	–
Males	3,8 (0–42)	10	0,0 (0)	0	0,010
Females	6,4 (0–44)	8	0,7 (0–16)	1	–
Rhipicephalus muehlensi					
Larvae	3 561,8 (448–12 564)	24	3 833,2 (762–8 875)	24	–
Nymphs	625,9 (28–3 712)	24	662,2 (0–2 046)	23	–
Males	389,3 (78–1 239)	24	174,2 (14–555)	24	0,002
Females	256,4 (36–1 152)	24	117,5 (10–351)	24	0,010
Lice					
Damalinia sp.					
Total	159,8 (0–2 044)	17	2,0 (0–32)	2	0,001
Linognathus angasi					
Total	156,2 (0–1 056)	22	248,7 (0–3 504)	20	–
Louse flies					
Lipoptena paradoxa					
Adults	114,0 (28–340)	24	37,6 (0–220)	23	0,001

TABLE 6 The mean total arthropod parasite burdens of nyalas examined in the Umfolozi, Mkuzi and Ndumu Game Reserves during 1983/1984

Arthropod species	Mean total burdens per species		
	Umfolozi (40)	Mkuzi (19)	Ndumu (14)
Ixodid ticks			
Amblyomma hebraeum	485	427	30
Amblyomma spp.	1	67	3
Boophilus decoloratus	261	503	47
Haemaphysalis silacea	21	0	0
Ixodes sp. (near *I. pilosus*)	16	2	6
Rhipicephalus appendiculatus	1 136	338	250
Rhipicephalus evertsi evertsi	16	6	2
Rhipicephalus maculatus	623	742	777
Rhipicephalus muehlensi	2 984	7 158	8 717
Lice			
Damalinia sp.	85	11	5
Linognathus angasi	198	108	185
Louse flies			
Lipoptena paradoxa	59	42	59

( ) = Number of animals examined in each reserve

Mkuzi Game Reserve by Baker & Keep (1970), but we collected it only in the Umfolozi Game Reserve. The preferred habitat of this tick is localized areas of Valley Bushveld in the Eastern Cape Province (Walker 1991), where large numbers have been recorded on kudus (Horak *et al.* 1992).

Ixodes pilosus complex

McKay (1994) believes that there are three separate species in this complex. Although *I. pilosus* sensu stricto does occur in KwaZulu-Natal (McKay 1994), the nyalas in the present study harboured adult ticks which he describes as "thick haired *pilosus*".

Rhipicephalus spp.

The adults of *R. appendiculatus* prefer large bovids such as cattle, eland and buffaloes, but kudus, sable antelope and impalas are also good hosts (Norval, Walker & Colborne 1982; Horak *et al.* 1983, 1992). Adult male, but not female, nyalas can now be added to this list. Six male animals each harboured more than 600 adult ticks and one of them, 2262 ticks.

Baker & Ducasse (1967) recovered 69,3% of adult *R. appendiculatus* from the ear pinnae of cattle and 80,0% from the pinnae and the remainder of the cattle's heads. The three male nyalas examined in the Mkuzi Game Reserve during 1994 harboured a total of 1 461 adult *R. appendiculatus* of which 520 (35,6%) attached on their heads and ears. This distribution pattern could be the result of competition with the numerous adult *R. muehlensi* which were also present. The male nyalas harboured a total of 3 428 of these, of which 2316 (67,6%) were attached to their heads and ears. The three female nyalas examined at the same time, harboured a total of 49 adult *R. appendiculatus* and 1 899 adult *R. muehlensi*, of which 57,1% and 91,0%, respectively, were attached to their heads and ears.

The period of peak abundance of *R. appendiculatus* on the male nyalas (February to May) is the same as that recorded on kudus in north-eastern Eastern Transvaal (Horak *et al.* 1992).

R. evertsi evertsi has a very widespread distribution in South Africa (Howell, Walker & Nevill 1978) but, except on zebras and eland, the adults never occur in very large numbers (Horak, Fourie, Novellie & Williams 1991b). Nyalas, like kudus, appear to be poor hosts of this tick (Horak *et al.* 1992). Not only were few adults collected, but very few larvae of this two-host tick developed into nymphs.

Within the South African borders, *R. maculatus* is present in the coastal regions of KwaZulu-Natal (Walker 1991). The adults prefer large animals with thick skins, such as elephants, black and white rhinoceroses, buffaloes, bushpigs and warthogs (Baker & Keep 1970; Horak *et al.* 1983, 1991a). Excluding elephants, the immature stages are also found on these hosts as well as on various duiker species, reedbuck, impalas, and particularly on nyalas, also on scrub hares (Baker & Keep 1970; Horak *et al.* 1983, 1988, 1991a, 1995). The seasonal abundances of the immature stages are similar to those of *R. appendiculatus*.

Nyalas, and probably also bushbuck, must be regarded as the preferred hosts of all developmental stages of *R. muehlensi* (Horak *et al.* 1983, 1988; this study). This tick, like *R. maculatus*, is present in South Africa only in the coastal regions of northern KwaZulu-Natal (Walker 1991). Large numbers of nymphs, and probably also larvae (which at the time were lumped with other larvae and identified as *Rhipicephalus* spp.), have been recovered from red duikers and numerous larvae from scrub hares (Horak *et al.* 1991a, 1995). Nyalas, bushbuck and red duikers are all browsers and are found in habitats containing thickets, various types of woodland or forests, while scrub hares prefer savanna woodland and scrub (Smithers 1983). This implies that *R. muehlensi* also prefers these habitat types.

The large totals of these ticks recovered from nyalas, reflect the year-round abundance of all developmental stages of *R. muehlensi*. As discussed earlier, competition with adult *R. appendiculatus* may affect the proportion of adult *R. muehlensi* attaching to the heads and ears of nyalas.

Lice

With few exceptions, louse burdens were low, and adult male animals harboured significantly more *Damalinia* sp. than did adult females. No pattern of seasonal abundance was evident for either of the louse species.

Louse flies

The biology of *L. paradoxa*, with particular reference to kudus, was discussed by Visagie *et al.* (1992). The preferred hosts of this fly are all browsing antelopes, namely common duikers, bushbuck, nyalas and kudus. Adult male kudus and nyalas harbour significantly more of these flies than do adult female animals (Visagie *et al.* 1992; Table 5). Visagie *et al.* (1992) collected 3594 flies whose sex could be determined, from common duikers, bushbuck and kudus. Of these flies 2243 (62,4%) were females. In the present study 4622 *L. paradoxa* whose sex could be determined were collected, and 2573 (55,7%) of these were females.

ACKNOWLEDGEMENTS

This study is part of the Wildlife Research Programme of the Faculty of Veterinary Science, University of Pretoria.

The Natal Parks Board is thanked for placing the nyalas at our disposal, and we greatly appreciate the assistance of the staff of the three game reserves with the necropsies. Dr J.P. Louw, Mr E.J. Williams and Mr A.C. Uys assisted with the collection of parasites from the animals or from the processed material and Dr I.J. McKay, with the identification of the *Ixodes* sp. Miss Andrea van Niekerk constructed the figures.

This research was funded by the Foundation for Research Development.

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A ten-year study of ixodid tick infestations of bontebok and grey rhebok in the Western Cape Province, South Africa

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Received 16 August 1996; accepted 3 October 1996

Two to four bontebok *Damaliscus pygargus dorcas* and three to four grey rhebok *Pelea capreolus*, in the Bontebok National Park, Western Cape Province, South Africa, were examined for ticks during February of each year from 1983 to 1992. A total of 34 bontebok and 37 grey rhebok were examined. The bontebok harboured eight ixodid tick species of which *Rhipicephalus glabroscutatum* and *Rhipicephalus nitens* were the most abundant. The grey rhebok harboured six species of which the former two ticks and *Ixodes pilosus* were the most numerous. With the exception of 1986 and 1989, when *R. glabroscutatum* was most abundant on the bontebok and grey rhebok respectively, and 1985 when *I. pilosus* was most plentiful on the grey rhebok, *R. nitens* was the most abundant tick species on both host species. Despite *Boophilus microplus* being present on animals outside the Park, as well as the translocation of Cape mountain zebras *Equus zebra zebra* and red hartebeest *Alcelaphus buselaphus* to the Park, no foreign tick species became established on the two hosts during the 10 years of observation. Nor did any of the tick species present only in low numbers become more plentiful.

Keywords: bontebok, grey rhebok, ixodid ticks, 10-year study

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Introduction

The adverse effects, including mortality, of ticks on wild artiodactylids, are well documented (Lightfoot & Norval 1981; Melton 1987; Fourie & Vrahimis 1989). The nature and extent of host injury are dependent on the tick species and burdens (Lightfoot & Norval 1981; Fourie & Kok 1992). In order to anticipate such tick-related problems it is important to determine the status of wild animals as hosts for the various tick species which infest them. Several abiotic and biotic factors may affect tick burdens (Randolph 1994) and may also influence the various tick species differently (Theiler 1970). This implies that species which are dominant during a particular year may occur in lower numbers during subsequent years and *vice versa*. In addition translocation of animals or physical alteration of the environment may result in ticks and the diseases they transmit becoming established in regions in which they did not occur historically (Barré, Uilenberg, Morel & Camus 1987; Spickett & Heyne 1988). Such dynamic changes can only be established by long-term studies.

During 1983–84 a survey was conducted to quantify the arthropod parasites, particularly ticks, of bontebok *Damaliscus pygargus dorcas*, grey rhebok *Pelea capreolus* and scrub hares *Lepus saxatilis* in the Bontebok National Park (Horak, Sheppey, Knight & Beuthin 1986b). Nine ixodid tick species were collected from both bontebok and grey rhebok, whilst the scrub hares harboured 11 species. The ticks *Rhipicephalus glabroscutatum* and *Rhipicephalus nitens* were considered to be the definitive parasites of bontebok, *R. nitens* and *Ixodes pilosus* those of grey rhebok and *R. nitens* of scrub hares (Horak *et al.* 1986b). Two *Boophilus* nymphs were collected from the grey rhebok and five from scrub hares. A grey rhebok examined immediately outside the borders of the Park, however, harboured small numbers of *Boophilus microplus* and of *B. decoloratus*. This implied a potential for these ticks to become established in greater numbers within the Park.

During the present study ticks infesting bontebok and grey rhebok in the Bontebok National Park were collected over a period of 10 years. The objectives were to ascertain whether any foreign tick species became established in the Park and also to determine possible changes in the relative abundance of the ticks parasitizing the two host species.

Methods

Study site

The Bontebok National Park (34°02'S;20°25'E; alt. 90–200 m) encompasses 2803 ha and is situated in the southern Western Cape Province, South Africa. The vegetation, which forms part of the Cape macchia, is described as Coastal Renosterbosveld (Acocks 1988) and the Park topography consists of a series of gravel terraces gradually rising to the north-eastern corner. Sand flats, surrounded by low hills occur in the south-west (Theron 1967). Wildlife census results for the Park during the year preceding and for the 10 years of the survey are summarized in Table 1. During this period the bontebok and grey rhebok numbers were stabilized

Table 1 Wildlife counts in the Bontebok National Park, 1982–1992

		Numbers of animals counted		
Year	Month	Bontebok	Grey rhebok	Other species
1982	March	352	160	Springbok 16
1983	February	279	181	
1984	February	305	175	Grysbok 17; Steenbok 12
	September	232	148	
1985	January	274	180	Grysbok 15; Steenbok 18
	September	239	173	
1986	February	285	207	Grysbok 24; Steenbok 14
	September	268	211	
1987	June	208	153	
	September	215	122	
1988	January	253	112	
	June	178	185	Red hartebeest 5; Mountain zebra 2
	October	192	197	
1989	August	205	128	Red hartebeest 7; Mountain zebra 2
1990	January	256	142	
	August	198	64	Red hartebeest 8; Mountain zebra 5
1991	February	206	106	
	April	203	156	
	May	231	147	
	September	233	102	Red hartebeest 10; Mountain zebra 8
1992	February	252	95	Red hartebeest 13; Mountain zebra 11

or reduced by culling and by translocation. Cape mountain zebras *Equus zebra zebra* and red hartebeest *Alcelaphus buselaphus* were introduced during 1988 and their numbers increased naturally and by further translocations. Although steenbok *Raphicerus campestris* and Cape grysbok *Raphicerus melanotis* were not counted during 1983 or subsequent to 1986 it can be assumed that the numbers of these small antelopes remained fairly constant. Rainfall was recorded daily in the Park.

Survey animals

During February of each year from 1983 to 1992 two to four bontebok and three to four grey rhebok were shot for survey purposes. The animals examined during February of 1983 and of 1984 in the previously mentioned survey (Horak *et al.* 1986b) have been included in this survey for those years.

Parasite recovery and counting

The skins of the animals were processed for arthropod parasite recovery as described by Horak, Boomker, Spickett & De Vos (1992) and the parasites identified and counted under a stereoscopic microscope.

The lungs, livers and gastro-intestinal tracts of the antelopes were processed for the recovery of helminths. These findings will be reported separately, as will those of the arthropods other than ticks recovered from the animals.

Results

A total of 34 bontebok and 37 grey rhebok were examined. The ticks infesting the two hosts are summarized in Tables 2 & 3. Eight species were collected from bontebok of which *Boophilus* sp., *Haemaphysalis aciculifer*, *R. evertsi evertsi* and *Hyalomma truncatum* were present only occasionally and in very low numbers (Table 2). Six species were collected from grey rhebok, with *H. aciculifer* and *R. evertsi evertsi* present in low numbers and only infrequently (Table 3).

The relative abundances of the major tick species infesting the two hosts are graphically presented in Figures 1 & 2. Large variations in relative abundance were recorded during the 10 year study period. The relative abundance of *R. glabroscutatum* on the bontebok increased steadily from 1984, reached a peak (58%) during 1986 and declined to its lowest level (0.5%) during 1991 (Figure 1). *R. nitens* was the most abundant tick during nine of the 10 years (Figure 1). On grey rhebok, *I. pilosus* displayed the highest relative abundance during 1985 and *R. glabroscutatum* during 1989. During the other years *R. nitens* was the dominant species (Figure 2).

Discussion

The diversity of tick species which occurred on the two hosts during the 10 years of observation stayed the same. None of the ticks which were previously collected in low numbers by Horak *et al.* (1986b) became more abundant.

One of the ways in which ticks are introduced into new areas is by host translocation (Braack, Maggs, Zeller & Horak 1995). Either the ticks that were present on the Cape mountain zebras and red hartebeest when they were introduced into the Bontebok National Park during 1988 did not survive in the new habitat, or their numbers are still too low to be detected on other hosts. The zebras and hartebeest could potentially serve as hosts for *Boophilus* spp., *Hyalomma truncatum* and *R. evertsi evertsi.* Mountain zebras are particularly good hosts of the latter two ticks and of *Margaropus winthemi*, the dominant species in the mountainous regions from which these animals came (Horak, Knight & De Vos 1986a).

The relative abundance of the various tick species on the hosts displayed long-term fluctuations. These fluctuations were chiefly caused by considerable variations in the numbers of the immature stages of *R. glabroscutatum*, a two-host tick, and the larvae of *I. pilosus* and of *R. nitens*, both three-host species. The fluctuations could be associated with climatic factors which affect the various tick species differently, or which affect the vegetation, causing the animals to feed in different localities to those normally utilized at a particular time of the year. Analysis of individual tick species indicated that all stages of development of *R. glabroscutatum* appeared to decrease on the bontebok from February 1985 to February 1991 and the adults of *R. nitens* from 1984 until 1990. The adults of the latter tick also decreased, albeit erratically, on the grey rhebok from 1984 and 1985 to 1991. In the case of *R. nitens*, where the adult ticks attach to the ears and lower jaws, and of *I. pilosus*, of which the adult ticks attach to the head and body, intraspecific or interspecific competition (Andrews & Petney 1981; Petney & Al-Yaman 1985) for the site of attachment may also influence population size. The implication is

Table 2 Ixodid ticks collected from bontebok in the Bontebok National Park during February of each year from 1983–1992

Year	*Amblyomma marmoreum*				*Boophilus sp.*				*Haemaphysalis aciculifer*				*Hyalomma truncatum*				*Ixodes pilosus*				*Rhipicephalus e. evertsi*				*Rhipicephalus glabroscutatum*				*Rhipicephalus nitens*			
	L	N	♂	♀	L	N	♂	♀	L	N	♂	♀	L	N	♂	♀	L	N	♂	♀	L	N	♂	♀	L	N	♂	♀	L	N	♂	♀
1983																																
x	4.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9.0	0	0	1.0	0	0	0	0	22.0	4.0	2.0	0	666.0	5.0	3.0	3.5
SD	2.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12.7	0	0	1.4	0	0	0	0	22.6	2.8	2.8	0	169.7	4.2	1.4	4.9
1984																																
x	1.0	0	0	0	0	0	0	0	0	0	0	1.0	0	0	0	0	12	1.5	0	0	0	0	0	0	60.0	9.5	0	0	140.0	1.0	27.5	42.0
SD	1.4	0	0	0	0	0	0	0	0	0	0	1.4	0	0	0	0	2.8	2.1	0	0	0	0	0	0	70.7	7.8	0	0	65.1	1.4	24.7	48.1
1985																																
x	2.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3.3	0.7	0	0.7	0	8.7	0	0	357.0	32.7	2.7	1.3	564.0	14.0	20.7	27.0
SD	4.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.2	1.2	0	1.2	0	9.0	0	0	349.9	22.5	2.5	1.5	387.0	15.1	15.6	26.6
1986																																
x	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.0	1.5	0	0.5	0	0	0	0	242.5	10.0	0.5	1.0	148.0	2.5	14.0	17.5
SD	1.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.3	1.9	0	1.0	0	0	0	0	446.7	14.9	1.0	1.2	96.7	3.0	10.1	10.0
1987																																
x	8.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.7	0.7	0	0	0	0	0	0	19.3	38.7	0	0.7	42.0	2.0	11.3	12.3
SD	15.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.2	1.2	0	0	0	0	0	0	15.0	60.2	0	1.2	10.6	2.0	8.4	9.7
1988																																
x	3.5	0	0	0	0	0	0	0	1.0	0	0	0	0	0	0	0	0.5	0.5	0.5	0	2.0	0	0	0	4.0	5.5	0.5	0.5	92.0	1.0	7.5	7.0
SD	5.7	0	0	0	0	0	0	0	2.0	0	0	0	0	0	0	0	1.0	1.0	1.0	0	2.8	0	0	0	6.7	11.0	1.0	1.0	118.1	2.0	3.4	3.8
1989																																
x	1.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7.8	6.8	0	1.3	101.0	0.5	7.8	6.8
SD	1.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9.7	9.9	0	1.5	97.1	0.6	5.7	5.6
1990																																
x	0	0	0	0	1.0	0	0	0	0	0	0	0	0	0	0	0	3.0	0.5	0	0	0	0	0	0	6.0	0	0	0	272.5	1.0	7.0	1.0
SD	0	0	0	0	2.0	0	0	0	0	0	0	0	0	0	0	0	6.0	1.0	0	0	0	0	0	0	1.6	0	0	0	81.4	1.2	6.2	1.2
1991																																
x	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.0	0	0	0	191.5	1.5	7.3	7.0
SD	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.2	0	0	0	177.1	1.9	8.4	5.3
1992																																
x	1.0	0	0	0	0	0	0	0	0	0	0	0	0.5	0	0	0	4.0	1.0	0	0	0	0.5	0	0	17.5	7.0	1.0	2.5	615.0	9.0	19.0	19.3
SD	2.0	0	0	0	0	0	0	0	0	0	0	0	1.0	0	0	0	4.9	1.2	0	0	0	1.0	0	0	21.7	8.7	2.0	3.0	658.4	7.6	14.3	10.3

Table 3 Ixodid ticks collected from grey rhebok in the Bontebok National Park during February of each year from 1983–1992

Year	*Amblyomma marmoreum*				*Haemaphysalis acicultfer*				*Ixodes pilosus*				*Rhipicephalus evertsi evertsi*				*Rhipicephalus glabroscutatum*				*Rhipicephalus nitens*			
	L	N	♂	♀	L	N	♂	♀	L	N	♂	♀	L	N	♂	♀	L	N	♂	♀	L	N	♂	♀
1983																								
x	9.0	0	0	0	0	0	0	0.3	36.5	4.0	1.0	3.5	0	0	0	0	1.0	0	1.0	0	155.5	4.5	15.8	21.8
SD	13.2	0	0	0	0	0	0	0.5	15.1	4.3	0.8	4.1	0	0	0	0	2.0	0	1.2	0	163.5	4.1	20.8	22.5
1984																								
x	1.0	0	0	0	0	0	0	0	2.0	3.0	0.3	4.8	0	0	0.5	0	4.5	0	0.5	0.5	32.0	0	20.3	26.8
SD	2.0	0	0	0	0	0	0	0	2.8	4.8	0.5	3.6	0	0	1.0	0	5.7	0	1.0	1.0	38.1	0	16.8	22.2
1985																								
x	6.7	0	0	0	0	0	0	0	148.0	12.7	1.7	5.7	0	0	0	0	4.0	14.0	0.7	0.7	52.0	0.7	4.3	10.0
SD	3.1	0	0	0	0	0	0	0	126.6	12.1	0.6	2.5	0	0	0	0	2.0	22.5	1.2	1.2	84.9	1.2	2.9	4.6
1986																								
x	2.7	0	0	0	0	0	0	0	2.7	0.7	0	0.7	0	0	0	0	0	0	0	0	0.7	0	2.0	1.3
SD	4.6	0	0	0	0	0	0	0	4.6	1.2	0	1.2	0	0	0	0	0	0	0	0	1.2	0	2.0	1.2
1987																								
x	2.7	0	0	0	0	0	0	0	7.3	2.0	0	1.7	2.0	0.7	0	0.3	2.0	0	4.0	1.3	157.3	0	12.7	16.7
SD	3.1	0	0	0	0	0	0	0	12.7	2.0	0	1.5	3.5	1.2	0	0.5	3.5	0	3.5	1.6	231.6	0	10.0	17.7
1988																								
x	0	0	0	0	0	0	0	0	0.5	0	0.3	0	0	0	0	0	5.0	0.5	0.5	0.5	31.0	0	5.3	12.8
SD	0	0	0	0	0	0	0	0	1.0	0	0.5	0	0	0	0	0	7.6	1.0	1.0	1.0	12.5	0	4.3	11.2
1989																								
x	1.0	0	0	0	0	0	0	0	1.0	0.5	0	0.3	0.3	0	0	0	60.5	3.0	1.0	0.3	31.5	0.3	2.5	0.5
SD	2.0	0	0	0	0	0	0	0	1.4	1.0	0	0.5	0.5	0	0	0	77.1	4.1	1.4	0.5	42.4	0.5	1.7	0.6
1990																								
x	0	0	0	0	0	0	0	.0	7.5	2.5	0.5	3.5	0	0	0	0	3.0	2.5	0	0	37.0	0	1.5	0.5
SD	0	0	0	0	0	0	0	0	9.0	3.0	1.0	3.4	0	0	0	0	6.0	3.8	0	0	42.4	0	3.0	1.0
1991																								
x	0	0	0	0	0	0	0	0.5	6.0	0.5	1.0	0.5	0	0	0	0	0	1.5	0	0	24.5	0	0	0.5
SD	0	0	0	0	0	0	0	1.0	4.9	1.0	2.0	1.0	0	0	0	0	0	3.0	0	0	39.7	0	0	1.0
1992																								
x	4.0	0	0	0	0	0	0	0	50.0	0.5	0.3	2.3	1.0	5.5	0	0	128.0	2.0	0	1.0	353.0	2.0	3.0	5.3
SD	8.0	0	0	0	0	0	0	0	80.1	1.0	0.5	1.5	2.0	11.0	0	0	244.0	4.0	0	2.0	446.6	4.0	2.4	8.5

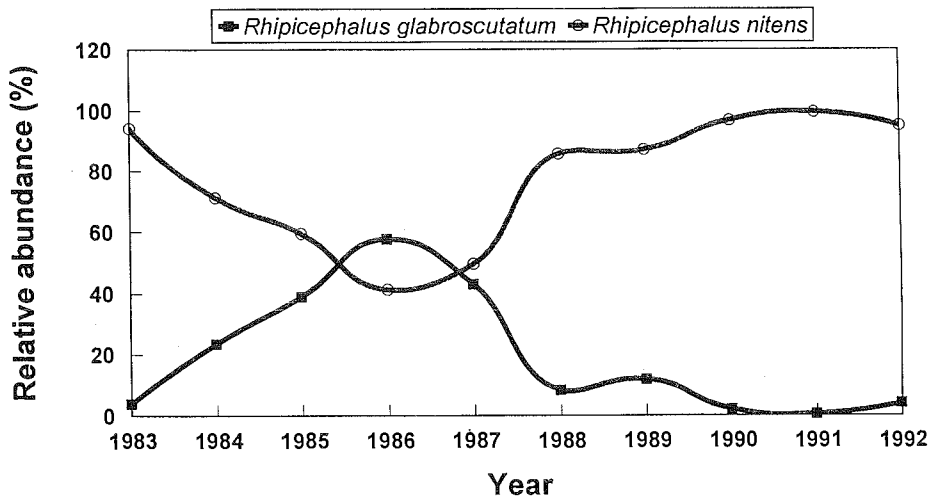

Figure 1 The relative abundance of the major tick species which infested bontebok in the Bontebok National Park as determined during February of 1983–1992.

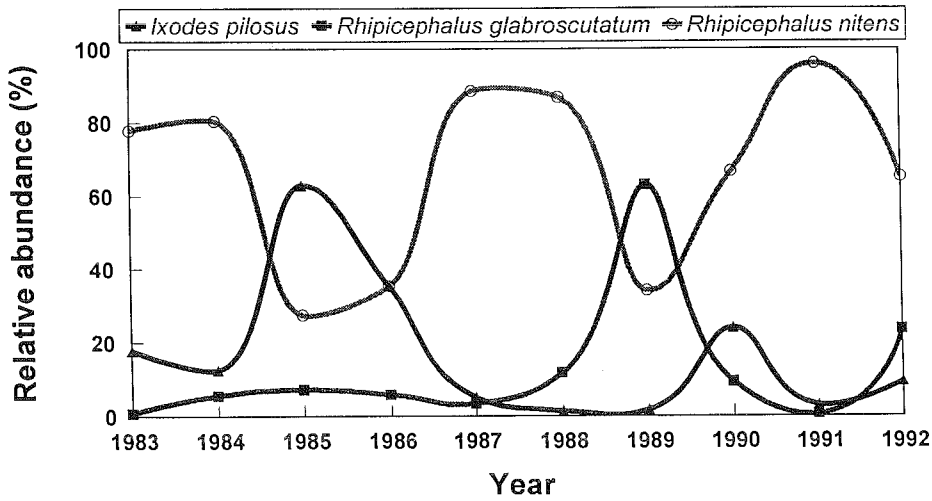

Figure 2 The relative abundance of the major tick species which infested grey rhebok in the Bontebok National Park as determined during February of 1983–1992.

that ticks attaching to non-preferential feeding sites may be removed more easily by the grooming actions of the host.

In terms of general tick ecology and host-tick interactions the results obtained during this long-term study are important for a number of reasons. Firstly, they illustrate the dynamic nature of tick populations on hosts in which a tick species, which is most abundant during a particular year, may not necessarily be so during subsequent years. This demonstrates the danger of determining relative species abundance for a region from a once-off collection, even though the latter may involve the examination of a number of endemic host species. This applies even more so in a stock-farming situation where several tick species may be more severely affected than others by acaricidal intervention.

Secondly, in terms of the epidemiology of tick-transmitted diseases, the population size of certain disease-inducing tick species may increase gradually until critical levels are reached, and hosts are affected. Karoo paralysis, caused by *Ixodes rubicundus*, is a pertinent example where a specific infestation level is required before paralysis is induced (Fourie & Horak 1987; Fourie & Vrahimis 1989). *R. nitens* may also cause a tick toxicosis similar to that recorded in cattle for *Rhipicephalus appendiculatus* by Thomas & Neitz (1958). Springbok *Antidorcas marsupialis* in the southern Western Cape Province, infested with large numbers of *R. nitens* during February, have been severely affected and have died (Horak, unpublished data). Whether this is also the case for bontebok and grey rhebok in the study area is unknown.

Furthermore, if drastic increases in total tick burdens were noted during a long-term study these could indicate management problems. This is particularly true in small nature reserves where overstocking could lead to territorial or nutritional stress or into which too many individuals of tick susceptible host species had been introduced during translocation operations. Finally, such studies could indicate whether non-endemic tick species had been introduced and become established in a particular habitat over a period of years.

Despite *B. microplus* being fairly widespread in South Africa (Howell, Walker & Nevill 1978), the recovery of small

numbers of this tick from a single grey rhebok grazing in a paddock with cattle outside the perimeter of the Park by Horak *et al.* (1986b), is the only record on a wild host in this country from the more than 1000 potentially suitable wild ruminant and equid hosts examined over a period of some 20 years by one of us (I.G.H.). Consequently its continued absence in the Park in spite of cattle grazing up to the boundary fences is not unexpected.

Acknowledgements

This study is part of the Wildlife Research Programme of the Faculty of Veterinary Science, University of Pretoria. We wish to thank the National Parks Board for placing the antelopes at our disposal, and the Park wardens and their staff for assisting with the necropsies. The project was funded by the Foundation for Research Development, the University of Pretoria and Rhodes University.

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Onderstepoort Journal of Veterinary Research, 65:205–211 (1998)

Parasites of domestic and wild animals in South Africa. XXXV. Ixodid ticks and bot fly larvae in the Bontebok National Park

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ABSTRACT

HORAK, I.G. & BOOMKER, J. 1998. Parasites of domestic and wild animals in South Africa. XXXV. Ixodid ticks and bot fly larvae in the Bontebok National Park. *Onderstepoort Journal of Veterinary Research*, 65:205–211

Ixodid ticks were collected during February of each year from 1983–1992 from bontebok and grey rhebok in the Bontebok National Park, Western Cape Province. When available other mammals as well as ground-nesting birds and leopard tortoises were examined. Eleven tick species were recovered. *Rhipicephalus nitens* followed by *Rhipicephalus glabroscutatum* and an *Ixodes* sp. (near *I. pilosus*) were the most abundant, while *Amblyomma marmoreum* infested the widest host range.

The larvae of three bot flies were also collected. *Gedoelstia* sp. and *Strobiloestrus* sp. larvae were recovered from bontebok and grey rhebok and larvae of *Oestrus ovis* only from grey rhebok.

Keywords: Birds, bontebok, Bontebok National Park, bot fly larvae, grey rhebok, hares, ixodid ticks, rodents, tortoises

INTRODUCTION

A bi-monthly study, lasting 13 months, of some of the arthropods infesting animals in the Bontebok National Park, Western Cape Province, South Africa, has already been conducted (Horak, Sheppey, Knight & Beuthin 1986b). That survey was carried out to ascertain not only the arthropod species, particularly ixodid ticks and bot fly larvae, parasitizing animals in the Park but also their seasonal abundances. The present study extended the scope of the previous one by including ground-nesting birds and tortoises. It also looked at possible changes that might have occurred in tick burdens of bontebok and grey rhebok over a period of 10 years. The latter aspect has been addressed in a separate publication (Horak, Fourie & Boomker 1997).

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Accepted for publication 22 June 1998—Editor

MATERIALS AND METHODS

Study locality

The study was conducted on animals resident in the Bontebok National Park (34°02'S, 20°25'E). The physiography of this park has previously been described by Boomker, Horak & De Vos (1981).

Survey period

Animals were examined during February of each year over a period of 10 years from 1983–1992. The animals examined during February 1983 and 1984 in the earlier study conducted by Horak *et al.* (1986b) have been included in this survey as being the first 2 years of the 10-year period.

Survey animals

The mammal, bird and tortoise species and the numbers of each examined are summarized in Table 1.

The species examined comprised two ruminants, two rodents, a hare, three ground-nesting birds and the leopard tortoise. The larger mammals and birds were

TABLE 1 Mammals, birds and reptiles examined for ixodid ticks in the Bontebok National Park

Common name	Specific name	No. examined
Mammals		
Bontebok	*Damaliscus pygargus dorcas*	34
Grey rhebok	*Pelea capreolus*	37
Cape gerbil	*Tatera afra*	1
Four-striped grass mouse	*Rhabdomys pumilio*	25
Scrub hare	*Lepus saxatilis*	11
Birds		
Cape francolin	*Francolinus capensis*	7
Greywing francolin	*Francolinus africanus*	7
Helmeted guineafowl	*Numida meleagris*	4
Reptiles		
Leopard tortoise	*Geochelone pardalis*	9

shot while the rodents were either shot or were trapped and then killed. The tortoises were examined alive.

Parasite recovery

The ticks on the antelopes were collected, identified and counted as described by Horak, Boomker, Spickett & De Vos (1992); those on the rodents and hares as described by Horak *et al.* (1986b); and those on the birds as described by Horak & Williams (1986). All ticks visible on the tortoises were removed with the aid of forceps and placed in 70% ethyl alcohol for later identification and counting. The length of the idiosoma of all engorging female ticks was measured to ascertain how many would have been likely to detach within the next 24 h.

Bot fly larvae were collected from the nasal passages and paranasal sinuses, the eyes, heart and the skin and subcutaneous tissue as described by Malan, Reinecke & Scialdo (1981), Horak, Brown, Boomker, De Vos & Van Zyl (1982) and Horak *et al.* (1986b).

RESULTS AND DISCUSSION

Ixodid ticks

Eleven species of ticks were recovered. Large numbers of four of them were collected and are listed in Table 2. The ticks collected in relatively small numbers or only from a few host species are listed in Table 3.

Amblyomma marmoreum

This tick was present on seven of the nine host species examined. The leopard tortoises were infested with all stages of development and the other animals mainly with larvae. Tortoises are the preferred hosts of the adults (Norval 1975). The immature stages, and particularly the larvae, will infest a large variety of reptiles, mammals and birds (Norval 1975; Horak, MacIvor, Petney & De Vos 1987a). As in the case of *Amblyomma hebraeum* the immature stages do not favour the four-striped grass mouse (Howell, Petney & Horak 1989), or probably any other rodent species, as hosts.

Boophilus sp.

Although no specific identification of the larvae recovered could be made both *Boophilus decoloratus* and *Boophilus microplus* have been collected from a grey rhebok just outside the park (Horak *et al.* 1986b). Infestations of these ticks are maintained by domestic cattle on the farms adjoining the park.

Haemaphysalis aciculifer

Both immature and adult stages were collected. Although this tick is widely distributed, particularly in the eastern regions of South Africa, where its presence is associated with bush and scrub, it is never encountered in large numbers (Walker 1991). The preferred hosts of the adults are various small and large wild bovids while the immatures feed on rodents and hares as well as on other small mammals and carnivores (Hoogstraal & El Kammah 1972; Walker 1991). Cape francolin also appear to be good hosts of the immature stages as nearly all were infested in the present study.

Haemaphysalis leachi

Adult ticks prefer domestic dogs and the larger wild carnivores while the immature stages can be found on these animals, hares and rodents (Norval 1984; Horak, Jacot Guillarmod, Moolman & De Vos 1987b; Fourie, Horak & Van den Heever 1992; Horak, Spickett, Braack & Penzhorn 1993). The source of infestation in the Bontebok Park is probably caracal (*Caracal caracal*) and feral domestic cats as well as domestic dogs which occasionally gain entrance.

TABLE 2 Host records of the more abundant ixodid tick species in the Bontebok National Park

Tick and host species	No. of hosts examined	No. infested	Total numbers of ticks collected				
			Larvae	Nymphs	Males	Females	Total
Amblyomma marmoreum							
Bontebok	34	11	70	0	0	0	70
Grey rhebok	37	11	96	0	0	0	96
Scrub hare	11	3	12	2	0	0	14
Cape francolin	7	3	15	1	0	0	16
Greywing francolin	7	4	129	0	0	0	129
Helmeted guineafowl	4	2	9	1	0	0	10
Leopard tortoise	9	7	7	5	77	19	108
Ixodes sp. (near *I. pilosus*)							
Bontebok	34	16	92	21	2	6	121
Grey rhebok	37	28	888	90	18	83 (11)	1 079
Four-striped grass mouse	25	2	1	1	0	0	2
Scrub hare	11	6	24	3	1	8	36
Rhipicephalus glabroscutatum							
Bontebok	34	29	2 408	358	20	27 (5)	2 813
Grey rhebok	37	27	828	80	26	15	949
Scrub hare	11	4	6	2	0	0	8
Rhipicephalus nitens							
Bontebok	34	34	9 110	122	407	469 (34)	10 108
Grey rhebok	37	35	3 306	29	250	357 (73)	3 942
Scrub hare	11	11	292	176	69	54 (14)	591
Helmeted guineafowl	4	1	1	0	0	0	1

( ) = number of engorging female ticks that could detach within the next 24 h

Hyalomma truncatum

All stages of development were recovered. Adult ticks prefer large herbivores (Norval 1982; Horak, Fourie, Novellie & Williams 1991b) and in the Bontebok Park the adults may be maintained by the Cape mountain zebras (*Equus zebra zebra*) introduced in 1988 and red hartebeest (*Alcelaphus buselaphus caama*). Leopard tortoises, which abound in the park, probably also harbour some adult ticks (Hoogstraal 1956; Table 3). Scrub hares and various rodents are the preferred hosts of the immature stages (Rechav, Zeederberg & Zeller 1987; Horak *et al.* 1991b, 1993). The Western Cape Province south of the Langeberg mountain range does not appear to be a particularly good habitat for this tick, hence the relatively small numbers collected.

Ixodes sp. (near *I. pilosus*)

This tick has been described by McKay (1994) as the "hairless palp" species within the *I. pilosus* group whose distribution is restricted to the coastal forests and coastal fynbos of the eastern and southern Cape. Grey rhebok appear to be its preferred host. This assumption, however, may be partially related to the habitat preferences of both the antelope and the tick. The grey rhebok frequent the gravel terraces and low hills within the park and the tick probably also prefers this habitat. *Ixodes rubicundus*, which is present in the Karoo less than 100 km to the north of the park, is more abundant on hill and mountain slopes than on open plains (Stampa 1959). All stages of development of the *Ixodes* sp. (near *I. pilosus*) were collected also from bontebok and from scrub hares. Females considerably outnumbered males on all hosts infested with adult ticks. As with other species in this genus copulation probably takes place off the host thus accounting for the small number of parasitic males collected (Fourie & Horak 1994).

Rhipicephalus evertsi evertsi

Both the immature and adult stages of development of this two-host tick prefer zebras as hosts (Hoogstraal 1956; Norval 1981; Horak *et al.* 1991b). The population in the park is probably now sustained by the mountain zebras, while the antelope and scrub hares serve as additional hosts for the immature stages.

Rhipicephalus gertrudae

Adults have previously been collected from bontebok and grey rhebok in the park (Horak *et al.* 1986b). The mountain zebras now in the park are also good hosts of the adults (Walker 1991). The latter author suggested

TABLE 3 Host records of the less abundant ixodid tick species in the Bontebok National Park

Tick and host species	No. of hosts examined	No. infested	Total numbers of ticks collected				
			Larvae	Nymphs	Males	Females	Total
Boophilus sp.							
Bontebok	34	1	4	0	0	0	4
Scrub hare	11	2	9	0	0	0	9
Haemaphysalis aciculifer							
Bontebok	34	2	4	0	0	2	6
Grey rhebok	37	2	0	0	0	3 (3)	3
Four-striped grass mouse	25	7	6	5	0	0	11
Cape francolin	7	6	11	7	0	0	18
Haemaphysalis leachi							
Four-striped grass mouse	25	4	83	2	0	0	85
Scrub hare	11	1	7	1	0	0	8
Hyalomma truncatum							
Bontebok	34	1	0	2	0	0	2
Cape gerbil	1	1	1	2	0	0	3
Four-striped grass mouse	25	2	0	4	0	0	4
Scrub hare	11	5	84	23	0	0	107
Leopard tortoise	9	2	0	0	0	2	2
Rhipicephalus evertsi evertsi							
Bontebok	34	5	8	28	0	0	36
Grey rhebok	37	4	11	24	2	1	38
Scrub hare	11	3	7	19	0	0	26
Rhipicephalus gertrudae							
Four-striped grass mouse	25	17	45	28	0	0	73
Scrub hare	11	1	0	3	0	0	3
Cape francolin	7	1	1	0	0	0	1
Helmeted guineafowl	4	1	1	0	0	0	1
Rhipicephalus lounsburyi							
Four-striped grass mouse	25	1	0	1	0	0	1

( ) = number of engorging female ticks that could detach within the next 24 h

that when the hosts of the immature stages were discovered they were likely to be small mammals, probably rodents. This supposition has been confirmed with the collection of larvae and nymphs from Namaqua rock mice (*Aethomys namaquensis*) in the Free State (Fourie *et al.* 1992), and from four-striped grass mice in the present study. The single larva collected in each case from a francolin and from a guineafowl must be regarded as accidental infestations.

Rhipicephalus glabroscutatum

All stages of development were present on the bontebok and grey rhebok. Both adult and immature ticks attach to the lower legs and around the hooves of wild and domestic ruminants and equids (Horak & Knight 1986; Horak, Knight & De Vos 1986a; Horak *et al.* 1991b). Although few ticks were found on scrub hares in the present study, they can be good hosts of the immature stages (Horak & Fourie 1991; Horak *et al.* 1991b).

The life cycle of *R. glabroscutatum* takes a year to complete. Adults are most abundant from July or August to January or February (Horak *et al.* 1986b; MacIvor & Horak 1987) and immatures from February or March to August or September (Horak *et al.* 1986b, 1991b; Horak & Fourie 1991). In the present study a considerably larger number of larvae than nymphs of this two-host tick were collected. This reflects the fact that all the animals were examined during February, at the very commencement of immature activity and consequently few larvae had probably as yet moulted to nymphs.

Rhipicephalus lounsburyi

Adults attach around the feet and hooves of several wild ruminants and of sheep (Walker 1990). The collection of a single nymph from a four-striped grass mouse in the present study is the first record of a host for the immature stages. Adults were previously recorded as *Rhipicephalus* sp. from bontebok and grey rhebok in the park (Horak *et al.* 1986b).

Rhipicephalus nitens

The distribution of this tick is associated with Cape shrubland vegetation (fynbos) in a coastal strip from Cape Town to approximately 60 km west of Port Elizabeth (Walker 1991). It is a three-host species and all stages of development were present on bontebok, grey rhebok and scrub hares. The adults are most abundant from November to February, larvae from February to June and nymphs from June to October (Horak *et al.* 1986b; Horak, Williams & Van Schalkwyk 1991a). These authors remarked that female ticks usually outnumbered males late in the season of adult activity. This trend is discernible in the present study.

The biology of *R. nitens* differs from those of *Rhipicephalus appendiculatus* and *Rhipicephalus zambeziensis*, two ticks that are morphologically similar to it and which also occur in South Africa. The adults of *R. nitens* are most abundant during the hot fairly dry summer and the immature stages during the cool wet winter of the Western Cape Province, and all stages of development are found on antelopes as well as on scrub hares (Horak *et al.* 1986b). The other two ticks occur in the North-West, Northern and Mpumalanga Provinces with *R. appendiculatus* also being present in KwaZulu-Natal and the Eastern Cape Province (Howell, Walker & Nevill 1978; Norval, Walker & Colborne 1982). Their adults are most abundant during the hot wet summer and cooler dry winter months characteristic of their habitats, and all stages of development are found on antelopes, while scrub hares harbour only the immature stages (Horak & Fourie 1991; Horak *et al.* 1992, 1993).

Bot fly larvae

The numbers of bot fly larvae collected from the bontebok and grey rhebok are summarized in Table 4.

Oestrus ovis

The larvae of this fly parasitize domestic sheep and goats and have also been collected from some wild sheep (*Ovis* sp.) and goats (*Capra* sp.) (Zumpt 1965). No wild bovids in Africa south of the Sahara have been found to serve as suitable hosts for the larvae (Zumpt 1965). Although seven grey rhebok in the present study were infested, the fly was apparently unable to complete its life cycle in these animals as all third stage larvae collected were dead. The reason for this failure is possibly twofold. Firstly in sheep and goats the development of second and third stage larvae takes place within the protected environment of the frontal sinuses (Horak 1977). In grey rhebok, which appear to have no frontal sinus cavities, this development has to take place in the more exposed nasal passages. Secondly some of the larvae enter the large maxillary sinuses of the grey rhebok and develop there to mature third stage larvae. These large larvae are, however, unable to leave these sinuses because of the narrowness of the openings and consequently die. The infestation in the park is maintained by sheep on the surrounding farms.

Gedoelstia sp.

No specific identification could be made but the spinulation and the shape of the post-anal bulge of the third stage larvae collected from the bontebok lie

TABLE 4 Host records of oestrid fly larvae collected in the Bontebok National Park

Fly and host species	No. of hosts examined	No. infested	Total numbers of larvae collected			
			1st stage	2nd stage	3rd stage	Total
Oestrus ovis						
Grey rhebok	37	7	2	5	14 (14)	21 (14)
Gedoelstia sp.						
Bontebok	34	34	1 464	765	1 093	3 322
Grey rhebok	37	1	2	0	0	2
Strobiloestrus sp.						
Bontebok	34	4	0	7 (5)	0	7 (5)
Grey rhebok	37	35	0	607	0	607

( ) = dead larvae included in totals

between those of *Gedoelstia cristata* and *Gedoelstia hässleri*. These larvae may well belong to a hitherto undescribed species of oestrid fly.

All the bontebok were infested. Twenty-two first stage larvae were recovered from the corneas of five animals, 639 first stage larvae from the auricle and the ventricle of the right heart and the commencement of the pulmonary artery of 23 animals, and two from the lungs of a single antelope. A slight corneal opacity was evident on an eye of one animal. The first stage larvae migrate via the eyes, the vascular system, the heart, the lungs and the trachea to reach the paranasal sinus cavities of the bontebok. The fairly large proportion of first stage larvae recovered from the chambers of the right heart implies that they may accumulate here before completing their migration. In blue wildebeest (*Connochaetes taurinus*) first stage *Gedoelstia* spp. larvae appear to accumulate on the dura mater before migrating to the paranasal sinus cavities (Horak, De Vos & Brown 1983).

Basson (1962, 1966) has described the pathology of infestation in natural and abnormal hosts. First stage *Gedoelstia* spp. larvae cause little macroscopically-visible damage to the eyes of their natural hosts, which include the bontebok (Basson, 1966). Hence the virtual absence of lesions in this animal. Grey rhebok are abnormal or accidental hosts of these fly larvae and corneal lesions were present in 11 animals, with both eyes of two rhebok being affected. The lesions varied from slight opacities to purrulent conjunctivitis, and in one case enucleation. Two first stage larvae were collected from the cornea of one animal. Basson (1962) also noted that the life cycle cannot progress beyond the first larval stage in abnormal hosts and no second or third stage larvae were collected from the grey rhebok.

Strobiloestrus sp.

The larvae collected from the grey rhebok and from the bontebok are probably those of *Strobiloestrus clarkii* (Zumpt 1965). As no mature third stage larvae were present we were unable to rear flies and confirm this.

All but two of the grey rhebok were infested with second instar larvae, the largest number harboured by a single animal comprising 130 larvae. The life cycle of this fly takes a year to complete, and only second stage larvae are present during February, the month in which all the animals were examined (Horak *et al.* 1986b). Grey rhebok are the normal hosts as virtually all were infested and third stage larvae, which were nearly mature, have previously been collected from these animals (Horak *et al.* 1986b). The small number of bontebok infested and the large proportion of dead larvae collected from them indicate that they are abnormal hosts and the infestations accidental. Accidental infestations have also been recorded in domestic cattle and in Merino sheep (Horak & Boomker 1981; Brain, Van der Merwe & Horak 1983).

ACKNOWLEDGEMENTS

We wish to thank the South African National Parks for placing the animals and the facilities in the Bontebok National Park at our disposal. We gratefully acknowledge the assistance of the successive park wardens Messrs E. Fourie, B. de Klerk, A. Hofmeyr and O. von Kaschke and their staff as well as that of Dr J.P. Louw with the processing of the necropsies. Mr E.J. Williams and Miss Louise Horak assisted with the collection of ticks from the processed material, and Dr I.J. McKay identified the *Ixodes* species.

The research was funded by the University of Pretoria, Rhodes University and the Foundation for Research Development.

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Onderstepoort Journal of Veterinary Research, 70:131–163 (2003)

Parasites of domestic and wild animals in South Africa. XLI. Arthropod parasites of impalas, *Aepyceros melampus*, in the Kruger National Park

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ABSTRACT

HORAK, I.G., GALLIVAN, G.J., BRAACK, L.E.O., BOOMKER, J. & DE VOS, V. 2003. Parasites of domestic and wild animals in South Africa. XLI. Arthropod parasites of impalas, *Aepyceros melampus*, in the Kruger National Park. *Onderstepoort Journal of Veterinary Research*, 70:131–163

Ectoparasites were collected from impalas, *Aepyceros melampus*, at four localities within the Kruger National Park, namely Skukuza, in the Biyamiti region, Crocodile Bridge and Pafuri. Animals were also examined at Skukuza during a severe drought and at Skukuza and Pafuri towards the end of a second drought. Parasite burdens were analysed in relation to locality, sex, age class, month and drought.

The impalas were infested with 13 ixodid ticks species, including two that were identified only to genus level. Except for four animals at Pafuri, all were infested with *Amblyomma hebraeum*. The highest intensity of infestation with larvae of this tick occurred from April to June and during November and December at Skukuza and in the Biyamiti region. Infestation with nymphs was highest during late winter. All animals were infested with *Boophilus decoloratus*, and the intensity of infestation was highest during spring. The intensity of infestation with *Rhipicephalus appendiculatus* was highest at Crocodile Bridge and at Pafuri, and that of *Rhipicephalus zambeziensis* at Skukuza. With both the latter species the intensity of infestation of larvae was highest from April to August, of nymphs from July to September or October and of adults during February and March. *Rhipicephalus kochi* was present only at Pafuri.

The impalas also harboured five louse species and two species of hippoboscid flies. The intensity of infestation with lice tended to be greater during late winter and spring than during other seasons and greater on lambs than on yearlings on which it was greater than on adult animals.

Keywords: *Aepyceros melampus*, drought, hippoboscid flies, impalas, intensity of infestation, ixodid ticks, Kruger National Park, lice, prevalence, seasonality

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Accepted for publication 3 March 2003—Editor

INTRODUCTION

Impalas, *Aepyceros melampus*, are widely distributed in the eastern woodland regions of Africa, from northern Kenya south to northern KwaZulu-Natal, South Africa, with their southern distribution extending north-westward to south-eastern Angola and northern Namibia. They prefer light, open woodland communities and generally avoid open grassland unless it abuts on woodland (Skinner & Smithers 1990). Impalas are classified as intermediate mixed feeders as they both graze and browse (Skinner &

Smithers 1990), and within their range they are often the most numerous medium-sized antelopes. In South Africa they are present in national, provincial and privately owned nature reserves as well as on many mixed cattle and wildlife ranches.

With the possible exception of African buffaloes, *Syncerus caffer*, more surveys have been conducted on the arthropods infesting impalas than on those of any other wild African mammal. The ixodid tick species infesting impalas in sub-Saharan Africa have been listed by Theiler (1962); those in Kenya by Walker (1974); in Tanzania by Yeoman & Walker (1967); in Zambia by MacLeod (1970), Colbo (1973) and MacLeod & Mwanaumo (1978); in Botswana by Paine (1982); in Mozambique by Santos Dias (1993); in Swaziland by Gallivan & Surgeoner (1995); and in South Africa by Meeser (1952) and Baker & Keep (1970). Total, or calculated total tick burdens have been determined on these animals in Zambia (Zieger, Horak, Cauldwell, Uys & Bothma 1998), Zimbabwe (Colborne 1989; Mooring & McKenzie 1995; Mooring & Mazhowu 1995), Swaziland (Gallivan, Culverwell, Girdwood & Surgeoner 1995) and in South Africa in Limpopo Province (Horak 1982; Matthee, Meltzer & Horak 1997), Mpumalanga Province (Horak, Boomker, Kingsley & De Vos 1983c; Horak, Fourie & Van Zyl 1995c), North West Province (Van Dyk & McKenzie 1992) and KwaZulu-Natal (Horak, Keep, Flamand & Boomker 1988a). The louse species that infest impalas are listed by Ledger (1980), and their total louse burdens have been determined by Horak (1982), Horak *et al.* (1983c), Van Dyk & McKenzie (1992) and Matthee, Horak & Meltzer (1998). The flies recorded on these animals are listed by Haeselbarth, Segerman & Zumpt (1966).

The tick species infesting impalas are similar to those found on domestic cattle farmed in the same regions (Yeoman & Walker 1967; Walker 1974; Horak 1982; Colborne 1989), and those on sympatric antelope species (Gallivan & Surgeoner 1995; Horak 1998). Impalas appear to harbour larger tick infestations than other medium-sized antelope species (Gallivan & Horak 1997; Horak 1998), and may thus serve as an important reservoir of tick infestation on mixed cattle and wildlife farms (Horak 1982; Colborne 1989), and on game ranches or wildlife reserves, on which they are frequently the most numerous antelope species (Gallivan & Surgeoner 1995; Zieger *et al.* 1998). As lice are obligate permanent parasites, and those infesting impalas are host-specific, there is little possibility of cross-infestation with these parasites occurring with sympatric wild or domestic animals.

In this paper we compare the tick, louse and hippoboscid fly burdens of impalas examined in four landscape zones within the Kruger National Park (KNP). We also examine the seasonal intensity of infestation, and the relationships between infestation with the most abundant species of ectoparasites and host age and sex class.

MATERIALS AND METHODS

Survey animals

A total of 229 impalas were examined in several surveys in the Kruger National Park. Each animal was killed during the morning by a single shot in the neck from a small or large calibre rifle. The locations, seasons and age and sex classes of the animals are summarised in Table 1. Because parturition in these animals in southern Africa is generally confined to the months November to January (Skinner & Smithers 1990), it is possible to visually age impalas fairly accurately until the age of 2 years, particularly the males because of the age-associated changes in the shape of their horns. It is more difficult with the females that are hornless.

Parasite recovery

The impalas were processed for the recovery of arthropod parasites as described by Horak, Boomker, Spickett & De Vos (1992) for greater kudus, *Tragelaphus strepsiceros*. Ticks, lice and hippoboscid flies were collected from the processed material under stereoscopic microscopes, and identified and counted under the same microscopes. We estimate that the idiosoma of female *Boophilus decoloratus* would reach a minimum length of 4.0 mm 24 h before detachment, and the length of the idiosoma of engorging female ticks of this species was measured.

Survey localities

Skukuza (24°58'S, 31°36'E; Alt. 262 m)

Skukuza is a tourist rest camp, and is also the headquarters of the South African National Parks Kruger Park Management and Research divisions, situated in the south-western region of the KNP in a landscape zone described as Thickets of the Sabie and Crocodile Rivers (Gertenbach 1983) of which the vegetation is classified as Lowveld (Acocks 1988). The impalas examined in this region were shot within a 25 km radius of Skukuza. Three to seven animals were shot each month from January 1980 to January 1981, and always included a lamb (< 12

months of age), a yearling male (12– 23 months) and an adult (> 24 months). From February to May 1981 two to four animals were shot each month, always including an adult male and an adult female.

During the drought that occurred in 1982/83 a large number of impalas died from starvation in October and November 1982. Ten animals, considered terminally affected by the drought, were shot for survey purposes during these months. At the same time 14 apparently healthy animals were shot for comparison at the same locality. A severe drought occurred during 1991/92, and in March 1992 six 15-month-old impala males were shot and examined for parasites. Three yearling males were shot at the same locality and examined every month thereafter until April 1993.

Biyamiti region (25°06'–25°28'S, 31°25'–31°39'E; Alt. 200–350 m)

This survey site is located in the central southern region of the KNP in a landscape zone described as Mixed Bushwillow Woodlands (Gertenbach 1983) of which the vegetation is classified as Lowveld (Acocks 1988). It extended from north of the Biyamiti River to north of the Malelane entrance gate to the KNP. Each month from January 1980 to May 1981 two to six impalas, generally of the same ages and sexes as those shot at Skukuza, were shot in this locality and examined.

Crocodile Bridge (25°22'S, 31°54'E; Alt. 217 m)

Crocodile Bridge is a tourist rest camp close to the south-eastern border of the KNP. The vegetation is classified as Lowveld by Acocks (1988) and the landscape zone described as Marula/Knobthorn (*Sclerocarya caffra/Acacia nigrescens*) Savanna (Gertenbach 1983). Each month from January 1980 to January 1981 a single adult male impala was shot in the Crocodile Bridge region and examined for parasites.

Pafuri (23°27'S, 31°19'E; Alt. 305 m)

Pafuri is located in the far north-east of the KNP. The vegetation here is classified as Mixed Bushveld (Acocks 1988) and the landscape described as Limpopo/Levubu Floodplains by Gertenbach (1983). During July 1980, a lamb, a yearling, an adult male, and an adult female impala were shot and examined. From March 1992 to April 1993, three yearling males were shot and examined at 2–3 month intervals.

Climate

Monthly mean minimum and maximum atmospheric temperatures and total monthly rainfall were recorded at Skukuza, and are presented graphically in Fig. 1 for the periods 1979–1983 and 1990–1993.

Statistical analysis

Factors of interest in the analysis of the data were the effects of the location, season, age class, sex of the adult impalas, differences between years, and drought. However, because the collections were independent and factors were not balanced across studies it was not possible to analyse the data in a single multivariate analysis. Therefore, the data were subdivided and analysed in the following groups:

- Skukuza versus the Biyamiti region in 1980/81
- Skukuza, the Biyamiti region and Crocodile Bridge in 1980/81 (adult males only)
- Skukuza 1980/81 versus 1992/93
- Skukuza versus Pafuri in 1992/93
- Skukuza, Biyamiti and Pafuri in July 1980
- The 1982 drought

The factors analysed in each grouping are presented in Table 1. Differences in location and season were assessed by comparisons of the results of the individual analyses.

Most analyses compared both the prevalence and the intensity of infestation. Differences in prevalence were analysed using contingency tables with a x^2. For differences in the intensity of infestation, the parasite count data were logarithmically transformed to reduce the inequality of variance created by overdispersion (Petney, Van Ark & Spickett 1990). The data were then analysed using analysis of variance. In all of the analyses, factors were restricted to ensure equal balance among the groups. When factors were significant, a t-test was used to test between two groups and a Student-Newman-Keuls multiple range test was used to test among multiple groups. Because the 1980/81 and 1992/93 collections extended over 2 consecutive years and there was a potential for year-to-year variation, month was converted to a continuous variable starting in January of the first year (1980 or 1992). Animals less than 3 years old were aged to month; i.e., they were classed as lambs (0–11 months), yearlings (12–23 months) or adults (older than 24 months) in the analyses. In 1992/93, three to six yearling males per month were collected at Skukuza, and three

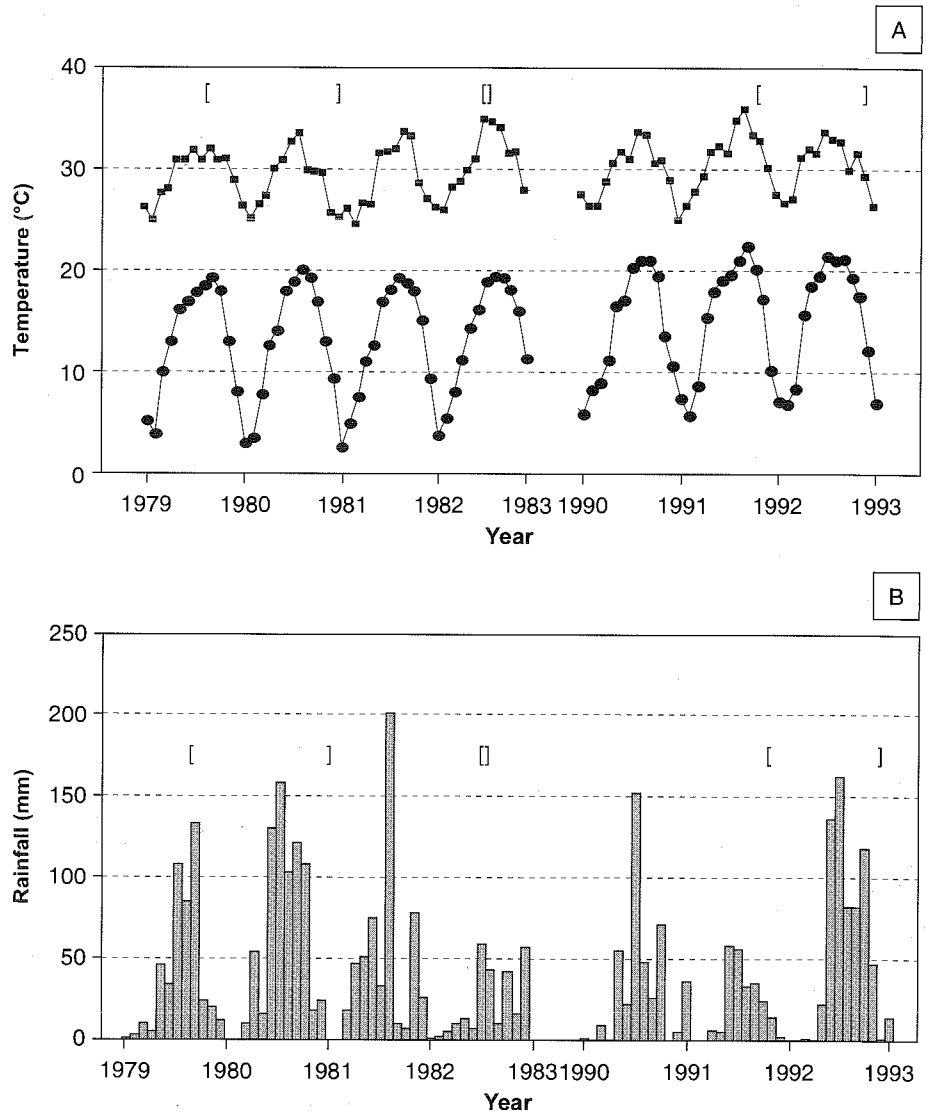

FIG. 1 [A] Average monthly minimum and maximum temperatures (°C) and [B] total monthly rainfall (mm) at Skukuza (1979–1983; and 1990–1993). Periods within brackets represent the survey periods

were collected at 2–3 month intervals at Pafuri. However, only one yearling was collected per month at Skukuza in 1980/81. To compare the parasite burdens at Skukuza in 1980/81 and 1992/93, the yearlings in 1992/93 were compared to the yearlings and adults in 1980/81 for the ticks, and to the lambs and yearlings for the lice. The groupings for 1980/81 were based on the results of the analysis for age effects. Because the 1982 drought potentially affected the parasite burdens of both the "terminal" and apparently healthy impalas, their parasite burdens were also compared to those from impalas collected during the same time period at Skukuza in 1980.

RESULTS AND DISCUSSION

IXODID TICKS

Total tick burdens

The impalas were infested with 13 species of ixodid ticks, of which 11 were identified to species level and two to genus level. Six species, *Amblyomma hebraeum, Amblyomma marmoreum, B. decoloratus, Rhipicephalus appendiculatus, Rhipicephalus evertsi evertsi and Rhipicephalus zambeziensis* were commonly collected at all locations, while *Rhipicephalus kochi* was only common at Pafuri (Table 2). The other species, *Amblyomma tholloni*,

TABLE 1 Groups, factors and ANOVA procedures used in the statistical analysis of the arthropod parasite burdens of impalas in the Kruger National Park

Group	Factors assessed	Statistical procedure	Comments
Skukuza vs Biyamiti	Location, month, age, sex	Three-factor ANOVAs: location, month and age; and location, month and sex	Location, month, age: month restricted to Jan 1980 to Jan 1981 Location, month, sex: adults only, month restricted to Mar 1980 to Apr 1981 (no adult females in Jan and Feb 1980)
Skukuza, Biyamiti and Crocodile Bridge	Location, month	Two-factor ANOVA	Adult males only, month restricted to Jan 1980 to Jan 1981
Skukuza 1980/81 vs 1992/93	Year, month	Two-factor ANOVA	Yearlings only in 1992/93 compared to yearlings and adults in 1980/81 for ticks; and to lambs and yearlings in 1980/81 for lice, months restricted to March 1980/92 to February 1981/93 (lice) or April 1981/93 (ticks)
Skukuza vs Pafuri 1992/93	Location, month	Two-factor ANOVA	Yearlings only, months matched to collections at Pafuri
Skukuza, Biyamiti and Pafuri	Location	One-factor ANOVA	July 1980 only, lamb, yearling and adults at each location
Skukuza 1982 drought	Group	One-factor ANOVA	"Terminal" vs "apparently healthy" impalas in 1982 compared to impalas collected in 1980 in same time period

TABLE 2 Proportional intensity of infestation of the major tick and louse species on impalas examined over a period of 12 months or more at four localities in the Kruger National Park

Arthropod species	Proportional intensity of infestation (%)				
	Skukuza (1980/81) (n = 63)	Skukuza (1992/93) (n = 45)	Biyamiti (1980/81) (n = 60)	Crocodile Bridge (1980/81) (n = 12)	Pafuri (1992/93) (n = 21)
Ticks					
Amblyomma hebraeum	24.07	25.05	10.56	21.49	6.31
Amblyomma marmoreum	0.60	1.38	0.05	0.14	0.07
Boophilus decoloratus	56.85	45.80	70.13	47.74	46.75
Rhipicephalus appendiculatus	2.13	0.64	5.37	24.03	15.82
Rhipicephalus evertsi evertsi	3.25	2.17	10.49	3.84	5.09
Rhipicephalus kochi	0.00	0.00	0.00	0.00	20.57
Rhipicephalus zambeziensis	13.08	24.95	3.39	2.75	5.34
Lice					
Damalinia aepycerus	18.57	22.75	21.02	10.05	18.93
Damalinia elongata	61.94	54.83	6.96	46.89	0.04
Linognathus aepycerus	11.35	18.14	34.53	42.82	65.20
Linognathus nevilli	6.58	3.17	33.68	0.24	14.33

n = Number of impalas examined

Haemaphysalis aciculifer, *Hyalomma truncatum*, *Ixodes* sp., *Rhipicephalus simus* and the *Rhipicephalus pravus* group were incidental or sporadic infestations (Tables 3–10).

The tick species infesting the impalas were similar to those collected from sympatric antelope species that had previously been examined in the KNP (Horak, Potgieter, Walker, De Vos & Boomker 1983a; Horak, De Vos & Brown 1983b; Horak *et al.* 1992; Horak 1998). Impalas appear to harbour disproportionately large tick burdens for their size (Gallivan & Horak 1997; Horak 1998), and the mean tick burden of the animals examined in the Biyamiti region was similar to the mean burden of greater kudus examined there 2 years later (Horak *et al.* 1992). However, a greater proportion of the ticks on the kudus consisted of adults, which supports the suggestion that larger ungulates are more important hosts for adult ticks (MacLeod 1970; Horak 1982). The tick burdens of the impalas would conceivably have been considerably larger if self-grooming, and probably also allogrooming, which are effective in removing ticks (A.A. McKenzie, unpublished data, cited by Hart & Hart 1992), are taken into account. Impalas are also one of the few smaller antelope species attended by red-billed oxpeckers, *Buphagus erythrorhynchus* (Stutterheim 1981), and these birds are capable of consuming large numbers of ticks (Bezuidenhout & Stutterheim 1980). In addition the method we used to collect ticks from the impalas was not the most efficient (Van Dyk & McKenzie 1992), but it did provide ticks, lice and flies that could all be identified.

The total tick burdens did not differ significantly among the locations, but there were differences in the prevalence and/or intensity of infestation of some species. These will be discussed in more detail below.

The total tick burden was significantly higher at Skukuza in 1980/81 than in 1992/93 ($P < 0.001$) (Table 11), and was higher at Pafuri in July 1980 than in August 1992 ($P < 0.1$). In contrast to 1992/93, the total tick burden of the impalas examined in 1980 at Skukuza was slightly higher than the burdens of the apparently healthy animals in the 1982 drought. The "terminal" impalas in 1982 had higher total tick burdens than the apparently healthy animals killed

TABLE 3 Arthropod parasites collected during 1980/81 from 63 impalas at Skukuza, Kruger National Park

Arthropod species	Number of arthropods collected				Total	Proportional abundance %	No. of impalas infested
Ixodid ticks	Larvae	Nymphs	Males	Females			
Amblyomma hebraeum	57 227	7 985	52	8	65 272	24.07	63
Amblyomma marmoreum	1 605	21	0	0	1 626	0.60	28
Boophilus decoloratus	88 620	43 029	15 148	7 353 (95)	154 150	56.85	63
Ixodes sp.	0	8	0	0	8	0.003	1
Rhipicephalus appendiculatus	3 298	1 387	737	355	5 777	2.13	53
Rhipicephalus evertsi evertsi	7 328	1 338	109	43	8 818	3.25	61
Rhipicephalus simus	16	0	0	0	16	0.006	1
Rhipicephalus zambeziensis	26 342	7 112	1 415	606	35 475	13.08	60
Lice	Nymphs		Adults				
Damalinia aepycerus	7 448		2 780		10 228	18.57	47
Damalinia elongata	22 188		11 928		34 116	61.94	47
Linognathus aepycerus	3 896		2 356		6 252	11.35	49
Linognathus nevilli	2 440		1 184		3 624	6.58	27
Linognathus sp.	428		428		856	1.55	18
Louse flies	Adults						
Hippobosca fulva	50				50	90.91	19
Lipoptena paradoxa	5				5	9.09	4

( ) = Number of maturing *B. decoloratus* females, i.e. idiosoma > 4.0 mm in length

TABLE 4 Arthropod parasites collected during 1980/81 from 60 impalas in the Biyamiti region, Kruger National Park

Arthropod species	Number of arthropods collected				Total	Proportional abundance %	No. of impalas infested
Ixodid ticks	Larvae	Nymphs	Males	Females			
Amblyomma hebraeum	27 225	3 559	25	4	30 813	10.56	60
Amblyomma marmoreum	159	0	0	0	159	0.05	8
Boophilus decoloratus	126 952	50 692	18 276	8 724 (134)	204 644	70.13	60
Haemaphysalis aciculifer	16	0	0	0	16	0.005	1
Rhipicephalus appendiculatus	9 393	5 892	225	151	15 661	5.37	54
Rhipicephalus evertsi evertsi	26 628	3 865	81	35	30 609	10.49	59
Rhipicephalus simus	0	0	1	0	1	0.0003	1
Rhipicephalus zambeziensis	7 575	1 889	303	123	9 890	3.39	54
Lice	Nymphs		Adults				
Damalinia aepycerus	1 328		944		2 272	21.02	37
Damalinia elongata	340		412		752	6.96	17
Linognathus aepycerus	2 164		1 568		3 732	34.53	37
Linognathus nevilli	2 388		1 252		3 640	33.68	34
Linognathus sp.	240		172		412	3.81	11
Louse flies	Adults						
Hippobosca fulva	117				117	97.50	18
Lipoptena paradoxa	3				3	2.50	1

( ) = Number of maturing *B. decoloratus* females, i.e. idiosoma > 4.0 mm in length

TABLE 5 Arthropod parasites collected during 1992/93 from 45 yearling impala males at Skukuza, Kruger National Park

Arthropod species	Number of arthropods collected				Total	Proportional abundance %	No. of impalas infested
Ixodid ticks	Larvae	Nymphs	Males	Females			
Amblyomma hebraeum	5 076	1 070	8	0	6 154	25.05	45
Amblyomma marmoreum	340	0	0	0	340	1.38	22
Boophilus decoloratus	4 678	3 792	1 619	1 164 (20)	11 253	45.80	45
Hyalomma truncatum	2	0	0	0	2	0.01	1
Rhipicephalus appendiculatus	12	4	96	46	158	0.64	18
Rhipicephalus evertsi evertsi	410	92	20	12	534	2.17	34
Rhipicephalus zambeziensis	3 840	936	942	412	6 130	24.95	40
Lice*	Nymphs		Adults				
Damalinia aepycerus	1 750		1 131		2 881	22.75	41
Damalinia elongata	2 707		4 237		6 944	54.83	29
Linognathus aepycerus	1 195		1 102		2 297	18.14	39
Linognathus nevilli	271		130		401	3.17	18
Linognathus sp.	66		75		141	1.11	16

* = Only 42 animals examined for lice

( ) = Number of maturing *B. decoloratus* females, i.e. idiosoma > 4.0 mm in length

TABLE 6 Arthropod parasites collected during 1980/81 from 12 adult male impalas at Crocodile Bridge, Kruger National Park

Arthropod species	Number of arthropods collected				Total	Proportional abundance %	No. of impalas infested
Ixodid ticks	Larvae	Nymphs	Males	Females			
Amblyomma hebraeum	9 679	1 811	9	2	11 501	21.49	12
Amblyomma marmoreum	77	0	0	0	77	0.14	2
Boophilus decoloratus	11 040	8 260	4 300	1 947 (126)	25 547	47.74	12
Rhipicephalus appendiculatus	10 420	1 888	286	265	12 859	24.03	–
Rhipicephalus evertsi evertsi	1 664	314	61	18	2 057	3.84	12
Rhipicephalus simus	0	0	1	0	1	0.002	1
Rhipicephalus zambeziensis	1 408	48	11	7	1 474	2.75	8
Lice	Nymphs		Adults				
Damalinia aepycerus	96		72		168	10.05	4
Damalinia elongata	552		232		784	46.89	5
Linognathus aepycerus	524		192		716	42.82	6
Linognathus nevilli	4		0		4	0.24	1
Louse flies	Adults						
Hippobosca fulva	4				4	100.00	2

( ) = Number of maturing *B. decoloratus* females, i.e. idiosoma > 4.0 mm in length

TABLE 7 Arthropod parasites collected during the 1982 drought from ten drought-affected "terminal" impalas at Skukuza, Kruger National Park

Arthropod species	Number of arthropods collected				Total	No. of impalas infested
Ixodid ticks	Larvae	Nymphs	Males	Females		
Amblyomma hebraeum	5 715	853	99	49	6 716	10
Amblyomma marmoreum	27	2	0	0	29	4
Boophilus decoloratus	34 964	16 437	8 354	4 967 (60)	64 722	10
Ixodes sp.	1	0	0	0	1	1
Rhipicephalus appendiculatus	56	48	15	21	140	8
Rhipicephalus evertsi evertsi	2 224	264	51	28	2 567	9
Rhipicephalus zambeziensis	80	315	41	48	484	10
Lice	Nymphs		Adults			
Damalinia aepycerus	272		517		789	9
Damalinia elongata	3 896		2 008		5 904	4
Linognathus aepycerus	7 582		8 359		15 941	9
Linognathus nevilli	552		265		817	6
Linognathus sp.	1 264		520		1 784	4
Louse flies	Adults					
Lipoptena paradoxa	4				4	2

( ) = Number of maturing *B. decoloratus* females, i.e. idiosoma > 4.0 mm in length

TABLE 8 Arthropod parasites collected during the 1982 drought from 14 apparently healthy impalas at Skukuza, Kruger National Park

Arthropod species	Number of arthropods collected				Total	No. of impalas infested
Ixodid ticks	Larvae	Nymphs	Males	Females		
Amblyomma hebraeum	11 127	1 160	35	6	12 328	14
Boophilus decoloratus	19 597	16 051	6 307	3 168 (43)	45 123	14
Ixodes sp.	0	17	0	0	17	2
Rhipicephalus appendiculatus	4	120	18	8	150	10
Rhipicephalus evertsi evertsi	1 393	260	16	13	1 682	14
Rhipicephalus zambeziensis	5	180	18	22	225	9
Lice	Nymphs		Adults			
Damalinia aepycerus	233		723		956	14
Damalinia elongata	266		558		824	7
Linognathus aepycerus	1 389		2 282		3 671	13
Linognathus nevilli	48		152		200	5
Linognathus sp.	90		216		306	7
Louse flies	Adults					
Hippobosca fulva	2				2	1
Lipoptena paradoxa	5				5	3

( ) = Number of maturing *B. decoloratus* females i.e. idiosoma > 4.0 mm in length

TABLE 9 Arthropod parasites collected during 1980 from an impala lamb, yearling and adult male, and adult female at Pafuri, Kruger National Park

Arthropod species	Number of arthropods collected				Total	No. of impalas infested
Ixodid ticks	Larvae	Nymphs	Males	Females		
Amblyomma hebraeum	1 105	196	0	0	1 301	4
Amblyomma marmoreum	11	0	0	0	11	1
Boophilus decoloratus	3 252	736	301	82	4 371	4
Rhipicephalus appendiculatus	3 832	2 280	1	1	6 114	4
Rhipicephalus evertsi evertsi	88	40	0	1	129	3
Rhipicephalus kochi	32	80	0	0	112	4
Rhipicephalus pravus group	8	0	0	0	8	1
Rhipicephalus zambeziensis	116	0	0	0	116	3
Lice	Nymphs		Adults			
Damalinia elongata	28		36		64	4
Linognathus aepycerus	16		0		16	1
Linognathus nevilli	432		168		600	4

TABLE 10 Arthropod parasites collected during 1992/93 from 21 yearling impala males at Pafuri, Kruger National Park

Arthropod species	Number of arthropods collected				Total	Proportional abundance %	No. of impalas infested
Ixodid ticks	Larvae	Nymphs	Males	Females			
Amblyomma hebraeum	440	308	4	0	752	6.31	17
Amblyomma marmoreum	8	0	0	0	8	0.07	2
Amblyomma tholloni	0	6	0	0	6	0.05	2
Boophilus decoloratus	1 842	1 982	1 032	712 (52)	5 568	46.75	21
Rhipicephalus appendiculatus	1 076	756	30	22	1 884	15.82	13
Rhipicephalus evertsi evertsi	464	112	28	2	606	5.09	20
Rhipicephalus kochi	1 884	416	118	32	2 450	20.57	17
Rhipicephalus zambeziensis	266	54	190	126	636	5.34	16
Lice	Nymphs		Adults				
Damalinia aepycerus	624		264		888	18.93	15
Damalinia elongata	0		2		2	0.04	1
Linognathus aepycerus	2 072		986		3 058	65.20	19
Linognathus nevilli	482		190		672	14.33	14
Linognathus sp.	40		30		70	1.49	5

( ) = Number of maturing *B. decoloratus* females i.e. idiosoma > 4.0 mm in length

at the same time ($P = 0.065$) (Table 11), but when the 1980 impalas were included, the differences among the groups were marginal ($P = 0.11$).

The apparent differences in the effects of drought on tick burdens may result from differences in the timing of the collections in relation to rainfall. The collections in 1992/93 began in March 1992. They were made in a year of above average rainfall following 2 years of below average rainfall at the end of a dry cycle, with particularly low rainfall during the summer of 1991/92. There was a marked reduction in the number of questing ticks collected by drag-sampling at Skukuza in 1992/93 (Horak, De Vos & Braack 1995b). This probably resulted from a reduction in the number of hosts and a loss of habitat for free-living ticks. Only 1 000 impalas were counted in the 1992 game counts, a quarter of the average count for other years, and there was a decrease in the amount of standing vegetation and loss of the grass mat which provide habitat for the free-living stages of ticks (Horak *et al.* 1995b). The 1982 collections were made in November and early December, at the beginning of the 1982/83 drought. The collections followed an extended period of low rainfall beginning in February 1982. However, this drought occurred at the end of the wet cycle of the 1970s (Whyte & Joubert 1988), and was preceded by 2 years of average to above average rainfall and impala populations (Horak *et al.* 1995b). There were no collections of questing ticks in 1982 but the numbers were probably higher than in 1992. The higher total tick burden on the "terminal" impalas in 1982 is similar to the observation that impalas in poor condition in the spring in the Mlawula-Mbuluzi-Simunye Nature Reserve complex in Swaziland were more heavily infested than those in better condition (Gallivan *et al.* 1995).

The seasonal patterns of infestation were similar in the three southern locations. The total tick burdens of the impalas examined at Skukuza and in the Biyamiti region during 1980/81 were lowest in the summer and highest in the late winter and spring ($P < 0.001$), with a secondary peak in April (Fig. 2). The late winter/spring peak coincides with the hatch and subsequent availability of *B. decoloratus* larvae, and the April peak coincides with the availability of *R. appendiculatus* and *R. zambeziensis* larvae. There was a significant month x location interaction ($P = 0.002$) caused by higher burdens at Skukuza from January to June 1980, and higher burdens in the Biyamiti region from July 1980 to January 1981. The higher burdens at Skukuza were caused by the higher intensity of infestation of *R. zambeziensis* larvae, while the higher burdens in the Biyamiti region were caused by the higher intensity of infestation of *B. decoloratus*.

TABLE 11 Mean intensities of infestations of arthropods on impalas during the 1982 and 1992 droughts in the Kruger National Park compared to animals examined during 1980/81

Arthropod species	Stage of development	1982			1992	
		"Terminal" (n = 10)	Healthy (n = 14)	1980 (n = 14)	1980/81 (n = 41)	1992/93 (n = 45)
Ixodid ticks						
Amblyomma hebraeum	Larvae	571.5	794.8	1 023.5	892.6	112.8
	Nymphs	85.3	82.9	138.4	138.3	23.8
	Adults	14.8	2.9	0.8	1.1	0.2
Amblyomma marmoreum	Larvae	2.7	0	13.6	29.9	7.6
Boophilus decoloratus	All	6 472.2	3 223.1	3 161.1	2 641.6	250.1
Rhipicephalus appendiculatus	Larvae	5.6	0.3	5.7	40.1	0.3
	Nymphs	4.8	8.6	1.1	23.1	0.1
	Adults	3.6	1.9	0.8	18.8	3.1
Rhipicephalus evertsi evertsi	Immatures	248.8	118.1	155.4	141.9	11.2
	Adults	7.9	2.1	3.0	2.8	0.7
Rhipicephalus zambeziensis	Larvae	8.0	0.4	0.0	342.5	85.3
	Nymphs	31.5	12.9	44.0	90.2	20.8
	Adults	8.9	2.9	2.1	37.3	30.1
Total ixodid ticks		7 492.7	4 251.8	4 549.6	4 400.9	546.0
Lice					*	*
Damalinia aepycerus	Nymphs, adults	78.9	68.3	108.0	249.3	70.2
Damalinia elongata	Nymphs, adults	590.4	58.9	207.4	1 029.3	175.0
Linognathus aepycerus	Nymphs, adults	1 594.1	262.2	89.7	97.5	58.5
Linognathus nevilli	Nymphs, adults	81.7	14.3	46.9	77.7	10.1
Linognathus sp.	Nymphs, adults	178.4	21.9	22.3	23.2	3.3
Total lice		2 523.5	425.5	474.3	1 477.1	317.2

* For lice n = 21 in 1980/81 and 39 in 1992/93

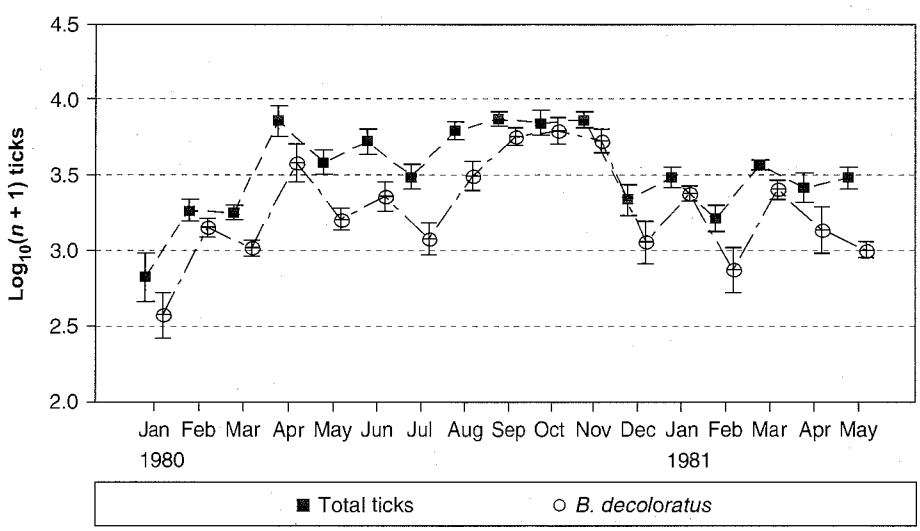

FIG. 2

Seasonal pattern of the total tick burden and intensity of infestation of all life stages of *Boophilus decoloratus* (x ± 1SE) on impalas at Skukuza and in the Biyamiti region in 1980/81. No lambs were collected after January 1981 and no yearlings after February 1981. The monthly sample at each locality ranged from two to six or seven impalas

The seasonal pattern at Skukuza was similar in 1980/81 and 1992/93. However, there was a significant month x location interaction (P = 0.004) between Skukuza and Pafuri in 1992/93. Burdens were significantly higher ($P < 0.05$) at Skukuza in the spring and summer, and tended to be higher at Pafuri in the autumn and winter, although the latter differences were not statistically significant ($P > 0.05$). The higher tick burdens at Pafuri corresponded to periods with the highest intensity of infestation of *B. decoloratus* and *R. kochi* at this location, and the higher burdens at Skukuza corresponded with the peak activity period of *B. decoloratus* at the southern locations in the KNP.

The total tick burdens during 1980/81 at Skukuza and in the Biyamiti region were significantly lower on lambs than on yearlings and adults ($P = 0.004$), with significant month x age ($P = 0.001$) and location x age ($P = 0.005$) interactions. The age x month interaction was caused by low burdens on newborn lambs relative to yearlings and adults in December, and higher burdens on yearlings in April, June and October. The location x age interaction resulted from high burdens on yearlings at Skukuza compared to those on yearlings in the Biyamiti region, and on lambs and adults at Skukuza. The intensity of infestation on lambs and adults did not differ between Skukuza and the Biyamiti region, and there was no difference between the age classes in the latter region. The total tick burdens of the adult male and female impalas did not differ significantly ($P = 0.38$).

Amblyomma hebraeum

Adult *A. hebraeum* prefer large herbivores as hosts, whereas the immature stages feed on these animals and on a variety of smaller herbivores, leporids and ground-nesting birds (Theiler 1962; Norval 1983; Horak, MacIvor, Petney & De Vos 1987). Impalas, which we consider to be medium-sized herbivores, are excellent hosts of the immature stages and harbour virtually identical burdens to those of greater kudus in the KNP (Horak *et al.* 1992; Horak 1998).

All the impalas were infested with *A. hebraeum* larvae and nymphs in 1980/81. The intensity of infestation of both stages was higher at Skukuza and Crocodile Bridge than in the Biyamiti region ($P \leq 0.001$), but the intensity of infestation did not differ significantly among Skukuza, Biyamiti and Pafuri in July 1980 ($P = 0.14$). All the yearling males were infested with nymphs and 96 % were infested with larvae at Skukuza in 1992/93, but the intensities of infestations of both stages were significantly lower ($P < 0.001$) than in 1980/81, reflecting the low number of questing larvae in 1992/93 (Horak *et al.* 1995b). Only 67 % of the yearling males collected at Pafuri during 1992/93 were infested with larvae, and the same percentage with nymphs. The prevalence and intensities of infestation of both stages were lower at Pafuri than at Skukuza ($P \leq 0.006$). This corresponds with observations on scrub hares, *Lepus saxatilis* (Horak, Spickett, Braack & Penzhorn 1993), that the intensity of infestation of *A. hebraeum* was lower in the north of the KNP.

While impalas appear to be good hosts for the immature stages, they are poor hosts for adult *A. hebraeum*. The prevalence of adults was 31.7 % in 1980/81, and did not differ among locations ($P \geq 0.19$). The largest infestation was seven ticks, with 33 of the 44 infested impalas only harbouring one or two ticks. At Skukuza the prevalence of *A. hebraeum* adults was significantly higher ($P < 0.001$) in 1980/81 (46 %) than in 1992/93 (9 %), but the prevalence of adults did not differ between Skukuza and Pafuri in 1992/93. The maximum infestation in 1992/93 was two ticks, and no females were collected.

The intensity of infestation of *A. hebraeum* larvae varied significantly by month ($P < 0.001$) at Skukuza and in the Biyamiti region in 1980/81. There appeared to be two peaks of infestation, one from April to June, and the other during November and December (Fig. 3). The intensity of infestation was significantly higher at Skukuza than in the Biyamiti region from June to August ($P < 0.05$). The seasonal patterns of *A. hebraeum* larvae did not differ significantly ($P > 0.18$) between Skukuza and Crocodile Bridge, or between 1980/81 and 1992/93 at Skukuza. The seasonal pattern was similar at Skukuza and Pafuri from March to August 1992, but the intensity of infestation increased at Skukuza in October 1992 and declined at Pafuri. The intensity of infestation remained lower at Pafuri through April 1993. The intensity of infestation of *A. hebraeum* nymphs was significantly higher ($P < 0.001$) in late winter than in the summer. The seasonal patterns of occurrence of nymphs were similar at Skukuza in 1980/81 and 1992/93, and at Skukuza and Pafuri in 1992/93. The prevalence of adults did not differ seasonally in any of the collections ($P > 0.2$).

In earlier surveys in the KNP there was no clear pattern of seasonal abundance of the immature stages of *A. hebraeum* on greater kudus, scrub hares and helmeted guineafowls, *Numida meleagris* (Horak, Spickett, Braack & Williams 1991; Horak

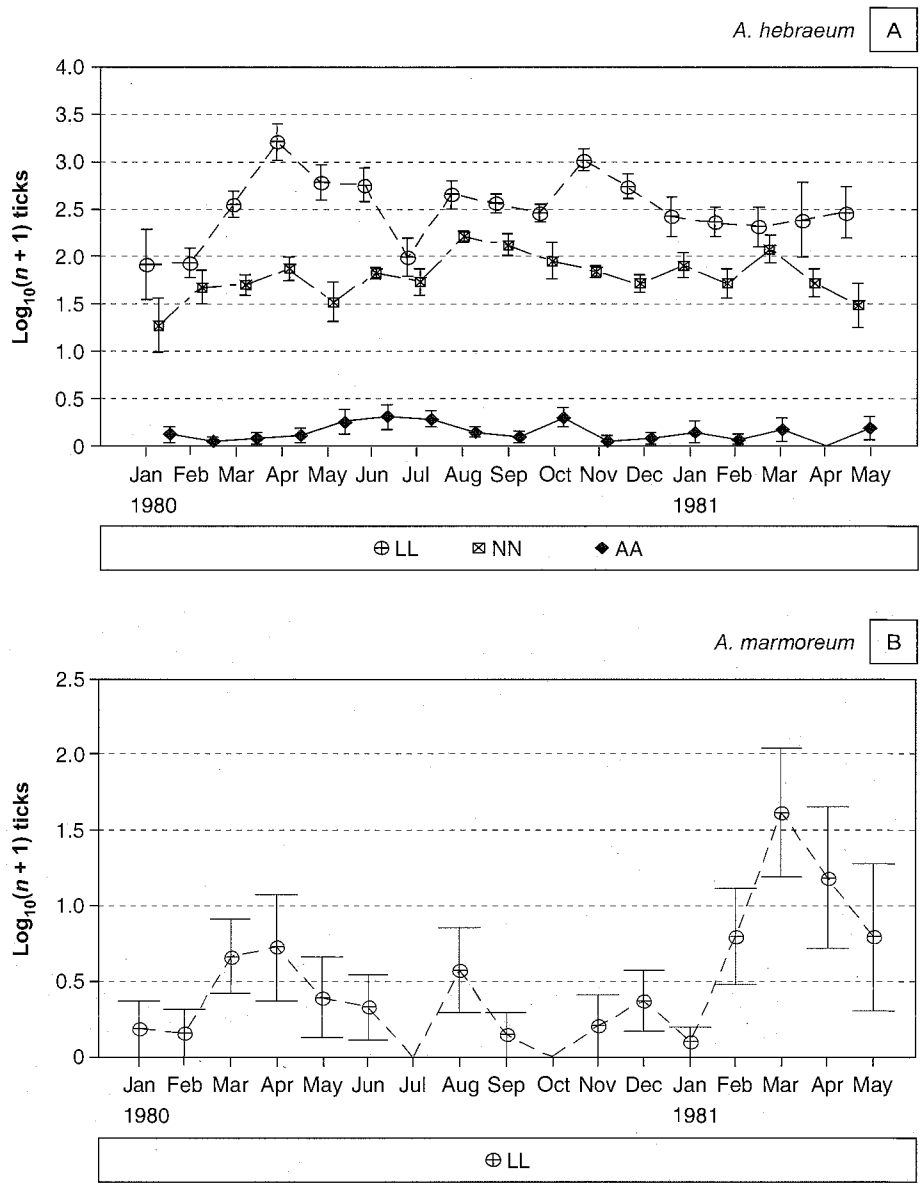

FIG. 3 Seasonal pattern of the intensity of infestation of [A] all life stages of *Amblyomma hebraeum* (x ± 1SE), and [B] larvae of *Amblyomma marmoreum* (x ± 1SE) on impalas at Skukuza and in the Biyamiti region during 1980/81. No lambs were collected after January 1981 and no yearlings after February 1981. The monthly sample at each locality ranged from two to six or seven impalas

et al. 1992; 1993). There were apparent peaks on warthogs, *Phacochoerus africanus* (Horak, Boomker, De Vos & Potgieter 1988b), and Burchell's zebras, *Equus burchellii* (Horak, De Vos & De Klerk 1984), but these seasonal patterns differ from those observed on impalas. The apparent seasonal patterns on some host species may be a function of the animals selected in the survey rather than the number of questing ticks as there does not appear to be a seasonal pattern in the number of questing *A. hebraeum* larvae (Spickett, Horak, Van Niekerk & Braack 1992).

The intensity of infestation of *A. hebraeum* larvae did not differ significantly among age classes (P = 0.20), but the intensity of infestation of nymphs was significantly higher on yearlings and adult impalas than on lambs (P<0.001). The prevalence of adults was also significantly higher (P = 0.017) on yearlings (40 %) and adults (43 %) than on lambs (11.5 %). The intensities of infestations of larvae

and nymphs did not differ significantly between the sexes in the adult animals ($P \geq 0.88$), but the prevalence of *A. hebraeum* adults was significantly higher ($P = 0.02$) on adult males (54 %) than on adult females (26 %). The higher prevalence and intensity of infestation of *A. hebraeum* adults on adult animals, and on adult males in particular, are consistent with the patterns reported for impalas in Swaziland (Gallivan *et al.* 1995) and kudus in the KNP (Horak *et al.* 1992).

The intensities of infestations of *A. hebraeum* larvae and nymphs did not differ significantly among the impalas examined at Skukuza in 1980 and those examined at the same locality during the 1982 drought. However, both the prevalence (100 %) and intensity of infestation of adults were significantly higher ($P < 0.002$) on the "terminal" impalas in 1982 than on the apparently healthy animals and on the impalas examined in 1980. In Swaziland, impalas infested with *A. hebraeum* adults were in poorer condition than uninfested animals, and the highest intensities of infestation with adult ticks were on adult males at the end of the dry season and after mating, periods in which these animals were already in poor condition (Gallivan *et al.* 1995). This suggests that the infestation may be secondary to the loss of resistance in stressed animals rather than a primary effect.

Amblyomma marmoreum

Amblyomma marmoreum prefers tortoises as hosts in all its stages of development (Norval 1975; Dower, Petney & Horak 1988), but the immature stages will feed on other reptiles and the larvae will also feed on carnivores, herbivores, leporids and ground-nesting birds (Norval 1975; Horak *et al.* 1987). In 1980/81, 37.6 % of the impalas were infested with *A. marmoreum* larvae. The prevalence was lower than that on helmeted guineafowls and scrub hares, but higher than on kudus examined in the KNP (Horak *et al.* 1991; 1992; 1993).

The intensity of infestation of *A. marmoreum* larvae on impalas ranged from 4–235, but 71 % of the infested animals harboured fewer than 50 larvae. The prevalence was significantly higher ($P = 0.001$) at Skukuza (34.6 %) than in the Biyamiti region (8.0 %). However, it did not differ among adult males at Skukuza, Crocodile Bridge and the Biyamiti region. This apparent contradiction occurred because the prevalences of *A. marmoreum* larvae on lambs and yearlings were much higher at Skukuza (50 %) than in the Biyamiti region (8 %) while the prevalence on adult impalas did not differ significantly between the two areas ($P = 0.24$). The prevalence at Skukuza did not differ significantly between 1980/81 and 1992/93, but the intensity of infestation was marginally higher in 1980/81 than in 1992/93 ($P = 0.07$). Prevalence at Skukuza in 1992/93 (48 %) was significantly higher ($P = 0.004$) than at Pafuri (9.5 %). This is similar to the differences recorded on scrub hares at Skukuza and in the north of the KNP (Horak *et al.* 1993). Only two impalas, both at Skukuza in 1981, were infested with *A. marmoreum* nymphs.

The prevalence and intensity of infestation of *A. marmoreum* larvae did not differ significantly ($P \geq 0.25$) on impalas at Skukuza and in the Biyamiti region from January 1980 to January 1981. However, the intensity of infestation was higher from February to May 1981 (Fig. 3). The pattern was similar in the 1992/93 ($P = 0.51$) samples where the intensity of infestation was higher in March and April in 1993 than in 1992. The higher larval burdens from March to May reflect the seasonal pattern of questing larvae on the vegetation in the park during these months (Spickett *et al.* 1992), and are similar to the patterns recorded on helmeted guineafowls, greater kudus and scrub hares in the KNP (Horak *et al.* 1991; 1992; 1993).

The prevalence and intensity of infestation of *A. marmoreum* larvae did not differ significantly among age classes ($P \geq 0.10$), or between sexes in the adult impalas ($P = 0.97$). The intensity of infestation of *A. marmoreum* larvae was higher on the "terminal" impalas in the 1982 drought at Skukuza than on the apparently healthy animals ($P = 0.05$). It was also marginally higher ($P = 0.08$) on the impalas examined in 1980 than on the apparently healthy animals in 1982.

Amblyomma tholloni

African elephants, *Loxodonta africana*, are the preferred hosts of all stages of *A. tholloni*, but the immature stages will also infest birds, reptiles, other wild mammals, and domestic cattle, sheep and goats (Theiler 1962; Norval 1983; Walker 1991). The recovery of nymphs from two impalas at Pafuri must be viewed as accidental infestations in a habitat in which there are many elephants.

Boophilus decoloratus

All the impalas were infested with *B. decoloratus*. Considering their relatively small size, impalas are remarkably good hosts of this tick as the burdens in

the Biyamiti region were similar to those on greater kudus in the same region (Horak *et al.* 1992; Horak 1998). *Boophilus decoloratus* accounted for 5.6–98.6 % (mean = 57.8 %) of the total tick burden on individual impalas, and also accounted for most of the tick burden on blue wildebeest, *Connochaetes taurinus*, Burchell's zebras and greater kudus in the KNP (Horak *et al.* 1983b; 1984; 1992). However, questing larvae of *B. decoloratus* are not the most abundant species on the vegetation in the Crocodile Bridge region or at Skukuza (Spickett *et al.* 1992; Horak *et al.* 1995b; Spickett, Horak, Heyne & Braack 1995; Horak 1998), even though it was the most common tick on impalas at both localities (Table 2). Its predominance on host animals is probably because it is present throughout the year in the KNP, infests a wide range of medium to large-size ungulates, and, because it is a one-host tick, survival from one developmental stage to the next is high (Baker & Ducasse 1967; Mason & Norval 1980; Horak *et al.* 1983a; 1984; 1992).

The one-host life cycle strategy of *B. decoloratus* reduces the losses between developmental stages that occur in the multi-host ticks during their moults off the host. The mean ratio of *B. decoloratus* larvae to nymphs to adults on all the impalas examined in the KNP was 3.49:1.69:0.00, and the ratio of males to females 1.97:1.00. These ratios imply a very satisfactory transition from one developmental stage to the next on impalas. Colborne (1989) recorded a ratio of 2.31:1.31:1.00 for larvae to nymphs to adults and a ratio of males to females of 1.89:1.00 on impalas in the south-eastern lowveld of Zimbabwe. The ratio of larvae to nymphs to adults on impalas is also within the range recorded on Burchell's zebras, bushbuck, *Tragelaphus scriptus* and greater kudus in the KNP (Horak *et al.* 1983a; 1984; 1992).

In 1980/81 the intensity of infestation was higher and *B. decoloratus* accounted for a greater proportion of the tick burden in the Biyamiti region than at Skukuza ($P \leq 0.001$). At Skukuza the intensity of infestation was lower in 1992/93 than in 1980/81, and *B. decoloratus* accounted for a lower proportion of the total tick burden ($P < 0.001$). The intensity of infestation did not differ significantly between Skukuza and Pafuri in 1992/93, but *B. decoloratus* accounted for a higher proportion of the total tick burden at Pafuri ($P = 0.001$). (The latter observation appears to contradict the data in the tables. However, the tabulated data summarize all of the ticks collected, whereas this compares the percentages on individual animals). The intensity of infestation was higher on adult males in the Biyamiti region than at Crocodile Bridge, and on impalas in the Biyamiti region than at Pafuri in July 1980, but the differences were not statistically significant ($P > 0.1$). *Boophilus decoloratus* accounted for a greater proportion of the total tick burden on adult males in the Biyamiti region than at Crocodile Bridge (69 % vs 50 %; $P = 0.003$), and in the Biyamiti region than at Pafuri in July, 1980 (55 % vs 36 %), although the latter difference was not statistically significant.

The differences in the intensity of infestation of *B. decoloratus* and its proportion of the total tick burden among regions and between years may result from a number of factors, particularly climate and host availability. There appears to be a close association between the number of questing *B. decoloratus* larvae and rainfall during the preceding year at Skukuza (Horak *et al.* 1995b), and in the present study, the intensity of infestation of *B. decoloratus* appears to be higher in regions where *R. appendiculatus* predominates over *R. zambeziensis*, a tick normally found in drier areas (Norval, Walker & Colborne 1982). In addition, the availability of hosts may play an important role as exemplified by the decrease in the number of questing *B. decoloratus* larvae at Skukuza in 1992/93 following the decline in the impala population in 1992.

The seasonal patterns in the intensity of infestation of *B. decoloratus* on impalas were similar in the three southern locations. In 1980/81 the intensity was lowest in the summer and highest in the spring at Skukuza and in the Biyamiti region ($P < 0.001$; Fig. 2). *Boophilus decoloratus* accounted for the highest proportion of the total tick burden in the spring and early summer, and the lowest proportion in the late autumn and winter ($P < 0.001$). The intensity of infestation did not differ between Skukuza and the Biyamiti region in the autumn and winter, but was significantly higher in the Biyamiti region during the winter and spring. *Boophilus decoloratus* accounted for a greater proportion of the tick burden in the Biyamiti region than at Skukuza during July and August, and November and December ($P < 0.05$). The seasonal pattern was similar at Skukuza in 1980/81 and 1992/93, but *B. decoloratus* accounted for a greater proportion of the tick burden from March to September in 1980 than in 1992. The proportion was similar from October 1980 to April 1981 and from October 1992 to April 1993. In 1992/1993, the intensity of infestation was higher at Pafuri from March to August 1992, and higher at Skukuza from October 1992 to April 1993 ($P = 0.002$). Peak intensity of infestation occurred in August at Pafuri and in October at Skukuza.

The seasonal pattern in the intensity of infestation of *B. decoloratus* on impalas is similar to that on blue wildebeest, Burchell's zebras and greater kudus in the KNP (Horak *et al.* 1983b; 1984; 1992). The pre-hatch period of *B. decoloratus* eggs is longer in the cooler winter months than in the warmer months, and eggs laid in the winter hatch synchronously with those produced at higher temperatures in the spring (Robertson 1981; Spickett & Heyne 1990). The synchronous hatch and extended period of larval survival during the winter (Spickett & Heyne 1990) result in an increase in the number of questing free-living *B. decoloratus* larvae on the vegetation in the southern KNP from August to November (Spickett *et al.* 1992; Horak, Spickett & Braack 2000a). Impalas may also have a reduced resistance to tick infestation at this time because they are on a lower plane of nutrition during the dry winter season and are in poorer condition (Gallivan *et al.* 1995), which reduces their resistance to tick infestation. The higher burdens in the autumn and winter at Pafuri, and the peak in infestation during August, may be due to the 2 °C higher average winter temperature there, resulting in earlier hatching of larvae than at Skukuza.

The intensity of infestation of *B. decoloratus* was highest on yearlings and lowest on lambs ($P < 0.001$) at Skukuza and in the Biyamiti region during 1980/81. This was caused by the low intensity of infestation on newborn lambs in December and the high intensity on yearlings in April. The intensity of infestation did not differ among the age classes in the other months. The intensities of infestations of all stages of *B. decoloratus* were significantly lower on lambs in December ($P < 0.01$) indicating that the low intensity did not occur simply because there was not sufficient time for the development of the nymph and adult stages. In the other months, the intensity of infestation of larvae was lower on adult impalas ($P = 0.004$) and the intensity of infestation of adult *B. decoloratus* was lower on lambs ($P = 0.003$) while the intensity of infestation of nymphs was highest on yearlings ($P = 0.05$). The proportion of the total tick burden did not differ among the age classes ($P = 0.20$), except in December when it was significantly lower on lambs than on yearlings and adults ($P < 0.001$). The intensity of infestation and proportion of the total tick burden on adult impalas did not differ between the sexes ($P \geq 0.27$). The age/sex pattern in the distribution of *B. decoloratus* on impalas differs from that on kudus in the KNP on which there was no difference in the intensity of infestation between age classes (Horak *et al.* 1992). However, the intensity of infestation of adult *B. decoloratus* was higher on adult male kudus than on adult females. There was no difference in the intensities of infestations of any stage of development of *B. decoloratus* between the sexes of adult impalas.

The "terminal" impalas at Skukuza in the 1982 drought were more heavily infested with *B. decoloratus* than the apparently healthy animals examined at the same time or the animals examined in 1980. *Boophilus decoloratus* also accounted for a higher percentage of the total tick burden on the impalas in 1982 than in 1980 ($P = 0.002$). Comparing only the two groups of impalas examined in 1982, the percentage was marginally higher on the "terminal" animals than on the apparently healthy animals ($P = 0.07$). The collections in the 1982 drought were made during the period of peak infestations of *B. decoloratus*, and followed 2 years of above average rainfall. A reduction in resistance in impalas on a low plane of nutrition and the potentially high number of questing *B. decoloratus* larvae probably contributed to the higher burdens in 1982, particularly on the "terminal" animals.

Haemaphysalis aciculifer

The preferred hosts of the adults of this tick are wild bovids, on which it seldom occurs in large numbers (Walker 1991; Horak, Keep, Spickett & Boomker 1989). The immature stages parasitize rodents and ground-nesting birds (Horak & Boomker 1998). Since 1977 one of us (I.G.H.) has examined more than 1 200 animals belonging to many species in the KNP and has collected a total of only two male *H. aciculifer* from an eland, *Taurotragus oryx*, and 15 adults from a honey badger, *Mellivora capensis* (Horak *et al.* 1983a; Horak, Braack, Fourie & Walker 2000b), the collection of 16 larvae from a single impala must be viewed as an accidental infestation with a tick that is apparently rare in the KNP.

Hyalomma truncatum

Adult *H. truncatum* prefer large ungulates, and frequently those with thick skins as hosts (Walker 1991). This tick is abundant in the KNP judging by the large numbers of its immature stages collected from scrub hares (Horak *et al.* 1993; Horak, Spickett, Braack, Penzhorn, Bagnall & Uys 1995a), and the presence of adults on giraffes, *Giraffa camelopardalis*, and Burchell's zebras (Horak *et al.* 1983a; 1984). No adults were collected from the impalas confirming that they are not good hosts of this stage of development. The recovery of larvae from a single impala examined at Skukuza is unusual because the

preferred hosts of the immature stages at this locality, and elsewhere, are scrub hares, bushveld gerbils, *Tatera leucogaster* and other rodents (Walker 1991; Horak *et al.* 1993; Braack, Horak, Jordaan, Segerman & Louw 1996).

Rhipicephalus appendiculatus

All stages of development of *R. appendiculatus* prefer the larger bovids as hosts (Yeoman & Walker 1967; Walker 1974; Norval *et al.*1982; Walker, Keirans & Horak 2000). Large numbers of adults have also been collected from lions, *Panthera leo*, in the KNP (Horak *et al.* 2000b). The immature stages are found on medium-sized and smaller antelope species, on carnivores and on hares, as well as on the larger bovids (Norval *et al.* 1982; Walker *et al.* 2000). The intensities of infestations of *R. appendiculatus* larvae and nymphs on impalas in the Biyamiti region were similar to those on greater kudus in the same area (Horak *et al.* 1992), but the intensity of infestation of *R. appendiculatus* adults was much higher on kudus.

Rhipicephalus appendiculatus larvae were present from March to October with a peak in April to June at Skukuza and in the Biyamiti region during 1980/81. Nymphs were present from March or April to December with a June to September peak, and adults were present from October to June with a February to March peak (Fig. 4). With minor differences, the seasonal patterns were similar in all locations, and were similar to those on greater kudus in the Biyamiti region (Horak *et al.* 1992) and on impalas in the Limpopo Province (Horak 1982) and in Swaziland (Gallivan & Surgeoner 1995). The seasonal patterns of *R. appendiculatus* larvae and adults were similar to their activity periods on the vegetation near Crocodile Bridge 8 to 10 years later (Spickett *et al.* 1992), but the peak activity period of the nymphs was later (August to January) on the vegetation. Although varying in intensity, *R. appendiculatus* adults were present throughout the year on the greater kudus, while their activity period appeared to be delayed on impalas in Swaziland. However, these differences, like the minor differences between locations in the present study, may reflect differences in microclimatic conditions and the spatial distributions of the hosts, two factors which influence the activity of *R. appendiculatus* (Minshull & Norval 1982).

The intensities of infestations of *R. appendiculatus* larvae and nymphs were higher in the Biyamiti region than at Skukuza during 1980/81 ($P = 0.005$ and $P < 0.001$ respectively), but the intensity of infestation of adults was higher at Skukuza ($P = 0.039$). The intensity of infestation of *R. appendiculatus* larvae was significantly higher on adult male impalas at Crocodile Bridge than at Skukuza and in the Biyamiti region ($P < 0.001$). The intensities of infestations of nymphs were higher at Crocodile Bridge and in the Biyamiti region than at Skukuza ($P = 0.008$), but the intensity of infestation of adults did not differ among the three locations ($P = 0.91$).

At Skukuza the prevalences of *R. appendiculatus* larvae, nymphs and adults on the impalas examined during 1992/93 (6.7 %, 4.4 % and 33.3 %, respectively) were significantly lower ($P = 0.02$) than in 1980/81 (48.8 %, 31.7 % and 61 %, respectively). Only four *R. appendiculatus* larvae and two nymphs were collected from each of the infested impala in 1992/93. The mean intensity of infestation of *R. appendiculatus* adults was also lower in 1992/93 than in 1980/81 ($P < 0.001$) and no adults were collected from June 1992 to January 1993. The reduction in 1992/93 may reflect both the lack of hosts (Horak *et al.* 1995b) and the reduced survival of all life stages of *R. appendiculatus* under dry conditions and reduced cover (Short, Floyd, Norval & Sutherst 1989).

The intensities of infestations of *R. appendiculatus* larvae and nymphs were higher at Pafuri and in the Biyamiti region than at Skukuza ($P = 0.04$ and 0.001, respectively) during July 1980. The prevalence of larvae was significantly higher at Pafuri ($P = 0.002$) in 1992/93, where larvae were collected in May and August 1992 and April 1993. Nymphs were present at Pafuri from May to October 1992 and in April 1993. The prevalence and intensity of infestation were higher at Pafuri than at Skukuza ($P = 0.022$ and $P < 0.001$ respectively). The prevalence of *R. appendiculatus* adults did not differ between the two locations ($P = 0.60$). The intensity of infestation was significantly higher ($P < 0.05$) at Skukuza in March 1992, but did not differ between the two locations in the other months. No adults were collected in October and December 1992.

The intensity of infestation of *R. appendiculatus* larvae did not differ among age classes ($P = 0.66$), but the intensities of infestations of nymphs and adults were higher on yearling and adult impalas than on lambs ($P = 0.001$). The intensity of infestation of larvae was higher on adult female impalas than on adult males ($P = 0.044$), whereas the intensity of infestation of the nymphs did not differ between the sexes ($P = 0.29$). The intensity of infestation of adults was higher on adult male impalas than on adult females ($P = 0.001$), particularly from March

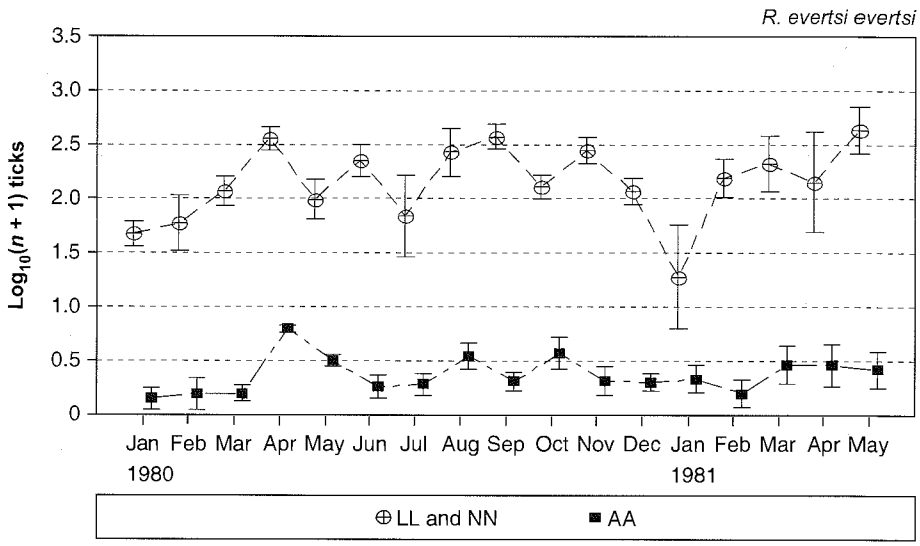

FIG. 5 Seasonal pattern of the intensity of infestation of *Rhipicephalus evertsi evertsi* (x ± 1SE) on impalas at Skukuza and in the Biyamiti region during 1980/81. No lambs were collected after January 1981 and no yearlings after February 1981. The monthly sample at each locality ranged from two to six or seven impalas

similar to the variability on impalas and kudus. The apparent peaks on impalas also differ from those on Burchell's zebras (Horak *et al.* 1984), one of the preferred hosts in the KNP. Based on the lack of a seasonal pattern and month-to-month variability in the number of questing larvae, the apparent seasonal patterns in the intensity of infestation of *R. evertsi evertsi* on impalas may simply reflect differences in the number of questing larvae and differences in the intensity of infestations among hosts.

The intensity of infestation of the immature stages of *R. evertsi evertsi* was higher in the Biyamiti region than at Skukuza in 1980/81 ($P < 0.001$), particularly during July and August, and was higher in the Biyamiti region than at Crocodile Bridge on adult male impalas ($P < 0.05$). The intensity of infestation was lowest at Pafuri in July 1980, but did not differ significantly among the three locations ($P = 0.09$). The prevalence and intensity of infestation of *R. evertsi evertsi* adults did not differ among the locations in 1980/81 ($P \leq 0.15$).

At Skukuza, the prevalences and intensities of infestations of the immature stages and adults of *R. evertsi evertsi* were significantly lower in 1992/93 than in 1980/81 ($P < 0.002$). The prevalence of the immature stages was higher ($P = 0.05$) on the yearling male impalas examined at Pafuri during 1992/93 (95.3 %) than on those at Skukuza (71 %). The intensity of infestation of the immature stages was also higher at Pafuri ($P = 0.022$), but the difference between the two locations was only significant in August 1992. The prevalence and intensity of infestation of adults did not differ significantly between the two locations 1992/93 ($P \geq 34$).

The intensity of infestation of the immature stages did not differ significantly among the age classes ($P = 0.42$), or between sexes of the adult impalas ($P = 0.72$). The prevalence of *R. evertsi evertsi* adults on adult impalas (76.5 %) was significantly higher ($P = 0.04$) than on lambs (50 %) and yearlings (56 %), and the intensity of infestation was significantly higher on adults than on lambs ($P = 0.013$). The prevalence and intensity of infestation with adult ticks did not differ between the sexes in adult animals ($P = 0.15$). These patterns are similar to those in Swaziland where the prevalence of *R. evertsi evertsi* nymphs did not differ among the age classes, the prevalence of adults was higher on adult and yearling impalas than on lambs, and the prevalence of adults did not differ between the sexes on adult impalas (Gallivan *et al.* 1995).

The intensity of infestation of the immature stages of *R. evertsi evertsi* did not differ significantly among the "terminal" impalas and the apparently healthy impalas in the 1982 drought at Skukuza and the impalas in 1980 ($P = 0.43$). The intenstity of infestation of adults was significantly higher on the "terminal" impalas than on the apparently healthy animals in 1982 ($P = 0.05$), but did not differ from the impalas examined in 1980 ($P > 0.20$).

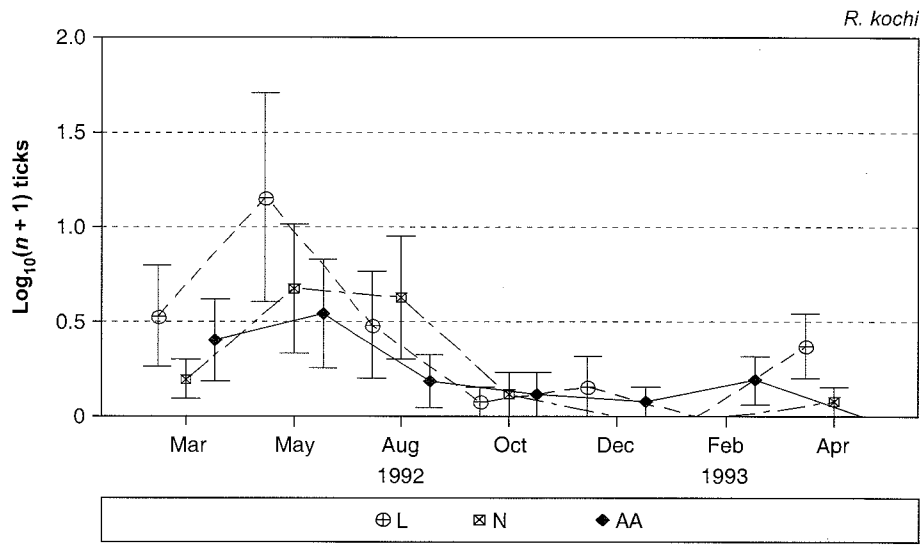

FIG. 6 Seasonal pattern of the intensity of infestation of *Rhipicephalus kochi* (x ± 1SE) on yearling male impalas at Pafuri during 1992/93. Three impalas were examined at 2–3 month intervals

Rhipicephalus kochi

Rhipicephalus kochi was only collected from impalas examined at Pafuri, and in South Africa it has been collected only in the far north-east of the Limpopo Province and of KwaZulu-Natal Province (Walker *et al.* 2000). The preferred hosts of all stages of development are medium-sized and larger antelopes and scrub hares (Walker *et al.* 2000). The prevalence and intensities of infestation of *R. kochi* larvae and nymphs were significantly higher ($P < 0.05$) from March to August 1992 than from October 1992 to February 1993 (Fig. 6). The prevalence and intensity of infestation of adults appeared to decline from March 1992 to April 1993.

Rhipicephalus pravus group

The presence on a single impala of the larvae of a *Rhipicephalus pravus*-like tick that parasitizes scrub hares in the north of the KNP (Horak *et al.* 1993) represents an accidental infestation. This tick has been described by Walker *et al.* (2000) as belonging to a *Rhipicephalus* sp. near *R. pravus*.

Rhipicephalus simus

The adults of *R. simus* prefer equids, suids, large carnivores and large ruminants as hosts, and the immature stages prefer murid rodents (Norval & Mason 1981; Braack *et al.* 1996; Walker *et al.* 2000). The collection of only one male tick each from two impalas in regions where adults are plentiful on Burchell's zebras, warthogs and large carnivores (Horak *et al.* 1984; 1988b; 2000b), supports the view that impalas are not suitable hosts. The 16 larvae collected from a single impala at Skukuza, where the majority of red veld rats, *Aethomys chrysophilus*, are infested with the immature stages of *R. simus* (Braack *et al.* 1996), also represent an accidental infestation.

Rhipicephalus zambeziensis

The preferred hosts of all stages of development of *R. zambeziensis* are domestic and wild ruminants (Norval *et al.* 1982; Walker *et al.* 2000). Numerous adults have also been collected from lions and leopards, *Panthera pardus* (Horak *et al.* 2000b). The intensities of infestations of *R. zambeziensis* larvae and nymphs on impalas in the Biyamiti region were similar to those on greater kudus (Horak *et al.* 1992), but the intensity of infestation of adults was higher on kudus, similar to the pattern for *R. appendiculatus*.

The marked seasonal changes ($P < 0.001$) in the prevalences and intensities of infestations of all stages of *R. zambeziensis* were similar to those for *R. appendiculatus*. At Skukuza and in the Biyamiti region during 1980/81, *R. zambeziensis* larvae were present from March to October with a peak from April to August, nymphs were present from May to December with a July to October peak, and adults were present in all months except July 1980, with a

February to March peak (Fig. 4). With minor differences, the seasonal patterns were similar in all locations, and were similar to those on greater kudus in the Biyamiti region (Horak *et al.* 1992)

During 1980/81, the intensities of infestations of all three stages of *R. zambeziensis* were significantly higher at Skukuza than in the Biyamiti region ($P < 0.007$) and at Crocodile Bridge ($P < 0.05$). The intensity of infestation of larvae was also significantly higher at Skukuza and Biyamiti than at Pafuri in July 1980 ($P = 0.003$), but no nymphs or adults were collected at Pafuri at this time. The intensities of infestations of all three stages were significantly higher at Skukuza than at Pafuri in 1992/93 ($P = 0.001$), particularly during the peak periods.

In South Africa *R. zambeziensis* occurs in north-eastern Mpumalanga Province, in Limpopo Province and in the north-western regions of North West Province (Walker *et al.* 2000), and its distribution overlaps that of *R. appendiculatus* in the KNP. It is the more common species at Skukuza, whereas *R. appendiculatus* is more common at Crocodile Bridge and Pafuri. In Zimbabwe *R. zambeziensis* occurs in the lower, drier regions with mean annual rainfall of 400–700 mm, and *R. appendiculatus* is found in the higher, wetter regions with 500–2 000 mm mean annual rainfall. There is an overlap of the two species in the regions with 500–700 mm rainfall (Norval *et al.* 1982). The locations where impalas were collected in the KNP receive an average of 500–700 mm of rainfall, but the ratios of *R. zambeziensis* to *R. appendiculatus* were not consistent with the rainfall between locations. Not only was *R. appendiculatus* more common at Crocodile Bridge, which receives more rainfall than Skukuza, but also at Pafuri which receives less (Gertenbach 1980). Thus other factors such as local microclimatic conditions and habitats may influence the apparent abundance of the two species.

At Skukuza the prevalences of *R. zambeziensis* larvae and nymphs did not differ significantly between 1980/81 and 1992/93 ($P \geq 0.4$), but the intensities of infestations of both stages were significantly higher ($P \leq 0.001$) in 1980/81 than in 1992/93. There was a significant month x year interaction for both stages ($P \leq 0.035$) caused by the lower peak intensities of infestation in 1992/93. There was no difference in the prevalence or intensity of infestation of adults between years ($P \geq 0.54$), but there was a significant month x year interaction ($P < 0.001$) as the intensity of infestation was higher from March to May 1992 than from March to May 1980, and higher from January to March 1981 than from January to March 1993. The lower intensities of infestations of *R. zambeziensis* larvae and nymphs in 1992/93 and the lower intensity of infestation of adults in 1993 probably reflect the influence of the 1992 drought on the free-living stages. However, the relative decrease was much less than the decrease in the numbers of *R. appendiculatus*, which exhibited marked decreases in the prevalences and intensities of infestation of all developmental stages. This is consistent with the greater sensitivity of *R. appendiculatus* to dry conditions.

The age/sex distribution of *R. zambeziensis* was similar to that of *R. appendiculatus*. In 1980/81 the prevalences and intensities of infestations of *R. zambeziensis* larvae and nymphs did not differ among the age classes ($P = 0.79$). The prevalence of adults did not differ among the age classes ($P = 0.55$), but the intensities of infestations were higher on yearlings and adults than on lambs ($P < 0.001$), particularly during the peak periods. The prevalence of the three life stages of *R. zambeziensis* did not differ on adult male and female impalas ($P = 0.26$), but the intensity of infestation of larvae was higher on adult female impalas than on adult males ($P = 0.005$), particularly during March and April 1981. The intensity of infestation of adults was higher on adult male impalas ($P = 0.029$), particularly during April and May. Combining the burdens of adult *R. zambeziensis* and *R. appendiculatus*, adult male impalas were more heavily infested than adult females ($P = 0.01$), with the largest differences from March to May. The prevalence and intensity of infestation of adult *R. zambeziensis* and *R. appendiculatus* combined was similar at Skukuza, Biyamiti and Crocodile Bridge ($P = 0.45$).

The intensities of infestations of *R. zambeziensis* larvae and adults were significantly higher ($P < 0.001$ and $P = 0.03$ respectively) on the "terminal" impalas at Skukuza in the 1982 drought than on the apparently healthy impalas killed at the same time or on the impalas examined in 1980. The intensity of infestation of nymphs did not differ between the three groups. When the burdens of adult *R. appendiculatus* and *R. zambeziensis* were combined, the prevalence was higher ($P = 0.004$) on the impalas examined in 1980 (93 %) and on the "terminal" impalas in 1982 (90 %) than on the apparently healthy animals in 1982 (43 %). However, the intensity of infestation of the adult ticks was higher on the "terminal" impalas in 1982 than on those examined in 1980 or on the apparently healthy impalas killed in 1982 ($P = 0.01$).

LICE

Total louse burdens

The impalas were infested with five louse species, one of which, a *Linognathus* sp., has not been described. The four described species are regularly collected from impalas (Ledger 1973; 1980; Horak 1982; Horak *et al.* 1983c; Matthee *et al.* 1998). The dominant species differed among areas in the KNP, with *Damalinia elongata* the most numerous at Skukuza, *Linognathus aepycerus* the most numerous at Pafuri, *D. elongata* and *L. aepycerus* the primary species at Crocodile Bridge, and *L. aepycerus* and *Linognathus nevilli* the most common species in the Biyamiti region (Table 2).

The highest total louse burdens were recorded in the late winter/early spring (August to October) (P = 0.026–0.17) and the lowest burdens in the summer (December to February) (Fig. 7). The seasonal patterns were the result of seasonal changes in the intensities of infestations of *Damalinia aepycerus* and *Linognathus aepycerus* (see below), and the decline in the summer is possibly related to the higher temperatures during this period. The seasonal pattern conforms to that observed in other studies of lice infesting impalas and other antelopes (Horak *et al.* 1983b; Horak, Sheppey, Knight & Beuthin 1986b; Matthee *et al.* 1998).

The total lice burdens were significantly higher at Skukuza than in the Biyamiti region (P = 0.001) in 1980/81. On adult males, the prevalence of lice at Skukuza (100 %) was significantly higher (P = 0.031) than in the Biyamiti region (77 %) and at Crocodile Bridge (58 %), and the total louse burden was higher at Skukuza than in the Biyamiti region and at Crocodile Bridge (P = 0.06). The total louse burdens were significantly higher at Skukuza during 1980/81 than during 1992/93 (P < 0.001) (Table 11), but did not differ significantly between Skukuza and Pafuri during the latter period (P = 0.46).

Lice tend to be parasites of young animals (Horak *et al.* 1983b; 1986b), and the total burdens were significantly higher on lambs and yearlings than on adult impalas (P = 0.002). Most louse species were present on lambs within a month of birth suggesting that they were passed from the dam. The burdens on adult impalas were higher on females than on males, but the differences were not statistically significant (P = 0.17).

The "terminal" impalas in 1982 had significantly higher total louse burdens than the apparently healthy impalas and those killed in 1980 (P = 0.03) (Table 11). The "terminal" impalas were obviously stressed and this probably lowered their resistance to lice, allowing effective and rapid translation from one developmental stage to the next. In addition, they probably lacked the energy to groom properly or conserved energy by reducing their grooming rate, thus allowing sustained levels of infestation.

Damalinia aepycerus

Damalinia aepycerus was collected at all locations in the KNP, and although it was the most numerous species on impalas in the Nylsvley Nature Reserve, Limpopo Province (Horak 1982), it was never so in the KNP. The preferred biotopes of *D. aepycerus* are the body and tail, with 60.4 % of the population present in the former and 36.0 % in the latter site (Matthee *et al.* 1998).

The intensity of infestation of *D. aepycerus* was significantly higher at Skukuza than in the Biyamiti region and at Crocodile Bridge in 1980/81 (P < 0.03). At Skukuza, the intensity of infestation did not differ significantly between 1980/81 and 1992/93 (P > 0.17), nor did the intensity of infestation differ significantly between Skukuza and Pafuri during 1992/93 (P = 0.34). In 1980/81 there were two apparent peaks in the intensity of infestation (Fig. 7), one in April or March caused by high infestations on lambs and yearlings, and a more generalized peak in the late winter/spring (August to October). However, in 1992/93 the peak infestations occurred from March to May 1992 and the intensity of infestation declined through 1993. There was no clear seasonal pattern in the intensity of infestation on impalas in the Nylsvley Nature Reserve (Horak 1982), while Matthee *et al.* (1998) reported the highest intensities of infestation in February and July on impala ewes examined on Letaba Ranch, Limpopo Province during February, July and October.

The intensity of infestation of *D. aepycerus* was higher on lambs and yearlings than on adult impalas (P = 0.065). Infestation of lambs occurred within a month after birth. The prevalence and intensity of infestation on adult impalas did not differ significantly between sexes (P = 0.12). The prevalence and intensity of infestation did not differ among the three groups of impalas at Skukuza compared for the effects of the 1982 drought (P = 0.18 and 0.81 respectively). The prevalence of adult lice was higher on the "terminal" and apparently healthy impalas in the 1982 drought (100 % and 90 % respectively) than on those examined in

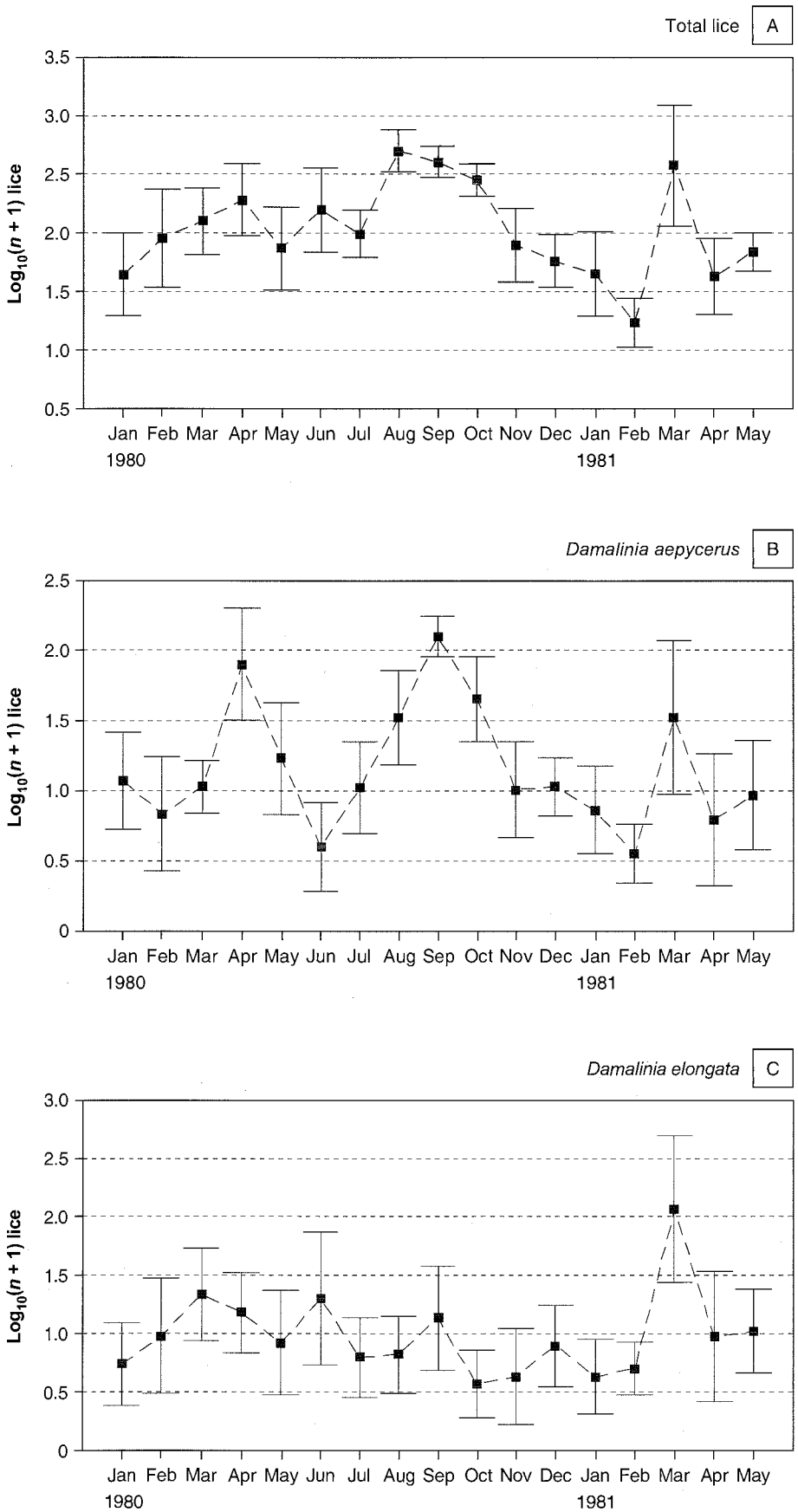

FIG. 7

Seasonal pattern of the intensity of infestation of [A] the total lice burden (x ± 1SE), [B] *Damalinia aepyceus* (x ± 1SE), and [C] *Damalinia elongata* (x ± 1SE) on impalas at Skukuza and in the Biyamiti region during 1980/81. No lambs were collected after January 1981 and no yearlings after February 1981. The monthly sample at each locality ranged from two to six or seven impalas

1980 (57 %), but the intensity of infestation did not differ among the three groups ($P = 0.13$).

Damalinia elongata

Damalinia elongata was the most numerous louse species on impalas at Skukuza in 1980/81 and 1992/93, and accounted for much of the higher louse burden at this locality in 1980/81. The prevalence and intensity of infestation were significantly higher ($P > 0.014$) at Skukuza than in the Biyamiti region in 1980/81. Although the intensity of infestation was higher on adult male impalas at Skukuza than at Crocodile Bridge, the difference was not statistically significant ($P > 0.1$). The prevalence of *D. elongata* at Skukuza did not differ significantly between 1980/81 and 1992/93 ($P > 0.25$), but the intensity of infestation was significantly higher in 1980/81 than in 1992/93 ($P = 0.004$). The intensity of infestation was similar at Skukuza and Pafuri in July 1980, but only two adult *D. elongata* were collected at Pafuri in 1992/93.

There was no seasonal pattern in the prevalence or intensity of infestation of *D. elongata* (Fig. 7). Lambs were infested by 2 months of age. The intensity of infestation was higher on yearlings than on adult impalas ($P = 0.044$), with the most pronounced differences at Skukuza. The prevalence and intensity of infestation on adult impalas did not differ significantly between sexes ($P > 0.31$). At Skukuza, the prevalence and intensity of infestation did not differ among the three groups of animals compared to assess the effect of the 1982 drought ($P = 0.46$). The intensity of infestation appears to be much higher on the "terminal" impalas, but one individual accounted for > 91 % of the total burden, and only four of ten "terminal" animals were infested.

Linognathus aepycerus

Even though the greatest numbers of *L. aepycerus* were collected from the body, this louse appears to be spread fairly evenly over the whole skin surface if the much larger surface area of the body, as opposed to those of the head, neck, legs and tail is taken into account (Matthee *et al.* 1998). It was the most common louse at Pafuri, and was also common in the Biyamiti region and at Crocodile Bridge. The prevalence of *L. aepycerus* on adult male impalas did not differ between Skukuza, the Biyamiti region and Crocodile Bridge in 1980/81 ($P > 0.3$), but the intensity of infestation was marginally higher at Skukuza than in the Biyamiti region ($P = 0.078$). At Skukuza the prevalence of *L. aepycerus* did not differ significantly between 1980/81 and 1992/93 ($P > 0.58$), but the intensity of infestation was higher in 1980/81 than in 1992/93 ($P = 0.02$). The prevalence of infestation (100 % and 87.5 % respectively) did not differ significantly ($P = 0.12$) between Pafuri and Skukuza in 1992/93, but its intensity was significantly higher at Pafuri than at Skukuza ($P < 0.02$).

There was a strong seasonal pattern in both the prevalence and intensity of infestation ($P < 0.02$) of *L. aepycerus* at Skukuza and in the Biyamiti region during 1980/81, with the highest prevalence and intensity of infestation from July to October (Fig. 8). The intensity of infestation was similar in the two areas from July to October, but tended to be higher at Skukuza in the other months. The seasonal pattern was similar at Skukuza in 1980/81 and 1992/93, but there was a significant month x location interaction between Skukuza and Pafuri in 1992/93. The intensity of infestation at Pafuri declined from March 1992 to February 1993, with only a slight increase in October 1992, whereas the pattern at Skukuza was similar to that in Fig. 11. Matthee *et al.* (1998) recorded the highest intensity of infestation with *L. aepycerus* during October on Letaba Ranch, but there was no clear seasonal pattern on impalas in the Nylsvley Nature Reserve (Horak 1982).

Lambs were infested with *L. aepycerus* within the first month after birth, and the prevalence and intensity of infestation were significantly higher on lambs than on adult impalas ($P \leq 0.004$). The prevalence and intensity of infestation on adult animals did not differ significantly between the sexes ($P > 0.16$). The prevalence and intensity of infestation of *L. aepycerus* were higher on impalas in the 1982 drought than on the animals examined in 1980 ($P \leq 0.04$), but did not differ ($P > 0.1$) between the "terminal" and the apparently healthy animals in 1982.

Linognathus nevilli

Linognathus nevilli was originally collected and described from around the feet of impalas (Ledger 1973), and is most commonly found on the feet and hind legs (Matthee *et al.* 1998). Small numbers may also be present on the head, neck and body, possibly transferred there when these regions are scratch-groomed with the hind feet, an action illustrated by Mooring (1995).

The prevalence and intensity of infestation of *L. nevilli* did not differ between Skukuza, the Biyamiti region and Crocodile Bridge in 1980/81 ($P > 0.3$). At Skukuza, the prevalence was marginally higher

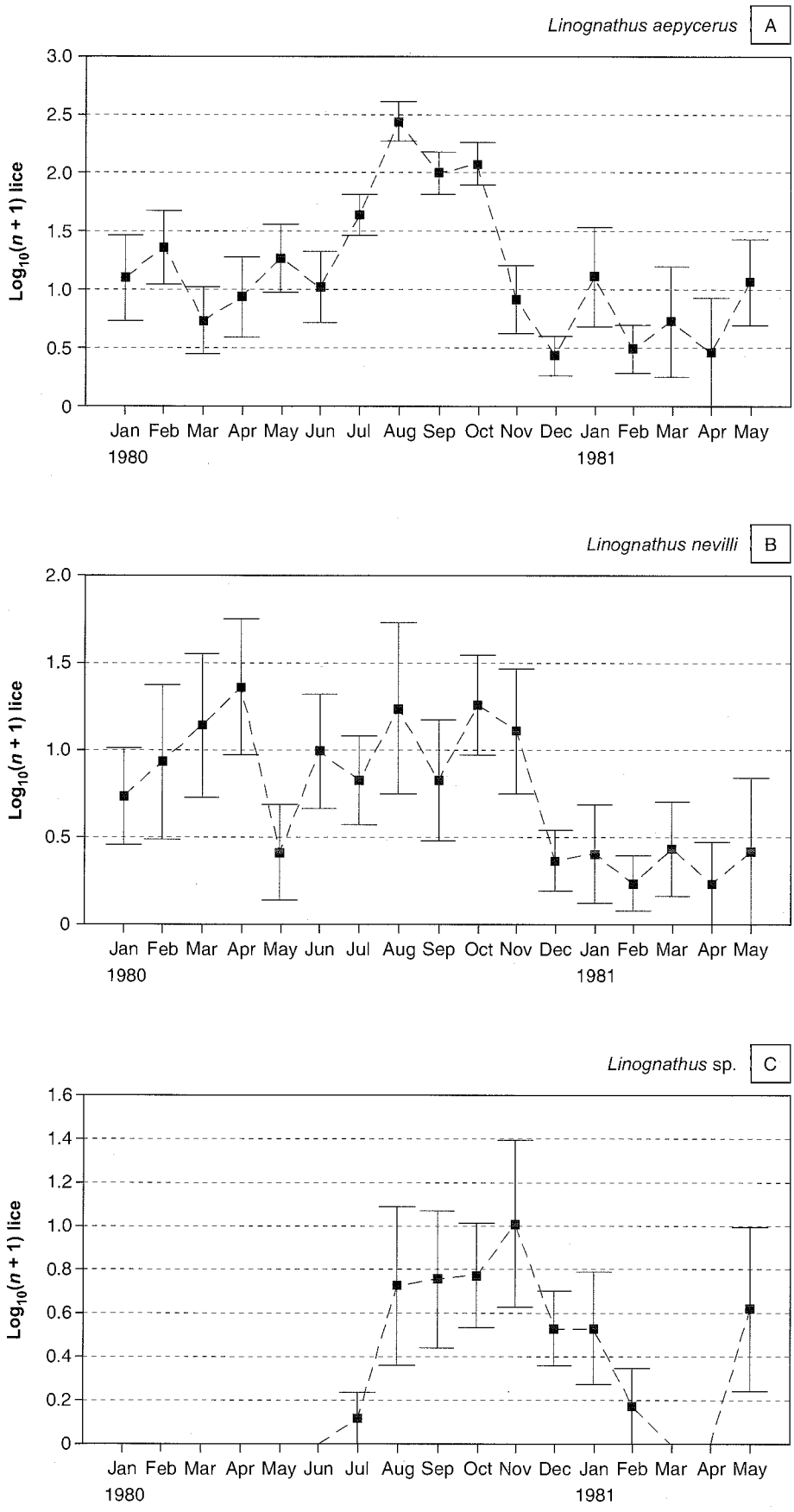

FIG. 8

Seasonal pattern of the intensity of infestation of [A] *Linognathus aepycerus* (x ± 1SE), [B] *Linognathus nevilli* (x ± 1SE), and [C] *Linognathus* sp. (x ± 1SE) on impalas at Skukuza and in the Biyamiti region during 1980/81. No lambs were collected after January 1981 and no yearlings after February 1981. The monthly sample at each locality ranged from two to six or seven impalas

($P = 0.09$) and the mean intensity of infestation was significantly higher ($P < 0.001$) in 1980/81 than in 1992/93. The prevalence did not differ significantly between Pafuri and Skukuza ($P = 0.15$), but the intensity of infestation was significantly higher at Pafuri ($P = 0.023$).

Although there were two apparent peaks, one in the late summer and early autumn, and another in the late winter and spring, there was no clear seasonal pattern in the intensity of infestation of *L. nevilli* at Skukuza and in the Biyamiti region during 1980/81 (Fig. 8). The seasonal patterns at Skukuza were statistically significant ($P = 0.008$) in the comparison of 1980/81 and 1992/93, and were more pronounced in 1980/81. No seasonal pattern was evident in the comparison of Skukuza and Pafuri in 1992/93 ($P = 0.41$). The prevalence of *L. nevilli* was significantly higher ($P < 0.001$) on lambs (81 %) and yearlings (68 %) than on adult impalas (37 %), and the intensity of infestation was significantly higher on lambs than on yearlings ($P < 0.05$), and higher on yearlings than on adult impalas ($P < 0.01$). No *L. nevilli* were collected from lambs until they were a month old. The prevalence and intensity of infestation of *L. nevilli* were significantly higher on adult female impalas than on adult males ($P \leq 0.006$).

Although the prevalence and intensity of infestation of nymphs were higher on the "terminal" impalas than on the apparently healthy animals in 1982 ($P = 0.05$ and 0.09, respectively), the prevalence and intensity of infestation of *L. nevilli* did not differ significantly between the three groups of animals ($P = 0.21$).

Linognathus sp.

Although this louse accounted for only a small percentage of the lice collected, it was common, with an overall prevalence of 27.4 %. The prevalence and intensity of infestation did not differ between Skukuza and the Biyamiti region in 1980/81, or between Skukuza and Pafuri in 1992/93 ($P = 0.35$). At Skukuza the prevalence did not differ between 1980/81 and 1992/93 ($P = 0.74$) but the intensity of infestation was higher in 1980/81 than in 1992/93 ($P = 0.01$). The prevalence was considerably lower ($P = 0.004$) on adult male impalas (9 %) than on adult females (39 %), and none were collected from the adult males at Crocodile Bridge.

The intensity of infestation of *Linognathus* sp. peaked in late winter to early summer (Fig. 8). None were collected at Skukuza or in the Biyamiti region from January to June 1980, but they were present during some of these months in 1981 and 1992/93. The1992/93 peak at Skukuza occurred in September and was of shorter duration than the peak in 1980/81. The prevalence of *Linognathus* sp. did not differ among age classes ($P = 0.44$), but the intensity of infestation was higher on lambs than on yearlings and adults ($P = 0.01$). Infestation of the lambs took place within the first month after birth. The prevalence and intensity of infestation did not differ among the "terminal" and apparently healthy impalas examined during the 1982 drought and those examined in 1980 ($P = 0.49$).

FLIES

The impalas were infested with the hippoboscid flies *Hippobosca fulva* and *Lipoptena paradoxa*.

Hippobosca fulva

According to Haeselbarth *et al.* (1966) the main hosts of *H. fulva* are probably small antelopes such as steenbok, *Raphicerus campestris*, common duikers, *Sylvicapra grimmia*, and Kirk's dik-diks, *Madoqua kirkii*, with impalas also being infested. However, we have not collected this fly from steenbok or common duikers in South Africa (I.G.H. unpublished observations 1999), and although they were collected from impalas in Swaziland, none were collected from common duikers (Gallivan & Surgeoner 1995).

The *H. fulva* collected in the current surveys do not represent the actual numbers infesting impalas in the KNP. Large numbers of these flies are visible on the white underside and perineum of impalas, where they are frequently mistaken for ticks. However, when the impalas were shot, many of them took flight and only those still present in the haircoat were collected when the carcasses were processed for tick recovery.

The prevalence and intensity of infestation of *H. fulva* were significantly higher ($P = 0.003$) on impalas in the Biyamiti region than at Skukuza during 1980/81. On adult males the prevalence was higher ($P = 0.05$) in the Biyamiti region (62 %) than at Skukuza (29 %) and Crocodile Bridge (17 %), but the intensity of infestation did not differ significantly among the three locations ($P = 0.10$). The prevalence and intensity of infestation of *H. fulva* were significantly lower (P 0.001) in spring and mid-summer than in autumn and winter (Fig. 9) on the impalas at Skukuza and in the Biyamiti region during 1980/81. The seasonal pattern in the intensity

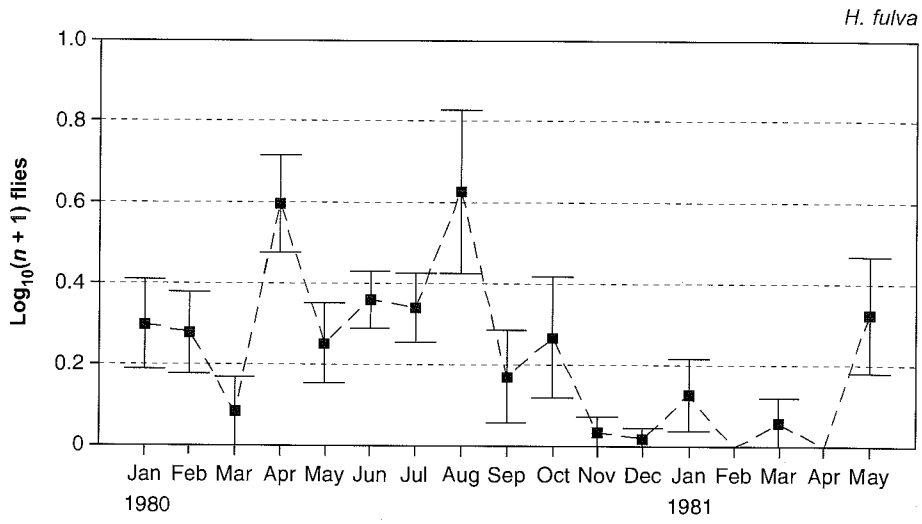

FIG. 9 Seasonal pattern of the intensity of infestation of *Hippobosca fulva* (x ± 1SE) on impalas at Skukuza and in the Biyamiti region during 1980/81. No lambs were collected after January 1981 and no yearlings after February 1981. The monthly sample at each locality ranged from two to six or seven impalas

of infestation of *H. fulva* on impalas at these localities during 1980/81 was almost the exact opposite to that noted for *L. paradoxa* on greater kudus in the Biyamiti region (Visagie, Horak & Boomker 1992). These different seasonal patterns could reflect differences in the months during which the majority of flies of the two species emerge from pupae, or differences in seasonal habitat usage by the two host species.

The prevalence and intensity of infestation of *H. fulva* did not differ among age classes ($P > 0.43$), or between the sexes of adult impalas ($P > 0.26$). Prevalence did not differ among the groups of impalas examined during the drought of 1982 and the group examined during 1980 at Skukuza ($P = 0.44$), it was, however, low during the months in which these animals were examined.

Lipoptena paradoxa

Lipoptena paradoxa is common on nyalas, bushbuck and greater kudus, and is also frequently encountered on common duikers (Visagie *et al.* 1992). All these antelopes utilize woodland habitats (Skinner & Smithers 1990). Once the fly has found a host its wings break off and it becomes a permanent parasite. Only five impalas examined during 1980/81 were infested with *L. paradoxa*, one in the Biyamiti region and four at Skukuza, and no flies were collected from adult male animals at Crocodile Bridge. Its presence on impalas must be regarded as coincidental as they frequently share woodland habitats with greater kudus.

General discussion

This paper summarises the results of several collections of arthropod parasites of impalas made over a 13-year period in the KNP. Despite differences in the age and sex composition of the animals in the surveys, we were able to examine the effects of location, season, age, sex, and two droughts. The seasonal patterns for each species of tick and louse are discussed above. The remaining factors are summarized below.

There were several differences in the ixodid tick species among locations. *Boophilus decoloratus* was most common in the Biyamiti region, while *A. hebraeum* larvae and nymphs were most common at Skukuza and Crocodile Bridge, *A. marmoreum* larvae at Skukuza, *R. evertsi evertsi* in the Biyamiti region and at Pafuri, and *R. zambeziensis* at Skukuza. *Rhipicephalus appendiculatus* larvae and nymphs were more common in the Biyamiti region and at Crocodile Bridge and Pafuri than at Skukuza, but *R. appendiculatus* adults were most common at Skukuza. [Several of the adult ticks collected from impalas at Skukuza, and identified as *R. appendiculatus*, could actually have been *R. zambeziensis* because of the difficulty of distinguishing between these species in the adult stage (Walker *et al.* 2000)]. Rainfall and temperature are important factors determining the distribution and abundance of tick species. However, the apparent abundance of tick species was not consistent with the rainfall and temperature patterns within the KNP. Part of this inconsistency may be caused by differential

habitat use within heterogenous landscape types where differences in microclimates create marked differences in tick challenge (Minshull & Norval 1982). The presence of preferred or alternate hosts may also be a factor. The higher intensity of infestation of *R. appendiculatus* adults at Skukuza differs from the patterns in the intensities of infestation of the larvae and nymphs. This may, however, be due to the difficulty experienced in specifically identifying the adults as discussed above. Impalas appear to be good hosts for the immature stages of *R. appendiculatus* but poor hosts for the adults. However, in Swaziland where impalas were the most numerous ungulate species and there were few large ungulates, they were important hosts of *R. appendiculatus* adults (Gallivan & Surgeoner 1995).

The intensities of infestation of the lice *D. aepycerus* and *D. elongata* were higher at Skukuza than in the Biyamiti region and at Crocodile Bridge, while *L. aepycerus* and *L. nevilli* were more common at Pafuri. These differences in the louse populations are not easily explained, but may be due to climatic differences, or differences in the age composition of the impala populations. At Pafuri impalas tend to become older than elsewhere in the KNP because of a lower density of lions, and very old animals in this region are often unable to groom effectively because their dental grooming apparatus has become worn down (McKenzie 1990).

It is often assumed that young animals are the most prone to infestation, but the total tick burdens, and the burdens of *B. decoloratus* and *B. decoloratus* adults, *A. hebraeum* nymphs and adults, *R. appendiculatus* nymphs and adults, *R. zambeziensis* nymphs and adults, and *R. evertsi evertsi* adults were higher on yearling and adult impalas than on lambs. In contrast, with the exception of *D. elongata*, the intensity of infestation of lice was higher on lambs. The lower burdens of *B. decoloratus* on lambs were caused by a low intensity of infestation on newborn lambs in December, and the low intensity of infestation of larvae indicates that these lambs had not yet been exposed. With the exception of *B. decoloratus*, the differences among age classes were similar to those reported for tick prevalence on impalas in Swaziland (Gallivan *et al.* 1995). The lower intensities of infestations of the nymph and adult stages of ixodid ticks on impala lambs may be a function of the higher allogrooming rate of these animals (Mooring & Hart 1992). This would presumably be effective in removing the larger nymphal and adult ticks, but less so in removing the larvae. The age distribution of lice infestation conforms to observations on other species that lice tend to be parasites of young animals and that infestation occurs early in life (Horak *et al.* 1983b; 1986b; Horak, MacIvor & Greeff 2001).

The prevalence of adult *A. hebraeum* and the intensities of infestations of adult *R. appendiculatus* and *R. zambeziensis* were higher on adult male impalas than on adult females, while the intensities of infestations of *R. zambeziensis* and *R. appendiculatus* larvae were higher on adult female impalas. The higher prevalence of adult *A. hebraeum* and intensity of infestation of adult *R. appendiculatus* on adult male impalas are similar to the pattern in Swaziland (Gallivan *et al.* 1995). Gallivan *et al.* (1995) reported an increased prevalence of *B. decoloratus* adults on male impalas, and Mooring & Hart (1995) reported increased infestations of *B. decoloratus* and *R. zambeziensis* on adult male impalas during the rut in the Omay Communal lands in Zimbabwe. The differences reported for *B. decoloratus* may be caused by variations in sampling techniques among the three studies.

The contrasts in the intensities of infestations of adult *R. appendiculatus* and *R. zambeziensis* between the sexes were most pronounced during the rut. Mooring & Hart (1995) suggest that the increase in testosterone during the rut reduces immunity in the males. However, this should cause an increase in the intensity of infestation of all stages of ticks. The intensities of infestations of *R. appendiculatus* and *R. zambeziensis* larvae were actually higher on the adult female than on the adult male impalas during the rut. The higher intensities of infestations of adult *R. appendiculatus* and *R. zambeziensis* on adult male impalas during the rut are most likely caused by a reduction in grooming activity (Mooring & Hart 1995). The higher intensities of infestations of *R. appendiculatus* and *R. zambeziensis* larvae on the adult female impalas may be the consequence of increased exposure. Adult male impalas have restricted home ranges during the rut, whereas the home range of the females encompasses several male territories (Murray 1982). Because peak activity of *R. appendiculatus* and *R. zambeziensis* larvae occurs during the rut, the mobile female impalas are more likely to be exposed to them.

In contrast to the ticks, lice tended to be more common on adult female impalas than on adult males, and the differences were statistically significant for *L. nevilli* and *Linognathus* sp. Female impalas occur in larger herds, maintain shorter distances between neighbours and allogroom more frequently than

males (Mooring 1995), all factors that could facilitate the transfer of lice between individuals. Both *L. nevilli* and *Linognathus* sp. have relatively low prevalences and intensities of infestation, and increased interaction among females may be essential to maintain transmission.

The collections included two droughts, in 1982 and in 1992 (Fig. 1). The 1982 collections were made in November and early December, following an extended period of low rainfall beginning in February 1982, and the 1992/93 collections began at the end of the summer after a year of low rainfall and continued through a year of normal rainfall. Consequently the collections represent different phases of the drought. The 1982 collections were also preceded by two years of above normal rainfall and impala populations, while the 1992/93 collections were preceded by two years of below average rainfall and impala populations.

In 1982 there was an increase in the total tick and louse burdens on the "terminal" impalas, primarily because of the increase in the intensities of infestations of *B. decoloratus* and *L. aepycerus*, and the burden of *D. elongata* on one individual. There was also an increase in the intensities of infestations of adult *A. hebraeum*, *R. appendiculatus*, *R. evertsi evertsi* and *R. zambeziensis*. These patterns reflect the seasonal activity of the ticks and lice, and are consistent with a reduction in resistance in animals in poor condition. There were few differences in the tick and louse burdens between the "apparently healthy" impalas in 1982 and those examined in 1980. In 1992/93 there was a reduction in the intensities of infestations of all tick and louse species relative to 1980/81. The reductions in the louse burdens and intensities of infestations of *R. zambeziensis* larvae and nymphs were proportional to the reduction in the size of the impala population, indicating that the availability of the hosts was a major factor in maintaining ectoparasite populations. The reductions in the infestations of *A. hebraeum*, *B. decoloratus*, *R. evertsi evertsi* and *R. appendiculatus* in 1992/93 relative to 1980/81 were greater than the reduction in the impala population. The drier environmental conditions probably reduced the survival of the free-living stages of these species as there was a greater reduction in the number of questing *B. decoloratus* larvae than *R. zambeziensis* larvae (Spickett *et al.* 1995), and *R. zambeziensis* tolerates drier conditions than *R. appendiculatus*. Thus, while the collections in the 1982 drought indicate that the immediate impact of a drought may be an increase in ectoparasite infestations because of the nutritional stress, the collections in the 1992 drought suggest that a reduction in impala populations as well as reduced survival of the free-living ticks may reduce the ectoparasite burdens over time.

ACKNOWLEDGEMENTS

We are greatly indebted to the South African National Parks for placing the animals as well as their staff and facilities in the Kruger National Park at our disposal. We gratefully acknowledge the assistance of Messrs C. Cheney, J. Sithole and the late B.D. de Klerk with processing the carcasses for the recovery of ectoparasites, and that of Mrs E.L. Visser, Miss M.L. Horak and Mr A.C. Uys who assisted in the recovery of the parasites from the processed material.

This research was funded by the Faculty of Veterinary Science, University of Pretoria, the South African National Parks, the Foundation for Research Development (now the National Research Foundation), and Bayer Animal Health.

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HELMINTH AND

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PARASITES AND DISEASES OF CAPE MOUNTAIN ZEBRA, BLACK WILDEBEEST, MOUNTAIN REEDBUCK AND BLESBOK IN THE MOUNTAIN ZEBRA NATIONAL PARK

by

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Abstract – The results of a special survey are supplemented in this report with a review of all other applicable information on the diseases and parasites of Cape mountain zebra, black wildebeest, mountain reedbuck and blesbok in the Mountain Zebra National Park. The possible significance of some of these infections is discussed and various suggestions are made which aim at the continued and successful preservation of the Cape mountain zebra and other species in this National Park.

Infectious diseases and parasites isolated from or identified in *Equus zebra zebra* (Cape mountain zebra), *Connochaetes gnou* (black wildebeest), *Redunca fulvorufula* (mountain reedbuck), *Damaliscus dorcas phillipsi* (blesbok) in the Mountain Zebra National Park (M.Z.N.P.), are summarized in tabular form.

Babesia equi was found in blood smears of three of the five Cape mountain zebra captured and sampled (Neitz, *pers. comm.*). These animals were all heavily infested with ticks but were otherwise clinically normal. Latent infections of *B. equi* are known to flare up and produce deleterious and often fatal effects in the horse when the host animal is subjected to certain stressful conditions. Similarly wild animals, pre-immune to certain protozoal infections, may fall victim to such infections under certain circumstances. The apparent high incidence of subclinical equine babesiosis in this very rare subspecies of *Equus zebra* is therefore viewed with great concern.

The interpretation of the results of serological tests for horse sickness and equine rhinopneumonitis was complicated by the anti-complementary nature of the zebra serum as well as by other technical difficulties and

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Table 1

Parasites and infectious diseases of Cape Mountain Zebra, Black Wildebeest, Mountain Reedbuck and Blesbok in the Mountain Zebra National Park

Host	Parasite/disease		Remarks
Cape mountain zebra	Endoparasites	*Gasterophilus pecorum*	"Bots" in stomach
		G. intestinalis	"Bots" in stomach
		Anoplocephala magna	Cestode in stomach and duodenum
		Trichonema (larvae)	Found in numerous cysts in the intestinal wall
	Ectoparasites	*Rhipicephalus e. evertsi*	Heavy tick infestation
		R. glabroscutatum	Heavy tick infestation
		Hyalomma rufipes	Heavy tick infestation
		Margaropus winthemi	Heavy tick infestation
	Infectious diseases	Babesiosis (*B. equi*)	Bloodsmears positive
		Horse sickness	Results indefinite (serum anti-complimentary)
		Equine rhinopneumonitis	Results indefinite (serologically suspicious)
Black wildebeest	Endoparasites	*Haemonchus* sp.	Nematode in abomasum
		Oesophagostomum sp.	Nematode in colon
		Trichinella spiralis	Microscopic examination of digested tissues negative
	Ectoparasites	*Rhipicephalus glabroscutatum*	Ticks, especially on thin-skinned parts
		Lipoptena sepiacea	Biting fly (hippoboscid)
		Gedoelstia sp.	Larvae (L II + III) in the nasal cavity
	Infectious diseases	Bluetongue	Serological tests negative
		Rift valley fever	Serological tests negative
		Wesselsbron disease	Serological tests negative
		Protozoa	Blood smears and histological preparations negative
Mountain reedbuck	Endoparasites	*Haemonchus* sp.	Nematode in abomasum
		Nematodirus spathiger	Nematode in duodenum
		Moniezia expansa	Cestode in duodenum
		Setaria boulengeri	Nematode in abdominal cavity
		Trichinella spiralis	Microscopic examination of digested tissues negative

Table 1 (cont.)

Host	Parasite/disease		Remarks
	Ectoparasites	*Rhipicephalus glabroscutatum*	Heavy tick infestation
		Linognathus reduncae	Sucking lice (Anoplura)
		Damalinia trabeculae	Biting lice (Ischnocera)
	Infectious diseases	Bluetongue	Serological tests negative
		Rift valley fever	Serological tests negative
		Wesselsbron disease	Serological tests negative
		Protozoa	Blood smears and histological preparations negative
Blesbok	Endoparasites	*Haemonchus contortus*	Nematode in abomasum
		Nematodirus spathiger	Small red nematode in duodenum
		Cysticercus tenuicollis	Cysts on mesentery
		Trichinella spiralis	Microscopic examination of digested tissues negative
	Ectoparasites	*Rhipicephalus glabroscutatum*	Ticks
		Oestrus variolosus	Larvae (L I–III) in nasal cavities and frontal sinuses
	Infectious diseases	Bluetongue	Serological tests negative
		Rift valley fever	Serological tests negative
		Wesselsbron disease	Serological tests negative
		Protozoa	Blood smears and histological preparations negative

special tests for these and other important diseases of the Equidae obviously have to be repeated and even extended.

One young zebra foal was found to be heavily infested with various internal parasites which resulted in parasitic enteritis. Nematodes (*Trichonema* sp.) could be detected macroscopically in numerous cystic lesions in the intestinal mucosa. This particular case left very little doubt that such heavy infestations may sometimes end fatally.

Since the proclamation of the M.Z.N.P. in 1937, the zebra have increased steadily in this Park from relatively few animals to their present number of about 130 individuals. Inbreeding could already have reduced the inherent resistance of these animals to diseases and parasitism by now and may even become a bigger problem in the future if the necessary provision is not made for the introduction of sufficient new genetic material. In addition trace-element deficiencies, which seem to exist in this park, may also exert some decimating effects. Domestic horses, which may harbour

infectious diseases to which the Cape mountain zebra is susceptible, are furthermore kept in this park and on adjoining farms and the possibilities of introducing and establishing new infections are therefore not excluded.

Apart from the possible introduction of sufficient new genetic material from other populations of Cape mountain zebra, the continued existence of this subspecies may expectedly be further ensured by capturing a considerable number of the animals in the M.Z.N.P., by deworming these and treating and vaccinating them against all the diseases and parasites which they may harbour or contract and to subsequently use these animals to establish a further breeding nucleus of Cape mountain zebra at another suitable and safe reserve. Decentralization of this population and active attempts at prophylactic disease and parasite control seem imperative if this subspecies is to be safely protected for the future.

Considerable numbers of other animals (i.e. more than 500 springbok) exert a severe grazing pressure on this park which was primarily proclaimed for the preservation of the Cape mountain zebra. Apart from their direct effects on the grazing and therefore the possible threat which the apparent excessive numbers of these more common species may pose to the zebra, especially during very dry years, the high population densities of these other species have already resulted in heavy parasitic infestations in themselves. This seems to be particularly true in the springbok *Antidorcas marsupialis*. Post mortem examinations on a limited number of carcasses created the impression that heavy infestations of *Cooperioides antidorci* may, under certain circumstances, be responsible for mortalities in springbok. *Nematodirus spathiger* infestations were furthermore repeatedly associated with signs of enteritis and/or intestinal catarrh in heavily infested blesbok and mountain reedbuck. *Haemonchus contortus*, which is known to infest 19 antelope species (Neitz, 1965) and can be responsible for mortalities in blesbok (own observations), has been recovered from blesbok, springbok, black wildebeest and mountain reedbuck in the M.Z.N.P.

As with the zebra, the necessary precautions should also be taken to prevent the introduction of diseases and parasites to which these other species are susceptible. Furthermore, developing problems of localized overgrazing and concomitant superinfestation of certain areas with parasites may possibly be overcome by the well planned further distribution of watering points, as well as by the provision of mineral licks at strategic places in underutilized areas. Mineral licks, if adequately utilized, may also be used as a medium for the administration of anthelmintics, should parasitism become a real threat as may be foreseen under the present circumstances.

Acknowledgements

We wish to extend our thanks and appreciation to the Director of the National Parks Board for making the study material available. Special thanks are due to Mr. A. M. Brynard and Dr. G. de Graaff, Deputy

Director and Assistant Director (Other National Parks) respectively of the National Parks Board, for special arrangements. We also thank all other personnel of the National Parks Board, as well as the Onderstepoort Veterinary Research Institute, the S.A.I.M.R. (ectoparasite studies supported financially by the S.A. Medical Research Council) and Mrs. B. Young for their invaluable assistance in collecting and/or examining the sample material.

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NOTES ON THE PARASITOLOGY, PATHOLOGY AND BIO-PHYSIOLOGY OF SPRINGBOK IN THE MOUNTAIN ZEBRA NATIONAL PARK

by

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Abstract – Thirteen species of parasitic metazoa and two protozoa have been identified. Pathological effects are described where applicable. Serological tests for virus diseases were negative but biochemical analyses revealed certain mineral deficiencies. The possible decimating effects of the former are discussed and appropriate guide lines for control suggested.

During a preliminary survey in October, 1971 in the Mountain Zebra National Park (M.Z.N.P.) near Cradock, Cape Province, 10 live and eight dead springbok, *Antidorcas marsupialis*, were captured or culled. These were examined and the necessary specimens collected for subsequent analyses. The results of this preliminary survey can be very briefly summarized as follows:

Endoparasites

Haemonchus contortus was collected from the abomasum, *Cooperioides antidorci*, *Paracooperia serrata*, *Nematodirus* sp. and *Trichostrongylus faculatus* from the duodenum, *Agriostomum equidentatum* from the colon and *Cysticercus tenuicollis* from the abdominal cavity.

Cooperioides antidorci caused extensive duodenal lesions in some of the animals and it is suspected that this parasite may, under certain circumstances, be responsible for very adverse effects on super-infested springbok. The parasites (small nematodes) were found in numerous small but macroscopically visible glistening cysts. Microscopically it could be seen that many of the duodenal crypts, containing the parasites, had become occluded and cystic. The cystic lesions were present in the mucosa as well as in the submucosa, and in the latter the parasites were in some cases

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surrounded by considerable granulomatous reaction and fibrosis. In cross section, the helminths have 10 to 14 longitudinal ridges with cross striations.

The aetiology of the abomasal erosions and ulcerations has not yet been established without doubt but it is suspected that these lesions, as well as the mixed cell abomasitis, seen in some animals, might have been due secondarily to haemonchosis.

It is also suspected that endoparasites, such as *C. tenuicollis* and *A. equidentatum* and possibly others whose migratory patterns are still unknown, while migrating through the liver at some stage of their life cycle, could have been responsible for the lesions frequently seen in this organ. These lesions included localized patches of necrosis and subacute to chronic hepatitis, as well as proliferative and granulomatous reactions and fibrosis in some portal areas. Localized segmental eosinophilic endophlebitis of the portal veins was also observed which strengthens the suspicion of migrating parasites being involved.

Ectoparasites

The ticks, *Hyalomma rufipes*, *Rhipicephalus glabroscutatum* and *R. e. evertsi* and the lice, *Linognathus euchore*, *L. armatus* and *L. bedfordi* parasitised the sampled springbok.

H. rufipes caused extensive dermal necrosis and localized, superficial mastitis in one animal. The other external parasites were not associated with any lesions.

Sarcoptes scabiei, associated with severe mange, has recently been isolated from springbok in the Kalahari Gemsbok National Park (Young and Zumpt, ms.). Springbok in the M.Z.N.P., however, seem to be free of this potentially fatal infestation.

Protozoal, viral and bacterial diseases

Examination of blood smears revealed a *Cytauxzoon* sp. (Neitz, *pers. comm.*) while mild sarcosporidiosis was diagnosed by microscopic examination of the cardiac musculature of one animal.

Serological tests on serum samples failed to show antibodies against blue tongue, Rift valley fever or Wesselsbron disease.

No specific bacterial diseases were diagnosed although one very sick and debilitated animal suffered from severe, purulent pneumonia and another from otitis externa, both conditions apparently having been due to bacterial infection.

Nutrition, biochemistry and general bio-physiology

Liver-samples were collected from five adult springbok and analysed for trace-elements according to the techniques used by Boyazoglu, Barrett, Young and Ebedes (1972). The average figures (p.p.m. on wet basis) were: Mn (4,8), Cu (11,8), Co (13,4), Zn (126), Fe (183) and Mg (118).

These results were compared with those obtained from the analyses of liver-samples of three adult springbok from the Kalahari Gemsbok National Park. From these comparisons it appears that relative deficiencies of manganese, cobalt, magnesium and especially of copper may occur in the M.Z.N.P. Values for zinc and especially for iron were, on the contrary, higher for the latter park. When compared with average results obtained from analyses of samples from 250 wild mammals of 16 different species from the Kruger and Etosha National Parks (Boyazoglu, Barrett, Young and Ebedes, 1972), deficiencies of manganese, cobalt, magnesium and especially copper again seem to occur in the M.Z.N.P.

It is suspected that deficiencies of some of these trace elements, notably of copper and cobalt, as well as a possible phosphate deficiency, severe parasitism and inbreeding may be responsible for the apparent smaller size of these springbok, compared to springbok from some places elsewhere in the Republic of South Africa or South West Africa. The macro-element survey has not yet been completed but dental and other skeletal abnormalities observed point towards a possible deficiency of phosphorus. Excessive mineral deposits in the urine of slaughtered animals (in some individuals associated with mucosal haemorrhages of the urinary bladder) suggest the possible excessive intake of dietary calcium which may result in, or aggravate phosphorus deficiency. This supposition, however, still has to be evaluated by further research.

Electrophoretic and other analyses of serum and haemoglobin samples have also not yet been completed but the considerable increase of this population from about 20 individuals (1943) to more than 1 200 animals leaves no doubt as to the possibility that a remarkable degree of inbreeding must already be present in these springbok. Pathognomic clinical signs of inbreeding which have during the past few years repeatedly been encountered in an inbred population of springbok in the Warmbaths district of the Transvaal have, however, not yet been observed in springbok of the M.Z.N.P.

General remarks

Despite the prolific and very successful numerical increase of this population over the past few years, the continued and unrestricted increase of springbok in this relatively small National Park does not seem feasible and may eventually prove disastrous*. Optimal population density has apparently been exceeded and intra and interspecific competition has already become a reality. Excessive concentrations of animals weakened by nutritional deficiencies, parasitism and inbreeding are usually extremely liable to the development of catastrophes and special attention must preferably be paid in the case of this population to the advisability and possibilities of reduction campaigns, the introduction of new genetic material, mineral supplementation and possibly also to periodic and controlled low level anthelmintic treatment via mineral licks.

Acknowledgements

We wish to extend our thanks and appreciation to the Director of the National Parks Board for making the study material available. Special thanks are due to Mr. A. M. Brynard and Dr. G. de Graaff, Deputy Director and Assistant Director (Other National Parks) respectively of the National Parks Board, for special arrangements. We also thank all other personnel of the National Parks Board, the Onderstepoort Veterinary Research Institute, the S.A.I.M.R. (ectoparasite research supported financially by the S.A. Medical Research Council) and Mrs. B. Young for their invaluable assistance in collecting and/or examining the sample material.

**Towards the end of* 1972, *the numbers of springbok were reduced by* 700 *individuals – Eds.*

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Onderstepoort J. vet. Res., 49, 139–146 (1982)

HELMINTH AND ARTHROPOD PARASITES OF BLESBOK, *DAMALISCUS DORCAS PHILLIPSI*, AND OF BONTEBOK, *DAMALISCUS DORCAS DORCAS*

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ABSTRACT

HORAK, I. G., BROWN, MOIRA R., BOOMKER, J., DE VOS, V. & VAN ZYL, ELSA A., 1982. Helminth and arthropod parasites of blesbok, *Damaliscus dorcas phillipsi*, and of bontebok, *Damaliscus dorcas dorcas*. *Onderstepoort Journal of Veterinary Research*, 49, 139–146 (1982).

The helminth burdens of 8 blesbok shot in the north-eastern Orange Free State, 8 from the eastern Cape Province, 28 from the eastern Transvaal and 3 from the central Transvaal were determined. In addition, the arthropod burdens of 11 of these animals were ascertained. Twenty-one nematode species, 2 cestode species, 6 ixodid ticks, 2 lice and the larvae of 5 oestrid flies were recovered. Three of the nematode species, 2 of the oestrid flies and 4 of the tick species had apparently not previously been recovered from blesbok.

Thirty-one bontebok culled in the south-western Cape Province were examined for endoparasites and 8 of these animals were also examined for ectoparasites. They harboured 12 nematode species, 3 ixodid ticks, a louse and the larvae of an oestrid fly. In common with some of the blesbok they were parasitized by *Dictyocaulus magnus, Longistrongylus curvispiculum, Trichostrongylus axei, Nematodirus spathiger* and the larvae of a large *Gedoelstia* sp. Five of the nematode species, the larvae of the oestrid fly species and the 3 ixodid tick species had not previously been recorded from bontebok.

INTRODUCTION

Blesbok, *Damaliscus dorcas phillipsi*, are distributed in the Cradock and Cathcart districts in the eastern Cape Province, north and north-east through the north-eastern Cape Province and the Orange Free State to the southern Transvaal. Bontebok, *Damaliscus dorcas dorcas*, formerly distributed in the south-western Cape Province in the coastal area between Caledon and Mossel Bay, now survive only in a semi-captive state on enclosed land mainly around Bredasdorp and in the Bontebok National Park (Ansell, 1971). Round (1968) has listed the helminth parasites, Zumpt (1965) the oestrid larvae and Ledger (1980) the lice recovered from these animals. Horak (1980 a) has tabulated the helminth and arthropod parasites he has recovered from blesbok, while Verster, Imes & Smit (1975) have listed the helminths they have recovered from bontebok with those recorded by Ortlepp (1961, 1962).

The seasonal prevalence of the larvae of oestrid flies and of helminths in blesbok was determined in the northern Transvaal (Horak & Butt, 1977; Horak, 1978 a), a region considered to lie outside the original habitat of these animals (Ansell, 1971). Those blesbok were grazing Sour Bushveld (Acocks, 1975) at a low stocking density with tsessebe and roan antelope and were not examined for the presence of other ectoparasites. The numbers of parasites harboured by 2 bontebok, which died a few days after translocation from the Bontebok National Park to the National Zoological Gardens, Pretoria, were determined by Verster *et al.* (1975).

The present paper reports the worm burdens and some ectoparasite burdens of blesbok in 4 small nature reserves located in the north-eastern Orange Free State, the eastern Cape Province and the eastern and central Transvaal, and of bontebok in a small park in the south-western Cape Province.

MATERIALS AND METHODS

A total of 8 blesbok were shot at various times in the Golden Gate Highlands Park (28°31′S; 28°37′E; Alt. 1 798–2 731 m) near Clarens in the north-eastern Orange Free State, a park 4 792 ha in extent and situated in a region classified as Highland Sourveld (Acocks, 1975). It contains blesbok, black wildebeest, eland, oribi, red hartebeest, springbok and Burchell's zebra. A similar number of blesbok were shot in the Mountain Zebra National Park (32°15′S; 25°41′E; Alt. 1 200–1 957 m) near Cradock in the eastern Cape Province. This park, 6 536 ha in extent and situated in Karroid *Merxmuellera* Mountain Veld replaced by Karoo (Acocks, 1975), contains blesbok, black wildebeest, eland, gemsbok, mountain reedbuck, red hartebeest, vaal ribbok, steenbok, klipspringer, springbok and Cape mountain zebra.

Twenty-eight blesbok were shot in the Rob Ferreira Nature Reserve at Badplaas (25°57′S; 30°34′E; Alt. ± 1 067 m) in the eastern Transvaal. This reserve is situated in a region classified as Piet Retief Sourveld (Acocks, 1975) and is approximately 400 ha in extent and, in addition to blesbok, contains black wildebeest, eland, impala, oribi, springbok, tsessebe and Burchell's zebra, a total of approximately 450 animals. Two animals were shot during May 1978, 11 during June and 15 during July of the same year.

Three blesbok were shot during June 1981 in the Rietvlei Nature Reserve (25°53′S; 28°17′E; Alt. ± 1 500 m) to the south-east of Pretoria in the central Transvaal. This reserve, which is approximately 3 000 ha in extent, lies within a region classified as Bankenveld (Acocks, 1975) and, in addition to blesbok, contains black wildebeest, red hartebeest, eland, springbok, duiker, steenbok, oribi and Burchell's zebra.

Eight bontebok were shot during June 1975, 9 during September 1975, 6 during March 1976 and 8 during December 1979 in the Bontebok National Park (34°02′S; 20°25′E; Alt. 90–200 m) near Swellendam in the south-western Cape Province. The park is situated in Coastal Renosterbosveld (Acocks, 1975) and has an area of 2 786 ha. In addition to bontebok, it also contains vaal ribbok, springbok, Cape grysbok, steenbok, bushbuck and grey duiker.

The lungs and some of the livers of the blesbok and some of the lungs and livers of the bontebok were processed for worm recovery as described by Horak (1978 b), while the contents of their abomasa and small intestines were sieved separately over sieves with 38 μm apertures and that of their large intestines over sieves with 150 μm apertures. The contents of the sieves were formalinized and retained for future examination. The mucosae of the abomasa and intestinal tracts of all the blesbok at Badplaas and from near Pretoria and only those of the blesbok and the bontebok shot during December 1979 near Clarens, Cradock and Swellendam were digested with pepsin and HCl.

The nasal passages and paranasal sinuses of 2 blesbok from near Clarens, 2 from Cradock, 4 from Badplaas and 3 from near Pretoria and 8 bontebok from Swellendam

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Received 7 April 1982—Editor

were examined for oestrid larvae as described by Horak (1977) and their hearts washed for the recovery of these larvae, as described by Horak & Butt (1977). The cranial cavities and brain surfaces of the same 2 blesbok from Clarens and 2 from Cradock and 3 from near Pretoria and 8 bontebok from Swellendam were also examined for oestrid larvae.

The skins of the heads and of the bodies of 4 animals at Badplaas and the 3 from near Pretoria, plus all 4 legs of each animal from below the knee and hock joints with their skin intact were immersed in a tick detaching agent*. The skin of 1 side of the head and 1 side of the body, as well as 1 front leg and 1 back leg with their skin intact, of 2 blesbok at Clarens, 2 at Cradock and 8 bontebok at Swellendam were similarly processed. Thereafter the skins and legs were stored overnight in tightly closed plastic bags. The following morning they were scrubbed with brushes with 20 mm long steel bristles and thoroughly washed. The washings were sieved through sieves with 150 μm apertures and the contents of the sieves collected and preserved with formalin for future examination.

RESULTS

The mean helminth burdens of the blesbok from the Golden Gate and Mountain Zebra Parks are summarized in Table 1.

Ten nematode species were recovered from these animals. Eight of these were present in both parks, while *Nematodirus helvetianus* was present only in the Golden Gate reserve and *Nematodirus spathiger* only in the Mountain Zebra reserve. In general, the animals in the former reserve harboured more worms than those in the latter. The blesbok is a new host record for *Longistrongylus curvispiculum, Longistrongylus sabie* and *Nematodirus helvetianus*.

The ectoparasite burdens of the blesbok shot during December 1979 in the Golden Gate and Mountain Zebra Parks are summarized in Table 2.

Of the 7 species of ectoparasites recovered, only *Damalinia crenelata* was present on animals in both reserves.

The mean worm burdens of the blesbok from Badplaas are summarized in Table 3.

A total of 16 nematode and 1 cestode species were recovered from these animals. Every animal was infested with 4th state larvae of *Haemonchus* spp. and *Oesophagostomum* sp. and with adult *Dictyocaulus magnus, Longistrongylus albifrontis* and *Trichostrongylus thomasi*. With few exceptions they also harboured adult *Cooperia hungi, Cooperia yoshidai* and *Impalaia tuberculata*.

Fourth stage larvae of *Haemonchus* spp. and *Oesophagostomum* sp. constituted the major portion of the worm burdens of these 2 genera, while large numbers of 4th stage larvae of *Longistrongylus* sp., *Cooperia* spp. and *Impalaia* sp. were also recovered.

The first 2 animals shot had considerably more *Skrjabinema alata* than any other buck, but no other marked differences in worm burdens were noticeable between the various slaughter dates.

The ectoparasite burdens of 4 blesbok at Badplaas are summarized in Table 4.

TABLE 1 The mean helminth burdens of blesbok in the Golden Gate and Mountain Zebra Parks

No. of blesbok slaughtered	Date slaughtered	Mean numbers of helminths recovered												
		Dictyocaulus magnus	*Haemonchus* spp.			*Longistrongylus* spp.			*Trichostrongylus* spp.			*Nematodirus* spp.		
			H. bedfordi		*H. contortus*		*L. curvispiculum	*L. sabie	*T. axei*	*T. colubriformis*	*T. falculatus*		*N. helvetianus	*N. spathiger*
		Adult	4th	Adult	Adult	4th	Adult	Adult	Adult	Adult	Adult	4th	Adult	Adult
Golden Gate Highlands Park														
2	June 1975	17	0	13	0	0	1 338	100	163	25	25	0	3 375	0
2	Sep. 1975	14	0	70	0	0	115	135	15	0	0	0	75	0
2	March 1976	0	38	163	0	0	50	0	0	0	0	13	175	0
2	Dec. 1979	8	3	61	20	1	169	53	25	0	0	88	203	0
Mountain Zebra National Park														
2	June 1975	5	0	0	0	0	80	0	0	518	0	30	0	520
2	Sep. 1975	1	0	0	0	0	0	135	5	0	0	0	0	30
2	March 1976	0	50	63	0	0	0	0	0	63	0	50	0	63
2	Dec. 1979	0	1	14	0	0	0	0	1	0	13	75	0	60

4th = 4th stage larvae

* New host record

TABLE 2 The ectoparasite burdens of 2 blesbok shot in the Golden Gate Park and 2 blesbok shot in the Mountain Zebra Park during December 1979

Numbers of ectoparasites recovered												
Gedoelstia cristata		*Damalinia crenelata*		*Linognathus damaliscus*		*Boophilus decoloratus*		*Hyalomma marginatum turanicum*	*Rhipicephalus evertsi evertsi*		*Rhipicephalus glabroscutatum*	
1st	3rd	N	Adult	N	Adult	L	Adult	Adult	N	Adult	N	Adult
Golden Gate Highlands Park												
3	1	2	0	0	0	0	0	0	0	0	0	0
0	0	22	80	26	6	2	2	0	0	0	0	0
Mountain Zebra National Park												
0	0	0	2	0	0	0	0	4	0	16	0	18
0	0	8	14	0	0	0	0	0	8	4	2	8

1st, 3rd = 1st and 3rd larval stages L = Larvae N =Nymphae

* New host record

* Triatix: Coopers SA (Pty) Ltd

TABLE 3 The mean helminth burdens of blesbok shot in the Rob Ferreira Nature Reserve during 1978

No. of blesbok slaughtered	Date slaughtered	Mean numbers of helminths recovered																	Other helminths recovered
		Dictyocaulus magnus	*Haemonchus* spp.			*Longistrongylus albrifrontis*		*Trichostrongylus* spp.			*Cooperia* spp.			*Impalaia tuberculata*		*Oesophagostomum columbianum*		*Skrjabinema ovata*	
		A	4th	*H. bedfordi* A	*H. contortus* A	4th	A	4th	*T. axei* A	*T. thomasi* A	4th	*C. hungi* A	*C. yoshidai* A	4th	A	4th	A	Imm	A	
2	17 May	20	3 323	88	0	223	776	0	1	295	1 067	832	2 588	2 070	7 041	17	2	1 488	3 488	1 animal 2 *Gongylonema* sp.
6	19 June	15	3 835	21	13	410	740	1	1	244	949	1 042	967	1 780	3 821	40	1	104	192	1 animal 328 *T. colubriformis* and 1 510 *T. falculatus;* 1 animal 1 *T. falculatus;* 1 animal 1 *Moniezia* sp.
5	28 June	12	4 270	20	0	146	860	0	70	336	616	1 745	2 730	2 261	6 246	59	2	155	820	
15	19 July	16	5 645	18	42	781	650	1	12	466	1 832	1 162	2 127	2 280	4 851	54	3	93	103	1 animal 1 *Agriostomum equidentatum* and 1 *Trichuris* sp.; 1 animal 1 *Trichuris* sp.

A = Adult
Imm = Immature worms
4th = 4th stage larvae

TABLE 4 The ectoparasite burdens of 4 blesbok shot in the Rob Ferreira Nature Reserve at Badplaas

Date slaughtered	Numbers of ectoparasites recovered														
	**Gedoelstia* sp.			*Kirkioestrus minutus*	*Oestrus macdonaldi*			*Damalinia crenelata*		*Rhipicephalus appendiculatus*			*Rhipicephalus evertsi evertsi*			**Haemaphysalis* sp.
	1st	2nd	3rd	1st	1st	2nd	3rd	Nymphae	Adult	Larvae	Nymphae	Adult	Larvae	Nymphae	Adult	Adult
17 May 1978	138	5	45	2	2	19	43	1	3	6 212	1 354	30	564	336	0	0
17 May 1978	128	6	29	67	0	0	0	0	0	11 846	2 538	27	623	158	0	1
19 June 1978	7	13	21	0	0	0	0	1	0	3 928	1 043	0	329	396	0	0
19 June 1978	67	4	29	2	0	0	0	4	28	2 376	828	4	118	231	1	0

1st, 2nd, 3rd = 1st, 2nd and 3rd stage larvae

* New host record

These animals were infested with the larvae of a *Gedoelstia* sp., the mature 3rd stage larvae of which were very large and differed in certain characteristics from those of *Gedoelstia hässleri* and *Gedoelstia cristata*. They were also infested with larvae of *Kirkioestrus minutus* and *Oestrus macdonaldi*. In addition, they harboured all sages of development of *Rhipicephalus appendiculatus, Rhipicephalus evertsi evertsi* and *D. crenelata*.

The mean helminth and arthropod parasite burdens of the 3 blesbok shot in the Rietvlei Nature Reserve near Pretoria are summarized in Tables 5 & 6.

A total of 7 nematode species, 1 cestode, the larvae of 4 oestrid fly species, a louse and 2 ixodid ticks were recovered from these animals. Of the nematodes *Impalaia nudicollis* constituted the major portion of the burden of 2 of the blesbok, while the same 2 animals also had fairly large burdens of *C. yoshidai*.

No 1st stage *Gedoelstia* sp. larvae were seen in the eyes or recovered from the brains, cranial cavities, hearts or lungs of any of the blesbok, but they were recovered from the nasal passages, which also harboured 2nd and 3rd stage *G. cristata* larvae. The nasal passages of the 3 animals also contained 1st stage larvae of *K. minutus* but no 1st stage *Oestrus* spp. larvae. These, however, were recovered from the lungs of 2 animals.

The mean helminth burdens of the bontebok are summarized in Table 7.

The lungs and the abomasal and intestinal mucosae of only the 8 animals shot during December 1979 were processed for helminth recovery. All these animals were infested with *D. magnus* and *Protostrongylus capensis;* and 1 also harboured *Pneumostrongylus cornigerus*. The majority of these animals also had large burdens of 4th stage larvae of *Longistrongylus* spp. and *N. spathiger*. The lungs of the animals shot during September 1975 were examined for the presence of lungworms. All were infested with *P. capensis*, 2 with *P. cornigerus* and 1 with *D. magnus*.

A total of 9 gastro-intestinal nematode species were recovered from the bontebok. Of these *Cooperia curticei* was present in the animals shot during 1975 and 1976 but not during 1979. The bontebok is a new host record for *Longistrongylus curvispiculum, Longistrongylus namaquensis, Cooperia curticei, Agriostomum equidentatum* and *Trichostrongylus pietersi*.

The ectoparasite burdens of the 8 bontebok shot during December 1979 are summarized in Table 8.

Haemonchus spp.			*Trichostrongylus axei*	*Cooperia yosidai*		*Impalaia nudicollis*		*Skrjabinema alata*		*Trichuris* sp.	*Avitellina* sp.
	H. bedfordi	*H. contortus*									
4th	Adult	Adult	Adult	4th	Adult	4th	Adult	Imm	Adult	Adult	Scolices
70	0	75	70	75	975	280	0	100	225	0	0
75	6	5	10	370	1 925	770	5 750	50	325	1	1
1 055	26	24	50	970	4 750	1 375	19 275	0	0	0	0

Gedoelstia cristata			*Kirkioestrus minutus*	*Oestrus* spp.			*O. variolosus*	*Damalinia crenelata*		*Boophilus* sp.	*Rhipicephalus evertsi evertsi*		
					O. macdonaldi								
1st	2nd	3rd	1st	1st	2nd	3rd	3rd	Nymphae	Adults	Larvae	Larvae	Nymphae	Adults
55	12	2	90	0	2	7	0	1 148	688	8	356	144	2
129	11	9	147	3	15	30	0	6 260	4 256	0	78	30	0
31	20	17	94	8	14	23	1	128	88	0	360	192	0

1st, 2nd, 3rd = 1st, 2nd and 3rd stage larvae

TABLE 7 The mean helminth burdens of bontebok in the Bontebok National Park

No. of bontebok slaughtered	Month slaughtered	Mean numbers of helminths recovered											Other helminths recovered
		Dictyocaulus magnus	*Protostrongylus capensis*	*Haemonchus contortus*		*Longistrongylus* spp.			*Trichostrongylus axei*	**Cooperia curticei*	*Nematodirus spathiger*		
							**L. curvispiculum*	**L. namaquensis*					
		A	A	4th	A	4th	A	A	A	A	4th	A	
8	June 1975	—	—	0	0	0	3 903	584	153	38	44	1 459	
9	Sept 1975	—	Positive	0	0	7	1 177	169	72	17	35	1 125	1 animal positive *Dictyocaulus magnus;* 2 animals positive *Pneumostrongylus cornigerus;* 1 animal 2 **Agriostomum equidentatum;* 1 animal 4 390 **Trichostrongylus pietersi* and 4 390 *Trichostrongylus rugatus.*
6	March 1976	—	—	0	0	175	2 817	363	8	29	165	483	
8	Dec 1979	29	66	17	3	7 994	4 870	73	225	0	7 464	8 606	1 animal 4 *Pneumostrongylus cornigerus.*

4th = 4th stage larvae
A = Adult
* = New host record

TABLE 8 The ectoparasite burdens of 8 bontebok shot in the Bontebok National Park during December 1979

Numbers of ectoparasites recovered									
Gedoelstia sp.			*Damalinia* sp.		*Ixodes* sp.	**I. pilosus*	*Rhipicephalus* sp.	**R. nitens*	**Amblyomma marmoreum*
1st	2nd	3rd	Nymphae	Adult	Nymphae	Adult	Nymphae	Adult	Adult
59	26	79	12	22	0	0	5	318	0
81	36	15	4	0	2	1	5	343	0
70	25	42	0	0	6	0	7	79	0
111	19	61	0	10	0	0	2	366	0
42	16	41	0	8	0	0	8	18	1
44	25	66	0	6	0	3	4	152	0
43	31	23	0	0	0	2	2	73	0
83	28	38	0	12	7	4	4	83	0

1st, 2nd, 3rd = 1st, 2nd and 3rd larval stages
* New host record

All the buck were infested with the larvae of a *Gedoelstia* sp., the mature 3rd stage larvae of which were very large and similar in appearance to those recovered from the blesbok at Badplaas. A large proportion of the 1st stage larvae of this fly was recovered from the right ventricles of the hearts of these animals but no larvae were found in the cranial cavities. All were also infested with adult *Rhipicephalus nitens*.

Discussion

A total of 21 nematode and 2 cestode species were recovered from blesbok in the 4 parks. Of these only *Haemonchus bedfordi* and *Trichostrongylus axei* were present in animals from each region. The larvae of 5 oestrid flies and the immature and/or adult stages of 6 ixodid ticks and 2 lice were also recovered. Of these only *D. crenelata* was present on animals in each of the 4 parks.

The bontebok harboured 12 nematode species, the larvae of an oestrid fly, a biting louse and 3 ixodid tick species. Of these *D. magnus, L. curvispiculum, T. axei, N. spathiger,* and the larvae of a large *Gedoelstia* species were also recovered from some of the blesbok.

Golden Gate and Mountain Zebra Parks

The small number of nematodes recovered from blesbok in both these parks is probably largely due to the low stocking density. In addition, the particularly small numbers present in the antelope in the Mountain Zebra Park can be ascribed to the fact that this is a semi-arid region with a mean annual rainfall of 398 mm.

The majority of species recovered had previously been recorded from blesbok (Horak, 1978 a) or were present in the animals slaughtered at Badplaas. *L. curvispiculum,* however, had not previously been reported in blesbok. This nematode was originally described from Grant's gazelle (Gibbons, 1973) and has also been recovered from several wild ruminants in East Africa (Gibbons, 1977).

But for its presence in the blesbok in the Golden Gate Park and in springbok near Krugersdorp in the western Transvaal (Horak, Meltzer & De Vos, 1982), *N. helvetianus* has apparently not previously been recovered from wild ruminants.

Only 1 of the 2 blesbok examined in the Golden Gate Park was infested with larvae of *G. cristata*. Four of an additional group of 5 blesbok examined in the park at the same time were infested but harboured a total of only 23 larvae.

Linognathus damaliscus was originally described from material obtained from both bontebok, which is the type-host, and blesbok (Bedford, 1936), and the *Linognathus* sp. recovered from 1 of the blesbok at Golden Gate, has provisionally been assigned to this species. Ledger (1980), however, suggests that a detailed study of adequate material may indicate that the species on blesbok differ from those on bontebok and could be a separate species as proposed by Fiedler & Stampa (1956).

Few ticks were recovered from the animals in either of the reserves, the difference in the species recovered from the 2 localities being a reflection of the differences in their geographical distributions (Howell, Walker & Nevill, 1978).

Badplaas

The blesbok at Badplaas harboured a greater number and a considerably greater variety of helminth parasites than the blesbok at Lunsklip or near Pretoria (Horak, 1978 a). Although other buck ran with the blesbok at each of those localities, the smaller area of the reserve at Badplaas, coupled with the high stocking rate, probably accounted for the larger worm burdens and greater number of species recovered.

H. bedfordi was recently recovered from blesbok for the first time (Horak, 1978 a) and, although originally described from blue wildebeest and African buffalo by Le Roux (1929), it has been recovered from numerous antelope species (Round, 1968; Gibbons, 1979). It thus appears not to be particularly host specific.

T. thomasi was originally described from impala (Mönnig, 1932, 1933) and had apparently not been encountered in any other species. However, it has recently been recovered from springbok (Horak *et al.*, 1982) and blue wildebeest (Horak, unpublished data, 1978), and the fact that all the blesbok at Badplaas were infested indicates a considerably wider host range than was previously thought. Male worms of *C. hungi* were originally described from waterbuck (Mönnig, 1931) and females from tsessebe (Mönnig, 1932) and numerous other antelope species are also infested with this worm (Round, 1968). Impala examined at Boekenhout (Horak, 1978 b) and at Pafuri (Horak, 1980 b) also harboured *C. hungi,* and it is probable that, if *T. thomasi* and *C. hungi* are not specific parasites of blesbok, the presence of a herd of 122 impala in the confined space of the reserve at Badplaas, and presumably harbouring these parasites, ensured that the blesbok became infested.

Until recently *C. yoshidai* had been recovered only from reedbuck (Mönnig, 1939) and mountain reedbuck (Baker & Boomker, 1973). It has subsequently been found in blesbok (Evans, 1978), however, and its presence in virtually every animal at Badplaas indicates that it is well-adapted to this host.

Mönnig (1932) recovered *Oesophagostomum columbianum* from blesbok artificially infested with larvae of this worm. Its presence in naturally infested blesbok has been recorded, however, by Fourie (1951) and Ortlepp

(1961), and its recovery from a large number of African antelope species (Round, 1968) seems to indicate an old association.

The recovery of a single *Agriostomum equidentatum* from 1 of the 28 blesbok examined indicates that its presence is probably accidental and a result of the fact that 93 springbok, the antelope from which it was originally described (Mönnig, 1929), grazed the reserve with the blesbok.

The recovery of *S. alata* from blesbok at Lunsklip and in the Rietvlei Nature Reserve near Pretoria (Horak, 1978 a) and Badplaas and Rietvlei in the present survey, infers that it should be considered a parasite of blesbok, although it was originally described from sheep (Mönnig, 1932).

The large proportion of early 4th stage larvae of *Haemonchus* spp., *Longistrongylus* sp., *Cooperia* spp. and *Impalaia* sp. recovered is probably because the animals were all culled during the period May–July (winter) and that these nematodes were overwintering in the blesbok as arrested 4th stage larvae.

The fairly substantial numbers of adult *L. albifrontis*, *Cooperia* spp. and *I. tuberculata* recovered from the same animals are probably the result of the warm, frost-free winters experienced at Badplaas, which makes survival outside the host possible and removes the necessity for complete inhibition of development. Even these conditions were probably not favourable for the development and survival of the free-living stages of *Haemonchus* spp. and arrest in development was virtually complete. It seems likely that the same phenomenon accounted also for the large proportion of 4th stage larvae of *Oesophagostomum* sp. recovered.

The mature 3rd stage larvae of the *Gedoelstia* sp. recovered from blesbok at Badplaas gave rise to adult flies considerably larger than adult *G. cristata* or *G. hässleri*. Basson, Zumpt & Bauristhene (1963) have described a giant variety of *G. cristata*, which they assumed to be a hybrid between *G. hässleri* and *G. cristata*. As neither *G. hässleri* nor *G. cristata* larvae were recovered from the blesbok at Badplaas, it can be assumed that no adult flies of these species were present. Hence, the larvae recovered could hardly be a hybrid between these 2 flies and probably belong to a valid separate species.

K. minutus is a parasite of blue wildebeest (Zumpt, 1965) and it has been suggested by Horak, Boomker & De Vos (1980) that, as only 1st stage larvae were recovered from the blesbok at Badplaas, it may not be capable of completing its parasitic life cycle in this host. *O. macdonaldi* has been recovered from blesbok near Pretoria and near Lunsklip in the northern Transvaal (Horak & Butt, 1977). Third stage larvae of this fly appear to be present only from May–September (Horak & Butt, 1977).

The large burdens of immature *R. appendiculatus* present on the blesbok were probably due to 3 factors. Firstly, the time of the year, as peak immature activity occurs between March and September (Londt, Horak & De Villiers, 1979); secondly, the high stocking density in the reserve which thus supplies an abundance of hosts for all stages of development and, thirdly, the presence of eland, which are good hosts for adult ticks and which in turn give rise to large immature populations.

The large numbers of immature *R. evertsi evertsi* can also be ascribed to the 1st 2 of the above-mentioned 3 factors and to the presence of zebras in the reserve, as these animals are good hosts of the adults of this tick (Horak, unpublished data, 1980).

Rietvlei Reserve

The parasite burdens of the blesbok in this reserve are of interest, not only because they can be compared with those of the blesbok in other reserves, but also because they can be compared with those of 4 blesbok shot almost exactly 9 years previously in the same reserve (Horak & Butt, 1977; Horak, 1978 a).

In contrast to the blesbok at Badplaas, which harboured *I. tuberculata*, these animals were infested with *I. nudicollis*, a parasite also recovered from blesbok in the Percy Fyfe Nature Reserve in the northern Transvaal (Horak, 1978 a). Each of the 3 blesbok from the Rietvlei Reserve also harboured *C. yoshidai*, a parasite recovered from nearly all the animals at Badplaas but not recovered from the 4 blesbok shot 9 years previously in the Rietvlei Reserve (Horak, 1978 a).

Horak & Butt (1977) also recovered large numbers of 1st stage larvae (which they assumed to be *Oestrus* spp.), from the nasal passages of those 4 blesbok. One of those animals also harboured *Oestrus* spp. larvae in its lungs. At the time, the 1st stage larvae of *K. minutus*, which have only recently been described (Horak *et al.*, 1980), were not known. However, because of the findings in the 3 blesbok in the present survey in the Rietvlei Reserve, the 1st stage larvae recovered from the nasal passages of the previously examined blesbok were re-examined and found to be 1st stage larvae of *K. minutus*. Unfortunately, the larvae recovered from the lungs of 1 of those animals had been lost, and thus it could not be determined if they were indeed *Oestrus* sp. larvae.

It was also suggested by Horak & Butt (1977) that 3rd stage larvae of *O. macdonaldi* were present in blesbok only during the period May–Sepember, a suggestion now supported by the fact that 1 of the blesbok slaughtered at Badplaas during May 1978 harboured these larvae, as did the 3 blesbok now examined in the Rietvlei Reserve. They also suggested that, if blesbok in the Rietvlei Reserve were examined at other times of the year, they might be found to harbour *Oestrus variolosus* as well. The recovery of a single 3rd stage larva of *O. variolosus* from 1 of the animals now examined and from 3 black wildebeest culled a little later in the Rietvlei Reserve confirms that this parasite does occur in this reserve.

Each of the 3 blesbok was infested with larvae of *G. cristata*, and on re-examination of the larvae recovered from the 4 blesbok previously examined at Rietvlei it was found that all the larvae previously identified as *G. hässleri* were in fact also *G. cristata* larvae.

The presence of substantial numers of immature *R. evertsi evertsi* in the ears of the blesbok was probably due to the presence of zebras in the Rietvlei Reserve.

Bontebok Park

Although *D. magnus* was originally described from the closely related blesbok (Mönnig, 1932), it seems equally well adapted to bontebok. It would appear, however, that this parasite was not introduced into the present Bontebok Park with the bontebok when they were transferred thither from the old Bontebok Park near Bredasdorp during 1960, a fact also mentioned by Verster *et al.* (1975). This observation is supported by the fact that no *D. magnus* were recovered from the animals in the original park before they were transferred (Ortlepp, 1962). Springbok, which are also good hosts of *D. magnus*, were subsequently introduced into the new park (Penzhorn, 1971) and the infestation probably came with them. Both *Pneumostrongylus cornigerus* and *Protostrongylus capensis* were originally described from bontebok (Ortlepp, 1962).

Longistrongylus namaquensis was originally described from the abomasum of a sheep (Ortlepp, 1963), but has subsequently been found in springbok in the Bontebok National Park (Horak *et al.*, 1982). It may well prove to be a parasite of wild ruminants in common with the other members of this genus (Gibbons, 1977).

More than 60% of the total *Longistrongylus* spp. burdens of the animals culled during December 1979, the abomasal mucosae of which had been digested, were in the 4th stage of larval development. This can probably be ascribed to arrested development ensuring the survival of the nematode in a stable internal environment during a time when the external dry and hot conditions of summer in the western Cape Province are unsuitable for survival of the free-living stages. Unfortunately this statement cannot be substantiated from a comparison with the burdens of the animals slaughtered during June and September 1975 and March 1976. The abomasal mucosae of these animals had not been digested and, consequently, their burdens of *Longistrongylus* spp. larvae cannot be considered complete, as very large numbers of 4th stage larvae of this genus are frequently present in the mucosa of the abomasum.

The presence of large numbers of adult *N. spathiger* in adult bontebok is worth noting. In a helminth survey conducted in sheep in the Karoo, Viljoen (1969) found that once the sheep reached 12–15 months of age, regardless of the season of the year, fewer *N. spathiger* became adult. He thought that this was probably a manifestation of age resistance similar to that found against this and other species of the genus (Brunsdon, 1962 a). Whether the large proportion of adult *N. spathiger* found in the present survey was indicative of a well-adapted, definitive host/parasite relationship (Horak, 1980 b) or of a decrease in host resistance brought about by inadequate nutrition (Brunsdon, 1962 b) or by the presence of large burdens of other parasites, could not be determined within the limits of this survey.

Few *N. spathiger* larvae were recovered from the digested intestinal mucosae of the animals slaughtered during December 1979. Hence the larval burdens of this species in the animals culled during 1975 and 1976 can be taken as a reasonably accurate reflection of the actual number of larvae present. From these observations it would appear that a degree of arrested development in the 4th larval stage was present during December 1979.

Verster *et al.* (1975) recovered fairly large numbers of *Ostertagia hamata* and *N. spathiger* from the bontebok they examined during 1973. Although *O. hamata* was absent in all the bontebok examined in the present survey, *N. spathiger* was recovered in large numbers.

The recovery of larvae of a very large *Gedoelstia* sp. from the bontebok in the absence of larvae of either *G. cristata* or *G. hässleri* is further support for our contention that this is a valid, separate species. The fairly large numbers of 1st stage larvae found in the hearts of the antelope, while none were present around the brains, suggests that the larvae of these flies follow a migratory route from the cornea to the blood vessels, heart, lungs, trachea, pharynx and nasal cavity in preference to the route via the cornea, optic nerve, dura mater and foramina of the cribriform plate to the nasal cavity (Horak & Butt, 1977).

The *Damalinia* sp. recovered from the bontebok has only been identified to generic level, as it is probable that this is an unnamed new species (Ledger, 1980).

The large numbers of adult *R. nitens* recovered from the bontebok indicate that they are efficient hosts of this tick, which has a geographical distribution limited to the south-western Cape Province (Morel, 1969). The single adult *Amblyomma marmoreum* recovered is an indication of the presence in the park of a large number of tortoises, which this tick parasitizes (Hoogstraal, 1956).

ACKNOWLEDGEMENTS

We should like to thank the National Parks Board for placing the blesbok in the Golden Gate Highlands Park and the Mountain Zebra National Park and the bontebok in the Bontebok National Park at our disposal. The Board of Public Resorts also kindly made available the blesbok in the Rob Ferreira Nature Reserve. Sentrachem (Pty) Limited and Hoechst Pharmaceuticals (Pty) Limited furnished financial support for the survey at the Rob Ferreira Nature Reserve and Dr W. M. O'Donovan arranged the culling of the animals at this venue.

This research was also funded by the University of Pretoria and the Council for Scientific and Industrial Research.

The assistance of Mrs Evelyn L. Visser and Messrs J. V. Badenhorst, B. D. de Klerk, I. L. de Villiers, N. H. Jonker, P. C. Pieterse and H. Scott with processing the necropsies is gratefully acknowledged.

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Printed by and obtainable from the Government Printer, Bosman Street, Private Bag X85, Pretoria, 0001

Onderstepoort J. vet. Res. 55, 145–152 (1988)

PARASITES OF DOMESTIC AND WILD ANIMALS IN SOUTH AFRICA. XXIII. HELMINTH AND ARTHROPOD PARASITES OF WARTHOGS, *PHACOCHOERUS AETHIOPICUS,* IN THE EASTERN TRANSVAAL LOWVELD

I. G. HORAK[1], J. BOOMKER[2], V. DE VOS[3] and F. T. POTGIETER[4]

ABSTRACT

HORAK, I. G., BOOMKER, J., DE VOS, V. & POTGIETER, F. T., 1988. Parasites of domestic and wild animals in South Africa. XXIII. Helminth and arthropod parasites of warthogs, *Phacochoerus aethiopicus,* in the eastern Transvaal Lowveld. *Onderstepoort Journal of Veterinary Research,* 55, 145–152 (1988).

A total of 69 warthogs, *Phacochoerus aethiopicus,* were collected from 4 localities within the Kruger National Park, eastern Transvaal Lowveld. These animals harboured 16 nematode species, 2 trematodes, 1 or 2 species of adult cestodes and the larval stages of 4 cestodes. No pattern of seasonal abundance could be determined for any of the helminths.

The warthogs were also infested with 3 flea species, 1 louse species, 8 ixodid tick species. 1 argasid tick and the nymphae of a pentastomid. The seasonal abundance of fleas of the genus *Echidnophaga,* of the sucking louse *Haematopinus phacochoeri* and the ixodid ticks *Amblyomma hebraeum, Rhipicephalus appendiculatus, Rhipicephalus simus* and *Rhipicephalus zambeziensis* was determined.

INTRODUCTION

The prevalence of several endo- and ectoparasites of warthogs, *Phacochoerus aethiopicus,* in South West Africa/Namibia has recently been reported (Horak, Biggs, Hanssen & Hanssen, 1983). The warthogs were infested with 9 nematode species, 1 or 2 cestode species, 6 species of ixodid ticks, 1 argasid tick species, a flea and a louse species and the larvae of a dipteran fly. Only the spirurid stomach worm *Physocephalus sexalatus* and the sucking louse *Haematopinus phacochoeri* exhibited clear patterns of seasonal abundance.

The present paper describes a similar survey conducted on warthogs in the Kruger National Park in the eastern Transvaal Lowveld.

MATERIALS AND METHODS

Survey region

Warthogs were collected from 4 localities within the Kruger National Park. These were Skukuza (24° 58′ S, 31° 36′ E; Alt. 262 m), Crocodile Bridge (25° 22′ S, 31° 54′ E; Alt. 217 m) and Lower Sabie (25° 07′ S, 31° 55′ E; Alt. 180 m) all situated in a vegetation zone classified as Lowveld; and Pafuri (23° 27′ S, 31° 19′ E; Alt. 305 m) where the vegetation is classified as Mixed Bushveld (Acocks, 1975). Gertenbach (1983) has identified 35 landscape types within the Park. According to his classification Skukuza lies within a region classified as Thickets of the Sabie and Crocodile Rivers; Crocodile Bridge and Lower Sabie in *Sclerocarya caffra/Acacia nigrescens* Savanna; and Pafuri within the Limpopo/Levumbu Flood plains.

Survey animals

With the exception of June 1980, when 1 extra warthog was shot, 1 animal from the most recent litter of piglets (which are generally born in November or December) and 1 older animal were shot at Skukuza each month from January 1980 to January 1981. Except for 1 animal of approximately 11 months of age, 2 warthogs of 12 months or older were shot each month at Crocodile Bridge over the same period. A total of 53 warthogs were collected at the 2 localities in this manner.

In addition 5 warthogs were shot at Pafuri during July 1980 and 2 during October 1981; 2 were shot at Lower Sabie during July 1980, 3 were shot at Skukuza during October and November 1982; and 4 animals were shot at Crocodile Bridge during November 1982.

Parasite recovery

The carcasses of the warthogs shot at Skukuza, Crocodile Bridge and Lower Sabie were transported to the laboratory at Skukuza where they were processed for parasite recovery. Those shot near Pafuri were transported to a nearby field laboratory where they were similarly processed.

At the laboratories unattached fleas and ticks were collected and stored in 70 % alcohol. Thereafter the carcasses were skinned and the skins were processed for ectoparasite recovery as described by Horak, De Vos & De Klerk (1984).

Numerous fleas being deeply imbedded in the skin, were not loosened by the parasite recovery process, and could not be removed with forceps without damage. Consequently, they were counted *in situ* and a small number removed for identification. This procedure, however, made it impossible to determine the exact numbers of the stick-tight fleas *Echidnophaga inexpectata* and *Echidnophaga larina* separately.

The nasal passages and paranasal sinuses of the first 13 warthogs shot were cut open and examined for oestrid larvae as described by Horak (1977). When these contained no larvae no further nasal passages were examined.

The carcasses were eviscerated and all visible cestode cysts collected. The lungs, the livers and the gastro-intestinal tracts were processed for helminth recovery as described by Horak, De Vos & Brown (1983).

Parasite counts

The lung and liver washings were examined *in toto* under a stereoscopic microscope for helminths as were several of the digests of the gastro-intestinal mucosae. Representative samples of the remaining digests as well as of all the gastro-intestinal ingesta were examined under the same microscope. The remains of the gastro-intenstinal contents were examined macroscopically for large nematodes and for cestodes in a flat-bottomed tray.

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Received 4 May 1988—Editor

TABLE 1 The helminth parasite recovered from 52 warthogs in the Kruger National Park

Helminth species	Total numbers of helminths recovered				Number of warthogs infested
	3rd stage	4th stage	Adult	Total	
Ascaris phacochoeri	25	2	35	62	16
Impalaia tuberculata	0	236	566	802	11
Murshidia spp.	0	4 411	—	4 411	17
Murshidia hamata	—	—	87 506	87 506	39
Murshidia pugnicaudata	—	—	18 706	18 706	35
Oesophagostomum spp.	0	2 256	—	2 256	17
Oesophagostomum mocambiquei	—	—	52 291	52 291	43
Oesophagostomum mwanzae	—	—	5 185	5 185	26
Physocephalus sexalatus	196	36	666	898	25
Probstmayria vivipara	—	Millions	—	—	52
Strongyloides sp.	0	0	116	116	3
Trichostrongylus spp.	0	139	—	139	8
Trichostrongylus falculatus	—	—	50	50	1
Trichostrongylus instabilis	—	—	793	793	4
Trichostrongylus thomasi	—	—	7 892	7 892	39
Trichuris sp.	0	10	0	10	1
Schistosoma sp.	—	—	15	15	1
Moniezia/Paramoniezia sp.	—	—	58*	58	11
Echinococcus sp.		Cysts			8
Taenia crocutae		Cysticerci			4
Taenia hyaenae		Cysticerci			3
Taenia regis		Cysticerci			15

* Scolices

TABLE 2 The arthropod parasites recovered from 51 warthogs in the Kruger National Park

Arthropod species	Total numbers of arthropods recovered					Number of warthogs infested
Fleas	Adults				Total	
Echidnophaga inexpectata/larina	12 932				12 932	46
Moeopsylla sjoestedti	143				143	23
Lice	Nymphae		Adults		Total	
Haematopinus phacochoeri	2 902		533		3 435	34
Ixodid ticks	Larvae	Nymphae	Males	Females	Total	
Amblyomma hebraeum	3 777	3 014	1 028*	348* (24)	8 167	51
Boophilus decoloratus	112	63	39	24 (0)	238	29
Hyalomma truncatum	0	0	7	3 (0)	10	7
Rhipicephalus appendiculatus	—	1 537	—	—	1 537	23
Rhipicephalus appendiculatus/zambeziensis	904	—	27	10 (0)	941	20
Rhipicephalus evertsi evertsi	8	9	0	0	17	11
Rhipicephalus simus	0	0	387	173 (5)	560	27
Rhipicephalus zambeziensis	—	526	—	—	526	19
Argasid ticks	Larvae	Nymphae	Adults		Total	
Ornithodoros porcinus porcinus	0	374	0		374	27
Pentastomids		Nymphae			Total	
Linguatula nuttalli		91			91	18

* Including *A. hebraeum* 525 males, 128 females collected from a single male adult warthog

() Number of maturing female ticks, i.e. the idiosoma of *A. hebraeum* >9,0 mm; *B. decoloratus* >4,0 mm; *H. truncatum* >7,5 mm; *R. appendiculatus/zambeziensis* >5,0 mm, *R. simus* >6,0 mm

The cestodes were not specifically identified but belonged to the genera *Moniezia* or *Paramoniezia*. Ticks, lice and unattached fleas were counted by the methods described by Horak, Potgieter, Walker, De Vos & Boomker (1983). The larvae and adults of *Rhipicephalus appendiculatus* and *Rhipicephalus zambeziensis* were not separated and these were lumped as *Rhipicephalus appendiculatus/zambeziensis*. The length of the idiosoma of adult engorging female ticks of all species was measured. The *Ornithodoros* ticks recovered from the warthogs have been assigned to *Ornithodoros porcinus porcinus* on host preference as suggested by Walton (1962).

Blood parasites

Blood smears were prepared as soon as possible after death. Impression smears of the spleen and lymphnodes were made during necropsy. Smears were made from 18 animals in 3 localities: 8 each from Skukuza and Crocodile Bridge and 2 from Pafuri. All the smears were fixed in methanol, stained in 10 % Giemsa stain for 35

TABLE 3 A comparison of the burdens of *Amblyomma hebraeum* of warthogs examined during a normal and a dry year using the Mann-Whitney U-test

Months examined	Rainfall (mm) Feb–Nov	Number of warthogs examined (sex rations)	Mean numbers (range) of *A. hebraeum* recovered								
			Larvae	U (sign)	Nymphae	U (sign)	Males	U (sign)	Females	U (sign)	Total
Oct/Nov 1980	414,5	8 (1 male: 7 females)*	18,6 (0–35)		24,4 (11–44)		7,6 (2–28)		3,3 (1–11)		53,9
Oct/Nov 1982	175,4	7 (5 males: 2 females)*	416,0 (56–1233)	0 (<0,001)	259,7 (27–858)	8 (<0,01)	203,1 (12–75)	8 (<0,01)	88,6 (5–308)	16 (=0,052)	967,4

* There is no statistical difference between the burdens of the male and female warthogs (sign) = (significance)

min and examined in immersion oil under 1 000 × magnification.

Climatic data

Mean monthly minimum and maximum atmospheric temperatures and monthly rainfall were recorded at Skukuza.

RESULTS

Helminths

The total numbers of helminths recovered from 52 warthogs slaughtered at monthly intervals at Skukuza and Crocodile Bridge are summarized in Table 1 (the ingesta of 1 animal were mislaid).

Thirteen nematode species, 1 trematode, 1 or 2 cestode species and the larval stages of 4 cestodes were recovered. *Probstmayria vivipara, Murshidia hamata* and *Oesophagostomum mocambiquei* were the most abundant helminths recovered. A large proportion of the total numbers of the latter 2 worms came from a single animal, which harboured 5 000 adult *O. mocambiquei* and 38 200 adult *M. hamata*.

All the *Impalaia tuberculata* recocvered from the warthogs were considerably smaller than normal and the males' spicules were markedly reduced in length.

A young warthog, 1 month of age, was infested with *Strongyloides* sp. This was the only helminth recovered from this animal. No *Strongyloides* sp. were recovered from the piglets of 2 or 3 months of age, but the 4-month-old animal and an adult animal from Crocodile Bridge were also infested. No other warthogs harboured this parasite.

Ascaris phacochoeri, O. mocambiquei, P. sexalatus, Trichostrongylus thomasi and *Trichostrongylus instabilis* and *Moniezia/Paramoniezia* sp. were recovered from the 2-month-old warthog. *M. hamata* and *Murshidia pugnicaudata* were first encountered when the warthogs were 6 months of age and *Oesophagostomum mwanzae* in a 7-month-old animal.

No pattern of seasonal abundance could be determined for any of the helminths.

The animals shot at Skukuza and Crocodile Bridge during October and November 1982 harboured the same parasites as those examined 2 years earlier at these localities and in addition 1 harboured 28 adult *Haemonchus krugeri* and another 100 adult *Oesophagostomum santos-diasi*. Those examined at Pafuri harboured only *A. phacochoeri, I. tuberculata, M. hamata, M. pugnicaudata, O. mocambiquei, P. vivipara* and *Moniezia/Paramoniezia* sp. One was also infested with 2 *Gastrodiscus aegyptiacus*. The 2 arthogs examined at Lower Sabie harboured only *M. hamata, M. pugnicaudata, O. mocambiquei* and *T. thomasi*.

Two of the warthogs had unidentified adult filarid nematodes in the lymphatic vessels adjacent to peripheral and visceral lymph nodes and 13 had microfilariae in the lymph nodes and the circulating blood (Palmieri, Pletcher, De Vos & Boomker, 1985).

Arthropods

The total numbers of ectoparasites recovered from 51 warthogs slaughtered at monthly intervals at Skukuza and Crocodile Bridge are summarized in Table 2 (no preservative had been added to the skin scrubbings of 2 animals and these could not be examined).

These animals harboured 3 flea species, a louse species, 7 ixodid tick species, 1 argasid tick and the nymphae of a pentastomid. All the animals were infested with *Amblyomma hebraeum* and the majority with 1 or both *Echidnophaga* species.

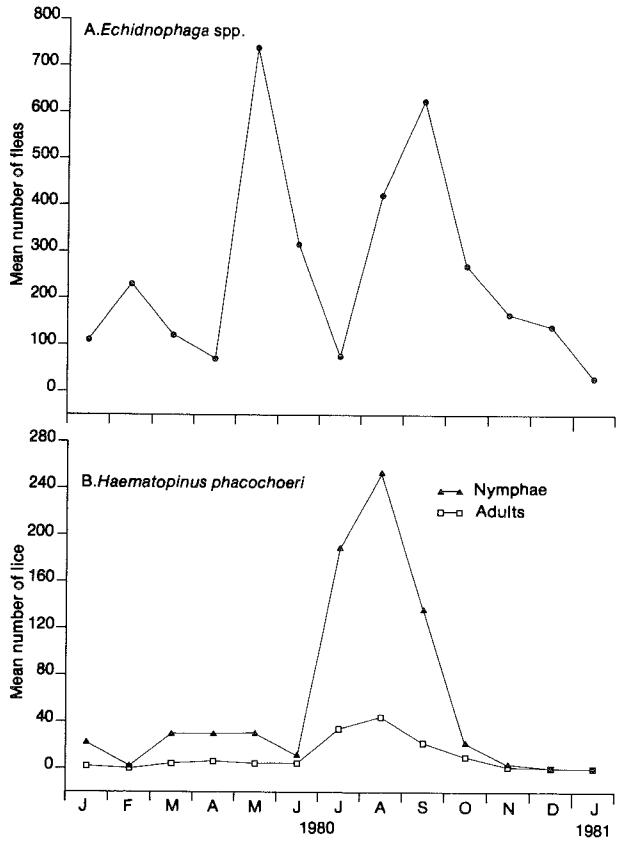

FIG. 1 The seasonal abundance of
A. *Echidnophaga* spp. and
B. *Haematopinus phacochoeri*
on warthogs in the Kruger National Park

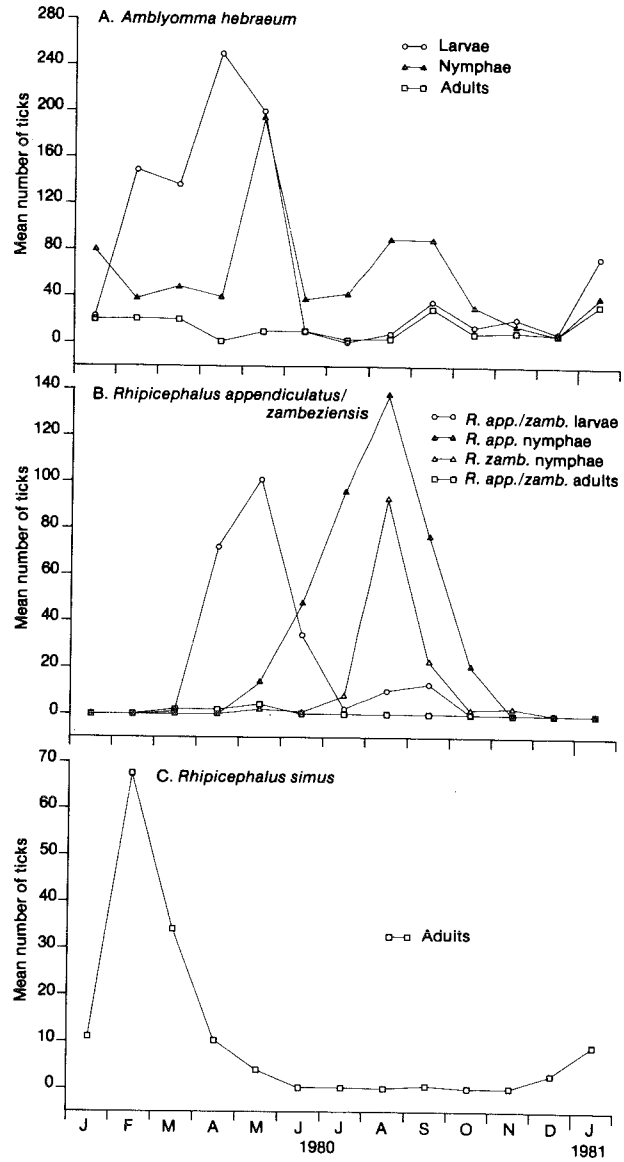

FIG. 2 The seasonal abundance of
A. *Amblyomma hebraeum* (excluding 1 animal with an exceptionally large adult burden)
B. *Rhipicephalus appendiculatus/zambeziensis* and
C. *Rhipicephalus simus*
on warthogs in the Kruger National Park

At 1 month of age a warthog piglet had acquired infestation with *H. phacochoeri* and with 3 ixodid tick species. At 2 months of age a piglet harboured *H. phacochoeri, Echidnophaga* spp., 4 ixodid tick species and *Ornithodoros porcinus porcinus*. The piglets were 5 months old before the nymphae of *Linguatula nuttalli* were recovered from 1 of them.

The numbers of *A. hebraeum* larvae, nymphae and males recovered from the animals shot at Skukuza and Crocodile Bridge in October and Novemvber 1982, during a severe drought, were significantly greater ($P<0,01$) than those recovered from the animals shot at the same sites during the same months in 1980, a year of normal rainfall. The tick burdens of the 2 groups of animals are summarized in Table 3.

With the exception of adult *Rhipicephalus kochi*, which were recovered in small numbers from 4 out of the 7 warthogs shot at Pafuri, the animals from Pafuri and those from Lower Sabie were infested with the same parasites as those shot at Skukuza and Crocodile Bridge.

Some of the arthropod parasites exhibited distinct patterns of seasonal abundance. These are graphically illustrated in Fig. 1 & 2.

Peak burdens of the 2 *Echidnophaga* species were present during May and September. Peak numbers of *H. phacochoeri* were recovered from July to September.

The larvae of *A. hebraeum* peaked from February to May, the nymphae during May and during August and September, while peak adult burdens were recovered from January to March and during September 1980 and January 1981. The larvae of *R. appendiculatus/zambeziensis* were recovered in the greatest numbers from April to June and the adults from March to May. The nymphae of both *R. appendiculatus* and *R. zambeziensis* peaked during August. Peak burdens of adult *Rhipicephalus simus* were present during February.

Blood parasites

All smears examined were negative for blood parasites.

Climate

The mean monthly atmospheric temperatures and total monthly rainfall at Skukuza for the period January 1980 to January 1981 are graphically illustrated in Fig. 3.

The highest maximum temperatures were recorded during January to April and December 1980 and during January 1981, and the lowest minimum temperatures during June and July 1980. Rain fell mainly during January and February 1980 and during November 1980 to January 1981. Total annual rainfall for 1980 at Skukuza was 660,0 mm. Total annual rainfall during 1982 (the year of the severe drought) was 437,2 mm, 202,5 mm of which fell during January 1982 and 59,3 mm during December 1982, leaving 175,4 mm for the remaining 10 months.

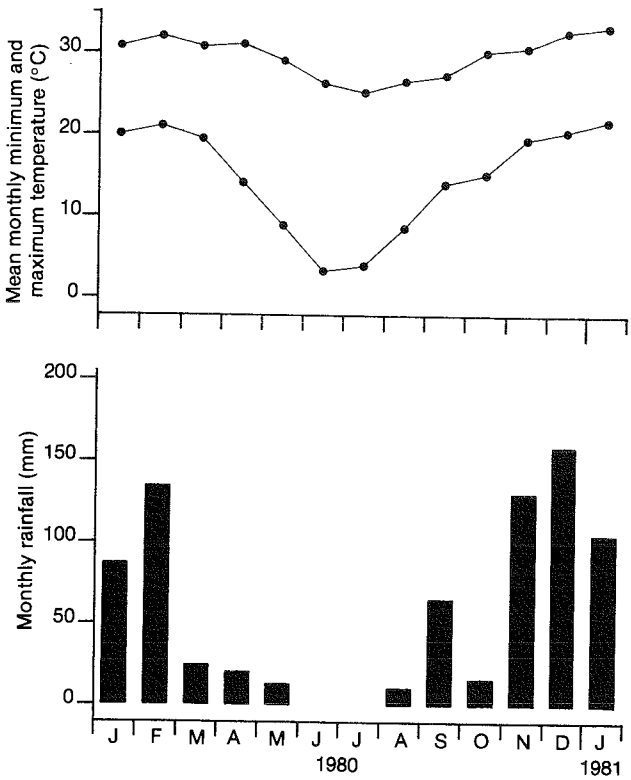

FIG. 3 Monthly mean minimum and maximum atmospheric temperatures and monthly rainfall at Skukuza from January 1980 to January 1981

Comment: The 60 year mean rainfall for February to November at Skukuza is 375,1 mm (Gertenbach, unpublished data, 1981). If the annual rainfall is calculated per season, i.e. from 1 July to 30 June (Gertenbach, 1980), the total for 1982/83 (275,6 mm) is the lowest ever recorded at Skukuza since records were started in 1919 (Gertenbach, unpublished data, 1985).

DISCUSSION

The warthogs examined in Namibia by Horak, Biggs, Hanssen & Hanssen (1983) harboured at least 10 helminth species and 10 arthropod species. Those examined in the Kruger National Park were infested with at least 19 helminth species (plus the larval stages of 4 cestodes), and 14 species of arthropod parasites. The helminths harboured in common by the 2 groups of warthogs are *O. mwanzae, P. sexalatus, P. vivipara* and *Moniezia/Paramoniezia* sp. and the arthropods are *E. larina, H. phacochoeri, Hyalomma truncatum, R. simus* and *O. porcinus porcinus*.

Helminths

Ascaris phacochoeri

This helminth has previously been recovered from warthogs in Zululand by Ortlepp (1939). The percentage of warthogs infested (30,8 %) in the present survey is identical to that of a group of domestic pigs infested with *Ascaris suum* (Horak, 1978a). These pigs had been consigned by farmers to the Pretoria Municipal Abattoir over a period of 1 year. The mean burden of adult *A. phacochoeri* (0,67 worms, range 0–7 worms) in the warthogs is, however, slightly lower than that of adult *A. suum* in the domestic pigs (2 worms, range 0–15 worms).

Impalaia tuberculata

This nematode, and the related species *Impalaia nudicollis,* are usually recovered from antelope, particularly impala *(Aepyceros melampus)* (Horak, 1978d) and blesbok *(Damaliscus dorcas phillipsi)* (Horak, 1978c). However, *I. nudicollis* has been recovered from warthogs in Namibia (Horak, Biggs, Hanssen & Hanssen, 1983), while those examined in the Kruger National Park harboured *I. tuberculata*. The measurements of both these worms from the warthogs were considerably smaller than those given by Gibbons, Durette-Desset & Daynes (1977) and Boomker (1977) in their reviews of the genus *Impalaia*. Contrary to the findings for *I. nudicollis* in the Namibian warthogs, in which few worms were adult, the majority of *I. tuberculata* in the Kruger National Park warthogs were adult (Table 1). Nevertheless the small size of the latter worms indicates that warthogs are not definitive hosts of this nematode.

Mushidia *spp.*

Ortlepp (1964) noted that there were no worms of the genus *Murshidia* in warthogs from Moçambique, while warthogs at Pilgrim's Rest and in Zululand were infested. Moçambique lies to the east and north of the Kruger National Park, Pilgrim's Rest to the west and Zululand to the south-east. It is possible that the warthogs from Moçambique examined by Ortlepp (1964), were by chance not infested with *Murshidia* spp. If, however, *Mushidia* spp. are indeed absent in warthogs in Moçambique it would be interesting to determine the exact boundary of infestation between the Kruger National Park and that territory. Very large burdens of worms of this genus are possible as 1 of the warthogs from Crocodile Bridge harboured a total of 48 000 immature and adult *M. hamata* and *M. pugnicaudata* and 1 from Pafuri harboured 40 775 immature and adult *M. hamata*.

Oesophagostomum *spp.*

Ortlepp (1964) identified *O. mocambiquei, O. mwanzae* and *O. santos-diasi* in material collected from warthogs in Moçambique and Pilgrims' Rest. No oesophagostomes were present in the specimens he examined from warthogs in Zululand. *O. mwanzae* has a very widespread distribution being present in warthogs in northern Moçambique and at Pilgrim's Rest (Ortlepp, 1964), in the Kruger National Park (present survey) and in northern Namibia (Horak, Biggs, Hanssen & Hanssen, 1983). In both Namibia and the Kruger National Park it was not the dominant oesophagostome, being outnumbered by *Oesophagostomum mpwapwae* at the former and *O. mocambiquei* at the latter locality.

The largest total number of immature and adult *Oesophagostomum* spp. recovered from a single warthog in the present survey was 7 400 worms, compared with 30 510 adult worms from a warthog in Namibia (Horak, Biggs, Hanssen & Hanssen, 1983).

Physocephalus sexalatus

Horak, Biggs, Hanssen & Hanssen (1983) recovered speak burdens of this nematode from January to March in warthogs from northern Namibia, while Horak (1978b) found that the related *Ascarops strongylina* was most abundant in domestic pigs in the Transvaal from November to March. No pattern of seasonal abundance could be determined in the present survey. Ortlepp (1964) has recorded both *A. strongylina* and *P. sexalatus* from bushpigs *(Potamochoerus porcus)* in the northern Transvaal, but *A. strongylina* has apparently not been recovered from warthogs (Round, 1968).

Probstmayria vivipara

As in the case of the animals in Namibia (Horak, Biggs, Hanssen & Hanssen, 1983) extremely large burdens, of which we did not attempt to ascertain the numbers, were present.

Strongyloides *sp.*

The fact that a 1-month-old animal and another young animal were infested with this worm seems to indicate a milk-borne route of infestation as in the case of *Strongyloides papillosus* in sheep and goats (Moncol & Grice, 1974).

Trichostrongylus *spp.*

We think that the small number of warthogs infested with *Trichostrongylus falculatus* and *T. instabialis*, and the small burdens of these worms in the infested warthogs, indicate that these are accidental infestations, as the true hosts are 1 or more of the antelope species in the park.

In the same way that *Trichostrongylus axei* appears to be an abomasal parasite in both domestic ruminants and horses (Soulsby, 1968), *T. thomasi* fills this niche in antelope (Round, 1968; Horak, Meltzer & De Vos, 1982; Horak, Brown, Boomker, De Vos & Van Zyl, 1982; Horak, De Vos & Brown, 1983; Boomker, Horak & De Vos, 1986), Burchell's zebras (Scialdo, Reinecke & De Vos, 1982) and warthogs (present survey).

Larval cestodes

The *Echinococcus* sp. cysts could have originated from adult cestodes of this genus present in a variety of carnivore species in the park. Adult *Taenia crocutae* and *Taenia hyaenae* are parasites of hyaenas while adult *Taenia regis* is found in lions (Round, 1968).

Arthropods

Echidnophaga *spp.*

Both *E. inexpectata* and *E. larina* are stick-tight fleas found firmly attached mainly along the softer undersides of the warthogs. *E. larina* is frequently encountered on warthogs, while *E. inexpectata* is supposedly a rarer parasite of these animals (Haeselbarth, Segerman & Zumpt, 1966). Although because of their stick-tight habit, it was not possible to obtain exact counts for either species in the present survey, the numbers of *E. inexpectata* generally seemed to exceed those of *E. larina*.

Whether the peak early winter and spring abundances of these fleas were real or due to large variations in individual burdens could not be ascertained. In Namibia no clear pattern of seasonal abundance of *E. larina* on warthogs could be determined (Horak, Biggs, Hanssen & Hanssen, 1983).

Moeopsylla sjoestedti

This is a jumping flea and was found mainly around the necks and heads of the warthogs. This species has been recovered from warthogs in east Africa from Kenya in the north to the eastern Transvaal Lowveld in the south (Haeselbarth *et al.*, 1966).

Haematopinus phacochoeri

This is the large sucking louse of warthogs (Ledger, 1980). In Namibia peak burdens were present on the warthogs in September of 1 year and during June of the following year (Horak, Biggs, Hanssen & Hanssen, 1983). In the present survey there was a clear peak of abundance of both nymphae and adults from July to September.

The months of peak abundance are also the months during which the available feed is at its driest. Perhaps the warthogs conserve energy during this time of nutritional stress by reducing the time spent on grooming and increasing the time devoted to foraging, hence the increasae in lice burdens.

Amblyomma hebraeum

Excluding the burdens of the 1 warthog carrying exceptionally large numbers of adult ticks (Table 2), warthogs must still be considered 1 of the preferred hosts of the adults of this tick. They carry more adult ticks than do blue wildebeest (Horak, De Vos & Brown, 1983), Burchell's zebras (Horak *et al.*, 1984), large and small carnivores (Horak, Jacot Guillarmmod, Moolman & De Vos, 1987) and impala (Horak, Boomker & De Vos, unpublished data, 1987) examined in the park. The ratio of larvae to nymphae to adults indicates a high proportion of adults, and this suggests that the warthog is a better host of adult *A. hebraeum* than of the immature stages.

The very large burdens of *A. hebraeum* recovered from the warthogs shot during the drought of 1982 do not imply that these ticks prefer dry conditions. They reflect rather that the animals' resistance was markedly reduced because of nutritional stress, and that they probably conserved energy by reducing grooming to a minimum, both these factors presumably leading to increased tick burdens (O'Kelly & Seifert, 1969).

The seasonal abundance of immature *A. hebraeum* on the warthogs is similar to that observed by Knight & Rechav (1978) on kudu, by Rechav (1982) on cattle, and by MacIvor & Horak (1984) on goats in the eastern Cape Province. The period of adult abundance on the warthogs, however, was longer than that observed on the other hosts.

Rhipicephalus appendiculatus/zambeziensis

Judging by the numbers recovered, warthogs are not important hosts of these ticks and particularly not of the adults. Burchell's zebra (Horak *et al.*, 1984) and more particularly impala and kudu (Horak, Boomker & De Vos, unpublished data, 1987) are better hosts. The seasonal abundance of all stages of development is similar to that of *R. appendiculatus* on impala and cattle in the northern Transvaal (Horak, 1982). The larvae of the 2 species were most abundant on the warthogs during the same months in which maximum abundance of this developmental stage has been recorded on blue wildebeest in the park (Horak, De Vos & Brown, 1983). The nymphal peak of *R. appendiculatus* on the warthogs corresponds to that on blue wildebeest and Burchell's zebra in the park (Horak, De Vos & Brown, 1983; Horak *et al.*, 1984).

Not only are *R. appendiculatus* and *R. zambeziensis* similar in appearance (Walker, Norval & Corwin, 1981), but their distributions overlap in certain regions and their seasonal abundance is similar (Norval, Walker & Colborne, 1982; present study).

Rhipicephalus kochi

This tick has previously been recovered from animals at Pafuri (Gertrud Theiler, unpublished data, 1964, as *Rhipicephalus neavei;* Horak, Potgieter, Walker, De Vos & Boomker, 1983). This is as yet the only site in the Republic of South Africa at which *R. kochi* is known to occur (Clifford, Walker & Keirans, 1983). The warthog does not appear to be a preferred host of this tick as no immature stages and few adults were recovered. Kudu, nyala and bushbuck examined at Pafuri during October 1981 harboured fairly large numbers of nymphae and adults (Horak, Potgieter, Walker, De Vos & Boomker, 1983), while only 1 of the 2 warthogs examined at the same time was infested and that with only 4 male *R. kochi*.

Rhipicephalus simus

In the park the adults of this tick seem to prefer monogastric animals such as Burchell's zebra (Horak *et al.*, 1984), carnivores (Horak *et al.*, 1987) and warthogs (present survey) rather than ruminants. Norval & Mason (1981) state that the larger ungulate and carnivore species are the most important wild hosts with warthogs frequently being parasitized.

The seasonal abundance on the warthogs roughly corresponds to the times of maximum abundance on Burchell's zebra in the park (Horak *et al.*, 1984) and on cattle in the northern Transvaal (Horak, 1982).

Other ixodid ticks

We consider *Boophilus decoloratus, H. truncatum* and *Rhipicephalus evertsi evertsi* to be accidental infestations on the warthogs. They are more a reflection of ticks present in the environment rather than host preference.

Ornithodoros porcinus porcinus

Chorley (1943) cited by Hoogstraal (1956) and Horak, Biggs, Hanssen & Hanssen (1983) recovered this tick on warthogs, although it is usually encountered in their burrows (Hoogstraal, 1956). In the present study 1 animal harboured 97 nymphae and another 107. These ticks had probably not completed feeding when the warthogs left their burrows in the mornings and some would presumably have remained on the animals until they returned to the burrows in the evenings. This would probably explain how the ticks spread from 1 burrow to the next.

Linguatula nuttalli

The recovery of the nymphae of this pentastomid from a high proportion of warthogs is a reflection of the large number of lions, the final host of this parasite, in the park. Horak, De Vos & Brown (1983) have recovered the nymphae of *L. nuttalli* from a fairly large proportion of blue wildebeest in the park.

Blood parasites

Trypanosomes, resembling *Trypanosoma vivax*, were seen by Curson (1928) in the blood of a single warthog in Zululand. Neitz (1931) examined blood, spleen and lymphnode smears of 56 warthogs from Zululand and, with the exception of 5 animals with microfilarial infections, no other haemoparasites were observed. In a subsequent investigation, 7 out of 34 warthogs in Zululand were found to be infected with microfilariae and a small *Theileria*-like piroplasm was found in the blood of 1 of these animals (Neitz, 1933). According to Neitz (1933) this was the 1st observation of small piros in the red cells of a warthog. No trypanosomes were seen.

In the persent survey an effort was made to detect *Theileria*-like parasites in the blood smears of the warthogs, but none were found. More animals from different geographical regions should be examined, however, as vector distribution may play a role in the prevalence of this parasite.

ACKNOWLEDGEMENTS

We wish to express our thanks to the National Parks Board of Trustees who made the warthogs available to us. We gratefully acknowledge the technical assistance of Mrs Moira R. Brown and Mr B. D. de Klerk. Dr E. M. Nevill of the Veterinary Research Institute, Onderstepoort, pointed out the differences between *E. larina* and *E. inexpectata*, and Dr Jane B. Walker, of the same institute, identified *R. kochi*. Prof. Anna Verster, of the Faculty of Veterinary Science, University of Pretoria, identified the larval stages of the cestodes.

This research was funded by the University of Pretoria and the Council for Scientific and Industrial Research.

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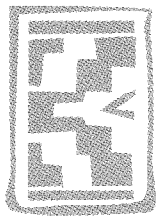
Printed by the Government Printer, Private Bag X85, Pretoria, 0001

Onderstepoort Journal of Veterinary Research, 65:137–141 (1998)



RESEARCH COMMUNICATION

Helminths and bot fly larvae of wild ungulates on a game ranch in Central Province, Zambia

U. ZIEGER[1], J. BOOMKER[2], A.E. CAULDWELL[1] and I.G. HORAK[2]*

ABSTRACT

ZIEGER, U., BOOMKER, J., CAULDWELL, A.E. & HORAK, I.G. 1998. Helminths and bot fly larvae of wild ungulates on a game ranch in Central Province, Zambia. *Onderstepoort Journal of Veterinary Research*, 65:137–141

Helminths and bot fly larvae were collected from 11 wild ungulate species on a game ranch in the Central Province of Zambia. New host-parasite records are: *Calicophoron* sp. from defassa waterbuck *Kobus ellipsiprymnus defassa* and Kafue lechwe *Kobus leche kafuensis*; *Avitellina centripunctata*, *Gaigeria pachyscelis* and *Gedoelstia cristata* from tsessebe *Damaliscus lunatus lunatus*; *Cooperia rotundispiculum* from common reedbuck *Redunca arundinum*; *Dictyocaulus filaria* from greater kudu *Tragelaphus strepsiceros*; *Dictyocaulus* sp. from tsessebe and defassa waterbuck and *Strobiloestrus* sp. from sable antelope *Hippotragus niger*. Most of the other parasites collected are first records for Zambia and thus extend the distribution ranges of several species.

Keywords: Bot fly larvae, helminths, ungulates, Zambia

INTRODUCTION

Since the first private ranches were licensed in 1989 game ranching is a growing industry in Zambia. The opportunity arose to collect parasites on one of these ranches during meat inspection of wild animals that had been shot either for venison, for trophies or because of injuries. The purpose of this investigation was to document new host-parasite records and to extend records of the distribution ranges of parasites of African ungulates. The animals' parasite burdens were not counted, but merely estimated subjectively.

MATERIALS AND METHODS

The animals were all examined on Mtendere Game Ranch (15°05´S, 28°15´E) situated approximately 20 km north of Lusaka in the Chisamba District of Central Province, Zambia. The ranch covers an area of 960 ha and lies within the miombo woodland zone of Zambia. At the time of the investigation it accommodated 18 larger wildlife species at a stocking density of one large stock unit per 4,7 ha.

Thirty-eight animals were examined between December 1995 and November 1996, comprising one Burchell's zebra *Equus burchellii*, 12 impala *Aepyceros melampus*, three tsessebe *Damaliscus lunatus lunatus*, one Lichtenstein's hartebeest *Sigmoceros lichtensteinii*, two eland *Taurotragus oryx*, three bushbuck *Tragelaphus scriptus*, four greater kudu *Tragelaphus strepsiceros*, two sable antelope *Hippotragus niger*, six defassa waterbuck *Kobus ellipsiprymnus defassa*, two Kafue lechwe *Kobus leche kafuensis*, one puku *Kobus vardonii* and one common reedbuck *Redunca arundinum*. Immediately after death their carcasses were transported to a nearby abattoir. The thorax and abdominal cavity were opened, examined for helminths and eviscerated. The gastro-intestinal tract was opened in its entirety, and its contents, together with the thoracic organs, liver, kidneys, paranasal sinuses and skins were examined for parasites

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Accepted for publication 2 April 1998—Editor

according to standard necropsy procedures. Macroscopically visible parasites or samples of these parasites were collected and stored in 70% ethyl alcohol for later identification.

RESULTS AND DISCUSSION

The trematode and cestode species recovered are listed in Table 1, the nematodes in Table 2 and the bot fly larvae in Table 3. The tables include references to the first record of each parasite per host species in their natural environment, as well a comment as to whether this is a first record for Zambia.

Eight new host-helminth associations were recorded in this study. As only a few studies on the helminths of wildlife have ever been undertaken in Zambia, most of the findings are new for this country. Two of the bot fly larvae recovered are also new host-parasite records.

The wild ruminants generally appeared to harbour small burdens and in most cases only a few parasites were encountered in each individual. However, *Calicophoron* sp. as well as *Stilesia hepatica* was found in large numbers in the defassa waterbuck. The single Burchell's zebra examined seemed to be heavily infected with *Gastrodiscus aegyptiacus*, *Anoplocephala perfoliata* and *Strongylus vulgaris*.

It would appear as if several of the helminth species collected in this study were not particulariy host specific, as they were often found in more than one host species. The high stocking density of wildlife on the ranch would facilitate such cross-infection (Horak

TABLE 1 Trematodes and cestodes recovered from wild ungulates on a game ranch in Central Province, Zambia

Host and helminth species	Number of animals infected	First record	New record for Zambia
Burchell's zebra (1 animal)			
Gastrodiscus aegyptiacus	1	Le Roux 1932	No
Anoplocephala perfoliata	1	v. Linstow 1901	Yes
Impala (12 animals)			
Calicophoron sp.	1	Ortlepp 1961[a]	Yes
Stilesia hepatica	0	Meeser 1952	Yes
Cysticercus sp.	1	Meeser 1952	No
Moniezia benedeni	2	Hudson 1934	Yes
Tsessebe (3 animals)			
Calicophoron sp.	1	Eduardo 1982a, b	Yes
Avitellina centripunctata	1	This paper	Yes
Eland (2 animals)			
Moniezia benedeni	1	Hudson 1934	Yes
Bushbuck (3 animals)			
Stilesia hepatica	1	Fuhrman 1909	Yes
Greater kudu (4 animals)			
Fasciola gigantica	1	Condy 1972	No
Sable antelope (2 animals)			
Calicophoron sp.	1	Ortlepp 1961[a]	Yes
Defassa waterbuck (6 animals)			
Calicophoron sp.	6	This paper	Yes
Fasciola gigantica	1	Stunkard 1929	Yes
Stilesia hepatica	6	Baer & Fain 1955	Yes
Kafue lechwe (2 animals)			
Calicophoron sp.	1	This paper	Yes
Fasciola gigantica	1	Gallagher *et al.* 1972	No
Schistosoma sp.	1	Le Roux 1932	No

[a] *C. calicophorum*

1980). The presence of *Haemonchus contortus* on the ranch warrants attention as it is established in five host species. It is a bloodsucking parasite that can be pathogenic even at low levels of infection. *Haemonchus* sp. infection was suspected as the main cause of mortality in sable antelope in Zimbabwe under particularly moist conditions (Grobler 1981). Another potentially lethal parasite is *Fasciola gigantica*, which has been incriminated in mortalities in several wildlife species (Hammond 1972; Condy 1972; Knottenbelt 1990). However, in the present study only three animals were infected. Despite repeated intensive searches involving all water sources on the ranch for the fresh water snail *Lymnaea natalensis*, the principle intermediate host of this fluke in southern Africa, only two empty shells were found

TABLE 2 Nematodes recovered from wild ungulates on a game ranch in Central Province, Zambia

Host and nematode species	Number of animals infected	First record	New record for Zambia
Burchell's zebra (1 animal)			
Cylicocyclus insigne	1	Le Roux 1932	No
Draschia sp.	1	Mönnig 1928[a]	No
Strongylus vulgaris	1	Leiper 1909	Yes
Impala (12 animals)			
Cooperioides hamiltoni	1	Mönnig 1932b	Yes
Cooperioides hepaticae	4	Ortlepp 1938	Yes
Cooperioides sp.	3	Mönnig 1932b[b]	Yes
Gaigeria pachyscelis	1	Meeser 1952	Yes
Haemonchus contortus	1	Meeser 1952	Yes
Tsessebe (3 animals)			
Agriostomum cursoni	1	Mönnig 1932a	Yes
Dictyocaulus sp. females	2	This paper	Yes
Gaigeria pachyscelis	1	This paper	Yes
Impalaia sp. females	1	Boomker 1977[c] Gibbons *et al* 1977	Yes
Lichtenstein's hartebeest (1 animal)			
Haemonchus contortus	1	Le Roux 1934	No
Eland (2 animals)			
Cooperia rotundispiculum	1	Boomker 1991	Yes
Haemonchus contortus	1	Mönnig 1933	Yes
Oesophagostomum sp.	1	Mönnig 1932b[d]	Yes
Greater kudu (4 animals)			
Agriostomum gorgonis	1	Le Roux 1934	No
Cooperia rotundispiculum	1	Boomker *et al.* 1991	Yes
Dictyocaulus filaria	1	This paper	Yes
Elaeophora sagitta	3	Mönnig 1926	Yes
Haemonchus contortus	1	Veglia 1919	Yes
Defassa waterbuck (6 animals)			
Dictyocaulus sp. females	1	This paper	Yes
Kafue lechwe (2 animals)			
Haemonchus contortus	1	Le Roux 1930	Yes
Reedbuck (1 animal)			
Cooperia rotundispiculum	1	This paper	Yes
Setaria bicoronata	1	Yeh 1959	Yes

[a] *D. megastoma*
[b] *C. hamiltoni*
[c] *I. tuberculata*
[d] *O. walkeri*

TABLE 3 Bot fly larvae recovered from wild ungulates on a game ranch in Central Province, Zambia

Host and bot fly species	Number of animals infected	First record	New record for Zambia
Burchell's zebra (1 animal)			
Gasterophilus haemorrhoidalis	1	Zumpt 1965	No
Gasterophilus meridionalis	1	Zumpt 1965	No
Gasterophilus nasalis	1	Zumpt 1965	No
Gasterophilus pecorum	1	Zumpt 1965	Yes
Gasterophilus ternicinctus	1	Zumpt 1965	No
Tsessebe (3 animals)			
Gedoelstia cristata	1	This paper	Yes
Oestrus variolosus	1	Zumpt 1965	No
Sable antelope (2 animals)			
Strobiloestrus sp.	1	This paper	Yes
Kafue lechwe (2 animals)			
Strobiloestrus sp.	1	Zumpt 1961[a]	No

[a] *S. vanzyli*

(Zieger 1998). It is possible that some *F. gigantica* were introduced onto the ranch with their mammal hosts during the initial game stocking programme in 1990/1991. If indeed there are no intermediate snail hosts on the ranch, the infection could be self-limiting.

ACKNOWLEDGEMENTS

We thank Mr and Mrs M. O'Donnell who provided U. Zieger and A.E. Cauldwell with accommodation and permitted us to undertake this study on their ranch. We are grateful to Mr C. Harvey, whose abattoir facilities were used.

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Onderstepoort J. vet. Res., 58, 195–202 (1991)

PARASITES OF SOUTH AFRICAN WILDLIFE. VIII. HELMINTH AND ARTHROPOD PARASITES OF WARTHOGS, *PHACOCHOERUS AETHIOPICUS*, IN THE EASTERN TRANSVAAL

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ABSTRACT

BOOMKER, J., HORAK, I. G., BOOYSE, D. G. & MEYER, SANTA, 1991. Parasites of South African wildlife. VIII. Helminth and arthropod parasites of warthogs, *Phacochoerus aethiopicus*, in the eastern Transvaal. *Onderstepoort Journal of Veterinary Research*, 58, 195–202 (1991)

Helminth and arthropod parasites were collected from 41 warthogs, *Phacochoerus aethiopicus*, in the Hoedspruit Nature Reserve, eastern Transvaal. This reserve consists of a military base, which is a restricted area and is surrounded by a reserve, which is open to the public. Eleven nematode species, 1 or 2 cestode species and the larvae of 2 cestode species were recovered from the animals in the reserve, and 8 nematode species and 1 or 2 cestode species were recovered from those in the military base.

Oesophagostomum spp. were generally most abundant in warthogs in the reserve during the cooler months of the year, while *Probstmayria vivipara* also occurred in peak numbers during the cooler months, with an additional peak in October and November 1988 in warthogs in the reserve and the base, respectively. No pattern of seasonal abundance could be determined for the other helminth species.

The warthogs also harboured 8 ixodid and 1 argasid tick species, 3 flea species and 1 louse species. Adult and immature *Haematopinus phacochoeri* were most numerous during August and September, and the largest numbers of adult *Rhipicephalus simus* were present from December to April.

INTRODUCTION

The seasonal abundance of endo- and ectoparasites of warthogs, *Phacochoerus aethiopicus*, in northern Namibia and in the Kruger National Park (KNP) in the eastern Transvaal have recently been reported (Horak, Biggs, Hanssen & Hanssen, 1983; Horak, Boomker, De Vos & Potgieter, 1988). The warthogs from Namibia were infested with 9 nematode species, 1 or 2 cestode species, 6 ixodid tick species, 1 argasid tick species, a flea and a louse species and the larvae of a calliphorid fly. Those from the KNP harboured 13 nematode species, 1 trematode species, 1 or 2 cestode species, the larval stages of 4 cestode species, 7 ixodid tick species, 1 species of argasid, 3 flea species, 1 louse species and the nymphs of a pentastomid.

This paper describes a similar survey conducted on warthogs in the Hoedspruit Nature Reserve which is also situated in the eastern Transvaal Lowveld.

MATERIALS AND METHODS

Survey area

The warthogs were all shot in the Hoedspruit Nature Reserve (HNR) which is situated in a vegetation zone classified as Lowveld (Acocks, 1988). The temperature is warm to hot in summer and mild in winter, and frost does not occur.

The HNR is owned by the South African Defence Force and comprises approximately 4 000 ha. It consists of an inner area of about 2 000 ha, the restricted military base, around which lies another 2 000 ha, the reserve, which is open to the public. The base is separated from the reserve by a series of security fences, thus making it impossible for warthogs on either side to pass through. The outer fence of the reserve, however, is of such a nature that warthogs from the surrounding privately owned game farms can pass through with ease.

Climatological data

The mean monthly maximum and minimum atmospheric tempatures as well as the total monthly rainfall were recorded during the survey period.

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Received 23 May 1991—Editor

Survey animals

With the exception of March 1989, when none could be located, warthogs were shot each month for 12 consecutive months from August 1988 to July 1989. Although often unsuccessful, an attempt was made at each occasion to collect the same number of warthogs of the same ages and sexes from the reserve and the base. A total of 41 warthogs was shot, of which 5 adult males, 11 adult females, 5 subadult males, 2 subadult females 1 juvenile male and 4 juvenile females were shot in the reserve and 1 adult male, 4 adult females, 2 subadult males, 2 subadult females, 1 juvenile male and 3 juvenile females were shot on the base.

Parasite recovery

The carcasses were transported to a field laboratory where they were eviscerated and macroscopically visible parasites removed and preserved in 70 % alcohol.

The carcasses were skinned and eviscerated, and the gastro-intestinal tracts were divided into the stomachs, the small intestines and the large intestines, and placed in shallow, flat-bottomed plastic trays. The stomachs were cut open and the ingesta carefully removed so as not to disturb the underlying mucosa. The ingesta were discarded, but the stomach was thoroughly washed in normal saline and the volume of the resulting suspension measured. The small and the large intestines were opened separately with bowel scissors and washed in saline. The washings were added to the respective ingesta. The volumes of the ingesta were measured and poured into separate plastic buckets. A $\frac{1}{4}$th aliquot by volume was made of the ingesta of each of the small intestines and a $\frac{1}{5}$th aliquot of the ingesta of each of the large intestines. The worms in the various aliquots as well as those in the various stomach contents were killed by adding an equal volume of boiling saline to each. The suspensions were then individually washed over a sieve with apertures of 0,15 mm and the residues preserved in separate bottles in 10 % formalin. Digests of the gastro-intestinal mucosae were not done.

The hearts, lungs and livers of the first 16 animals were processed for helminth recovery as described by Boomker, Horak & De Vos (1989) and examined. When no parasites were found, these organs were no longer processed or examined.

TABLE 1 Amended list of the helminth parasites of warthogs in the Republics of South Africa and Namibia with reference to the first record and the authors of the descriptions used to assist with the identification

Helminth species	First record	Identification
Trematodes		
Gastrodiscus aegyptiacus Railliet, 1893	Horak *et al.*, 1988	+
Schistosoma sp.	Horak *et al.*, 1988	+
Cestodes		
Echinococcus sp. larvae	Horak *et al.*, 1988	+
Moniezia mettami Baylis, 1934	Ortlepp, 1964	Baylis, 1934
Paramoniezia phacochoeri Baylis, 1927	Baylis, 1927	Baylis, 1927
Taenia crocutae larvae	Horak *et al.*, 1988	+
Taenia hyaenae larvae	Horak *et al.*, 1988	+
Taenia regis larvae	Horak *et al.*, 1988	+
Nematodes		
Ascaris phacochoeri Gedoelst, 1916	Ortlepp, 1939	Ortlepp, 1939
Cooperia hungi Mönnig, 1931	This paper	Gibbons, 1981
Haemonchus krugeri Ortlepp, 1964	Horak *et al.*, 1988	+
Impalaia nudicollis Mönnig, 1931	Horak *et al.*, 1983	+
Impalaia tuberculata Mönnig, 1923	Horak *et al.*, 1988	Boomker, 1977
Microfilaria sp. (*sensu* Neitz, 1931)	Neitz, 1931	+
Microfilariae	Palmieri *et al.*, 1985	+
Murshidia hamata Daubney, 1923	Daubney, 1923	Daubney, 1923
Murshidia pugnicaudata (Leiper, 1909)	Daubney, 1923	Daubney, 1923
Odontogeton phacochoeri Allgrén 1921	Allgrén, 1921*	+
Oesophagostomum mocambiquei Ortlepp, 1964	Ortlepp, 1964	Ortlepp, 1964
Oesophagostomum mpwapwae Duthy, 1947	Horak *et al.*, 1983	+
Oesophagostomum mwanzae Daubney, 1924	Ortlepp, 1964	Ortlepp, 1964
Oesophagostomum roubaudi Daubney, 1926	Horak *et al.*, 1983	+
Oesophagostomum santosdiasi Ortlepp, 1964	Ortlepp, 1964	+
Oesophagostomum simpsoni Goodey, 1924	Ortlepp, 1964	+
Physocephalus sexalatus Diesing, 1861	Horak *et al.*, 1983	Yorke & Maplestone, 1926
Probstmayria vivipara Ransom, 1911	Le Roux, 1940	Yorke & Maplestone, 1926
Strongyloides spp.	Horak *et al.*, 1988	+
Trichostrongylus falculatus Ransom, 1911	Horak *et al.*, 1988	+
Trichostrongylus deflexus Boomker & Reinecke, 1989	Horak *et al.*, 1983	Boomker & Reinecke, 1989
Trichostrongylus thomasi Mönnig, 1932	Horak *et al.*, 1988	Mönnig, 1932
Trichuris sp.	Horak *et al.*, 1988	+

\+ Not found in this survey

* After Round (1968)

The ectoparasites were collected as described by Horak *et al.* (1988).

Parasite counts and identification

The lung, heart and liver washings of the first 16 animals, as well as the washings of the stomach walls and the aliquots of the small intestinal ingesta were examined under a stereoscopic microscope and all the worms removed.

The ingesta of the large intestines were examined in a flat-bottomed tray and all the macroscopically visible worms removed. Because of the large numbers of *Probstmayria vivipara* present, a 1/100th aliquot was made of each of the large intestinal ingesta after they had been macroscopically examined. The aliquot was examined under a stereoscopic microscope and *Probstmayria vivipara* counted.

With the exception of *Probstmayria vivipara,* all the worms were cleared in lactophenol and examined under a standard microscope with Nomarski's differential intereference illumination. They were identified with the aid of the descriptions by the authors listed in Table 1. This table also lists the helminth recovered to date from warthogs in South Africa and Namibia.

The ectoparasites were counted as described by Horak *et al.* (1988).

RESULTS

The total monthly rainfall and the mean monthly minimum and maximum atmospheric temperatures for the period August 1988–July 1989 are graphically illustrated in Fig. 1.

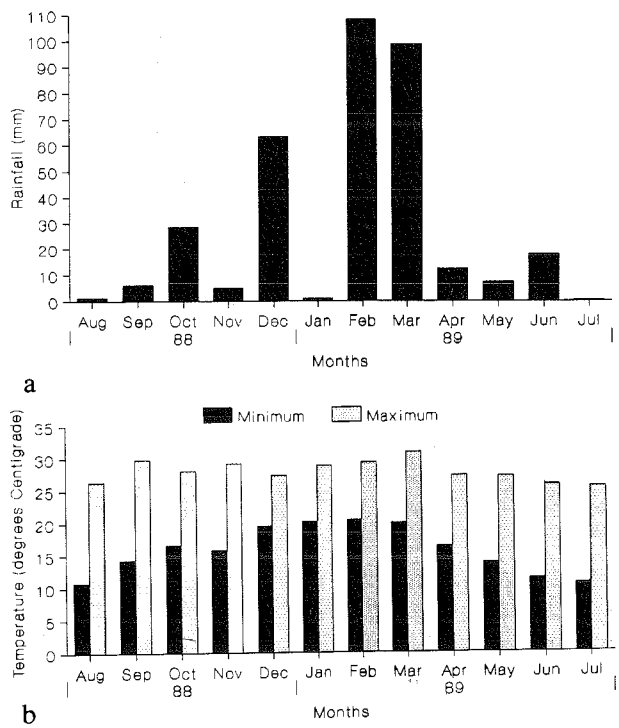

FIG. 1 Mean monthly rainfall (a) and minimum and maximum temperatures (b) at the Hoedspruit Nature Reserve

Helminths

The total numbers of helminths recovered from all the warthogs are summarised in Table 2.

TABLE 2 The helminths recovered from 41 warthogs from the Hoedspruit Nature Reserve

Helminth species	Larvae	Adults	Total	Number of warthogs infected
Reserve (28 warthogs)				
*Moniezia/Paramoniezia**	#	109	109	12
Taenia regis	2	#	2	2
Echinococcus	1	#	1	1
Ascaris phacochoeri	0	114	114	13
Cooperia hungi	0	100	100	1
Impalaia tuberculata	0	150	150	5
Murshidia hamata	+	34 361	34 361	28
Murshidia pugnicaudata	+	6 215	6 215	28
Murshidia spp.	118	–	118	8
Oesophagostomum mocambiquei	+	90 058	90 058	27
Oesophagostomum mwanzae	+	37 684	37 684	28
Oesophagostomum spp.	2 901	–	2 901	13
Physocephalus sexalatus	80	9 494	9 574	23
Probstmayria vivipara	$	$	267,255 million	28
Trichostrongylus deflexus	0	20	20	2
Trichostrongylus thomasi	0	60	60	4
Trichostrongylus spp. females	–	50	50	5
Mean nematode burden**	111	6 368	6 479	
Base (13 warthogs)				
*Moniezia/Paramoniezia**	#	53	53	5
Ascaris phacochoeri	0	32	32	5
Murshidia hamata	+	21 734	21 734	13
Murshidia pugnicaudata	+	4 588	4 588	12
Murshidia spp.	222	–	222	5
Oesophagostomum mocambiquei	+	8 507	8 507	12
Oesophagostomum mwanzae	+	4 090	4 090	12
Oesophagostomum spp.	94	–	94	3
Physocephalus sexalatus	0	610	610	10
Probstmayria vivipara	$	$	148,331 million	13
Trichostrongylus spp. females	–	10	10	1
Mean nematode burden**	24	3 044	3 068	

* Scoleces
** Excluding *Probstmayria vivipara*
\# Not found in warthogs
$ Larvae and adults not counted separately
\+ Counted together under the respective genera
– Not applicable

Eleven namatode species, 1 or 2 cestode species and the larval stages of 2 cestode were recovered from warthogs shot in the reserve. Of these, *Murshidia hamata, Murshidia pugnicaudata, Oesophagostomum mwanzae,* and *Probstmayria vivipara* occurred in all the warthogs. *Oesophagostomum mocambiquei* was recovered from 27 warthogs and *Physocephalus sexalatus* from 23. The remaining nematodes occured in less than 50 % of the animals examined.

Probstmayria vivipara was the most abundant of the nematodes, followed by *Oesophagostomum mocambiquei, Oesophagostomum mwanzae, Murshidia hamata, Physocephalus sexalatus* and *Murshidia pugnicaudata.*

Individual adult nematode burdens, excluding *Probstmayria vivipara* varied from 445 to 41 950 and the mean total adult nematode burden, excluding *Probstmayria vivipara,* was 6 368.

Eight species of nematodes and 1 or 2 cestode species were recovered from the 13 warthogs shot in the base. *Probstmayria vivipara* and *Murshidia hamata* were recovered from all these warthogs and *Murshidia pugnicaudata, Oesophagostomum mocambiquei* and *Oesophagostomum mwanzae* from 12 warthogs each. *Physocephalus sexalatus* occurred in 10 animals.

Probstmayria vivipara was again the most abundant nematode, followed by *Murshidia hamata, Oesophagostomum mocambiquei, Murshidia pugnicaudata* and *Oesophagostomum mwanzae.*

The individual adult nematode burdens, excluding *Probstmayria vivipara,* varied from 91 to 7 260 and the mean total adult nematode burden, excluding *Probstmayria vivipara,* was 3 044.

Ascaris phacochoeri and the *Moniezia/Paramoniezia* spp. were only recovered from animals younger than 18 months, while *Oesophagostomum* spp., *Murshidia* spp., *Physocephalus sexalatus* and *Probstmayria vivipara* were already present in the youngest animal in the survey, a male, 3–4 months old, shot in the reserve during August 1988.

No differences in the mean monthly nematode burdens or nematode species composition between the ages or the sexes of the warthogs shot at either locality, were evident.

The seasonal fluctuations of *Oesophagostomum* spp., *Murshidia* spp. and *Probstmayria vivipara* are graphically illustrated in Fig. 2–4.

In both groups of warthogs, peaks in the numbers of *Oesophagostomum* spp. occurred during the cooler months of the year. The high peak seen in warthogs from the reserve shot during August 1988, however, is due to 1 animal harbouring 30 700 *O. mocambiquei,* and probably does not reflect the true situation. No seasonal pattern of abundance was evident for the *Murshidia* spp. The largest numbers of *Probstmayria vivipara* were recovered during the cooler months of the year, with a peak occurring during October and November 1988 in the warthogs from the reserve and the base, respectively.

TABLE 3 Arthropod parasites recovered from 28 warthogs from the Hoedspruit Nature Reserve, eastern Transvaal

Arthropod species	Total numbers of arthropods recovered					Number of warthogs infested
Fleas	Males		Females		Total	
Echidnophaga inexpectata/larina	7 098*				7 098	27
Moeopsylla sjoestedti	72		132		204	18
Lice	Nymphs	Males	Females		Total	
Haematopinus phacochoeri	1 228	170	200		1 598	14
Ixodid ticks	Larvae	Nymphs	Males	Females	Total	
Amblyomma hebraeum	158	1 228	254	80 (0)	1 720	28
Amblyomma marmoreum	2	0	0	0	2	1
Boophilus decoloratus	126	0	0	0	126	3
Hyalomma truncatum	0	0	10	4 (0)	14	3
Rhipicephalus appendiculatus	2	0	0	0	2	1
Rhipicephalus evertsi evertsi	2	2	0	0	4	2
Rhipicephalus simus	0	0	82	40 (2)	122	16
Rhipicephalus zambeziensis	0	4	2	0	6	2
Argasid ticks	Larvae	Nymphs	Adults		Total	
Ornithodoros porcinus porcinus	0	232	0		232	13

() = Number of maturing female ticks, i.e. the idiosoma of *A. hebraeum* > 9,0 mm; *H. truncatum* > 7,5 mm; *R. simus* > 6,0 mm
* = Sexes not determined

TABLE 4 Arthropod parasites recovered from 13 warthogs on a military base near Hoedspruit, eastern Transvaal

Arthropod species	Total numbers of arthropods recovered					Number of warthogs infested
Fleas	Males		Females		Total	
Echidnophaga inexpectata/larina	1 036*				1 036	13
Moeopsylla sjoestedti	2		6		8	3
Lice	Nymphs	Males	Females		Total	
Haematopinus phacochoeri	534	46	68		648	8
Ixodid ticks	Larvae	Nymphs	Males	Females	Total	
Amblyomma hebraeum	0	18	2	2 (2)	30	8
Rhipicephalus simus	0	0	40	12 (2)	52	8
Argasid ticks	Larvae	Nymphs	Adults		Total	
Ornithodoros porcinus porcinus	0	2	2		4	2

() = Number of maturing female ticks, i.e. the idiosoma of *A. hebraeum* > 9,0 mm and *R. simus* > 6,0 mm
* = Sexes not determined

Arthropods

The total numbers of arthropods recovered from the warthogs in the reserve and on the base are summarised in Tables 3 and 4.

The warthogs harboured 3 flea species, 1 louse species 8 ixodid tick species and 1 argasid tick species. The animals in the reserve not only harboured a greater variety but also greater numbers of parasites than the animals on the base.

The seasonal abundance of the adults of the tick *Rhipicephalus simus*, the fleas *Echidnophaga inexpectata* and *Echidnophaga larina* combined and the louse *Haematopinus phacochoeri* for both groups of warthogs are graphically illustrated in Fig. 5–7. Because of the large variation in the burdens of the lice, the burdens have been transformed to their square roots (Fig. 7).

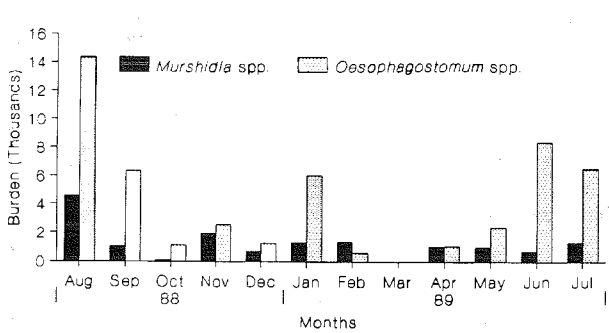

FIG. 2 Seasonal fluctuation in the numbers of *Oesophagostomum* spp. and *Murshidia* spp. in warthogs in the reserve

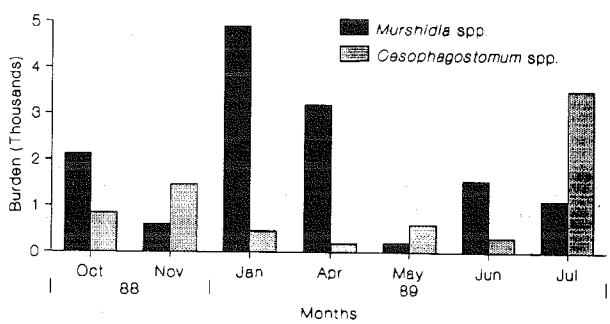

FIG. 3 Seasonal fluctuation in the numbers of *Oesophagostomum* spp. and *Murshidia* spp. in warthogs on the military base

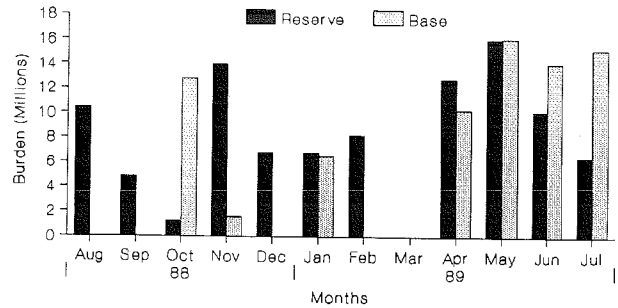

FIG. 4 Seasonal fluctuation in the numbers of *Probstmayria vivipara* in warthogs in the reserve and the military base

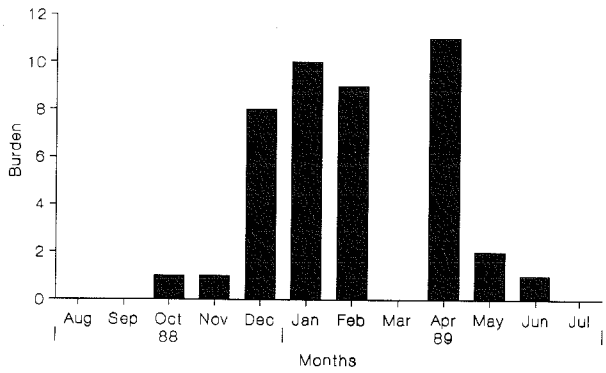

FIG. 5 Seasonal fluctuation in the numbers of *Rhipicephalus simus* on warthogs in the Hoedspruit Nature Reserve

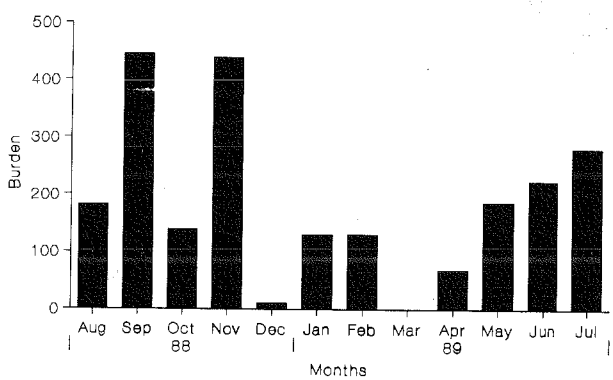

FIG. 6 Seasonal fluctuation in the numbers of *Echidnophaga* spp. on warthogs in the Hoedspruit Nature Reserve

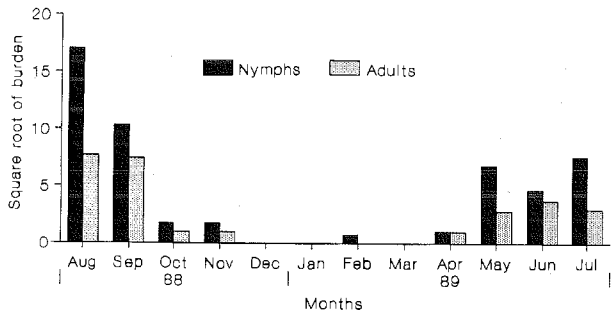

FIG. 7 Seasonal fluctuation in the numbers of *Haematopinus phacochoeri* on warthogs in the Hoedspruit Nature Reserve.

Although variation was considerable, peak flea burdens were generally recorded from August to November and May to July, while peak burdens of immature and adult *H. phacochoeri* were present during August and September. No lice were recovered during December and January. Adult *R. simus* were present from October to June, with the largest numbers being recovered from December to April. The other ectoparasites did not exhibit clear patterns of seasonal abundance.

DISCUSSION

Helminths

Fourteen helminth species were recovered in this study from the warthogs in the reserve. This is 5 species fewer than from warthogs in the KNP, but 4 more than from warthogs in Namibia (Horak, Biggs, Hanssen & Hanssen, 1983; Horak *et al.*, 1988). At least 9 helminths species were recovered from the animals on the base.

The small number of species recovered from warthogs on the base is probably firstly due to the fact that they are an isolated population, consisting of about 80 animals, that has no contact with other warthogs, and secondly because very few other animals species occur on the base. Thus, if cross-infection does take place it can only occur to a limited degree. Neither the carnivore associated *Taenia* sp. and *Echinococcus* sp. larvae, nor *Cooperia hungi, Impalaia tuberculata* or the *Trichostrongylus* spp. were recovered from these warthogs, although they were present in those in the reserve.

The difference in the mean total adult nematode burdens between the 2 groups of warthogs is presumably also due to the above-mentioned factors.

Ascaris phacochoeri, which we consider a definitive parasite of warthogs, has previously been recorded from warthogs from Zululand (Ortlepp, 1939, 1964) and the KNP (Horak *et al.*, 1988). The mean adult burden of the warthogs from the reserve was approximately double that of those in the KNP, while that of the warthogs from the base was about the same (Horak *et al.*, 1988). Only 1 immature *Ascaris* sp. was recovered from the warthogs from Namibia (Horak, Biggs, Hanssen & Hanssen, 1983).

C. hungi is a common parasite of impala, *Aepyceros melampus* (Horak, 1978b). Although the spicules of the specimens recovered during this survey were of normal size, the fact that they were present in only 1 animal confirms their status as an accidental parasite of warthogs. This assumption is augmented by the fact that although large numbers of impala occur in the area in the KNP where warthogs were previously surveyed, *C. hungi* was not found in a single warthog (Horak *et al.*, 1988).

All the *I. tuberculata* recovered in this survey were considerably smaller and the males' spicules shorter than those in antelope (Boomker, 1977; Gibbons, Durette-Desset & Daynes, 1977). This agrees with the findings of Horak *et al.* (1988) for *I. tuberculata* from warthogs in the KNP and those of Horak, Biggs, Hanssen & Hanssen (1983) for *Impalaia nudicollis* from warthogs in Namibia. It indicates that both *Impalaia* species can survive in warthogs but that these animals are not preferred hosts.

Worms of the genus *Murshidia* were not recovered from warthogs in Mozambique or Namibia (Ortlepp, 1964; Horak, Biggs, Hanssen & Hanssen, 1983). Two species of this genus were, however, present in warthogs in the Central African Republic (Troncy, Graber & Thal, 1972), Zululand (Daubney, 1923; Ortlepp, 1964), on the escarpment of the eastern Transvaal and in the eastern Transvaal Lowveld (Ortlepp, 1964; Horak *et al.*, 1988). Only

Murshidia hamata was present in a warthog from the north-western Transvaal (Boomker & Horak, unpublished data, 1989). Horak *et al.* (1988) found large numbers of *Murshidia* spp. in warthogs in the KNP but only moderate numbers were recovered during this survey.

It appears that certain individuals harbour large numbers of *Oesophagostomum* spp. or *Murshidia* spp. but the factors predisposing to such burdens are not known.

With the exception of *Oesophagostomum santosdiasi*, which was recovered from only 1 warthog in the KNP (Horak *et al.*, 1988), the same *Oesophagostomum* spp. as those in the KNP were present in warthogs in this survey. *Oesophagostomum mwanzae* appears to have a very wide distribution and has been recovered from warthogs in the Central African Republic (Troncy *et al.*, 1972), in Uganda, Kenya, Tanzania and Malawi (Daubney 1924; Goodey, 1924), in northern Mozambique and on the escarpment of the eastern Transvaal (Ortlepp, 1964), in the eastern Transvaal Lowveld (Horak *et al.*, 1988), in the north-western Transvaal (Boomker & Horak, unpublished data, 1989) and in northern Namibia (Horak, Biggs, Hanssen & Hanssen, 1983). In the survey of warthogs in Namibia it was outnumbered by *Oesophagostomum mpwapwae* and in the eastern Transvaal Lowveld by *Oesophagostomum mocambiquei*. The latter worm has only been recorded from warthogs on the eastern side of the continent, namely northern Mozambique (Ortlepp, 1964) and the eastern Transvaal escarpment and Lowveld (Ortlepp, 1964; Horak *et al.*, 1988; present survey).

The largest number of *Oesophagostomum* spp. recovered from a single warthog in the present survey was 35 000 worms. This is 4 490 more than recovered from a single animal in Namibia (Horak, Biggs, Hanssen & Hanssen, 1983) and 27 600 more than from an animal in the KNP (Horak *et al.*, 1988). As is apparent from the various surveys, burdens of nematodes of this genus may vary considerably.

From Fig. 1a & 2 it seems that peak numbers of *Oesophagostomum* spp. occurred in warthogs in the reserve approximately 3 months after good rainfall, and that the size of the peak depends on the amount of rain. During October 1988 approximately 30 mm rain fell and a small peak occurred during January 1989. Rainfall in excess of 100 mm was measured during February 1989 and 98 mm during March 1989. Small numbers of *Oesophagostomum* spp. were recovered during May 1989 but a peak was reached during June 1989. No such pattern was, however, seen in the warthogs on the base, nor was it apparent for the *Murshidia* spp. or *Probstmayria vivipara* in both groups of warthogs.

Physocephalus sexalatus occurs in warthogs, bushpigs and domestic pigs in South Africa (Ortlepp, 1964, Horak, 1978a; Reinecke, 1983; Horak *et al.*, 1988). The numbers of *Physocephalus sexalatus* recovered during this survey are similar to those in warthogs in Namibia, but are considerably greater than those in warthogs in the KNP. Contrary to the findings of Horak *et al.* (1988), no seasonal pattern of abundance was evident in this survey.

The related *Ascarops strongylina* has been recorded from bushpigs in the northern Transvaal (Ortlepp, 1964) and domestic pigs (Horak, 1978a) but has as yet not been recorded from warthogs.

As in the case of the warthogs in Namibia and the KNP, *Probstmayria vivipara* occurred in vast numbers and peak burdens were present during the cooler months of the year.

Trichostrongylus deflexus (= *Trichostrongylus colubriformis* of Horak, Biggs, Hanssen & Hanssen, 1983 and *Trichostrongylus instabilis* of Horak *et al.*, 1988) is a recently described nematode of several antelope species (Boomker & Reinecke, 1989). It appears to infect a wide range of hosts, but its presence in warthogs should be regarded as accidental.

Trichostrongylus thomasi is an abomasal parasite of a number of antelope species (Round, 1968; Horak, Meltzer & De Vos, 1982; Horak, Brown, Boomker, De Vos & Van Zyl, 1982; Horak, De Vos & Brown, 1983; Boomker, Horak & De Vos, 1986, 1989) and also occurs in the stomach of Burchell's zebra (Scialdo, Reinecke & De Vos, 1982) and warthogs (Horak *et al.*, 1988; present survey). It fills the same niche in wild animals as is occupied by *Trichostrongylus axei* in domestic animals, but should be regarded as an accidental parasite of warthogs.

Since *Moniezia/Paramoniezia* sp. were recovered only from the younger animals, we postulate that immunity against these tapeworms develops after initial infection, similar to that seen in domestic ruminants infected with *Moniezia expansa* (Reinecke, 1983).

Arthropods

The smaller numbers of species and smaller overall numbers of ectoparasites recovered from the warthogs on the military base than from those in the nature reserve are probably due to the same factors affecting their respective helminth burdens, as mentioned earlier.

Only *Echidnophaga larina* was recovered from the warthogs in Namibia (Horak, Biggs, Hanssen & Hanssen, 1983), while the animals in the KNP and the present survey harboured both *Echidnophaga larina* and *Echidnophaga inexpectata* (Horak *et al.*, 1988). As in the case of the KNP warthogs, the 2 flea species could not be counted separately because of their stick-tight habit, and consequently many were counted *in situ*. This also prevented the determination of their sex. Although considerable variation occurred in the monthly mean flea burdens of the warthogs in Namiba, the KNP and the present survey, it would appear as if the largest numbers of fleas are present during the period May or June to November or December.

The mean burdens of *Moeopsylla sjoestedti* on the warthogs in the HNR were higher than those on the warthogs in the KNP (Horak *et al.*, 1988). The warthogs examined in Namibia did not harbour this flea (Horak, Biggs, Hanssen & Hanssen, 1983). No pattern of seasonal abundance was evident and more female than male fleas were recovered.

In Namibia peak burdens of *Haematopinus phacochoeri* were recorded on warthogs in September of 1 year and June the following year (Horak, Biggs, Hanssen & Hanssen, 1983), while in the KNP peak burdens were present from July to September (Horak *et al.*, 1988). The recovery of large numbers of lice during August and September in the present survey confirms the winter to early spring abundance of this species.

The complete absence of lice on the KNP warthogs during January 1981 (Horak *et al.*, 1988) and during December and January in this survey leads

one to speculate as to where and in what stage these permanent ectoparasites oversummer. The most likely explanation would seem to be as eggs attached to the hair of the warthogs or loose in the burrows of the animals. It could also be that the piglets, which are generally born during November or December in South Africa (Smithers, 1983), acquire infestation from their dams and ensure the survival of the lice during the summer months. This was indeed so in the KNP where a 1-month old piglet examined during January 1980 was fairly heavily infested compared with the absence of infestation on the other warthogs slaughtered at the same time. The same, however, did not apply in the case of a similarly aged warthog examined during January 1981.

If one excludes the adult ticks of the single warthog in the KNP that carried an exceptionally large burden of *Amblyomma hebraeum,* then the mean burdens for the warthogs examined there were 74 larvae, 59 nymphs and 14 adults (Horak *et al.,* 1988). The mean burden for the warthogs examined in the reserve in the present survey was 6 larvae, 44 nymphs and 12 adults. With the exception of the larval numbers (for which we have no explanation), the mean burdens of the 2 groups of warthogs were thus reasonably similar. These findings confirm that warthogs are one of the preferred hosts of adult ticks of this species. The immature stages, and more particularly the larvae, feed on a large variety of mammals and also one some ground-nesting birds (Theiler, 1962; Horak, MacIvor, Petney & De Vos, 1987). Consequently, the immature stages which feed on warthogs are not solely responsible for generating the adult burdens on the same animals.

The warthogs in Namibia, the KNP and the present survey were infested with adult *Hyalomma truncatum* but burdens were never very large (Horak, Biggs, Hanssen & Hanssen, 1983: Horak *et al.,* 1988). Preferred hosts of the adults are large herbivores such as zebras, eland and cattle (Horak, 1982; Rechav, 1986; Horak & MacIvor, 1987). Scrub hares are preferred hosts of the immature stages, which are also found on rodents (Rechav, 1986: Horak & MacIvor, 1987).

Horak *et al.* (1988) state that in the KNP adult *Rhipicephalus simus* seem to prefer monogastric animals such as Burchell's zebras, carnivores and wart-hogs rather than ruminants. The fairly large numbers of adults recovered from the warthogs in the present investigation confirm their observations for this host species. The immature stages of *R. simus* feed on rodents (Norval & Mason, 1981).

The period of peak adult abundance from December to April corresponds to that of January to April with a peak in February on the warthogs in the KNP (Horak *et al.,* 1988). The mean burden of *R. simus* on the warthogs in that survey was more than double that in the present study.

The larvae of *Amblyomma marmoreum* utilise a large number of mammals and some ground-frequenting birds as hosts (Horak *et al.,* 1987). Their presence on the warthogs, albeit in small numbers, is therefore not unexpected. We consider *Boophilus decoloratus, Rhipicephalus appendiculatus, Rhipicephalus evertsi evertsi* and *Rhipicephalus zambeziensis* to be accidental infestations. Their occurrence on the warthogs probably reflects their periods of peak seasonal abundance rather than host preference.

The presence of *Ornithodoros porcinus porcinus* on warthogs that are out of their burrows has been discussed by Horak *et al.* (1988). Its recovery from warthogs in Namibia, the KNP and the present survey indicates that this must be considered a normal occurrence.

ACKNOWLEDGEMENTS

We thank the South African Defence Force for placing the animals at our disposal, and Messrs D. Breytenbach, P. Oosthuizen, C. du Plessis and J. Botha for assistance with the autopsies. This study was partly funded by the Foundation for Research Development.

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HELMINTH COMMUNITIES

J. Parasitol., 89(5), 2003, pp. 899–907

PATTERNS OF ASSOCIATION, NESTEDNESS, AND SPECIES CO-OCCURRENCE OF HELMINTH PARASITES IN THE GREATER KUDU, *TRAGELAPHUS STREPSICEROS*, IN THE KRUGER NATIONAL PARK, SOUTH AFRICA, AND THE ETOSHA NATIONAL PARK, NAMIBIA

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ABSTRACT: The helminth parasites of the greater kudu from the Kruger National Park (KNP), South Africa, and the Etosha National Park (ENP), Namibia, were examined to determine the major patterns of spatial and demographic variation in community structure and to evaluate nonrandomness in parasite community assembly. Nonmetric multidimensional scaling ordination procedures were used to test for differences in parasite community composition between hosts of the 2 parks and between hosts of different demographic groups within KNP. Infracommunities within KNP were also examined for patterns of nonrandomness using 2 null models, i.e., nestedness and species co-occurrence. Infracommunities of KNP and ENP were significantly different from each other, as were infracommunities of different host demographic groups within KNP. Parasite species in the greater kudu from KNP displayed significant levels of nestedness and were found to co-occur less frequently than expected by chance; however, this lack of co-occurrence was significant only when all demographic groups were considered. When restricted to any particular age class, co-occurrence patterns could not be distinguished from random. Overall, these data suggest that biogeography and host demographics are important factors in determining community organization of helminth parasites in the greater kudu.

One of the key concerns of community ecology is to establish whether species assemblages are structured entities or stochastic groupings and, if structured, what mechanisms are responsible for their organization (Gotelli and McCabe, 2002; Janovy, 2002). A common way to conclude whether an assemblage of species is a structured or ordered community is to determine whether specific groupings of species are associated with a particular habitat or biogeographic area (Brown and Lomilino, 1998), i.e., whether there are observable patterns in the distribution of species (Roberts et al., 2002). Within the context of host–parasite systems, the combination of species assemblages with habitat can be further subdivided by testing for associations among hosts of different genders and age classes. Structured communities can also be delineated by a departure from randomness, where an assemblage of species is significantly more ordered than would be expected by chance. To test whether communities are significantly structured, pattern-based null models are often formulated. These null models are pattern-generating methods that intentionally exclude a mechanism of interest to determine whether a specific pattern can be produced by a stochastic process (Gotelli, 2000, 2001). Two useful null models that have been used to assess community structure are species nestedness (Atmar and Patterson, 1993) and species co-occurrence (Gotelli and McCabe, 2002).

Community nestedness represents a Russian doll-like pattern in which species-poor communities are an ordered subset of more diverse communities (Atmar and Patterson, 1993). Nestedness has been well documented for both free-living (Patterson and Atmar, 1986; Fernandez-Juricic, 2002) and parasitic taxa (Poulin and Valtonen, 2001; Šimková et al., 2001) and has been used extensively to test for nonrandom patterns among species assemblages. Nested patterns were originally thought to develop through ordered extinction (Patterson and Atmar, 1986) but have subsequently been shown to arise through colonization as well (Simberloff and Martin, 1991). Although nestedness can evolve through both colonization and extinction processes, it suggests a higher-level order that renders community structure predictable.

Species co-occurrence models are largely built upon Diamond's (1975) community assembly rules, i.e., forbidden species combinations, checkerboard distributions, and incidence functions (Gotelli and McCabe, 2002), where species are predicted to co-occur less frequently than would be expected by chance alone owing to competitive interactions. Many of Diamond's (1975) original assembly rules have been converted to measurable co-occurrence indices and have been used to determine whether communities lack certain species combinations. One of the more powerful co-occurrence indices is Stone and Roberts' (1990) C-score metric, which is used to measure the average number of ''checkerboard'' units in a species presence–absence matrix. A checkerboard pattern refers to the case where species A is present in a host while species B is absent, combined with the presence of species B in another host where species A is absent. Such a pattern is thought to arise when competitive interactions are important in structuring a community (Diamond, 1975; Gotelli and McCabe, 2002).

The parasites of a wide range of African ruminants have been the subject of extensive surveys (Mönnig, 1932; Boomker, 1982, 1991; Horak et al., 1983; Boomker et al., 1991, 1997). These studies have culminated into several substantial checklists detailing the species present, levels of abundance and prevalence, and insights into seasonal fluctuations (Boomker et al., 1986, 1989). Despite the considerable progress that has been made, there is a dearth of detailed community studies from this region.

To this end, we examined an exceedingly diverse and abundant assemblage of helminths from 119 greater kudus (*Tragelaphus strepsiceros*) from 2 localities in southern Africa. The effort was designed to determine whether (1) parasite communities differ between geographic locations, (2) parasite communities differ between hosts of different age classes or gender, (3) parasite infracommunities form nested subsets, and (4) helminth communities in the greater kudu exhibit evidence of competitive exclusion.

Received 3 February 2003; revised 23 June 2003; accepted 23 June 2003.
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METHODS

Study areas

Kudus were collected from the southern part of the Kruger National Park (KNP) in South Africa and the Etosha National Park (ENP) in Namibia. The KNP is a 19,485-km^2 park located in the northeast portion of South Africa. The vegetation in the southern region of KNP is relatively diverse, consisting of 4 veld types (Boomker et al., 1989). The climate varies from warm or hot summers to mild winters, with an annual rainfall between 600 and 700 mm. The ENP is a 22,269-km^2 reserve located in the northern region of Namibia. The ENP is centered on the Etosha salt pan in a semiarid habitat with an annual rainfall around 389 ± 118 mm (Simmons, 1996). Vegetation consists largely of desert scrub and mopane forests.

Study animals

The greater kudu, *T. strepsiceros*, is a large antelope, reaching upwards of 315 kg, and is distributed widely throughout southern and eastern Africa. Kudus are consummate browsers, feeding primarily on flowers, fruits, seeds, pods, leaves, and twigs of a variety of plants, but they seldom consume grass (Owen-Smith and Cooper, 1987; Boomker et al., 1989). Social organization is based on the cow social unit, where a closed matriarchal kinship group consisting of several cows and their offspring is formed. Calves stay concealed for the first 3 mo of their lives before joining the maternal group (Boomker et al., 1989). Males leave the maternal group at approximately 2 yr of age and form temporary associations with peers. Adult bulls show a tendency to become increasingly solitary with age and form transient associations with cows during the breeding season.

Data collection

A total of 119 kudus were collected from KNP and ENP. Ninety-six kudus were taken from KNP between April 1981 and March 1983 as part of a previous survey (Boomker et al., 1989). In brief, monthly collections from KNP included 1 adult male, 1 adult female, 1 young adult male, and 1 juvenile or calf of either sex. Full-body necropsies of these animals were performed, and all helminths were identified and counted. Twenty-three kudus were culled from ENP on a bimonthly basis from June 1983 to April 1984. Two adult males and 2 adult females were taken on each occasion. Necropsies were performed using the same procedures as those used in KNP.

Data analysis

Nonmetric multidimensional scaling (NMDS) was used to elucidate differences in community structure between KNP and ENP. NMDS has been used extensively in free-living ecology to examine the associations of species assemblages with different habitats (Bailey and Whitham, 2002), and it has also been used to examine differences in parasite communities along a stream gradient in Appalachian fishes (Barger and Esch, 2001). Ordinations were performed using 2 separate distance matrices, one constructed from quantitative abundance data using the Sorenson distance measure and the other created from presence–absence data also using Sorenson distance. Sorenson distance was used for distance matrices because it is well suited for both quantitative data and presence–absence data (McCune and Medford, 1999). Differences in community composition between KNP and ENP were analyzed using multiresponse permutation procedures (MRPP). An indicator species analysis that calculates species indicator values (IV) was used to determine which species differed between the 2 parks. This analysis was used because it combines both abundance and prevalence data to determine whether a particular species is indicative of a given habitat (McCune and Medford, 1999). Ordination procedures, MRPP, and indicator species analyses were all performed using PC-ORD software (McCune and Medford, 1999).

Differences in parasite community composition among hosts of different age classes and genders were examined using NMDS, MRPP, and indicator species analyses. No difference was detected between male and female hosts and between juvenile and adult hosts. Subsequently, male and female hosts and adults and juveniles were lumped together for all the remaining analyses. A Kruskal–Wallis test was performed to test for differences in species richness among different age-class hosts.

The presence of nested communities was examined using Nested Calculator software (Atmar and Patterson, 1995) to compare the degree of nestedness in kudu infracommunities from KNP, with the level of nestedness from 1,000 randomly generated communities based on presence–absence data from KNP. The level of significance was determined by calculating the frequency of randomly generated communities that contained greater levels of nestedness.

A co-occurrence module developed by Gotelli and Entsminger (1999) was used to determine whether parasite species co-occurred less frequently than expected by chance. This module was performed using the C-score index of Stone and Roberts (1990), which measures the average number of checkerboard units among all possible combinations of species and has been shown to be resistant to type I error (Gotelli, 2002). This model was run 4 different times using data from KNP for the following scenarios: (1) for all helminths of all kudus, (2) for all helminths of adults only, (3) for enteric nematodes of all kudus, and (4) for enteric nematodes of adults only. Each of the observed C-score values was compared with C-score values for 5,000 randomly generated matrices to establish significance.

RESULTS

Twenty-two species of helminths were recovered from 96 kudus in KNP. Of these, 16 species were nematodes, 4 cestodes, and 2 trematodes (Tables I–III). Eleven of the 16 species of nematodes were trichostrongylids. Four of the 16 nematode species were common, infecting more than 50% of the hosts. Three were of intermediate prevalence, infecting more than 10% of the hosts but less than 50%, whereas the remaining 9 nematode species were rare, infecting less than 10% of the kudus from KNP. The 2 trematodes from KNP, *Schistosoma mattheei* and *Calicophoron* sp., had intermediate levels of prevalence, whereas 3 of the 4 cestode species infected less than 10% of the hosts; *Taenia* sp. infected 11% of the kudus from KNP.

Thirteen species of helminths were recovered from 23 kudus in ENP, including 11 species of nematodes and 2 cestodes (Tables IV, V). Nine of the 11 nematode species were trichostrongylids. Only 2 species from ENP, *Cooperia neitzi* and *Haemonchus vegliai*, infected more than 50% of the hosts. Five species were intermediate in abundance, whereas the remaining 6 (including the 2 cestode species) were rare, infecting <10% of the hosts.

Quantitative abundance ordination of kudu infracommunities from both KNP and ENP explained 79% of the variation in these data (axis 1 = 48%, axis 2 = 31%, stress = 0.11) and displayed a high level of segregation in ordination space between hosts from different geographic locations (Fig. 1A). A 2-dimensional ordination solution based on presence–absence data revealed similar results, explaining 84% of the variation among infracommunities (stress = 0.20) and suggesting even greater levels of infracommunity segregation between KNP and ENP with almost no overlap in ordination space (Fig. 1B). MRPP were performed to test the hypothesis that there is no difference in parasite community composition between KNP and ENP. This hypothesis was rejected for both quantitative ($P < 0.0001$; A = 0.08) and presence–absence data ($P < 0.0001$; A = 0.06). Further examination of the 2 component communities showed significant differences in the indicator values (a metric of abundance and prevalence combined) of 10 species between the 2 parks (Table VI). Six parasite species were found to be more commonly associated with kudus from KNP, whereas 4 species were more indicative of kudus from ENP. The indicator value for *S. mattheei*, which occurs only in KNP, was not statistically significant ($P = 0.07$: IV = 20.8); however, the

TABLE I. Mean abundance (±SE), prevalence, and trait matrix for nematode species recovered from 96 kudus from the Kruger National Park.

Nematodes	Abundance	Prevalence	Transmission	Site	Family
*Haemonchus vegliai**	122.5 ± 137.5	88	Ingestion	GI tract†	Trichostrongylidae
*Cooperia neitzi**	502.8 ± 578.7	83	Ingestion	GI tract	Trichostrongylidae
*C. acutispiculum**	120.9 ± 144.2	77	Ingestion	GI tract	Trichostrongylidae
*Elaeophora sagittus**	10.8 ± 21.6	68	Vector	PA and CBV‡	Onchocercidae
*Trichostrongylus deflexus**	106.3 ± 254.6	44	Ingestion	GI tract	Trichostrongylidae
Agriostomum gorgonis§	9.3 ± 25.5	28	Penetration, vertical	GI tract	Chabertiidae
Impalaia tuberculata§	21.5 ± 82.9	22	Ingestion	GI tract	Trichostrongylidae
T. falculatus‖	4.7 ± 15.9	10	Ingestion	GI tract	Trichostrongylidae
C. hungi‖	6.8 ± 29.6	8	Ingestion	GI tract	Trichostrongylidae
Strongyloides papillosus‖	46.8 ± 283.1	6	Penetration, vertical	GI tract	Strongyloididae
Trichuris sp.‖	1.3 ± 5.6	5	Ingestion	GI tract	Trichuridae
C. fuelleborni‖	1.6 ± 9.5	4	Ingestion	GI tract	Trichostrongylidae
Paracooperia devossi‖	0 ± 0.1	2	Ingestion	GI tract	Trichostrongylidae
Setaria sp.‖	0 ± 0.1	2	Vector	Body cavity	Onchocercidae
C. yoshidai‖	0.5 ± 5.1	1	Ingestion	GI tract	Trichostrongylidae
Parabronema sp.‖	0 ± 0.1	1	Vector	GI tract	Habronematidae

* Common species infecting more than 50% of the host population.
† Gastrointestinal tract.
‡ Pulmonary artery and coronary blood vessels.
§ Occasional species infecting more than 10% but less than 50% of the host population.
‖ Rare species infecting less than 10% of the host population.

parasite was found to be statistically more prevalent in KNP ($\chi^2 = 0.99$; $P < 0.001$).

An MRPP analysis of hosts from different age classes within KNP revealed significant differences in community composition between calves and adults ($P < 0.0001$; A = 0.06) and between calves and juveniles ($P = 0.0003$; A = 0.07); however, there was no significant difference between adults and juveniles ($P = 0.15$; A = 0.007). These differences are readily apparent in ordination space based on quantitative (stress = 0.11) (Fig. 2A) and presence–absence (stress = 0.17) (Fig. 2B) matrices. Both quantitative and presence–absence ordination solutions show a high level of segregation for parasites in calves from those in adults and juveniles, whereas those in adults and juveniles largely cluster together. Because there was no detectable difference in parasite community composition between adults and juveniles, these 2 age classes were lumped together, and a species indicator analysis was performed to test for associations between individual species and specific age-class hosts. Twelve species, all nematodes, were found to be indicative of a particular age-class host (Table VII). Six species were more commonly associated with adults and juveniles, and 6 species were more commonly associated with calves. Furthermore, a Kruskal–Wallis test was performed to determine whether there were differences in parasite species richness among different age-class hosts. This analysis returned a significant P value ($P = 0.01$), with adult kudus harboring the greatest number of species, juveniles the second greatest number of species, and calves the least number of species.

An examination of 2 community null models revealed highly nonrandom patterns of parasite infracommunity structure within KNP kudus. Kudu infracommunities were significantly nested ($P < 0.0001$; Fig. 3), demonstrating that rare species primarily occur in more diverse infracommunities. A comparison of observed C-score indices with C-score values from randomly generated communities exposed a lack of species co-occurrence for all helminths ($P = 0$; C-score = 92.1) and for enteric nematodes ($P = 0$; C-score = 109.6) when all kudus from KNP were examined (Table VIII). When this co-occurrence null model was restricted to a specific age class, including adults from ENP, parasite species were distributed randomly with respect to co-occurrence patterns (Table VIII).

DISCUSSION

The greater kudu parasite communities from KNP and ENP are species rich and abundant. Both communities are largely composed of enteric nematodes primarily from the Trichostrongylidae. *Haemonchus veglia*, *C. neitzi*, and *C. acutispiculum* were the 3 most abundant helminths in both KNP and ENP. It is unclear why these worms are more common then other helminths in this system. However, Horak (1980) and Boomker et al. (1989) have suggested that kudus in KNP serve as the pri-

TABLE II. Mean abundance (±SE), prevalence, and trait matrix for trematode species recovered from 96 kudus from the Kruger National Park.

Trematodes	Abundance	Prevalence	Transmission	Site	Family
Calicophoron sp.*	31.8 ± 92.7	32	Ingestion	GI tract†	Paramphistomatidae
*Schistosoma mattheei**	3.9 ± 11.3	20	Penetration	Blood vascular system	Schistosomatidae

* Occasional species infecting more than 10% of the host population.
† Gastrointestinal tract.

TABLE III. Mean abundance (±SE), prevalence, and trait matrix for cestode species recovered from 96 kudus from the Kruger National Park.

Cestodes	Abundance	Prevalence	Transmission	Site	Family
Taenia sp*	0.2 ± 0.9	11	Ingestion	Muscle	Taeniidae
*Moniezia benedeni**	0.2 ± 0.7	10	Ingestion	GI tract†	Anoplocephalidae
Avitellina sp*	0.1 ± 0.7	3	Ingestion	GI tract	Anoplocephalidae
Echinococcus sp.*	0 ± 0.1	1	Ingestion	Liver	Taeniidae

* Rare species infecting less than 10% of the host population.
† Gastrointestinal tract.

mary definitive host for these worms along with *Trichostrongylus deflexus*. Many of the other species found in this study are probably maintained commonly in other ungulate, or herbivorous, hosts, only occasionally or rarely infecting kudus.

The segregation of kudu infracommunities of different geographic locations in ordination space suggests strong differences in component parasite community structure between kudus from the 2 parks. This contention is further supported by the MRPP results, which revealed that kudu infracommunities of KNP and ENP were compositionally distinct, i.e., parasite communities within a park are more similar to each other than to parasite communities from the other park. These data also confirm the results demonstrated by Goüy de Bellocq et al. (2002), who examined parasite communities of 16 species of mammals and found parasites to be a reliable biogeographic marker. It is likely that these disparities stem from major differences in climate and vegetation between the 2 parks, as well as slight differences in the ungulate fauna and the absence of the required intermediate snail hosts in ENP. Thus, ENP is generally considered as semiarid, and the vegetation consists largely of desert scrub in the south and mopane forests in the north. KNP tends to be a wetter region of southern Africa, with an annual rainfall of 600–700 mm/yr and a more diverse flora (Boomker et al., 1989). The ungulate faunas of the 2 parks are relatively similar, although there are some slight differences. For example, springbok and gemsbok are not present in KNP but occur in ENP, whereas, buffalo, oribi, and grysbok are absent from ENP but present in KNP. It is possible that the presence or absence of these potential host species could influence the transmission dynamics for a number of the generalist parasites.

Another important difference between the 2 parks is the absence of *Bulinus globosus* in ENP (K. de Kock, pers. comm.). The absence of this snail explains the lack of *S. mattheei* in ENP. Even though 2 closely related species, *B. forskali* and *B. angolensis*, both occur in Etosha, there is no report of natural infection of *S. mattheei* in ENP. The absence of *Onchocerca* sp. in KNP is perplexing because the vectors for this parasite, *Simulium* spp., are abundant in the park (E. Nevill, pers. comm.). It is possible that *Onchocerca* sp. could be absent from KNP because of historical factors; however, it seems reasonable that it could easily spread throughout the range of *Simulium* spp. in Africa, and thus it is likely that there are unknown abiotic factors preventing the transmission of *Onchocerca* sp. in KNP. Further studies are needed to establish the factors limiting the range of *Onchocerca* sp. in southern Africa.

Within KNP, host demographics appear to be a reliable predictor of infracommunity structure. Both quantitative and presence–absence ordination solutions displayed a strong separation of calf infracommunities from juvenile and adult infracommunities. This segregation of calves from juvenile and adult infracommunities in ordination space was confirmed using an MRPP analysis, demonstrating that calf infracommunities are compositionally distinct from those of adults and juveniles. The factor driving this difference in community composition is not solely an accumulation of parasites associated with age but rather that 6 species are more commonly associated with calves and 6

TABLE IV. Mean abundance (±SE), prevalence, and trait matrix for nematode species recovered from 23 kudus from the Etosha National Park.

Nematodes	Abundance	Prevalence	Transmission	Site	Family
*Cooperia neitzi**	88 ± 113.8	68.4	Ingestion	GI tract†	Trichostrongylidae
*Haemonchus vegliai**	26 ± 29.4	63.2	Ingestion	GI tract	Trichostrongylidae
C. acutispiculum‡	63 ± 120.3	47.4	Ingestion	GI tract	Trichostrongylidae
Onchocerca sp.‡	1 ± 1.7	47.4	Vector	Conn. tissue§	Onchocercidae
Cooperiodes hamiltoni‡	8 ± 18.7	21.1	Ingestion	GI tract	Trichostrongylidae
Impalaia nudicollis‡	9 ± 22.4	15.8	Ingestion	GI tract	Trichostrongylidae
Trichostrongylus thomasi‡	4 ± 12.5	10.5	Ingestion	GI tract	Trichostrongylidae
Paracooperia devossi‖	11 ± 45.9	5.3	Ingestion	GI tract	Trichostrongylidae
Elaeophora sagittus‖	0 ± 0.5	5.3	Vector	PA and CBV#	Onchocercidae
I. tuberculata‖	3 ± 11.5	5.3	Ingestion	GI tract	Trichostrongylidae
T. falculatus‖	1 ± 5.7	5.3	Ingestion	GI tract	Trichostrongylidae

* Common species infecting more than 50% of the host population.
† Gastrointestinal tract.
‡ Occasional species infecting more than 10% but less than 50%, of the host population.
§ Connective tissue.
‖ Rare species infecting less than 10% of the host population.
Pulmonary artery and coronary blood vessels.

TABLE V. Abundance (±SE), prevalence, and trait matrix for cestode species recovered from 23 kudus from the Etosha National Park.

Cestode	Abundance	Prevalence	Transmission	Site	Family
*Moniezia expansa**	0 ± 0.2	5.3	Ingestion	GI tract†	Anoplocephalidae
*Thysaniezia giardi**	0 ± 0.2	5.3	Ingestion	GI tract	Anoplocephalidae

* Rare species infecting less than 10% of the host population.
† Gastrointestinal tract.

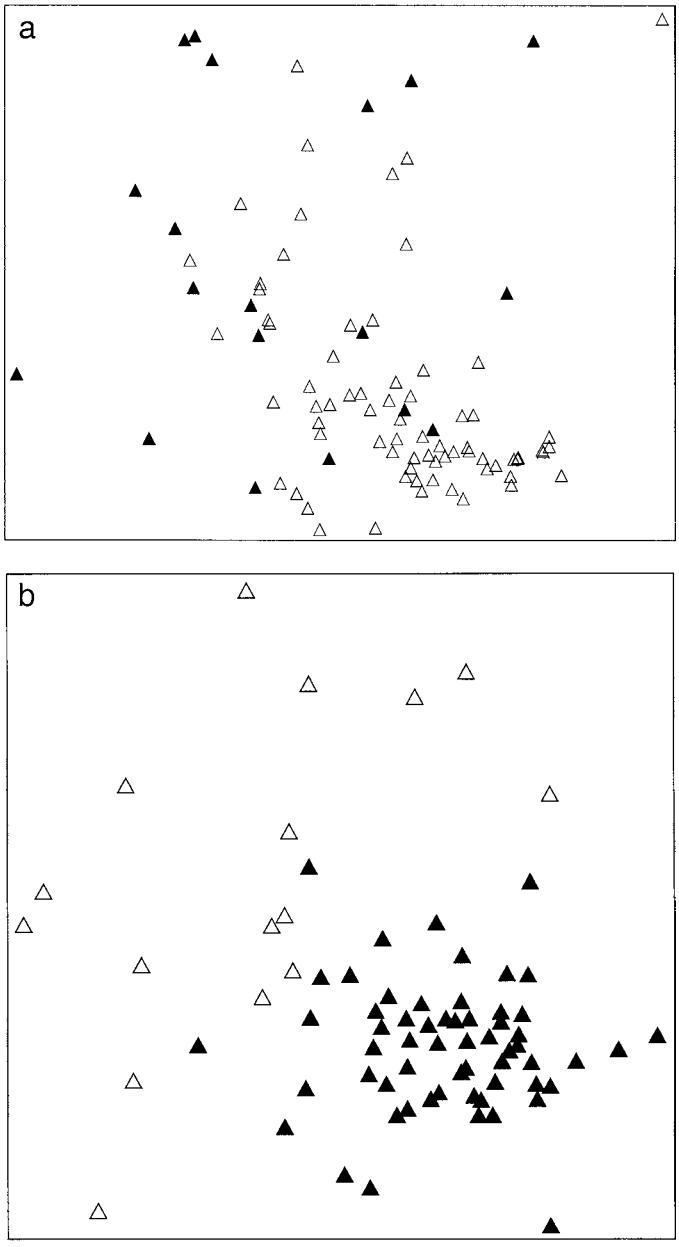

FIGURE 1. Nonmetric multidimensional solutions for kudu infracommunities from Kruger and Etosha National Parks (KNP and ENP, respectively) based on (**A**) quantitative abundance data (axis 1 = 48%, axis 2 = 31%, stress = 0.11) and (**B**) presence–absence data (axis 1 = 34%, axis 2 = 50%, stress = 0.20). △ and ▲ = infracommunities from KNP and ENP National Parks, respectively.

other species are more common in adult or juvenile hosts. Five trichostrongylids, as well as *Strongyloides papillosus*, were found to be significantly more indicative of calf hosts than of any other demographic group. Several explanations are possible for the increased ''association'' with calves. Calves are still undergoing an experimental learning period, when they are likely to eat any vegetation that is present, including grass, whereas adults are consummate browsers, rarely grazing on grass. Because transmission of these trichostrongylid species requires the ingestion of grass to which infective larvae adhere, calves would have a greater exposure and, therefore, opportunity to recruit larval parasites. Density-dependent mechanisms, such as acquired immunity and parasite-induced host mortality, are also potential factors that could be important in generating the differences between calf infracommunities and those of adults and juveniles. Explanatory models elucidating the aggregation of trichostrongylid infections in ruminant hosts have attributed similar patterns to the density-dependent effects of acquired immunity and parasite-induced host mortality (Grenfell et al., 1995). Acquired host resistance has been well documented for several trichostrongylid species (Reinecke, 1983), and, as such, many of these infections may be maintained through immunologically naive hosts. The greater occurrence and abundance of *S. papillosus* in calves may be due to the vertical transmission of the parasite, even though this parasite may also be acquired via a percutaneous route or by direct ingestion of L3 stages. Because *S. papillosus* may be transmitted by the transmammary route (Moncol and Grice, 1974), an infected mother could pass the parasite infection to all her offspring.

The greater association of the 6 parasite species in adult hosts can be attributed to differences in behavior as well as increased exposure of parasites over time. Presumably, adult kudus have greater overall energy demands and spend more time feeding. Further, calves remain hidden from the maternal group for the first few months of their lives, resulting in a differential exposure to parasites. Finally, by chance alone, adults are likely to be exposed to a wider array of parasites over time and will likely accumulate new, but rare, parasite species throughout their lives. This pattern has been well documented in many other host–parasite systems (Esch and Fernandez, 1993). Similarly, Poulin (1997) has reviewed major patterns of parasite species richness and has documented a positive correlation between parasite species richness and host geographic range for several rodent species, suggesting that vagile species will tend to acquire more parasites and parasite species. Because adult kudus are more mobile than calves, they will be exposed to more parasites not only as a function of time but also as a function of space.

Nested analyses of kudu data from KNP displayed a highly ordered distribution of parasite species among kudu infracom-

TABLE VI. Parasite species indicative of Kruger and Etosha National Parks (KNP and ENP, respectively).

KNP			ENP		
Species	IV†	*P* value	Species	IV†	*P* value
*Cooperia acutispiculum**	65.9	0.001	*Cooperiodes hamiltoni*	21.1	0.003
*C. neitzi**	80.3	0.001	*Impalaia nudicollis*	15.8	0.009
*Elaeophora sagitta**	86.9	0.001	*Onchocerca* sp.	47.4	0.001
*Haemonchus vegliai**	79.2	0.001	*Trichostrongylus thomasi*	10.5	0.033
T. deflexus	33.3	0.022			
Calicophoron sp.	40.3	0.015			

* Parasite species recovered in both KNP and ENP.
† IV = observed species indicator value.

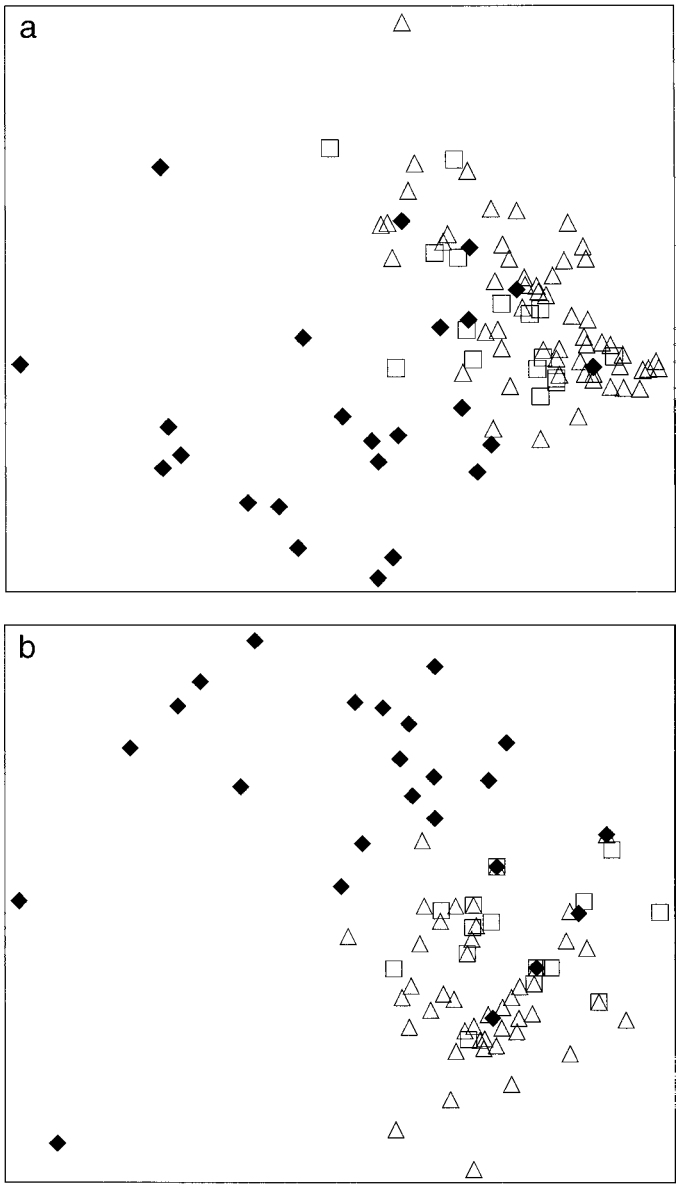

FIGURE 2. Nonmetric multidimensional solutions for adult and calf kudu infracommunities based on (**A**) quantitative data (axis 1 = 44%, axis 2 = 27%, stress = 0.11) and (**B**) presence–absence data (axis 1 = 59%, axis 2 = 30%, stress = 0.17). △ = adult infracommunities, □ = juvenile infracommunities, ♦ = calf infracommunities.

munities. A nested pattern implies a hierarchical community structure, where species-poor infracommunities represent an ordered subset of more diverse communities. Moreover, nestedness suggests that rare species are likely to be found in only the most diverse communities. Several explanations have been proposed for nested patterns for free-living organisms (Atmar and Patterson, 1993) as well as for parasites (Poulin and Valtonen, 2001). An ordered extinction of species due to low population density of species-poor patches has been proposed for nestedness among insular mammal communities, but it is not a feasible explanation for most parasites because of varied indirect life cycles and metapopulation dynamics (Guégan and Hugueny, 1994). Other hypotheses that have been put forth to explain nested subsets include (1) positive interactions, where the presence of one species facilitates the presence of another, either through suppresion of the host's immune response or through an alteration of the host–parasite in such a way as to make recruitment of another species more conducive; (2) increased habitat heterogeneity, where there is a positive association between niche diversification and host size or age; and (3) passive sampling of parasites by the host, where hosts are exposed to a greater diversity of species over time by chance alone (Guégan and Hugueny, 1994). Although these hypotheses are not necessarily mutually exclusive and are difficult, if not impossible, to distinguish from each other by observation alone, the passive sampling hypothesis appears to be the most parsimonious explanation. A comparison of species richness values between different age classes is consistent with this hypothesis, where adult kudus were found to harbor the greatest number of species, juveniles the second greatest number of species, and calves the least number of species. Whereas experimental studies are needed to tease apart the various hypotheses generating nestedness in this system, the fact that kudu infracommunities form a nested pattern is central to understanding the patterns for commonness and rarity among ungulate parasites.

The lack of co-occurrence observed among all helminth species, and among species of enteric nematodes in KNP, is likely the result of age-related differences in hosts and not of competitive exclusion. Patterns of species co-occurrence, i.e., checkerboard distributions, are often regarded as evidence for competitive exclusion (Diamond, 1975; Gotelli and McCabe, 2002); however, in the present study, significant C-score values were obtained only when hosts of all age classes were examined. When these analyses were restricted to any particular age group, they were found to occur randomly with regard to com-

TABLE VII. Parasite species indicative of adult or calf hosts.

Adults			Calves		
Species	IV*	*P* value	Species	IV*	*P* value
Agriostomum gorgonis	36.0	0.006	*Cooperia fuelleborni*	16.7	0.003
C. acutispiculum	80.0	0.001	*C. hungi*	28.8	0.001
C. neitzi	75.2	0.001	*Impalaia tuberculata*	32.7	0.006
Elaeophora sagitta	85.7	0.001	*Strongyloides papillosus*	20.8	0.001
Haemonchus vegliai	73.4	0.001	*Trichostrongylus deflexus*	64.0	0.001
Calicophoron sp.	35.1	0.001	*T. falculatus*	22.2	0.004

* IV = observed species indicator value.

petitive exclusion. Similarly, when the data matrix of kudus from ENP, which contained only adults, was examined for checkerboard distributions, the lack of co-occurrence was not detected. These results support the findings of Gotelli and Rohde (2002), who examined checkerboard patterns in the ectoparasite communities of marine fishes and found largely random co-occurrence patterns. They surmised that the life history characteristics of many parasites, i.e., small size and limited vagility, have prevented the saturation of ecological niches, and as a consequence, the interspecific interaction of parasites remains a rare phenomenon.

Although the nonrandom co-occurrence patterns found in this study are unlikely to be the result of competitive exclusion, this does not diminish their importance but rather serves to illustrate that parasite species in the greater kudu from KNP are segregated in ecological time. D. P. Pielou and E. C. Pielou (1968) and Gotelli and Rohde (2002) noted that nonrandom co-occurrence patterns can arise in the absence of competition if there exists a level of site–host heterogeneity. These authors also warned that it is difficult, and often impossible, to distinguish between these 2 alternative hypotheses; however, the examination of co-occurrence patterns within, and among, different age-class hosts allows for a distinction between these 2 hypotheses. In the present study, it has been demonstrated that calf infracommunities harbor parasite assemblages that are compositionally distinct from those of adults and juveniles. It is therefore reasonable to suspect that the checkerboard distribution of parasites among all age classes is the result of differential associations of parasites with specific age-class hosts and not of a competitively structured community.

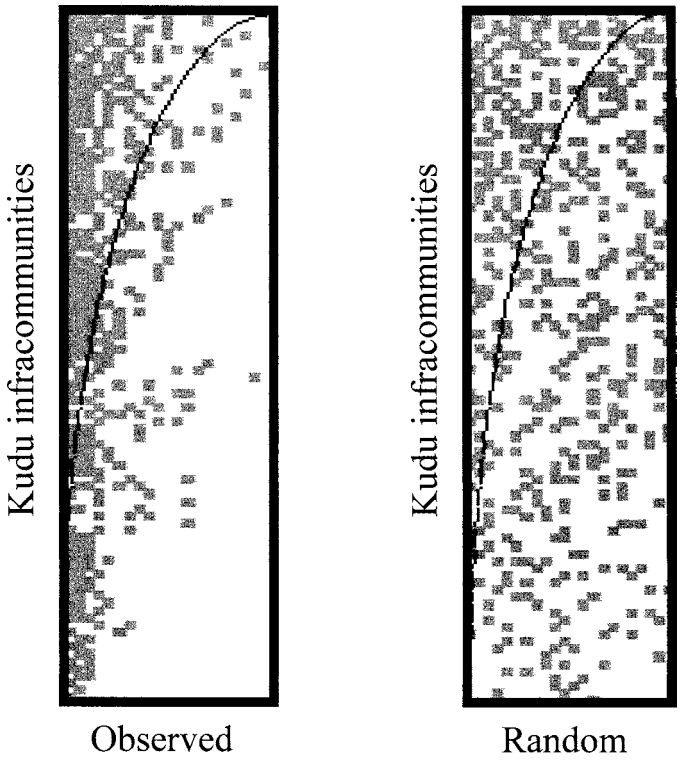

FIGURE 3. Maximally packed presence–absence matrices for observed kudu infracommunities from the Kruger National Park and 1 randomly generated community based on observed data.

Fisher and Lindemayer (2002) have recently warned that blindly relying on *P*-values generated by null models in general and the nestedness temperature calculator in particular may lead to false conclusions. Their point is well taken and has been foreshadowed for several decades as the heart of 1 of the longest debates in community ecology (Lewin, 1983; Gotelli, 2000). Statistical significance acquired from null models does not necessarily equate with ecological significance and should not be used without a thorough understanding of the biology of a given system and the assumptions and limitations of the model. However, null models, like inferential statistics, are powerful tools, which can be used to gain insight that would be otherwise unavailable. Fisher and Lindemayer (2002) demonstrated that the nestedness temperature calculator may be susceptible to type I error with some data sets and thus may not be appropriate for communities composed primarily of ubiquitous and rare species or where statistical significance approaches the desired α-level. Despite the limitations of the nestedness temperature calculator, Fisher and Lindemayer (2002) acknowledge its usefulness as an analytical tool.

On the basis of this analysis, it can be concluded that the helminth parasites of the greater kudu from southern Africa show significant levels of association with hosts of a different geographic location and demography. As a result, parasite communities from these various groups can readily be distinguished from each other and lend a level of predictability to community patterns. Null model analyses displayed high levels of nonrandomness among infracommunities of KNP and suggest a higher-level order that can be attributed to both the accumulation of species over time and the segregation of species among different age-class hosts.

TABLE VIII. Species co-occurrence summary for all helminths and enteric nematodes from Kruger and Etosha National Parks (C-obs = observed C-score value, C-sim = average C-score from randomized communities).

	All worms present			Enteric nematodes		
	C-obs	C-sim	*P* value	C-obs	C-sim	*P* value
KNP						
All kudus	92.1	83.6	0*	109.6	89.5	0*
Adults and juveniles	28.35	28.22	0.39	25.68	24.6	0.15
Calves	8.9	8.7	0.28	11.29	11.1	0.23
ENP						
Adults	28.35	28.22	0.39	6.04	6.33	0.9

* None of the C-score values from the 5,000 randomized communities was greater than the observed C-score value.

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AN EXAMINATION OF THE INFRACOMMUNITIES AND COMPONENT COMMUNITIES FROM IMPALA (*AEPYCEROS MELAMPUS*) IN THE KRUGER NATIONAL PARK, SOUTH AFRICA

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ABSTRACT: The intestinal helminth parasites of the impala from the Kruger National Park, South Africa, were examined to describe the parasite community structure. Demographic variation and the associated differences in behavior were used to further investigate the patterns of community composition. Monte Carlo simulations were performed to test for differences in species richness and mean abundance between the various demographic groups, and nonmetric multidimensional scaling ordination was used to compare community composition. Seventeen species of nematodes, totaling more than 1.3 million worms, were recovered. Males harbored a greater number of nematode species than did females, but adult females were more heavily infected than their male counterparts. Lambs acquired infections early in life, and their parasite community composition rapidly approached that of the older animals. The parasite community in the juvenile and adult males was significantly different from the community of the adult females. These data suggest that social and feeding behavior of the different age–sex classes structure the parasite component community of impala. Additionally, the distinction between common and rare parasites, and their classification in other herbivores, implies complex transmission dynamics that includes extensive species sharing within the Kruger National Park.

Recently, Fellis et al. (2003) examined the infracommunities of the greater kudu (*Tragelaphus strepsiceros*) from 2 locations in southern Africa. In this case, host demographics were found to be a reliable predictor of parasite infracommunity structure. Specifically, behavioral changes associated with aging appear to alter the degree of exposure to infective larvae of numerous nematode species. Additionally, the component parasite community structure was more similar for kudu within a given location than between locations. Environmental differences are likely the dominant factor in producing the observed differences, but presence or absence of other hosts can not be ignored (Fellis et al., 2003).

A survey from 1980 through 1982 produced a large data set for the nematode infracommunities of impala (*Aepyceros melampus*) in the Kruger National Park, South Africa. The present study extends the knowledge of parasite communities in Kruger National Park by describing the nematode component community of this antelope species. Based on the infracommunity study of kudu by Fellis et al. (2003), we predict that host demographics will affect the infracommunities in impala. The component community is also compared to those of other large herbivores residing in the Kruger National Park, and a discussion of ideas pertaining to species sharing is presented.

METHODS

Study site

The Kruger National Park (KNP) is in the northeast portion of South Africa. It is a 19,548-km^2 park and experiences a seasonal climate, from warm or hot summers, to mild winters. Annual rainfall in the KNP averages 600–700 mm. Impala were collected from the southern portion of the park where few areas are >5 km from a water source (Redfern et al., 2003). Vegetation in the southern region is fairly diverse, with 4 veld types being recognized (Boomker et al., 1989).

Study animals

The impala is a medium-sized bovid belonging to the tribe Aepycerotini. Males are larger (60 kg) than females (45 kg) and possess rigid, S-curved horns. They are intermediate feeders, capable of eating browse, but preferentially consuming grass when it is green and available (Okello et al., 2002; Wronski, 2002). Impala are gregarious and territorial (Estes, 1990). Females congregate in discrete clans. During the lambing season, pregnant females isolate in cover several hours before birth. Lambs typically associate with each other, only returning to their mother to nurse, during herd movements, and for protection. Male offspring leave the natal clan when they develop obvious male traits and form temporary peer groups, whereas females usually remain in the maternal herd.

Adult male impala associate in bachelor herds that adhere to a linear hierarchy. Top males compete for territory during the rut, which commences in mid-April and persists through July and mid-August. The male maintains 1 or 2 lookout points where he also defecates. During this time, territorial males will remain alone or as the only male in a female herd. Although the male remains in a small territory, probably not even a hectare in size, he is physically exhausted and emaciated from herding his harem and keeping other males away. He then rejoins the bachelor herd at the bottom of the hierarchy ladder at the end of the breeding season.

Data collection

Beginning in January 1980 and ending in December 1982, 158 impala were culled from the southern region of KNP. A concerted effort was made to take 1 impala of each age class (adult, juvenile, lamb) on a monthly basis. Once killed, the animals were assigned an age class (adult, juvenile, or lamb) and sex (male or female). At necropsy, enteric parasites were identified and counted for each individual impala, following the procedures of Boomker et al. (1989). Reference specimens are deposited into the National Collection of Animal Helminths at the Onderstepoort Veterinary Institute.

Received 5 May 2006; revised 20 September 2006; accepted 26 October 2006.
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Age classification follows Hanks and Howell (1975). Lambs are defined as individuals <6 mo of age. Female impala older than 6 mo are difficult to distinguish, so juvenile females were classified as adults (ADF). By the end of the first year, males leave the natal herd and are considered juveniles (JUM). They retain juvenile status until their fourth year, when they become adults (ADM) and can acquire territory.

Data analysis

Descriptive analysis of the parasite community consisted of investigations into differences in average intensity and helminth richness between the various classifications of impala. Unless specifically stated in the results, only those nematodes identified to species were included in the analyses. This eliminated larval and female worms. Investigations into seasonal changes of the infracommunity of adult impala were attempted, but monthly sample sizes for each age–sex class rarely exceeded 5 individuals, with a few months consisting of 1 or 2 individuals. Consequently, data were pooled across month. In nearly all cases, the data did not meet the requirements for parametric statistics, most notably the requirement for equal variances. Natural log transformations were, therefore, performed on worm burden data and, if the assumptions for parametric statistics were achieved, the appropriate parametric test was performed to investigate differences in the means. If transformation of the data did not correct for heterogeneity of variances, the nonparametric equivalents to standard parametric tests were utilized to determine statistical significance. When significant differences were observed, a Steel-type multiple comparison (MC) post-hoc test was performed to look at differences among treatment levels.

Analyses also extended beyond standard statistical methods. Age–sex classes represent a composite between age and sex effects. Distinguishing between these 2 components using parametric statistics is difficult in that unequal sample sizes, distributions, and variances can limit statistical power. As such, randomization tests were performed (Manly, 1991; Crowley, 1992). To test for a sex effect, the sex variable was randomized among the adult impala for 10,000 iterations, maintaining the observed proportion of male to female adults. This kept overall prevalence and intensity for each nematode species equal throughout the simulations. Furthermore, richness and mean worm burden for each impala remained constant, even though age and sex categories changed. For each iteration, a test value for species richness and worm burden was obtained by taking the absolute value of the difference between the ADF and ADM values. The P value is the number of iterations that produced an absolute difference that is equal to or greater than the difference observed in the unaltered data set divided by the number of iterations (Manly, 1991). For these simulations, a P value of ≤ 0.05 was considered significant. Age differences between the ADM and JUM were also examined using the same methods described previously. The age variable for the males, excluding lambs, was randomized instead of the sex variable.

Randomization tests were also performed to investigate infracommunity differences between the various age–sex classes. Unlike previous procedures, we randomized the data for each nematode species to remove correlations in host occupancy, i.e., the data for each species are randomized independently for the remaining species. Overall prevalence is kept constant, and only the distribution among the impala is changed. Differences in richness and worm burden between the various age–sex categories were inspected.

Infracommunity similarity between individual impala was examined with ordination. Nonmetric multidimensional scaling (NMDS) uses quantitative data on species in multiple hosts to construct a dissimilarity matrix. From this matrix, the rank order dissimilarities are used to construct an ordination plot so that rank order distances of each host are as similar to the dissimilarity matrix as possible. NMDS has advantages over other ordination procedures that make it more suitable for a study such as this. Thus, there are no requirements regarding the distribution of the underlying data, and both presence or absence and abundance of each helminth species can be used to determine dissimilarity values (McCune and Mefford, 1999). NMDS of the presence/absence data produced a 1-dimensional ordination (distance = Sorensen, stress = 0.19) that reflects the variation in species richness among individual impala (McCune and Mefford, 1999). So, the analysis was rerun using Sorensen distances of abundance data. Sorensen distances are suitable for both abundance and presence/absence data, and were used for a similar analysis in the greater kudu (Fellis et al., 2003).

Differences in community composition between the various methods of classification of the impala can be tested with an analysis of similarities (ANOSIM) and indicator species analysis. ANOSIM is an analog of ANOVA, comparing compositional dissimilarity (Sorensen distances) within each group to those between the various groups (Clarke, 1993). In this data set, ANOSIM was performed on impala that were classified by age, sex, and age–sex. Indicator species analysis utilizes both prevalence and abundance data to calculate an indicator value (IV) for each nematode species. Monte Carlo analysis (10,000 iterations) was used to determine if the largest IV for each species occurs more often than dictated by chance alone (McCune and Mefford, 1999). Furthermore, the IV is a measure of the percentage of perfect indication, i.e., how often that particular species can correctly assign a classification to an unknown impala. NMDS and indicator species analysis were performed on PC-ORD software (McCune and Mefford, 1999); the vegan package in R 2.2.1 (http://www.R-project.org) was used for ANOSIM.

RESULTS

Seventeen species of nematodes, totaling >1.3 million worms, were recovered from the gastrointestinal tracts of impala (Table I). Following the classification of Fellis et al. (2003), 10 species are common (>50% prevalence), 2 are intermediate (between 10% and 50% prevalence), and 5 are rare (<10% prevalence). All but 2 species belong to the Trichostrongylidae. *Oesophagostomum columbianum* and *Strongyloides papillosus* are both strongylids. Infection by all but 1 species occurs via ingestion of L3 worms. The exception was *S. papillosus*, whose routes of infection are percutaneous and transmammary (Lyons et al., 1970).

Community richness and average worm load are summarized in Table II. Total nematode species richness differs between age (KW: $P < 0.001$) and sex (KW: $P < 0.005$) and between sexes within an age class (KW: $P < 0.0001$). However, natural log-

TABLE I. Percent prevalence, mean abundance (±SE), and mean intensity (±SE) for gastrointestinal nematodes recovered from 158 impala of Kruger National Park, South Africa.

Species	Prevalence	Abundance	Intensity
*Cooperia conochaeti**	4.4	6.7 ± 5.1	150.9 ± 109.2
*Cooperia fuelleborni**	17.1	59.0 ± 18.3	345.1 ± 89.3
*Cooperia hungi**	89.2	1086.8 ± 161.3	1217.9 ± 177.7
*Cooperia neitzi**	2.5	1.3 ± 0.7	50.3 ± 10.2
*Cooperioides hamiltoni**	94.9	869.5 ± 146.6	915.9 ± 153.6
*Cooperioides hepaticae**	81.0	147.6 ± 29.4	182.2 ± 35.7
*Haemonchus bedfordi**	3.8	1.9 ± 0.9	50.5 ± 14.1
*Haemonchus contortus**	0.6	0.01 ± 0.01	2.0 ± 0.0§
*Haemonchus krugeri**	64.6	246.8 ± 54.1	382.3 ± 80.9
*Haemonchus vegliai**	2.5	0.5 ± 0.48	20.5 ± 18.2
*Impalaia tuberculata**	81.6	745.6 ± 114.0	913.2 ± 135.4
*Longistrongylus sabie**	82.3	174.9 ± 25.4	212.5 ± 29.9
Oesophagostomum columbianum†	75.9	84.1 ± 13.2	110.7 ± 16.7
Strongyloides papillosus‡	88.6	325.6 ± 22.8	367.4 ± 23.5
*Trichostrongylus deflexus**	89.9	1688.2 ± 253.8	1878.4 ± 278.0
*Trichostrongylus falculatus**	22.8	19.9 ± 4.5	87.6 ± 15.1
*Trichostrongylus thomasi**	85.4	375.4 ± 42.5	439.4 ± 47.6

* Trichostrongylidae; infection via consumption.
† Strongylidae; infection via consumption.
‡ Strongyloididae; vertical infection and via percutaneous transinission.
§ One individual was infected.

transformed mean intensities differ only between age (KW: $P < 0.0001$) and age–sex (KW: $P < 0.001$). In general, male impala harbor a greater richness of intestinal nematodes than do females. In fact, the 5 rare species are unique to males (Table III). Within the different age classes, juvenile impala harbor the greatest number of nematode species, and lambs have the lowest mean worm burden (Table II). Female lambs typically possess fewer species and total worms than do older impala (Table II). ADF, although infected with approximately the same number of nematode species, tend to possess a larger worm burden than both ADM and JUM.

Randomization tests examining the effect of sex on the infracommunity of ADM and ADF revealed that average species richness did not differ ($P > 0.05$), but mean intensity was significantly different ($P < 0.042$). This agrees with the post-hoc MC performed on the data, and strongly suggests that adult worm burden is affected by the sex of the host. Age differences between the male impala, excluding lambs, was found to be a significant contributor to species richness ($P < 0.02$), but not to worm burden ($P > 0.05$). This confirms the result of the Steel-type multiple comparison test (Munzel and Hothorn, 2001) for both log-transformed intensity ($P > 0.05$) and species richness ($P < 0.022$).

A 2-dimensional NMDS ordination of abundance data explains 82.7% of the variation (stress = 0.14) among the infracommunities of impala (Fig. 1). Two points are clear. First, the

TABLE II. Infection summary of the impala collected from Kruger National Park. Summaries included all impala, and impala classified by sex, age, and age-sex. Differences in species richness (±SE) and natural-log-transformed intensity (Ln ± SE) within the individual classifications were tested for normality, and the appropriate statistical test was performed. When a significant P value was obtained, a Steel-type multiple comparison test was performed. Values with the same superscript are considered not significantly different. N = total number of individuals, S = species richness, N.S. = not significant.

Classification	N	S	Test (P value)	Ln (intensity)	Test (P value)
Total	158	8.87 ± 0.18		8.09 ± 0.09	
Sex					
Male	108	9.30 ± 0.17	Kruskal-Wallis	8.10 ± 0.08	N.S.
Female	50	7.96 ± 0.40	(<0.005)	8.08 ± 0.24	
Age					
Adult	98	8.77 ± 0.21*	Kruskal-Wallis	8.28 ± 0.11*	Kruskal-Wallis
Juvenile	45	9.73 ± 0.19†	(<0.001)	8.20 ± 0.17*	(<0.0001)
Lamb	15	7.00 ± 0.94*		6.59 ± 0.34†	
Age-sex					
Adult male	56	8.91 ± 0.27*	Kruskal-Wallis	8.08 ± 0.11*	Kruskal-Wallis
Adult female	42	8.57 ± 0.35*	(<0.0001)	8.54 ± 0.22*	(<0.001)
Juvenile male	45	9.73 ± 0.19*		8.20 ± 0.12*	
Lamb male	7	9.57 ± 0.53*†		7.62 ± 0.19*	
Lamb female	8	4.75 ± 1.24†		5.68 ± 0.41†	

TABLE III. Percentage of prevalence and mean intensity (±SE) for the 108 male and 50 female impala.

Species	Prevalence		Intensity	
	Male	Female	Male	Female
Cooperia conochaeti	6.5	0	150.9 ± 27.8	0*
Cooperia fuelleborni	16.7	18.0	342.3 ± 39.0	350.9 ± 83.8
Cooperia hungi	91.7	84.0	888.2 ± 67.6	1994.9 ± 512.5
Cooperia neitzi	3.7	0	50.3 ± 2.0	0*
Cooperioides hamiltoni	98.1	88.0	554.0 ± 52.1	1787.5 ± 457.0
Cooperioides hepaticae	86.1	70.0	169.8 ± 22.6	215.0 ± 95.7
Haemonchus bedfordi	5.6	0	50.5 ± 3.3	0*
Haemonchus contortus	0.9	0	2.0 ± 0†	0*
Haemonchus krugeri	66.7	60.0	263.2 ± 47.7	668.2 ± 179.1
Haemonchus vegliai	3.7	0	20.5 ± 3.5	0*
Impalaia tuberculata	86.1	72.0	533.8 ± 61.0	1893.4 ± 352.7
Longistrongylus sabie	86.1	74.0	149.7 ± 13.3	370.6 ± 81.5
Oesophagostomum columbianum	82.4	62.0	102.4 ± 16.7	134.5 ± 29.3
Strongyloides papillosus	92.6	80.0	387.8 ± 28.3	316.5 ± 32.5
Trichostrongylus deflexus	92.6	84.0	1379.5 ± 187.3	3066.4 ± 728.5
Trichostrongylus falculatus	19.4	30.0	65.2 ± 3.8	118.9 ± 18.2
Trichostrongylus thomasi	90.7	74.0	325.2 ± 34.0	741.7 ± 116.1

* None of the impala harbored the nematode.

female lambs form a group separate from the older impala. The 4 most distant female lambs in ordination space are those individuals collected in January and less than 1 mo of age. The February collection consisted of 2 female lambs, and these individuals are more similar to the older impala (=closer in ordination space) than are the youngest lambs. NMDS ordination also reveals 2 groups, an ADM/JUM group and an ADF group. The pattern or groups signified by NMDS was further tested using ANOSIM. Second, significant differences were observed between the age ($P = 0.008$), sex ($P < 0.001$), and age–sex groupings ($P < 0.0001$). When testing differences in age–sex, only the comparison between ADM and JUM was not significant (ANOSIM: $P > 0.05$).

Indicator species analysis was performed to determine if certain nematode species are more indicative of a particular age and/or sex classification (Table IV). Like NMDS and ANOSIM, indicator values include both the presence/absence and abundance data within and between the different classification schemes. When examining age, 7 nematodes produce significant indicator values, and 6 of these are the common species; only *O. columbianum* and *Cooperioides hepaticae* are indicative of an age group other than adult. Only 3 nematodes with significant indicator values for age also predict sex. Along with *S. papillosus*, these nematodes are common in the impala, but *Trichostrongylus falculatus* occurs just occasionally. All but one, *S. papillosus*, most accurately predict that the impala host is female. Analysis by age–sex classification produces 6 significant indicator values. Nearly all are common species and are indicative of ADF. *Haemonchus vegliai* is a rare species and is most indicative of male lambs.

DISCUSSION

Dogiel et al. (1964) identified similarities in the intestinal component communities of animals with overlapping diets, a pattern that has been identified numerous times in fishes (Price and Clancy, 1983; Bell and Burt, 1991; Nelson and Dick, 2002; Johnson et al., 2004). Since most of the helminths in the intestine are acquired via ingestion of infective stages, diet of the host should play a major role in structuring the component community. In the present study, infection occurs via forage consumption for nearly all of the nematodes recovered from the impala. The single exception, *S. papillosus*, is transmitted percutaneously, or via suckling. Vertical transmission is the probable route of infection for lambs, since all individuals >2 wk old were infected. Successful transmission for the remaining nematode species requires that the infective larvae to disperse onto, and up, vegetation so that they can be consumed. Vertical dispersal is dependent on several factors, including the plant species (Callinan and Westcott, 1986; Niezen et al., 1998). Grazers are more likely to consume the infective larvae because their food source is closer to the ground, and larvae are required to only travel a short distance up a blade of grass. On the other hand, browsers consume fallen leaves, foliage, and other woody plant parts. Fallen leaves provide a means by which parasitic nematodes can infect the browsing host. When the host is consuming dicots, then infective larvae must disperse a considerable distance up the stem and onto the leaves to ensure transmission. Reports on lateral and vertical dispersal of L3 worms suggest that most remain within 15 cm of the dung pat (Callinan and Westcott, 1986; Stromberg, 1997). Rainfall can increase the dispersal distance (Stromberg, 1997), however, and dew likely aids in dispersal up blades of grass (Gruner et al., 1989). Intermediate feeders, such as the impala, are exposed to nematode species commonly found in both grazers and browsers. Thus, their nematode fauna will include species common to both grazers and browsers, and the infracommunity composition will reflect sex and age-class variation in feeding behavior.

The nematode infracommunity of impala also reflects the demographics of the host. This was seen in the ordination of abundance data, where the lambs formed a group separate from the juvenile and adult group as a whole (Fig. 1). An obvious factor that could produce these unique communities is age of the host.

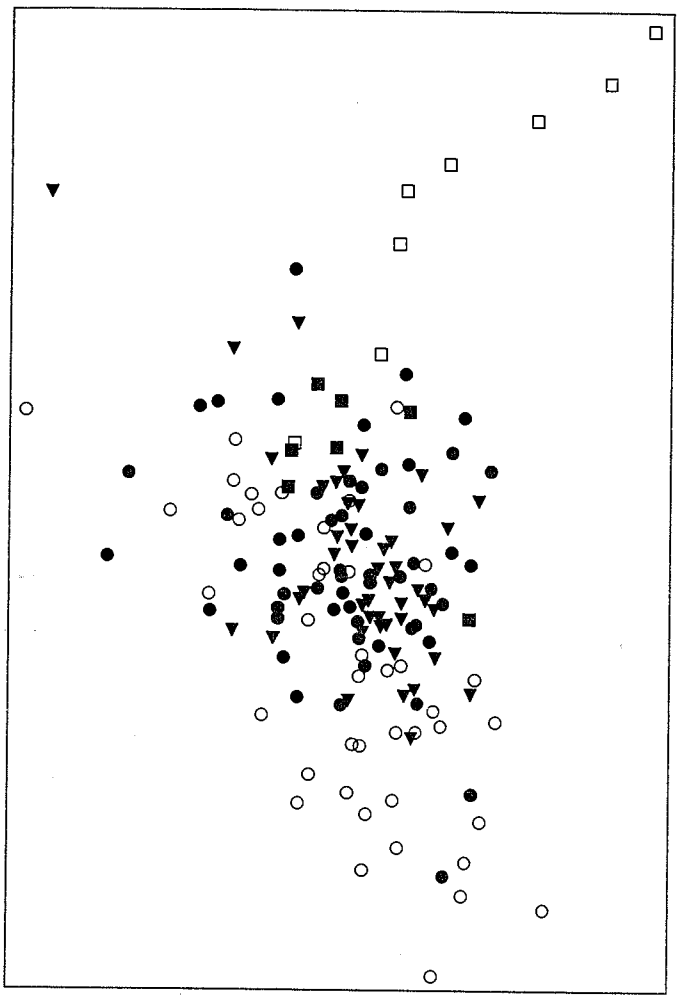

FIGURE 1. Nonmetric multidimensional scaling solution for the infracommunities of 158 impala using abundance data (axis 1 = 29.5%, axis 2 = 52.2%, stress = 0.14). Only those nematodes that were identified to the species level were included in the analysis. (● = Adult male, ○ = adult female, ▼ = juvenile male, ■ = lamb male, □ = lamb female.)

Aging increases the time of exposure to the infective stages, and thus the likelihood of infection. To illustrate, the youngest impala were CAF. Two impala <2 wk of age were uninfected or infected with larval stages of a single species. By 1 mo, CAF were infected with an average of 2 different species. Although the lambs are nursing until 5 mo of age, they are naive and consume a wide variety of vegetation (Frost, 1981). Therefore, impala lambs rapidly acquire additional nematode species, and their infracommunities begin to resemble those of the older impala. The oldest lambs in the study were 6 mo old. Their nematode species richness was equal to the average across all impala, but their mean worm burden was much lower than the average for the older individuals. Nursing reduces the nutritional requirement and hence the food intake of the lambs, resulting in a lower mean intensity for this age group.

The age effect is further compounded by changes in social behavior. Animals that share diets and habitats are often exposed to the same parasites (Dogiel et al., 1964; Holmes and Podesta, 1968; Price and Clancy, 1983). For example, the CAF, by remaining in the natal herd, harbor an infracommunity that resembles the ADF. All of the nematode species recovered from the CAF were also recovered from the ADF, albeit in lower numbers (Tables V,VI). Males, however, leave the herd by the first year and form juvenile clans. These juveniles remain at the periphery of the female herd; thus, they are exposed to the same infective stages as the females in addition to those stages not present in the female clan's feeding area. Increased movement of JUM exposes these individuals to a greater variety of infective stages, most notably those of species that utilize other ungulates as their primary host. Later in life, the rare species acquired by young males are usually lost and seldom replaced.

Infracommunity differences are caused by the presence and abundance of specific species. Only 2 species are most indicative of juveniles (Table IV). *Oesophagostomum columbianum* infects over 86% of the JUM, compared to 71% of adults and 73% of lambs. The higher prevalence in JUM is likely because of increased movement rates of the juvenile males when they leave the natal herd. Those individuals that are not infected with *O. columbianum* are able to acquire the infective stage released by other susceptible ungulates residing in the same area, while infected individuals retain their infection. There is a slightly different explanation for the second nematode. *Cooperioides*

TABLE IV. Indicator values (IV) and *P* value of those nematode species that most accurately predict impala by age, sex, and age-sex. I.C. = indicative class, A = adult, J = juvenile, F = female, M = male, ADF = adult female, CAM = lamb male, N.S. = not significant.

Species	Age			Sex			Age-sex		
	IV	I.C.	*P*	IV	I.C.	*P*	IV	I.C.	*P*
Cooperioides hamiltoni	62.5	A	0.007	65.4	F	0.024	55.8	ADF	0.011
Impalaia tuberculata	65.7	A	0.001	71.5	F	0.001	61.9	ADF	0.001
Longistrongylus sabie	62.6	A	0.001	64.7	F	0.005	56.1	ADF	0.001
Oesophagostomum columbianum	51.9	J	0.004		N.S.			N.S.	
Trichostrongylus thomasi	55.8	A	0.002		N.S.		42.4	ADF	0.008
Cooperioides hepaticae	56.1	J	0.019		N.S.			N.S.	
Cooperia hungi	50.4	A	0.048		N.S.			N.S.	
Strongyloides papillosus		N.S.		54.3	M	0.017		N.S.	
Trichostrongylus falculatus		N.S.		22.1	F	0.030		N.S.	
Haemonchus vegliai		N.S.			N.S.		14.1	CAM	0.024
Trichostrongylus deflexus		N.S.			N.S.		44.3	ADF	0.036

TABLE V. Percentage of prevalence of each nematode species in the various age-sex classes of impala. The number of impala in each category is listed in parentheses. ADM = adult male, ADF = adult female, JUM = juvenile male, CAM = lamb male, CAF = lamb female.

	% Prevalence				
Species	ADM (n = 56)	ADF (n = 42)	JUM (n = 45)	CAM (n = 7)	CAF (n = 8)
Cooperia conochaeti	7.1	0	6.7	0	0
Cooperia fuelleborni	17.9	19.0	13.3	28.6	12.5
Cooperia hungi	89.3	90.5	93.3	100.0	50.0
Cooperia neitzi	5.4	0	2.2	0	0
Cooperioides hamiltoni	98.2	97.6	100.0	85.7	37.5
Cooperioides hepaticae	75.0	71.4	97.8	100.0	62.5
Haemonchus bedfordi	3.6	0	6.7	14.3	0
Haemonchus contortus	0	0	2.2	0	0
Haemonchus krugeri	62.5	61.9	71.1	71.4	50.0
Haemonchus vegliai	1.8	0	4.4	14.3	0
Impalaia tuberculata	82.1	78.6	91.1	85.7	37.5
Longistrongylus sabie	83.9	83.3	88.9	85.7	25.0
Oesophagostomum columbianum	76.8	64.3	86.7	100.0	50.0
Strongyloides papillosus	92.9	76.2	91.1	100.0	100.0
Trichostrongylus deflexus	85.7	92.9	100.0	100.0	37.5
Trichostrongylus falculatus	17.9	33.3	24.4	0	12.5
Trichostrongylus thomasi	91.1	88.1	93.3	71.4	0

hepaticae is acquired early in life (Pletcher et al., 1988). The adult worms live in the bile duct and stimulate formation of hepatic lesions (Pletcher et al., 1988; Anderson, 1992). Pletcher et al. (1988) recorded the heaviest infections from the yearlings, or JUM, and prevalence and mean intensity declined as the impala aged. They concluded that the decrease in prevalence and intensity of *C. hepaticae* is a result of acquired, or protective, immunity, which is consistent with the decrease in prevalence and intensity observed when comparing JUM to ADM. Mean intensity of *C. hepaticae* in ADF is slightly larger than JUM. However, controlling for outliers with a log transformation reveals that JUM are in fact more heavily infected than the ADF (ANOVA: $P < 0.0003$). The most severe infections are likely occurring in the yearling females, which are classified as adults and skew the mean intensity in ADF.

The remaining species that are most indicative of adults (Table IV) reflect typical aging effects. Specifically, the mean intensity of each species increases for each age group (Table VII). Prevalence increases as the lambs become juveniles and decreases slightly as they become adults. Studies have shown that domestic sheep and cattle are able to develop an immune response to a number of nematode species, including *Cooperia*

TABLE VI. Mean intensity (±SE) of each nematode species for the various age-sex classes of impala. The number in parentheses indicates how many individual impala were included in the sample. ADM = adult male, ADF = adult female, JUM = juvenile male, CAM = lamb male, CAF = lamb female.

	Mean intensity				
Species	ADM (n = 56)	ADF (n = 42)	JUM (n = 45)	CAM (n = 7)	CAF (n = 8)
Cooperia conochaeti	221.5 ± 51.6	0*	56.7 ± 8.8	0*	0*
Cooperia fuelleborni	407.5 ± 66.3	388.5 ± 96.0	301.8 ± 43.4	137.5 ± 46.8	50.0 ± 0†
Cooperia hungi	958.2 ± 92.2	2187.8 ± 580.4	893.3 ± 111.1	357.9 ± 57.4	162.5 ± 68.7
Cooperia neitzi	50.3 ± 3.3	0*	50.0 ± 0†	0*	0*
Cooperioides hamiltoni	612.0 ± 87.0	1913.5 ± 511.4	517.0 ± 58.2	300.0 ± 123.9	66.7 ± 5.1
Cooperioides hepaticae	102.9 ± 29.1	247.7 ± 112.2	243.3 ± 36.8	109.3 ± 36.7	19.0 ± 7.2
Haemonchus bedfordi	14.0 ± 2.1	0*	75.0 ± 3.7	50.0 ± 0†	0*
Haemonchus contortus	0*	0*	2.0 ± 0†	0*	0*
Haemonchus krugeri	405.9 ± 90.6	760.3 ± 206.6	129.4 ± 17.1	120.0 ± 23.5	69.5 ± 31.5
Haemonchus vegliai	3.0 ± 0†	0*	2.0 ± 0.0	75.0 ± 0†	0*
Impalaia tuberculata	624.8 ± 103.3	2056.5 ± 392.6	472.9 ± 70.3	251.7 ± 57.2	100.0 ± 38.5
Longistrongylus sabie	156.5 ± 21.1	389.8 ± 90.5	157.0 ± 17.4	46.7 ± 11.3	35.0 ± 12.5
Oesophagostomum columbianum	99.5 ± 29.8	151.7 ± 33.5	116.7 ± 17.7	41.3 ± 11.4	19.0 ± 9.4
Strongyloides papillosus	339.7 ± 37.0	346.9 ± 37.5	430.2 ± 47.1	496.4 ± 96.4	195.0 ± 36.5
Trichostrongylus deflexus	1382.7 ± 314.0	3286.7 ± 815.5	1499.7 ± 227.8	585.3 ± 432.8	201.7 ± 47.8
Trichostrongylus falculatus	74.5 ± 5.4	119.9 ± 20.6	56.7 ± 5.7	0*	105.0 ± 0†
Trichostrongylus thomasi	392.1 ± 57.9	741.7 ± 126.7	266.3 ± 33.2	138.6 ± 64.5	0*

* None of the impala harbored the nematode.
† A single impala was infected.

TABLE VII. Percentage of prevalence and mean intensity (±SE) for 108 adult, 45 juvenile, and 15 lamb impala. A = adult, J = juvenile, C = lamb.

Species	Prevalence			Mean intensity		
	A	J	C	A	J	C
Cooperia conochaeti	4.1	6.7	0.0	221.5 ± 193.0	56.7 ± 34.2	0*
Cooperia fuelleborni	18.4	13.3	20.0	399.1 ± 126.9	301.8 ± 118.8	108.3 ± 58.3
Cooperia hungi	89.8	93.3	73.3	1489.2 ± 275.1	893.3 ± 115.0	286.8 ± 56.3
Cooperia neitzi	3.1	2.2	0.0	50.3 ± 14.4	50.0 ± 0.0	0*
Cooperioides hamiltoni	98.0	100.0	60.0	1167.8 ± 234.6	517.0 ± 58.2	222.2 ± 94.8
Cooperioides hepaticae	73.5	97.8	80.0	163.2 ± 58.8	243.3 ± 37.2	71.7 ± 24.9
Haemonchus bedfordi	2.0	6.7	6.7	14.0 ± 11.0	75.0 ± 14.4	50.0 ± 0†
Haemonchus contortus	0.0	2.2	0.0	0*	2.0 ± 0†	0*
Haemonchus krugeri	62.2	71.1	60.0	557.0 ± 130.5	129.4 ± 20.2	97.6 ± 25.0
Haemonchus vegliai	1.0	4.4	6.7	3.0 ± 0†	2.0 ± 0.0	75.0 ± 0†
Impalaia tuberculata	80.6	91.1	60.0	1222.8 ± 210.6	472.9 ± 73.6	201.1 ± 50.6
Longistrongylus sabie	83.7	88.9	53.3	256.1 ± 45.8	157.0 ± 18.5	43.8 ± 10.3
Oesophagostomum columbianum	71.4	86.7	73.3	119.6 ± 26.3	116.7 ± 19.0	33.2 ± 9.0
Strongyloides papillosus	85.7	91.1	100.0	342.4 ± 28.7	430.2 ± 49.4	335.7 ± 61.9
Trichostrongylus deflexus	88.8	100.0	66.7	2236.2 ± 432.4	1499.7 ± 227.8	470.2 ± 302.1
Trichostrongylus falculatus	24.5	24.4	6.7	101.0 ± 21.6	56.7 ± 11.6	105.0 ± 0†
Trichostrongylus thomasi	89.8	93.3	33.3	539.1 ± 68.8	266.3 ± 34.4	138.6 ± 76.3

* None of the impala harbored the nematode.
† A single impala was infected.

spp., *Haemonchus* spp., and *Trichostrongylus* spp. (Armour, 1989; Ploeger et al., 1995; Vercruysse and Claerebout, 1997). In each study, prevalence or intensity, or both, decreased as the animal aged. Of the species examined in the previous studies, only *Haemonchus contortus* was recovered from the impala. A single impala harbored this nematode, which implies an accidental infection and not host immunity. It is unlikely that the *Cooperia* spp., *Haemonchus* spp., and *Trichostrongylus* spp. occurring in the impala are stimulating a significant immunological memory response, because mean intensity increases with age of the host.

Age is not the only factor associated with infracommunity differences. Sex of the individual animal influences their feeding preference and social behavior. In the impala, 5 nematode species are indicative of a specific sex (Table IV). All but one, *S. papillosus*, predict the sex of the host to be female. The species most indicative of females are those most likely to benefit from the reinfection that occurs within the female clans (Altizer et al., 2003). Reinfection increases the mean intensity among the females of the group, and improves the chances that the uninfected members of the group are acquiring the infection. Males gain reprieve from reinfection because their clans are smaller (Estes, 1990), and they tend to move more than the female herds (Murray, 1982).

Increased home range and rates of movement more likely expose males to a greater variety of nematode species. In the Sengwa Wildlife Research Area, Zimbabwe, the average annual home range of 4-yr-old males is 90 ha, and declines to 49 ha in males 5–6 yr of age (Murray, 1982). Furthermore, JUM travel an average of 1.2 km after leaving their natal herd (Murray, 1982). These estimates also apply to impala of KNP. Dispersal and large home ranges explain why the JUM harbor all of the nematode species that infect impala in KNP (Table V). Moreover, adults >4 yr of age avoid the rare infections by restricting the range they travel during any given year.

Female impala congregate in large herds and have an average home range of 51.6 ha (Murray, 1982). The natal clans typically remain in a small area, but they will move during the dry season as food resources dwindle. Members of the female herds can only be exposed to those infective stages present in the area where they reside. Therefore, female clans are not exposed to the rare species that infect the males. However, less movement increases the chance of repeated exposure to infective stages in their home range (Altizer et al., 2003). The most extreme example of reinfection occurred during the drought of 1982. J. Boomker (unpubl. obs.) found that impala at Skukuza congregated on a golf course, which was maintained with regular watering and careful tending. This soon resembled an irrigated pasture with the numbers of worms in individual animals trebling and ultimately causing the death of the antelope. In other vertebrates, studies have demonstrated an increase in parasite prevalence and intensity within larger groups of individuals (Freeland, 1979; Brown and Brown, 1986; Moore et al., 1988; Davies et al., 1991; Altizer et al., 2003). The relationship likely results from an increased risk of infection, especially if a few members currently harbor infections. Impala exhibit this trend, with members of the larger ADF clan having greater worm burdens than their male counterparts.

Food selection and variation in dispersal of the infective larvae are factors affecting the community composition differences between adult male and female impala. During the rut, the strongest males claim the prime territory, which contain most of the grass and shrubs consumed by the females. At this time, the territorial males constantly attempt to exclude other males while keeping the females within their territory (Van Rooyen and Skinner, 1989). These males have less time for feeding, and must consume what is available without being selective. Typically, the males will consume significantly fewer dicots than are consumed by bachelor males on the periphery of their territory (Van Rooyen and Skinner, 1989). Females, in contrast,

are very selective, preferentially consuming the high-quality dicots (Rodgers, 1976; Fritz and De Garine-Wichatitsky, 1996) within the male impala's territory (Van Rooyen and Skinner, 1989). The difference in food preference produces differential exposure probability to the various infective stages present in the habitat. Thus, indiscriminate feeders, i.e., territorial males, are more likely to consume and become infected with those species commonly occurring in other antelope and ungulate species. This assumes that vegetation type is affecting the dispersal of infective larvae, which has been demonstrated for a variety of common pasture plants (Callinan and Westcott, 1986; Niezen et al., 1998; Hoste et al., 2006). Alternatively, preferential food selection may be providing a type of antihelminthic treatment against certain nematode species, particularly *Haemonchus* spp. Condensed tannins reduce fecundity and total egg output of *H. contortus* in goats (Kahiya et al., 2003; Paolini et al., 2003). By consuming plants that are high in tannins, the hosts are reducing their future infection risk by limiting the number of eggs that enter the environment. Over time, the condensed tannins would decrease the species diversity within a particular group of hosts, or lower the mean intensity of those nematodes adversely affected by the chemical.

Niche overlap appears to be the dominant factor structuring the component community of impala. As in Holmes and Podesta (1968), hosts with similar ranges and diets are exposed to nearly the same parasites. For impala, significant overlap in local habitat occurs within the sexes, such that females congregating in clans harbor a component community different from the less social males. Additionally, the cost of territoriality in males, namely indiscriminate food consumption, exposes them to a greater array of infective stages, including those species commonly occurring in other ungulate hosts.

It is clear that age and sex of impala influence the structure of the parasite community. A combination of social organization and behavior is probably producing these differences. A comparison of impala infracommunities to those of the greater kudu reveal striking differences (Fellis et al., 2003). Those nematodes that are common in the impala are rare or occasional in the kudu, and vice versa. Both the diet and social organization of the kudu, a nongregarious browser (Estes, 1990), probably produce these differences. The wildebeest infracommunity (Horak et al., 1983) also includes species that infect both the kudu and impala. Of the 4 common species recovered from the wildebeest, *Trichostrongylus thomasi* and *O. columbianum* are common in the impala, whereas *Cooperia conochaeti* and *Haemonchus bedfordi* are rare. Although they are not ungulates, scrub hares (Boomker et al., 1997) show similar patterns. Five of the 6 nematodes infecting the hares also infect impala, i.e., *Cooperia hungi*, *Impalaia tuberculata*, *Trichostrongylus deflexus*, *T. falculatus*, and *T. thomasi*. Additionally, 4 of these 5 species have prevalences greater than 40%. None of the common species of the kudu infect wildebeests or scrub hares.

The various feeding preferences will expose the host to a specific set of infective larvae that are capable of migrating onto their food source. Thus, nematodes species that are most adept at dispersing up blades of grass will likely be rare in browsers, and vice versa. Of the mammals mentioned, kudu are browsers, impala are intermediate feeders, and wildebeest and scrub hares consume grass (Estes, 1990). It is not surprising then, that some of the common species of the intermediate feeding impala are also common or occasional in either browsing or grazing species. Furthermore, rough estimates of commonness or rarity of the nematodes of 2 browsers, the grey duiker and bushbuck (Boomker et al., 1986), show that they are most similar to the kudu.

Food preference is only 1 factor that shapes the infracommunities of antelope in KNP. Social organization, i.e., gregarious vs. nongregarious species, is another. As previously discussed, impala are gregarious and form herds. Living in herds increases the risk of repeated exposure to infective larvae (Altizer et al., 2003). Kudu, on the other hand, are much less social. Herds are formed, but the average number of kudu in these herds is much less than the average number of impala in a herd (Skinner and Smithers, 1990). Even though kudu are larger than impala, and have the potential to hold a greater number of nematodes (Halvorsen, 1986), the intensity of infection is only 20% that of the impala. Lack of repeated exposure may be causing the lower intensity levels.

Careful inspection of Boomker et al. (1986) reveals that component communities of different host species can be similar within a region. Describing the transmission dynamics within KNP requires an understanding of the factors that shape the component community of a host species (Fig. 2). First, preferred habitat and activity of a host will determine the species of parasites that can potentially infect a host. If the infective stages are not present or encountered, then that parasite will be absent from the host in that region. Second, food preference will dictate which infective stages are consumed. Infective larvae migrate onto and up certain types of vegetation better than others (Callinan and Westcott, 1986; Niezen et al., 1998). Those hosts preferentially consuming the infested plants are more likely to harbor a heavy infection. Third, the host does not come in contact with those infective larvae common on unpalatable vegetation. Thus, food preference not only affects the presence or absence of specific nematodes, but it also influences the relative abundance within the host. Finally, the last host factor that shapes the component community is social organization. The degree of gregarious behavior can often indicate the level of repeated exposure experienced by members of the herd (Altizer et al., 2003).

Attention to host factors is only a single dynamic in understanding parasite component communities. Within a habitat, there can be multiple host species that are infected by the same subset of parasites. The movement patterns within and between habitats promote the dispersal of infective stages, thus homogenizing the component communities of various host species. This is offset by variations in habitat and food preference, which inhibit successful species sharing. Consider a region with 6 host species living in 3 habitats (Fig. 3). Of the host species, 2 are pure grazers, 2 are pure browsers, and 2 are intermediate or mixed feeders. Within the same habitat, 2 grazers have the potential to share a larger number of parasite species than 2 host species with different feeding preferences. Moreover, differences in habitat preference restrict the number of parasite species shared between 2 browsers. Intermediate feeders are the link between browsers and grazers. They harbor species common to both, and can disperse infective stages so that browsers are exposed to the parasites of grazers, and vice versa.

Niche overlap, whether in diet or habitat, likely explains the

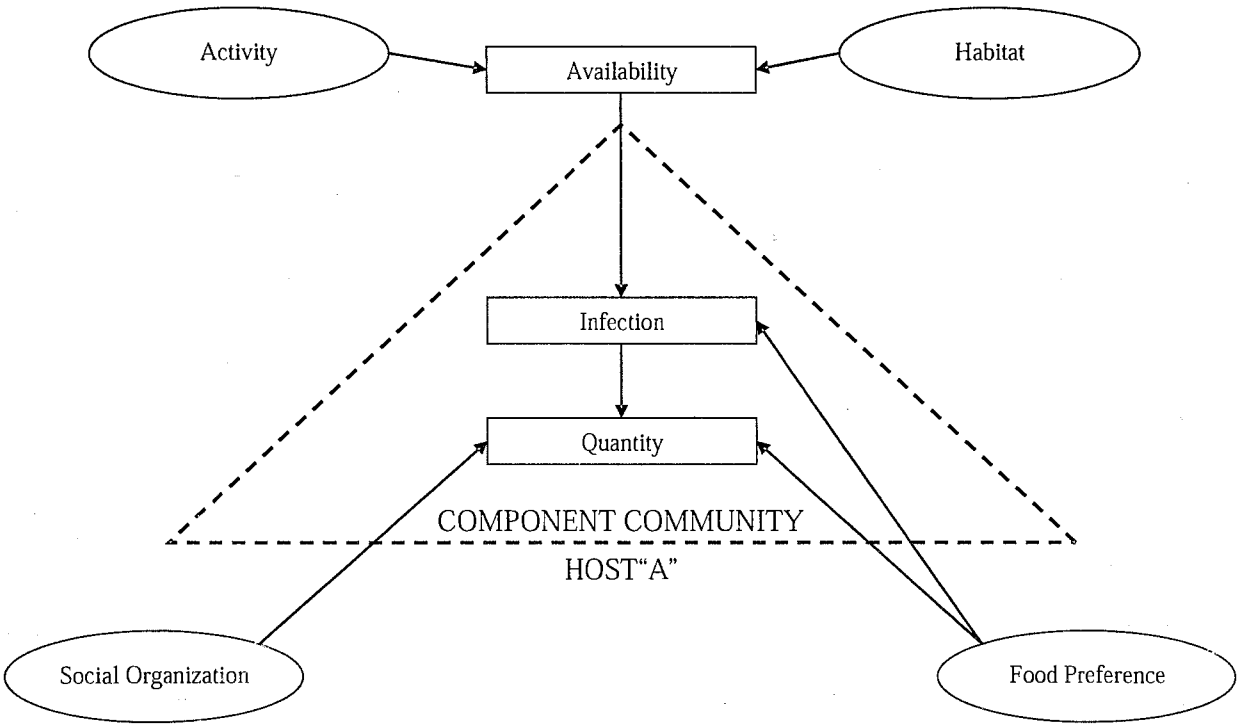

FIGURE 2. Diagram showing the determinants of the component community of a single host species. Both habitat preference and level of activity will determine the number of species that could be potentially encountered by the host. Infection requires that the parasite is present in the area and consumed by the host. The worm burden is controlled by food preference and social organization. Factors related to the host are placed in ovals.

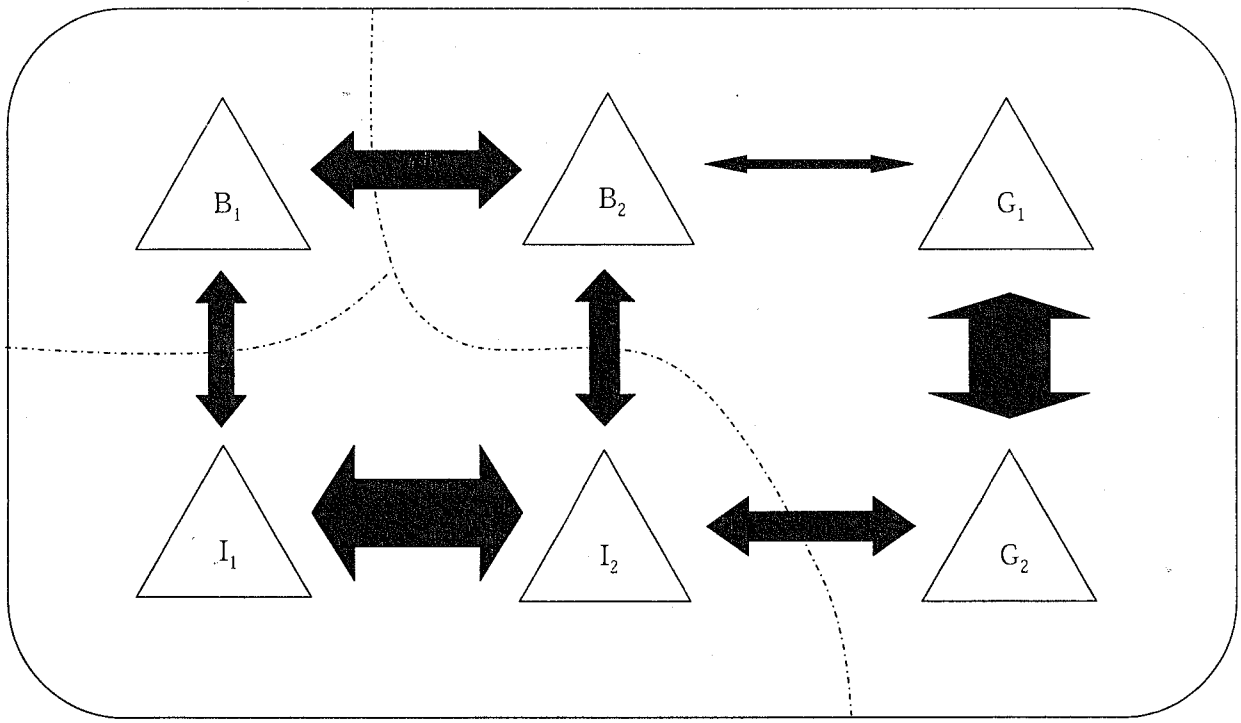

FIGURE 3. Concept of species sharing between different hosts (triangles) in various habitats (dashed line). The hosts include browsers (=B), grazers (=G), and mixed feeders (=I), with the subscript indicating differences in host species. Arrow thickness represents the relative amount of overlap in reference to those parasites infecting both host species.

patterns observed in the component communities of hosts from KNP. This idea has also been proposed for freshwater fishes (Nelson and Dick, 2002; Johnson et al., 2004). The latter authors concluded that dominance of parasite species in a compound community reflects the presence of specific host species and the degree of overlap of infected intermediate hosts in the definitive hosts' diet. For KNP, dietary overlap pertains to food preference, i.e., whether an animal is a browser, a grazer, or intermediate, and habitat dictates which hosts are present and contributing parasites to the compound community pool.

Transmission between host species is, therefore, likely occurring in KNP. With complete records of all antelope in KNP, we will likely see that certain nematode species are common in specific subsets of antelope. For example, *C. conochaeti* and *H. vegliai* may be common only in browsers, and accidental in grazing antelopes. *Trichostrongylus falculatus* may be common only in grazers (Horak, 1978). The common species of intermediate feeders probably include common species from both browsers and grazers. Variability in this pattern, such as the presence of "host-specific" nematodes, may arise from differences in habitat preference of the host (grassland vs. woodland habitat).

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CHAPTER 3

Miscellaneous contributions

Introduction

In this chapter a number of miscellaneous finding made during the years of the research are listed. These have been incidental findings, but nevertheless interesting ones. The article on *Strobiloestrus* in cattle is included here as the fly larvae are normally parasitic in especially klipspringer, *Oreotragus oreotragus*. I was also involved in the compilation of the parasite lists of various animals that were seen as possible game ranch animals. The references below are listed in chronological order because of their miscellaneous nature.

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STROBILOESTRUS SP. LARVAE IN CATTLE

I.G. HORAK* and J. BOOMKER*

ABSTRACT: Horak I.G., Boomker J. ***Strobiloestrus* sp. larvae in cattle.** *Journal of the South African Veterinary Association* (1981) **52** No. 3, 211–212 (En) Department of Parasitology, Faculty of Veterinary Science, University of Pretoria, P.O. Box 12580, 0110 Onderstepoort, Republic of South Africa.

A number of calves and a two year-old heifer in the Middelburg District of the Transvaal were found to harbour *Strobiloestrus* sp. larvae in nodules along their sides. Each nodule contained a single larva and these larvae developed from the early second stage to the third stage during the 25 day period between the first and last visit to the district.

A particular set of circumstances involving the presence of klipspringers, which are considered to be the normal hosts of *Strobiloestrus clarkii,* grazing practice, hair colour of the calves and tick control probably resulted in the cattle becoming infested. A pour-on formulation of an insecticide was highly effective against the larvae.

INTRODUCTION

The larvae of the warble flies, *Hypoderma bovis* and *Hypoderma lineata,* are parasites of the cutaneous and subcutaneous tissue of cattle in the Northern Hemisphere[3]. They are occasionally encountered in imported cattle in southern Africa but there is no record of their having become established in this region.

Warble flies do, however, occur in the Republic of South Africa. These belong to the genus *Strobiloestrus,* and their larvae are found in the skin and subcutaneous tissue of reedbuck, klipspringer and kudu and have also been recovered from a domestic goat[3] and from cattle[1].

The present paper describes an investigation following the earlier recovery of *Strobiloestrus* sp. larvae from warble-like lesions in the skin of cattle in the Middelburg District of the Transvaal[1].

HISTORY

During a visit to the farm Buffelskloof in the Middelburg District, raised, circumscribed nodules in the skin of the sides of a number of young calves were noticed[1]. A single oestrid larvae belonging to the genus *Strobiloestrus* was expressed from each of some of these nodules.

The farm was visited on two subsequent occasions. These visits revealed that a steep rocky cliff effectively divided it into a section of Highveld grasslands and another of Bushveld Savanna. Several klipspringers lived on this cliff.

The cattle on the farm were mainly Africander-type cows which were bred to a Charolaise and to two Brahman bulls. The age of the crossbred calves at the time of the investigation ranged between approximately five and nine months. During the summer months the cattle were sprayed once weekly with amitraz (Triatix: Coopers SA (Pty) Ltd), a tick detaching agent, administered by means of a spray race.

INVESTIGATION

The farm was originally visited on 3 March 1979 and the larvae expressed on that occasion were identified as being in the early second stage of development (Fig. 1). The farm was again visited on 9 March 1979 and it was found that 13 of 57 calves in one herd and one of 52 calves in another were infested. The majority of calves

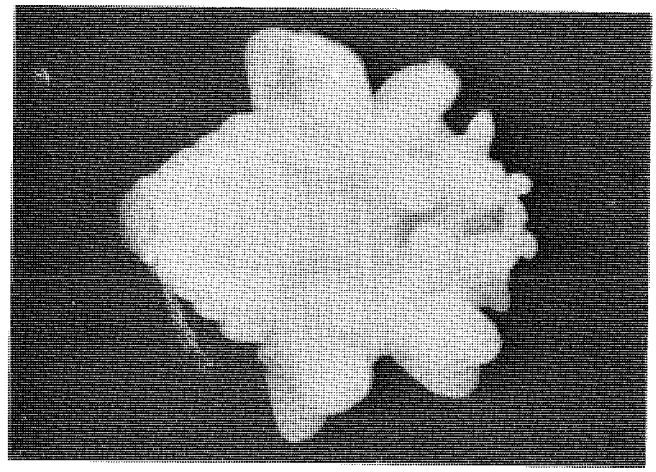

Fig. 1 Early second stage larva of *Strobiloestrus* sp. expressed from the skin of a calf. Actual length of larva 9,5 mm

in each of the herds was red in colour and had short hair but with the exception of one of the latter calves, the infested calves were yellow to fawn in colour and had medium length hair and were probably offspring of the Charolaise bull. No adult cattle appeared to be infested.

Infestation was characterized by the presence of circumscribed, raised nodules, approximately 15 mm in

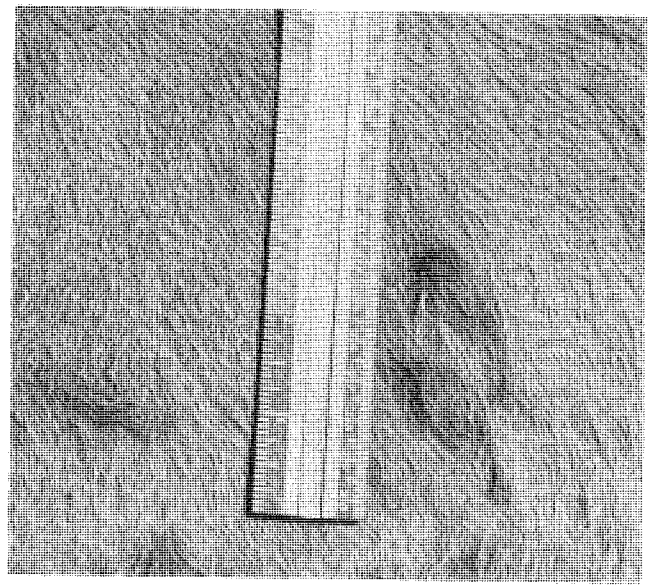

Fig. 2 Circumscribed, raised nodules caused by the larvae of *Strobiloestrus* sp. in the skin of a calf.

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diameter and 4 mm high, in the skin of the upper halves of the shoulders and sides (Fig. 2). Approximately two to 12 nodules were present in the skins of the infested calves, but one had 31 nodules.

A small opening was present in the centre of each nodule and a single larva could be expressed through this opening (Fig. 3). The larvae recovered from the nodules on this occasion were late second stage larvae.

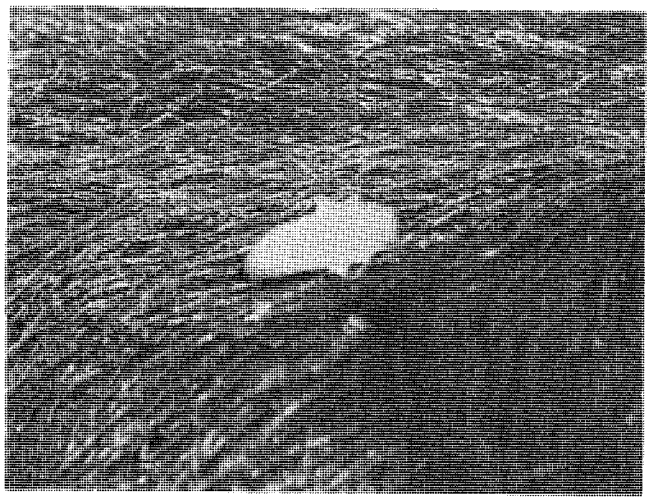

Fig. 3 Second stage larva of *Strobiloestrus* sp. expressed from a nodule in the skin of a calf.

The calf with the 31 nodules was treated with a pour-on formulation of famphur (Warbex: Coopers SA (Pty) Ltd.) administered on its hide along the length of its back.

The farm was visited again on 28 March 1979. The nodules on the treated animal had regressed in size and while larvae were still present these were in an advanced stage of decomposition. No nodules were seen on any of the other calves. A neighbouring farm was also visited on this occasion and a single, red-coloured two year-old heifer was found to be infested. Immature third stage larvae were expressed from the nodules on this heifer.

DISCUSSION

No specific identification of the *Strobiloestrus* infesting the calves could be made as according to Zumpt[3] these flies are not yet separable in the larval stage.

The life cycle of flies of the genus *Strobiloestrus* is unknown[3] and consequently the sites on which the eggs are deposited and the route by which the larvae reach the skin are also not known. The opening in the skin in the centre of each nodule serves both for respiration, as the larval spiracles are applied to it, and as exit for the mature third stage larvae. The fact that at each visit to the farm the larvae recovered were in a more advanced state of development and in one animal on an adjoining farm had reached the third stage indicates that the larval life cycle could probably be completed in cattle. The absence of nodules on the untreated calves on the third visit to Buffelskloof was probably due to the fact that the larvae had left the skin either as mature third stage larvae or perhaps as immature larvae. If these larvae had died in the skin, nodules containing dead larvae would possibly still have been present as they were in the case of the treated calf.

The infestation of calves at Buffelskloof probably resulted from a particular set of circumstances prevailing on the farm. Firstly the presence of a large number of klipspringers, a definitive host of the larvae of *Strobiloestrus clarkii*[3]. Secondly the cattle grazed part of the cliff on which the klipspringers occurred thus presumably entering the habitat of the flies. Thirdly the presence of calves somewhat similar in colour to the klipspringers, a fact which may have led to the flies laying eggs on these calves. Lastly the cattle were regularly sprayed with a tick-detaching agent which had no insecticidal effect. If such an insecticidal effect had been present the larvae would probably have been killed in an early stage of development before they caused the formation of nodules.

The fact that warbles caused by the larvae of *Strobiloestrus* spp. have not become an economic problem in cattle in South Africa can probably be ascribed to the regular application of acaricides, which usually also have an insecticidal effect, to cattle in extensive regions of the subcontinent.

Pour-on formulations of insecticides are used extensively for the control of warbles, caused by *Hypoderma* spp., in the Northern Hemisphere[2] and famphur in a pour-on formulation was highly effective against the larvae of *Strobiloestrus* sp. in the present investigation. In addition the stockowner was advised to alternate tick-detaching agents and acaricides with an insecticidal effect in his tick control programme in order to prevent a recurrence of the condition.

ACKNOWLEDGEMENTS

We wish to thank Mr. J.P. van Heerden, on whose farm the infestation occurred, for his cooperation with the investigation and for use of the facilities on the farm.

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THE EFFICACY OF IVERMECTIN* AGAINST HELMINTH AND ARTHROPOD PARASITES OF IMPALA

I.G. HORAK**, J. BOOMKER***, SHIRLEY A. KINGSLEY*** and V. DE VOS****

ABSTRACT: Horak I.G.; Boomker J.; Kingsley Shirley A.; De Vos V. **The efficacy of ivermectin against helminth and arthropod parasites of impala.** *Journal of the South African Veterinary Association* (1983) **54** No. 4, 251-253 (En). Tick Research Unit, Rhodes University, 6140 Grahamstown, Republic of South Africa.

The efficacy of ivermectin, injected subcutaneously at a dosage rate of 200 mcg/kg live mass, was determined against nematodes, ixodid ticks and lice infestations acquired by free-living impala, *Aepyceros melampus*, in the Kruger National Park. Although the parasite burdens of the untreated control animals varied considerably, ivermectin appeared to be highly effective against 7 nematode species and effective against 3 others. Of the 4 tick species recovered, only *Boophilus decoloratus* appeared to have been affected. In the case of the lice infestations, ivermectin was highly effective against 3 species of *Linognathus*, but ineffective against the 2 *Damalinia* species present.

Key words: Ivermectin, lice, tick, nematode infestation, impala.

INTRODUCTION

The efficacy of ivermectin against parasitic nematodes in cattle and sheep has previously been demonstrated[1,2,10]. It is also effective against single-host ticks[5] and some multi-host ticks[6] on cattle and against sucking lice[5,8]. The present paper records its efficacy against helminth and arthropod parasites of impala, *Aepyceros melampus*, a wild ruminant species.

MATERIALS AND METHODS

Fourteen free-living impala, of various ages and both sexes, were caught without the use of chemicals during May 1982 in the vicinity of Skukuza, in the south of the Kruger National Park. These animals were confined at Skukuza in an enclosure (70 x 30 m), in which they had free access to water and were fed dry hay cut from the veld. There was also a little grass on which they could nibble, in the enclosure.

Six animals were treated with ivermectin administered subcutaneously at a dosage rate of 200 mcg/kg live mass on the day after their capture and 2 untreated animals were slaughtered at the same time. The treated animals were marked with paint on the rump and ran with the untreated controls until they had all been slaughtered.

Six to eight days after treatment, 3 treated impala and 3 untreated controls were slaughtered. Fourteen and 15 days after treatment the remaining two treated impala and two controls were slaughtered. One of the treated animals and one of the controls, destined to be slaughtered at the latter occasion, had been caught by a leopard during the intervening period.

Helminths and arthropods were recovered from these animals as previously described[4]. The lungs were, however, not processed for worm recovery.

Table 1: THE ANTHELMINTIC EFFICACY OF IVERMECTIN IN IMPALA

Impala No.	Age	Sex	Treatment	Day slaughtered	Numbers of nematodes recovered														
					Longistrongylus sabie		*Haemonchus krugeri*		*Trichostrongylus thomasi*	*Trichostrongylus colubriformis*	*Cooperia hungi*		*Cooperioides hamiltoni*	*Impalaia tuberculata*		*Strongyloides* sp.	*Gaigeria pachyscelis*	*Oesophagostomum columbianum*	
					4th	Adult	4th	Adult	Adult	Adult	4th	Adult	Adult	4th	Adult	Adult	Adult	4th	Adult
1	29 months	M	Control	0	0	27	0	6	0	0	0	32	27	0	0	0	26	0	0
2	17 months	M	Control	0	0	96	0	53	179	1457	0	205	531	0	252	400	25	25	0
3*	Adult	F	Control	6	620	106	90	0	353	0	0	1680	453	0	101	0	0	0	3
4°°	29 months	F	Control	6	0	3	0	0	111	681	0	278	278	0	26	515	1	0	1
5*	Adult	F	Control	7	0	1	0	25	84	53	25	229	157	25	0	625	0	50	0
6	29 months	F	Ivermectin	8	1	0	0	0	0	0	0	1	51	0	0	73	0	0	0
7	17 months	F	Ivermectin	8	0	0	0	0	0	0	0	50	105	0	0	1	0	0	0
8*	17 months	M	Ivermectin	8	0	1	0	1	0	0	0	128	100	0	0	57	0	0	0
9°°	17 months	M	Control	14	1	9	0	25	463	2329	1	553	431	0	79	156	4	0	25
10°°°	Adult	M	Control	15	100	552	25	25	1029	5147	228	734	1329	575	462	200	1	0	75
11	17 months	M	Ivermectin	15	0	0	0	0	0	75	0	125	1	0	0	50	0	0	0
12	17 months	F	Ivermectin	15	0	0	0	0	0	25	0	0	52	0	0	25	0	0	0

*Infested with adult paramphistomes 4th = Fourth stage larvae
°*Trichostrongylus falculatus* 47 Adults
°°*Trichostrongylus falculatus* 474 Adults, *Cooperia neitzi* 145 Adults
°°°*Cooperioides hepaticae* 269 Adults

*Ivomec: MSD (Pty) Ltd.
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****National Parks Board, Skukuza.

0038-2809/83/04/0251-0253

RESULTS

The nematode burdens of the impala are summarized in Table 1.

With the exception of *Cooperia hungi*, *Cooperoides hamiltoni* and *Strongyloides* sp., against which efficacy seemed variable, ivermectin was highly effective against the various nematode species present in the impala.

The ixodid tick burdens of the impala are summarized in Table 2.

The tick burdens of the control and treated animals generally decreased the longer the animals were kept in the enclosure prior to slaughter. With the exception of the treated animals slaughtered 15 days after treatment, on which there may have been some activity against adult *Boophilus decoloratus*, ivermectin appeared to have had no effect on the adult or immature stages of the other ticks.

The lice burdens of the impala are summarized in Table 3.

Ivermectin was highly effective against the sucking lice *Linognathus aepycerus*, *Linognathus nevilli* and *Linognathus* sp., but had no apparent effect on the biting lice *Damalinia aepycerus* and *Damalinia elongata*.

DISCUSSION

Thirteen species of nematodes were recovered from the impala and, as can be expected with naturally acquired infestations, the worm burdens varied considerably. Although ivermectin was generally highly effective against most nematodes present its efficacy against *Cooperia hungi* and the related *Cooperioides hamiltoni* was variable. A similar phenomenon has also been noted with *Cooperia curticei* in sheep[10]. The efficacy against *Strongyloides* sp. also appeared variable. The effect of ivermectin against this genus has apparently not previously been determined in ruminants.

Table 2: THE ACARICIDAL EFFICACY OF IVERMECTIN ON IMPALA

Impala No.	Treatment	Day slaughtered	Numbers of ticks recovered													
			Amblyomma hebraeum			*Boophilus decoloratus*				*Rhipicephalus appendiculatus/ zambeziensis*				*Rhipicephalus evertsi evertsi*			
			Larvae	Nymphae	♂	Larvae	Nymphae	♂	♀	Larvae	Nymphae	♂	♀	Larvae	Nymphae	♂	♀
1	Control	0	464	192	0	1776	1568	256	250	448	0	36	12	240	0	0	2
2	Control	0	1216	386	0	3744	1904	528	146	432	0	14	2	304	96	2	0
3	Control	6	58	18	0	320	678	288	124	8	0	24	8	12	20	0	0
4	Control	6	50	46	2	360	798	244	130	0	0	10	10	120	8	0	0
5	Control	7	32	34	0	396	1026	266	132	12	0	16	6	56	106	0	0
6	Ivermectin	8	94	54	0	464	864	234	248	14	0	6	8	24	8	0	0
7	Ivermectin	8	546	54	0	376	384	130	60	10	0	0	2	56	0	0	0
8	Ivermectin	8	144	0	0	624	1280	216	80	8	0	2	2	64	96	0	0
9	Control	14	26	16	0	0	354	116	98	16	0	4	0	2	8	0	0
10	Control	15	10	16	0	30	600	298	128	12	6	2	0	0	6	18	0
11	Ivermectin	15	12	2	0	36	196	6	12	4	6	4	2	4	0	0	0
12	Ivermectin	15	58	4	0	214	210	42	28	0	0	2	2	0	4	0	0

Table 3: THE INSECTICIDAL EFFICACY OF IVERMECTIN ON IMPALA

Impala No.	Treatment	Day slaughtered	Numbers of lice recovered									
			Damalinia aepycerus		*Damalinia elongata*		*Linognathus aepycerus*		*Linognathus nevilli*		*Linognathus* sp.	
			Nymphae	Adults	Nymphae	Adults	Nymphae	Adults	Nymphae	Adults	Nymphae	Adults
1	Control	0	0	0	0	16	0	0	0	0	0	0
2	Control	0	880	512	160	96	64	96	0	0	64	96
3	Control	6	18	4	4	6	14	20	36	12	0	4
4	Control	6	4	4	16	12	32	36	0	4	0	12
5	Control	7	0	6	4	20	0	2	2	2	0	0
6	Ivermectin	8	6	2	4	4	0	0	0	0	0	0
7	Ivermectin	8	8	32	1160	650	0	0	0	0	0	0
8	Ivermectin	8	32	0	464	184	0	0	0	0	0	0
9	Control	14	10	2	0	2	60	62	0	0	0	2
10	Control	15	96	0	16	12	140	198	54	46	52	216
11	Ivermectin	15	12	0	6	2	0	0	0	0	0	0
12	Ivermectin	15	76	38	28	26	0	0	0	0	0	2

The impala harboured 4 species of ixodid ticks. As they were probably not exposed to further infestation in the pen, their tick burdens decreased fairly rapidly as the ticks engorged and dropped off. This makes interpretation of the results difficult, but with the possible exception of *B. decoloratus*, ivermectin was not effective against the tick species present. As *B. decoloratus* is a one-host tick, the apparent efficacy against the adult ticks may partially have been due to an effect against the immature stages resulting in delayed maturation. Improved control of *B. decoloratus* and possibly the other ticks, too, can probably be obtained by regular short interval treatment of animals[6,7].

The efficacy of ivermectin against *Linognathus* spp. and its inefficacy against *Damalinia* spp. on cattle has previously been reported[8]. The present experiment shows a similar pattern for these lice genera on impala.

Although free-living wild ruminants are seldom treated for parasites such treatment is advisable upon capture and translocation[3]. Ivermectin with its low toxicity[9] and high efficacy against most parasitic nematodes, sucking lice and the parasitic larvae of several fly species[5] would appear to be the drug of choice on such occasions.

ACKNOWLEDGEMENTS

We wish to thank the National Parks Board of Trustees for placing the impala at our disposal. The assistance of Messrs B.D. de Klerk and E.J. Williams with the necropsies and parasite collections is gratefully acknowledged.

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BOOK REVIEW **BOEKRESENSIE**

HANDBOOK OF VETERINARY NEUROLOGIC DIAGNOSIS

JOHN E. OLIVER & MICHAEL D. LORENZ

W.B. Saunders Company, Philadelphia. 1983 pp IX and 371. Figs. 179, Tables 109. Price R47,50. (ISBN 0-7216-6967-0)

Professors Oliver and Lorenz are to be congratulated on a well-written text providing a logical approach to the solving of neurological disorders in animals. The dog has been used as the model in their book with brief reference to appropriate species differences.

The text is divided into two major sections. The first dwells on the essential fundamentals of neurologic diagnosis such as the history, physical examination of the nervous system, localization of lesions in the nervous system and ancillary diagnostic aids. A chapter dealing briefly with the principles of medical treatment has also been included.

The second part of the text presents the most common clinical neurological problems presented to the clinician such as seizures, blindness, coma and paresis of a limb. The anatomic diagnosis is firstly reviewed, followed by a diagnostic and treatment plan. A brief discussion on the major differential diagnostic conditions is also presented.

A very useful and stimulating self-assessment section concludes every chapter throughout the book.

The text is amply illustrated with numerous photographs, sketches, diagrams and tables.

This book is a must for veterinary clinicians and students with an interest in veterinary neorology. I have no hesitation in strongly recommending it as a valuable aid in the diagnosis of neurological disorders.

J. van Heerden

THE WILD DOG (*LYCAON PICTUS*): A NEW HOST FOR *ANCYLOSTOMA CANINUM*

J VAN HEERDEN*, J BOOMKER**, D G BOOYSE** and M G L MILLS+

ABSTRACT

Faecal nematode egg counts performed on one captive and 49 free-ranging wild dogs (*Lycaon pictus*) revealed the presence of eggs of *Ancylostoma* spp. in 12 (24%) of the animals. The captive wild dog pup showed anorexia, general malaise, pale mucous membranes and black stools. Adult male and female *Ancylostoma caninum* were recovered from an approximately 3-month-old pup which died of distemper-like disease and a 9-year-old severely debilitated captive wild dog. A single adult *A. caninum* was also recovered from the intestines of a free-ranging wild dog in the Kruger National Park. These findings confirm the wild dog to be a host for *A. caninum*.

Key words: Wild dog, *Lycaon pictus, Ancylostoma caninum*

Van Heerden J.; Boomker J.; Booyse D.G.; Mills M.G.L. **The wild dog (*Lycaon pictus*): A new host for *Ancylostoma caninum*.** *Journal of the South African Veterinary Association* (1994) 65 No. 1, 18-19 (En.) Department of Companion Animal Medicine and Surgery, Faculty of Veterinary Science, Medical University of Southern Africa, 0204 Republic of South Africa.

Ancylostoma caninum is a common nematode parasite of canids and occasionally felids in many parts of the world. In South Africa it is likewise a common parasite in the domestic dog. In Africa, it has been recorded in the cheetah (*Acinonyx jubatus*), black-backed jackal (*Canis mesomelas*), side-striped jackal (*Canis adustus*), golden jackal (*Canis aureus*), fennec (*Vulpes zerda*), African wild cat (*Felis lybica*), small-spotted genet (*Genetta genetta*), bat-eared fox (*Otocyon megalotis*), Cape fox (*Vulpes chama*) and leopard (*Panthera pardus*)[3]. Anderson[1], however, considered *A. caninum* to be a parasite of canids, whereas *A. tubaeforme*, *A. ceylanicum* and *A. braziliense* occur in both canine and feline hosts. Earlier records on felids and mustelids should therefore be treated with reserve.

Although eggs of *Ancylostoma* spp. have been identified in the faeces of captive[5] and free-ranging wild dogs (*Lycaon pictus*) (J Richardson 1992, private practitioner, Nairobi, Kenya, personal communication, and J W McNutt and S Osofsky, 1994 Botswana Wild Dog Research Project, Maun, Botswana), neither adult nor larval hookworms have been recovered from this carnivore. This report documents the presence of *A. caninum* in both captive and free-ranging wild dogs.

A wild dog pup, born in captivity, was presented with anorexia, general malaise, very pale mucous membranes and black stools. At least one littermate had died of a severe anaemia. The packed cell volume was 0,08. A faecal flotation revealed the presence of numerous eggs of *Ancylostoma* spp.. The pup was treated with an anthelmintic and given an intravenous infusion of canine blood; it made an uneventful recovery.

Only 2 out of 9 captive wild dogs autopsied and processed for intestinal helminth recovery yielded *A. caninum*. Nine male and 3 female nematodes were found in the small intestine of an approximately 3-month-old pup which had died of a distemper-like disease, following vaccination against canine distemper. Two male and 2 female nematodes were recovered from the small intestine of an approximately 9-year-old, severely debilitated, male wild dog, which was clinically anaemic and had severe dental attrition. The packed cell volume of this animal was 0,22.

Faecal specimens (n=49) from free-ranging wild dogs were collected during August 1990, December 1991 and March 1993 in the southern part of the Kruger National Park. Most specimens were collected directly from the rectums of immobilised animals. Eleven or 22,4% of the faecal specimens were found to contain eggs of *Ancylostoma* spp. The hookworm egg counts varied from 100 to 1 300 per gram of faeces. Physical examination of immobilised wild dogs failed to reveal clinical signs of ancylostomosis. In addition, a single adult female *A. caninum* was recovered from the intestinal contents of a free-ranging wild dog that had been run over by a vehicle in the Kruger National Park.

Hookworms can perhaps be regarded as the most pathogenic nematode parasite of young domestic dogs and cats. The pups of domestic dogs are usually infected via the colostrum or milk of their dams and *Ancylostoma* larvae may be found in the milk during the first 20 d of lactation[4]. The percutaneous and transplacental routes of infection appear to be far less important in hookworm disease in domestic dog pups[2].

The most common, untoward side-effects in domestic dogs include anaemia, hypoproteinaemia and diarrhoea. The classical clinical signs in heavily infected pups, are pale mucous membranes and the production of black tarry faeces. In captive wild dog pups, infection with *Ancylostoma* spp. has been associated

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Received: October 1993 Accepted: January 1994

with anaemia, loss in body condition, weakness and diarrhoea[5].

Immunity to hookworm infections in domestic dogs is influenced by age, diet and the number of infective larvae[1]. Pups and malnourished domestic dogs are considered to be more susceptible, and this is in agreement with our findings of infections in suspected immuno-compromised wild dogs.

Although hookworm infections have not been found to be pathogenic in free-ranging wild dogs, ancylostomosis may well become a contributing mortality factor in pups or subadults under adverse conditions. The social organisation of wild dogs, which usually implies living in a pack, would facilitate transmission. The denning period, in particular, during which pups and the rest of the pack are restricted to the den and surroundings, may be conducive to the spread of infection. In captive wild dogs, ancylostomosis should definitely be considered as an important disease syndrome similar to that experienced in domestic dogs. Factors that compound the condition in both domestic and captive wild dogs, include the difficulty in the eradication of hookworms in both the dam and the environment.

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Book review/Boekresensie

CYTOLOGY AND HAEMATOLOGY OF THE HORSE

Editors, R L Cowell & R D Tyler

American Veterinary Publications, Thornwood Drive, Goleta, California 93117 1993, pp 242 (ISBN 939674-34-3)

This practical, easy-to-read, yet remarkably complete manual, will be used very often in a practice where there is an interest in equine cytology, and will give anyone who would like to add the fascinating, rewarding and cost-effective field of cytology to his diagnostic armour the confidence, reference and support to do so.

It is very clearly written with step-by-step, detailed instructions on how to separate specimens from different fluids and tissues; description of the pitfalls in staining, transporting and interpretation of cytological specimens; and excellent explanations, complimented with diagrams and colour photographic plates on the recognition of cytological features from normal to inflammatory, infectious and neoplastic features in each system. In most sections, other tests which complement cytology and aid in diagnostics are also mentioned, with emphasis on the relevance of each, i.e. cytology's place as seen in perspective to the "whole" of diagnostic procedures.

There are 11 chapters, beginning with a complete and simple introduction on sample collection in general, staining and trouble-shooting, the principles of identification of cells and their tissues-of-origin, signs of inflammation and infections, and criteria of malignancy.

The subsequent chapters each deal with a specific tissue, area or fluid: cutaneous and subcutaneous lesions: masses, cysts and fistulous tracts; the eyes and occular adnexa; the oral and nasal cavities; pharynx, guttoral pouches and paranasal sinuses; the lower respiratory tract; the gastrointestinal tract; the lymph nodes; pleural fluid; peritoneal fluid; synovial fluid; cerebrospinal fluid; the endometrium; semen evaluation; peripheral blood smears, and bone marrow. In addition to each chapter having its own excellent colour plates and diagrams, 7 additional colour plates appear at the end of the book. One of the very few errors in the book occurs in Plate 5 where the captions to 5E and 5G have been reversed).

One of the chapters of note for practicality, is the one on peritoneal fluid - it covers predictions for colic cases when the fluid analyses are compared with blood values of eg. glucose, lactate, total nucleated cell count, fibrinectin and enzymes. The pathogenesis of the biochemical changes in peritoneal fluid compared with those in bood in colic is given, and several flow diagrams help with interpretation of fluid findings.

The chapters on the reproductive tracts, emphasise the cytological differences with different cycle stages in the mare, and the part played by semen evaluation in the whole fertility examination, with an example of a comprehensive semen examination sheet as well as various methods of semen preparation for the haemocytometer method of measuring sperm concentration. There are clear diagrams and photographs of all the sperm abnormalities - classified as head, neck, midpiece and tail problems.

Haematological "reference intervals" are given in the chapter on peripheral blood smears.

This book is very highly recommended and many of the cytological principles apply to all species, as anyone already practising cytology will realise.

J H Williams

Proceedings of a Symposium on "Rhinos as Game Ranch Animals", Onderstepoort, 9 & 10 September 1994

Parasites of African rhinos: a documentation

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INTRODUCTION

In free-living wild animals a balance usually exists between hosts and parasites. Both have evolved together over the millennia. The presence of parasites under these conditions is usually incidental and of limited clinical significance. Under stressful conditions, such as droughts and especially human interference such as capture, captivity, transportation and release into strange surroundings, the host's immune system is suppressed, the balance is disturbed and parasite populations may escalate to such an extent that clinical symptoms become evident.

In this paper we attempt to document all the parasites that have been recovered from both black (*Diceros bicornis*) and white rhinos (*Ceratotherium simum*). Very few, if any, quantitative studies have been conducted; the records are primarily random collections or observations.

PROTOZOA

Trypanosoma species

Trypanosoma brucei[9, 23], *Trypanosoma congolense*[24] and *Trypanosoma vivax*[23,25] have been reported from black rhinos. These tsetse fly-borne blood parasites cause Nagana in livestock. Wild animals born in tsetse-infested areas often serve as reservoir hosts of trypanosomes, but clinical trypanosomosis only manifests when these animals are stressed. Mortalities due to trypanosomosis have been reported in recently captured young black rhinos in Tanzania after 9–25 days in captivity[23]. The deaths of four out of five white rhinos introduced to the tsetse-infested Zambezi Valley of Zimbabwe were attributed to trypanosomosis[47].

As these rhinos originated from KwaZulu Natal and had been kept in a tsetse-free area in southern Zimbabwe, they had never been exposed to trypanosomes. Chronic trypanosome-related health problems, including abortions, arose in white rhinos introduced into Meru National Park in Kenya from KwaZulu-Natal[25].

Babesia and *Theileria* species

Large Babesias, as yet unnamed, have been reported from black rhinos in Kenya[6] and from white rhinos in KwaZulu-Natal[5]. Babesiosis was regarded as the cause of death of two black rhinos[23]. Small piroplasms, either *Babesia* sp. or *Theileria* sp. but probably the latter, have been reported from black rhinos in East Africa[6,7] and KwaZulu-Natal[5,15]. Small piroplasms were seen in 42,8% of young white rhinos and 23,9% of adults examined in KwaZulu-Natal[5].

Balantidium

Balantidiosis has been reported in white rhinos[37]; the paper was not seen by us.

ARTHROPODS

Ticks

The majority of tick species are not host-specific, but are found on a great variety of vertebrate hosts. It is not surprising, therefore, that 40 tick species have been recovered from black and white rhinos (Table 1), though there is little doubt that the vast majority of these records represent incidental infestations only. Three species, however, are primarily rhino parasites. Two, *Amblyomma rhinocerotis* and *Dermacentor rhinocerinus*, have been collected from both black and white rhinos in many parts of eastern, central and southern Africa[16,50]. The third species, *Amblyomma personatum*, has been recorded from black rhinos, originally from Gabon and Kenya and subsequently also from Tanzania[50,55,58]. With the great reduction in black rhino numbers that has occurred in recent years this tick could easily become extinct. A fourth species, *Amblyomma sparsum*, has a strong predilection for black rhinos, although it has been recorded from a wide range of other mammalian hosts and also reptiles[50,55,58]. All these ticks are large, ornate species. Unfed adults of *A. rhinocerotis* are *ca.* 9 mm long and have a pattern of dark reddish-brown spots and stripes on an ochre-yellow background. *Dermacentor rhinocerinus* are 6-8 mm long and the male bears yellow-ochrous blotches on a chocolate-brown background[16,61]. The male of *A. personatum* is distinguished by having a dark brown figure resembling a flying bird on the pale background of its scutum. *Amblyomma sparsum* also has a brownish pattern of spots and stripes against a yellowish background. As its name implies, *Cosmiomma hippopotamensis* was originally described from hippos (*Hippopotamus amphibius*), but black rhinos are now regarded as its most likely host[4,55]. Common sites of tick attachment are skin folds in the perineal region, in and around the ears and around the eyes.

Flies

Glossina species – tsetse flies

Although the occurrence of trypanosomes in rhinos indicates that tsetse flies may feed on rhinos, they are not generally considered to be preferred hosts of the flies. In Kenya, however, *Glossina longipennis*, a tsetse species living in low densities in the typical dry bushveld habitat favoured by black rhinos, was found to feed primarily on rhinos[24,57]. Stereo-electron

micrographs of the labellar armature of *G. longipennis* indicate that it is specialised for feeding on elephants and rhinos[35].

Gyrostigma species – rhinoceros bot flies

This genus is closely related to *Gasterophilus,* the horse bot flies. *Gyrostigma pavesii* occurs in both rhino species. The flies are 24-35 mm long, with an orange and reddish head, a predominantly deep black thorax with a central reddish line, and a black abdomen with a reddish tip[61]. The adults are short-lived and do not feed, their mouthparts being rudimentary. The female deposits her eggs mainly in front of and below the anterior horn and between the two horns. The larvae that hatch from the eggs are *ca.*2 mm long. These larvae are thought to migrate in the epidermal tissue of the cheeks and mouth to the oesophagus. The second and third larval stages are found in the stomach, where they grow up to 4 cm long. Mature larvae leave the host with the faeces and pupate in the soil. The flies hatch after *ca.* 6 weeks. Zumpt[61] stated that the adults are rarely seen in the field and represent great rarities for the collector. This is largely explained by the fact that they live only a few days. Another reason lies in their behaviour: they stay in the close vicinity of rhinos, their only hosts, and who would approach a rhino armed only with a fly-net? *Gyrostigma conjungens,* a smaller species, parasitises black rhinos in East Africa.

Rhinomusca dutoiti

This blood-sucking fly is closely related to the stable fly (*Stomoxys calcitrans*). The larvae develop only in rhino dung, and the adults feed on both rhino species[60, 61]. These flies are somewhat larger than a house fly (*Musca domestica*), and have a stout, horn-coloured proboscis. A similar species, *Rhinomusca brucei*, occurs in East Africa.

Lyperosia species

This small fly has been found in association with black rhinos in Kenya[32]. The adult flies spend their life closely associated with their host, and the females fly down and lay their eggs on freshly deposited dung before returning to their feeding place on the host. The use of dung middens by rhinos ensures a continuously moist breeding place for the flies.

HELMINTHS

The diversity of helminth species is extensive. At least 40 known species have been reported in the two rhinos discussed here (Table 2). While most of these are nematodes, two trematodes and two cestodes have been reported. Several strongylid nematode genera predominate, including *Khalilia*, *Kiluluma*, *Murshidia* and *Quilonia*. The most abundant species is a small pinworm, *Probstmayria*, which was recorded in black rhinos in South Africa and Namibia in numbers of 399 000 000 in a single animal (R.C. Krecek, unpublished). *Probstmayria* is an example of a nematode not previously recorded. Its absence from the literature may be attributed to the method of previous collections. *Probstmayria* is 2-3 m in size and unless collection of the worm parasites is complete, i.e. quantitative samples are collected for microscopic examination, it is quite possible to miss recovery of these nematodes. Often new species are revealed in a host when quantitative studies are undertaken. In recent zebra helminth studies, six new nematode species were revealed when quantitative studies were done[41].

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Table 1: A list of ticks recovered from white and black rhinos

Tick species	White rhino	Black rhino		Reference
		S. Africa	E. & C. Africa	
Amblyomma cohaerens			X	14
Amblyomma eburneum			X	54
Amblyomma gemma			X	54, 58
Amblyomma hebraeum	X	X		1, 50
Amblyomma lepidum			?	50
Amblyomma personatum*			X	50, 54, 58
Amblyomma rhinocerotis*	X	X	X	1, 22, 50, 54
Amblyomma sparsum			X	50, 54, 58
Amblyomma tholloni			X	50, 54, 58
Amblyomma variegatum	X		X	50, 54, 58
Cosmiomma hippopotamensis*		X		4, 55
Dermacentor rhinocerinus*	X	X	X	1 22, 50, 54, 58
Haemaphysalis leachi	?	?		50
Haemaphysalis silacea		X		Horak (unpubl.)
Hyalomma albiparmatum			X	50, 54, 58
Hyalomma impeltatum			X	58
Hyalomma impressum			X	31
Hyalomma marginatum rufipes			X	50, 54
Hyalomma truncatum	X	X	X	1, 50
Rhipicephalus appendiculatus	X	X	X	1, 50, 54
Rhipicephalus sp. near *bequaerti*		X		1
Rhipicephalus capensis		?		50
Rhipicephalus compositus			X	50, 54, 58
Rhipicephalus humeralis			X	50, 54, 58
Rhipicephalus hurti			X	54, 58
Rhipicephalus jeanneli			X	54, 58
Rhipicephalus kochi			X	58
Rhipicephalus longus			X	54
Rhipicephalus lunulatus			X	56
Rhipicephalus maculatus	X	X	X	1, 50, 54
Rhipicephalus muehlensi		X		1, 50, 54
Rhipicephalus pravus			X	54
Rhipicephalus pulchellus			X	50, 54, 58
Rhipicephalus sanguineus			X	31, 50
Rhipicephalus senegalensis			?	50
Rhipicephalus simus	X	X	X	1, 50, 54, 58
Rhipicephalus supertritus			X	50
Rhipicephalus zambeziensis	X			Horak (unpubl.)
Rhipicephalus ziemanni			?	50
Rhipicephalus zumpti		X		1

* Rhinos are preferred hosts

Table 2: Helminth parasites of white and black rhinos

Parasite	White rhino	Black rhino S. Africa	Black rhino E. & C. Africa	Reference
Trematodes				
Brumptia bicaudatum			X	21
Gastrodiscus aegyptiacus	X			45
Cestodes				
Anoplocephala diminuta			X	40
Anoplocephala gigantea	X	X	X	27, 33, 34, 38, 43, 44, 61
Nematodes				
Grammocephalus intermedius			X	28
Habronema spp.	X			59
Habronema khalili		?	?	11
Khalilia rhinocerotis			X	28
Kiluluma africana		X	X	26, 46, 48, 61
Kiluluma brevicauda			X	49
Kiluluma brevivaginata			X	49
Kiluluma cylindrica			X	49
Kiluluma goodeyi		X	X	26, 49, 61
Kiluluma macdonaldi			X	46, 49
Kiluluma magna		X	X	11, 26, 46, 48
Kiluluma pachyderma		X	X	11, 26, 48
Kiluluma rhinocerotis		X	X	11, 26, 46, 48
Kiluluma solitaria		X	X	11, 26, 46, 48
Kiluluma stylosa			X	19, 20, 42, 53
Murshidia africana			?	8, 11
Murshidia aziza			X	8, 11, 28
Murshidia bozasi			X	8, 11, 28
Murshidia memphisia			X	8, 11, 28
Murshidia omoensis			X	8, 11, 28, 29
Murshidia pugnicaudata	X			Boomker & Booyse (Unpubl.)
Necator americanus			*	3
Oxyuris equi		X		26
Oxyuris karamoja	X	X	X	2, 40, 52, 61
Parabronema rhinocerotis			X	17
Parabronema roundi			X	12, 40
Physocephalus sexalatus		?	?	11
Probstmayria species		X		Krecek & Boomker (unpubl.)
Quilonia africana			X	8, 11, 29
Quilonia parva			X	8, 29
Setaria africana		X		10
Stephanofilaria dinniki		X	X	13, 18, 39, 40, 51
Strongylus tremletti			X	23, 38
Thelazia sp.			X	40
Trichuris sp.			**	36

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Proceedings of a Symposium on the African Buffalo as a Game Ranch Animal, Onderstepoort, 26 October 1996

PARASITES OF AFRICAN BUFFALOES: A DOCUMENTATION

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INTRODUCTION

In South Africa, the parasites of buffalo have not received much attention, despite the animals' relative abundance in this country. Although Young & van den Heever[102] and Basson *et al.*[6] examined the carcasses of many buffaloes culled in the Kruger National Park (KNP), no surveys of the parasites have been conducted and those parasites that are known have been collected incidentally. A survey involving thousands of buffaloes was conducted in Mozambique, and despite the numbers of animals involved, few parasites were reported on.

In this paper we attempt to bring together the literature pertaining to the parasites of buffaloes. The list is by no means complete as much of the older literature was inaccessible. We further attempted to separate those parasites recorded from South Africa from those of the rest of Africa, and those occurring in *Syncerus caffer caffer* from those of *Syncerus caffer nanus*.

PROTOZOA AND RICKETTSIAS (Table 1)

Babesia **species and** ***Anaplasma*** **species**
Although common in cattle, in which these organisms cause severe disease, they have to the best of our knowledge not yet been recorded from buffaloes in South Africa. Both of these organisms are transmitted by the blue tick, *Boophilus decoloratus*.

Theileria **and** ***Haematoxenus*** **species**
Buffaloes have long been known to be the main carriers of the *Theileria* spp., of which *T. parva parva*, *T. parva lawrencei* and *T. mutans* are transmissible to cattle. The first two subspecies are transmitted by one or more of the *Rhipicephalus* spp., and are highly pathogenic to cattle, causing East Coast Fever and Corridor Disease, respectively. *Theileria mutans* is a non-clinical infection that is transmitted by *Amblyomma hebraeum*. A fourth species, *Theileria barnetti* appears to be specific to buffaloes. Clinical disease or deaths due to these organisms, as well as the *Haematoxenus* spp. which are closely related to the *Theileria* spp., appear to be rare in buffaloes.

Trypanosoma **species**
A number of *Trypanosoma* spp. have been recorded in buffaloes in East and Central Africa, but none have been reported from buffaloes from the KNP. It is, however, quite possible that buffaloes in the northern game reserves in KwaZulu-Natal are infected since the vectors, *Glossina* spp., occur there. *Trypanosoma brucei*, *T. congolense* and *T. vivax* cause nagana in cattle but do not seem to affect the buffaloes adversely.

Sarcocystis **spp.**
These organisms are sometimes visible as elongated white spots in especially the tongue, oesophagus and muscles of buffaloes. In the KNP, 59 % and 86 % of buffaloes examined were

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positive[6 102]. Although not thought to be infective to man, the presence is aesthetically unacceptable.

Coccidia

Coccidia occur in the small intestine an are excreted as oocysts, which have a tough shell and can survive in the environment for quite a while. Despite these organisms being present in varying numbers in most animals examined, nothing about the species and numbers that occur in buffaloes is known.

HELMINTHS (Table 2)

A large diversity of helminths occurring in almost every organ in the animals, have been recorded. Out of the 81 species and/or genera listed, only 32 occur in buffaloes in South Africa.

Nematodes

With the exception of the *Elaeophora* spp. which occur in distensions of the blood vessels of the lung and in aneurysms of the coronary vessels, the *Gongylonema* sp. in the mucosa of the oesophagus, the *Onchocerca* spp. and *Parafilaria bassoni* in the subcutaneous tissue, the *Setaria* spp. free in the abdominal cavity and the *Thelazia* spp. in the conjunctival sac of the eyes, all the nematodes occur in the intestinal tract. Apart from *Elaeophora poeli*, *Oesophagostomum synceri*, *Onchocerca synceri* and *Toxocara manzadiensis*, which appear to occur only in buffalo, all the nematodes have been recorded from sheep, cattle or antelope. Quantitative surveys have not been reported and our limited experience indicate that buffaloes do not harbour large burdens. For example, four buffaloes from the KNP harboured a mean of 1 086 (range 148 - 2 017) nematodes, and four from the Hluhluwe-Umfolozi Park 2 096 (range 0 - 8 383). Taking the nematode species diversity into account, the burdens are not significant and animals should be in no way inconvenienced by the worms.

Trematodes

Only five of the 24 trematode species and/or genera have been found in South Africa. An interesting record is that of *Schistosoma haematobium*[6], which is primarily a parasite of man. Other noteworthy trematodes are the *Fasciola* spp. which also occur in domestic ruminants.

Cestodes

Surprisingly few cestodes have been recorded, all of which are the typical herbivore cestodes and all of which have been recorded from a number of antelopes. The larval cestodes may have some significance, depending on their potential infectivity for humans. The larvae of *Taenia saginata* have as yet only been found in Angola[78] but there is little doubt that they occur in buffalo in South Africa as well.

ARTHROPODS AND PENTASTOMES (Table 3)

Ticks

A total of 59 species and/or genera of ticks have been reported as occurring on buffaloes. Many of these ticks are the vectors of protozoal and other diseases, e.g. *Boophilus decoloratus* for *Babesia* and *Anaplasma*, *Rhipicephalus appendiculatus*, *R. maculatus*, *R. muehlensi* and *Amblyomma hebraeum* for the *Theileria* spp. and *A. hebraeum* for heartwater (*Cowdria ruminantium*). However, none of the ticks is specific for buffaloes and most occur in larger numbers on antelopes, although several of the *Rhipicephalus* spp. prefer buffaloes. A noteworthy record is that of *Amblyomma tholloni*, which occurs almost exclusively on elephant, with few records of other hosts[20 96].

Mites

Demodex infections in buffalo present as cutaneous nodules[102] and were present in 10 % of the buffaloes examined[6], while infections with *Psoroptes* cause a scaly alopecia that is greyish in colour[6]. Basson *et al.*[6] believe that the incidence in buffaloes in the KNP is fairly high.

Flies
Only a few of the flies that are associated with buffaloes have been identified. The Tabanidae are large blood-sucking flies that have a high irritation value but are opportunistic feeders. Others, like the *Haematobia* spp., are more permanently associated with the animals and they breed in freshly deposited dung. It appears that the majority of the flies have nuisance value but some are also vectors for diseases such as Wesselsbron Disease, Bluetongue and possible Ephemeral Fever and Lumpy Skin Disease[102].

Lice
Only two species of lice, both the so-called 'blue' or blood-sucking, have been described. No data as to infection rates and seasonal occurrence are available.

Pentastomes
The large carnivores, especially lions, are the final hosts of the pentastomes and various antelopes and buffaloes, the intermediate hosts. The pentastomes occur in the cardio-vascular system, notably the blood vessels of the liver and in the heart. They cause large migration tracts in the parenchyma of the liver but despite their size (8 - 10 mm) they seem to cause little damage[6,102]. The incidence in buffaloes in the KNP varied from 64 %[102] to 69 %[6].

CONCLUSION

A large number of parasites are associated with buffalo, many of which are transmissible to other wildlife as well as to man and his domestic animals. Of particular importance are the theilerioses, fasciolosis, taenioses and sarcoptic mange. In view of this situation, one should carefully consider the consequences of introducing buffalo onto a game farm.

A large diversity of helminths have been recorded, with at least 20 identified species of nematodes, five trematodes, two adult cestodes and three larval cestodes being recorded from buffaloes in South Africa. A fairly constant feature is the presence of *Elaeophora poeli* in the blood vessels of the heart and lungs in buffaloes from Mozambique, and the presence of *Onchocerca nelsoni* in the majority of buffalo throughout Africa.

ACKNOWLEDGEMENTS

We thank Prof D G A Meltzer for making available literature from his private collection and Mr D G Booyse for his assistance with the numerous literature searches.

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Table 1: The protozoan parasites of African buffaloes

GENUS AND/OR SPECIES	SOUTH AFRICA	REST OF AFRICA	REFERENCES
Babesia spp.	-	+	26, 46
Anaplasma centrale	-	+	11, 26, 51
Anaplasma marginale	-	+	14
Anaplasma spp	-	+	46
Haematoxenus veliferus	-	+	86
Haematoxenus sp.	-	+	101
Sarcocystis spp.	+	+	6, 26, 34, 102
Theileria barnetti	-	+	10
Theileria parva lawrencei	+	+	55, 56, 58, 102
Theileria parva parva	-	+	5, 56, 57
Theileria mutans	+	+	11, 56, 57
Theilerial piroplasms	+	+	14, 57
Trypanosoma brucei	?	+	1, 14, 57
Trypanosoma congolense	?	+	1, 14, 99, 102
Trypanosoma theileri	?	+	3
Trypanosoma vivax	?	+	1, 99
Trypanosoma uniforme	?	+	1, 99
Coccidia oocysts	+	+	36[a], 102

[a] Found in *Syncerus caffer nanus*

Table 2: The helminth parasites of African buffaloes

GENUS AND/OR SPECIES	SOUTH AFRICA	REST OF AFRICA	REFERENCE
NEMATODES			
Agriostomum gorgonis	+	+	6, 38, 102
Ashworthius lerouxi	0	+	18
Bunostomum sp.	0	+	20
Chabertia ovina	0	+	12, 34
Cooperia fuelleborni	+	+	6, 20, 30, 38, 102
Cooperia hungi	-	+	30, 38
Cooperia pectinata	+	+	38, 42[a]
Cooperia punctata	+	+	38, 42[a]
Elaeophora poeli	-	+	8, 12, 20, 27, 74, 75
Elaeophora sagitta	+	+	38, 48
Gaigeria pachyscelis	-	+	18
Gongylonema pulchrum	-	+	38
Gongylonema sp.	-	+	70
Haemonchus bedfordi	+	+	6, 20, 29, 38, 41, 42[a], 62, 102
Haemonchus contortus	+	+	6, 17, 26, 29, 32b, 38, 42[a]
Haemonchus sp.	+	-	102
Impalaia tuberculata	-	+	38
Longistrongylus meyeri	-	+	20, 38
Longistrongylus schrenki	+	-	Boomker & Horak, unpubl
Mammomonogamus sp.	-	+	69
Oesophagostomum radiatum	+	-	6, 102
Oesophagostomum synceri	-	+	85
Onchocerca armillata	-	+	75
Onchocerca gibsoni	-	+	66, 67
Onchocerca synceri	+	+	6, 75, 102
Onchocerca sp.	-	+	20, 81
Ostertagia ostertagi	+	-	Boomker & Horak, unpubl
Ostertagia sp.	-	+	20
Parabronema skrjabini	+	+	6, 12, 20, 102

Parabronema sp.	+	-	62
Parafilaria bassoni	+	-	40
Setaria africana	-	+	16
Setaria bicoronata	-	+	38
Setaria labiatopapillosa	-	+	16, 20, 26, 49, 53, 68, 72, 73, 80, 84, 87
Setaria nelsoni	-	+	76
Thelazia lachrymalis	+	-	6
Thelazia rhodesii	+	+	6, 20, 102
Thelazia sp.	+	-	102
Toxocara manzadiensis	-	+	92
Toxocara vitulorum	-	+	92
Trichuris barbertonensis	-	+	20, 38
Trichuris globulosa	+	+	6, 32, 102
Trichuris sp.	+	+	34, Boomker & Horak, unpubl
Trichostrongylus axei	+	-	6, Boomker & Horak, unpubl
Trichostrongylus colubriformis	-	+	28
Trichostrongylus deflexus	+	?	Boomker & Booyse, unpublished
Trichostrongylus sp.	+	-	102
Ascaridoidea	-	+	36[b]
Strongyloidea	-	+	36[b]
Microfilariae	-	+	4
Unidentified filarids	+	-	102
TREMATODES			
Calicophoron calicophorum	-	+	91
Calicophoron clavula	-	+	25, 38
Calicophoron microbothrium	+	+	6, 20, 38, 62, 65, 82, 102
Calicophoron phillerouxi	-	+	20, 25, 91
Calicophoron raja	-	+	25, 38
Calicophoron sukari	-	+	25, 91
Calicophoron sukumum	-	+	25, 91
Calicophoron sp.	-	+	36[b]
Carmyerius endopapillatus	-	+	21, 22

Carmyerius exporus	-	+	38, 65
Carmyerius gregarius	-	+	21, 22, 53
Cotylophoron cotylophorum	+	+	6, 20, 17, 44, 47, 49, 62, 65, 80, 88, 102
Cotylophoron fuelleborni	-	+	20, 54
Cotylophoron indicum	-	+	20
Cotylophoron macrosphinctris	-	+	20
Dicrocoelium hospes	-	+	33
Fasciola gigantica	-	+	9, 53
Fasciola hepatica	+	+	19, 62, 72, 73, 80
Fasciola sp.	-	+	36[b]
Gigantocotyle gigantocotyle	-	+	38
Schistosoma haematobium	+	-	6
Schistosoma leiperi	-	+	43
Schistosoma margrebowiei	-	+	43
Schistosoma mattheei	+	+	6, 43, 102
CESTODES			
Adult			
Avitellina centripunctata	+	+	2, 6, 38, 62, 102
Moniezia benedeni	-	+	38
Moniezia expansa	-	+	38
Stilesia hepatica	-	+	38, 79
Thysaniezia giardi	-	+	77
Thysaniezia ovilla	-	+	31
Larvae			
Cysticercus sp.	+	+	42[a], 43, 102
Diphyllobothrid tapeworm	-	+	69
Echinococcus sp.	+	+	6, 34, 102
Taenia gonyamai	+	-	6, 89
Taenia regis	+	-	6
Taenia saginata	-	+	34, 78

[a] Recovered from sheep after artifical infection with larvae obtained from the faeces of animals in the Johannesburg Zoological Gardens

[b] Found in *Syncerus caffer nanus*

Table 3: The arthropod and pentastome parasites of African buffaloes

GENUS AND/OR SPECIES	SOUTH AFRICA	REST OF AFRICA	REFERENCE
TICKS			
Amblyomma astrion	-	+	64, 83, 96
Amblyomma cohaerens	-	+	34, 64, 83, 96
Amblyomma eburnum	-	+	83
Amblyomma gemma	-	+	83, 94, 97
Amblyomma hebraeum	+	+	4, 7, 36[a] 37, 39, 59, 83, 94, 102
Amblyomma lepidum	-	+	83, 97
Amblyomma marmoreum	+	-	Horak, unpublished
Amblyomma pomposum	-	+	45, 83
Amblyomma sparsum	-	+	64, 83, 95, 96
Amblyomma splendidum	-	+	83
Amblyomma tholloni	+	+	20, 94, 83
Amblyomma variegatum	-	+	36[a], 64, 83, 97
Boophilus decoloratus	+	+	4, 7, 15, 37, 39, 83, 102
Boophilus microplus	+	+	83
Dermacentor rhinocerinus	+	+	83
Haemaphysalis aciculifer	?	?	51, 95
Haemaphysalis hoodi	?	+	26
Haemaphysalis leachi	?	+	26
Haemaphysalis parmata	-	+	83
Haemaphysalis silacea	+	-	37
Hyalomma albiparmatum	-	+	51
Hyalomma rufipes	+	+	15, 35, 39, 83, 94, 95
Hyalomma truncatum	+	+	4, 15, 35, 39, 83, 97
Ixodes cumulatimpunctatus	-	+	83
Ixodes lewisi	-	+	13, 51
Ixodes pilosus	+	-	4, 39, 83
Ixodes rasus	-	+	51
Ixodes sp.	+	-	83
Rhipicephalus appendiculatus	+	+	4, 7, 37, 39, 60, 83, 102

Rhipicephalus bequaerti	-	+	83
Rhipicephalus capensis	+	+	83
Rhipicephalus cliffordi	-	+	51, 52
Rhipicephalus complanatus	-	+	83
Rhipicephalus compositus	-	+	83
Rhipicephalus dux	-	+	83
Rhipicephalus evertsi evertsi	+	+	7, 15, 37, 83, 102
Rhipicephalus evertsi mimeticus	+	+	83
Rhipicephalus follis	+	?	Horak, unpublished
Rhipicephalus hurti	-	+	83
Rhipicephalus jeaneli	?	?	51
Rhipicephalus kochi	-	+	83
Rhipicephalus longicoxatus	-	+	83
Rhipicephalus longus	-	+	83
Rhipicephalus lunulatus	+	+	95
Rhipicephalus maculatus	+	+	7, 37, 83
Rhipicephalus masseyi	-	+	83
Rhipicephalus muehlensi	+	+	37, 83
Rhipicephalus pravus	+	+	83
Rhipicephalus pulchellus	-	+	83
Rhipicephalus reichenowi	-	+	83, 93, 103
Rhipicephalus sculptus	-	+	83
Rhipicephalus senegalensis	-	+	83
Rhipicephalus simus	+	+	15, 34, 37, 83, 95
Rhipicephalus sulcatus	-	+	63
Rhipicephalus supertritus	-	+	83
Rhipicephalus tricuspis	+	+	15, 83
Rhipicephalus turanicus	+	-	63
Rhipicephalus zambeziensis	+	+	60, Horak, unpublished
Rhipicephalus ziemanni	-	+	83
MITES			
Demodex cafferi	-	+	61
Demodex pienaari	+	?	6, 102, 105

Demodex sp.	+	-	102
Psoroptes sp.	+	-	6, 102
Sarcoptes sp.	+	-	102
FLIES			
Glossina spp.	-	+	1, 98
Haematobia thirouxi potans	+	-	23, 24, 102,104
Hippoboscid flies (includes keds)	+	-	102
Stomoxys sp.	+	-	102
Tabanidae	+	+	Boomker & Keet, unpublished
LICE			
Haematopinus bufali	+	+	7, 26, 50, 102
Linognathus sp.	+	-	101
PENTASTOMIDA			
Linguatula multiannulata	-	+	71, 90
Linguatula serrata	+	+	6, 26, 71, 102
Neolinguatula nuttalli	-	+	71

[a] Found in *Syncerus caffer nanus*

Proceedings of a Symposium on Lions and Leopards as Game Ranch Animals, Onderstepoort, October 1997

PARASITES OF LIONS (*PANTHERA LEO*) AND LEOPARDS (*PANTHERA PARDUS*) : A DOCUMENTATION

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INTRODUCTION

As is the case with many of the wild animals in South Africa, the helminths of lions and leopards are poorly known. Young[112] listed some of the diseases and parasites found in lions in the Kruger National Park, but those occurring in leopards are largely unknown. Those helminths that have been found in these carnivores have been collected incidentally, and no surveys have been conducted.

In this paper we attempt to bring together the existing literature pertaining to the parasites of free-living lions and leopards. The parasite records have been divided into those occurring in South Africa and those occurring in the rest of Africa. Records of helminth parasites collected from these carnivores in zoological gardens have not been included, as have the numerous records from India, China and Japan.

PROTOZOA AND RICKETTSIAE (Tables 1 and 2)

Babesia spp.
Elsa, the famous lioness, is said to have died of babesiosis[1]. Various babesias have been found in lion blood smears, but specific identification has not been confirmed. A small *Babesia*, morphologically indistinguishable from *B. felis*, was found on blood smears of all lions examined in Kruger National Park (KNP)[84] and also in Kenya and Tanzania[9, 20]. The KNP parasite has been shown to be serologically distinct from *B. felis*[57]. A large *Babesia* was also found, albeit rarely, in KNP lions[84]. *Babesia pantherae*, a large piroplasm, was described from leopards in Kenya[29]. Small Babesias, morphologically similar to *B. felis*, have been seen in blood smears of leopards in Kenya and KNP[20] (own observations - BLP).

Hepatozoon
Hepatozoon sp., morphologically resembling *H. canis*, commonly occurs on blood smears of lions and leopards in the KNP and East Africa[9, 15, 20, 45, 62, 112]. *Microbesnoitia leoni* [22, 23] has been shown to be a junior synonym of *Hepatozoon canis*[33].

Trypanosoma sp.
Trypanosoma congolense and *Trypanosoma brucei* have been reported from lion blood smears[10, 14, 21, 31, 36, 69, 91]. In the Serengeti National Park and Ngorongoro Conservation Area, Tanzania, 28 % of the lions were infected with *Trypanosoma* sp.[9]. It has been postulated that lions may become infected with trypanosomes by feeding on infected animals[66].

Trypanosoma congolense has been reported from leopard blood smears[14]. Leopards have been incriminated as a possible reservoir of *Trypanosoma brucei rhodesiense* in an outbreak of human sleeping sickness in Uganda[43]. *Trypanosoma evansi* has been reported from leopards in India[27, 28, 95].

Encephalitozoon cuniculi
Encephalitozoon cuniculi has been reported from a litter of lion cubs born at a breeding centre in the Lowveld of Northern Province (P.S. Rogers, personal communication).

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Coccidia

Isospora leonina, *Isospora pantheri* and *Isopora mohini* were described from captive lions in India, while *Isospora felis* oocysts have been recovered from lion faeces[3, 47, 59, 61]. *Isospora* species are commonly reported from captive lions[56, 85]. In Serengeti National Park and Ngorongoro Crater, Tanzania, 53% of lions sampled were shedding unidentified coccidian oocysts[70].

Table 1: The protozoan parasites of lions

GENUS AND/OR SPECIES	SOUTH AFRICA	REST OF AFRICA	REFERENCE
Babesia sp.	+	+	1, 8, 9, 20, 57, 84
Encephalitozoon	+	?	P.S. Rogers, pers. comm.
Hepatozoon sp.	+	+	9, 15, 20, 45, 62, 112
Unidentified coccidia	-	+	70
Microbesnoitia (syn. *Hepatozoon*)	+	+	22, 23, 33
Sarcocystis sp.	+	+	23, 32, 83, 97
Trypanosoma spp.	+	+	10, 14, 21, 31, 36, 69, 91

Table 2: The protozoan parasites of leopards

GENUS AND/OR SPECIES	SOUTH AFRICA	REST OF AFRICA	REFERENCE
Babesia pantherae	-	+	29
Babesia sp.	+	?	20
Hepatozoon sp.	+	+	9, 15, 20, 45, 62, 112
Isospora spp.	-	+	39
Microbesnoitia (syn. *Hepatozoon*)	+	+	20, 45, 62
Trypanosoma brucei	-	+	43
Trypanosoma congolense	+	?	14

Isospora rivolta oocysts have been recovered from leopard faeces[47, 60], while unidentified *Isospora* species oocysts have been reported from captive leopards[39]. Two distinctly different *Isospora* oocysts have been reported from leopards in Thailand[83].

Cryptosporidium
Oocysts of *Cryptosporidium* species have been recovered from a captive leopard[110].

Sarcocystis sp.
A *Sarcocystis* sp. recovered from a lioness in Nairobi National Park, Kenya[23] has been named *Sarcocystis felis*[32], and *Sarcocystis* cysts were found in the myocardium of a leopard in India[97]. *Sarcocystis*-like oocysts have been reported from the faeces of leopards in Thailand[83].

Besnoitia besnoiti
The definitive host of this tissue cyst-forming coccidian in Africa is still unknown. Attempts to infect lions and leopards were unsuccessful[30].
Microbesnoitia leoni

See *Hepatozoon* sp.

Table 3: The helminth parasites of lions

GENUS AND/OR SPECIES	SOUTH AFRICA	REST OF AFRICA	REFERENCE
TREMATODES			
Pharyngostomum cordatum	-	+	13, 50
CESTODES			
Diphyllobothrium theileri	-	+	13
Dipylidium sp.	-	+	50
Echinococcus granulosus felidis	+	+	80, 103, 104, 105
Mesocestoides sp.	-	+	48, 50
Taenia gonyamai (= *T. hlosei*)	±	+	23, 81
Taenia hydatigena	-	+	40, 78
Taenia regis (=*T. bubesi*)	+	+	7, 11, 58
Taenia taeniaeformis	±	-	37
Taenia sp.	-	+	48, 75
NEMATODES			
Ancylostoma paraduodenale	-	+	18, 50
Ancylostoma tubaeforme	+	+	50, 112
Cylicospirura subaequalis	-	+	93, 94, 99
Cylicospirura sp.	+		112
Dirofilaria repens	-	+	44, 50
Dirofilaria sudanensis	+	+	108, 112
Filaria leonis	-	+	11
Filaria martis	-	+	6
Filaria latala	+	-	24
Galonchus perniciosus	-	+	50
Gnathostoma spinigerum	-	+	50
Gnathostoma sp.	-	+	41, 49
Lagochilascaris major	-	+	34, 35, 51, 55
Ollulanus tricuspis	-	+	50
Physaloptera praeputialis	-	+	5, 25, 48, 50
Physaloptera malayensis	+	-	112
Physaloptera sp.	-	+	41
Toxocara canis	-	+	23, 68
Toxocara cati	-	+	12, 67, 68, 102
Toxascaris leonina	-	+	50
Trichinella spiralis	+	+	8, 73, 74

Toxoplasma
Acute disseminated toxoplasmosis has been reported from captive lions in Nigeria[77], while antibodies to *Toxoplasma gondii* were found in sera from lions in Etosha National Park, Namibia, and captive lions in the USA[82, 89, 98]. Captive lions in Kazakhstan were reported to be final hosts of *T. gondii*[86] however, the evidence presented appears rather suspect.

Toxoplasma-like oocysts have been reported from leopards in Thailand[83]. Serum from a single captive leopard in California was negative for *Toxoplasma* antibodies[89].

Giardia sp.
Cysts of *Giardia* species have been reported from leopards in Thailand [83].

HELMINTHS (Tables 3 and 4)

Nematodes
Relatively few nematode species have been collected from these carnivores. The more important ones are *Trichinella* (from a zoonotic point of view), the various hookworms (*Galonchus*, *Ancylostoma*), which may cause clinical disease in the animals, and the ascarids *Toxocara* and *Toxascaris*, both from a zoonotic and a disease causing point of view.

Cestodes
A large variety of species of the genus *Taenia* are present in the carnivores[107] and this appears to be the main genus of cestodes in these animals. All the *Taenia* spp. utilise ruminants as intermediate hosts, which implies that the ruminant should be eaten by the carnivore in order for the life cycle to continue.

Trematodes
A single trematode species has been reported from the intestines of lions and leopards, and it appears to be an incidental finding.

ARTHROPODS (Tables 5 and 6)

Ticks
Only 12 species of ticks were found on lions and leopards in the Kruger National Park. Lions were often heavily infested with the larvae and nymphs of *Amblyomma hebraeum* and these carnivores also seem to be a favoured host of the adult stages of the yellow dog tick, *Haemaphysalis leachii*. Two of 16 lions examined had heavy burdens of the brown ticks *Rhipicephalus appendiculatus*, one a heavy burden of *Rhipicephalus simus* and yet another a heavy burden of *Rhipicephalus zambeziensis*. Leopards were not infested to the same degree as lions and the most commonly encountered tick was *Rhipicephalus zambeziensis*.

Several of the ticks are implicated in the transmission of especially protozoal and bacterial diseases. The ticks also have a worrying effect on the animals, and those with the longer mouthparts may leave wounds through which other organisms may enter, such as bacteria (causing abscesses) and helminths (by the intermediate hosts feeding on the wounds).

Mites
Sarcoptes has caused severe clinical mange in free-living lions in the Kruger National Park, but no records of mites occurring on leopards could be found in the literature.

Flies
Hippobosca longipennis is a winged fly and is semi-permanently associated with carnivores in general. It is an avid blood sucker with a high irritation value, and may also be responsible for the transmission of bacterial and/or viral diseases. Adult females produce a fully mature third instar larva, one at a time, which immediately pupates in the soil.

Cordylobia anthropophaga, the Tumbu fly, is strongly attracted to urine or faeces and will deposit its eggs on dry sand contaminated with urine of faeces. The first instar larvae must enter the skin of a suitable host, in which it will cause a large boil (warble). After two moults the fully developed third instar larvae drops out of the boil in the skin and pupates in the soil. The lesion is irritating and can easily become infected.

Fleas
Both *Echidnophaga larina* and *Echidnophaga gallinacea* are stick-tight fleas of which the females burrow deeply into the skin, especially of the feet and that around the eyes. These females have expanded bodies and are difficult to remove. Once the eggs have been laid the females die and fall out of the skin. Both species are extremely common in Africa and it is said that both are vectors of bubonic plague, although not very good ones [38].

Table 4: The helminth parasites of leopards

GENUS AND/OR SPECIES	SOUTH AFRICA	REST OF AFRICA	REFERENCE
TREMATODA			
Pharyngostomum cordatum	-	+	13
CESTODA			
Diphyllobothrium decipiens	-	+	40
Diphyllobothrium theileri	-	+	13
Diphyllobothrium ? pretoriensis	-	+	42
Taenia acinonyxi	-	+	58
Taenia ingwei	+	+	81, 63, 64
Taenia regis (= *T. bubesi*)	+	-	107
Taenia sp.	-	+	75
NEMATODA			
Ancylostoma braziliense	-	+	2, 17
Ancylostoma caninum	-	+	2
Cyathospirura chevreuxi	-	+	4
Cyathospirura seurati	-	+	96
Cylicospirura subaequalis	-	+	94
Dracunculus medinensis	-	+	52, 53, 54
Filaria martis	-	+	100
Filaria russeli	-	+	100
Galonchus perniciosus	-	+	13, 88
Gnathostoma spinigerum	-	+	99
Onchocerca sp.	-	+	16
Physaloptera praeputialis	+	+	4, 16, 19, 41, 67, 79, 92
Toxocara cati	-	+	96, 109
Trichinella spiralis	+	+	8, 72, 73, 76
Troglostrongylus subcrenatus	-	+	87
Vigisospirura grimaldiae	-	+	96

Ctenocephalides felis is a jumping flea with a cosmopolitan distribution. Apart from causing physical damage, it also is a vector for numerous pathogens, including the tapeworm *Dipylidium*.

Lice

No records of lice were encountered in the literature, which is not really surprising since carnivores in general seem to have few louse species.

Pentastomes

The two genera that are listed in the tables occur as adults in the nasal cavities of the carnivores. *Armillifer* is a large pentastome with characteristic annulations and the infective nymphal stages occur encapsulated in various tissues of their intermediate hosts, the ruminants. The infective nymphal stages of *Linguatula*, however, wander freely through especially the livers of their ruminant intermediate hosts.

Acanthocephala

The spiny-headed worms are poorly known in Africa as a whole, and only the genus *Oncicola* has been recorded, once from a leopard in the Camerouns [65] and once from the same host in the Congo [13]. The worms attach to the mucosa of the stomach and intestine by means of several rows of well-developed hooks on a retractable proboscis. No records of pathology or deaths as a result of infection with these worms could be found in the literature.

Table 5: The arthropod and pentastomid parasites of lions

GENUS AND/OR SPECIES	SOUTH AFRICA	REST OF AFRICA	REFERENCE
INSECTS: FLIES			
Hippobosca longipennis	+	-	38
INSECTS: FLEAS			
Echidnophaga larina	+	-	38
Ctenocephalides felis	+	-	38
TICKS			
Ornithodoros moubata	-	+	101
Amblyomma eburneum	-	+	101
Amblyomma gemma	-	+	101
Amblyomma hebraeum	+	+	101, 112, I.G. Horak, unpublished
Amblyomma marmoreum	+	-	I.G. Horak, unpublished
Amblyomma sparsum	-	+	101
Boophilus microplus	-	+	101
Boophilus decoloratus	+	+	101, I.G. Horak, unpublished
Haemaphysalis leachii	+	+	101, 112, I.G. Horak, unpublished
Haemaphysalis spinulosa	+	-	I.G. Horak, unpublished
Ixodes sp.	-	+	101
Rhipicentor bicornis	-	+	101
Rhipicentor nuttalli	-	+	101
Hyalomma truncatum	+	+	101, 112, I.G. Horak, unpublished
Rhipicephalus appendiculatus	+	+	101, 112, I.G. Horak, unpublished
Rhipicephalus armatus	-	+	101
Rhipicephalus capensis	?	+	101
Rhipicephalus compositus	-	+	101
Rhipicephalus evertsi evertsi	+	-	112, I.G. Horak, unpublished
Rhipicephalus evertsi mimeticus	-	+	101
Rhipicephalus kochi	-	+	101
Rhipicephalus longus	-	+	101
Rhipicephalus pravus	-	+	101
Rhipicephalus pulchellus	-	+	101
Rhipicephalus reichenowi	-	+	101
Rhipicephalus sanguineus	+	+	101, 112
Rhipicephalus senegalensis	-	+	101
Rhipicephalus simus	+	+	101, 112, I.G. Horak, unpublished
Rhipicephalus sulcatus	-	+	101
Rhipicephalus supertritus	-	+	101
Rhipicephalus tricuspis	-	+	101
Rhipicephalus turanicus	+	-	I.G. Horak, unpublished
Rhipicephalus zambeziensis	+	-	I.G. Horak, unpublished
MITES			
Sarcoptes scabei	+	-	111
PENTASTOMES			
Armillifer armillatus	+	-	113
Linguatula serrata	+	-	112
Linguatula nuttalli	+	-	113

Table 6: The arthropod, pentastomid and acanthocephalan parasites of leopards

GENUS AND/OR SPECIES	SOUTH AFRICA	REST OF AFRICA	REFERENCE
INSECTS: FLIES			
Cordylobia anthropophaga	+	-	38, 113
Hippobosca longipennis	+	-	38
INSECTS: FLEAS			
Echidnophaga gallinacea	+	-	38
Echidnophaga larina	+	-	38
Ctenocephalides felis	+	-	38
TICKS			
Amblyomma hebraeum	-	+	101
Amblyomma nuttalli	-	+	101
Amblyomma tholloni	-	+	101
Amblyomma variegatum	-	+	101
Haemaphysalis aciculifer	-	+	101
Haemaphysalis leachi	-	+	101
Haemaphysalis parmata	-	+	101
Ixodes cavipalpus	-	+	101
Ixodes cumulatimpunctatus	-	+	101
Ixodes moreli	-	+	101
Ixodes muniensis	-	+	101
Ixodes pilosus	-	+	101
Ixodes oldi	-	+	101
Ixodes rasus	-	+	101
Ixodes vanidicus	-	+	101
Rhipicentor bicornis	-	+	101
Rhipicentor sp.	-	+	101
Hyalomma truncatum	-	+	101
Rhipicephalus appendiculatus	-	+	101
Rhipicephalus armatus	-	+	101
Rhipicephalus capensis	-	+	101
Rhipicephalus compositus	-	+	101
Rhipicephalus e. evertsi	+	-	I.G. Horak, unpublished
Rhipicephalus pravus	-	+	101
Rhipicephalus pulchellus	-	+	101
Rhipicephalus sanguineus	-	+	101
Rhipicephalus senegalensis	-	+	101
Rhipicephalus simus	-	+	101
Rhipicephalus sulcatus	-	+	101
Rhipicephalus tricuspis	-	+	101
Rhipicephalus turanicus	+	-	I.G. Horak, unpublished
Rhipicephalus zambeziensis	+	-	I.G. Horak, unpublished
Rhipicephalus ziemanni	-	+	101
PENTASTOMIDA			
Armilifer annulatus	+	-	113
ACANTHOCEPHALA			
Oncicola dimorpha	-	+	65
Oncicola fraterna	-	+	13

CONCLUSION

As is evident from the tables, a large number of parasites occur in and on lions and leopards. However, the diversity is small when compared to those that occur in ruminants, and the few records from South Africa is an indication that a lot of work still remains to be done as far as the parasites of these carnivores are concerned.

ACKNOWLEDGEMENTS

We thank Mr. D.G. Booyse for his valuable technical assistance.

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CHAPTER 4

Pathology of parasitic diseases

of

free-living mammals

Introduction

A few parasitic diseases of which the pathology had not yet been described, or the descriptions of which needed to be augmented, are listed here. My main contribution was the identification of the parasites and, in one case, supply of material. Together with Dr. Dewald Keet and Prof. Nick Kriek, the pathology of the lesions that were seen in buffaloes in the Kruger National Park were elucidated. I was co-promoter for Dr. Keet's M.Med.Vet thesis, and, of course, the first to identify the parasite as *Parafilaria bassoni*, an identification that was later confirmed by Dr. Odile Bain. The interesting aspect is that this parasite was for the first time recovered and described from the retro-orbital spaces of springbok, *Antidorcas marsupilalis*, from Marienthal in Namibia in 1964, and has since never been found again. The information on the parasite formed a part of the thesis and was rewritten to suit the format of the Onderstepoort Journal of Veterinary Research.

The references are in chronological order because of the nature of the contributions.

PLETCHER, JOHN M., HORAK, I.G., DE VOS, V. & BOOMKER, J., 1984. Nodular abomasitis in impala (*Aepyceros melampus*) caused by the nematode *Longistrongylus sabie*. *Journal of Parasitology*, 70, 907 - 910.

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NODULAR ABOMASITIS IN IMPALA (*AEPYCEROS MELAMPUS*) CAUSED BY THE NEMATODE *LONGISTRONGYLUS SABIE*

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ABSTRACT: The periodic occurrence of nodular abomasitis associated with the trichostrongylid nematode *Longistrongylus sabie* was observed in impala lambs of the Kruger National Park, Republic of South Africa. The condition was seen predominantly in animals less than 1 yr of age. Peak incidences occurred in the spring and fall, when more than 50% of the lambs studied had from several to numerous nodules in their abomasal mucosae. The nodular lesions in the lambs were macroscopically larger than, but microscopically similar to, those observed in domestic ruminants with ostertagiosis; however, *L. sabie* worm burdens were much lower than those in clinical cases of ostertagiosis, and no evidence of diarrhea could be found in any of the lambs studied. The physical condition of lambs with moderate to severe nodular abomasitis did not differ noticeably from that of lambs with mild involvement or those without lesions. Nodular abomasitis caused by this parasite was of minimal significance to impala herds in the Park under the circumstances prevailing at the time of the study.

During a recent parasitologic and pathologic study of free-ranging impala of the Kruger National Park (KNP), the periodic occurrence of a unique nodular abomasitis was noted. In many of the nodules the trichostrongylid parasite *Longistrongylus sabie* (Gibbons, 1977) and/or its eggs could be found. Herein, we consider some initial parasitologic information concerning this wildlife parasite and describe the gross and microscopic lesions it produces in the abomasal mucosa. Some comparisons are drawn between this condition in impala and ostertagiosis in domestic ruminants.

MATERIALS AND METHODS

Male impala from 3 age groups and some females were studied monthly over a period of 1½ yr. Each month several lambs (less than a year old), yearlings, and adults were taken at random from impala herds in the southern part of the KNP. External and internal parasite identification and enumeration as well as a complete pathologic examination were accomplished for each animal. More than 140 impala were included in the study. Recovery of parasites was carried out as described by Horak et al. (1982), and enumeration was accomplished by examining samples of digested abomasal mucosae and abomasal contents. Representative abomasal nodules were fixed in 10% neutral buffered formalin, embedded in paraffin and cut at 6 to 8 μm. Sections were stained with hematoxylin and eosin (HE) and the periodic acid-Schiff (PAS) technique.

Received 13 December 1982; revised 17 May 1984; accepted 17 May 1984.
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RESULTS

Parasitologic findings

Table I gives the numbers of 4th-stage larvae and adult *L. sabie* found in the first 60 impala studied. These animals were taken from the herds from January through July. Month by month evaluations of the total endoparasite and ectoparasite burdens are to be carried out, and pertinent information will be included in a subsequent report.

Pathologic findings

Nodular abomasitis occurred predominantly among lambs, with no apparent sex predilection. The condition was most prevalent in the spring (September–November) and fall (March–May). The number and size of mucosal nodules varied considerably. In some cases, more than 50 discrete nodules could be seen distributed throughout the abomasal mucosa (Fig. 1). Occasionally, coalescence of adjacent nodules produced irregular areas of mucosal thickening. Larger nodules measured 5 mm in diameter and were roughly circular, cream colored and raised 1 to 2 mm presenting a domelike appearance; many were slightly umbilicated (Fig. 2). It was often possible to extract the adult worms (usually 1 male with 1 or more females) by dissecting through nodules. The lambs with numerous nodules did not differ noticeably in physical condition from those with minimal or no abomasal involvement. Moreover, they showed no evidence of diarrhea, having well formed fecal pellets in their rectums.

Microscopically, individual nodules consisted of focal areas of mucosal hyperplasia (Fig. 3). The simple columnar mucus-secreting epithe-

TABLE I. *Mean intensity of 4th-stage larvae and adult Longistrongylus sabie listed by age groups/sex of host (ranges in parentheses).*

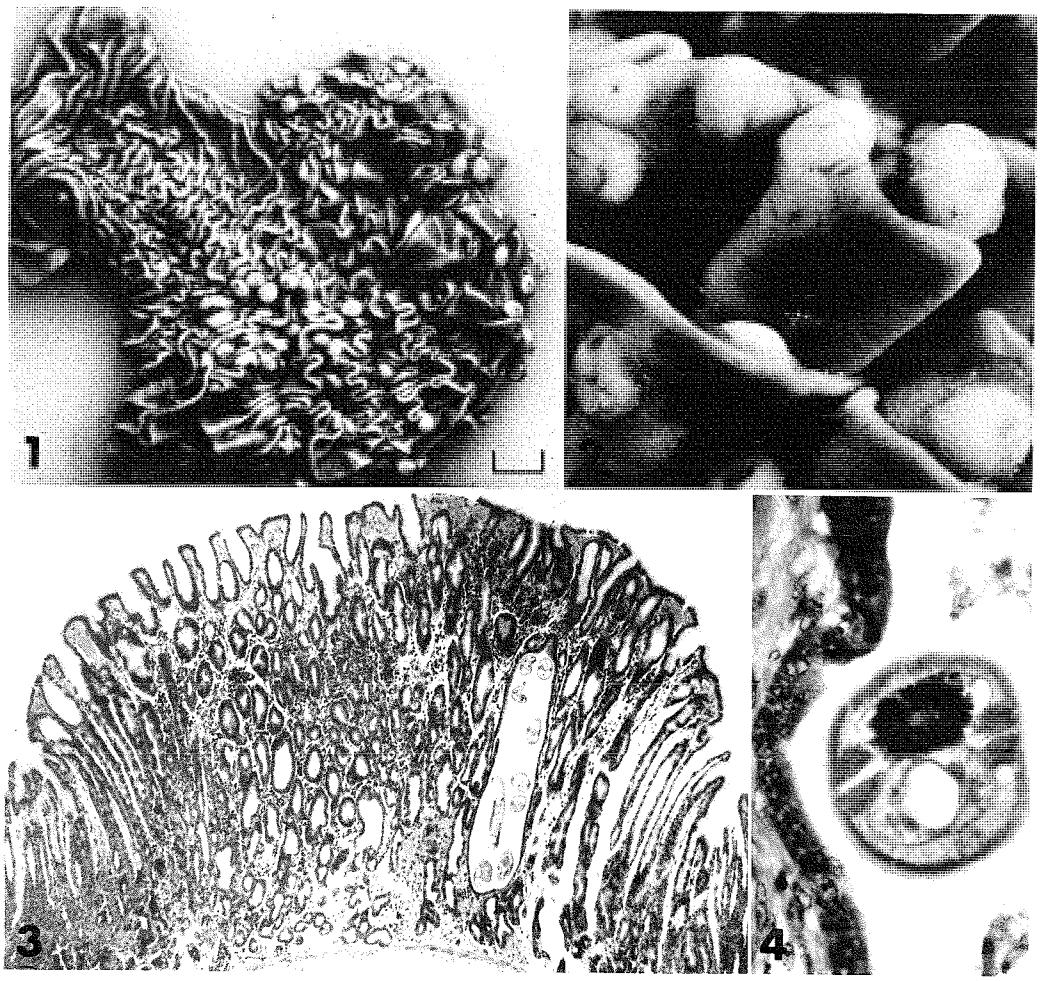
Impala age/sex	No. of impala	*Longistrongylus sabie*	
		No. of 4th-stage larvae	No. of adults
1–7 mo. (males and females)	15	11 (0–50)	55 (0–200)
13–19 mo. (males)	15	33 (0–130)	166 (0–450)
Adults (male)	22	66 (0–540)	97 (0–360)
Adults (female)	8	84 (0–430)	92 (0–410)

lium of the surface and gastric pits was not affected, but was elevated due to hyperplasia of the gastric glandular epithelium beneath and edema and inflammatory cell infiltration of the lamina propria. Gastric glands were often slightly dilated and elongated, when compared to those of the mucosa adjacent to a nodule. Moreover, these glands were lined by closely arranged cuboidal to columnar epithelial cells with large vesicular nuclei containing one or more prominent nucleoli and notably basophilic cytoplasm. Numerous mitotic figures were seen in these epithelial cells throughout the length of the glands, and differentiation to chief or parietal cells, seen in abundance in the adjacent mucosa, was lacking. The lamina propria within nodules was infiltrated by plasma cells, lymphocytes and eosinophils and often had a slightly loose appearance suggestive of mild edema. Frequently, oblique and cross sections through nematode parasites were seen in dilated glands within the nodules (Fig. 3). Morphologic features consistent with those of the trichostrongyles and the presence of 23 to 31 symmetrically arranged longitudinal cuticular ridges suggested the parasite to be *Longistrongylus sabie* (Fig. 4). Fibrosis of the lamina propria adjacent to parasitized glands was a frequent finding. Many nodules were devoid of worms but contained eggs, mucus and/or cellular debris located in central dilated and arborescent glandular spaces that were lined by undifferentiated or mucus-secreting epithelial cells. The submucosa beneath mucosal nodules was unaffected.

DISCUSSION

Nodular abomasitis caused by *L. sabie* appears to be a common, benign parasitic condition of impala lambs in the Kruger National Park. Similar lesions are associated with other *Longistrongylus* spp. in antelope of Kenya (Karstad, pers. comm.; Pester and Laurence, 1974). Its seasonal occurrence has been related to the resumed development of arrested fourth-stage larvae (Horak, 1978). The biannual occurrence noted in this study differs from that found in a similar study of impala in the northern Transvaal, where nodular abomasitis was seen only in November and December (early summer) after a prolonged period of arrested development from the fall to spring (Horak, 1978). It was suggested in that study that the normal rapid development of *L. sabie* through larval stages to adulthood, which occurs throughout the remainder of the year, is not associated with the formation of mucosal nodules. Although there may be an association between nodule development in impala lambs and release from arrested larval development, the factor(s) responsible for mucosal hyperplasia have not been identified.

The similarity of the lesions in impala to lesions in cattle and sheep with parasitic abomasitis caused by *Ostertagia* species is apparent and not unexpected, since both *L. sabie* and *Ostertagia* species are morphologically very similar and are included in the tribe Ostertagiea (Gibbons, 1977). The nodules produced by *L. sabie* are generally larger than those caused by *Ostertagia* species and are macroscopically discrete. Although they were larger, abomasal nodules never numbered more than 100 in the impala studied, reflecting the relatively small worm burdens (mean of 66 per lamb). Worm burdens of domestic ruminants with clinical ostertagiosis are hundreds of times greater (Raynaud and Bouchet, 1976); therefore, even though the resulting mucosal nodules are smaller, the entire mucosal surface is usually involved, presenting a "morocco leather" appearance. Histopathologically, the secondary nodules described in ostertagiosis (Jarrett, 1966) are identical to the nodules of *L. sabie,* with a substantial loss of well-differentiated parietal cells. An important development in the pathogenesis of ostertagiosis is the increase in pH of the abomasal contents at the time the adult worms emerge from the mucosa (Jarrett, 1966; Ritchie et al., 1966; Jubb and Kennedy, 1970; Thomson, 1978). The rise in pH is the result of hypochlorhydria caused either by a destruction/lack of differentiation of parietal cells in response to the presence of the worm in gastric glands (Jarrett, 1966; Ritchie et al., 1966), or, according to a recent study, a chemical associated with the parasite which inhibits acid secretion



FIGURES 1–4. **1.** Nodular abomasitis in an impala lamb. Larger nodules are 5 mm in diameter. Bar = 1 cm. **2.** Typical umbilicated nodules. **3.** Low magnification of a nodule showing hyperplasia of the glandular epithelium and one or more parasites within a dilated gland. H&E stain; ×20. **4.** Cross section of an adult *L. sabie* within a mucosal nodule. The cuticular ridges aid in identifying the parasite as belonging to the genus *Longistrongylus*. H&E stain; ×1,000.

(Eiler et al., 1981). A slightly acid or neutral abomasal environment is thought to enhance the survival of emerging adult parasites but also favors proliferation of bacteria, which closely parallels the period of severe diarrhea and loss of protein into the abomasal lumen in clinical ostertagiosis (Jarrett, 1966). It is possible that lambs experiencing a degree of abomasal disease which exceeds a threshold may sicken and die rapidly or become victims of predation, thus being unavailable for study and introducing a bias in our evaluation of the significance of this condition. However, the good condition and lack of diarrhea in impala lambs with nodular abomasitis as well as the burgeoning impala herds in the KNP, suggest that abomasal disease caused by *L. sabie* is not a serious problem at present in the Park. It must be assumed that most impala lambs do not develop serious hypochlorhydria as a result of *L. sabie*-related nodular abomasitis; the most reasonable explanation for this is the relatively low worm burdens. A balance between host physiology and parasitic numbers/pathogenicity has apparently evolved which favors the survival of both host and parasite.

The initial infection experienced by most lambs seems to produce a tolerance in later years; few yearlings or adults had abomasal nodules, al-

though on the average they harbored more of the parasites than did the lambs (Table I). The nature of this mucosal tolerance should be investigated further.

It should be appreciated that although nodular abomasitis is not a serious disease among the impala of the KNP at present, changes in the environment could destabilize the host/parasite relationship. For instance, a prolonged drought might force herds to concentrate near remaining water. Under such conditions, several parasitic diseases including nodular abomasitis may increase dramatically in significance.

ACKNOWLEDGMENTS

The authors thank the National Parks Board, Republic of South Africa, for sanctioning the study of impala in the Kruger National Park, Ben de Klerk and Cleve Cheney for their invaluable technical assistance, and LCDR Chris Gardiner, MSC, USN, for his advice and photographic expertise.

The opinions or assertions contained herein are the private views of the authors and are not to be construed as official or as reflecting the views of the Department of the Air Force or the Department of Defense.

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HEPATIC LESIONS ASSOCIATED WITH *COOPERIOIDES HEPATICAE* (NEMATODA: TRICHOSTRONGYLOIDEA) INFECTION IN IMPALA (*AEPYCEROS MELAMPUS*) OF THE KRUGER NATIONAL PARK

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ABSTRACT: Intrahepatic biliary lesions were observed in two of 12 lambs, seven of 12 yearlings and 10 of 25 adult impala (*Aepyceros melampus*) surveyed in the Kruger National Park, Republic of South Africa. Lesions were associated with the nematode *Cooperioides hepaticae*, a trichostrongyloid parasite that inhabits the bile ducts of impala, and ranged from a mild chronic-eosinophilic cholangitis to foci of florid hyperplastic cholangitis with duct ectasia. The latter almost always contained viable worms and, after the worms died, the lesions appeared as foreign-body granulomas. Infection was acquired early in life; severe lesions were seen most frequently in yearlings. Adults were less severely infected, which suggested an acquired immunity. Although the incidence of infection was high, cooperiiasis did not appear to be a serious herd-health problem at the time of this study.

Key words: Intrahepatic biliary lesions, pathology, nematode, *Cooperioides hepaticae*, impala, *Aepyceros melampus*, field survey.

INTRODUCTION

During a study of parasitic infections and pathologic changes in free-living impala (*Aepyceros melampus*) of the Kruger National Park (KNP), Republic of South Africa, it was noted that a large number of the antelope had varying degrees of intrahepatic biliary lesions due to infection by a trichostrongyloid nematode (*Cooperioides hepaticae*). Species of the genus *Cooperioides*, with the exception of *C. hepaticae*, are intestinal parasites found in domestic sheep and several types of antelope in eastern and southern Africa (Daubney, 1933; Messer, 1952; Round, 1968). Like members of the genus *Cooperia*, *C. hepaticae* are generally considered of minor pathologic significance unless present in large numbers in combination with other trichostrongyles, and/or in association with a poor nutritional condition. *Cooperioides hepaticae* is the only species of the genus with adults occupying an extraintestinal location. Moreover, the species appears to be the only trichostrongyloid that inhabits tissues other than those of the gastrointestinal tract (Daubney, 1933; Ortlepp, 1938; Soulsby, 1968).

We have conducted a systematic study of endoparasite and ectoparasite frequencies and numbers and associated pathologic changes of impala in the southern part of the KNP. Impala are the most abundant antelope in the eastern Transvaal. It has become evident from our work that *C. hepaticae* infection is very common among these impala and can cause substantial lesions. This report describes gross and microscopic lesions produced by *C. hepaticae* in the livers of impala and discusses the host response to the infection. Other aspects of this parasite such as taxonomic morphology and life cycle are not addressed except in acknowledgement of the facts that the taxonomy of the genus *Cooperioides* has been reviewed (Gibbons,

TABLE 1. Intensity of *Cooperioides hepaticae* infection in impala by sex and group.

Age group	Number of animals			Mean intensity (range)	
	Female	Male	Total	Female	Male
Lambs (0–6 mo)	3	9	12	67 (0–265)	71 (6–295)
Yearlings (12–18 mo)	3	9	12	230 (15–680)	226 (10–683)
Adults (over 24 mo)	7	18	25	32 (0–230)	31 (8–225)

1978) and that the life cycle of *C. hepaticae* has not been described but is thought to be direct.

MATERIALS AND METHODS

All impala in this study were collected at the Kruger National Park, Republic of South Africa (25°12′ to 24°24′S and 31°36′ to 32°02′E). The details of the park habitat are described briefly by Krecek et al. (1987).

Impala of the appropriate age were selected at random, shot through the neck with a high caliber rifle and then exsanguinated by severing the major vessels in the neck. The majority of the impala studied were males from three age groups—1 to 6 mo (lambs), 12 to 18 mo (yearlings), and over 2 yr (mainly prime adults). A smaller number of females of similar ages were also surveyed.

Tissues taken for histopathologic studies were fixed in 10% neutral buffered formalin and prepared and stained according to commonly accepted methods. Hematoxylin and eosin as well as Masson's trichrome stains were applied to the sections studied. The entire liver of each animal was macerated and the number of *C. hepaticae* tabulated for each. Liver sections containing *C. hepaticae* were deposited at the Armed Forces Institute of Pathology (Washington, D.C. 20306, USA; Accession Number 2168059) and by the U.S. National Parasite Collection (Animal Parasitology Institute, USDA, Beltsville, Maryland 20705, USA; Accession Number 80361).

RESULTS

The data on the intensity of infection in the impala are summarized in Table 1.

The general physical appearance of the animals ranged from poor to very good. Those in poor condition were usually yearlings or young adults, and necropsy of these animals revealed heavy parasite infections, with the lesions of *Pneumostrongylus calcaratus* in the lungs and of *C. hepaticae* in the liver being most notable. Impala <6 mo old did not have gross lesions associated with either of these parasites. Prime adults were generally in good condition, although many had macroscopic evidence of both lungworms and biliary cooperiiasis, but to a lesser degree than did the yearlings. The prevalence of infection by both parasites appears to be the same for male and female impala.

Lesions associated with *C. hepaticae* were limited to the liver. In mildly infected animals (those with <100 nematodes in the liver), macroscopic changes were subtle, consisting of a slight prominence of the portal tracts within the liver. These areas offered increased resistance when the parenchyma was incised, suggesting mild portal fibrosis. In several animals, the bile duct tapeworm *Stilesia hepatica* was present along with *C. hepaticae*. Gross lesions specific for *C. hepaticae* were observed in heavily infected impala (those having >200 nematodes in the liver); these animals were most often yearlings. In addition to prominent portal fibrosis, focal yellow-white spherical to ellipsoidal nodules were seen within the liver. Nodules were as large as 1 × 2 cm and often could be seen at the surface of the liver but were present throughout the parenchyma as well. A heavily infected liver would contain ≥eight nodules, which, when incised, revealed a substantial fibrous capsule encompassing a greatly thickened and dilated bile duct containing many reddish nematodes and a cloudy fluid (Fig. 1). Nodules of similar size were occasionally found to be firm and, on incision, to contain a caseous material that had a gritty consistency. Nematodes were not seen in these lesions.

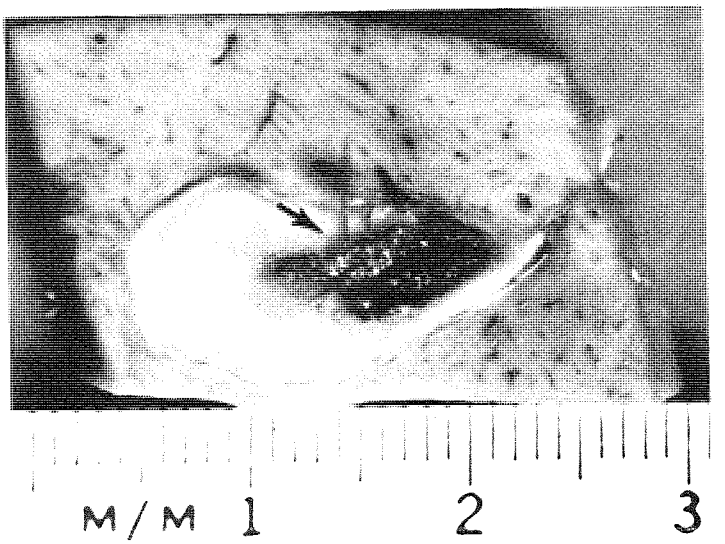

FIGURE 1. Sagittal section through an active *Cooperioides hepaticae* nodule. There are many reddish worms (arrow) in the greatly thickened and sacculated bile duct. Formalin-fixed specimen.

Microscopically, animals with early, or mild, infections showed a chronic-active eosinophilic cholangitis with an increase in periportal fibrous tissue. Eosinophils and plasma cells were the predominant inflammatory cells in the lamina propria, and the biliary epithelium was often noted to be slightly hyperplastic. Portal veins were frequently dilated and congested. In addition to these changes, severely infected animals had focal areas of moderate to extreme cholangiectasia with florid biliary epithelial hyperplasia often resulting in papillary structures which extended into the sacculated bile duct lumens. Within these lumens were adult *C. hepaticae*, their eggs, and mucoid material mixed with cellular debris (Fig. 2). The epithelium at the tips of the papillary structures often showed a marked squamous metaplasia; and eosinophils, as well as mononuclear cells with variably sized eosinophilic globules in their cytoplasm, were frequently seen within the epithelium. Remnants of both these cells also could be seen in the luminal debris. Connective tissue beneath the epithelium was infiltrated by many plasma cells and eosinophils, and these inflammatory cells, in addition to aggregates of lymphocytes, were prominent in the surrounding fibrous tissue. The hepatic parenchyma adjacent to these nodules appeared compressed, attesting to the expansile nature of the lesions. The firm nodules having no nematodes consisted of a central core of eosinophilic material containing mineralized debris and were surrounded by a zone of multinucleated giant cells and macrophages. At the periphery were inflammatory cells including eosinophils and plasma cells, but macrophages and lymphocytes predominated, and the development of lymphoid follicles was noted (Fig. 3). Biliary epithelium was not evident in these lesions.

DISCUSSION

The genus *Cooperioides* was originally described by Daubney (1933), who acknowledged the close relationship between it and the genus *Cooperia*. Various species have been recovered from the intestines of domestic sheep, springbok (*Antidorcas marsupialis*), Thomson's gazelle (*Gazella thomsoni*) and impala (*Aepyceros melampus*) (Daubney, 1933; Round, 1968); however, Ortlepp (1938) described *Cooperioides hepaticae* found "in small nod-

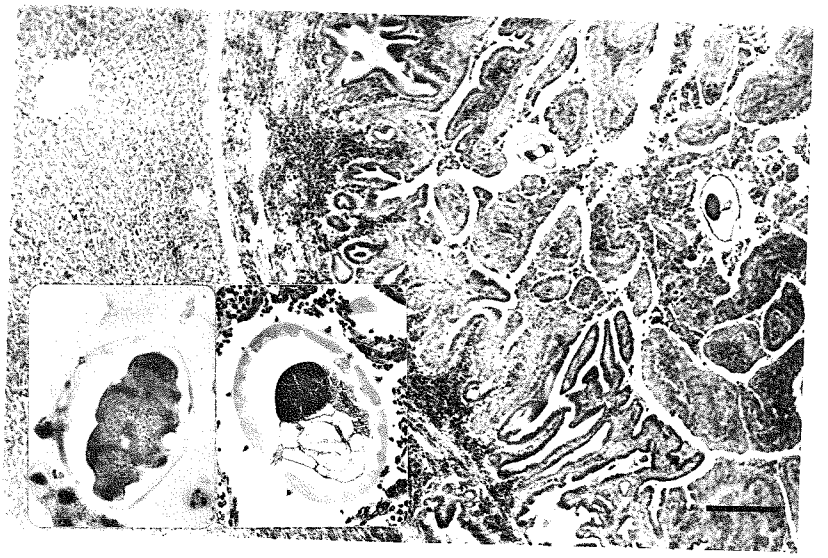

FIGURE 2. An active parasitic nodule. Note the papillary hyperplasia of biliary epithelium with superficial squamous metaplasia and the nematodes in cross section. H&E (bar = 1 mm). Insets: left, *Cooperioides hepaticae* egg measuring 30 × 40 μm; right, mature *C. hepaticae* in cross section.

ules in the terminal portions of the bile ducts" of an impala from the northern Transvaal. Messer (1952) described an identical nematode from the intrahepatic bile ducts of an impala in the eastern Transvaal. He referred to this parasite as "*Cooperia hepaticae*" and briefly described the pathologic changes associated with it (Messer, 1952). Mugera (1969) provided brief descriptions of the lesions produced by *C. hepaticae* and the tapeworm *Stilesia hepatica* in the liver of impala but it appears that he confused the lesions produced by the two species. Basson et al. (1971) mentioned *Cooperioides hepaticae* as a parasite of the biliary ducts of impala from the KNP, identified it as a "bile duct hookworm" and grouped it with true hookworms such as *Grammocephalus clathratus*, the bile duct hookworm of the African elephant (*Loxodonta africana*).

Gross and microscopic observations of *C. hepaticae* lesions and the intensity of infection suggest that there is a progression of events. An initial infectious phase proceeds through the development of active parasitic nodules and peak intensity. This is followed by subsequent destruction of adult nematodes and resolution of nodules. Mild eosinophilic cholangitis with a resulting increase in portal connective tissue occurs during the initial stages. These changes are first recognized at about 6 mo of age and probably reflect the migration of larvae and/or adult worms up the biliary tree. Similar lesions could occur as a result of the bile duct tapeworm *S. hepatica*; however, the occurrence of cholangiectasia and nodule formation is specific for biliary cooperiiasis. Although initial infection probably occurs early in life, substantial macroscopic lesions (parasitic nodules) are not observed until the animals approach 1 yr of age. Active parasitic nodules incite an immune response characterized by large numbers of plasma cells and eosinophils. Eosinophils and mononuclear cells with eosinophilic cytoplasmic globules were seen within the epithelium and in the luminal debris of parasitic nodules, and it seemed that both types of cells, as well as the plasma cells in the lamina propria, were intimately involved in the host response to the parasites. The cytoplasmic globules in the mononuclear cells appeared similar to Russell bodies, and their

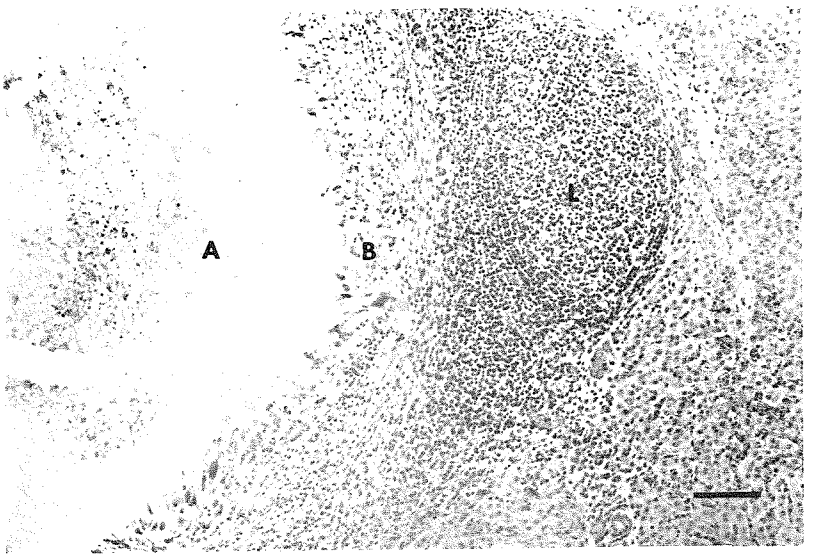

FIGURE 3. A resolving parasitic nodule with central core of partially mineralized eosinophilic debris (A), a zone of multinucleated giant cells and macrophages (B), and a peripheral zone predominantly of lymphocytes and macrophages with lymphoid follicle development (L). Note that biliary epithelium is not evident. H&E (bar = 250 μm).

possible role in the transport of antibody across the epithelium is the subject of continuing study. It has been demonstrated recently that eosinophils, in the presence of specific antibodies, can function as effector cells in the destruction of metazoan parasites (Zucker-Franklin, 1978). Once the adult worms are dead, the lesions appear to resolve as foreign-body granulomas. Macrophages and multinucleated giant cells predominate and lymphoid follicles are formed. The hyperplastic biliary epithelium observed in active nodules is obliterated in the process of resolution. Although many adult impala are infected, these tend to have fewer active parasitic nodules, and the prevalence of infection is lower than that for the yearlings. One can deduce from these findings that most adult impala acquire at least a partial immunity.

The florid biliary hyperplasia and metaplasia seen in active nodules is of interest. Apparently, biliary stimulation results from some parasite-associated factor(s) similar to that described in trematode-induced biliary hyperplasia observed in domestic ruminants (Isseroff et al., 1977).

Cooperioides hepaticae infection is one of the most common extraintestinal parasitic infections of impala in the KNP. Substantial lesions can accrue as a result of severe infection, particularly in yearlings, and it is highly probable that such lesions adversely affect the health of animals. However, it is doubtful whether *C. hepaticae* alone is a primary factor limiting the population of the large impala herds of the eastern Transvaal. Impala are the most numerous antelope in the KNP, despite a high prevalence of infection. Conversely, it is reasonable to assume that biliary cooperiiasis, in concert with lung worms, gastrointestinal helminths and ectoparasites could cause excessive losses in certain environmental settings. The depletion of impala herds in the eastern Transvaal during the dry seasons of 1949 and 1950 is an example (Messer, 1952). Game farmers and conservationists should be familiar with the conditions that tend to en-

hance these various parasitic diseases so that appropriate preventive measures can be applied when feasible.

ACKNOWLEDGMENTS

We wish to express our appreciation to the National Parks Board, Republic of South Africa, for sanctioning the study of impala in the Kruger National Park. The services of technicians Ben de Klerk and Cleve Cheney were invaluable. We would also like to thank Mr. Tonie du Bruyn and his staff for photographic services. The views expressed herein are those of the authors and are not to be construed as official or as reflecting the views of the U.S. Army or the Department of Defense. In conducting the research described in this report, the investigators adhered to the "Guide for Laboratory Animal Facilities and Care," as promulgated by the Committee on the Guide for Laboratory Animal Facilities and Care of the Institute of Laboratory Animal Resources, National Academy of Sciences–National Research Council.

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Received for publication 23 September 1982.

Onderstepoort Journal of Veterinary Research, 64:217–225 (1997)

Parafilariosis in African buffaloes (*Syncerus caffer*)

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ABSTRACT

KEET, D.F., BOOMKER, J., KRIEK, N.P.J., ZAKRISSON, G. & MELTZER, D.G.A. 1997. Parafilariosis in African buffaloes (*Syncerus caffer*). *Onderstepoort Journal of Veterinary Research*, 64:217–225

This is the first report on the occurrence of *Parafilaria bassoni* in the African buffalo (*Syncerus caffer*). Previously this parasite has been recorded only in springbok (*Antidorcas marsupialis*) in Namibia. Haemorrhagic perforations (bleeding points), the usual lesions seen in infected animals, were caused by gravid female parasites ovipositing embryonated eggs. These lesions occurred mainly on the dorsal and lateral sides of buffaloes. Complications of these lesions developed in a small number of buffaloes because of secondary bacterial infection [subcutaneous abscesses (3/178)] and as a consequence of a localized Type 1 hypersensitivity [large cutaneous ulcers (7/178)]. Red-billed oxpeckers (*Buphagus erythrorynchus)* appeared to play an important role in the epidemiology of this parasite as well as in the pathogenesis of the lesions. They reduced the likelihood of spread by ingesting blood containing embryonated eggs, and caused the development of large ulcers by feeding on superficial necrotic skin. From the results of an ELISA test it was determind that *P. bassoni*-infected buffaloes occur throughout the Kruger National Park complex, with a seroprevalence of approximately 34%.

Keywords: African buffalo, *Antidorcas marsupialis, Buphagus erythrorynchus*, eosinophilic arteritis, Kruger National Park, *Parafilaria bassoni*, red-billed oxpeckers, springbok, *Syncerus caffer*

INTRODUCTION

Parafilariosis is a condition commonly seen in cattle (Pienaar & Van den Heever 1964) and rarely in equids, in South Africa (Ortlepp 1962a); it has not been reported in other ruminants. During 1992, large ulcerated skin lesions on African buffaloes, *Syncerus caffer*, were reported by game rangers from the Sabi Sand Game Reserve (SSGR), a privately owned reserve adjacent to the Kruger National Park (KNP). The ulcers occurred mainly on the dorsal and dorsolateral aspects of the thorax of adult animals and resembled those caused by *Stephanofilaria* spp. in cattle and buffaloes (*Bos bubalis*) in India (Sharma Deorani 1965; Patnaik & Roy 1967). Their occurrence was strictly seasonal, lesions appearing in about November and disappearing towards the middle of March in the following year, thus suggesting insect transmission. Initially, the lesions are inconspicuous bleeding points arising from small cutaneous ulcers, similar to those caused by *Parafilaria bovicola* in cattle. Red-billed oxpeckers, *Buphagus erythrorhynchus*, were attracted to the bleeding points to feed on the exuding blood, simultaneously removing embryonated eggs.

The condition has long been suspected to occur in African buffaloes in the KNP because of the presence

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Accepted for publication 15 July 1997—Editor

of non-specific lesions in their subcutis and its musculature, but parasites were never found (Young & Van den Heever 1969). Basson, McCully, Kruger, Van Niekerk, Young & De Vos (1970) necropsied 100 buffaloes in the KNP and found some of them to have an eosinophilic cellulitis and panniculitis, but did not recover any adult nematodes. They did, however, find sheathed microfilariae in the infra-orbital skin and suggested that these could be either *Stephanofilaria* spp. or *Parafilaria* spp. or both (Basson *et al.* 1970).

This paper is a report on the cause and pathogenesis of the lesions, as well as on the distribution and prevalence of parafilariosis in buffaloes in the greater KNP complex.

MATERIALS AND METHODS

Study area

The KNP is a large reserve, about 20 000 km^2 in extent. It is situated in the north-eastern corner of South Africa, adjoining Zimbabwe in the north and Mozambique in the east (Fig. 1). The vegetation is diverse and several types and subtypes of Lowveld, Mopane veld and Bushveld are recognized (Acocks 1988). The SSGR is a privately owned and managed reserve on the western border of the KNP (Fig.1). It is approximately 570 km^2 in size and forms part of the greater KNP complex. The vegetation is classified as Lowveld (Acocks 1988).

Animals

A buffalo herd in the SSGR was monitored from October 1993 to April 1994. One dominant female in the herd was identified and immobilized according the method described by Bengis (1993). A radio transmitter (Telonics, 932E Impala Avenue, Mesa, Arizona, USA) was fitted around her neck. The herd was tracked on the ground twice a week with the aid of a radio receiver (Yaesu 2M FT-290R 2, Yaesu C.P.O. Box 1500, Tokyo, Japan) and an H-antenna. When the herd was difficult to find, a light aircraft was used to track it.

Buffaloes showing lesions suggestive of parafilariosis were immobilized and a skin-biopsy specimen was taken. When the lesion was a bleeding point, an incision 20 mm in length was made in a ventral direction, starting 30 mm above the lesion. An index finger was used as a probe to locate the granuloma (Fig. 2a) caused by the nematode in the subcutis. On locating the granuloma, the incision was extended in that direction so as to include the granuloma in the biopsy specimen. Tissue blocks, 15 mm square and containing all the layers of the skin, were removed from the edge and centre of ulcerated lesions. In all instances the biopsy wounds were packed with a sulphonamide-containing ointment (Acrisulph, Kyron Laboratories, 84 Main Reef Road, Benrose, 2094, South Africa) and sutured with vertical interrupted mattress stitches and no. 1 nylon. The biopsy specimens were fixed in 10% buffered formalin. Tissue blocks of the specimens were processed routinely, embedded in paraffin wax, sectioned (4–6 µm thick) and stained with haematoxylin and eosin for light microscopy.

Buffaloes were examined from a vehicle, by binoculars, and all lesions were recorded on a silhouette diagram of a buffalo. The lesions of each buffalo were plotted on a separate diagram. The behaviour of oxpeckers towards lesions was monitored and categorized as follows: ingestion of crusts around bleeding points; the extent of beak penetration into a bleeding point; attention given to large cutaneous ulcers; the number of oxpeckers feeding on a single ulcer; the frequency at which buffaloes fended off the oxpeckers; the reaction of the oxpeckers to the behaviour of the buffaloes; and the way in which buffaloes attempted to evade the oxpeckers.

Parasites

At first, attempts were made to remove the worms surgically from the subcutis of immobilized buffaloes. Then two buffaloes were killed at an interval of three weeks. The animals were skinned and the worms dissected from the bright green granulomas in which they were present (Fig. 2b) Worms collected in this manner were fixed in cold, 70% ethyl alcohol.

A third buffalo was killed during January 1994 and its skin cut into pieces of approximately 40 x 70 cm. These were placed in normal saline at 40 °C on expanded metal sheets in plastic trays and incubated for 24 h. The saline was replaced every 4 h; each volume of saline was sieved through a sieve (150 µm apertures). The residue was inspected visually and the worms removed and fixed in boiling 70% ethyl alcohol. The remaining residue was washed into a container, fixed by heating to 60 °C and preserved by adding 10% buffered formalin.

A total of 15 specimens consisting of fresh blood and blood crusts from bleeding points of 15 buffaloes were collected in glass tubes. Water was added and the mixture was left for a period of 12 h for haemolysis to occur. The resulting suspension was centrifuged for 4 min at 3 000 *g*. The supernatant was discarded and an unstained smear prepared from the residue. This preparation was examined under a standard microscope at 50x magnification.

Seroprevalence

Serum samples collected from 184 buffaloes from 11 localities throughout the KNP complex, together with nine positive and six negative controls, were submitted for diagnosis. Each locality represented one

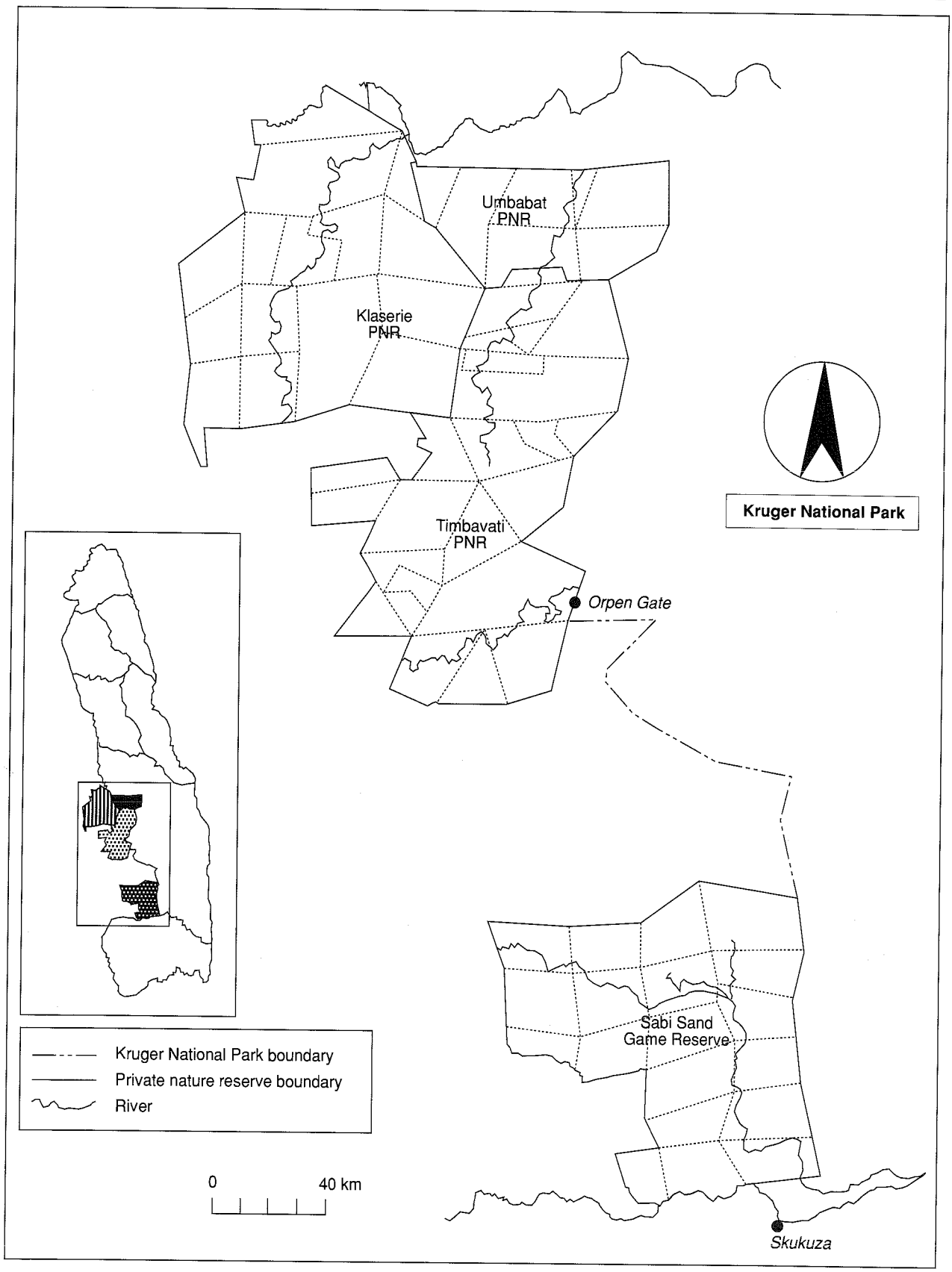

FIG. 1 Map of the Sabi Sand Game Reserve and other private nature reserves in relation to the Kruger National Park. Together they form the greater KNP complex

cluster and from these clusters samples were picked at random, with replacement. Positive control samples were obtained from animals in the SSGR and their status confirmed by the presence of the parasites as well as histopathology. Negative control samples were obtained from buffaloes born and bred in confinement. They were removed from the cows at about 3 months of age. These animals were regarded as negative as they had never shown bleeding points and had never had contact with free-ranging buffaloes. An ELISA test as described by Voller, Bidwell & Bartlett (1980) was employed. This test was developed for polypeptides of *P. bovicola* exoantigens with molecular masses of 41 and 36 Kda (Sundquist, Bech-Nielsen & Zakrisson 1989). Antigens were purified and characterized by chromatofocussing to eliminate cross-reactivity with antigens produced by concurrent nematode infections (Sundquist *et al.* 1989).

RESULTS

Animals

The lesions seen on the animals were categorized into three macroscopically discernible types that occurred at different times during summer. The primary lesion, the bleeding point or haemorrhagic perforation (Fig. 2c) was observed from the beginning of November to the beginning of February. Two secondary lesions developed subsequently: subcutaneous abscesses (Fig. 2d), which were seen from the middle of December to the middle of January; and large cutaneous ulcers (Fig. 2e) which appeared from about the middle of January and had healed by the middle of March, leaving a conspicuous scar (Fig. 2f).

The bleeding points were equally distributed on the left and right sides of the buffaloes (81 points on the left side and 84 on the right). The dorso-ventral distribution, however, was not uniform: 15,85% occurred dorsally, 58,53% laterally and 25,6% ventrally. The cranio-caudal distribution was even less uniform, with 83% of the lesions recorded cranial to the loins. Of these, 20,6% were seen on the neck, 23,6% on the shoulders, 39,4 % on the ribs, 4,5% on the loins and 11,5% on the hindquarters. No lesions were encountered on the head or the tail.

Each bleeding point was located centrally in a poorly circumscribed swelling raised about 3–5 mm above the surface of the skin. These openings were about 1 mm in diameter and occluded by a coagulum of serum in which the heads of the female nematodes were embedded, though not visible externally. Intermittent haemorrhaging from the bleeding points occurred for up to 2 d from the time of their first appearing. The volume of blood seeping from these bleeding points could not be estimated as it was rapidly consumed by oxpeckers. On visual inspection of the subcutis, the female nematodes were found in their migration tracts which were enveloped in an elongated, brilliant green granuloma, measuring about 20 x 3 mm. The area immediately surrounding the granuloma appeared unaffected macroscopically (Fig. 2a).

Histologically, sections cut transversely through the migration tract, revealed a central core of necrotic eosinophils, cellular and fibrin. A pronounced granulomatous reaction consisting of epithelioid cells in palisade formation and a dense infiltrate of eosinophils, plasma cells and lymphocytes, together with oedema and fibroplasia, surrounded the necrotic core. Vascular lesions that occurred in the surrounding tissue included chronic proliferative phlebitis and a perivascular eosinophil and lymphocyte infiltration.

The subcutaneous abscesses were well-defined swellings, measuring up to 60 x 60 mm. The swellings contained circumscribed cavities filled with necrotic debris. The adjacent subcutis was pale green and slightly oedematous. Three out of 178 buffaloes had such abscesses as a complication.

Histologically, the walls of the abscesses consisted of granulation tissue, containing vast numbers of eosinophils. Fibrin and large numbers of erythrocytes, eosinophils and neutrophils accumulated in their centre. Vascular lesions in the surrounding tissue included eosinophilic arteritis, eccentric endarterial fibrosis, fibrinoid necrosis of the vessel wall, proliferative endarteritis and recanalization of thrombi.

Large cutaneous ulcers developed, mainly on the dorso-lateral area immediately behind the shoulders, but were also to be seen on the top of the hump of infected buffaloes. One ulcer was noted on the loin and two on the hindquarters. Ulcers were seen on seven of 178 buffaloes and only on adult animals. They varied in size from 50x40 mm to 300 x 200 mm, were well-circumscribed, had ragged, elevated edges and an irregular base. Even the largest lesions developed rapidly, the entire process taking about 10 d. During the early phase of development, intermittent haemorrhage occurred from the ulcerated areas, but this was caused mostly by oxpeckers feeding on the wound. The adjacent subcutis had a yellowish-green tinge, with signs of haemorrhage and oedema. Pruritus was never seen.

Microscopically, there was a sudden transition from normal to ulcerated skin. A marked acanthosis occurred at the junction, which progressed to full-thickness necrosis with ulceration. The ulcerated surfaces were covered by a scab consisting of fibrin containing numerous eosinophils. Below the scab a prominent layer of immature granulation tissue containing masses of eosinophils was seen. The dermis was relatively unaffected, with the exception of marked perivascular infiltrates of eosinophils. The inner layer

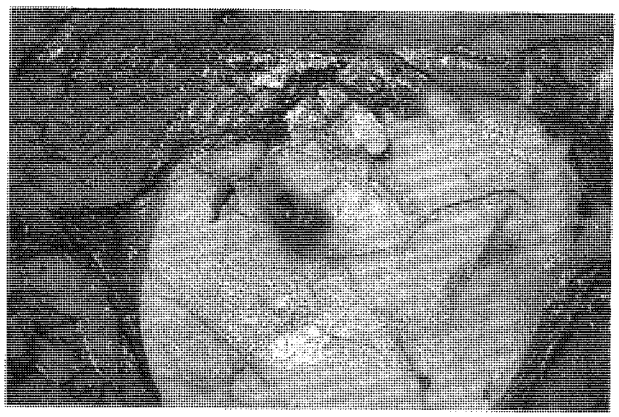

FIG. 2a A brilliant green subcutaneous granuloma containing a gravid female filariid

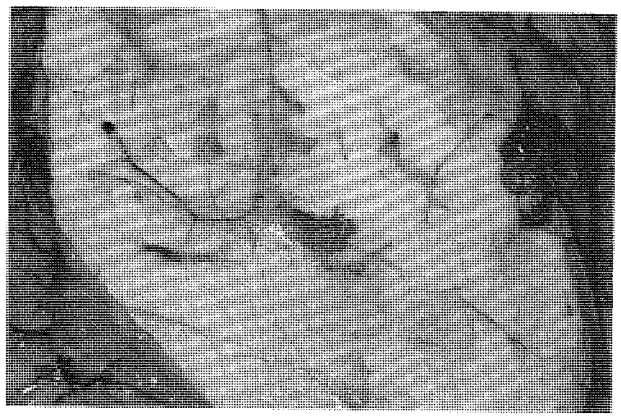

FIG. 2b An exposed female filariid

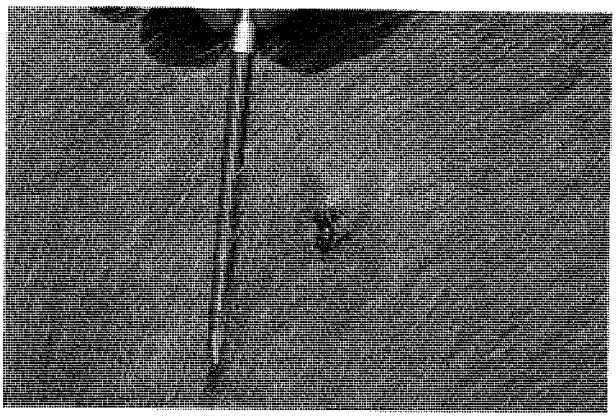

FIG. 2c A typical bleeding point

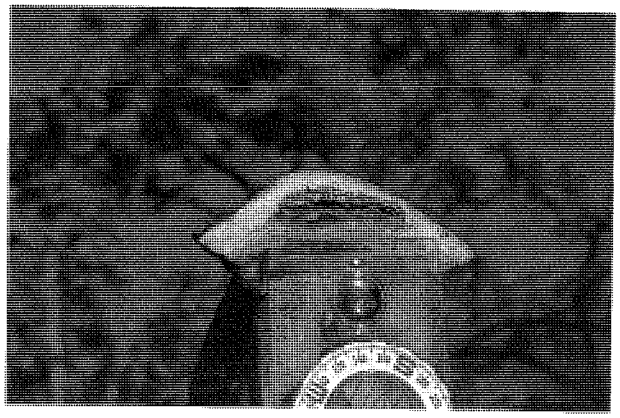

FIG. 2d A subcutaneous abscess

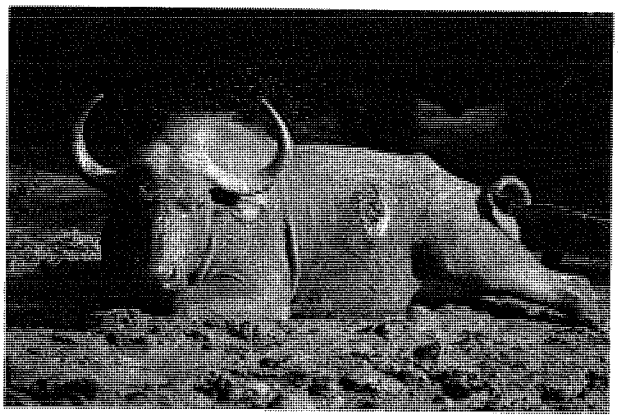

FIG. 2e A large cutaneous ulcer

FIG. 2f A conspicuous scar that remains visible for a long time

of the dermis and the subjacent subcutaneous interface showed severe oedema and marked vascular involvement and contained numerous eosinophils. Mostly arteries were involved, a marked eosinophilic vasculitis, segmental medial hyperplasia and extensive recanalization of thrombi being the most common lesions present. Marked endothelial proliferation occurred in the affected vessels and some showed mild villous endarteritis. These lesions were accompanied by pronounced endothelial hyperplasia and subendothelial oedema, as well as eccentric, chronic, eosinophilic endophlebitis and early villous

endophlebitis. In addition to the eosinophils, the perivascular reaction also contained plasma cells and a few lymphocytes. In the central area of the lesion eosinophilic granulomas occurred deeper in the dermis. These exhibited the Splendore-Hoepplé phenomenon, the eosinophilic mass containing necrotic nematode fragments.

All the cutaneous ulcers healed spontaneously towards the beginning of March, leaving conspicuous scars characterized by greyish-white alopecic areas sometimes with marked hyperkeratosis that remained visible for years.

Microscopically, the regenerated epidermis covering the large ulcers, contained only a few hair follicles, sebaceous glands and dilated sweat glands. Excessive keratinization was a constant feature. The outer dermis showed few changes, while the inner dermis consisted of maturing connective tissue. Vascular lesions were advanced and consisted of marked, eccentric, medial and endothelial hyperplasia and hypertrophy. Vascular occlusion and angiogenesis in close association with affected blood vessels were also seen.

Oxpeckers were attracted to bleeding points and ulcers. Wet streaks and dry crusts were rapidly ingested with scissor-like movements of their beaks. Occasionally, they inserted the full length of their beaks into a perforation to feed on the contents. Up to 12 oxpeckers were seen feeding simultaneously on one large ulcer. They also fed off biopsy wounds within minutes of the buffalo being revived after having been immobilized. The attacks were so vigorous that wound dehiscence occurred within 12 h. During daylight hours buffaloes continually fended off the oxpeckers. On occasion they were seen to use their horns up to seven times per minute to chase the birds off. White areas of alopecia developed on the buffaloes' shoulders owing to the trauma caused by the impact of their horns. The oxpeckers reacted aggressively when buffaloes tried to fend them off. They made growling sounds, puffed themselves up and assumed a threatening posture. The animals also tried to protect the ulcers from the oxpeckers by positioning their bodies close to shrubs so that the wounds would not be visible or accessible. Temporary relief from harassment was also obtained by wallowing in mud.

Parasites

Surgical removal of the nematodes from the subcutis of immobilized buffaloes was relatively unsuccessful and only fragments of female worms were recovered, while entire female worms were recovered only by dissection of the subcutaneous granulomas. Incubation of pieces of skin in saline was more successful and one entire male, two entire females and two entire early fourth-stage larvae were recovered. A total of 23 nematodes were collected by use of the various techniques. A considerable number of these nematodes were already dead at the time of collection.

The nematodes were identified as *Parafilaria bassoni* because of the similarity of the morphological characteristics with the species described by Ortlepp (1962b) from the orbital connective tissue of a springbok (*Antidorcas marsupialis*).

Embryonated eggs were found in all the blood crusts and wet blood streaks that were examined, but no free microfilariae. No attempt was made to count the number of eggs, but from one to seven eggs were noticed on each slide.

Seroprevalence

All six the negative controls tested negative and eight of the nine sera from buffaloes with parafilariosis, tested positive. These trends indicate a specificity of 100% and a sensitivity of 89%. Twenty-five of 71 (35,21%) male buffaloes tested positive and 37 of 113 (32,74%) females, a total of 62 of 184 (33,7%) animals examined. The youngest seropositive buffaloes were 2 years old. Twenty-three (12,5%) suspicious readings were recorded and 99 (53,8%) buffaloes tested negative.

DISCUSSION

Parafilariosis has been recorded in various Asian buffalo species (Srivastava & Dutt 1959; Patnaik & Pande 1963; Sahai, Singh & Varma 1973; Chauhan, Arora & Ahluwalia 1974) but never in African buffaloes. This is the first description of parafilariosis in African buffaloes. The lesions in buffaloes and the life cycle of the parasite resemble those seen in cattle parasitized by *P. bovicola*. Most typical lesions (bleeding points) heal without complications while some develop into abscesses or large distinct cutaneous ulcers. Red-billed oxpeckers appear to play an important role in the epidemiology of the parasite by feeding on blood containing embryonated eggs, and in the pathogenesis of lesions by removing superficial necrotic skin while feeding on large cutaneous ulcers, enlarging these ulcers. Infected buffaloes occur throughout the entire KNP complex and the prevalence of the infection is approximately 34%.

The external appearance of bleeding points seen on buffaloes is similar to that seen on cattle infected with *P. bovicola*, with the difference that oxpeckers may have removed most of the oozing blood on buffaloes. No difference was seen between the histopathology of the granulomatous reaction surrounding nematodes or the polymorphonuclear cell composition seen in buffaloes and that reported in cattle (Pienaar & Van den Heever 1964). Patnaik & Pande (1963) attributed complications of lesions caused by *Parafilaria* in Asian

buffaloes to contamination with bacteria when wallowing, and myiasis. Abscesses that developed from bleeding points caused the skin to slough, leaving an ulcer (Srivastava & Dutt 1959). In our study, none of the abscesses developed into ulcers and it appears that abscessation is an uncommon complication in African buffaloes. Concurrent myiasis was never observed and wound-breeding blowflies were not observed to feed on these lesions. The known vectors of *Parafilaria* are dung breeders and they do not deposit eggs or larvae in open wounds. However, myiasis was observed during the study period in wounds caused by lions on the withers of two buffaloes.

The histopathologic changes in the large ulcers and underlying tissues suggest that the pathogenesis of the lesion is a localized Type 1 hypersensitivity reaction of which the severity is enhanced by an excessive anamnestic response. At the subcutaneous site of dermal penetration the female, while ovipositing, becomes enveloped in an eosinophilic parasitic granuloma. The fact that the female is relatively stationary leads to the continuous local deposition of eosinophils involved with immune reactions directed against metabolic products secreted by the nematode. It appears that female parasites do not survive ovipositing, as the enveloping immune reaction develops into an impermeable mass which restricts and kills her, as evidenced by the number of dead and decaying worms that were recovered. Female worms may also be killed by oxpeckers when they feed on the bleeding points.

Oxpeckers are usually associated with the larger mammals in the KNP where they play a beneficiary role by removing especially ticks. Once they have settled on a buffalo, they move to an area where blood is present on the skin. They have been incriminated as aggressively and actively attacking and enlarging open cutaneous wounds (McLachlan & Liversidge 1982). In this study it appeared that they were causing haemorrhage by removing necrotic debris and damaging granulation tissue that developed in the ulcer, and then feeding on the blood. The carnivorous behaviour of this otherwise mutualistic companion of the buffalo must reduce the possibility of vectors becoming infected, which in turn could ultimately reduce the prevalence of *P. bassoni* in buffaloes in the complex.

The continuous presence of feeding oxpeckers annoyed infected buffaloes during the day, their action clearly inflicting pain, and they made it difficult for the buffaloes to feed or ruminate. In addition, since the majority of large ulcers occurred on the dorsal and dorso-lateral aspects of the buffaloes, we presume that it was more convenient for the birds to enlarge existing wounds. The ulcers in different buffaloes began to heal simultaneously during March, despite the fact that the birds continued feeding on them.

The reproductive phase of *P. bassoni* appears to be shorter than that of *P. bovicola*. Nevill (1984) found that in cattle the first bleeding points appeared in June and disappeared the following May, with a peak during October and November. In buffalo, the first bleeding points appeared only in November and persisted to the end of February. The synchronous healing of the large ulcers during March, when the hypersensitivity reaction diminishes in the absence of living and/or dead adult nematodes, supports this assumption of a short reproductive phase.

Adult *P. bassoni* has so far been recovered only from the orbital connective tissue of springbok in Namibia (Ortlepp 1962b). Although *P. bovicola*, which cause similar lesions in cattle, occur primarily in the subcutis, Chauhan *et al.* (1974) and Chauhan, Arora, Agrawal & Ahluwalia (1976) recovered a juvenile male *P. bovicola* from the anterior chamber of the eye of an Asian buffalo, and Ortlepp (1962a), a gravid female *P. multipapillosa* from the posterior chamber of the eye of a horse. Nevill (1980) successfully infected cattle with infective third-stage larvae of *P. bovicola* per conjunctiva. Adult *P. bassoni* occurred in the orbital connective tissue of all five springbok examined (Ortlepp 1962b). He assumed that this site was not abnormal for this parasite (Ortlepp 1962b). In view of the above findings it seems that the eye is a normal site of entry of infective larvae of this genus. Unfortunately the eyes of buffaloes killed during this study were not examined for the presence of nematodes.

The factors governing the predilection sites of *P. bovicola* during oviposition in cattle are undetermined (Nevill 1984) but the dorsal and lateral aspects of the body seem to be preferred. The same tendency was observed with *P. bassoni* in buffaloes, 74,4% of bleeding points occurring in these regions. Since haematophagous or partially haematophagous flies are the intermediate hosts of all the *Parafilaria* spp. this may be to ensure that the vectors, which usually feed around the face, are attracted to blood containing embryonated eggs. It may also be that the higher up on the body the bleeding points occur, the longer the blood streak will be, thus providing a larger feeding area and greater volume of blood for the vectors. In cattle only 7,8% of lesions occur on the ventral aspects (Nevill 1980) as opposed to 25,6% in buffaloes. This suggests that in buffaloes a wider spectrum of vectors may be involved, some of which may be attracted to the shaded areas of the body.

The presence of embryonated eggs in fresh and crusted blood collected from primary lesions provides an easy method to immediately confirm a preliminary diagnosis of parafilariosis. However, the collection of specimens was complicated by the following factors: it took considerable time to immobilize and sample a buffalo after a fresh bleeding point had been seen and clotting may have set in; oxpeckers were quick to attend to the fresh bleeding spot and remove crusts;

buffaloes do not have a thick hair coat and it was often necessary to virtually scrape off remnants of crusts left behind by the oxpeckers; and the buffaloes were often covered with mud, which was of necessity included in the sample.

According to Sundquist *et al.* (1989) the 4l and 36 Kda antigens are specific for *P. bovicola*, and the ELISA test performed on bovine material showed a 95% specificity and a 92% sensitivity. Infected cattle were identified even before bleeding points appeared. The results obtained with the sera of the buffaloes suggest that the test is genus-specific. Cross-reactivity with antigens of other nematode genera (Neppert 1974) was not observed in any of the studies described by Sundquist, Zarkrisson, Bech-Nnielsen & Bianco (1988) and Sundquist *et al.* (1989).

Four to five months are required to develop a positive titre in cattle (Sundquist *et al.* 1989). It is not known for how long a positive titre persists in buffaloes but cattle have to be re-infected annually for the continuity of the life cycle from one season to the other, thus to maintain a positive titre (Sundquist *et al.* 1989). Suspicious reactions in buffaloes could either reflect recent infections or animals losing their positive titre because of not being re-infected. The absence of serologically positive buffaloes younger than 2 years of age can be ascribed to the fact that the majority of buffalo calves in the KNP complex are born between January and April (Pienaar 1969). During this period the number of bleeding points declines to such an extent that the possibility of newly-born calves being infected is probably very low. One can therefore assume that they are not infected shortly after birth but only during the following summer season.

The presence of this parasite throughout the KNP complex suggests that it must have been present for a long time and may even be endemic.

ACKNOWLEDGEMENTS

We would express our gratitude to the following institutions and persons: The Chief Directorate of Veterinary Services for permission to publish this article; Messrs Michael Rattray and John Varty and the Executive Committee of the Sabi Sand Game Reserve for making the material available and for permission to conduct the survey; Mr John Dixon, warden, and the staff of Rattray Reserves for their assistance; Drr. Roy Bengis and L.E.O. Braack for advice and technical support; Messrs A. Dekker, J. Dragt, D. Erasmus, D. Draper, A. Linsky and D. Uys for technical assistance; Mr I. White for valuable advice and for locating the buffalo herds by fixed-wing aircraft; Dr E. Nevill for advice and Dr E.V. Schwan for advice on serodiagnosis; Dr Odile Bain, Muséum National d'Histoire Naturelle, Paris, France, for identification of the *Parafilaria* and the National Parks Board for the infrastructure to enable this research to be conducted.

This study was done for a thesis in partial fulfilment of the degree M.Med.Vet. in wildlife diseases in the Department of Veterinary Tropical Diseases at the University of Pretoria. The supervisor of the study was Prof. D.G.A. Meltzer.

It was also presented at the 1996 "The African buffalo as a game ranch animal" symposium and published in the proceedings of this symposium.

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LESIONS IN THE HEART AND LUNGS OF GREATER KUDU (*TRAGELAPHUS STREPSICEROS*) CAUSED BY *CORDOPHILUS SAGITTUS* (NEMATODA: FILARIOIDEA)

John M. Pletcher, D.V.M., M.P.H., Joop Boomker, B.V.Sc., Valerius de Vos, B.V.Sc., and Chris H. Gardiner, Ph.D.

Abstract: Lesions in the heart and lungs resulting from infection by the filarial nematode *Cordophilus sagittus* were observed in 31 of 42 free-ranging greater kudu (*Tragelaphus strepsiceros*) of the Kruger National Park, Republic of South Africa. Animals less than 1 yr old were free of lesions whereas many of those over 1 yr old, irrespective of sex, were affected. Adult worms were found free in the right ventricle of the heart, in coronary arteries, and in the pulmonary artery and its branches. In the coronary arteries, worms were usually found coiled within aneurysmal lesions, which were often visible on the epicardial surfaces and occasionally on the endocardial surfaces of the right and left ventricles. Within pulmonary arteries, the presence of the parasites provoked a unique intimal proliferative response similar to that seen in canine dirofilariasis.
Key words: *Cordophilus sagittus,* kudu, *Tragelaphus strepsiceros,* vasculitis.

INTRODUCTION

Cordophilus sagittus (v. Linstow, 1907) Monnig, 1926 is a member of the nematode family Filarioidea. The parasite infects the chambers and vessels of the heart and the branches of the pulmonary artery of certain antelope. Von Linstow[5] described the original specimen, which was found in the heart of a bushbuck (*Tragelaphus scriptus*) in the Cameroon. Turner[4] reported *C. sagittus* in a bushbuck from Malawi and suggested that kudu (*T. strepsiceros*) may also be parasitized. McCully et al.[3] described the pathologic lesions associated with the parasite in kudu, bushbuck, and African buffalo (*Syncerus caffer*). Cordophilosis is also known to occur in nyala (*Tragelaphus angasi*) in the Kruger National Park (KNP), Republic of South Africa.[2] Young and Basson[6] reported fatal cordophilosis in eland (*Taurotragus oryx*) translocated to the KNP.

The purpose of this study was to identify pathological lesions associated with *C. sagittus* in free-ranging greater kudu. The location of the parasites within the coronary vessels differs from that described previously.

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MATERIALS AND METHODS

Free-ranging kudu from the Malalane area of the KNP were shot in the neck, exsanguinated, and necropsied. Most of the kudu were taken between 0700 and 0900 hr on the day of their necropsy. Forty-two animals were examined as part of a study of external and internal parasitic infections and pathological lesions in the kudu. Filarial worms from the heart and lungs were fixed in alcohol and later identified as *C. sagittus.*[4,5] Tissue samples containing lesions of cordophilosis were fixed in 10% neutral buffered formalin, embedded in paraffin, and processed by standard methods.

RESULTS

Macroscopic findings

Lesions resulting from *Cordophilus* infection were found in 31 of 42 kudu examined (Table 1). Macroscopic lesions were observed in both the heart and lungs of most kudu over 1 yr old. Pale round-to-oval cyst-like lesions measuring 1–2 cm in diameter were usually visible from the epicardial sur-

Figure 1. Heart of a greater kudu with aneurysmal lesion (arrow) of coronary artery caused by adult *Cordophilus sagittus.*

faces of the ventricles but were only occasionally visible from the endocardial surfaces (Fig. 1). Dissection revealed these cystic lesions to be parasitic aneurysms within branches of the coronary arteries. Up to six worms (both sexes) could be found coiled within an aneurysmal cavity. It was not unusual to find as many as five aneurysms in a heart. They were most often located adjacent to the intermediate or longitudinal grooves. Adult worms were also found free in the right ventricular chamber and in the pulmonary artery at the base of the heart as well as along its course into the pulmonary parenchyma. Parasites were also found in the smaller branches of the pulmonary arteries, particularly in the distal diaphragmatic lobes (Fig. 2), where their presence provoked a florid, sharply demarcated villous proliferation of the intima (Fig. 3).

Table 1. Distribution of lesions caused by *Cordophilus sagittus* by age group and sex in greater kudu from Kruger National Park, Republic of South Africa.

Sex and age	No. lesions	Lesions		
		Lungs only	Heart only	Heart and lungs
Male				
1 yr	2	0	0	0
1–2 yr	2	1	0	3
Adult	0	2	0	8
Female				
1 yr	5	0	0	0
1–2 yr	1	1	1	2
Adult	1	0	2	11
Totals	11	4	3	24

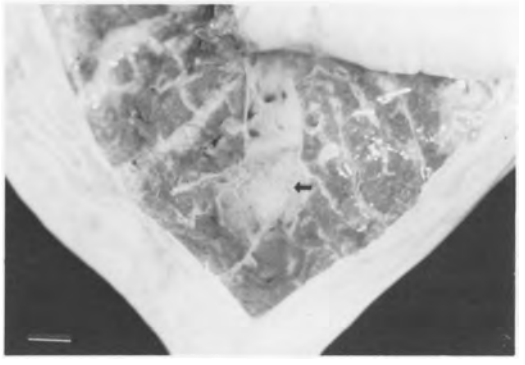

Figure 2. Cut surface of distal diaphragmatic lobe of lung from a greater kudu. Florid villous proliferation of the intima of the pulmonary artery (arrow) is caused by adult *Cordophilus sagittus.* Bar = 1 cm.

Histological findings

Histological sections of parasitic aneurysms in the branches of the coronary arteries revealed a greatly dilated vascular space containing worms. The walls of these affected arteries and their branches were thickened above and below the parasitic aneurysms (Fig. 4). Focal areas of ventricular myocardial scarring were noted in the more heavily parasitized hearts. Often a mild villous proliferation of the intima was present but never to the degree observed in the affected pulmonary arteries. The normal architecture of the coronary artery wall was replaced by fibrous tissue. Bundles of medial smooth muscle cells were isolated by thick bands of fibrous tissue or had been pushed to the periphery by fibrosis of the intima. External and internal elastic lami-

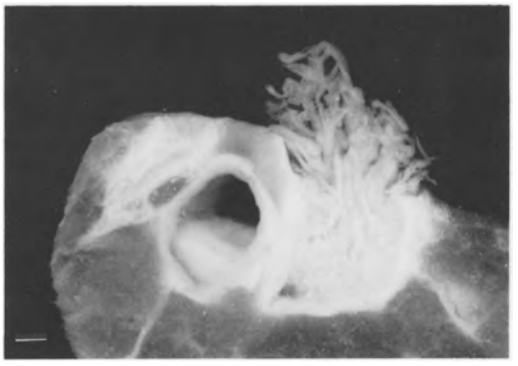

Figure 3. Cut section of distal diaphragmatic lobe of lung from a greater kudu infected with *Cordophilus sagittus*. Note the extended fronds (arrow) of the villous proliferation of the pulmonary artery. Bar = 1 mm.

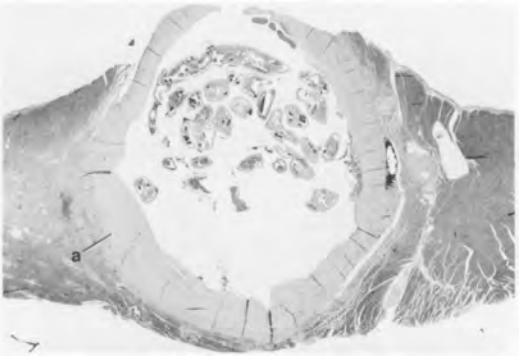

Figure 4. Histological section of heart from a greater kudu infected with *Cordophilus sagittus* revealing thickened wall of the coronary artery (a) and numerous sections of adult parasites within the lumen. H&E, ×6.

nae were disrupted and distorted. Thick-walled arterioles were prominent within the fibrous tissue surrounding the affected coronary vessels, and nodular collections of lymphocytes were occasionally seen in the adventitia. Foci of mineralized debris (parasitic "mummies") could sometimes be found within the walls of the parasitized arteries (Fig. 5). Arterioles in the adjacent myocardium were prominent as a result of smooth muscle hyperplasia, and venules were dilated. Perivascular inflammatory infiltrates consisted of lymphocytes and eosinophils. Focal areas of fibrosis and lymphocytic interstitial myocarditis were also noted. Changes in the myocardium were prominent in areas adjacent to parasitized arteries, but changes gradually diminished distal to these areas. In a few kudu, microfilariae were observed in the myocardium, where they seemed to elicit a moderately severe, but localized, eosinophilic myocarditis. Multinucleated giant cells were often closely associated with these microfilariae. Eosinophilic lymphadenitis and focal areas of eosinophilic pneumonia were attributed to the presence of microfilariae, but such lesions were few in number.

Microscopic changes observed in the parasitized branches of the pulmonary arteries were similar to those in coronary arteries, with one notable difference: a localized florid villous intimal proliferation enveloped worms within branches of the pulmonary arteries (Fig. 6). Fronds of intimal tissue measuring 20–200 μm in diameter extended from the intimal surface of the vessel. Each frond was composed of a fibrovascular core that contained occasional smooth muscle cells and was covered by one to multiple layers of endothelial cells (Fig. 7). Eosinophils and plasma cells were often abundant within these intimal fronds. Arterioles adjacent to the parasitized pulmonary arteries had thickened walls as a result of medial smooth muscle hyperplasia, and accumulations of lymphocytes and eosinophils were

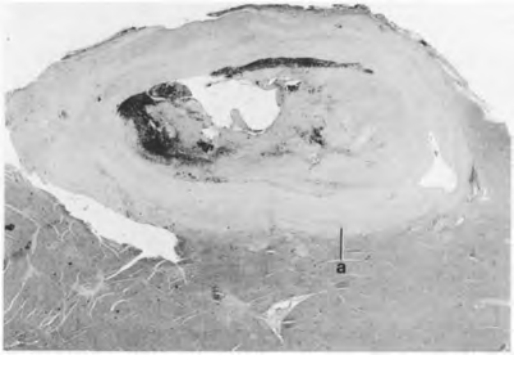

Figure 5. Histological section of heart from a greater kudu revealing thickened wall of a coronary artery (a) surrounding a focus of mineralized debris. H&E, ×5.

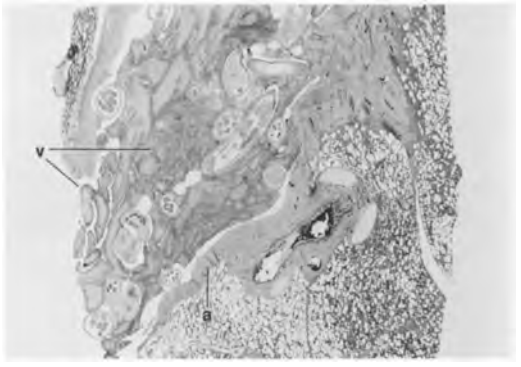

Figure 6. Histological section of distal diaphragmatic lobe of lung from a greater kudu. The lumen of a branch of the pulmonary artery is occluded by an intimal proliferation that envelops adult *Cordophilus sagittus*. a, wall of pulmonary artery; v, proliferation of intima of pulmonary artery. H&E, ×15.

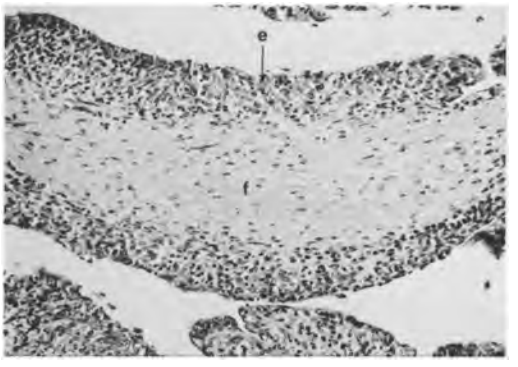

Figure 7. Histological section of frond composing the intimal proliferation of the pulmonary artery from a greater kudu. Note that the fibrovascular core (f) is covered by multiple layers of endothelial cells (e). H&E, ×150.

in adventitial tissues. The surrounding lung parenchyma was essentially normal except in those few kudu that had localized areas of eosinophilic pneumonia associated with the presence of microfilariae.

Adult male and female parasites exhibited morphological characteristics (i.e., coelomyarian musculature, a small intestine, and lateral internal cuticular ridges) of a filarial nematode (Figs. 8, 9).

DISCUSSION

The presence of *Cordophilus sagittus* and associated lesions in the hearts and/or lungs of 31 of 35 kudu over 1 yr old suggests a high rate of infection. The absence of adult worms and associated lesions in a number of kudu lambs studied could be the result of lowered susceptibility to cordophilosis in this age range. However, because many filarial parasites have lengthy prepatent periods, it is more likely that lambs receive infective larvae via one or more species of biting insects at an early age followed by a long period of migration and maturation of parasites. This may culminate in aggregations of adult parasites in the right ventricle of the heart and in coronary and pulmonary arteries as observed in the adult animals in this study. It seems reasonable to assume that whereas some infective larvae mature in the right heart and pulmonary arteries, others pass through the lungs and left heart to find their way into the coronary arteries. Once the worms reach maturity, it is unlikely that further migration occurs.

Aneurysmal lesions similar to those in this study have been reported in kudu, bushbuck, and an African buffalo,[3] but the *C. sagittus* adults were supposedly said to be found in coronary veins rather than arteries. In that study, hypertrophy and hyperplasia of medial smooth muscle cells of "smaller branches" of the coronary arteries were ascribed to hypertension created by obstruction of the venous drainage. It seems unlikely that the parasite changed its site of predilection from coronary veins to arteries. It may be that the intimal proliferation and transmural fibrosis that characterized the well-developed arterial lesions obliterated the histological features of the parasitized coronary vessels thus causing them to be mistaken for veins.

The medial smooth muscle hyperplastic changes observed in smaller coronary and pulmonary arteries and arterioles of parasitized kudu are reminiscent of those observed in the lungs of dogs and cats with certain nematode parasites (e.g., *Dirofilaria immitis*) that live in or migrate through pul-

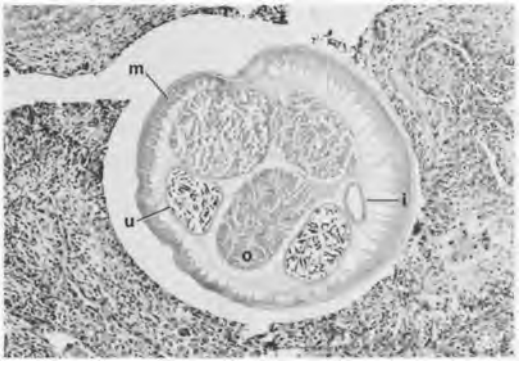

Figure 8. Histological section of lung from a greater kudu containing cross section of an adult female *Cordophilus sagittus* surrounded by fronds of intimal proliferation. Note the coelomyarian muscles (m), small intestine (i), and sections of ovary (o) and uteri (u) containing mature microfilariae. H&E, ×150.

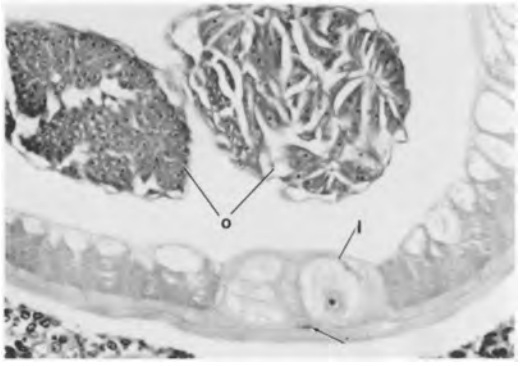

Figure 9. Higher magnification of adult female parasite (*Cordophilus sagittus*). Note sections of ovary (o) and a lateral internal ridge of cuticle (arrow) at the level of the lateral chord (l). H&E, ×300.

monary arteries.[1] Theories on the pathogenesis of such lesions include pulmonary hypertension, inflammatory stimulation by the parasites, thrombosis, and local anaphylaxis in response to parasitic antigens.

The absence of microfilariae in the tissues of most kudu in this study contrasts with descriptions of microfilariae and associated inflammation that were reported in the myocardium and lymph nodes of most kudu in another study.[3] It was conceded in that study that the microfilariae seen in lymph nodes may have been from an unidentified subcutaneous filarial nematode found in the sternal region of several of the kudu. No subcutaneous filarial nematodes were found in the kudu in our study. In only a few kudu, microfilariae and associated lesions were observed in the myocardium, lymph nodes, and/or lungs.

The most significant and interesting lesions of cordophilosis in kudu were the aneurysms in the coronary arteries and branches of the pulmonary arteries and the associated proliferative endarteritis lesions seen most strikingly in the pulmonary vessels. Both of these lesions appear to result from the presence of mature worms; however, the pathogenesis of arterioaneurysms such as these in response to filarial parasitization is not clear. Mechanical, toxic, and/or immune-mediated damage could initially weaken the artery wall with subsequent dilatation resulting from blood pressure. The tendency for these parasitic aneurysms to occur at specific locations (in the epicardium adjacent to the intermediate and longitudinal grooves) is most likely related to vessel diameter and the increased hydrodynamics of coronary circulation of this segment. Although villous intimal proliferations were present in many parasitic aneurysms of the coronary arteries, they never attained the floridity observed in the parasitized branches of the pulmonary arteries, where the aneurysmal dilatation of the vessel lumens were filled with both fine and coarse intimal villi that embraced the parasites. It was apparent in some cases that worms had been incarcerated through the process of intimal proliferation, and calcified remains with attending granulomatous inflammation were occasionally observed within fibrous tissue adjacent to the vascular lumen. Villous intimal proliferation in response to a pulmonary arterial filarial nematode is not unique. A similar response is seen in canine dirofilariasis.[1]

As is often the case with diseases in wildlife, it is difficult to assess the importance of cordophilosis to the general health of kudu herds. The physical condition of heavily

parasitized animals did not differ noticeably from that of animals with few parasites, or even from those free of infection. Pulmonary lesions were remarkable in microcosm; however, even in the heavily parasitized kudu, pulmonary arterial lesions due to *C. sagittus* were not considered significant.

The coronary vascular lesions produced by *C. sagittus* would seem to portend greater physical disability than do the pulmonary lesions; however, the lesions described herein were limited to the parasitized coronary arteries and the adjacent myocardium. Inflammatory changes were generally modest, and neither the livers nor lungs of parasitized kudu showed signs of cardiac decompensation.

The apparent benign nature of *C. sagittus* infection in these kudu is in contrast to cordophilosis reported in eland translocated from Addo Elephant National Park in the Western Cape Province to the Kruger National Park in the eastern Transvaal.[6] During this episode, numerous fatalities attributable to *C. sagittus* occurred among the eland, which apparently had no previous exposure to this parasite. Hearts from dead eland showed many more parasitic aneurysms than did the kudu hearts in our study. Reports of similar fatalities in domestic cattle appear in the files of the Pathology Section, Onderstepoort Veterinary Research Institute.

Although it is seemingly a subclinical condition in kudu (most probably nyala and bushbuck as well), game farmers and wildlife managers should be aware of cordophilosis. In these and other susceptible animals, including domestic cattle, infection may result in severe disease with fatal consequences if, having had no previous exposure to *C. sagittus*, animals are translocated to endemic areas or are otherwise exposed to the parasite.

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Received for publication 21 March 1989.

SECTION 2

PARASITES

OF

GAMEBIRDS

Introduction

In 1937 R.J. Ortlepp described the first worms from South African guineafowls. Since then, seven publications have appeared, approximately one every ten years. When Dr. Junker joined the Department of Veterinary Tropical Diseases, she started examining the helminths of guineafowls that had been collected over the years by Prof. I.G Horak, mainly from the KNP. The opportunity arose to extend the geographical range for this project to include hosts from Musina, Limpopo Province, in the northern part of the country, otherwise the date from these hosts would have been lost.

Infections with thorny-headed worms, tapeworms and roundworms are common in guineafowls and their helminth fauna is diverse. A total of 22 species were recovered from the alimentary canal, comprising eleven tapeworms, ten roundworms and a single thorny-headed worm. A single trematode (fluke) species was present in the liver.

I funded most of the project, and was also intimately involved with the collection of the helminths from Musina, and the preparation of the manuscripts. This part is divided into two chapters, one dealing with the descriptions of new species or re-descriptions of known ones, and the other dealing with the population dynamics of the worms. A check list of the parasites of guinea fowls is included in this section. The publications in the first chapter are listed in chronological order and thos in the second one by subject and then chronologically.

DESCRIPTIONS AND RE-DESCRIPTIONS OF PARASITES OF GAME BIRDS (P 429)

JUNKER, K. & BOOMKER, J. 2006. *Mediorhynchus gallinarum* (Acanthocephala: Gigantorhynchidae) in Helmeted guineafowls, *Numida meleagris*, in the Kruger National Park, South Africa. *Onderstepoort Journal of Veterinary Research*, 73, 283-292.

JUNKER, K. & BOOMKER, J. 2007. *Tetrameres numida* n.sp. (Nematoda: Tetrameridae) from Helmeted guineafowls (Linnaeus, 1758), in South Africa. *Onderstepoort Journal of Vteterinary Research*, 74, 115-128.

JUNKER, K., DAVIES, O.R., JANSEN, R., CROWE, T.M. & BOOMKER, J. 2008. Nematodes from Swainson's spurfowl *Pternistis swainsonii* and an Orange River francolin *Scleroptila levaillantoides* in Free State Province, South Africa, with a description of *Tetrameres swainsonii* n. sp.(Nematoda: Tetrameridae) *Journal of Helminthology,*82, 365 – 371.

POPULATION DYNAMICS (P 463)

JUNKER, K. & BOOMKER, J. 2007. Helminths of guineafowls in Limpopo Province, South Africa. *Onderstepoort Journal of Veterinary Research*, 74, 265-280.

JUNKER, K., DEBUSHO, L. & BOOMKER, J. 2008. The helminth community of Helmeted Guineafowls, *Numida meleagris* (Linnaeus, 1758), in the north of Limpopo Province, South Africa. *Onderstepoort Journal of Veterinary Research*, 75:225-235.

JUNKER, K. & BOOMKER, J. 2007. A check list of the helminths of guineafowls (Numididae) and a host list of these parasites. *Onderstepoort Journal of Veterinary Research*, 74, 315-337.

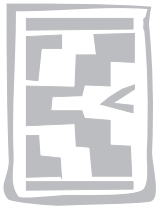
CHAPTER 1

Descriptions and re-descriptions

of

parasites of gamebirds

Onderstepoort Journal of Veterinary Research, 73:283–292 (2006)



Mediorhynchus gallinarum (Acanthocephala: Gigantorhynchidae) in Helmeted guineafowls, *Numida meleagris*, in the Kruger National Park, South Africa

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ABSTRACT

JUNKER, K. & BOOMKER, J. 2006. *Mediorhynchus gallinarum* (Acanthocephala: Gigantorhynchidae) in Helmeted guineafowls, *Numida meleagris*, in the Kruger National Park, South Africa. *Onderstepoort Journal of Veterinary Research*, 73:283–292

Mediorhynchus gallinarum was recovered from the small intestines of 36 of 50 Helmeted guineafowls sampled from August 1988 to May 1989. The intensity of infection ranged from 1–141 worms per host, with a mean intensity of 23.2 (± 34) and a median intensity of 5. The Wilcoxon-Mann-Whitney test revealed no significant differences between the mean worm burdens of male and female birds at the 5% level ($P > 0.05$). Slightly more female than male acanthocephalans were collected. The majority (63.4%) of females had eggs with fully-developed embryos, 9% had immature eggs, 21.2% had no eggs and the egg status of 6.4% could not be determined. No seasonal pattern of intensity of infection emerged from the data, but worm burdens were markedly higher after good rains in February 1989. South Africa constitutes a new geographic record for *M. gallinarum*.

Keywords: Acanthocephala, Helmeted guineafowls, *Mediorhynchus gallinarum, Numida meleagris*

INTRODUCTION

The guineafowl family Numididae is widespread and common in the Afrotropical region, where they utilize a wide variety of habitats ranging from dense rainforest to semi-desert. Of the four genera of guineafowls, *Agelastes*, *Acryllium*, *Guttera* and *Numida*, the last-named's helminth fauna has been studied the most extensively. There are few references to cestodes and nematodes from *Guttera* (Crested guineafowl) and even fewer from *Acryllium* (Vulturine guineafowl) (Yamaguti 1959, 1961, 1963; Ortlepp 1963; Schmidt 1986). The authors are aware of only one publication pertaining to acanthocephalans from guineafowls other than *Numida,* namely *Mediorhynchus taeniatus* (syn. *Empodius segmentatus*) from *Guttera pucherani edouardi* in the former Belgian Congo (Southwell & Lake 1939).

Many of these studies were conducted in North and West Africa, where guineafowls are commercially reared as a source of protein and necessitated a more detailed knowledge of the birds and their parasites (Hodasi 1976). The possibility of wild guineafowls as alternative or reservoir hosts for helminths of domestic chickens and vice versa, also required investigation (Fatunmbi & Olufemi 1982). In South Africa three studies concerning the gastrointestinal worms of Helmeted guineafowls have been conducted, one each in the Eastern Cape Province, the Kimberly area in the Northern Cape Province and in the surroundings of Pretoria in Gauteng Province (Saayman 1966; Crowe 1977; Verster & Ptasinska-Kloryga 1987).

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Accepted for publication 3 July 2006—Editor

The present paper describes a survey in which the acanthocephalan burdens of free-ranging guineafowls in the southern part of the Kruger National Park (KNP) were determined, as well as those of "scavenger" guineafowls frequenting the refuse dump at the Skukuza tourist rest camp. Some scanning electron micrographs and measurements intended to supplement the descriptions of *Mediorhynchus gallinarum* given by Bhalerao (1937) and Nath & Pande (1963) are included.

MATERIAL AND METHODS

Study site

The KNP is situated in the eastern part of Limpopo Province and the north-eastern part of Mpumalanga Province. It encompasses an area of 1 948 528 ha. The survey region in the southern part of the park (South of 24°50' S; Skukuza 24°50 S, 31°35' E) comprises vegetation classified as Lowveld Sour Bushveld and Arid Lowveld (Acocks 1975). Helmeted guineafowls are present throughout the study area. The refuse dump at Skukuza tourist rest camp offers easy foraging and attracts hundreds of birds (Horak, Spickett, Braack & Williams 1991).

Survey birds

Each month from August 1988 to May 1989, two Helmeted guineafowls on or near the refuse dump at Skukuza, and three at other sites in the southern part of the park were shot. An effort was made to shoot only adult birds, but two of the total of 50 birds were 7 to 10-month-old sub-adults. No birds were collected in March 1989, but of the ten guineafowls that were examined in February 1989, five were sampled in the beginning of the month and five were shot on 28 February. The latter birds are listed as hosts examined in March 1989.

Parasite collection

After the birds had been shot their carcasses were transported to the laboratory at Skukuza. The entire viscera were removed and placed in separate labelled bottles in which they were stored in 10% buffered formalin. During 2005 and 2006 the lungs, crop, small intestine (SI) and the caecum-colon (CC) were removed from the bottles and separated. Macroscopically visible helminths were recovered from each of the organs and transferred to 70% ethanol. Thereafter the content of each organ was washed with tap water over a 150 µm sieve. The residue on the sieve was transferred to a vessel containing 70% ethanol and examined under a stereoscopic microscope for the presence of endoparasites.

Following the procedures described by Gibbons, Jones & Khalil (1996) some acanthocephalans were stained with aqueous aceto alum carmine and mounted in Canada balsam, while others were cleared in Hoyer's medium.

Specimens for scanning electron microscopy (SEM) were dehydrated through graded ethanol series and critical point dried from 100% ethanol through carbon dioxide. They were mounted on viewing stubs and sputter-coated with gold. The photography was done using a Hitachi S-2500 scanning electron microscope.

In order to investigate differences in the worm burdens of male versus female hosts, the Wilcoxon-Mann-Whitney test for independent samples was used to compare the mean worm burden of the two groups at the 5% level ($P > 0.05$) (Thrusfield 1995).

RESULTS

Mediorhynchus gallinarum (Bhalerao, 1937) van Cleave, 1947 (Fig. 1 & 2)

MORPHOLOGY

Mediorhynchus gallinarum is characterized by a so-called acanthopseudoannelid holdfast, an attachment mechanism involving proboscis hooks as well as pseudo-segmentation of the body, considered typical for Moniliformidae and some of the Gigantorhynchidae (Petrochenko 1956).

The trunk is elongate and tapers slightly towards the posterior end. The prominence of the pseudo-segmentation is influenced by the extent of muscle contraction: it can be conspicuous, as in craspedote cestodes or nearly smooth as in sebekiid pentastomes. Pseudo-segmentation also appears to be more pronounced in older, larger specimens. The most anterior part, and in some specimens the caudal tip, is usually unsegmented. Annulus counts range from 52 in a 48-mm-long male to 76 in a 61-mm-long female. In some specimens muscle contraction creates a neck-like zone behind the proboscis, which is absent in relaxed specimens. The protoboscis is almost conical in shape and the teloboscis is trapezoid.

The hooks on the protoboscis are arranged in 18–20 roughly longitudinal rows of 4–5 hooks each. The total length of the hooks, including their roots, ranges from 0.048–0.076 mm, with the hooks in the top

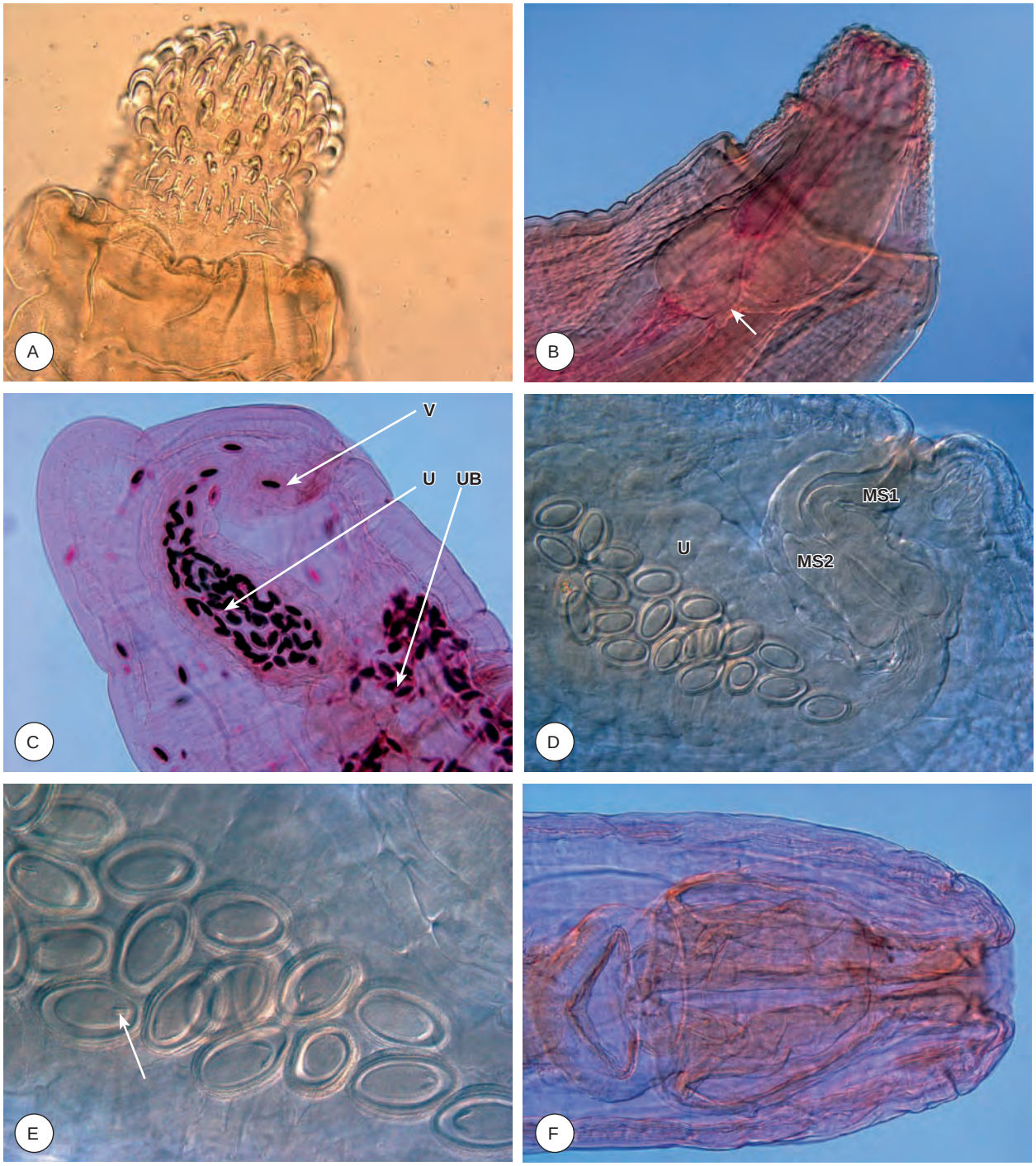

FIG. 1 *Mediorhynchus gallinarum*

A. Proboscis showing the hooks on the protoboscis and spines on the teloboscis; x 200. B. Proboscis receptacle. The muscular wall of the receptacle is visible together with the dorsal protrusor muscles (arrow), giving the impression of a double walled proboscis sheath; x 100. C. Female posterior end. Dark colouration of eggs due to staining. U = uterus, UB = uterine bell, V = vagina; x 100. D. Female posterior end. Detail of the two muscular sphincters (MS1, MS2) surrounding the vagina. U = uterus; x 200. E. Eggs with compact granular outer shell and fully developed embryo with anterior larval hooklets (arrow); x 400. F. Male posterior depicting terminal genital pore and copulatory bursa with complicated internal structure; x 100

row usually the shortest. Two longitudinal grooves extend from the base of the hook blade to its tip. The rootless spines on the teloboscis vary in length from 0.032–0.047 mm.

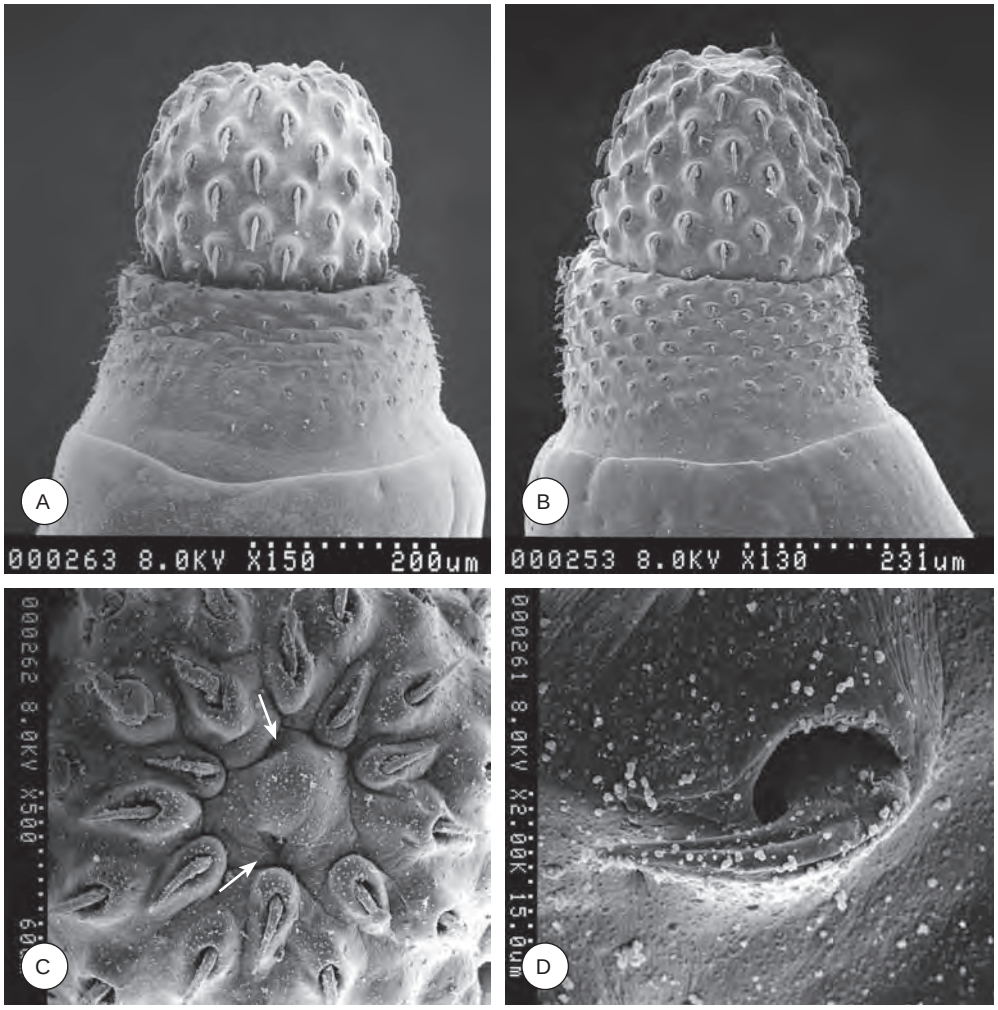

FIG. 2 *Mediorhynchus gallinarum*

A. Anterior part displaying the arrangements of hooks on the protoboscis and smaller spines on the teloboscis; x 150. B. Same specimen rotated 180°; x 130. C. En face view. The two apical pores of the apical organ are visible (arrows); x 500. D. Close-up of a hook partially retracted into the surrounding pouch. Note the grooved surface of the hook; x 2 000

The lemnisci are slender and approximately 2.5-2.9 times longer than the proboscis receptacle. In some specimens up to six nuclei, possibly more, per lemniscus were counted. Lemniscus length ranged from 2.09 mm in a 13-mm-long male to 3.47 mm in a 50-mm-long male, but the length of the lemnisci did not necessarily increase with body length. The lemnisci ranged from 0.191–0.343 mm in width. No obvious differences were evident between males and females.

Females: The average body length is 32 ± 17 mm (*N* = 423), ranging from 4–110 mm, with a median of 35 mm. The maximum body width varies from 0.6–4 mm (mean = 1.4 ± 0.6 mm), with large gravid females, especially when the body was contracted, the widest.

The length of the proboscis receptacle ranges from 0.701 mm in a 6-mm-long female to 1.19 mm in a 48-mm-long female (mean = 1.0 ± 0.162 mm). The width of the proboscis receptacle varies from 0.296–0.554 mm, with an average of 0.399 ± 0.072 mm. Eggs with a compact, granular outer shell and fully developed embryos measure on average 0.049 mm (range: 0.043–0.052 mm) in width and 0.079 mm (range: 0.070–0.86 mm) in length. The embryo itself is 0.054 mm (range: 0.047–0.058 mm) long and 0.025 mm (range: 0.021–0.028 mm) wide.

Males: The mean body length is 25 ± 14 mm (*N* = 284) with a range of 3–70 mm. The median is 25 mm. The average maximum width ranges from 0.5–2.8 mm (mean = 1.1 ± 0.4 mm) and the measurements taken from 14 males are presented in Table 1.

TABLE 1 Morphological data of *Mediorhynchus gallinarum* males recovered from Helmeted guineafowls in the Kruger National Park. All measurements given in micrometer unless otherwise indicated

Spec. no.	Length (mm)	Width (mm)	PRL	PRW	PBL	TBL	TBA	TBP	RLL	LLL	LLW	ATL	PTL	CGL	SVL	CBL
GF38/8	6	0.8	609	311	318	332	369	591	2 341	nm	nm	369	321	362	367	531
GF3/13	12	0.7	786	nm	324	321	442	689	nm	nm	nm	815	800	nm	528	666
GF38/9	13	0.9	762	328	286	291	411	653	2 093	2 156	206	949	988	1 190	709	712
GF38/4	14	nm	791	333	339	316	378	685	2 470	2 713	nm	848	969	nm	742	892
GF38/6	24	1.1	967	359	299	312	470	668	2 291	2 573	nm	1 477	1 434	nm	1 002	1 079
GF3/8	33	1.4	1 170	nm	nm	nm	nm	nm	2 386	2 975	298	2 727	nm	nm	nm	nm
GF3/12	33	1.1	1 066	404	nm	nm	nm	nm	3 144	3 036	nm	2 008	2 038	2 871	1 379	1 401
GF3/6	37	1.6	938	371	nm	nm	nm	nm	2 166	2 447	313	2 478	nm	nm	nm	nm
GF4/7	40	1.6	nm	nm	nm	nm	nm	nm	nm	nm	nm	2 513	2 525	4 448	1 827	1 841
GF3/5	44	1.5	1 176	367	nm	nm	nm	nm	3 051	2 887	306	2 156	2 095	3 555	1 864	1 804
GF3/4	48	1.4	1 201	437	nm	nm	nm	nm	3 380	3 470	nm	3 023	2 915	4 640	1 494	1 741
GF1/1	50	1.5	1 226	416	nm	nm	nm	921	3 113	2 612	nm	2 715	3 015	2 715	1 825	1 659
GF3/11	53	1.8	nm	nm	nm	nm	nm	nm	nm	nm	nm	2 642	2 732	7 303	1 793	2 286
GF38/1	nm	1.1	1 067	330	nm	nm	nm	nm	nm	2 708	258	nm	nm	nm	nm	nm

ATL = Anterior testis length
CBL = Copulatory bursa length
CGL = Cement gland area length
LLL = Left lemniscus length
LLW = Left lemniscus width
nm = Not measured
PBL = Protoboscis length
PRL = Proboscis receptacle length
PRW = Proboscis receptacle width
PTL = Posterior testis length
RLL = Right lemniscus length
RLW = Right lemniscus width
SVL = Seminal vesicle length
TBA = Width of anterior border of teloboscis
TBL = Teloboscis length
TBP = Width of posterior border of teloboscis

Measurements of the proto- and teloboscis were only taken from specimens in which these features were fully extended.

The oblong shaped testes are located in the posterior third of the body. In young males the sexual organs are clustered in the caudal region. Testes move anteriorly and the gap between the anterior and posterior testis widens as the males grow larger.

Taxonomic remarks

Harris (1973) described *Mediorhynchus selengensis* from *Francolinus leucoscepus* in Kenya. In their revision of the genus *Mediorhynchus* Schmidt & Kuntz (1977) classified this species as a junior synonym of *M. gallinarum* after comparing material of *M. gallinarum* to the description of Harris (1973). Vercruysse, Harris, Bray, Nagalo, Pangui & Gibson (1985) chose to retain the name *M. selengensis* for acanthocephalans collected from guineafowls in Burkina Faso until such time as Asian and African material could be more thoroughly compared.

The main difference between our specimens and those of Harris (1973) is the number of proboscis spines. Harris (1973) described only two to three spines per row, whereas our specimens carry five to seven spines per row. Nevertheless, Harris' (1973) illustration suggests that more spines per row may be present. The remaining measurements overlap to a large extent. Not having examined Harris' specimens we would tend to agree with Schmidt & Kuntz (1977) and assign our specimens to *M. gallinarum*.

Epidemiology

Small numbers of acanthocephalans were recovered from the CC of six guineafowls, and these have been included in the SI counts.

The prevalence of infection with *M. gallinarum* was 72%, i.e. of the 50 hosts examined 36 harboured parasites. A total of 846 worms were recovered from the 36 hosts. Worm burdens were usually low, with a median intensity of 5, and the intensity of infection ranged from 1–141, with a mean intensity of 23.2 ± 34. Hosts infected with less than 10 acanthocephalans accounted for 58% of the total host population, hosts with a burden ranging between 10 and 20 parasites comprised 14% and in 28% of the guineafowls the worm burden exceeded 20. The mean intensity of infection of male and female birds was 19.8 ± 36.4 and 27 ± 31.8, respectively. No significant differences between the mean intensities of infection at the 5% level, with a two-tailed *P* value of 0.2892, were observed with the Wilcoxon-Mann-Whitney test.

The mean intensity of infection with male and female acanthocephalans was 9 and 13, respectively, and the sex ratio favoured females (55.9% versus 37.7%). The small number of males and females recovered from the majority of hosts did not provide an adequate sample size for statistical testing. However, in nine of 10 hosts in the group harbouring more than 20 acanthocephalans, female parasites outnumbered males and constituted 60% of the adult parasites in this group. Immature *M. gallinarum* comprised a mere 0.4% of the infrapopulation, and the gender of 6% of the acanthocephalans could not be determined because they were poorly preserved.

The uteri of the majority of the females (63.4%) contained mature eggs, 9% only immature eggs and 21.2% contained no eggs. The status of eggs in the uteri of 6.4 % of females could not be determined.

The mean intensities of infection during the various months of collection are presented in Table 2, and the seasonal variation in infection in Fig. 3. Infection peaked during late summer and autumn, but because the sampling period did not cover a full year the seasonality of infection cannot be determined with certainty.

TABLE 2 The mean numbers of *Mediorhynchus gallinarum* recovered from 50 Helmeted guineafowls in the Kruger National Park

Collection date	Mean intensity of infection (range)	No. of birds infected/examined
Aug. 1988	7.8 (1–14)	4/5
Sep. 1988	3.5 (1–5)	4/5
Oct. 1988	2.5 (1–4)	2/5
Nov. 1988	4.0 (4)	1/5
Dec. 1988	6.2 (2–16)	5/5
Jan. 1989	4.3 (2–8)	4/5
Feb. 1989	41.0 (3–67)	5/5
Mar. 1989	74.4 (5–141)	5/5
Apr. 1989	26.5 (4–52)	4/5
May 1989	25.0 (2–48)	2/5

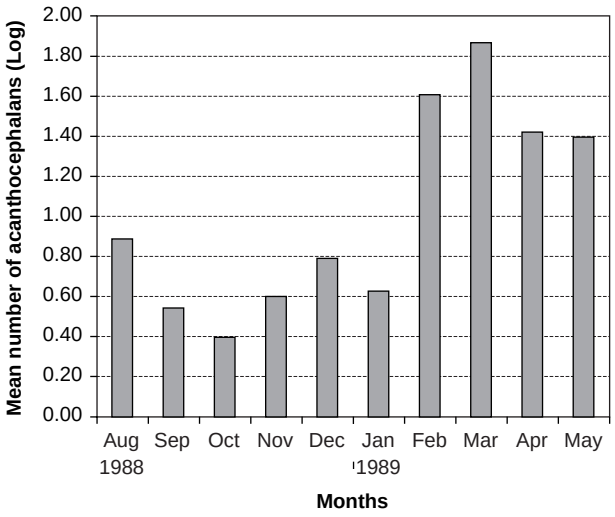

FIG. 3 The mean seasonal intensities of infection with *Mediorhynchus gallinarum* in Helmeted guineafowls in the Kruger National Park

Few hosts were examined from the different localities in the southern part of the KNP on the various collection dates. Consequently, data pertaining to differences in the mean intensities of infection at the different sites versus the dump at Skukuza should not be overinterpreted. However, in February and March 1989 the worm burdens of all six guineafowls sampled along the Lower Sabie Road were markedly lager than the overall mean intensity of 23.2, with individual burdens consisting of 51, 37, 48, 141, 86 and 119 worms. In contrast, the acanthocephalan burdens of four guineafowls sampled at the dump at Skukuza at the same time varied from far below to far above average, namely 76, 3, 5 and 21.

DISCUSSION

We have not been able to establish whether the grooves on the surface of the hooks of *M. gallinarum* are a unique feature of this parasite or genus or whether it is a characteristic with a wider taxonomic significance.

No grooves were seen on SEM photographs taken by Taraschewski, Sagani & Mehlhorn (1989, cited by Taraschewski 2000) of hooks of *Echinorhynchus truttae* and *Moniliformis moniliformis*. The function of these structures is open for speculation. They might simply improve the holdfast of the hooks in the surrounding host tissue. Alternatively, the increased surface area could assist in the uptake as well as secretion of substances. Polzer & Taraschewski (1992, cited by Taraschewski 2000) discuss the discharge of penetration enzymes through the hook pores of *Pomphorhynchus laevis*.

The majority of acanthocephalans in this study were recovered from the SI and only a small number were found in the CC. While the caecum is a predilection site of some acanthocephalans (De Buron & Nickol 1994), we are not sure whether our findings represent a true distribution pattern or are the result of contamination during the processing of the hosts. There is also the likelihood of post mortem migration. *Mediorhynchus gallinarum* parasitizing domestic fowls in Papua and New Guinea were confined to the mid and lower small intestine (Talbot 1971), and Crowe (1977) recovered *Mediorhynchus taeniatus* only from the small intestine of Helmeted guineafowls. We are not aware of any controlled studies concerning the site preferences of any members of the genus *Mediorhynchus*.

Morphologically *M. gallinarum* falls into the category of acanthocephalans with a short neck and the associated shallow mode of attachment as described by Taraschewski (2000). Histological examination of *M. gallinarum* in domestic fowls revealed that their attachment rarely penetrated below the muscularis mucosa (Nath & Pande 1963; Talbot 1971). Taraschewski (2000) states that non-perforating species remain mobile and can alter their point of attachment. They do not occupy extra-intestinal sites within their hosts. According to Kennedy & Lord (1982) acanthocephalans can successfully utilize a much larger region of the digestive tract than their predilection site, and at high levels of infection are known to expand their distributional range within the alimentary canal (Taraschewski 2000). The hosts from which acanthocephalans were collected from both the CC and the SI in the present study carried relatively low worm burdens (4, 4, 8, 36 and 67) and infections involving considerably higher intensities were restricted to the SI in some of the other hosts. In view of the above, post mortem migration appears the more probable explanation for the specimens we found in the CC.

Only a small percentage of *M. gallinarum* were immature, and this can be attributed to the short period of time required by the cystacanth, once ingested by a final host, to develop into an adult. In experimental infections of several species of woodpeckers with cystacanths of *Mediorhynchus centurorum* the mean prepatent period was 35 days (Nickol 1977).

More than 60% of the female *M. gallinarum* examined during this study contained eggs with shelled embryos. This is contrary to Van Cleave's (1947a) report that fully grown female specimens of *Mediorhynchus* spp. recovered from a variety of birds invariably lacked embryonated eggs. His speculation that sterility might be seasonal, is not supported by

our data in the case of *M. gallinarum*. We do, however, accept his view on sterility possibly being due to the absence of males or an indication of the unsuitability of a certain bird species as final host.

One of the hosts examined in this study was infected by a single large (6.5 cm) female containing only immature eggs, which in view of the many gravid females recovered from other guineafowls, we interpret as lack of fertilization. A relatively large female in another bird contained sterile eggs, despite the presence of a male. In the latter case it is possible that the male was acquired during a more recent infection. In pentastomid parasites copulation occurs when the uterus of the female is undeveloped and the sexes are of approximately equal size. As the uterus develops it becomes impossible for the male to deposit sperm in the female spermathecae (Riley 1986). As in pentastomes insemination in the acanthocephala is possibly restricted to a short critical period during female development. Riley (1986) suspects that the absence of male pentastomids retards female development. This does, however, not seem to be the case in the Acanthocephala.

Van Cleave (1947a), who examined collections of the genus *Mediorhynchus* from various parts of the world, found the intensity of infection to be extremely low in many avian hosts. Often a single worm was present. He saw this as an indication of the absence of reservoir hosts, reasoning that the normal final hosts of *Mediorhynchus* would not feed on possible reservoir hosts, i.e. animals large enough to consume the intermediate host (Van Cleave 1947a). Given the catholic diet of guineafowls, this argument would not be valid for this particular final host. Since nothing is known about the intermediate hosts of *M. gallinarum* in South Africa, it would be difficult to speculate whether the higher mean intensity of infection is due to the inclusion of reservoir hosts in the life-cycle, or is due to a wide range of possible intermediate hosts, or both.

According to Petrochenko (1956) most individual hosts harbour a single acanthocephalan species only, even if the particular host species serves as host for several different species of acanthocephalans. Our own data and the literature pertaining to guineafowls support this. *Mediorhynchus taeniatus* was the only acanthocephalan present in 42 guineafowls from Nigeria and 13 guineafowls from South Africa (Fabiyi 1972; Verster & Ptasinska-Kloryga 1987). Saayman (1966) recovered *Mediorhynchus numidae* (syn. *Empodisma numidae*) from 14 guineafowls, and Vercruysse *et al.* (1985) report only *M. selengensis* Harris, 1973 from guineafowls in Burkina Faso.

Compared to *Mediorhynchus* spp. infections in guineafowls in other African countries the prevalence of infection in the guineafowls in the Kruger National Park was high. *Mediorhynchus taeniatus* in *N. meleagris* in Nigeria had a prevalence of 26.6 % with the intensity ranging from two to 74 worms (Fabiyi 1972). The prevalence of *M. gallinarum* in guineafowls in Burkina Faso was 14 %, the intensity ranging from one to 142 (Vercruysse *et al*. 1985). In Ghana 16 % of the Helmeted guineafowls harboured *M. taeniatus*, with a maximum intensity of 15 worms (Hodasi 1976).

Mediorhynchus taeniatus has also been recorded from South Africa by Verster & Ptasinska-Kloryga (1987). This species differs from *M. gallinarum* in that it has less than 40 hooks and that the lemnisci are not much longer than the proboscis receptacle (Meyer 1932; Schmidt & Kuntz 1977). *Numida meleagris* shot in the Pretoria area (Gauteng Province) had burdens reaching up to 22 worms per bird, with a mean of 1.7. The prevalence of *M. taeniatus* was 27 % (Verster & Ptasinska-Kloryga 1987).

Saayman (1966) recovered *M. numidae* from Helmeted guineafowls in the Eastern Cape Province. This parasite is characterized by the absence of pseudo-segmentation and possesses only three hooks per row (Schmidt & Kuntz 1977). Intensity of infection ranged from one to 27 worms (mean = 11.5) and the prevalence was 39 %. It is interesting that in three different geographical regions in which guineafowls were examined in South Africa the genus *Mediorhynchus* is represented by three different species and that only one species was recovered per region. This, as well as the differences in prevalence and intensity of infection, might be the result of different climatological conditions, vegetation types and resulting differences in the arthropod fauna, suspected of being intermediate hosts, present at the three study sites.

While no pattern of seasonal abundance emerged from our data, worm burdens were markedly higher in guineafowls collected during February, April and May 1989. This coincides with the exceptionally high rainfall of 286.3 mm in February (Penzhorn, Horak, Spickett & Braack 1991). The annual mean rainfall for Skukuza recorded by Gertenbach (1980) is 546.3 mm. The high rainfall probably resulted in a rapid increase of insect and other arthropod populations ensuring a ready supply of intermediate hosts for *M. gallinarum* and a convenient source of infection for the final hosts.

All guineafowls are highly terrestrial and feed exclusively on the ground. They are omnivorous oppor-

tunists and the composition of their diet at any given moment is determined by the local abundance of the various food items (Del Hoyo, Elliot & Sargatal 1994). The overall diet is very varied and consists of plant matter such as leaves, roots, bulbs, seeds, fruits and flowers, as well as grit and animal food (Saayman 1966). The latter, while including a few vertebrates like small frogs, toads and lizards, is mainly made up of a wide array of insects, small molluscs, arachnids and millipedes.

About 12 % of the annual volume of food consumed by guineafowls consists of invertebrates, but Helmeted guineafowls, in particular, prefer to feed on insects when these are sufficiently abundant. The crop of a single Helmeted guineafowl yielded 5 100 harvester termites, *Hodotermes mossambicus* (Del Hoyo *et al*. 1994). Saayman (1966) reports that crops examined during the winter season yielded the highest average amount of live food, mainly because of the large numbers of *H. mossambicus*.

There is a marked individual variation in feeding intensity of guineafowls, and crop contents have been observed to vary considerably between individual members of the same flock (Saayman 1966). This might explain why some of the hosts from the same locality examined at the same time carried very low worm burdens while others harboured large numbers of acanthocephalans. It was especially evident in the guineafowls collected in February/March 1989 from the dump in Skukuza. Overdispersion is a well described phenomenon in parasitology, and amongst others, it is thought to reflect certain traits of individual hosts, such as behavioural differences or immune reactions (Horak & Boomker 2000).

Penzhorn *et al*. (1991) observed that the guineafowls foraging at the dump were able to maintain good body condition despite the fact that the mass of food-intake compared with veld-collected birds was low. They concluded that the refuse dump provided a rich source of food. The mean intensity of infection increased markedly in the free-ranging guineafowls after the good rains in February 1989, but not to the same extent in the birds frequenting the refuse dump. It therefore appears that the good quality diet that is continuously available for these “scavenging” guineafowls buffers the effects that environmental changes have on the free-ranging guineafowls in the rest of the study area, and that they are not as reliant on arthropods to supply their diet and hence are less likely to ingest the possible intermediate hosts of the acanthocephalans. Unfortunately, little is known about the intermediate hosts in the life cycle of *Mediorhynchus*. *Mediorhynchus grandis* develops to the infective stage in a variety of grasshoppers in the USA (Van Cleave 1947b) and it would certainly be interesting to investigate potential intermediate hosts for *M. gallinarum*.

Talbot (1971) reports that even in heavy infections of domestic fowls in Papua and New Guinea with *M. gallinarum* little evidence of severe pathology was seen during the histological examination and he concluded that *M. gallinarum* is not a parasite of major economic importance.

Louw, Horak, Meyer & Price (1993) when determining the lice burdens of the guineafowls examined in this study found no overt signs of distress when observing the birds prior to collection, and Penzhorn *et al.* (1991) found no indication of emaciation during their morphometric studies of the same birds. Crowe (1977) did not see any signs of gross pathological conditions in 206 Helmeted guineafowls, which amongst other helminth parasites, carried acanthocephalans. It would thus appear that guineafowls, at least under natural conditions, tolerate infections with *Mediorhynchus* well. One must, however, bear in mind, that, although not primary pathogens, these parasites compete with their host for nutrients and in the case of heavy infections might well be detrimental to the host’s condition.

ACKNOWLEDGEMENTS

The authors thank the Board of Trustees, South African National Parks, for making the guineafowls available and Prof Ivan Horak for collecting their viscera. Mr Ryno Watermeyer has provided technical assistance and the scanning electron micrographs were taken by Mr John Putterill. Mr Dean Reynecke did the statistical analyses. This study was supported by a Claude Leon Foundation Postdoctoral Fellowship grant to the senior author.

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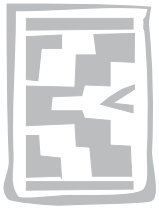

Tetrameres numida n. sp. (Nematoda: Tetrameridae) from Helmeted guineafowls, *Numida meleagris* (Linnaeus, 1758), in South Africa

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ABSTRACT

JUNKER, K. & BOOMKER, J. 2007. *Tetrameres numida* n. sp. (Nematoda: Tetrameridae) from Helmeted guineafowls, *Numida meleagris* (Linnaeus, 1758), in South Africa. *Onderstepoort Journal of Veterinary Research*, 74:115–128

Tetrameres numida n. sp. from the proventriculus of Helmeted guineafowls, *Numida meleagris*, in South Africa is described from eight male and four female specimens. The new species shares some characteristics with other *Tetrameres* species, but can be differentiated by a unique combination of characters. It bears two rows of cuticular spines extending over the whole length of the body and possesses two spicules. The left spicule measures 1 699–2 304 µm and the right one 106–170 µm. Caudal spines are arranged in three ventral and three lateral pairs and the tail is 257–297 µm long. Diagnostic criteria of some of the previously described species of the genus *Tetrameres* from Africa and other parts of the world have been compiled from the literature and are included here.

Keywords: Helmeted guineafowls, nematodes, *Tetrameres numida*

INTRODUCTION

The genus *Tetrameres* Creplin, 1846 are cosmopolitan parasites, infecting a variety of aquatic and terrestrial avian hosts. Females are usually located in the proventricular glands, and the males are found free in the lumen of the proventriculus (Anderson 1992).

Several *Tetrameres* species have been recorded from the African continent, of which *Tetrameres fissispina* (Diesing, 1861) Travassos, 1914 that parasitises ducks, pigeons and domestic chickens and *Tetrameres americana* Cram, 1927 that parasitises domestic chickens, turkeys and quails are the most commonly reported ones (Permin, Magwisha, Kassuku, Nansen, Bisgaard, Frandsen & Gibbons 1997; Poulsen, Permin, Hindsbo, Yelifari, Nansen & Bloch 2000).

Tetrameres coccinea (Seurat, 1914) Travassos, 1914 from the Greater flamingo, *Phoenicopterus ruber*, Linnaeus, 1758, Cattle egret, *Bubulcus ibis* (Linnaeus, 1758) and Eurasian spoonbill, *Platalea leucorodia* Linnaeus, 1758, as well as *Tetrameres lhuillieri* (Seurat, 1918) from the Rock partridge, *Alectoris graeca* (Meisner, 1804) and the Stock pigeon, *Columba oenas* Linnaeus, 1758 were recorded from Algeria (Yamaguti 1961). *Tetrameres nouveli* (Seurat, 1914) Travassos, 1914 was present in the Black-winged stilt, *Himantopus himantopus* (Linnaeus, 1758) in Algeria (Yamaguti 1961), and in Nigeria *Tetrameres plectropteri* Thwaite 1926 was found in the Spur-winged goose, *Plectropterus gambensis* (Linnaeus, 1766) (Yamaguti 1961).

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Accepted for publication date 4 April 2007—Editor

Both *Tetrameres paradisea* Ortlepp, 1932 and *Tetrameres prozeskyi* (Ortlepp, 1964) were described from South African hosts. *Tetrameres paradisea* was recovered from a Stanley's crane, *Anthropoides paradisea* (Lichtenstein, 1793) (Ortlepp 1932), and *T. prozeskyi* occurred in Red-billed hornbills, *Tockus erythrorhynchus* (Temminck, 1823) and Southern Yellow-billed hornbills, *Tockus leucomelas* (Lichtenstein, 1842) (= *Tockus flavirostris leucomelas*), respectively (Ortlepp 1964).

Previous records of *Tetrameres* spp. from guineafowls pertain mostly to studies in North and West Africa, *Tetrameres fissispina* being recorded from Helmeted guineafowls in these countries (Fabiyi 1972; Vercruysse, Harris, Bray, Nagalo, Pangui & Gibson 1985). Appleton (1983) found *Tetrameres* sp. females in Crested guineafowls, *Guttera edouardi* (Hartlaub, 1867) (= *Guttera pucherani*), in Natal (now KwaZulu-Natal Province), South Africa, but because males were not present, the species could not be determined.

We here describe a new species of the genus *Tetrameres* from Helmeted guineafowls in South Africa for which we propose the name *Tetrameres numida* n. sp.

With regards to the classification of the genus *Tetrameres* we have followed that of Chabaud (1975), placing the genus into the subfamily Tetramerinae Railliet, 1915 within the family Tetrameridae Travassos, 1914, which is one of four families comprising the superfamily Habronematoidea. At the time the genus had been divided into the subgenera *Tetrameres* s. str., *Gynaecophila* Gubanov, 1950, *Petrowimeres* Chertkova, 1953 and *Gubernacules* Rasheed, 1960. Chabaud (1975), arguing that this division could lead to errors and bore little phylogenetic significance, chose not to retain these, but divided the genus *Tetrameres* into the two subgenera *Tetrameres* (*Tetrameres*) Creplin, 1846 and *Tetrameres* (*Microtetrameres*) Travassos, 1915. In the light of new findings, especially concerning the morphology of adults and larval stages of these two subspecies, Anderson (1992), while retaining their position within the subfamiliy, recognized *Tetrameres* Creplin, 1846 and *Microtetrameres* Travassos, 1915 as two distinct genera, a generic classification that had been suggested by Skrjabin (1969). We adopt his view in the present paper.

MATERIAL AND METHODS

Fifteen Helmeted guineafowls, *Numida meleagris* (Linnaeus, 1758), were collected on a farm 60 km to the west of Musina (Messina), Limpopo Province, South Africa (22°22.139' S, 29°30.399' E) between July 2005 and November 2006. Ten of these were mature guineafowls and five were young birds, about 6–10 months old (Siegfried 1966).

Eight male *Tetrameres* sp. were recovered from the proventriculus, where they occurred free in the lumen and four females were dissected from the proventricular glands. Two guineafowls harboured a single male each, two hosts harboured two and three males respectively, and from a single host one male and four females were recovered. All hosts were mature guineafowls. The worms were fixed in 70% ethanol and cleared in lactophenol for identification. All measurements, unless otherwise indicated, are in micrometres.

DESCRIPTION

***Tetrameres numida* n. sp.** (Fig. 1–3; Tables 1, 2)

With characters of the genus. Sexual dimorphism marked.

MALE: Body elongated, tapering towards both ends, posteriorly to a tail with a short, pointed tip. Cuticle with fine transverse striation and longitudinal cuticular grooves. Total length 4.3–4.5 mm; maximum width 0.16–0.17 mm. Inconspicuous lateral alae extending down the length of the body; parallell to these run two lateral rows of cuticular spines (Fig. 2F). One row of spines is situated dorsally, the second row ventrally to the lateral alae (Fig. 1B). A pair of deirids with apical spines is situated at approximately the height of the second pair of cuticular spines at a distance of 139–204 from the apex (Fig. 1B). Cuticular spines start at 93–154 from the apex, numbering approximately 42–47 per row. The nerve ring and excretory pore are 215–284 and 236–331 from the anterior extremity, respectively. The excretory pore is slightly posterior to the nerve ring. The triangular mouth is bounded by a pair of trilobed pseudolabia. The inner surface of each lobe carries two to four tooth-like processes. The precise number is difficult to assess in our specimens (Fig. 1A, 2A). Depth of buccal capsule 16–28, inner diameter 8–11. Oesophagus divided into muscular and glandular portion, 232–401 and 734–984, respectively. Total length of oesophagus 1023–1318. Spicules unequal and dissimilar. Right spicule tubular, with slight bend and spatulate tip, 106–170 long (Fig. 1C, 2D). Left spicule long and thin, trough-shaped, with spatulate tip. Shaft slightly twisted at 100–120 from proximal end. Total length 1699–2304 (Fig. 1D–F, 2C, 2E). A gubernaculum is absent. Tail

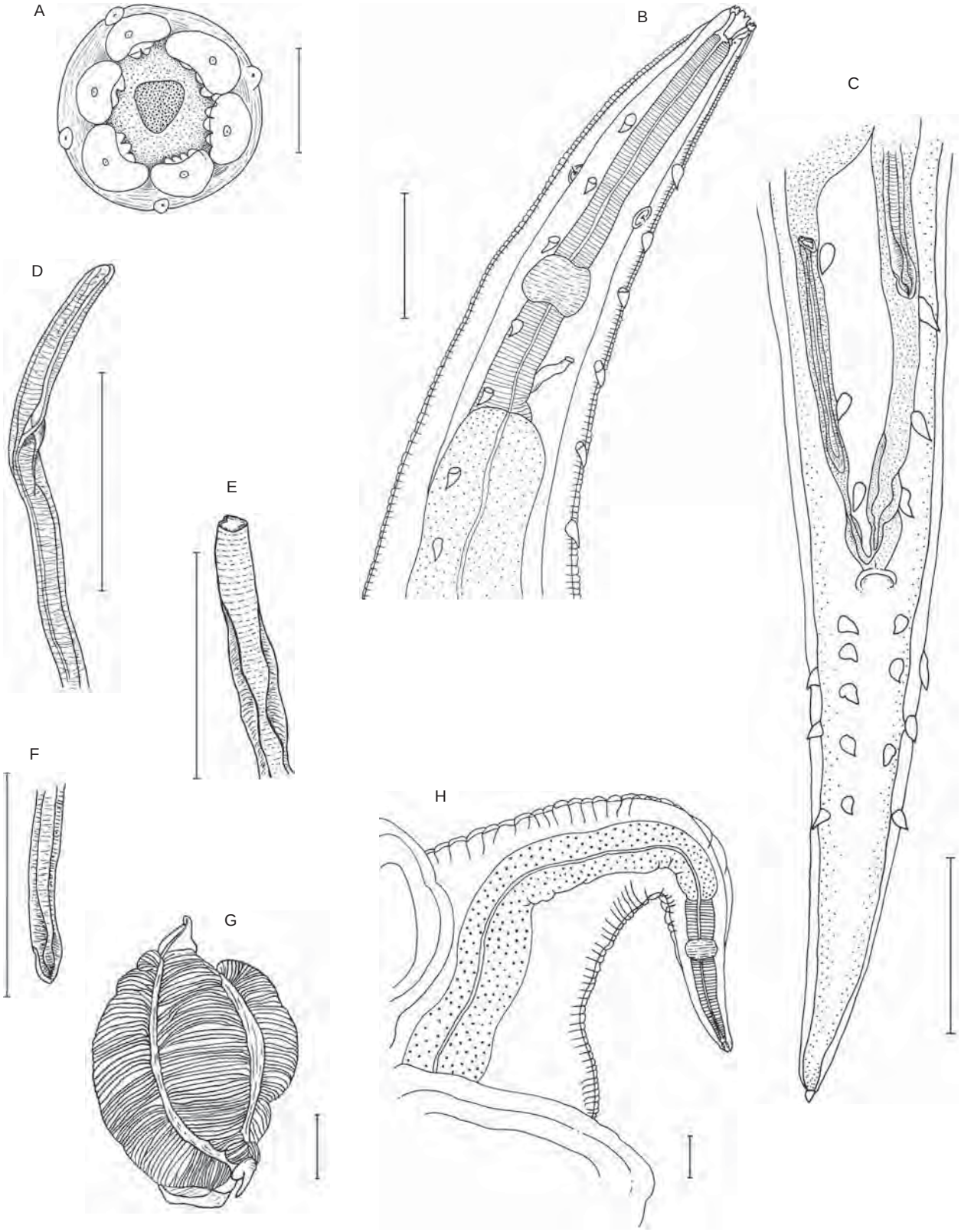

FIG. 1 *Tetrameres numida* n. sp. Male. A. Apical view of the trilobed pseudolabia surrounding the triangular mouth. Note the tooth-like processes (scale bar = 10 µm). B. Ventro-lateral view of the anterior end (scale bar = 100 µm). C. Ventral aspect of the posterior end (scale bar = 100 µm). D. Lateral view of the proximal end of the left spicule showing the slight twist (scale bar = 100 µm). E. Ventral view of the proximal end of the left spicule (scale bar = 100 µm). F. Distal end of the left spicule, ventral view (scale bar = 100 µm). Female. G. Complete female (scale bar = 1 mm). H. Anterior extremity (scale bar = 100 µm)

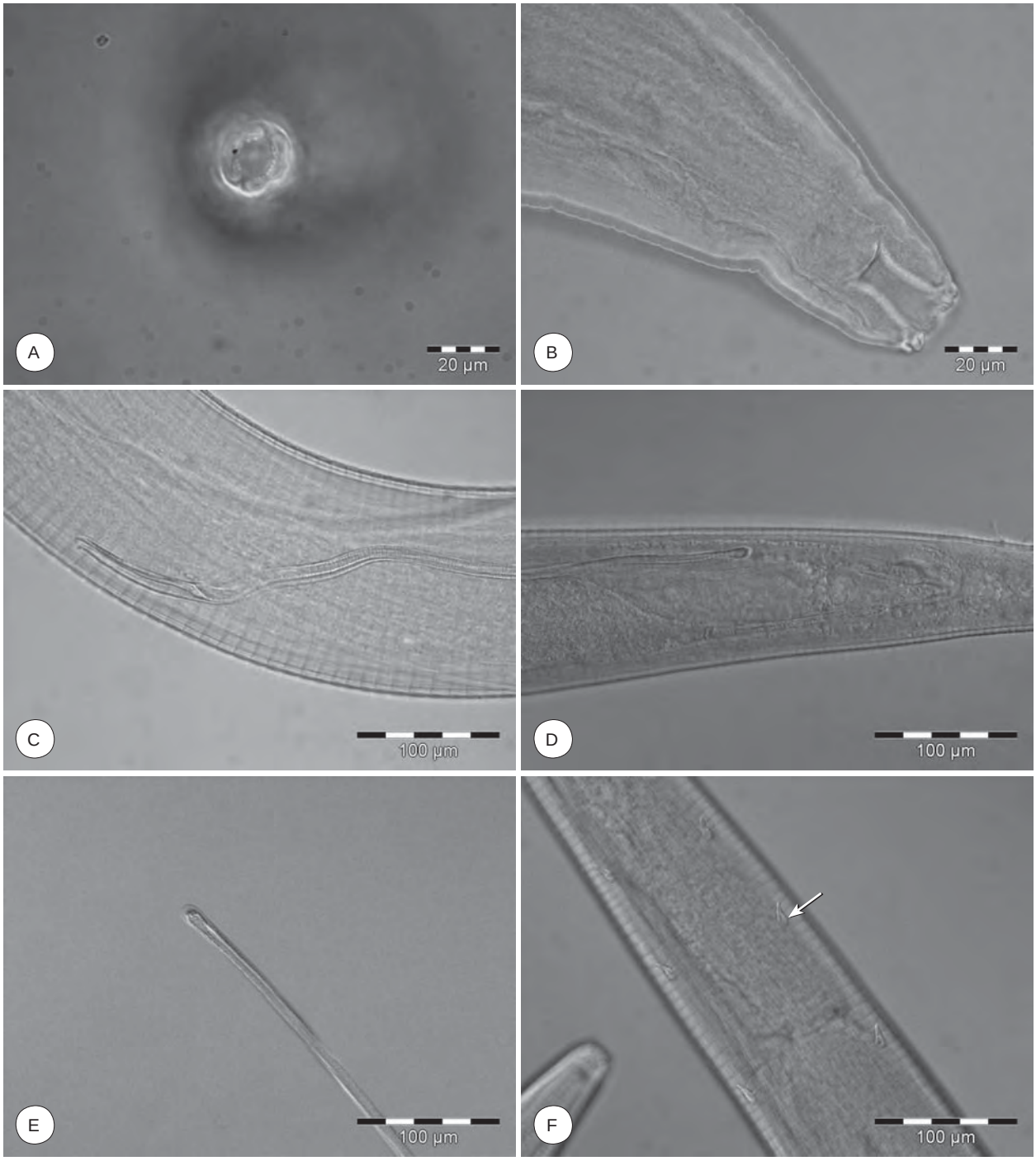

FIG. 2 *Tetrameres numida* n. sp. Male. A. Head, apical view. B. Anterior extremity, ventral view. C. Left spicule, anterior end. D. Posterior extremity with right spicule and distal tip of left spicule. E. Tip of left spicule. F. Body spines (see arrow)

length 257–297. Six pairs of caudal spines, three pairs each in two ventral and two lateral rows, respectively. One or two additional ventral spines may be present (Fig. 1C).

FEMALE: Specimens *in situ* red. A minute head and tail of regular nematode shape, but often twisted or bent, emerge at opposite sides from the central part of the body which is distinctly globular and slightly bent along the axis (Fig. 1G–H, 3A, 3C). The cuticle bears marked transverse striation and four longitudinal cuticular grooves. The latter divide the body into four segments of which the two segments following the outer curve are slightly longer (Fig. 1G). Much of the internal detail is obscured by the egg-

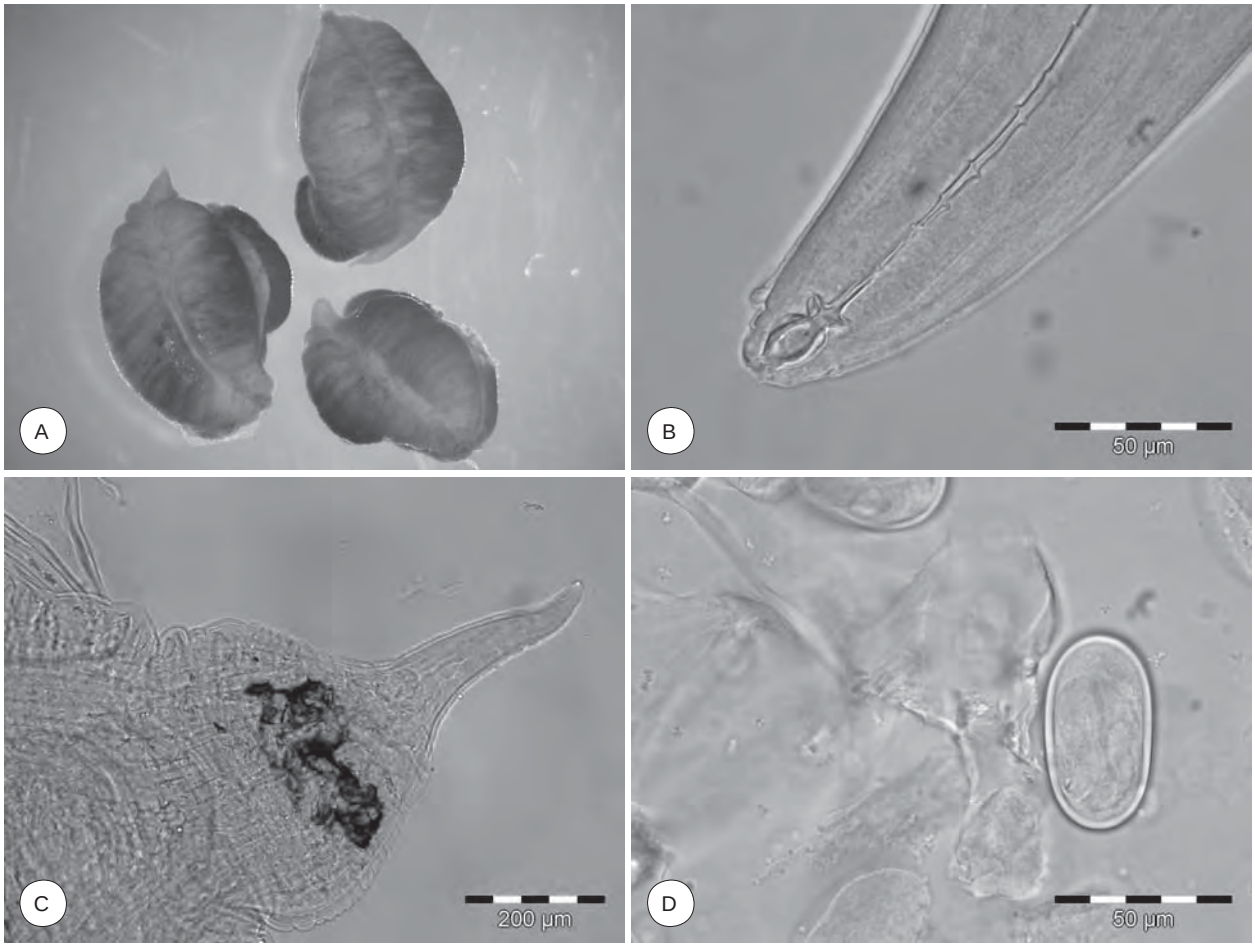

FIG. 3 *Tetrameres numida* n. sp. Female. A. Three whole specimens, approximately 4 mm in length. Note the globular shape. B. Anterior extremity. C. Posterior end. Note the digested blood showing as dark smudge. D. Egg containing fully developed larva

filled uterus coils surrounding a large sacular intestine. Body length 4.2–5.3 mm, maximum width 2.6–3.5 mm. The following measurements were derived from a single specimen: The deirids are at 179 and 190 and the nerve ring at 215 from the apex, respectively. The excretory pore could not be located. Depth of buccal capsule 23, inner diameter 7. Muscular part of oesophagus 333, the distal part of the glandular oesophagus obscured by the uterus. Eggs are elongate with near parallel sides, polar filaments were not seen (Fig. 3D). Eggs containing fully developed larvae are 56–59 long and 31–34 wide. Anus and vulva appeared to be confined in body folds. Emerging from the last body fold is a tail approximately 336 long with a simple tip.

SPECIFIC DIAGNOSIS: *Tetrameres numida* is differentiated from other members of the genus, by the possession of two rows of somatic spines and the arrangement of its caudal spines in two ventral and two lateral rows with usually three pairs of spines each, although deviation might occur. A short right and a long left spicule are present, ranging from 106–131 and from 1699–2 304 in length, respectively.

HOST: *Numida meleagris* (Linnaeus, 1758), Helmeted guineafowl.

SITE: Males occur free in the lumen of the proventriculus, females are situated in the proventricular glands.

LOCALITY: Musina (Messina), Limpopo Province, South Africa (22°22.139' S, 29°30.399' E).

ETYMOLOGY: The specific epithet *numida* refers to the host.

Types deposited in the National Collection of Animal Helminths at the Onderstepoort Veterinary Institute, Pretoria, South Africa. Holotype male: T.2191, Alotype female: T.2192, Paratype males: T.2193–T.2195.

TABLE 1 The morphological characteristics of *Tetrameres numida* sp. n. males from Helmeted guineafowls, compared to *Tetrameres paradisea* Ortlepp, 1932 and to *Tetrameres prozeskyi* (Ortlepp, 1964), all described from South African hosts. All measurements in micrometres unless otherwise indicated

Morphological criteria	**GFM1/N4**	**T.2191**	**T.2193**	**T.2194**	**T.2195**	**GFM11/1**	**GFM12/1**	***Tetrameres paradisea***	***Tetrameres prozeskyi***
Source	This paper	This paper	This paper	This paper	This paper	This paper	This paper	Ortlepp (1932)	Ortlepp (1964)
Body length (mm)	4.3	4.4	4.4	4.3	4.3	n	4.5	5.8	1.3–2.4
Body width maximum	n	n	160	160	164	170	162	140	60-70
Distance apex to first somatic spine	n	126 & 117	96 & 100	102 & 93	105 & 94	131 &154	96 & 113	n	n
Distance apex to deirids	n	174 &180	139 & 149	179 & 172	165 & 177	174 & 181	175 & 204	85	~ 50–60
Distance apex to nerve ring	n	256	215	234	244	284	264	n	~ 150–160
Distance apex to excretory pore	268	307	236	287	296	331	316	n	n
Depth of buccal capsule	22	25	28	23	21	22	16	25	5.0–7.0
Width of buccal capsule (inner)	n	10	10	8	8	11	8	12	11.0–13.0
Muscular oesophagus	n	351	304	232	260	401	400	310	160–210
Glandular oesophagus	n	734	769	984	781	812	918	900	300–400
Oesophagus total length	n	1085	1073	1216	1023	1213	1318	1210	n
Length of tail	284	297	287	257	296	n	290	115	140–160
Length of right spicule	131	130	106	110	131	120	170	Absent	Usually absent[b]
Length of left spicule	1 988	2 103	2 304	2 169	1 699	n	2 204	690; 504–626[a]	230–260

n Data not available

[a] Range given by Mollhagen (1976) in Cremonte *et al.* (2001)

[b] A right spicule was present in three of more than 30 males

TABLE 2 A comparison of morphological characteristics of some species of the genus *Tetrameres Creplin*, 1846

Species	Bodylength of male (mm)	Number of rows of somatic spines	Length of rows of somatic spines	Number of spicules	Spicule length (mm)	Arrangement of caudal spines or papillae	Polar filaments on eggs	Source
Tetrameres americana Cram, 1927	5–5.5	4	n	2	Left: 0.29–0.31; right: 0.1–0.13	5 ventral pairs, no lateral pairs	n	Schmidt (1962); Gibbons *et al.* (1996)
Tetrameres araliensis Efimov & Rijowa, 1939	2.55	4	Whole body length	2	Long: 0.913 ; short: 0.22	2 ventral pairs and 2 sublateral rows with 6 and 7 spines, respecitvely. Two lateral tail papillae also present	n	Skrjabin & Sobolev (1963)
Tetrameres australis Johnston & Mawson, 1941	7.8–9.0	2	Whole body length	2	Long: 5.8–6.3; short: 0.8	5 to 6 small spines	n	Skrjabin & Sobolev (1963)
Tetrameres biziurae Johnston & Mawson, 1941	4.2–4.4	4	Whole body length	2	Long: 0.25–0.26; short: 0.07	n	n	Skrjabin & Sobolev (1963)
Tetrameres calidris Mawson, 1968	2.2–2.5	4/2	4 rows anteriorly, from glandular oesophagus onwards only 2	2	Left: 0.75–1.0; right: 0.08–0.09	5 ventral pairs, 2 lateral pairs	Only males known	Mawson (1968)
Tetrameres cardinalis Quentin & Barre, 1976	4.2–4.95	2	Whole body length	2	Left: 0.365–0.400; right: 0.065–0.085[a]	4–5 pairs of postcloacal spines	Present	Quentin & Barre (1976)
Tetrameres cladorhynchi Mawson, 1968	2.0–2.9	4	Whole body length	1	Left: 1.0–1.37	3 subventral pairs, 3 sublateral pairs	Present	Mawson (1968); Pence *et al.* (1975); Cremonte *et al.* (2001)
Tetrameres coloradensis Schmidt, 1962	2.05	4	Whole body length	2	Left: 0.777; right: 0.067	4 ventral pairs, 3 lateral pairs	Present	Schmidt (1962)
Tetrameres confusa Travassos, 1919	4.0–5.0	4	n	2	Long: 0.291; short: 0.068	3 ventral pairs, 3 lateral pairs		Skrjabin & Sobolev (1963)
Tetrameres cordoniferens Rasheed, 1960	n	4	n	n	Left spicule: 0.40	n	n	Pence *et al.* (1975)
Tetrameres crami Swales, 1936	2.9–4	4	n	2	Left: 0.27–0.35; right: 0.136–0.185	n	n	Schmidt (1962); Gibbons *et al.* (1996)
Tetrameres crami asiatica Ryjikov, 1963	3.25–3.6	4	Whole body length	2	Long: 0.238–0.254; short: 0.099–0.106	5 ventral pairs, 3 lateral pairs	n	Skrjabin & Sobolev (1963)

TABLE 2 (*cont.*)

Species	Bodylength of male (mm)	Number of rows of somatic spines	Length of rows of somatic spines	Number of spicules	Spicule length (mm)	Arrangement of caudal spines or papillae	Polar filaments on eggs	Source
Tetrameres cygni Ryjikov & Kozlov, 1960	n	4	n	2	Left: about one half the length of that of *T. tinamicola*	3 rows of 5 caudal papillae	n	Pence et al. (1975)
Tetrameres dubia Travassos, 1917[b]	1.35–2.28	4/2	Dorsolateral rows reach only the level of the posterior end of the glandular oesophagus	2	Long: 0.71–0.77; short: 0.06–0.08	4 ventral pairs, 3 lateral pairs	Present	Mamaev (1959) cited by Skrjabin & Sobolev (1963)
Tetrameres fermini Vigueras, 1935	2.5	n	n	2	Long: 0.073; short: 0.023	3 pairs of postcloacal spines	n	Skrjabin & Sobolev (1963)
Tetrameres fissispina (Diesing, 1861) Travassos, 1914	3.0–6.0	n	n	2	Left: 0.82–1.5; right: 0.28–0.49	8 pairs of postanal spines	n	Gibbons *et al*. (1996)
	3.2–3.9	4	n	2	Long: 0.37–0.49; short: 0.165–0.198	3 ventral pairs, 5 lateral pairs	n	Skrjabin & Sobolev (1963)
Tetrameres galericulatus Oschmarin, 1956	3.4	4	Whole body length	2	Longer: 0.450; short: 0.086	Present	n	Skrjabin & Sobolev (1963)
Tetrameres gigas Travassos, 1919	7.5	4	Whole body length	2	Long: 0.74; short: 0.016	Tail papillae have not been found	n	Skrjabin & Sobolev (1963)
Tetrameres globosa (Von Linstow, 1879)	3.6–3.75	4	Whole body length, sparser in posterior half	2/1	Long: 0.3; short spicule rudimentary	Small spines posterior to cloaca	n	Skrjabin & Sobolev (1963)
Tetrameres grusi Shumakovitsh, 1946	3.45–4.40	2	2 distinct rows, but spines scattered anterior to nerve ring and posterior to anus	1	0.638–0.783	Several irregular rows of spines	n	Skrjabin & Sobolev (1963); Bush *et al.* (1973); Pence *et al*. (1975)
Tetrameres gubanovi Shigin, 1957	6.67	2	Whole body length, starting at transition from muscular to glandular oesophagus	2	Long: 3.996; short: 0.131	4 ventral pairs of conical papillae, 3 lateral pairs of stalked papillae	n	Skrjabin & Sobolev (1963)
Tetrameres hagenbecki Travassos & Vogelsang, 1930	3.1–3.4	2?	Rows of cuticular spines along lateral fields (2 rows illustrated)		Long spicule: thin and ending as a spur, proximal 0.07–0.08 twisted. Short spicule 0.032–0.04	4 ventral pairs, 2 lateral pairs	n	Skrjabin & Sobolev (1963)
Tetrameres lhuillieri (Seurat, 1918)	n	4	n	1	0.48	n	Present	Ortlepp (1964)

TABLE 2 (*cont.*)

Species	Bodylength of male (mm)	Number of rows of somatic spines	Length of rows of somatic spines	Number of spicules	Spicule length (mm)	Arrangement of caudal spines or papillae	Polar filaments on eggs	Source
Tetrameres lobibycis Mawson, 1968	1.5	4/2	4 rows anteriorly, from nerve ring onwards only 2	1	Left: 0.73	6 subventral pairs	Only male known	Mawson (1968)
Tetrameres megaphasmidiata Cremonte, Digiani, Bala & Navone (2001)	1.94–2.03	4	Whole body length	1	Left: 0.96–1.22	6 subventral pairs, 2 lateral pairs	n	Cremonte *et al.* (2001)
Tetrameres micropenis Travassos, 1915	4.0–5.0	2	Whole body length	2	Long: 0.355; short: 0.056	2 ventral pairs	n	Ortlepp (1932); Skrjabin & Sobolev (1963)
Tetrameres microspinosa Vigueras, 1935	3.0	2	Whole body length	2	Long: 1.135; short: 0.065	5 ventral pairs	Absent	Skrjabin & Sobolev (1963)
Tetrameres mohtedai Bhalerao and Rao, 1944	4.27–5.8	4/2	Submedian spines end posterior to middle of glandular oesophagus	2	Long: 0.397–0.430; short: 0.142–0.160	5 subventral pairs	n	Skrjabin & Sobolev (1963)
Tetrameres nouveli (Seurat, 1914)	1.0–2.4	4	Whole body length	1	Left: 350–580[c]	3 or 4 subventral pairs, 2 or 3 sublateral pairs	Present	Ortlepp (1932); Mawson (1968); Cremonte *et al*. (2001)
	2.16	4	Whole body length	1	0.480; second spicule rudimentary (Seurat 1914, cited by Skrjabin & Sobolev 1963)	4 venral and 3 lateral pairsillustrated;according to text 2 papillae in posterior third of tail	Present	Skrjabin & Sobolev (1963)
Tetrameres numenii Mamaev, 1959	1.64–2.4	4/2	Dorsolateral rows reach only the level of the posterior part of the oesophagus	2	Long: 1.08–1.24; short: 0.08–0.10	4 ventral pairs, 3 lateral pairs	Absent	Skrjabin & Sobolev (1963)
Tetrameres numida n. sp.	4.3–4.4	2	Whole body length	2	Left: 1.699–2.304; right: 0.106–0.131	3 ventral pairs, 3 lateral pairs	Absent	This paper
Tetrameres oxylabiatus Oschmarin, 1956	5.0	n	Whole body length	2	Long: 0.940; short: 0.125	Extend posteriorly to middle of tail, getting very small	n	Skrjabin & Sobolev (1963)
Tetrameres paraaraliensis Oschmarin, 1956	1.71	4	Whole body length	1	0.405–0.420	n	n	Skrjabin & Sobolev (1963); Mawson (1968); Mollhagen (1976) in Cremonte *et al*. (2001)

TABLE 2 (*cont.*)

Species	Bodylength of male (mm)	Number of rows of somatic spines	Length of rows of somatic spines	Number of spicules	Spicule length (mm)	Arrangement of caudal spines or papillae	Polar filaments on eggs	Source
Tetrameres paradisea Ortlepp, 1932	5.8	2	Whole body length	1	Left: 0.69[d]	3 ventral pairs, 3 dorso-external pairs	Absent	Ortlepp (1932)
Tetrameres paradoxa (Diesing, 1835)	12–15	2	n	2	Long: 3.0 or longer ; short: 0.480	Drashe (1884) illustrated a very small pair of ventral papillae and 3 and 4 lateral papillae respectively	n	Skrjabin & Sobolev (1963), Drashe (1884) cited by Skrjabin & Sobolev (1963)
Tetrameres pattersoni Cram, 1933	4.2–4.6	2	Whole body length	1	1.2–1.5	n	n	Skrjabin & Sobolev (1963)
Tetrameres paucispina Sandground, 1928	n	2	Few, only in posterior 2/3	2	Left: 0.328–0.371; right:0.012–0.154[e]	3 caudal papillae	n	Bush *et al.* (1973); Quentin & Barre (1976)
	3.1–4.5	1	1 row in median ventral field, not more than 25 spines, only in post 2/3	2	Long: 0.328–0.371; short: 0.154	3 caudal papillae	n	Skrjabin & Sobolev (1963)
Tetrameres pavlovskii Iygis, 1965	n	4	n	1	n	4 ventral pairs, 4 lateral pairs	n	Pence *et al.* (1975)
Tetrameres pavonis Tschertkova, 1953	4.7	n	Irregular and dense anteriorly, in middle and posterior part almost invisible	2	Long: 0.43; short: 0.105	4 rows of spines, and 3 papillae: 1 lateral pair, 1 unpair median papilla	n	Skrjabin & Sobolev (1963)
Tetrameres phaenicopterus Ali, 1970	n	4	n	2	n	n	n	Pence *et al.* (1975)
Tetrameres plectropteri Thwaite, 1926	n	n	n	n	Left: 0.85	n	n	Ortlepp (1964)
Tetrameres prozeskyi (Ortlepp, 1964)	1.3–2.4	4	Whole body length	1	Left: 0.23–0.26[f]	3 ventral pairs, 3 lateral pairs[g]	n	Ortlepp (1964)
Tetrameres puchovi Gushanskaja, 1949	3.86–4.339	2	Whole body length	1	0.307–0.309; second spicule rudimentary: 0.008	n	n	Skrjabin & Sobolev (1963)
Tetramers ryjikovi Chuan, 1961	4.5	4	Whole body length	2	Long: 0.208; short: 0.062	4 ventral pairs, 3 lateral pairs	n	Skrjabin & Sobolev (1963)
Tetrameres sakharowi Petrow, 1926	9.47	4	n	2	Left: 0.195; right: 1.021	n	n	Skrjabin & Sobolev (1963)

TABLE 2 (*cont.*)

Species	Bodylength of male (mm)	Number of rows of somatic spines	Length of rows of somatic spines	Number of spicules	Spicule length (mm)	Arrangement of caudal spines or papillae	Polar filaments on eggs	Source
Tetrameres scolopacidis Mawson, 1968	1.06–1.8	4/2	4 rows anteriorly, from end of oesophagus only 2 rows	2	Left:0.70–0.85; right: 0.07–0.105	4 subventral pairs, 3 sublateral pairs	Present	Mawson (1968)
Tetrameres somateriae Ryjikov, 1963	4.8	4	No spines in the middle part of the body	2	Long: 0.576; short: 0.086	5 ventral pairs, 4 lateral pairs	n	Skrjabin & Sobolev (1963)
Tetrameres spirospiculum Pinto & Vincente, 1995	2.52–4.06	n	Thinly dispersed and poorly developed	2	Left: 0.82–1.08; right: n	n	n	Pinto & Vicente (1995)
Tetrameres skrjabini Panowa, 1926	2.6	4	Whole body length	2	Long: 1.543; short: 0.103	Not found	n	Skrjabin & Sobolev (1963)
Tetrameres tetrica Travassos, 1917	2.6	4	Dissapear near last quarter of body length	2	Long: 0.2; short: 0.022	4 lateral pairs, 4 sublateral pairs	n	Skrjabin & Sobolev (1963)
Tetrameres timopheewoi Travassos, 1950	4.7	n	Whole body length	2	Long: 0.421; short: 0.189	n	n	Skrjabin & Sobolev (1963)
Tetrameres tinamicola Pence, Mollhagen & Prestwood, 1975	6.52	4	Ventral rows whole body length, dorsal rows end 1.02 mm from apex	2	Left: 2.26; right: 0.207	5 subventral pairs, 3 ventro-lateral pairs	Absent	Pence *et al.* (1975)
Tetrameres uxorius Mamaev, 1959	n	4	n	2	Left: 2.1–2.3[h]; right: 0.088	4 ventrolateral pairs, 2 subdorsal pairs	Absent	Mamaev (1959); Pence *et al.*(1975)
	4.76–5.0	4/2	Dorsolateral rows reach only the beginning of the glandular oesophagus	2	Long: 2.1–2.24; short: 0.086–0.088	4 ventrolateral pairs, 2 subdorsal pairs	Absent	Skrjabin & Sobolev (1963)
Tetrameres vietnamensis Fan the Viet, 1968	n	4	n	2	Left: 1.28; right: 0.148	5 ventral pairs (lateral absent)	n	Fan the Viet (1968) in Helminthological Abstracts (1970), Pence *et al.* (1975)

n No information at our disposal

[a] The original reads 65-350 µm. We consider this a typing error and include the range of single measurements provided by Quentin & Barre (1976)

[b] Skrjabin & Sobolev (1963) also include a description after Cram (1927), which differs slightly from that of Mamaev (1959)

[c] Cremonte *et al*. (2001) give a range of 0.312–0.587 mm

[d] Cremonte *et al*. (2001) quote Mollhagen (1976) giving a range of 0.504–0.626 mm

[e] The length provided by Quentin & Barre (1976) is 12–154 µm. We consider this an error. Skrjabin & Sobolev give the width of the right spicule as 12 µm

[f] According to Ortlepp (1964) in three of about 30 males a right spicule was present

[g] Cremonte *et al*. (2001) quote Mollhagen (1976) as *T. prozeskyi* having varying caudal papillae (3/0, 3/3, 4/1, 4/2)

[h] Calculated from a 1:24 to 1:26 ratio between right and left spicule

DISCUSSION

Some of the main morphological characteristics of many of the species belonging to the genus *Tetrameres* are listed in Table 2.

Of the *Tetrameres* species with two rows of cuticular spines, *Tetrameres pattersoni* Cram, 1933, *T. paradisea* and *Tetrameres grusi* Shumakovitsh, 1946 have only one spicule and the spicule measurements of the latter two species differ distinctly from those in our specimens (Ortlepp 1932; Schmidt 1962; Bush, Pence & Forrester 1973).

Tetrameres gubanovi Shigin, 1957 bears two rows of body spines, but has seven pairs of caudal papillae (Pence *et al*. 1975), as opposed to six pairs of caudal spines in *T. numida* n. sp.

The use of the term caudal spines or caudal papillae is not always clear. Pence *et al*. (1975) use the term caudal papillae for several species in their publication. They list *T. paradisea* as well as *T. prozeskyi* as having caudal papillae, but in the original descriptions Ortlepp (1932, 1964) clearly refers to cuticular spines. Thus, Pence *et al*. (1975) seem to use the term indiscriminately. Mawson (1968), however, describes *T. nouveli* as having caudal spines, but points out that in *Tetrameres lobibycis* Mawson, 1968 the spines are more like elongate papillae, and refers to *Tetrameres calidris* Mawson, 1968 and *Tetrameres scolopacidis* Mawson, 1968 as having papillae.

The left spicules of *Tetrameres cardinalis* Quentin & Barre, 1976 and *Tetrameres paucispina* Sandground, 1928 are much shorter than those measured in our specimens (Quentin & Barre 1976). *Tetrameres micropenis* Travassos, 1915 has been recovered from ciconiiform hosts, *Nyctanassa violacea* (Linnaeus, 1758) and *Cochlearius cochlearia* (Linnaeus, 1766) (Yamaguti 1961), whose geographic distribution is restricted to North and South America (Lepage 2006).

Tetrameres fissispina has been recorded from guineafowls in Africa (Fabiyi 1972; Vercruysse *et al.* 1985) and, like *T. americana*, has a high prevalence in domestic chickens, whose nematode fauna is similar to that of guineafowls (Mukaratirwa, Hove, Esmann, Hoj, Permin & Nansen 2001; Magwisha, Kassuku, Kyvsgaard & Permin 2002). *Tetrameres fissispina* distinguishes itself from the new species by its shorter spicules and the larger number of caudal spines. *Tetrameres americana* differs not only in the spicule size and the number and arrangement of caudal spines, but also in its four rows of somatic spines (Schmidt 1962; Gibbons, Jones & Khalil 1996).

The head of the female and the apical view of the head of the male of *T. numida* n. sp. most closely resemble *Tetrameres tinamicola* Pence, Mollhagen & Prestwood, 1975. The authors of the latter species describe the male head as possessing a triangular mouth surrounded by a pair of trilobed structures originating from the inner surface of the pseudolabia. Each lobe bears a pair of tooth-like processes in *T. tinamicola.* Similar processes can be seen in our specimens, but it is difficult to determine their exact number. However, there seem to be three or four per lobe. Pronounced lateral alae, as illustrated by Pence *et al.* (1975), were not found in our specimens. Moreover, *T. tinamicola* has a total of four rows of cuticular spines and the deirids are without apical spines. While the length of the left spicule of both species is similar, the right spicule of *T. numida* is only approximately half the length of *T. tinamicola*.

Ortlepp (1932) described the buccal capsule of *T. paradisea* as having trilobed structures showing two to three bright refringent markings towards its posterior border. This, as well as other features of our specimens such as the transverse grooves anterior to the cloaca and the size of the spines, appeared so similar to *T. paradisea* that we initially considered assigning them to *T. paradisea*, especially in view of the fact that both were recovered from South African hosts. Close examination has nevertheless revealed distinct differences between the two. *Tetrameres paradisea* possesses a single spicule, whereas in our males two spicules are consistently present. While the arrangement of caudal spines is nearly identical and both carry three pairs of ventral and three pairs of externo-dorsal or lateral spines, the tail of *T. paradisea* is considerably shorter than that of our specimens (see Table 1).

Ortlepp (1932) described and illustrated two rows of body spines found in *T. paradisea* and he uses this criterion to distinguish his species from *Tetrameres nouveli* which he lists as possessing four rows of spines. Cremonte, Digiani, Bala & Navone (2001) record *T. paradisea* as having four rows of spines, but cite Mollhagen (1976) as describing the dorsal rows of spines as very short, ending at 94–155 from the anterior end.

When comparing *T. paradisea* to *T. prozeskyi*, Ortlepp (1964) lists the length of the left spicule of the former species as 0.48 mm, but his original description of *T. paradisea* (Ortlepp, 1932) clearly states the length of the spicule as 0.69 mm. We list *T. pro-*

zeskyi as monospicular, which differentiates it from our bispicular specimens. As regards *T. prozeskyi* it should be borne in mind that Ortlepp (1964) found a well-chitinized right spicule in three of the more than 30 males he examined.

In the summary of the description of *Tetrameres cardinalis* Quentin & Barre, 1976, the range of the length of the right spicule is given as 65–350 µm (Quentin & Barre 1976). As this seems erroneous, we decided to include the range provided in the same paper, namely 365–400, in Table 2. Similarly, we consider the first measurement these authors provide for the short spicule of *T. paucispina* as incorrect and believe it should read 120 instead of 12.

Apart from *T. numida* n. sp., only *T. tinamicola* and *Tetrameres uxorius* Mamaev, 1959 have a left spicule that reaches 2 mm in length, while in the remaining *Tetrameres* spp. the long spicule usually does not exceed 1 mm (Mamaev 1959; Pence *et al*. 1975). Relative to body length, however, there are other species with long spicules, such as *T. lobibycis* where the single spicule reaches about half of the body length (1.5 mm) and *T. scolopacidis* where the spicule length reaches almost two thirds of the body length (1.06–1.8 mm) (Mawson 1968).

To our knowledge, *Tetrameres phaenicopterus* Ali, 1970 is the only member of the genus *Tetrameres* possessing a gubernaculum (Pence *et al.* 1975) and *Tetrameres greeni* Mawson, 1979 is unique in the genus *Tetrameres* in that it has caudal alae (Mawson 1979). *Tetrameres spirospiculum* Pinto & Vicente, 1995 is distinguished from our specimens and all the other species of *Tetrameres* by the spiral shaped distal end of the longer of its two spicules (Pinto & Vicente 1995).

The numbers of *T. numida* n. sp. recovered from the guineafowl hosts from Musina (Messina) were low, and the parasite was only found in the older birds, being absent in young adults. While it is possible that guineafowls are not the main host for this parasite, we attribute the low intensity of infection to the fact that the area had been experiencing a severe drought during the past years. This would decrease the survival rates of nematode eggs while at the same time causing the numbers of possible intermediate hosts necessary for the completion of the life-cycle to decline. While differences in the immune status between guineafowls of different age might play a role in the intensity of infection, we believe that the presence of *T. numida* n. sp. in older hosts simply reflects the increased possibility of prior exposure to the parasite as a function of time.

ACKNOWLEDGEMENTS

The authors are indebted to Dr S. Sokolov of the Institute of Parasitology, Russian Academy of Science, Moscow, for obtaining the extensive chapter on the genus *Tetrameres* in “Principles of nematodology XI” (Skrjabin & Sobolev 1963) and to Dr D.A. Apanaskevich, Georgia Southern University, for the translation from the original Russian into English. The authors thank Mr K. Meyer and Mr M. Storm, the previous and current owners of the farm Sandown, Musina (Messina), respectively, for placing the guineafowls at our disposal and Mr H.E. Hattingh, University of Limpopo, for collecting them. Dr W.J. Luus-Powell, University of Limpopo, has kindly facilitated the co-operation. Ms D.T. Durand, University of Pretoria, photographed the three complete females of *T. numida*. This research was made possible through a Claude Leon Foundation Postdoctoral Fellowship grant to the first author.

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Journal of Helminthology (2008) **82,** 365–371 doi:10.1017/S0022149X08054126

Nematodes from Swainson's spurfowl *Pternistis swainsonii* and an Orange River francolin *Scleroptila levaillantoides* in Free State Province, South Africa, with a description of *Tetrameres swainsonii* n. sp. (Nematoda: Tetrameridae)

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Abstract

Five Swainson's spurfowl collected in Free State Province, South Africa, were examined for helminth parasites, and the nematodes *Acuaria gruveli*, *Cyrnea parroti*, *Gongylonema congolense*, *Subulura dentigera*, *Subulura suctoria* and a new *Tetrameres* species were recovered. Their respective prevalence was 100, 20, 80, 20, 20 and 20%. These nematodes are all new parasite records for Swainson's spurfowl, and *Acuaria gruveli* constitutes a new geographical record as well. A single specimen of *Cyrnea eurycerca* was found in an Orange River francolin, representing a new host and geographical record for this parasite. The new species, for which the name *Tetrameres swainsonii* is proposed, can be differentiated from its congeners by a combination of the following characters of males: two rows of body spines, a single spicule which is 1152–1392 μm long, and eight pairs of caudal spines arranged in two ventral and two lateral rows of four spines each. The single female has the globular shape typical of the genus.

Introduction

Swainson's spurfowl *Pternistis swainsonii* (Smith, 1836) (Phasianidae: spurfowls) is endemic to southern Africa. In South Africa it has undergone a major southward range expansion and can now be found east of approximately 23°E and south as far as 30°S in the Eastern Cape, Free State, Gauteng, Limpopo, Mpumalanga, Northern Cape and North West Provinces. It is absent from the coastal lowlands of KwaZulu-Natal Province (Little, 2005). Its preferred habitat in South Africa is dense grassland in proximity to cultivated lands, where it exploits crops and associated insects. While some authors refer to Swainson's spurfowl as one of the most water-dependent perdicine birds in Africa (del Hoyo *et al.*, 1994; Little, 2005), a study in Limpopo Province, South Africa, revealed no or little reliance on easily accessible drinking water and birds seldom drank (Jansen & Crowe, 2002).

The Orange River francolin *Scleroptila levaillantoides* (Smith, 1836) (Phasianidae: francolins) is found in two distinct geographical areas on the African continent

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(del Hoyo *et al.*, 1994). While it is a frequent to common bird in Ethiopia and Somalia, numbers appear to have declined in its southern population, especially in South Africa and Namibia. This is thought to be mainly due to habitat pressure following the conversion of natural grass- and woodland habitats into farmland, despite the fact that, like Swainson's spurfowl, it will forage at the edges of cultivated land (Little *et al.*, 2000). The natural range of Orange River francolin in South Africa used to be restricted to north-western Northern Cape Province (del Hoyo *et al.*, 1994), but it has expanded to include north-eastern Eastern Cape Province, and Free State and North West Provinces, as well as the region east of the highveld of Mpumalanga and Gauteng Provinces (Little *et al.*, 2000; Little, 2005).

Only incidental findings on helminth parasites of both these gamebirds in South Africa have been published. Oosthuizen & Markus (1967) collected *Subulura* sp. from a single Swainson's spurfowl, while the only record pertaining to helminths of *S. levaillantoides* is that of Bennett *et al.* (1992) who reported *Microfilaria* sp. when cataloguing haematozoa of sub-Saharan birds.

This paper reports on helminths collected from the gastrointestinal tract (GIT) of five Swainson's spurfowl and a single Orange River francolin in Free State Province, South Africa and describes a new nematode, *Tetrameres swainsonii*, from the proventriculus of the former.

Materials and methods

Five Swainson's spurfowl, a single second-year male and four adult females (at least third-year), and a single adult male Orange River francolin were collected during a gamebird hunt in the vicinity of Petrus Steyn (27°39′S; 28°8′E), Free State Province, in August 2007. The habitat in the survey area was made up primarily of cereal plantings (maize) and sunflower, in a mosaic of grazing land.

Within 4 hours of being shot, the entire GIT was removed from the birds and placed in a plastic tray. The crop was ligated at the entrance of the oesophagus and the entrance to the proventriculus. The proventriculus was separated from the gizzard, and the small intestine was separated from the gizzard and caeca. The GITs of the various birds were placed in individual containers, stored at 2°C overnight and then fixed in 70% ethanol.

Subsequently, the crop, proventriculus, gizzard, small intestine and caeca were washed separately over a 150 µm sieve and, together with the residue, examined under a stereoscopic microscope. Helminths in the gizzard usually only became visible after removal of the lining.

All helminths were stored in 70% ethanol. For identification purposes, nematodes were cleared in lactophenol and studied under a standard microscope. Intensity of infection, mean intensity of infection, mean abundance and prevalence are used in accordance with Margolis *et al.* (1982).

Results

All five Swainson's spurfowl harboured nematodes and a total of six species, *Acuaria gruveli* (Gendre, 1913), *Cyrnea parroti* Seurat, 1917, *Gongylonema congolense* Fain, 1955, *Subulura dentigera* Ortlepp, 1937, *S. suctoria* (Molin, 1860) and *T. swainsonii* n. sp., was recovered. Their habitat, prevalence, mean intensity of infection and mean abundance are listed in table 1. A single host harboured a total of four species, a second three, and three birds had two nematode species each. The mean species richness was 2.6 (SD = 0.9). The intensity of infection ranged from 3 to 68, with a mean intensity of 19 (SD = 27.7). The second-year male had the highest species diversity as well as highest intensity of infection.

Two nematode species were recovered from both the gizzard and caeca, and a single nematode species from the proventriculus and crop, respectively. No helminths were found in the small intestine.

With the exception of a single *C. eurycerca* Seurat, 1914 in its gizzard, the Orange River francolin harboured no helminth parasites.

The presence of *A. gruveli* in Swainson's spurfowl constitutes both a new host record and a new geographical record for this parasite, while *C. parroti*, *G. congolense* and *S. suctoria* are new parasite records for this host. This is the first report of *S. dentigera* from a host other than helmeted guineafowl *Numida meleagris* (Linnaeus, 1758) (Phasianidae: guineafowls). *Cyrnea eurycerca* is recorded from Orange River francolin as well as from South Africa for the first time.

Tetrameres swainsonii n. sp

Description. *Tetrameres swainsonii* is described from four males and one female from a single Swainson's spurfowl. Males were found free in the lumen of the proventriculus, while the female was dissected from the proventricular glands. All measurements are in micrometres unless otherwise stated (fig. 1).

Female. Bright red *in situ* as typical for the genus, damaged; only buccal capsule, 24 deep and 16 wide, maximum body width (3 mm) and length (4 mm) as

Table 1. Nematodes recovered from five Swainson's spurfowl *Pternistis swainsonii* in Free State Province, South Africa.

Nematode	Habitat	Prevalence (%)	Mean intensity (± SD)	Range	Mean abundance (± SD)
Acuaria gruveli	Gizzard	100	2.4 (0.9)	1–3	2.4 (0.8)
Cyrnea parroti	Gizzard	20	2.0	2	0.4 (0.8)
Gongylonema congolense	Crop	80	4.25 (5.9)	1–13	3.4 (4.8)
Subulura dentigera	Caeca	20	12.0	12	2.4 (4.8)
Subulura suctoria	Caeca	20	47.0	47	9.4 (18.8)
Tetrameres swainsonii n. sp.	Proventriculus	20	5.0	5	1.0 (2.0)

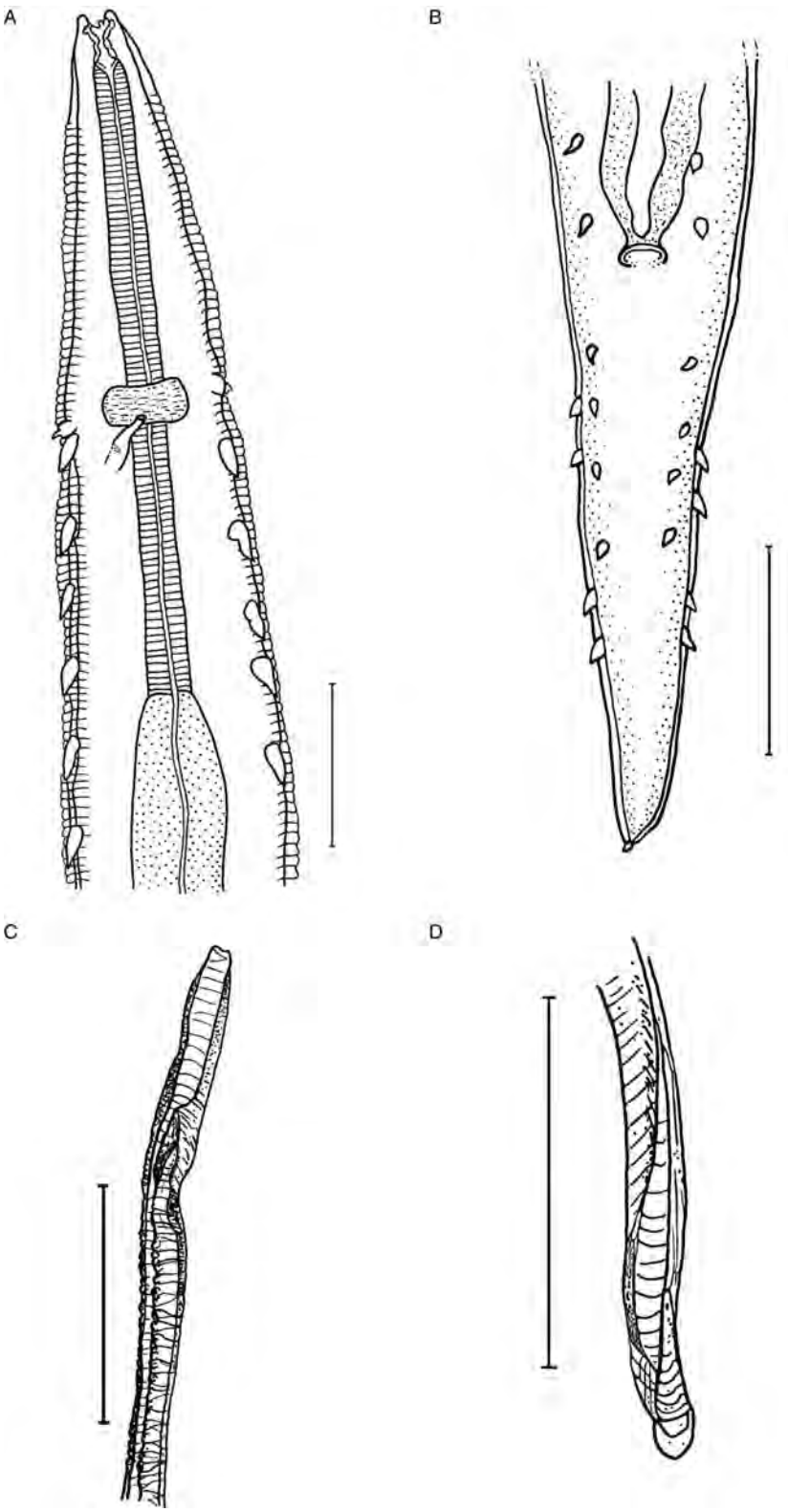

Fig. 1. *Tetrameres swainsonii* n. sp. male. (A) Ventral view of anterior extremity illustrating the position of the deirids, nerve ring, excretory pore and first pair of body spines. (B) Ventral view of posterior extremity showing the arrangement of the caudal spines. (C) Proximal end of the single spicule, lateral view. (D) Distal end of the spicule, lateral view. Scale bars = 100 μm.

well as egg length and width could be measured. Eggs ($n = 10$), length 49 (SD = 2.98), between 43 and 52, width 32 (SD = 1.47), between 30 and 34; polar filaments not seen. Body globular with anterior and posterior extremities forming short protuberances; surface divided into four segments by four conspicuous longitudinal cuticular grooves; each segment with numerous transverse striations.

Male. Measurements of holotype male given in text, those of two paratypes and a further specimen in table 2. Body elongated, tapered at both ends, 5.1 mm long and 188 wide. Cuticle striated transversely as well as longitudinally. Cuticular spines arranged in two lateral rows, one dorsal and one ventral to inconspicuous lateral alae; 41 spines per row in holotype, 40 to 43 in paratypes; first pair of spines at 269 and 285 from anterior extremity. Deirids with apical spines at 261 and 251 from anterior extremity. Nerve ring and excretory pore at 252 and 265 from apex, respectively. Deirids at approximately centre of nerve ring with first pair of cuticular spines in close proximity, but posterior to deirids. Excretory pore in same vicinity, sometimes slightly anterior, slightly posterior or on same level as first pair of cuticular spines (fig. 1A). Depth of buccal capsule 19, inner diameter 6. Oesophagus divided into muscular and glandular parts, 412 and 914, respectively; total length of oesophagus 1326. Single spicule, slender, 1384 long, trough-shaped with spatulate, almost square tip (fig. 1D); proximal tip slightly angled away from longitudinal axis (fig. 1C). Gubernaculum absent. Tail 330 long, with short pointed tip. Eight pairs of caudal spines arranged in two ventral and two lateral rows, containing four spines each (fig. 1B).

Specific diagnosis. *Tetrameres swainsonii* n. sp. is characterized by two rows of body spines, starting just posterior to the deirids situated at the level of the nerve ring. The single spicule is 1152 to 1392 long, and 16 caudal spines are arranged in two ventral and two lateral rows, each bearing four spines.

Host. Swainson's spurfowl *Pternistis swainsonii* (Smith, 1836).

Habitat. Males occur free in the lumen of the proventriculus, females are sedentary in proventricular glands.

Locality. Vicinity of Petrus Steyn (27°39′S; 28°8′E), Free State Province, South Africa.

Etymology. The specific epithet *swainsonii* refers to the host.

Deposition of type specimens. Holotype male: 2008.6.20.1, allotype female, paratype males: 2008.6. 20.2–5.

Taxonomy of Tetrameres

To date three species belonging to the genus *Tetrameres* have been described from avian hosts in South Africa, *Tetrameres paradisea* Ortlepp, 1932 from Stanley's crane *Anthropoides paradiseus* (Lichtenstein, 1793) (Gruidae: cranes), *Tetrameres prozeskyi* (Ortlepp, 1964) from red-billed and southern yellow-billed hornbills *Tockus erythrorhynchus* (Temminck, 1823) (Bucerotidae: typical hornbills) and *Tockus leucomelas* (Lichtenstein, 1842) (Bucerotidae: typical hornbills), respectively, and *Tetrameres numida* Junker & Boomker, 2007 from helmeted guineafowl. *Tetrameres paradisea* is similar to the new taxon in that it has two rows of cuticular spines and possesses a single spicule. However, Ortlepp (1932) illustrates three cuticular spines anterior to the deirids, with the latter placed well anterior to the nerve ring, whereas in the present specimens, the first pair of cuticular spines only appears posterior to the deirids, and both the first pair of cuticular spines and the deirids are in the immediate vicinity of the nerve ring. Moreover, the spicule length of *T. paradisea* only reaches 690 as opposed to a minimum length of 1152 in the present specimens.

In *T. prozeskyi* a single spicule measuring 230–260 is usually present and in those instances where a second spicule was found, it was shorter than the first (Ortlepp, 1964). A further distinguishing feature between *T. prozeskyi* and *T. swainsonii* n. sp. is the presence of four rows of cuticular spines in the former (Ortlepp, 1964) versus two rows in the latter. Only 12 caudal spines were reported for *T. prozeskyi* as well as for *T. paradisea* (Ortlepp, 1932, 1964) as opposed to the 16 caudal spines seen in the new taxon.

Like *T. swainsonii* n. sp., *T. numida* is characterized by two rows of cuticular spines, but the arrangement of the first pair of spines, the deirids and the nerve ring is

Table 2. Morphological characteristics of *Tetrameres swainsonii* n. sp. males from Swainson's spurfowl *Pternistis swainsonii*. All measurements in micrometres unless otherwise indicated.

Morphological criteria	Specimen A	Paratype 1	Paratype 2
Body length (mm)	4.7	4.8	5.1
Body width max.	203	200	216
Distance from apex to first pair of somatic spines	276; 260	250; 272	340; 340
Distance from apex to nerve ring	244	245	263
Distance from apex to deirids	243; 235	237; 242	268; 286
Distance from apex to excretory pore	282	275	310
Depth of buccal capsule	21	23	23
Width of buccal capsule (inner)	5	6	5
Muscular oesophagus	368	418	428
Glandular oesophagus	1005	914	1031
Oesophagus total length	1377	1285	1451
Length of tail	291	306	309
Length of single spicule	1152	1392	1183

distinctly different from that seen in the present specimens (Junker & Boomker, 2007a). The first pair of cuticular spines of *T. numida* is situated anterior to the deirids, which are approximately at the level of the second pair of cuticular spines, and the nerve ring is distinctly posterior to the deirids. Only 12 caudal spines are described for *T. numida* and, although additional ventral spines may occasionally be present, the two lateral rows consistently carried three spines each. In addition, *T. numida* possesses a right and a left spicule, ranging from 106 to 170 and from 1699 to 2304, respectively (Junker & Boomker, 2007a).

Of the 54 species of *Tetrameres* listed by Junker & Boomker (2007a), only *T. paradisea*, *Tetrameres grusi* Shumakovitsh, 1946, *Tetrameres pattersoni* Cram, 1933 and *Tetrameres puchovi* Gushanskaja, 1949 share the combination of two rows of cuticular spines and a single spicule with the present specimens. However, the spicules of *T. grusi* (638–783) and of *T. puchovi* (307–309) (Skrjabin & Sobolev, 1963) are distinctly shorter than those of *T. swainsonii* n. sp. (1152–1392). Moreover, the caudal spines of *T. grusi* are arranged in several irregular rows, and several pairs of cuticular spines originate anterior to the nerve ring (Skrjabin & Sobolev, 1963), whereas in *T. swainsonii* n. sp. the first pair of cuticular spines emerges posterior to the nerve ring. The distance from the apex to the deirids is 160 in *T. puchovi* (Skrjabin & Sobolev, 1963), which is considerably shorter than that observed in the new taxon, namely 235–286.

Tetrameres pattersoni is closest to *T. swainsonii* n. sp. in spicule length, with a single, strongly chitinized spicule of length 1200–1500; but it differs in the arrangement of caudal spines in three lateral and four subventral pairs, as opposed to four pairs each in the new taxon. The distance of the deirids from the apex, which is less than half that seen in *T. swainsonii* n. sp., namely 83–112 (Skrjabin & Sobolev, 1963), clearly separates *T. pattersoni* from *T. swainsonii* n. sp.

Discussion

The single second-year male Swainson's spurfowl yielded the largest number of helminth species as well as individuals. Phasianid chicks are reported to rely heavily on insect food in the early stages of their lives (del Hoyo *et al.*, 1994). Chicks of grey partridge *Perdix perdix* Linnaeus, 1758 (Phasianidae: partridges) in Europe, for example, consume a diet consisting of 80% insect matter for the first 2 weeks after hatching (del Hoyo *et al.*, 1994). Arthropods only make up approximately 7% of the crop weight of adult *P. swainsonii*, reaching a maximum of up to 20% in summer (del Hoyo *et al.*, 1994). Higher intake of live food by juvenile versus adult birds is likely to increase exposure to infected intermediate hosts, which, in turn, would result in higher worm burdens. However, because of the small sample size it is not possible to establish whether our findings are due to chance or reflect a true pattern in the helminth community of Swainson's spurfowl.

Only nematodes were collected from Swainson's spurfowl and the single Orange River francolin. This is noteworthy, especially taking into account that all nematodes collected from these two hosts are heteroxenous; that is, their life cycles include various arthropod intermediate hosts, such as orthopterans and coleopterans (Anderson, 1992), which in addition serve as intermediate hosts for cestodes and acanthocephalans (Moore, 1962; Reid, 1962). Moreover, helmeted guineafowl collected at the same locality during the course of this study harboured nematodes and cestodes as well as acanthocephalans (Davies *et al.*, in review), thereby confirming their presence in the environment.

While Swainson's spurfowl had a markedly less diverse helminth fauna than helmeted guineafowl at the study site, the former seem to be more suitable hosts of the gizzard nematode *A. gruveli*, since it was collected from all five spurfowl, but was absent in more than 40 helmeted guineafowl (Davies *et al.*, in review). Other galliform birds recorded as final hosts of *A. gruveli* include double-spurred spurfowl *Pternistis bicalcaratus* (Linnaeus, 1766) (= *Francolinus bicalcaratus*) (Phasianidae: spurfowls) in Togo (Quentin & Seureau, 1983), common quail *Coturnix coturnix* (Linnaeus, 1758) (Phasianidae: quails) in the Palearctic region (Baruš & Sonin, 1983) and red-legged partridge *Alectoris rufa* (Linnaeus, 1758) (Phasianidae: partridges) in Spain (Tarazona *et al.*, 1979), suggesting that perdicine birds feature more prominently in the life cycle of this parasite than do guineafowls.

A possible explanation for the presence/absence of helminths in Swainson's spurfowl versus helmeted guineafowl at the same locality might be a difference in their dietary preferences, which in turn would influence the probability of exposure to intermediate hosts of certain parasites. Moreover, differences in the immune competence of the two bird species might result in a higher resistance in guineafowl. Similarly, morphological differences between hosts, such as the nature of the gizzard lining, could prevent establishment of, for example, *A. gruveli* in guineafowl, but allow colonization of spurfowl.

Cyrnea parroti, *G. congolense* and *S. suctoria* collected from Swainson's spurfowl are also commonly found in other galliform birds (Junker & Boomker, 2007b). Contrary to this, *S. dentigera* had hitherto been recorded from helmeted guineafowl only.

Cyrnea eurycerca, which was present in the single Orange River francolin, seems a relatively common parasite in francolins and spurfowls, and has previously been collected from black francolin *Francolinus francolinus* (Linnaeus, 1766) (Phasianidae: francolins) in Italy, grey francolin *Francolinus pondicerianus* (Gmelin, 1789) (Phasianidae: francolins) in India and double-spurred spurfowl in Togo (Marconcini & Triantafillu, 1970; Jehan, 1974; Seureau & Quentin, 1983).

The low prevalence and intensity of infection of *T. swainsonii* n. sp. in Swainson's spurfowl is in keeping with data obtained for *T. numida* from helmeted guineafowls in Limpopo Province, as well as in the present study area (Junker & Boomker, 2007a; Davies *et al.*, in review). Similarly, only two of 158 bobwhite quail *Colinus virginianus* (Linnaeus, 1758) (Phasianidae: quails) examined in northern Florida harboured *T. pattersoni*, and intensity of infection ranged from 0 to 1 (Moore & Simberloff, 1990).

The overall low helminth diversity and intensity of infection seen in Swainson's spurfowl at the study site might be attributable to several factors. First, they occur in pairs or small family groups rather than in large flocks (Little, 2005; Jansen & Crowe, 2006), which would facilitate parasite transmission (Moore *et al.*, 1988). Jansen & Crowe (2002) reported a covey size ranging from 1 to 4. Second, the birds were collected in winter, when the volume of their diet consists mainly of grass seeds, weed seeds and agricultural seeds, while invertebrates play a minor role (Jansen & Crowe, 2006). In terms of crop volume, 5.74% is made up of invertebrates during the summer months and 3.64% during the winter months (Jansen & Crowe, 2006). Third, much of their habitat consisted of cultivated lands, the insect fauna of which might be depauperate because of low habitat diversity and the use of pesticides. In addition, while Swainson's spurfowl from a cereal-crop habitat, similar to that found in the current study area, ingested the greatest number and volume of invertebrates, when compared to savanna and a cotton habitat, more than 90% of the total number of invertebrates consumed consisted of lepidopteran larvae (Jansen & Crowe, 2006). The latter, however, have not been reported as intermediate hosts for nematode species recovered from Swainson's spurfowl and would thus have no influence on helminth diversity or intensity of infection in these birds.

Acknowledgements

We thank Mr J.P. Wales for access to 'The Jimmy Wales Shoot' for collection of gastrointestinal tracts. The research was supported financially by the Centre of Excellence in Birds at the Percy FitzPatrick Institute (funded by the South African Department of Science and Technology and the National Research Foundation), the University of Cape Town's Research Committee, and the Department of Veterinary Tropical Diseases, University of Pretoria. K.J. was supported by a University of Pretoria Postdoctoral Fellowship Grant.

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(Accepted 30 June 2008)
First Published Online 28 August 2008

CHAPTER 2

Population dynamics

of

parasites of guineafowls

Onderstepoort Journal of Veterinary Research, 74:265–280 (2007)

Helminths of guineafowls in Limpopo Province, South Africa

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ABSTRACT

JUNKER, K. & BOOMKER, J. 2007. Helminths of guineafowls in Limpopo Province, South Africa. *Onderstepoort Journal of Veterinary Research*, 74:265–280

Between July 2005 and November 2006 the gastro-intestinal helminths of 15 Helmeted guineafowls and a single Crested guineafowl from Musina, Limpopo Province were examined, and in July and August 2005 helminths were collected from five Helmeted guineafowls from Mokopane in the same province. The acanthocephalan *Mediorhynchus gallinarum*, the cestodes *Abuladzugnia gutterae*, *Davainea nana*, *Hispaniolepis multiuncinata*, *Hymenolepis cantaniana*, *Numidella numida*, *Octopetalum numida*, *Porogynia paronai*, *Raillietina angusta*, *Raillietina pintneri*, *Raillietina steinhardti* and *Raillietina* sp. and the nematodes *Ascaridia numidae*, *Cyrnea parroti*, *Gongylonema congolense*, *Hadjelia truncata*, *Sicarius caudatus*, *Subulura dentigera*, *Subulura suctoria*, *Subulura* sp., *Tetrameres numida* and an unidentified subulurid were recovered. A single trematode species, *Dicrocoelium macrostomum*, was present in the liver. *Mediorhynchus gallinarum*, *A. gutterae*, *H. multiuncinata*, *H. truncata* and *S. caudatus* are recorded for the first time from Helmeted guineafowls, as well as from South Africa. South Africa is a new geographic record for *D. macrostomum*, *G. congolense* and *D. nana*. *Subulura suctoria*, *G. congolense* and *H. truncata* from the Crested guineafowl constitute new host-parasite associations.

Keywords: Acanthocephalans, cestodes, guineafowls, *Guttera edouardi*, nematodes, *Numida meleagris*, trematodes

INTRODUCTION

Helmeted guineafowls, *Numida meleagris* (Linnaeus, 1758), are distributed throughout most of South Africa and almost the entire African continent (Del Hoyo, Elliot & Sargatal 1994). Studies to elucidate the helminth fauna of these hosts in South Africa have been undertaken by Saayman (1966), Crowe (1977) and Verster & Ptasinska-Kloryga (1987), but were restricted to the Eastern Cape, the Northern Cape and Gauteng Provinces.

Although relatively wide-spread in Africa, Crested guineafowls, *Guttera edouardi* (Hartlaub, 1867), are scarce and have a limited distribution within South Africa. They occur in the Limpopo, North West, Mpumalanga and KwaZulu-Natal Provinces and are listed as rare or accidental in Gauteng Province (Hockey, Dean & Ryan 2005; Lepage 2007). To date our knowledge concerning their helminth fauna is virtually non-existent.

Ortlepp (1937, 1938a,b, 1963) reported on the cestode and nematode parasites of guineafowls of southern Africa present in the National Collection of Animal Helminths, formerly known as the Onderstepoort Helminthological Collection, or material made

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Accepted for publication 13 April 2007—Editor

available to him by various collectors. He described several new species of cestodes and nematodes and added numerous parasites to the host-parasite list of guineafowls in South Africa. His reseach, however, was of a taxonomic nature and the material at his disposal represented incidental findings rather than complete collections.

In this paper we present data obtained from 16 birds, including a single Crested guineafowl, at Musina, Limpopo Province, and from five Helmeted guineafowls at Mokopane, Limpopo Province, South Africa.

MATERIAL AND METHODS

In July and August 2005 a total of five Helmeted guineafowls were sampled in the vicinity of Mokopane (Potgietersrus), Limpopo Province. A complete helminth recovery was not possible, but some of the worms present in the small intestine of three of the birds, the complete caeca of one of them and part of the intestinal and caecal contents of another were collected and fixed separately in 70% ethanol.

In July 2005 and in May, July and November 2006, three, five, three and four Helmeted guineafowls (eight males and seven females) were collected on a farm approximately 60 km west of Musina (Messina), Limpopo Province (22°22' S, 29°30' E, Altitude 700–800 m). The vegetation-type in the study area is classified as Mopani veld (Acocks 1988).

The birds were aged according to the criteria established by Siegfried (1966) and in total ten adults and five juveniles were collected. The juveniles were between six and ten months old (Siegfried 1966). In November 2006 a single adult female Crested guineafowl, found moribund in a wire snare, was made available to us for examination.

The carcasses of the birds were opened according to standard techniques for necropsies of chickens, and the viscera removed. The trachea was opened and macroscopically examined for helminths.

The crop, proventriculus, gizzard, small intestine and caecum/colon were separated and individually washed over a 150 µm sieve. The livers of nine Helmeted guineafowls and the single Crested guineafowl were sliced into 5 mm wide sections and incubated in phosphate-buffered saline at 40° C for 30 min. Subsequently, the slices together with the saline were washed over a 150 µm sieve. The gastrointestinal and liver residues left on the sieves, as well as the organs themselves were fixed separately in 70% ethanol and transported to the laboratory at Onderstepoort. Each sample was examined under a stereoscopic microscope and the helminths removed.

Cestodes were stained in haematoxylin and mounted in Canada balsam or mounted and cleared in Hoyer's medium. Acanthocephalans were cleared in Hoyer's medium and studied as temporary mounts in the same medium. All nematodes were cleared in lactophenol for identification.

The ecological terms are used in accordance with the definitions of Margolis, Esch, Holmes, Kuris & Schad (1982).

RESULTS

All the guineafowls were infected and all were concurrently parasitized by acanthocephalans, cestodes and nematodes.

Data on the prevalence, intensity and habitat preference of the parasites from the Helmeted guineafowls in Musina are presented in Tables 1 and 2. Five of the nine hosts (55.6%), whose livers were examined, harboured *Dicrocoelium macrostomum*, the intensity of infection ranging from 8 to 182 flukes. In addition, the livers of three of the nine birds yielded five, 11 and five young specimens of *Porogynia paronai*. These had the typical three circles of large hammer-shaped rostellar hooks and small, unarmed suckers. No differential development could be seen in any of the proglottids of the short strobilae which ranged from 2.3 to 3.8 mm (n = 5) in length. The scolices were 689–746 µm wide and the rostella were 261–329 µm wide.

Birds from Mokopane yielded the nematodes *Subulura suctoria*, *Subulura dentigera* and *Ascaridia numidae* and seven cestodes, namely *Hispaniolepis multiuncinata*, *Porogynia paronai*, *Raillietina steinhardti*, *Raillietina pintneri*, *Raillietina* sp., *Numidella numida* and *Octopetalum numida*.

Subulura dentigera and *S. suctoria* were co-specific in the two hosts from Mokopane. One of these harboured a total of 579 nematodes consisting of 142 male and 159 female *S. suctoria*, 134 male and 126 female *S. dentigera* and 18 immature *Suctoria spp.* These nematodes were suspended freely in the contents of the posterior saccate part of the caeca, virtually occupying the entire lumen (Fig. 2D).

Eight of the 15 helmeted guineafowls from Musina harboured *S. dentigera* and *S. suctoria* concurrently, and in all these hosts *S. suctoria* by far outnumbered

TABLE 1 The site preference, prevalence and intensity of infection of acanthocephalans and cestodes collected from 15 Helmeted guineafowls in Limpopo Province, South Africa. Additional data on guineafowl helminths in southern Africa from various authors are included for comparison

Parasite	This paper				Verster & Ptasinska-Kloryga (1987)			Saayman (1966)			Crowe (1977)	Ortlepp (1963)
	Site	Prevalence (%)	Intensity		Prevalence (%)	Intensity		Prevalence (%)	Intensity		Presence	Presence
			Mean (± SD)	Range		Mean	Range		Mean	Range		
Acanthocephalans												
Mediorhynchus gallinarum	SI	100	55.7 (± 78.3)	2–231	–	–	–	–	–	–	–	–
Mediorhynchus numidae	SI	–	–	–	–	–	–	39	11.5	?–27	–	–
Mediorhynchus taeniatus	SI	–	–	–	27	1.7	0–22	–	–	–	+	–
Cestodes												
Abuladzugnia gutterae	SI	80	11.7 (± 8.2)	1–28	–	–	–	–	–	–	–	+
Abuladzugnia transvaalensis	SI	–	–	–	–	–	–	–	–	–	–	+
Davainea nana	SI	33	5.8 (± 4.4)	1–10	–	–	–	–	–	–	–	+
Hispaniolepis multiuncinata	SI	87	9.3 (± 5.2)	2–14	–	–	–	–	–	–	–	+
Hymenolepis cantaniana	SI	40	42.7 (± 70.4)	1–124	–	–	–	–	–	–	–	–
Numidella numida	SI	67	55.9 (± 72.7)	1–144	29	1.8	0–42	47	8.7	?–14	–	+
Octopetalum numida	SI	67	91.9 (± 110.7)	1–360	48	8	0–72	75	16.0	?	+	+
Paroniella sp.[a]	SI	–	–	–	25	1.5	0–17	–	–	–	–	–
Porogynia paronai	SI	47	12.3 (± 13.3)	5–39	–	–	–	75	?	?–5	+	+
Raillietina angusta	SI	53	10.3 (± 7.9)	1–25	8	< 1.0	0–21	–	–	–	–	+
Raillietina pintneri	SI	80	5.3 (± 3.9)	2–12	44	3.9	0–45	36	6.3	3–27	+	+
Raillietina steinhardti	SI	53	49.0 (± 60.2)	4–137	31	1.9	0–20	–	–	–	–	+
Raillietina sp.	SI	73	15.8 (± 8.8)	6–28	–	–	–	–	–	–	–	–
Raillietina sp.[a]	SI	–	–	–	35	2.7	0–17	–	–	–	–	–
Skrjabinia deweti	SI	–	–	–	–	–	–	–	–	–	–	+

[a] Listed by Verster & Ptasinska-Kloryga (1987) as a new species, but were not subsequently described
SI = small intestine

TABLE 2 The site preference, prevalence and intensity of infection of nematodes collected from 15 Helmeted guineafowls in Limpopo Province, South Africa. Additional data on guineafowl nematodes in southern Africa from various authors are included for comparison

Nematodes	This paper				Verster & Ptasinska-Kloryga (1987)			Saayman (1966)			Crowe (1977)	Ortlepp (1937, 1938b, 1964)[b]
	Site	Prevalence (%)	Intensity		Prevalence (%)	Intensity		Prevalence (%)	Intensity		Presence	Presence
			Mean (± SD)	Range		Mean	Range		Mean	Range		
Ascaridia galli	SI	–	–	–	2	< 1	0–2	64	5.4	?–9	–	–
Ascaridia numidae	SI	6	4.0[a]	4[a]	13	< 1	0–19	–	–	–	–	+
Cyrnea parroti	Giz	100	13.8 (± 18.2)	2–75	13	< 1	0–16	–	–	–	–	+
Dispharynx nasuta	Prov	–	–	–	10	1.8	0–59	–	–	–	–	–
Gongylonema congolense	Crop	40	23.0 (± 22.0)	2–61	–	–	–	–	–	–	–	–
Gongylonema ingluvicola	Crop	–	–	–	–	–	–	–	–	–	–	+
Hadjelia inermis	Giz	–	–	–	–	–	–	–	–	–	–	+
Hadjelia truncata	Giz	53	1.6 (± 0.5)	1–2	–	–	–	–	–	–	–	–
Heterakis gallinarum	Caeca	–	–	–	4	< 1	0–2	?	148	?–257	–	+
Sicarius caudatus	Giz, SI	53	2.1 (± 1.7)	1–6	–	–	–	–	–	–	–	–
Subulura dentigera	Caeca	53	15.9 (± 13.4)	1–31	6	1.3	0–54	–	–	–	+	+
Subulura suctoria	Caeca	100	536.3 (± 589.2)	9–2 214	23	< 1	0–40	–	–	–	+	+
Subulura sp.	Caeca	40	44.0 (± 65.4)	1–170	10	< 1	0–4	–	–	–	–	–
Unidentified subulurid	SI	13	2.5 (± 0.7)	2–3	–	–	–	–	–	–	–	–
Tetrameres numida	Prov	33	2.4 (± 1.7)	1–5	–	–	–	–	–	–	–	–

[a] Only a single host harboured this parasite
[b] Unpublished records of Ortlepp cited in Verster & Ptasinska-Kloryga (1987)
SI = small intestine
Giz = gizzard
Prov = proventriculus

S. dentigera, the ratio ranging from 4.5:1 to 53:1. In the remaining hosts only *S. suctoria* was present (Fig. 2E, F).

The Crested guineafowl harboured a single acanthocephalan species, *Mediorhynchus gallinarum* (*n* = 48), five species of cestodes, namely *Abuladzugnia gutterae* (*n* = 1), *H. multiuncinata* (*n* = 1), *N. numida* (*n* = 114), *O. numida* (*n* = 57) and *P. paronai* (*n* = 52), as well as three species of nematodes, *S. suctoria* (*n* = 260), *Gongylonema congolense* (*n* = 56) and *Hadjelia truncata* (*n* = 2), representing a total of 591 helminths.

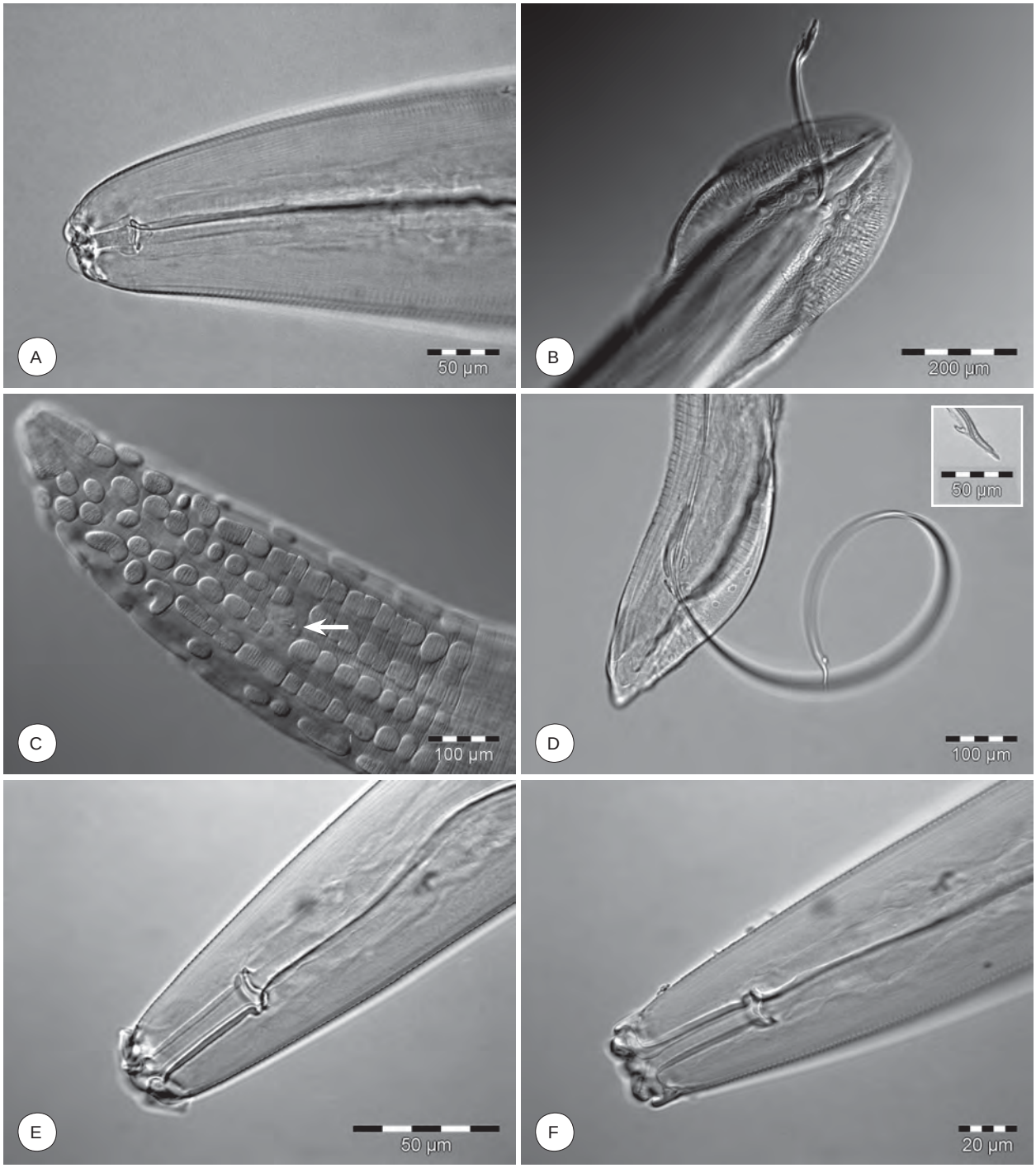

FIG. 1 A, B. *Cyrnea parroti* male. A. Anterior end. B. Posterior end. C, D. *Gongylonema congolense*. C. Anterior extremity of female, ventral view. The arrow points to the excretory pore. D. Posterior extremity of male. The inset illustrates the barbed tip of the long spicule. E, F. *Hadjelia truncata* male. E. Ventral view of anterior extremity. F. Lateral view of anterior extremity

Our finding of *M. gallinarum*, *A. gutterae*, *H. multiuncinata*, *H. truncata* and *Sicarius caudatus* in Helmeted guineafowls in South Africa constitutes new host associations, as well as new geographic records for these parasites. *Dicrocoelium macrostomum*, *G. congolense* and *Davainea nana* are recorded in South Africa for the first time, and the Crested guineafowl is a new host for the nematodes *S. suctoria*, *G. congolense* and *H. truncata*.

Despite the generally high helminth burdens, the Helmeted guineafowls were in good physical condi-

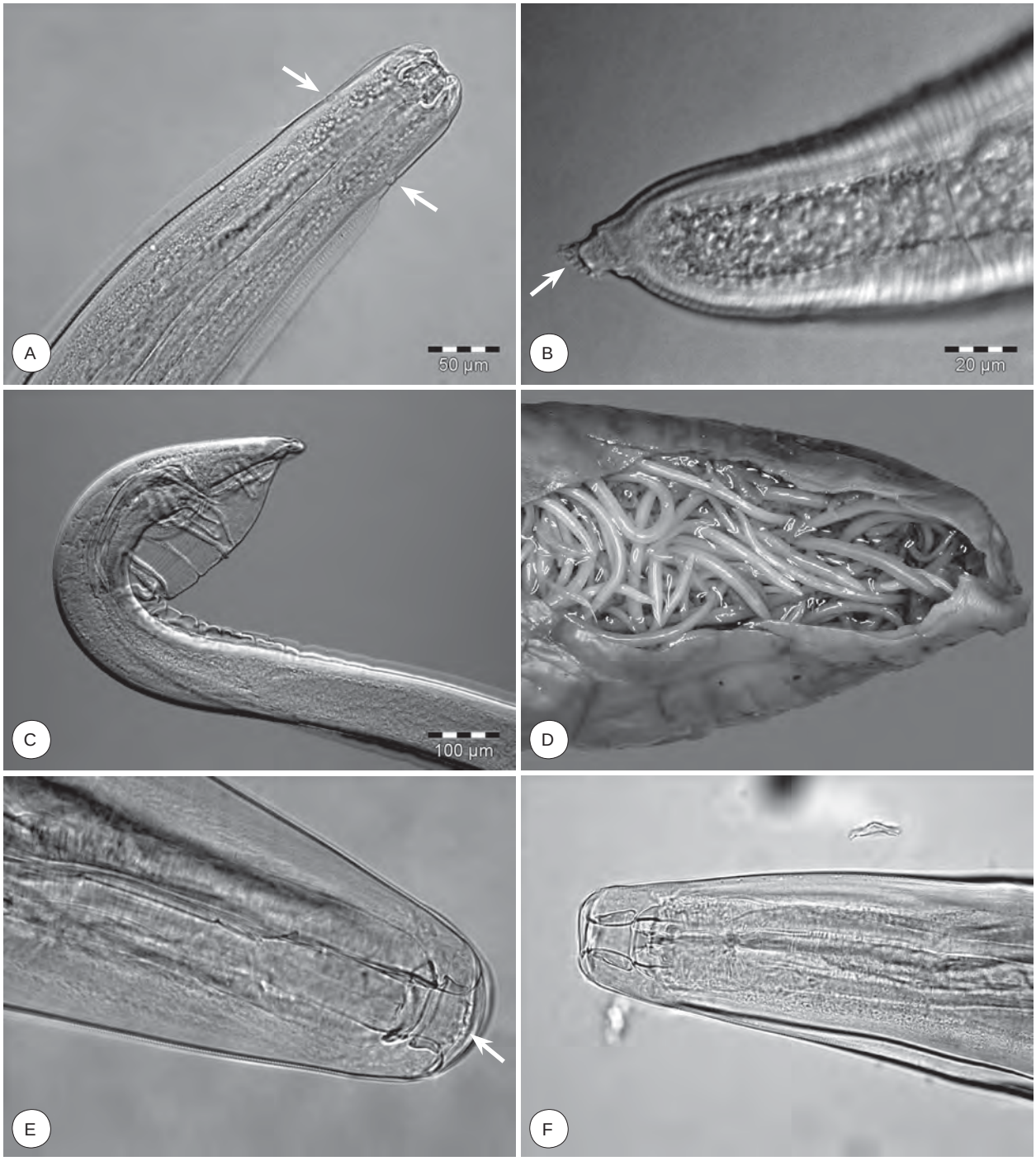

FIG. 2 A, B, C. *Sicarius caudatus*. A. Anterior extremity of male. The deirids are marked by arrows. B. Posterior extremity of female. Note the finger-like protruberances (arrow) at the tip of the tail. C. Posterior extremity of male. D. Distal part of guineafowl caecum filled with *Subulura* spp. E. *Subulura dentigera* female, anterior part. The arrow indicates the cuticular denticles as described by Ortlepp (1937); x 400. F. *Subulura suctoria* female, anterior part; x 400

tion and no obvious lesions were associated with the presence of helminths. The crop mucosa of a single bird from Musina had an inflamed appearance. This, however, did not seem to be related to *G. congolense* living in shallow tunnels under the crop lining, but rather to the presence of numerous thorny seeds of *Tribulus terrestris*.

TAXONOMIC REMARKS

***Cyrnea parroti* Seurat, 1917** (Table 3; Fig. 1A, B)

Ortlepp (1938b) described *Habronema numidae* from Helmeted guineafowls in Malawi, South Africa and Swaziland. This nematode has subsequently been included in the genus *Cyrnea* Seurat, 1914, but it is still listed under its original name in Yamaguti (1961) as well as in Verster & Ptasinska-Kloryga (1987).

In his work on the Habronematinae, Chabaud (1958) divided the genus *Cyrnea* into two subgenera, *Procyrnea* Chabaud, 1958 and *Cyrnea* Chabaud, 1958, which he later raised to genus level (Chabaud 1975). Following an in-depth study of the cephalic structures, he synonymized *Cyrnea* (*Cyrnea*) *numidae* (Ortlepp, 1938) with *Cyrnea* (*Cyrnea*) *parroti* Seurat, 1917 (Chabaud 1958).

Specimens from our hosts mounted *en face* show the same arrangement of submedian lobes and simple lips as illustrated for *C. parroti* by Chabaud (1958) and otherwise conform well with the description and measurements supplied by Ortlepp (1938b) for *C. numidae*. The range of measurements in our specimens was, however, generally wider than that provided by the latter author (Table 3). Ortlepp (1938b) himself stated that his new species most closely resembled *C. eurycerca* and *C. parroti* and that the arrangement of the caudal papillae in the males as well as the spicules were very similar.

***Gongylonema congolense* Fain, 1955** (Table 4; Fig. 1C, D)

This parasite was first described by Fain (1955a) from domestic chickens, a single duck, *Cairina moschata domestica* and from *N. meleagris* from the Democratic Republic of the Congo and Rwanda. Subsequently it has been recorded from *N. meleagris* in Burundi, Nigeria, Ethiopia, Ghana and Burkina Faso (Fain & Thienpont 1958; Fabiyi 1972; Graber 1976; Hodasi 1976; Vercruysse, Harris, Bray, Nagalo, Pangui & Gibson 1985).

One of the main morphological characteristics of this species is the hook situated at a distance of about 50 µm from the distal tip of the left spicule (Fain 1955a) (Fig. 1D). The hook itself carries three fine barbs. In our specimens the barbed hook of the tip of the left spicule was often difficult to see, but in specimens where the distance could be determined it varied from 31 to 46 µm.

It is not always easy to judge whether the left spicule is intact or damaged, which could lead to measuring errors. There are, however, sufficient other characteristics, such as the gubernaculum, the extent and arrangement of the cuticular plaques (Fig. 1C), as well as the length of the right spicule to differentiate *G. congolense* from other species utilizing avian hosts (Fain 1955a).

While our specimens fit in well with Fain's (1955a, b) description of *G. congolense*, we have not been able to confirm that the excretory pore opens on a transversally elongated plaque as was described by him. In our specimens it would seem that the two median ventral longitudinal rows of plaques are interrupted, leaving a plaque-free zone immediately anterior and posterior to the excretory pore (Fig. 1C).

Measurements of our specimens and those of Fain (1955a) taken from guineafowl hosts are presented in Table 4. These indicate that there is little geographic variation in the morphology of *G. congolense* from the same host species.

***Hadjelia truncata* (Creplin, 1825)** (Table 5; Fig. 1E, F)

The most obvious differences between *H. truncata* and sympatric specimens of *C. parroti* are the position of the vulva and the winged appearance of the lips of *H. truncata* in ventral view (Fig. 1E, F). In *H. truncata* the vulva is distinctly anterior and positioned in front of the posterior end of the oesophagus. These characteristics are in accordance with the generic diagnosis of *Hadjelia* provided by Yamaguti (1961).

Measurements of the specimens from the guineafowls fall well within the range of measurements provided by Ortlepp (1964) for *Hadjelia inermis* (Gedoelst, 1919) (Table 5). *Hadjelia inermis* had been synonymized with *H. truncata* by Chabaud & Campana (1950), and Ortlepp (1964) commented on this, but chose to retain the former species. He lists his own measurements for *H. inermis* collected from Red- and Yellow-billed hornbills from South Africa, together with measurements for *H. inermis* taken from Gedoelst (1919) and for *H. inermis* and *H. truncata* as provided by Cram (1927, cited by Ortlepp

TABLE 3 The main morphological criteria of *Cyrnea parroti* Seurat, 1917 from Helmeted guineafowls. The range of measurements is provided. All measurements in micrometres unless otherwise stated

Source	**Present study**		**Ortlepp (1938b)**	
Morphological criteria	**Males (*n* = 6)**	**Females (*n* = 4)**	**Males**	**Females**
Body length (mm)	9–11	11–16	11–13	18–19
Maximum width	229–274	232–380	180–210	300–360
Distance apex to nerve ring	187–262	237–263	210–240	210–240
Distance apex to deirids	220–370	309–364	–	–
Distance apex to excretory pore	220–362	311–357	250–290	250–290
Depth of buccal capsule	29–36	34–45	30	36
Width of buccal capsule (inner)	10–15	12–16	10	12
Muscular oesophagus	304–393	–	270–300	330
Glandular oesophagus	2 234–2 526	–	1 700–2 000	2 400–2 600
Oesophagus total length	2 284–2 830	2 039–3 056	–	–
Length of tail	120–193	128–150	–	126–130
Distance vulva to posterior end	–	661–897	–	~ 750
Egg length x egg width	–	45–46 x 25–27	–	42–45 x 24
Length of right spicule	410–510[a]	–	420–438	–
Length of left spicule	834–1 354[a]	–	1 080–1 110	–
Length of gubernaculum	63–84[a]	–	70	–
Length of caudal alae	437–618	–	420–520	–

[a] Measurements of the spicules and the gubernaculum are derived from ten males

TABLE 4 The main morphological criteria of *Gongylonema congolense* Fain, 1955 males from Helmeted guineafowls from South Africa (present study, GFM/N represents our specimen number) and from the Democratic Republic of the Congo and Rwanda (Fain 1955a). All measurements in micrometres unless otherwise stated

Source	**Present study**								**Fain (1955b)**
Morphological criteria	**GFM3/N1**	**GFM1/N16**	**GFM1/N17**	**GFM1/N21**	**GFM1/N22**	**GFM1/N23**	**GFM1/N24**	**GFM1/N25**	**(*n* = 5)**
Body length (mm)	17	15	14	13	–	14	17	–	12–24
Maximum width	266	228	244	215	–	230	247	230	170–200
Distance apex to deirids	84	70; 86	107	88	98	109; 104	96; 83	–	85–125
Distance apex to nerve ring	210	190	232	188	224	223	191	–	196–235
Distance apex to excretory pore	305	303	355	322	340	362	337	–	310–350
Distance apex to end of plaques	440	385	484	470	–	486	500	–	450–475
Distance apex to cervical ailes	102; 110	118	153	107; 123	–	150; 141	125; 123	–	125–175
Depth of buccal capsule	31	–	30	30	–	34	31	–	30–45
Muscular oesophagus	–	362	216	304	431	387	332	–	290–400
Glandular oesophagus	–	2 967	3 934	3 075	3 879	3 417	3 523	–	2 520–3 920
Oesophagus total length	4 125	3 407	4 150	3 379	4 310	3 804	3 853	–	–
Length of tail	207	173	183	170	–	197	202	165	185–200
Caudal alae (left; right)	600 (left)	–	–	–	–	–	630; 583	–	575–700; 450–500
Length of gubernaculum	87	73	85	87	82	–	80	80	68–85
Length of right spicule	98	101	79	86	99	98	100	94	104–140
Length of left spicule (mm)	8.7	–	4.8	5.5	7.4	5.5	8.1	8.2	7–11

TABLE 5 The main morphological criteria of *Hadjelia truncata* (Creplin, 1825) from Helmeted guineafowls. The range of measurements is provided. All measurements in micrometres unless otherwise stated

Source	**Present study**					**Gedoelst (1919)**		**Ortlepp (1964)**	
Morphological criteria	**Males**		**Females**			**Males**	**Females**	**Males**	**Females**
	GFM9/1	**GFM/11**	**GFM1/10**	**GFM1/14**	**GFM6/1**				
Body length (mm)	7	8	10	–	11	6.1–6.45	18–21.8	6–7	17–19
Maximum width	160	145	209	217	140	140–144	240–260	–	–
Distance apex to nerve ring	208	212	185	159	–	180–215	260–275	–	–
Distance apex to deirids	237; 239	238; 231	206; 204	160; 161	257; 259	210–260	330	–	–
Distance apex to excret. pore	275	259	234	179	290	220–275	360	–	–
Depth of buccal capsule	44	42	39	40	41	–	–	40–50	47–52
Width of buccal capsule (inner)	5	7	5	7	6	–	–	10	12
Muscular oesophagus	369	397	358	346	495	–	–	230–280	400–450
Glandular oesophagus	1 750	1 927	1 948	2 076	1 988	–	–	1 900–2 200	2 000–2 300
Oesophagus total length	2 119	2 324	2 306	2 422	2 483	2 000	2 400–3 600	2 130–2 480	2 400–2 750
Distance apex to vulva	–	–	1 698	1 691	2 238	–	1 860–2 970	–	2 200–2 500
Length of tail	–	–	138	–	121	120	90–120	120–140	110–120
Egg length x egg width	–	–	50 x 32	53 x 35	–	–	54–57 x 30–32	–	32–37 x 25–27
Length of left spicule	1 346	1 434	–	–	–	1 600–1 900	–	1 200–1 500	–
Length of right spicule	271	254	–	–	–	200	–	215–280	–

TABLE 6 Morphological criteria of *Sicarius dipterum* (Popova, 1927), *Sicarius hoopoe* Sharma, 1971, *Sicarius caudatus* Quentin & Wertheim, 1975 and *Sicarius renatae* Cancrini, Balbo & Iori, 1991 described from avian hosts. All measurements in micrometres unless otherwise stated

Source	**Ali (1961)**		**Sharma (1971)**		**Quentin & Wertheim (1975)**		**Present study**		**Cancrini, Balbo & Iori (1991)**	
Morphological criteria	***Sicarius dipterum***		***Sicarius hoopoe***		***Sicarius caudatus***		***Sicarius caudatus***		***Sicarius renatae***	
	Male	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**
Body length (mm)	10.2–11.9	12.9–16.1	6.7–9.4	11.2–18.2	7.3	13.3	5.9	8.3	4.9	7.3
Distance apex to deirids	70–74[a]	80–90[a]	60–70	50–60	85	85	63; 68	78; 87	68; 70	65; 75
Distance apex to nerve ring	180–200	240–260	110–140	165–210	215	250	208	226–227	150	165
Distance apex to excret. pore	240–260	280–320	130–180	180–220	270	310	–	278–298	–	–
Depth of buccal capsule	43–45	52–58	14–17	25	28	38	28	31–33	25	25
Muscular oesophagus	510–530	560–610	240–320	320–380	380	410	–	–	250	236
Glandular oesophagus	2 880–2 920	3 160–3 910	2 800–3 040	3 200–3 600	2 170	2 900	–	–	1 950	2 365
Oesophagus total length	3 400–3 500	3 700–4 500	–	–	2 550	3 310	2 535	2 722	2 200	2 601
Length of tail	210	185–210	176–208	167–256	190	250	161	168	–	110
Length of right spicule	93–160	–	440–560	–	170–190	–	171	–	175	–
Length of left spicule	620–690	–	470–600	–	400–450	–	413	–	360	–
Distance vulva to tip of tail	–	5 000	–	–	–	4 950	–	2 960	–	2 800
Egg length	–	38–40	–	33–46	–	43	–	38	–	37–40
Egg width	–	30–37	–	29–39	–	30	–	29	–	25–27
Max. width of alae	–	–	–	–	45	45	36	40–50	–	–
Extension alae	Whole body	Whole body	Whole body	Whole body	Whole body	Whole body	Whole body	Whole body	Whole body	Whole body

[a] Cervical papillae in Ali (1961) interpreted here as deirids

1964) (Table 5). As we have not been able to examine the type-specimens of either species, we have chosen to adopt the conclusion of the in-depth morphological study of Chabaud & Campana (1950).

The single complete specimen in our collection appears slightly shorter than previously described ones. The depth of the buccal cavity of our specimens corresponds with the lower range of the pharynx sizes provided by Ortlepp (1964) and all three authors he quoted.

The oesophagus length is relatively uniform in all the sources quoted by Ortlepp (1964). In our specimens the total length of the oesophagus only reached 2.1 and 1.9 mm which, considering that these specimens are short, does not seem extraordinary. The egg size is very similar to that of *H. inermis* as recorded by Gedoelst (1919) and Cram (1927, cited by Ortlepp 1964), but larger than given by Ortlepp (1964). Ortlepp (1964) pointed out that this was the only noteworthy difference between his specimens and those described by Gedoelst (1919).

According to Chabaud (1958) the genus *Hadjelia* has been described from numerous birds, especially Coraciiformes, from Europe, Asia and Africa. Data pertaining to African hosts mainly list Bucerotiformes (Ortlepp 1964) and we are aware of only one reference to *Hadjelia* from galliform birds, namely *Hadjelia lhuillieri* Seurat, 1916 from *Alectoris barbara* (= *Caccabis petrosa* from Algeria in Seurat 1916). Incidentally, Chabaud (1958) speculated that the latter species might be identical with *H. truncata*, but thought that the characteristics of the single known female specimen of *H. lhuillieri* were not sufficient to draw a final conclusion.

Sicarius caudatus Quentin & Wertheim, 1975

(Table 6; Fig. 2A, B, C)

Four species of the genus *Sicarius* are known from avian hosts, namely *Sicarius dipterum* (Popova, 1927), *Sicarius hoopoe* Sharma, 1971, *Sicarius caudatus* Quentin & Wertheim, 1975 and *Sicarius renatae* Cancrini, Balbo & Iori, 1991. The left spicule of *Sicarius dipterum* is distinctly longer (660–670 µm) than that of our specimens, whereas the subequal spicules of *Sicarius hoopoe* are 440–560 and 470–600 µm in length (Cancrini, Balbo & Iori 1991). Our specimens best fit the description of *S. caudatus*, as they have six pairs of caudal papillae as opposed to the eight pairs of *S. renatae* (Cancrini *et al.* 1991).

According to Quentin & Wertheim (1975) the deirids in *S. caudatus* are situated at the origin of the lateral alae. In some of our specimens, we have observed the same arrangement, but in one male and one female the right and left deirids emerge 11 and 27 µm, and 17 and 37 µm anterior to the origin of the alae (Fig. 2A). We have too little material to comment on the significance of this observation.

Quentin & Wertheim (1975) describe the cuticular processes in the tail of *S. caudatus* as atrophied, the tail consisting merely of a smooth stump, which at best has rugged edges. Our specimens possess about seven distinct, albeit short, cuticular extensions similar to those illustrated by Cancrini *et al*. (1991) for *S. renatae* (Fig. 2B). Despite these differences we have allocated our specimens to *S. caudatus*. Apart from the original description and their inclusion in some taxonomic reviews (Chabaud 1958; Ali 1961), we have not found any other references to *S. caudatus* in the literature. The measurements of the specimens collected during this study are included in Table 6.

DISCUSSION

Despite the fact that various studies on the helminths of guineafowls in South Africa have been conducted, direct comparisons between the results of these studies are not always possible, as they had different objectives. Ortlepp (1937, 1938a, b, 1963) studied the helminths of all the organs and the entire alimentary canal, but his work was of a taxonomic nature, based on incidental findings, and presented no epidemiological data. Crowe (1977) listed the helminth species recovered from the small intestine, caeca and rectum of guineafowls, but in his subsequent analysis grouped them as acanthocephalans, cestodes and nematodes respectively. The two studies providing data on the prevalence and intensity of the helminths are those of Saayman (1966) and Verster & Ptasinska-Kloryga (1987). However, Saayman (1966) only examined the intestinal tract and Verster & Ptasinska-Kloryga (1987) collected helminths from the gizzard, intestine and caeca. Thus, their data on species richness would not reflect worms located in e.g. the crop or proventriculus.

The study conducted on guineafowls in Burkina Faso by Vercruysse *et al*. (1985) lends itself best to comparison with ours, as they examined the complete alimentary tract, including the crop and proventriculus. Of the total of 13 helminth species collected by these authors, eight species coincide with species recovered from our hosts. If the single acanthocephalan present in the birds from Burkina Faso

is taken into account, this number will increase by one. Vercruysse *et al*. (1985) record the acanthocephalan *Mediorhynchus selengensis*, which has been synonymized with *M. gallinarum* by Schmidt & Kuntz (1977), and the nematodes *Cyrnea parroti*, *S. suctoria*, *G. congolense* and *A. numidae*, which are also recorded in this study. In addition to these species, Vercruysse *et al.* (1985) recorded the cestode *Cotugnia digonopora* and the nematodes *Eucoleus annulatus*, *T. fissispina* and *Dispharynx spiralis*.

Nematodes

Cyrnea

With the exception of *C. parroti*, helminths were recovered from their usual predilection sites. According to Anderson (1992) members of the genus *Cyrnea* occur in the proventriculus of birds and he records *Cyrnea colini* in the wall of the proventriculus near the gizzard of Bobwhite quails. We did not recover *C. parroti* from the proventriculus, but in all infected guineafowls the parasites were situated under the gizzard lining and could only be seen after the horny layer had been removed. There seemed, however, to be a preference for the proventricular-gizzard isthmus as described for *Cyrnea neeli* from wild turkeys in the south-eastern United States (Davidson, Hon & Forrester 1977). Similarly, *C. parroti* recovered from Helmeted guineafowls in Burkina Fasso were also present in the gizzard (Vercuysse *et al.* 1985).

Subulura

The genus *Subulura* has a wide distribution in gallinaceaous birds on the African continent and records exist from Zimbabwe, Tanzania, Ghana, Nigeria and Somalia (Nicholls, Bailey, Gibbons, Jones & Samour 1995; Nfor, Ajanusi, Agbede & Esievo 1999; Poulsen, Permin, Hindsbo, Yelifari, Nansen & Bloch 2000; Permin, Esmann, Hoj, Hove & Mukaratirwa 2002; Magwisha, Kassuku, Kyvsgaard & Permin 2002). However, the genus is not restricted to the African continent and, according to Yamaguti (1961) is a cosmopolitan species.

Ortlepp (1937) recovered *S. suctoria* in association with *S. dentigera* from guineafowls from various regions in South Africa and Swaziland and concluded that the two species had a wide distribution. Contrary to our findings, he found *S. dentigera* to be far more abundant than *S. suctoria*.

Verster & Ptasinska-Kloryga (1987) collected helminths from 48 guineafowls in the vicinity of Pretoria. *Subulura suctoria* was present in 11 and *S. dentigera* in three of the hosts examined. From these and our own results it is apparent that the two species, *S. suctoria* and *S. dentigera* often share the same habitat. It is difficult to judge from our data whether these two species are interactive and compete for the same resources. If so, *S. suctoria* would seem the stronger competitor as it consistently occurred in higher numbers than *S. dentigera*. However, the numbers of *S. dentigera* were not greater in hosts with relatively low burdens of *S. suctoria*, but rather the numbers of *S. dentigera* were low in these hosts as well. It is possible, that this association is similar to the major-minor species concept, as seen with *Theladorsagia circumcincta* and *Theladorsagia davtiani* in sheep and goats.

A literature study confirms the dominance of *S. suctoria* in guineafowls and Vercruysse *et al*. (1985) recorded a 100 % prevalence of *S. suctoria* from 103 Helmeted guineafowls in Burkina Faso. In addition to being the most prevalent nematode, these authors also found *S. suctoria* to be one of the most numerous parasites (26–1071 worms per host). *Subulura dentigera* was not reported from these hosts.

Ascaridia numidae

Ascaridia numidae is another nematode commonly encountered in Helmeted guineafowls and has been recorded from various geographic localities in Africa. The prevalence and intensity of this parasite varies greatly from 98.1 % with a range of intensity from 1 to 1452 in hosts in Burkina Faso (Vercruysse *et al.* 1985) and 86.7 % with intensities ranging from 1 to 504 in birds in Ghana (Hodasi 1976) to a low prevalence of 13 % with a maximum of 19 worms per host in South Africa (Verster & Ptasinska-Kloryga 1987). In the present study *A. numidae* was present in a single host only.

Gongylonema

Both Hodasi (1976) and Vercruysse *et al.* (1985), record *G. congolense* from hosts they examined, with a prevalence of 48.9 and 73.8 %, respectively. This indicates that *G. congolense* not only forms a regular part of the helminth community of guineafowls in South Africa, but throughout the African continent. With the exception of *Gongylonema ingluvicola* allegedly recorded by Ortlepp (“1937, 1938, unpublished records” cited by Verster & Ptasinska-Kloryga 1987), the absence of this genus in previous reports on helminths of guineafowls in South

Africa, is most likely due to the fact that earlier authors did not examine the crop of the hosts in their studies.

Tetrameres

While *Tetrameres numida* was recovered in low numbers from the Musina guineafowls, none of the more commonly reported species of this genus was present in our material. A second species, which has been recorded from guineafowls and is also a common parasite of domestic chickens, is *Tetrameres fissispina* Diesing, 1861. Vercruysse *et al.* (1985) report a 48.5% prevalence and an intensity of infection ranging from 1 to 146 worms per host from Helmeted guineafowls in Burkina Faso, and 23.3% of 126 Helmeted guineafowls in Nigeria were infected with *T. fissispina* (Fabiyi 1972). In Ghana the prevalence of infection in the same host was 8.9% with a mean worm burden of 2.8, ranging from one to eight. Young scavenging chickens in Ghana had a prevalence of *T. fissispina* of 58% (Poulsen *et al.* 2000).

We are aware of a single record of three females of *T. fissispina* from a single Helmeted guineafowl in South Africa (Le Roux 1926), and the same author reports a high percentage of infection (78%) in 60 domestic chickens in the same country. The proventriculus of a single, heavily infected host contained a minimum of 150 females (Le Roux 1926).

A third species commonly infecting domestic chickens, namely *Tetrameres americana,* which had a 60 and 62% prevalence in adult chickens in Tanzania and Zimbabwe, respectively (Permin, Magwisha, Kassuku, Nansen, Bisgaard, Frandsen & Gibbons 1997; Permin *et al.* 2002), has not yet been recorded from guineafowls.

From the literature cited above it would appear that the prevalence of the genus *Tetrameres* is slightly higher in domestic chickens than in Helmeted guineafowls. Since the data above concerning the domestic chickens above pertain to free-ranging or scavenging chickens, guineafowls and domestic fowls probably had an equal chance of exposure to the parasite. Whether the higher infection rates in chickens are a result of higher host densities or whether guineafowls are generally more resistant towards helminth infections remain speculation.

Trematodes

The literature contains few reports of trematodes from guineafowl hosts, but a number of trematodes have been listed as parasitizing not only the digestive tract and urogenital system, but also the respiratory system of domestic fowls (Soulsby 1968). To our knowledge the only published records of trematodes from the liver of guineafowls are those of *D. macrostomum*, that occurs in the gall bladder and bile ducts of *N. meleagris* (= *N. ptilorhyncha*) in Egypt (Lesbouyries 1941) and *Lutztrema* sp. from the gallbladder of Helmeted guineafowls in Ghana (Hodasi 1976). The former parasite has also been found in the liver of Helmeted guineafowls in the Kruger National Park (Horak 2007, personal communication) and was present in the Musina hosts. The results of this study and unpublished data of Horak (2007) suggest that *D. macrostomum* is not uncommon in South African guineafowls and can reach high intensities in individual hosts.

Postharmostomum gallinum has been reported from the gastro-intestinal tract from Crested guineafowls in Pakistan (Khan, Khan & Rayaz 1984). Hodasi (1969, 1976) collected *Postharmostomum ntowi* and *Episthmium ghanense* and *Episthmium africanus* from the gastro-intestinal tracts of domestic chickens. Intensities and prevalences were low and the latter author concluded that trematodes were rare parasites in gallinaceous birds.

The fact that the intermediate hosts of trematodes are mainly molluscs or rarely annelids (Gibbons, Jones & Khalil 1996), both of which are typically associated with moist environmental conditions, might well explain why trematodes played a minor role as parasites of the guineafowls in our dry study area.

Cestodes

Porogynia

The presence of young stages of *Porogynia paronai* in the liver of infected hosts is unusual. Hodasi (1976), however, recovered adult *Cotugnia meleagridis* from the small intestine of Helmeted guineafowls in Ghana, and recorded numerous young forms of this parasite from the host's gallbladder. Since the life cycle of *Porogynia* is not known, one can only speculate on the presence of immatures in the liver.

During the normal course of cestode development in avian hosts, the cysticercoid is freed from the arthropod intermediate host in the intestine as a result of mechanical and chemical actions. Subsequently, the scolex evaginates and the cysticercoid attaches itself to the gut wall (Reid 1962). The fact that young *P. paronai* were recovered from the liver of three birds and in relatively high numbers, in addition to

their uniform stage of development, suggests that their presence is not a result of post-mortem migration. Whether the newly freed cysticercoid, assuming that an arthropod is the intermediate host, migrates up the common bile duct to mature to a certain stage, before leaving the liver to resume its final maturation in the small intestine, or whether we have observed aberrant migration of juvenile stages will remain speculation until the development of *P. paronai* can be studied in more detail.

Abuladzugnia

Interestingly, the cestode *A. gutterae*, which was common in the guineafowls examined by us was not found in any of the previous surveys. Ortlepp (1963) originally described this species as *Cotugnia gutterae* from three specimens that had been collected from Crested guineafowls in Mozambique. Since then there seem to have been no further records of this parasite. Spasskii (1973) created the genus *Abuladzugnia* to accommodate *A. gutterae* and another of Ortlepp's (1963) species formerly described as *Cotugnia transvaalensis*.

Conclusion

The above findings suggest, that despite geographical variation in the prevalence and intensity of individual helminth species, probably caused by environmental conditions, such as temperature, rainfall and soil conditions, the helminth community of guineafowls in Africa is composed of a relatively stable body of core and secondary species enriched by satellite species. The latter probably depend on local conditions and can be influenced by abiotic conditions, but also the presence or absence of certain intermediate hosts and other terrestrial birds which may serve as reservoir hosts for certain parasites. We interpret the relative uniformity in the helminth community of Helmeted guineafowls in Africa as flowing from a long host/parasite association during which parasites have spread in conjunction with their hosts.

ACKNOWLEDGEMENTS

We thank Dr W.J. Luus-Powell, University of Limpopo, who enabled the collection of Helmeted guineafowls in Musina and Mr H.E. Hattingh, University of Limpopo, for collecting and placing the Mokopane material at our disposal as well as for collecting the birds at Musina. Mr K. Meyer and Mr M. Storm kindly made the guineafowls available to us. The technical assistance of Mr. Ryno Watermeyer, University of Pretoria, especially with the processing of the cestodes, is greatly appreciated. This study was made possible by a Claude Leon Foundation Postdoctoral Fellowship grant to the first author.

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Onderstepoort Journal of Veterinary Research, 75:225–235 (2008)

The helminth community of Helmeted Guineafowls, *Numida meleagris* (Linnaeus, 1758), in the north of Limpopo Province, South Africa

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ABSTRACT

JUNKER, K., DEBUSHO, L. & BOOMKER, J. 2008. The helminth community of Helmeted Guineafowls, *Numida meleagris* (Linnaeus, 1758), in the north of Limpopo Province, South Africa. *Onderstepoort Journal of Veterinary Research*, 75:225–235

The helminths of 15 Helmeted Guineafowls were collected in the north of Limpopo Province, South Africa. A total of 11 cestode, ten nematode and a single acanthocephalan species were present. Species richness ranged from 8 to 16 species per host, and nine core and nine secondary species accounted for 40.9% of the component parasite community. The remaining 18.2% comprised satellite species. Core species represented 91% of all the worms present. Individual intensities ranged from 66 to 2 724 per host and overdispersion was pronounced. There were no significant differences regarding the abundance and species richness between male and female hosts. The number of component species and overall abundance did not differ significantly between juvenile and adult hosts, but *Cyrnea parroti* was significantly more abundant, and the prevalence of *Hadjelia truncata* was higher in young birds than in adults. In contrast, *Gongylonema congolense* and *Porogynia paronai* were absent in juveniles, but had a prevalence of 60% and 70%, respectively, in adults. Pairwise Spearman's rank correlation yielded one positive and 10 negative significant species correlations. A single trematode, *Dicrocoelium macrostomum*, was collected from five of nine guineafowls, but was not included in the helminth community study.

Keywords: Acanthocephala, Cestoda, Helmeted Guineafowls, Nematoda, *Numida meleagris*

INTRODUCTION

Despite the remarkable diversity of South African birdlife, knowledge concerning their helminth parasites is scant (Ortlepp 1937, 1938a, b, 1963; Verster-Patsinska-Kloryga 1987) and even sparser on the structure of their helminth communities.

A first step was taken by Crowe (1977), who compared the influence of sex, age and habitat on the intestinal helminths of Helmeted Guineafowls, *Numida meleagris* (Linnaeus, 1758), at Kimberley, Northern Cape Province, South Africa. Thereafter, Alexander & McLaughlin (1997) provided a comprehensive analysis of the helminth communities of four species of ducks at Barberspan, South Africa. It is also apparent from Bush's (1990) chapter on helminth communities in avian hosts, that considerably more information on helminth community dynamics in birds from aquatic environments than those from terrestrial habitats is available.

This paper analyses the composition and structure of the helminth community of 15 Helmeted Guineafowls in the Limpopo Province, even though small numbers of hosts were available and a larger sample might have a different outcome. Data on the various

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Accepted for publication 28 May 2008—Editor

helminth species collected have been presented in a companion publication (Junker & Boomker 2007a).

MATERIAL AND METHODS

During July 2005 to November 2006 the gastrointestinal helminths of 15 Helmeted Guineafowls on a farm about 60 km west of Musina (Messina), Limpopo Province (22°22' S, 29°30' E), were examined as detailed in Junker & Boomker (2007a). Three of the birds shot in May 2006 and two collected in July 2006 were young birds, between 6 and 10 months old (Siegfried 1966), the remainder were adults. Three of the juveniles were females and two males, and the adults comprised four females and six males.

The terms prevalence, intensity and abundance are used in accordance with the proposals of Margolis, Esch, Holmes, Kuris & Schad (1982) and Bush, Lafferty, Lotz & Shostak (1997). Infrapopulation and infracommunity follow Bush & Holmes (1986a, b), metapopulation follows Riggs & Esch (1987) and component parasite community is used as defined by Holmes & Price (1986). As suggested by Bush & Holmes (1986a) and Alexander & McLaughlin (1997), species with a prevalence of 70% and higher, were categorized as core species, those with prevalences of <40% as satellite species and those with prevalences ≥40% but <70% as secondary species. A summary of these definitions is to be found in Esch, Shostak, Marcogliese & Goater (1990).

A Wilcoxon rank sum test was performed to determine differences in species richness, as well as in the abundance of the various species between male and female hosts, juveniles and adults and between birds shot in winter and spring. A variance ratio test of Schluter (1984) and McCulloch (1985) was used to detect species association with presence-absence data for all parasites, parasites in the small intestine (SI) and parasites in the caeca.

Pairwise Spearman's rank correlation for every possible species combination in the small intestine, gizzard and caeca respectively were calculated. To avoid possible distortions inherent to this form of analysis, double zero matches, i.e. absence of both species from a host, were eliminated. Of the 14 helminth species present in the small intestine only the single acanthocephalan and the 12 cestodes were included in the analysis, because the occurrence of two nematodes, *Ascaridia numidae* and an unidentified subulurid, was restricted to one and two hosts respectively, while a third nematode, *Sicarius caudatus*, utilized the SI as well as the gizzard. We tested for a correlation between *Subulura dentigera* and *Subulura suctoria* from the caeca only, as *Subulura* sp. most probably represents either of the former two nematodes.

Significance was set at the 95% level throughout. In the absence of scoleces, counts were not always possible for all the cestodes of a particular host. While these hosts were included in analyses based on presence/absence data, they were excluded from the sample pool in the Wilcoxon rank sum tests pertaining to the abundance of helminths at species level.

RESULTS

A total of 11951 helminths representing ten nematode, 11 cestode and a single acanthocephalan species were recovered from the alimentary canal of the 15 guineafowls. Data on their prevalence, intensity of infection and abundance, as well as their feeding guild classification and status as core, secondary or satellite species are summarized in Table 1. In all likelihood, *Raillietina* sp. and *Subulura* sp. are representatives of the remaining species of these two genera listed in Table 1. A single trematode species, *Dicrocoelium macrostomum*, was present in five of nine guineafowls examined for this parasite. Although included in the general results and discussion, these trematodes do not form part of the community study outlined below.

Following the classification of Bush (1990) four feeding guilds, i.e. organisms using the same feeding-mode, without regard to their taxonomic affinity, were present in the helminth community. The trematode guild, feeding actively on semi-solid food materials such as blood, bile, mucus and intestinal debris as well as directly absorbing nutrients through their tegumental surface, was restricted to the liver and represented by a single species. The nematode guild, being mucosal and engulfing tissue and/or lumen contents, occupied the largest number of sites along the alimentary canal, namely the crop, proventriculus, gizzard as well as the small and large intestine. The females of *Tetrameres numida* are an exception in so far as they inhabit the glands of the proventriculus, where they suck blood.

The cestodes and acanthocephalans occurred in the small intestine only. *Mediorhynchus gallinarum* has a short neck and its attachment to the mucosa remains superficial. The larger part of its abdomen is suspended freely in the intestinal lumen, absorbing nutrients via the body surface (Junker & Boomker

TABLE 1 Helminths recovered from 15 Helmeted Guineafowls in Musina, Limpopo Province, South Africa

Parasite	Guild	Site	Status	No. of inf. hosts	Prev-alence (%)	Intensity				Abundance		
						Median	Mean	SD	Range	Median	Mean	SD
Acanthocephala												
Mediorhynchus gallinarum	L	SI	C	15	100	23	55.7	78.3	2–231	23	55.7	78.3
Cestoda												
Abuladzugnia gutterae	L	SI	C	12	80	13	11.7	8.2	1–28	7.5	9.2	8.8
Davainea nana	M	SI	Sat	5[a]	36	6	5.8	4.4	1–10	0	1.7	3.5
Hymenolepis cantaniana	M	SI	Sec	6	40	3	42.7	70.4	1–124	0	10.7	35.7
Numidella numida	L	SI	C	10	67	14	55.9	72.7	1–203	2.5	35.9	63.4
Octopetalum numida	L	SI	C	10	67	79	91.9	110.7	1–360	6	61.2	99.4
Ortleppolepis multiuncinata	M	SI	C	13	87	11	9.3	5.2	2–14	7	7	6.1
Porogynia paronai	L	SI	Sec	7	47	6.5	12.3	13.3	5–39	0	5.3	10.4
Raillietina angusta	L	SI	Sec	8	53	10	10.3	7.9	1–25	0.5	5.1	7.6
Raillietina pintneri	L	SI	C	12	80	4	5.3	3.9	2–12	2	3.8	4.1
Raillietina steinhardti	L	SI	Sec	8	53	27.5	49.0	60.2	4–137	0	17.8	41.2
Raillietina sp.	L	SI	C	11	73	13	15.8	8.8	6–28	8	10.9	10.5
Nematoda												
Ascaridia numidae	N	SI	Sat	1	6	4	4.0	0.0	4	0	0.3	1
Cyrnea parroti	N	Giz	C	15	100	7	13.8	18.2	2–75	7	13.8	18.2
Gongylonema congolense	N	Crop	Sec	6	40	19	23.0	22.0	2–61	0	9.2	17.6
Hadjelia truncata	N	Giz	Sec	8	53	2	1.6	0.5	1–2	1	0.9	0.9
Sicarius caudatus	N	Giz, SI	Sec	8	53	1.5	2.1	1.7	1–6	1	1.1	1.6
Subulura dentigera	N	Caeca	Sec	8	53	15	15.9	13.4	1–31	1	8.5	12.5
Subulura suctoria	N	Caeca	C	15	100	345	536.3	589.2	9–2 214	370	536.3	589.2
Subulura sp.	N	Caeca	Sec	6	40	15	44.0	65.4	1–170	0	17.6	45
Unidentified subulurid	N	SI	Sat	2	13	2.5	2.5	0.7	2–3	0	0.3	1.5
Tetrameres numida	N	Prov	Sat	5	33	2	2.4	1.7	1–5	0	0.8	1.4

[a] Data from 14 hosts only
L = lumenal absorber; M = mucosal absorber; N = nematode
SI = small intestine, Giz = gizzard, Prov = proventriculus
C = core species; Sat = satllite species; Sec = secondary species

2006). It is therefore included in Bush's (1990) category of lumenal absorbers, together with the majority of the larger cestodes. Small and delicate cestodes such as *Davainea nana*, *Hymenolepis cantaniana* and *Ortleppolepis multiuncinata*, whose entire body is virtually buried amongst the mucosal villi, constitute the fourth guild, namely that of mucosal absorbers.

Except for the monoxenous nematode *Ascaridia numidae*, all members of the component community have indirect life-cycles.

The component community comprised nine core species as well as nine secondary species, each representing 40.9% of the total number of species, and four satellite species accounting for 18.2% of the species present (Table 1). Despite their prevalence of 67% being slightly below the 70% threshold, we have arbitrarily included *Numidella numida* and *Octopetalum numida* with the core species, as they were two of the most numerous helminths recovered in this study. The core species accounted for 91% of all individuals, the secondary species for

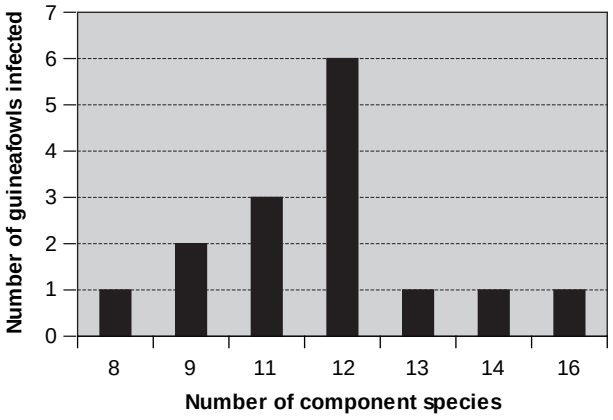

FIG. 1 Frequency distribution of the total number of helminth species found in Helmeted Guineafowls in Musina, Limpopo Province, South Africa. The number of individual hosts infected by a certain number of helminth species is indicated by the vertical bars

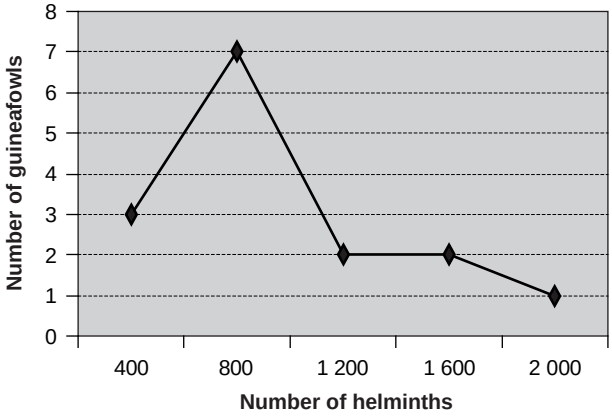

FIG. 2 The frequency distribution of the total number of helminths in individual Helmeted Guineafowls in Musina. Helminth burdens were grouped into size classes (0–400, 401–800, etc. to 2 000+ helminths per guineafowl) represented on the x-axis. The y-axis displays the number of guineafowls infected with a certain size class of helminth burdens

TABLE 2 Number of helminth species recovered from 15 Helmeted Guineafowls in Musina, Limpopo Province, South Africa

Host	Number of species			Total number of species
	Acanthocephalans	Cestodes	Nematodes	
GFM1	1	9	6	16
GFM2	1	7	4	12
GFM3	1	7	5	13
GFM4	1	7	4	12
GFM5	1	4	4	9
GFM6	1	5	6	12
GFM7	1	5	3	9
GFM8	1	5	6	12
GFM9	1	5	5	11
GFM10	1	5	2	8
GFM11	1	8	5	14
GFM12	1	6	5	12
GFM13	1	7	3	11
GFM14	1	5	5	11
GFM15	1	6	5	12
Average	1	6.1	4.5	11.6
SD	0	1.4	1.2	2.0
Range	1	5–9	2–6	8–16

TABLE 3 Pairwise Spearman's rank correlations for helminths in the small intestine of Helmeted guineafowls. Only species significantly correlated with at least one other species have been included. The correlation coefficients are displayed in the upper right corner of the matrix. The lower left half includes the respective p-values for each pair of species

	Core species					Secondary species				Satellite species
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1. *Mediorhynchus gallinarum*		**0.576***	–0.464	0.096	0.060	–0.202	0.198	–0.165	–0.042	–0.427
2. *Numidella numida*	**0.031***		**–0.662***	–0.570	–0.419	0.335	0.060	–0.282	–0.532	–0.457
3. *Octopetalum numida*	0.082	**0.010***		0.303	0.356	**–0.835***	**–0.895***	0.035	0.275	–0.587
4. *Ortleppolepis multiuncinata*	0.820	0.140	0.467		0.112	–0.664	–0.711	0.275	0.544	**–0.794***
5. *Raillietina pintneri*	0.860	0.228	0.347	0.811		–0.447	**–0.696***	0.156	0.170	–0.439
6. *Hymenolepis cantaniana*	0.528	0.463	**0.005***	0.150	0.267		0.105	**–0.782***	**–0.801**	0.800
7. *Porogynia paronai*	0.498	0.879	**<0.0001***	0.074	**0.025***	0.866		–0.446	**–0.817***	–0.112
8. *Raillietina angusta*	0.574	0.375	0.915	0.550	0.689	**0.022***	0.196		–0.383	**–0.810***
9. *Raillietina steinhardti*	0.092	0.113	0.474	0.343	0.717	**0.056**	**0.013***	0.349		**–0.846***
10. *Davainea nana*	0.146	0.255	0.010	**0.033***	0.276	0.200	0.811	**0.008***	**0.016***	

* Data pertaining to significantly correlated pairs ($P < 0.05$) are in bold and marked with an asterisk

8.6 % and satellite species made up 0.4 % of the total worm count.

Infracommunities in the Helmeted Guineafowls from Musina were moderately species rich, ranging from 8 to 16 species, with a mean number of 11.6 ± 2. Sixty percent of the hosts were infected with 12 or more species (Table 2, Fig. 1). The total number of helminths in individual guineafowls was highly aggregated and ranged from 66 to 2 724. In ten of the 15 hosts the intensity of infection was below 800 (Fig. 2), but three guineafowls had worm burdens of 1 457, 1 496 and 2 724 worms and when combined, these accounted for 48 % of the component parasite community. *Subulura suctoria*, which was by far the most common of all the helminths recovered, constituted 86, 74 and 81 % of the total worm load of the above three hosts.

Excluding *S. suctoria*, the acanthocephalans and cestodes, especially *O. numida* and *N. numida*, occurred in higher numbers than nematodes. *Cyrnea parroti*, *Gongylonema congolense*, *S. dentigera* and *Subulura* sp. were moderately abundant with occasional high numbers in individual hosts. The abundance of the remaining nematodes was low, ranging from one to six in single hosts.

The Wilcoxon rank sum test yielded no significant evidence of differences between male and female hosts or between the winter and spring season in respect of species richness.

Despite the group of five juvenile Helmeted Guineafowls including the two birds with the lowest number of helminth species, and three of the five birds harboured a lower than average number of helminths, no significant differences were found between the number of component species and overall abundance seen in juvenile versus adult hosts.

However, when the Wilcoxon rank sum test was performed at species level, some differences related to host age became apparent. Of the gizzard nematodes, the abundance of *C. parroti* was significantly higher in young guineafowls, averaging 26.4 ± 27.7, than in adults, in which the mean abundance was 7.5 ± 6.6 (P = 0.0312), and, although not statistically significant, the prevalence of *Hadjelia truncata* was twice as high in young birds than in older ones (80 % vs 40 %). Conversely, *Gongylonema congolense* from the crop was absent in young birds, but had a prevalence of 60 % in adult guineafowls. The abundance of this parasite was thus significantly higher in adults (P = 0.0451). Similarly, the cestode *Porogynia paronai* occurred in 70 % of the adult birds, but was not found in the juveniles. Therefore, its abundance was significantly lower in the latter hosts (P = 0.032). The abundance of *Subulura* sp. was significantly higher in juvenile birds than in adults (P = 0.0156).

The pairwise Spearman's rank correlation test yielded 11 significantly correlated species pairs in the small intestine, of which one was positive and 10 negative. The results are presented in Table 3. The gizzard nematodes, *C. parroti* and *H. truncata*, were positively correlated, whereas *S. dentigera* and *S. suctoria* from the caeca were negatively correlated. Both results were, however, not significant.

DISCUSSION

Helmeted Guineafowls are non-selective omnivores feeding on a large variety of dietary items that, among others, include arthropods. Saayman (1966) recovered a wide variety of prey taxa, namely Orthoptera (four families), Coleoptera (five families), Isoptera, Hemiptera, Lepidoptera, Hymenoptera, Diptera, Myriapoda and Araneida, from the crops of 36 Helmeted Guineafowls in the Eastern Cape Province.

Notwithstanding their being a sedentary species, the birds can cover a considerable distance during their daily forays (Del Hoyo, Elliot & Sargatal 1994). These characteristics and a well structured, complex alimentary canal are among the major host factors contributing to parasite community richness (Kennedy, Bush & Aho 1986). This might explain why, despite the harsh climatic conditions and the largely undiversified mopani (*Colophospermum mopane*) veld habitat of the study area (Acocks 1988), the helminth community of Helmeted Guineafowls from Musina is diverse. The inclusion of live food in their diet, up to 12 % of the annual total, but higher during the summer months when insects are abundant (Mentis, Poggenpoel & Maguire 1975), may also account for the dominance of helminths with an indirect life cycle in the guineafowls.

We attribute the low prevalence and intensity of *D. nana* and especially of *A. numidae* to the arid environment characteristic of the study area. *Ascaridia* spp. were also the only nematodes with a direct life cycle recovered from guineafowls by Verster & Ptasinska-Kloryga (1987). Their eggs are resistant and can survive for several months in suitable moist soil conditions (Anderson 1992), but these were certainly not met in the present study area. Furthermore, earthworms can harbour eggs and larvae, thus serv-

ing as paratenic hosts (Anderson 1992), but environmental conditions were not conducive for this route of transmission either. No information is available as to the intermediate hosts of *D. nana*, but we assume that they are similar to those used by the congeneric *Davainea proglottina*, namely snails and slugs (Anderson 1992). Little evidence of these invertebrates was seen in or around water troughs and one would not expect them to occur in large number under the prevailing conditions. Thus, despite the high numbers of available final hosts, the scarcity of intermediate hosts seems to limit these parasites.

Similarly, the absence of the trematode guild from the small intestine of the guineafowls appears to be related to the availability of intermediate hosts. Most digeneans are dependant on molluscs or very rarely an annelid intermediate host for completion of their life cycles (Gibbons, Jones & Khalil 1996). Hence, they are more frequently associated with an aquatic habitat. Hodasi (1969, 1976) concluded that trematodes were rare parasites in gallinaceous birds.

It is difficult to determine the host specificity of helminths, and whether a certain parasite is regarded as a specialist or a generalist is often subjective, especially as helminths which are specialists in a certain host can nevertheless occur in other, often related hosts (Bush 1990). Based on the host-parasite check list of guineafowls of Junker & Boomker (2007b), we consider the following helminths as generalists: *S. suctoria*, *G. congolense*, *H. truncata* and possibly *A. numidae* as well as the cestode *H. cantaniana* and the acanthocephalan *M. gallinarum*. Each of these has been reported from a variety of hosts.

Many of the remaining helminths collected during this study are currently recorded from the guineafowl genera *Numida* and/or *Guttera* only, such as the nematodes *S. dentigera* and *T. numida* or the cestodes *O. numida*, *Raillietina angusta*, *Raillietina pintneri* and *Raillietina steinhardti*. *Numidella numida* which is equally common in guineafowls in the USA was also found in turkeys and domestic chickens in that country. However, failure to experimentally infect the latter hosts with the parasite (Jones 1933) led Reid (1962) to believe that chickens and turkeys were not natural hosts. While *S. dentigera*, *T. numida*, *N. numida*, *O. numida*, *R. angusta*, *R. pintneri* and *R. steinhardti* would therefore seem to be specialists in guineafowls, this, at best tentative, classification might simply reflect a general lack of data and could well change as more information on other gamebirds, such as korhaans, bustards, francolins, spurfowls and quails, becomes available. In an environment where high temperatures combined with low rainfall jeopardize successful completion of helminth life cycles, spreading the risk of transmission between various final hosts would appear a more reliable way to assure high parasite survival rates than a specialist approach. We would therefore expect the generalists to outweigh the specialists.

Similarly, helminths collected from the guineafowls in this study use a wide range of intermediate hosts and are often not limited to a specific host or even host taxon. *Numidella numida*, for example, is reported to use ground and dung beetles as well as grasshoppers (Reid 1962), and the common nematode, *S. suctoria* makes use of coleopterans, dermapterans and orthopterans (Anderson 1992). This strategy of spreading the risk of transmission between several intermediate hosts, all serving as prey to the final host, might well explain the aforementioned helminths' success in colonizing their final hosts, resulting in a prevalence of 100% in *S. suctoria*, even under adverse environmental conditions. However, intermediate host data are usually very generalized in respect of the taxonomic status of the hosts. Hence, as more life cycle data become available especially elucidating parasite-intermediate host associations at species level, this picture of lack of specificity might change.

The aggregated pattern of dispersion seen in our data is common in parasite communities (Pielou 1974; Bush & Holmes 1986a, b; Alexander & McLaughlin 1997) and is a result of a number of factors, such as differences in the individual host's immune competence, feeding preferences and species specific host behaviour (Petney, Van Ark & Spickett 1990; Horak & Boomker 2000). Saayman (1966) demonstrated a pronounced difference in feeding-preferences between different members of the same guineafowl flock both in the amount of food consumed as well as the composition of crop contents. The higher the food intake and the higher the percentage of insect matter in the individual's diet, the higher the probability of ingesting an infected intermediate host and becoming infected.

A further reason for the aggregation of helminths in certain host individuals is the fact that a single infected guineafowl can excrete hundreds of nematode eggs in its faeces and a single tapeworm proglottid can contain hundreds of hexacanth larvae. Consequently, dung beetles, or other insects, feed-

ing on contaminated faeces or around contaminated patches can be exposed to large numbers of parasite eggs during a single meal. Reid (1962) records up to 50 cysticercoids of *N. numida* in infected intermediate hosts, up to 930 cysticercoids of *Skrjabinia cesticillus* were present in a single beetle, while dung beetles have been found to contain 100 or more cysticercoids of *H. cantaniana*. Thus the ingestion of a single infected intermediate host can lead to the presence of a large number of helminths in individual final hosts.

Nine core species were identified within the helminth community of Helmeted Guineafowls at Musina. The helminth infracommunity of a single Crested Guineafowl, *Guttera edouardi*, from a nearby locality examined by Junker & Boomker (2007a) suggests a considerable overlap between the two parasite communities. Nine helminth species were present in the Crested Guineafowl, of which seven are core species and two are secondary species in Helmeted Guineafowls. This can probably be attributed to much the same feeding habits, exposing them to a similar pool of intermediate arthropod hosts.

Core species are usually the first to appear in juvenile birds (Hair 1975) and our data reflect the high colonization ability of these species, in that their proportional density in juvenile birds was distinctly higher than that seen in the overall host population (60.6% vs 40.9%). In contrast, the percentage of secondary species in juvenile birds was 34.8% compared to 40.9% in the overall population, and satellite species averaged 4.6% in comparison with an overall average of 18.2%.

Pairwise Spearman's rank correlation detected 11 significant correlations between helminth species in the small intestine. Of these, the only significant positive correlation occurred between the acanthocephalan *M. gallinarum* and the cestode *N. numida*, in that their intensities increased or decreased in unison. Positive associations between species can be due to several factors, amongst others the use of a common intermediate host. In this case a positive association in the source community would merely be transferred to the target community and would not necessarily reflect an interaction of the two species in the final host (Lotz & Font 1994). As is the case with many of the other parasite species collected in our study, there is no data on the intermediate hosts used by *M. gallinarum* in South Africa. Its North American counterpart, *Mediorhynchus grandis*, however, has been reported to use several species of grasshoppers as intermediate hosts (Moore 1962), and grasshoppers also form part of the life cycle of *N. numida* (Mohler 1936; Reid 1962). Whether a source community is the origin of the positive correlation between these two species, or if one parasite indeed changes the habitat in the final host in such a way as to facilitate the colonization by the other, would necessitate experimental studies. Conversely, *N. numida* had a significant negative correlation with *O. numida*, which also uses orthopterans as intermediate hosts (Gwyun & Hamilton 1935), and *O. numida* was negatively, albeit not significantly so, correlated with *M. gallinarum*.

Another positive correlation, although not significant ($P = 0.0819$), was found between *C. parroti* and *H. truncata* in the gizzard. The few data available on their intermediate hosts suggest that these do not overlap. *Cyrnea parroti* has been reported from orthopteran intermediate hosts and *H. truncata* from beetles (Anderson 1992). Their positive correlation might be a result of the fact that both seem to make use of a window period during the development of their host in which the latter is more susceptible to infection (see below).

Negative correlations between species, where an increased intensity of the one leads to a decreased intensity of the other, may result from competition for resources such as carbohydrates or attachment sites (Smyth & McManus 1989). Or it could indicate that the presence of one species alters the habitat to such an extent that it is less suitable for the other. Smyth & McManus (1989) report a number of substances that are produced by *Hymenolepis diminuta* and which might act as inhibitory factors, producing a crowding effect. Moreover, the host's immune response triggered by a certain species could well make this host less susceptible to subsequent colonization by other parasites.

Some of the factors influencing parasite community patterns in other hosts seem to be of little importance in structuring the helminth communities of Helmeted Guineafowls. One of these is age. Moore, Freehling, Horton & Simberloff (1987) concluded that age can occasionally have an important influence on the prevalence and intensity of helminth infections of Bobwhite Quail, *Colinus virginianus* (Linnaeus, 1758), and Pence (1990) reported changes in host age over seasons to be one of the factors most frequently cited when discussing prevalence and intensity. However, in the present study neither overall abundance nor species richness in juvenile guineafowls differed significantly from those in adults.

In contrast, Crowe (1977) reported that juvenile Helmeted Guineafowls, i.e. birds younger than 10

months, from the Kimberley district, South Africa had significantly higher burdens of cestodes and acanthocephalans than adults, and Davies, Junker, Jansen, Crowe & Boomker (in preparation) found higher burdens of *S. suctoria*, *O. numida* and *M. gallinarum* in juveniles during a study on Helmeted Guineafowls in the Free State Province. Forrester, Conti, Bush, Campbell & Frohlich (1984) found no significance in the differences between the prevalence of helminth species in chick and adult bobwhites, but the intensity of infection of a single helminth species was higher in chicks than in adults. When studying the helminth communities in willets, *Tringa semipalmatus* (Gmelin, 1789) (= *Catoptrophorus semipalmatus*), both on their breeding grounds (freshwater) and in their wintering habitat (saltwater), Bush (1990) found young birds to be depauperate, but within the course of 2 weeks the diversity of their helminth communities increased considerably and, in the case of helminths with freshwater life cycles, at 3 months of age no longer differed from those of adult birds.

Several factors could influence the prevalence and intensity of helminths in guineafowls of different ages. Young birds might well be more susceptible to helminth infections when compared to adults, as has been suggested by a number of authors (Ackert & Reid 1937; Biester & Schwarte 1959; Soulsby, 1969). However, this would be counterbalanced by a time-dependant higher probability of previous exposure to infected intermediate hosts, and thus to the various parasites, in older birds, therefore evening out differences between different ages on component community level. On the other hand, it is well documented that the diet of juvenile Helmeted Guineafowls and other gamebirds consists of a larger percentage of arthropods than that of adults (Del Hoyo *et al*. 1994; Crowe 2000), increasing their exposure to possible intermediate hosts.

Some age-related differences on metapopulation level, i.e. when singling out certain parasite species from the Musina hosts, were observed. *Cyrnea parroti*, whose predilection site is under the lining of the gizzard, was significantly more abundant in juvenile birds. We observed a distinct hardening of the gizzard lining in adult guineafowls which was not nearly as pronounced in the younger birds and which could easily impede establishment of this parasite in older hosts. This phenomenon might also explain why the prevalence of *H. truncata*, using the same site, decreased from 80% in juveniles to only 40% in older guineafowls. Dogiel (1964) suggested that the normal development of a host, such as a thickening of skin, could result in a habitat being no longer suitable for the parasite, hence leading to resistance against the latter.

The same mechanism is obviously not in play with *G. congolense*, which lives in tunnels under the crop mucosa. While the observed thickening of the mucosa should make colonization with *G. congolense* more difficult with increasing host age, this parasite was not found in any of the younger birds, but was present in 60% of the older hosts. A possible explanation might be that *G. congolense* is only a secondary species indicating that its prevalence in the entire ecosystem is lower than that of a core species such as *C. parroti.* Consequently, age, if seen as an increase of the probability of prior exposure to a certain parasite with time, might have a more pronounced influence on the distribution pattern of this particular parasite. Using the same reasoning, one could expect the prevalence of *H. truncata*, also a secondary species, to increase in adult birds. As has been discussed this is not the case. However, the hardening of the crop mucosa never seems as pronounced as that of the gizzard's and, while the latter would seem likely to form a suitable barrier against the establishment of parasites, this is not necessarily so in the former.

Similarly to *C. congolense*, the cestode *P. paronai* had a significantly higher abundance in adult guineafowls, being absent in young birds. Little is known about the life cycle of this parasite except that it is one of the cestodes making use of sites other than the small intestine, in this case the bile ducts of guineafowls (Smyth & McManus 1989). Junker & Boomker (2007a) have reported immature stages of this parasite from the liver/bile ducts and adults from the small intestine of Helmeted Guineafowls. Whether morphological changes, such as the size of the bile ducts, or biochemical changes, such as the bile composition, during the ontogenesis of the guineafowl hosts in some way facilitate the migration and establishment of developing *P. paronai* has to remain speculation. On the other hand, a change in the prey preference in growing birds, possibly taking larger prey items not formerly included in the diet, may expose older guineafowls to a wider range of parasites.

The significantly higher abundance of *Subulura* sp. in juvenile birds can be attributed to the fact that the population of *Subulura* spp. in these hosts was mainly represented by infective larvae that do not yet display sufficient diagnostic characters to distinguish between the two species *S. dentigera* and *S.*

suctoria. We consider this a result of the fact that infections in the juvenile hosts had been recently acquired, thus comprising a high number of immatures, as opposed to the more mature infections found in older guineafowls.

Host gender was another determinant that had no significant influence on the distribution of worm burdens and species richness within the guineafowl population from Musina. Similar results were obtained by Crowe (1977), who attributed the absence of sexual variation in helminth infections to the fact that there is little behavioural or dietary difference between sexes outside the breeding season. All hosts in our and also Crowe's (1977) study were collected during the non-breeding season, extending from March to October in South Africa (Del Hoyo *et al*. 1994). Helmeted Guineafowls collected in the Free State Province during August 2007, however, showed sex related differences regarding the intensities of some helminths (Davies *et al*. in preparation). Possible reasons for this given by the latter authors are a difference in the length of the small intestine and caeca between males and females, as demonstrated by Prinsloo (2003), resulting in a larger habitat in the females. Moreover, females have a relatively higher intake of insects prior to breeding, which is often aided by the male's foraging for its mate (Hockey, Dean & Ryan 2005).

When discussing helminth communities in avian hosts, Bush (1990) concluded that host age and sex played a minor role, whereas the overall environment and habitat diversity therein exercised a major influence on the patterns of helminth communities. He argued that the latter would directly influence the "supply" of helminths available in the system. Keeping in mind that the current set of data was based on a limited number of hosts, and that a larger sample size might change the emerging picture, it nevertheless suggests that Helmeted Guineafowls are no exception to this general pattern.

ACKNOWLEDGEMENTS

We thank Dr W.J. Luus-Powell and Mr H.E. Hattingh, University of Limpopo, for providing logistic support to collect the guineafowls, and Mr K. Meyer and Mr M. Storm for making the latter available to us. Mr R. Watermeyer, University of Pretoria, is thanked for his assistance with the processing of the cestodes. Ms R. Owen, University of Pretoria, has greatly assisted with the statistical analyses. This study was made possible by a University of Pretoria Postdoctoral Fellowship grant to the first author.

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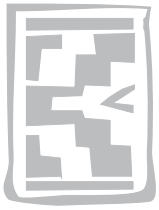
Onderstepoort Journal of Veterinary Research, 74:315–337 (2007)



A check list of the helminths of guineafowls (Numididae) and a host list of these parasites

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ABSTRACT

JUNKER, K. & BOOMKER, J. 2007. A check list of the helminths of guineafowls (Numididae) and a host list of these parasites. *Onderstepoort Journal of Veterinary Research*, 74:315–337

Published and personal records have been compiled into a reference list of the helminth parasites of guineafowls. Where data on other avian hosts was available these have been included for completeness' sake and to give an indication of host range. The parasite list for the Helmeted guineafowls, *Numida meleagris*, includes five species of acanthocephalans, all belonging to a single genus, three trematodes belonging to three different genera, 34 cestodes representing 15 genera, and 35 nematodes belonging to 17 genera. The list for the Crested guineafowls, *Guttera edouardi*, contains a single acanthocephalan together with 10 cestode species belonging to seven genera, and three nematode species belonging to three different genera. Records for two cestode species from genera and two nematode species belonging to a single genus have been found for the guineafowl genus *Acryllium*. Of the 70 helminths listed for *N. meleagris*, 29 have been recorded from domestic chickens.

Keywords: Acanthocephalans, cestodes, check list, guineafowls, host list, nematodes, trematodes

INTRODUCTION

Guineafowls (Numididae) originated on the African continent, and with the exception of an isolated population of Helmeted guineafowls in north-west Morocco, their natural distribution is restricted to sub-Saharan Africa (Del Hoyo, Elliott & Sargatal 1994). In the wake of commercial game bird farming, but also as ornamental birds in aviculture, they have been introduced to many other parts of the world, such as France, Hungary, Italy, Greece, the United Kingdom, the USA, Australia and different regions of the former USSR (Haziev & Khan 1991). According to Belshaw (1985) guineafowls were imported into the southern Mediterranean region several millennia before turkeys and hundreds of years before junglefowls from which today's domestic chickens were derived. Currently four genera of guineafowls are recognized, namely *Acryllium* Gray, 1840, *Agelastes* Bonaparte, 1850, *Guttera* Wagler, 1832 and *Numida* Linnaeus, 1766 (Del Hoyo *et al.* 1994).

Many publications on the helminth fauna of guineafowls originate from northern and western Africa, where, second only to the introduced and native domestic fowls, they are farm-reared as a source of protein. The economic importance of guineafowls and domestic fowls within the poultry industry, as well as the fact that domestic fowls are kept by many private households to augment their income, necessitated a better understanding of factors, such as gastro-intestinal parasites, influencing the success-

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Accepted for publication 9 May 2007—Editor

ful rearing of these birds. Consequently studies have been conducted to assess the extent to which guineafowls and domestic fowls can serve as alternative hosts for their respective helminths and possibly be adversely affected by them (Hodasi 1969, 1976; Fabiyi 1972; Fatunmbi & Olufemi 1982; Vercruysse, Harris, Bray, Nagalo, Pangui & Gibson 1985).

In southern Africa Ortlepp (1937, 1938a, b, 1963), Saayman (1966), Crowe (1977) and Verster & Ptasinska-Kloryga (1987) have published on the helminth fauna of guineafowls. No data on the helminths infecting species of the guineafowl genus *Agelastes* could be found, and we are of the opinion that the comparatively short parasite lists for the genera *Acryllium* and *Guttera* reflect a lack of data rather than an absence of parasites.

The check list herein is intended as a quick reference aid and is split into two sections. The first section contains the parasites listed under their scientific names and authorities. Synonyms are provided either as generic synonyms in the case where whole genera have been synonymized or specific synonyms. The second section lists the hosts and their synonyms alphabetically, together with their respective parasites, also in alphabetical order.

The synonymy of the acanthocephalan genus *Mediorhynchus* Van Cleave 1916 is as given by Van Cleave (1947) and Schmidt & Kuntz (1977) and specific synonymy is according to Yamaguti (1963). For an in-depth review of the involved history of this genus's nomenclature the reader is referred to Van Cleave (1947).

The taxonomy of digenean trematodes follows Yamaguti (1958), but since the application of molecular techniques to this group has recently led to many changes, the reader is encouraged to consult the latest literature.

The classification of cestodes is based on the works of Khalil, Jones & Bray (1994). Information on generic synonyms and type species follows Khalil *et al.* (1994), while that on other species as well as the hosts and geographic distribution has mainly been derived from Yamaguti (1959), Schmidt (1986) and additional published records.

As regards nematode taxonomy, the authors have followed the CIH Keys to the nematode parasites of vertebrates (Anderson, Chabaud & Willmott, 1974–1983) and, where differences have occurred, have accepted the validity of genera and species as listed by Gibson (2005). With regard to generic synonyms, only synonyms listed in the CIH keys and by Gibson (2005) have been included in the check list. Specific synonyms, Type species and other species, as well as much of the data on hosts and geographic distribution are according to Yamaguti (1961) and Gibson (2005). Host and geographic data have been supplemented by including additional literature references.

The families and subfamilies of cestodes and nematodes are listed according to the system of Khalil *et al*. (1994) and the CIH Keys, respectively, but genera within these families are presented in alphabetical order. Synonyms have been arranged chronologically. The hosts and geographic localities per author are listed alphabetically. If several authors made reference to the same host, the authors are listed in chronological order.

The nomenclature and taxonomy of the avian hosts mainly follows Peterson (1999) and has been supplemented by Lepage (2007). Avian orders and families, as well as the nomenclature of southern African hosts follow Hockey, Dean & Ryan (2005).

In order to avoid excessive duplication, Helmeted guineafowls are listed below as *N. meleagris* only without regards to the subspecies. A total of nine subspecies of *N. meleagris* are currently recognized (Del Hoyo *et al.* 1994, Peterson 1999). These are: *N. m. coronatus* Gurney, 1868, *N. m. galeatus* Pallas, 1767, *N. m. marungensis* Schalow, 1884, *N. m. meleagris* (Linnaeus, 1758), *N. m. mitratus* Pallas, 1767, *N. m. papillosus* Reichenow, 1894, *N. m. reichenowi* Ogilvie-Grant, 1894, *N. m. sabyi* Hartert, 1919 and *N. m. somaliensis* Neumann, 1899. Del Hoyo *et al*. (1994) give a detailed list of the geographic range of the various subspecies of Helmeted guineafowls.

In the case of the Crested guineafowls, *Guttera edouardi* (Hartlaub, 1867) we follow Hockey *et al.* (2005) and Lepage (2007). Crowe (1978, cited in Hockey *et al.* 2005) had synonymized *G. edouardi* with *Guttera pucherani* (Hartlaub, 1861), but this decision was reversed and *G. edouardi* reinstated (Little & Crowe 2000, cited in Hockey *et al.* 2005). Peterson (1999) still lists *G. edouardi* as a subspecies of *G. pucherani*.

Hosts listed in the literature as *Gallus domesticus* or *Gallus gallus domesticus* are referred to below as domestic chicken. Lepage (2007) lists domestic chicken as unconfirmed subspecies, *G. g. domesticus* (no authority given), of the Red Junglefowl, *Gallus gallus* (Linnaeus, 1758). However, this subspecies is not included in the five subspecies listed by Peterson (1999).

PARASITE/HOST CHECK LIST

PHYLUM ACANTHOCEPHALA

Class Archiacanthocephala

Order Gigantorhynchidea

Family GIGANTORHYNCHIDAE Hamann, 1892

GENUS *MEDIORHYNCHUS* VAN CLEAVE 1916

Echinorhynchus Zoega in Müller, 1776, in part; *Gigantorhynchus* Hamann,1892, in part; *Heteroplus* Kostylev, 1914; *Empodius* Travassos, 1916; *Micracanthorhynchus* Travassos, 1917; *Leiperacanthus* Bhalerao, 1937; *Disteganius* Lehmann, 1953, *nomen nudum; Empodisma* Yamaguti, 1963

Type species: *Mediorhynchus papillosus* Van Cleave, 1918

1. *Mediorhynchus empodius* (Skrjabin, 1913) Meyer, 1933

   Ardea, Ardeotis arabs, Numida meleagris
   Yamaguti (1963), Belgium, Russia

2. *Mediorhynchus gallinarum* (Bhalerao, 1937) Van Cleave, 1947

   Domestic chicken
   Yamaguti (1963), India, Philippines
   Talbot (1971), Papua and New Guinea

   Gallinaceaous birds
   Schmidt & Kuntz (1977), (East-) Africa, India, Papua and New Guinea, Philippines

   Numida meleagris
   Junker & Boomker (2006), South Africa

3. *Mediorhynchus numidae* (Baer, 1925) Meyer, 1933

   Numida meleagris
   Meyer (1932), Namibia
   Oosthuizen & Markus (1967), South Africa

4. *Mediorhynchus selengensis* Harris, 1973

   Numida meleagris
   Vercryusse *et al.* (1985), Burkina Faso
   Schmidt & Kuntz (1977) synonymized this species with *M. gallinarum*.

5. *Mediorhynchus taeniatus* (Von Linstow, 1901) Dollfus, 1936

   Empodius segmentatus De Marval, 1902

   Ardeotis arabs
   Dollfus (1951) in Yamaguti (1963), Mauritania

   Chlamydotis undulata
   Dollfus (1951) in Yamaguti (1963), Morocco

   Guttera edouardi
   Southwell & Lake (1939), Democratic Republic of the Congo

   Numida meleagris
   Von Linstow (1901), Kenya
   Meyer (1932), Africa, Malawi
   Southwell & Lake (1939), Democratic Republic of the Congo
   Graber (1959), Chad
   Fabiyi (1972), Nigeria
   Hodasi (1976), Ghana
   Crowe (1977), South Africa

   Burhinus oedicnemus, *Chlamydotis macquenii*, *Otis tarda*
   Meyer (1932), Africa, Malawi

PHYLUM PLATHYHELMINTHES

Class Trematoda

Order Digenea

Family BRACHYLAEMIDAE Joyeaux & Foley, 1930

GENUS *POSTHARMOSTOMUM* WITENBERG, 1923

Type species: *Postharmostomum gallinum* (Witenberg, 1923)

1. *Postharmostomum gallinum* (Witenberg, 1923)

   Crested guineafowl
   Khan, Khan & Rayaz (1984), Pakistan

   Domestic chicken
   Yamaguti (1958), Hawaii, Japan, Russian Turkestan

   Numida meleagris
   Yamaguti (1958), North Africa

Family DICROCOELIIDAE Odhner, 1911

GENUS *DICROCOELIUM* DUJARDIN, 1845

Type species: *Dicrocoelium lanceatum* Stiles & Hassal, 1898

1. *Dicrocoelium macrostomum* Odhner, 1911

   Coturnix coturnix
   Yamaguti (1958), Russia

   Numida meleagris
   Lesbouyries (1941), Egypt
   Junker & Boomker (2007b), South Africa

GENUS *LUTZTREMA* TRAVASSOS, 1941

Type species: *Lutztrema olliquum* (Travassos, 1917)

Numida meleagris
Hodasi (1976), Ghana

Class Cestoda

Subclass Eucestoda

Order Cyclophyllidea

Family DAVAINEIDAE Braun, 1900

Subfamily Davaineinae Braun, 1900

GENUS *ABULADZUGNIA* SPASSKII, 1973

Type species: *Abuladzugnia gutterae* (Ortlepp, 1963)

1. *Abuladzugnia gutterae* (Ortlepp, 1963)

   Cotugnia gutterae Ortlepp, 1963

   Guttera edouardi
   Ortlepp (1963), Mozambique

   Numida meleagris
   Junker & Boomker (2007b), South Africa

2. *Abuladzugnia transvaalensis* (Ortlepp, 1963)

Cotugnia transvaalensis Ortlepp, 1963

Numida meleagris
Ortlepp (1963), South Africa

Genus *Cotugnia* Diamare, 1893

Ershovitugnia, Spasskii, 1973; *Pavugnia* Spasskii, 1984; *Rostelugnia* Spasskii, 1984

Type species: *Cotugnia digonopora* (Pasquale, 1890) Diamare, 1893

1. *Cotugnia crassa* Fuhrmann, 1909

Guineafowl
Hudson (1934), East Africa
Bwangamoi (1968), Uganda

Numida meleagris
Fuhrmann (1909) in Ortlepp (1963), the White Nile
Baer (1925), Namibia
Baer (1926), East Africa, West Africa
Ortlepp (1963), Tanzania

The White Nile rises from Lake Victoria in Uganda and enters the Sudan where it joins the Blue Nile in Karthoum to form the Nile. White Nile is one of the states of Sudan.

2. *Cotugnia digonopora* (Pasquale, 1890) Diamare, 1893

Taenia digonopora Pasquale, 1890

Anser, *Columba livia*, *Gallus gallus*, *Numida meleagris*
Schmidt (1986), Africa, Burma, India, Indonesia, Philippines

Guineafowl
Baylis (1934), Uganda

3. *Cotugnia meleagridis* Joyeux, Baer & Martin, 1936

Numida meleagris
Joyeux, Baer & Martin (1936), Northern Somaliland
Graber (1959), Chad
Fabiyi (1972), Nigeria
Hodasi (1976), Ghana

4. *Cotugnia shohoi* Sawada, 1971

Acryllium vulturinum
Schmidt (1986), Somalia

5. *Cotugnia tuliensis* Mettrick, 1963

Numida meleagris
Schmidt (1986), Zimbabwe

Genus *Davainea* Blanchard, 1891

Type species: *Davainea proglottina* (Davaine, 1860) Blanchard, 1891

1. *Davainea nana* Fuhrmann, 1912

Guttera edouardi
Ortlepp (1963), Zambia

Numida meleagris
Fuhrmann (1912), Northern Africa
Junker & Boomker (2007b), South Africa

Vanellus cinereus
Schmidt (1986), Africa, Japan

2. *Davainea paucisegmentata* Fuhrmann, 1909

Numida meleagris
Baer (1926), Sudan, West Africa
Schmidt (1986), Africa, Europe

3. *Davainea paucisegmentata* var. *dahomeensis* Joyeux & Baer, 1928

Numida meleagris
Schmidt (1986), France

4. *Davainea proglottina* (Davaine, 1860) Blanchard, 1891

Taenia proglottina Davaine, 1860; *Davainea varians* Sweet, 1910; *Davainea dubius* Meggitt, 1916

Alectoris graeca, *Bonasa umbellus*, *Gallus gallus*, *Perdix perdix*
Schmidt (1986), Cosmopolitan

Domestic chicken
Baer (1926), South Africa
Magwisha, Kassuku, Kyvsgaard & Permin (2002), Tanzania

Numida meleagris
Nfor, Ajanusi, Agbede & Esievo (1999), Nigeria

Genus *Numidella* Spasskaya & Spasskii, 1971

Type species: *Numidella numida* (Fuhrmann, 1912) Spasskaya & Spasskii, 1971

1. *Numidella numida* (Fuhrmann, 1912) Spasskaya & Spasskii, 1971

Davainea numida Fuhrmann, 1912; *Raillietina* (*Paroniella*) *numida* (Fuhrmann, 1912) Fuhrmann, 1920; *Raillietina* (*Paroniella*) *magninumida* Jones, 1930

Guineafowl
Baylis (1934), Uganda

Guttera, *Numida meleagris*
Schmidt (1986), Africa, Cuba, North America

Guttera
Baer (1933), Zimbabwe

Baer (1933) lists '*Guttera eduardi* Elliot' as host. None of the subspecies of *Guttera edouardi* listed in Lepage (2007) has been described by Elliot, but Lepage (2007) lists *Guttera pucherani verreauxi* (Elliot, 1870).

Meleagris gallopavo, *Numida meleagris*
Jones (1930), North America

Numida meleagris
Baer (1925), Namibia
Ortlepp (1963), South Africa
Fabiyi (1972), Nigeria

Genus *Porogynia* Railliet & Henry, 1909

Polycoelia Fuhrmann, 1907, preoccupied

Type species: *Porogynia paronai* (Moniez, 1892) Railliet & Henry, 1909

1. *Porogynia paronai* (Moniez, 1892) Railliet & Henry, 1909

Taenia paronai Moniez, 1892; *Linstowia lata* Fuhrmann, 1901; *Polycoelia lata* (Fuhrmann, 1901) Fuhrmann, 1907; *Malika numida* Woodland, 1929; *Raillietina* (*Paroniella*) *woodlandi* Baylis, 1934

Guttera edouardi, *Numida meleagris*, *Pternistis natalensis*
Schmidt (1986), Africa, Europe

Guineafowl
Woodland (1928), Sudan
Baylis (1934), Uganda

Guttera edouardi
Ortlepp (1963), Zambia

Numida meleagris
Baer (1925), Namibia
Baer (1926), East Africa, West Africa
Woodland (1928), Sudan
Ortlepp (1963), South Africa, Swaziland
Cruz e Silva (1971), Mozambique
Fabiyi (1972), Nigeria

GENUS *RAILLIETINA* FUHRMANN, 1920

Kotlania López-Neyra, 1929; *Nonarmiella* Movsesyan, 1966; *Nonarmina* Movsesyan, 1966; *Kotlanotaurus* Spasskii, 1973; *Roytmania* Spasskii, 1973; *Skrjabinotaurus* Spasskii & Yurpalova, 1973; *Oschmarinetta* Spasskii, 1984

Type species: *Raillietina tetragona* (Molin, 1858)

1. *Raillietina angusta* Ortlepp, 1963

Raillietina (*Raillietina*) *angusta* Ortlepp, 1963

Numida meleagris
Ortlepp (1963), South Africa

2. *Raillietina cohni* (Baczynska, 1914) Fuhrmann, 1924

Davainea cohni Baczynska, 1914; *Raillietina* (*Ransomia*) *cohni* (Baczynska, 1914) Fuhrmann, 1920; *Raillietina* (*Raillietina*) *cohni* (Baczynska, 1914) Fuhrmann, 1924

Gallus gallus, *Numida meleagris, Pterocles exustus*, *Pterocles orientalis arenarius*
Schmidt (1986), Africa, Nepal

Domestic chicken
Baer (1926), East Africa

3. *Raillietina echinobothrida* (Megnin, 1880) Fuhrmann, 1924

Taenia echinobothrida Megnin, 1880; *Taenia botrioplites* Piana, 1881; *Davainea parechinobothrida* Magalhães, 1898; *Davainea penetrans* Baczynska, 1914; *Raillietina* (*Johnstonia*) *echinobothrida* (Megnin, 1880) Fuhrmann, 1920; *Raillietina* (*Raillietina*) *echinobothrida* (Megnin, 1880) Fuhrmann, 1924; *Raillietina* (*Fuhrmannetta*) *echinobothrida* (Megnin, 1880) Stiles & Orleman, 1926

Columba livia, *Gallus gallus*, *Gallus gallus bankiva*, *Meleagris gallopavo*, *Numida meleagris*, *Perdix perdix*, *Phasianus colchicus*
Schmidt (1986), Cosmopolitan

Domestic chicken
Baer (1926), West Africa
Le Roux (1926), South Africa
Joyeux *et al.* (1936), Northern Somalia
Poulsen, Permin, Hindsbo, Yelifari, Nansen & Bloch (2000), Ghana
Magwisha *et al.* (2002), Tanzania
Permin, Esmann, Hoj, Hove & Mukaratirwa (2002), Zimbabwe

Gallus gallus bankiva
Baer (1933), Zimbabwe

Numida meleagris
Baer (1933), Zimbabwe
Southwell & Lake (1939), Democratic Republic of the Congo
Cruz e Silva (1971), Mozambique
Ayeni, Dipeolu & Okaeme (1983), Nigeria

4. *Raillietina pintneri* (Klaptocz, 1906) Fuhrmann, 1924

Davainea pintneri Klaptocz, 1906; *Raillietina* (*Ransomia*) *pintneri* (Klaptocz, 1906) Fuhrmann, 1920; *Raillietina* (*Raillietina*) *pintneri* (Klaptocz, 1906) Fuhrmann 1924; *Kotlania pintneri* (Klaptocz, 1906) López-Neyra, 1931

Guttera
Baer (1933), Zimbabwe
Baer (1933) lists '*Guttera eduardi* Elliot' as host. None of the subspecies of *Guttera edouardi* listed in Lepage (2007) have been described by Elliot, but Lepage (2007) lists *Guttera pucherani verreauxi* (Elliot, 1870).

Guttera edouardi, *Numida meleagris*
Schmidt (1986), Africa

Guttera edouardi
Ortlepp (1963), Mozambique, Zambia

Numida meleagris
Baer (1925), Namibia
Baer (1926), Sudan, West Africa
Graber (1959), Chad
Ortlepp (1963) South Africa, Swaziland
Fabiyi (1972), Nigeria

5. *Raillietina somalensis* Sawada, 1971

Raillietina (*Raillietina*) *somalensis* Sawada, 1971

Acryllium vulturinum
Schmidt (1986), Somalia

6. *Raillietina steinhardti* Baer, 1925

Raillietina (*Ransomia*) *steinhardti* Baer, 1925

Guttera edouardi
Ortlepp (1963), Mozambique, Zambia

Numida meleagris
Yamaguti (1959), Africa
Verster & Ptasinska-Kloryga (1987), South Africa

7. *Raillietina tetragona* (Molin, 1858) Fuhrmann, 1924

Taenia tetragona Molin, 1858; *Taenia longicollis* Molin, 1858; *Davainea tetragona* (Molin, 1858) Blanchard, 1891; *Davainea bothrioplitis* Fillippi, 1892; *Raillietina* (*Ransomia*) *tetragona* (Molin, 1858) Fuhrmann, 1920; *Raillietina (Raillietina) tetragona* (Molin, 1858) Fuhrmann, 1924; *Kotlania tetragona* (Molin, 1858) López-Neyra, 1931; *Raillietina* (*Raillietina*) *galli* (Yamaguti, 1935) Sawada, 1955

Gallus gallus, *Guttera edouardi*, *Lagopus lagopus*, *Lagopus muta*, *Meleagris gallopavo*, *Numida meleagris*, *Pavo cristatus*, *Pavo muticus*
Schmidt (1986), Cosmopolitan

Domestic chicken
Baer (1926), East Africa, West Africa
Le Roux (1926), South Africa
Poulsen *et al.* (2000), Ghana

Magwisha *et al.* (2002), Tanzania
Permin *et al.* (2002), Zimbabwe

Numida meleagris
Baer (1926), East Africa, West Africa
Ayeni *et al.* (1983), Nigeria
Haziev & Khan (1991), Republic of Bashkortostan

8. *Raillietina tetragonoides* (Baer, 1925) Fuhrmann, 1932

Raillietina (*Ransomia*) *tetragonoides* Baer, 1925; *Raillietina* (*Raillietina*) *tetragonoides* (Baer, 1925) Fuhrmann, 1932; *Raillietina* (*Raillietina*) *tetragona* var. *cohni* (Baczynska, 1914) López-Neyra, 1944

Numida meleagris
Baer (1925), Namibia
Schmidt (1986), Africa

9. *Raillietina toyohashiensis* Sawada & Chikada, 1972

Numida meleagris
Schmidt (1986), Japan (zoo)

GENUS *SKRJABINIA* FUHRMANN, 1920

Raillietina (*Skrjabinia*) Fuhrmann, 1920; *Brumptiella* López-Neyra, 1929; *Armacetabulum* Movsesyan, 1966; *Markewitchella* Spasskii & Spasskaya, 1972; *Daovantienia* Spasskii & Spasskaya, 1976

Type species: *Skrjabinia cesticillus* (Molin, 1858) Fuhrmann, 1920

1. *Skrjabinia cesticillus* (Molin, 1858) Fuhrmann, 1920

Taenia cesticillus Molin, 1858; *Davainea cesticillus* Blanchard, 1891; *Raillietina (Raillietina) mutabilis* Rüther, 1901; *Raillietina* (*Skrjabinia*) *cesticillus* (Molin, 1858) Fuhrmann, 1920

Colinus virginianus, *Coturnix coturnix*, *Gallus gallus*, *Lagopus lagopus*, *Lagopus lagopus scotica*, *Lyrurus tetrix*, *Meleagris gallopavo*, *Numida meleagris*, *Perdix perdix*, *Phasianus colchicus*, *Tetrao urogallus*, *Tetrastes bonasia*
Schmidt (1986), Cosmopolitan

Domestic chicken
Baer (1926), West Africa
Le Roux (1926), South Africa
Joyeux *et al.* (1936), Northern Somalia
Poulsen *et al.* (2000), Ghana
Magwisha *et al.* (2002), Tanzania
Permin *et al.* (2002), Zimbabwe

Numida meleagris
Nfor *et al.* (1999), Nigeria

2. *Skrjabinia deweti* Ortlepp, 1938

Numida meleagris
Ortlepp (1938a), South Africa

Subfamily Idiogeninae Fuhrmann, 1907

GENUS *IDIOGENES* KRABBE, 1867

Ersinogenes Spasskaya, 1961; *Paraidiogenes* Movsesyan, 1971

Type species: *Idiogenes otidis* Krabbe, 1867

1. *Idiogenes* sp.

Numida meleagris
Hodasi (1976), Ghana

Family DILEPIDIDAE Railliet & Henry, 1909

GENUS *CHOANOTAENIA* RAILLIET, 1896

Type species: *Choanotaenia infundibulum* (Bloch, 1779) Railliet, 1896

1. *Choanotaenia infundibulum* (Bloch, 1779) Railliet, 1896

Taenia infundibulum Bloch, 1779

Domestic chicken
Poulsen *et al.* (2000), Ghana
Magwisha *et al.* (2002), Tanzania

Numida meleagris
Haziev & Khan (1991), Republic of Bashkortostan
Nfor *et al.* (1999), Nigeria

Family PARUTERINIDAE Fuhrmann, 1907

GENUS *OCTOPETALUM* BAYLIS, 1914

Type species: *Octopetalum gutterae* Baylis, 1914

1. *Octopetalum gutterae* Baylis, 1914

Ascometra gutterae (Baylis, 1914) Baer,1955

Guttera edouardi, *Numida meleagris*
Baer (1926), East Africa
Baer (1955), Democratic Republic of Congo, Malawi, South Africa
Schmidt (1986) Africa, France

2. *Octopetalum numida* (Fuhrmann, 1909) Baylis, 1914

Rhabdometra numida Fuhrmann, 1909; *Octopetalum longicirrosum* Baer, 1925; *Unciunia sudanea* Woodland, 1928; *Ascometra numida* (Fuhrmann, 1909) Baer, 1955

Guineafowl
Baylis (1934), Uganda

Guttera edouardi
Baer (1955), Sub-Saharan Africa
Ortlepp (1963), South Africa, Zambia

Numida meleagris
Baer (1925), Namibia
Baer (1926), Sudan, West Africa
Woodland (1928), Sudan
Baer (1955), Sub-Saharan Africa
Ortlepp (1963), Central Africa, North Africa, South Africa, southern Africa, Swaziland
Fabiyi (1972), Nigeria
Hodasi (1976), Ghana

GENUS *METROLIASTHES* RANSOM, 1900

Hexaparuterina Palacios & Barroeta, 1967

Type species: *Metroliasthes lucida* Ransom, 1900

1. *Metroliasthes lucida* Ransom, 1900

Alectoris graeca, *Alectoris rufa*, *Coturnix coturnix*, *Gallus gallus*, *Gallus gallus bankiva*, *Guttera edouardi*, *Meleagris gallopavo*, *Numida meleagris*, *Perdix perdix*
Schmidt (1986), Africa, Australia, Europe, India, North and South America, Russia

Numida meleagris
Southwell & Lake (1939), Democratic Republic of Congo

Family HYMENOLEPIDIDAE Ariola, 1899

Subfamily Hymenolepidinae Perrier, 1897

GENUS *ECHINOLEPIS* SPASSKII & SPASSKAYA, 1954

Type species: *Echinolepis carioca* (Maghalães, 1898) Spasskii & Spasskaya, 1954

1. *Echinolepis carioca* (Maghalães, 1898) Spasskii & Spasskaya, 1954

   Davainea carioca Maghalães, 1898; *Taenia conardi* Zürn, 1898; *Hymenolepis carioca* (Maghalães, 1898) Ransom, 1902; *Hymenolepis pullae* Cholodkovsky, 1913; *Weinlandia rustica* Meggitt, 1926; *Hymenolepis rustica* Fuhrmann, 1932; *Dicranotaenia carioca* (Maghalães, 1898) Skrjabin & Mathevossian, 1945; *Dicranotaenia rustica* (Meggitt, 1926) Skrjabin & Mathevossian, 1945

   Alectoris graeca, *Bonasa umbellus*, *Colinus virginianus*, *Coturnix coturnix*, *Gallus gallus*, *Meleagris gallopavo*
   Schmidt (1986), Cosmopolitan

   Domestic chicken
   Le Roux (1926), South Africa
   Magwisha *et al.* (2002), Tanzania

   Numida meleagris
   Baer (1926), West Africa

GENUS *HYMENOLEPIS* WEINLAND, 1858

Triorchis Clerc, 1903 preoccupied; *Cloacotaenia* Wolffhügel, 1938; *Amphipetrovia* Spasskii & Spasskaya, 1954; *Australiolepis* Spasskii & Spasskaya, 1954; *Orlovilepis* Spasskii & Spasskaya, 1954; *Staphylepis* Spasskii & Oshmarin, 1954; *Arhynchotaenia* Saakova, 1958 *nec* Pagenstecher, 1877; *Schmelzia* Yamaguti, 1959; *Woodlandia* Yamaguti, 1959; *Arhynchotaeniella* Schmidt, 1986; *Cloacotaeniella* Schmidt, Bauerle & Wertheim, 1988; *Amazilolepis* Schmidt & Daily, 1992

Type species: *Hymenolepis diminuta* (Rudolphi, 1819) Weinland, 1858

1. *Hymenolepis cantaniana* (Polonio, 1860) Ransom, 1909

   Taenia cantaniana Polonio, 1860; *Davainea oligophora* Maghalães, 1898; *Davainea cantaniana* Railliet & Lucet, 1899; *Hymenolepis inermis* (Yoshida, 1910) Fuhrmann, 1932

   Colinus virginianus, *Coturnix coturnix*, *Gallus gallus*, *Meleagris gallopavo*, *Numida meleagris*, *Pavo cristatus*, *Perdix perdix*, *Phasianus colchicus*, *Tetrao parvirostris*, *Tetrastes bonasia*, *Turnix suscitator*
   Schmidt (1986), Cosmopolitan

   Domestic chicken
   Le Roux (1926), South Africa
   Magwisha *et al.* (2002), Tanzania

   Le Roux (1926) chose to retain the name *H. inermis* for his unarmed specimens and not to accept the synonymy of *H. inermis* and *H. cantaniana* since the latter had been described as having an armed rostellum.

   Numida meleagris
   Hodasi (1976), Ghana
   Junker & Boomker (2007b), South Africa

GENUS *HISPANIOLEPIS* LÒPEZ-NEYRA, 1942

Satyolepis Spasskii, 1965

Type species: *Hispaniolepis villosa* (Bloch, 1782) López-Neyra, 1942

1. *Hispaniolepis falsata* (Meggitt, 1927) López-Neyra, 1942

   Hymenolepis falsata Meggitt, 1927.

   Numida meleagris
   Myers, Wolfgang & Kuntz (1960), Sudan

   Chlamydotis undulata
   Schmidt (1986), Egypt

2. *Hispaniolepis fedtschenkoi* (Solowiow, 1911) López-Neyra, 1942

   Hymenolepis fedtschenkoi Solowiow, 1911; *Hymenolepis gwiletica* Dinnik, 1938

   Gallus gallus, *Lyrurus tetrix*, *Numida meleagris*, *Tetraogallus himalayensis*, *Tetraogallus caucasicus*, *Tetrastes bonasia*
   Schmidt (1986), Russia, Europe, Asia, Africa

3. *Hispaniolepis hilmyi* (Skrjabin & Mathevossian, 1942) López-Neyra, 1942

   Hymenolepis tetracis Hilmy, 1936

   Numida meleagris
   Schmidt (1986), Liberia

4. *Hispaniolepis villosa* (Bloch, 1782) López-Neyra, 1942

   Numida meleagris
   Baer (1926), East Africa

GENUS *ORTLEPPOLEPIS* SPASSKII, 1965

Type species: *Ortleppolepis multiuncinata* (Ortlepp, 1963) Spasskii, 1965

1. *Ortleppolepis multiuncinata* (Ortlepp, 1963) Spasskii, 1965

   Hispaniolepis multiuncinata Ortlepp, 1963

   Guttera edouardi
   Ortlepp (1963), Zambia

   Numida meleagris
   Junker & Boomker (2007b), South Africa

PHYLUM NEMATHELMINTHES

Class Nematoda

Subclass Adenophorea

Order Enoplida

Superfamily Trichinelloidea Hall, 1916

Family TRICHURIDAE (Ransom, 1911) Railliet, 1915

Subfamily Capillariinae Railliet, 1915

GENUS *AONCHOTHECA* LÓPEZ-NEYRA, 1947

Avesaonchotheca auct.; *Baruscapillaria* auct.; *Capillaria* auct.; *Pterothomix* auct.; *Skrjabinocapillaria* Skarbilovich, 1946

1. *Aonchotheca caudinflata* (Molin, 1858)

Calodium caudinflata Molin, 1858; *Capillaria blomei* Travassos, 1915; *Trichosoma longicollis* Rudolphi, 1819

Chrysolophus, *Columba*, *Coturnix*, *Gallus*, *Lagopus*, *Lyrurus*, *Otis*, *Numida meleagris*, *Passer*, *Perdix*, *Phasianus*, *Sturnus*, *Tetrao*, *Turdus*
Yamaguti (1961), Europe, North America

Yamaguti (1961) lists *Aonchotheca caudinflata* from *Otis* without giving the host's species name. It is therefore not clear whether *Otis* refers to the current genus *Otis*, *Ardeotis*, *Neotis* or *Chlamydotis*.

Domestic chicken
Magwisha *et al.* (2002), Tanzania

Numida meleagris
Ayeni *et al*. (1983), Nigeria

GENUS *CAPILLARIA* ZEDER, 1800

Trichosoma Rudolphi, 1819; *Trichosomum* Creplin, 1829; *Thominx* Dujardin, 1845; *Tridentocapillaria* Barus & Sergeeva, 1990; *Aonchotheca* auct; *Baruscapillaria* auct.; *Ptherominx* auct.; *Trichocephalus* auct.

Type species: *Capillaria anatis* (Schrank, 1790) Travassos, 1915

1. *Capillaria anatis* (Schrank, 1790)
Trichocephalus capillaris Rudolphi, 1809

Anas, *Anser*, *Clangula*, *Lyrurus*, *Melanitta*, *Merganser*, *Perdix*, *Phasianus*
Yamaguti (1961), Europe, Sakhalin, Siberia

Domestic chicken
Magwisha *et al.* (2002), Tanzania

Numida meleagris
Nfor *et al.* (1999), Nigeria

GENUS *EUCOLEUS* DUJARDIN, 1845

Capillaria auct.; *Thominx* auct.; *Trichocephalus* auct.

1. *Eucoleus annulatus* (Molin, 1858)
Trichosoma annulatus Molin, 1858

Bonasa, *Chrysolophus*, *Colinus*, *Gallus*, *Lyrurus*, *Meleagris*, *Numida meleagris*, *Perdix*, *Phasianus*, *Syrmaticus*, *Tetrao*
Yamaguti (1961), Asia, Europe, North and South America

Domestic chicken
Magwisha *et al.* (2002), Tanzania

Numida meleagris
Fabiyi (1972), Nigeria
Hodasi (1976), Ghana
Vercruysse *et al.* (1985), Burkina Faso

Subclass Secernentea

Order Rhabditida

Superfamily Rhabditoidea

Family STRONGYLOIDIDAE Chitwood & McIntosh, 1934

GENUS *STRONGYLOIDES* GRASSI, 1879

1. *Strongyloides avium* Cram, 1929
Gallus
Yamaguti (1961), North America, Puerto Rico

Numida meleagris
Fabiyi (1972), Nigeria

Order Strongylida

Superfamily Strongyloidea

Family SYNGAMIDAE Leiper, 1912

Subfamily Syngaminae Baylis & Daubney, 1926

GENUS *SYNGAMUS* SIEBOLD, 1836

Cyathostoma auct.; *Ornithogamus* Ryjikov, 1948

Type species: *Syngamus trachea* (Montagu, 1811) Siebold, 1836

1. *Syngamus trachea* (Montagu, 1811) Siebold, 1836
Fasciola trachea Montagu, 1811; *Syngamus trachealis* Siebold, 1836; *Strongylus trachealis* Nathusius, 1937 in Ortlepp (1923); *Strongylus pictus* Creplin, 1849; *Sclerostomum syngamus* Diesing, 1951 in Ortlepp (1923); *Syngamus furcatus* Theob., 1896; *Syngamus primitivus* Molin, 1861; *Syngamus sclerostomum* Molin, 1861

Galliformes, Passeriformes; rarely Anseriformes, "Ardeiformes", "Pelicaniformes", Piciformes, Otidiformes
Yamaguti (1961), Africa, Australia, Europe, India, North and South America

Domestic chicken
Magwisha *et al.* (2002), Tanzania

Numida meleagris
Hodasi (1976), Ghana
Nfor *et al*. (1999), Nigeria

Order Ascaridida

Superfamily Heterakoidea

Family HETERAKIDAE Railliet & Henry, 1912

Subfamily Heterakinae Railliet & Henry, 1912

GENUS *HETERAKIS* DUJARDIN, 1845

Ganguleterakis Lane, 1914; *Raillietakis* Freitas, 1956; *Inglisakis* Freitas, Vicente & Santos, 1969

Type species: *Heterakis vesicularis* (Frölich, 1791)

1. *Heterakis vesicularis* (Frölich, 1791)
Ascaris vesicularis Frölich, 1791; *Ascaris papillosa*, Bloch, 1782, in part

Anas, *Colinus*, *Coturnix*, *Cygnus*, *Gallus*, *Lagopus*, *Meleagris*, *Numida meleagris*, *Oreortyx pictus*, *Otis*, *Pavo*, *Perdix*, *Phasianus colchicus*, *Polyplectron*, *Tetrao*
Yamaguti (1961), Africa, Europe, North America

Lophophorus, *Lophura*
Yamaguti (1961), Nepal

Yamaguti (1961) lists *Heterakis vesicularis* from *Otis* without giving the host's species name. It is therefore not clear whether *Otis* refers to the current genus *Otis*, *Ardeotis*, *Neotis* or *Chlamydotis*.

2. *Heterakis brevispiculum* Gendre, 1911
Domestic chicken, *Numida meleagris*, *Pternistis bicalcaratus*

Yamaguti (1961), Africa, Puerto Rico, South America

Numida meleagris
Fabiyi (1972), Nigeria
Hodasi (1976), Ghana

3. *Heterakis dispar* (Schrank, 1790)
Ascaris dispar Schrank, 1790

Alectoris, *Anas*, *Anser*, *Anser cygnoides*, *Branta, Bernicla*, *Cairina*, *Chloephaga*, *Glaucidium*, *Numida meleagris*, *Strix*, *Surnia*, *Tadorna*
Yamaguti (1961), Cosmopolitan

Domestic chicken
Permin, Magwisha, Kassuku, Nansen, Bisgaard, Frandsen & Gibbons (1997), Tanzania

4. *Heterakis gallinarum* (Schrank, 1788)
Ascaris gallinarum Schrank, 1788; *Heterakis gallinae* Gmelin, 1790; *Heterakis longicaudata* Von Linstow, 1879

Acryllium, *Alectoris*, *Anas*, *Anser*, *Bonasa*, *Cairina*, *Chrysolophus*, *Colinus*, *Corvus*, *Coturnix*, *Cupidonia*, domestic chicken, *Francolinus*, Houbara, *Lagopus*, *Lophophorus*, *Lophura*, *Lyrurus*, *Meleagris*, *Otis*, *Pavo*, *Pedioecetes*, *Perdix*, *Phasianus*, *Pterocles*, *Strix*, *Syrmaticus*, *Tetrao*, *Tragopan*, *Tympanuchus*
Yamaguti (1961), Cosmopolitan

Yamaguti (1961) lists *Heterakis gallinarum* from *Otis* without giving the host's species name. It is therefore not clear whether *Otis* refers to the current genus *Otis*, *Ardeotis*, *Neotis* or *Chlamydotis*.

Domestic chicken
Poulsen *et al.* (2000), Ghana
Magwisha *et al.* (2002), Tanzania
Permin *et al.* (2002), Zimbabwe

Numida meleagris
Ayeni *et al*. (1983), Nigeria
Verster & Ptasinska-Kloryga (1987), South Africa
Haziev & Khan (1991), Republic of Bashkortostan
Santa Cruz, Ortis de Rott & Resoagli (1998), Argentina

5. *Heterakis tenuicauda* Von Linstow, 1883
Alectoris graeca, *Alectoris graeca saxatilis*
Yamaguti (1961), Turkestan

Acryllium vulturinum
Canavan (1929) in Yamaguti (1961), East Africa

Family ASCARIDIIDAE Travassos, 1919

Genus *Ascaridia* Dujardin, 1845

Cotylascaris Sprent, 1971

Type species: *Ascaridia hermaphrodita* (Frölich, 1789) Railliet & Henry, 1914

1. *Ascaridia calcarata* (Gendre, 1909)
Numida meleagris
Yamaguti (1961), Africa

Junior synonym of *Ascaridia numidae* (Leiper, 1908) according to Sprehn (1932) in Yamaguti (1961).

2. *Ascaridia compar* (Schrank, 1790) Travassos, 1913
Ascaris compar Schrank, 1790

Alectoris, Coturnix, Gallus, Lyrurus, Numida meleagris, Oreortyx pictus, Perdix, Tetrao, *Tetrastes*
Yamaguti (1961), America, Europe, India, Philippines

3. *Ascaridia galli* (Schrank, 1788) Freeborn, 1932
Ascaris galli Schrank, 1788; *Fusaria inflexa* Zeder, 1800 (Baylis 1932, cited in Yamaguti 1961); *Fusaria reflexa* Zeder, 1800, in part; *Fusaria strumosa* Zeder, 1800, in part (López-Neyra 1946, cited in Yamaguti 1961); *Heterakis brasiliensis* Magalhães, 1892 (Pinto & Lins de Almeida 1935, cited in Yamaguti 1961); *Heterakis granulosa* Von Linstow, 1906 (Baylis 1932, cited in Yamaguti 1961); *Ascaridia hamia* Lane, 1914

Domestic chicken, guineafowl
Yamaguti (1961), Europe, Japan

Alectoris, *Bonasa*, *Cairina*, *Colinus*, duck, *Ithaginis*, *Lyrurus*, *Meleagris*, *Numida meleagris*, *Perdix*, *Phasianus*, *Streptopelia*, *Tetrao*, *Tympanuchus*
Yamaguti (1961), Cosmopolitan

Domestic chicken
Poulsen *et al.* (2000), Ghana
Magwisha *et al.* (2002), Tanzania
Permin *et al.* (2002), Zimbabwe

Numida meleagris
Ayeni *et al.* (1983), Nigeria
Verster & Ptasinska-Kloryga (1987), South Africa
Haziev & Khan (1991), Republic of Bashkortostan

4. *Ascaridia lineata* (Schrank, 1866)
Ascaris lineata Schrank, 1866

Alectoris, *Anas*, *Anser*, *Bonasa*, duck, *Francolinus*, *Gallus*, goose, *Meleagris*, *Meleagris ocellata*, *Numida*, partridge, *Phasianus*, pigeon, *Tympanuchus*
Yamaguti (1961), Africa, Brazil, China, Cuba, Europe, Formosa, India, Malaya, North America, Philippines, Puerto Rico, Turkestan

Domestic chicken
Le Roux (1926), South Africa

5. *Ascaridia numidae* (Leiper, 1908) Travassos, 1913
Heterakis numidae Leiper, 1908

Alectoris, Guttera
Yamaguti (1961), Africa

Guineafowl
Yamaguti (1961), Puerto Rico
Bwangamoi (1968), Uganda

Numida meleagris
Graber (1959), Chad
Yamaguti (1961), Africa, the White Nile
Myers *et al*. (1960), Sudan
Fabiyi (1972), Nigeria
Hodasi (1976), Ghana
Vercruysse *et al.* (1985), Burkina Faso
Verster & Ptasinska-Kloryga (1987), South Africa

The White Nile rises from Lake Victoria in Uganda and enters the Sudan where it joins the Blue Nile in Karthoum to form the Nile. White Nile is one of the states of Sudan.

6. *Ascaridia perspicillum* (Rudolphi, 1803)
Ascaris perspicillum Rudolphi, 1803

Anas acuta, domestic chicken, *Meleagris gallopavo*, *Numida meleagris*, *Pavo cristatus*, *Tetrao urogallus*, *Tetrastes bonasia rupestris*, *Turdus viscivorus*
Yamaguti (1961), Europe, Hawaii, India, Indonesia, Japan, Malaya

Superfamily Subuluroidea

Family SUBULURIDAE (Travassos, 1914) Yorke & Maplestone, 1926

Subfamily Subulurinae Travassos, 1914

GENUS *SUBULURA* MOLIN, 1860

Allodapa auct.

Type species: *Subulura acutissima* Molin, 1860

1. *Subulura acuticauda* (Von Linstow, 1901) Railliet & Henry, 1914
Oxysoma acuticauda Von Linstow, 1901; *Heterakis acuticauda* (Von Linstow, 1901) Von Linstow, 1909

Numida meleagris
Von Linstow (1901), Kenya
Yamaguti (1961), Africa

2. *Subulura brumpti* (Lopez-Neyra, 1922)
Allodapa brumpti Lopez-Neyra, 1922

Alectoris graeca, *Anas*, *Colinus virginianus texanus*, domestic chicken, *Meleagris gallopavo*, *Numida*, *Perdix perdix*, *Streptopelia orientalis*
Yamaguti (1961), Europe, Palestine, Cyprus, Cuba, Puerto Rico, Panama, North America, Africa, China

Domestic chicken
Hodasi (1969), Ghana
Mukaratirwa, Hove, Esmann, Hoj, Permin & Nansen (2001), Zimbabwe

Numida meleagris
Graber (1959), Chad
Hodasi (1976), Ghana
Nfor *et al.* (1999), Nigeria

3. *Subulura dentigera* Ortlepp, 1937

Numida meleagris
Ortlepp (1937), South Africa

4. *Subulura differens* (Sonsino, 1890)
Heterakis differens Sonsino, 1890

Alectoris graeca, *Centropus phasianus*, domestic chicken, *Euplectes orix*, *Numida meleagris*, *Perdix perdix canescens*, *Pternistis bicalcaratus*
Yamaguti (1961), Cosmopolitan

5. *Subulura suctoria* (Molin, 1860)
Heterakis suctoria Molin, 1860; *Ascaris forcipata* Rudolphi, 1819, in part

Caprimulgus, *Podager*, *Nyctibius*
Yamaguti (1961), Brazil

Burhinus, *Coturnix*, *Numida*, *Pternistis*
Yamaguti (1961), South Africa (Transvaal)

Coturnix coturnix, *Lagopus lagopus*, *Phasianus colchicus*, *Phasianus colchicus mongolicus*, *Phasianus colchicus principalis*
Yamaguti (1961), Russia, Turkestan

Domestic chicken
Permin *et al.* (1997), Tanzania
Permin *et al.* (2002), Zimbabwe

Guttera edouardi
Junker & Boomker (2007b), South Africa

Numida meleagris
Ortlepp (1937), South Africa
Fabiyi (1972), Nigeria
Vercruysse *et al.* (1985), Burkina Faso

6. *Subulura strongylina* (Rudolphi, 1819)
Ascaris strongylina Rudolphi, 1819; *Strongylus spiculatus* Cobbold, 1861 (Boughton 1939, cited in Yamaguti 1961)

Bonasa, *Bucco*, *Callipepla*, *Caprimulgus*, *Chelidoptera*, *Colinus*, *Cuculus*, *Gallus*, *Malocoptila*, *Monasa*, *Nonnula*, *Numida meleagris*, *Odontophorus*, *Perdix*, *Podager*, *Tetrao*, *Tympanuchus*
Yamaguti (1961), North America, Puerto Rico

Crypturellus, *Odontophorus capueira*, *Tinamus*
Yamaguti (1961), Brazil

Domestic chicken
Permin *et al.* (1997), Tanzania
Poulsen *et al.* (2000), Ghana

Order Spirurida Diesing, 1861

Superfamily Thelazioidea

Family THELAZIIDAE Skrjabin, 1915

GENUS *OXYSPIRURA* DRASCHE IN STOSSICH, 1897

Cramispirura Skrjabin, 1931

Type species: *Oxyspirura cephaloptera* (Molin, 1860)

1. *Oxyspirura mansoni* (Cobbold, 1879)
Filaria mansoni Cobbold, 1879; *Spiroptera emmerezii* Emmerez & Mégnin, 1901 (Marotel & Carougeau 1902, cited in Yamaguti 1961)

Domestic chicken, *Gallus gallus*, *Meleagris gallopavo*, *Pavo cristatus*
Yamaguti (1961), Atlantic and Pacific islands, Australia, Democratic Republic of Congo, Formosa, India, Japan, North America

Numida meleagris
Hodasi (1976), Ghana

Superfamily Spiruroidea

Family GONGYLONEMATIDAE (Hall, 1916, subfam.) Sobolev, 1949

GENUS *GONGYLONEMA* MOLIN, 1857

Type species: *Gongylonema musculi* (Rudolphi, 1819) Neumann, 1894

1. *Gongylonema ingluvicola* Ransom, 1904
Gongylonema sumani Bahlerao, 1933 (Baylis 1939, cited in Yamaguti 1961)

Gallus, *Meleagris*, pheasants
Yamaguti (1961), Cosmopolitan
Domestic chicken
Poulsen *et al.* (2000), Ghana
Magwisha *et al.* (2002), Tanzania
Permin *et al.* (2002), Zimbabwe
Numida meleagris
Nfor *et al.* (1999), Nigeria

2. *Gongylonema congolense* Fain, 1955
Cairina moschata
Fain (1955), Democratic Republic of the Congo
Gallus
Fain (1955), Burundi, Democratic Republic of the Congo, Rwanda
Guttera edouardi
Junker & Boomker (2007b), South Africa
Numida meleagris
Fain (1955), Burundi, Democratic Republic of the Congo, Rwanda
Fabiyi (1972), Nigeria
Graber (1976), Ethiopia
Hodasi (1976), Ghana
Vercruysse *et al.* (1985), Burkina Faso
Junker & Boomker (2007b), South Africa
Scleroptila levaillantii
Fain (1955), Rwanda

3. *Gongylonema sumani* Bhalerao, 1933
Gallus gallus
Bhalerao (1933), India
Numida meleagris
Fain & Thienpont (1958), Burundi

Superfamily Habronematoidea

Family HABRONEMATIDAE (Chitwood & Wehr, 1932) Ivaschkin, 1961

Subfamily Habronematinae Chitwood & Wehr, 1932

Genus *Cyrnea* Seurat, 1914

Seurocyrnea Strand, 1929; *Skrjabinochona* Guschkanskaja, 1931; *Chenspirura* Hsü, 1957 *nec* Kou, 1958

Type species: *Cyrnea eurycerca* Seurat, 1914

1. *Cyrnea eurycerca* Seurat, 1914
Alectoris, *Coturnix*, *Francolinus*, *Phasianus*, *Merops*
Yamaguti (1961), Africa, Europe
Numida meleagris
Ortlepp (1938a), Southern Africa
Alectoris rufa ("*Perdix rouge*" in Yamaguti [1961])
Yamaguti (1961), Corsica

2. *Cyrnea parroti* Seurat, 1917
Cyrnea seurati Lopéz-Neyra, 1918; *Habronema numidae* Ortlepp, 1938; *Cyrnea numidae* (Ortlepp, 1938)
Alectoris barbara
Yamaguti (1961), Algeria
Alectoris rufa
Yamaguti (1961), Spain
Numida meleagris
Ortlepp (1938b), Malawi, South Africa, Swaziland
Fabiyi (1972), Nigeria
Vercruysse *et al.* (1985), Burkina Faso
Chabaud (1958) divided the genus *Cyrnea* into the two subgenera *Procyrnea* Chabaud, 1958 and *Cyrnea* Chabaud, 1958, subsequently raising them to genus level (Chabaud, 1975). He also synonymized *Cyrnea* (*Cyrnea*) *numidae* Ortlepp, 1938 and *Cyrnea* (*Cyrnea*) *seurati* Lopéz-Neyra, 1918 with *Cyrnea* (*Cyrnea*) *parroti* Seurat, 1917. Our specimens of *Cyrnea parroti* collected from *Numida meleagris* in South Africa comply with Ortlepp's (1938b) description of *C. numidae*, but the arrangement of cephalic structures in apical view is that of *C. parroti.* Not having examined Otlepp's (1938b) specimens we adopt the classification of Chabaud (1958) and list Ortlepp's specimens as *C. parroti*.

Genus *Sicarius* Li, 1934

Type species: *Sicarius dipterum* (Popova, 1927) Li, 1934

1. *Sicarius caudatus* Quentin & Wertheim, 1975
Numida meleagris
Junker & Boomker (2007b), South Africa
Pycnonotus capensis
Quentin & Wertheim (1975), Israel
Quentin & Wertheim (1975) described *S. caudatus* from *P. capensis* present in the collection of the "Helminthological Laboratory Jerusalem" and list Jerusalem as locality. It should be noted that *P. capensis* is endemic to South Africa (Lepage 2007). We therefore conclude that the authors were either looking at birds kept in captivity in Israel, making it difficult to determine the geographic origin of the parasites or did not have any information on the original locality if the birds had been collected in South Africa.

2. *Sicarius renatae* Cancrini, Balbo & Iori, 1991
Acryllium vulturinum
Cancrini, Balbo & Iori (1991), Somalia

Subfamily Histiocephalinae Gendre, 1922

Genus *Hadjelia* Seurat, 1916

Gilsonia Gedoelst, 1919; *Stellobronema* Guschanskaja, 1937; *Sobolevicephalus* Parukhin, 1964

1. *Hadjelia truncata* (Creplin, 1825)
Spiroptera truncata Creplin, 1825; *Hadjelia inermis* (Gedoelst, 1919)
Aceros corrugatus
Ortlepp (1964), Malucca Islands, Indonesia
Columba livia
Tadros & Iskander (1975), Egypt
Guttera edouardi, *Numida meleagris*
Junker & Boomker (2007b), South Africa
Tockus erythrorhynchus, *Tockus leucomelas*
Ortlepp (1964), South Africa
Tockus fasciatus semifasciatus
Cram (1927, cited in Ortlepp 1964), Africa

Coracias benghalensis, *Halcyon smyrnensis*, *Upupa epops*
Singh (1949), India
Chabaud & Campana (1950) synonymized *H. inermis* with *H. truncata.* Ortlepp (1964) did not follow this and recorded his specimens as *H. inermis.* Tadros & Iskander (1975) synonymized *H. inermis*, *H. parva* and *H. lhuillieri* with *H. truncata*, designating *H. truncata* as the new type species of the genus.

Family TETRAMERIDAE Travassos, 1914

Subfamily Tetramerinae Railliet, 1915

GENUS *TETRAMERES* CREPLIN, 1846

Tropisurus Diesing, 1835; *Tropidurus* Wiegmann, 1835, preoccupied; *Gynaecophila* Gubanov, 1950; *Petrowimeres* Tschertkova, 1953; *Microtetrameres* auct.

Type species: *Tetrameres paradoxa* (Diesing, 1835)

1. *Tetrameres fissispina* Diesing, 1861
Acanthophorus horridus Von Linstow, 1876; *Acanthophorus tenuis* Von Linstow, 1876; *Filaria pulicis* Von Linstow, 1894
Alectoris, *Anas acuta*, *Anas clypeata*, *Anas platyrhynchos*, *Anas querquedula*, *Aythya ferina*, *Bucephala clangula*, *Columba livia*, *Cygnus melanocoryphus*, *Fulica atra*, *Gallus*, *Melanitta fusca*, *Meleagris*, *Meleagris gallopavo*, *Mergus merganser*, *Nycticorax nycticorax*, *Perdix*, *Somateria molissima*, *Tachybaptus fluviatilis*
Yamaguti (1961), Africa, Canton, Europe, Formosa, Guam, India, Malaya, North and South America, Philippines, Russian Turkestan, Siberia, Turkey
Domestic chicken
Le Roux (1926), South Africa
Poulsen *et al.* (2000), Ghana
Magwisha *et al.* (2002), Tanzania
Guineafowl
Le Roux (1926), South Africa
Numida meleagris
Fabiyi (1972), Nigeria
Hodasi (1976), Ghana
Vercruysse *et al.* (1985), Burkina Faso
2. *Tetrameres numida* Junker & Boomker 2007
Numida meleagris
Junker & Boomker (2007a), South Africa
Chabaud (1975) divided the genus *Tetrameres* into the two subgenera *Tetrameres* (*Tetrameres*) Creplin, 1846 and *Tetrameres* (*Microtetrameres*) Travassos, 1915. We adopt the view of Anderson (1992) and consider the two as valid genera.

Superfamily Acuarioidea

Family Acuariidae (Railliet, Henry & Sisoff, 1912, subfam.)

Subfamily Acuariinae Railliet, Henry & Sisoff, 1912

GENUS *ACUARIA* BREMSER, 1811

Cheilospirura auct.

Type species: *Acuaria anthuris* (Rudolphi, 1819)

1. *Acuaria hamulosa* (Diesing, 1851)
Spiroptera hamulosa Diesing, 1851; *Cheilospirura hamulosa* Diesing, 1861; *Spiroptera perforans* Centoscudi, 1911
Coturnix coturnix, *Gallus gallus*, *Meleagris*, pheasant
Yamaguti (1961), Cosmopolitan
Domestic chicken
Le Roux (1926), South Africa
Poulsen *et al.* (2000), Ghana
Magwisha *et al.* (2002), Tanzania
Numida meleagris
Fabiyi (1972), Nigeria
Hodasi (1976), Ghana

GENUS *SYNHIMANTUS* RAILLIET, HENRY & SISOFF, 1912

Type species: *Synhimantus laticeps* (Rudolphi, 1819)

1. *Synhimantus spiralis* (Linstow, 1883)
Dispharagus spiralis Linstow, 1883
Accipiter, *Alectoris*, *Bonasa*, *Ciconia*, *Colinus*, *Columba*, *Coracias*, *Corvus*, *Gallus*, *Meleagris*, *Metopidius*, *Numida meleagris*, *Passer*, *Perdix*, *Phasianus*, *Quiscalus*, *Turdus*, *Turdus migratorius*
Yamaguti (1961), Cosmopolitan
Numida meleagris
Fabiyi (1972), Nigeria
Hodasi (1976), Ghana
Vercruysse *et al.* (1985), Burkina Faso

GENUS *DISPHARYNX* RAILLIET, HENRY & SISOFF, 1912

Type species: *Dispharynx nasuta* (Rudolphi, 1819)

1. *Dispharynx nasuta* (Rudolphi, 1819)
Spiroptera nasuta Rudolphi, 1819
Passer domesticus
Yamaguti (1961), Europe
Gallus gallus
Yamaguti (1961), Africa, America, Australia, Ceylon, Cuba, Formosa
Domestic chicken, turkeys
Gibbons, Jones & Khalil (1996), no geographic data given
Numida meleagris
Verster & Ptasinska-Kloryga (1987), South Africa

HOST/PARASITE CHECK LIST

Order Tinamiformes

Family Tinamidae (Tinamous)

GENUS *TINAMUS* HERMANN, 1783

Subulura strongylina

GENUS *CRYPTURELLUS* BRABOURNE & CHUBB, 1914

Crypturus
Subulura strongylina

Order Galliformes

Domestic chicken

Mediorhynchus gallinarum
Postharmostomum gallinum
Choanotaenia infundibulum
Davainea proglottina
Echinolepis carioca
Hymenolepis cantaniana
Raillietina cohni
Raillietina echinobothrida
Raillietina tetragona
Skrjabinia cesticillus
Acuaria hamulosa
Aonchotheca caudinflata
Ascaridia galli
Ascaridia lineata
Ascaridia perspicillum
Capillaria anatis
Dispharynx nasuta
Eucoleus annulatus
Gongylonema ingluvicola
Heterakis brevispiculum
Heterakis dispar
Heterakis gallinarum
Oxyspirura mansoni
Subulura brumpti
Subulura differens
Subululra strongylina
Subulura suctoria
Syngamus trachea
Tetrameres fissispina

Gallinaceaous birds, galliformes

Mediorhynchus gallinarum
Syngamus trachea

Family Numididae (Guineafowls)

Crested guineafowl

Postharmostomum gallinum

Guineafowl

Cotugnia crassa
Cotugnia digonopora
Numidella numida
Octopetalum numida
Porogynia paronai
Ascaridia galli
Ascaridia numidae
Tetrameres fissispina

Genus *Numida* Linnaeus, 1766

1. *Numida meleagris* (Linnaeus, 1758) (Helmeted Guineafowl)

Phasianus meleagris

Numida meleagris galeatus Pallas, 1767

Numida galeata

Numida meleagris meleagris (Linnaeus, 1758)

Numida ptilorhyncha

Numida meleagris mitratus Pallas, 1767

Numida mitrata

Numida meleagris marungensis Schalow, 1884

Numida frommi, Numida marungensis, Numida meleagris bodalyae, Numida meleagris frommi, Numida meleagris maxima, Numida meleagris rikwae, Numida mitrata frommi, Numida mitrata maximia, Numida mitrata rikwae, Numida rikwae

Mediorhynchus empodius
Mediorhynchus gallinarum
Mediorhynchus numidae
Mediorhynchus selengensis
Mediorhynchus taeniatus
Dicrocoelium macrostomum
Lutztrema sp.
Postharmostomum gallinum
Abuladzugnia gutterae
Abuladzugnia transvaalensis
Choanotaenia infundibulum
Cotugnia crassa
Cotugnia digonopora
Cotugnia meleagridis
Cotugnia tuliensis
Davainea nana
Davainea paucisegmentata
Davainea paucisegmentata var. dahomeensis
Davainea proglottina
Echinolepis carioca
Hispaniolepis falsata
Hispaniolepis fedtschenkoi
Hispaniolepis hilmyi
Hispaniolepis villosa
Hymenolepis cantaniana
Idiogenes sp.
Metroliasthes lucida
Numidella numida
Octopetalum gutterae
Octopetalum numida
Ortleppolepis multiuncinata
Porogynia paronai
Raillietina angusta
Raillietina cohni
Raillietina echinobothrida
Raillietina pintneri
Raillietina steinhardti
Raillietina tetragona
Raillietina tetragonoides
Raillietina toyohashiensis
Skrjabinia cesticillus
Skrjabinia deweti
Acuaria hamulosa
Ascaridia calcarata
Ascaridia compar
Ascaridia galli
Ascaridia lineata
Ascaridia numidae
Ascaridia perspicillum
Aonchotheca caudinflata
Capillaria anatis
Cyrnea eurycerca

Cyrnea parroti
Eucoleus annulatus
Gongylonema congolense
Gongylonema ingluvicola
Gongylonema sumani
Hadjelia truncata
Heterakis brevispiculum
Heterakis dispar
Heterakis gallinarum
Heterakis vesicularis
Oxyspirura mansoni
Sicarius caudatus
Sicarius renatae
Subulura acuticauda
Subulura brumpti
Subulura dentigera
Subulura differens
Subulura strongylina
Subulura suctoria
Strongyloides avium
Syngamus trachea
Dispharynx nasuta
Synhimantus spiralis
Tetrameres fissispina
Tetrameres numida

GENUS: *GUTTERA* WAGLER, 1832

Numidella numida
Raillietina pintneri
Ascaridia numidae

1. *Guttera edouardi* (Hartlaub, 1867) (Crested Guineafowl)

   Numida edouardi (Hartlaub, 1867); *Guttera pucherani edouardi* (Hartlaub, 1867)

   Mediorhynchus taeniatus
   Abuladzugnia gutterae
   Davainea nana
   Metroliasthes lucida
   Octopetalum gutterae
   Octopetalum numida
   Ortleppolepis multiuncinata
   Porogynia paronai
   Raillietina pintneri
   Raillietina steinhardti
   Raillietina tetragona
   Gongylonema congolense
   Hadjelia truncata
   Subulura suctoria

GENUS: *ACRYLLIUM* GRAY, 1840

Heterakis gallinarum

1. *Acryllium vulturinum* Gray, 1840 (Vulturine Guineafowl)

   Cotugnia shohoi
   Raillietina somalensis
   Heterakis tenuicauda
   Sicarius renatae

Family ODONTOPHORIDAE (New World quails)

GENUS *OREORTYX* BAIRD, 1858

Ortyx in Yamaguti (1961)

1. *Oreortyx pictus* (Douglas, 1829) (Mountain Quail)

   Ortyx picta
   Ascaridia compar
   Heterakis vesicularis

GENUS *CALLIPEPLA* WAGLER, 1832

Lophortyx
Subulura strongylina

GENUS *COLINUS* GOLDFUSS, 1820

Ascaridia galli
Eucoleus annulatus
Heterakis vesicularis
Heterakis gallinarum
Subulura strongylina
Synhimantus spiralis

1. *Colinus virginianus* (Linnaeus, 1758) (Northern Bobwhite)

   Tetrao virginianus
   Echinolepis carioca
   Hymenolepis cantaniana
   Skrjabinia cesticillus

1a. *Colinus virginianus texanus* Lawrence, 1853

Subulura brumpti

GENUS *ODONTOPHORUS* VIEILLOT, 1816

Subulura strongylina

1. *Odontophorus capueira* (Spix, 1825) (Spot-winged Wood-quail)

   Perdix capueira
   Subulura strongylina

Family PHASIANIDAE (Partridges, francolins, spurfowls, pheasants, etc.)

Partridge

Ascaridia lineata

Pheasant

Acuaria hamulosa
Gongylonema ingluvicola

Turkey

Dispharynx nasuta

GENUS *MELEAGRIS* LINNAEUS, 1758

Acuaria hamulosa
Ascaridia galli
Ascaridia lineata
Eucoleus annulatus
Gongylonema ingluvicola
Heterakis vesicularis
Heterakis gallinarum
Synhimantus spiralis

Tetrameres fissispina

1. *Meleagris gallopavo* Linnaeus, 1758 (Wild Turkey, Common Turkey)
   Echinolepis carioca
   Hymenolepis cantaniana
   Metroliasthes lucida
   Numidella numida
   Raillietina echinobothrida
   Raillietina tetragona
   Skrjabinia cesticillus
   Ascaridia perspicillum
   Oxyspirura mansoni
   Subulura brumpti
   Tetrameres fissispina
2. *Meleagris ocellata* Cuvier, 1820 (Ocellated Turkey)
   Agriocharis ocellata
   Ascaridia galli

Genus *Bonasa* Stephens, 1819

Ascaridia galli
Ascaridia lineata
Eucoleus annulatus
Heterakis gallinarum
Subulura strongylina
Synhimantus spiralis

1. *Bonasa umbellus* (Linnaeus, 1766) (Ruffed Grouse)
   Tetrao umbellus
   Davainea proglottina
   Echinolepis carioca

Genus *Tetrastes* Keyserling & Blasius, 1840

Ascaridia compar

1. *Tetrastes bonasia* (Linnaeus, 1758) (Hazel Grouse)
   Bonasa bonasia, Bonasia bonasia, Tetrao bonasia
   Hispaniolepis fedtschenkoi
   Hymenolepis cantaniana
   Skrjabinia cesticillus

1a. *Tetrastes bonasia rupestris* (Brehm, 1831)
   Ascaridia perspicillum

Genus *Tetrao* Linnaeus, 1758

Aonchotheca caudinflata
Ascaridia compar
Ascaridia galli
Eucoleus annulatus
Heterakis vesicularis
Heterakis gallinarum
Subulura strongylina

1. *Tetrao urogallus* Linnaeus, 1758 (Western Capercaillie)
   Tetrao major
   Skrjabinia cesticillus
   Ascaridia perspicillum

2. *Tetrao parvirostris* Bonaparte, 1856 (Black-billed Capercaillie)
   Tetrao urogalloides
   Hymenolepis cantaniana

Genus *Lyrurus* Swainson, 1832

Aonchotheca caudinflata
Ascaridia compar
Ascaridia galli
Capillaria anatis
Eucoleus annulatus
Heterakis gallinarum

1. *Lyrurus tetrix* (Linnaeus, 1758) (Black Grouse)
   Tetrao tetrix
   Hispaniolepis fedtschenkoi
   Skrjabinia cesticillus

Genus *Tympanuchus* Gloger, 1841

Cupidonia
Ascaridia lineata
Heterakis gallinarum

1. *Tympanuchus phasianellus* (Linnaeus, 1758) (Sharp-tailed Grouse)
   Pedioecetes phasianellus (Linnaeus, 1758), *Tetrao phasianellus*
   Ascaridia galli
   Ascaridia lineata
   Heterakis gallinarum
   Subulura strongylina

Genus *Lagopus* Brisson, 1760

Aonchotheca caudinflata
Heterakis gallinarum
Heterakis vesicularis

1. *Lagopus lagopus* (Linnaeus, 1758) (Willow Ptarmigan)
   Tetrao lagopus
   Raillietina tetragona
   Skrjabinia cesticillus
   Subulura suctoria

1a. *Lagopus lagopus scotica* (Latham, 1787)
   Lagopus scotica
   Skrjabinia cesticillus

2. *Lagopus muta* (Montin, 1781) (Rock Ptarmigan)
   Raillietina tetragona

Genus *Tetragallus* Gray, 1832

1. *Tetraogallus caucasicus* (Pallas, 1811) (Caucasian Snowcock)
   Tetrao caucasica
   Hispaniolepis fedtschenkoi
2. *Tetraogallus himalayensis* Gray, 1843 (Himalayan Snowcock)
   Megaloperdix nigelli
   Hispaniolepis fedtschenkoi

Genus *Alectoris* Kaup, 1829

Caccabis in Yamaguti (1961)

Ascaridia compar
Ascaridia galli
Ascaridia numidae
Cyrnea eurycerca
Heterakis dispar
Heterakis gallinarum
Synhimantus spiralis
Tetrameres fissispina

1. *Alectoris barbara* (Bonnaterre, 1792) (Barbary Partridge)

   Caccabis petrosa, Perdix barbara

   Cyrnea parroti

2. *Alectoris graeca* (Meisner, 1804) (Rock Partridge)

   Perdix graeca

   Davainea proglottina
   Echinolepis carioca
   Metroliasthes lucida
   Heterakis tenuicauda
   Subulura brumpti
   Subulura differens

2a. *Alectoris graeca saxatilis* (Bechstein, 1805)

   Caccabis saxatilis chukar

   Heterakis tenuicauda

   Lepage (2007) states that the original *Alectoris graeca* has been split into four species, namely *Alectoris graeca*, *Alectoris chukar* (Gray, 1830), *Alectoris philbyi* Lowe, 1934 and *Alectoris magna* (Prjevalski, 1876).

3. *Alectoris rufa* (Linnaeus, 1758) (Red-legged Partridge)

   Caccabis rufa, Coturnix rufa, Tetrao rufus

   Metroliasthes lucida
   Cyrnea eurycerca
   Cyrnea parroti

Genus *Francolinus* Stephens, 1819

Ascaridia lineata
Cyrnea eurycerca
Heterakis gallinarum

Genus *Scleroptila* Blyth, 1852

1. *Scleroptila levaillantii* (Valenciennes, 1825) (Red-winged Francolin)

   Francolinus levaillantii, *Perdix levaillantii*

   Gongylonema congolense

Genus *Pternistis* Wagler, 1832

Subulura suctoria

1. *Pternistis natalensis* (Smith, 1834) (Natal Spurfowl)

   Francolinus natalensis, *Pternistes natalensis*

   Porogynia paronai

2. *Pternistis bicalcaratus* (Linnaeus, 1766) (Double-spurred Spurfowl)

   Francolinus bicalcaratus, *Tetrao bicalcaratus*

   Heterakis brevispiculum
   Subulura differens

Genus *Perdix* Brisson, 1760

Aonchotheca caudinflata
Ascaridia compar
Ascaridia galli
Capillaria anatis
Eucoleus annulatus
Heterakis vesicularis
Heterakis gallinarum
Subulura strongylina
Synhimantus spiralis
Tetrameres fissispina

1. *Perdix perdix* (Linnaeus, 1758) (Grey Partridge)

   Tetrao perdix

   Davainea proglottina
   Hymenolepis cantaniana
   Metroliasthes lucida
   Raillietina echinobothrida
   Skrjabinia cesticillus
   Subulura brumpti

1a. *Perdix perdix canescens* Buturlin, 1906

   Subulura differens

Genus *Coturnix* Bonnaterre, 1791

Aonchotheca caudinflata
Ascaridia compar
Cyrnea eurycerca
Heterakis gallinarum
Heterakis vesicularis
Subulura suctoria

1. *Coturnix coturnix* (Linnaeus, 1758) (Common Quail)

   Tetrao coturnix

   Dicrocoelium macrostomum
   Echinolepis carioca
   Hymenolepis cantaniana
   Metroliasthes lucida
   Skrjabinia cesticillus
   Acuaria hamulosa
   Subulura suctoria

Genus *Ithaginis* Wagler, 1832

Ascaridia galli

Genus *Tragopan* Cuvier, 1829

Ceriornis

Heterakis gallinarum

Genus *Lophophorus* Temminck, 1813

Heterakis gallinarum
Heterakis vesicularis

Genus *Gallus* Brisson, 1760

Aonchotheca caudinflata
Ascaridia compar
Ascaridia lineata
Eucoleus annulatus
Gongylonema congolense

Gongylonema ingluvicola
Heterakis vesicularis
Strongyloides avium
Subulura strongylina
Synhimantus spiralis
Tetrameres fissispina

1. *Gallus gallus* (Linnaeus, 1758) (Red Junglefowl)

Gallus ferrugineus, *Phasianus gallus*

Davainea proglottina
Echinolepis carioca
Hispaniolepis fedtschenkoi
Hymenolepis cantaniana
Metroliasthes lucida
Raillietina cohni
Raillietina echinobothrida
Raillietina tetragona
Skrjabinia cesticillus
Acuaria hamulosa
Dispharynx nasuta
Gongylonema sumani
Oxyspirura mansoni

1a. *Gallus gallus bankiva* Temminck, 1813

Metroliasthes lucida
Raillietina echinobothrida

Genus *Lophura* Fleming, 1822

Gennaeus

Heterakis gallinarum

1. *Lophura nycthemera* (Linnaeus, 1758) (Silver Pheasant)

Euplocamus nycthemerus, Gennaeus nycthemerus, Phasianus nycthemerus

Heterakis vesicularis

Genus *Syrmaticus* Wagler, 1832

Graphophasianus

Eucoleus annulatus

1. *Syrmaticus soemmeringii* (Temminck, 1830) (Copper Pheasant)

Graphophasianus soemmeringii, Phasianus soemmeringii

Heterakis gallinarum

Genus *Phasianus* Linnaeus, 1758

Aonchotheca caudinflata
Ascaridia galli
Ascaridia lineata
Capillaria anatis
Cyrnea eurycerca
Eucoleus annulatus
Heterakis gallinarum
Synhimantus spiralis

1. *Phasianus colchicus* Linnaeus, 1758 (Common Pheasant, Ring-necked Pheasant)

Hymenolepis cantaniana
Raillietina echinobothrida
Skrjabinia cesticillus
Heterakis vesicularis
Subulura suctoria

1a. *Phasianus colchicus mongolicus* Brandt, 1844

Phasianus mongolicus turkestanicus

Subulura suctoria

1b. *Phasianus colchicus principalis* Sclater, 1885

Phasianus principalis

Subulura suctoria

Genus *Chrysolophus* Gray, 1834

Thaumalea

Aonchotheca caudinflata
Eucoleus annulatus
Heterakis gallinarum

Genus *Polyplectron* Temminck, 1807

Heterakis vesicularis

Genus *Pavo* Linnaeus, 1758

Heterakis gallinarum
Heterakis vesicularis

1. *Pavo cristatus* Linnaeus, 1758 (Indian Peafowl)

Hymenolepis cantaniana
Raillietina tetragona
Ascaridia perspicillum
Oxyspirura mansoni

2. *Pavo muticus* Linnaeus, 1766 (Green Peafowl)

Raillietina tetragona

Order Anseriformes

Syngamus trachea

Family ANATIDAE (Ducks, geese and swans)

Duck

Ascaridia galli
Ascaridia lineata

Goose

Ascaridia lineata

Genus *Anser* Brisson, 1760

Cotugnia digonopora
Ascaridia lineata
Capillaria anatis
Heterakis dispar
Heterakis gallinarum

1. *Anser cygnoides* (Linnaeus, 1758) (Swan Goose)

Cygnopsis cygnoides

Heterakis dispar

Genus *Branta* Scopoli, 1769

Heterakis dispar

1. *Branta bernicla* (Linnaeus, 1758) (White-bellied Brant)

Anas bernicla
"Bernicla"
Heterakis dispar

GENUS *CYGNUS* BECHSTEIN, 1803

1. *Cygnus atratus* (Latham, 1790) (Australian Black Swan)
   Chenopsis atrata
   Heterakis vesicularis
2. *Cygnus melanocoryphus* (Molina, 1782)
   Tetrameres fissispina

GENUS *CHLOEPHAGA* EYTON, 1838

Heterakis dispar

GENUS *TADORNA* BOIE, 1822

Todorna
Heterakis dispar

GENUS *CAIRINA* FLEMING, 1822

Ascaridia galli
Heterakis dispar
Heterakis gallinarum

1. *Cairina moschata* (Linnaeus,1758) (Muscovy Duck)
   Gongylonema congolense

GENUS *ANAS* LINNAEUS, 1758

Ascaridia lineata
Heterakis dispar
Heterakis gallinarum
Heterakis vesicularis
Subulura brumpti

1. *Anas platyrhynchos* Linnaeus, 1758 (Mallard)
   Anas boschas
   Tetrameres fissispina
2. *Anas clypeata* Linnaeus, 1758 (Northern Shoveler)
   Anas spathula, Spatula clypeata
   Tetrameres fissispina
3. *Anas acuta* Linnaeus, 1758 (Northern Pintail)
   Dafila acuta
   Ascaridia perspicillum
   Tetrameres fissispina

   According to Lepage (2007) *A. acuta* has been split into *A. acuta* and *Anas eatoni*, but some authors consider *A. eatoni* a subspecies *of A. acuta.* Peterson (1999) lists the two as separate species.
4. *Anas querquedula* Linnaeus, 1758 (Garganey)
   Querquedula querquedula
   Capillaria anatis
   Tetrameres fissispina

GENUS *AYTHYA* BOIE, 1822

1. *Aythya ferina* (Linnaeus, 1758) (Common Pochard)
   Anas ferina, Aristonetta ferina, Nyroca ferina
   Tetrameres fissispina

GENUS *SOMATERIA* LEACH, 1819

1. *Somateria mollissima* (Linnaeus, 1758) (Common Eider)
   Anas mollissima
   Tetrameres fissispina

GENUS *MELANITTA* BOIE, 1822

Oedemia, Oidemia
Capillaria anatis

1. *Melanitta fusca* (Linnaeus, 1758) (Velvet Scooter)
   Anas fusca, *Oidemia fusca*
   Tetrameres fissispina

GENUS *CLANGULA* LEACH, 1819

1. *Clangula hyemalis* (Linnaeus, 1758) (Oldsquaw, Long-tailed Duck)
   Anas hyemalis, *Harelda hyemalis*, *Ereunetes occidentalis*
   Capillaria anatis

GENUS *BUCEPHALA* BAIRD, 1858

1. *Bucephala clangula* (Linnaeus, 1758) (Common Goldeneye)
   Anas clangula, *Clangula clangula*, *Glaucionetta clangula*
   Tetrameres fissispina

GENUS *MERGUS* LINNAEUS, 1758

Merganser
Capillaria anatis

1. *Mergus merganser* Linnaeus, 1758 (Common Merganser)
   Tetrameres fissispina

Order Turniciformes

Family TURNICIDAE (Buttonquail)

GENUS *TURNIX* BONNATERRE, 1791

1. *Turnix suscitator* (Gmelin, 1789) (Barred Buttonquail)
   Tetrao suscitator
   Hymenolepis cantaniana

Order Piciformes

Syngamus trachea

Order Galbuliformes

Family BUCCONIDAE (Puffbirds)

GENUS *BUCCO* BRISSON, 1760

Subulura strongylina

GENUS *MALOCOPTILA* GRAY, 1841

Subulura strongylina

GENUS *NONNULA* SCLATER, 1854

Subulura strongylina

GENUS *MONASA* VIEILLOT, 1816

Subulura strongylina

GENUS *CHELIDOPTERA* GOULD, 1837

Subulura strongylina

Order Bucerotiformes

Family BUCEROTIDAE (Hornbills)

GENUS *ACEROS* HODGSON, 1844

1. *Aceros corrugatus* (Temminck, 1832) (Wrinkled Hornbill)
   Buceros corrugatus, Rhyniceros corrugatus
   Hadjelia truncata

GENUS *TOCKUS* LESSON, 1830

1. *Tockus erythrorhynchus* (Temminck, 1823) (Red-billed Hornbill)
   Buceros erythrorhynchus
   Hadjelia truncata
2. *Tockus fasciatus semifasciatus* (Hartlaub, 1855) (Allied Hornbill)
   Lophoceros semifasciatus
   Hadjelia truncata
3. *Tockus leucomelas* (Liechtenstein, 1842) (Southern Yellow-billed Hornbill)
   Buceros leucomelas
   Hadjelia truncate

   Some authors consider *T. leucomelas* a subspecies of *Tockus flavirostris* (Rüppell, 1853) (Lepage 2007)

Order Upupiformes

Family UPUPIDAE (Hoopoes)

GENUS *UPUPA* LINNAEUS, 1758

1. *Upupa epops* Linnaeus, 1758 (Hoopoe)
   Hadjelia truncata

Family CORACIIDAE (Rollers)

GENUS *CORACIAS* LINNAEUS, 1758

Synhimantus spiralis

1. *Coracias benghalensis* (Linnaeus, 1758) (Indian Roller)
   Corvus benghalensis
   Hadjelia truncata

GENUS *HALCYON* SWAINSON, 1821

1. *Halcyon smyrnensis* (Linnaeus, 1758) (White-throated Kingfisher)
   Hadjelia truncata

Family MEROPIDAE (Bee-eaters)

GENUS *MEROPS* LINNAEUS, 1758

Cyrnea eurycerca

Order Cuculiformes

Family CUCULIDAE (Cuckoos, coucals, anis, roadrunners, couas, etc.)

GENUS *CUCULUS* LINNAEUS, 1758

Subulura strongylina

GENUS *CENTROPUS* ILLIGER, 1811

1. *Centropus phasianinus* (Latham, 1802) (Pheasant Coucal)
   Cuculus phasianinus
   Subulura differens

Order Strigiformes

Family STRIGIDAE (Typical owls)

GENUS *STRIX* LINNAEUS, 1758

Heterakis dispar
Heterakis gallinarum

GENUS *SURNIA* DUMERIL, 1805

Heterakis dispar

GENUS *GLAUCIDIUM* BOIE, 1826

Heterakis dispar

Family NYCTIBIIDAE (Potoos)

GENUS *NYCTIBIUS* VIEILLOT, 1816

Subulura suctoria

Family CAPRIMULGIDAE (Nightjars)

GENUS *PODAGER* WAGLER, 1832

Subulura strongylina
Subulura suctoria

GENUS *CAPRIMULGUS* LINNAEUS, 1758

Subulura strongylina
Subulura suctoria

Order Columbiformes

Family COLUMBIDAE (Pigeons and doves)

Pigeon
Ascaridia lineata

GENUS *COLUMBA* LINNAEUS, 1758

Aonchotheca caudinflata
Synhimantus spiralis

1. *Columba livia* Gmelin, 1785 (Rock Pigeon)

Cotugnia digonopora
Raillietina echinobothrida
Hadjelia truncata
Tetrameres fissispina

GENUS *STREPTOPELIA* BONAPARTE, 1855

Spilopelia

Ascaridia galli

1. *Streptopelia orientalis* (Latham, 1790) (Oriental Turtle-Dove)

   Columba orientalis, *Turtur orientalis*

   Subulura brumpti

Order Gruiformes

Family RALLIDAE (Rails, crakes, moorhens and coots)

GENUS *FULICA* LINNAEUS, 1758

1. *Fulica atra* Linnaeus, 1758 (Common Coot)

   Tetrameres fissispina

Family OTIDIDAE (Bustards and korhaans)

Yamaguti (1961) lists *Aonchotheca caudinflata*, *Heterakis gallinarum* and *Heterakis vesicularis* from *Otis* without giving the host's species name. It is therefore not clear whether *Otis* refers to the current genus *Otis*, *Ardeotis*, *Neotis* or *Chlamydotis*.

Otidiformes in Yamaguti (1961)

Syngamus trachea

GENUS *OTIS* LINNAEUS, 1758

1. *Otis tarda* Linnaeus, 1758 (Great Bustard)

   Mediorhynchus taeniatus

GENUS *ARDEOTIS* LE MAOUT, 1853

1. *Ardeotis arabs* (Linnaeus, 1758) (Arabian Bustard)

   Choriotis arabs, Otis arabs

   Mediorhynchus empodius
   Mediorhynchus taeniatus

GENUS *CHLAMYDOTIS* LESSON, 1839

Houbara

Hetrakis gallinarum

According to Lepage (2007) the common name Houbara has been split into *Chlamydotis undulata* and *Chlamydotis macqueenii*.

1. *Chlamydotis undulata* (Jacquin, 1784) (Houbara Bustard)

   Otis houbara, *Psophia undulata*

   Mediorhynchus taeniatus
   Hispaniolepis falsata

2. *Chlamydotis macqueenii* Gray, 1832 (Macqueen's Bustard)

   Otis macqueenii

   Mediorhynchus taeniatus

Order Charadriiformes

Family PTEROCLIDIAE (Sandgrouse)

GENUS *PTEROCLES* TEMMINCK, 1815

Calopterocles

Heterakis gallinarum

1. *Pterocles exustus* Temminck, 1825 (Chestnut-bellied Sandgrouse)

   Pteroclidurus exustus, *Pterocles senegalensis*

   Raillietina cohni

   Lepage (2007) lists *Pterocles senegalensis* as synonym for *Pterocles exustus*.

2. *Pterocles orientalis arenarius* (Pallas, 1775) (Eastern Black-bellied Sandgrouse)

   Pterocles arenarius

   Raillietina cohni

   Lepage (2007) and Peterson (1999) list *Pterocles arenarius* as subspecies of *Pterocles orientalis* (Linnaeus, 1758).

Family JACANIDAE (Jacanas)

GENUS *METOPIDIUS* WAGLER, 1832

Synhimantus spiralis

Family BURHINIDAE (Thick-knees)

GENUS *BURHINUS* ILLIGER, 1811

Oedicnemus

Subulura suctoria

1. *Burhinus oedicnemus* (Linnaeus, 1758) (Eurasian Thick-knee)

   Charadrius oedicnemus, *Oedicnemus crepitans*

   Mediorhynchus taeniatus

Family CHARADRIIDAE (Plovers, dotterels, lapwings)

GENUS *VANELLUS* BRISSON, 1760

1. *Vanellus cinereus* (Blyth, 1842) (Grey-headed Lapwing)

   Hoplopterus cinereus, *Microsarcops cinereus, Pluvianus cinereus*

   Davainea nana

Order Falconiformes

Family ACCIPITRIDAE (Eagles, hawks, buzzards, kites, vultures)

GENUS *ACCIPITER* BRISSON, 1760

Synhimantus spiralis

Order Ciconiiformes

Family PODICIPEDIDAE (Grebes)

GENUS *TACHYBAPTUS* REICHENBACH, 1853

1. *Tachybaptus novaehollandiae* (Stephens, 1826) (Australian Grebe)

Podiceps fluviatilis, Podiceps novaehollandiae
Tetrameres fissispina

Family ARDEIDAE (Herons, egrets and bitterns)

"Ardeiformes"
Syngamus trachea

GENUS *ARDEA* LINNAEUS, 1758

Mediorhynchus empodius

GENUS *NYCTICORAX* FORSTER, 1817

1. *Nycticorax nycticorax* (Linnaeus, 1758) (Black-crowned Night-Heron)
Ardea nycticorax
Tetrameres fissispina

Family PELECANIDAE (Pelicans)

"Pelicaniformes"
Syngamus trachea

Family CICONIIDAE (Storks)

GENUS *CICONIA* BRISSON, 1760

Synhimantus spiralis

Order Passeriformes

Syngamus trachea

Family CORVIDAE (Crows and ravens)

GENUS *CORVUS* LINNAEUS, 1758

Heterakis gallinarum
Synhimantus spiralis

Family PYCNONOTIDAE

GENUS *PYCNONOTUS* BOIE, 1826

1. *Pycnonotus capensis* (Linnaeus, 1766) (Cape Bulbul)
Sicarius caudatus

Family MUSCICAPIDAE (Old World flycatchers)

GENUS *TURDUS* LINNAEUS, 1758

Aonchotheca caudinflata
Synhimantus spiralis

1. *Turdus viscivorus* Linnaeus, 1758 (Mistle Thrush)
Ascaridia perspicillum
2. *Turdus migratorius* Linnaeus, 1766 (American Robin)
Planesticus migratorius
Synhimantus spiralis

Family STURNIDAE (Starlings)

GENUS *STURNUS*

Aonchotheca caudinflata

Family PASSERIDAE (Old World sparrows, sowfinches and relatives)

GENUS *PASSER* BRISSON, 1760

Aonchotheca caudinflata
Synhimantus spiralis

1. *Passer domesticus* (Linnaeus, 1758) (House Sparrow)
Fringilla domestica
Dispharynx nasuta

GENUS *EUPLECTES* SWAINSON, 1829

1. *Euplectes orix* (Linnaeus, 1758) (Red Bishop)
Pyromelana oryx
Subulura differens

Family FRINGILLIDAE (Canaries and buntings)

GENUS *QUISCALUS* VIEILLOT, 1816

Synhimantus spiralis

ACKNOWLEDGEMENTS

The first author was supported by a Claude Leon Foundation Postdoctoral Fellowship grant. Funds for this research were made available by the Department of Veterinary Tropical Diseases, as well as the Faculty of Veterinary Science of the University of Pretoria.

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SECTION 3

PARASITES

OF

REPTILES

Introduction

The parasites of reptiles are poorly known in South Africa. Dr. Stephan Hering-Hagenbeck came to this country to initially do the helminths of nyalas, but I convinced him to rather do the helminths of reptiles. He sought, and got, permission to collect from a number of geographical regions, and recorded a whole host of new species. I was one of his co-promoters, and some of the funding was borne by my laboratory. What follows is a selection of the papers that were published from his PhD thesis on snakes and lizards.

As stated earlier, Dr Junker arrived in South Africa to do the pentastomid parasites of fish and crocodiles. Again, a selection of papers produced as result of her research on pentastomids and the results of some routine identifications or crocodile helminths are presented here.

The section is arranged in two chapters, the helminths and pentastomes, and within each chapter the papers are listed firstly by the species descriptions in chronological order and then by the helminth communities, also chronologically.

HELMINTH PARASITESS OF REPTILES (P 519)

HERING-HAGENBECK, S.F.B.N & BOOMKER, J. 1998. *Spauligodon timbavatiensis* n. sp. (Nematoda: Pharyngodonidae) from *Pachydactylus turneri* (Sauria: Gekkonidae) in the Northern Province, South Africa. *Onderstepoort Journal of Veterinary Research*, 65, 153 – 158.

HERING-HAGENBECK, S., BOOMKER, J., PETIT, G., KILLICK-KENDRICK, M. & BAIN, O. 2000. Description of *Madathamugadia hiepei* n. sp. (Nematoda: Splendidofilariinae), a parasite of a South African gecko, and its development in laboratory bred *Phlebotomus dubosqi* (Diptera: Psychodidae). *Systematic Parasitology*, 47, 207-213.

HERING-HAGENBECK, S.F.B.N., PETTER, A.J. & BOOMKER, J. 2002. Redesription of some *Spauligodon* spp. and of *Skrjabinodon mabuyae* (Sandground, 1936) Inglis, 1968 (Pharyngodonidae: Oxyuroidea) from insectivorous South African lizards. *Onderstepoort Journal of Veterinary Research*, 69, 7-29.

HERING-HAGENBECK, S.F.B.N., PETTER, A.J. & BOOMKER, J. 2002. Redescription of some *Thelandros* and *Tachygonetria* spp. (Pharyngodonidae: Oxyuroidea) from the omnivorous plated lizard, *Gerrhosaurus validus validus* A. Smith, 1849 in South Africa. *Onderstepoort Journal of Veterinary Research*, 69, 31-51.

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HERING-HAGENBECK, S.F.B.N. & BOOMKER, J., 2000. A check list of the nematode parasites of South African Serpentes (snakes) and Sauria (lizards). *Onderstepoort Journal of Veterinary Research*, 67, 1 - 13.

PENTASTOMID PARASITESS OF REPTILES (P 599)

JUNKER, KERSTIN, BOOMKER, J., BOLTON, LORNA A. 1999.Pentastomid infections in Nile crocodiles (*Crocodylus niloticus*) in the Kruger National Park, South Africa, with a description of the males of *Alofia simpsoni*. *Onderstepoort Journal of Veterinary Research*, 66, 65-71.

JUNKER, K., BOOMKER, J., SWANEPOEL, D. & TARASCHEWSKI, H. 2000. *Leiperia cincinnalis* Sambon, 1922 (Pentastomida) from Nile crocodiles *Crocodylus niloticus* in the Kruger National Park, South Africa, with a description of the male. *Systematic Parasitology*, 47, 29 – 41.

JUNKER, K. & BOOMKER, J. 2002. Description of *Pelonia africana* n.g., n. sp. (Pentastomida: Sebekidae) from the lungs of *Pelomedusa subrufa* and *Pelusios siniatus* (Chelonia) in South Africa. *Onderstepoort Journal of Veterinary Research*, 69, 53-59.

JUNKER, K., RILEY, J & BOOMKER, J. 2003. Redescription of of *Diesingia megastoma* (Diesing, 1836) Sambon, 1922, a pentastomid parasite from the South American terrapin *Hydromedusa tectifera* Cope. *Systematic Parasitology*, 56, 211-218.

JUNKER, K. & BOOMKER, J. 2006. A check-list of the pentastomid parasites of crocodilians and freshwater chelonians. *Onderstepoort Journal of Veterinary Research*, 73, 27-36.

CHAPTER 1

Helminth parasites

of

reptiles

Onderstepoort Journal of Veterinary Research, 65:153–158 (1998)

Spauligodon timbavatiensis n. sp. (Nematoda: Pharyngodonidae) from *Pachydactylus turneri* (Sauria: Gekkonidae) in the Northern Province, South Africa

S.F.B.N. HERING-HAGENBECK[1] and J. BOOMKER[2]

ABSTRACT

HERING-HAGENBECK, S.F.B.N. & BOOMKER, J. 1998. *Spauligodon timbavatiensis* n. sp. (Nematoda: Pharyngodonidae) from *Pachydactylus turneri* (Sauria: Gekkonidae) in the Northern Province, South Africa. *Onderstepoort Journal of Veterinary Research*, 65:153–158

Spauligodon timbavatiensis n. sp. (Nematoda: Pharyngodonidae) from the large intestine of *Pachydactylus turneri* (Sauria: Gekkonidae) in the Northern Province (RSA) is described and illustrated. It is the fifth species in the Ethiopian region, the others being *Spauligodon smithi* from *Pachydactylus bibronii* and *Spauligodon petersi* from *Mabuya sulcata*, both in the Northern Cape Province, South Africa, *Spauligodon morgani* from *Mabuya striata* in Malawi, and *Spauligodon dimorpha* from *Chamaeleo pardalis* in Madagascar.

The males of the new species differ from *S. smithi* in that the adcloacal papillae are single (bifid in *S. smithi*), from *S. petersi* in the presence of a spicule and having narrow lateral alae (wide and triangular in *S. petersi*) and from *S. dimorpha* and *S. morgani* in having a spicule. Furthermore, *S. timbavatiensis* differs from *S. morgani* in lacking spines on the tail. The females of the new species have a long tail and truncated egg ends as opposed to the short, spiky tail and pointed eggs of *S. morgani*; a spiny tail and truncated eggs as opposed to the smooth tail and pointed eggs of S. *petersi* and a longer oesophagus than *S. smithi*. Furthermore, the females of *S. dimorpha* and *S. morgani* are much larger than those of *S. timbavatiensis*. In addition, the excretory pore opens behind the posterior end of the oesophageal bulb in the new species, while in *S. smithi* and *S. dimorpha* it opens at the level of the end of the oesophageal bulb.

Keywords: Gekkonidae, nematode, *Pachydactylus turneri*, Pharyngodonidae, reptiles, South Africa, *Spauligodon timbavatiensis* n. sp.

INTRODUCTION

As part of a study on the parasites of reptiles, several species of Sauria were collected from the Klaserie Private Game Reserve, Northern Province, South Africa. Among these were two specimens of *Pachydactylus turneri*, a common large gecko in southern Africa. They occur on rocky outcrops, under loose tree bark and sometimes on houses. The geckos are gregarious and are often found in colonies. Their prey consists of a variety of insects including ants, termites, beetles and grasshoppers, and even smaller lizards are consumed on occasion (Branch 1998). The *Pachydactylus bibronii-laevigatus* complex was recently revised (Benyr 1995), but Branch (1998) does not accept this revision.

The genus *Spauligodon* was created when the genus *Pharyngodon* Diesing, 1861 was divided into three new genera: *Pharyngodon, Parathelandros* Baylis, 1930 and *Spauligodon* Skrjabin, Schikhobalova & Lagodovskaja, 1960 (Skrjabin, Schikhobalova & Lagodovskaja 1960). Thirty-four *Spauligodon* species have as yet been described, four of which occur in the Ethiopian region (Bursey, McAllister & Freed 1997).

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Accepted for publication 21 May 1998—Editor

In this paper the fifth species, recovered from the large intestine of the geckos and for which the name *Spauligodon timbavatiensis* n. sp. is proposed is described and illustrated.

MATERIAL AND METHODS

Two geckos were collected by hand in the Klaserie Private Game Reserve and taken back alive to the laboratory. They were euthanazed, weighed and measured, and the internal organs removed. The trachea, lungs, liver, oesophagus, stomach, small intestines, large intestines and rectum were placed in phosphate buffered saline (PBS) in separate petri dishes, and examined for helminths under a stereoscopic microscope. In order to obtain clean specimens, nematodes were removed from the ingesta, placed in another petri dish in PBS for 20–30 min, whereafter they were fixed in boiling 70% ethanol. For detailed light microscopic studies they were transferred to a 50% lactophenol-water solution and examined while clearing. The material was studied under a Nikon compound microscope and drawings made with a drawing tube. Measurements were made by measuring the drawings. Measurements are those of the holotype and allotype and, where available, followed by those of the paratypes (in parentheses). All measurements are given in millimeters (mm).

Specimens for scanning electron microscopy were dehydrated through graded ethyl alcohol and critical point dried. They were sputter coated with gold and examined with a Leica Stereoscan 420 scanning electron microscope at an accelerating voltage of 5 kV.

The geckos were deposited in the herpetological collection of the Transvaal Museum (TM. 81535 and TM. 81536).

RESULTS

Characterization of the genus *Spauligodon* Skrjabin, Schikhobalova & Lagodovskaja, 1960

Pharyngodonidae with a triangular mouth opening, each lip partially or completely divided into two. Excretory pore behind the oesophageal bulb, in females always near the vulva. Oesophageal bulb with a well-sclerotized valvular apparatus. Lateral alae are present. The cloacal papillae of the males are clearly separated into precloacal, adcloacal and postcloacal pairs. Papillae of the last named pair are well separated from each other and usually only a short distance from the adcloacal pair and never rosette-shaped. The protruding genital cone may be supported by sclerotized structures, but the pre- and adcloacal pairs of papillae are never situated on the cone. Caudal alae are always present, but never support the last pair of papillae. Spicules are often absent. The usually long and tapering tail may be spinose or aspinose (amended from Skrjabin *et al.* 1960 and Petter & Quentin 1976). Parasites of carnivorous reptiles.

DESCRIPTION OF THE SPECIES

Spauligodon timbavatiensis n. sp. (Fig. 1 and 2)

Small nematodes with a cylindrical body, tapering at both ends. In both sexes lateral alae are present and the nerve ring surrounds the oesophagus in the anterior half, more or less at the commencement of the lateral alae. The conspicuous excretory pore always lies posterior to the oesophageal bulb and is a transverse slit surrounded by a chitinous rim. The tail is long and flexible.

MALES

Small nematodes, 2,24 (1,74–2,05) long and 0,19 (0,12–0,14) wide at mid-body. Three well-developed lips surround a triangular mouth opening. Each lip is incompletely divided in two lobes with a shallow notch in each lobe. Cephalic papillae were not seen. Behind the anterior margin of the lips, on their inner side, two tooth-like structures are visible.

Narrow lateral alae start at 0,09 (0,12–0,18) and 0,14 (0,12–0,15), respectively, from the anterior end, and are 1,54 (1,49–1,83) and 1,49 (1,47–1,82) long.

The oesophagus consists of a fairly short, clavate corpus, 0,26 (0,26–0,35) long, before it joins the slightly oval bulbus that is 0,09 (0,07–0,08) long and 0,07 (0,07–0,08) wide. The nerve ring and excretory pore are situated 0,15 (0,12–0,15) and 0,65 (0,56–0,65), respectively, from the anterior end.

The cloacal papillae comprise a pair of pre-cloacal papillae, a pair of adcloacal papillae and a pair of post cloacal papillae. Caudal alae have a finely sculptured inner surface. A characteristic genital cone surrounded by an ornate, folded membranous lip is present. Only one very weakly sclerotized spicule measuring 0,08 is visible. The tail is 0,25 (0,17–0,24) long and aspinose.

FEMALES

Females are larger than males, 3,49 (2,13–2,41) long and 0,22 (0,21–0,27) wide at mid-body. As in the males, there are three well-developed lips surrounding a triangular mouth opening. Each lip is divided into two lobes and tooth-like structures are borne on the inside of each lip. Cephalic papillae were not seen.

The lateral alae start at 0,14 (0,09–0,12) from the anterior end and are 2,54 (2,15–2,46) long and 0,02 wide.

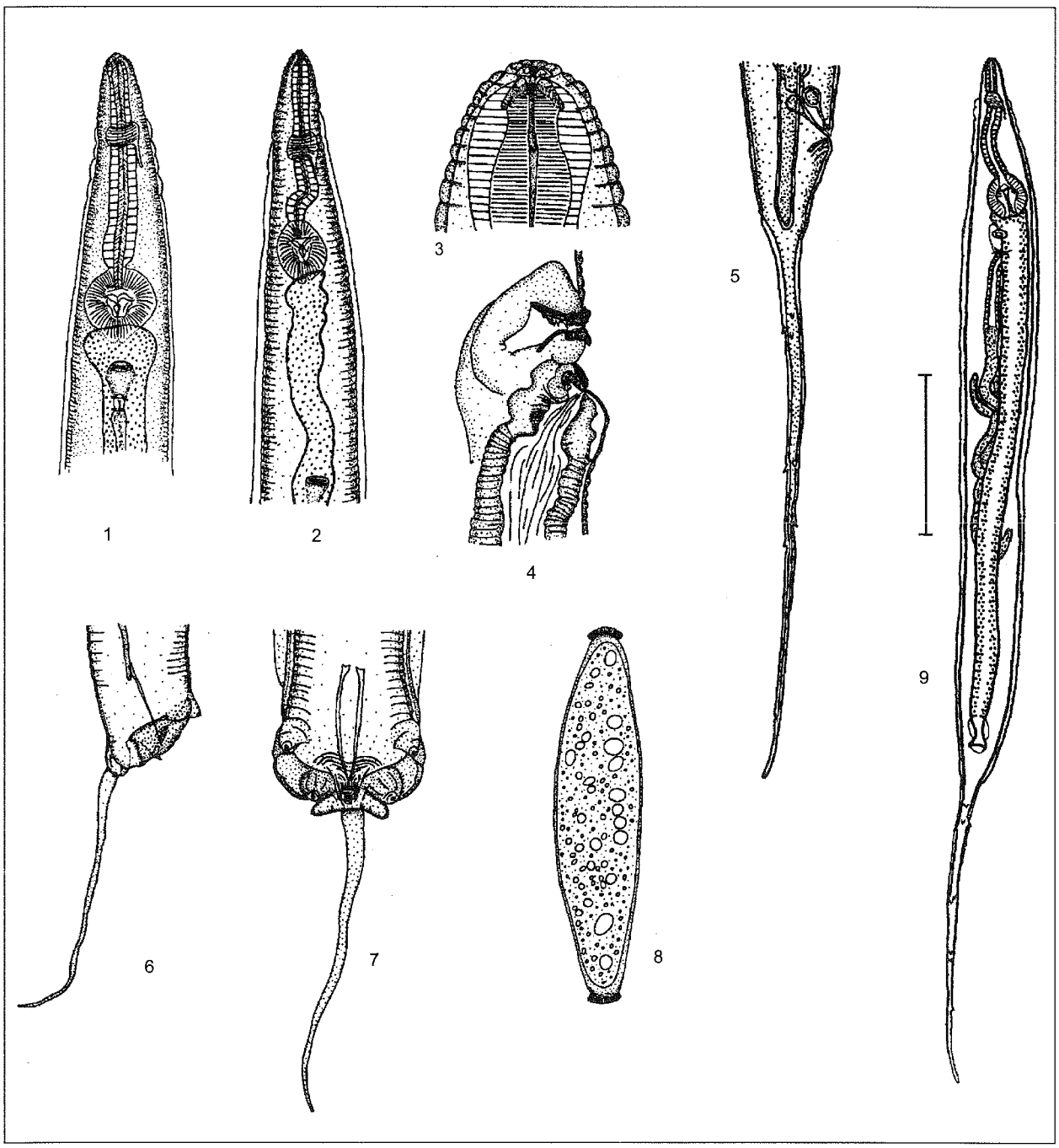

FIG. 1 *Spauligodon timbavatiensis* n. sp.

1. Anterior part, ventral view, paratype male (bar = 0,1 mm)
2. Anterior part, ventral view, paratype female (bar = 0,1 mm)
3. Detailed anterior part, ventral view, paratype female (bar = 0,05 mm)
4. Vulva and excretory pore, lateral view, paratype female (bar = 0,1 mm)
5. Posterior end, lateral view, paratype female (bar = 0,05 mm)
6. Posterior end, lateral view, paratype male (bar = 0,1 mm)
7. Posterior end, ventral view, paratype male (bar = 0,1 mm)
8. Egg (bar = 0,1 mm)
9. Entire, lateral view, paratype female (bar = 0,5 mm)

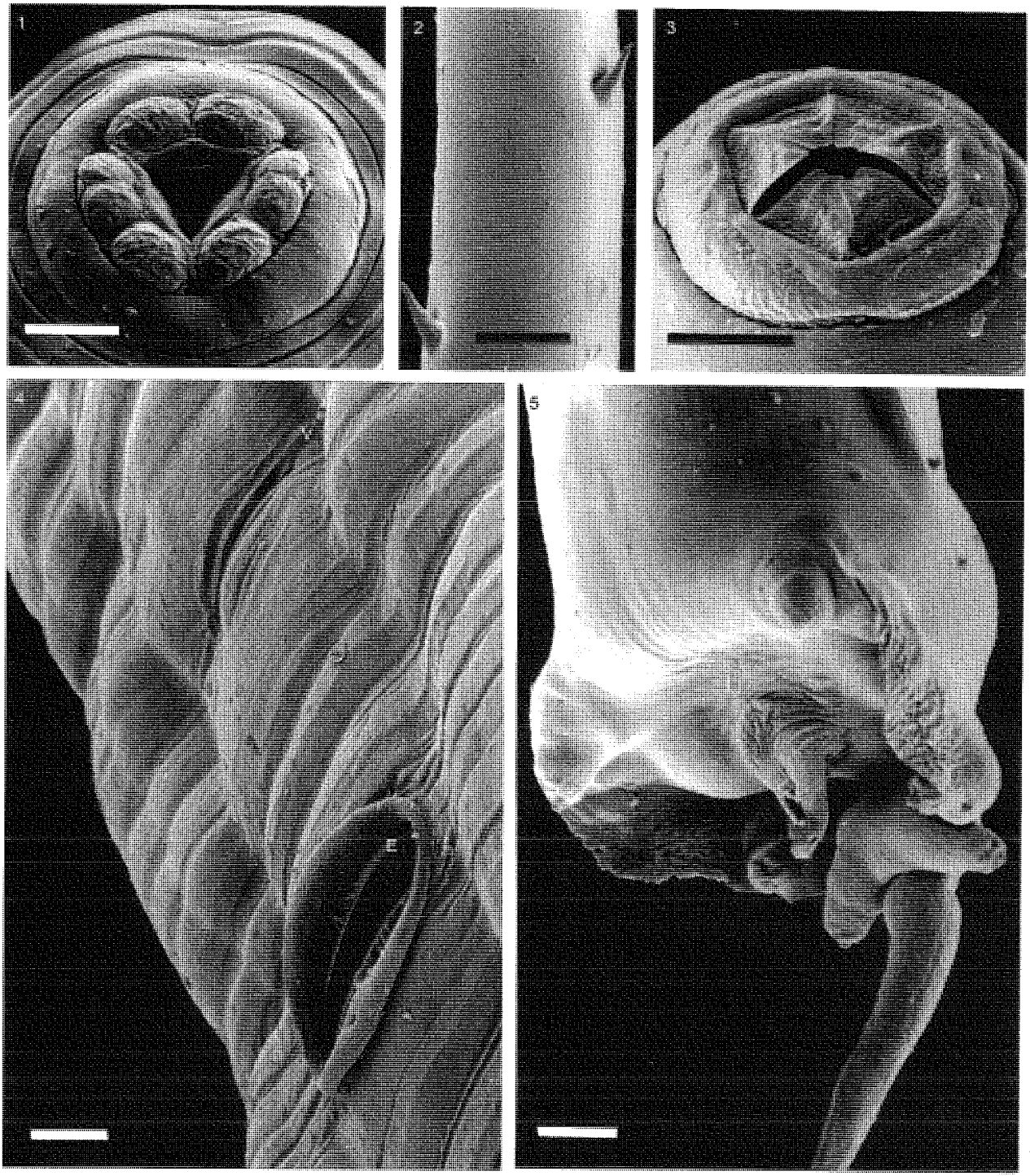

FIG. 2 *Spauligodon timbavatiensis* sp. n.

1. Anterior part, paratype female (bar = 0,05 mm)
2. Spines on tail of paratype female (bar = 0,05 mm)
3. Anterior part, paratype male (bar = 0,05 mm)
4. Midbody paratype female, V = vulva; E = excretory pore (bar = 0,05 mm)
5. Posterior part, paratype male (bar = 0,09 mm)

The body of the oesophagus is 0,41 (0,37–0,40) long, and the bulb 0,14 (0,11–0,14) long and 0,14 (0,14–0,15) wide. The nerve ring and excretory pore are situated 0,16 (0,13–0,17) and 0,62 (0,57–0,63) from the anterior end, respectively.

The vulva lies slightly behind the excretory pore, 0,68 (0,56–0,66) from the anterior end. The muscular ovejector extends posteriorly into a thin-walled common uterus, 0,33 long, into which join the anterior and posterior uteri. Thin-shelled eggs in the uterus measure 0,156 (0,133–0,162) x 0,033 (0,032–0,034), and are elongated and fusiform, with caps on each truncated end. They are unsegmented when laid. The long, flexible, filiform tail, 0,96 (0,83–1,11) long, always carries between seven and nine cuticular spines.

TYPE HOST

Pachydactylus turneri (Gekkonidae).

TYPE LOCALITY

Timbavati/Klaserie/Umbabat Private Nature Reserves (25°36´51,8´´S; 28°01´30,5´´E), Northern Province, Republic of South Africa.

TYPE MATERIAL

Holotype male, allotype female, ten paratype males and ten paratype females. The paratypes included immature males and females without eggs. The type specimens are deposited in the collection of the Museum National d'Histoire Naturelle, Paris, France, access number 579HF.

HABITAT

Mucosa of large intestine.

ETYMOLOGY

The species is named after the locality of the host.

DISCUSSION

The general morphology of the new species allows its inclusion into the family Pharyngodonidae. Only in the genera *Pharyngodon* (syn. *Neopharyngodon* Chakravarty & Bhaduri, 1948), *Skrjabinodon* Inglis, 1968 and *Spauligodon* does the vulva open just behind the post bulbar excretory pore in the anterior part of the body. In contrast to the males of *Pharyngodon*, which have well-developed caudal alae enveloping all genital papillae, *Skrjabinodon* males lack the caudal alae, while the males of *Spauligodon* have caudal alae that do not enclose the posterior pair of papillae. Based on the position of the vulva and the configuration of the caudal alae of the male, the new species conforms to the description of the genus *Spauligodon*.

There currently are 34 species of *Spauligodon* that are separated on the presence or absence of spines on the tail and the shape of the eggs (Bursey & Goldberg 1995). However, Chabaud & Brygoo (1962) suggested that the most important factor in speciation of reptilian oxyurids would be the geographical distribution. Only four *Spauligodon*-species have presently been described for the Ethiopian region. Three of these, *S. dimorpha*, *S. morgani* and *S. petersi* lack spicules. The females of *S. dimorpha* and *S. morgani* are much larger than those of *S. timbavatiensis*, their tails are short and the excretory pore of *S. dimorpha* is situated on the same level as the oesophageal bulb. *S. dimorpha* was described from *Chamaeleo pardalis* in Madagascar (Chabaud & Brygoo 1962). Furthermore, the males of *S. morgani* have a spinose tail and the species was described from *Mabuya striata* in Malawi (Fritzsimmons 1961).

The female of *S. petersi* lacks spines on the tail and the male has wide lateral alae. In addition, the eggs are pointed with smaller terminal plugs on each end and are flattened on one side. *S. petersi* was described from *Mabuya sulcata sulcata* in South Africa (Bursey *et al.* 1997).

The remaining species, *S. smithi*, is very similar to *S. timbavatiensis* as regards the host and locality. The most conspicuous difference is that the adcloacal pair of papillae is bifid in *S. smithi* and single in *S. timbavatiensis*. Furthermore, the excretory pore and vulva of female *S. smithi* are situated more anterior than in *S. timbavatiensis*, although the body lengths are nearly the same. Both sexes of the last named species also have slightly oval oesophageal bulbs as opposed to the round bulb in both sexes of *S. smithi*.

We believe that the differences between the new and already described species are sufficient to warrant the creation of a new species, for which the name *S. timbavatiensis* n. sp. is proposed.

ACKNOWLEDGEMENTS

We wish to express our appreciation to the following persons and institutions: Dr Salomon Joubert, Mr Brian Harris, Mr Collin Rowles and the private landowners for permission to do the field collection in the Timbavati/Klaserie/Umbabat Private Game Reserves; Mr Wulf Haacke and Mr Richard Newbery for much help as regards the reptiles; the Department of Environmental Affairs, Northern Province, for the collecting permits; Miss Chantelle Baker and Miss Nishi Prabdial, Medical University of Southern Africa, for help in preparing and scanning of the specimens.

This study was financially supported by the Arthur & Aenne Feindt Stiftung, Hamburg, Germany.

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Systematic Parasitology **47:** 207–213, 2000.

Description of *Madathamugadia hiepei* n. sp. (Nematoda: Splendidofilariinae), a parasite of a South African gecko, and its development in laboratory bred *Phlebotomus dubosqi* (Diptera: Psychodidae)

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Accepted for publication 15th January, 2000

Abstract

Madathamugadia hiepei n. sp., Splendidofilariinae, a parasite of a South African gecko *Pachydactylus turneri* is described together with its development obtained experimentally in *Phlebotomus duboscqi* (Diptera: Psychodidae: Phlebotominae). This new species differs from the two small, more highly evolved groups with a short tail and atrophied postcloacal papillae, the first group consisting of two Madagascan species, *M. zonosauri* and *M. hopluri*, parasites of the Gerrhosauridae and Iguanidae, and the second containing three species from the Ethiopian Region, *M. huambensis*, *M. versterae* and *M. bissani*, parasites of the Scincidae. It also differs from *M. ineichi*, the most primitive species of the genus (cuticularised buccal capsule, no atrophy of head papillae and largest number of precloacal papillae), a parasite of the Cordylidae in South Africa. *M. hiepei* is close to the two species parasitic in the Gekkonidae of the Mediterranean subregion, *M. ivaschkini* and *M. wanjii*, all three of which have a post-oesophageal vulva. However, the new species can be distinguished from the Mediterranean parasites by (a) the shorter oesophagus, (b) the number and position of the cloacal papillae and (c) the microfilaria. The three filariae of this group and *M. ineichi*, the only ones of which aspects of the life-cycles are known, experimentally develop in phlebotomine sand flies.

Introduction

Three genera of filarial worms of the subfamily Splendidofilariinae are parasites of saurians: *Thamugadia* Seurat, 1917 from the Mediterranean subregion represented by four species (Seurat, 1917; Sulahian & Schacher, 1968; Annaev & Sonin, 1973; Bain et al., 1993); *Pseudothamugadia* Lopez-Neyra, 1956 from Australia which is monospecific (Johnston, 1912); and *Madathamugadia* Chabaud, Anderson & Brygoo, 1959 which is comprised of two Madagascan species (Chabaud et al., 1959), two from the Mediterranean subregion (Bain et al., 1992) and four from the Ethiopian Region (Bain et al., 1993).

The filariid described in the present paper belongs to the last of these genera, *Madathamugadia*, which is characterized by the presence of precloacal papillae of the male and dissimilar left and right spicules (Bain et al., 1992). It was collected from a South African gecko, *Pachydactylus turneri* (Gray). *Madathamugadia* was known previously only from the Scincidae and Cordylidae of the Ethiopian Region and the Gekkonidae of the Mediterranean subregion.

The larval development of three *Madathamugadia* species have been seen in experimentally infected sand flies (Reznik, 1982; Bain et al., 1992, 1993). For this reason, sand flies were used in the present study.

Materials and methods

Pachydactylus turneri, a common, large thick-toed gecko, is widely distributed in the northern parts of southern Africa where it occurs on rocky outcrops, often living in colonies (Branch, 1998). The systematics of the *P. bibronii-laevigatus-turneri* complex is currently not clear (Benyr, 1995; Branch, 1998; Haacke, 1998, pers. com.).

As part of a study of nematode parasites of reptiles in various places in South Africa (Hering-Hagenbeck & Boomker, 1998), 60 specimens of this gecko were caught in two different areas of the former Transvaal, Republic of South Africa. Microfilaraemia was determined in Giemsa-stained blood films. In the Hoedspruit Nature Reserve/Timbavati-Klaserie Private Game Reserves, Northern Province (24°04′23″ S; 31°03′18″ E), none of 22 geckos caught was infected. In contrast, in the campus of the Medical University of Southern Africa, Gauteng Province (25°36′51″ S; 28°01′30″ E), 25 of 38 geckos were infected with the new parasite (65.7%); however, microfilariae were seen only in the blood of adults and not in the blood of juveniles or subadults.

Six geckos with microfilariae in the blood were imported into France under a permit issued by Ministry of the Environment. They were kept in captivity in Paris to recover adult worms and study the life cycle. All six had concomitant infections with blood Protozoa. The filarial worms were situated in the dorsal parietal peritoneum, often under the intestine or rectum, sometimes more anteriorly under the lungs, and were inside thin-walled, transparent pockets which are probably dilated lymphatic vessels. Adults were non-motile and could be detected only by examination with a dissecting microscope. They became active when liberated into the dissecting medium, RPMI 1640 supplemented with 20% calf serum.

Wild sand flies were collected in the habitat of the geckos and dissected. Larval development was studied experimentally in *Phlebotomus duboscqi* Neveu-Lemaire from a colony originating from Keur Moussa, Senegal, and maintained by the methods described by Killick-Kendrick & Killick-Kendrick (1987). A single breeding box containing larvae and nymphs was used. The majority of adult flies emerged within 3 days; they were daily collected and placed in 3 cages. A parasitised gecko (217ES) restrained in a wire mesh was placed successively in these cages of sand flies. Fed female flies were collected each day, maintained at 25 °C and dissected 7 days later. A total of 70 sand flies were fed, although not all were used for the filarial cycle, because some were reserved to study the development of blood protozoa. Infective larvae obtained experimentally were inoculated in a single dose to a gecko which was necropsied 8 days later.

Adult worms were fixed in hot 70% ethanol, cleared in lactophenol and all examined. Blood microfilariae from the geckos were studied with vital Meldolan Blue staining and in Giemsa-stained thick blood films. Developing larvae were examined alive in the dissecting medium. All filarial stages were studied under a compound microscope and illustrated using a camera lucida. Measurements were made after drawings and are given in micrometres, unless otherwise specified.

Geographical regions are named after the Physical Geographic Atlas of the World Anonymous, 1964).

Madathamugadia hiepei n. sp. (Figures 1–3)

Type-host: Pachydactylus turneri (Gray) (Gekkonidae).
Site: Peritoneal wall.
Type-locality: Campus of the Medical University of Southern Africa, Gauteng Province, Republic of South Africa.
Type-material (collection number followed by the number of the host): Holotype female 213ES (477); allotype male 213ES (477) and paratypes 213ES: three males, four females and a posterior region of each sex. Housed in the collection of the Muséum National d'Histoire Naturelle, Paris.
Other material: 215ES (475), one female; 217ES, two females (with developing eggs but no microfilariae) and two males, 218ES (476), one young female. 217ES is deposited in the collection of the Muséum National d'Histoire Naturelle, Paris; 213 ES, 215ES and 218ES are deposited in the collection of the Transvaal Museum, Pretoria.

Description

Mouth, buccal cavity and oesophageal lumen laterally flattened. Head papillae partly atrophied: 4 external labial papillae present, but only 2 of the 4 cephalic papillae. Oesophagus short and clearly divided, often with 3 conspicuous glandular pores (close to nerve-ring, at mid-length and posterior third of glandular oesophagus). Anterior intestinal wall with granules regularly disposed.

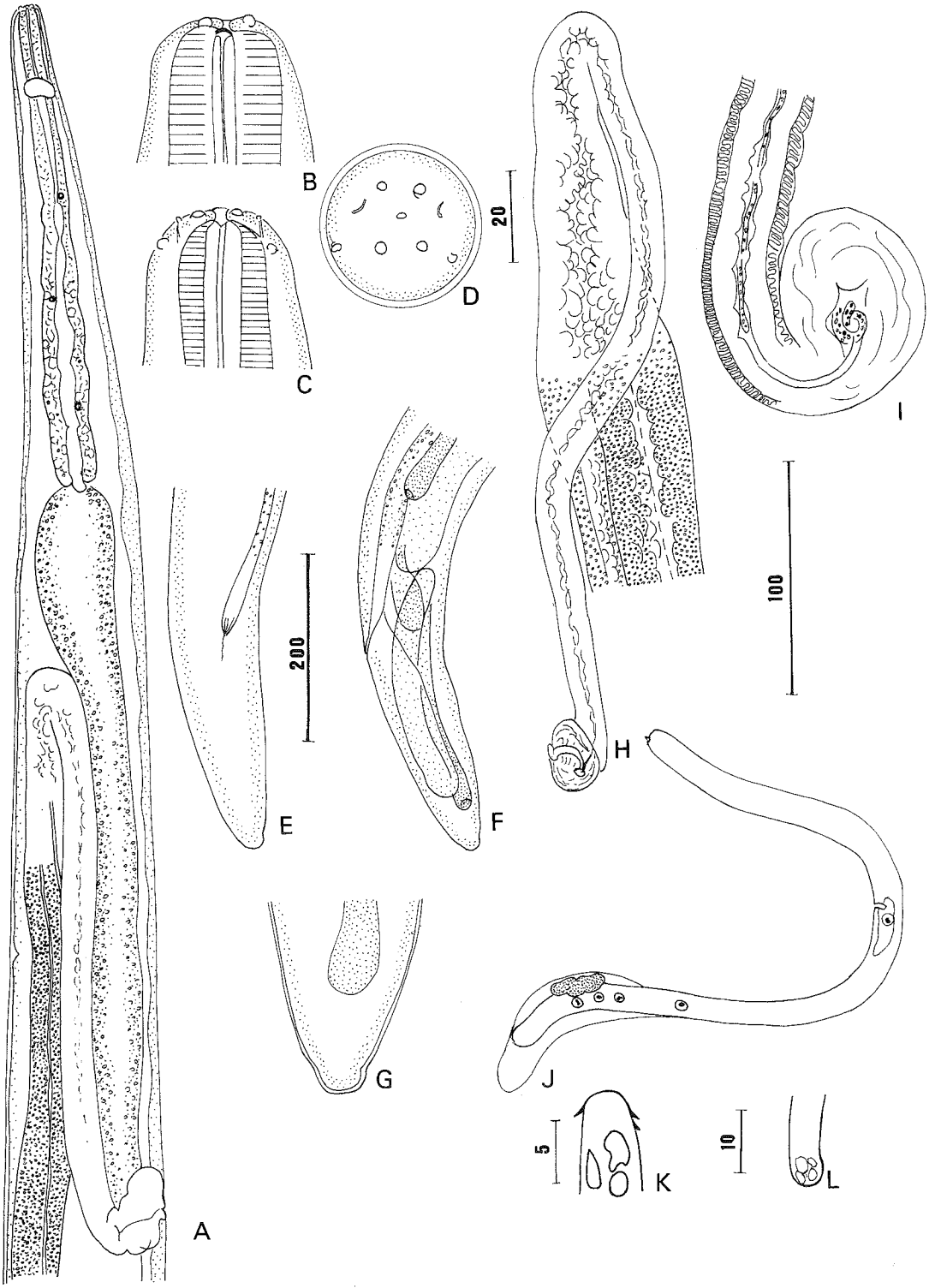

Figure 1. Madathamugadia hiepei n. sp., female: A. Anterior region, lateral view; B & C. Head, lateral and median view; D. Apical view of the head of a paratype; E & F. Tail, median and lateral view; G. Caudal extremity, dorso-median view; H. Vagina and ovijector of a paratype; I. Detail of vagina; J. Microfilaria, in vital coloration; K. & L. Detail of head and caudal extremity of a microfilaria. *Scale-bars:* A,E,F,H, 200 μm; B,C,D, 20 μm; G,I, 100 μm; J,L, 10 μm; K, 5 μm.

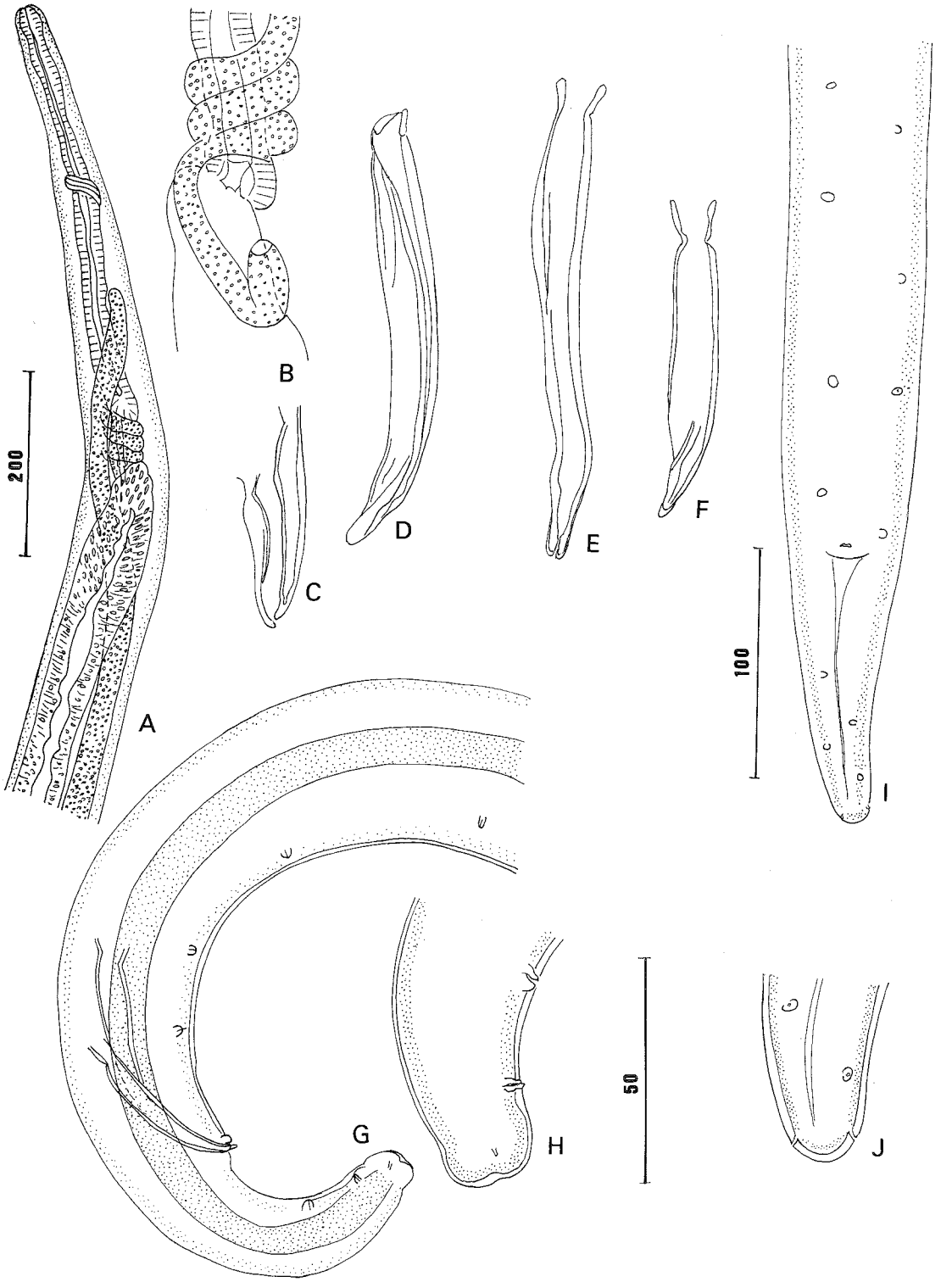

Figure 2. Madathamugadia hiepei n. sp., male. A. Anterior region of a paratype, lateral view; B. Oesophageal intestinal junction and testis, lateral view; C. Spicules, ventral view; D-E. Left spicule, lateral and ventral view; F. Right spicule, lateral view; G. Male allotype, posterior region, lateral view; H. Caudal extremity, lateral view; I. Paratype, ventral view; J. Caudal extremity, ventral view. *Scale-bars:* A, 200 μm; B,C,G,I, 100 μm; D,E,F,H,J, 50 μm.

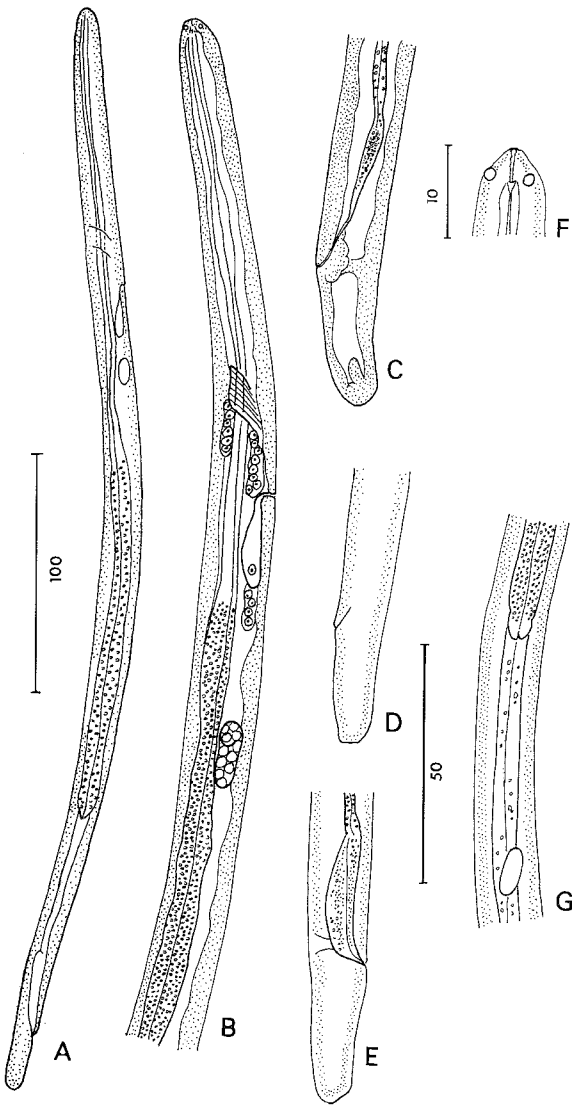

Figure 3. Madathamugadia hiepei n. sp., infective larva. A. Female, general aspect, lateral view; B. Anterior region of another larval female, with genital primodium at level of glandular oesophagus, lateral view; C. Tail, lateral view; D-E. Two other tails, lateral view; F. Head, median view; G. Male, genital primodium posterior to oesophageal intestinal junction, lateral view. *Scale-bars:* A, 100 μm; F, 10 μm; others, 50 μm.

Female (measurements of holotype, one paratype and, in parentheses, 2 females 217 ES). Body length 15.52, 14.66 (12.8, 12.15) mm, width 230, 175 (190, 120); nerve-ring 245, 195 (220, 180) from apex; oesophagus 445, 490 (475, 500) long; vulva in mature females post-oesophageal, 990, 1125 (940, 1070) from apex; ovijector wider in posterior third, just before dividing in 2 uteri, 1300, 970 long; ovaries coiled in posterior part of body; tail 290, 330 (200, 225) long.

Young female (218 ES): body length 8.4 mm, width 145; oesophagus 550 long with muscular portion 250 long; vulva at level of oesophagus, near junction with intestine, 550 from apex; tail 345 long (Figure 1).

Microfilaria (mean measurements of 7 specimens and range in parentheses). 147.8 (140–155) long and 4.5 (4–5.5) wide; corpuscle 7 to 10 long. Sheath inflated posteriorly; at this level, refringent, ovoid corpuscle; head more or less as wide as body; left cephalic hook and 2 right spines; caudal extremity thick even sometimes inflated, rounded, with 2–3 terminal nuclei (Figure 1).

Male (measurements of the allotype, one paratype and, in parentheses, 2 males 217 ES). Body 10.62, 9.97 (11.1, 9.9) mm long, width 118, 108 (135, 135); nerve-ring 223, 195 (210, 240) from apex; oesophagus 570, 515 (450, 475) long. 6 pairs of caudal papillae, 4 precloacal and 2 postcloacal. Tail 117, 100 (98, 110) long. Left and right spicules different in shape and size, respectively 114, 97 (93, 92) and 80, 82 (70, 68) (Figure 2).

Larval development

Approximately 100 specimens of a *Sergentomyia* sp. were collected in the habitat of the geckos; they were not found infected.

In *P. duboscqi*, the infective larvae (Figure 3) developed within 7 days. A total of 15 infective larvae were recovered from a batch of 20 sand flies fed the same day on the infected gecko. Three were used for the morphological study. Head attenuated, with buccal capsule cuticularised at its basement; only cephalic papillae visible; oesophagus divided, glandular part irregularly granulated; ratio length of oesophagus/bodylength 55–85%; tail without caudal lappets, straight or slightly bent in posterior third, cylindrical or slightly tapered, or with subterminal constriction; female genital primordium at level of muscular oesophagus; male genital primordium at level of intestine.

Measurements (2 female and one male infective larvae). Body length 490, 410, 480; width 16, 17, 15; buccal cavity 4, 4, 3 long; oesophagus 270, 350, 300 in length with muscular portion 120, 110, 130. Nerve ring 80, 100, 80, excretory pore 108, 140, 132, and female genital primordium 130, 170, all respectively from anterior end. Tail length 32, 30, 27.

Younger stages were collected in the thoracic muscles of the intermediate host. Larva at first moult 90

long and 22 wide; larva at second moult 335 long and 19 wide; length of oesophagus 180.

Among the 10 infective larvae inoculated to the gecko, 4 were recovered 8 days later. Three of the larvae were in the subcutaneous tissue and not very motile; one very motile larva was found in the dissecting medium (unfortunately these larvae were lost).

Discussion

The genus *Madathamugadia* is comprised of eight species divided into four groups (Bain et al., 1993), all different from the material studied in the present work:

– The two Madagascan species, *M. zonosauri* Chabaud, Anderson & Brygoo, 1959 and *M. hopluri* Chabaud, Anderson & Brygoo, 1959, are respectively parasites of the Gerrhosauridae and Iguanidae. Their males have a short conical tail (with the length equalling the width at the level of the anus), without postcloacal papillae or with a single pair near the cloaca; the pairs of pre-cloacal papillae are reduced in number (two and three pairs); the vulva is at the level of the oesophagus, not far from the junction with the intestine; and the microfilariae are notably small (a third of the length of those of our parasite).

– The three species parasitic in the Scincidae of the Ethiopian Region, *M. huambensis* (Petit, Bain, Gomes & Touratier, 1983), *M. versterae* Bain, Wanji, Petit, Paperna & Finkelman, 1993 and *M. bissani* Bain, Wanji, Petit, Paperna & Finkelman, 1993 have a very special character, i.e. two paracloacal protuberances in the males; the other adult characters are the same as those of the first group.

– The species from the Cordylidae in South Africa, *M. ineichi* Bain, Wanji, Petit, Paperna & Finkelman, 1993, of which the female is unknown, is distinctive in the following characters: cuticularised buccal capsule, no atrophy of the head papillae (four external labial and four cephalic papillae), long tail, eight pairs of precloacal papillae, oesophagus and spicules longer than in our specimens despite having a smaller body, and smaller microfilariae without a refringent corpuscle and without a swollen caudal extremity. The infective larva is like that of our material (Bain et al., 1993).

– The two species parasitic in the Gekkonidae of the Mediterranean subregion, *M. ivashkini* (Annaev, 1976) in Turkmenistan and *M. wanjii* Bain, Petit, Paperna, Finkelman & Killick-Kendrick, 1992 in Israel, resemble our specimens by the long tail of the male with two pairs of postcloacal papillae and by the post-oesophageal position of the vulva; the sensorial system of the head, when studied, shows an atrophy of the cephalic papillae (*M. wanjii*). However, these two species can be distinguished from our material by the following features: three pairs of precloacal papillae instead of four; oesophagus twice as long; and microfilariae without a refringent corpuscle and a tapering posterior end, especially in *M. ivashkini* (in Reznik, 1982). The infective larvae of *M. ivashkini* are thinner (12–13 μm) and have a shorter tail (18–21 μm, Reznik, 1982); those of *M. wanjii* are also slightly thinner (14–15 μm) but have a longer tail (37-40 μm, Bain et al., 1992). The parasite of *Pachydactylus turneri* from Gauteng Province is therefore a new species for which we propose the name *Madathamugadia hiepei* n. sp., named for Prof. em. Dr. med. vet. habil. Dr. h. c. Th. Hiepe, the former Chief-Director of the Institute of Parasitology and Tropical Veterinary Medicine in Berlin-Mitte, with best wishes for his 70th birthday.

Madathamugadia spp. parasitic in the Gekkonidae represent a small line occurring in the Ethiopian Region and Mediterranean subregion. The three species of this line develop in phlebotomines and the infective larvae are almost identical. The clear post-oesophageal position of the vulva is a late acquisition and constitutes a good synapomorphy: the female genital primordium is anterior in the infective stage and still at the level of the oesophageal intestinal junction in the juvenile female.

Although the Cordylidae is a more recent family than the Gekkonidae (in Estes et al., 1988), its parasite (*M. ineichi*) remains the most primitive representative of *Madathamugadia*, but its biology offers no special feature and clearly demonstrates the close relationship between the species.

Of the nine species of *Madathamugadia* so far described, five, including *M. ineichi*, are found on the African continent (Mali, Angola and South Africa) and two in Madagascar. This suggests an Ethiopian origin of the genus.

Acknowledgements

We wish to express our appreciation to the following persons and institutions: Major Phillip Oosthuizen, Dr Salomon Joubert, Mr Brian Harris, Mr Collin Rowles and the private landowners (especially the Buffalo Lodge) for permission to do the field col-

lection in the Hoedspruit Nature Reserve and the Timbavati/Klaserie/Umbabat Private Game Reserves, respectively; Mr Wulf Haacke and Mr Richard Newbery for much help as regards the reptiles; the Department of Nature Conversation, Gauteng Province, and the Department of Environmental Affairs, Northern Province, for the collecting permits; Dr Errol Nevill for helpful suggestions and discussions concerning the intermediate host; Dr Torsten J. Naucke for the identification of the wild caught sandflies; and Prof. R. Killick-Kendrick for the translation of the manuscript.

This study was financially supported by the Arthur & Aenne Feindt Stiftung, Hamburg, Germany.

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Onderstepoort Journal of Veterinary Research, 69:7–29

Redescription of some *Spauligodon* spp. and *Parapharyngodon* spp., and of *Skrjabinodon mabuyae* (Sandground, 1936) Inglis, 1968 (Pharyngodonidae: Oxyuroidea) from insectivorous South African lizards

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ABSTRACT

HERING-HAGENBECK, S.F.B.N., PETTER, A.J. & BOOMKER, J. 2002. Redescription of some *Spauligodon* spp. and *Parapharyngodon* spp., and of *Skrjabinodon mabuyae* (Sandground, 1936) Inglis, 1968 (Pharyngodonidae: Oxyuroidea) from insectivorous South African lizards. *Onderstepoort Journal of Veterinary Research*, 69:7–29

As part of a study on the helminth parasites of South African lizards several species of saurians were collected from localities in the North West Province, the Northern Province, Mpumalanga Province and Gauteng Province. *Spauligodon blydeensis* (Hering-Hagenbeck, 2001) from the Cape thick-toed gecko, *Pachydactylus capensis, Spauligodon molopoensis,* (Hering-Hagenbeck, 2001) from Wahlberg's velvet gecko, *Homopholis wahlbergii, Parapharyngodon margaritiferi*, Hering-Hagenbeck, 2001 from the skink, *Mabuya margaritifer, Parapharyngodon gerrhosauri,* Hering-Hagenbeck, 2001 from the plated lizard, *Gerrhosaurus flavigularis* and *Skrjabinodon mabuyae* (Sandground, 1936) Inglis, 1968 from the skinks *Mabuya punctatissima, Mabuya spilogaster* and *Mabuya varia* are redescribed.

The different *Spauligodon* spp. in the subcontinent may be separated on the presence or absence of spicules in the males, the presence or absence of spines on the tail of both the males and females, as well as on the size and shape of the eggs, and the configuration of the polar caps.

The *Parapharyngodon* spp. are distinguished mainly by the morphological characters of the males, such as the width of the caudal alae and the size of the pre- and adanal papillae. Female *Parapharyngodon* spp. closely resemble each other and some could not be identified to the species level since males were absent.

Spinose larvae, together with adult *Parapharyngodon* spp. were recovered from *Mabuya margaritifer*. All *Parapharyngodon* spp. larvae described to date are spinose and since the larvae in this study were collected together with adult *Parapharyngodon* spp., we consider them to belong to the same genus.

Skrjabinodon mabuyae differs from the closely related *Skrjabinodon mabuiensis* in the presence of a spicule in the male and lateral alae in the female. The former nematode is described for the first time from skinks in South Africa.

Keywords: Gekkonidae, Gerrhosauridae, *Gerrhosaurus, Homopholis, Mabuya*, Nematoda, Oxyuroidea, *Pachydactylus, Parapharyngodon*, Pharyngodonidae, Sauria, Scincidae, *Skrjabinodon*, South Africa, *Spauligodon*

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Accepted for publication 11 January 2002—Editor

INTRODUCTION

In total there are approximately 6 550 species of reptiles, of which 480 occur in South Africa. The country is considered to have the highest reptile diversity in Africa, with an average of one new reptile species being described every 44 days (Branch 1998). Surprisingly little information, however, as regards the parasites of these reptiles is available. Reports are few and are generally limited to the description of a new species from a single host or occasionally a small number of hosts, or new host records for some well-known parasites.

Recently, some publications on the helminths of several lizard species in the Western and Northern Cape Provinces have appeared (Bursey, McAllister & Freed 1997; Goldberg & Bursey 2001). The helminths occurring in Turner's thick-toed gecko, *Pachydactylus turneri*, and the skink *Mabuya spilogaster*, as well as a checklist of the helminths of South African snakes and lizards have also been published (Hering-Hagenbeck & Boomker 1998, 2000; Hering-Hagenbeck, Boomker, Petit, Killick-Kendrick & Bain 2000; Hering-Hagenbeck, Boomker & Bain 2001).

As part of a study of the helminth parasites of South African reptiles several species of Sauria were collected from various localities in the northern part of the country. A number of new pharyngodonid nematode species were recovered from the plated lizard *Gerrhosaurus flavigularis*, the Cape thick-toed gecko *Pachydactylus capensis*, Wahlberg's velvet gecko, *Homopholis wahlbergii* and the skinks *Mabuya punctatissima*, *Mabuya spilogaster*, *Mabuya varia* and *Mabuya margaritifer*. The helminth species were described and named by Hering-Hagenbeck (2001) and the purpose of this paper is to validate the new species. Some names are emended to comply with the rules of the International Committee for Zoological Nomenclature and are so indicated.

MATERIALS AND METHODS

The study was conducted in the Molopo Nature Reserve, the campus of the Medical University of Southern Africa, the government farm 'Delftzyl', the Hoedspruit Nature Reserve, the Timbavati, Klaserie and Umbabat complex of private nature reserves and the Blyde River Canyon Nature Reserve, all in the northern regions of the country.The exact localities, as determined by GPS-reading, are provided with the description of each species. The biogeography of each of the study areas has been described by Hering-Hagenbeck (2001), and the vegetation type of each locality by Acocks (1988), Nel, Dell & Newbery (1998) and Low & Rebelo (1996).

The lizards were collected in several ways. The most successful was a modified funnel trap-line, but many specimens were collected by hand by either stunning them with elastic bands or catching them with a butterfly net.

The reptiles were transported live to the laboratory were they were euthanased and their helminths collected, fixed and preserved according to standard procedures. The helminths were placed in a 50 % lactophenol-water solution and examined under a compound microscope while clearing.

Drawings were made with a drawing tube and measurements derived from the drawings. Unless stated otherwise, all measurements are given in millimetres (mm). Measurements are those of the holo- and/or allotype, and, when available, followed by those of the paratypes (in parentheses). Where sufficient material was available specimens were dissected or sectioned to study the spicules, the apical region and transverse sections of the body. Larval stages were identified on the development and the degree of differentiation of the reproductive organs (Jones 1995).

Specimens for scanning electron microscopy were prepared using the techniques of Crang & Klomparens (1995), Dykstra (1992), Robenek (1995) and Flegler, Heckman & Klomparens (1995). The specimens were dehydrated in graded alcohol, critically point dried, sputter coated with gold and examined with a Leica Stereoscan 420 scanning electron microscope at an accelerating voltage of 5kV.

RESULTS AND DISCUSSION

CHARACTERIZATION OF THE GENUS *SPAULIGODON* SKRJABIN, SCHIKHOBALOVA & LAGODOVSKAJA, 1960

TYPE SPECIES: *Spauligodon extenuatus* (Rudolphi, 1819) Skrjabin, Schikhobalova & Lagodovskaja, 1960

Pharyngodonidae with a triangular mouth opening, each lip partially or completely divided into two. Excretory pore posterior to the bulbus, in females always near the vulva. Bulbus with a well-sclerotized valvular apparatus. Lateral alae present. Caudal papillae of males clearly separated into pre-

cloacal, adcloacal and postcloacal pairs. Caudal alae not supported by the last pair of genital papillae, the latter being well-separated from each other and usually only a short distance from the adcloacal pair. The protruding genital cone may be supported by sclerotized structures, but the pre- and adcloacal pairs of papillae are never situated on the cone. Spicules are often absent. The usually long and tapering tail may be spinose or aspinose (Skrjabin, Schikhobalova & Lagodovskaja 1960; Petter & Quentin 1976). Parasites of carnivorous reptiles.

Redescription of the species *Spauligodon molopoensis* (Hering-Hagenbeck, 2001) (emended) (Fig. 1 and 2)

Lateral alae are present in both sexes and the nerve ring is situated in the anterior half of the oesophagus, posterior to the commencement of the lateral alae. A conspicuous excretory pore consisting of a transverse slit surrounded by a chitinous rim is present posterior to the bulbus. The tail is long, flexible and, in both sexes, armed with conspicuous cuticular spines.

MALE (n = 11) (Fig. 1)

The worms are 2.01 (1.92–2.04) long and 0.15 (0.14–0.16) wide at mid-body. Three lips surround a triangular mouth opening. Each lip is incompletely divided in two lobes. Four cephalic papillae and two lateral amphids are present. Narrow lateral alae start 0.05 (0.05–0.07) from the apex. They are 1.71 (1.59–1.71) long, of more or less uniform width and only widen towards the posterior end. In cross-section the alae carry 6–7 serrations that are not supported by underlying structures (Fig. 1E & E').

The clavate corpus is 0.19 (0.19–0.20) long, the isthmus is 0.02 (0.01–0.02) long, and the almost round bulbus is 0.06 (0.05–0.06) long and 0.07 (0.06–0.07) wide. The nerve ring and excretory pore are situated 0.07 (0.07–0.12) and 0.59 (0.54–0.59) from the anterior end, respectively.

Narrow caudal alae with finely sculptured inner surfaces commence immediately behind the lateral alae. There are three pairs of caudal papillae of which one pair is situated pre-cloacal, one pair adcloacal and one pair post-cloacal. The last-named pair is situated posterior to the caudal alae. The prominent genital cone is surrounded by an ornate, folded membranous lip (Fig. 1I). The weakly sclerotized, V-shaped spicule measures 0.06, with a maximum width of 0.01. The tail is 0.25 (0.17–0.24) long and armed by 6–9 cuticular spines.

FEMALE (n = 11) (Fig. 2)

Females are 3.42 (3.02–3.42) long and 0.25 (0.19–0.25) wide at mid-body. The triangular mouth opening is surrounded by three well-developed lips. Each lip carries two papilla-like structures. Cephalic papillae were not seen. The narrow lateral alae start 0.10 (0.09–0.13) from the apex, and are 2.54 (2.15–2.46) long; their outer edges are bilobed (Fig. 2E).

The corpus of the oesophagus is 0.24 (0.23–0.24) long, the isthmus 0.03 (0.03–0.04), and the bulbus 0.10 (0.09–0.10) long and 0.11 (0.11–0.09) wide. The nerve ring and excretory pore are situated 0.10 (0.08–0.12) and 0.41 (0.40–0.43) from the anterior end, respectively. The vulva is slightly posterior to the excretory pore, 0.45 (0.45–0.48), from the anterior end.

The short muscular ovejector together with the common uterus are 0.28 (0.27–0.28) long in total. Two uteri, both running posteriorly for the first third and then diverging into opposite directions, are present. The total length of the uteri is 0.86 (0.85–1.03). Thin-shelled eggs in the uterus measure 0.12 x 0.041; they are elongately ellipsoid with caps on each truncated end and unsegmented when laid. The flexible, filiform tail is 0.96 (0.83–1.11) long, with 10–12 cuticular spines.

TYPE HOST

Pachydactylus capensis (Gekkonidae) 758/II.

TYPE LOCALITY

Molopo Nature Reserve (25°42'48.1"S; 22°48'29.1"E), North West Province, Republic of South Africa.

TYPE MATERIAL

The holotype male, allotype female, ten paratype males and ten paratype females have been deposited in the collection of the Museum National d'Histoire Naturelle, Paris, France, access number 276HS.

HABITAT

Large intestine.

ETYMOLOGY

The species is named after the locality of the host.

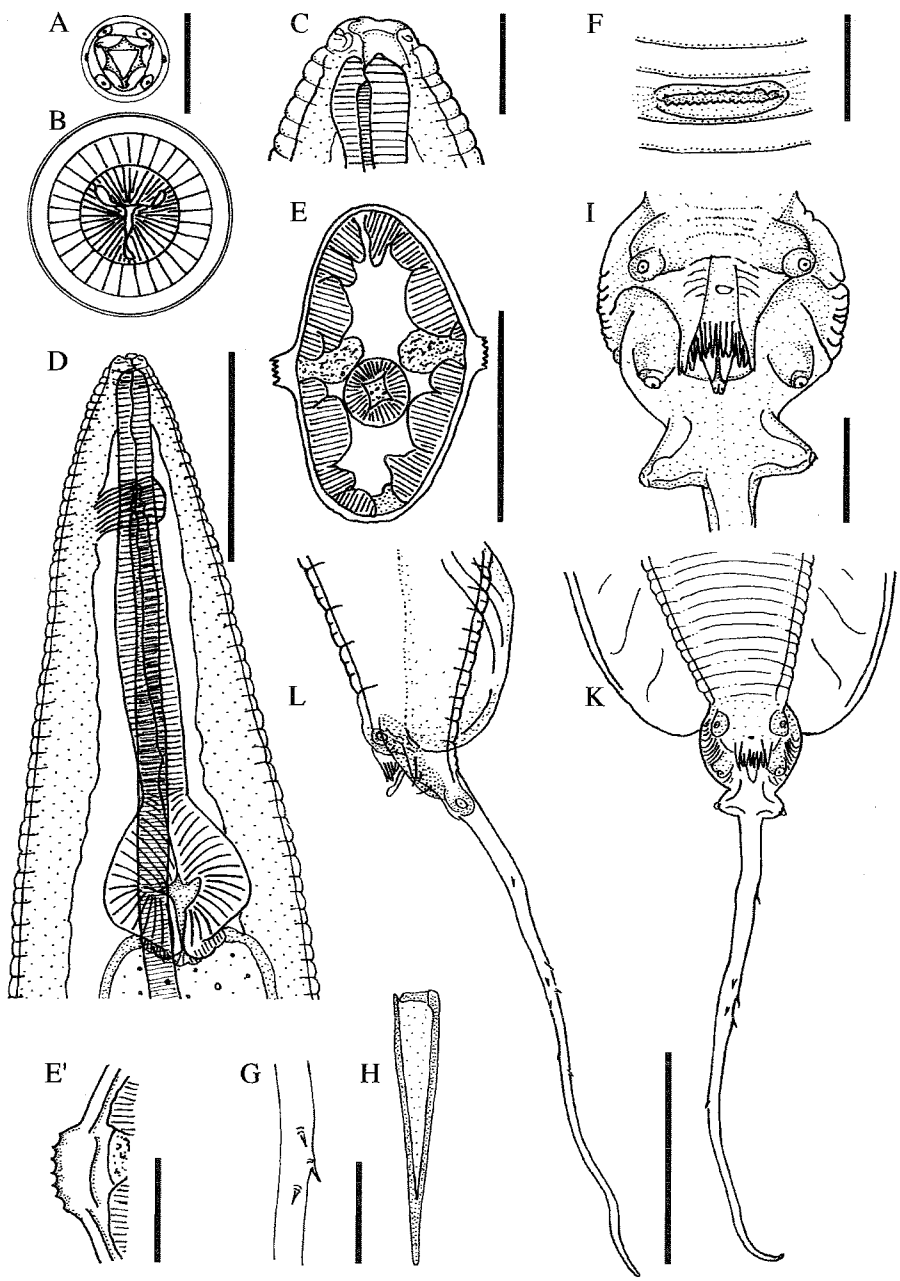


FIG. 1 *Spauligodon molopoensis*, paratype male

A Apical view of the head
B Transverse section of the head, 0.02 mm below the apex
C Median view of the anterior part
D Lateral view of the anterior part, showing the beginning of the lateral alae
E Transverse section at mid-body
E' Higher magnification of a lateral ala showing the serrations
F Lateral view of the excretory pore
G Detail of spines on the tail
H Lateral view of the spicule
I Ventral view of the genital cone and genital papillae
K Ventral view of the posterior end
L Lateral view of the posterior end

Scale bars: A, B, C,E', F, G, H—0.02 mm; D, E, I, K, L—0.1 mm

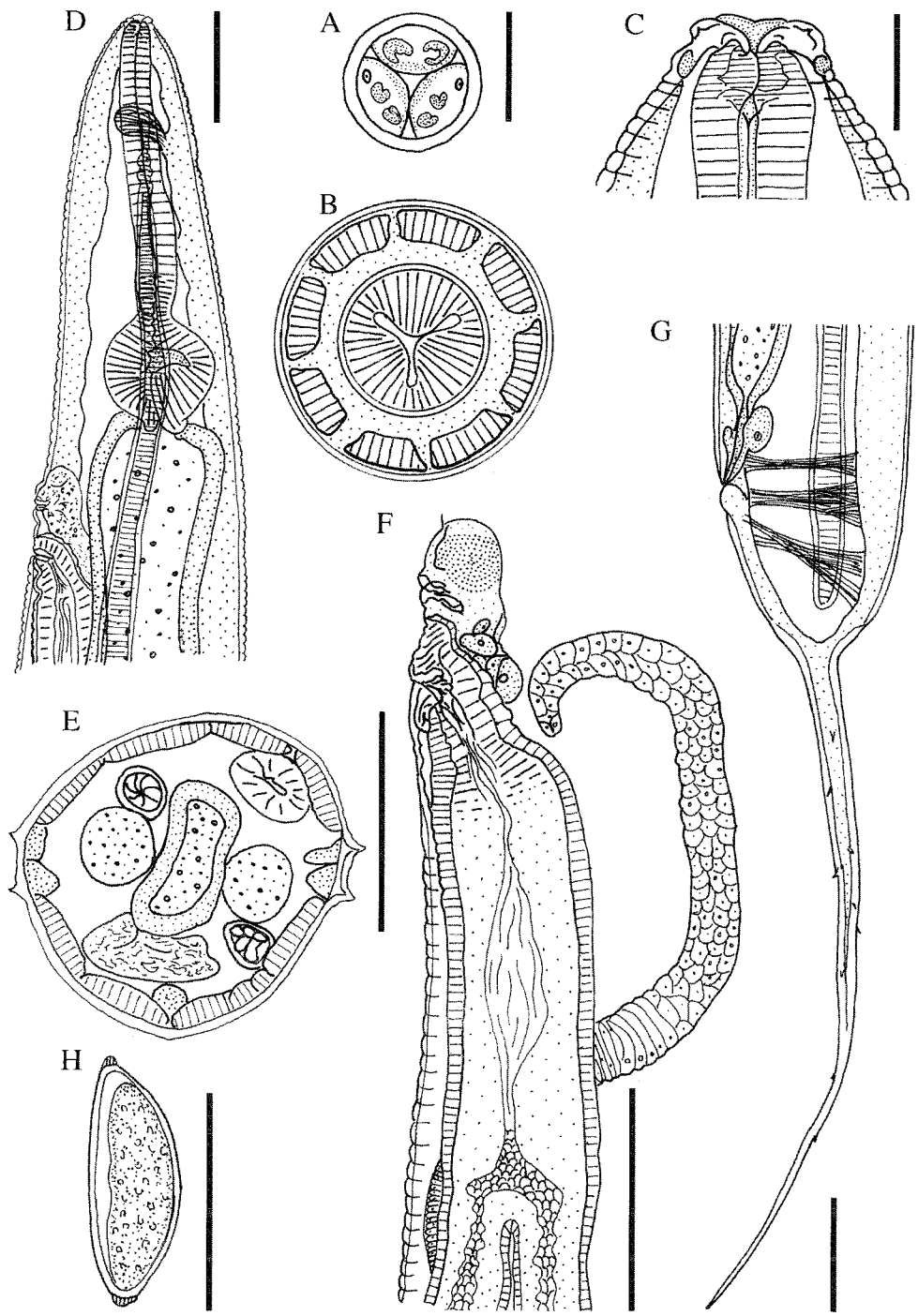


FIG. 2 *Spauligodon molopoensis*, paratype female
A Apical view of the head
B Transverse section of the head, 0.02 mm below the apex
C Median view of the anterior part
D Lateral view of the anterior part showing the beginning of the alae, as well as the excretory pore and vulva
E Transverse section at mid-body
F Lateral view of the vulva and excretory pore
G Lateral view of the posterior end
H Egg

Scale bars: A, B, C—0.02 mm; D, E, F, G, H—0.1 mm

***Spauligodon blydeensis* (Hering-Hagenbeck, 2001) (emended)** (Fig. 3 and 4)

Lateral alae present in both sexes. The conspicuous excretory pore is a transverse slit surrounded by a chitinous rim, always posterior to the bulbus. The tail is long, flexible and, in both sexes, armed with conspicuous spines.

MALE (n = 2) (Fig. 3)

The holotype male is 2.36 long (paratype damaged) and 0.23 (0.22) wide at mid-body. The triangular mouth opening is surrounded by three sharply pointed lips. Cephalic papillae were not seen. Two prominent amphids occur on the lateral edges of the apex. Distinct lateral alae arise at 0.07 (0.09) from the anterior end, are 1.78 (1.74) long, and of more or less uniform width, only widening towards the posterior end. Just posterior to the bulbus, the alae, in cross section, are 0.02 high and approximately 0.02 wide. They have ten serrations without underlying support (Fig. 3D).

The inner margin of the oesophagus is symmetrical and strongly chitinized. The clavate corpus is 0.29 (0.26) long, the isthmus 0.02 (0.03), and the almost

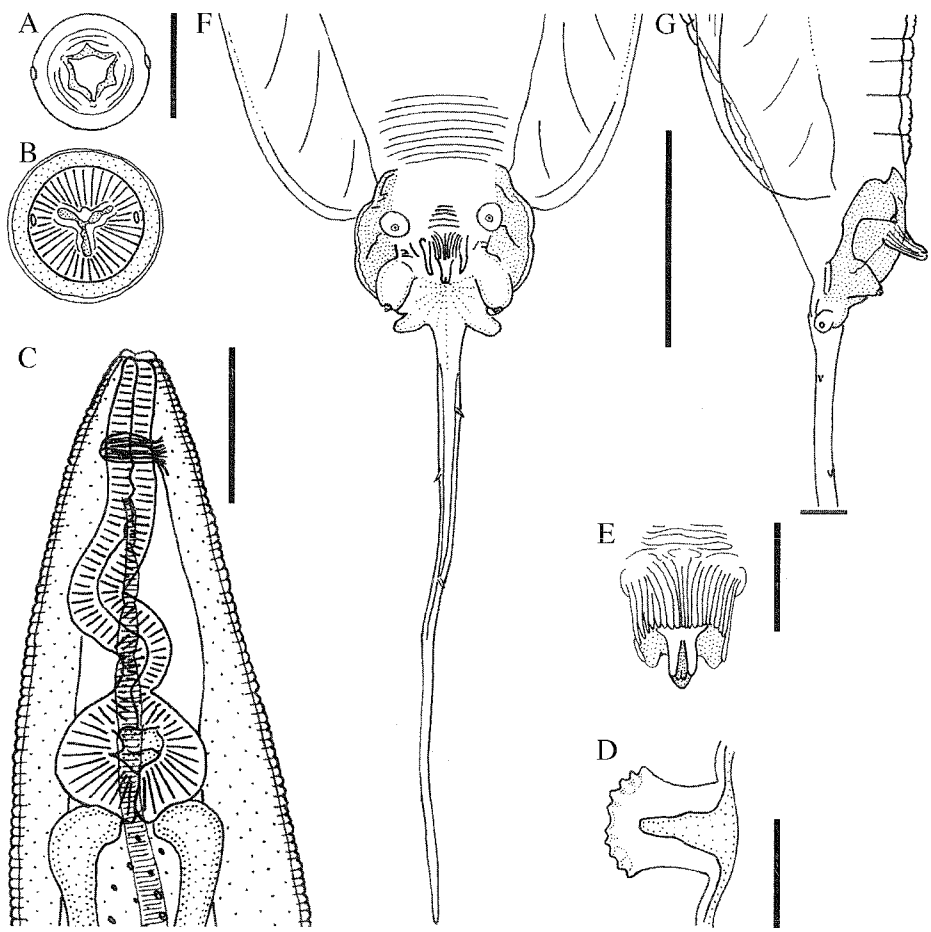


FIG. 3 *Spauligodon blydeensis*, paratype male

A Apical view of the head
B Transverse section of head, 0.02 mm below the apex
C Lateral view of the anterior part with the beginning of the lateral alae
D Transverse section of a lateral ala, showing the serrations
E Ventral view of the genital cone
F Ventral view of the posterior end
G Lateral view of the posterior end

Scale bars: A, B, D, E—0.02 mm; C, F, G—0.1 mm

round bulbus is 0.09 (0.07) long and 0.08 (0.08) wide. The nerve ring and excretory pore are situated 0.06 (0.06) and 0.64 (0.65) from the anterior end, respectively.

Narrow caudal alae commence immediately behind the lateral alae. Three pairs of caudal papillae are present, one pair pre-cloacal and two pairs post cloacal, the posterior pair of which is situated behind the caudal alae.

The prominent genital cone is surrounded by an ornate, folded membranous lip (Fig. 3E). On the tip of the genital cone two minute papilla-like structures are present. A spicule was not seen. The tail is 0.40 long (paratype without tail) and armed by four cuticular spines.

FEMALE (n = 4) (Fig. 4)

The females are 1.92 (1.83–2.19) long and 0.19

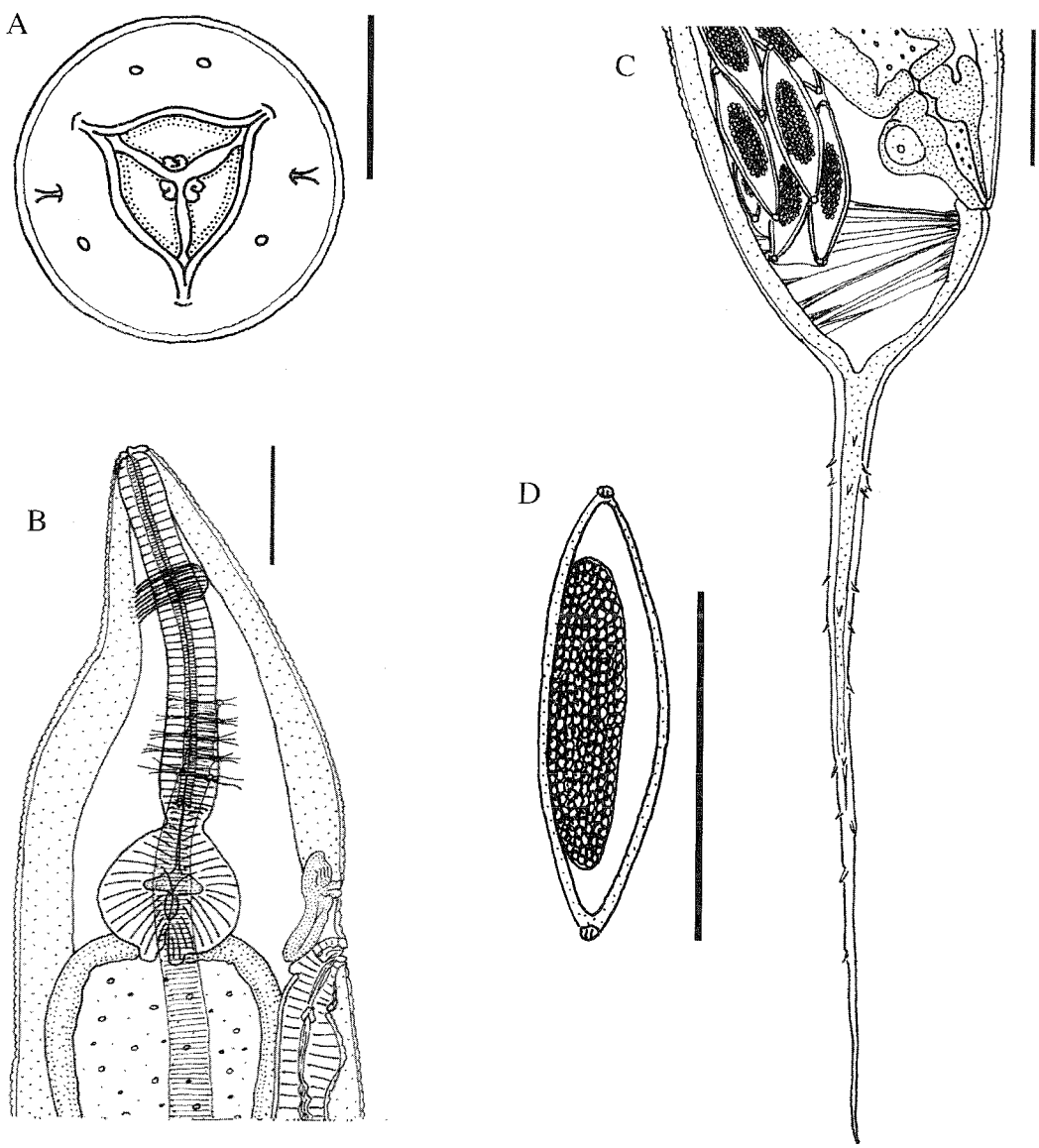


FIG. 4 *Spauligodon blydeensis*, female

A Apical view of the head
B Anterior part showing the beginning of the alae, as well as the excretory pore and vulva, lateral view
C Lateral view of the posterior end, with eggs in the uterus
D Egg

Scale bars: A—0.02 mm; B, C, D—0.1 mm

(0.15–0.17) wide at mid-body. Three prominent, well-developed lips surround a triangular mouth opening. Minute ornamentation is present on the apex of each lip. There are four outer cephalic papillae of which two are situated dorsally and two subventrally. An amphid is present on each side. Narrow lateral alae start 0.22 from the apex, run parallel to the long axis of the body and end just anterior to the anus. The outer borders consist of two prominent expansions, 0.03 apart.

The corpus of the oesophagus is 0.37 (0.39–0.40) long, the isthmus 0.02 (0.01–0.02), and the bulbus 0.13 (0.13–0.14) long and 0.15 (0.14–0.15) wide. The nerve ring and excretory pore are situated 0.12 (0.12–0.15) and 0.41 (0.47–0.53) from the apex, respectively. The vulva is posterior to the excretory pore, 0.47 (0.55–0.62) from the anterior end.

A short muscular ovejector and two uteri are present, the latter running posteriorly, slightly extending beyond the level of the anus. Thin-shelled eggs measure 0.132 x 0.038 *in utero*. They are elongately ellipsoid in shape, with small caps on each sharply truncated end, and unsegmented when laid. The flexible, filiform tail is 0.40 (0.38–0.39) long, with 17–20 prominent cuticular spines.

TYPE HOST

Homopholis wahlbergii (Gekkonidae) 740/II.

TYPE LOCALITY

Blyde River Canyon Nature Reserve (24°40'15.4"S; 30°48'48.0"E), Mpumalanga Province, Republic of South Africa.

TYPE MATERIAL

The holotype male, allotype female, paratype male and three paratype females are deposited in the collection of the Museum National d'Histoire Naturelle, Paris, France, access number 277HS.

HABITAT

Large intestine.

ETYMOLOGY

The species is named after the locality of the host.

Discussion

Only in the genera *Pharyngodon* Diesing, 1861, *Skrjabinodon* Inglis, 1968 and *Spauligodon* Skrjabin, Schikhobalova & Lagodovskaja, 1960, does the vulva open just behind the post-bulbar excretory pore in the anterior part of the body. In contrast to the males of *Pharyngodon*, which have well-developed caudal alae enveloping all genital papillae, *Skrjabinodon* males lack the caudal alae, while the males of *Spauligodon* have caudal alae that do not enclose the posterior pair of papillae.

The most important factor in identifying reptilian oxyurids is their geographical distribution and the identification of their hosts, to at least the family level (Chabaud & Brygoo 1962; Bursey *et al.* 1997; A.G. Chabaud, personal communication 1999). Currently there are 34 species of *Spauligodon* that are separated mainly on the presence or absence of spines on the tail and the shape of the eggs (Bursey & Goldberg 1995). Only five *Spauligodon* species have as yet been described from the Ethiopian region (Table 1).

The males of *S. molopoensis* and *S. blydeensis* are very similar in appearance to *Spauligodon morgani* (Fitzsimmons, 1961), especially as regards the small, almost round, posterior body extremity, the caudal alae, the genital papillae and the genital cone. However, they differ distinctly in the width of the lateral alae, which widen progressively in *S. morgani*, but are almost of a uniform width until they reach the posterior fifth of the body in *S. molopoensis* and *S. blydeensis*. Furthermore, *S. morgani, Spauligodon dimorpha* (Chabaud & Brygoo, 1962) and *Spauligodon petersi* Bursey, McAllister & Freed, 1997 lack spicules and except for *S. morgani* they have aspinose tails. *Spauligodon molopoensis* is currently the only African species that has a spicule and a spinose tail. The males of *S. blydeensis* differ from the other species occurring on the continent by the few (four) spines on the tail and in having by far the longest tail. The host and locality of *Spauligodon smithi* Bursey, McAllister & Freed, 1997 is very similar to that of *Spauligodon timbavatiensis* Hering-Hagenbeck & Boomker, 1998, *S. molopoensis* and *S. blydeensis*. The most conspicuous difference is that the adcloacal pair of papillae is bifid in *S. smithi*.

There are few differences between the females of the African *Spauligodon* spp. *Spauligodon molopoensis* differs only slightly from *S. timbavatiensis, S. smithi* and *S. morgani* in the position of the vulva and the excretory pore. *Spauligodon dimorpha* and *S. petersi* are the only ones with an aspinose tail. The females of *S. blydeensis* differ distinctly from the rest by having the largest number of spines on the tail.

TABLE 1 Comparative measurements of the five Ethiopian species of *Spauligodon*

Species	*Spauligodon petersi*	*Spauligodon morgani*	*Spauligodon dimorpha*	*Spauligodon smithi*	*Spauligodon timbavatiensis*	*Spauligodon molopoensis*	*Spauligodon blydeensis*
Author	Bursey *et al.* 1997	Fitzsimmons 1961	Chabaud & Brygoo 1962	Bursey *et al.* 1997	Hering-Hagenbeck & Boomker 1998	This paper	This paper
Males							
Length	1.203	1.690	1.150	1.710	1.990	1.988	2.163
Width	140	140	190	130	155	153	223
Oesophagus	210	270	350	290	305	275	372
Bulbus	60 x 60	65 x 65	70 x 75	60 x 60	80 x 75	63 x 66	79 x 78
Nerve ring	90	80	130	110	135	98	64
Excretory pore	320	500	620	550	625	564	650
Tail	240	290	180	200	210	252	400
Spicule	–	–	–	90	80	56	–
Spines	Smooth	6 spines	Smooth	Smooth	Smooth	6–9 spines	4 spines
Females							
Length	3.100	4.400	4.300	3.100	2.830	3.181	1.979
Width	300	460	350	380	240	214	170
Oesophagus	340	480	590	320	385	361	556
Bulbus	90 x 100	110 x 110	130 x 130	100 x 100	125 x 130	94 x 101	132 x 149
Nerve ring	110	120	140	110	150	98	129
Excretory pore	480	690	580	290	600	415	470
Tail	460	730	530	580	970	759	391
Vulva	530	760	650	330	620	461	547
Eggs	130 x 40	143 x 35	100 x 41	140 x 48	147 x 33	118 x 41	132 x 38
Spines	Smooth	9–11 spines	Smooth	4–10 spines	5–9 spines	10–12 spines	17–20 spines
Host	*Mabuya sulcata sulcata*	*Mabuya striata*	*Chamaeleo pardalis*	*Pachydactylus bibronii*	*Pachydactylus turneri*	*Pachydactylus capensis*	*Homopholis wahlbergii*
Country	South Africa	Malawi	Madagascar	South Africa	South Africa	South Africa	South Africa

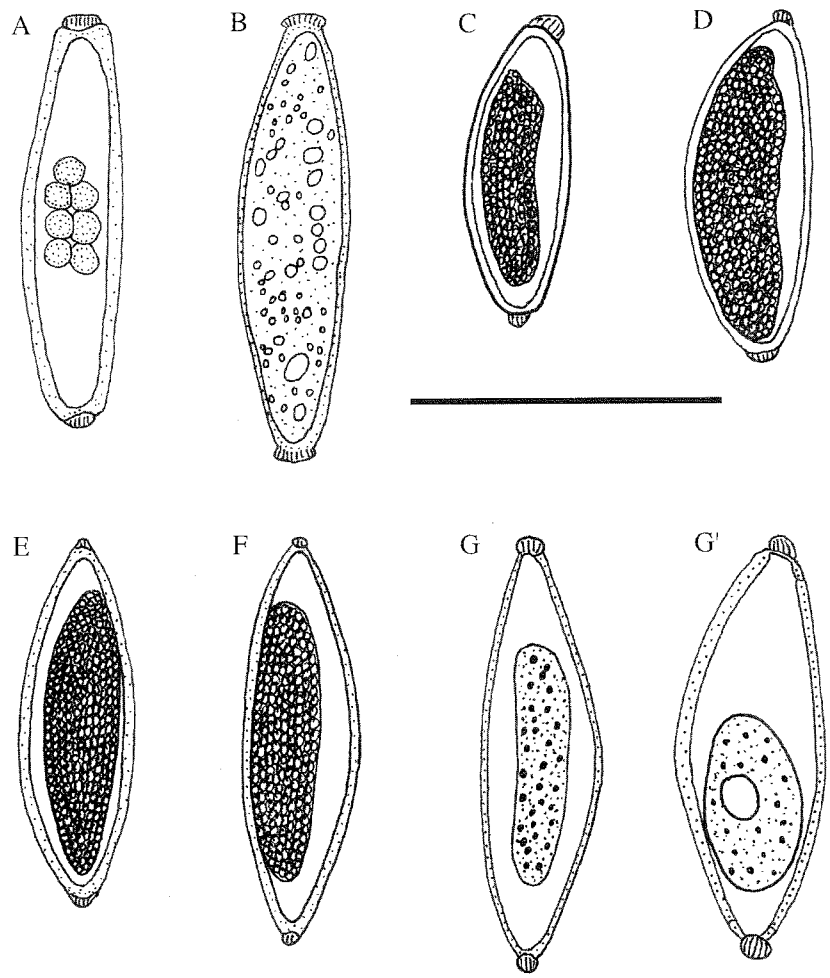


FIG. 5 Eggs of the *Spauligodon* species occurring in reptiles in the Ethiopian region

A *Spauligodon smithi* (After Bursey *et al.* 1997)
B *Spauligodon timbavatiensis* (After Hering-Hagenbeck & Boomker 1998)
C *Spauligodon dimorpha* (After Chabaud & Brygoo 1962)
D *Spauligodon molopoensis*
E *Spauligodon petersi* (After Bursey *et al.* 1997)
F *Spauligodon blydeensis*
G, G' *Spauligodon morgani* and a variation (After Fitzsimmons 1961)

Scale bar: Bar of 0.1 mm applies to all illustrations

Three characters seem to be of value to distinguish the eggs of the various species, namely the size, the shape and the configuration of the polar caps (Fig. 5). Those of *S. dimorpha* and *S. molopoensis* are the smallest, equal each other in shape, but differ by the arrangement and size of the polar caps. The eggs of *S. petersi*, *S. morgani* and *S. blydeensis* all have the same ellipsoid shape and small, pointed polar caps. However, the caps on the eggs of *S. morgani* are slightly larger and the eggs themselves differ slightly in size. This is also the case for the eggs of *S. timbavatiensis* and *S. smithi*, which are fusiform and truncated, and have large polar caps.

CHARACTERIZATION OF THE GENUS *PARAPHARYNGODON* CHATTERJI, 1933

TYPE SPECIES: *Parapharyngodon maplestonei* (Chatterji, 1933)

Pharyngodonidae with a simple and short buccal cavity and an oesophagus with a typically valved

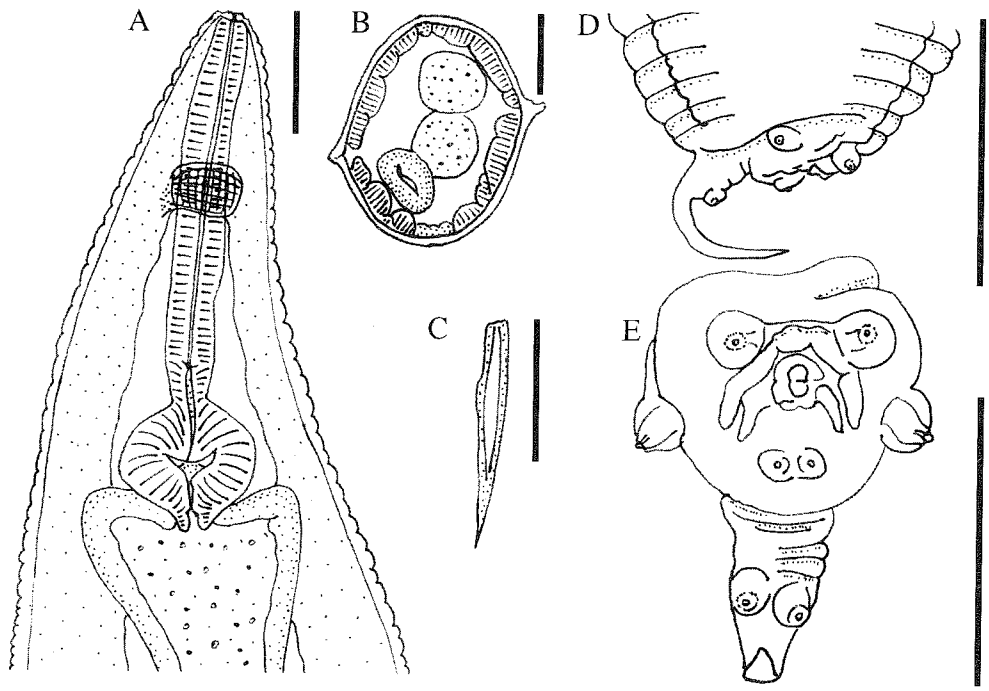


FIG. 6 *Parapharyngodon margaritiferi*, male

A Lateral view of the anterior part
B Transverse section at mid-body
C Spicule in lateral view
D Lateral view of the posterior end
E Posterior end, ventral view

Scale bars: A, B, D—0.1 mm; C, E—0.05 mm

bulbus. Caudal alae are absent in males and the genital cone is absent or reduced. The caudal appendage is truncated immediately posterior to the anus and bears a slim tail. Three to five pairs of mammilliform genital papillae, some of which may be fused, are present, the most posterior pair occurring on the tail. Females are didelphic and prodelphic and the vulva is median. The dorsally curved tail is short and rounded. The eggs have a sub-polar operculum and a thick shell. Parasites of carnivorous reptiles and amphibians (Adamson 1981; Adamson & Nasher 1984).

Redescription of the species *Parapharyngodon margaritiferi* Hering-Hagenbeck, 2001 (Fig. 6 and 7)

Stout, robust nematodes with a thick and distinctly transversely folded cuticle. The cephalic extremity is flattened and the triangular oral opening is surrounded by six prominent elevations. Lateral alae are absent in females.

MALE (n = 1) (Fig. 6)

The male is 2.42 long and 0.35 wide at mid-body. The oesophagus is 0.42 long in total. The isthmus is 0.03 long, and the slightly oval bulbus is 0.09 long and 0.11 wide. The intestine is expanded immediately posterior to the bulbus. The nerve ring is situated 0.15 from the apex and the excretory pore 0.74. Lateral alae arise 0.37 from the anterior end and taper off 0.41 from the tip of the tail.

Four pairs of caudal papillae are present, consisting of prominent, mammilliform preanal and adanal pairs, of which the adanal pair lies posterolateral to the anus. Posterior to the genital opening a sessile pair of papillae occurs. The genital cone is minute and surrounded by crescent-shaped and elongated cuticular ornamentation. The spicule pouch opens immediately posterior to the anal opening. The spicule is 0.08 long; the anterior half is of uniform width (0.01), thereafter tapering to a pointed tip. An accessory piece is absent. The crescent-shaped tail is 0.12 long and tapers towards a pointed tip. A

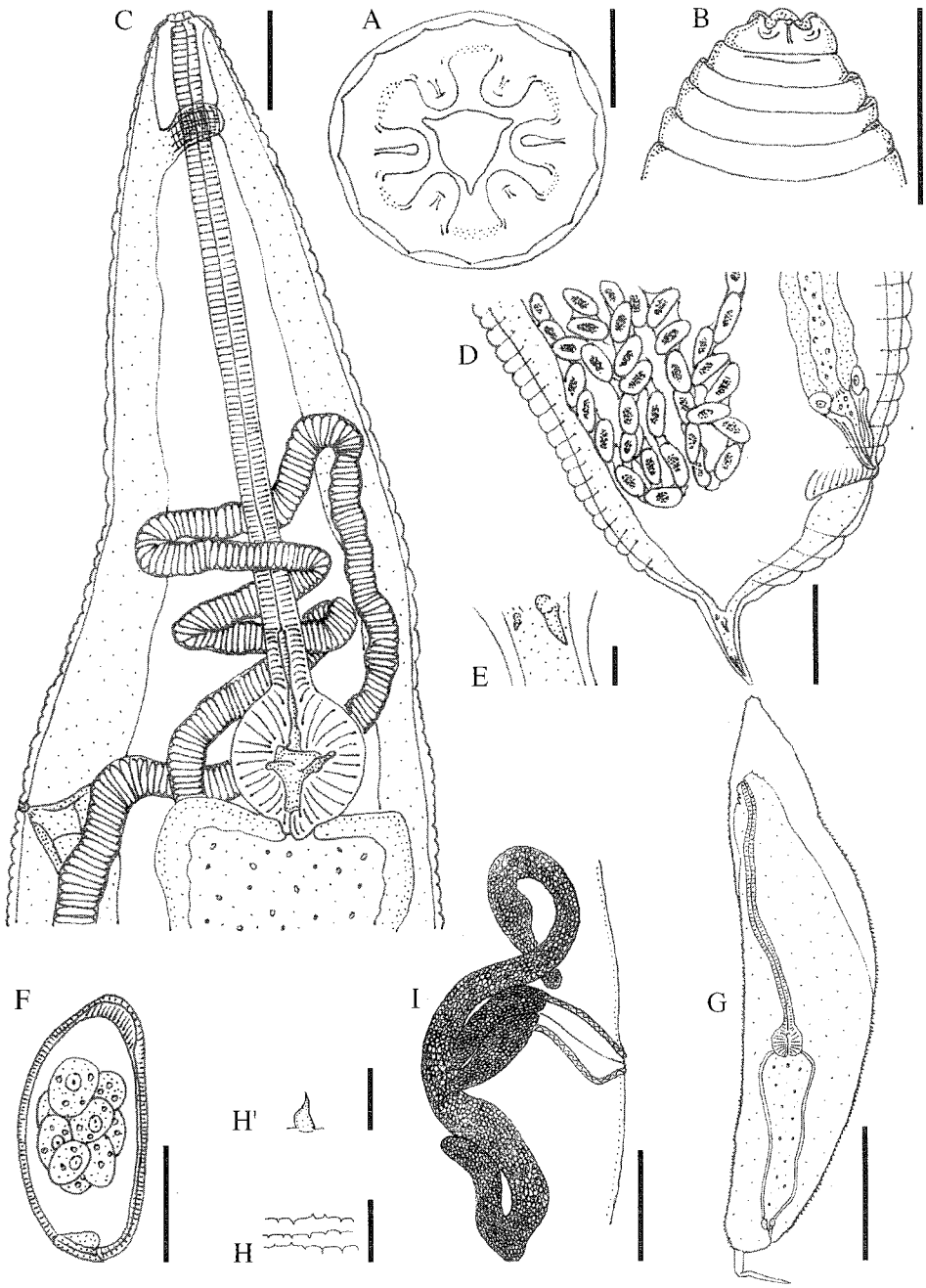


FIG. 7 *Parapharyngodon margaritiferi* female and *Pharyngodon* sp. larva

A Apical view of the head
B Median view of the head
C Lateral view of the anterior part, showing the excretory pore and the anterior uterus loops
D Lateral view of the posterior end
E Details of a spine on the tail
F Egg
G Lateral view of a 3rd stage larva. Note the long oesophagus
H Arrangement of spines on the cuticle of a 3rd stage larva
H' Detail of a cuticular spine of a 3rd stage larva
I Lateral view of the genital primordium of a female 4th stage larva

Scale bars: C, D—0.2 mm; B, I—0.1 mm; F, H, H'—0.05 mm; A—0.02 mm; E—0.01 mm

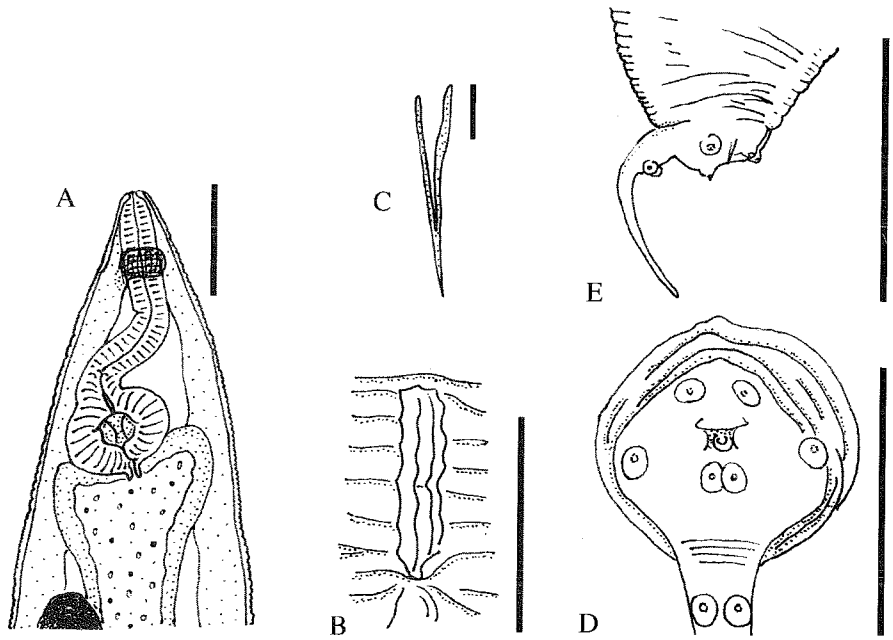


FIG. 8 *Parapharyngodon* sp. no. 1, holotype male

A Lateral view of the anterior part with the cranial part of the testes behind the oesophagus and intestine
B The region where the lateral ala starts in lateral view
C Lateral view of the spicule
D Ventral view of the posterior extremity
E Lateral view of the posterior extremity

Scale bars: A, B, E—0.1 mm; I, D—0.05 mm; H, C—0.01 mm

single pair of papillae is present ventrally in the middle of the tail.

FEMALE ($n = 2$) (Fig. 7)

Length 5.89 (5.27) and width 0.82 (0.87) at mid-body. The mouth opening is triangular and surrounded by six prominent rounded elevations, four of which bear a papilla and the other two an amphid each (Fig. 7A). The total length of the oesophagus is 1.62 (1.69). A distinct isthmus is present 1.28 (1.39) from the apex and the bulbus is small and round to slightly oval, 0.29 (0.24) long and 0.29 (0.29) wide. The intestine immediately behind the bulbus is expanded to double the width of the bulbus. The nerve ring is 0.17 (0.22) from the anterior end and the excretory pore is posterior to oesophago-intestinal junction, 1.71 (1.69) from the apex.

The vulva lies more or less at the middle of the body, 3.04 (2.49) from the anterior end. The uterus is didelphic, first running in opposite directions but the posteriorly directed branch later turns anteriorly. The distance from the vulva to the uterus division is 0.85. The uteri are packed with eggs. The ovaries are partly coiled around the oesophagus immediately anterior to the bulbus. The anus is 0.36 (0.44) from the posterior extremity. The tail is orientated slightly dorsally, bearing one prominent and one or two minute spines. Eggs are asymmetrical, rough-shelled, slightly flattened on one side, with subpolar opercula and measure 0.109 x 0.052.

TYPE HOST

Mabuya margaritifer (Scincidae) 856/II.

TYPE LOCALITY

Klaserie Private Game Reserve (24°16'52.4"S; 31° 18'7.3"E), Northern Province, Republic of South Africa.

TYPE MATERIAL

The holotype male, allotype female and one paratype female are deposited in the collection of the Museum National d'Histoire Naturelle, Paris, France, access number 278HS.

HABITAT

Large intestine.

ETYMOLOGY

The species is named after the host.

***Parapharyngodon* species no. 1** (n = 1) (Fig. 8)

MALE

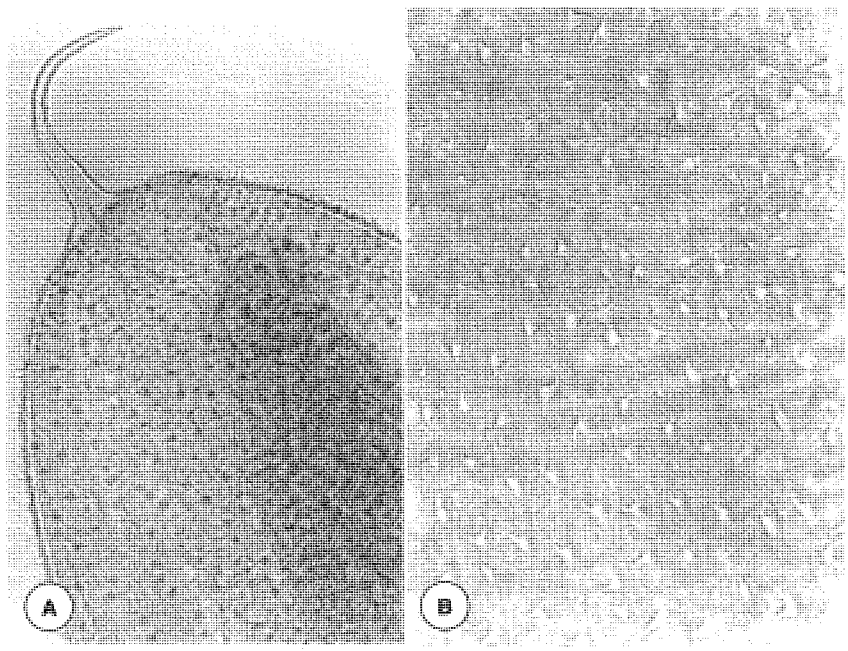
A small, stout worm 1.69 long and 0.24 wide at mid-body. The cuticle is thick and wide transverse striations are present. The total length of the oesophagus is 0.27, that of the isthmus 0.02, and the bulbus is 0.07 long and 0.10 wide. The intestine is slightly expanded posterior to the bulbus. The nerve ring is 0.07 and the excretory pore 0.53 from the anterior end. Lateral alae start at 0.24 from the anterior end and terminate 0.31 from the tip of the tail.

Four pairs of caudal papillae are present. Preanal and adanal pairs are mammilliform and slightly larger than the others. The adanal pair lies posterolateral to the anus. A pair of sessile papillae, situated very close to each other, is present directly posterior to the genital cone. The genital cone is minute, surrounded by two lateral lips and is slightly overlapped by a simple anterior cuticular projection. The spicule pouch opens immediately posterior to the anal opening. The spicule is 0.04 long, with a maximum width of 0.007. It is V-shaped in lateral view. An accessory piece is absent. The thin, crescent-shaped tail is initially directed dorsally, but curves slightly ventrally. It is 0.11 long, tapers to a pointed end and bears a single pair of sessile papillae in the proximal third.

***Parapharyngodon* species no. 2** (n = 1)

FEMALE

Apart from the principal measurements, there are no morphological differences between this female and the females of *P. margaritiferi*. The worm is



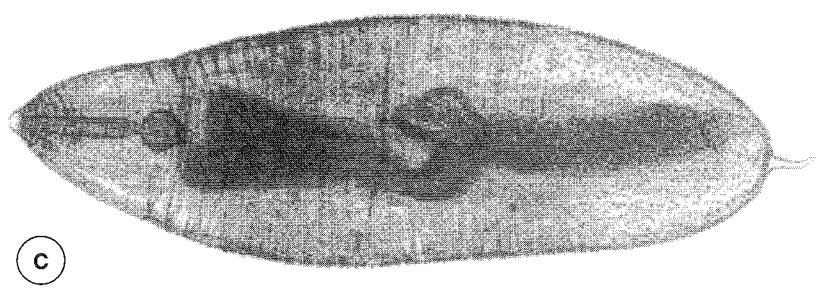


FIG. 9 *Parapharyngodon* spp. third stage larva

A SEM photograph of the posterior part of a 3rd stage larva showing the arrangements of the spines

B Higher magnification of the spines

C Photomicrograph of a 3rd stage larvae in lateral view. Note the short oesophagus

6,44 long and 0.91 wide at mid-body. The oesophagus is 1.42 long and the bulbus is 0.22 long and 0.26 wide. The nerve ring is 0.22 from the anterior end, the excretory pore 1.68 and the vulva 3.22. The tail is 0.36 long.

TYPE HOST

Mabuya margaritifer (Scincidae) 859/2.

TYPE LOCALITY

Klaserie Private Game Reserve (24°16'52.4"S; 31° 18'7.3"E), Northern Province, Republic of South Africa.

TYPE MATERIAL

The specimens of *Parapharyngodon* species no. 1 and no. 2 are deposited in the collection of the Museum National d'Histoire Naturelle, Paris, France, access number 279HS.

HABITAT

Gastrointestinal tract.

Larval stages

Among some hosts infected by the *Parapharyngodon* spp. described above, a few sheathed early 4th stage larvae were recovered.

EARLY STAGE (Fig. 7G, H)

Robust larvae tapering to both ends, 2.50 long and 0.50 wide. The oesophagus is 1.05 long, the bulbus distinct and occurs in the posterior half of the body. Prominent armed transverse striations begin about 0.50 from anterior extremity and continue to the level of the anus. Anterior striations carry 6–8 irregular transverse rows of small conical spines. Posteriorly the spines become larger and more numerous, and in total there are about 74 rows of spines. The latter are either hooked or S-shaped (Fig. 7H and H') and disappear after the 4th moult.

The vulvar primordium lies anterior to the oesophago-intestinal junction, 0.94 from the apex. The vagina is clearly divided into muscular and glandular parts. The muscular vagina is 0.09 long and the divergent uteri divide 0.2 from the vulvar primordium. The posterior uterus is 0.32 long and the ante-

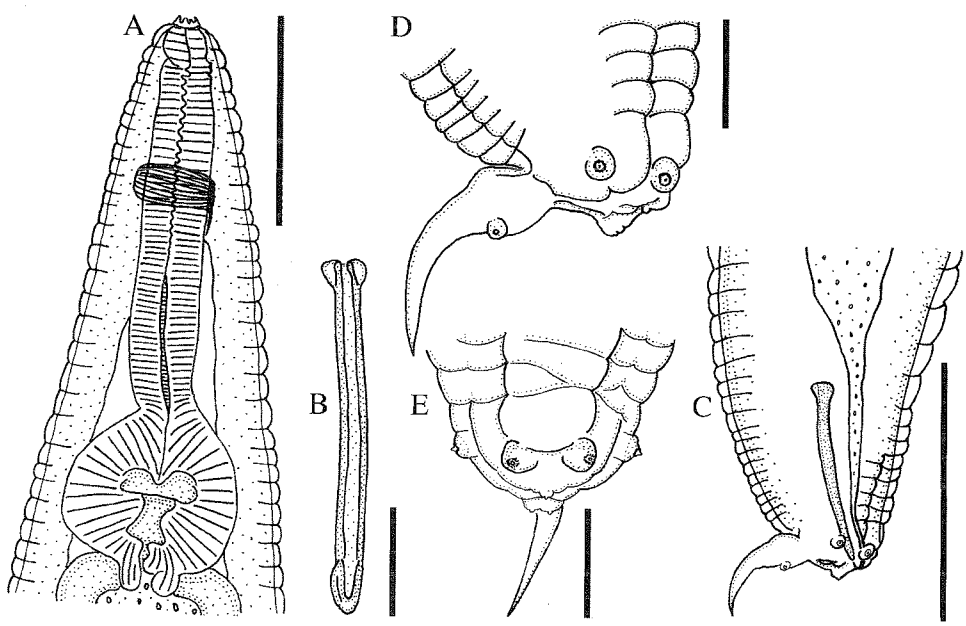


FIG. 10 *Parapharyngodon gerrhosauri*, holotype male

A Median view of the anterior part
B Lateral view of the spicule
C Lateral view of the posterior end showing the position of the spicule
D Lateral view of the posterior end showing the papillae
E Ventral view of the posterior end

Scale bars: A, C—0.1 mm; B, D, E—0.02 mm

rior one 0.40, both changing direction in their distal third.

The tail is 0.30 long, unarmed and crescent-shaped. Male larvae were not recovered.

Two more larvae of unknown sex, were in general appearance very similar the one described above, but had a conspicuously short oesophagus (Fig. 7G and Fig. 9C).

LOST

Mabuya margaritifer (Scincidae).

LOCALITY

Klaserie Private Game Reserve (24°16'52.4"S; 31° 18'7.3"E) and Hoedspruit Nature Reserve, Northern Province, Republic of South Africa.

HABITAT

Gastrointestinal tract.

***Parapharyngodon gerrhosauri* Hering-Hagenbeck, 2001** (*n* = 1) (Fig. 10)

MALE

A stout worm, 2.38 long and 0.19 wide at mid-body, with distinct transverse cuticular striations. Oral opening surrounded by six triangular lips. In lateral or ventral view, the cephalic papillae and amphids are not visible. The oesophagus is 0.26 long, the isthmus is indistinct, and the bulbus is almost round, 0.09 long and 0.08 wide. The nerve ring is situated in the anterior third of the oesophagus, 0.08 from the anterior end and the excretory pore 0.85. Lateral alae arise 0.13 from the cephalic extremity and extend to 0.37 from the tip of the tail.

Three pairs of mammilliform caudal papillae are present, one pair preanal, one adanal, posterolateral to the anus, and one pair occurs on the proximal third of the tail. The genital cone is simple, without ornamentation and projections. Posterior to the genital cone a single, minute papilla is present. The

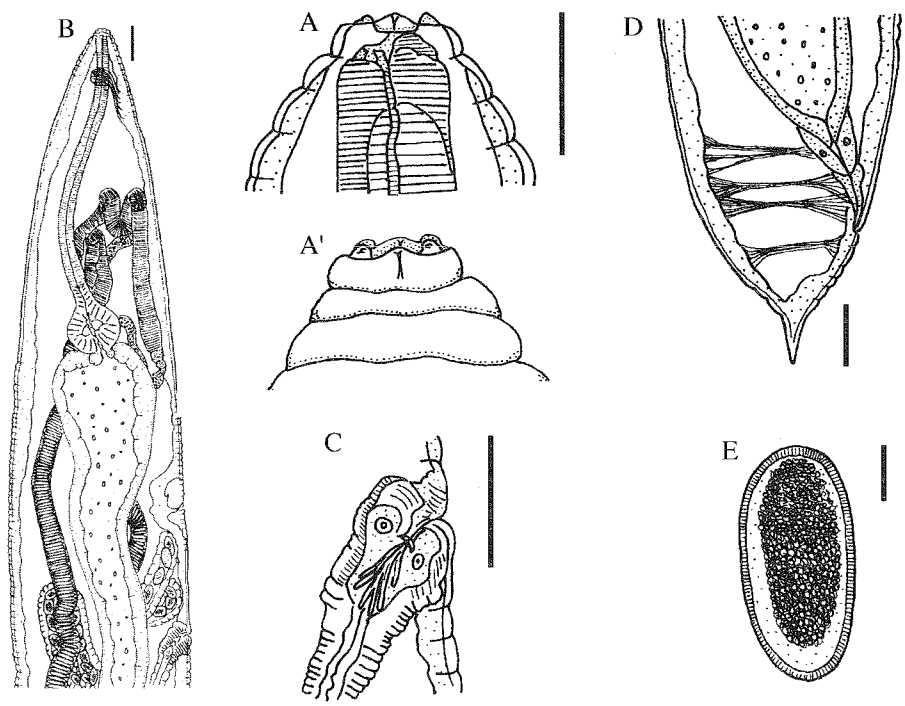


FIG. 11 *Parapharyngodon* sp. no. 3, female

A, A' Median view of the anterior end
B Anterior part, showing the position of the excretory pore, the vulva and the cranial parts of the uterus
C Lateral view of the vulva and ovejector
D Lateral view of the posterior end
E Egg

Scale bars: A, A', B, C, D—0.1 mm; E—0.02 mm

spicule pouch opens immediately posterior to the anal opening. The spicule is 0.07 long, weakly sclerotized and of almost uniform width (0.005) with a rounded tip. The tail is dorsally directed, crescent-shaped, 0.06 long, and tapers to a pointed tip.

TYPE HOST

Gerrhosaurus flavigularis (Gerrhosauridae) 168/II.

TYPE LOCALITY

Timbavati Private Game Reserve (24°29'56.5"S; 31°17'50.8"E), Northern Province, Republic of South Africa.

TYPE MATERIAL

The holotype male is deposited in the collection of the Museum National d'Histoire Naturelle, Paris, France, access number 280HS.

HABITAT

Large intestine.

ETYMOLOGY

The species is named after the host.

***Parapharyngodon* sp. no. 3** ($n = 1$) (Fig. 11)

FEMALE

Total length 4.29, maximum width 0.56.

Distinct transverse striations occur on the body cuticle between the oesophago-intestinal junction and the rectum, while the remainder of the body is indistinctly striated. The oral opening is surrounded by six prominent lips, the lateral ones of which each bear an amphid. The oesophagus is 0.96 long, the isthmus is distinct and 0.05 long, and the bulbus more or less round, 0.07 long and 0.08 wide. The nerve ring is situated close to the anterior end, 0.08 from the apex, and the excretory pore and vulva 1.44 and 1.78, respectively.

The vulva is prominent, didelphic and prodelphic. Parts of the ovaries are coiled around the oesophagus immediately anterior to the bulbus. The reproductive organs in this specimen were partly destroyed, therefore no further description is possible. Uteri are filled with eggs measuring 0.069 x 0.034 and which seem to be infertile due to the absence of males. An operculum was not observed.

HOST

Gerrhosaurus flavigularis (Gerrhosauridae) 166/II.

LOCALITY

Timbavati Private Game Reserve (24°29'56.5"S; 31°17'50.8"E), Northern Province, Republic of South Africa.

MATERIAL

The specimen is deposited in the collection of the Museum National d'Histoire Naturelle, Paris, France, access number 281HS.

HABITAT

Large intestine.

Discussion

For many years there have been conflicting views on the taxonomic validity of *Parapharyngodon* (Jones 1992). Although some authors consider the genus as a synonym of *Thelandros* Wedl, 1862 (Baylis 1936; Petter & Quentin 1976; Vincente, Rodrigues, Gomes & Pinto 1993), we regard *Parapharyngodon* as an independent genus as redefined by Adamson (1981). According to Adamson (1981) and Adamson & Nasher (1984), *Thelandros* is readily distinguishable from *Parapharyngodon* by the presence of a prominent genital cone, a marked distance between the anus and the spicule pouch, and the caudal pre- and adanal papillae which are pedunculated in *Thelandros* but mammilliform in *Parapharyngodon*. The eggs of *Thelandros* have terminal opercula and *in utero* already contain a larva. In addition, *Thelandros* is known to occur in omni- or herbivorous reptiles, whereas *Parapharyngodon* is found in insectivorous reptiles and amphibians. These characteristics have been accepted by Baker (1987), Moravec, Barûs & Rysavy (1987), Hobbs (1996) and Moravec, Salgado-Maldonado & Mayen-Peña (1997).

In addition to the several *species inquirendae* (Adamson 1981), which can probably be referred to the genus, more than 30 *Parapharyngodon* species have so far been described (Baker 1987) and the genus can be considered cosmopolitan.

Except for one species which is known from South Africa, namely *Parapharyngodon rotundatus* (Malan, 1939) Freitas, 1957 from *Agama atra* and *Pseudocordylus microlepidotus*, all the African species occur in countries north of the equator. Adamson

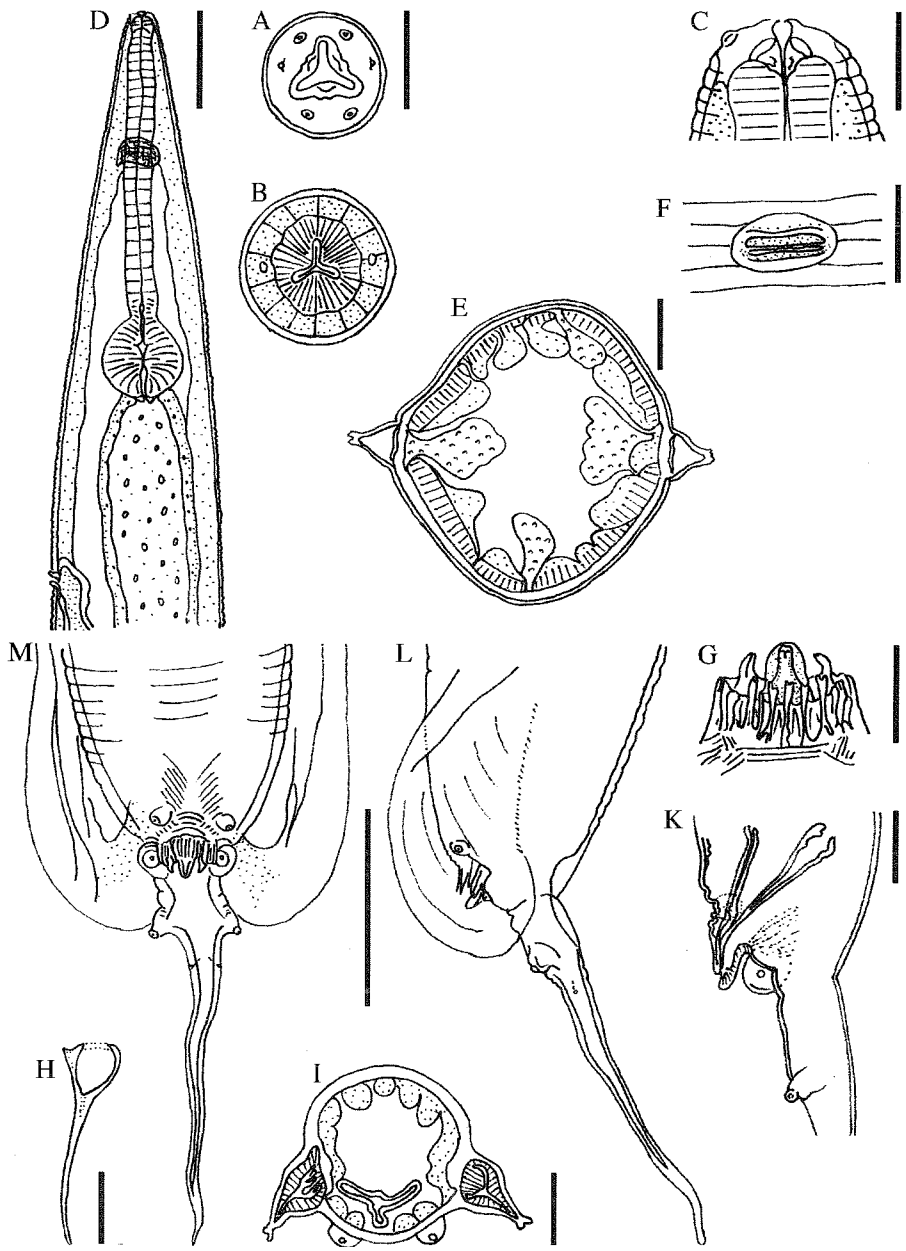


FIG. 12 *Skrjabinodon mabuyae* male from *Mabuya striata*

A Apical view of the head
B Transverse section of the head, 0.011 mm below the apex
C Median view of the head
D Lateral view of the anterior part including the excretory pore
E Transverse section at mid-body
F Ventral view of the excretory pore
G Ventral view of the genital cone
H Lateral view of the spicule
I Transverse section between the anterior pair of genital papillae and the genital cone
K Lateral view of the posterior end showing the position of the spicule
L Lateral view of the posterior end
M Ventral view of the posterior end

Scale bars: D, L, M—0.1 mm; A, B, C, E, F, G, H, I, K—0.02 mm

(1981) and Baker (1987) mistakenly quoted *Parapharyngodon rousseti* (Tcheprakoff, 1966) Adamson, 1981 from *Agama bibronii boneti* as a South African species. Besides the fact that Tcheprakoff (1966) names "In'Ekker, région d'In' Anguel Hoggar" (equivalent to Ahaggar in Algeria) as the host locality, *A. bibronii boneti* does not occur in South Africa.

The males of *P. rotundatus* differ distinctly from our *Parapharyngodon* spp. in having prominent and wide alae. Furthermore, the morphology of the caudal extremity as well as the size of the pre- and adanal papillae differ completely between *P. rotundatus* and the species redescribed here. The latter can be differentiated from each other in that the genital cone of *P. margaritiferi* is surrounded by

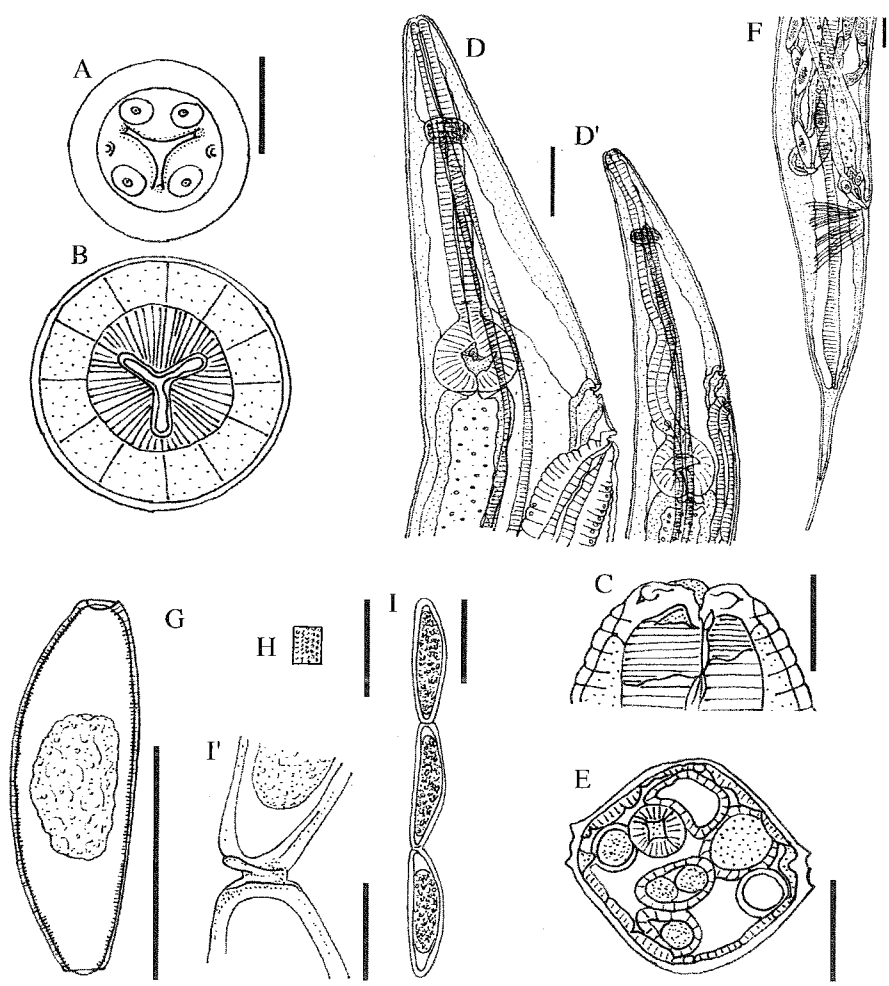


FIG. 13 *Skrjabinodon mabuyae* female from *Mabuya striata*

- A Apical view of the head
- B Transverse section of the head 0.02 mm below the apex
- C Median view of the head
- D, D' Anterior parts of two females of different size, showing the relative position of the of the vulva and excretory pore as well as the beginning of the alae
- E Transverse section at mid-body
- F Lateral view of the posterior end
- G Egg
- H Detail of the egg-shell's surface
- I, I' A string consisting of three eggs and detail of the connection between the eggs

Scale bars: D, D', E, F, G, H, I—0.1 mm; A, B, C, I'—0.02 mm

crescent-shaped and elongated cuticular ornamentation, that of *P. gerrhosauri* is simple, without ornamentation and projections, and that of *Parapharyngodon* sp. no. 1 is surrounded by two lateral lips and is slightly overlapped by a simple anterior cuticular projection.

The different species of the genus *Parapharyngodon* are mainly distinguished by morphological characters of the males. The similarity of the females of this genus makes it impossible to distinguish them without accompanying male specimens. For this reason the female from *G. flavigularis* cannot be linked to *P. gerrhosauri* although the host species and collecting area indicate a possibility of the two belonging together.

All *Parapharyngodon* larvae described to date are spinose (Barûs 1973; Adamson & Nasher 1984) and the arrangement of the spines is very similar to that of adult *Indiana* Chakravarty, 1943 (Thelastomatidae: Oxyuroidea), a parasite of insects (Bain 1965). In nematodes the ontogenesis is often expressed in the phylogeny and the larval characters of *Parapharyngodon* strengthen the hypothesis that this nematode genus may be derived from a nematode of insects. According to Blaxter, De Ley, Garey, Liu, Scheldeman, Vierstraete, Vanflenteren, Mackey, Dorris, Frisse, Vida & Kelley (1998) the Oxyuroidea of vertebrates have evolved from arthropod ancestors and Petter & Quentin (1976) presumed the thelastomatids to be the ancestors of the Pharyngodonidae. The spiny cuticle of the *Parapharyngodon* larvae may be a remnant of this ancestry (Adamson & Nasher 1984).

Since the L4-larvae described above were collected together with adult members of the genus, we consider the larvae to belong to the genus *Parapharyngodon.* This identification, however, assumes that spiny larvae are characteristic for the genus.

A detailed description of the developing female reproductive system has so far only been reported by Adamson & Nasher (1984). Contrary to their observations, coelomocytes surrounding each growing ovary were not visible in the *Parapharyngodon* larvae redescribed here, which could be due to advanced larval age. What remains unclear is whether the two different larval forms, distinguishable by the length of the oesophagus, are different sexes or even different species.

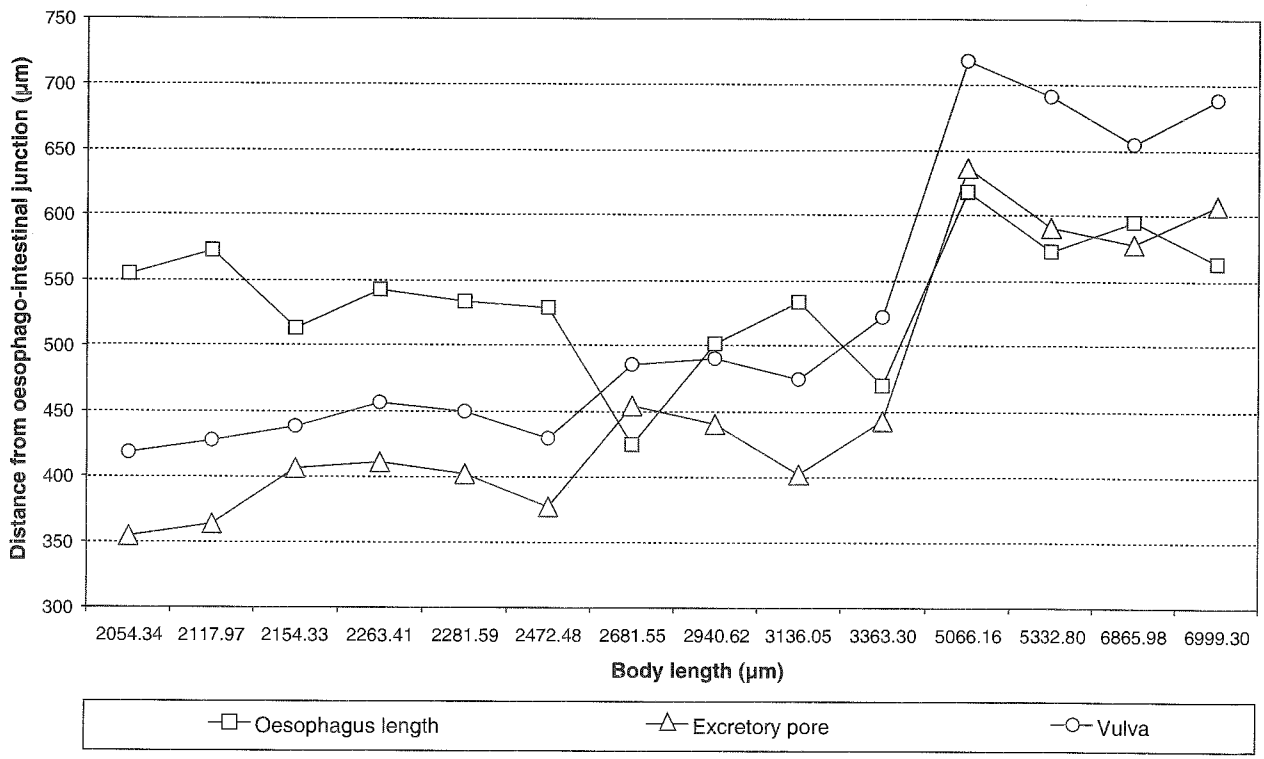


FIG. 14 The relationship between the body length, length of the oesophagus, and the position of the vulva and excretory pore in adult and subadult *Skrjabinodon mabuyae* females

CHARACTERIZATION OF THE GENUS *SKRJABINODON* INGLIS, 1968

TYPE SPECIES: *Skrjabinodon mabuyae* (Sandground, 1936) Inglis, 1968

Pharyngodonidae, with lateral alae frequently very narrow, particularly in females. The mouth opening is bound by three bilobed lips. The tail terminates in a long spike, often barbed in the female. Spicules may be absent. The cloacal region is raised forming a narrow elongated cone. Caudal alae are absent. Two pairs of cloacal papillae are always separate from the cone and one pair of postcloacal papillae is often present near the cloacal pairs. The caudal papillae are sessile and often reduced. Cosmopolitan parasites of reptiles (Inglis 1968; Petter & Quentin 1976).

Redescription of the species *Skrjabinodon mabuyae* (Sandground, 1936) Inglis, 1968
(Fig. 12 and 13)

Cuticle thick and transversely striated. Lateral alae are present in both sexes. The mouth opening is triangular and surrounded by three small lips. There are four more or less conspicuous cephalic papillae. The lateral lips each have one papilla and an amphid, and each of the submedian lips bears one cephalic papilla. The prominent excretory pore is surrounded by a cuticular rim. Lateral alae arise at the level of the nerve ring. A long and thin tail, unarmed in both sexes, is present.

MALE (*n* = 9, from five different hosts) (Fig. 12)

Males are 2.01 (1.35–2.35) long and 0.19 (0.12–0.24) wide at mid-body. The oesophagus is 0.41 (0.37–0.45) long and of uniform width. The bulbus is 0.08 (0.07–0.09) long and 0.09 (0.07–0.10) wide, and the isthmus is 0.29 (0.29) from the cephalic extremity. The alae are 1.75 (1.42–2.07) long and arise 0.13 (0.09–0.15) from the anterior end, near the nerve ring which is situated 0.17 (0.10–0.25) from the apex. The excretory pore lies at the level of the bulbus or slightly posterior to it, 0.54 (0.36–0.61) from the anterior end. In transversal section, the alae are longitudinally grooved, the groove deepening towards the posterior end (Fig. 12E and I).

The caudal papillae are arranged as described by Sandground (1936). The spicule is poorly sclerotized and hardly visible, V-shaped, 0.062 long and 0.017 in maximum width. The tail is 0.22 (0.19–0.25) long.

FEMALE (*n* = 16, from five different hosts) (Fig. 13)

Length 3.62 (2.05–6,99) and width at mid-body 0.23 (0.15–0.38). The total length of the oesophagus is 0.54 (0.43–0.62); the bulbus is 0.10 (0.09–0.12) long and 0.11 (0.09–0.14) wide and the isthmus is 0.43 (0.42–0.45) from the anterior end. Alae arise 0.13 (0.11–0.16) from the anterior end, often anterior to the nerve ring which is situated 0.15 (0.10–0.19) from the apex. The prominent vulva lies 0.52 (0.42–0.72) from the apex, always posterior to excretory pore which is 0.46 (0.36–0.64) from the anterior end. The alae are 3.05 (1.60–6,08) long and configured as in the males, but in transverse section the longitudinal groove is shallower (Fig. 13E).

A well-developed muscular vagina, 0.81 long, leads into a long common uterus which divides 1.26 from the vulva into two uteri that run anteriorly for a short distance and then divert in opposite directions. Ovaries are about 1.87 long. Eggs are asymmetrical, being flattened on one side. They are operculated at both poles, have a rough surface and measure 0.156 (0.142–0.161) x 0.053 (0.051–0.055). Eggs, containing a morula, are laid in long strings (Fig. 13I and I').

In Fig. 14 the variation in the position of the excretory pore and vulva in relation to the oesophagointestinal junction is shown. As expected, the older (larger) the specimens were, the more posterior the vulva and excretory pore were to the oesophagointestinal junction.

TYPE HOST

Mabuya varia (Scincidae).

TYPE LOCALITY

Mount Elgon, Uganda.

OTHER HOSTS AND LOCALITIES

Mabuya punctatissima from Delftzyl Government Farm (24°40'39.6"S; 29°14'23.8"E), Northern Province, Republic of South Africa.

Mabuya varia from the Timbavati Private Game Reserve (24°16'52.4"S; 31°18'7.3"E), Northern Province and the Blyde River Canyon Nature Reserve (24°43'5.9"S; 30°50'31.0"E), Mpumalanga Province, Republic of South Africa.

Mabuya punctatissima and *Mabuya varia* from the campus of the Medical University of Southern Africa

(25°36'51.8"S; 28°01'30.5"E), Gauteng Province, Republic of South Africa.

Mabuya spilogaster and *Mabuya punctatissima* from the Molopo Nature Reserves (25°40'–53'S; 22°49'–56'E), North West Province, Republic of South Africa.

TYPE MATERIAL

The type specimens are deposited in the collection of the U.S. Department of Agriculture-Agricultural Research Service (U.S. National Parasite Collection).

OTHER MATERIAL

The specimens collected during this survey are deposited in the collection of the Museum National d'Histoire Naturelle, Paris, France, access number 282HS.

HABITAT

Large intestine.

Discussion

The genus *Skrjabinodon* was established by Inglis (1968) when revising the genus *Parathelandros* Diesing, 1861, restricting the latter to accommodate only species parasitic in Australian frogs. This has been accepted by a number of authors (Petter & Quentin 1976; Baker 1987; Moravec *et al.* 1987, 1997; Ainsworth 1990; Hornero & Roca 1992). Since Inglis's (1968) revision several of *Parathelandros* spp. have been described from lizards outside Australia, the validity of which was questioned by Baker (1987).

Morphologically and morphometrically our specimens are very close to *S. mabuyae,* differing mainly in host species and host locality. *Skrjabinodon mabuiensis* (Malan 1939) described from *Mabuya striata* in the Western Cape Province differs by the absence of spicules in the males and lateral alae in the females (Malan 1939). Comparison with specimens of *S. mabuiensis* could have excluded the possibility of synopnymy but it was not possible to trace the type specimens and the present specimens are therefore assigned to *S. mabuyae*.

ACKNOWLEDGEMENTS

We wish to thank the following persons and institutions without whose assistance this study would not have been possible: Messrs. P. Leitner and S. Dell (Molopo Nature Reserve), P. du Toit (†) (Delftzyl Government farm), J. Theron and J. Coetzee (Blyde River Canyon Nature Reserve), C. Rowles (Klaserie Private Game Reserve), B. Harris and Dr. S. Joubert (Timbavati Private Game Reserve), Major P. Oosthuizen (Hoedspruit Nature reserve) and Dr D.W. Verwoerd (the farm 'Kaalplaas'). The Conservation Authorities of the Gauteng, Mpumalanga, Northwest and Northern Provinces are thanked for their assistance in obtaining the material, as are the staff of Kings Camp and Buffalo Lodge. Dr W. Haacke of the Transvaal Museum of Natural History and R. Newbery provided much assistance and herpetological advice. This study was funded by the Arthur & Aenne Feindt Stiftung, Hamburg, Germany.

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Onderstepoort Journal of Veterinary Research, 69:31–51

Redescription of some *Thelandros* and *Tachygonetria* spp. (Pharyngodonidae: Oxyuroidea) from the omnivorous plated lizard, *Gerrhosaurus validus validus* A. Smith, 1849 in South Africa

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ABSTRACT

HERING-HAGENBECK, S.F.B.N., PETTER, A.J. & BOOMKER, J. 2002. Redescription of some *Thelandros* and *Tachygonetria* spp. (Pharyngodonidae: Oxyuroidea) from the omnivorous plated lizard, *Gerrhosaurus validus validus* A. Smith, 1849 in South Africa. *Onderstepoort Journal of Veterinary Research*, 69:31–51

Thelandros schusteri Hering-Hagenbeck, 2001, *Thelandros luciusi* Hering-Hagenbeck, 2001, *Thelandros boomkeri* Hering-Hagenbeck, 2001, *Tachygonetria bainae* Hering-Hagenbeck, 2001, *Tachygonetria chabaudi* Hering-Hagenbeck, 2001 and *Tachygonetria petterae* Hering-Hagenbeck, 2001 from the plated lizard, *Gerrhosaurus validus validus* A. Smith 1849 from three localities in the north-eastern region of South Africa are redescribed. Classification keys are available only for the males of the species and because male and female nematodes *in copula* were not observed in this study as well as the similarity of the females, it was not possible to identify the females to the species level. *Thelandros schusteri*, *Thelandros boomkeri* and *Thelandros luciusi* were provisionally paired with female Type E, *Tachygonetria bainae* with female Type C, *Tachygonetria chabaudi* with female Type A and *Tachygonetria petterae* with female Type D. Female Types B and F could not be paired.

The richness and composition of species of the Pharyngodonidae of *Gerrhosaurus validus validus* is close to that of tortoises and differs from the pharyngodonid fauna of the insectivorous lizards that have been studied. In the latter, only the genera *Spauligodon*, *Skrjabinodon* and *Parapharyngodon* were recovered. The pharyngodonid fauna of *Gerrhosaurus validus validus* seems to have originated by capture from local herbivorous reptiles. The three *Tachygonetria* spp. most closely resemble forms in South African tortoises. The three *Thelandros* spp. redescribed here not only show strong similarities to those of herbivorous *Agama* spp., but also to those parasitic in tortoises and could have been acquired from either.

Keywords: Gerrhosauridae, *Gerrhosaurus validus validus*, Oxyuroidea, Pharyngodonidae, South Africa, *Tachygonetria*, *Thelandros*

INTRODUCTION

Gerrhosaurus validus validus is widely spread in the eastern and northern regions of South Africa and also occurs in Mozambique, Malawi and Zimbabwe. The other subspecies, *Gerrhosaurus validus maltzahni* is limited to northern Namibia and southern Angola. *Gerrhosaurus validus validus* is the largest of the genus, attaining a length of about 70 cm. They are rupicolous and largely confined to rocky and boulder-strewn hills and outcrops in arid and mesic savannah habitats (Hering-Hagenbeck

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Accepted for publication 11 January 2002—Editor

2001). They hide in cracks from which it is nearly impossible to remove them and they wedge themselves in place by laying the tail around the body and filling the lungs with air. The lizards are highly territorial and live in small family groups. Their food consists of leaves, flowers and fruits but insects, spiders, millipedes, scorpions and small lizards and mammals are also taken (Branch 1998). They wander over a large area in search of food, but when disturbed they run along the quickest route back to their territory.

As part of a study of the helminth parasites of South African reptiles the helminths of *G. validus validus* were collected from various localities in the north-eastern part of the country. The helminths were described and named by Hering-Hagenbeck (2001) and the purpose of this paper is to validate the new species. All the helminths redescribed here are new host records and are also the first helminths to be described from *G. validus validus*.

MATERIALS AND METHODS

The study was conducted in the Hoedspruit Nature Reserve, and the Timbavati and Klaserie complex of private nature reserves, Northern Province, South Africa. The exact localities, as determined by GPS-reading, are provided with the redescription of each helminth species. The biogeography of these areas has been described by Hering-Hagenbeck (2001), and the vegetation type of each by Acocks (1988) and Low & Rebelo (1996).

The lizards were collected and processed for helminth recovery as described by Hering-Hagenbeck, Petter & Boomker (2002). The helminths were placed in a 50 % lactophenol-water solution and examined under a compound microscope while clearing. Drawings were made with a drawing tube and measurements derived from the drawings. Unless stated otherwise, all measurements are given in millimetres (mm). Measurements are those of the holo- and/or allotype, and, when available, followed by those of the paratypes (in parentheses). Where sufficient material was available specimens were dissected or sectioned to study the spicules, the apical region and transverse sections of the body.

RESULTS AND DISCUSSION

CHARACTERIZATION OF THE GENUS *THELANDROS* WEDL, 1862

TYPE SPECIES: *Thelandros alatus* Wedl, 1862

Pharyngodonidae. Cuticle with distinct transverse striations. Females with variable tail characters. Eggs often with a terminal cap, containing a larva when laid. Males with reduced caudal appendages. Genital cone prominent, supported by an anterior anal lip. Four pairs of caudal papillae are present; one pre-anal and one adanal pair of pedunculated rosette papillae, one postanal pair of nerve endings, median on the genital cone and opening into the spicule pouch, and one ventral pair in the middle of the tail. Parasites of herbivorous or omnivorous lizards (Adamson 1981; Adamson & Nasher 1984).

Redescription of the species *Thelandros schusteri* Hering-Hagenbeck, 2001 (Fig. 1)

MALE (n = 10)

Length 2.43 (2.39–2.44) and maximum width 0.20 (0.19–0.22).

Lateral alae are present, triangular in cross section with a broad base and a pointed edge. Oral opening triangular, surrounded by one dorsal and two subventral lips. Except for two amphids, no cephalic sensory organs were visible. The oesophagus occupies the anterior third of the body and its total length is 0.81 (0.75–0.81). The isthmus is 0.65 (0.61–0.65) long and the bulbus round, 0.12 (0.11–0.12) long and 0.11 (0.09–0.12) wide. The nerve ring is 0.14 (0.14–0.16) from the anterior end and the excretory pore 1.04 (1.03– 1.10), approximately at mid-body.

The genital cone is prominent. The tip of the anterior anal lip is divided into two parts of variable shape (Fig. 1F and F'). The spicule is prominent and rather well-sclerotized, sharply pointed at both ends, 0.14 (0.13–0.15) long and 0.009 wide. A gubernaculum was not observed. The tail is 0.05 (0.04–0.06) long, stout and bent slightly ventrally, tapering to a pointed tip from the posterior half caudally.

TYPE LOCALITY

Klaserie Private Game Reserve (24°05'49.9"S; 31° 07'16.2"E), Northern Province, Republic of South Africa.

TYPE MATERIAL

The holotype male and nine paratype males are deposited in the collection of the Museum National d'Histoire Naturelle, Paris, France, access number 283HS.

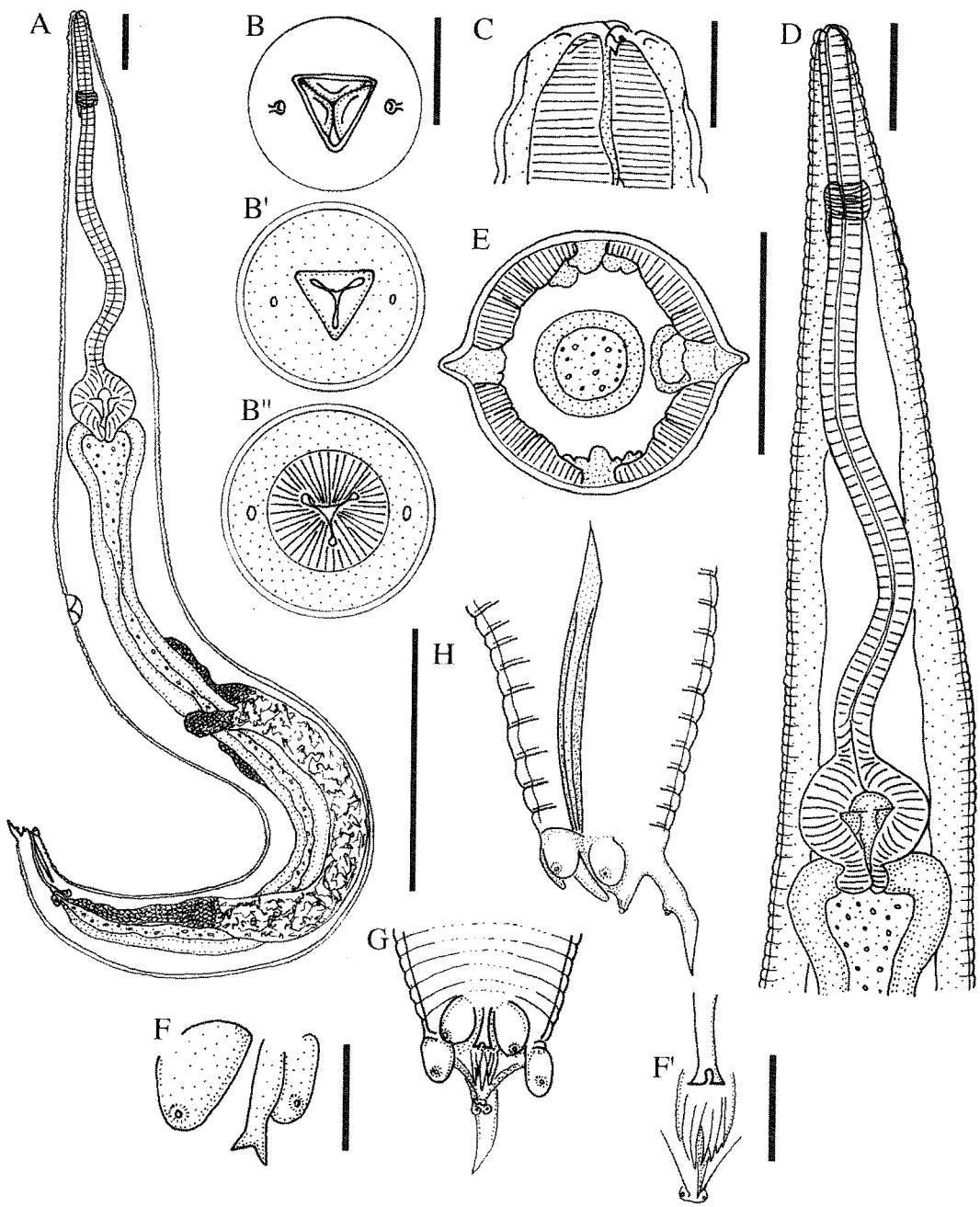

FIG. 1 *Thelandros schusteri*, male

A Lateral view of the entire nematode
B Apical view of the head
B' Transverse section through the anterior part, 0.002 mm and 0.023 mm below the apex respectively
C Median view of the head
D Lateral view of the anterior region
E Transverse section at mid-body showing the lateral alae and the shape of the body
F Variations in the anterior anal lip with the genital cone, subventral view
F' Variations in the anterior genital papillae, ventral view
G Ventral view of the posterior end
H Lateral view of the posterior end, showing the position of the spicule

Scale bars: A, D, E, G, H—0.1 mm; B, B', B'', C, F F'—0.02 mm

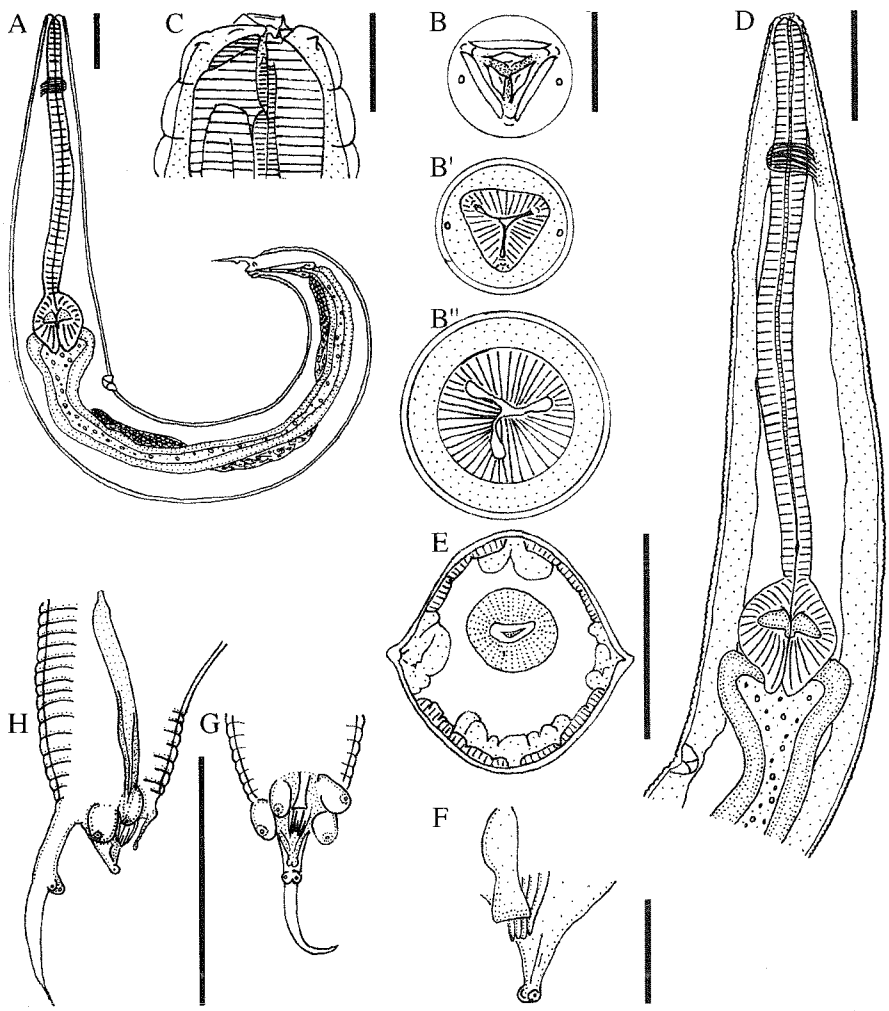

FIG. 2 *Thelandros boomkeri*, male

A	Lateral view of the entire nematode
B	Apical view of the head
B'–B''	Transverse section through the anterior part, 0.004 mm and 0.018 mm below the apex respectively
C	Median view of the head
D	Lateral view of the anterior region
E	Transverse section at mid-body showing the lateral alae and the shape of the body
F	Detail of the anterior anal lip with the genital cone, subventral view
G	Ventral view of the posterior end
H	Lateral view of the posterior end, showing the position of the spicule

Scale bars: A, D, E, G, H—0.1 mm; B, B' B'', C, F—0.02 mm

HABITAT

Stomach and large intestine.

***Thelandros boomkeri* Hering-Hagenbeck, 2001** (Fig. 2)

MALE (n = 3)

The worms are 1.89 (1.75–1.90) in length and 0.15 (0.14–0.18) in maximum width. Lateral alae are present, pointed in cross-section. The oral opening is triangular, surrounded by one dorsal and two subventral lips. Just below the lips, three triangular tooth-like projections are present. Except for amphids, no cephalic papillae were observed. The oesophagus is 0.69 (0.62–0.70) long, the isthmus 0.57 (0.53–0.59), and the round bulbus is 0.09 (0.08–0.11) long and 0.10 (0.09–0.12) wide. The nerve ring is 0.15 (0.14–0.16) from the anterior end

and the excretory pore 0.85 (0.72–0.85), just posterior to the oesophago-intestinal junction.

The anterior anal lip is plain, with rounded or pointed edges (Fig. 2F). The spicule is slightly arcuate, its distal extremity curved ventrally, its total length 0.13 (0.11–0.13) and the maximum width 0.009. A gubernaculum is absent. The caudal extremity is 0.08 (0.07–0.09) long, slender and often curved ventrally.

TYPE LOCALITY

Hoedspruit Air Base Nature Reserve (24°19'18"S; 31°01'39.2"E), Northern Province, Republic of South Africa.

TYPE MATERIAL

The holotype male and two paratype males are deposited in the collection of the Museum National d'Histoire Naturelle, Paris, France, access number 284HS.

HABITAT

Stomach and large intestine.

***Thelandros luciusi* Hering-Hagenbeck, 2001**
(Fig. 3)

MALE (n = 3)

Total length 2.52 (1.99–2.65) with a maximum width of 0.19 (0.16–0.22) at mid-body. Lateral alae are absent. The oral opening is triangular and surrounded by one dorsal and two subventral, sharply pointed, cuticular lips. Except for the amphids, cephalic sense organs are not visible. The lumen of the oesophagus is twisted (Fig. 3B" and B"') and its total length is 0.77 (0.71–0.82). The isthmus is 0.60 (0.57–0.65) from the anterior end and the bulbus is round, 0.09 (0.09–0.12) long and 0.11 (0.10–0.12) wide. The nerve ring is 0.13 (0.13–0.18) from the anterior end and the excretory pore 1.06 (0.86–1.12), always posterior to the bulbus.

The tip of the anterior anal lip is divided into between five to more than ten branches (Fig. 3F and F'). The spicule is prominent and well sclerotized, more or less straight, 0.13 (0.13–0.15) long and 0.014 (0.012–0.014) wide. Gubernaculum not seen. The tail is 0.13 (0.12–0.15) long and slender, strongly curved ventrally.

TYPE LOCALITY

Timbavati Private Game Reserve (24°24'56.5"S; 31°17'50.8"E), Northern Province, Republic of South Africa.

TYPE MATERIAL

The holotype male and two paratype males are deposited in the collections of the Museum National d'Histoire Naturelle, Paris, France, access number 285HS.

HABITAT

Stomach and large intestine.

Discussion

According to Adamson (1981) and Adamson & Nasher (1984), *Thelandros* is readily distinguishable from *Parapharyngodon*, to which it is closely related, by the presence of a prominent genital cone, a marked distance between the anus and the spicule pouch, and the caudal pre- and adanal papillae which are pedunculated in *Thelandros* but mammilliform in *Parapharyngodon*. The eggs of *Thelandros* have terminal opercula and *in utero* already contain a larva. In addition, the genus *Parapharyngodon* occurs in insectivorous reptiles.

Members of the genus *Thelandros* occur in herbivorous and omnivorous hosts (Adamson 1981), predominantly in *Agama* spp. and *Uromastix* spp. (Agamidae). The omnivorous Gerrhosauridae have never before been described as suitable hosts for *Thelandros*. Of the more than 15 described species, the three redescribed here most closely resemble *Thelandros chabaudi* Caballero, 1968 from *Oplurus quadrimaculatus* in Madagascar, *Thelandros agama* Adamson & Nasher, 1984 from *Agama yemenensis* from Saudi Arabia and *Thelandros alatus* from *Uromastix* spp. in Egypt, Tunisia, Algeria and Afghanistan (Barûs & Tenora 1976) especially in the general structure of the caudal extremity. However, *Thelandros chabaudi, Thelandros agama* and *Thelandros alatus* all have spicules shorter than 0.1 mm. Furthermore, *Thelandros agama* has caudal alae, which are lacking in the three redescribed species. The tail of *Thelandros chabaudi* appears more solid and the last pair of papillae, situated in the posterior half of the tail, seem much smaller than is the case with the species redescribed here.

In South Africa the genus *Thelandros* is represented by four species parasitic in tortoises. The fifth species, *Thelandros sexlabiata* Ortlepp, 1933, has been removed from the genus by Adamson & Nasher (1984).

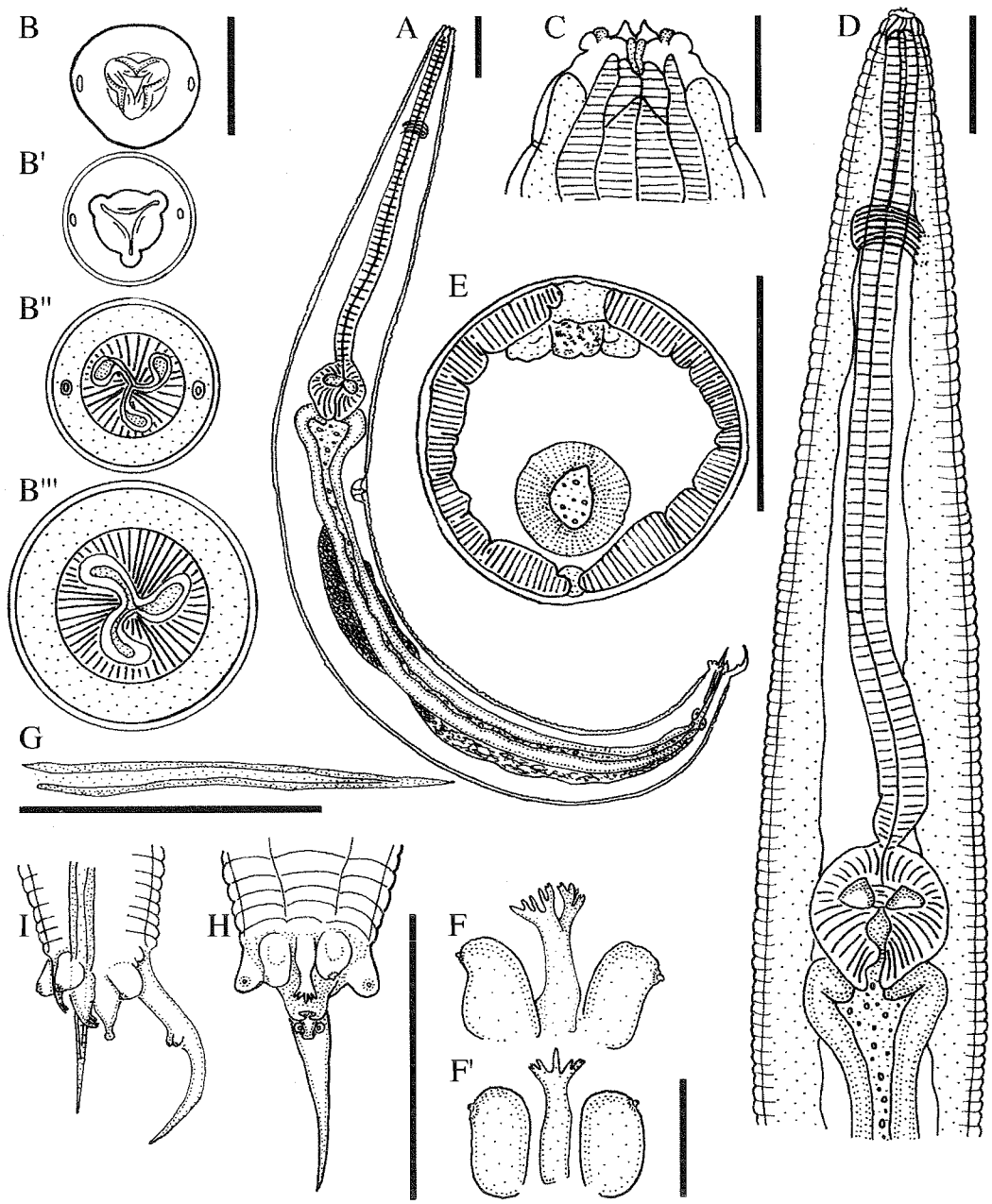

FIG. 3 *Thelandros luciusi*, male

A Lateral view of the entire nematode
B Apical view of the head
B'–B''' Transverse section through the anterior part, 0.002 mm, 0.012 mm and 0.023 mm below the apex respectively
C Median view of the head
D Lateral view of the anterior region
E Transverse section at mid-body showing the shape of the body
F Variations of the anterior anal lip with the anterior genital papillae, ventral view
G Lateral view of the spicule
H Ventral view of the posterior end
I Lateral view of the posterior end, showing the position of the spicule

Scale bars: A, D, E, G, H, I—0.1 mm; B, B', B'', B''', C, F, F'—0.02 mm

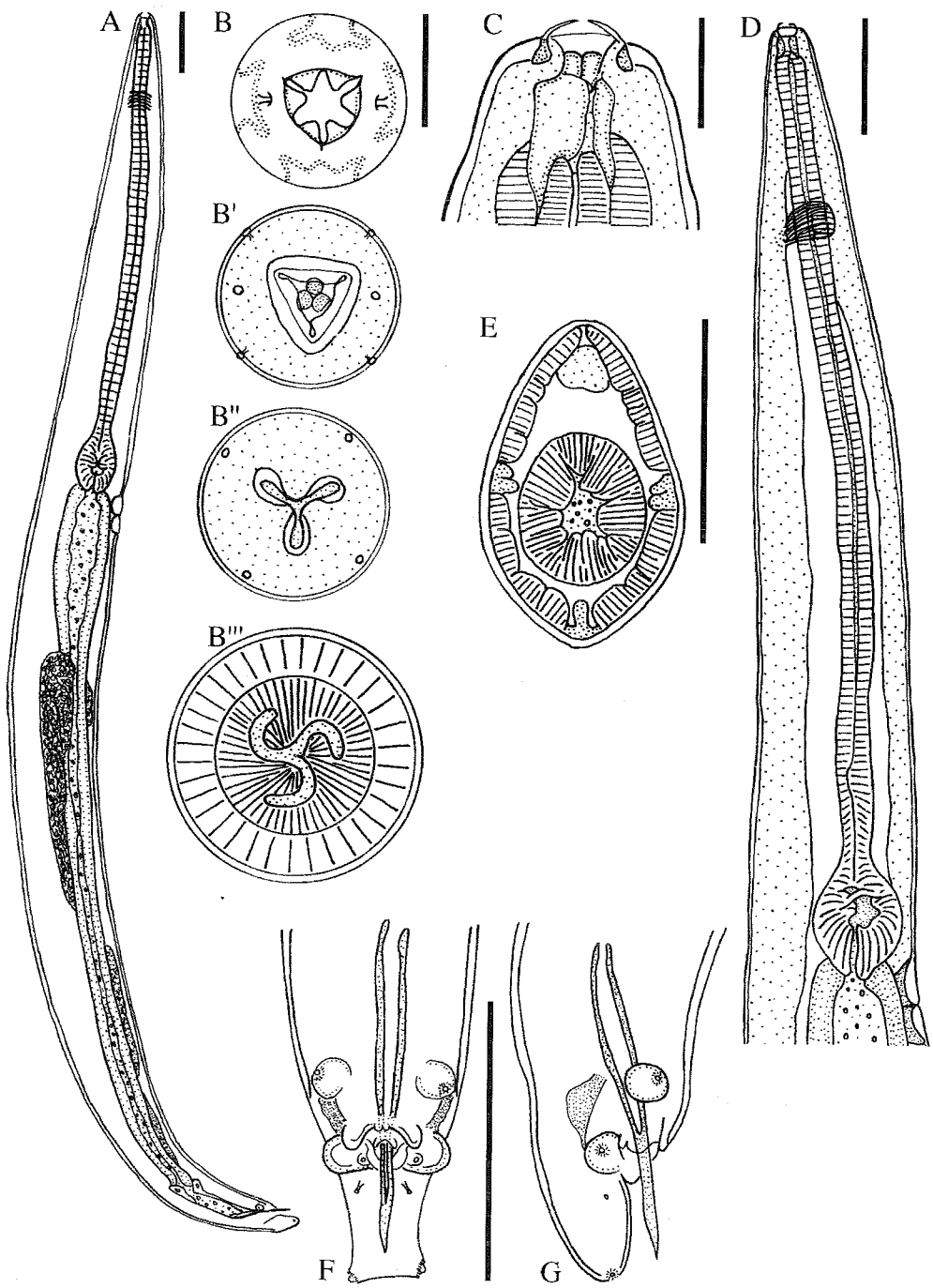

FIG. 4 *Tachygonetria bainae*, male

- A Lateral view of the entire nematode
- B Apical view of the head
- B'–B''' Transverse sections of the anterior part, 0.004, 0.008 and 0.02 mm from the apex respectively
- C Median view of the head
- D Lateral view of the anterior region
- E Transverse section at mid-body, showing the body shape
- F Ventral view of the posterior end
- G Lateral view of the posterior end

Scale bars: A, D, E, F, G—0.1 mm; B, B', B'', B'''—0.02 mm

Thelandros ortleppi Petter, 1966 differs from the redescribed species in having large caudal alae. Petter (1966) considered *Thelandros versterae* Petter, 1966, *Thelandros weilliae* (Petter, 1966) and *Thelandros tcheprakovae* (Petter, 1966) to be three subspecies of *Thelandros versterae*. They are close to the redescribed species but the caudal papillae are bigger and more distant from one another. In addition, the spicules of *Thelandros versterae*, *Thelandros weilliae* and *Thelandros tcheprakovae* are shorter than those of the species redescribed, and the oesophagi of *Thelandros versterae* and *Thelandros weilliae* are very short. The characteristic shape of the anterior anal lip differs distinctly between *Thelandros schusteri*, *Thelandros boomkeri* and *Thelandros luciusi* and their shape is also unique among the existing species. The configuration of this delicate appendage should be taken into consideration in future studies.

CHARACTERIZATION OF THE GENUS *TACHYGONETRIA* WEDL, 1862

TYPE SPECIES: *Tachygonetria vivipara* Wedl, 1862

Pharyngodonidae. Body cuticle with distinct transverse striations. Caudal extremity of the male abruptly truncate posterior to the last pair of caudal papillae and often supported by a short caudal spine. The last pair of caudal papillae is situated almost laterally. Widely distributed parasites of herbivorous and omnivorous reptiles, mainly tortoises (Petter 1966; Adamson & Nasher 1984).

Redescription of the species *Tachygonetria bainae* Hering-Hagenbeck, 2001 (Fig. 4)

MALE (n = 20)

Body 2.64 (2.44–2.64) long and 0.22 (0.18–0.22) wide near the mid-body. In cross-section the body is ovoid with the narrower part dorsally, and without lateral alae. The cephalic extremity is flattened and the apex ornamented with four cuticular relief patterns (Fig. 4B), the two lateral ones of which enclose an amphid. Amphids have two projections. Four cephalic papillae, visible 0.004 below the apex, occur on the edges of the ventral and dorsal relief patterns. The mouth opening is triangular, guarded by two dorsal, two lateral and two ventral membranous cuticular flaps. The cuticular lining at the anterior end of the oesophagus forms two lateral and one dorsal, anteriorly directed, tooth-like structures. The oesophagus is 0.87 (0.84–0.91) long, with a twisted inner margin (Fig. 4B'''). The isthmus is 0.74 (0.71–0.78) from the anterior end and the bulbus is subspherical, 0.09 (0.09–0.10) long and 0.11 (0.09–0.11) wide. The nerve ring is 0.20 (0.18–0.21) from the anterior end and the excretory pore 1.02 (0.91–1.04), always posterior to the oesophago-intestinal junction.

The anterior anal lip is formed by two prominent fleshy lobes, enclosing two small projections, while the posterior anal lip is supported by a hardly visible accessory piece. Four pairs of caudal papillae are present (Fig. 4F): one pre-anal and subventral pair of large pedunculated rosette papillae, a second pair has the same shape and size but lie adanal, the third pair is small and sessile, and occurs more median while the fourth and most posterior pair is visible on the lateral end of the caudal appendage. The caudal alae, 0.027 long and 0.009 wide, are present between the first and the second pairs of papillae. The well-sclerotized and prominent spicule is 0.12 (0.12–0.14) long and 0.011 wide. The tail is 0.06 (0.05–0.06) long.

TYPE LOCALITY

Timbavati Private Game Reserve (24°24'56.5"S; 31°17'50.8"E), Northern Province, Republic of South Africa.

TYPE MATERIAL

The holotype male and 19 paratype males are deposited in the collection of the Museum National d'Histoire Naturelle, Paris, France, access number 286HS.

HABITAT

Stomach and large intestine.

Tachygonetria petterae Hering-Hagenbeck, 2001 (Fig. 5)

MALE (n = 3)

Body 2.11 (2.08–2.11) long and 0.13 (0.09–0.13) wide near the mid-body. Minute lateral alae are present, and the body is almost square in cross section. The cephalic extremity is flattened and the mouth opening triangular, without lips. The cephalic sense organs consist of four dorsal and four subventral papillae. Amphids occur between the outer subventral and dorsal cephalic papillae (Fig. 5B). The oesophagus measures 0.50 (0.47–0.50), the isthmus 0.37 (0.36–0.38) and the bulbus is more or less round, 0.09 (0.06–0.09) long and 0.09 (0.08–0.09) wide. The nerve ring is in the anterior fourth

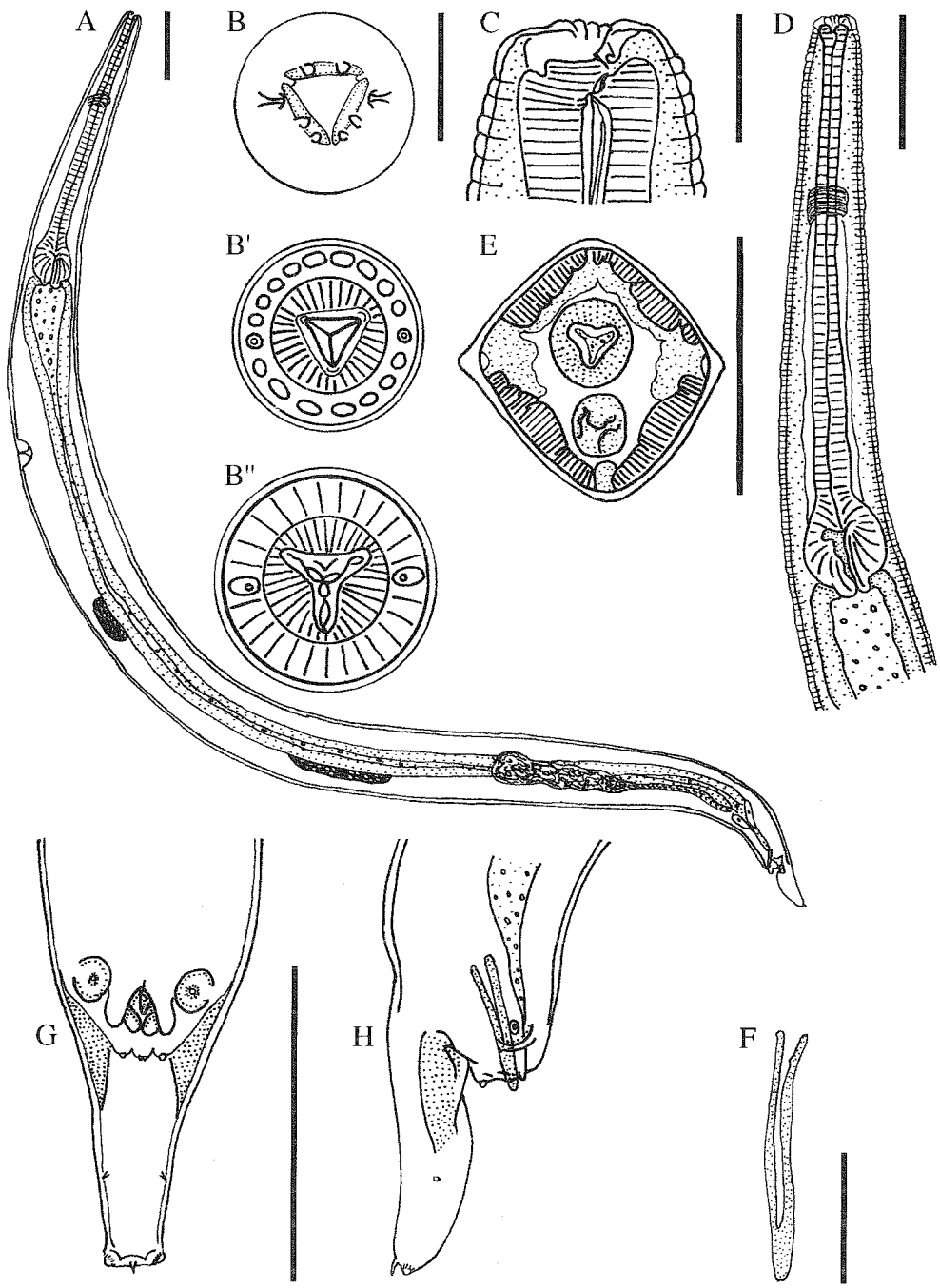

FIG. 5 *Tachygonetria petterae*, male

A Lateral view of the entire nematode
B Apical view of the head
B'–B" Transverse sections of the anterior part, 0.007 and 0.014 mm from the apex respectively
C Median view of the head
D Lateral view of the anterior region
E Transverse section at mid-body, showing the body shape
F Lateral view of the spicule
G Ventral view of the posterior end
H Lateral view of the posterior end

Scale bars: A, D, E, G, H—0.1 mm; B, B', B", C, F—0.02 mm

of the oesophagus, 0.15 (0.10–0.12) from the apex and the excretory pore 0.70 (0.69–0.71), always posterior to the bulbus.

The anterior anal lip is formed by two long, fleshy, curved lobes connected by a membranous cuticular sheath. Four pairs of caudal papillae are present (Fig. 5G), a subventral, mammilliform pre-anal pair, a smaller, adanal pedunculated second pair, covered by the anterior anal lip and a third pair, median and postanal, similar in size and shape as the first pair. Two tiny projections are present on the tip of the posterior anal lip. The fourth pair of papillae occurs laterally on the posterior end of the caudal appendage. The latter is 0.045 (0.040–0.049) long and bears a minute terminal spine. Caudal alae, 0.022 long and 0.011 wide, are present on the anterior half of the caudal extremity. The spicule is weakly sclerotized, 0.051 long and 0.004 wide, with a rounded distal end.

TYPE LOCALITY

Timbavati Private Game Reserve (24°0.5'51.4"S; 31°0.7'18.1"E), Northern Province, Republic of South Africa.

TYPE MATERIAL

The holotype male and two paratype males are deposited in the collection of the Museum National d'Histoire Naturelle, Paris, France, access number 287HS.

HABITAT

Stomach and large intestine.

***Tachygonetria chabaudi* Hering-Hagenbeck, 2001** (Fig. 6)

MALE (n = 20)

Males are 1.75 (1.72–1.81) long with a maximum width of 0.11 (0.09–0.12). Lateral alae are not visible. The body outline is almost square in cross-section. The anterior extremity is flattened and the triangular mouth opening is without lips. Cephalic sense organs consist of four dorsal and four subventral papillae. Amphids are present between the outer subventral and dorsal cephalic papillae (Fig. 6B). The oesophagus is 0.44 (0.41–0.45) long, the isthmus 0.34 (0.30–0.34) and the bulbus is slightly oval, 0.07 (0.06–0.07) long and 0.06 (0.06–0.07) wide. The nerve ring is 0.11 (0.10–0.12) from the apex, at the end of anterior third of the oesophagus, and the excretory pore is always posterior to the bulbus, 0.59 (0.57–0.63) from the apex.

Four pairs of caudal papillae are present (Fig. 6E); a prominent pre-anal pair, mammilliform and situated subventrally, a second adanal pair is long and pedunculated and enclosed by the anterior anal lip. The latter is formed by two half-moon-shaped cuticular flaps. Pair three occurs median and postanal and is similar in size and shape to the first pair. Between pair 3 a single, minute papillae-like projection is present. The fourth pair occurs laterally on the posterior end of the caudal appendage. The latter is 0.06 (0.05–0.07) long, and carries a minute terminal spine. Caudal alae, 0.040 long and 0.016 wide, are present in the anterior half of the caudal extremity. The spicule is straight, with a rounded distal extremity, and is 0.037 (0.036–0.043) long and 0.005 wide.

TYPE LOCALITY

Timbavati Private Game Reserve (24°24'56.5"S; 31°17'50.8"E), Northern Province, Republic of South Africa.

TYPE MATERIAL

The holotype male and 19 paratype males are deposited in the collections of the Museum National d'Histoire Naturelle, Paris, France, access number 288HS.

HABITAT

Stomach and large intestine.

Discussion

Tachygonetria, as one of the nine pharyngodonid genera which occur in herbivorous and omnivorous reptiles (Petter & Douglass 1976; Petter & Quentin 1976), is one of the most widely distributed. Together with the genera *Alaeuris* Thapar, 1925 and *Thaparia* Ortlepp, 1933 it is found in the Ethiopian, Oriental, Madagascan, Neotropical, Palaearctic and Nearctic regions. Their absence from the Australian continent is probably the result of the absence of terrestrial tortoises (Adamson & Nasher 1984). *Tachygonetria* is essentially a parasite of tortoises, particularly of the genus *Testudo* (Petter 1966).

Currently more than 20 *Tachygonetria* species are known. Except for the type species *Tachygonetria vivipara* Wedl, 1862, a parasite of *Uromastix* spp. (Agamidae) in Egypt, Morocco and Algeria (Baylis

1923; Baker 1987) and *Tachygonetria paradentata* Adamson & Nasher, 1984 from *Agama yemenensis* in Saudi Arabia, all the other species are known from chelonians.

Because of the presence of characteristically broad cephalic extremities, *Tachygonetria chabaudi* and *Tachygonetria petterae* belong to the "*Tachygonetria dentata*" complex, which currently includes the five species *Tachygonetria dentata* Drasche, 1883, *Tachygonetria paradentata*, *Tachygonetria quentini* Petter, 1966, *Tachygonetria richardae* Petter, 1966 and *Tachygonetria nearctica* Petter & Douglass, 1976. The last named three species were originally described as subspecies of *Tachygonetria dentata* by Petter (1966) and Petter & Douglass (1976). The species *Tachygonetria quentini* is parasitic in tortoises in South Africa and, although closely related, differs from the species redescribed here by the absence of caudal alae. With the exception of *Tachygonetria paradentata*, none of the species mentioned above has alae at the base of the caudal appendage. *Tachygonetria chabaudi* and *Tachy-*

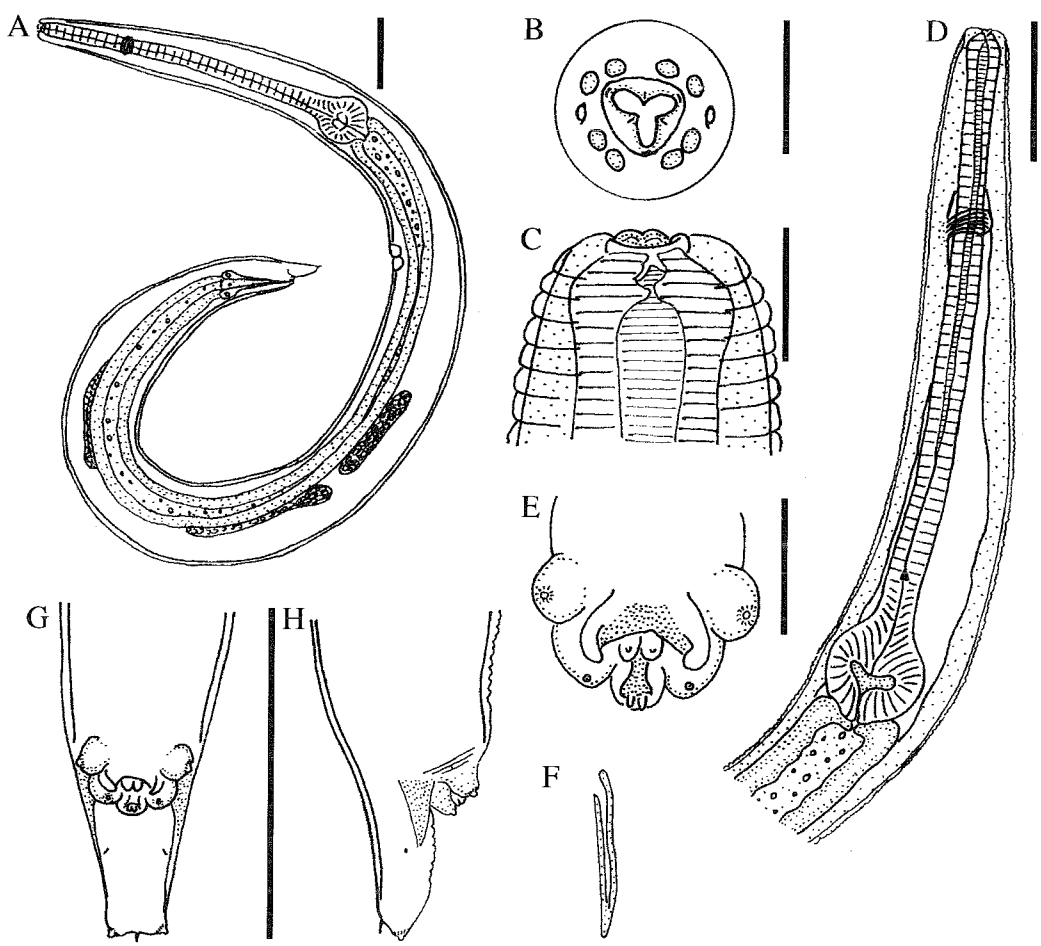

FIG. 6 *Tachygonetria chabaudi*, male

- A Lateral view of the entire nematode
- B Apical view of the head
- C Median view of the head
- D Lateral view of the anterior region
- E Ventral view of the genital cone and associated papillae
- F Lateral view of the spicule
- G Ventral view of the posterior end
- H Lateral view of the posterior end

Scale bars: A, D, F, G, H— 0.1 mm; B, C, E—0.02 mm

gonetria petterae both lack tooth-like structures in the buccal cavity, which are present in *Tachygonetria paradentata*, and both have slightly longer tails. Furthermore, they differ by the appearance of the anterior and posterior anal lips which appear more elongated and thicker in the last-named species.

In its general appearance, *Tachygonetria bainae* resembles *Tachygonetria longicollis fitzsimonsi* Petter, 1966 from *Geochelone pardalis* in Swaziland and the Pretoria zoo. This subspecies also has six cuticular flaps in the mouth opening, lacks a terminal spine, has a prominent spicule which is slightly longer than the tail and a conspicuously long oesophagus. The tail of *Tachygonetria bainae* is more robust and shorter than that of *Tachygonetria l. fitzsimonsi,* the spicule is slightly longer and different in shape, the phasmids are located more anteriorly and *Tachygonetria l. fitzsimonsi* lacks caudal alae.

The genus *Tachygonetria* is highly host-specific and our three species are the first to be recorded from the family Gerrhosauridae.

Thelandros and *Tachygonetria* females

FEMALE TYPE A ($n = 20$) (Fig. 7)

Round nematodes, tapering towards both extremities and without lateral alae. Total length 4.87 (4.55–5.01) and maximum width 0.36 (0.36–0.45) near mid-body. Cephalic extremity flattened. Mouth opening triangular, surrounded by one dorsal and two broad subventral membranous cuticular flaps. Cephalic papillae consisting of four submedian pairs of nerve endings and two amphids. Nerve endings are surrounded by prominent U-shaped cuticular relief patterns. Below the apex, at the anterior end of the oesophagus, the cuticular lining forms one dorsal and two subventral serrated, tooth-like structures.

The oesophagus is 0.61 (0.53–0.65) long and of more or less uniform width, the isthmus is distinct, 0.45 long, and a bulbus, 0.12 (0.11–0.31) long and 0.12 (0.10–0.29) wide, is present. At the oesophago-intestinal junction the intestine is clavate, and is as wide as the body. The conspicuous nerve ring is 0.17 (0.17–0.19) from the anterior end, the excretory pore 1.26 (1.19–1.30) and the vulva 2.33 (2.25–2.42), more or less at mid-body.

The prominent muscular vagina is directed anteriorly but flexes posteriorly into a common uterus. The latter divides near the anus and the uteri run anteriorly, reaching the oviducts near the level of the vulva. The blind ends of the ovaries extend to just anterior of the excretory pore. Eggs measure 0.127 x 0.073, are thin-shelled, with a small polar operculum and are not embryonated when laid. The tail is 0.42 (0.37–0.43) long.

HOST LOCALITY

Timbavati Private Game Reserve (24°24'56.5"S; 31°17'50.8"E), Northern Province, Republic of South Africa.

TYPE MATERIAL

Twenty females are deposited in the collection of the Museum National d'Histoire Naturelle, Paris, France, access number 289HS.

HABITAT

Stomach and large intestine.

FEMALE TYPE B ($n = 20$) (Fig. 8)

Body 3.53 (3.36–3.69) long and 0.27 (0.22–0.30) wide near mid-body; lateral alae are absent. The triangular mouth opening is covered by one dorsal and two broad subventral membranous cuticular flaps. The distal margins of the latter enclose two conspicuous papillae dorsally, and the subventral ones a prominent amphid and a distinct papilla each. The buccal capsule is markedly thickened dorsally and subventrally, and one dorsal and two subventral projections, subtriangular in apical view, arise from the anterior end of the oesophagus.

The oesophagus is 0.52 (0.49–0.53) long, and the maximum width is attained immediately behind the buccal capsule. The distinct isthmus is 0.31 (0.30–0.31) from the anterior end and the bulbus is oval, slightly longer than wide, measuring 0.13 (0.10–0.13) x 0.11 (0.09–0.12). The nerve ring lies 0.14 (0.12–0.14) from the apex, and the excretory pore 1.18 (1.16–1.22), both in the anterior third of the body.

The vulva lies just anterior to the anus, 2.96 (2.84–3.13) from the anterior end. Its opening is directed posteriorly and a prominent pre-vulvar swelling, almost forming a flap over the vulva, is present. The short muscular vagina with a conspicuous sphincter runs anteriorly, joins the common uterus which turns posteriorly and divides into two uteri at the level of the vulva. The uteri then turn anteriorly, going over into the oviducts. The ovaries coil around the intestine and their blind ends terminate just posterior to the oesophago-intestinal junction, often

facing posteriorly. Eggs measure 0.113 x 0.054, are thin-shelled and operculated, and contain a morula when laid. The tail is 0.26 (0.26–0.29) long, tapering strongly immediately behind the anus to end in a blunt tip.

HOST LOCALITY

Timbavati Private Game Reserve (24°24'56.5"S; 31°17'50.8"E), Northern Province, Republic of South Africa.

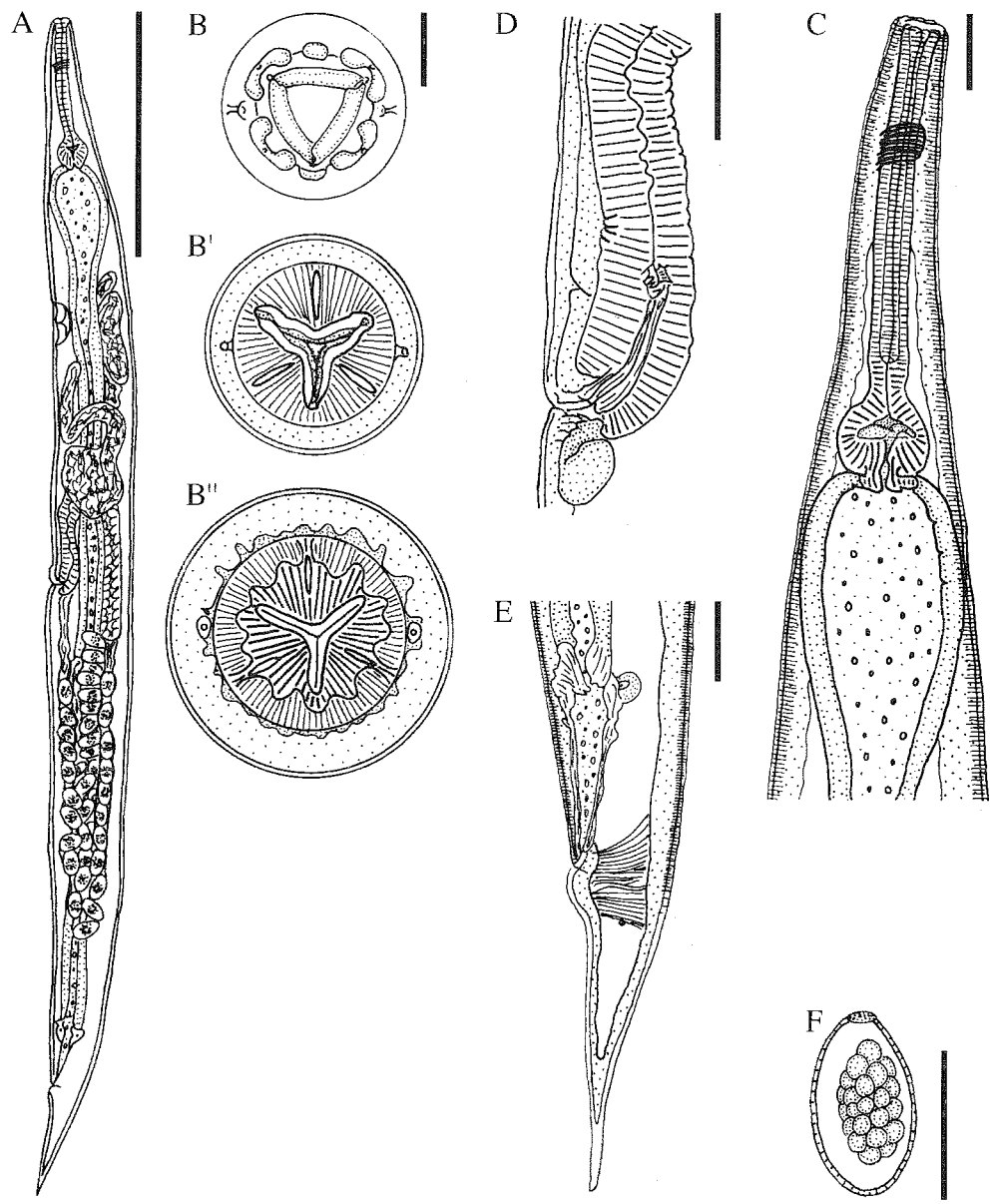

FIG. 7 Female type A

A Lateral view of the entire nematode
B Apical view of the head
B'–B'' Transverse sections of the anterior part, 0.008 and 0.024 mm from the apex respectively
C Lateral view of the anterior region
D Lateral view of the vulva and ovejector
E Lateral view of the posterior end
F Egg

Scale bars: A—1 mm; C, D, E, F—0.1 mm; B, B', B''—0.02 mm

Type Material

Twenty females, deposited in the collection of the Museum National d'Histoire Naturelle, Paris, France, access number 290HS.

Habitat

Stomach and large intestine.

Female Type C ($n = 20$) (Fig. 9)

The nematodes are spindle-shaped and the body is subhexagonal in transverse section. They are 4.64 (4.36–4.74) long and 0.47 (0.45–0.51) wide at mid-body. Lateral alae are absent. The cephalic extremity is slightly flattened. Lips are absent and the subtriangular mouth opening is guarded by one dorsal and two broad subventral membranous cuticular flaps. Just below the flaps, the cuticular lining forms one dorsal and two subventral serrated tooth-like structures. Cephalic sense organs consist of four pairs of submedian papillae, at the sides of the apex, and two lateral amphids. Below the apex, at the anterior end of the oesophagus, are three tooth-like structures.

The oesophagus is extremely long, 1.58 (1.54–1.69), and its inner margin is slightly twisted. The isthmus is 1.39 from the anterior end, and the bulbus is small and round, 0.13 (0.13–0.15) x 0.13 (0.13–0.16) in diameter. The intestine at the oesophago-intestinal junction is club-shaped with a maxi-

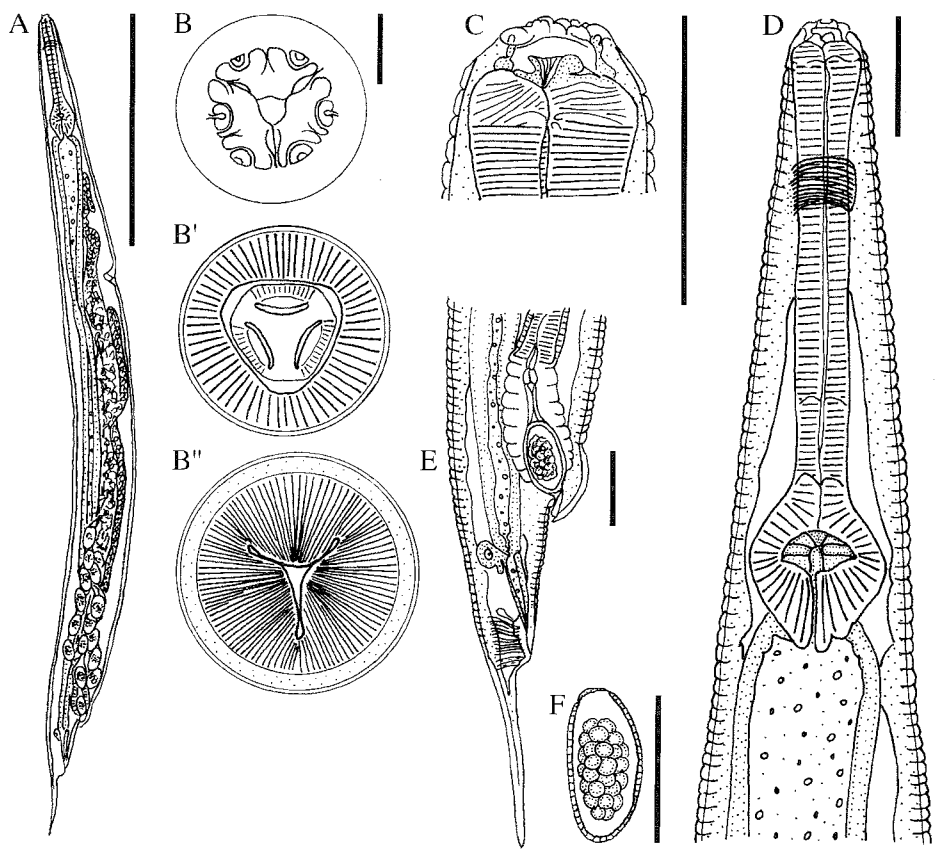

FIG. 8 Female type B

- A Lateral view of the entire nematode
- B Apical view of the head
- B'–B" Transverse sections of the anterior part, 0.011 and 0.024 mm from the apex respectively
- C Median view of the head
- D Lateral view of the anterior region
- E Lateral view of the posterior end
- F Egg

Scale bars: A—1 mm; C, D, E, F—0.1 mm; B, B', B"—0.02 mm

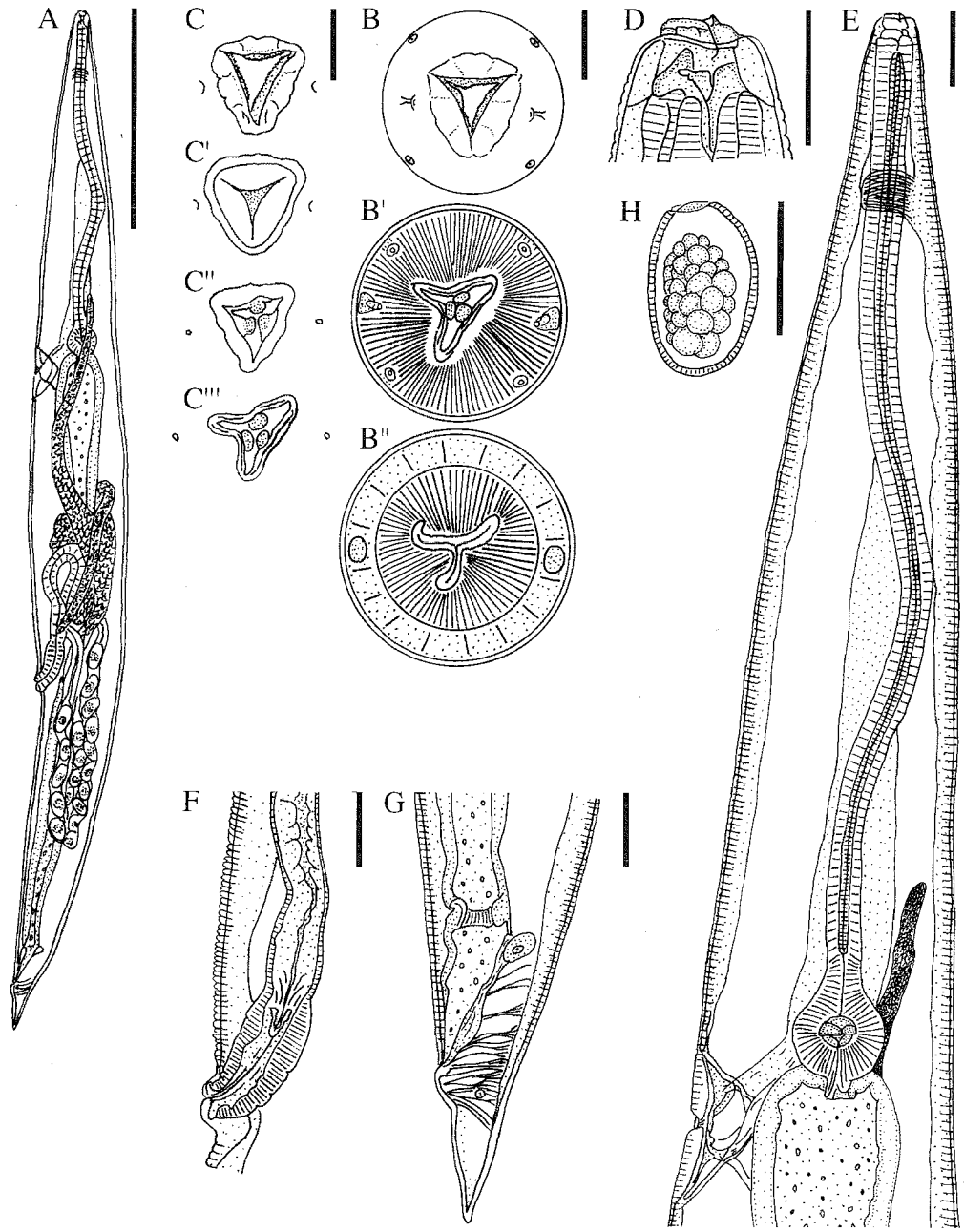

FIG. 9 Female type C

- A Lateral view of the entire nematode
- B Apical view of the head
- B'–B'' Transverse sections of the anterior part, 0.016 and 0.037 mm from the apex respectively
- C Apical view
- C'–C''' Transverse sections of the pharynx, 0.006, 0.01 and 0.016 mm from the apex respectively. Note the tooth-like structures in C'' and C'''
- D Median view of the head
- E Lateral view of the anterior region
- F Lateral view of the vulvar region
- G Lateral view of the posterior end
- H Egg

Scale bars: A—1 mm; D, E, F, G, H—0.1 mm; B, B', B'',C, C', C'' C'''—0.02 mm

mum width exceeding that of the bulbus by 1.5 times. The nerve ring is 0.27 (0.26–0.58) from the anterior end and the conspicuous excretory pore 1.62 (1.60–1.83), just posterior to the bulbus.

The vulva lies in the posterior body half 3.02 (2.84–3.18) from the apex. The short muscular vagina runs anteriorly, joins a common uterus which turns posteriorly and divides halfway between the vulva and the anus into two anteriorly directed uteri. The uteri become the oviducts at about the level of the vulva. The ovaries extend anteriorly for a short distance, the one turning posteriorly and ending anterior to the ovejector, the other extending anteriorly to beyond the level of the bulbus. Eggs are large, thin-shelled, with prominent polar opercula and unsegmented when laid. They measure 0.132 x 0.081. The tail is 0.19 (0.16–0.19) long.

HOST LOCALITY

Timbavati Private Game Reserve (24°24'56.5"S; 31°17'50.8"E), Northern Province, Republic of South Africa.

TYPE MATERIAL

Twenty females are deposited in the collection of the Museum National d'Histoire Naturelle, Paris, France, access number 291HS.

HABITAT

Stomach and large intestine.

FEMALE TYPE D ($n = 20$) (Fig. 10)

The total length is 4.64 (4.36–4.74) and the maximum width 0.47 (0.45–0.51) near mid-body; lateral alae absent. The triangular mouth opening is covered by six rounded lips, the two subventral and two dorsal ones ornamented and each bearing a single cephalic papilla, the two lateral lips plain and bearing amphids. Just below the lips, at the anterior end of the oesophagus, the prominent cuticular lining forms one dorsal and two subventral, serrated, tooth-like structures.

The oesophagus is 0.77 (0.76–0.84) long and the isthmus is 0.55 from anterior end. The bulbus is round, 0.17 (0.16–0.18) long and 0.17 (0.16–0.18) wide. The intestine envelops the posterior third of the bulbus. The nerve ring is 0.14 (0.13–0.16) from the apex. A prominent excretory pore is present in the anterior third of the body, 1.36 (1.33–1.41) from the anterior end and the vulva 2.93 (2.84–3.10), at the start of the posterior third of the body. The vulva opening is directed posteriorly. A short muscular vagina with a conspicuous sphincter runs anteriorly, joins a common uterus which turns posteriorly and divides into two just posterior to the vulva. The two uteri run anteriorly going over into the oviducts. The ovaries coil around the intestine, one blind end turning posteriorly and the other anteriorly, the latter reaching the level of the excretory pore. Eggs measure 0.104 x 0.056, are thin shelled and operculated and laid in the morula stage. The tail measures 0.48 (0.29–0.52) and tapers strongly immediately behind the anus to end in a blunt tip.

HOST LOCALITY

Timbavati Private Game Reserve (24°24'56.5"S; 31°17'50.8"E), Northern Province, Republic of South Africa.

TYPE MATERIAL

Twenty females are deposited in the collection of the Museum National d'Histoire Naturelle, Paris, France, access number 292HS.

HABITAT

Stomach and large intestine.

FEMALE TYPE E ($n = 20$) (Fig. 11)

The body is 4.04 (3.88–4.15) long and 0.29 (0.28–0.38) wide at mid-body. The cephalic extremity is slightly flattened and lips are absent. The triangular mouth opening is surrounded by six bean-shaped cuticular elevations. Except for amphids no cephalic sense organs were observed. Below the apex, at the anterior end of the oesophagus, three prominent tooth-like structures are present.

The long oesophagus measures 1.06 (1.02–1.14). The indistinct isthmus is 0.91 (0.88–0.96) from the anterior end and the small, oval bulbus is 0.12 (0.12–0.15) long and 0.14 (0.14–0.17) wide. The intestine has approximately the same width as the bulbus and envelops the latter. The nerve ring is 0.19 (0.17–0.19) from the apex, the excretory pore 1.47 (1.47–1.60), in the anterior half of the body, and the vulva 2.87 (2.76–2.96) from the anterior end, in the posterior third of the body.

Prominent post-vulvar and less prominent pre-vulvar swellings are present. The short muscular vagina runs anteriorly into a common uterus, which turns posteriorly and divides into two, halfway between the vulva and the anus. The uteri run anterior and go over into the oviducts near the middle of

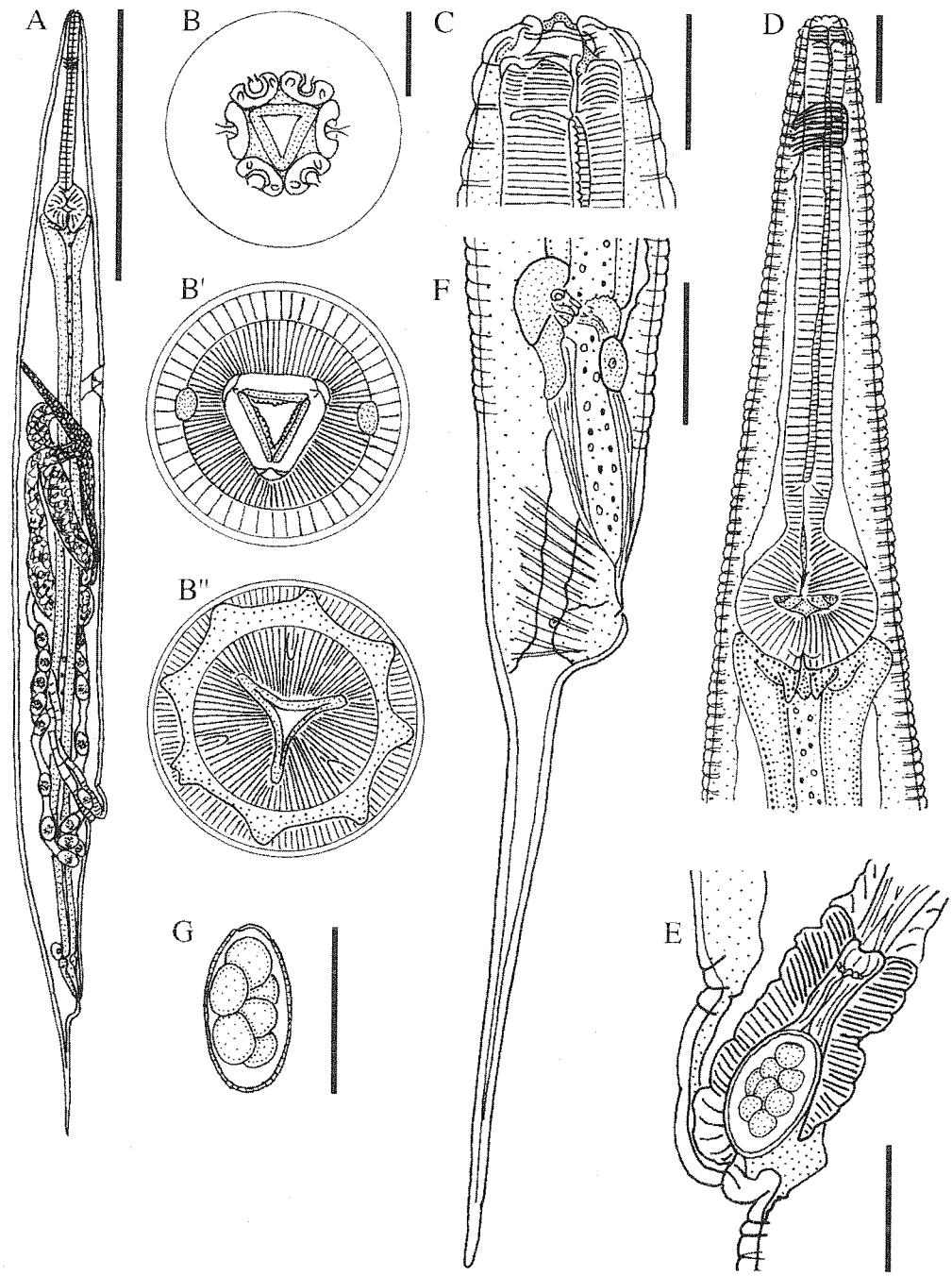

FIG. 10 Female type D

A Lateral view of the entire nematode
B Apical view of the head
B'–B" Transverse sections of the anterior part, 0.011 and 0.024 mm from the apex respectively
C Median view of the head
D Lateral view of the anterior region
E Lateral view of the vulvar region. An egg is present in the ovejector
F Lateral view of the posterior end
G Egg
Scale bars: A—1 mm; D, E, F, G—0.1 mm; C—0.05 mm; B, B', B"—0.02 mm

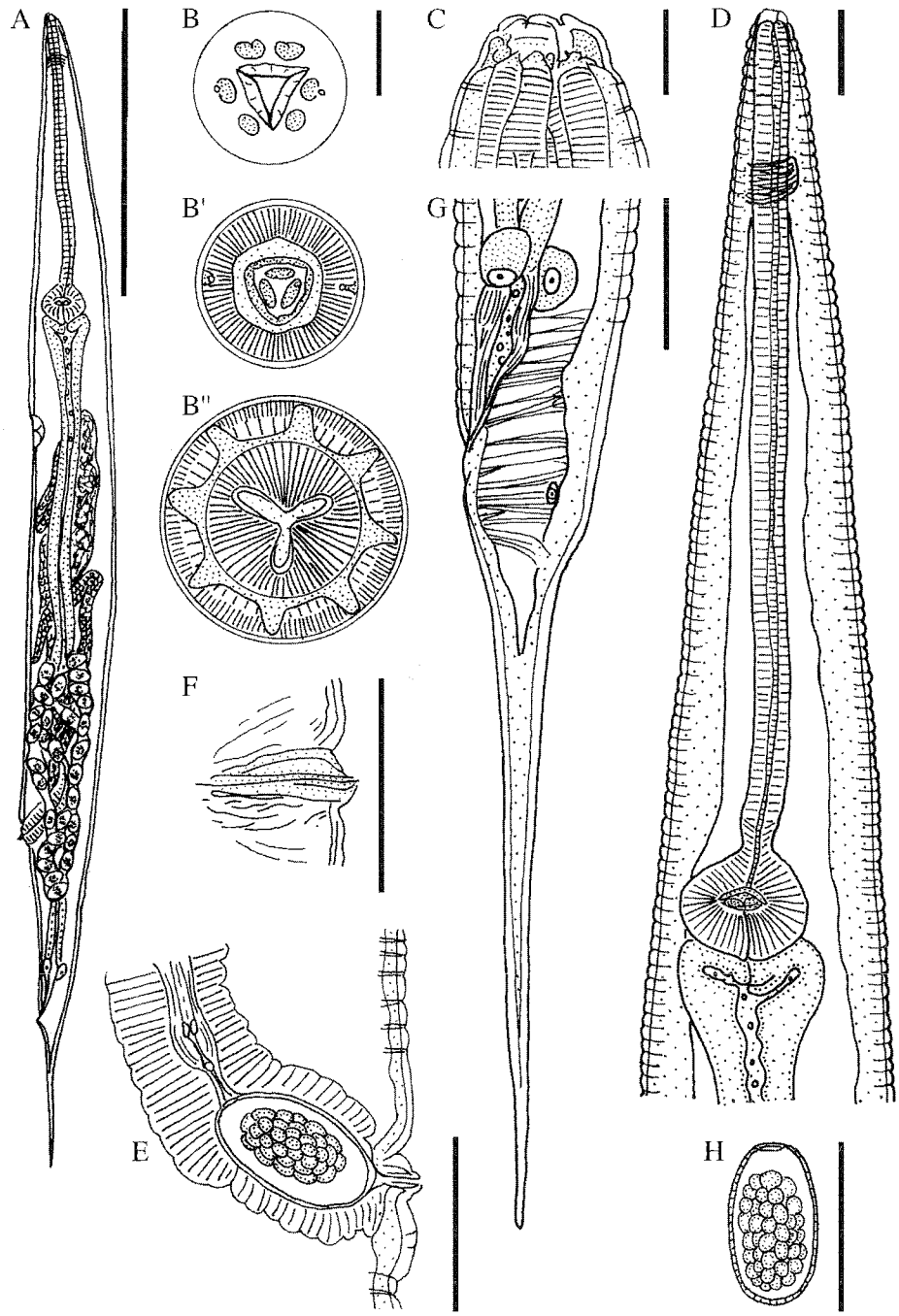

FIG. 11 Female type E

- A Lateral view of the entire nematode
- B Apical view of the head
- B'–B" Transverse sections of the anterior part, 0.012 and 0.034 mm from the apex respectively
- C Median view of the head
- D Lateral view of the anterior region
- E Lateral view of the vulvar region. An egg is present in the ovejector
- F Lateral view of the vulva
- G Lateral view of the posterior end
- H Egg

Scale bars: A—1 mm; D, E, F, G, H—0.1 mm; B, B', B", C—0.02 mm

the body. The blind ends of the ovaries terminate near the excretory pore. Eggs measure 0.095 x 0.054, are thin- shelled, have a terminal operculum and are deposited in early stage of cleavage. The tail is thin and 0.52 (0.52–0.59) long.

HOST LOCALITY

Timbavati Private Game Reserve (24°24'56.5"S; 31°17'50.8"E), Northern Province, Republic of South Africa.

TYPE MATERIAL

Twenty females are deposited in the collection of the Museum National d'Histoire Naturelle, Paris, France, access number 293HS.

HABITAT

Stomach and large intestine.

FEMALE (TYPE F) ($n = 5$) (Fig. 12)

Stout nematodes, dorsally curved when fixed, 4.38 (2.86–4.38) long and 0.51 (0.25–0.51) wide at mid-body. The cephalic extremity is flattened and lips are absent. The triangular mouth opening is guarded by one dorsal and two thin subventral membranous cuticular flaps, the latter with fringed outer edges that project into the buccal cavity from the anterior end of the buccal capsule. The mouth opening is surrounded by six bean-shaped cuticular elevations, the two lateral ones bearing prominent amphids, the two ventral and two dorsal ones each with a cephalic papilla.

The oesophagus is 0.77 (0.51–0.77) long, nearly as wide as the bulbus. The isthmus is 0.48 (0.30–0.48) from the anterior end and the bulbus is 0.17 (0.10–0.17) long and 0.15 (0.11–0.15) wide. The intestine at the oesophago-intestinal junction is narrower than the bulbus. The nerve ring is 0.17 (0.15–0.18) from the anterior end, the prominent excretory pore 1.24 (0.80–1.24) and the vulva 2.98 (1.51–2.98), at the beginning of posterior third of the body.

A prominent pre-vulvar swelling is present and the short muscular ovejector has a distinct sphincter. The vagina is coiled, running anteriorly, joining the common uterus which turns posteriorly and divides into two uteri near the anus. The uteri run anteriorly, forming the oviducts near the mid-body. The blind ends of the ovaries both terminate near the excretory pore. Eggs are elongated, 0.129 long by 0.064 wide, thin shelled, and the terminal operculum is indistinct. Eggs are laid in an early stage of cleavage. The tail, tapering towards the posterior end, is slightly bent dorsally and is 0.33 (0.26–0.45) long.

HOST LOCALITY

Timbavati Private Game Reserve (24°0.5'51.4"S; 31°0.7'18.1"E), Northern Province, Republic of South Africa.

TYPE MATERIAL

Twenty females are deposited in the collection of the Museum National d'Histoire Naturelle, Paris, France, access number 294HS.

HABITAT

Stomach and large intestine.

Discussion

Contrary to the observations of Adamson & Nasher (1984), males and females *in copula* were not observed in this study. Furthermore, the key to the identification of the genera *Tachygonetria* and *Thelandros* (Petter & Quentin, 1976) is based on only the males and it was therefore impossible to identify the females with certainty to the species, or even the genus, level. Therefore the species were provisionally paired taking into consideration the anatomical similarities: *Tachygonetria bainae* with female Type C; *Tachygonetria chabaudi* with female Type A; *Tachygonetria petterae* with female Type D and *Thelandros schusteri*, *Thelandros boomkeri* or *Thelandros luciusi* with female Type E. Females Type B and F could not be paired. The morphological criteria employed were the length of oesophagus, the configuration of the cephalic papillae, the oesophago-intestinal junction and the length of the tail. Considering the difficulties with the identifications the pairings listed above should be treated with reserve

Since the Type E female could be paired to either *Thelandros schusteri*, *Thelandros boomkeri* or *Thelandros luciusi*, the possibility of male di- or polymorphism should also be considered (Jones 1992). Ainsworth (1990) originally described male dimorphism in two *Skrjabinodon* species (Pharyngodonidae) from New Zealand lizards. Furthermore, male polymorphism also occurs in the trichostrongylid subfamily Ostertagiinae (Lancaster & Hong 1981; Lichtenfels, Pilitt & Lancaster 1988; Andrews & Beveridge 1990; Stevenson, Gasser & Chilton 1996). However, whether male dimorphism does occur in the genus *Thelandros* is not clear. Because

of the morphological differences between them, and until further studies prove the contrary, *Thelanddros schusteri*, *Thelandros boomkeri* and *Thelandros luciusi* should remain valid species.

The Pharyngodonidae seem to have evolved in two distinct lines, the one parasitic in insectivorous reptiles and the other in herbivorous ones (Petter 1966; Petter & Quentin 1976; Adamson 1981; Adamson

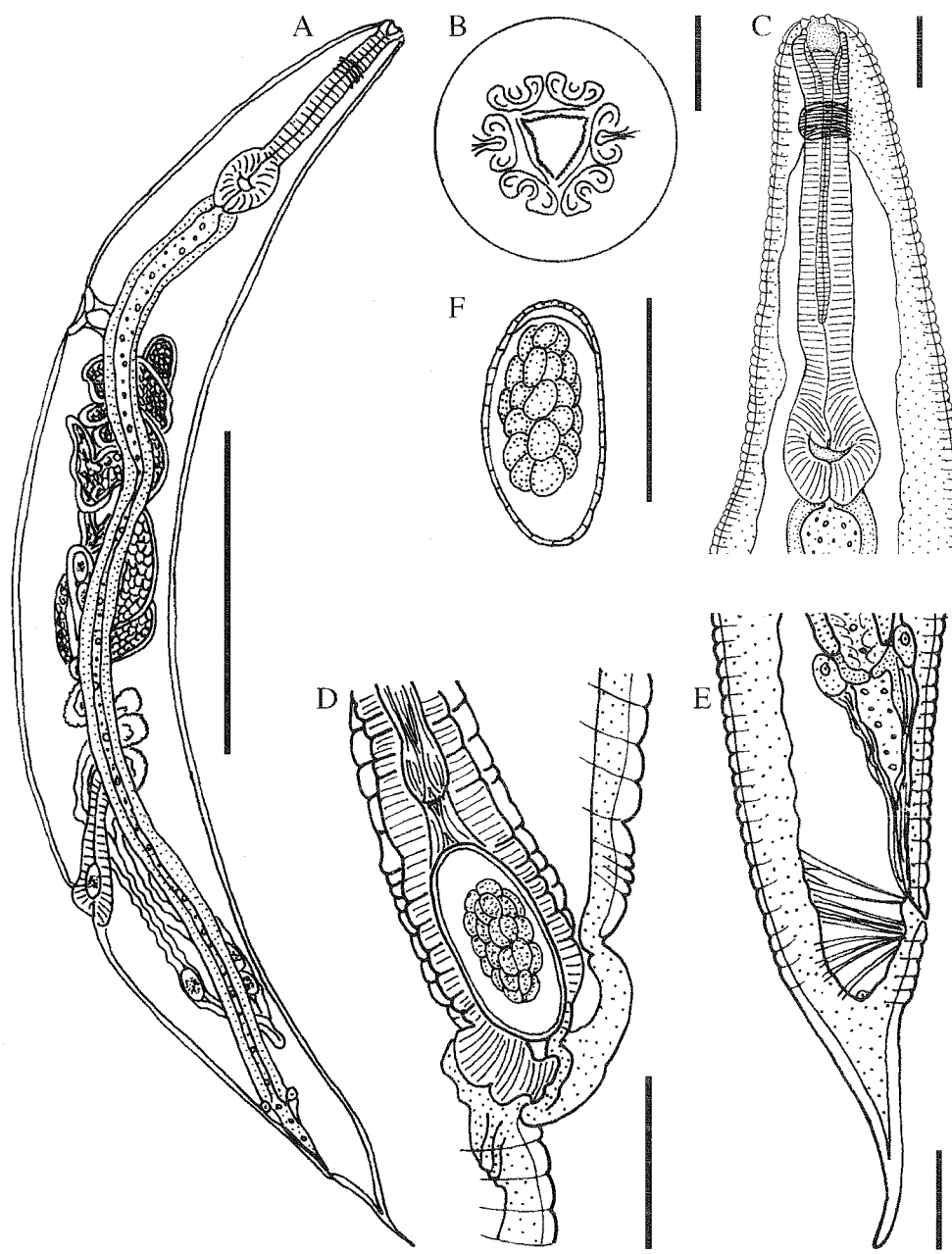

FIG. 12 Female type F

A Lateral view of the entire nematode
B Apical view of the head
C Lateral view of the anterior region
D Lateral view of the vulvar region. An egg is present in the ovejector
E Lateral view of the posterior end
F Egg

Scale bars: A—1 mm; C, D, E, F—0.1 mm; B—0.02 mm

& Nasher 1984). Adamson & Nasher (1984) emphasized that most of the radiation of the Pharyngodonidae of herbivorous reptiles probably took place in tortoises, which presumably have largely been herbivorous since their origin in the early and middle Eocene. Lizards are essentially insectivorous and a lineage of herbivorous lizards does not exist. Herbivorous and omnivorous feeding have only recently appeared in a number of isolated species. This is the case with *G. validus validus* which, unlike most other South African lizards, is omnivorous.

The richness and composition of the pharyngodonid fauna of *G. validus validus* is close to that of tortoises (Petter 1966). It differs from the pharyngodonid fauna of the insectivorous lizards that have been studied in which only the genera *Spauligodon*, *Skrjabinodon* and *Parapharyngodon* were recovered (Hering-Hagenbeck *et al.* 2002). The pharyngodonid fauna of *G. validus validus* seems to have originated by capture from local herbivorous reptiles. The three *Tachygonetria* spp. most closely resemble forms in South African tortoises (Petter, 1966). The three *Thelandros* spp. not only show strong similarities to those of herbivorous *Agama* spp. (Adamson & Nasher 1984), but also to those parasitic in tortoises and could have been acquired from either.

ACKNOWLEDGEMENTS

We thank the following persons and institutions, without whose assistance this study would not have been possible: Messrs P. Leitner and S. Dell (Molopo Nature Reserve), P. du Toit (†) (Delftzyl Government farm), J. Theron and J. Coetzee (Blyde River Canyon Nature Reserve), C. Rowles (Klaserie Private Game Reserve), B. Harris and Dr S. Joubert (Timbavati Private Game Reserve), Major P. Oosthuizen (Hoedspruit Nature reserve) and Dr D.W. Verwoerd (the farm "Kaalplaas"). The Conservation Authorities of the Gauteng, Mpumalanga, Nortwest and Northern Provinces are thanked for their assistance in obtaining the material, as are the staff of Kings Camp and Buffalo Lodge. Dr W. Haacke of the Transvaal Museum of Natural History and R. Newbery provided much assistance and herpetological advice. This study was funded by the Arthur & Aenne Feindt Stiftung, Hamburg, Germany.

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Onderstepoort Journal of Veterinary Research, 73:111–114 (2006)

Gastric nematodes of Nile crocodiles, *Crocodylus niloticus* Laurenti, 1768, in the Okavango River, Botswana

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ABSTRACT

JUNKER, K., WALLACE, K., LESLIE, A.J. & BOOMKER, J. 2006. Gastric nematodes of Nile crocodiles, *Crocodylus niloticus* Laurenti, 1768, from the Okavango River, Botswana. *Onderstepoort Journal of Veterinary Research*, 73:111–114

The ascaridoid nematodes *Dujardinascaris madagascariensis* Chabaud & Caballero, 1966, *Dujardinascaris dujardini* (Travassos, 1920), *Gedoelstascaris vandenbrandeni* (Baylis, 1929) Sprent, 1978 and *Multicaecum agile* (Wedl, 1861) Baylis, 1923 were recovered from the stomach contents of *Crocodylus niloticus* Laurenti, 1768 from the Okavango River, Botswana, together with *Eustrongylides* sp., a dioctophymatoid nematode usually parasitizing piscivorous birds. *Dujardinascaris madagascariensis* was present in most of the infected hosts, while the remaining species were mostly represented in single collections in one to three hosts. All four ascaridoid nematodes represent new geographic records.

Keywords: Ascaridoidea, crocodilians, *Crocodylus niloticus*, nematodes, Nile crocodiles

INTRODUCTION

A number of gastrointestinal nematodes from crocodilian hosts have been reported in the literature (Baker 1983). Amongst these the ascaridoid nematodes belonging to the subfamily Heterocheilinae and Anisakinae are some of the most prominent species (Sprent 1977, 1978, 1979a, b).

Eight of the 11 genera are included in the subfamily Heterocheilinae parasitize crocodilians, namely *Brevimulticaecum* Mozgovoy, in Skrjabin, Shikhobalova & Mozgovoy, 1952, *Dujardinascaris* Baylis, 1947, *Gedoelstascaris* Sprent, 1978, *Hartwichia* Chabaud & Bain, 1966, *Multicaecum* Baylis, 1923, *Ortleppascaris* Sprent, 1978, *Trispiculascaris* Skrjabin, 1916 and *Typhlophorus* Von Linstow, 1906 (Sprent 1983). The genus *Terranova* Leiper & Atkinson, 1914 is included in the subfamily Anisakinae (Sprent 1979a).

The genera *Hartwichia* and *Trispiculascaris* have as yet only been recorded from the African continent, while *Brevimulticaecum* occurs in South and North American crocodilians, and *Typhlophorus* seems exclusive to India. *Gedoelstascaris* and *Multicaecum* have both been found in Africa and Australasia, whereas *Ortleppascaris* is known from African as well as South and North American hosts.

To date, *Terranova* and *Dujardinascaris* are the only ascaridoid genera occurring throughout the entire range of the crocodilians' geographic distribution, with representatives in the Neotropics, Africa and Australasia (Sprent 1977, 1978, 1979a, b, 1983). Even genera with a wide geographic distribution are generally characterized by strict species separation with respect to the various geographic areas. *Multi-*

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Accepted for publication 16 March 2006—Editor

caecum agile (Wedl, 1861) Baylis, 1923 and *Terranova crocodilii* (Taylor, 1924) Hartwich, 1957, in fact, are the only two species that have been listed from Africa as well as Australia.

In this paper we report on some nematodes recovered from the stomach contents of Nile crocodiles, *Crocodylus niloticus* Laurenti, 1768, in Botswana.

MATERIAL AND METHODS

During August 2003 to August 2005 a study was conducted by one of us (K. Wallace) on the composition of the diet of Nile crocodiles from the Okavango River, Botswana. The stomach contents of the crocodiles were pumped into separate containers and macroscopically examined. Nematodes present in these contents were collected and fixed in 70% ethanol. They were subsequently cleared in lactophenol and identified using the descriptions of the authors listed below. Nematodes were recovered from 57 crocodiles.

The results compiled herein are not based on a complete collection of the helminth parasites, for which the hosts would have had to be sacrificed, but represent incidental findings from the stomach contents of the various crocodile hosts.

RESULTS

The ascaridoids *Dujardinascaris madagascariensis* Chabaud & Caballero, 1966, *Dujardinascaris dujardini* (Travassos, 1920), *M. agile* and *Gedoelstascaris vandenbrandeni* (Baylis, 1929) Sprent, 1978 were recovered from the crocodiles. One male and one female specimen of the dioctophymatoid genus *Eustrongylides* Jägerskiöld, 1909 were present in a single host.

Helminth diversity was low in the Nile crocodiles examined, with the genus *Dujardinascaris* being the most commonly encountered. *Dujardinascaris madagascariensis* was recovered from most of the infected hosts, while the remaining species, *D. dujardini*, *G. vandenbrandeni* and *M. agile*, only occurred in a few (1–3) of the crocodiles.

The majority of the crocodiles (46) were only parasitized by one ascaridoid species, usually *Dujardinascaris madagascariensis*. Two of the ascaridoid species were present at the same time in only six hosts. Multiple infections with more than two species per host were not encountered.

DISCUSSION

While it is difficult to distinguish between some of the females of the various *Dujardinascaris* spp., *D. madagascariensis* is distinct from the other four African species in that the vagina opens through a distinct papilla between the lips of the vulva. In some of our specimens remains of copulatory cement could still be observed on the papilla. The majority of the male specimens were assigned to *D. madagascariensis* on the basis of the length of their spicules. The spicules of *D. dujardini* are distinctly longer than those of *D. madagascariensis*, whereas the spicules of both *Dujardinascaris gedoelsti* Sprent, 1977 and *Dujardinascaris puylaerti* Sprent, 1977 are considerably shorter (Sprent 1977). *Dujardinascaris petterae* Sprent, McKeown & Cremin, 1998 has short, unequal spicules (Sprent, McKeown & Cremin 1998). A single male specimen possessed the typical trifurcate gubernaculum of *D. dujardini* and a single female with a sinuous vagina, but without a vaginal papilla was assigned to the same species.

All the parasites reported in this study have previously been reported from crocodiles.

Dujardinascaris dujardini has been recorded from *C. niloticus* and *Crocodylus cataphractus* from Africa, as well as from *Crocodylus porosus* in India (Yamaguti 1961). Sprent (1977) lists “crocodile” as its type host and the Nile crocodile as additional host from Zambia and the Democratic Republic of the Congo. More recently, *D. dujardini* was reported from *C. niloticus* from Egypt (El-Dien Mahmoud 1999). *Dujardinasceris madagascariensis* is listed from *C. niloticus* and *C. cataphractus* in Madagascar, Angola and the Democratic Republic of the Congo (Sprent 1977). However, the recovery of *D. dujardini* and *D. madagascariensis* from crocodiles in Botswana represents a new geographic record for these parasites.

Three additional representatives of the genus *Dujardinascaris* have been reported from the African continent. Sprent *et al*. (1998) described *D. petterae* from *Osteolaemus tetraspis* in the Congo. *Dujardinascaris gedoelsti* Sprent, 1977 and *D. puylaerti* Sprent, 1977 were collected from *C. niloticus* in the Republic of the Congo (Sprent 1977). The latter species was also present in Zambia (Sprent 1977). None of the above three species was recovered from crocodiles in Botswana.

Gedoelstascaris vandenbrandeni is one of two species that Sprent (1978) removed from the genus *Dujardinascaris* and placed in a new genus, namely *Gedoelstascaris*. *Gedoelstascaris vandenbrandeni*

occurs only in African crocodiles and has been recorded from *C. niloticus* and *C. cataphractus* in Angola, Zambia and the Democratic Republic of the Congo. Its Australian counterpart, *Gedoelstascaris australiensis* (Baylis 1931) Sprent, 1978, parasitizes *Crocodylus johnstoni* and *C. porosus* and has been found in hosts from Australia as well as the Solomon Islands (Sprent 1978). There are no previous records of *G. vandenbrandeni* in Botswana.

Of the four ascaridoid nematodes found in this study, *M. agile* is the only one with a geographic distribution extending beyond the African continent and utilizing hosts other than African crocodilians. Its type host is *C. niloticus* from Egypt, but it has also been recovered from *C. cataphractus* and was recorded from the Republic of the Congo, Zambia and Zimbabwe. Hosts from the Australasian region are *C. palustris*, *C. johnstoni* and *Gavialis gangeticus*. India and Australia are listed as localities (Sprent 1979b). Botswana constitutes a new geographic record for *M. agile*.

Literature regarding the prevalence and intensity of gastric nematode infections in crocodiles and alligators is scant and the data on both are somewhat variable (Cherry & Ager 1982; Ladds & Sims 1990; Goldberg, Bursey & Aquino-Shuster 1991). The latter might be explained by the fact that not many concise studies regarding the gastric nematode fauna of crocodilians have been conducted and findings often represent the data from few or single hosts.

Ladds & Sims (1990) report a prevalence of 41% for *Dujardinascaris mawsonae* Sprent, 1977 in young crocodiles belonging to two species, *C. porosus* and *Crocodylus novaeguineae*, in Papua New Guinea. The range of intensity of infection is given as 1–20, but as many as 60 and 100 worms were recovered from two crocodiles in good condition. Histological examination of the gastric wall revealed the presence of *Capillaria* sp. in 60% of the hosts.

Dujardinascaris waltoni Sprent, 1977 was the only nematode parasite present in *Alligator mississippiensis* in South Florida. It was collected from 93% of the hosts and the mean intensity of infection was high (89%), with a maximum burden of 413 specimens per alligator (Cherry & Ager 1982).

Contrary to our findings, *Dujardinascaris* was the least prevalent ascaridoid genus in *Caiman yacare* in Paraguay, but was nevertheless the one with the highest mean intensity of infection. *Brevimulticaecum baylisi* Travassos, 1933 had the highest prevalence followed by *Ortleppascaris alata* Baylis, 1947 (Goldberg *et al.* 1991). The genus *Brevimulticaecum* is exclusive to caimans and alligators in the New World (Sprent 1979). The genus *Ortleppascaris* is represented in Africa by a single species, *Ortleppascaris nigra* Gedoelst, 1916 from *C. niloticus* and *C. cataphractus* (Sprent 1978), but was not present in the crocodiles in Botswana.

No clear picture regarding the occurrence of multiple infections with ascaridoid nematodes emerges from the literature. Some authors report single species infections (Cherry & Ager 1982; Ladds & Sims 1990), while others list three or four species, without, however, specifying how many of these were recovered per individual host (Goldberg *et al.* 1991; Scott, Simcik & Craig 1997). Scott *et al.* (1997) examined the helminth fauna of 50 American alligators and came to the conclusion that the infracommunity structure was “depauperate when compared to homoiothermic hosts”, a statement which complies with the well documented fact that the helminth diversity of reptiles, in general, is less pronounced than that of mammalian and avian hosts (Hering-Hagenbeck & Boomker 2000).

With the exception of *Eustrongylides* sp., all the parasites were collected from their typical predilection site in the host, but *D. dujardini*, *D. gedoelsti* and *G. vandenbrandeni* have also been reported from the intestine (Sprent 1977; Sprent *et al.* 1998). The genus *Eustrongylides* occurs in the wall of the proventriculus of its piscivorous avian final hosts and utilizes fish as intermediate hosts (Measures 1987).

Little is known about the life-cycle of any of the parasites found during this study, but fishes seem to play an important role as intermediate hosts of all the species (Sprent 1977, 1978, 1979a, b). Studies on the stomach contents of Nile crocodiles reveal a significant change in their feeding habits as the individuals grow larger. Despite this ontogenetic food-shift, fish remain one of the most important dietary items throughout the crocodiles’ lifespan. Fish were found in the stomachs of 60% of crocodiles ranging from 2.5–3.0 m in total length, and fish were still recovered from nearly 40% of specimens >4.5 m, (Ross 1989; Alderton 1992). As one of the main prey items, fish would appear to be the intermediate host of choice to ensure the successful completion of the life-cycle of these gastric nematodes.

ACKNOWLEDGEMENTS

This study was made possible by a grant to A.J. Leslie by the National Research Foundation and the

Earthwatch Institute, USA. We thank the Department of Wildlife and National Parks, Botswana and the Ministry of Environment, Wildlife and Tourism, Botswana. Our thanks also go to Pertec International and the entire Okavango Crocodile Project field team.

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Onderstepoort Journal of Veterinary Research, 73:315–317 (2006)

RESEARCH COMMUNICATION

Eustrongylides sp. (Nematoda: Dioctophymatoidea) from the stomach of a Nile crocodile, *Crocodylus niloticus* Laurenti, 1768, in Botswana

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ABSTRACT

JUNKER, K., BAIN, O. & BOOMKER, J. 2006 *Eustrongylides* sp. (Nematoda: Dioctophymatoidea) from the stomach of a Nile crocodile, *Crocodylus niloticus* Laurenti, 1768, in Botswana. *Onderstepoort Journal of Veterinary Research*, 73:315–317

During a study conducted between 2003 and 2005 on the diet of Nile crocodiles in Botswana, two young adult nematodes, one male and one female, belonging to the genus *Eustrongylides* Jägerskiöld, 1909 were recovered from the stomach contents of one of these animals. The caudal bursa of the male is present and the ejaculatory duct could be identified, but the spicule could not be seen. The vulva of the female has opened and the anus is situated on a terminal protruberance. Measurements and drawings of these specimens are provided, together with some data on the occurrence and life-cycles of members of the genus *Eustrongylides* in crocodilians world-wide and in African hosts in particular. Piscivorous birds are the usual final hosts of these nematodes. It is probable that the specimens described herein had developed in a paratenic fish host, and that the latter had been eaten by the crocodile.

Keywords: Botswana, *Crocodylus niloticus*, *Eustrongylides* sp., Nile crocodile???

During a study conducted between 2003 and 2005 on the composition of the diet of Nile crocodiles, *Crocodylus niloticus* Laurenti, 1768, in Botswana, nematode parasites were collected from their stomach contents and identified (Junker, Wallace, Leslie & Boomker 2006). Two large young adult specimens of the genus *Eustrongylides* Jägerskiöld, 1909, one male and one female, were recovered from a single crocodile only (Fig. 1).

The male is 110 mm long, 650 µm wide; posterior part with subterminal constriction; ventral precloacal sucker; caudal bursa with peripheral cuticular ornamentation, similar to that described for the genus (Karmanova 1968; Measures 1988a); ejaculatory duct identified but not the spicule.

The female is 122 mm long, 1 000 µm wide; vulva opened, close to anus; anus on a flattened terminal protruberance, which is 35 µm high.

The specimens are deposited at the Muséum National d'Histoire Naturelle Paris, Access number 169 JW.

This is a somewhat unusual finding since the genus *Eustrongylides* usually occurs in the wall of the proventriculus of its piscivorous avian final hosts and utilizes oligochaetes as intermediate hosts, in which it reaches the third larval stage (Anderson 2001). Fish subsequently serve as paratenic hosts in which the parasites reach the fourth stage and continue to grow. At this stage the reproductive system is highly developed (Measures 1988b; Anderson 2000). Coy-

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Accepted for publication 18 May 2006—Editor

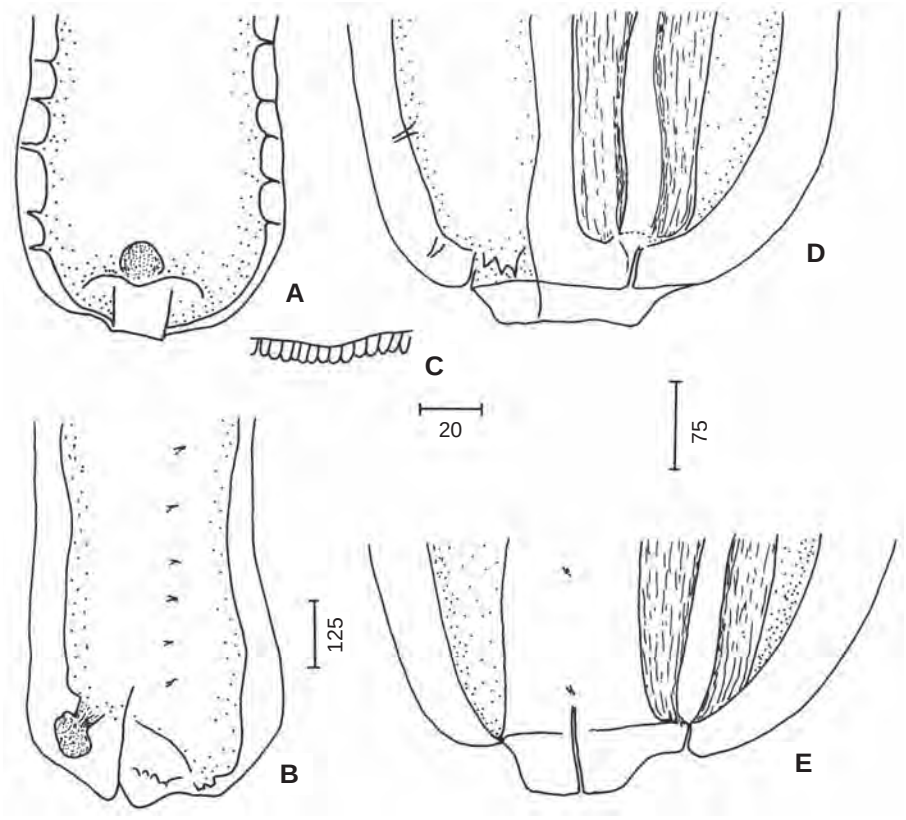

FIG. 1 *Eustrongylides* sp.. Caudal extremities of immature adults. A–C Male. A: Ventral view. B: Left lateral view. C: Internal peripheral ornamentation of the caudal sucker. D–E Female. D: Subventral view. E: Right lateral view. Note that the anus is situated on a terminal protruberance. Scales in µm: A, B = 125; C = 20; D, E = 75

ner, Spalding & Forrester (2002) found that fish could serve as intermediate as well as paratenic hosts for *Eustrongylides ignotus* Jägerskiöld, 1909.

Only a few publications refer to *Eustrongylides* sp. from crocodilian hosts. Ladds & Sims (1990) found immature *Eustrongylides* sp., 30–35 mm in length, free in the abdomen of two of 54 crocodiles in Papua New Guinea and Goldberg, Bursey & Aquino-Shuster (1991) report *Eustrongylides* sp. from the stomach contents of three of 115 wild-caught *Caiman yacare* (Daudin, 1802) in Paraguay. However, they could not determine whether the specimens of *Eustrongylides* they collected were recently released from intermediate host cysts and were likely to die, or whether they may have survived, with *C. yacare* becoming a paratenic host.

Similarly, our data is insufficient to decide whether the presence of *Eustrongylides* sp. in the stomach of the crocodile is accidental or represents an unusual life-cycle. Without the benefit of further life-cycle studies, it would appear as if the crocodile had ingested an infected fish and that the parasites were released from their host during the digestive process or had actively started migrating upon the death of their host. Considering that the specimens were adults, albeit immature, one could also speculate that the crocodile had ingested an infected waterbird. However, no remains of feathers were found in the stomach contents of the crocodile (Kevin Wallace, personal communication **date?**).

A substantial portion of the diet of Nile crocodiles, ranging from very small to large in size, is made up of fish, with aquatic birds also forming part of their diet (Ross 1989; Alderton 1999). It is thus not too surprising to find fish or bird parasites in a crocodile's stomach.

Little information is available on the prevalence of *Eustrongylides* in African paratenic as well as final hosts, and despite Measures' (1988a) revision of the genus, many taxonomic problems remain unsolved. She only confirmed three species, namely *Eustrongylides tubifex* (Nitzsch in Rudolphi, 1819) Jägerskiöld, 1909, *Eustrongylides excisus* Jägerskiöld, 1909 and

E. ignotus and declared nine species as *species inquirendae*.

A 26.5% prevalence of larvae of *Eustrongylides africanus* Jägerskiöld, 1909, one of the species considered doubtful by Measures (1988a), and which is only known by the female, has been reported in catfish, *Clarias gariepinus* (Burchell, 1822) as well as *Clarias anguillaris* (Linnaeus, 1758), from the Bida floodplain of Nigeria (Ibiwoye, Balogun, Ogunsusi & Agbontale 2004). The latter authors indicate that fish can serve as intermediate, reservoir and as final hosts.

Eustrongylides africanus has also been recorded as part of the parasite fauna of two of six marabou storks, *Leptoptilus crumeniferus* (Lesson, 1831), in Uganda (Moriearty, Pomeroy & Wanjala 1972) as well as in *Ardea goliath* Cretzschmar, 1829, *Pelecanus rufescens* Gmelin, 1789, and *Anhinga melanogaster* (Daudin, 1802) in the Sudan (Measures 1988a).

Eustrongylides sp. has been recovered from fish at Lake Tana, Ethiopia (Eshetu & Enyew 2003). Asanji (1990) examined 2576 *C. gariepinus* in Cameroon and found an overall prevalence of infection of 68.9%. The latter author reports that cysts containing various larval stages were present in the muscles and visceral organs.

While the above indicates that *Eustrongylides* sp. is indeed quite common and wide-spread on the African continent, it equally emphasizes the paucity of data available on this parasite in Africa. It is to be hoped that an effort will be made to rectify this and to clarify the uncertain systematic status of, amongst others, *E. africanus*.

ACKNOWLEDGEMENTS

The senior author is supported by a Claude Leon Foundation Post Doctoral Fellowship grant.

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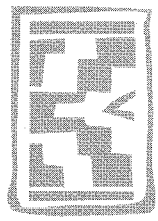

A check-list of the nematode parasites of South African Serpentes (snakes) and Sauria (lizards)

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ABSTRACT

HERING-HAGENBECK, S.F.B.N. & BOOMKER, J. 2000. A check-list on the nematode parasites of South African Serpentes (snakes) and Sauria (lizards). *Onderstepoort Journal of Veterinary Research*, 67:1–13

Published records, in combination with own data have been brought together to provide data on parasite/host relationships of reptiles that occur in the Republic of South Africa.

A total of 62 nematode species belonging to 23 genera and 11 families are recorded from 20 snake and 21 lizard species. The genera *Kalicephalus, Spauligodon, Ophidascaris* and *Abbreviata* are especially well represented with between five and eight species per genus. The most nematode species were recorded from the flap-neck chameleon, *Chamaeleo dilepis* (eight), the puff-adder, *Bitis arietans* (eight) and the water monitor, *Varanus niloticus* (seven). All synonyms of parasites and hosts are given.

Keywords: Lizards, nematodes, reptiles, snakes, South Africa

INTRODUCTION

More than 400 species of reptiles occur in South Africa in biomes that vary from the Western Cape macchia to the grasslands of the Free State, the mountainous highlands of KwaZulu-Natal and the arid regions of the Northern Cape. Their helminth parasites, however, have attracted little attention and few records exist in the literature. Those that do exist are mostly of a taxonomic nature and only a single one deals with a survey.

The aim of this check-list is to provide a source of reference to the original records of the nematodes of reptiles occurring in South Africa.

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Accepted for publication 6 December 1999—Editor

Synonyms of the nematodes and their host species are provided. Only adult worms have been included and doubtful records or host identifications are indicated by a question mark (?). Records from reptiles that also have a distribution outside South Africa are included in this list.

We have partly followed Round's (1968) and Khalil & Polling's (1997) format and thus present the check-list in two parts. In the first part, the parasites are listed under their scientific names together with the synonyms and authorities, and the host and country from which the parasite was reported.

In the second part, the hosts are listed, together with their synonyms and their parasites, the latter in alphabetical order.

The system of classification of the nematodes conforms with the views held by Anderson, Chabaud & Willmott (1974–1983), while the classification and synonymies of the hosts are based on the works by Broadley (1983) and Branch (1998).

PARASITE/HOST CHECK-LIST

Nematoda

Family RHABDIASIDAE Railliet, 1915

GENUS *RHABDIAS* STILES & HASSALL, 1905

1. *Rhabdias fuscovenosa* (Railliet, 1899) Goodey, 1924

   Ascaris humilis Leidy, 1856; *Strongylus catanensis* Rizzo, 1902; *Rhabdias ophida* Goodey, 1924; *Rhabdias vellardi* Pereira *sensu* Harwood, 1932; *Rhabdias annulosa* Hsu, 1933

   Bitis arietans
   Fantham & Porter (1950), South Africa

   Hemachatus haemachatus
   Fantham & Porter (1950), South Africa

   Naja nivea
   Fantham & Porter (1950), South Africa

Family DIAPHANOCEPHALIDAE Travassos, 1920

GENUS *KALICEPHALUS* MOLIN, 1861

Subgenus *Kalicephalus* (*Variabiliformis*) Lichtenfels, 1980

1. *Kalicephalus colubri colubri* (Ortlepp, 1923) Lichtenfels, 1980

   Kalicephalus minutus Boulenger, 1926; *Kalicephalus minutus* Fantham & Porter, 1950; *Kalicephalus obliquus* Schuurmans Stekhoven, 1937

   Bitis arietans
   Peirce (1984), Zambia
   Schad (1962), Congo

   Naja melanoleuca
   Schad (1962), West Africa

   Peudoaspis cana
   Schad (1962), Kenya

2. *Kalicephalus paracolubri paracolubri* Ghadirian, 1968

   Naja melanonleuca
   Ghadirian (1968), Central African Republic

3. *Kalicephalus vipera obliquus* (Daubney, 1923)

   Diaphanocephalus obliquus Daubney, 1923; *Kalicephalus obliquus* Ortlepp, 1923; *Kalicephalus bitisi* Campana-Rouget & Chabaud, 1950

   Bitis arietans
   Daubney (1923), Africa
   Fantham & Porter (1950), South Africa

   Bitis gabonica
   Campana-Rouget & Chabaud (1950), Ivory Coast
   Ortlepp (1923); Fantham & Porter (1950), South Africa

   Causus rhombeatus
   Daubney (1923), Africa
   Fantham & Porter (1950), South Africa

   Psammophylax tritaeniatus
   Fantham & Porter (1950), South Africa

Subgenus *Kalicephalus* (*Schadius*) Lichtenfels, 1980

4. *Kalicephalus costatus micrurus* (Daubney, 1923) Schad, 1962

   Diaphanocephalus micrurus Daubney, 1923; *Kalicephalus micrurus* Yorke & Maplestone, 1926

   Crotaphopeltis hotamboeia
   This paper, South Africa
   Wahid (1961), Malawi

   Dispholidus typus
   Schad (1962), London Zoo

   Macrelaps microlepidotus
   Daubney (1923); Baylis (1929), South Africa

5. *Kalicephalus simus simus* (Daubney, 1923) Yorke & Maplestone, 1926

   Kalicephalus nigeriensis Ortlepp, 1923

   Dendroaspis angusticeps
   Fantham & Porter (1950), South Africa

   Dendroaspis polylepis
   Ortlepp (1926) in Schad (1962), Congo

   Naja melanoleuca
   Van den Berghe (1943); Schad (1962), Congo

   Naja mossambica
   Peirce (1984), Zambia
   Fantham & Porter (1950), South Africa

   Psammophis brevirostris
   Fantham & Porter (1950), South Africa

   Species inquirendae (After Schad 1962)

6. *Kalicephalus rotundatus* v. Linstow, 1908

   Pseudoaspis cana
   Von Linstow (1908), South Africa

Family PHARYNGODONIDAE Travassos, 1919

GENUS *PARAPHARYNGODON* CHATTERJI, 1933

1. *Parapharyngodon rotundatus* (Malan, 1939) Freitas, 1957

   Thelandros rotundatus Malan, 1939

Agama atra
Malan (1939); Freitas (1957), South Africa

Pseudocordylus microlepidotus
Malan (1939); Freitas (1957), South Africa

GENUS *PHARYNGODON* DIESING, 1861

Neopharyngodon Chakravarty & Bhaduri, 1948

1. *Pharyngodon* sp.

Agama aculeata aculeata
Heideman (1995), Namibia

GENUS *SPAULIGODON* SKRJABIN, SCHIKHOBALOVA & LAGODOVSKAJA, 1960

1. *Spauligodon auziensis* (Seurat, 1917) Skrjabin *et al.*, 1960

Hemidactylus mabouia
Moravec *et al.* (1987), Egypt

2. *Spauligodon morgani* (Fitzsimmons, 1961) Barus & Coy Otero, 1974

Pharyngodon morgani Fitzsimmons, 1961

Hemidactylus mabouia
Simonsen & Sarda (1985), Tanzania

Mabuya quinquetaeniata
Simbotwe (1979), Zambia

Mabuya striata
Fitzsimmons (1961), Malawi
Simbotwe (1979), Zambia

3. *Spauligodon petersi* Bursey, McAllister & Freed, 1997

Mabuya sulcata sulcata
Bursey *et al.* (1997), South Africa

4. *Spauligodon smithi* Bursey, McAllister & Freed, 1997

Pachydactylus bibronii
Bursey *et al.* (1997), South Africa

5. *Spauligodon timbavatiensis* Hering-Hagenbeck & Boomker, 1998

Pachydactylus turneri
Hering-Hagenbeck & Boomker (1998), South Africa

6. *Spauligodon vojteki* Moravec, Barus & Rysavy, 1987

Mabuya quinquetaeniata
Moravec *et al.* (1987), Egypt

GENUS *THELANDROS* WEDL, 1862

Avilandros Skrjabin, Schikhobalova & Mozgovoi, 1951

1. *Thelandros alatus* Wedl, 1862

Oxyuris uromasticola Galeb, 1889; *Thelandros micruris* Rauther, 1918; *Thelandros sahariensis* Baylis, 1930; *Thelandros avis* Maplestone, 1940

Agama mossambica
Myers *et al.* (1960), Sudan

GENUS *SKRJABINODON* INGLIS, 1968

1. *Skrjabinodon dossae* (Caballero, 1968) Schmidt & Kuntz, 1972

Hemidactylus mabouia
Schmidt & Kuntz (1972), Madagascar

2. *Skrjabinodon mabuyae* (Sandground, 1936) Inglis, 1968

Mabuya varia
Baker (1987), Uganda

3. *Skrjabinodon mabuiensis* (Malan, 1939) Inglis, 1968

Pharyngodon mabuiensis Malan, 1939

Mabuya striata
Malan (1939), South Africa

Family COSMOCERCIDAE Travassos, 1925

Subfamily Cosmocercinae Railliet, 1916

GENUS *APLECTANA* RAILLIET & HENRY, 1916

1. *Aplectana macintoshii* (Stewart, 1914) Travassos, 1931

Aplectana agubernaculum Gupta, 1960; *Aplectana asiatica* Gupta, 1960; *Aplectana schneideri* Travassos, 1931; *Aplectana stormi* Travassos, 1931; *Aplectana varelai* Rodrigues, Rodrigues & Cristofaro, 1972; *Ascaris commutata* Diesing, 1851 *sensu* Claparede, 1859; *Neyraplectana ranae* Wang, Zhao & Chen, 1978; *Neoraillietnema ranae* Wang, 1980; *Neoraillietnema praeputiale* Skrjabin, 1916; *Nematoxys commutatus* Rudolphi *sensu* Schneider, 1866; *Oxysomatium stomatici* Biswas & Chakravarty, 1963; *Oxysomatium longicaudata* Yuen, 1965; *Oxysomatium minutum* Rasheed, 1965; *Oxysomatium macintoshii kirtipuri* Singh, 1969; *Oxysomatium mehdii* Ilyas, 1980; *Raillietnema praeputiale* (Skrjabin, 1916) *sensu* Kozak, 1969; Deshmukh, 1970; Vojtkova, 1976

Varanus niloticus
Rasheed (1965), Cameroon

Varanus niloticus
Baker (1980), Sudan

Family HETERAKIDAE Railliet & Henry, 1912

Subfamily Spinicaudinae Travassos, 1920

GENUS *AFRICANA* TRAVASSOS, 1920

Preterakis Freitas, 1956

1. *Africana acuticeps* (Gedoelst, 1916) Travassos, 1920

   Chamaeleo dilepis
   Baylis (1937), Congo

2. *Africana africana* (Gendre, 1909) Travassos, 1920

   Varanus niloticus
   Graber (1981), Congo

GENUS *STRONGYLURIS* MUELLER, 1894

1. *Strongyluris brevicaudata* Mueller, 1894

   Agama sp.
   Cowper (1969), Nigeria

   Bradypodion pumila
   Boomker & Petter (unpublished), South Africa

   Chamaeleo dilepis
   Schmidt & Canaris (1968), Kenya
   Sand-ground (1928), Tanzania

2. *Strongyluris capensis* Pruedhoe & Harris, 1971

   Bradypodion pumila pumila
   Prudhoe & Harris (1971), South Africa

3. *Strongyluris elegans* (Gendre, 1909) Railliet & Henry, 1914

   Chamaeleo dilepis
   Gedoelst (1916), Congo

4. *Strongyluris ornata* (v. Linstow, 1897) Railliet & Henry, 1914

   Acanthocerus atricollis
   Harwood (1935), Tanzania

   Agama atra
   This paper, South Africa

Family ASCARIDIDAE Baird, 1853

GENUS *HEXAMETRA* TRAVASSOS, 1919

1. *Hexametra applanata* (v. Linstow, 1899) Sprent, 1978

   Chamaeleo dilepis
   Gedoelst (1916), Zaire

2. *Hexametra hexametra* (Gedoelst, 1916) Travassos, 1920

   Chamaeleo dilepis
   Sprent (1978), Zaire
   Baylis (1920), Congo
   Cowper (1969), Nigeria

3. *Hexametra quadricornis* (Wedl, 1861) Kreis, 1944

   Ascaris gestri Parona, 1889; *Ascaris quadrilobata* v. Linstow, 1908; *Hexametra anguinea* Wu & Hu, 1938; *Hexametra daelhlholtzlii* Kreis, 1944; *Hexametra multicornis* Mozgovoi & Romanova 1970; *Hexametra boskovi* Moravec, 1966; *Hexametra skrjabini* Markov, Bogdanov & Persianova, 1970; *Hexametra dagestanica* Markov, Khonyakina & Grigor´eva, 1972; *Ophidascaris natricis* Yamaguti, 1935; *Ophidascaris genoheteromegala* Kreis, 1938; *Ophidascaris microspicula* Kreis, 1938; *Polydelphis waterstoni* Baylis, 1921; *Polydelphis sewelli* Baylis & Daubney, 1922; *Polydelphis dalmatina* Kreis, 1940; *Polydelphis najae* Mozgovoi, 1953

   Bitis arietans
   Fantham & Porter (1950), South Africa
   Baylis (1920); Sprent (1978), Africa

   Bitis gabonica
   Fantham & Porter (1950), South Africa
   Sprent (1978), Africa

   Causus rhombeatus
   Fantham & Porter (1950), South Africa

   Lamprophis fuliginosus
   Fantham & Porter (1950), South Africa

   Naja melanoleuca
   Fantham & Porter (1950), Malawi
   Sprent (1978), Africa

   Naja nigricollis
   Sprent (1978), Africa

   Psammophis subtaeniatus
   Wahid (1961), Zimbabwe

   Pseudoaspis cana
   Baylis (1920); Sprent (1978), Africa
   Fantham & Porter (1950), South Africa

   Python sebae
   Sprent (1978), Africa

GENUS *OPHIDASCARIS* BAYLIS, 1920

1. *Ophidascaris amucornata* Schuurmans Stekhoven, 1937

   Python sebae
   Sprent & McKeown (1979), Kenya

2. *Ophidascaris filaria* (Dujardin, 1845) Baylis, 1920

   Ascaris rubicunda Schneider, 1866; *Ophidascaris ajarensis* Khera, 1954, *pro parte*

   Lamprophis fuliginosus
   Fantham & Porter (1950), South Africa

   Naja melanoleuca
   Fantham & Porter (1950), Malawi

   Python sebae
   Aruo (1977) in Baker (1987), Uganda
   Baylis (1920), Zanzibar
   Fantham & Porter (1950), South Africa

3. *Ophidascaris intorta* (Gedoelst, 1916) Baylis, 1920

   Bitis arietans
   Fantham & Porter (1950), South Africa

Bitis gabonica
Fantham & Porter (1950), South Africa

4. *Ophidascaris mombasica* Baylis, 1921

Lycodonomorphus rufulus
Fantham & Porter (1950), South Africa

Psammophis subtaeniatus
Baylis (1920), Kenya

5. *Ophidascaris naiae* (Gedoelst, 1916) Baylis, 1920

Ophidascaris daubaylisi Baylis & Daubney, 1922; 1923

Naja mossambica
Fantham & Porter (1950), South Africa

Naja nivea
Fantham & Porter (1950), South Africa

"Python"
Bwangamoi (1968), Uganda

6. *Ophidascaris radiosa* (Schneider, 1866) Baylis, 1920

Bitis gabonica
Baylis (1920), Africa

Causus rhombeatus
Fantham& Porter (1950), South Africa

GENUS *ORNEOASCARIS* SKRJABIN, 1916

Amplicaecum Baylis, 1920

1. *Orneoascaris chrysanthemoides* Skrjabin, 1916

Ascaris involuta Gedoelst, 1916; *Ascaris bufonis* Gedoelst, 1916 *nec* Schrank, 1788; *Ascaris colura* Baylis, 1919; *Amplicaecum africanum* Taylor, 1924; *Amplicaecum causi* Thwaite, 1926; *Amplicaecum gedoelsti* Yorke & Maplestone, 1926; *Amplicaecum novempapillatum* Sandground, 1933; *Amplicaecum pesteri* Rasheed, 1965

Bitis cornuta
Vuylsteke (1964), Central Africa

Causus rhombeatus
Fantham & Porter (1950), South Africa

Chamaeleo dilepis
Thwaite (1926), Africa

Dispholydus typus
Rasheed (1965), Cameroon

2. *Orneoascaris schoutedeni* (Baylis, 1940) Le Van Hoa, 1960

Varanus albigularis
Sprent (1985a), Tanzania

Varanus niloticus
Le Van Hoa (1960), Zaire

GENUS *POLYDELPHIS* DUJARDIN, 1845

1. *Polydelphis anoura* Dujardin, 1845

Ascaris attenuata Molin, 1858; *Ascaris oculata* v. Linstow, 1899; *Ascaris pythonis* Retzius, 1830; *Ascaris rubicunda* Schneider, 1866 (*pro parte*); *Polydelphis bicornuta* Robinson, 1934; *Polydelphis mucronata* Panagia, 1933

Bitis arietans
Von Linstow (1899), South Africa

Python sebae
Fantham & Porter (1950), South Africa
Baylis (1940), Congo
Peirce (1984), Zambia

GENUS *RAILLIETASCARIS* SPRENT, 1935

1. *Raillietascaris varani* (Baylis & Daubney, 1922) Sprent, 1935

Amplicaecum monitor Khera, 1954; *Amplicaecum iguanae* Wahid, 1961; *Amplicaecum mackerrasae* Thomas, 1959

Varanus niloticus
Sprent (1985b), Congo

Family GNATHOSTOMATIDAE Railliet, 1915

GENUS *TANQUA* BLANCHARD, 1904

Ctenocephalus v. Linstow, 1904; *Tetradenos* v. Linstow, 1904; *Anomala* Travassos, 1920

1. *Tanqua tiara* (v. Linstow, 1879) Blanchard, 1904

Varanus albigularis
Baylis (1939), South Africa

Varanus niloticus
Sandground (1933), Tanzania
Baylis & Lane 1920), Zanzibar
Gretillat & Gaillard (1966), Senegal

Family PHYSALOPTERIDAE (Railliet, 1893) Leiper, 1908

GENUS *ABBREVIATA* TRAVASSOS, 1920

Polydelphyoptera Schultz,1927; *Didelphyoptera* Schultz, 1927

1. *Abbreviata affinis* (Gedoelst, 1916) Chabaud, 1956

Crotaphopeltis hotamboeia
Chabaud (1956), Congo

Psammophis brevirostris
Fantham & Porter (1950), South Africa

2. *Abbreviata baylisi* Chabaud, 1956

Physaloptera quadrovaria Leiper, 1908; *Physaloptera paradoxa* v. Linstow, 1908

Varanus albigularis (?)
Chabaud (1956), Central Africa

3. *Abbreviata damarensis* Prudhoe & Harris, 1971

   Chamaeleo namaquensis
   Prudhoe & Harris (1971), Namibia

4. *Abbreviata nyassae* Fitzsimmons, 1964

   Aconthocercus atricollis
   Fitzsimmons (1964), Malawi

5. *Abbreviata ortleppi ortleppi* (Sandground, 1928) Morgan, 1945

   Chamaeleo dilepis
   Sandground (1928), Tanzania
   Morgan (1945), Tanzania

6. *Abbreviata polydentata* (Walton, 1932) Morgan, 1945

   Hemidactylus mabouia
   Morgan (1945), Tanzania

7. *Abbreviata quadrovaria* (Leiper, 1908) Schultz, 1927

   Varanus niloticus
   Ortlepp (1922), Sudan

8. *Abbreviata* sp.

   Agama aculeata
   Heideman (1995), Namibia

GENUS *SKRJABINOPTERA* SCHULTZ, 1927

Didelphysoma Schultz, 1927

1. *Skrjabinoptera chamaeleontis* (Gedoelst, 1916) Schultz, 1927

   Chamaeleo dilepis
   Vuylsteke (1964), Congo

2. *Skrjabinoptera simplicidens* (Ortlepp, 1922) Schultz, 1927

   Unidentified lizard
   Schultz (1927), South Africa

3. *Skrjabinoptera wetzeli* Hörchner & Weissenburg, 1965

   Agama hispida (?)
   Hörchner & Weissenburg (1965), Congo

   Agama hispida
   Simbotwe (1979), Zambia

GENUS *THUBUNAEA* SEURAT, 1914

1. *Thubunaea fitzsimmonsi* Ortlepp, 1931

   Ichnotropis squamulosa
   Ortlepp (1931), South Africa

GENUS *PHYSALOPTEROIDES* WU & LIU, 1940

Thubunaea Seurat,1914 (*pro parte*)

1. *Physalopteroides agamae* (Sandground, 1933) Chabaud & Brygoo, 1960

   Agama hispida
   Chabaud & Brygoo (1960), Mozambique

2. *Physalopteroides asymmetrica* (Baylis, 1930) Chabaud & Brygoo, 1960

   Hemidactylus mabouia
   Simonsen & Sarda (1985), Tanzania

3. *Physalopteroides grayicola* (Sandground, 1933) Chabaud & Brygoo, 1960

   Bitis arietans
   Chabaud & Brygoo (1960), Africa

4. *Physalopteroides impar impar* (Malan, 1939) Chabaud & Brygoo, 1960

   Agama atra
   Malan (1939); Chabaud & Brygoo (1960), South Africa

   Cordylus cordylus
   Chabaud & Brygoo (1960), South Africa

Family RHABDOCHONIDAE (Travassos, Artigas & Pereira, 1928) Skrjabin, 1946

GENUS *RHABDOCHONA* RAILLIET, 1916

Ichthyospirura Skrjabin, 1917; *Pseudorhabdochona* Liu & Wu, 1941; *Rhabdochonoides* Janizewska, 1955

1. *Rhabdochona puylaerti* Moravec, 1983

   Causus rhombeatus
   Moravec (1983), Uganda

Family DIPLOTRIAENIDAE (Skrjabin, 1916 subfam.) Anderson, 1958

GENUS *HASTOSPICULUM* SKRJABIN, 1923

Setarospiculum Mirza & Basir, 1939

1. *Hastospiculum macrophallos* (Parona, 1889) Baylis, 1930

   Filaria varani Baylis & Daubney 1922; *Hastospiculum spinigerum* Chandler, 1929; *Setarospiculum varani* Mirza & Basir, 1939; *Hastospiculum indicum* Yamaguti, 1961

   Varanus niloticus
   Thurston (1971), Uganda
   Gretillat & Gaillard (1966), Senegal

Family ONCHOCERCIDAE Leiper, 1911

Dipetalonematidae Wehr, 1935; Setariidae Yorke & Maplestone, 1926 subfam.

GENUS *BEFILARIA* CHABAUD, ANDERSON & BRYGOO, 1959

1. *Befilaria pseudocordyli* Gibbons, 1989

   Pseudocordylus microlepidotus
   Gibbons (1989), South Africa

GENUS *MADATHAMUGADIA* CHABAUD, ANDERSON & BRYGOO, 1959

1. *Madathamugadia hiepei* Hering-Hagenbeck, Boomker, Petit, Killick-Kendrick & Bain, 1999

   Pachydactylus turneri
   Hering-Hagenbeck *et al.* (1999), South Africa

2. *Madathamugadia ineichi* Bain, Wanji, Petit, Paperna & Finkelman, 1993

   Pseudocordylus microlepidotus
   Bain *et al.* (1993), South Africa

3. *Madathamugadia versterae* Bain, Wanji, Petit, Paperna & Finkelman, 1993

   Mabuya quinquetaeniata margaritifer
   Bain *et al.* (1993), South Africa

HOST/PARASITE CHECK-LIST

Serpentes

Family ATRACTASPIDIDAE (African burrowing snakes)

GENUS *MACRELAPS*

1. *Macrelaps microlepidotus* (Günther, 1860) (Natal blacksnake)

   Uriechis microlepidotus Günther, 1860; *Atractaspis natalensis* Peters, 1877; *Macrelaps microlepidotus* Boulenger, 1896

   Kalicephalus costatus micrurus

Family BOIDAE (Boas and phythons)

GENUS *PYTHON*

1. *Python sebae* A. Smith, 1840 (African rock python)

   Python natalensis A. Smith, 1840; *Hortulia natalensis* Gray, 1842

   Hexametra quadricornis
   Ophidascaris amucronata
   Ophidascaris filaria
   Polydelphis anoura

Family VIPERIDAE (Vipers)

GENUS *BITIS*

1. *Bitis arietans* (Merrem, 1820) Günther, 1858 (Puff-adder)

   Cobra lachesis Laurenti, 1768; *Cobra clotho* Laurenti, 1768; *Coluber lachesis* Gmelin, 1788; *Coluber bitin* Bonnaterre, 1789; *Coluber intumescens* Donndorf, 1798; *Vipera (Echidna) arietans* Merrem, 1820; *Vipera inflata* Burchell, 1822; *Echidna arietans* Wagler, 1828; *Vipera brachyura* Cuvier, 1829; *Clotho arietans* Gray, 1842; *Clotho lateristriga* Gray, 1842; *Echidna clotho* Steindachner, 1867; *Bitis lachesis* Bogert, 1940

   Hexametra quadricornis
   Kalicephalus colubri colubri
   Kalicephalus viperae obliquus
   Ophidascaris intorta
   Ophidascaris amucronata
   Physalopteroides grayicola
   Polydelphis anoura
   Rhabdias fuscovenosa

2. *Bitis gabonica* (Duméril & Bibron, 1854) Boulenger, 1896 (Gaboon adder)

   Cerastes nasicornis (*non* Shaw) Hallowell, 1847; *Echidna gabonica* Duméril & Bibron, 1854; *Bitis rhinoceros* (*non* Schlegel) Peters, 1882; *Cobra gabonica* Mertens, 1937

   Hexametra quadricornis
   Kalicephalus viperae obliquus
   Ophidascaris radiosa
   Ophidascaris intorta

3. *Bitis cornuta* (Daudin, 1803) (Many-horned adder)

   Verpera cornuta Daudin, 1803; *Vipera lophophris* Couvier, 1929; *Cerastes cornuta* Gray, 1842; *Vipera lophophrys* A. Smith, 1843; *Clotho cornuta* Gray, 1849; *Cerastes lophophrys* Duméril & Bibron, 1854; *Cobra cornuta* Mertens, 1937; *Bitis cornuta* Boulenger, 1896

   Orneoascaris chrysanthemoides

GENUS *CAUSUS*

1. *Causus rhombeatus* (Lichtenstein, 1823) Wagler, 1830 (Rhombic night-adder)

   Sepedon rhombeata Lichtenstein, 1823; *Aspidelaps rhombeatus* Jan, 1859; *Causus rhombeatus* var. *taeniata* Sternfeld, 1912

   Hexametra quadricornis
   Kalicephalus viperae obliquus
   Ophidascaris radiosa
   Orneoascaris chrysanthemoides
   Rhabdochona puylaerti

Family COLUBRIDAE (Typical snakes)

GENUS *LAMPROPHIS*

1. *Lamprophis fuliginosus* (Boie, 1827) Broadley, 1983 (Brown house-snake)

Lycodon fuliginosus Boie, 1827; *Lycodon geometricus* (*non* Schlegel) A. Smith, 1843; *Boaedon lineatum* (*pro parte, non* Duméril & Bibron) Günther, 1858; *Boaedon capense* Duméril & Bibron 1854; *Alopecion variegatum* Bocage, 1867; *Boodon quadrilineatus* Peters, 1867; *Boaedon quadrilineatus* var. *variegata* Jan, 1870; *Boodon geometricus* Fischer, 1888; *Boodon bipraeocularis* Günther, 1888; *Boodon mentalis* Günther, 1888; *Boodon lineatus* (*pro parte*) Boulenger, 1893; *Boaedon lineatus* Cott, 1935; *Boaedon mentalis* Rose, 1950; *Boaedon fuliginosus* Pitman, 1958

Hexametra quadricornis
Ophidascaris filaria

GENUS *LYCODONOMORPHUS*

1. *Lycodonomorphus rufulus* (Lichtenstein, 1823) Loveridge, 1953 (Common brown water-snake)

Coluber rufulus Lichtenstein, 1823; *Coronella leucopilus* A. Smith, 1831; *Coronella rufula* Schlegel (*pro parte*), 1837; *Lycodonomorphus rufula* Fitzinger, 1843; *Lamprophis rufulus* A. Smith, 1847; *Alabes rufula* Duméril & Bibron, 1854; *Ablabophis rufulus* Boulenger, 1893

Ophidascaris mombasica

GENUS *PSEUDOASPIS*

1. *Pseudoaspis cana* (Linnaeus, 1754) Cope, 1864 (Mole snake)

Coluber cana Linnaeus, 1754; *Coluber elegantissimus* Laurenti, 1768; *Coluber ocellatus* Gmelin, 1789; *Duberria cana* Fitzinger, 1826; *Coronella cana* Dumérgil & Bibron, 1854; *Cadmus cuneiformis* Theobald, 1868; *Coronella phocarum* Günther, 1872; *Ophirhina anchietae* Bocage, 1882; *Dasypeltis scabra* (*nec* Linnaeus) Gaerdes, 1962

Hexametra quadricornis
Kalicephalus colubri colubri
Kalicephalus rotundatus

GENUS *PSAMMOPHIS*

1. *Psammophis brevirostris* (Peters, 1881) Brandstädter, 1996 (Short-snouted grass-snake)

Psammophis sibilans sibilans (*non* Linnaeus) FitzSimmons, 1970; *Psammophis sibilans brevirostris* Broadley, 1977; *Psammophis brevirostris* Brandstädter, 1996

Abbreviata affinis
Kalicephalus simus simus

2. *Psammophis subtaeniatus* (Peters, 1882) Boulanger, 1896 (Stripe-bellied sand-snake)

Psammophis moniliger Peters (*pro parte, non* Daudin), 1854; *Psammophis sibilans* var. *bilineatus* Peters, 1867; *Psammophis sibilans* var. *subtaeniata* Peters, 1882; *Psammophis bocagii* Boulenger, 1896; *Psammophis transvaalensis* Gough, 1908; *Psammophis notostictus* (*non* Peters) Isemonger, 1955

Hexametra quadricornis
Ophidascaris mombasica

GENUS *PSAMMOPHYLAX*

1. *Psammophylax tritaeniatus* (Günther, 1868) Loveridge, 1953 (Striped skaapsteker)

Rhagerrhis tritaeniatus Günther, 1868; *Coronella tritaeniata* Günther, 1881; *Trimerorhinus tritaeniatus* Boulenger (*pro parte*) 1896; *Cerastes tritaeniatus* Gaerdes, 1962

Kalicephalus obliquus

GENUS *CROTAPHOPELTIS*

1. *Crotaphopeltis hotamboeia* (Laurenti, 1768) Barbour & Amaral, 1927 (Herald snake)

Coronella hotamboeia Laurenti, 1768; *Coronella virginica* Laurenti, 1768; *Coluber rufescens* Gmelin, 1789; *Coluber hitamboeia* Gmelin, 1789; *Coluber bicolor* Leach, 1819; *Ophis heterurus* Duvernoy, 1833; *Ophis albocinctus* Duvernoy, 1833; *Coronella rufescens* Schlegel, 1837; *Crotaphopeltis rufescens* A. Smith, 1849; *Dipsas inornatus* A. Smith 1849; *Heterurus rufescens* Duméril & Bibron, 1854; *Leptodeira rufescens* Günther, 1858; *Oxyropus melanocrotaphos* Cope, 1860; *Crotaphopeltis hitamboeia* Peters, 1882; *Leptodira rufescens* Boettger, 1887; *Leptodira hotamboeia* Boulenger, 1896; *Leptodira hitamboeia* Werner, 1898; *Leptodira hotamboeia* Flower, 1929; *Trabophis barnumbrowni* Bogert, 1940

Abbreviata affinis
Kalicephalus costatus micrurus

GENUS DISPHOLIDUS

1. *Dispholidus typus* (A. Smith, 1829) (Boomslang)

Bucephalus typus A. Smith, 1829; *Bucephalus jardinii, Bucephalus gutturalis, Bucephalus bellii* A. Smith, 1829; *Dispholidus lalandii* Duvernoy, 1832; *Dendrophis colubrina* Schlegel, 1837; *Bucephalus viridis* A. Smith, 1841; *Bucephalus capensis* A. Smith, 1841; *Dendrophis pseudodipsas* Bianconi, 1848; *Dispholidus typicus* Boulenger, 1896; *Thrasops jacksonii mossambicus* Mertens, 1937; *Dispholidus typicus* Boulenger, 1896

Kalicephalus costatus micrurus
Orneoascaris chrysanthemoides

Family ELAPHIDAE (Cobras, mambas and their relatives)

GENUS *DENDROASPIS*

1. *Dendroaspis angusticeps* (A. Smith, 1849) Hewitt, 1937 (Green mamba)

Naia angusticeps A. Smith, 1849; *Dendraspis angusticeps* Günther (*pro parte*), 1858; *Dendroaspis intermedius* Günther, 1865; *Dendroaspis sjöstedti* Lönnberg, 1907

Kalicephalus simus simus

2. *Dendroaspis polylepis* (Günther, 1864) FitzSimmons, 1946 (Black mamba)

Naia angusticeps A. Smith, 1849; *Chloroechis angusticeps* (*non* A. Smith) Peters, 1854; *Dendraspis angusticeps* (*non* A. Smith) Günther (*pro parte*), 1858; *Dendraspis polylepis* Günther, 1864; *Dendraspis antinorii* Peters, 1873; *Dinophis angusticeps* Peters, 1882; *Dendraspis mamba* Gough, 1908; *Dendroaspis angusticeps* (*non* A. Smith) Flower, 1937; *Dendroaspis mamba* Rose, 1950

Kalicephalus simus simus

GENUS *HEMACHATUS*

1. *Hemachatus haemachatus* (Lacépède, 1788) Stejneger, 1936 (rinkhals)

   Vipere haemachate Lacépède, 1788; *Coluber haemachata* Lacépède, 1789; *Coluber haemachates* Bonnaterre, 1789; *Vipera haemachates* Latreille, 1802; *Sepedon haemachates* Merrem, 1820; *Naia capensis* A. Smith, 1826; *Naja haemachates* Schlegel, 1837; *Aspidelaps haemachates* Jan, 1863; *Sepedon haemachata* Flower, 1929; *Haemachatus haemachates* FitzSimmons, 1946

   Rhabdias fuscovenosa

GENUS *NAJA*

1. *Naja melanoleuca* Hallowell, 1857 (Forest cobra)

   Naja haje var *melanoleuca* Hallowell, 1857; *Aspidelaps bocagii* Sauvage, 1884; *Naja haje* var. *leucosticta* Fischer, 1885; *Naia melanoleuca* Boulenger, 1896; *Naja melanoleuca* Bogert, 1942

   Hexametra quadricornis
   Kalicephalus colubri colubri
   Kalicephalus paracolubri paracolubri
   Kalicephalus simus simus
   Ophidascaris filaria

2. *Naja mossambica* Peters, 1854 (Mozambique spitting cobra)

   Naja mossambica Peters, 1854; *Naja nigricollis* (*non* Reinhardt) Peters, 1882; *Naia nigricollis* Boulenger, 1898; *Naia nigricollis* var. *mossambica* Boulenger, 1896; *Naja nigricollis mossambica* Mertens, 1937; *Naja mossambica* Broadley, 1968

   Ophidascaris naiae
   Kalicephalus simus simus

3. *Naja nivea* (Linnaeus, 1758) Boie, 1827 (Cape cobra)

   Coluber niveus Linnaeus, 1758; *Vipera* (*Echidna*) *flava* Merrem, 1820; *Naja haje* var. Schlegel, 1837; *Naja gutturalis* A. Smith, 1838; *Naja intermixta* Duméril & Bibron, 1854; *Naja haje* var. *capensis* Jan, 1863; *Naia flava* Boulenger, 1887; *Naja flava* Sternfeld, 1910

   Ophidascaris naiae
   Rhabdias fuscovenosa

Squamata

Family SCINCIDAE (Skinks)

GENUS *MABUYA*

1. *Mabuya quinquetaeniata* (Peters, 1854) (Rainbow skink)

   Euprepes margaritifer Peters,1854; *Euprepes savignyi* Peters, 1854; *Euprepis gularis* Gray, 1864; *Euprepis kirkii* Gray, 1864; *Mabouia quinquetaeniata* de Jeude, 1895; *Mabouia margaritifer* Bocage, 1896; *Mabouia binotata* Bocage, 1896

   Madathamugadia versterae
   Spauligodon morgani
   Spauligodon vojteki

2. *Mabuya striata* (Peters, 1844) (Striped skink)

   Tropidolepisma striatum Peters, 1844; *Euprepes punctatissimus* A. Smith 1849; *Euprepes sundervallii* A. Smith 1849; *Euprepis granti* Gray, 1864; *Euprepes variegatus* Peters, 1869; *Euprepes wahlbergi* Peters, 1869; *Euprepes grutzneri* Peters, 1869; *Euprepes* (*Euprepis*) *striatus* Peters, 1882; *Mabuia wahlbergii* Boulenger, 1887; *Mabouia grutzneri* Boulenger, 1887; *Mabouia striata* Boulenger, 1887; *Mabuya striata* Parker, 1936

   Skrjabinodon mabuiensis
   Spauligodon morgani

3. *Mabuya sulcata sulcata* (Peters, 1862) (Western rock skink)

   Euprepes olivaceus (*non* Gray) Peters, 1862; *Euprepes sulcatus* Peters, 1867; *Mabuya sulcata* Boulenger, 1887

   Spauligodon petersi

4. *Mabuya varia varia* (Peters, 1867) (Variable skink)

   Euprepes (*Euprepis*) *varius* Peters, 1867; *Euprepes olivierii* (*non* Dumeril & Bibron) A. Smith, 1849; *Euprepes olivieri* var. *albopunctatus* Bocage, 1869; *Euprepes* (*Mabuya*) *laevigatus* Peters, 1869; *Euprepes angolensis* Bocage, 1872; *Mabuya homalocephala* part., Boulenger, 1910; *Mabuya varia* Parker, 1936

   Skrjabinodon mabuyae

Family LACERTIDAE (Old world lizards)

GENUS *ICHNOTROPIS*

1. *Ichnotropis squamulosa* Peters, 1854 (Common rough-scaled lizard)

   Thubunaea fitzsimmonsi

Family GEKKONIDAE (Gekkos)

GENUS *HEMIDACTYLUS*

1. *Hemidactylus mabouia* (Moreau de Jonnes, 1818) (Moreau´s tropical house gecko)

   Gecko mabouia Moreau de Jonnes, 1818; *Hemidactylus mercatorius* Gray 1831; *Hemidactylus gardineri* Boulenger, 1909; *Hemidactylus persimilis* Barbour & Loveridge, 1928; *Hemidactylus mandanus* Loveridge, 1936; *Hemidactylus platycephalus* Peters, 1854; *Hemidactylus mabouia* Dumeril & Bibron, 1836

   Abbreviata polydentata
   Physalopteroides asymmetrica
   Skrjabinodon dossae
   Spauligodon auziensis (?)
   Spauligodon morgani

GENUS *PACHYDACTYLUS*

1. *Pachydactylus bibronii* A. Smith, 1846 (Bibron´s thick-toed gecko)

   Pachydactylus bibronii A. Smith, 1846; *Homodactylus turneri* Gray, 1864; *Homodactylus bibronii* Gray, 1865; *Pachydactylus elegans* (*non* Gray) F. Müller, 1885; *Pachydactylus laevigatus* Fischer, 1888; *Pachydactylus bibronii laevigatus* Methuen & Hewitt, 1914

   Spauligodon smithi

2. *Pachydactylus turneri* Gray, 1864 (Turner´s thick-toed gecko)

   Pachydactylus bibronii A. Smith, 1846; *Homodactylus turneri* Gray, 1864; *Homodactylus bibronii* Gray, 1865; *Pachydactylus elegans* (*non* Gray) F. Müller, 1885; *Pachydactylus bibronii* A. Smith, 1846; *Pachydactylus laevigatus* Fischer, 1888; *Pachydactylus stellatus* Schmidt, 1933; *Pachydactylus bibronii turneri* Parker, 1936

   Madathamugadia hiepei
   Spauligodon timbavatiensis

Family AGAMIDAE (Agamas)

GENUS *ACANTHOSCERCUS*

1. *Acanthocerus atricollis* (A. Smith, 1849) (Southern tree agama)

   Agama atricollis A. Smith, 1849; *Stellio capensis* A. Dumeril, 1851; *Stellio nigricollis* Bocage, 1866; *Stellio atricollis* Peters, 1881; *Agama gregorii* Gunther, 1894

   Abbreviata nyassae
   Strongyluris ornata

GENUS *AGAMA*

1. *Agama atra* Daudin, 1802 (Southern rock agama)

   Agama atra Daudin, 1802; *Agama subspinosa* Gray, 1827; *Trapelus subhispidus* Kaup, 1827; *Phrynopis atra* Fitzinger, 1843; *Agama micropholis* Matschie, 1890; *Agama microp-terolepis* Boulenger, 1896; *Agama holubi* Bocage, 1896

   Parapharyngodon rotundatus
   Physalopteroides impar impar
   Strongyluris ornata

2a. *Agama aculeata aculeata*

   Abbreviata sp.
   Pharyngodon sp.

2b. *Agama aculeata distanti* Boulenger, 1902 (Ground agama)

   Agama aculeata (*non* Merrem) Boettger, 1889; *Agama distanti* Boulenger, 1902;

   Physalopteroides agamae

3. *Agama hispida armata* Peters, 1854 (Southern spiny agama)

   Agama armata Peters, 1854, *Agama hispida mertensi* Wermuth, 1967; *Agama hispida distanti* (*non* Boulenger) Loveridge, 1923

   Physalopteroides agamae
   Skrjabinoptera wetzeli (?)

4. *Agama mossambica* Peters, 1854 (Mozambique agama)

   Agama mossambica Peters, 1854; *Agama carniventris* Peters, 1874; *Agama colonorum* part. Loveridge, 1920

   Thelandros alatus

Family CORDYLIDAE (Girdled lizards and their relatives)

GENUS *CORDYLUS*

1. *Cordylus cordylus* (Linnaeus 1758) (Cape girdled lizard)

   Lacerta cordylus Linnaeus 1758; *Corylus verus* Laurenti, 1768; *Stellio cordylus* Daudin, 1802; *Cordylus griseus* Cuvier, 1829; *Corylus niger* Cuvier, 1829; *Cordylus dorsalis* Cuvier, 1829; *Zonorus vertebralis* Gray, 1838; *Zonorus cordylus* var. *niger* Rose, 1926; *Cordylus cordylus* Mertens, 1937

   Physalopteroides impar impar

GENUS *PSEUDOCORDYLUS*

1. *Pseudocordylus microlepidotus* (Couvier, 1829) (Cape crag lizard)

   Cordylus microlepidotus Couvier, 1829; *Zonurus microlepidotus* Gray,1831; *Zonurus wittii* Schlegel, 1834; *Cordylus* (*Pseudocordylus*) *montanus* and *melanotus* A. Smith, 1838; *Pseudocordylus montanus* Hewitt, 1927; *Pseudocordylus microlepidotus* Boulenger, 1885

   Befilaria pseudocordyli
   Madathamugadia ineichi
   Parapharyngodon rotundatus

Family VARANIDAE (Monitor lizards)

GENUS *VARANUS*

1. *Varanus albigularis* (Daudin, 1802) (Rock monitor)

   Tupinambis albigularis Daudin, 1802; *Monitor* (*Psammosaurus*) *albogularis* Gray, 1831; *Varanus gillii* A. Smith, 1831; *Varanus albogularis* Dumeril & Bibron, 1836; *Empagusia albogularis* Gray, 1838; *Monitor exanthematicus* var. *capensis* Schlegel, 1844; *Regenia albogularis* Gray, 1845; *Monitor albigularis* Peters, 1882; *Varanus exanthematicus albigularis* Schmidt, 1919

   Abbreviata baylisi (?)
   Orneoascaris schoutedeni
   Tanqua tiara

2. *Varanus niloticus* Linnaeus, 1762 (Water monitor)

Lacerta nilotica Linnaeus, 1762; *Monitor saurus* Peters, 1882; *Varanus niloticus* Dumeril & Bibron, 1836

Abbreviata quadrovaria
Africana africana
Aplectana macintoshii
Hastospiculum macrophallos
Orneoascaris schoutedeni
Raillietascaris varani
Tanqua tiara

Family CHAMAELEONIDAE (Chameleons)

GENUS *CHAMAELEO*

1. *Chamaeleo dilepis* Leach, 1819 (Flap-neck chameleon)

   Chamaeleo dilepis Leach, 1819; *Chamaeleon quilensis* Bocage, 1895; *Chamaeleon dilepis quilensis* Werner, 1902; *Chamaeleon parvilobus* Boulenger, 1887; *Chamaeleon dilepis parvilobus* Gunther, 1892

   Abbreviata ortleppi ortleppi
   Africana acuticeps
   Hexametra applanata
   Hexametra hexametra
   Orneoascaris chrysanthemoides
   Skrjabinoptera chamaeleontis
   Strongyluris brevicaudata
   Strongyluris elegans

2. *Chamaeleo namaquensis* A. Smith, 1831 (Namaqua chameleon)

   Chamaeleo namaquensis A. Smith, 1831; *Chamaeleon namaquensis* Boulenger, 1887; *Chamaeleo tuberculiferus* Gray, 1845; *Phumanola namaquensis* Gray, 1864

   Abbreviata damarensis

GENUS *BRADYPODION*

1. *Bradypodion pumila pumila* (Daudin, 1802) (Cape dwarf chameleon)

   Chamaeleo pumilus Daudin, 1802; *Chamaeleon pumilus* Boulenger, 1887; *Chamaeleon margaritaeus* Merrem, 1820; *Bradypodium pumilus* Fitzinger, 1843; *Lophosaura pumila* Gray, 1864; *Chamaeleon ventralis* (*pro parte*) Werner, 1902; *Chamaeleon damaranus* (*pro parte*) Werner, 1902; *Microsaura pumila pumila* Fitzsimmons, 1943?

   Strongyluris brevicaudata
   Strongyluris capensis

ACKNOWLEDGEMENTS

We wish to express our appreciation to the following persons and institutions: Mr Wulf Haacke, Natural History Museum, Gauteng, and Mr Richard Newbery Department of Nature Conservation, Gauteng, for much help as regards the reptiles; the Departments of Environmental Affairs of the Mpumalanga Province, Gauteng Province, North West Province and Northern Province for the collecting permits, and the Timbavati/Umbabat/Klaserie Private Game Reserves, the Hoedspruit Nature Reserve, the Blyderiver Canyon Nature Reserve, the Delftzyl Government Farm and the Molopo Nature Reserve for allowing us to catch the reptiles at these sites.

This study was financially supported by the Arthur & Aenne Feindt Stiftung, Hamburg, Germany.

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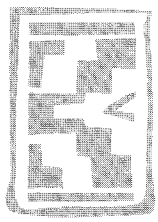
CHAPTER 2

Pentastomid parasites

of

reptiles

Onderstepoort Journal of Veterinary Research, 66:65–71 (1999)



Pentastomid infections in Nile crocodiles (*Crocodylus niloticus*) in the Kruger National Park, South Africa, with a description of the males of *Alofia simpsoni*

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ABSTRACT

JUNKER, KERSTIN, BOOMKER, J. & BOLTON, LORNA A. 1999. Pentastomid infections in the Nile crocodile (*Crocodylus niloticus*) in the Kruger National Park, South Africa, with a description of the males of *Alofia simpsoni*. *Onderstepoort Journal of Veterinary Research*, 66:65–71

Two Nile crocodiles were obtained from two different localities in the Kruger National Park, one a healthy specimen, the other in a severely debilitated condition. Both were males over 3 m long and both harboured the three pentastome genera *Sebekia*, *Alofia* and *Leiperia*. The genus *Sebekia* was represented by three species, *Sebekia wedli* Giglioli, 1922, *Sebekia cesarisi* Giglioli, 1922 and *Sebekia okavangoensis* Riley & Huchzermeyer, 1995. Of the genus *Alofia* two species, *Alofia simpsoni* Riley, 1994 and *Alofia nilotici* Riley & Huchzermeyer, 1995 were found. The male of *A. simpsoni*, formerly unknown, is described and the description of the females emended. *Leiperia cincinnalis* Sambon, 1922 was the only *Leiperia* present. Whereas *Sebekia* and *Alofia* were recovered from the bronchioles and lung parenchyma, female *Leiperia* occurred in the trachea and bronchi, and infective larvae as well as immature males and females, were collected from the lungs, the heart and the aorta. Adult *Subtriquetra* (Family Subtriquetridae) were not present in the nasopharynx of either crocodile. The intensity of infection was low in the healthy crocodile and had no negative effect on the host. In contrast, the debilitated crocodile was heavily infected and its poor condition is ascribed to its high pentastome burden. Histopathology revealed lesions in the tracheal wall and the lungs accompanied by chronic granulomata with secondary fungal infection as well as severe chronic multifocal granulomatous pneumonia.

Keywords: *Alofia*, *Crocodylus niloticus*, histopathology, *Leiperia*, pentastomes, *Sebekia*

INTRODUCTION

Pentastomes are endoparasites that mature in the respiratory tract of their final hosts, more than 90% of which are reptilians, such as crocodiles, snakes and saurians (Baer 1952; Riley 1986). Of the existing eight families of pentastomes, two families, the Sebekidae and Subtriquetridae are known to infect crocodilians, using fish as intermediate hosts. The family Sebekidae comprises the genera *Sebekia* Sambon, 1922, *Alofia* Giglioli, 1922, *Selfia* Riley, 1994, *Leiperia* Sambon, 1922, *Agema* Riley, Hill & Huchzermeyer, 1997 and *Diesingia* Sambon, 1922. The first five genera, with the exception of a single species of *Sebekia*, which can reach maturity in freshwater chelonians (Dukes, Shealy & Rogers 1971), occur only in crocodilians while *Diesingia* has a chelonian definitive host (Overstreet, Self & Vliet 1985). The monogeneric family Subtriquetridae is exclusive to crocodilians (Riley, Spratt & Winch 1990).

The Nile crocodile, *Crocodylus niloticus*, is parasitised by three sebekiid genera, *Sebekia*, *Alofia* and *Leiperia* (Sambon 1922; Fain 1961). Most data were derived from studies conducted in Central Africa during the first part of this century and only recently have Riley & Huchzermeyer (1995) and Riley, Hill & Huchzermeyer (1997) studied new material.

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Accepted for publication 23 February 1999—Editor

One of the *Alofia* species present in Africa, *Alofia simpsoni* Riley, 1994, has been described from only two females recovered from an unknown host in Ghana. In this article we add to the description of the females and describe the main characteristics of the males.

A fourth sebekiid genus present in Africa, *Agema*, has to date only been recorded from the slender-snouted crocodile, *Crocodylus cataphractus*, and the dwarf crocodile, *Osteolaemus tetraspis*, both of which occur in the equatorial rain forests of West and Central Africa (Riley *et al.* 1997). The only reports regarding pentastome infections in crocodilians in southern Africa are from a single Nile crocodile in Botswana (Riley & Huchzermeyer 1995) and two in the Kruger National Park, South Africa (Junker 1996; Junker, Boomker & Booyse 1998a, b).

In order to determine the pentastome fauna and their prevalence in crocodiles in the southern parts of Africa, a study on crocodile pentastomes was conducted in the Kruger National Park, South Africa during 1995 (Junker 1996). Some of the results of the unpublished thesis are presented in this paper.

MATERIALS AND METHODS

Hosts

Two Nile crocodiles were obtained from different localities in the Kruger National Park. Both specimens were male and measured 3,2 and 3,3 m in length, respectively. Crocodile A was caught in the Phabeni Dam (25°1'S, 31°15'E) in February 1995 with a baited cage-trap. It was immobilized with gallamine triethiodide (Flaxedil™) by means of an intra-muscular injection given with a pole dart. Subsequently the crocodile was transported to the laboratory at Skukuza where it was shot and examined immediately after death.

Crocodile B was in a severely debilitated condition and was shot at the Shimuwini Dam (23°42'S, 31°17'E) in June 1995. Its heart, lungs and trachea were placed in separate plastic bags filled with saline and kept cool. The organs were examined within 13 h of death. After removal of the trachea and the oesophagus, the nasopharynx, especially the area around the internal nostrils, was visually inspected for subtriquetrids.

Parasites

Pentastomes visible underneath the pleurae of the lungs were removed through an incision. Both lungs of each of the reptiles were opened along the bronchi and bronchioli with a pair of scissors and the parasites dissected out of the tissue. The hearts were opened with a pair of scissors, as well as the left and right aorta, and truncus pulmonalis.

All pentastome material was transferred into saline and used for experimental infections or fixed in 70% ethanol and mounted in Hoyer's medium for identification. Measurements were taken from whole mounted specimens according to the methods described by Riley *et al.* (1990).

The prevalence and intensity of pentastome infections were determined and the use of ecological terms is in accordance with the definitions given by Margolis, Esch, Holmes, Kuris & Schad (1982).

Pathology

Tissue samples of the trachea, lungs and heart were collected and fixed in 10% buffered formalin for histopathological examination. Tissue blocks were embedded in paraffin wax, sectioned at 5 mm and stained with eosin and haematoxylin. Fungi in the lung lesions were demonstrated by staining sections with Gomori's methenamine-silver nitrate (GMS) (Luna 1968) and the periodic acid-Schiff reaction (Pearse 1961).

RESULTS

Parasites

Both crocodiles harboured the three sebekiid genera *Leiperia*, *Sebekia* and *Alofia*. Female *Leiperia cincinnalis* occurred in the trachea and the bronchi, while *Sebekia* and *Alofia* were found in the bronchioles and the lung parenchyma. *Subtriquetra* was not found in the nasopharynx of either crocodile.

Fifteen adult pentastomes and 14 nymphs were obtained from Crocodile A. *Sebekia okavangoensis* was the dominant species with nine adult specimens being present. A single *S. okavangoensis* male was found in the aorta, the remainder being in the bronchioles. One *Sebekia wedli* male was collected from the lungs, as well as a single *Sebekia cesarisi* female and one male *Alofia nilotici*. All adult pentastomes were sexually mature specimens as indicated by the fully developed copulatory spicules of the males and the presence of eggs in the uteri of the females. Also present in the lungs were 11 infective sebekiid larvae other than *Leiperia*. Three infective larvae of *L. cincinnalis* were attached to the aorta, while three adult females were collected from the trachea.

Crocodile B was heavily parasitised and harboured six different pentastome species. A total of 177 adults and 62 infective larvae were recovered of which *S. wedli* from the lungs (n=75) accounted for nearly half of the adult collection. A single *S. cesarisi* female and seven males, one male and two female *S. okavangoensis* and six adult *Sebekia* spp. females that could not be identified to the species level were present in the lungs. Four infective larvae were recovered from the same site. The genus *Alofia* was

represented by 61 *A. simpsoni* together with one male and one female *A. nilotici*. A single infective *Alofia* sp. larva (ascribed to this genus because of the characteristically U-shaped oral cadre) occurred in the heart. The sex ratio was in favour of females, it being 91 % in *S. wedli* and 79 % in *A. simpsoni*.

Fifteen patent *L. cincinnalis* females were obtained from Crocodile B. Two were attached to the tracheal wall and three were recovered from the right bronchus. The remaining *Leiperia* females were lumped together in a mucous matrix in the left bronchus, severely obstructing the airflow. Males were not present. Infective *L. cincinnalis* larvae ($n = 57$) were collected from both lungs, the heart and from two big clusters in the pulmonary artery. The latter larvae were embedded in a mucous matrix that partially obstructed the lumen of the vessel. Also isolated from the clusters were seven specimens that carried simple hooks and retained the old cuticle of the infective larval stages. One immature male and an immature female were identified while the sex of the other five specimens remains undetermined.

Additions to the description of *Alofia simpsoni* Riley, 1994

FEMALES ($n = 12$)

The body-shape is dominated by the bulbous caudal extremity. The body length is 29 ± 1,6 mm and the maximum width is 2,0 ± 0,2 mm. The oral cadre is 318,2 ± 27,3 µm long and 151,3 ± 16,4 µm wide, with an overall length of 366,7 ± 32,2 µm. Hooks are 124,6 ± 8,5 µm long and the fulcra measure 274,5 ± 30,9 µm. Annuli number 82 ± 2.

MALES ($n = 13$)

Males of *A. simpsoni* are markedly smaller than the females and lack the bulbous tail. The body length averages 8,7 ± 0,9 mm and it is 1,1 ± 0,2 mm wide. The smooth hooks are long (104,4 ± 3,5 µm) and slender, bent almost through a right angle and are devoid of spines (Fig. 1A, B). The fulcra measure 230,1 ± 15,2 µm. The oral cadre is U-shaped, possesses a small peg-like extension into the pharynx, and is 207,2 ± 15,7 µm long and 104,1 ± 5,0 µm wide (Fig. 1A, C). It has an overall length of 267,6 ± 16,9 mm. The copulatory spicules are typically alofian in that the smooth-surfaced shorter extension of the base of the cowry-shell ends in a double hooked collar. The second projection is elongated and its surface marked by transverse grooves (Fig. 1A, D, E). The length of the cowry-shell, including the short extension, averages 300,4 ± 14,3 µm and the total length, including the longer extension, is 372,8 ± 30,5 µm. The opening in the cowry-shell is shaped like a long ellipse. The number of annuli varies from 79–83.

Pathology

Crocodile A was in good condition and the lungs and heart were not impaired in their functionality. The attachment sites of pentastomes in the lungs and trachea were characterized by an area of mild coagulative necrosis with eosinophilic and heterophilic infiltrates, with associated oedema and haemorrhage in the surrounding tissue. Migration tracts were seen as multifocal thin-walled cavities lined by scattered multinucleated giant cells and containing coagulated blood and haematoidin. A pentastome was present in the aorta lumen, attached to the endothelium. At the attachment site focal erosion of the endothelium, associated oedema, haemorrhage and infiltration of small numbers of macrophages and lymphocytes were seen.

Crocodile B was severely emaciated. It only weighed between 105 and 110 kg whereas the average normal weight of a crocodile of 3,3 m is around 155 kg (Loveridge & Blake 1972). Macroscopically part of the bronchi and pulmonary aorta were obstructed by females and infective larvae of *L. cincinnalis*, respectively. The outer surface of the trachea was covered by numerous brown nodules, which represented migration tracts and attachment sites of the pentastomes. Their histopathological appearance was as described for Crocodile A. The anterior part of a female embedded in the tracheal mucosa and attached to the wall of the trachea is illustrated in Fig. 2A. A chronic multifocal granulomatous pneumonia associated with many intralesional pentastome adults, larvae and eggs (Fig. 2B) was present. Several of the lesions in the trachea and lung were enlarged, containing abundant eosinophilic necrotic debris surrounded by multinucleated giant cells. Associated with some of these lesions were a myriad of fungal hyphae, 3–6 µm diameter, regularly septate with random branches at 90° angles. One such a fungal lesion is illustrated in Fig. 2C. Alternatively, these lesions contained many bacterial colonies within the necrotic centres. The hooks of the pentastomes attached to the pulmonary arterial wall elicited a moderate chronic multifocal granulomatous arteritis.

DISCUSSION

Parasites

The pentastomid fauna of *C. niloticus* is characterized by a high diversity. Three different genera of pentastomes were recovered from both the crocodiles examined and a total of six sebekiid species were present. Although adults of *Subtriquetra* were not recovered from either of the crocodiles, the presence of infective larvae of *Subtriquetra rileyi* in two cichlid fish species in the Kruger National Park indicates that Nile crocodiles probably also serve as hosts for this pentastome (Junker *et al.* 1998a). *A.*

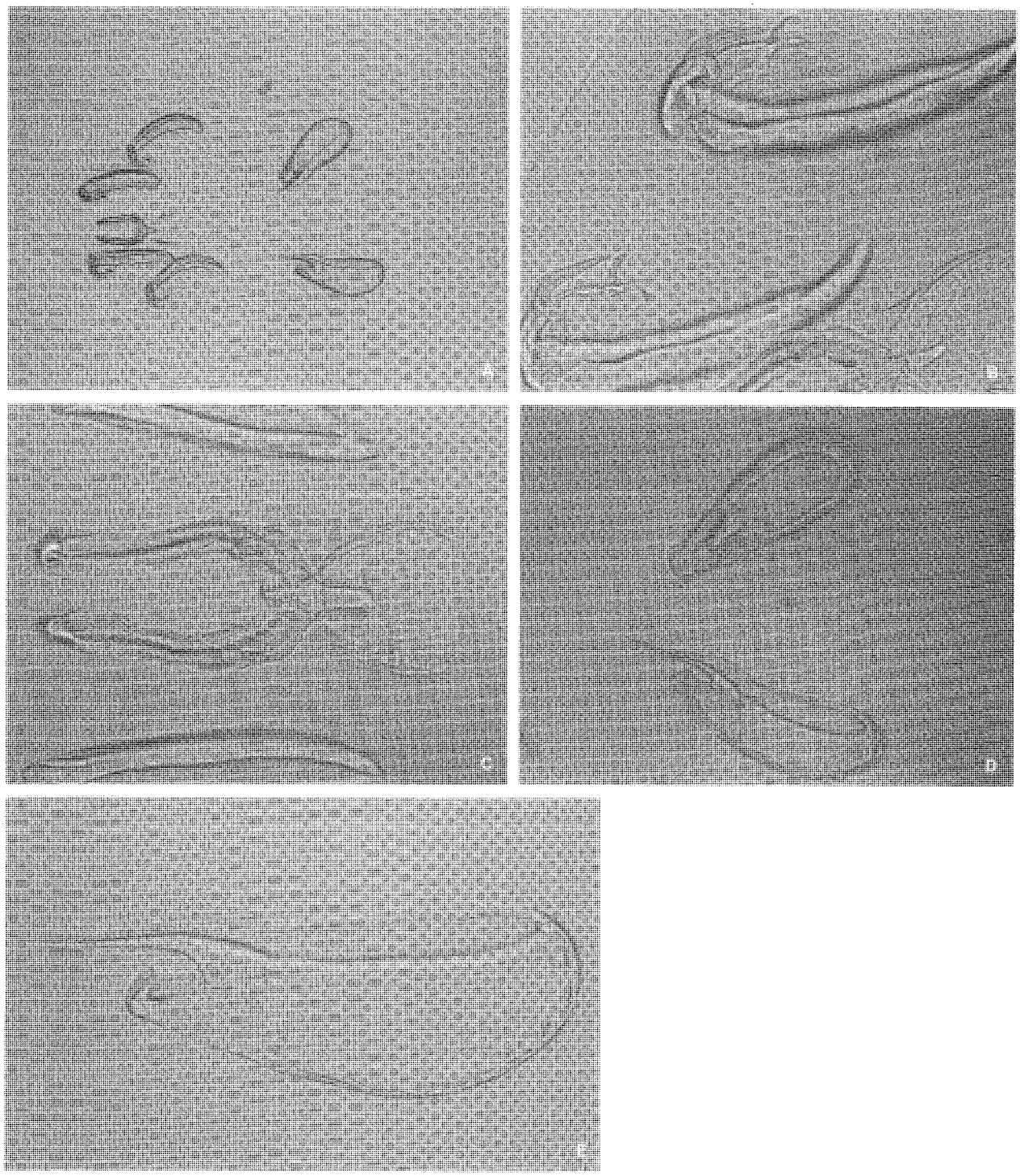


FIG. 1 *Alofia simpsoni*

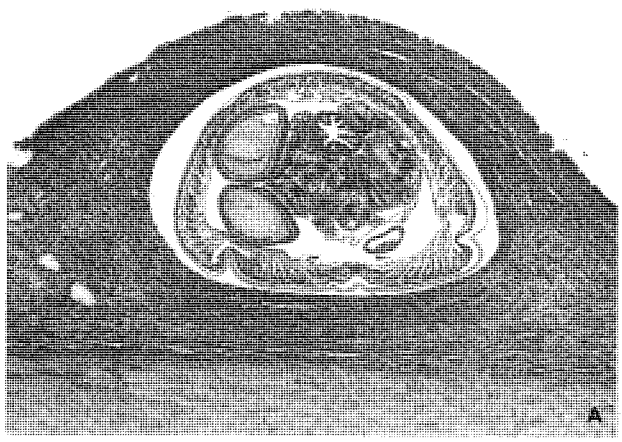
A Cephalothorax of a male, depicting the alignment of the hooks, the oral cadre and the copulatory spicules

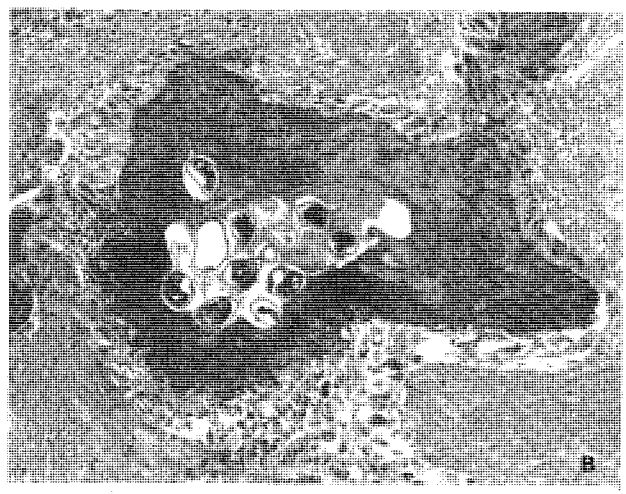
B Detail of the left posterior and anterior hook of a male. The hooks are smooth and bent at almost a right angle

C U-shaped oral cadre of a male showing the peg-like extension into the oesophagus

D Right and left copulatory spicule, in lateral and ventral view, respectively. Note the double hooked collar of the shorter extension of the cowry-shell

E Detail of right copulatory spicule seen in A. The long, spatulate extension of the cowry-shell is marked by chitinized ridges. In the right upper corner parts of the coiled cirrus are visible





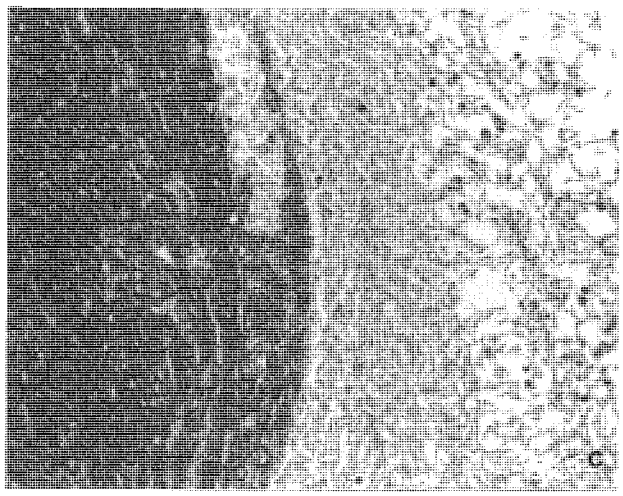


FIG. 2 A A transverse section of the anterior part of a female *Leiperia cincinnalis* embedded in the mucosa of the lumen of the trachea. HE, x 40

B A granulomatous lesion in the lung associated with pentastome eggs. HE, x 100

C A fungal granuloma (left) surrounded by fairly normal lung tissue (right). GMS, x 100

simpsoni has thus far only been recorded from an unknown host, probably a crocodilian (Riley 1994), and its presence in Nile crocodiles constitutes a new host record for the parasite.

As opposed to snakes in which multiple infections seldom occur (Fain 1961), multiple infections in crocodilians are common. Riley & Huchzermeyer (1995) found four different pentastome species in a single Nile crocodile from Botswana. Similarly, the Indo-pacific crocodile, *Crocodylus porosus*, is known to be the final host of seven species representing four genera (Riley 1994).

Most pentastomes were encountered at attachment sites considered typical for the genus and its developmental stages. Thus, infective larvae of *L. cincinnalis* were in the heart and aorta from where they invade the trachea and bronchi (Rodhain & Vuylsteke 1932; Heymons 1939).

The occurrence of a *S. okavangoensis* male in the aorta of Crocodile A and an infective larva of *A. simpsoni* in that of Crocodile B is unusual, since these sebekiids occur in the bronchioli and lung parenchyma (Fain 1961; Riley 1994). Adult pentastomes start migrating from the lung tissue following the death of the host (Overstreet *et al.* 1985) which is ascribed to declining oxygen levels (Riley & Huchzermeyer 1995). Crocodile A was necropsied immediately following its death but the muscle relaxant may have impaired its breathing. We therefore assume that the parasite's presence was due to post-mortal migration. Due to the long interval before the organs of Crocodile B were processed, we make the same assumption for *A. simpsoni*.

Some authors have observed that in spite of a balanced sex ratio in the infective larvae, the sex ratio in mature infections shifts in favour of the females (Leuckart 1860; Hett 1924; Riley 1972). Based on observations of the genera *Kiricephalus* and *Waddycephalus*, Riley & Self (1980; 1981) conclude that this is due to the comparatively shorter life span of pentastome males. Our findings, especially concerning *S. wedli* and *A. simpsoni*, support this.

Few data exist as regards the prevalence and intensity of pentastomid infections in the Nile crocodile.

The Phabeni Dam in the south-west and the Shimuwini Dam in the north-west of the Park are part of two unrelated river systems, the Sabie River/ Phabeni River in the south and the Letaba River in the north. The recovery of pentastomes in each of the Nile crocodiles indicates that the parasites are widespread in the Park and not limited to a single river system.

Apart from this study, only Riley & Huchzermeyer (1995) provide the intensity of pentastome infection of a single Nile crocodile in Botswana. This reptile harboured 94 adult pentastomids. Almost as little is known about the slender-snouted crocodile and the dwarf crocodile. Riley *et al.* (1997) collected eight pentastomids from a juvenile *C. cataphractus* from the Congo Republic. At the same occasion, pentastomes from 15 specimens of *O. tetraspis* were recovered. The prevalence of infection was 80 % with a mean intensity of 24 (Riley *et al.* 1997). More detailed information is available for North American alligators. Seven alligators from Georgia were infected with 30–40 pentastomids each (Deakins 1971), and 93 % of 30 alligators examined by Cherry & Ager (1982) had 10,6 (1–77) adults. The intensity of infection in the two crocodiles examined during this study differed considerably. While Crocodile A carried a light pentastome burden (15 adults), Crocodile B was heavily infected, and the recovery of 177 adults exceeds the intensities formerly recorded for crocodilians by far.

Alofia simpsoni Riley, 1994

The main characteristics of the females of *A. simpsoni* described in this paper fit in well with Riley's (1994) description. The overall length of the oral cadre was given as 355 µm, but according to Riley (1994) it was not possible to measure any other dimensions of the buccal complex due to the way in which the specimens were mounted.

There is a notable difference in our annulus counts when compared to that given by Riley (1994). We are not able to explain the discrepancy, but considering the number of specimens at our disposal we believe our counts to be representative.

The males of *A. simpsoni* are distinctly different from *A. nilotici*, in that the hooks of *A. simpsoni* are smooth whereas those of *A. nilotici* are equipped with a patch of minute spines. The copulatory spicules of *A. simpsoni* are markedly smaller than those of *A. nilotici* (372,8 µm long as opposed to 585 and 520 µm, respectively).

Pathology

Ladds & Sims (1990) necropsied 54 young crocodiles, *C. porosus* and *C. novaeguineae*, eight of which were infected with pentastomes. The same histopathological picture was evident in our crocodiles. In three of the cases, the infection with pentastomes was considered one of the main reasons for the poor condition of these animals (Ladds & Sims 1990). The presence of granulomata in the lungs and trachea of Crocodile B were often associated with bacterial colonies or fungal infiltration, which conforms to the findings of Deakins (1971). The damage caused to the lung epithelium by pentastomes often gives way to secondary infections (Deakins 1971). In alligators, *Sebekia* spp. facilitate infection with *Aeromonas* sp. (Shotts, Gaines, Martin & Prestwood 1972; Hazen, Aho, Murphy, Esch & Schmidt 1978).

The mild pentastome infection in Crocodile A had no apparent adverse effect, indicating that, under natural conditions, Nile crocodiles are able to tolerate pentastome infections. Boyce, Cardheilac, Lane, Buergelt & King (1984) came to the same conclusion when studying sebekiosis in alligators. The distinct clinical signs seen in Crocodile B, however, emphasize that given the right circumstances, pentastomids can have a serious impact on the host. We ascribe the poor condition of Crocodile B to the heavy infection, the pentastome activity causing extensive damage to the lungs and heart of the host. During post mortem examination no injuries accounting for Crocodile B's condition were found. A possible explanation for the large number of pentastomes may be found in the environmental circumstances at the Shimuwini Dam during the months prior to our studies: a large number of crocodiles congregated in front of the dam wall, feeding extensively on fish that got trapped against this structure.

Unfortunately, the prevalence and intensity of infection in fish at the Shimuwini Dam could not be established. However, infection rates in Mozambique bream, *Oreochromis mossambicus*, and red-breasted bream, *Tilapia rendalli*, from the Phabeni Dam were low (Junker *et al.* 1998a). This suggests that the high density of intermediate hosts and thus the high intake of fish by the final hosts, even though the infection rate in the fish might have been low, exposed the crocodiles to a concentration of infective pentastomid larvae that would otherwise not be encountered. These are important considerations as regard the conservation of the Nile crocodile. It illustrates that under certain conditions, pentastomes can pose a serious threat to their definitive hosts. Environmental destruction and decreasing water levels due to human activity imply that crocodiles are restricted to a decreasing number of suitable habitats. The resulting increase in population density may enhance the spreading of parasitic infections drastically.

ACKNOWLEDGEMENTS

We are indebted to the Board of Trustees, South African National Parks Board, for placing the animals at our disposal, to Dr L.E.O. Braack and Mr D.

Swanepoel, Kruger National Park, for their help with organization and logistics, and to Dr John Riley, Department of Biological Sciences, University of Dundee, Scotland, for his interest and advice. We thank Mr D.G. Booyse, Department of Veterinary Pathology, Medical University of Southern Africa, for his excellent technical support.

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Systematic Parasitology **47:** 29–41, 2000.

Leiperia cincinnalis Sambon, 1922 (Pentastomida) from Nile crocodiles *Crocodylus niloticus* in the Kruger National Park, South Africa, with a description of the male

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Accepted for publication 7th September, 1999

Abstract

A single male and several adult females of the pentastomid *Leiperia cincinnalis* were recovered from the trachea of five of six Nile crocodiles examined in 1995 and 1998. Infective larvae, pre-adult males and females, as well as mature males, occurred in clusters in the pulmonary artery but infective larvae and pre-adult females were also occasionally taken from the lungs. Irrespective of the developmental stage, the intensity of infection was 3, 6, 48, 72 and 79. Sixty-four percent of eggs recovered from the posterior part of the uterus of a patent *L. cincinnalis* female contained fully-developed primary larvae and these were used to infect 24 Mozambique bream *Oreochromis mossambicus*. Within a week of infection all the fish died and hatched primary larvae were recovered from the stomach and anterior part of the intestine. Eggs that had not hatched were found to be unsegmented. The total primary larval count in seven fish was 18, 12, 1, 25, 16, >40 and >50. Descriptions with detailed measurements are given of the females, the males, the eggs, the primary larvae and the infective larvae of *L. cincinnalis*.

Introduction

Leiperia cincinnalis Sambon, 1922 (syn. *Reighardia cincinnalis* Vaney & Sambon, 1910) (Pentastomida) is common in Nile crocodiles *Crocodylus niloticus* Laurenti on the African continent (Sambon, 1922; Heymons, 1940; Fain, 1961; Junker, 1996). Although known for a long time, little information was available on the life-cycle of *L. cincinnalis* and the descriptions given were often inadequate. Riley & Huchzermeyer (1996) re-assessed the genus *Leiperia* Sambon, 1922 and re-examined material of *L. cincinnalis* collected by various authors. None of the collections included mature males, but the morphology of the females, nymphs and pre-adults were described in considerable detail (Riley & Huchzermeyer, 1996).

In 1995 and 1998 experimental and field studies were conducted on pentastome infections of fish and crocodiles in the Kruger National Park (KNP) in South Africa (Junker, 1996; Junker, Boomker & Booyse, 1998a,b). Although the pentastome genera *Alofia* Giglioli, 1922 and *Sebekia* Sambon, 1922 were recovered from the crocodiles, in this paper we describe our findings and present additional data on the measurements and morphology of the females and the infective larvae of *L. cincinnalis*. The eggs and primary larvae are also described, and observations on the life-cycle are provided. The morphology of the males of *L. cincinnalis* is described for the first time.

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Table 1. Collection data of Nile crocodiles from the Kruger National Park.

Host number	Date collected	Locality	Sex	Length (m)	Condition
A/95	22/2/95	Phabeni Dam (25°1′ S, 31°15′ E)	M	3.2	good
B/95	27/6/95	Shimuwini Dam (23°42′ S, 31°17′ E)	M	3.3	emaciated
1/98	10/6/98	Silwervis Dam (23°13′ S, 30°12′ E)	F	2.8	good
2/98	10/6/98	Silwervis Dam (23°13′ S, 30°12′ E)	M	2.4	good
3/98	10/6/98	Silwervis Dam (23°13′ S, 30°12′ E)	F	3.2	good
4/98	10/6/98	Silwervis Dam (23°13′ S, 30°12′ E)	F	2.7	good

F, Female; M, Male.

Materials and methods

The collection data of the crocodiles examined are listed in Table 1. The crocodiles from the Phabeni and Silwervis Dams were caught in a baited cage and immobilised with gallamine triethiodide (Flaxedil^{TM}) before they were shot. The specimen from the Shimuwini Dam was killed with a single shot through the brain.

The nasopharynx, trachea, lungs, heart and aorta of each crocodile were examined. After removal of the trachea and the oesophagus, the nasopharynx, especially the area just above the internal nostrils, was visually checked for pentastomids belonging to the genus *Subtriquetra* Sambon, 1922. The trachea was opened lengthwise and all *Leiperia* removed. The lungs were cut open along the bronchi and bronchioles using a pair of scissors and placed into trays containing phosphate buffered saline (PBS). Pentastomes were either removed directly from the lung tissue or collected from the PBS after migrating out of the lungs.

The heart and its blood vessels were cut open and the chambers and inner surface of the blood vessels examined.

For morphological studies pentastomes were fixed and stored in cold 70% ethyl alcohol, and later mounted and cleared in Hoyer's medium. Those pentastomes used for infection of the intermediate fish hosts were kept in PBS.

Twenty-four Mozambique bream *Oreochromis mossambicus* Peters (50–70 mm long, obtained from a local breeder) were infected with eggs of *L. cincinnalis* from the crocodile from the Phabeni Dam. Eggs were collected from the posterior part of the uterus and concentrated in regular tap-water. In order to check the viability of the eggs, a drop of the egg-suspension was heated to 30°C and the number of hatched larvae was estimated.

Groups of four bream each were placed into one-litre beakers supplied with air stones and filled with 600 ml of water. To each beaker a drop of the egg-suspension was added. The fish were infected overnight and all died after 6–8 d. Within a few hours of death the abdominal cavity of each fish was opened by ventral incision and rinsed over a 38 μm sieve. The stomach, intestine and swim-bladder of each were placed between two perspex slides exerting light pressure. These, as well as the residue on the sieve, were examined under a stereoscopic microscope.

Results

Leiperia cincinnalis is a common pentastome in the Nile crocodile and five of six crocodiles examined in this study harboured this parasite (Table 2 summarises the numbers and developmental stages recovered from the respective hosts).

Three adult *L. cincinnalis* females were attached to the trachea and three infective larvae recovered from the pulmonary artery of Crocodile A/95 while Crocodile B/95 harboured 15 patent females in the trachea and bronchi. A total of 64 immature instars were recovered from the lungs, the heart and mainly the aorta pulmonalis, where the immatures occurred in two clusters.

A single infective larva of *L. cincinnalis* was found in the lungs of Crocodile 1/98, and a cluster of 47 specimens, representing different developmental stages together with cast cuticles, were recovered from the aorta pulmonalis. Six of the *Leiperia* were fully-developed males. In two other specimens well sclerotised cirrus tips were visible, but the single hooks, the oral cadre and the copulatory spicules were hardly chitinised. Eleven of the parasites were infective nymphs carrying double hooks. Many of the specimens with

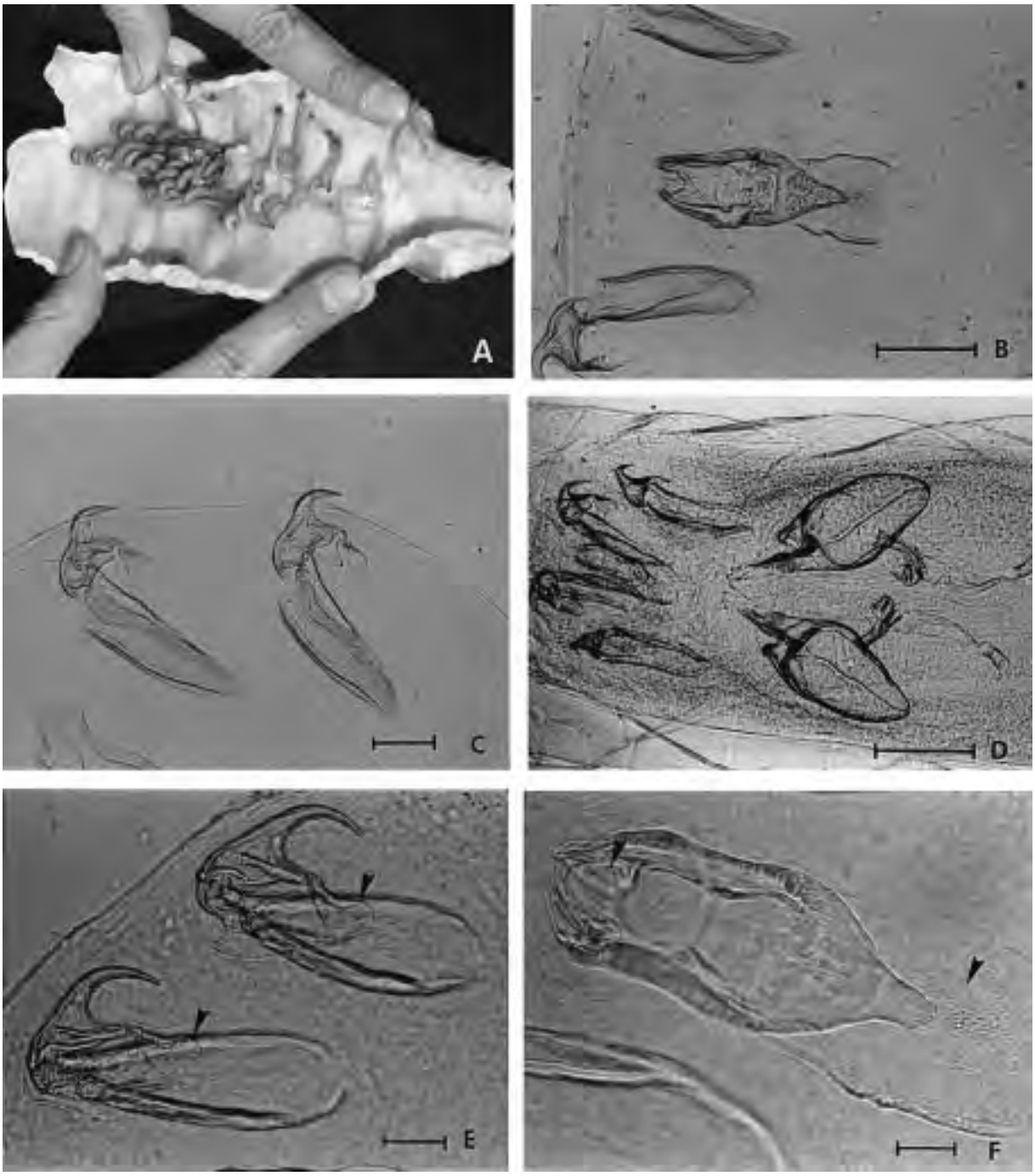

Figure 1. A. Mature females attached to a bronchus of the crocodile from the Shimuwini Dam, Kruger National Park. B. The right anterior hook and oral cadre of a mature female recovered from the same crocodile. The hook carries a distinct dorsal notch. C. Detail of the left hooks of another mature female from the Shimuwini crocodile, possessing a prominent dorsal notch. D. The anterior part of a male (No. 4.18/98) showing the hooks, the oral cadre and the copulatory spicules. The elaborate cirrus tips as well as the chitinised armoured tubes that form part of the cirri are visible furthest right. E. Detail of the left posterior and anterior hook of the male recovered from the trachea (No. 2.3/98). The hooks are flat-topped with only a slight indent in the dorsal margin. The anterior apodemes are lobe-like and permeated by pores (arrows). F. Oral cadre of specimen No. 2.3/98 showing the numerous pores around the pharynx as well as the large anterior flanges (arrows). *Scale-bars*: B,D, 400 μm; C, 200 μm; E, 100 μm; F, 50 μm.

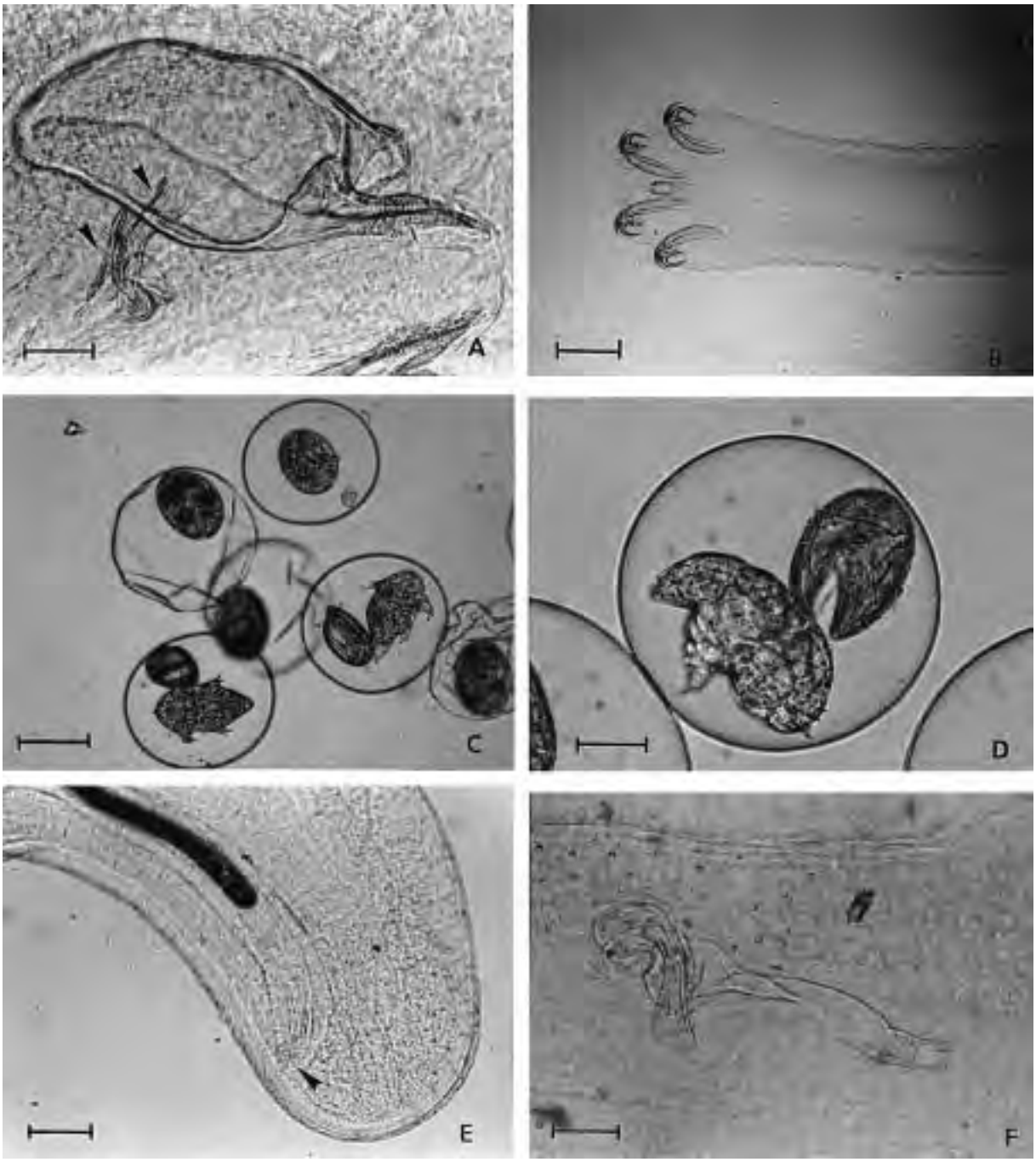

Figure 2. A. Right copulatory spicule (No. 4.19/98). The collar around the spatulate extension is heavily chitinised and carries rings of chitin. The cirrus tip is flared (upper arrow) and accompanied by a strongly-chitinised scoop-like structure (lower arrow). B. The anterior part of an infective larva, showing the large double-hooks and the comparatively small oral cadre. C. Eggs of *L. cincinnalis* and two hatching primary larvae. D. Detail of a primary larva and split inner egg membrane. E. Posterior end of female (No. 2.1/98) found *in copula* showing the eversed vaginal lips (arrow). Part of the ruptured cirrus, visible as a transparent thread (left), is next to the abdomen. F. Cirrus tip of the male located in the vagina of No.2.1/98. Note the prominent chloride cell pore caps on the cuticula of the female. *Scale-bars*: A,C,F, 100 μm; B,E, 500 μm; D, 50 μm.

Table 2. The numbers and developmental stages of *Leiperia cincinnalis* recovered from Nile crocodiles in the Kruger National Park.

Host number	Developmental stage				Total
	Females	Males	Pre-adults	Infective larvae	
A/95	3	0	0	3	6
B/95	15	0	7	57	79
1/98	0	6	30	12	48
2/98	2	1	0	0	3
3/98	0	0	0	0	0
4/98	7	10	22	33	72

simple hooks were still surrounded by the old cuticula of the infective larva.

Crocodile 2/98 harboured two female *L. cincinnalis* in the trachea and a single male was found attached next to one of the females. The cirrus tips were absent and the anterior part of the spatulate extension of both the copulatory spicules projected through the anterior genital opening. One of the cirrus tips was seen in the anterior third of the vagina of female No. 2.1/98 (Figure 2F) and the vaginal lips of the latter specimen were still everted (Figure 2E). The female was 4.5 cm long and 1 mm wide, and the abdomen was only just beginning to coil. No *Leiperia* were found in the pulmonary artery or the lungs.

No *L. cincinnalis* were recovered from Crocodile 3/98, but Crocodile 4/98 harboured 72 specimens. Eleven females, ranging in body length from 4.5 to 10.5 cm, were attached to the trachea and the uteri of four, all of them less than 6 cm long, contained no eggs, but the latter were present in the remainder. Two prepatent *Leiperia* females were found in the lungs but were damaged in the recovery process. The remaining 59 specimens were collected from the pulmonary artery, where they formed a cluster similar to that found in Crocodile 1/98. A total of 15 males were isolated from this cluster; 10 of these were fully mature, but in the remainder the copulatory spicules were not yet fully developed. One of the mature males was still within the cuticula of the infective larva and the simple hooks of another preceding instar were visible. The sex of another 11 *L. cincinnalis*, with simple hooks, remained undetermined. In addition, 33 infective larvae were present.

Six days after the experimental infection, two *O. mossambicus* were found dead and during the following two days all the fish died. Upon dissection, empty egg shells or the primary larvae themselves were found in the stomach and anterior part of the intestine. We also recovered intact pentastomid eggs, the majority of which were unsegmented. The primary larval count in seven fish was 18, 12, 1, 25, 16, >40 and >50.

***Leiperia cincinnalis* Sambon, 1922**

Description

Females (Table 3)
The general morphology of the females of *L. cincinnalis* examined in this study conformed largely to that described by Riley & Huchzermeyer (1996). Additional and comparative data are presented in Table 3.

Every fully-mature, gravid female examined (n = 6) possessed hooks with a prominent dorsal notch (Figure 1B,C). Two females recovered from the trachea (No. 2.1/98 and No. 4.7/98, 5.5 cm long) had hooks marked by only a slight indentation in the dorsal surface. These specimens were considerably shorter and had not reached patency. The hooks, as well as measurements of the oral cadre of one specimen (No. 4.7/98), were slightly smaller than those of the patent females. An immature female from the aorta pulmonalis carried flat-topped hooks, while those of another specimen (No. 2.1/98) could not be measured.

Males (Table 4)
Well-fixed male specimens possessed a straight, cylindrical abdomen, tapering slightly to a rounded end. The male recovered from the trachea was 2.0 cm long while the body length of 3 males taken from the aorta ranged from 1.8 to 2.0 cm.

Heavily chitinised fulcra supported the prominent hooks (Figure 1E). In comparison to the length of the hooks, the fulcra appeared rather broad and compact.

Table 3. The main characteristics of female *Leiperia cincinnalis* recovered from Nile crocodiles in the Kruger National Park in 1995 and 1998. For comparative purposes data of Riley & Huchzermeyer (1996) and Junker (1996) are included. All measurements are in micrometres unless otherwise indicated.

Source	Specimen number	Number of annuli	Body length (mm)	Mouth dimensions			Hook dimensions			
				Overall length	Cadre length	Width	Hook length	Base length	Hook depth	Fulcrum length
This paper	4.1/98	NM	105	920	727	285	NM	NM	NM	NM
	4.3/98	NM	100	925	750	322	313	259	NM	NM
	4.7/98[a]	NM	55	690	552	212	262	203	86	528
	4.9/98	NM	95	NM	NM	NM	353	267	94	644
	2.1/95	NM	NM	925	736	308	NM	NM	NM	NM
	2.2/95	NM	NM	925	745	281	NM	NM	NM	NM
Junker (1996)	CWT2	NM	131	NM	NM	NM	354	NM	NM	645
	CWT3	100	110	824	689	275	348	NM	NM	651
	Lei3	100	120	915	750	NM	355	NM	NM	703
Riley & Huchzermeyer (1996)	1947.12.1.57-59	NM	NM	NM	NM	NM	480	220	NM	810
	1927.11.15.28-30	NM	NM	NM	NM	NM	463	218	NM	705
	1932.7.22.1	NM	85?	1020	850	375	400	180	NM	640

[a]Uterus devoid of eggs.
NM, Not measured.
The term “base length” in this paper refers to the same structure as the term “hook depth” used by Riley & Huchzermeyer (1996).

Table 4. The main characteristics of the males of *Leiperia cincinnalis* recovered from Nile crocodiles in the Kruger National Park. All specimens were recovered from the pulmonary artery (AP), excepting 2.3/98 from the trachea of Crocodile 2/98. For comparative purposes data of three immature males (1927.III.10-6-11) examined by Riley & Huchzermeyer (1996) are included. All measurements are in micrometres.

Specimen number	Mouth dimensions			Hook dimensions				Copulatory spicules				
	Overall length	Cadre length	Width	Hook length	Base length	Hook depth	Fulcrum length	Total length	Cowry shell length	Width	Length of armoured tube	Number of grooves
4.18/98	432	340	106	194b	150b	90b	420b	782	607	NM	104	14
4.19/98	405	306	120	NM	NM	NM	NM	757	612	NM	113	13
4.20/98	426	338	113	232a	166a	87a	437a	782	605	207a	108	14a
4.21/98	474	363	113	232a	163a	90a	426b	814	637	NM	115a	11
4.22/98	465	366	NM	240b	166b	78b	447b	817	621	202a	124a	13
4.23/98	460	343	124	216a	161a	NM	431c	780	614	NM	115a	13
4.24/98	458	336	129	196b	153b	NM	411	821	623	NM	127	12
4.25/98	451	331	120	189a	145a	NM	423c	819	621	NM	133a	13
4.26/98	449	343	133	NM	NM	NM	432b	803	616	NM	120	14
4.27/98	446	331	120	244b	174b	NM	407a	798	623	NM	133a	16
1.16/98	426	317	104	NM	NM	NM	428b	NM	637	NM	110a	NM
1.17/98	NM	NM	NM	216a	152a	90a	NM	791a	607	NM	104	NM
1.18/98	NM	NM	NM	255a	182a	90a	437a	805a	649a	NM	NM	NM
1.19/98	462	340	110	245c	171c	87c	NM	837	637	NM	108	14
1.20/98	497	386	115	206b	158b	93b	NM	787a	616a	NM	101a	NM
1.6/98	492	386	136	245c	169c	82c	453a	844	628	NM	129	12
Average (AP)	453	345	119	224	162	87	429	802	622	205	116	13
SD (AP)	26	23	10	23	11	5	14	24	13	NM3	11	1
2.3/98	405	320	127	273	170c	81c	NM	780	614	NM	NM	13a
1927.III.10-6.11d	NM	NM	NM	290	NM	115	645	NM	NM	NM	NM	NM
	NM	NM	NM	280	NM	120	600	NM	NM	NM	NM	NM
	430	280	125	NM	NM	120	580	NM	NM	NM	NM	NM

[a]Only one feature was measured.
[b]Only two features were measured.
[c]Only three features were measured.
[d]After Riley & Huchzermeyer (1996).

The anterior apodeme of the hooks widened into a lobe-like structure permeated by numerous pores (Figure 1E). A certain degree of variability characterised the hook morphology of male *L. cincinnalis* (n = 17). In some specimens the hooks were flat-topped, in others only slight depressions were visible and in yet others, hooks had a distinct dorsal notch. Flat-topped hooks and hooks with a dorsal notch could at times be seen in the same specimen. The hooks and fulcra of the males were considerably shorter than those of the females and the measurements were actually nearer to those of the infective larvae (Junker, 1996). However, their gross morphology closely resembled that of females. This was true of the oral cadre with its characteristic *Leiperia* shape (Figure 1F). Starting in the posterior third of the oral cadre, the lateral prongs of the oral cadre merged gradually, giving it a V-shaped profile (Riley & Huchzermeyer, 1996). Both the large anterior flanges, as well as the area between the sclerotized supports of the pharynx, possessed the same pores as females (Riley & Huchzermeyer, 1996) (Figure 1B,F).

The paired copulatory spicules were strongly chitinised and the spatulate anterior extension carried an average of 13 rings of chitin folds while the collar around the neck of the latter extension was marked by heavy chitinous rugosities (Figures 1D, 2A, 3A,B). The cirrus tip was “a flattened trumpet of longitudinally-striated chitin” (Riley & Huchzermeyer, 1996) (Figures 2A, 3A,C) and the whole structure was demarcated from the remaining unmodified section of the cirrus by “a short armoured tube supported by rings of chitin”, as described for *Leiperia australiensis* Riley & Huchzermeyer, 1996 by the latter authors. Parallel to the trumpet, and in close association, a second chitinous structure was visible (Figures 2A, 3C). This structure gave the impression of a scoop with serrated sides rolled up towards the mid-line. It was very similar in shape to the gubernaculum of *Sambonia lohrmanni* (Sambon 1910) Noc & Giglioli, 1922 (see Fain, 1961). While often separated under cover-slip pressure, in some specimens the trumpet ran through the scoop and the latter served as a support.

Infective larvae (Table 5)

The distinctly elongate and slender body, together with the rounded shape of the head, gave the infective larvae of *L. cincinnalis* a characteristic appearance, which sets it apart from other sebekiid larvae (Junker et al., 1998a). As detailed descriptions of the morphology of the infective larvae of *L. cincinnalis* are available (Junker, 1996; Riley & Huchzermeyer, 1996), we present only the main measurements of infective larvae examined in this study.

Primary larvae

The primary larvae (Figures 2C,D, 3D) have a distinct penetration apparatus located in front of the U-shaped mouth ring, in the anterior part of the body. It consisted of a lancet-shaped median stylet and 2 lateral stylets. The latter were split into a Y-shaped tip with 2 blades. Two pairs of stubby limbs were double-hooked and the tip of the tail carried 2 minute chitinous terminal thorns. Curled larvae measured 101 ± 7 μm (n = 11), but reached 122 ± 9 μm in length when the double-hooked tail was extended. The width of the primary larvae taken midway between the front and the hind pair of limbs averaged 60 ± 5 μm.

Eggs

The eggs of *L. cincinnalis* (Figure 2C,D) consisted of 2 membranes: a spherical outer shell, 233 ± 14 μm in diameter which surrounded a hyaline substance; and an ovoid inner membrane, 103 ± 13 μm long and 80 ± 7 μm wide, which enclosed the primary larva.

Of the eggs recovered from the posterior part of the uterus, 64% contained fully-developed primary larvae, of which 19% hatched when warmed to 30°C. When placed into a hypertonic sugar solution the eggs lost their spherical shape and shrivelled up. Depending on the time of exposure, eggs would swell up again when transferred back into regular tap-water.

Primary larvae hatched in 2 stages. Using its penetration apparatus and the claws, the primary larva started tugging at the inner membrane until it broke. Subsequently, the larva stretched to its full length, unfolding its ventrally curved tail, and started random movements which split the outer egg membrane lengthwise, setting the larva free.

Movements during the migration through host tissue were stereotyped, and fore and hind extremities were used alternately. While the anterior pair of limbs pulled towards the body, the posterior limbs moved away from the body in a downward motion. Subsequently, the hind limbs were brought back to the ventral side and the anterior limbs were spread widely. At the same time the tail alternately stretched and curled ventrally.

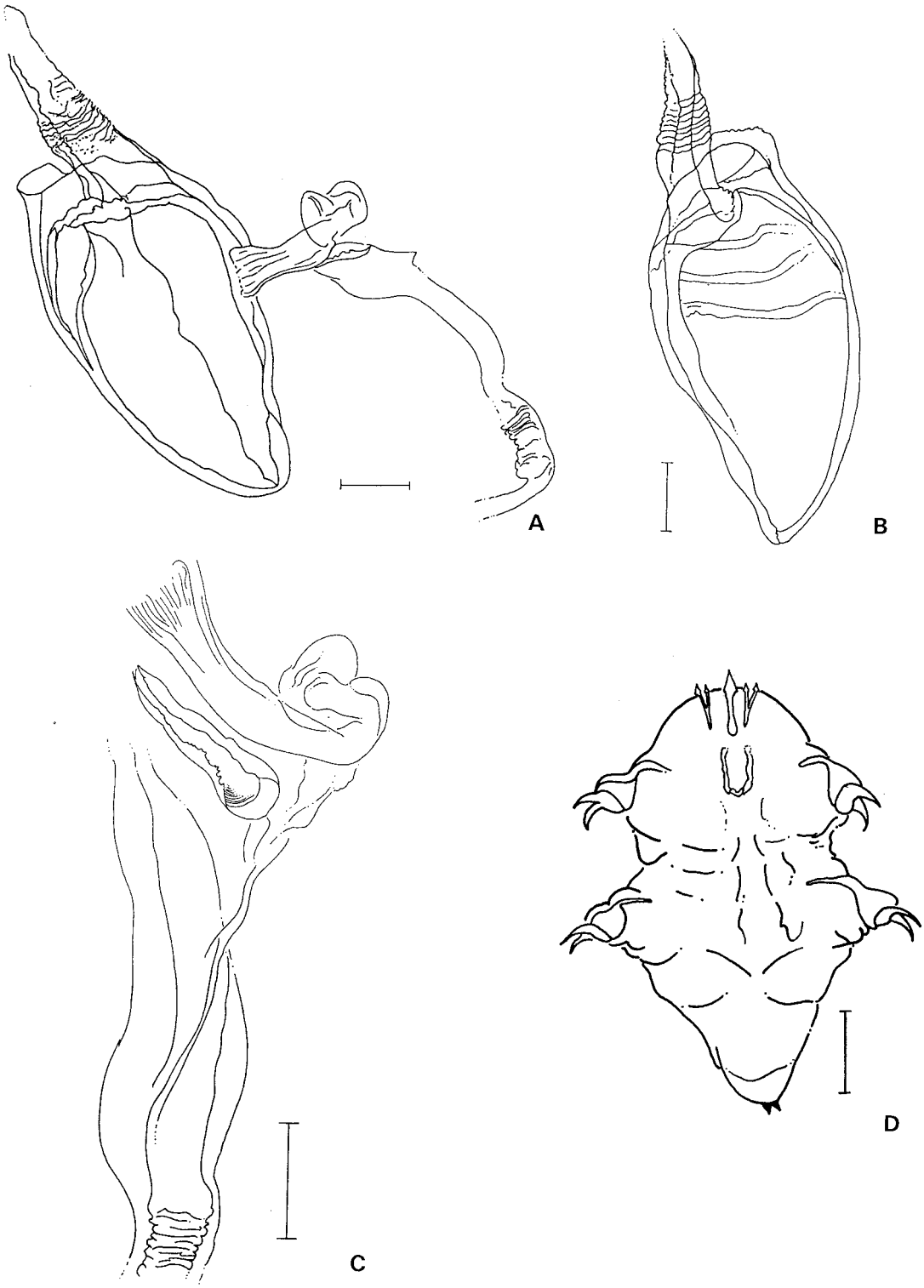

Figure 3. A. Right copulatory spicule and cirrus tip (No. 4.18/98). B. Left copulatory spicule (No. 2.3/98). C. Detail of cirrus tip (No. 4.27/98). D. Primary larva showing the penetration apparatus, the U-shaped oral cadre, the clawed limbs and the tail carrying two minute terminal thorns. *Scale-bars*: A-C, 100 μm; D, 25 μm.

Table 5. The main characteristics of the infective larvae of *Leiperia cincinnalis* recovered from Nile crocodiles from the Shimuwini Dam and from cichlids from the Phabeni Dam in the Kruger National Park in 1995 (LM19, LM20). For comparison additional data are included (Riley & Huchzermeyer, 1996; Junker, Boomker & Booyse, 1998a). All measurements are in micrometres unless otherwise indicated.

Source	Specimen number	Number of annuli	Body length (mm)	Mouth dimensions			Hook dimensions	
				Overall length	Cadre length	Width	Hook length	Fulcrum length
This paper	CW12.2	105	35	447	343	146	290	577
	CWA1	99	22	416	291	117	250	577
	CWA2	105	38	NM	NM	NM	299	563
	CWA3	104	31	424	333	130	262	622
	CWA4	98	23	421	296	125	256	517
	CWA5	105	25	471	341	140	287	587
	CWA9	104	30	437	322	153	278	609
	CWH4	106	28	437	333	138	265	561
	Average	103	29	436	323	136	273	577
	SD	3	6	19	21	13	18	32
Junker, Boomker & Booyse (1998a)	LM19	100	22	377	281	120	243	545
	LM20	NM	27	406	315	133	287	567
Riley & Huchzermeyer (1996)	F1832	106	21	400	285	113	270	620
	F1832	107	22	NM	NM	NM	280	650
	F1832	106	22	420	310	125	260	550

NM, not measured.

Discussion

Leiperia cincinnalis was the dominant pentastome species in the three crocodiles from the Silwervis Dam, but the intensity of infection was variable. Infective larvae and pre-adults recovered from the pulmonary artery accounted for most of these infections (Table 2).

The development of *L. cincinnalis* in its final hosts has been largely speculative. Rodhain & Vuylsteke (1932) described tufts of double- as well as single-hooked larvae attached to the aorta of a crocodile from the Congo. Their reference to the genital apparatus being more developed in the single-hooked specimens suggested the presence of males, but, unfortunately, these authors did not describe them. Rodhain & Vuylsteke (1932) discussed the possibility of an obligatory developmental phase in the circulatory system, but thought it exceptional rather than the rule. That it is indeed a specific pattern of development within the genus of *Leiperia* has since been confirmed in *L. australiensis* and by this study. We recovered infective larvae, as well as young females, from the lungs. Thus the lungs are a route of migration for the infective larvae on their way to the cardio-vascular system and for the adults on their way to their attachment sites in the trachea. Considering the high numbers of infective larvae and young adults often encountered in the pulmonary artery, the question arises why comparatively few adults are found in the trachea. This is especially true for the males, which occur in substantial numbers in the cardio-vascular system, but hardly ever in the trachea or lung. The relatively shorter life-span of male versus female pentastomes may partly explain this (Riley & Self, 1980; Riley, 1986; Junker et al., 1998b). Whether the majority of pre-adults get lost during migration, or whether an immune reaction from the host reduces their number, will remain speculative until more extensive studies can be undertaken.

A male and a female *L. cincinnalis*, recovered from one crocodile were attached next to each other in the trachea and probably had been *in copula* but were separated during recovery. We conclude that *L. cincinnalis* copulate in the trachea and not in the circulatory system; Riley & Huchzermeyer (1996) had already stated their doubts as to the likelihood of such a difficult procedure taking place in the narrow surroundings of the pulmonary artery.

We have found males with single hooks and completely developed copulatory spicules still encased in the cuticle of the infective larva in the pulmonary artery and this supports the speculation of Riley & Huchzermeyer (1996) that only one moult is necessary for the infective larva to develop into a fully adult male. However, another fully mature male surrounded by both the cuticula of the infective larva and the cuticula of a preceding single-hooked stage indicates that the males of *L. cincinnalis* undergo at least one additional moult after having reached sexual maturity. Unlike moulting in females, moulting in the males does not seem to be related to any further growth. Specimen No. 4.18/98, in addition to the male recovered from the trachea, was well within the range of the measurements of the other males (Table 4). Once again, these data emphasise the variability of structures encountered when dealing with pentastomes as already stated by Riley & Huchzermeyer (1995).

Riley & Huchzermeyer (1996) compared the hook morphology of females of *L. cincinnalis* from Uganda and the Congo. While both Ugandan specimens had flat-topped hooks, the hooks of the two Congo specimens, one of them described by Fain (1961), were characterised by a dorsal notch. Riley & Huchzermeyer (1996) speculated that the difference in hook morphology might indicate geographical variation, pointing out that the data set was too small to draw any final conclusions.

Our collection comprises male and female *Leiperia*, some of which carry flat-topped hooks and some of which possess hooks with a dorsal notch; sometimes both hook types occur in the same specimen. Visibility of the dorsal notch in the hooks can be influenced by the orientation of the hooks under cover-slip pressure and, especially in females, it becomes more prominent as specimens mature and grow. The dorsal notch is generally more distinct in the females than in the males. Measurements of the males and females were relatively uniform, especially the dimensions of the copulatory spicules, and gave no indication of the presence of two species. Our findings suggest that all the specimens belong to *L. cincinnalis*.

This, however, does not exclude the existence of a second *Leiperia* species in Africa, especially in view of the fact that the flat-topped hooks of the Ugandan specimens were considerably larger than the notched hooks of specimens collected from South Africa. The size of the hosts, as well as the intensity of infection, may influence the final size reached by the parasites, but our data do not support this speculation. Morphometric analysis of mature females taken from the heavily infected crocodile from the Shimuwini Dam, from the moderately infected Crocodile 4/98, and

from the lightly infected Crocodile 2/98 did not differ substantially. Unfortunately, the oral cadres of the *Leiperia* from Uganda could not be measured and no male specimens were available for comparison.

In terms of gross morphology, the copulatory spicules of the *L. cincinnalis* males examined during this study and those of *L. australiensis* are very similar (Riley & Huchzermeyer, 1996). The cirrus tip in particular is very distinctive. The collar around the spatulate extension of the copulatory spicules of *L. cincinnalis* does not extend as far as the double collar found in *L. australiensis*. While the copulatory spicules of *L. cincinnalis* are larger than the ones of *L. australiensis,* the hook and mouth dimensions are quite similar.

Fish have long been known to be the intermediate hosts for *L. cincinnalis* (Fain, 1961) and field studies indicate that the infection with pentastomes has no adverse effect on the development of the intermediate host (Junker et al., 1998a). We believe that two factors are responsible for the high mortality of the experimentally infected *O. mossambicus*. These fish had a fungal infection that was aggravated by stress experienced during the experimental infection. Furthermore, we are convinced that the damage caused by the tissue migration of the hatched primary larvae contributed substantially to the subsequent death of the fish. This was especially true where 10 or more primary larvae were present.

It has been reported that porocephalid females shed a relatively high number of eggs per day, all of which contain fully-developed primary larvae (Riley, 1981, 1986). Junker et al. (1998b) recovered 3,400 eggs, 70% of which contained fully-developed, active primary larvae, from a single female *Sebekia wedli* Giglioli, 1922 that had been placed into phosphate buffered saline for one hour. While this figure is impressive, we are of the opinion that our experimental fish were exposed to a concentration of eggs that they would not normally encounter.

Once the eggs have been ingested by a suitable host, hatching of primary larvae seems to be a highly successful process, as most of the eggs recovered intact from fish did not contain fully-developed larvae.

The eggs of *L. cincinnalis* offer maximum protection for the primary larvae during the transition between the final and the intermediate host. Eggs are passed into the water via the faeces or sputum and depend entirely on chance ingestion by a bottom-feeding fish. The inner vitelline membrane is tough and it takes a considerable effort on the part of the primary larva to rupture it. Our findings suggest that the hyaline substance surrounding the inner shell protects the larva; however, the egg-shells are too thin to offer lasting protection from desiccation once removed from their natural aquatic environment.

Several authors have shown that pentastome eggs are in fact very resistant to environmental influences. Salazar (1965) found a high resistance towards acids and preservatives. Bosch (1987) reported that eggs maintained in physiological solution at 4–8°C remained infective for more than three months and assumed that high temperatures and dehydration were the main factors in killing larvae.

The eggs of *L. cincinnalis* began to hatch under cover-slip pressure when warmed to 30°C and needed no additional stimuli. Increase in temperature has the same effect in the pentastomid genera *Elenia* Heymons, 1932 (Porocephalida) and *Raillietiella* Sambon, 1910 (Cephalobaenida) (Bosch, 1987), but in *Reighardia sternae* (Diesing, 1864) Ward, 1899 (Cephalobaenida) hatching occurred only at 40°C (Banaja, James & Riley, 1975). These data reflect the physiology of their respective hosts. *R. sternae* has a direct life-cycle in homoiothermic seabirds (Banaja et al., 1975), which maintain a constant body-temperature of 37–41°C (Eckert, 1993), whereas the intermediate hosts of *Leiperia*, *Elenia* and *Raillietiella* are heterothermic.

The eggs of *L. cincinnalis*, as well as the hatching of the primary larva and subsequent movements during tissue migration, conform largely to those of *Porocephalus crotali* (Humboldt, 1808) Humboldt, 1811 of the Louisiana muskrat (Penn, 1942). It appears that the primary larvae of pentastomes are capable of generalised, very basic and stereotyped movements that are nevertheless sufficient for simple tissue migration from the alimentary tract into tissues.

Acknowledgements

We wish to thank the Board of Trustees, South African National Parks Board, for placing the animals at our disposal. This work was supported by a grant to the senior author from the Landesgraduiertenförderung, Baden-Württemberg, Germany.

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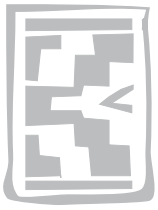

Description of *Pelonia africana* n. g., n. sp. (Pentastomida: Sebekidae) from the lungs of *Pelomedusa subrufa* and *Pelusios sinuatus* (Chelonia) in South Africa

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ABSTRACT

JUNKER, K. & BOOMKER, J. 2002. Description of *Pelonia africana* n. g., n. sp. (Pentastomida: Sebekidae) from the lungs of *Pelomedusa subrufa* and *Pelusios sinuatus* (Chelonia) in South Africa. *Onderstepoort Journal of Veterinary Research*, 69:53–59

The terrapins *Pelomedusa subrufa* and *Pelusios sinuatus* taken from a water reservoir in the Northern Province, South Africa, were examined for pentastome infections. Two immature specimens, a patent female and a mature male, were obtained from the lungs of four hosts, each of which harboured a single specimen. Based on the morphology of the specimens the new monospecific genus, *Pelonia africana* n. g., n. sp., is described. It is characterized by smooth, dorsally convex hooks with sharply bent blades. The oral cadre is more or less U-shaped. Delicate chitinous fibres, which can be difficult to see, connect the lateral prongs anteriorly. In this, as well as the morphology of the copulatory spicules, it is most like *Sebekia wedli*. The latter, however, possesses spinous hooks, which are absent in *P. africana.* The hooks are slightly and the copulatory spicules markedly larger in *P. africana* than in *S. wedli*. The lack of a double-hooked collar at the terminal end of the cowry-shell shaped base of each copulatory spicule and the absence of a peg-like extension of the oral cadre into the oesophagus, distinguishes *P. africana* from members of the genus *Alofia*.

The oral cadre of the South American species *Diesingia megastoma*, from aquatic chelonians, is more than twice the size than that of *Pelonia* and there is a distinct difference in shape. The hooks of the genus *Diesingia* are flat-topped, and both the anterior as well as the posterior fulcra carry cowl-like extensions. The number of annuli, 55–60 in *D. megastoma* and approximately 30 in *P. africana*, further separates the two genera. The most striking feature of *Diesingia* which sets it apart from *Pelonia* and the other genera of the family Sebekidae, is the configuration of its copulatory spicules.

Pelonia and *Diesingia* share morphological features with all the other sebekiids, but it is the unique combination of diagnostic characters that separates the two genera from those, as well as from each other.

Keywords: Chelonia, *Pelomedusa*, *Pelonia africana*, *Pelusios*, pentastomes, terrapins

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Accepted for publication 23 January 2002—Editor

INTRODUCTION

The majority of the six genera comprising the family Sebekidae Fain, 1961 occur exclusively in crocodilians. However, it has been speculated that a single species of the genus *Sebekia* Sambon, 1922 may also reach maturity in piscivorous turtles (Dukes, Shealy & Rogers 1971). Until now, only the South American genus *Diesingia* Sambon, 1922 has been known to be exclusive to a chelonian definitive host (Sambon 1922; Heymons 1941; Over-

street, Self & Vliet 1985; Riley 1994) and, generally speaking, information on the pentastome fauna of tortoises, terrapins and turtles is scarce.

Fain (1961) refers to a nymphal pentastome found encysted in the liver of *Kachuga lineata*, a semi-aquatic oriental tortoise, which Hett (1924) assumed to be the infective larva of *Subtriquetra megacephala* (Baird, 1853) Sambon, 1922. The latter genus belongs to the family Subtriquetridae Fain, 1961, which is also believed to be exclusive to crocodilians (Riley 1986; Winch & Riley 1986; Junker, Boomker & Booyse 1998a). In addition, some five genera of terrapins from North America have been reported to harbour nymphs of *Sebekia mississippiensis* Overstreet, Self & Vliet, 1985, a crocodilian pentastome described from the American alligator, *Alligator mississippiensis* (Dukes *et al*. 1971; Boyce 1985; Overstreet *et al*. 1985). Significantly, all the literature cited above pertains to nymphal developmental stages of pentastomes.

It would appear that *Diesingia megastoma* (Diesing, 1836) (Sambon, 1922) is currently the only pentastome of which mature specimens have been recovered from the chelonian hosts, *Hydromedusa tectifera* and *Phrynops geoffroanus* (= *Hydraspis geoffroyana*) from Brazil (Diesing 1836; Heymons 1941; Self & Rego 1985; Da Fonseca & Ruiz 1956). The authors are not aware of any publications dealing with adult pentastomid parasites of chelonians from any other continent.

In this paper a pentastome from the lungs of two South African terrapins, *Pelomedusa subrufa* and *Pelusios sinuatus*, is described. *P. subrufa* occurs in pans, marshy areas and slow moving waters throughout southern Africa, and *P. sinuatus* inhabits large rivers and pans in the north-east of southern Africa. Both terrapins are omnivorous and fish form part of their diet (Patterson 1991).

Pelonia africana n. g, n. sp. shares morphological similarities with all the other genera of the family Sebekidae, but nevertheless possesses a unique combination of diagnostic criteria. Slide mounted specimens of *D. megastoma* were re-examined and found to be distinctly different from the pentastomes recovered from the South African terrapins. We thus consider it appropriate to erect a new genus to accommodate these specimens.

MATERIAL AND METHODS

In 2000 five *P. sinuatus* (host numbers Psin1–5) and a single *P. subrufa* (host number Psub1), with carapace lengths varying from 15–25 cm, were obtained from pans or marshy areas near the Arabie Dam, Northern Province. This dam is fed mainly by the Olifants River, but the Elands, Moses and Motsiphiri Rivers also feed into it (A. Hoffman, personal communication 2000).

Terrapins were either killed by intraperitoneal injection with sodium pentobarbitone (Eutha-naze™) or decapitated. The plastron and carapace were removed and the trachea, as well as the nasopharynx, were examined for pentastomes. The liver and heart were transferred into separate vials containing tap water, and the soft and delicate lungs were placed into a Petri dish, also containing tap water. Pentastomes were either dissected from the organs or collected from the tap water after they had migrated out of the organs. For morphological studies, pentastomes were fixed and preserved in 70 % ethanol and subsequently mounted in Hoyer's medium.

Three more pentastomid specimens, WIII/1, and Psub2/1 and Psub3/1 from the lungs of *P. sinuatus* and *P. subrufa* respectively, were collected during another unrelated study at the same locality and made available to us.

RESULTS

The nasopharynx and trachea of all hosts examined were free of pentastomes and hosts number Psin1, 3, 4 and 5 and Psub1 harboured no pentastomes at all. Single specimens of *P. africana* were recovered from the lungs of each of the remaining hosts. Premature females, without eggs in the uterus, were obtained from hosts WIII and Psin2. A gravid female collected from Psub2 contained eggs with fully developed primary larvae. A mature male was present in the lungs of Psub3.

Description of *Pelonia africana* n. g., n. sp. (Table 1)

Type hosts and Locality

Pelusios sinuatus and *Pelomedusa subrufa* from the Arabie Dam (24°53'S, 29°22'E), Northern Province, South Africa.

Type Material

Holotype male, no. T 2186 from *Pelomedusa subrufa*, allotype female, no. T 2187 from *Pelomedusa subrufa* and paratypes (immature) from *Pelomedusa subrufa* and *Pelusios sinuatus*, no. T 2188. All spec-

TABLE 1 Comparative measurements of *Pelonia africana* n. g., n. sp., *Diesingia megastoma* and *Sebekia wedli*. All measurements are given in micrometres unless otherwise stated

Specimen number	Body length (mm)	Number of annuli	Mouth dimensions			Hook dimensions		Copulatory spicules		
			Overall length	Cadre length	Width	Hook length	Fulcrum length	Total length	Cowry shell length	Width
WIII/1 (Paratype F, T 2188)	15	28	322	248	127	NM	NM	NA	NA	NA
Psin2/1 (Paratype F, T 2188)	13	27	313	216	133	115	239	NA	NA	NA
Psub2/1 (Allotype F, T 2187)	27	30a	380	301	182	NM	NM	NA	NA	NA
Psub3/1 (Holotype M, T 2186)	9	27	265	207	150	NM	NM	515	324	214
Diesingia megastoma M (After Heymons 1941)	7	70	NM	524	205	NM	NM	NM	NM	NM
Diesingia megastoma M (After Heymons 1941)	6	70	NM	496	180	140	NM	NM	NM	NM
Diesingia megastoma F (After Self & Rego 1985)	10	65	NM	670	380	140*	520	NA	NA	NA
Sebekia wedli F (After Riley & Huchzermeyer 1995a)	15–19	NC	355	229	121	80	176	NA	NA	NA
Sebekia wedli M (After Riley & Huchzermeyer 1995a)	8	NC	212	136	76	59	134	310	213	115

F Female
M Male
NA Not applicable
NC Not counted
NM Not measured
* Only the length of the blade was measured

imens are mounted in Hoyer's medium and deposited in the National Animal Helminth Collection, ARC-OVI, Onderstepoort, South Africa.

Etymology

Pelonia has been named after its two host species that belong to the family Pelomedusidae which comprises freshwater chelonians from Africa, Madagascar and southern Australia.

Description

The body is claviform, the abdomen being widest in the anterior third and tapering to a bluntly rounded caudal tip. Ventrally the small trapezoid cephalothorax is continuous with the ventrally flattened abdomen but dorsally demarcated from the remainder of the body. A small number of wide annuli are present.

Female

The strongly chitinised oral cadre is more or less U-shaped, the gap between the lateral prongs only slightly narrowing anteriorly. Muscle contraction or the amount of pressure applied when mounting, can result in a more ovoid profile. The oral cadre appeared to be open anteriorly as the delicate chitinous fibres connecting the two sides were difficult to see. A heavily chitinised, bowl-shaped base unites the two lateral prongs posteriorly (Fig. 1B, C). The oral cadre of the allotype female was slightly larger than that of the two immature specimens, WIII/1 and Psin2/1.

The smooth hooks are dorsally convex with a slight dorsal notch where the strongly curved blade emerges from the base (Fig. 1F). The configurations of the posterior and anterior hooks appear to be identical and are supported by strong fulcra. Unfortunately, measurements could only be made from a single hook from an immature female.

It was not possible to decide whether the females were heterogynous, with the utero-vaginal pore being situated one or two annuli anteriorly from the anus, or ophistogynous. The eggs of *P. africana* consist of a spherical outer membrane, 183 ± 8 mm in diameter that surrounds a hyaline substance and an ovoid inner eggshell, 96 ± 7 µm long and 70 ± 4 µm wide (Fig. 1G), that encloses the primary larva.

Male

Although the oral cadre of the male is slightly smaller than those of the two immature females (Fig. 1A), its general morphology, as well as that of the hooks and the fulcra, is similar to that of the females. The paired copulatory spicules are heavily sclerotised and cowry-shell shaped (Fig. 1D). The anterior spatulate extension carries rows of rounded, chitinous teeth, which become progressively indistinct towards the tip (Fig. 1E).

DISCUSSION

The body-shape of *P. africana* corresponds closely to the illustration of a mature female of *D. megastoma* from *H. tectifera* (Self & Rego 1985). One of the main differences between *P. africana* and *D. megastoma* lies in the oral cadre. That of *D. megastoma* is more than twice the length and width than that of the African species. Own observations show the oral cadre of *Diesingia* to carry a small peg-like extension into the oesophagus, not unlike that of the genus *Alofia* Giglioli, 1922, which is absent in specimens of *Pelonia*. Furthermore, the prominent bowl-shaped chitinous structure at the base of the oral cadre of the latter genus is absent in *Diesingia*.

Both genera of chelonian pentastomes possess smooth hooks. However, the fulcra of *Pelonia* are devoid of any extensions, while the fulcra of *Diesingia* are furnished with cowl-like extensions, similar to those seen in the genus *Selfia* (Riley 1994). The hooks of *D. megastoma* appear to be flat-topped with a sharply curved blade, demarcated from the shank by a single notch (Self & Rego 1985), while those of *P. africana* are dorsally convex and marked by a slight dorsal notch.

So far, no conclusive description of the copulatory spicules of *Diesingia* has been given, and the two male specimens we examined, possess copulatory spicules that are unique among the members of the family Sebekidae. The cowry-shell shaped base and the long spatulate extension of the open side are reminiscent of other sebekiid genera (Riley, Spratt & Winch 1990), but the shorter of the two anterior extensions has been transformed into a tiller-like, chitinous spike.

The genus *Pelonia* is distinct from the genus *Diesingia*, and represents the first record of a new genus of pentastomes exclusive to chelonian final hosts from the African continent.

Pelonia africana is similar to the African crocodilian pentastome *Sebekia wedli* Giglioli, 1922 in Sambon, 1922. This is especially true for the oral cadre, which in the latter species is also approximately U-

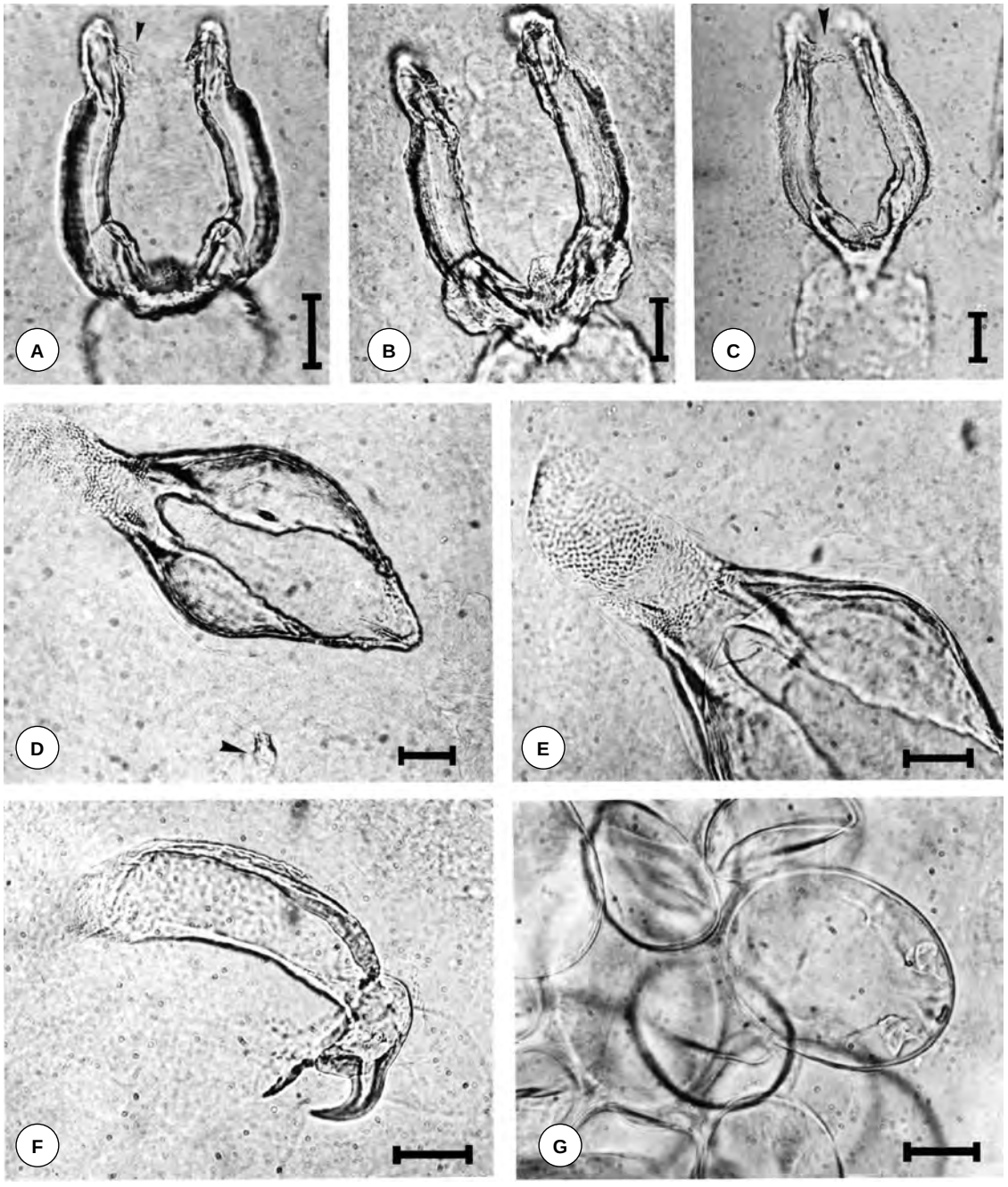

FIG. 1 *Pelonia africana* n. g., n. sp.

A Oral cadre of holotype male. The delicate chitinous fibres connecting the lateral prongs of the oral cadre anteriorly are partly visible (arrow). Scale bar: 50 mm

B Oral cadre of the allotype female. The anterior chitinous bridge is not visible in this photograph. Scale bar: 50 mm

C Oral cadre of an immature female. The chitinous fibres connecting the lateral prongs are clearly visible (arrow). Scale bar: 25 mm

D Ventral view of the right copulatory spicule of the holotype male. It is obpyriform and the spatulate extension carries small chitinous teeth. The arrow marks a chitinous part of the cirrus. Scale bar: 50 mm

E Detail of the left copulatory spicule

F Right posterior hook of an immature female. Scale bar: 50 mm

G Egg with fully developed primary larva. Scale bar: 50 mm

shaped, and because of an almost invisible, very delicate anterior bridge of chitin, it seems to be open anteriorly (Riley & Huchzermeyer 1995a). A comparison of measurements, however, shows the buccal complex of *S. wedli* to be slightly smaller than that of *P. africana* (Riley & Huchzermeyer 1995a, Junker, Boomker & Booyse 1998b). The copulatory spicules of male *P. africana* are strongly reminiscent of *S. wedli*, and they could easily be confused, in that both are obpyriform and carry chitinous teeth on the spatulate extensions. Nevertheless, the spicules of *P. africana* are markedly larger than those of *S. wedli* (Riley & Huchzermeyer 1995a).

The main distinguishing character between *P. africana* and *S. wedli* is the absence of the prominent spines on the dorsal hook surface. The lack of anterior extensions to the fulcra further serves to separate *Pelonia* from the other species of the genus *Sebekia* as defined by Riley *et al*. (1990).

Superficially, the aspinose hooks, the curve of the blade and the shape of the oral cadre might lead to confusion of *P. africana* with the *Alofia* spp. The copulatory spicules of *P. africana*, however, lack the double-hooked collar diagnostic for *Alofia* and the genus *Selfia* Riley, 1994 (Riley 1994). Moreover, the oral cadre neither possesses the distinct, open *Alofian* U-shape nor the peg-like extension into the oesophagus (Riley & Huchzermeyer 1995a, b; Junker, Boomker & Bolton 1999).

Recently *Agema* Riley, Hill & Huchzermeyer, 1997, a new pentastomid genus, has been described from African dwarf crocodiles, *Osteolaemus tetraspis osborni*, and slender-snouted crocodiles, *Crocodylus cataphractus* (Riley, Hill & Huchzermeyer 1997). While the hooks of *P. africana* exhibit the already mentioned abrupt right-angle bend near the base, those of *Agema* are very smoothly curved and the ovoid oral cadre of the latter genus is closed anteriorly by prominent chitinous crescents (Riley *et al*.1997).

Pelonia africana morphologically resembles especially the genus *Sebekia* and to a lesser extent the genus *Alofia*. Heymons (1941) pointed out the similarity between *D. megastoma* and its South American sebekian and alofian counterparts. Therefore there is a strong case for the inclusion of the genera *Pelonia* and *Diesingia* into the family Sebekidae, as was suggested for the latter genus by Riley (1993). The fact that all sebekiid genera have a similar life-cycle using fish as intermediate hosts and semi-aquatic definitive hosts (Fain 1961; Riley 1986, 1994; Riley *et al*. 1997) indicates a close relationship between the two genera parasitising chelonians and those of crocodilians.

ACKNOWLEDGEMENTS

We wish to thank the Department of Agriculture, Land & Environment, Northern Province, for placing the animals at our disposal and Mr A.C. Hoffman, Department of Agriculture, Conservation and Environment, Mpumalanga, for collecting the hosts. Mr D. Hoffman has generously collected and provided the majority of specimens for this study. Our sincere thanks go to Dr J. Riley for letting us examine his collection of specimens of *D. megastoma*. This work was supported by a grant to the senior author from the Landesgraduiertenförderung, Baden-Württemberg, Germany and the Deutscher Akademischer Austausch Dienst, Germany.

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Redescription of *Diesingia megastoma* (Diesing, 1836) Sambon, 1922, a pentastomid parasite from the South American terrapin *Hydromedusa tectifera* Cope

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Accepted for publication 29th May, 2003

Abstract

Slide-mounted material of the pentastomid parasite *Diesingia megastoma* (Diesing, 1836) Sambon, 1922 from the South American chelonian *Hydromedusa tectifera* Cope is reviewed and the perfunctory, often omissive, description of the species is amended. The strong morphological similarities between *D. megastoma* and the crocodilian and chelonian pentastome genera of the family Sebekiidae Sambon, 1922, *Alofia* Giglioli, 1922, *Selfia* Riley, 1994, *Sebekia* Sambon, 1922, *Agema* Riley, Hill & Huchzermeyer, 1997, *Leiperia* Sambon, 1922 and *Pelonia* Junker & Boomker, 2002, clearly place *Diesingia* Sambon, 1922 within the same family. However, the unique combination of its main diagnostic criteria makes *Diesingia* a distinct genus. The absence of an elaborate, flared cirrus-tip in *D. megastoma* distinguishes it from *Leiperia*, while emphasizing its similarity to the remaining genera mentioned above. *D. megastoma* resembles *Alofia* in that it possesses smooth, flat-topped hooks and an anteriorly open oral cadre with an oesophageal peg. The copulatory spicules of *Diesingia*, however, lack the double-hooked collar, typical for *Alofia* and *Selfia*. Unlike the peg-like extension of the fulcra of the hooks of *Sebekia*, that of *D. megastoma* is cowl-like and carries spines only on the anterior fulcra. Moreover, the hooks of *Sebekia* are usually convex and spinose and the ovoid oral cadre is closed anteriorly. *Diesingia* differs from *Pelonia* through the latter's smooth but dorsally convex and extension-free hooks. The copulatory spicules of *Pelonia* and *Agema* are reminiscent of the basic build found in *Sebekia*, whereas in *D. megastoma* the short, ventral extension of the cowry shell-shaped base of the copulatory spicules has been transformed into a structure resembling the collembolan fulcrum. The latter is connected to the base via a joint, a configuration which is unique in the Sebekiidae.

Introduction

Despite their discovery more than one-and-a-half centuries ago, the present knowledge on pentastomes parasitising chelonian final hosts is scant. A single species, *Diesingia megastoma* (Diesing, 1836) Sambon, 1922, from South American terrapins was recognised. It was first described from two adult males recovered from the lungs of a Geoffrey's side-necked turtle *Phrynops geoffroyanus* (Schweigger) (syn. *Hydraspis geoffroana*) in Brazil by Diesing as *Pentastoma megastomum* Diesing, 1836 (Diesing, 1836; Sambon, 1922; Fain, 1961). Since then, it has caused much confusion. The two original specimens, kept at the Museum of Natural History at Vienna, have been renamed and re-examined by several authors. Leuckart (1860), referring to Diesing's (1836) description only, changed the name to *Pentastomum megastomum*, while Shipley (1898) ex-

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amined the Vienna specimens himself. Without adding much detail to the initial, very superficial description, Shipley (1898) redescribed them as *Porocephalus megastomus*, a name previously given to them by Stiles (1893, in Sambon 1922) in accordance with the then common trend to include the majority of the exotic pentastomes in *Porocephalus* Humboldt, 1811 (Heymons, 1941).

When Sambon (1922) reviewed the known pentastomid genera, Diesing's type-specimens no longer fitted the diagnostic criteria of the genus *Porocephalus* and he suggested the inclusion of *P. megastomum* in the new genus *Diesingia* Sambon, 1922. This genus had been created to accommodate *D. kachugensis* Sambon, 1922 from the liver of *Kachuga kachuga* (Gray) (syn. *K. lineata*), a semi-aquatic oriental tortoise. Riley (1986) pointed out that Hett (1924, in Fain, 1961) considered *D. kachugensis* to be the larval stage of *Subtriquetra megacephala* (Baird, 1835) Sambon, 1922, a crocodilian pentastome. Heymons (1941) was the first author to provide a more detailed description of the type-specimens for which the name *D. megastoma* had become accepted, and included measurements and drawings of the hooks and the oral cadre. Da Fonseca & Ruiz (1956) created *Butantanella* Da Fonseca & Ruiz, 1956 to accommodate *D. megastoma* and the specimens of a collection of pentastomes recovered from the lungs of 15 *Hydromedusa tectifera* Cope from Brazil.

Self & Rego (1985) examined pentastome specimens from collections from the Instituto Oswaldo Cruz and from the British Museum (Natural History) Collection. These included fully mature males and females from the lungs of the Brazilian terrapins, *H. tectifera* and *P. geoffroanus*, and Self & Rego (1985) concluded that these were identical with Diesing's specimens. On morphological grounds, Self & Rego (1985) reclassified *D. megastoma* as *Sebekia megastoma*, dismissing Da Fonseca & Ruiz's (1956) previous classification.

The uncertainty surrounding its type-species led to considerable confusion as regards the systematic status of the genus *Diesingia*. Fain (1961) included it in the family Sebekiidae Sambon, 1922, whereas Riley (1983), in an outline classification of the pentastomes, placed the genus separately, directly following the genera of the family Sambonidae Fain, 1961, substituting the family name by a question mark. Subsequently, Self & Rego (1985) abandoned *Diesingia* in favour of *Sebekia* Sambon, 1922, a view that was not adopted by Riley (1986), who created the monogeneric family Diesingiidae Riley, 1986. In a later publication, Riley (1994) placed *Diesingia* back in the family Sebekiidae.

In this paper slide-mounted specimens of *D. megastoma*, collected from *H. tectifera* from Brazil, are described. Based on our findings, we support the validity of the genus *Diesingia* as well as its inclusion in the family Sebekiidae.

Materials and methods

All specimens described here were originally recovered from *H. tectifera* from Brazil by an unknown collector. The collection comprises slide-mounted specimens as well as specimens that had previously been fixed in formalin (Da Fonseca & Ruiz, 1956), but are now preserved in alcohol. These are, however, in an extremely poor condition and very brittle. The anterior and posterior hooks had been removed and mounted in Hoyer's medium several years ago and the bottle with alcohol specimens now contains only the abdomens of the specimens F2463-5, F2463-6 and KI-3. These are mature females, as evidenced by hook measurements and the egg-filled uteri of two specimens. The *D. megastoma* material studied comprises the following:

F2463-2. A male specimen, mounted whole and stained with a chromatin stain. The slide was originally labelled '*Butantanella megastoma*, from the Instituto do Butantan ex *Hydromedusa tectifera*' (see below).

F2463-3. A young female, mounted whole and originally identified as 'Butantan F 5960, *Butantanella megastoma* of the lung of *H. tectifera*, from the Paraná State, Brazil'. The slide is dated 7 December, 1951 and carries the names Da Fonseca & Ruiz.

We conclude that F2463-2 and F2463-3 are two of the specimens on which Da Fonseca & Ruiz (1956) based their description of *B. megastoma*. In fact, Da Fonseca & Ruiz (1956) stated that specimen 5960 forms part of a collection of male and female pentastomes taken from the lungs of 15 *H. tectifera* in August, 1951 at Tranqueira, Paraná State.

F2463-4. A male specimen. The abdomen, including the copulatory spicules, is mounted on one slide and a second slide contains the posterior and anterior hooks, as well as the oral cadre. The latter, however, is severely damaged.

F2463-5 and F2463-6. The hooks of two females were dissected out and the posterior and anterior hooks are mounted under separate cover-slips on the same slide. The oral cadres of both specimens have apparently been lost.
KI-3. The whole slide-mounted cephalothorax of a mature female.

All measurements were made according to the procedures described by Fain (1961), Riley, Spratt & Winch (1990) and Riley (1994).

Diesingia megastoma (Diesing, 1836) Sambon, 1922

Description (Figures 1,2)

The abdomens of 2 alcohol-preserved females are slender and elongate, with pointed caudal tips that appear slightly curled ventrally. Since the only intact specimens are slide-mounted, little else can be said about the body-shape. In the male specimens F2463-4 and F2463-2, as well as in the female F2463-3, a single row of chloride cells with prominent pore caps is present on the anterior border of each annulus.

Females (Table 1) According to its slide label, specimen F2463-6 was 1.5 cm in length prior to the dissection of hooks from its cephalothorax. The single prepatent female, F2463-3, has 55-60 annuli, but, since the caudal tip is slightly damaged accurate counting is difficult. The same specimen possesses smooth hooks with long, slender, canaliculate blades that are sharply curved. A slight, but distinct, notch demarcates the blade from the flat dorsal hook surface. While the anterior and posterior hooks are equal in size, the morphology of their fulcra differs in that all possess a cowl-like anterior extension, but that the cowl of the anterior fulcra is spinose, while those of the posterior ones are smooth (Figures 1E,F, 2C,D). The hooks of 3 mature females are distinctly larger but otherwise similar to those described above. The cowl of the fulcrum is not always readily visible. The posterior hooks of specimen F2463-6 display the cowl clearly (Figure 2D) and a structure next to one of the anterior hooks is assumed to be the broken-off spinose extension of the fulcrum. The second anterior hook of specimen F2463-6 and the hooks of specimens F2463-5 and KI-3 are in too poor a condition to observe any extensions to the fulcra.

The oral cadre of the prepatent female is about half the size of that of KI-3, but otherwise similar in shape. Seen from a slightly lateral view, the overall profile is ovoid and the oral cadre is open anteriorly. A small peg-like extension into the oesophagus measures 23 μm in the young female (F2463-3) and 92 μm in specimen KI-3. The lateral prongs widen into chitinous lobes anteriorly (Figures 1B, 2A).

Males (Table 1) Specimen F2463-2 is 1.1 cm long and 58 annuli are present. The hooks of both males are more or less the same size as those of the young female and are morphologically similar. One of the anterior hooks of specimen F2463-4 has a spinose cowl of the fulcrum but no extensions could be seen in the remaining hooks. The hooks of specimen F2463-2 were too obscured by the dark stain to observe much detail.

The oral cadre of the male F2463-2 is slightly larger than that of the young female, F2463-3 and the peg-like extension into the oesophagus measures 60 μm (Figures 1A, 2B). Although seen ventrally, the shape of the oral cadre corresponds well with that of the female. Starting with a narrow base, the middle section of the oral cadre is slightly expanded, and narrows again towards the anterior end.

The copulatory spicules of the males consist of a cowry shell-shaped base from which 2 extensions protrude anteriorly (Figures 1C, 2F). The longer of the 2 extensions emerges ventrally, i.e. from the open side of the base. It consists of 2 lateral prongs that unite in the anterior half of the extension, to form a spatula. The distal half is reinforced by transverse cuticular ridges. The short extension emerges from an articulated joint at the closed dorsal side of the base. It is strongly reminiscent of the fulcrum found in collembolans and runs through the gap formed by the lateral prongs of the ventral extension (Figures 1D, 2E).

Discussion

Comparative measurements of *Diesingia megastoma* from the literature are presented in Table 2. The number of annuli counted by Heymons (1941) and Da Fonseca & Ruiz (1956) are slightly higher than those of Self & Rego (1985) and the present authors. We assume this variation to be a result of counting techniques as well as differences in the quality of the material. Heymons (1941) indicated, that the chloride cell pores of Diesing's two original specimens had become difficult to discern. Our counts exclude the tip of the tail, as well as the annuli on the cephalothorax that have incomplete rows of chloride cells.

Table 1. The main diagnostic characteristics of *Diesingia megastoma* (Diesing, 1836) from *Hydromedusa tectifera* Cope (Chelonia) from Brazil. In the case of the hooks and copulatory spicules, the figures on the left refer to the structures on the left and the figures on the right to the corresponding feature on the right side. All measurements are in micrometres.

Specimen no.	Sex	Oral cadre			Anterior hooks					Posterior hooks					Copulatory spicules		
		Overall length	Cadre length	Width	Hook length	Blade length	Base length	Plateau length	Fulcrum length	Hook length	Blade length	Base length	Plateau length	Fulcrum length	Cowry-shell length	Total length	Spike length
F2463-2	M	653	488	239	NM	NM	NM	NM	NM	166 NM	94 NM	60 NM	83 NM	281 NM	345 345	773 750	248 258
F2463-4	M	NM	NM	NM	184 NM	113 NM	58 NM	83 NM	373 NM	202 207	108 108	67 67	106 106	329 NM	303 363	754 741	184 235
F2463-3	F	570	446	207	163 NM	106 NM	62 NM	92 NM	334 NM	177 NM	99 NM	67 NM	104 NM	NM NM	NA	NA	NA
F2463-5	F	NM	NM	NM	260 258	143 136	108 97	145 154	442 451	244 246	147 140	99 94	133 147	NM NM	NA	NA	NA
F2463-6	F	NM	NM	NM	246 NM	136 NM	97 NM	133 NM	NM 506	255 253	124 131	87 101	147 145	NM NM	NA	NA	NA
KI-3	F	1081	814	NM	251 248	147 147	99 87	126 127	483 511	258 NM	138 NM	97 NM	145 NM	398 NM	NA	NA	NA

F, Female; M, Male; NA, Not applicable; NM, Not measured.

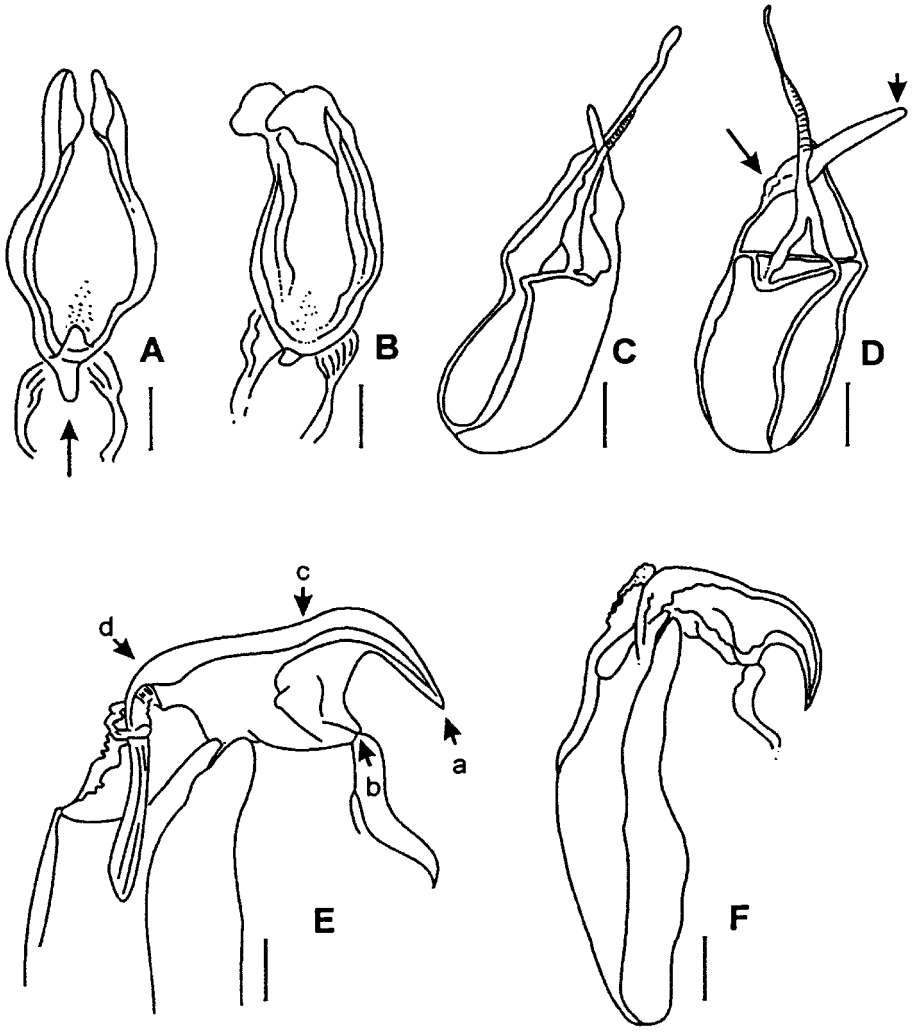

Figure 1. Diesingia megastoma. A. Ventral view of the oral cadre of male F2463-2 depicting the oesophageal peg (arrow). B. The oral cadre of female F2463-3 in ventrolateral view. The anterior chitinous lobes are prominent. C. Left copulatory spicule of F2463-4 seen ventrolaterally. D. Lateral view of the right copulatory spicule of the same male as in C. Note the cuticular ridges on the long spatulate extension. The shorter, fulcrum-like extension is jointed (large arrow); its length is the distance between the large and the small arrow. E. Posterior hook of female F2463-6 depicting the aspinose cowl-like extension of the posterior fulcrum. Points d and b are the points of insertion of the extensory and flexory musculature, respectively; Point c demarcates the notch in the dorsal hook surface. F. Anterior hook of female F2463-3. Note the spines on the cowl of the anterior fulcrum. *Abbreviations*: ac, blade length; ad, hook length; bc, base length; cd, plateau length. *Scale-bars*: A,B,C,D, 100 μm; E,F 50 μm.

According to Self & Rego (1985), the oral cadre of *D. megastoma* is closed anteriorly by fibres to form a ring. The same authors describe sharp anterior and posterior spurs that extend inwardly from the lateral prongs. Such structures were absent in the *Diesingia* material in the present study. Heymons (1941) described the oral cadre of *D. megastoma* as being U-shaped and open anteriorly, which is more in accordance with our findings. We believe the difference in shape of the oral cadre in Self & Rego's (1985) specimens to be due to a distortion caused by pressure while mounting the specimens. None of the previous descriptions (Heymons, 1941; Da Fonseca & Ruiz, 1956; Self & Rego, 1985) have mentioned the peg-like extension of the oral cadre into the oesophagus despite its being quite an obvious feature.

There is relatively little discrepancy in the description of the hooks of *D. megastoma* by earlier authors, all of which describe them as smooth, single and equal (Heymons, 1941; Da Fonseca & Ruiz, 1956; Self &

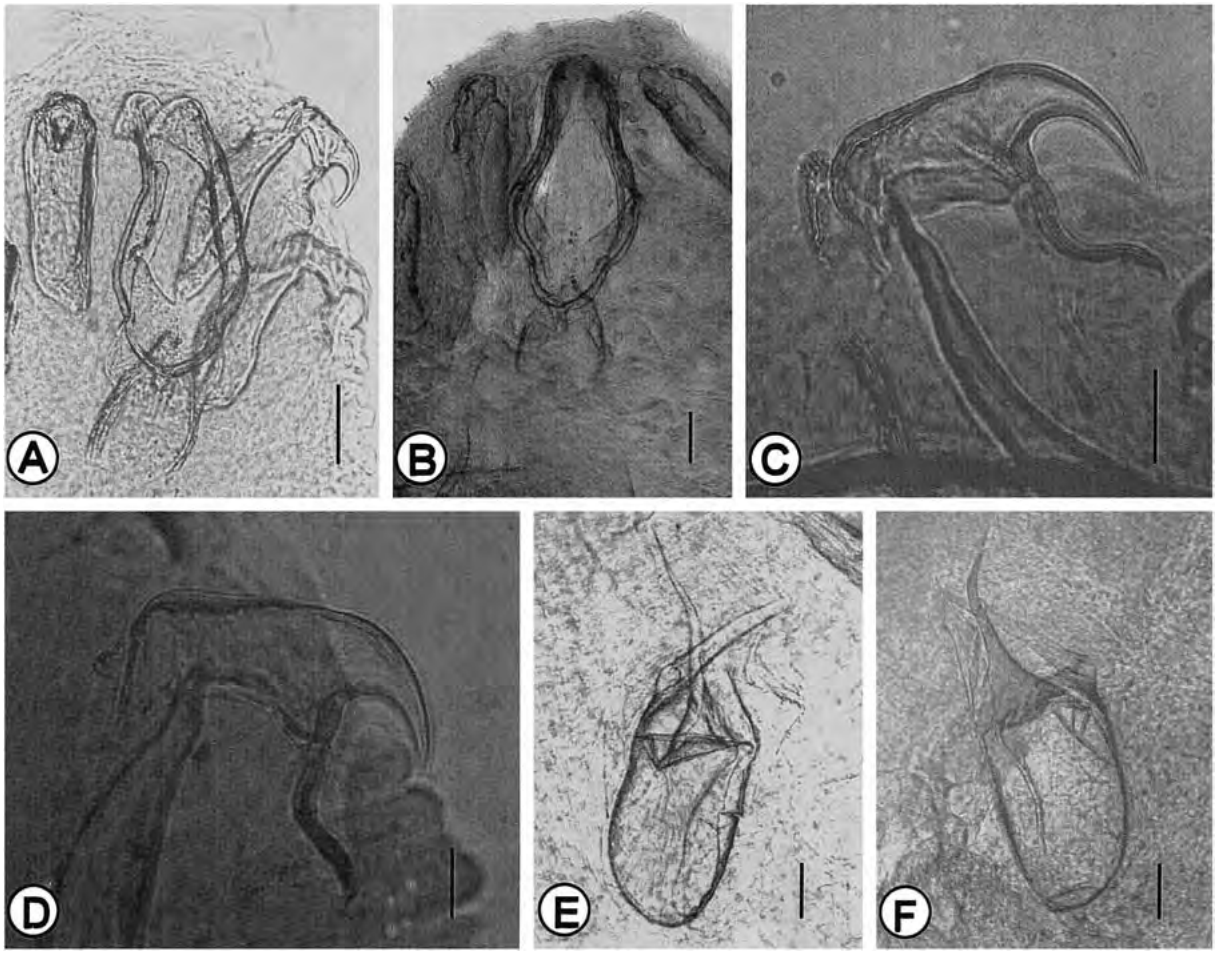

Figure 2. Diesingia megastoma. A. The oral cadre of female F2463-3. B. The oral cadre of male F2463-2. C. Close up of the left anterior hook of female F2463-3. D. Detail of the posterior hook of female F2463-6. E. Lateral view of the right copulatory spicule of male F2463-4. F. The left copulatory spicule of male F2463-4. S*cale-bars*: A, 120 μm; B,E,F, 100 μm; C,D, 50 μm.

Table 2. Comparative measurements of *Diesingia megastoma* (Diesing, 1836) found in the literature. All measurements are given in micrometres unless otherwise indicated.

Sex	Body length (mm)	Number of annuli	Oral cadre		Hooks				Source
			Cadre length	Width	Hook length (AD)	Blade length	Base length	Fulcrum length	
M	7	70	524	205	NM	NM	NM	NM	Heymons (1941)
M	6	70	496	180	140	NM	NM	NM	Heymons (1941)
F*	11 - 20	ca. 70	770	440	140?	140?	NM	550	Da Fonseca & Ruiz (1956)
F*	10	65	670	380	NM	140	110	520	Self & Rego (1985)

F, Female; M, Male; NM, Not measured.
*Combined data of several females; ?, It is not clear which of the two measurements the authors refer to.

Rego, 1985). Two shallow dorsal notches are visible in Heymon's (1941) drawing of a hook and, otherwise, it conforms well with that of Rego & Self (1985). In our experience, slight differences in the orientation of specimens on the slide on which they are mounted can interfere with the visibility of certain structural characteristics, and we attribute the fact that none of the above authors described the cowl-like anterior extensions of the fulcra to this.

Heymons (1941), as well as Self & Rego (1985), omitted the description of the copulatory spicules of the males, despite considering them fully mature specimens. This might be explained insofar as the true taxonomic value of these structures was only subsequently recognised (Riley, 1986). Unfortunately, Da Fonseca & Ruiz (1956) referred only briefly to the copulatory spicules of the males. However, their illustration of a slide mounted and stained male specimen depicts the characteristic outline of the copulatory spicules well. The latter authors provided a detailed description of the female reproductive organs and stated that the vulva is situated on a mammilliform protuberance on the 15th caudal annulus. Similarly, Self & Rego (1985) described the utero-vaginal pore as subterminal on a prominent papilla. These structures were not visible in neither the slide-mounted material or the alcohol-fixed remains of the female specimens.

The measurements of the oral cadre of one of the males in the present study and those of the two males examined by Heymons (1941) correspond well. The hooks of both males examined by us, however, are larger than the single measurement of Heymons (1941), although the author specifies that the hook length was measured from the tip of the blade to the insertion of the *musculus extensor unci*. There is a good correlation between the length of the blade and the length of the base in the hooks of mature females as determined by Self & Rego (1985) and our own data. Despite slight deviations, the measurements taken of the fulcra also appear uniform. The oral cadre of the single female measured in this study appears considerably larger than recorded by Self & Rego (1985) and Da Fonseca & Ruiz (1956). It is difficult to interpret the hook dimensions provided by the latter authors, as their terminology is not in accordance with that later defined by Fain (1961) and there are no explanatory illustrations. We do, however, believe that the length of the anterior and posterior hook refers to measurements of the blade only and we deduce that the term '*Bügel*' actually refers to the term fulcrum as it is used nowadays. We are in doubt as to the meaning of the term '*fulcrum*' as used by Da Fonseca & Ruiz (1956).

In addition to *Diesingia*, the crocodilian pentastome genera *Alofia* Giglioli, 1922 and *Sebekia*, represented by *A. platycephala* (Lohrmann, 1889) Giglioli, 1922 and *S. microhamus* Self & Rego, 1985, are also present in Brazil (Heymons, 1941; Self & Rego, 1985). The anteriorly open oral cadre of *D. megastoma*, and especially its oesophageal peg, is reminiscent of that of *Alofia*, but it is too oval in profile (Riley & Huchzermeyer, 1995a). The flat-topped, smooth, fang-like hooks are similar to alofian hooks, and it is mainly the presence of the anterior extensions of the fulcra which sets *Diesingia*'s hooks apart from the generic characteristics of *Alofia* (see Fain, 1961; Riley, 1994), although *A. parva* Riley & Huchzermeyer, 1995 has been described as possessing a spinose cowl-like extension to the anterior fulcrum (Riley & Huchzermeyer, 1995b). *S. microhamus* is atypical for the genus since it possesses aspinose hooks that are too small to be confused with those of *D. megastoma* (Self & Rego, 1985). The dorsally convex hooks of *Pelonia africana* Junker & Boomker, 2002 are smooth and the fulcra are without anterior extensions. Also, its oral cadre lacks the oesophageal peg (Junker & Boomker, 2002). However, the single most distinguishing characteristic of *Diesingia* from other sebekiid genera is the unique configuration of its copulatory spicules. The copulatory spicules of *Alofia* and *Selfia* Riley, 1994 are marked by the double-hooked collar terminating the shorter of the two anterior extensions originating from the base (Riley, 1994; Junker, Boomker & Bolton, 1999) and in *Agema* Riley, Hill & Huchzermeyer, 1997, *Sebekia* and *Pelonia* only the longer ventral extension may be present or the shorter extension ends in a smooth collar (Riley et al., 1990; Riley, Hill & Huchzermeyer, 1997). *Leiperia* Sambon, 1922 possesses an elaborate, flared cirrus-tip that is accompanied by a chitinous scoop-like structure (Riley & Huchzermeyer, 1996; Junker, Boomker, Swanepoel & Taraschewski, 2000). This characteristic sets *Leiperia* apart not only from *D. megastoma* but also from the other crocodilian and chelonian sebekiid genera.

For the above reasons we do not concur with Self & Rego's (1985) abandonment of the genus *Diesingia* and the placement of *D. megastoma* in *Sebekia*. Based on the morphological similarities between *D. megastoma* and its (South American) sebekiid counterparts, however, it is reasonable to include *Diesingia* in the family Sebekiidae, as suggested by Riley (1994).

Acknowledgements

This work was supported by a grant to the senior author from the Landesgraduiertenförderung, Baden-Württemberg, Germany and the Deutscher Akademischer Austausch Dienst, Germany.

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Onderstepoort Journal of Veterinary Research, 73:27–36 (2006)

A check-list of the pentastomid parasites of crocodilians and freshwater chelonians

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ABSTRACT

JUNKER, K. & BOOMKER, J. 2006. A check-list of the pentastomid parasites of crocodilians and freshwater chelonians. *Onderstepoort Journal of Veterinary Research*, 73:27–36

Based on published records and own data a summary is given of the geographical distribution of the currently known species of pentastomid parasites infecting crocodiles and alligators, as well as freshwater chelonians. A brief generic diagnosis is provided for each genus.

Fourteen out of the currently 23 living crocodilian species have been recorded as being host to one or more pentastomes. Out of the 32 pentastome species six are considered *species inquirendae*. Presently, six genera of crocodilian pentastomes, *Agema, Alofia, Leiperia, Sebekia, Selfia* and *Subtriquetra* are recognized. African crocodiles harbour eight pentastome species, six of which have been recorded from the Nile crocodile, *Crocodylus niloticus*. Three species belong to the genus *Sebekia*, *Alofia* being represented by two and *Leiperia* by only one species. Two species, *Alofia parva* and *Agema silvaepalustris*, occur in the dwarf crocodile, *Osteolaemus tetraspis*, and the slender-snouted crocodile, *Crocodylus cataphractus*, exclusively, but a single *Sebekia* species is shared with the Nile crocodile. The genus *Agema* is endemic to the African region. Infective stages of the pentastome *Subtriquetra rileyi*, thought to utilize Nile crocodiles as final hosts, have been recovered only from fishes. The largest number of pentastome species is found in the Australasian region. Of these, the Indo-Pacific crocodile, *Crocodylus porosus*, harbours seven, representing the genera *Alofia, Sebekia, Leiperia* and *Selfia*. *Selfia* is exclusive to the latter host. The genus *Subtriquetra* has been reported from "Indian crocodiles", a term possibly referring to either *Crocodylus palustris*, *Crocodylus porosus* or *Gavialis gangeticus*. Ten species of pentastomes parasitizing the crocodilian genera *Alligator*, *Caiman*, *Crocodylus* and *Melanosuchus* have been recorded from the Neotropical region including the southern states of the North American continent. The two most wide-spread pentastome genera, *Alofia* and *Sebekia*, have been recorded together with representatives of the genus *Subtriquetra* and immature and larval forms of *Leiperia*.

To date the two monospecific genera, *Pelonia*, from two terrapin species, *Pelusios sinuatus* and *Pelomedusa subrufa*, in South Africa, and *Diesingia* from *Hydraspis geoffroyana* and *Hydromedusa tectifera* in South America, are the only chelonian pentastomes recovered world-wide. A possible exception is the crocodilian pentastome *Sebekia mississippiensis* which can reach maturity in experimentally infected terrapins.

Keywords: *Agema*, *Alligator*, *Alofia*, *Caiman*, *Crocodylus*, *Diesingia*, *Gavialis*, *Hydraspis*, *Hydromedusa*, *Leiperia*, *Melanosuchus*, *Pelomedusa*, *Pelonia*, Pentastomida, *Phrynops*, *Sebekia*, *Selfia*, *Subtriquetra*, terrapins

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Accepted for publication 1 August 2005—Editor

INTRODUCTION

The pentastomid parasites of chelonians and crocodilians are currently divided into the family Sebekidae and Subtriquetridae. The former comprises seven genera, namely, *Agema, Alofia, Selfia, Sebekia, Leiperia, Diesingia* and *Pelonia*. While the first four genera inhabit the lungs and bronchioles of the crocodilian host, *Leiperia* occurs in the trachea and bronchi (Riley, Spratt & Winch 1990; Riley 1994; Riley & Huchzermeyer 1996; Riley, Hill & Huchzermeyer 1997). *Diesingia* and *Pelonia* parasitize the lungs of chelonian final hosts (Junker & Boomker 2002; Junker, Riley & Boomker 2003).

A single member of *Sebekia, Sebekia mississippiensis*, might be able to reach maturity in chelonians, too, but as yet no mature specimens have been collected from naturally infected hosts (Dukes, Shealy & Rogers 1971). Members of the monogeneric family Subtriquetridae inhabit the nasopharynx of their crocodilian final hosts, but *Subtriquetra rileyi*, of which currently only infective larvae have been recovered, needs verification (Winch & Riley 1986a; Junker, Boomker & Booyse 1998).

During the past 10 years renewed progress has been made as regards the taxonomy of crocodilian pentastomes. The older genera, *Alofia, Sebekia* and *Leiperia*, have been revised, and examination of new material has led to the description of several new genera and species (Riley 1994; Riley *et al.* 1990, 1997; Riley & Huchzermeyer 1996; Junker *et al.* 1998). However, there is a dearth of data concerning the chelonian pentastomids.

In order to provide a quick reference tool, this check-list consists of two parts, following the example of Sambon (1922). The first part lists the parasites under their scientific names, their synonyms and their authorities. A short generic diagnosis precedes each genus and the parasites are grouped according to the geographic distribution of their respective hosts. The list starts with Africa, followed by Australasia. South and North America are listed last.

The second part of the check-list alphabetically lists the hosts and their synonyms, and, also in alphabetical order, their respective parasites. The nomenclature and synonyms of the crocodilian and chelonian hosts are according to Getz (2002).

Only references dealing with mature pentastomes are included in the check-list, but for completeness' sake the intermediate hosts of pentastome species of which only larval forms are known are listed.

PARASITE/HOST CHECK-LIST OF THE PENTASTOMIDA

FAMILY SEBEKIDAE SAMBON, 1922

Genus *Agema* Riley, Hill & Huchzermeyer, 1997

GENERIC DIAGNOSIS: Overall shape typical of smaller members of the Sebekidae; males claviform, females with more uniform diameter and conical posterior terminating in a small blunt point; adult hooks smooth; blades smoothly curved without abrupt right-angled bend near to base; blade on anterior hook pair larger than that of posterior pair; fulcrum without cowl; mouth ovoid and sides of cadre united anteriorly and posteriorly by segments of chitin which appear as two crescents; copulatory spicules delicate and elongate; basal section without a hooked collar (Riley *et al.* 1997).

AFRICA

1. *Agema silvaepalustris* Riley, Hill & Huchzermeyer, 1997

   Crocodylus cataphractus

   Riley, Hill & Huchzermeyer (1997), Republic of the Congo

   Osteolaemus tetraspis

   Riley, Hill & Huchzermeyer (1997), Republic of the Congo

Genus *Alofia* Giglioli, 1922

GENERIC DIAGNOSIS: Size small; body banana-shaped; hooks large with long, narrow, slightly curved blade and a slender base; absence of chitinous formation at the base of the anterior hook; chitinous buccal cadre large and U-shaped; intestine as in *Sebekia*; found in crocodiles (Fain 1961 in Riley 1994); caudal extremity of female bluntly rounded, often swollen into a bulb (Riley 1994); hooks usually smooth (rarely with patches of minute spines [see *Alofia nilotici* and *Alofia parva* (Riley & Huchzermeyer 1995a, b)], blades finely canaliculated, bent through almost a right angle at the base; peg-like extension of oral cadre projects into oesophagus; copulatory spicules with double-hooked collar on the shorter of the two anterior extensions (Riley & Huchzermeyer 1995a, b; Junker, Boomker & Bolton 1999).

AFRICA

1. *Alofia nilotici* Riley & Huchzermeyer, 1995

   Crocodylus niloticus

Riley & Huchzermeyer (1995a), Botswana

Junker, Boomker & Bolton (1999), South Africa

2. *Alofia parva* Riley & Huchzermeyer, 1995

Crocodylus cataphractus

Riley & Huchzermeyer (1995b, 2000), Republic of the Congo

Osteolaemus tetraspis osborni

Riley & Huchzermeyer (1995b, 2000), Republic of the Congo

3. *Alofia simpsoni* Riley, 1994

Unknown crocodilian

Riley (1994), Ghana

Crocodylus niloticus

Riley & Huchzermeyer (1995a), Botswana

Junker, Boomker & Bolton (1999), South Africa

AUSTRALASIAN REGION

4. *Alofia ginae* Giglioli, 1922

Unknown crocodilian

Sambon (1922), Samoa

Most probably *Crocodylus porosus*, as it is the only crocodilian whose range extends as far as Fiji in the Pacific Ocean and it is known to have colonized many small islands as far as nearly 1 000 km from land (Ross 1989).

Crocodylus porosus (?)

Riley (1994), Philippines

The collector did not specify the host, but Riley (1994) concludes it to be *C. porosus,* as the only other Philippinian crocodile, *Crocodylus mindorensis*, does not occur in the region from which the parasites were recovered.

5. *Alofia merki* Giglioli, 1922

Sebekia merki Heymons, 1941

Unknown crocodilian

Sambon (1922), Samoa

Most probably *Crocodylus porosus*, as it is the only crocodilian whose range extends as far as Fiji in the Pacific Ocean and it is known to have colonized many small islands as far as nearly 1 000 km from land (Ross 1989).

Crocodylus porosus

Riley (1994), Northern Territory, Australia

Riley (1994), Philippines

6. *Alofia indica* (Von Linstow, 1906) Hett, 1924, *species inquirenda*

Gavialis gangeticus

Hett (1924), India

SOUTH & NORTH AMERICAN REGION

7. *Alofia platycephala* (Lohrmann, 1889) Giglioli, 1922

Pentastomum platycephalum Lohrmann, 1889; *Porocephalus platycephalus* Shipley, 1898; *Reighardia platycephala* Sambon, 1910

Unknown crocodilian

Lohrmann (1889), South America

Caiman crocodilus

Self & Rego (1985), Brazil

Caiman latirostris

Heymons (1941), Paraguay

Comment: Hirst (1922) described *Alofia adriatica* (Hirst, 1922) Giglioli, 1922 from an unknown host from the Adriatic. As crocodilians do not occur in the Adriatic this species will have to remain *species inquirenda* until further material becomes available.

Genus *Leiperia* Sambon, 1922

GENERIC DIAGNOSIS: Female with spirally coiled abdomen; broad bands of chloride cells; hooks smooth, flat-topped with sharply curved blade; oral cadre V-shaped with large anterior flanges, numerous pores around the pharynx; copulatory spicules heavily chitinized with complex internal supporting structures, shorter of the two anterior extensions forms a smooth collar (double in *L. australiensis*) around the longer spatulate extension; cirrus tip modified into a flattened trumpet of longitudinally-striated chitin (Riley & Huchzermeyer 1996; Junker, Boomker, Swanepoel & Taraschewski 2000).

AFRICA

1. *Leiperia cincinnalis* (Vaney & Sambon, 1910) Sambon, 1922

Reighardia cincinnalis Vaney & Sambon, 1910;

Porocephalus nematoides De Beauchamp, 1918

Crocodylus cataphractus

Fain (1961), Central Africa: infective larva

Crocodylus niloticus

Vaney & Sambon (1910), Uganda

Sambon (1922), Zimbabwe

Rodhain & Vuylsteke (1932), Democratic Republic of the Congo

Junker, Boomker, Swanepoel & Taraschewski (2000), South Africa

AUSTRALASIAN REGION

2. *Leiperia australiensis* Riley & Huchzermeyer, 1996

Crocodylus johnsoni

Riley & Huchzermeyer (1996), Northern Territory, Australia

Crocodylus porosus

Riley & Huchzermeyer (1996), Northern Territory, Australia

SOUTH & NORTH AMERICAN REGION

3. *Leiperia gracilis* Diesing, 1936, *species inquirenda*

Pentastoma gracile Diesing, 1836 (*partim*); *Pentastomum gracile* Leidy, 1856; *Pentastoma gracilis* Parona, 1891; *Porocephalus gracilis* Shipley, 1898; *Porocephalus crocodili* Wheeler, 1915 (*partim*); *Leiperia neotropica* Heymons & Vitzthum, 1935

Immature and larval forms were recovered from the following hosts, but adults have not been collected.

Alligator mississippiensis

Leidy (1856, in Sambon 1922), locality unknown, North America

Crocodylus acutus

Heymons (1935), South America

Caiman crocodilus

Heymons (1935), Brazil

Genus *Sebekia* Sambon, 1922

GENERIC DIAGNOSIS: Body short and squat with 58–94 compressed annuli; lateral lines conspicuous; cephalothorax small, wedge-shaped and projecting nipple-like from the abdomen, ventral surface continuous with that of the abdomen; mouth subterminal and shaped like an inverted 'U'; oral cadre oval to elongate, highly variable in shape, without long, parallel sides and generally united anteriorly; hooks small, equal or subequal, claw-shaped, with convex or flat dorsal surface; all hooks spiny (rarely only the anterior pair); all fulcra often with spinous anterior extension (rarely only the anterior pair); hook barb curved, strongly united and continuous with shank; spicules generally obpyriform, with one or two fine sclerotized rods supporting membranous region distally. Parasites of the lungs of crocodilians, rarely of chelonians (Riley *et al.* 1990).

AFRICA

1. *Sebekia cesarisi* Giglioli, 1922

Crocodylus sp.

Sambon (1922), Africa

Crocodylus niloticus

Riley & Huchzermeyer (1995a), Botswana

Junker, Boomker & Bolton (1999), South Africa

2. *Sebekia okavangoensis* Riley & Huchzermeyer, 1995

Sebekia cesarisi Riley, Spratt & Winch, 1990

Crocodylus cataphractus

Riley & Huchzermeyer (2000), Republic of the Congo

Crocodylus niloticus

Riley & Huchzermeyer (1995a), Botswana

Junker, Boomker & Bolton (1999), South Africa

Osteolaemus tetraspis

Riley & Huchzermeyer (2000), Republic of the Congo

3. *Sebekia wedli* Giglioli, 1922

Pentastoma oxycephalum var. *minor* Wedli, 1861; *Sebekia oxycephala* Self & Rego, 1985

Crocodylus niloticus

Devos (1939), Democratic Republic of the Congo

Riley, Spratt & Winch (1990), Uganda

Riley & Huchzermeyer (1995a), Botswana

Junker, Boomker & Bolton (1999), South Africa

AUSTRALASIAN REGION

4. *Sebekia johnstoni* Riley, Spratt & Winch, 1990

Crocodylus johnsoni

Riley, Spratt & Winch (1990), Northern Territory, Australia

Crocodylus porosus

Riley, Spratt & Winch (1990), Northern Territory, Australia

5. *Sebekia multiannulata* Riley, Spratt & Winch, 1990

Crocodylus johnsoni

Riley, Spratt & Winch (1990), Northern Territory, Australia

Crocodylus porosus

Riley, Spratt & Winch (1990), Northern Territory, Australia

6. *Sebekia purdieae* Riley, Spratt & Winch, 1990

Crocodylus porosus

Riley, Spratt & Winch (1990), Northern Territory, Australia

7. *Sebekia jubini* (Vaney & Sambon, 1910) Sambon, 1922, *species inquirenda*

Porocephalus jubini Vaney & Sambon, 1910

Crocodylus siamensis

Sambon (1922), locality unknown, south-east Asia

8. *Sebekia novaeguineae* Riley, Spratt & Winch, 1990

Crocodylus novaeguineae

Riley, Spratt & Winch (1990), Papua New Guinea

SOUTH & NORTH AMERICAN REGION

9. *Sebekia acuminata* Travassos, 1924, *species inquirenda*

Unknown crocodilian

Travassos (1924), Brazil

10. *Sebekia divestei* Giglioli, 1922

Crocodylus acutus

Sambon (1922), locality unknown, Neotropical region

11. *Sebekia microhamus* Self & Rego, 1985

Caiman crocodilus

Self & Rego (1985), Brazil

12. *Sebekia mississippiensis* Overstreet, Self & Vliet, 1985

Pentastoma oxycephalum Diesing, 1836 (*partim*); *Pentastomum gracile* (syn. *Leiperia gracilis*) Leidy, 1856

Alligator mississippiensis

Deakins (1971), USA

Hazen, Aho, Murphy, Esch & Schmidt (1978), USA

Overstreet, Self & Vliet (1985), USA

13. *Sebekia oxycephala* (Diesing, 1836) Sambon, 1922

Pentastoma proboscideum Rudolphi, 1819 (*partim*); *Pentastoma oxycephalum* Diesing, 1836 (*partim*); *Pentastoma gracile* Diesing, 1836 (*partim*); *Pentastomum oxycephalum* Diesing, 1850 (*partim*); *Pentastomum gracile* Diesing, 1850 (*partim*); *Pentastomum heterodontis* Leuckart, 1860; *Pentastomum oxycephalum* Chatin, 1882; *Porocephalus oxycephalus* Stiles, 1893; *Pentastoma proboscideum crocodili scleropis* Rudolphi (Shipley in Sambon 1922); *Reighardia oxycephala* Vaney & Sambon, 1910; *Porocephalus crocodili* Wheeler, 1913 (*partim*); *Sebekia oxycephala* Sambon, 1922 (*partim*); *Bdukus ichthyius* Holl, 1929; *Leiperia heterodontis* Heymons & Vitzthum, 1935; *Sebekia crocodili* Heymons & Vitzthum, 1935

Alligator mississippiensis

Sambon (1922), locality unknown

Caiman crocodilus

Sambon (1922), locality unknown

Winch & Riley (1986b), Trinidad, South America

Caiman latirostris

Heymons (1941), locality unknown

Crocodylus acutus

Sambon (1922), locality unknown

14. *Sebekia samboni* Travassos, 1924, *species inquirenda*

Unknown crocodilian

Travassos (1924), Brazil

15. *Sebekia trinitatis* Riley, Spratt & Winch, 1990

Caiman crocodilus

Riley, Spratt & Winch (1990), Trinidad, South America

Genus *Selfia* Riley, 1994

GENERIC DIAGNOSIS: Size small, cephalothorax minute in comparison with diameter of the abdomen; 78–82 well defined annuli; abdomen strongly curled ventrally; caudal extremity of female abruptly tapered to blunt point; hooks very small, with tiny blade only slightly offset from transversely creased and folded shank; rear of anterior hooks enveloped by soft, spinous cowl which forms an extension of the fulcrum; buccal cadre somewhat variable in shape, being oval to more U-shaped, but lacking parallel sides; copulatory spicule of male like that of *Alofia* (Riley 1994).

AUSTRALASIAN REGION

1. *Selfia porosus* Riley, 1994

Crocodylus porosus

Riley (1994), Northern Territory, Australia

Genus *Diesingia* Sambon, 1922

GENERIC DIAGNOSIS: Hooks smooth, flat-topped, with sharply curved blades; fulcra with anterior cowl-like extension, extension smooth in posterior and spiny in anterior fulcra; oral cadre open anteriorly with an oesphageal peg similar to that in *Alofia*; copulatory spicule with cowry shell-shaped base, the short, ventral extension is transformed into a structure resembling the collembolan fulcrum, and is connected to the base by a joint (Junker, Riley & Boomker 2003).

SOUTH & NORTH AMERICAN REGION

1. *Diesingia megastoma* (Diesing, 1836) Sambon, 1922

Pentastoma megastomum Diesing, 1836; *Pentastomum megastomum* Leuckart, 1860; *Porocephalus megastomus* Shipley, 1898; *Sebekia megastoma* Travassos, 1923; *Sebekia crocodili* Heymons & Vitzthum, 1935; *Diesingia megastoma* Heymons; 1941; *Butantanella megastoma* Da Fonseca & Ruiz, 1956; *Sebekia megastoma* Self & Rego, 1985

Phrynops geoffroanus

Diesing (1836), Brazil

Hydromedusa tectifera

Da Fonseca & Ruiz (1956), Brazil

Genus *Pelonia* Junker & Boomker, 2002

GENERIC DIAGNOSIS: Hooks smooth, dorsally convex, with sharply bent blades, fulcra without extensions; oral cadre more or less U-shaped, closed anteriorly by delicate chitinous fibres; copulatory spicules almost identical to those of *Sebekia wedli*, with cowry shell-shaped base and the short anterior extension ending in a smooth collar, the long spatulate extension carries small chitinous teeth (Junker & Boomker 2002).

AFRICA

1. *Pelonia africana* Junker & Boomker, 2002

Pelomedusa subrufa

Junker & Boomker (2002), South Africa

Pelusios sinuatus

Junker & Boomker (2002), South Africa

FAMILY SUBTRIQUETRIDAE FAIN, 1961

Genus *Subtriquetra* Sambon, 1922

GENERIC DIAGNOSIS: Body elliptical, ventrally flattened and dorsally dome shaped with flattened margins; hooks simple, slender and sharply pointed, disposed in a curved line; oral cadre rounded (Fain 1961; Winch & Riley 1986a; Junker *et al.* 1998).

AFRICA

1. *Subtriquetra rileyi* Junker, Boomker & Booyse, 1998

Infective larvae:

Tilapia rendalli swierstrae

Junker, Boomker & Booyse (1998), South Africa

Oreochromis mossambicus

Junker, Boomker & Booyse (1998), South Africa

AUSTRALASIAN REGION

2. *Subtriquetra megacephala* (Baird, 1853) Sambon, 1922

Pentastoma megacephalum Baird, 1853; *Porocephalus megacephalus* Shipley, 1898

Crocodylus palustris

Sambon (1922), Sunderbunds, India

Crocodylus palustris, *Crocodylus porosus* or

Gavialis gangeticus? ("Sangor crocodile")

Sambon (1922), Bengal, India

3. *Subtriquetra shipleyi* Hett, 1924

Crocodylus palustris Crocodylus porosus or *Gavialis gangeticus* ? ("Indian crocodile")

Hett (1924), India

SOUTH & NORTH AMERICAN REGION

4. *Subtriquetra subtriquetra* (Diesing, 1836)

Pentastoma proboscideum Bresmer, 1824 (*partim*); *Pentastoma subtriquetrum* Diesing, 1836; *Pentastomum subtriquetrum* Diesing, 1850; *Pentastomum pusillum* Diesing, 1856; *Linguatula subtriquetra* Raillet, 1883; *Linguatula pusilla* Shipley, 1898

Caiman crocodilus

Sambon (1922), South America

Winch & Riley (1986a), Trinidad, South America

Melanosuchus niger

Sambon (1922), South America

HOST/PARASITE CHECK-LIST OF THE PENTASTOMIDA

Crocodylia

FAMILY ALLIGATORIDAE (CUVIER, 1807) (Alligators and caimans)

Genus *Alligator* Cuvier, 1807

1. *Alligator mississippiensis* (Daudin, 1801) Daudin, 1802 (American alligator)

Crocodilus mississipiensis Daudin, 1801

Leiperia gracilis, species inquirenda, larval forms only

Sebekia mississippiensis

Sebekia oxycephala

Genus *Caiman* Spix, 1825

1. *Caiman crocodilus* (Linnaeus, 1758) (Common or Spectacled caiman)

Lacerta crocodilus Linnaeus, 1758; *Caiman sclerops* Schneider, 1801 (fide Medem 1981); *Perosuchus fuscus* Cope, 1868; *Alligator* (*Jacare*) *chiapasius* Bocourt, 1876

Alofia platycephala

Leiperia gracilis, species inquirenda, larval forms

Sebekia microhamus

Sebekia oxycephala

Sebekia trinitatis

Subtriquetra subtriquetra

2. *Caiman latirostris* (Daudin, 1801) (Broad-snouted caiman)

Crocodilus latirostris Daudin, 1801; *Caiman fissipes* Spix, 1825; *Champsa fissipes* Wagler, 1828 (*fide* Hoogmoed & Gruber, 1983); *Alligator cynocephalus* Duméril & Bibron, 1836; *Jacare latirostris* Gray, 1862; *Alligator latirostris* Boulanger, 1886; *Jacaretinga latirostris* Vaillant, 1898

Alofia platycephala

Sebekia oxycephala

Genus *Melanosuchus* Gray, 1862

1. *Melanosuchus niger* (Spix, 1825) (Black caiman)

Caiman niger Spix, 1825

Subtriquetra subtriquetra

FAMILY CROCODYLIDAE (CUVIER, 1807) (Crocodiles)

SUBFAMILY CROCODYLINAE (CUVIER, 1807)

Genus *Crocodylus* Laurenti, 1768

1. *Crocodylus acutus* (Cuvier, 1807) (American crocodile)

Crocodilus acutus Cuvier, 1807

Leiperia gracilis, species inquirenda, larval forms only

Sebekia divestei

Sebekia oxycephala

2. *Crocodylus cataphractus* Cuvier, 1825 (Slender-snouted crocodile)

Crocodilus cataphractus Falconer, 1846

Agema silvaepalustris

Alofia parva

Leiperia cincinnalis, infective larva

Sebekia okavangoensis

3. *Crocodylus johnsoni* Krefft, 1873 (Australian freshwater crocodile)

   Tomistoma kreffti Gray in Krefft, 1873 (*nomen nudum*); *Crocodilus* (*Philas*) *johnstoni* Gray, 1874; *Crocodylus johnstoni* Cogger, 2000

   Leiperia australiensis

   Sebekia johnstoni

   Sebekia multiannulata

4. *Crocodylus niloticus* Laurenti, 1768 (Nile crocodile)

   Crocodilus vulgaris Cuvier, 1807; *Crocodilus multiscutatus* Rüppell in Cretzschmar, 1826; *Crocodilus marginatus* Geoffroy, 1827; *Crocodilus madagascariensis* Grandidier, 1872; *Crocodilus vulgaris* var. *madagascariensis* Boettger, 1877

   Alofia nilotici

   Alofia simpsoni

   Leiperia cincinnalis

   Sebekia cesarisi

   Sebekia okavangoensis

   Sebekia wedli

5. *Crocodylus novaeguineae* Schmidt, 1928 (New Guinea crocodile)

   Sebekia novaeguineae

6. *Crocodylus palustris* Lesson, 1831 (Mugger, Marsh crocodile)

   Subtriquetra megacephala

   Subtriquetra shipleyi ("Indian crocodile")

7. *Crocodylus porosus* Schneider, 1801 (Indo-Pacific or Saltwater crocodile)

   Crocodylus natans Meyer, 1795; *Crocodilus porosus* Schneider, 1801; *Crocodilus oopholis* Schneider, 1801; *Crocodilus biporcatus* Cuvier, 1807; *Crocodilus biporcatus raninus* Müller & Schlegel, 1844; *Oopholis pondicherianus* Gray, 1862; *Crocodylus porosus australis* Deraniyagala, 1953; *Crocodylus porosus minikanna* Deraniyagala, 1953

   Alofia ginae (possibly *Crocodylus mindorensis*, but distributionally unlikely)

   Alofia merki

   Leiperia australiensis

   Sebekia johnstoni

   Sebekia multiannulata

   Sebekia purdieae

   Selfia porosus

   Subtriquetra shipleyi ("Indian crocodile")

8. *Crocodylus siamensis* Schneider, 1801 (Siamese crocodile)

   Crocodilus galeatus Cuvier, 1807

   Sebekia jubini, species *inquirenda*

Genus *Osteolaemus* Cope, 1861

1. *Osteolaemus tetraspis* Cope, 1861 (Dwarf crocodile)

   Crocodilus frontatus Murray, 1862; *Halcrosia afzelii* Lilljeborg, 1867; *Halcrosia nigra* Gray, 1867; *Halcrosia nigra* Gray, 1870; *Osteoblepharon osborni* Schmidt, 1919; *Osteolaemus tetraspis tetraspis* Wermuth & Mertens, 1961

   Agema silvaepalustris

   Alofia parva

   Sebekia okavangoensis

FAMILY GAVIALIDAE ADAMS, 1854 (Gharials)

Genus Gavialis Oppel, 1811

1. *Gavialis gangeticus* (Gmelin, 1789) (Gharial)

   Lacerta gangetica Gmelin, 1789

   Subtriquetra megacephala ("Indian crocodile")

   Subtriquetra shipleyi ("Indian crocodile")

CHELONIA

Suborder Pleurodira (Side-necked turtles)

FAMILY PELOMEDUSIDAE COPE, 1868

Genus *Pelomedusa* Wagler, 1830

1. *Pelomedusa subrufa* (Lacépède, 1788) (Cape terrapin)

   Testudo subrufa Lacépède, 1788; *Testudo galeata* Schoepff, 1792; *Testudo badia* Donndorf, 1798; *Testudo rubicunda* Suckow, 1798; *Emys olivacea* Schweigger, 1812 (*non Emys olivacea* Gray, 1855); *Pentonyx capensis* Duméril & Bibron, 1835; *Pentonyx gehafie* Rüppell, 1835; *Pentonix americana* Cornalia, 1849; *Pelomedusa mozambica* Peters (*nomen nudum*) in Gray 1855 (?); *Pelomedusa mossambicensis* Peters (*nomen nudum*) in Lichtenstein 1856; *Pelomedusa*

nigra Gray, 1863; *Pelomedusa gasconi* Rochebrune, 1884; *Pelomedusa galeata* Boulanger, 1889; *Pelomedusa galeata* var. *disjuncta* Vaillant & Grandidier, 1910; *Pelomedusa galeata orangensis* Hewitt, 1935; *Pelomedusa galeata devilliersi* Hewitt, 1935; *Pelomedusa galeata damarensis* Hewitt, 1935; *Pelomedusa subrufa wettsteini* Mertens, 1937; *Testudo emys arabica* N.-Ehrenberg in Stresemann 1954

Pelonia africana

Genus *Pelusios* Wagler, 1830

1. *Pelusios sinuatus* (Smith, 1838) (Serrated hinged terrapin, African serrated mud turtle)

   Sternotherus sinuatus Smith, 1838; *Sternotherus dentatus* Peters, 1848 (*nomen nudum*); *Sternothaerus sinuatus* Boulanger, 1889; *Sternothaerus bottegi* Boulanger, 1895; *Pelusios sinuatus zuluensis* Hewitt, 1927; *Pelusios sinuatus leptus* Hewitt, 1927

   Pelonia africana

FAMILY CHELIDAE GRAY, 1825 (Snake-necked turtles)

Genus *Hydromedusa* Wagler, 1830

1. *Hydromedusa tectifera* Cope, 1869 [1870] (South American snake-necked turtle, Uruguay snake-necked turtle)

   Hydromedusa platanensis Gray, 1873; *Hydromedusa wagleri* Günther, 1884

   Diesingia megastoma

Genus *Phrynops* Wagler, 1830

1. *Phrynops geoffroanus* (Schweigger, 1812) Gorzula & Señaris, 1999 (Geoffroy's side-necked turtle)

   Emys geoffroana Schweigger, 1812; *Emys geoffreana* Schweigger, 1812 (fide Boulanger, 1886); *Emys depressa* Merrem, 1820 (*non Emys depressa* Spix, 1824); *Emys viridis* Spix, 1824 (?); *Emys geoffroyana* Gray, 1831; *Platemys geoffreana* Duméril & Bibron, 1835; *Platemys neuwiedii* Duméril & Bibron, 1835; *Platemys waglerii* Duméril & Bibron, 1835; *Platemys tuberosa* Peters, 1870; *Platemys geoffroyana* Boulanger, 1886; *Hydraspis geoffroyana* Boulanger, 1889; *Hydraspis wagleri* Boulanger, 1889; *Hydraspis tuberosa* Boulanger, 1889; *Hydraspis boulangeri* Bohls, 1895; *Phrynops geoffroana* Mertens *et al.*, 1934; *Phrynops geoffroana geoffroana* Müller, 1939; *Phrynops tuberosa* Mertens *et al.*, 1934; *Phrynops geoffroana tuberosa* Müller, 1939

   Diesingia megastoma

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SECTION 4

PARASITES

OF

FRESHWATER FISHES

CHAPTER 1

Descriptions and re-descriptions

of

parasites of freshwater fishes

Introduction

A number of new parasites of a variety of freshwater fishes are described here. Most of the helminth descriptions is my own work. Professor Horst Taraschewski visited Medunsa in the early part of 1994, and we went hunting for the nematode *Anguillicola papernae*, that had been described by Moravec and Taraschewski in 1988 from longfin eels in East London, Eastern Cape Province. The aim was to elucidate the life cycle and pathology caused by the parasite, and this has been reported in the 2005 publication. My involvement was, amongst others, to keep an active culture of *Cyclops* going, feed them the first stage larvae of *Anguillicola* and supervise one of his students, Anette Felsch, when she came to South Africa to specifically work on *Anguillicola*. As part of this study all helminths were collected and a new species of *Paraquimperia* found. Since I was not an expert on the genus, I sent the specimens to Dr Franticek Moravec, who described the species as *Paraquimperia africana*, with Taraschewski and myself as co-authors.

Prof. Taraschewski, while examining fishes caught in the Sabie river in the KNP, found some pentastomid nymphs. This lead to Dr. Kerstin Junker coming to South Africa to do an MSc under my supervision, and, to a large extent, with funding provided by me. The article listed here is an excerpt of her MSc thesis, but has been extensively modified to suit the formats of the journals that it was eventually published in.

The chapter has been arranged in chronological order, but the helminths have been grouped together and is followed by the single publication on the pentastomids.

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HELMINTHS

Onderstepoort J. vet. Res., 51, 129–139 (1984)

PARASITES OF SOUTH AFRICAN FRESHWATER FISH. II. REDESCRIPTION OF THE AFRICAN SPECIES OF THE GENUS *PHYLLODISTOMUM* BRAUN, 1899 (TREMATODA: GORGODERINAE) AND THE DESCRIPTION OF A NEW SPECIES

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ABSTRACT

BOOMKER, J., 1984. Parasites of South African freshwater fish. II. Redescription of the African species of the genus *Phyllodistomum* Braun, 1899 (Trematoda: Gorgoderinae) and the description of a new species. *Onderstepoort Journal of Veterinary Research*, 51, 129–139 (1984).

During 1980 a survey of the parasites of freshwater fish was conducted in the Sabie and Crocodile Rivers in the southern part of the Kruger National Park, Transvaal. A new species of *Phyllodistomum*, Braun, 1899, for which the name *Phyllodistomum bavuri* is proposed, was found in the urinary bladder of many of the catfish, *Clarias gariepinus* (Burchell, 1822), examined. The new species resembles *Phyllodistomum linguale* Odhner, 1902 and *Phyllodistomum vanderwaali* Prudhoe & Hussey, 1977, but may be differentiated from the former species in that the ovary and the vitellaria are smooth, while those of *P. linguale* are irregularly lobed. The ovary of *P. vanderwaali* is irregularly lobed while that of *P. bavuri* never has more than 3 indistinct lobes. In addition, *P. bavuri* is much larger than *P. vanderwaali*.

P. bavuri is readily differentiated from the other 4 African species of *Phyllodistomum*, namely, *Phyllodistomum spatula* (Odhner, 1902), *Phyllodistomum spatulaeforme* (Odhner, 1902), *Phyllodistomum ghanense* Thomas, 1958 and *Phyllodistomum symmetrorchis* Thomas, 1958. For comparative purposes the African species are briefly redescribed and illustrated.

P. bavuri occurred throughout the year and their numbers do not appear to fluctuate seasonally in the Kruger National Park.

INTRODUCTION

During 1980, a survey of the parasites of a number of species of freshwater fish was conducted in 2 major rivers, the Sabie and the Crocodile, in the southern part of the Kruger National Park, Transvaal. Both rivers form part of the eastern drainage system (Wellington, 1955, as cited by Jubb, 1967), and both arise in the mountains of the eastern Transvaal escarpment.

The object of the present study was to determine the various species of parasites that occur in fish in these rivers and also to determine their seasonal variation. This paper includes the description of a new species of the genus *Phyllodistomum* Braun, 1899 that was found in the urinary bladders of many of the catfish *Clarias gariepinus* (Burchell, 1822), as well as its prevalence.

To date, 6 species of this genus have been described from African freshwater fish. They are *Phyllodistomum linguale* Odhner, 1902, *Phyllodistomum spatulaeforme* (Odhner, 1902) and *Phyllodistomum spatula* (Odhner, 1902) from the Sudan, *Phyllodistomum ghanense* Thomas, 1958 and *Phyllodistomum symmetrorchis* Thomas, 1958 from Ghana, West Africa, and *Phyllodistomum vanderwaali* Prudhoe & Hussey, 1977 from South Africa. The 7th species, for which the name *Phyllodistomum bavuri* is proposed, was collected from catfish from both the Sabie and the Crocodile Rivers as well as from the Bangu River, a tributiary of the Olifants River in the central part of the Park.

MATERIALS AND METHODS

All the fish were caught with baited handlines and the parasites collected as described by Boomker (1982).

After being opened with scissors, the entire urinary bladder was placed in 70 % ethyl alcohol and vigorously shaken for about 1 min. The majority of the parasites were thus fixed in a flat plane and as they are very thin and leaf-like, fixation was almost immediate.

The parasites were stained with Mayer's haemalum, acid carmine and Grenacher's borax carmine. After dehydration in graded concentrations of ethyl alcohol and clearing in oil of cloves, the parasites were mounted in a synthetic resin.*

* Histoclad, Clay-Adams

Received 13 March 1984—Editor

During the course of the study, specimens of *P. spatulaeforme*, *P. spatula* and *P. linguale* as well as the type specimens of *P. vanderwaali* and the holotypes of *P. ghanense* and *P. symmetrorchis* were loaned from the British Museum (Natural History), London, for comparison with each other and with *P. bavuri*.

REDESCRIPTION OF THE AFRICAN SPECIES OF THE GENUS *PHYLLODISTOMUM* BRAUN, 1899

Phyllodistomum bavuri n. sp. (Fig. 1, Table 1)

Type host

Clarias gariepinus from the Bangu River, Kruger National Park, Transvaal.

Material examined

Syntypes: 6 mounted, mature specimens from the type host from the type locality have been deposited with the Onderstepoort Helminthological Collection, No. T7.

Paratypes: 8 mounted, mature specimens from the type host from the Sabie River have been deposited with the British Museum (Natural History), London, No. 1983.7.5.1–8.

Additional material: Numerous specimens from the type host from both the Sabie and Crocodile Rivers have been examined. Additional material consisting of 40 specimens have been deposited with the syntypes and the paratypes.

Description

When alive, the trematodes form a pale brown film covering the white mucosa of the urinary bladder. If only a few worms are present, they may be difficult to find, as they are often hidden by the mucosal folds.

The body is aspinose and ampullate in shape. The anterior part is subcylindrical and amounts to about ¼ of the total body length. The posterior ¾'s of the body is thin and flattened dorsoventrally and the various internal structures are microscopically visible without prior staining.

The oral sucker is round and situated subventrally, while the ventral sucker is situated at or slightly behind the junction of the anterior and posterior parts of the

body. The oral sucker is smaller than the ventral one, giving an oral to ventral sucker ratio that varies from 1:1,55–1:2,06.

A pharynx is absent and the oesophagus is short. The intestine bifurcates about halfway between the oral and ventral suckers, or in some specimens, slightly more towards the oral sucker. The intestinal caecae almost reach the posterior margin of the body. The excretory vesicle and pore could not be seen.

The genital pore lies in the midline of the body, between the bifurcation of the gut and the ventral sucker. A cirrus sac is absent and the cirrus and the opening of the vagina in the genital atrium were indistinct.

The testes are fairly large, deeply and irregularly lobed structures lying in the middle of the body on either side of the midline. They are usually opposite one another but may be slightly displaced so that the one lies in front of the other. In a single specimen only, 1 of the testes appeared more degenerate than the other.

The vitellaria are compact bodies that are oval to roughly triangular in outline, or they may occasionally be slightly lobed. They are situated near the posterior margin of the ventral sucker. In one of the paratype specimens, only 1 vitellarium was seen. The shell-gland lies between the vitellaria and is ill-defined.

The ovary may be situated either to the left or to the right of the midline, between the vitellaria and the testes. It stains intensely and is round to oval in shape, sometimes weakly trilobed.

The uterus consists of numerous tortuous loops that occupy the area between the intestinal caecae and the testes, and only a few loops extend laterally and posteriorly beyond the caecae. It runs anteriorly and passes between the testes and the vitellaria to reach the genital pore. The metroterm could not be seen. The uterine loops are filled with eggs, and those closest to the genital pore contain miracidia.

Phyllodistomum linguale Odhner, 1902 (Fig. 2, Table 1)

Material examined: One mounted mature specimen from *Gymnarchus niloticus*, Egypt.

The body was the characteristic shape of the genus. The forebody constitutes about ⅓ of the total body length. The suckers are round and the oral to ventral sucker ratio is 1:2,3.

The oesophagus is short and the intestine bifurcates at the junction of the 1st and 2nd thirds of the distance between the oral and the ventral suckers. The intestinal caecae terminate some distance away from the posterior margin. The excretory vesicle and pore could not be seen.

The genital pore lies between the gut bifurcation and the rim of the ventral sucker, in the midline of the body. A cirrus sac is absent and the cirrus and opening of the vagina were indistinct.

The testes are fairly large, deeply indented and irregularly lobed structures, lying in the middle of the body on either side of the midline. In the specimen examined by me, the testes were slightly displaced so that the one was situated in front of the other.

The vitellaria are compact, oval to roughly triangular bodies that lie immediately behind the posterior rim of the ventral sucker. They lie opposite each other and in front of the ovary.

The ovary is situated on the left side of the body, between the vitellaria and the testes. It is deeply indented and irregularly lobed.

The uterus consists of numerous loops that lie in the area between the caecae laterally and the testes anteriorly, and only a few loops extend laterally beyond the caecae. The uterus runs anteriorly between the testes and the vitellaria to reach the genital pore. The loops are filled with eggs, of which the ones closest to the genital pore contain miracidia.

Phyllodistomum spatulaeforme (Odhner, 1902) (Fig. 3, Table 1)

Material examined: Two mounted mature specimens from *Malopterurus electricus*, Egypt.

The body has the characteristic shape of the genus and its margin is thrown into folds. The forebody constitutes about ⅓ of the total body length. The suckers are round and the oral to ventral sucker ratio is 1:1.

The oesophagus, intestine and genital pore have the same positions as described for *P. linguale* and, as was the case with *P. linguale*, the excretory vesicle, the excretory pore and the cirrus and the opening of the vagina could not be seen. The intestinal caecae are inflated and bulge anteriorly.

The testes are comparatively small, shallowly indented and irregularly lobed structures, lying on either side of the midline in the middle of the body. In one of the 2 specimens they were opposite each other but in the other specimen the one testis was slightly in front of the other.

The vitellaria are small compact bodies, round to oval, sometimes slightly indented, situated behind the posterior margin of the ventral sucker. In one of the 2 specimens examined they were situated between the ovary on the one side and one of the testes on the other side, but in the other specimen, they were lateral to the ovary only, as the testis on that side was displaced posteriorly.

The ovary is situated either on the left or on the right side of the body. It is round to kidney-shaped.

The uterus consists of loops situated in the space between the testes anteriorly, the intestinal caecae laterally and the terminations of the intestinal caecae posteriorly. They do not extend beyond the caecae either laterally or posteriorly.

Phyllodistomum spatula (Odhner, 1902) (Fig. 4, Table 1)

Material examined: One mounted mature specimen from *Bagrus bayad*, Egypt.

The body is ampullate in shape. The forebody constitutes about ⅓ of the total body length. The suckers are round and the oral to ventral sucker ratio is 1:1,26–1,35.

The oesophagus and intestine have the same position and configuration as those of *P. spatulaeforme*. The excretory vesicle is ampullate in shape and appears to open through the excretory pore situated in a notch in the posterior margin of the body. The genital pore lies in the midline of the body behind the bifurcation of the gut in the posterior ⅓ of the distance between the oral and ventral suckers. The cirrus and opening of the vagina in the genital atrium could not be seen.

The testes are large, irregularly lobed and variably indented. The one testis lies in front of the other.

The vitellaria are compact bodies that are pear-shaped to round with occasional shallow indentations. They are situated some distance posterior to the margin of the ventral sucker and lie lateral to the ovary. One vitellarium is situated slightly in front of the other.

The ovary is oval and lies opposite the vitellaria on the left side of the body.

The uterus consists of numerous tortuous loops that occupy the space between the testes anteriorly, the intestinal caecae laterally and the ends of the intestinal caecae posteriorly. They extend beyond the caecae laterally, but do not pass the ends of the caecae posteriorly.

***Phyllodistomum ghanense* Thomas, 1958 (Fig. 5, Table 1)**

Material examined: The holotype mounted specimen from *Mastacembelus nigromarginatus*, Ghana.

The body has the characteristic shape of the genus. The forebody constitutes about ⅓ of the total body length and the suckers are round. The oral to ventral sucker ratio is 1:1,3. The oesophagus is short and the intestine bifurcates in the anterior third of the distance between the suckers. The intestinal caecae terminate some distance away from the posterior margin of the body. The excretory bladder and pore could not be seen.

The genital pore lies behind the gut bifurcation, in the midline of the body. A cirrus and cirrus pouch are lacking. The vesicula seminalis is large and is situated posterior to the genital opening. The opening of the vagina could not be seen.

The testes are diagonally arranged, with the one testis well in front of the other. They are irregularly lobed and the indentations are shallow. The posterior testis is slightly larger than the anterior one.

The vitellaria are approximately round or bean-shaped structures lying close to the posterior rim of the ventral sucker. They are opposed and are flanked by the ovary on one side and the anterior testis on the other.

The ovary lies on the left side of the body, opposite the vitellaria. It is roughly oval in shape.

The uterus consists of dense coils that occupy the entire space behind the vitellaria that is not occupied by the gonads. Laterally and posteriorly, they extend to the margin of the body and anteriorly they are situated laterally to the caecae and extend to the posterior rim of the ventral sucker. The uterine coils are filled with eggs, the ones closest to the genital pore containing miracidia.

***Phyllodistomum symmetrorchis* Thomas, 1958 (Fig. 6, Table 1)**

Material examined: The mounted holotype specimen from *Auchenoglanis occidentalis*, Ghana.

The body has the characteristic shape of the genus and the margin of the posterior part has a wrinkled appearance. The forebody constitutes about ¼ of the total body length. The oesophagus is very short and the intestine bifurcates a short distance behind the oral sucker. The caecae bulge anteriorly and appear inflated, and posteriorly they end in blind sacs some distance from the margin of the body. The excretory vessel was not seen but the excretory pore opens in a distinct notch.

The suckers are round. The oral sucker is situated subventrally and is slightly smaller than the ventral sucker. The ratio of the size of the oral sucker to that of the ventral sucker is 1:1,4.

The genital pore lies halfway between the oral and ventral suckers. The vesicula seminalis is distinct and is next to the genital atrium. A cirrus and cirrus sac are absent, and the vaginal opening was not seen.

The testes are large, round, symmetrical structures lying opposite each other on either side of the midline.

The vitellaria are small, deeply indented and irregularly lobed structures, lying on either side of the midline posterior to the ovary. They are directly opposed. The shell gland is distinct and lies immediately in front of the vitellaria.

The ovary is comparatively small and lies on the left side of the body, opposite the shell gland, and in front of the vitellaria. It is round in shape.

The uterine coils are sparsely distributed in the space behind the testes and occasionally extend beyond the caecae laterally and posteriorly.

***Phyllodistomum vanderwaali* Prudhoe & Hussey, 1977 (Fig. 7, Table 1)**

Material examined: Three mounted syntype specimens from *Clarias gariepinus*, South Africa.

The body is pear-shaped and the forebody constitutes about ⅓ of the total length. The suckers are round and the oral to ventral sucker ratio is 1:1,5–1,8.

The oesophagus is very short and the intestine bifurcates immediately behind the oral sucker. The caecae bulge somewhat anteriorly and terminate near the posterior body margin. The excretory vesicle and opening could not be seen.

The genital pore opens halfway between the oral and ventral suckers. The vesicula seminalis opens into the genital atrium, which is large. A cirrus and cirrus sac are absent, and the opening of the vagina in the genital atrium could not be seen.

The testes are small, shallowly indented and irregularly lobed structures lying on either side of the midline in the middle of the body. They may be opposed or one testis may be slightly in front of the other.

The vitellaria are compact bodies, roughly triangular and diagonally opposed. They lie directly behind the posterior rim of the ventral sucker, in front of the ovary.

The ovary is situated either on the left or the right side of the body, between the testes and the vitellaria. It is shallowly indented and irregularly lobed. The shell gland is small and situated between the vitellaria.

The uterus consists of numerous loops that occupy the area between the intestinal caecae and the testes. They may extend beyond the ends of the caecae, but do not cross the caecae laterally. The uterine coils are filled with eggs, of which the ones closest to the genital pore contain miracidia.

SEASONAL INCIDENCE OF *P. BAVURI*

One hundred and three catfish from the Sabie and Crocodile Rivers were examined from April 1980–March 1981. The numbers of *P. bavuri* recovered from those fish that harboured them are listed in Table 2.

P. bavuri was recovered from only 31 (30,1%) of the catfish, and the size of the fish did not noticeably influence the number or the size of the parasites.

From these results it is apparent that there is no seasonal fluctuation in the numbers of *P. bavuri* and that infestation of the catfish seems to take place erratically.

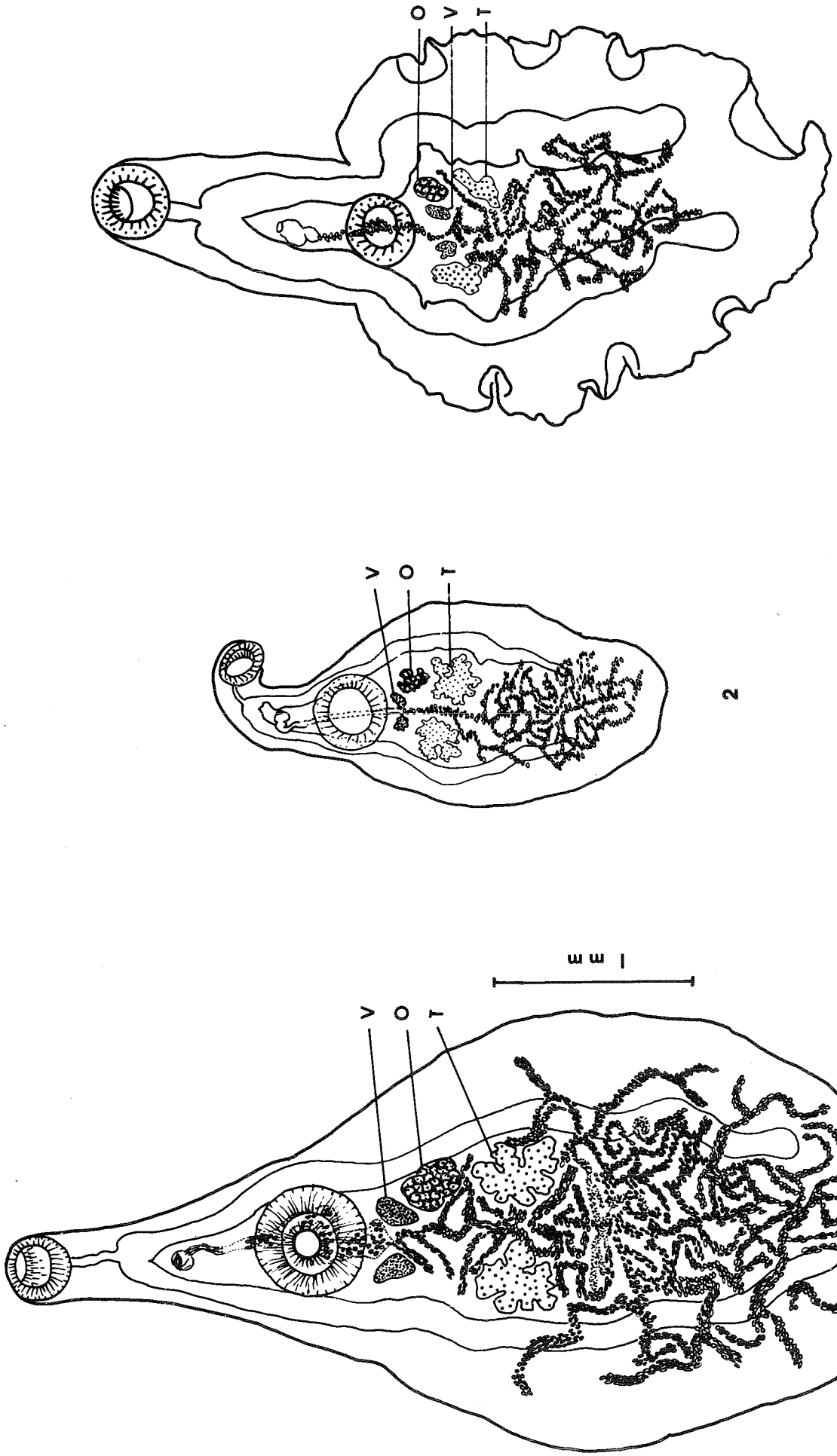

FIG. 1–7 The African species of the genus *Phyllodistomum* drawn to the same scale. The following abbreviations are used in the figures: O = ovary; S = shell gland; T = testis; V = vitellarium

FIG. 1 *Phyllodistomum bavuri*, ventral view

FIG. 2 *Phyllodistomum linguale*, ventral view

FIG. 3 *Phyllodistomum spatulaeforme*, ventral view

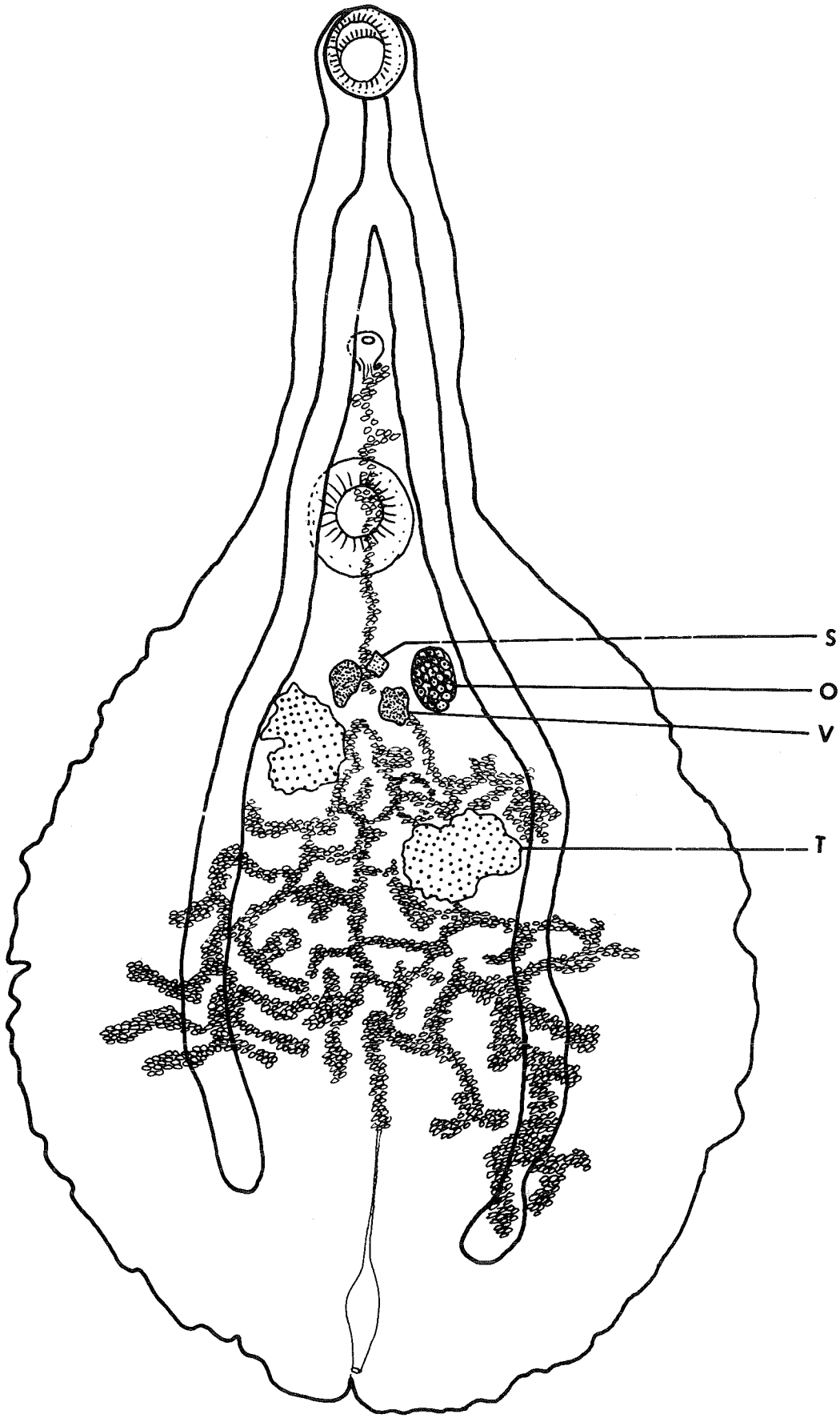

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FIG. 4 *Phyllodistomum spatula*, ventral view

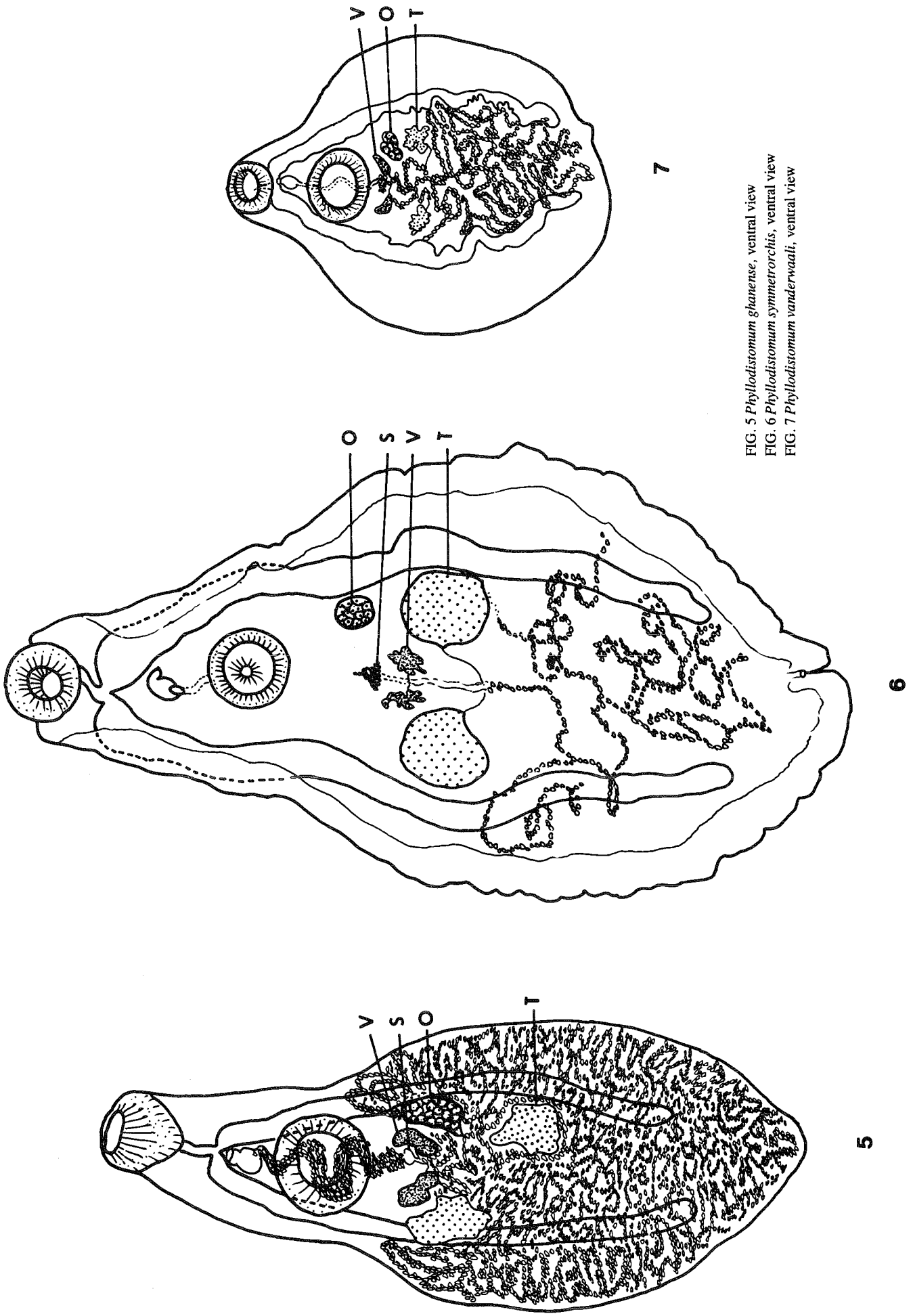

FIG. 5 *Phyllodistomum ghanense*, ventral view
FIG. 6 *Phyllodistomum symmetrorchis*, ventral view
FIG. 7 *Phyllodistomum vanderwaali*, ventral view

TABLE 1 The principal measurements of the 7 African species of the genus *Phyllodistomum*[1]

Species	Author	Length	Width	Diameter of oral suckers	Diameter of ventral suckers	Distance between suckers
P. bavuri	—	3,49–5,18	0,99–2,54	0,27–0,36	0,41–0,63	0,99–1,71
P. linguale	Odhner, 1902 Lewis, 1935 This paper	5,30 5,36 2,99	2,30 2,35 1,48	0,43 0,43 0,18	0,73 0,73 0,41	— — 0,78
P. spatulaeforme	Odhner, 1902 Lewis, 1935 This paper	4,75 4,75 4,05	2,80 2,80 2,20	0,35 0,35 0,40	0,40 0,40 0,40	— — 1,25
P. spatula	Odhner, 1902 Lewis, 1935 This paper	5,0–5,75 5,0–5,75 5,31–6,35	3,3–3,6 3,3–3,6 3,19–3,42	0,48 0,48 0,36–0,38	0,52 0,52 0,49	— — 2,07–2,16
P. ghanense	Thomas, 1958 This paper	3,65 3,69	1,50 1,53	0,39 0,41	0,50 × 0,53* 0,54	— 1,04
P. symmetrorchis	Thomas, 1958 This paper	4,34–4,35 4,40	2,16–2,69 2,39	0,37–0,40×0,38–0,42* 0,40	0,41–0,45×0,41–0,43* 0,45	— 1,08
P. vanderwaali	Prudhoe & Hussey, 1977 This paper	1,9–2,5 1,82–2,27	1,3–1,6 0,63–1,65	0,23–0,25 0,22–0,25	0,35–0,40 0,38–0,40	— 0,36–0,47

[1] All measurements given in mm

* Ventral sucker not round according to Thomas (1958)

TABLE 1 The principal measurements of the 7 African species of the genus *Phyllodistomum*[1] (*continued*)

Species	Author	Testes				Ovary	
		Left		Right		Length	Width
		Length	Width	Length	Width		
P. bavuri	—	0,33–0,67	0,21–0,47	0,31–0,61	0,16–0,43	0,19–0,38	0,15–0,32
P. linguale	Odhner, 1902	—	—	—	—	—	—
	Lewis, 1935	1–1,5 times size of ovary**				0,285	0,212
	This paper	0,27	0,30	0,25	0,26	0,14	0,18
P. spatulaeforme	Odhner, 1902	—	—	—	—	—	—
	Lewis, 1935	1–2 times size of ovary**				0,22	0,163
	This paper	0,27	0,18	0,31	0,13	0,20	0,14
P. spatula	Odhner, 1902	—	—	—	—	—	—
	Lewis, 1935	2–3 times size of ovary**				0,562	0,462
	This paper	0,52–0,54	0,38–0,43	0,49–0,61	0,36–0,41	0,27–0,29	0,20–0,25
P. ghanense	Thomas, 1958	0,42	0,30	0,50	0,40	0,40	0,27
	This paper	0,49	0,32	0,45	0,27	0,40	0,20
P. symmetrorchis	Thomas, 1958	0,43–0,49**	0,40–0,41**	—	—	0,01–0,21	0,14–0,18
	This paper	0,47	0,43	0,47	0,47	0,22	0,20
P. vanderwaali	Prudhoe & Hussey, 1977	—	—	—	—	0,12–0,17	0,08–0,12
	This paper	0,11–0,27	0,09–0,15	0,09–0,16	0,09–0,15	0,13–0,15	0,09–0,11

[1] All measurements given in mm

** Measurements of both the organs

TABLE 1 The principal measurements of the 7 African species of the genus *Phyllodistomum*[1] (Continued)

Species	Author	Vitellaria				Eggs	
		Left		Right			
		Length	Width	Length	Width	Length	Width
P. bavuri	—	0,13–0,25	0,08–0,16	0,13–0,23	0,08–0,16	0,036–0,043	0,018–0,032
P. linguale	Odhner, 1902	—	—	—	—	0,033	—
	Lewis, 1935	⅓–½ of size of ovary**				0,033	0,033
	This paper	0,11	0,06	0,10	0,07	0,043–0,054	0,021–0,028
P. spatulaeforme	Odhner, 1902	—	—	—	—	0,028	—
	Lewis, 1935	½ of size of ovary**				0,028	0,028
	This paper	0,16	0,09	0,14	0,09	0,020–0,032	0,018–0,022
P. spatula	Odhner, 1902	—	—	—	—	0,030	—
	Lewis, 1935	¼–⅓ of size of ovary**				0,030	0,030
	This paper	0,18–0,25	0,14–0,16	0,23–0,26	0,14–0,16	0,018–0,020	0,014
P. ghanense	Thomas, 1958	0,27–0,33**	0,12**	—	—	0,028–0,032	0,018
	This paper	0,32	0,11	0,31	0,14	0,021–0,032	0,018–0,021
P. symmetrorchis	Thomas, 1958	0,19–0,24**	0,10–0,15**	—	—	0,022–0,024	0,016–0,018
	This paper	0,20	0,11	0,23	0,11	—	—
P. vanderwaali	Prudhoe & Hussey, 1977	0,11–0,16**	0,042–0,058**	—	—	0,016–0,028	0,01–0,017
	This paper	0,12–0,16	0,04–0,05	0,11–0,13	0,04–0,05	0,036	0,022

[1] All measurements given in mm
** Measurements of both the organs

TABLE 2 Variations in the numbers of *Phyllodistomum bavuri* recovered from catfish from the Kruger National Park

Date and locality	Fish			*P. bavuri* recovered	
	No.	Sex	Length (cm)	No./fish	Monthly mean
Sabie River					
Apr. 80	24	♂	70	26	26
Aug. 80	60	♂	61	37	
Aug. 80	61	♂	52	25	
Aug. 80	62	♂	44	20	27
Sept. 80	70	♂	64,5	4	
Sept. 80	75	♂	70	12	
Sept. 80	84	♂	49,5	22	13
Nov. 80	94	♀	51	5	
Nov. 80	95	♂	55,5	13	
Nov. 80	96	♂	44,5	1	6
Dec. 80	100	♀	46	71	
Dec. 80	101	♂	50	95	83
Jan. 81	107	♀	73	11	
Jan. 81	108	♀	50	28	
Jan. 81	109	♂	40	10	
Jan. 81	110	♂	58	15	
Jan. 81	116	♂	?	5	14
Feb. 81	117	♂	65,5	60	
Feb. 81	118	♀	63,5	36	
Feb. 81	119	♀	49	29	42
March 81	120	♀	90,5	32	
March 81	121	♀	57,5	154	
March 81	122	♀	44,5	56	
March 81	123	♀	49,5	6	62
Apr. 81	130	♂	65	7	7
Crocodile River					
Apr. 80	32	♂	52,5	2	2
May 80	38	♂	60	1	1
Aug. 80	65	♂	85	27	
Aug. 80	66	♂	54	65	
Aug. 80	67	♂	50,5	4	32
Jan. 81	111	♀	36	1	1

DISCUSSION

There are several characteristics on which the African species of the genus *Phyllodistomum* may be differentiated from one another, but the most convenient one appears to be the position of the ovary relative to the vitellaria, i.e. whether the ovary lies anterior, opposite or posterior to the vitellaria.

The only species in which the ovary lies in front of the vitellaria is *P. symmetrorchis*. This is a distinctive species in that the testes are large and round and that there are few uterine coils.

In *P. spatula* and *P. ghanense* the ovary lies opposite or slightly posterior to the vitellaria and in *P. spatulaeforme* it lies opposite or slightly anterior to the vitellaria. Of these 3 species, *P. ghanense* is distinctive in that it is the only species in which the uterine coils fill the entire posterior ⅔ of the body, apart from the space occupied by the testes, ovary and vitellaria. The ovary of *P. spatula* is almost round and the excretory pore opens in a distinct notch in the posterior extremity of the body. In *P. spatulaeforme* the ovary is kidney-shaped, the testes are very small in relation to the body size and the vitellaria are close to the posterior rim of the ventral sucker.

The species in which the ovary lies behind the vitellaria are *P. vanderwaali*, *P. linguale* and *P. bavuri*. *P. vanderwaali* may be differentiated from the other 2 species in that the testes are weakly lobed, the vitellaria lie immediately behind the ventral sucker, the oesophagus is very short and the intestine bifurcates almost immediately behind the oral sucker. Furthermore, the body is pear-shaped and the forebody is very short. These trematodes are the smallest of the African species and do not exceed 2,5 mm in length.

P. linguale and *P. bavuri* are both large trematodes, measuring from 3–5,2 mm. *P. bavuri* may be differentiated from the former species in that the ovary is smooth, round or, at most, weakly bilobed and that the vitellaria are also smooth and oval to triangular in outline. The uterine coils often cross the intestinal caecae laterally, and the intestinal caecae terminate close to the posterior body margin. In *P. linguale*, the ovary and the vitellaria are irregularly lobed, the uterine coils seldom cross the intestinal caecae laterally and the intestinal caecae terminate some distance from the posterior body margin.

The various species of *Phyllodistomum* described prior to 1932 were revised by Lewis (1935), who also examined a co-type of *P. linguale*. The measurements given by Odhner (1902, 1911) and Lewis (1935) differ considerably from those of the single specimen examined in this study. The shape and position of the various internal organs, however, are similar and it can only be assumed that the specimen examined by me was an abnormally small one.

The data presented in Table 2 indicate that there is no seasonal variation in the numbers of the parasite. This can be explained when the life cycles of members of the genus are considered. In his study of the life cycles of

Phyllodistomum lohrenzi Löwen, 1935 and *Phyllodistomum caudatum* Steelman, 1938, Beilfuss (1954) found that miracidia of *P. lohrenzi* entered a mussel passively through the incurrent siphon and transformed to sporocysts in the gills of the mussel. A single generation of daughter sporocysts were produced which gave rise to cercaria that either left the mussel through the excurrent siphon, or remained inside the daughter sporocysts where they lost their tails and encysted. The released cercaria were unable to swim and attracted the attention of caddisfly larvae (Trichoptera) through movement of their tails. They were subsequently eaten by the insects and developed into metacercaria. The cercaria of *P. caudatum*, however, were able to swim, and a second intermediate host was not found (Beilfuss, 1954).

As freshwater mussels, *Unio* spp., were regularly found in the stomach and intestinal contents of the catfish throughout the year it can be assumed that catfish became infested by eating infested shell-fish. Furthermore, in the warmer areas of the country, such as the Lowveld, where this study was conducted, water temperatures remain fairly high during winter and both the 1st and 2nd intermediate hosts remain active for most of the year. Infestation of catfish therefore probably takes place throughout the year, with the result that there is no seasonal variation in the numbers of *P. bavuri*.

ACKNOWLEDGEMENTS

The author wishes to express his gratitude to the Board of Trustees, National Parks Board, for placing the fish at his disposal, to Dr V. de Vos, Kruger National Park, for the arrangements, to Dr I. G. Horak, for supplying some of the material and to Mr N. H. Jonker for technical assistance. Special thanks are due to Mr R. Bray, British Museum (Natural History), London, for the loan of the type specimens of *P. symmetrorchis*, *P. ghanense* and *P. vanderwaali* and specimens of *P. linguale*, *P. spatula* and *P. spatulaeforme*.

This project was funded by the University of Pretoria.

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Parasites of South African freshwater fish. III *Rhabdochona (Rhabdochona) versterae* n. sp. (Nematoda: Rhabdochonidae) from the spot-tailed robber, *Alestes imberi* Peters 1852

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ABSTRACT

BOOMKER, J. & PETTER, ANNIE J. 1993. Parasites of South African freshwater fish. III. *Rhabdochona (Rhabdochona) versterae* n. sp. (Nematoda: Rhabdochonidae) from the spot-tailed robber, *Alestes imberi* Peters 1852. *Onderstepoort Journal of Veterinary Research*, 60:23–27 (1993)

A new species of *Rhabdochona* was recovered from the spot-tailed robber, *Alestes imberi* Peters 1852 in the Sabie River, Kruger National Park. It differs from its nearest relative, *Rhabdochona moraveci* Puylaert 1973 in that it has shorter spicules and fewer prostomal teeth. The new species also shows affinities with *Rhabdochona paski* Baylis 1928 and *Rhabdochona congolensis* Campana-Rouget 1961, but differs from the first-named species in that it has shorter spicules and fewer precloacal papillae. It differs from the last-named species in the number and arrangement of the labial and cephalic papillae, and the absence of finger-like processes on the tip of the female tail.

The subgenus *Rhabdochona* Moravec 1972 is characterized by the absence of filaments or floats on the mature eggs. These structures are also lacking in the new species, which is therefore described here as *Rhabdochona (Rhabdochona) versterae* n. sp.

INTRODUCTION

The genus *Rhabdochona* Railliet, 1916 consists of more than 60 species world-wide, 7 of which have been recorded from freshwater fish in Africa (Moravec 1972a; Puylaert 1973; Mashego 1990). Of these *Rhabdochona congolensis* Campana-Rouget, 1961, *Rhabdochona esseniae* Mashego, 1990, *Rhabdochona paski* Baylis, 1928 and *Rhabdochona moraveci* Puylaert, 1973 belong to the subgenus *Rhabdochona* Railliet, 1916 which is characterised by the absence of filaments or floats on the surface of the mature eggs. Only *R. esseniae* has been recorded from South Africa, and was recovered from *Barbus lineomaculatus* Boulenger, 1903, *Barbus marequensis* Smith, 1814, *Barbus paludinosus* Peters, 1852 and *Barbus trimaculatus* Peters, 1852 from Lebowa and Venda (Mashego 1989, 1990).

During a survey of the parasites of freshwater fish at several localities in the Kruger National Park, a new species of this genus was recovered from the spot-tailed robber, *Alestes imberi* Peters, 1852. The worms were present in the stomach or intestine of 11 of the 30 spot-tailed robbers examined. Only a few parasites were recovered from the fish that harboured them, the most being 5 males and 8 females from a spot-tailed robber caught in the Sabie River.

In this paper these parasites are described as *Rhabdochona (Rhabdochona) versterae*, n. sp., and their affinities and differences with other members of the genus in Africa are discussed.

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Received 17 September 1992—Editor

DESCRIPTION OF *RHABDOCHONA (RHABDOCHONA) VERSTERAE*

Type host

Alestes imberi Peters, 1852 from the Sabie River, Kruger National Park, South Africa.

Material examined

Holotype male and allotype female, No. MNHN 607 BC. Paratypes, 5 males and 5 females, No. MNHN 608 BC, from *A. imberi* from the type locality.

Description of the species

The principal measurements are presented in Table 1.

Small to moderately sized worms. The mouth opening is hexagonal and 4 internal labial and 4 cephalic papillae are present. The amphids are large and a pair of what could be cuticular adjournments are present close to each amphid (Fig. 1). The prostomium is funnel-shaped and basal teeth are present; their number, however, could not be determined. Longitudinal ridges in the prostomium of both sexes form 8 forwardly directed teeth anteriorly (Fig. 2). The deirids are small setose structures close to the anterior extremity (Fig. 2). The tip of the tail is smooth and rounded in both sexes (Fig. 3a, b).

Males

The spicules are unequal and weakly sclerotised. The shorter right spicule is simple and bears 2 small protuberances on the ventral aspect. Membranous alae are present on the proximal half (Fig. 4a). The longer left spicule is curved and its distal tip is shaped like a claw, with several indistinct, weakly sclerotised structures between the pinchers (Fig. 4b–d). The ratio of the right to left spicule is 1:2,11–2,74.

The number of pre-cloacal subventral papillae varies from 11 on the one side and 13 on the other to 14 on the one side and 15 on the other. The most commonly encountered combination is 12 on the one side and 13 on the other. The first lateral pre-cloacal papillae arise approximately at the level of the 3rd subventral papillae (Fig. 5). The number of lateral pre-cloacal papillae varies from 2 on either side to 3 on the one side and 5 on the other. The most commonly encountered combination, however, is 3 on either side. There are 6 pairs of post-cloacal papillae; the 2nd pair lies laterally and the remaining pairs subventrally (Fig. 3b & 5). Their number and arrangement were constant in all the specimens examined.

Females

The vulva is situated in the posterior half of the body and is a simple transverse slit. The vagina runs perpendicular to the long axis of the body for a short distance; it then curves sharply backwards to join the caudally directed ovejector (Fig. 6). Eggs are elongated ovoid and devoid of any structures on the shells; they contain a fully formed larva when laid (Fig. 7).

DISCUSSION

Moravec (1972b) divided the genus *Rhabdochona* into 3 subgenera depending on the presence or absence of floats or filaments on mature eggs. Thus, the subgenus *Rhabdochona* Railliet, 1916,

TABLE 1 The principal measurements of *Rhabdochona (Rhabdochona) versterae* n. sp.*

Measurements	Males		Females	
	Holotype	Paratypes	Allotype	Paratypes
Length (mm)	11,7	12,25 — 14,00	28,58	17,28 — 22,80
Maximum width	175	210 — 267	453	158 — 390
Prostomium, length	39	36 — 47	41	38 — 50
Prostomium, width	23	22 — 26	24	26 — 30
Length of prostomium and vestibulum	179	191 — 222	214	192 — 220
Length of muscular oesophagus	508	407 — 498	326	477 — 576
Length of glandular oesophagus	3 848	4 520 — 6 000	7 716	4 533 — 7 540
Distance of deirids from anterior end	76	64 — 70	103	56 — 67
Distance of nerve ring from anterior end	219	231 — 264	265	230 — 249
Distance of excretory pore from anterior end	319	356 — 394	435	332 — 358
Length of left spicule	186	225 — 246	—	—
Length of right spicule	74	82 — 108	—	—
Length of tail	250	247 — 296	289	200 — 308
Distance of vulva from posterior end (mm)	—	—	11,98	6,32 — 9,16
Eggs (in utero), length**	—	—	35	35 — 37
Eggs (in utero), width**	—	—	21	20 — 21

* All measurements given in µm unless otherwise stated

** Mean measurements of 3 eggs from each female

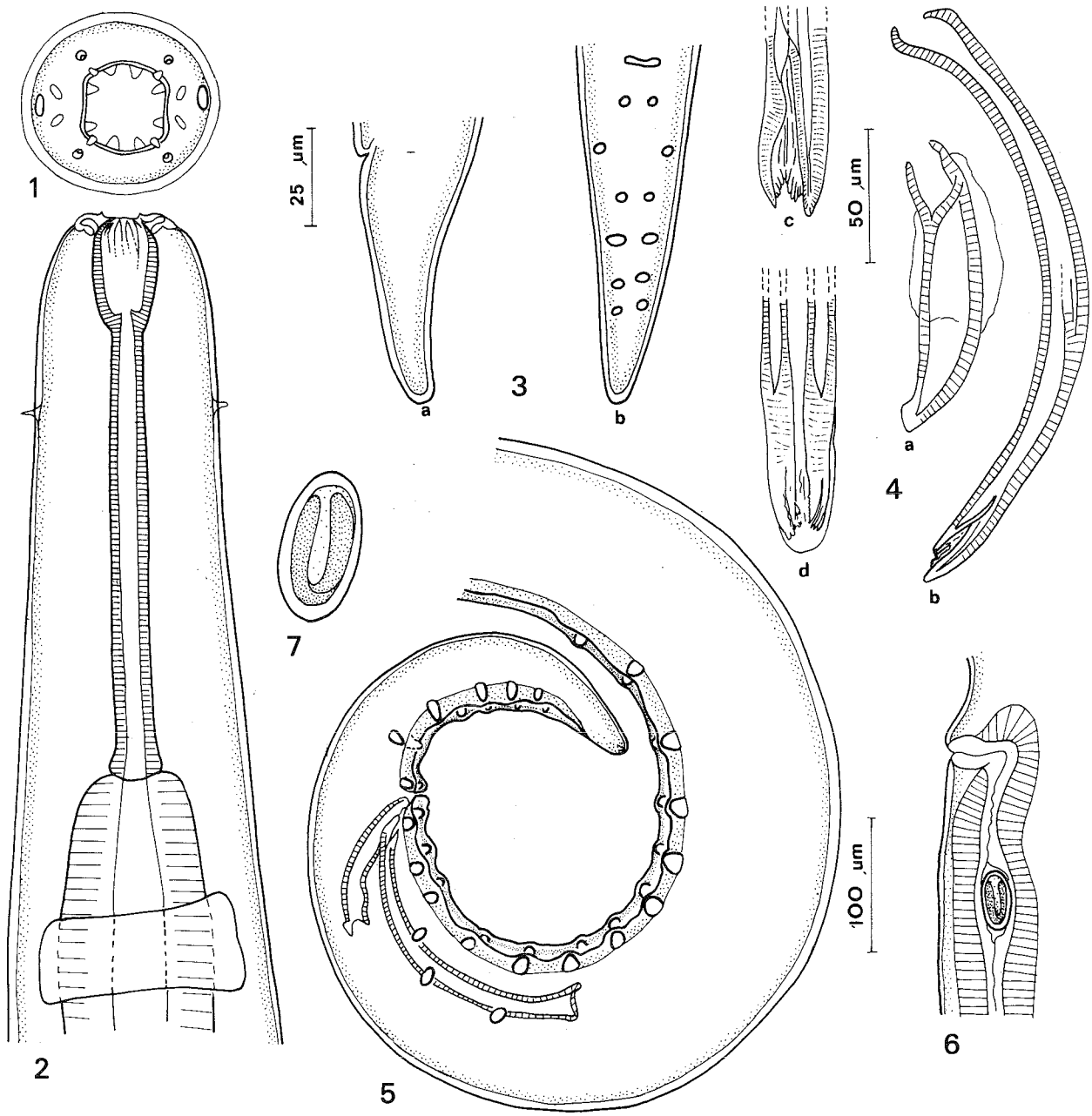

FIG. 1–7 *Rhabdochona versterae* n. sp.

FIG. 1 Apical view of the head of a male

FIG. 2 Ventral view of the anterior part of a female

FIG. 3 Tail of (a) female, lateral view and (b) male, ventral view, showing the arrangement of the post-cloacal papillae

FIG. 4 Lateral view of (a) the right and (b) the left spicules, and the tip of the left spicule in lateral (c) and ventral (d) views

FIG. 5 Lateral view of the posterior end of the male, showing the arrangement of the pre- and post-anal papillae

FIG. 6 Lateral view of the vagina and ovejector

FIG. 7 Egg containing a larva

Scale bars: Fig. 1, 4c, 4d, 7 = 25 µm; Fig. 2, 4a, 4b = 50 µm; Fig. 3a, 3b, 5, 6 = 100 µm

has eggs that are either smooth or are covered with a thin, almost indistinguishable gelatinous layer, the subgenus *Filochona* Saidov, 1953 has eggs that are provided with filaments and the subgenus *Globochona* (Moravec 1972b) has eggs with hemispherical floats. Chabaud (1975) states that the floats or filaments have no phylogenetic importance, but serve as a useful means to separate the numerous species. From the above it follows that the absence of floats or filaments on the eggs or *R. versterae* places this species in the subgenus *Rhabdochona* (Moravec 1972b).

According to the description of Mashego (1990), *R. esseniae* has eggs without any floats or filaments and should therefore also be placed in the subgenus *Rhabdochona.*

R. versterae shows affinities with *R. moraveci* from *Aphyosemion cameronensis* Boulenger, 1903 from the Cameroon, as far as the structure of the mouth and the arrangement of the labial and cephalic papillae are concerned. In both species the mouth is hexagonal and external labial papillae are lacking. Puylaert (1973) illustrates what he believes are nerve bundles near the amphids, but we believe that structures in the same region of *R. versterae* are cuticular adjournments. The 2 species can be easily separated, in that the left spicule of *R. moraveci* are approximately 3 × longer than that of *R. versterae;* consequently, the ratio of the right to left spicule is 1:5,9–7,7 in the former species and 1:2,1–2,7 in the latter. Furthermore, in apical view of the head, female *R. moraveci* have 12 and the males 14 prostomal teeth, some of which may be double (Puylaert 1973), while both male and female *R. versterae* have 8 teeth, none of which are double.

Moravec (1972a) comments on the similarity between *R. paski* and *R. congolensis* and states that the only difference that can be taken into account is the presence of about 10 finger-like processes on the tip of the female tail. The differences in the various measurements could be the result of the age of the parasite or the influence of the host, and, in addition, there is considerable variation in the number of subventral pre-anal papillae within a species (Moravec 1972a). Nevertheless, Moravec (1972a) considers *R. paski* and *R. congolensis* to be valid species.

R. versterae shows affinities to both *R. paski* Baylis, 1928 and *R. congolensis* in that the ratio of the right to left spicules overlaps, and that each of the 3 species has 8 prostomal teeth (Baylis 1928; Campana-Rouget 1961; Moravec 1972a).

R. paski differs from *R. versterae* in the longer spicules (108–140 µm and 282–300 µm, respectively in the former, and 74–108 µm and 186–246 µm, respectively in the latter), and in the different configuration of the tip of the left spicule. In addition, the males of *R. paski* have a longer tail (405–411 µm) and have 16–19 pairs of subventral pre-anal papillae as opposed to the shorter tail (200–250 µm) and 12–15 pairs of subventral pre-anal papillae of *R. versterae.* Furthermore, the ratio of the length of the glandular oesophagus to the total body length is greater in *R. paski* (1:7,38–8,89 for the males and 1:6,00–8,14 for the females) than in *R. versterae* (1:1,95–3,64 for the males and 1:2,24–6,00 for the females), indicating that, on average, *R. versterae* has a longer glandular oesophagus.

R. versterae differs from *R. congolensis* in that the tail of the female of the former species is smooth, while that of the latter species has about 10 finger-like processes. The number and arrangement of the labial papillae of the last-named species, as illustrated by Moravec (1972a), also appears to be different in *R. versterae.*

R. versterae differs from *R. esseniae* in the number of subventral pre-anal papillae (12–15 pairs in the former, 8 pairs in the latter), the length of the spicules (74–180 µm and 186–246 µm, respectively in the former and 115–154 µm and 500–560 µm, respectively in the latter), and thus the ratio of the right to left spicules (1:2,1–2,7 in the former and 1:3,25–4,87 in the latter).

We believe that the above differences are sufficient to warrant the creation of a new species. The parasites are therefore described here as *Rhabdochona (Rhabdochona) versterae* n. sp., in honour of Prof. Anna Verster, in recognition of her extensive contribution to the study of helminths in South Africa.

ACKNOWLEDGEMENTS

The authors wish to express their gratitude to the Board of Trustees, National Parks Board for making the material available, to Prof. Alain Chabaud for his constructive criticism of the manuscript and to Mme Roselyne Tcheprakoff for the illustrations. This work was done at the Laboratoire de Biologie Parasitaire, Musèum National d'Histoire Naturelle, Paris, France, with a study grant to the senior author from the Foundation for Research Development.

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Onderstepoort Journal of Veterinary Research, 60:131–137 (1993)

Parasites of South African freshwater fish. IV. Description of *Spirocamallanus daleneae* n. sp. (Nematoda: Camallanidae) from *Synodontis zambezensis* Peters, 1852 (Mochokidae) with comments on *Spirocomallanus spiralis* (Baylis, 1923)

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ABSTRACT

BOOMKER, J. 1993. Parasites of South African freshwater fish. IV. *Spirocamallanus daleneae* n. sp. (Nematoda: Camallanidae) from *Synodontis zambezensis* Peters, 1852 (Mochokidae) with comments on *Spirocamallanus spiralis* (Baylis, 1923). *Onderstepoort Journal of Veterinary Research*, 60: 131–137 (1993)

During a survey of the parasites of fish in the Kruger National Park, a new species of *Spirocamallanus* Olson, 1952 was recovered from the small intestines of squeakers, *Synodontis zambezensis* Peters, 1952. The males of the new species differ from *Spirocamallanus spiralis* (Baylis, 1923) in having more spiral thickenings in the buccal capsule, the different configuration of the buccal capsule and its anterior margin, and in having a longer oesophagus, especially the muscular part. They differ from *Spirocamallanus mazabukae* Yeh, 1957 in having fewer thickenings in the buccal capsule, considerably shorter spicules and more caudal papillae. The new species also differs from the members of the genus described, but not named, by Yeh (1957) and Campana-Rouget (1961). In view of these differences and because of geographical and host differences, the new species is described here as *Spirocamallanus daleneae* n. sp.

Specimens of *Spirocamallanus spiralis* (Baylis, 1923) from *Synodontis eupterus* Boulenger, 1801 were re-examined and additional morphological and morphometrical data are provided.

Two male nematodes, originating from *Synodontis* spp. from Gabon and both labelled *Spirocamallanus spiralis,* were examined. The specimen from *Synodontis haugi* Pellegrin, 1906 conformed to the description of *Spirocamallanus daleneae*. The one from *Synodontis tessmanni* Pappenheim, 1911 had a buccal capsule resembling that of *Spirocamallanus spiralis,* but the principal measurements are different from those of either nematode species. Because of extensive damage to the specimen, it is not named here and should be regarded as a species inquirenda.

INTRODUCTION

Spirocamallanus spiralis (Baylis, 1923) was first recorded from the fish *Clarias anguillaris* (Linnaeus, 1758) (syn. *Silurus anguillaris* Linnaeus, 1758 nec *Heterobranchus anguillaris* Geoffroy St Hilaire, 1827 *sensu* Baylis, 1923a) in Cairo, Egypt. To the best of my knowledge, *Heterobranchus anguillaris* is a synonym of *Clarias gariepinus* (Burchell, 1922) which occurs only in southern Africa (Daget, Gosse & Thys van den Audenaerde 1986). The same nematodes were subsequently also recovered from *Synodontis eupterus* Boulenger, 1901, in Khartoum, Egypt (Baylis 1923b).

The 2nd species from Africa, *Spirocamallanus mazabukae* Yeh, 1957 was described from a 'Homa

Received 23 March 1993—Editor

fish' (*Clarias* sp.) in Zambia (Yeh 1957). Both Yeh (1957) and Campana-Rouget (1961) recorded unidentified *Spirocamallanus* spp. from 'Homa fish' and *Synodontis schall* (Bloch & Schneider, 1801), respectively. A large number of species have been described since, mostly from the Orient and South America, but none were recorded from southern Africa (Khalil 1971; Van As & Basson 1984).

During a survey of the parasites of freshwater fish in the Kruger National Park, numerous specimens of a *Spirocamallanus* sp., that differed from both *Spirocamallanus spiralis* and *Spirocamallanus mazabukae,* were recovered from the small intestine of the squeaker, *Synodontis zambezensis* Peters, 1852. The new species, for which the name *Spirocamallanus daleneae* n. sp. is proposed, is described here.

As part of this study, specimens of *Spirocamallanus spiralis* (Baylis, 1923) from *Synodontis eupterus* were loaned from the British Museum (Natural History) and examined. Specimens in the collection of the Muséum National d'Histoire Naturelle, Paris, France, labelled *Spirocamallanus spiralis* and originating from *Synodontis* spp. in Gabon, were also examined. Additional morphological and morphometrical data are provided for *Spirocamallanus spiralis sensu stricto* and the affinities of the members of the genus in Africa are discussed.

SPIROCAMALLANUS DALENEAE n. sp.

Type host

Synodontis zambezensis Peters, 1852, from the Sabie river, Kruger National Park, South Africa.

Material examined

The type specimens and numerous additional specimens have been deposited in the collection of the Muséum National d'Histoire Naturelle, Paris, France (MNHN). Holotype male and allotype female, no. MNHN 394 MD. Paratypes, 8 males, 9 females, no. MNHN 395 MD.

Etymology

The species is named after my wife, Dalene, for her continued support of and interest in my work on the helminths of fish and wild animals.

Description

The principal measurements are given in Table 1 and the nematodes are illustrated in Fig. 1–8.

Medium-sized worms, with an elliptical mouth opening bordered by 6 internal labial papillae, 2 amphids, 4 external labial and 4 cephalic papillae (Fig. 1). In lateral, dorsal or ventral view, the buccal capsule is well-sclerotized, globosely funnel-shaped and has 13–14 spiral ridges on the inner surface (Fig. 2a, b). The anterior margin of the buccal capsule is formed by 4 transverse, smooth, crescent-shaped projections and a well-sclerotized basal ring is present. The outline of a model made of the anterior margin of the buccal capsule is illustrated in Fig. 1b. The oesophagus is divided into a muscular and a glandular part which may be of equal lengths or the one part may be longer than the other. The nerve ring lies approximately in the middle of the muscular oesophagus. Small, inconspicuous deirids are situated near the buccal capsule (Fig. 2a). The excretory pore is small, often difficult to locate, and opens behind the nerve ring. The tail is rounded and in both sexes narrows abruptly near its end to form a short, stumpy projection that may carry a protuberance (Fig. 5, 6 & 8).

Males

The spicules are unequal in size and are weakly sclerotised. The tip of the larger right spicule bears 2 membranous projections that appear different in different views (Fig. 3a–d). The shorter left spicule is shaped like a golf club and bears a weakly sclerotised spur ventrally (Fig. 4a, b). The left spicule appears to act as a guide for the right one.

The caudal alae are narrow and at their cranial junction they form a raised membranous structure, that is quite distinct in lateral view (Fig. 5 & 6). There are 3 pairs pre-cloacal papillae, 2 pairs peri-cloacal papillae, and 3 pairs subventral and 1 pair lateral post-cloacal papillae; considering the size of the worms, all these papillae are quite small (Fig. 5 & 6).

Females

The vulva is a simple transverse slit in the anterior half of the body, near the middle, and the muscular vagina immediately runs posteriorly. The walls of the 2 uteri are thin and transparent, and their junction with the vagina could not be seen.

Morulae of different sizes and stages of development, each surrounded by a very thin, transparent membrane, are scattered in the uterus. Developing larvae contained within these thin membranes develop to a certain stage before escaping to lie free in the uteri. Younger larvae do not have the spiral thickenings in the buccal capsule, but those closest to the vagina and vulva have a weakly sclerotised buccal capsule in which the spiral thickenings can clearly be seen.

Larvae in the 4th stage and the 4th moult are illustrated in Fig. 7a–d.

SPIROCAMALLANUS SPIRALIS (BAYLIS, 1923)

Type hosts and localities

Clarias anguillaris (Linnaeus, 1758) (syn. *Silurus anguillaris* Linnaeus, 1758), Cairo, Egypt. An incom-

TABLE 1 The principal measurements of *Spirocamallanus daleneae* #

	Males		Females	
	Holotype	Paratypes	Allotype	Paratypes
Length (mm)	17,50	11,66–14,66	28,57	20,90–31,09
Width (mm)	285	278–333	618	455–678
Buccal capsule, length	114	107–121	149	116–145
Buccal capsule, width	93	79–97	126	110–121
Muscular oesophagus, length	652	666–730	873	804–959
Glandular oesophagus, length	708	494–621	896	655–850
Oesophagus, total length	1 360	1 224–1 287	1 769	1 614–1 654
Nerve ring from anterior end	333	290–363	425	385–414
Deirids from anterior end	223	184–235	235	193–276
Excretory pore from anterior end	538	569–657	655	583–678
Right spicule, length	207	179–224	–	–
Left spicule, length	152	128–166	–	–
Tail length	269	228–269	173	193–276
Vulva from anterior end (mm)	–	–	12,62	6,90–13,00
Vulva from posterior end (mm)	–	–	15,95	11,15–17,87

All measurements given in µm unless otherwise stated

TABLE 2 Comparison of the principal measurements of *Spirocamallanus spiralis* from different hosts #

	Host species, author and sex of parasites					
	Clarias anguillaris	*Synodontis eupterus*	*Synodontis eupterus*		*Synodontis tessmanni*	*Synodontis haugi*
	Baylis, 1923a	Baylis, 1923b	This paper		This paper	This paper
	Male	Female	Males	Female	Male	Male
Length (mm)	More than 7	22,25	8,34–10,66	21,57	**	15,05
Width (mm)	160	400	132–183	448	207	264
Buccal capsule, length	70	90	71–76	100	98+	108
Buccal capsule, width	–	–	59–73	100	76+	93
Muscular oesophagus, length	450	580	333–437	448	**	689
Glandular oesophagus, length	330	520	287–437	477	414	609
Oesophagus, total length	780	1 100	724–770	925	**	1 298
Nerve ring from anterior end	–	270	241–310	279	**	391
Deirids from anterior end	–	–	NS	134	**	205
Excretory pore from anterior end	–	–	NS	NS	**	NS
Right spicule, length	150	–	193–218	–	127	196
Left spicule, length	100	–	126–160	–	99	101
Tail length	–	160	197–259	170	69	176
Vulva from anterior end (mm)	–	9,25	–	8,95	–	–
Vulva from posterior end (mm)	–	–	–	12,45	–	–

All measurements given in µm unless otherwise stated
\+ Measured from the drawing by Petter & Thatcher (1988)
** No measurements due to damage
NS Not seen

plete description of the male nematode from this host is given by Baylis (1923a).

Synodontis eupterus Boulenger, 1901, Khartoum, Egypt. Additional characteristics of the male nematodes as well as an illustration of a male caudal end, together with the description of the female of the species from this host, are provided by Baylis (1923b).

Material examined

Five males, 1 mature female, 1 immature female and 1 larva in the 4th stage, all labelled *Spirocamallanus spiralis* and all mounted in glycerine jelly, collected from *Synodontis eupterus*, Khartoum, Egypt, 3-VII-1913 (British Museum (Natural History), no. 1984.3595, 1984.3596, and 1984.3597). Unfortunately all the specimens are in poor condition and

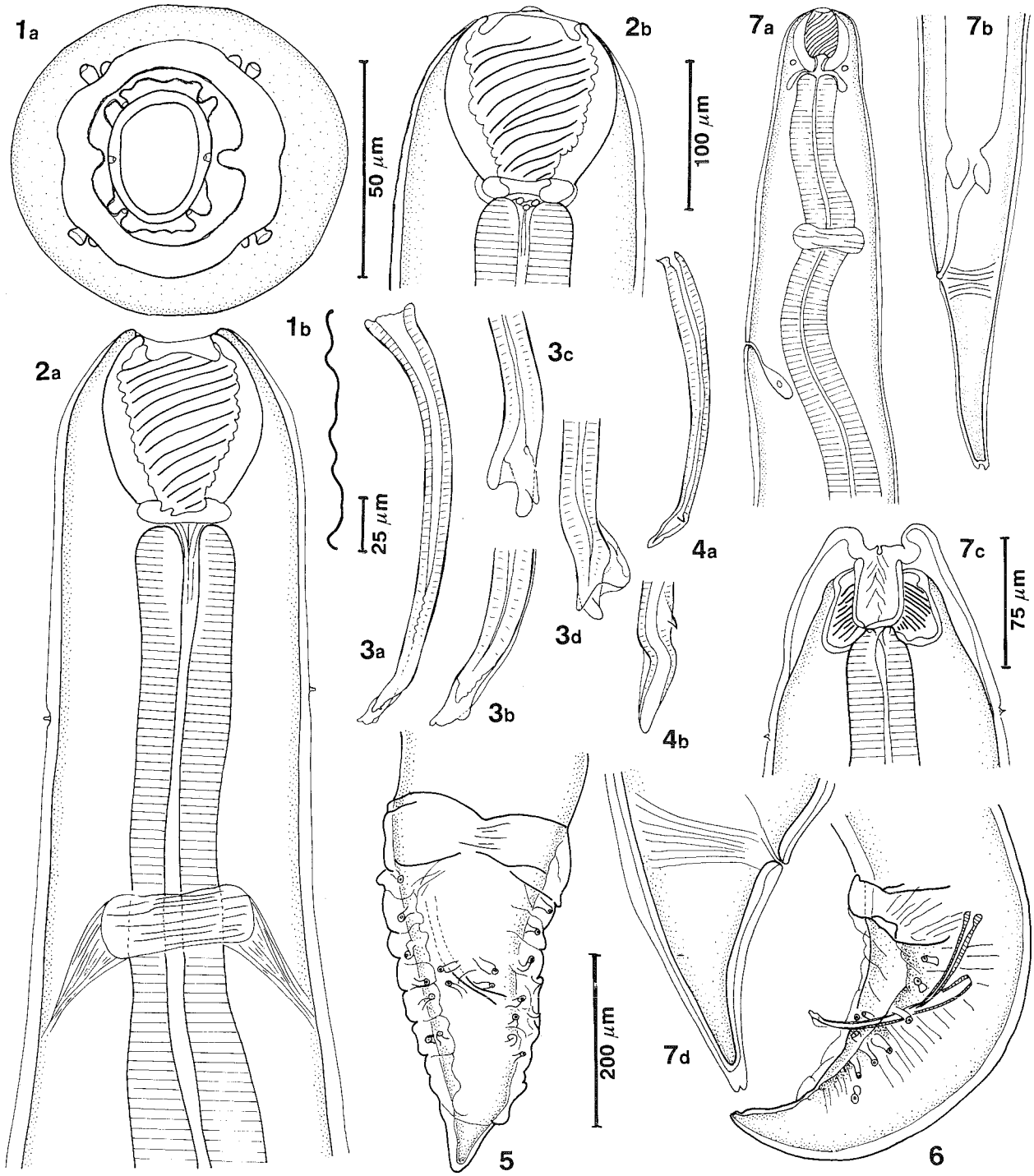

FIG. 1–7 ***Spirocamallanus daleneae*** **from** ***Synodontis zambezensis***

FIG. 1 Apical view of (a) the head of a female and (b) schematic representation of the anterior margin of the buccal capsule
FIG. 2 Lateral view of (a) the anterior part and (b) dorsal view of the head of a male
FIG. 3 The right spicule in (a) lateral view and its tip in (b) lateral, (c) ventral and (d) dorsolateral views
FIG. 4 The left spicule in (a) lateral view, and its tip in ventrolateral view
FIG. 5 Ventral view of the caudal area of the male
FIG. 6 Lateral view of the caudal area of the male
FIG. 7 Lateral view of (a) the anterior part and (b) the tail of an early 4th stage larva, and (c) ventral view of the head and (d) lateral view of the tail of a 4th larval moult

Scale bars: 25 µm—FIG. 1, 3a, 4a
50 µm—FIG. 3b, 3c, 3d, 4b
75 µm—FIG. 2a, 2b, 7c, 7d
100 µm—FIG. 7a, 7b
200 µm—FIG. 5, 6

all the measurements could therefore not be made, nor could the specimens be adequately illustrated. These nematodes are illustrated in Fig. 12–15.

One male, broken in half, in the collection of the Muséum National d'Histoire Naturelle, no. MNHN 43 KG, from *Synodontis haugi* Pellegrin, 1906 from Gabon. Petter & Thatcher (1988) erroneously refer to the host as *Synodontis hangi*. The nematode is illustrated in Fig. 9–11.

One male in the collection of the Muséum National d'Histoire Naturelle, no. MNHN 35 KG, from *Synodontis tessmanni* Pappenheim, 1911 from Gabon. The head of this specimen had been removed previously and was illustrated by Petter & Thatcher (1988). The male nematode and a 4th stage female larva are illustrated in Fig. 16–19.

Description

The measurements that could be made are listed in Table 2.

Medium-sized worms with an elliptical mouth opening around which the apical structures are arranged as illustrated in Fig. 1 & 16a. The buccal capsule is well-sclerotized, globose and bears 9–11 fine, weakly sclerotized spiral ridges on the inner surface (Fig. 12a, b). The anterior margin of the buccal capsule is formed by 4 processes, 2 of which are small and usually triangular in the males and trapezoidal in the female, with smooth or usually serrated edges, and 2 of which are in the shape of double crescents next to each other, but unequal in height, usually with smooth edges. The outline of a model made of the anterior part of the buccal capsule is illustrated in Fig. 12c. The oesophagus consists of a muscular and glandular part, which may be of equal length or the one part may be longer than the other. The nerve ring lies in the posterior half to third of the muscular oesophagus. The deirids and the excretory pore were not seen in the available specimens.

Males

The spicules are unequal and lightly sclerotised. Due to the method and state of preservation, the tips of the spicules could not be made out. The caudal alae are narrow, and the number and arrangement of the caudal papillae is in accordance with the description of Baylis (1923a, b). The tail appears conical in lateral view and apparently does not bear mucrons (Fig. 13).

Females

The females are similar to those of the previous species as regards the position of the vulva and the configuration of the uterus. Few larvae, however, were seen in the uterus. The tail narrows abruptly a short distance behind the anus and ends in a sharp point and, as far as could be ascertained, mucrones are absent (Fig. 14).

The head and tail of a larva in the 4th moult are illustrated in Fig. 15.

DISCUSSION

Baylis (1923a) created the genus *Procamallanus* for those nematodes that resembled *Camallanus* Railliet & Henry, 1915, but whose buccal capsule was not divided into 2 shell-like valves. Subsequently, Olson (1952) created the genus *Spirocamallanus* for those species of *Procamallanus* having spiral thickenings in the buccal capsule. The genus *Spirocamallanus* has been accepted by most workers. Moravec & Amin (1978), however, found that spiral ridges, the main distinguishing characteristic of the genus *Spirocamallanus,* were always present in the buccal capsule of female *Procamallanus siluri* Osmanov, 1964, but always absent in the males. The genus *Spirocamallanus* is therefore considered a subgenus of *Procamallanus* by Moravec & Amin (1978), De & Moravec (1980) and Moravec & Sey (1988).

Numerous species have been described since, mostly from South America and the Orient. *Spirocamallanus daleneae* is the 3rd species to be recorded from Africa and the 1st species from South Africa. It differs from *Spirocamallanus mazabukae* in having considerably shorter spicules (Table 2) and having only 4 pairs of post-cloacal papillae as opposed to the 6 pairs seen in *Spirocamallanus mazabukae*, as illustrated by Yeh (1957).

Spirocamallanus daleneae differs from the unnamed *Spirocamallanus* sp. described by Campana-Rouget (1961) in not having the chitinized structures encircling the buccal capsule, in having a larger buccal capsule with more spiral thickenings, and in having shorter spicules. Campana-Rouget (1961) states that there are 4 or 5 pairs of post-cloacal papillae, whereas *Spirocamallanus daleneae* has only 4 pairs.

Although the principal measurements of the unnamed *Spirocamallanus* sp. female described by Yeh (1957) are comparable to those of the females of *Spirocamallanus daleneae*, the former species has 10 spiral thickenings in the buccal capsule and the vagina runs anteriorly, as opposed to the 13–14 spiral thickenings and the posteriorly directed vagina in the latter.

Baylis (1923a) did not record the number and arrangement of the caudal papillae from the damaged male *Spirocamallanus spiralis* from *Clarias anguillaris*. Baylis (1923b), however, recorded the specimens from *Synodontis eupterus* as having 7 pairs

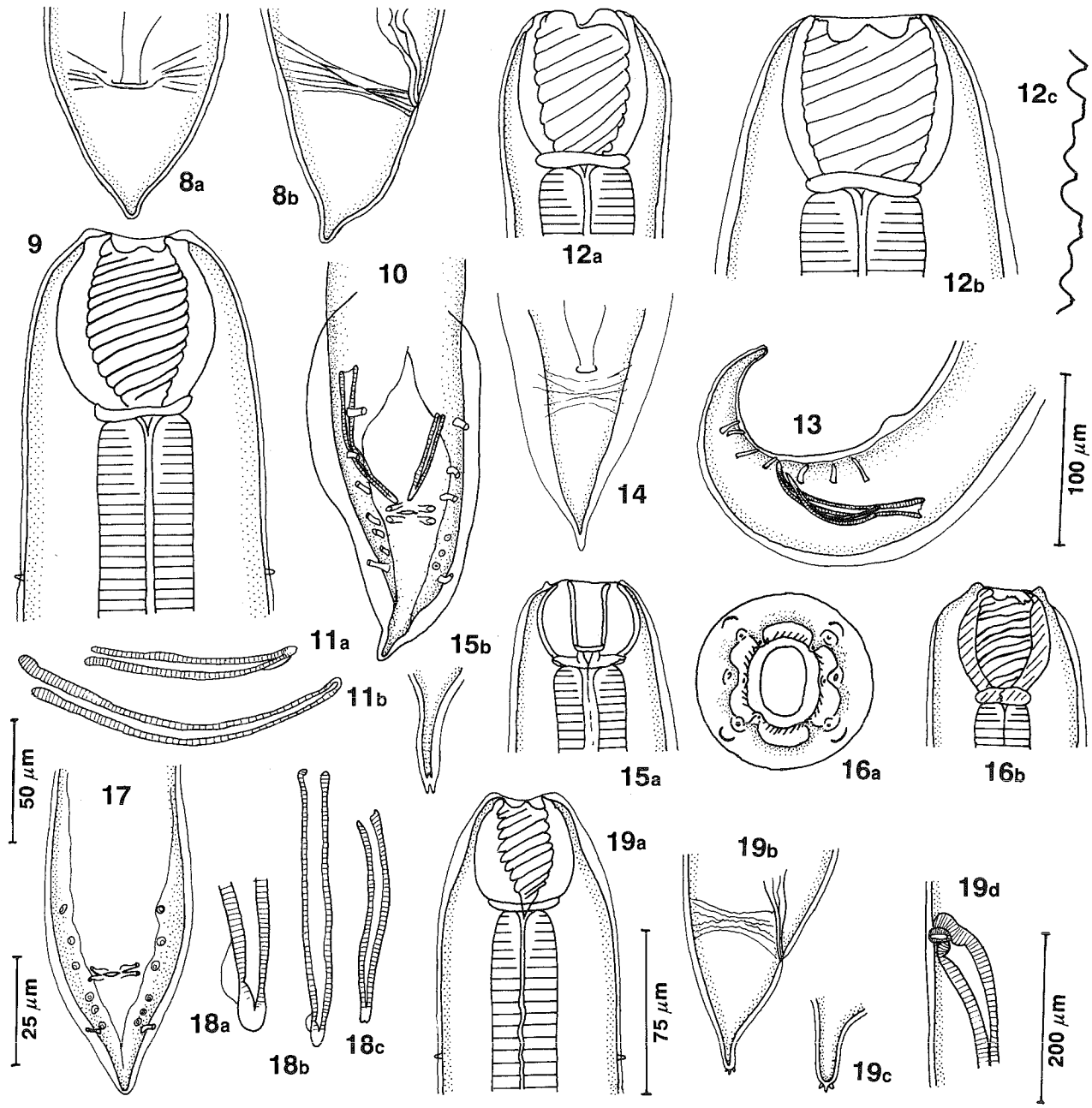

FIG. 8 *Spirocamallanus daleneae* from *Synodontis zambezensis*. Tail of a female in (a) ventral and (b) lateral views

FIG. 9–11 *Spirocamallanus daleneae* from *Synodontis haugi*

FIG. 9 Lateral view of the head of the male
FIG. 10 Ventral view of the caudal region of the male
FIG. 11 Lateral view of (a) the left and (b) the right spicules

FIG. 12–15 *Spirocamallanus spiralis* from *Synodontis eupterus*

FIG. 12 Median view of (a) the head of the male and (b) the female and (c) a schematic representation of the anterior margin of the buccal capsule
FIG. 13 Lateral view of the caudal area of a male
FIG. 14 Ventral view of the female tail
FIG. 15 Female 4th stage larvae, (a) head in lateral view and (b) the tip of the tail

FIG. 16–19 *Spirocamallanus* sp. indet from *Synodontis tessmanni*

FIG. 16 Apical (a) and lateral (b) views of the head (redrawn from Petter & Thatcher 1988)
FIG. 17 Ventral view of the caudal area of the male
FIG. 18 Lateral views of (a) the left spicule, (b) the right spicule and (c) the tip of the right spicule
FIG. 19 Lateral views of (a) the head, (b) the posterior end and (c) the tip of the tail, and (d) ventrolateral view of the vulvar region of a female 4th stage larva

Scale bars: 25 µm—FIG. 18a
50 µm—FIG. 16a, 16b
75 µm—FIG. 12a, 12b, 18b, 18c
100 µm—FIG. 9, 11a, 11b, 15a, 15b, 19a, 19c
200 µm—FIG. 8a, 8b, 10, 13, 14, 17, 19b, 19d

of subventral and 2 pairs of pari-anal papillae which are identical to those of *Spirocamallanus daleneae* and *Spirocamallanus spiralis sensu lato* from the 2 *Synodontis* species from Gabon (Fig. 10 & 17). However, the buccal capsule illustrated by Baylis (1923a) is unlike that of *Spirocamallanus spiralis* from *Synodontis eupterus* examined in this study (Fig. 12a, b). It is possible that Baylis (1923a, 1923b) could have dealt with 2 different species and, in the absence of material from *Clarias anguillaris*, we consider the species from *Synodontis eupterus* as *Spirocamallanus spiralis*, as both sexes were available for examination.

Spirocamallanus spiralis differs from *Spirocamallanus daleneae* in that the buccal capsule of both sexes is more globular with fewer and finer striations and that the configuration of the processes forming the anterior margin of the buccal capsule is entirely different (Fig. 1b & 12c). In addition, particularly the muscular, but also the glandular parts of the oesophagi are considerably shorter in *Spirocamallanus spiralis* than in *Spirocamallanus daleneae*, and this appears to be irrespective of the length of the nematode.

Spirocamallanus spiralis sensu lato from *Synodontis haugi* seems to be very similar to *Spirocamallanus daleneae* as far as the principal measurements and the configuration of the buccal capsule, and the spicules and caudal end of the male are concerned (Fig. 9–11). It is probably conspecific with *Spirocamallanus daleneae* and is provisionally assigned to that species until more material becomes available.

Spirocamallanus spiralis sensu lato from *Synodontis tessmanni* appears to be very similar to *Spirocamallanus spiralis sensu* Baylis (1923a, b) in so far the configuration of the buccal capsule is concerned (Fig. 16b). The tip of the right spicule, however, seems to be nearer to *Spirocamallanus daleneae* (Fig. 18a–c). The principal measurements that could be made are less than those of either *Spirocamallanus spiralis* or *Spirocamallanus daleneae*. In view of these differences, but also because of extensive damage, this species has to remain unnamed until more material becomes available.

Despite the arrangement of the apical structures being the same in *Spirocamallanus daleneae* and the *Spirocamallanus* sp. indet. (and probably also *Spirocamallanus spiralis*), there are several morphological and host differences between the African species of the genus. The name *Spirocamallanus daleneae* n. sp. is therefore proposed for the species recovered from *Synodontis zambezensis* from South Africa.

ACKNOWLEDGEMENTS

The author wishes to express his gratitude to the Board of Trustees, National Parks Board for making the material available, to Dr D.I. Gibson of the British Museum (Natural History), England, for the loan of the specimens of *Spirocamallanus spiralis* from *Synodontis eupterus*, to Prof. Alain Chabaud for his criticism of the manuscript, to Dr Annie J. Petter for valuable advice and to Mme Roselyne Tcheprakoff for the illustrations of *Spirocamallanus daleneae* from *Synodontis zambezensis*. This work was done at the Laboratoire de Biologie Parasitaire, Muséum National d'Histoire Naturelle, Paris, France, with a study grant to the author from the Foundation for Research Development.

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Parasites of South African freshwater fish. V. Description of two new species of the genus *Spinitectus* Fourment, 1883 (Nematoda: Cystidicolidae)

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ABSTRACT

BOOMKER, J. 1993. Parasites of South African freshwater fish. V. Description of two new species of the genus *Spinitectus* Fourment, 1883 (Nematoda: Cystidicolidae). *Onderstepoort Journal of Veterinary Research*, 60:139–145 (1993)

Spinitectus petterae n. sp. was recovered from catfish, *Clarias gariepinus* (Burchell, 1822) and *Spinitectus zambezensis* n. sp. from squeakers, *Synodontis zambezensis* Peters, 1852 in the Kruger National Park. The nematodes are easily differentiated from each other in that *Spinitectus petterae* has an additional pair of papillae on the pseudolabia, the males have considerably longer spicules and a different configuration of the tips of the left spicule, and the vulva of the females is considerably closer to the anus than is the case with *Spinitectus zambezensis*. The new species differ from *Spinitectus allaeri* Campana-Rouget, 1961, *Spinitectus mormyri* Campana-Rouget, 1961 and *Spinitectus thurstonae* Ogden, 1967 in having more spines per row in the 1st 2 rows. Despite possible conspecificity with *Spinitectus polli* Campana-Rouget, 1961, *Spinitectus zambezensis* should be regarded as a valid species because of the morphological, geographical and host differences.

INTRODUCTION

The genus *Spinitectus* Fourment, 1883 is represented by a large number of species in marine and freshwater fish, some amphibians and a mammal. In Africa, *Spinitectus allaeri* Campana-Rouget, 1961, *Spinitectus mormyri* Campana-Rouget, 1961, *Spinitectus polli* Campana-Rouget, 1961, *Spinitectus thurstonae* Ogden, 1967, and unnamed male and female *Spinitectus* spp. have been recorded from freshwater fish (Campana-Rouget 1961; Ogden 1967; Khalil 1970). *Spinitectus camerunensis* Vaucher & Durette-Desset, 1980 has been recovered from an amphibian (Vaucher & Durette-Desset 1980) and *Spinitectus menzalei* Hugot, 1979 from an otter shrew, *Potamogale* sp. (Hugot 1979). The last named species is, as far as is known, the only species of the genus to occur in a mammal. No members of this genus have as yet been recorded from South Africa.

During a survey of the parasites of fish in the Kruger National Park, a new species of this genus was recovered from catfish, *Clarias gariepinus* (Burchell, 1822) and another from the squeaker, *Synodontis zambezensis* Peters, 1852. Numerous worms, all deeply embedded in the mucosa of the stomach, were found in both host species.

In this paper these parasites, for which the names *Spinitectus petterae* n. sp. for the species recovered from catfish and *Spinitectus zambezensis* n. sp. for that from squeakers are proposed, are described and their affinities with other members of the genus in Africa are discussed.

Received 23 March 1993—Editor

DIAGNOSIS OF THE GENUS *SPINITECTUS* FOURMENT, 1883

Pseudolabia relative large, without teeth and with enlarged anterior borders, covering the greater part of the oral opening; papillae usually reduced to 4 at the base of the pseudolabia, but sometimes 8 are present. Pharynx cylindrical, relatively short; oesophagus clearly divided into anterior muscular and posterior glandular parts. Head retractile. Cuticle with transverse rows of posteriorly directed spines; anteriorly, the rows are closer together and interrupted laterally, forming 2 semi-circles; spines decreasing in size and number posteriorly and semi-circles no longer evident. Males with spirally coiled tail, narrow caudal alae; usually 4 pairs of pre-cloacal papillae, but these may be absent; denticular ridges (area rugosa) anterior to cloaca sometimes observed; spicules lightly sclerotized, unequal in length. Females usually straight; vulva in posterior part of the body (pre-equatorial in some Indian species). Oviparous; eggs small with a thick shell, sometimes with polar plugs with filaments (amended from Baylis & Daubney 1926; Chabaud 1975; Skryabin 1991).

DESCRIPTION OF *SPINITECTUS PETTERAE* n. sp.

Type host

Clarias gariepinus (Burchell, 1822) from the Crocodile river, Kruger National Park, South Africa.

Material examined

All the type specimens together with numerous additional specimens have been deposited in the collection of the Muséum National d'Histoire Naturelle, Paris, France (MNHN).

C. gariepinus, holotype male and allotype female, MNHN 578 MD; paratypes, 9 males and 8 females, MNHN 578 MD.

Etymology

The species is named after Dr Annie J. Petter, Laboratoire de Biologie Parasitaire, Muséum National d'Histoire Naturelle, Paris, France in recognition of her extensive contribution to the knowledge of nematodes of freshwater fish.

Description of the species

The principal measurements are given in Table 1.

Spinitectus with 40–52 spines in the 1st row (Fig. 2). The spines are large and lightly sclerotized and, in lateral view, appear to be implanted on a chitinous base (Fig. 1a–c, 18a). First row of spines slightly smaller than those of the 2nd row, 1st 2 rows closer together than subsequent rows. Spines becoming smaller from the 3rd row, and from about the middle of the body onwards, the spines are reduced to triangular prickles (Fig. 18). In the posterior half of the female body, the prickles are irregularly scattered and in the males, virtually absent.

The mouth opening is oval and is bordered by 2 pseudolabia with enlarged anterior borders. Eight sub-median papillae and the amphids are situated on the pseudolabia (Fig. 2a).

The oesophagus is clearly divided into a relatively short muscular and a long glandular part. In both sexes the ratio of the muscular to the glandular parts is 1:2,68–3,57. The deirids were not seen and the nerve ring is situated in the anterior third of the muscular oesophagus, between the 1st and 2nd rows of spines (Fig. 1a). The excretory pore opens ventrally at the level of the 4th row of spines (Fig. 1a).

Males

There are 40–44 spines in the 1st row (Fig. 2b). The caudal alae are weakly developed. There are 4 pairs of pre-cloacal and 6 pairs of post-cloacal papillae. The latter are arranged in 3 pairs of large papillae immediately posterior to the cloaca and a cluster of 3 smaller papillae on each side near the tip of the tail (Fig. 3). The spicules are lightly sclerotized and unequal in length. The tip of the larger left spicule is twisted and bears 2 membranaceous structures (Fig. 5). The right spicule is curved and bears 2 large membranaceous alae, and in ventral view is boat-shaped and hollow. It appears to be a guide for the left one. The tips of both spicules bear membranous bulbs (Fig. 4 & 5).

Females

There are 50–52 spines in the 1st row (Fig. 2a). The vulva is a slightly raised, transverse slit near the anus. The ovejector runs anteriorly (Fig. 6) and, in the females examined, the junction with the 2 uteri was indistinct. The tail is fairly slender with a rounded tip (Fig. 6 & 7). Eggs are ovoid, thick-shelled and smooth, and contain a larva when laid (Fig. 8).

DESCRIPTION OF *SPINITECTUS ZAMBEZENSIS* n. sp.

Type host

Synodontis zambezensis Peters, 1852 from the Sabie river, Kruger National Park, South Africa.

Material examined

The type specimens as well as additional material consisting of numerous males and females have been deposited in the collection of the Muséum National d'Histoire Naturelle, Paris, France. Holotype

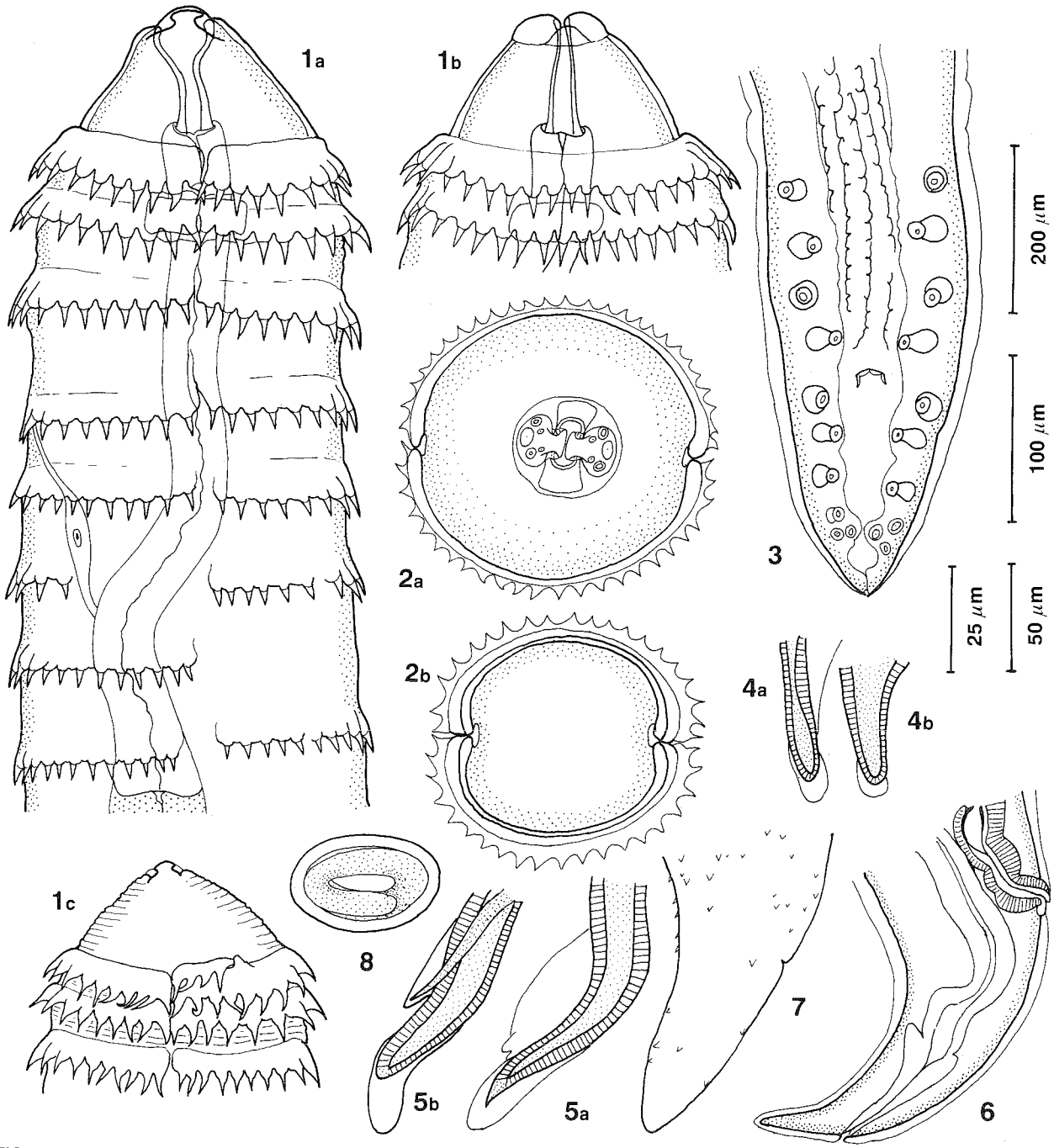

FIG. 1–8 ***Spinitectus petterae***

FIG. 1 Anterior end of (a) the holotype male in lateral view, showing a large interruption in the spines of row 6 and an additional semi-circle of spines between rows 6 and 7, (b) a paratype male in median view and (c) a male with a few spines in front of row 1

FIG. 2 Cross-section at the level of the 1st row of spines of (a) a female and (b) a male. The apical structures are illustrated in the inner circle in Fig. 2a

FIG. 3 Ventral view of the caudal end of a male, showing the arrangement of the caudal papillae

FIG. 4 The tips of the shorter right spicule in (a) lateral and (b) dorsal views

FIG. 5 The tips of the longer left spicule in (a) lateral and (b) ventral views

FIG. 6 Caudal end of a female, showing the proximity of the vulva to the anus

FIG. 7 The tail of a female showing the spinulation

FIG. 8 An egg containing a larva

Scale bars: 25 µm—FIG. 4, 5, 8
50 µm—FIG. 1a, 1b, 2, 7
100 µm—FIG. 1c, 3
200 µm—FIG. 6

TABLE 1 The principal measurements of *Spinitectus petterae* n. sp.*

	Males		Females	
	Holotype	Paratypes	Allotype	Paratypes
Length (mm)	4,524	4,281–5,747	5,759	4,420–6,370
Width	191	131–226	233	213–269
Distance of nerve ring from end of pharynx	59	31–128	42	60–77
Distance of excretory pore from end of pharynx	111	52–132	84	153–178
Pharynx length	63	56–77	70	62–76
Muscular oesophagus length	295	230–372	336	304–483
Glandular oesophagus length	1 103	965–1 603	1 319	944–1 985
Total length of oesophagus	1 398	1 235–1 878	1 665	1 266–2 468
Left spicule length	790	644–790	–	–
Right spicule length	153	93–146	–73	–
Tail length	132	113–202	423	69–135
Distance of anus from vulva	–	–	496	242–404
Distance of vulva from tip of tail	–	–	37	328–502
Eggs, in utero, length	–	–	23	34–37
Eggs, in utero, width	–1:3,74	–	1:3,48	22–26
Ratio of muscular:glandular oesophagus		1:3,04–5,83		1:2,58–4,11

* All measurements given in μm except where otherwise indicated

TABLE 2 The principal measurements of *Spinitectus zambezensis* n. sp.*

	Males		Females	
	Holotype	Paratypes	Allotype	Paratypes
Length (mm)	4,770	2,840–4,360	7,970	4,665–7,640
Width	147	117–159	218	172–258
Distance of nerve ring from end of pharynx	52	16–114	55	18–66
Distance of excretory pore from end of pharynx	182	153–183	NS	70–117
Pharynx length	67	52–79	76	64–101
Muscular oesophagus length	213	152–186	230	179–254
Glandular oesophagus length	958	780–1 006	1 184	965–1 329
Total length of oesophagus	1 171	953–1 158	1 414	1 158–1 559
Left spicule length	461	366–462	–	–
Right spicule length	81	77–90	–95	–
Tail length	126	97–124	2 034	64–104
Distance of anus from vulva	–	–	2 129	1 087–1 668
Distance of vulva from tip of tail	–	–	41	1 160–1 772
Eggs, in utero, length	–	–	23	38–41
Eggs, in utero, width	–1:4,50	–	1:5,15	24–28
Ratio of muscular:glandular oesophagus		1:4,51–6,62		1:4,05–7,34

* All measurements given in μm except where otherwise indicated

male and allotype female, No. MNHN 394 MD; paratypes, 10 males and 8 females, MNHN 395 MD.

Etymology

This nematode species is named after its host.

Description of the species

The principal measurements are given in Table 2.

Spinitectus with 48–51 spines in the 1st row. The spines are large and in lateral view appear to be implanted on lightly sclerotized bases (Fig. 10a, 11). Subsequent rings are progressively further removed from each other and contain fewer and smaller spines (Fig. 18). In the posterior half of the body, the spines are reduced to prickles in the female worms and are virtually absent in the males.

The configuration of the apical structures of the mouth is essentially the same as that of the previous species but only 4 submedian papillae are present (Fig. 11b).

The oesophagus is divided into muscular and glandular parts and the ratio of the muscular to the glandular parts is 1:4,51–6,62 in the males and 1:4,05–

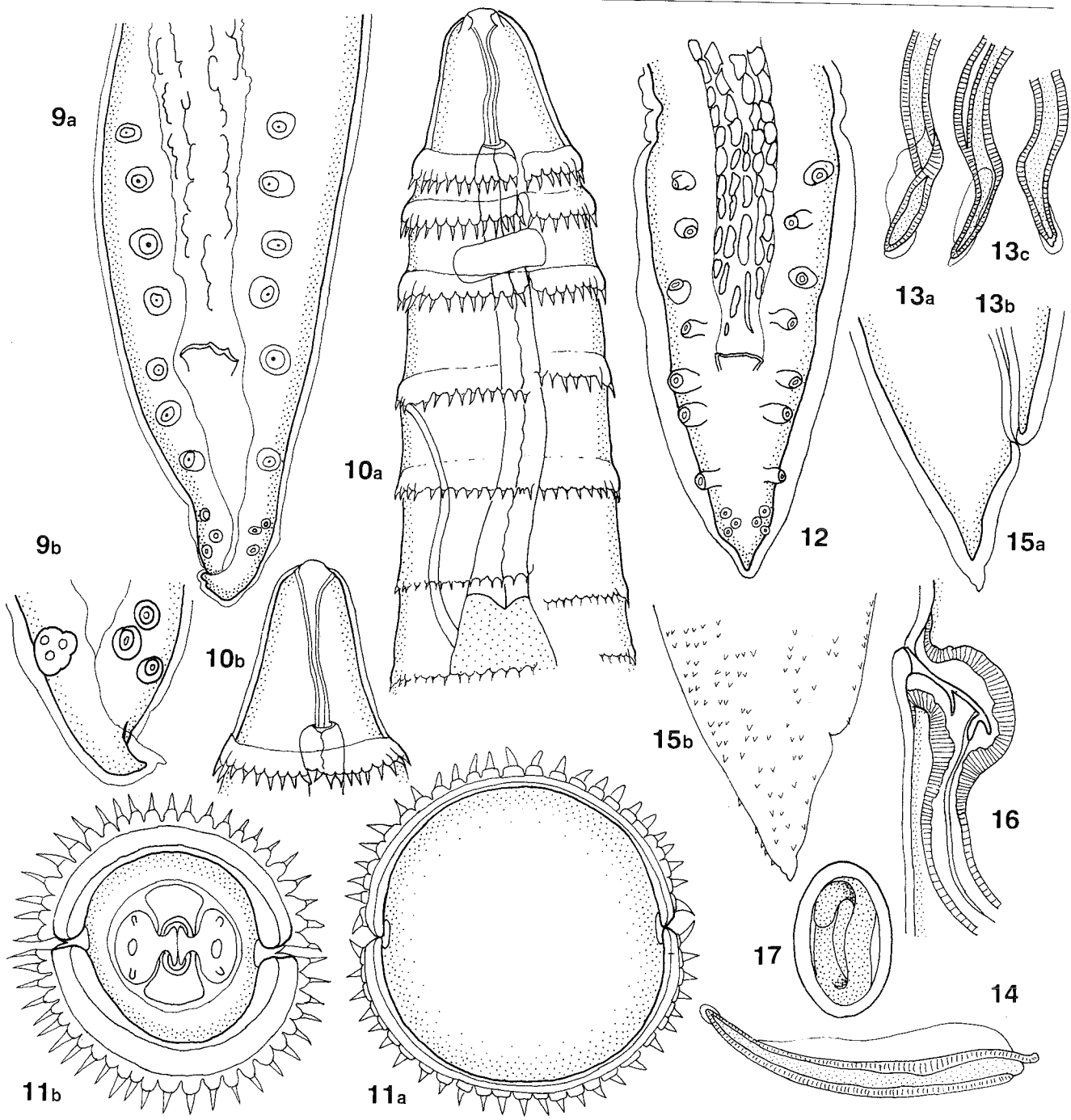

FIG. 9 Abnormalities in the configuration of the caudal papillae; (a) papilla 6 on the left side absent and (b) fusion of papillae 8—10 on the right side

FIG. 10–17 ***Spinitectus zambezensis***

FIG. 10 Anterior end of (a) the holotype male in lateral view and (b) a paratype male in dorsal view

FIG. 11 Cross-section at the level of the 1st row of spines of (a) a female and (b) a male; the innermost circle illustrates the apical structures

FIG. 12 Ventral view of the caudal end of the male, showing the arrangement of the caudal papillae

FIG. 13 The tip of the longer left spicule in (a) ventrolateral, (b) ventral and (c) lateral views

FIG. 14 The shorter right spicule in lateral view

FIG. 15 The caudal end of a female showing (a) the short stumpy tail and (b) the spinulation

FIG. 16 Vulvar region and ovejector of a female (down is anteriorly)

FIG. 17 An egg containing a larva

Scale bars (cf. Fig. 1–8): 25 μm—FIG. 9b, 11, 13, 14, 17
50 μm—FIG. 10, 12, 15
100 μm—FIG. 9a, 16

7,34 in the females. The deirids were not seen. The nerve ring is situated between the 2nd and 3rd rows and the excretory pore opens ventrally at the level of the 4th row of spines Fig. 10a).

Males

The caudal alae are weakly developed and there are 4 pairs of precloacal and 6 pairs of post-cloacal papillae; the latter are arranged in 3 pairs of large papillae behind the cloaca and a group of 3 papillae on each side of the body near the tip of the tail (Fig. 12). The spicules are lightly sclerotized and unequal in length. The smaller right spicule is curved and bears large membranaceous alae (Fig. 14). In ventral view the right spicule is boat-shaped and hollow and appears to act as a guide for the left spicule. The tip of the longer left spicule is twisted and bears a small membranaceous ala on the ventral aspect (Fig. 13). The tips of both the spicules bear small transparent, membranaceous bulbs (Fig. 13 & 14).

Females

The vulva is a slightly raised, simple transverse slit at least 1 mm from the posterior end. The ovejector runs anteriorly, (Fig. 16) but the junction of the uteri with the ovejector could not be seen. The tail is short and stumpy with an acute tip (Fig. 15). The eggs are ovoid, thick-walled and contain a fully developed larva when laid (Fig. 17).

DISCUSSION

It is difficult to distinguish between the various species of the genus that occur in freshwater fish because of the relatively constant arrangement of the caudal papillae in the males and the general lack of specific characteristics. Furthermore, the head is retractile, and its shape as well as the distances of the nerve ring and excretory pore from the anterior end are therefore highly variable within a species (Baylis & Daubney 1926; Ogden 1967). Specific characteristics include the configuration of the anterior rows of spines, the position of the excretory pore in both sexes, and the distance of the vulva from the anus in the females.

Spinitectus petterae can be distinguished from *Spinitectus zambezensis* according to the following characteristics: in apical view, each of the lateral lips of the former species bears 4 papillae as opposed to the 2 in the latter; the spicules of the males of *Spinitectus petterae* are considerably longer than those of *Spinitectus zambezensis* and the configuration of the tip of the left spicule differs in the 2 species. The females can be distinguished in that the vulva of *Spinitectus petterae* is much nearer to the anus than that of *Spinitectus zambezensis*, the tip of the tail is rounded and the spinulation on

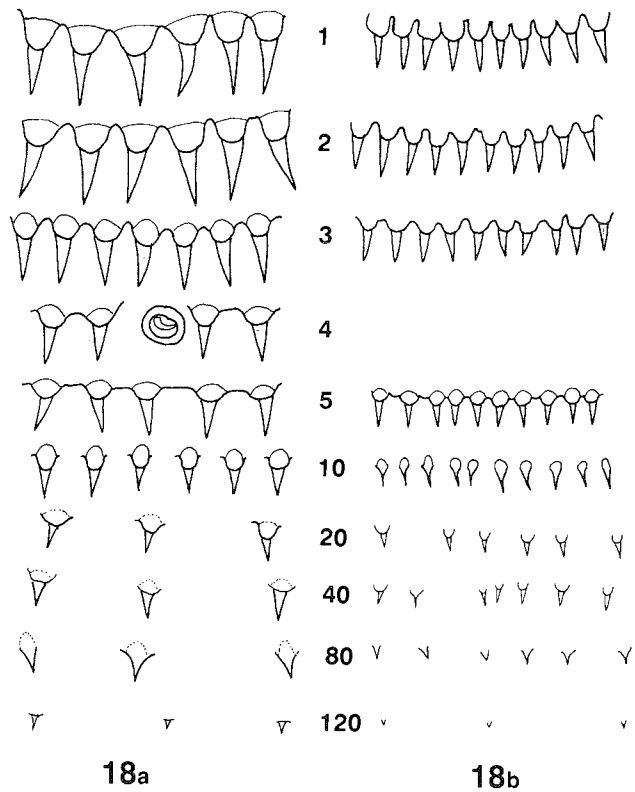

FIG. 18 Spinulation of the holotype males of (a) *Spinitectus petterae* and (b) *Spinitectus zambezensis* drawn to the same scale. Row numbers are indicated, as is the large excretory pore between the spines of row 4 of *Spinitectus petterae*

Scale bar (cf. Fig. 1–8): 25 µm

the tail is much less dense in the former species as opposed to the more acute tail with dense spinulation in the latter. The ratio of the muscular to the glandular oesophagus of especially the females of *Spinitectus petterae* is smaller than that of *Spinitectus zambezensis,* indicating that the muscular oesophagus of the former species is longer.

Petter (1984) illustrates the apical views of the heads of *Spinitectus mormyri*, *Spinitectus polli* and *Spinitectus camerunensis,* and Ogden (1967) that of *Spinitectus thurstonae*. From these illustrations it is apparent that the pseudolabia of *Spinitectus zambezensis* have a configuration similar to that of the other *Spinitectus* species of freshwater fish and differ from *Spinitectus camerunensis*, which was recovered from an amphibian, in lacking the additional pair of labial papillae. *Spinitectus petterae*, however, has the same papillae configuration on the pseudolabia as *Spinitectus camerunensis*.

Spinitectus petterae and *Spinitectus zambezensis* differ from *Spinitectus allaeri*, *Spinitectus mormyri* and *Spinitectus thurstonae* mainly in having more spines per row in the 1st 2 rows. *Spinitectus zambezensis*

appears to be closely related to *Spinitectus polli* and the 2 species may be conspecific. However, attempts to obtain positively identified material of *Spinitectus polli* were unsuccessful and, in view of the morphological, geographical and host differences, *Spinitectus zambezensis* should be regarded as a valid species.

While it is entirely possible that *Spinitectus petterae* and *Spinitectus zambezensis* may be conspecific with some of the Indian species, the lack of a recent revision of the latter precludes this determination.

ACKNOWLEDGEMENTS

The author wishes to express his gratitude to the Board of Trustees, National Parks Board, for making the material available, to Professor Alain Chabaud for his criticism of the manuscript and to Dr Annie Petter for valuable advice. This work was done at the Laboratoire de Biologie Parasitaire, Muséum National d'Histoire Naturelle, Paris, France, with a study grant to the author from the Foundation for Research Development.

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Tables 1 and 2 on page 142 are wrongly formatted. Please replace them with this insert

TABLE 1 The principal measurements of *Spinitectus petterae* n. sp.*

	Males		Females	
	Holotype	Paratypes	Allotype	Paratypes
Length (mm)	4,524	4,281 - 5,747	5,759	4,420 - 6,370
Width	191	131 - 226	233	213 - 269
Distance of nerve ring from end of pharynx	59	31 - 128	42	60 - 77
Distance of excretory pore from end of pharynx	111	52 - 132	84	153 - 178
Pharynx length	63	56 - 77	70	62 - 76
Muscular oesophagus length	295	230 - 372	336	304 - 483
Glandular oesophagus length	1 103	965 - 1603	1 319	944 - 1 985
Total length of oesophagus	1 398	1 235 - 1 878	1 665	1 266 - 2 468
Left spicule length	790	644 - 790	-	-
Right spicule length	153	93 - 146	-	-
Tail length	132	113 - 202	73	69 - 135
Distance of anus from vulva	-	-	423	242 - 404
Distance of vulva from tip of tail	-	-	496	328 - 502
Eggs, in utero, length	-	-	37	34 - 37
width	-	-	23	22 - 26
Ratio of muscular:glandular oesophagus	1:3,74	1:3,04 - 5,83	1:3,48	1:2,58 - 4,11

* All measurements given in μm except where otherwise indicated

TABLE 2 The principal measurements of *Spinitectus zambezensis* n. sp.*

	Males		Females	
	Holotype	Paratypes	Allotype	Paratypes
Length (mm)	4,770	2,840 - 4,360	7,970	4,665 - 7,640
Width	147	117 - 159	218	172 - 258
Distance of nerve ring from end of pharynx	52	16 - 114	55	18 - 66
Distance of excretory pore from end of pharynx	182	153 - 183	NS	70 - 117
Pharynx length	67	52 - 79	76	64 - 101
Muscular oesophagus length	213	152 - 186	230	179 - 254
Glandular oesophagus length	958	780 - 1 006	1 184	965 - 1329
Total length of oesophagus	1 171	953 - 1 158	1 414	1 158 - 1 559
Left spicule length	461	366 - 462	-	-
Right spicule length	81	77 - 90	-	-
Tail length	126	97 - 124	95	64 - 104
Distance of anus from vulva	-	-	2 034	1 087 - 1 668
Distance of vulva from tip of tail	-	-	2 129	1 160 - 1 772
Eggs, in utero, length	-	-	41	38 - 41
width	-	-	23	24 - 28
Ratio of muscular:glandular oesophagus	1:4,50	1:4,51 - 6,62	1:5,15	1:4,05 - 7,34

* All measurements given in μm except where otherwise indicated

Onderstepoort Journal of Veterinary Research, 61:127–142 (1994)

Eight new Afrotropical *Spinitectus* spp. (Nematoda: Cystidicolidae) from freshwater fishes with a key to the members of the genus in the Region

J. BOOMKER[1] and F.A. PUYLAERT[2]

ABSTRACT

BOOMKER, J. & PUYLAERT, F.A. 1994. Eight new Afrotropical *Spinitectus* spp. (Nematoda: Cystidicolidae) from freshwater fishes with a key to the members of the genus in the Region. *Onderstepoort Journal of Veterinary Research*, 61:127–142

Seven new species of the genus *Spinitectus* Fourment, 1883, recovered from several species of freshwater fishes from West and Central Africa, are described. The eighth species, *Spinitectus allaeri* Campana-Rouget, 1961 recorded by Moravec (1974) in Egypt, is assigned to *Spinitectus moraveci* n. sp.

The new and known species have been divided into three groups according to the number of spines in the first row behind the anterior end. The *Spinitectus* spp. in Group A have fewer than 20 spines in the first row and the group contains *Spinitectus mormyri* Campana-Rouget, 1961, *Spinitectus thurstonae* Ogden, 1967 and *Spinitectus micropectus* n. sp. Those in Group B have between 20 and 40 spines in the first row and comprise the species *S. allaeri*, *Spinitectus menzalei* Hugot, 1979, *Spinitectus maleficius* n. sp., *Spinitectus macilentus* n. sp., *Spinitectus minusculus* n. sp., *Spinitectus macherius* n. sp., *Spinitectus mucronatus* n. sp. and *Spinitectus moraveci* n. sp. Group C species have more than 45 spines in the first row and consist of *Spinitectus polli* Campana-Rouget, 1961, *Spinitectus petterae* Boomker, 1993, *Spinitectus zambezensis* Boomker, 1993, and *Spinitectus monstrosus* n. sp.

The species that are quite distinctive are *S. mucronatus*, which has characteristic spinulation and lateral floats on the eggs; *S. monstrosus*, which has characteristic spinulation and an exceptionally long left spicule; *S. micropectus*, which has approximately 80 rows of large spines and six post-cloacal papillae and *S. maleficius*, that has approximately 20 rows of large spines and seven post-cloacal papillae. The remaining species can be differentiated by the number of spines in the first row, the number of post-cloacal papillae, the number of labial papillae and, in the females, the distance between the anus and the vulva and the position of the gravid uterine coils in relation to the anterior end.

S. moraveci differs from *S. allaeri* in that the first six rows of spines are raised, giving the anterior end an inflated appearance, in the number of post-cloacal papillae, and in that the distance between the anus and the vulva is considerably shorter.

There are distinct morphological similarities between the *Spinitectus* species recovered from *Heterobranchus isopterus* and/or *Clarias vanderhorsti* (Clariidae) in Liberia, Ivory Coast and Sierra Leone, those recovered from *Mormyrus* spp. (Mormyridae) in western Zaire, Angola and Cameroon, and those recovered from *Mastacembelus* spp. (Mastacembelidae) in eastern Zaire. The differences lie mainly in the spinulation and the position at which the excretory pore opens, and they may be the result of host influence or represent adaptive radiation in the various regions.

The affinities of the different species are discussed and a key to the members of the genus in Africa is provided.

INTRODUCTION

The genus *Spinitectus* Fourment, 1883 consists of a large number of species that have been described from the digestive tracts of both marine and freshwater fishes, especially in the northern hemisphere and South

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Received 24 March 1994—Editor

America. The genus is poorly known in Africa and only eight species have been described to date. These are *Spinitectus allaeri* Campana-Rouget, 1961, *Spinitectus mormyri* Campana-Rouget, 1961, *Spinitectus polli* Campana-Rouget, 1961, *Spinitectus thurstonae* Ogden, 1967, *Spinitectus petterae* Boomker, 1993 and *Spinitectus zambezensis* Boomker, 1993, all from freshwater fishes. *Spinitectus camerunensis* Vaucher & Durette-Desset, 1980 was described from the frog, *Pedropedetes newtoni* (Bocage) and *Spinitectus menzalei* Hugot, 1979 from the otter shrew, *Potamogale velox* du Chaillu.

Material collected from a number of freshwater fishes of the families Clariidae, Mastacembelidae and Mormyridae in several African countries, is described here. *S. allaeri* recovered from *Bagrus bayad*, *Bagrus docmac*, *Synodontis schall*, and *Lates lates* in Egypt (Moravec 1974) is considered a distinct species for reasons given below. This brings the number of *Spinitectus* species described from the continent to 16.

MATERIALS AND METHODS

The specimens examined during this study originated from the collection of the Museé Royal de l'Afrique Central (MRAC), Belgium. All the specimens have been returned and deposited under their respective MRAC access numbers.

The nematodes were initially examined in water and, if necessary, cleared in lactophenol. Measurements were made by measuring drawings of the material; these were made with a Wild compound microscope and a drawing tube. Measurements given are those of the holotype or allotype and, where available, followed by those of the paratypes (in parentheses). All measurements are given in micron (μm).

Temporary en face preparations were made by hand-cutting sections of the anterior end and mounting these in water or lactophenol. The anterior end was not removed from the holotype and/or allotype specimens and those of the paratype and other specimens examined were returned to the tubes in which the particular worms are stored.

The species have been divided into three groups, depending on the number of spines in the first row. Group A has fewer than 20 spines, Group B has between 20 and 40 spines and group C has more than 40 spines in the first row, and they are described accordingly.

FAMILY CYSTIDICOLIDAE SKRJABIN, 1946

Characterization of the genus *Spinitectus* Fourment, 1883

Spirurida: anterior end retractile, pseudolabia relatively large, without teeth, and with enlarged anterior border covering the greater part of the oral opening; papillae usually reduced to four (eight in some species) at the base of the pseudolabia. Pharynx cylindrical, relatively short; oesophagus clearly divided into anterior muscular and posterior glandular parts. Cuticle with transverse rows of posteriorly directed spines, often on a swollen base. Anteriorly, the spines are close together and are interrupted laterally to form two semi-circles; spines decreasing in size and number posteriorly. Males with spirally coiled tail, narrow caudal alae; usually four pairs of pre-cloacal papillae, but these may be absent or there may be more than four pairs; usually six to seven pairs of post-cloacal papillae, more in some South American species. Spicules unequal in length, lightly sclerotized. Females usually straight; vulva in posterior third of the body (pre-equatorial in some Indian species); oviparous. Eggs small with a thick shell, sometimes with polar plugs or filaments, or lateral floats (amended from Baylis & Daubney 1926; Skrjabin 1949; Chabaud 1975).

DESCRIPTION OF THE SPECIES

Group A

Spinitectus micropectus n. sp. (Fig. 1)

Body relatively long and slender; first row with 16 spines, eight in each semi-circle; first two rows of spines on large, lightly sclerotized bases, giving the anterior end in that region an inflated appearance; bases become unapparent after about row five and spines only gradually diminish in size, those in the 80th row being almost the same length as those in the third row. Pseudolabia each with two lateral papillae and a median amphid, all relatively large. Anterior end of oesophagus slightly in front of the first row of spines. Nerve ring between second and third rows of spines; excretory pore opens ventrally at the level of the fifth row.

Males

Anterior rows of spines contiguous, becoming dissociated from about row ten onwards; approximately 165 rows of spines discernable, after which they become widely dispersed and difficult to see. Body 4 005 (4 362–4 812) long, 49 (62–66) wide; nerve ring 40 (46–50), excretory pore 95 (79–114) from end of pharynx; pharynx 38 (36–45), muscular oesophagus 155 (179–188), glandular oesophagus 930 (1 072–1 465), total oesophagus length 1 085 (1 251–1 653). Right spicule 60 (52–62), left spicule 337 (373–470) long, ratio of right:left spicule 1:5,62 (1:7,17–7,58), tail 84 (98–104) with a fairly long finger-like terminal process. Right spicule stout, left spicule slender. Four pair pre-cloacal papillae, six pairs post-cloacal papillae, arranged as three pairs of fairly large papillae close together near the cloaca, a single pair separated some distance from those nearer the cloaca and two small pairs near the tip of the tail. Area rugosa extends for 198 anterior of the cloaca.

FEMALES

Unknown.

TYPE HOST

Mastacembelus micropectum (Mastacembelidae).

HABITAT

Mucosa of stomach.

TYPE MATERIAL

Holotype male, MRAC 35.818, Makobola, Zaire (Lake Tanganyika), date unknown; paratypes, two males, MRAC 35.818 from the same host and locality.

ETYMOLOGY

The species is named after its host.

COMMENTS

S. micropectus differs from *S. mormyri* and *S. thurstonae*, the other two species in this group, in having fewer and smaller spines in the first row, in being thinner with a minimum of 80 rows of large spines. *S. mormyri* has 11 complete rows of spines that are

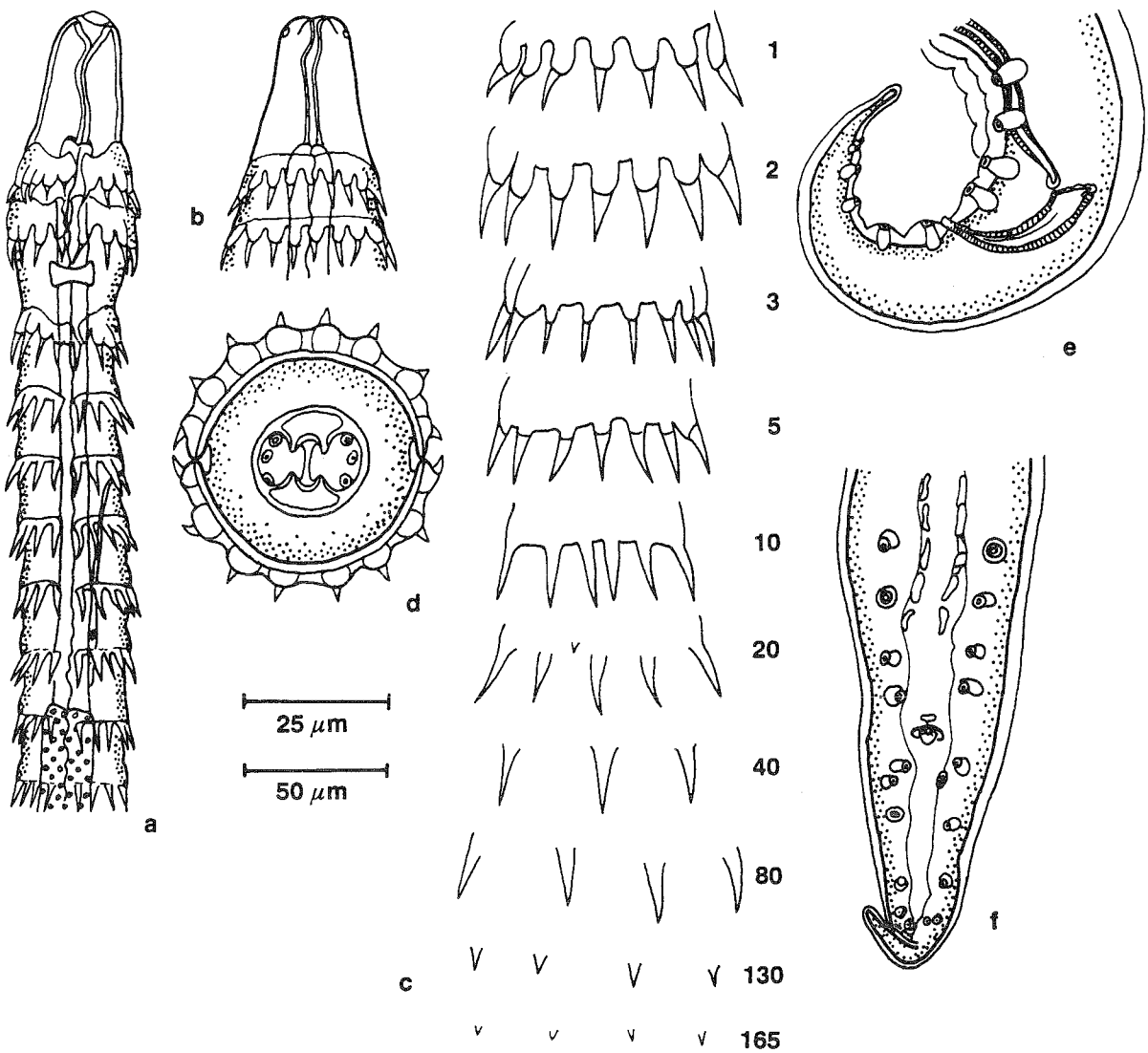

FIG. 1 *Spinitectus micropectus*: a. Anterior end of a paratype male, lateral view. b. Head, holotype male, dorsal view. c. Spines, holotype male, row number indicated. d. Apical structures and cross-section of first row of spines. e. Posterior end, holotype male. f. Posterior end, ventral view, paratype male

Scale bars: c, d, 25 μm; a, b, e, f, 50 μm

easily visible and there are 18 complete rows in *S. thurstonae* (Campana-Rouget 1961; Ogden 1967).

Group B

Spinitectus maleficius n. sp. (Fig. 2)

First row of spines rather small; subsequent rows becoming increasingly larger until about row ten, then gradually decreasing in size; 28–36 spines in the first row; anterior spines seated on distinct, inflated bases. Anterior part of body narrow but increasing gradually in width posteriorly; anterior region not inflated. Apical structures not seen. Anterior end of oesophagus in front of the first row of spines. Nerve ring at the level of the second row of spines or between the second and the third rows. Excretory pore opens ventrally at the level of the fifth row of spines.

Males

Twenty-eight spines in the first row. About 76 rows of spines discernable; those in the first ten rows increase in size, those in the next ten gradually become smaller and those following row 20 rapidly become smaller. Only the anterior quarter is covered by visible spines. Body 4 131 (3 220–3 739) long, 167 (80–104) wide; nerve ring 45 (45–52), excretory pore 119 (111) from posterior end of pharynx; pharynx 50 (45–59), muscular oesophagus 237 (191–247), glandular oesophagus 1 041 (847–1 131), total oesophagus length 1 278 (1 038–1 378). Right spicule 59 (59–72), left spicule 508 (425–449), ratio of right:left spicule 1:8,61 (1:5,90–7,61). Right spicule broadly boat-shaped with a rounded tip which is covered by a transparent membrane. Left spicule curves ventrally, ends in a rounded tip which is covered by a membrane; a spur is visible in lateral view.

There are four pairs of pre-cloacal and seven pairs of post-cloacal papillae; the latter arranged as three pairs nearer the cloaca and four pairs nearer the tip of the tail, all in a more or less straight line.

Females

Anterior rows of spines as in the males; first 80 rows of spines easily visible, spines decreasing gradually in length. From row 100 the spines become irregularly scattered prickles that in turn decrease in size until they are no longer visible on the cuticle, 215 behind the glandular oesophagus. Body 6 793 (3 912) long, 153 (94) wide; nerve ring 48 (21), excretory pore 133 (115) from end of pharynx; pharynx 52 (56), muscular oesophagus 250 (178), glandular oesophagus 1 392 (548), total oesophagus length 1 642 (726). Vulva situated 6 086 (3 526) from anterior end, 486 (309) from anus; tail 167 (77). Eggs thick-shelled, 33 x 22, containing a larva when laid. The anterior loops of the gravid uterus end about 550 behind the end of the glandular oesophagus, in the anterior third of the body.

Type host

Mastacembelus flavidus (Mastacembelidae).

Habitat

Mucosa of stomach.

Type material

Holotype male, allotype female, two paratype males and one paratype, an immature female, MRAC 35.813, Makobola, Zaire (Lake Tanganyika), 8.xi.1960.

Etymology

The specific name is derived from Latin, meaning 'harmful' and the species is so named after the considerable number of large spines.

Comments

S. maleficius is the only species in group B in which the ten anterior rows of spines gradually increase in size and in which the excretory pore opens at row 5. It is closest to *S. allaeri* but differs from it in the position of the excretory pore and in having seven post-cloacal papillae as opposed to six, and in the females the distance between the vulva and the anus is slightly longer.

Spinitectus macilentus n. sp. (Fig. 3)

Body thin and slender; first four rows of spines noticeably larger than those following, giving the region a distinct inflated appearance in relaxed specimens, less so in contracted ones; first row of spines smaller than those of second row; 32–34 spines in first row, 15–17 in one semi-circle, 17 in the other; loose spines appearing as early as between the sixth and seventh row. Anterior spines seated on inflated, lightly sclerotized bases, which become unapparent from about the eighth row onwards. Pseudolabia each with two large lateral papillae and a smaller median amphid; ornamentation on the lips may resemble additional papillae. Oesophagus starts in front of the first row of spines in relaxed specimens, but in contracted ones it starts at the level of the second row. Nerve ring at second row of spines, between second and third or at third row of spines, depending on state of contraction of the worms; excretory pore at level of fourth row of spines.

Males

The first four rows of spines are contiguous; spines in fifth row smaller and become separated; approximately 88 discernable rows of spines in anterior half of the body, thereafter spines are reduced to irregularly scattered prickles, few of which are present in the posterior half.

Body 3 605 (2 804–5 770) long, 66 (41–63) wide; nerve ring 20 (26–38), excretory pore 46 (64–88) from end of

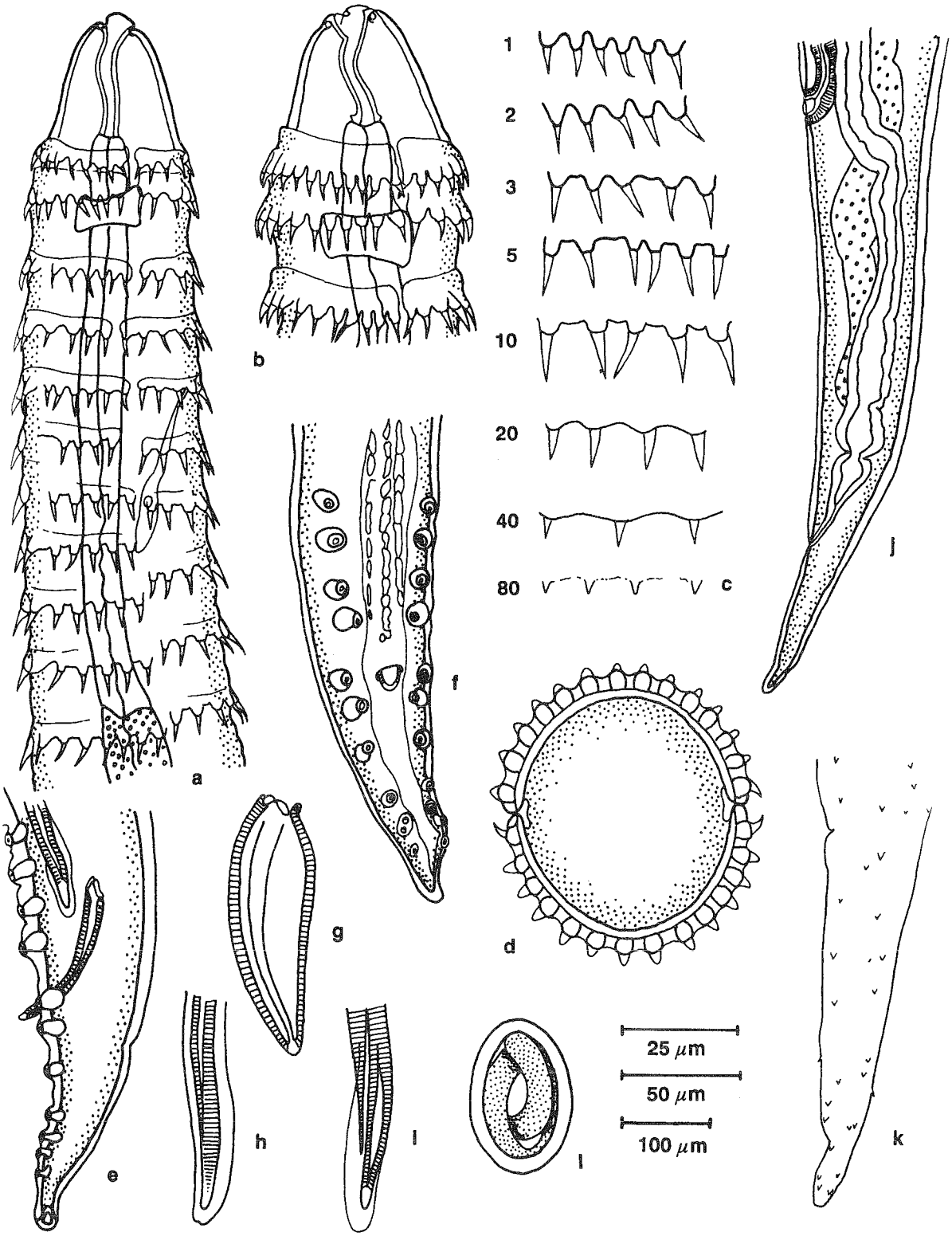

FIG. 2 *Spinitectus maleficius*: a. Anterior end of the holotype male, lateral view. B. Head, lateral view, allotype female. c. Spines, holotype male, row number indicated. d. Anterior row of spines of a male in cross-section. e, f. Lateral and ventral views, male posterior end. g. Right spicule, ventral view. h, i. Left spicule in ventral and lateral views. j. Female posterior end, lateral view. k. Female tail, showing the spinulation. l. Egg.

Scale bars: c, d, g, h, i, l, 25 µm; j, 100 µm

pharynx; pharynx 44 (45–65), muscular oesophagus 216 (139–157) long, glandular oesophagus 492 (421–557) long, total oesophagus length 708 (564–710). Right spicule 61 (50–62), left spicule 265 (304–363), ratio of right:left spicule 1:4,34 (1:5,27–6,60); tail 67 (40–69). Tip of right spicule rounded; left spicule enclosed in a thin membrane which is expanded terminally but does not enclose the tip of the spicule which ends in a fine point.

There are four pairs of pre-cloacal and seven pairs post-cloacal papillae; the latter are arranged in a group

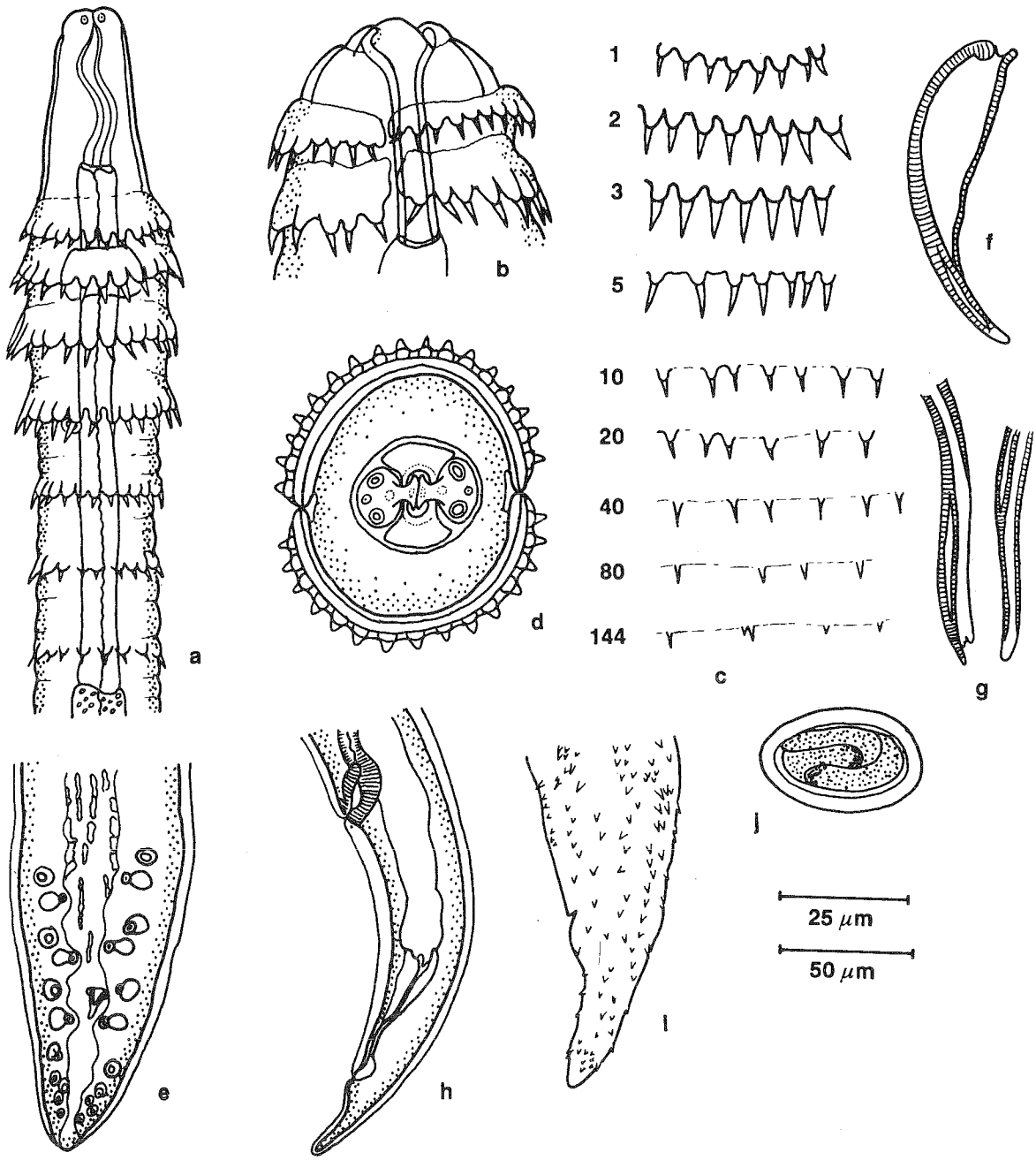

FIG. 3 *Spinitectus macilentus*: a. Dorsal view of anterior end of the allotype female. b. Head, lateral view, holotype male. c. Spines of holotype male, row number indicated. d. Apical structures and cross-section of first row of spines. e. Posterior end, holotype male, ventral view. f. Right spicule, ventrolateral view. g. Left spicule in lateral (left) and ventral (right) views. h. Lateral view of female posterior end. i. Lateral view of female tail, showing spinulation. j. Egg

Scale bars: b, c, d, f, g, i, j, 25 μm; a, e, h, 50 μm

of three pairs of stout papillae nearer the cloaca and four smaller pairs nearer the tip of the tail. Area rugosa 278, not measured in paratype males.

Females

First seven rows of spines contiguous, thereafter becoming single; 115 rows discernable, rows becoming incomplete posteriorly; from row 173 spines become prickles that are visible with difficulty and are scattered across the body; prickles becoming more numerous, but still irregularly scattered, from the vulva to the tip of the tail.

Body 5 459 (3 262–6 726) long, 89 (52–84) wide; nerve ring 45 (29–45), excretory pore 95 (79–84) from end of pharynx; pharynx 64 (46–67), muscular oesophagus 206 (157–187) long, glandular oesophagus 696 (477–642) long, total oesophagus length 902 (634–801). Vulva situated 5 182 (3 104–6 486) from anterior end, 237 (120–203) from anus; tail 40 (38–48). Eggs thick-shelled, 32 x 18 (31–48 x 17–21), containing a larva when laid. Anterior branch of uterus does not extend further cranially than the middle of the body.

Type host

Heterobranchus isopterus (Clariidae).

Habitat

Mucosa of stomach.

Type material

Holotype male, MRAC 34.682, Kombo-Kwaso, Liberia, 8.v.1963; allotype female, MRAC 34.673, Pendetum, Sierra Leone, 20.iv.1963; paratypes, MRAC 34.673, Pendetum, Sierra Leone, 20.iv.1963, six males, three females.

Other material

Several males and females from *Heterobranchus isopterus* from Zoquin, Ivory Coast, MRAC 34.674.

Etymology

The name "macilentus" is derived from the Latin, meaning "thin" or "slender".

Comments

S. macilentus resembles *S. allaeri* only as far as the number of spines in the first row is concerned. The former species has a more slender appearance, there are four anterior rows of raised spines and the spines on the anterior rows are bigger, the left spicule is considerably shorter and the vulva is nearer the anus.

S. macilentus is also near the males of *S. macherius* but differ in the following respects: the former species is more slender, has an oesophagus that is approximately half as long as that of the latter species, the spicules are considerably shorter and there are seven instead of six papillae behind the cloaca.

S. macilentus differs from *S. moraveci* in having four rows of raised spines, seven post-cloacal papillae as opposed to six rows of raised spines, and six post-cloacal papillae.

Spinitectus minusculus n. sp. (Fig. 4)

Body fairly stout, less than three mm long; 28–39 spines in the first row; first five rows of spines noticeably large, but spines of first row smaller than those of subsequent four rows; spines of sixth row noticeably smaller than those of the preceding rows; spines of anterior rows situated on swollen, semi-circular to elliptical bases. Pseudolabia with two papillae and a median amphid, all rather small. Anterior end of oesophagus at level of second row of spines. Nerve ring situated between rows two and three, excretory pore opens at level of the fourth row.

Males

First row with 28 spines. Approximately 45 discernable rows of spines, thereafter becoming irregularly dispersed over the posterior third of the body. Body 2 585 (2 239–2 608) long, 79 (80–87) wide; nerve ring 21 (5–7), excretory pore 60 (45–52) from end of pharynx; pharynx 55 (52–55), muscular oesophagus 144 (150–179), glandular oesophagus 628 (505), total oesophagus length 772 (655–684). Right spicule 68 (69–74), left spicule 298 (277–322), ratio of right:left spicule 1:4,38 (1:4,02–5,10), tail 86 (84–90). Tip of right spicule is rounded and covered by a membrane following the contour of the spicule; that of left spicule ends acutely and is covered by a bulbous membrane.

There are four pairs pre-cloacal and six pairs of post-cloacal papillae, the latter grouped into three large pairs nearest the cloaca, and one large and two smaller pairs nearest the tip of the tail. One or two sessile papillae are present immediately in front of the cloaca.

Females

First row with 39 spines. Approximately 94 discernable rows of spines; from row six the spines become discontinuous and after row 94 only a few scattered prickles remain, even on the tail. Body 2 504 (2 493–2 504) long, 79 (118–125) wide; nerve ring and excretory pore not seen in the allotype but 12–22 and 52–72, respectively, in the two paratype females; pharynx 29 (48–60), muscular oesophagus 174 (172–198), glandular oesophagus 569 (532–539), total oesophagus length 743 (711–730). Vulva 2 421 (2 364–2 371) from anterior end, 45 (67–77) from anus, tail 38 (55–63). Eggs 33 x 21 (31–33 x 20–22), with a shell that appears thicker than that of the other species, containing a larva when laid. Anterior branch of the vulva reflects approximately 120 (380–485) from the anterior extremity.

TYPE HOST

Heterobranchus isopterus (Clariidae).

HABITAT

Mucosa of stomach.

TYPE MATERIAL

Holotype and allotype female, MRAC 34.679, Zoquin, Ivory Coast, date not given. Paratypes, two males and two females, MRAC 34.784, from *Clarias vanderhorsti*, Zoquin, Ivory Coast, 20.iii.69.

ETYMOLOGY

The species is named for its size.

COMMENTS

S. minusculus differs from *S. macilentus* and *S. maleficius* in having six post-cloacal papillae instead

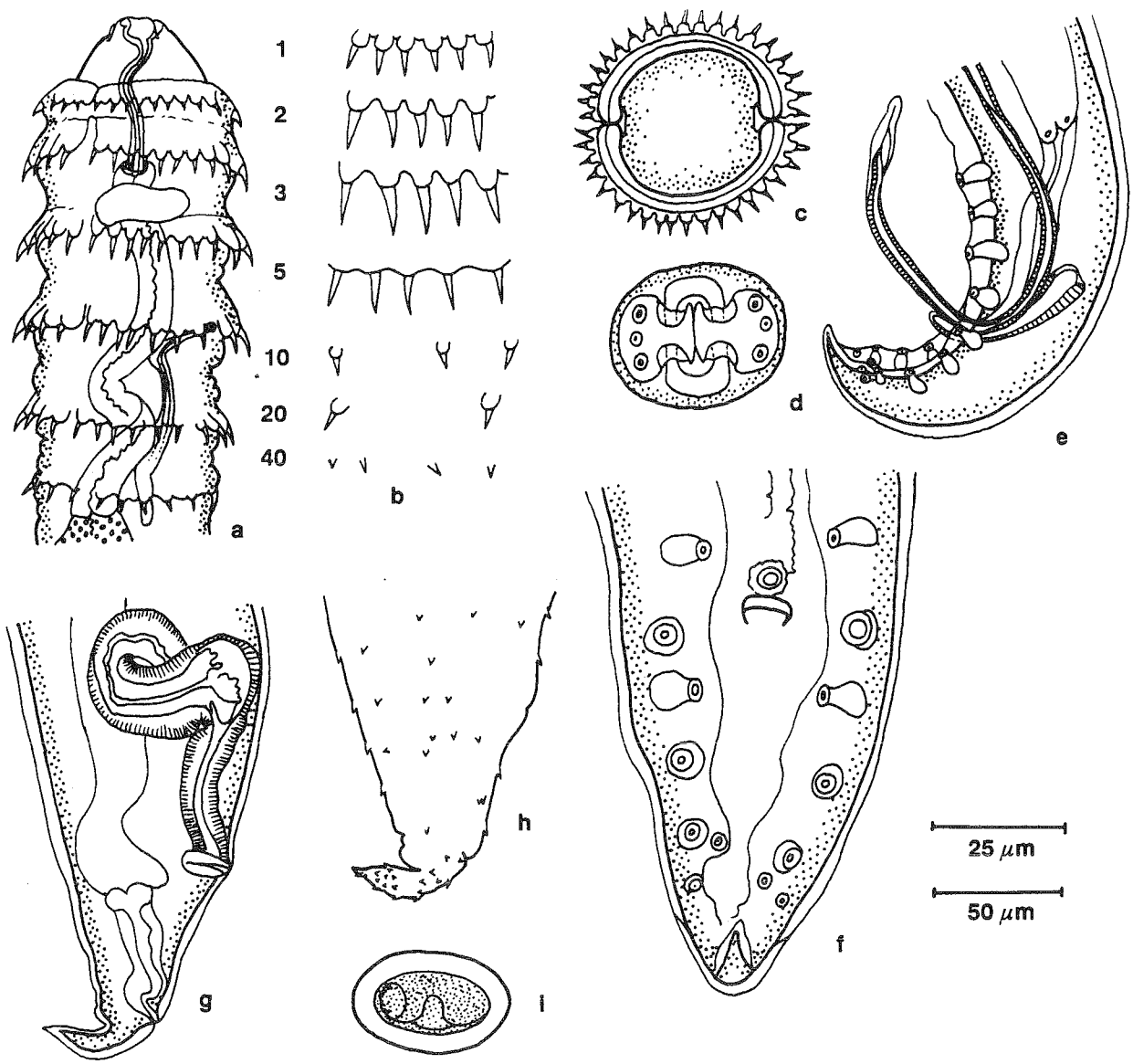

FIG. 4 *Spinitectus minusculus*: a. Lateroventral view of anterior end of the holotype male. b. Spines of holotype male, row number indicated. c. Cross-section of first row of spines of a female. d. Apical structures. e. Posterior end, holotype male, lateral view. f. Ventral view, male posterior end. Note papilla immediately in front of cloaca. g. Female posterior end, lateral view. h. Spinulation of posterior end of a female. i. Egg

Scale bars: b, d, f, g, h, i, 25 μm; a, c, e, 50 μm

of seven. The males of *S. allaeri* and *S. moraveci* differ from *S. minusculus* in having more spines in the first row, longer oesophagi, longer left spicules and slightly longer tails. With the exception of *S. macherius*, of which the females are unknown, the females of *S. minusculus* differ from the other species mentioned above, in that they have the most spines in the first row, and in the close proximity of the vulva to the anus (45–77 as opposed to 312 in *S. allaeri*, 82–144 in *S. moraveci*, 120–237 in *S. macilentus* and 309–486 in *S. maleficius*).

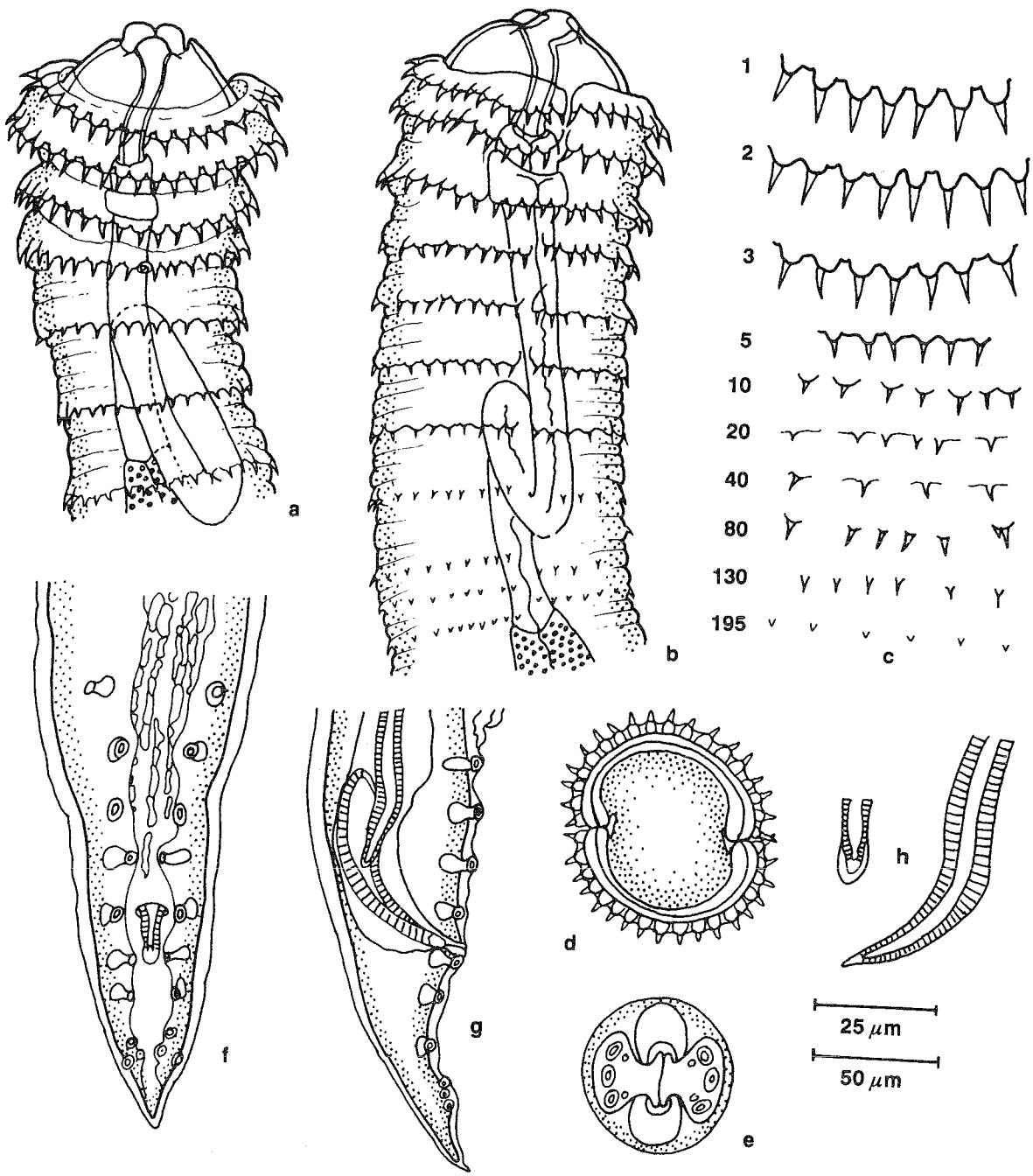

FIG. 5 *Spinitectus macherius*: a. Ventral view of anterior end of the holotype male. b. Lateral view of the anterior part of a paratype male. c. Spines of holotype male, row number indicated. d. Cross-section of the first row of spines of a male. e. Apical structures. f, g. Male posterior end, ventral and lateral views, respectively. h. Tip of the right spicule, dorsal view (left) and left spicule, lateral view (right)

Scale bars: c, e, h, 25 μm; a, b, d, f, g, 50 μm

In addition, the anterior part of the uterus reflects closer to the anterior end than any of the other species and, as is the case with the males, the spinulation of the four species is entirely different.

Spinitectus macherius n. sp. (Fig. 5)

First two rows of spines fairly large; 36 spines in the first row, 18 in each semi-circle; spines of third row approximately the same length as those of the first row, thereafter rapidly diminishing in size; those in row ten already difficult to see; anterior spines seated on a slightly inflated base, the latter becoming unapparent from about row 15. Pseudolabia with two large lateral and two small median papillae, amphids large and distinct. Oesophagus starts at level of the second row of spines. Nerve ring between second and third rows of spines, very close to the junction of the pharynx and the oesophagus; excretory pore at the level of the fourth row.

MALES

Approximately 205 rows of visible spines, last row 666 from tip of tail. Body 3 508 (3 751–3 785) long, 129 (122–132) wide; nerve ring 22 (14–26), excretory pore 41 (52) from end of pharynx; pharynx 64 (53–60), muscular oesophagus 286 (289–345) long, glandular oesophagus 909 (992–1 076) long, total oesophagus length 1 195 (1 281–1 421). Right spicule 100 (100–105), left spicule 616 (757–776), ratio of right:left spicule 1:6,16 (1:7,39–7,57). Right spicule with rounded tip covered by a transparent membrane; left spicule curves ventrally, ends acutely.

There are four pairs of pre-cloacal and six pairs of post-cloacal papillae. The latter are arranged in two groups of 3, those nearer the cloaca being regularly spaced, those nearer the tip of the tail clustered in a triangle. Area rugosa 687 (557–784) long.

FEMALES

Unknown.

TYPE HOST

Clarias vanderhorsti (Clariidae).

HABITAT

Mucosa of stomach.

TYPE MATERIAL

Holotype male and two paratype males, MRAC 34.785, Zoquin, Ivory Coast, 20.iii.1969.

ETYMOLOGY

The name is derived from the Latin, meaning "little sabre" or "sword".

COMMENTS

S. macherius resembles *S. allaeri* in having 36 spines in the first row and six papillae posterior to the cloaca, but differs from it in having an additional pair of papillae on the pseudolabia, a longer pharynx, a longer oesophagus and a longer left spicule. *S. macherius* differs from *S. moraveci* in not having raised anterior rows of spines, in the longer oesophagus and longer left spicule; from *S. maleficius* in the number of post-cloacal papillae (six in the former species and seven in the latter); from *S. macilentus* in not having raised rows of spines anteriorly; from *S. mucronatus* in the distinct spinulation of the last names species.

The spinulation of *S. macherius* somewhat resembles that of *S. minusculus*. The two species can be differentiated by the number of labial papillae (eight in the former and four in the latter), the number of spines in the first row (36 in the former and 28 in the latter) and the ratio of the spicules (1:6,16–7,57 in the former and 1:4,02–5,10 in the latter).

Spinitectus mucronatus n. sp. (Fig. 6)

The first two rows of spines are very large, those in the third row considerably smaller but increasing gradually in size until about row 30, thereafter gradually becoming smaller again; 27–28 spines in the first row. Pseudolabia with an accessory pair of papillae. Anterior end of oesophagus in front of first row of spines. Pharynx rather short, nerve ring between second and third rows, excretory pore at level of sixth rows of spines.

MALES

Twenty-seven spines in the first row. There are 85–90 discernable rows of spines on the anterior two-thirds of the body, becoming progressively smaller caudally; posterior third with hardly any prickles. Rows remain contiguous until about row 90.

Body 3 647 (3 058–4 316) long, 174 (132–164) wide; nerve ring 66 (35–80), excretory pore 153 (60–167) from end of pharynx; pharynx 45 (41–42), muscular oesophagus 275 (244–320), glandular oesophagus 1 235 (71–1 339), total oesophagus length 1 510 (959–1 712). Right spicule 87 (83–94), with a small bulbous tip, left spicule 292 (281–304), ratio of right:left spicule 1:3,36 (1:3,39–3,62); area rugosa consisting of three to five rows of plates that end some distance from the cloaca; a small bilobed structure is present immediately anterior to the cloaca; four pairs of pre-cloacal papillae; post-cloacal papillae arranged as four large pairs, approximately equidistant, and three small pairs, grouped in a triangle; tail 115 (107–119).

FEMALES

Number of spines in the first row and number of rows of spines not counted, but visible rows cover almost

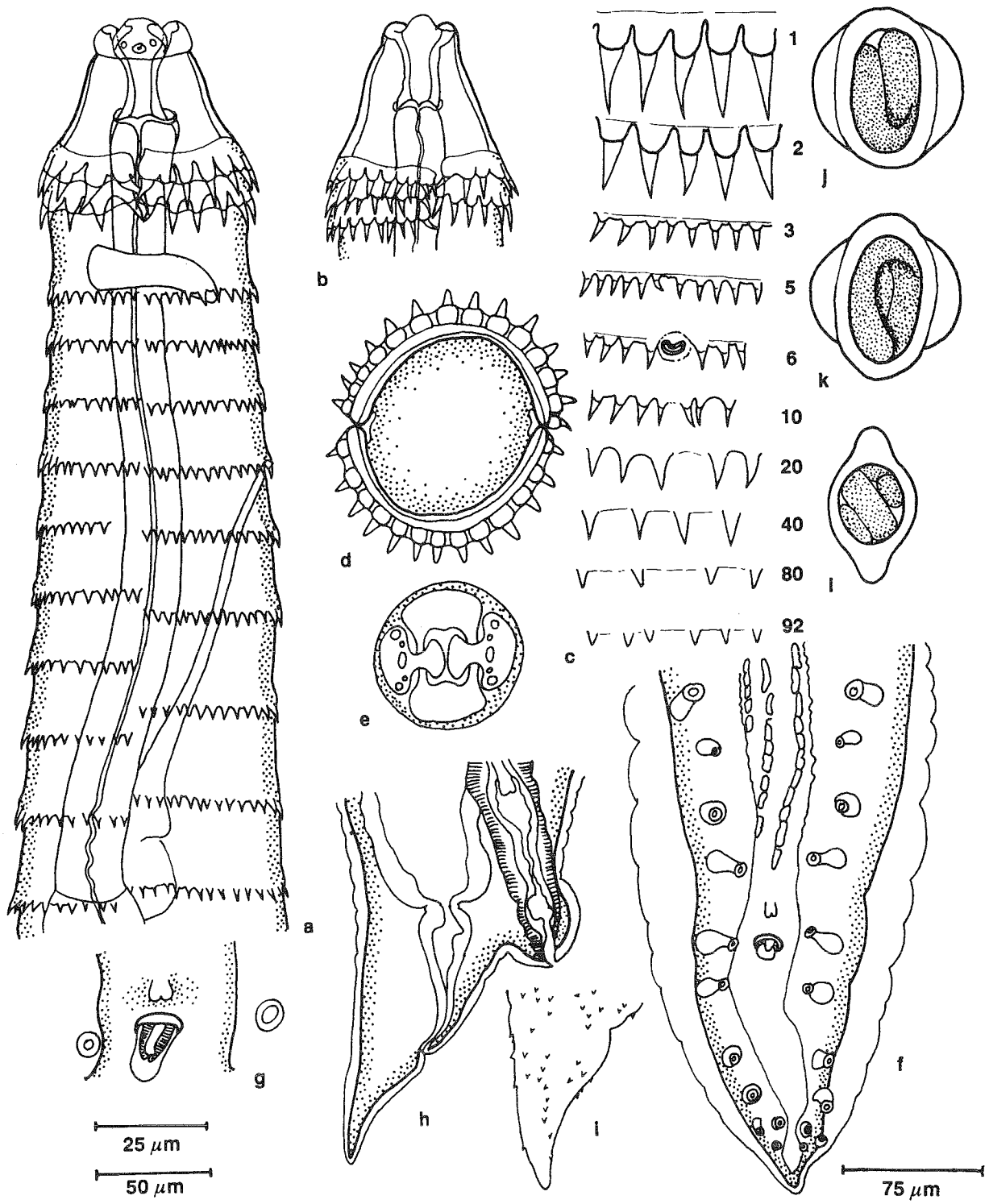

FIG. 6 *Spinitectus mucronatus*: a. Lateral view of anterior end of a paratype male. b. Lateral view of a male showing additional semi-circle of spines. c. Spines of holotype male with row number indicated. d. Cross-section at level of first row of spines. e. Apical structures. f. Male posterior end, ventral view. g. Cloacal region of male, showing the bilobed structure in front of the cloaca. h. Female posterior end. i. Female tail showing spinulation. j, k. Eggs in lateral view. l. Egg in optical cross-section. b and g from specimens from *Mormyrops zanclirostris*, all others from specimens from *Mormyrops deliciosus*

Scale bars: c, e, g, j, k, l, 25 μm; a, b, d, f, i, 50 μm; h, 75 μm

the entire anterior part of the body, leaving the posterior one-fifteenth with prickles that are difficult to see.

Body 3 901 (3 797–5 274) long, 174 (167–268) wide; pharynx 44 (42–52) long; nerve ring 80 (35–70), excretory pore 181 (66–164) from end of pharynx; muscular oesophagus 338 (265–383); glandular oesophagus 1 173 (1 173–1 596), total oesophagus length 1 511 (1 479–1 945). Vulva a transverse slit situated on a prominent swelling, 3 765 (3 675–5 057) from anterior end; vulva 77 (64–122) from anus; tail 59 (58–77). Eggs 36 x 34 (34–38 x 34–38), characteristic in that large lateral floats are present; relatively thick-shelled, containing a larva when laid. Anterior branch of gravid uterus does not extend further cranially than 140 in front of end of muscular oesophagus.

Type host

Mormyrops deliciosus (Mormyridae).

Habitat

Mucosa of stomach.

Type material

Holotype male and allotype female, MRAC 35.731, Lucoge river, Angola, no date given. Paratypes, two males, MRAC 35.731, Lucoge river, Angola, no date given; one male, three females, MRAC 35.733, Lucoge river, Angola, no date given; two males from *Mormyrops zanclirostris*, MRAC 35.740, Libange, Zaire, no date given.

Other material

Several males and females from *Mormyrops deliciosus*, MRAC 35.759, Dokoa, Cameroon, 3–6.iv.1970; one male, one female from *Mormyrops boulengeri*, MRAC 35.804, Kinshasa vicinity, Zaire, no date given.

Etymology

The species name is given after the large, curved spines in the first two rows that resemble the thorns of the African buffalo thorn tree, *Ziziphus mucronata*.

Comments

This species cannot be confused with any other species in Africa, as the first two rows of spines are very large, the excretory pore is situated at the sixth row of spines, and in the females, on the proximity of the anus to the vulva, the vulva that opens on a distinct prominence and that lateral floats are present on the eggs.

One of the paratype males has an additional semicircle of which the spines on the one lateral aspect are large and those on the other are small. This should be considered as abnormal, as members of the genus generally do not have incomplete rows of spines so near to the anterior end.

Spinitectus moraveci n. sp.

(= *Spinitectus allaeri* Campana-Rouget, 1961 *sensu* Moravec 1974: misidentification).

Moravec (1974) recovered what he considered to be *S. allaeri* from *Clarias lazera* (Clariidae), *Bagrus bayad* and *Bagrus docmac* (Bagridae), *Synodontis schall* (Mochokidae) and *Lates niloticus* (Centropomidae) in Egypt. These specimens differ from those of *S. allaeri* in a number of respects and the description of Moravec (1974) is repeated here. For the sake of continuity, the various measurements have been changed to micron.

Small nematodes with cuticle-bearing rings of minute spines; first six rings conspicuous, raised, the first two close to each other. Annulation starting at the level of the anterior end of the muscular oesophagus or close below it. Spines biggest on the anterior part of the body, considerably smaller and irregular on posterior part. Female tail with either two rings of spines or these may be completely lacking. On lateral view always 12–18 spines visible in one anterior ring; on apical view of female 35 spines in the first ring and 37 in the second. Mouth with two small, lobular, lateral lips, each bearing two oral papillae and an amphid at its base. Vestibule relatively long, anteriorly widened to form a small prostom. Muscular oesophagus slender, somewhat shorter than the glandular one.

Males

Length of body 3 330–4 840, maximum width 95–122. Maximum length of spines 6–9. Vestibule measuring 45–78, muscular oesophagus 168–237, glandular oesophagus 600–702. Nerve ring at 99–168 from anterior extremity. Posterior end of body provided with narrow alae ending a short distance from the tip of the tail. Of a total of nine subventral, pedunculate pairs of papillae, four are pre-anal, five post-anal; first post-anal papillae located at almost cloaca level. An additional pair of small, ventral, sessile papilla present in the space between the fourth and the fifth post-anal pedunculate pair. Several longitudinal cuticular ridges are developed on the ventral pre-cloacal surface. Spicules unequal. Larger spicule slender, 405–471, with a sharp tip; smaller spicule wider, 69–87 long. Length of conical tail 90–105.

Females

Length of female containing eggs 4 200–6 580, maximum width at posterior half, 163–204. Maximum length of spines 9. Vestibule measuring 63–75, muscular oesophagus 177–255, glandular oesophagus 600–840. Nerve ring at 123–144 from anterior extremity. Tail conical, 63–78, ending in a sharp cuticular spike. Vulva considerably shifted to posterior end of body (located a short distance in front of the anus), at 159–207 from the posterior extremity. Thick-walled eggs

smooth, without filaments, embryonated when laid; size of eggs 36–38 x 21–24.

COMMENTS

Upon comparison of the measurements and drawings of Campana-Rouget (1961) and Moravec (1974), the following differences were noted: the specimens examined by Moravec (1974) have a slightly longer pharynx (45–78 as opposed to 35), the nerve ring is more posterior (99–168 as opposed to 80), the left spicule is shorter and the right:left spicule ratio is 1:4,66–6,83 as opposed to 1:7,79, six pairs of post-cloacal papillae are present, as opposed to seven. The female tail is slightly longer and the vulva considerably closer to the anus than seen in the material examined by Campana-Rouget (1961). The excretory pore is situated at the fourth row of spines in *S. allaeri* but is not recorded for *S. moraveci*. Furthermore, from the drawings of Campana-Rouget (1961) and Moravec (1974) it appears that the anterior spines of *S. allaeri* are of almost equal size and the first rows are not raised. The spines in the first row of *S. moraveci* are small, those in the next five rows slightly larger, and from the seventh row onwards the spines abruptly become smaller. The spinulation of *S. moraveci* differs from all the other species in the group in that the spines of the first six rows are raised, giving the region an inflated appearance.

S. moraveci differs from *S. macherius* in having shorter spicules, a slightly shorter tail and a shorter oesophagus; from *S. maleficius* in the shorter oesophagus, the number of post-cloacal papillae, the shorter tail of the female, and the considerably shorter distance between the anus and the vulva; from *S. macilentus* in having six rows of raised spines instead of four, and in the slightly longer oesophagus, the slightly longer spicules, and the number of post-cloacal papillae; from *S. minusculus* in the slightly longer oesophagus, the longer left spicule and in the females, the longer distance between the anus and the vulva, and the longer tail; from *S. mucronatus* in the number of spines in the first row, the shorter oesophagus, the considerably longer left spicule, and the eggs that are without lateral floats.

These differences are, in our opinion, sufficient to warrant the creation of a new species, named in honour of Dr F. Moravec, in recognition of his extensive contribution to the knowledge of the nematodes of freshwater fishes.

Group C

***Spinitectus monstrosus* n. sp.** (Fig. 7)

The spines in the first rows are not noticeably larger than those of subsequent rows and the spines gradually decrease in size; approximately 46 spines in the first row, 23 in each semi-circle. Spines become dissociated from about the tenth ring onwards. About 70 rows of spines could be detected, whereafter only a few prickles are dispersed on the cuticle of the rest of the body. Apical structures not seen. Anterior end of oesophagus at the level of the fifth row of spines. Pharynx exceptionally long; nerve ring at level of row seven, excretory pore not seen.

MALES

Spines small when compared with the size of the nematode. Body 7 143 long, 171 wide; nerve ring 47 from the end of the pharynx; pharynx 130, muscular oesophagus 269, glandular oesophagus 1 208, total oesophagus length 1 477. Right spicule 115, massive and thick with a rounded tip covered by a membrane, left spicule 1 733, slender, with a membranaceous triangular tip in lateral view, ratio of right:left spicule 1:15,07. Area rugosa entirely lacking. Pre-cloacal papillae small when compared with the size of the body, close together, numbering four pairs; post-cloacal papillae also relatively small, three pairs close together near the cloaca, another group of three smaller pairs close together near the tip of the tail; tail 174, rounded.

FEMALES

Unknown.

TYPE HOST

Mormyrops boulengeri (Mormyridae).

HABITAT

Mucosa of stomach.

TYPE MATERIAL

Holotype male, MRAC 35.755, Kinshasa, Zaire, ix.1957.

ETYMOLOGY

The specific name is given after the massive right and the long left spicules.

COMMENTS

Only a single male of this species, of which the fourth and fifth post-cloacal papillae on the left side are fused, was available for study. It is quite unlike any other members of the genus from African freshwater fishes in that the caudal papillae occur in two widely separated groups. Furthermore, the tail is rounded, the short right spicule is massive when compared to that of the other members of the genus and the area rugosa in front of the cloaca is lacking. The left spicule and the pharynx are the longest yet recorded for this genus in Africa. The size and number of spines on the anterior part of the body further help to distinguish this species.

DISCUSSION

Baylis & Daubney (1926) have already shown that the anterior end is retractile and that features such as the elongated, conical or rounded shape of the anterior end, and whether the anterior extremity is close to the first row of spines or not, should not be considered when attempting to group the various species of the genus. This will obviously influence measurements such as the distance of the nerve ring and excretory pore from the anterior end, and also the position of the commencement of the muscular oesophagus in relation to the rows of spines. It is illustrated here (Fig. 3 and 5). We have therefore measured the distance of the nerve ring and excretory pore from the end of the pharynx (or the beginning of the muscular oesophagus). Characteristics such as the size, number and arrangement of the spines in the anterior rows and the position of the excretory pore in relation to the rows of spines are more reliable and constant, as are the number of caudal papillae in the males, and the distance of the vulva from the anus and the degree to which the loops of the gravid uterus extend anteriorly in the females.

There are several possible ways in which the *Spinitectus* species can be grouped on a primary character, such as the number of spines in the first row, the position of the opening of the excretory pore or, in the males, the number of post-cloacal papillae. While the number of

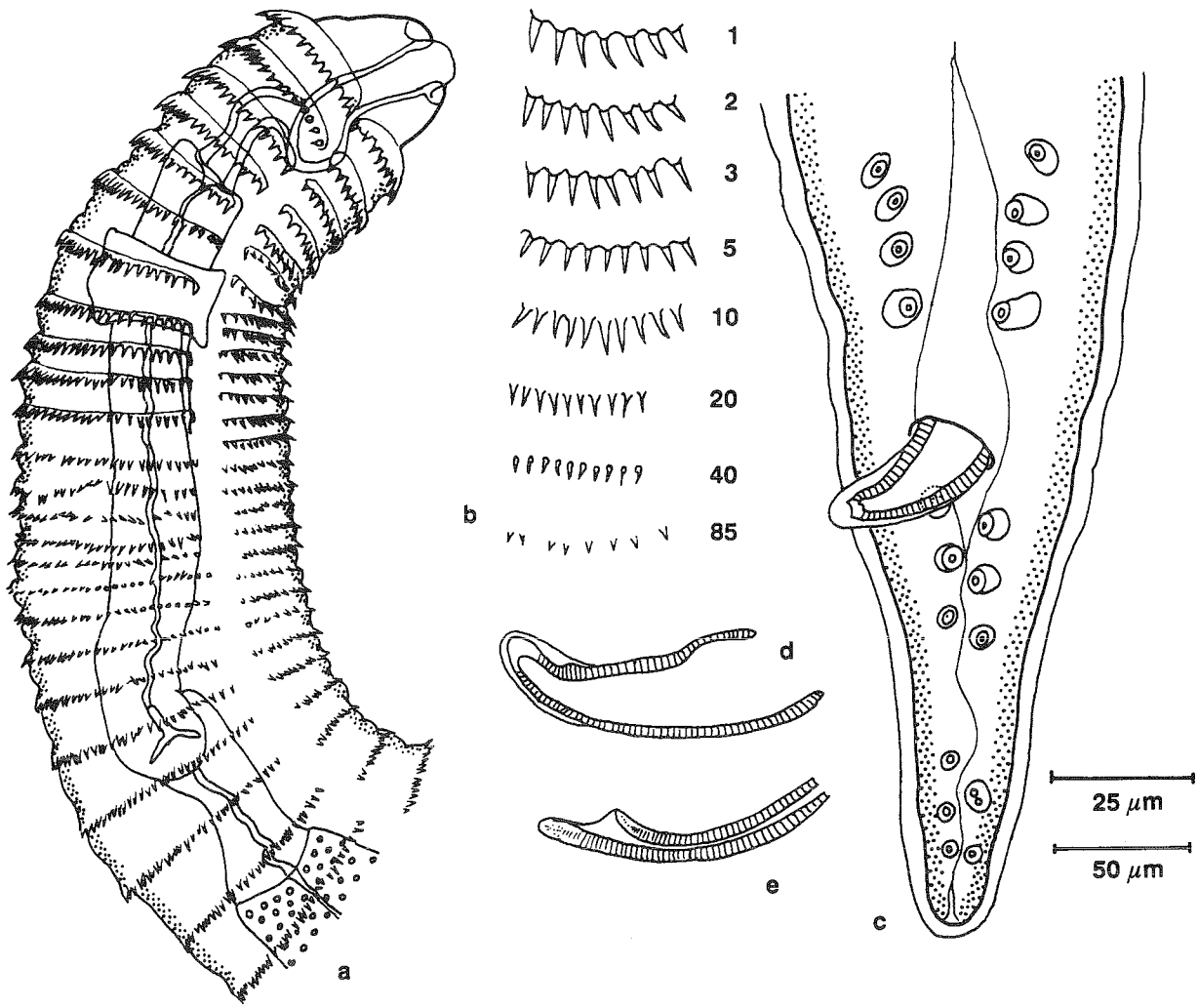

FIG. 7 *Spinitectus monstrosus*: Holotype male. a. Lateral view. b. Spines with row number indicated. c. Ventral view of caudal end. d. Right spicule, lateral view. e. Tip of left spicule, lateral view

Scale bars: b, 25 µm; a, c, d, e, 50 µm

spines in the first row probably has no phylogenetic importance, it serves as a useful means of separating the various species groups. We have therefore elected to group the species according to this criterion as the spines are easily counted in both sexes. Thus the 16 known *Spinitectus* species can be divided into three groups. Group A has fewer than 20 spines in the first row and contains *S. micropectus*, *S. mormyri* and *S. thurstonae*. Group B, the largest group, has between 20 and 40 spines in the first row and contains the species *S. allaeri*, *S. maleficius*, *S. macilentus*, *S. menzalei*, *S. minusculus*, *S. macherius*, *S. mucronatus* and *S. moraveci*. Group C has more than 45 spines in the first row and contains the species *S. monstrosus*, *S. petterae*, *S. polli* and *S. zambezensis*. Only *S. camerunensis* could not be placed in one of the groups, because the number of spines in the first ring were not recorded by Vaucher & Durette-Desset (1980).

It is interesting to note that of the species described here, *S. maleficius* and *S. micropectus* were collected from *Mastacembelus* spp. from Lake Tanganyika, eastern Zaire. Both have predominantly large spines on the body, and in both the excretory pore opens on the level of the fifth row. *S. macilentus* was recovered only from *Heterobranchus isopterus*, *S. minusculus* from both *Heterobranchus isopterus* and *Clarias vanderhorsti* and *S. macherius* only from *Clarias vanderhorsti*, in Sierra Leone, Liberia and the Ivory Coast. In these species the anterior five rows have fairly large spines and the excretory pore opens at the level of the fourth row of spines. Both *S. mucronatus* and *S. monstrosus* were collected only from *Mormyrops* spp. and both are quite distinct from the other species in their spinulation, and in that the excretory pore opens further posteriorly than the fourth row, or presumably so. *S. mucronatus* has the widest distribution, occurring in western Zaire (Kinshasa), Cameroon and Angola. The position of the excretory pore is not known in *S. moraveci,* but the spines of the first six rows are raised and their size and arrangement also differs from that of the other species in the group. Whether these characteristics indicate host influence on the spines, which are the primary organs of attachment of the nematodes, or adaptive radiation of the parasites in the respective geographical regions, cannot yet be determined. Similarly, it is at this stage uncertain whether the position of the excretory pore and the number of post-cloacal papillae have any phylogenetic importance, and many more specimens and species from these and other localities in Africa will have to be examined.

KEY TO THE AFRICAN SPECIES OF THE GENUS *SPINITECTUS* FOURMENT, 1883

1. Parasites of freshwater fishes 2
   Parasites of other vertebrate groups 15
2. First row with fewer than 20 spines 3
   First row with more than 20 spines 5
3. Eighteen spines in the first row 4
   Female unknown, male with 16 spines in the first row, first 80 rows of spines of about equal length, excretory pore opens at level of row five, parasites of *Mastacembelus micropectum*, LakeTanganyika, Zaire ..... *Spinitectus micropectus*
4. Left spicule 368–406, combined length of oesophagus of females 2 360–2 480, parasites of *Mormyrus* sp., Lake Victoria, Uganda ..... *Spinitectus thurstonae*
   Left spicule 600, combined length of oesophagus of females 1 330, parasites of *Mormyrus cashive*, Lake Edward, now Lake Idi Amin Dada, Zaire ..... *Spinitectus mormyri*
5. First row with 20–40 spines 6
   First row with more than 40 spines 12
6. Excretory pore opens at the level of the fourth row of spines 7
   Excretory pore opens at the level of the fifth or later rows of spines 11
7. Anterior region appears inflated 8
   Anterior region does not appear inflated 9
8. Six raised rows of spines gives anterior region an inflated appearance, left spicule 405–471, right spicule 69–87, six pairs of post-cloacal papillae, vulva 82–144 from anus, parasites of *Clarias lazera*, *Bagrus bayad*, *Bagrus docmac*, *Synodontis schall* and *Lates niloticus* in Egypt ..... *Spinitectus moraveci*
   Four raised rows of spines gives anterior region an inflated appearance, left spicule 265–363, right spicule 50–62, seven pairs of post-cloacal papillae, vulva 120–237 from anus, parasites of *Heterobranchus isopterus*, Liberia and Sierra Leone ..... *Spinitectus macilentus*
9. Male with six post-cloacal papillae 10
   Male with seven post-cloacal papillae, left spicule 545, vulva 312 from anus, parasites of *Malapterurus electricus*, *Eutropius niloticus*, *Bagrus bayad*, *Lates albertianus*, *Mormyrus cashive* and *Alestes dentex* in Lake Albert, now Lake Mobutu Sese Seko, Zaire ..... *Spinitectus allaeri*
10. Left spicule 277–322, right spicule 68–74, ratio of right:left spicule 1:4,02–5,10; 28 spines in the first row, females with 39 spines in the first row, vulva 45–77 from anus, parasites of *Clarias vanderhorsti* and *Heterobranchus isopterus* in Ivory Coast ..... *Spinitectus minusculus*

Left spicule 616–776, first three rows of spines of equal length, decreasing from row four onwards, female unknown, parasites of *Clarias vanderhorsti* in Ivory Coast ..... *Spinitectus macherius*

11. Excretory pore opens at the level of the fifth row of spines, 28–36 spines in the first row, anterior ten rows of spines of approximately the same length, vulva 309–486 from anus, parasites of *Mastacembelus flavidus* in Zaire ..... *Spinitectus maleficius*

    Excretory pore opens at the level of the sixth row of spines, 27–28 spines in the first row, anterior two rows of spines very large, following seven rows of spines distinctly smaller, vulva 64–122 from anus, eggs with large lateral floats, parasites of *Mormyrops* spp. in Angola, Cameroon and Zaire ..... *Spinitectus mucronatus*

12. Left spicule less than 1 000 13

    Left spicule 1 733, approximately 46 spines in the first row, female unknown, parasites of *Mormyrops boulengeri* in Zaire ..... *Spinitectus monstrosus*

13. Left spicule 500 or longer 14

    Length of left spicule 366–461, with round tip and twisted distal end, the latter S-shaped in lateral view, right spicule 77–90, tail 83–87, vulva 1 087–2 034 from anus, parasites of *Synodontis zambezensis* in South Africa ... *Spinitectus zambezensis*

14. Lateral lips each with four papillae, left spicule 553–790, tip strongly curved ventrally, tip also with ventral spur, right spicule 77–90, vulva 242–423 from anus, parasites of *Clarias gariepinus* in South Africa ..... *Spinitectus petterae*

    Lateral lips each with two papillae, left spicule 500, right spicule 125, vulva 800 from anus, parasites of *Synodontis schall* in Lake Albert, now Lake Mobutu Sese Seko, Zaire ..... *Spinitectus polli*

15. Parasites of amphibians 16

    Parasites of mammals 17

16. Excretory pore at level of fourth row of spines, left spicule 1 015, combined length of oesophagus 2 030–2 900, vulva 700 from anus, parasites of *Pedropedetes newtoni* in Cameroon ..... *Spinitectus camerunensis*

17. Left spicule 218, right spicule 62, ratio of right:left spicule 1:3,5, 26 spines in the first row, female unknown, parasites of *Potamogale velox* in Gabon ..... *Spinitectus menzalei*

ACKNOWLEDGEMENTS

The authors wish to thank Prof. Alain G. Chabaud and Dr Annie J. Petter for their help with and criticism of the manuscript. This work was done at the Muséum National d'Histoire Naturelle, Paris, France, with a study grant to the senior author from the Foundation for Research Development.

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J. Parasitol., 86(1), 2000 p. 113–117

PARAQUIMPERIA AFRICANA N. SP. (NEMATODA: QUIMPERIIDAE), A NEW INTESTINAL PARASITE OF THE EEL *ANGUILLA MOSSAMBICA* PETERS, IN SOUTH AFRICA

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ABSTRACT: A new seuratoid nematode of the family Quimperiidae, *Paraquimperia africana* n. sp., is described from the small intestine of the longfin eel, *Anguilla mossambica* Peters, from the Eastern Cape Province, South Africa. The new species is characterized mainly by the presence of a ventral sucker in mature males, short spicules (147–171 μm), the number and arrangement of caudal papillae, the postesophageal position of the excretory pore, and by the slender female tail. In this new species, a variability in the number (3–5 pairs) of subventral preanal papillae was observed. *Paraquimperia africana* is the first representative of the genus in Africa. In view of recent reports, *Paraquimperia aditum* (Mueller, 1934) is considered a junior synonym of *Paraquimperia tenerrima* (Linstow, 1878). *Paraquimperia xenentodonia* Gupta and Bakshi, 1984 is considered a species inquirenda.

While searching for specimens of *Anguillicola papernai* Moravec et Taraschewski, 1988 (Dracunculoidea), 41 specimens of the longfin eel, *Anguilla mossambica* Peters, were collected in the vicinity of East London in the Eastern Cape Province, South Africa. In addition to other species of intestinal helminths, specimens of a *Paraquimperia* Baylis, 1934, another nematode genus specific to eels, were encountered. These proved to be a new species that is described below.

MATERIALS AND METHODS

The eels were collected with baited hand lines and kept alive by placing them in an insulated container with a small amount of water. They were decapitated and their organs individually examined under a stereoscopic microscope for the presence of *A. papernai* and other helminth parasites. Intestinal parasites were removed, identified, and counted, and fixed in either boiling or cold 70% ethanol and preserved in 70% ethanol. *Paraquimperia* specimens were cleared with glycerine and examined under a light microscope. Drawings were made with the aid of a Zeiss drawing tube. For scanning electron microscopy (SEM), 2 nematode specimens were postfixed in 1% osmium tetroxide, dehydrated through graded alcohol, critically point dried, and sputter-coated with gold. They were examined with a JSM-6300 scanning electron microscope at an accelerating voltage of 15 kV. Measurements are in μm unless otherwise stated.

DESCRIPTION

Paraquimperia africana n. sp.
(Figs. 1–3)

Description: Medium-sized nematodes; anterior end curved dorsally in fixed specimens. Cuticle thin, with fine transverse striations. Lateral alae originate near anterior extremity, initially broad, becoming gradually narrower from deirids posteriorly, extending for approximately double length of esophagus from anterior end (Fig. 1A). Deirids well developed, situated near middle of posterior, broader part of esophagus (Fig. 1A, K). Oral aperture circular, surrounded by 4 submedian cephalic papillae and 2 lateral amphids (Figs. 1F, 3A, B). Inner surface of oral aperture lined with cuticular mound consisting of 3 (1 dorsal and 2 ventrolateral) sectors; both ends of each sector strengthened to form small toothlike structure oriented anteriorly; bottom of small buccal cavity formed by 3 flat sectors of esophagus, each armed with forwardly directed tooth (Figs. 1C–F, 3B). Anterior end of esophagus forming short muscular pharynx composed of 1 dorsal and 2 ventrolateral parts (Fig. 1C–D). Esophagus consisting of anterior thinner muscular and posterior wider musculoglandular part, the latter being slightly shorter than the muscular part (Fig. 1A, B). Esophagus opening into intestine through valve. Nerve ring situated in posterior two-thirds to three-quarters of anterior, narrower muscular part of esophagus. Excretory pore well posterior to termination of esophagus (Fig. 1B). Tail in both sexes conical, elongate, with sharp cuticular tip (Fig. 1J, M).

Male (based on 8 specimens; measurements of holotype in parentheses): Length of body 3,849–7,698 (5,916), maximum width at level of posterior part of esophagus 82–163 (150). Entire esophagus 558–802 (734) long; its anterior part including pharynx 299–435 (367) (pharynx 21–30 [24]) long and 27–42 (39) wide; posterior part of esophagus 245–367 (367) long and 45–81 (72) wide. Nerve ring, excretory pore, and deirids 258–315 (313), 653–952 (843), and 435–585 (558) from anterior end, respectively. Maximum width of lateral alae 27–36 (36). Anterior end of testis far posterior to esophagus. Preanal papillae: 3–5 (4) pairs of subventral papillae and 1 large median unpaired papilla present (Figs. 1J, O, 2, 3D, E); latter situated between first and second subventrals (counting from cloacal opening); adanal papillae: 1 subventral pair; postanal papillae: 6 pairs, of which 3 pairs being subventral and 3 pairs (second, third, and fifth) lateral (third, small lateral pair being in fact outlets of phasmids). Cloacal lips slightly elevated. Caudal alae absent. Ventral precloacal surface with about 30 well developed oblique muscle bands and a sucker situated anterior to them (Figs. 2, 1O); distance of sucker from cloacal opening 898–1,251 (966). Sucker absent in 2 smallest males (3,849 and 4,610). Spicules equal, curved, 147–168 (156) long and 24–30 (27) wide, each provided with 2 longitudinal, heavily sclerotized rodlike supports not reaching anteriorly to anterior end of spicule; proximal end of spicule blunt, distal end somewhat narrowed and provided with small round membrane (Fig. 1G). Gubernaculum well developed, 54–72 (57) long (Fig. 1H, I). Tail bent ventrally, 245–345 (326) long.

Female (based on 2 specimens; measurements of allotype in parentheses): Length of gravid specimens 5,263–5,766 (5,766), maximum width 150 (150). Entire esophagus 666–694 (694) long; its anterior portion including pharynx 367–394 (394) (pharynx 27 [27]) long and 39–42 (42) wide; posterior part of esophagus 299–313 (313) long and 60–66 (60) wide. Nerve ring, excretory pore and deirids 286–313 (313), 789 (789), and 541–544 (544), from anterior end, respectively. Maximum width of lateral alae 33 (33). Vulva with slightly elevated lips (Fig. 1L), situated in posterior third of body, 1,618–1,686 (1,686) from tip of tail (at 69–71% [71%] of body length). Muscular vagina directed first posteriorly and then anteriorly from vulva. Uterus opposed, extending caudally to tail, containing few eggs. Eggs oval, thin-walled, unembryonated (Fig. 1N), measuring 66–72 × 42–48 (66–72 × 42–450) (n = 11). Tail 340–367 (367) long (Fig. 1M).

Taxonomic summary

Type host: Longfin eel, *A. mossambica* Peters (Anguillidae, Anguilliformes).

Site of infection: Small intestine.

Type locality: Nahoon River, East London, South Africa (27°55′E, 33°10′S) (collected 2 February 1995).

Prevalence and intensity: Sixty-six percent (27 fishes infected/41 fishes examined); 1–10 (mean 4) nematodes per fish.

Received 11 March 1999; revised 8 June 1999; accepted 8 June 1999.
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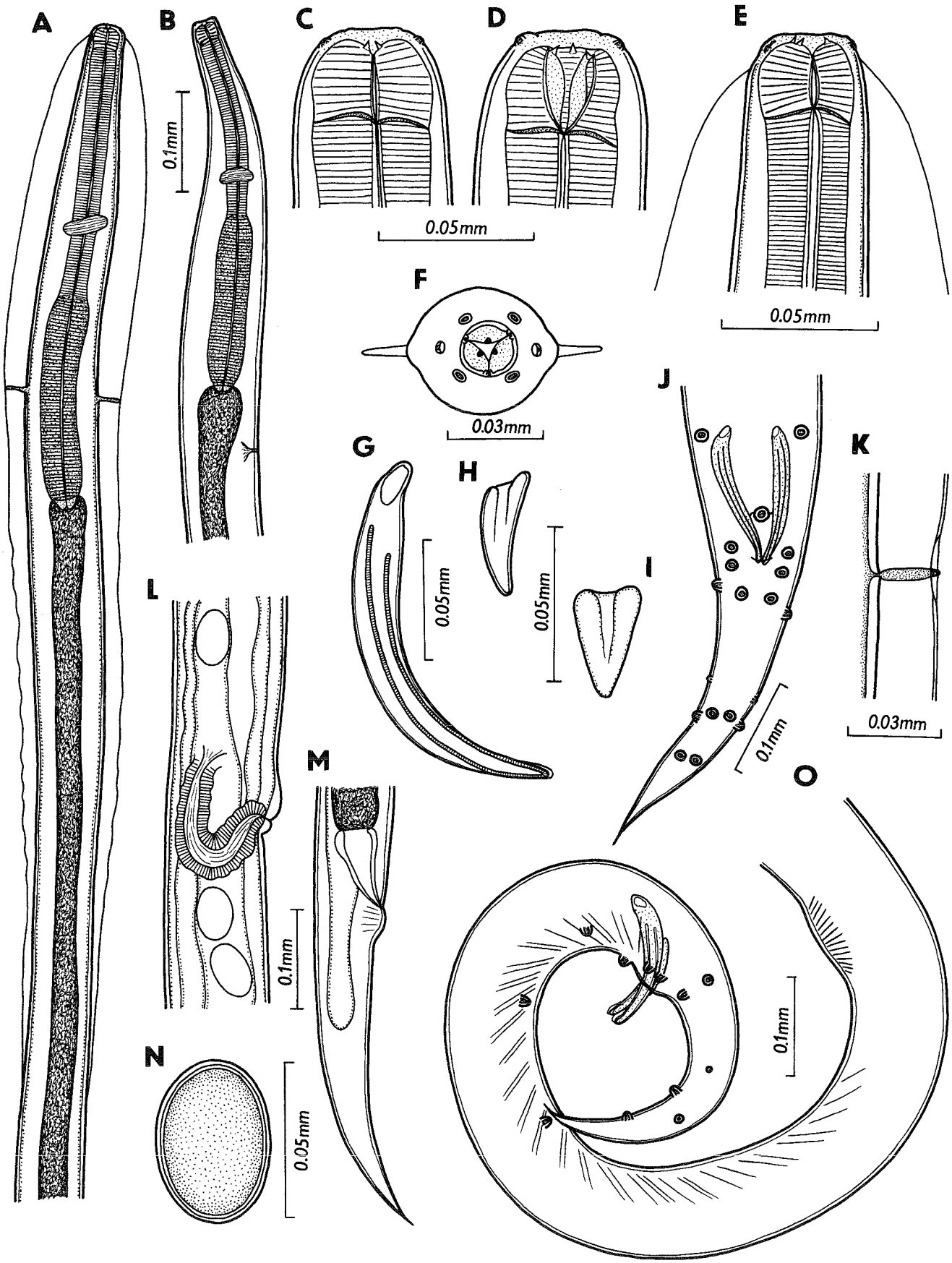

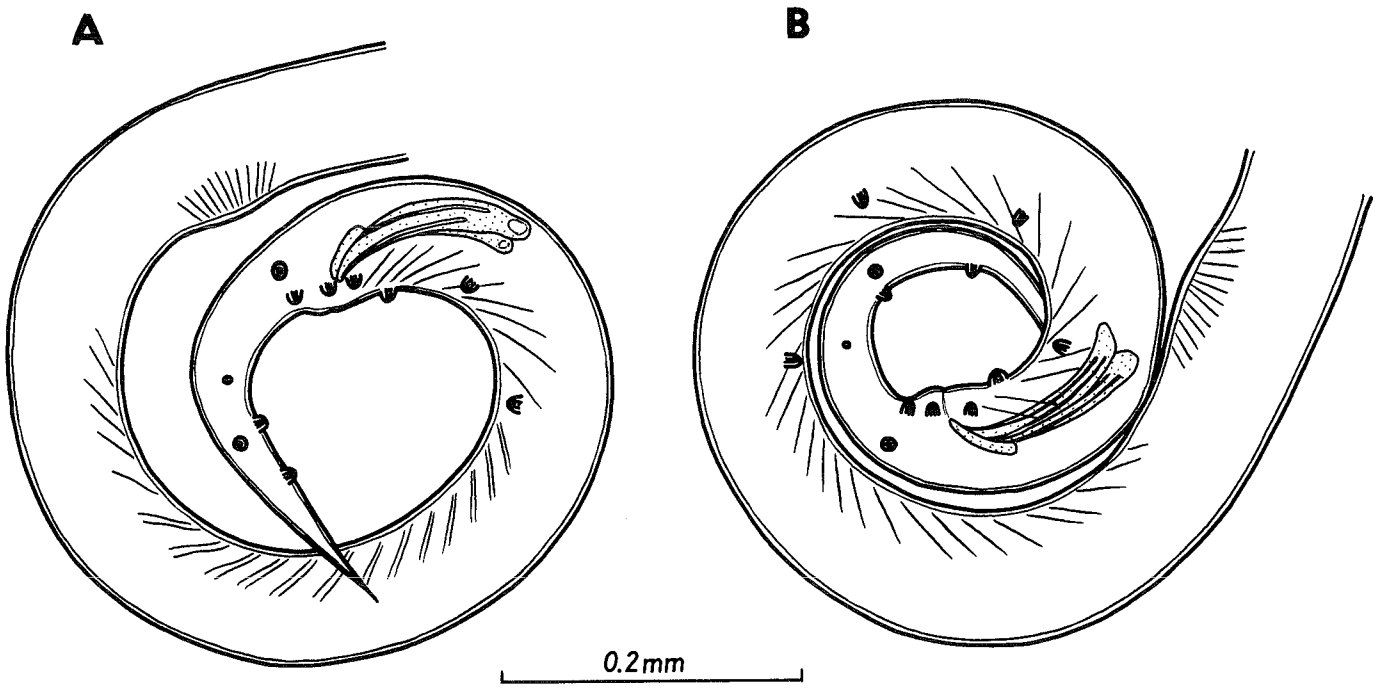

FIGURE 2. *Paraquimperia africana* n. sp., male caudal ends with different numbers of subventral preanal papillae. **A.** With 3 pairs. **B.** With 5 pairs.

Deposition of specimens: Holotype and allotype in the Natural History Museum in London, U.K. (cat. nos. holotype, 1999.2.23.1; allotype, 1999.2.23.2), paratypes in the Institute of Parasitology, Academy of Sciences of the Czech Republic, in České Budějovice (cat. no. N-744).

Etymology: The specific name refers to the continent of origin of the specimens.

Diagnosis

Paraquimperia africana n. sp. differs from 2 other valid congeneric species, *Paraquimperia tenerrima* (Linstow, 1878) and *Paraquimperia anguillae* Karve, 1941, mainly in the presence of a sucker in the males, it being absent only in the juveniles, and in the distinctly shorter spicules (147–171 μm as opposed to 250–394 μm in *P. tenerrima* and 220–260 μm in *P. anguillae*). Furthermore, the excretory pore is situated well behind the esophagus in *P. africana,* whereas it lies at the level of or slightly behind the nerve ring in the other 2 species and the female tail is more slender. The number and arrangement of the postanal papillae of *P. africana* are rather similar to those of *P. tenerrima* (6) but very different from those of *P. anguillae,* in which 11 pairs (?) of postanal papillae have been reported (Karve, 1941). The number of subventral preanal papillae of *P. africana* is variable, 3 pairs having been observed in 2 males, 4 pairs in 4 males, and 5 pairs in 1 male (Figs. 1O, 2). No such variation has been recorded for either *P. tenerrima* or *P. anguillae.*

DISCUSSION

The nematode genus *Paraquimperia* Baylis, 1934 includes specific intestinal parasites of eels (*Anguilla* spp.). Although its type species, *P. tenerrima,* was reported from several cyprinids and percids in the older European literature (Šrámek, 1901), some spiruroid nematodes were probably mistaken for this parasite (Moravec, 1994).

Moravec (1966a) revised the genus and recognized 3 species: *P. tenerrima* (Linstow, 1878) from *Anguilla anguilla* (Linnaeus) in Europe (Linstow, 1878; Šrámek, 1901; Baylis, 1934; Moravec, 1966b, 1994; Køie, 1988; Saraiva and Chubb, 1989; Nie and Kennedy, 1991), *Paraquimperia aditum* (Mueller, 1934) from *Anguilla rostrata* (LeSueur) from North America (U.S.A.) (Mueller, 1934; Hanek and Threlfall, 1970; Hanek and Molnar, 1974; Cone et al., 1993), and *P. anguillae* Karve, 1941 from *Anguilla bengalensis* (Shrestha) from India (Karve, 1941; Naidu, 1983). However, he remarked that subsequent studies with freshly collected *P. aditum* would probably show its conspecificity with *P. tenerrima.*

Cone et al. (1993) reported the occurrence of *P. tenerrima* in the American eel, *A. rostrata,* from Canada and mentioned again that the 2 nematode species may be conspecific but did not formally synonymize *P. aditum* with *P. tenerrima.* Moravec (1966a) re-examined the cotypes of *P. aditum* but did not find any substantial difference between these and *P. tenerrima.* Because the latter has been found in the type host of the former in North America, we now consider *P. aditum* (Mueller, 1934) Moravec, 1966 a junior synonym of *P. tenerrima* (Linstow, 1878) Baylis, 1934. *Paraqimperia xenentodonia* Gupta and Bakshi, 1984, a species inadequately described from the atheriniform fish *Xenentodon cancila* (Hamilton) in India (Naidu, 1984), is considered a species inquirenda. Thus, including the

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FIGURE 1. *Paraquimperia africana* n. sp. **A, B.** Anterior end, dorsoventral and lateral views. **C, D.** Cephalic end, lateral and sublateral views. **E, F.** Cephalic end, dorsoventral and apical views. **G.** Spicule. **H, I.** Gubernaculum, sublateral and ventral views. **J.** Tail of male, ventral view. **K.** Deirid. **L.** Region of vulva. **M.** Tail of female. **N.** Egg. **O.** Posterior end of male with 4 pairs of subventral preanal papillae.

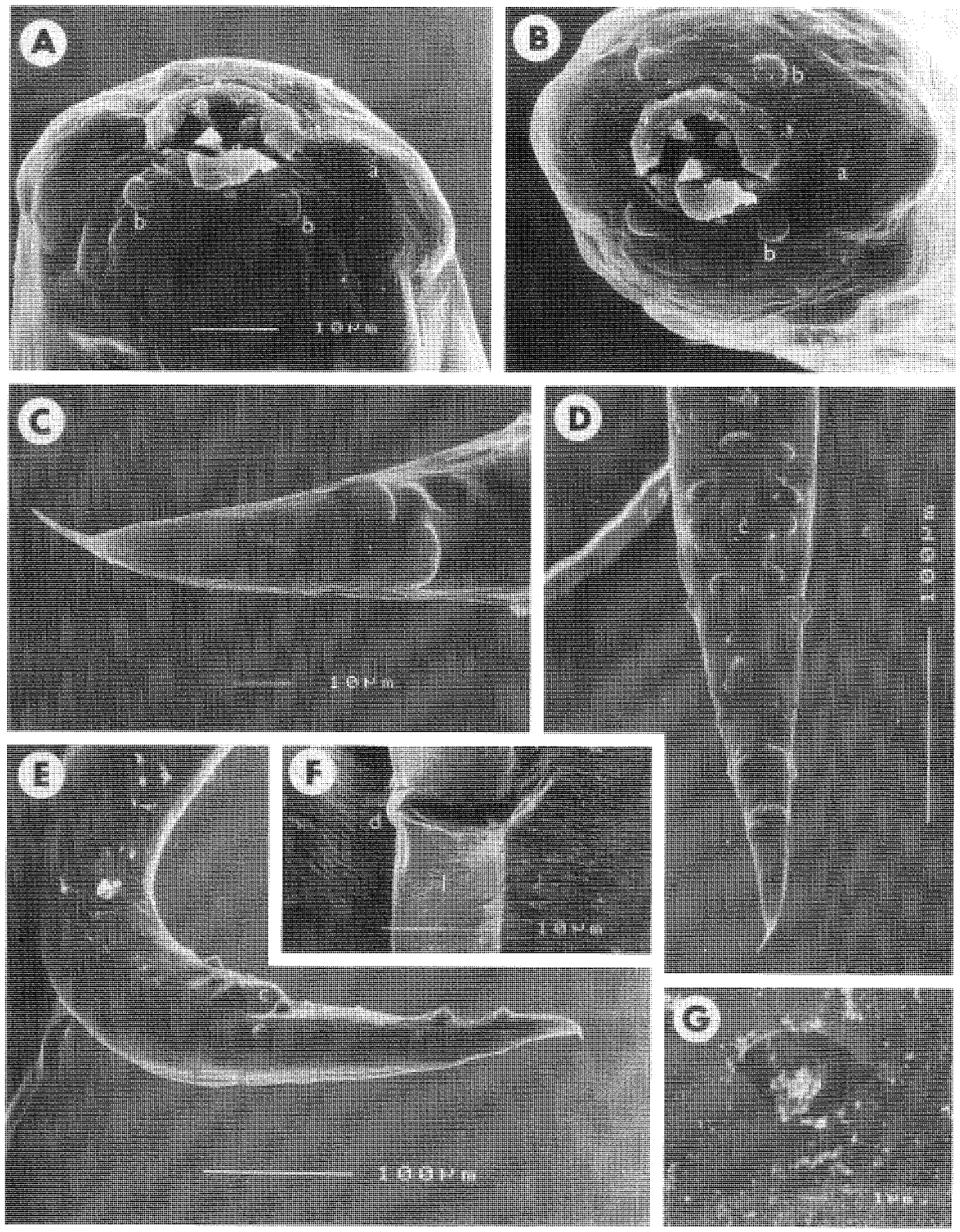

FIGURE 3. *Paraquimperia africana* n. sp., scanning electron micrographs. **A, B.** Cephalic end, dorsoventral and apical views. **C.** Posterior end of male tail, ventral view. **D, E.** Tail of male, ventral and lateral views. **F.** Deirid. **G.** Excretory pore. Abbreviations: **a.** Amphid. **b.** Cephalic papilla. **c.** Cloacal opening. **d.** Deirid. **l.** Lateral ala.

new species, the genus *Paraquimperia* contains only 3 valid species, *P. africana, P. anguillae,* and *P. tenerrima.*

A remarkable feature of *P. africana* is the presence of the ventral sucker in fully developed males. Until now, the absence of such a sucker has been a characteristic of the genus (Yamaguti, 1961; Ivashkin and Khromova, 1976). However, because in other features the morphology of *P. africana* is so similar to the other *Paraquimperia* species and because the sucker is absent in young males, we consider our specimens to belong to this genus. It is, however, necessary to modify the diagnosis of the genus in that a ventral sucker may be present.

The presence of a *Paraquimperia* sp. in eels in South Africa has been recorded for the first time by Jackson (1978). Because the material described here originates from the same locality as those of Jackson (1978), we are of the opinion that they are probably the same species and that the *Paraquimperia* spp., similar to the *Anguillicola* spp., are widely distributed in populations of eels on different continents.

ACKNOWLEDGMENTS

The help of Denzil Radloff of East London, whose intimate knowledge of the local conditions and who caught eels when no eels where to be found, is gratefully acknowledged. The authors' thanks are also due to the staff of the Laboratory of Electron Microscopy of the Institute of Parasitology, AS CR, in České Budějovice, for their technical assistance and to Irena Husáková from the Laboratory of Helminthology of the same institute for help with preparation of illustrations. This study was partly supported by grant 508/94/0284 from the Grant Agency of the Czech Republic, by grant K2-022-601 from the Academy of Sciences of the Czech Republic, and by a grant from the Foundation for Research Development, South Africa.

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Vol. 63: 185–195, 2005 | DISEASES OF AQUATIC ORGANISMS
Dis Aquat Org | Published February 28

Anguillicola papernai (Nematoda: Anguillicolidae) and other helminths parasitizing the African longfin eel *Anguilla mossambica*

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ABSTRACT: The swim bladder nematode *Anguillicola papernai* Moravec & Taraschewski, 1988 has been investigated as regards its occurrence in longfin eels *Anguilla mossambica* (Peters) in rivers in South Africa. *A. papernai* revealed a prevalence of around 50% and a mean intensity of about 6 adult worms at 1 sampling site but were less abundant in 3 others. Field observations suggest a more narrow habitat preference than that of *Anguillicola crassus* and a seasonal pattern of abundance. African longfin eels harboured a poor helminth community. In addition to *A. papernai*, 2 gastro-intestinal nematodes occurred, the stomach worm *Heliconema longissimum* Ortlepp, 1923 as the dominant species, and the intestinal *Paraquimperia africana* Moravec, Boomker & Taraschewski, 2000. Experiments were undertaken using European eels *Anguilla anguilla* (Linnaeus) and copepods as laboratory hosts. The morphology of larvae and adult parasites obtained from these experimental hosts is described. The ultrastructure of adult worms recovered from wild longfin eels was studied. The 'papilla-like excrescences of fibrous structure' on the adult worms' cuticle, as mentioned in the original description, are in fact the attachment points of thick cords of fibers interconnecting the epicuticle with the hypodermis. Such a structure has not yet been described from any other species of *Anguillicola* Yamaguti, 1935. At present in South Africa, Mozambique and Madagascar attempts are on the way to establish an eel management like in Asia and Europe including eel farming. In this context, care should be taken to prevent the introduction of non-endemic eel parasites into Africa and Madagascar. On the other hand, the future commercial management of African eel species should not lead to the spread of *A. papernai* or other parasites of African eel species to Europe or elsewhere. In this study *A. papernai* has been experimentally demonstrated to be capable of reproducing in the European eel and of using European copepods as intermediate hosts.

KEY WORDS: *Anguilla mossambica* · Eel · *Anguillicola papernai* · Swim bladder · Copepods · Life cycle · Morphology · Ultrastructure · Eel culture

INTRODUCTION

The genus *Anguillicola* Yamaguti, 1935, the members of which infect the swim bladders of eels, had attracted little attention until *A. crassus* Kuwahara, Niimi & Itagaki, 1974, known from *Anguilla japonica* Temminck & Schegel and cultured *Anguilla anguilla* (Linnaeus) in East Asia (Nagasawa et al. 1994, appeared in Europe in the 1980s. First occurring in the German river Weser (Neumann 1985), it quickly spread to populations of the European eel *A. anguilla* throughout Europe and North Africa, and finally

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reached North America, where it infected *Anguilla rostrata* (Lesueur) (Barse & Secor 1999, Maamouri et al. 1999, Knopf et al. 2000). It turned out to be highly pathogenic in European eels, which led to considerable public interest (Würtz & Taraschewski 2000). In the meantime, however, it is discussed whether wild European eels somehow have become adapted to chronic parasitism by *Anguillicola crassus* (Kelly et al. 2000).

Moravec & Taraschewski (1988) compiled and partly described 5 *Anguillicola* species parasitizing in different eel species in different regions of the world, namely *A. crassus*, *A. globiceps* Yamaguti, 1935, *A. australiensis* Johnston & Mawson, 1940, *Anguillicola novaezelandiae* Moravec & Taraschewski, 1988 and *Anguillicola papernai* Moravec & Taraschewski, 1988. Unlike *A. crassus*, the other *Anguillicola* species have been little studied (Moravec et al. 1994, Kennedy 1995, Lefèbvre et al. 2004). This is especially true for *A. papernai* which has been recorded only once in *Anguilla mossambica* (Peters) near East London, Eastern Cape Province, South Africa, leading to the first description of the parasite (Moravec & Taraschewski 1988).

The aim of this investigation was to gather information on the prevalence, abundance, habitat preference and life cycle of this nematode, as well as its morphology, including that of the larvae. Furthermore, we wanted to know with which other helminths it concurrently occurs in populations of *Anguilla mossambica*. The data presented in this paper are all we know about *Anguillicola papernai* thus far. The field studies were intended to be continued over the following years, but as it became increasingly difficult to obtain eels sampled in the vicinity of East London or at other sites in South Africa we decided to publish our data now, without any potential further supplementation.

MATERIALS AND METHODS

Collection localities. The sampling Stns 1 to 3 belong to the area around the city of East London (Eastern Cape Province). The first sampling site on the Nahoon River is situated about 10 km away from its mouth, i.e. the Indian Ocean, and is surrounded by diversely structured, extensively managed farmland with no human settlements close by ('Nahoon Farmland', Table 1). At the angling site the river formed a basin of about 15 m in width edged by steep rocks with trees on one side, and reeds and meadows on the other. This site was sampled only once during March 1994.

The second sampling site ('Nahoon Reservoir', Table 1) is about 4 km upstream of the first one, at the point where the Nahoon River is dammed up by a high concrete wall. Beneath this obstacle, which prevents upstream migration of fish, the river forms a pond surrounded by reeds, rocks and gravel. Prior to sampling, water was released from the dam in order to simulate rainfall and to create turbidity. This site was sampled twice, during March 1994 and January 1995.

Table 1. *Anguilla mossambica*. Field data and data on helminth parasites collected during 2 expeditions and at 3 sampling sites. nd: not determined; SD: standard deviation (in brackets)

		Nahoon Farmland	Nahoon Reservoir		Kwalega River	
		Mar 1994 (n = 14)	Mar 1994 (n = 25)	Jan 1995 (n = 21)	Apr 1994 (n = 2)	Jan 1995 (n = 8)
Mean eel mass (SD)		124.1 (38.6)	nd	90.8 (90.7)	nd	114.4 (41.0)
Mean eel length (SD)		40 (3.9)	32.6 (5.6)	33.0 (9.1)	33.8	37.4 (4.2)
Mean condition factor (SD)		0.19 (0.04)	nd	0.2 (0.03)	nd	0.21 (0.02)
Anguillicola papernai adults	Prevalence %	14.3	8	9.5	50	62.5
	Mean intensity	1	2	1	6	5.6 (4.2)
	Abundance	0.1 (0.4)	0.2 (0.6)	0.1 (0.3)	nd	3.5 (4.3)
Anguillicola papernai larvae	Prevalence %	0	0	14.3	50	75
	Mean intensity	0	0	1	0.5	5.2 (3.1)
	Abundance	0	0	0.1 (0.4)	nd	3.9 (3.4)
Paraquimperia africana	Prevalence %	64.3	64	nd	50	nd
	Mean intensity	14.8 (12.2)	2.6 (1.6)	nd	2	nd
	Abundance	9.5 (12.0)	1.6 (1.8)	nd	nd	nd
Heliconema longissimum	Prevalence %	92.9	92	76.2	100	87.5
	Mean intensity	59.6 (24.0)	17.8 (22.1)	31.8 (31.3)	5	36.4 (27.3)
	Abundance	55.4 (28.0)	16.4 (21.7)	28.2 (31.1)	nd	31.9 (28.4)
Anisakid larvae (*Contracaecum* spp.)	Prevalence %	57.1	92	nd	nd	nd
	Mean intensity	41.3 (28.8)	8 (14.6)	nd	nd	nd
	Abundance	23.6 (29.9)	7.4 (14.2)	nd	nd	nd

The Kwalega River, the third sampling site, is only half as wide as the Nahoon River, and because of the steeper slope, the current is stronger. The substrate is coarse, consisting mainly of rocks and sharp gravel. The sampling site was located on farmland with bushes about 2 km away from the coast and about 15 to 20 km northeast of the mouth of the Nahoon River. This site was also sampled twice, during April 1994 and January 1995.

A single longfin eel, 50.5 cm long and 345 g in mass, was collected from the Sabie River inside the Kruger National Park near the border to Mozambique during April 1994. No helminths were recovered.

Sampling and dissection of eels. Longfin eels (n = 70) as well as Mozambique mottled eels *Anguilla marmorata* Quoy & Gaimard (n = 2) were sampled. The eels were caught with baited handlines which, in the Eastern Cape Province, is successful only after heavy rain, usually between October and March (D. Radloff pers. comm.). Attempts to catch eels during the dry seasons failed, as did trapping them in an imported eel trap.

The caught eels were kept alive in insulated containers and brought to a laboratory at the Amalinda Fish Research Station in East London. They were housed overnight in large oxygenated tanks and dissected after decapitation the next morning. Mass and length were determined, whereafter the swim bladder was removed and examined for the presence of *Anguillicola papernai*. The opened swim bladder was examined between 2 plexiglas plates for histotropic L_3 and L_4 stages using a stereoscopic microscope with light from underneath. The entire alimentary canal was removed and divided into stomach and intestine, which were opened in separate Petri-dishes containing phosphate buffered saline, and examined for helminths under a stereoscopic microscope. The same was done with the gills and the remaining viscera. Squash preparations of muscle, kidney and heart, however, were not made and the eyes were not examined.

Processing of the helminths. For light microscopical studies the nematodes were fixed in either boiling or cold 70% ethanol and preserved in 70% ethanol. Helminths were cleared in 50% lactophenol in water and drawings were made with the aid of a Zeiss drawing tube. For scanning (SEM) and transmission electron microscopy (TEM) the specimens were processed using standard methods. Semi-thin sections of *Anguillicola papernai* were cut with a Reichert ultramicrotome, stained with methylene blue, and examined and photographed with a Zeiss Axiophot photomicroscope. The SEM-examination was done with a Cambridge S4/10 and TEM with a Phillips CM 200.

Experiments on the life cycle of *Anguillicola papernai*. Swim bladders of heavily infected eels from the Kwalega River, Eastern Cape Province, were rinsed with tap water into an aquarium containing unidentified copepods, collected from a pond in Gauteng Province, South Africa, and fed on suspended yeast. After the copepods had been allowed to feed on the L_2 stages washed from the swim bladders, they were kept outdoors for 2 wk at approximately 20°C. The copepods were transferred to Germany and after another 2 wk of laboratory maintenance under the same conditions as in South Africa, the copepods were force-fed with a stomach tube (Knopf et al. 1998) to 2 *A. crassus*-free European eels purchased from an eel farm (Limnotherm, Bergheim). The eels were kept together at 20°C in an 80 l aerated aquarium with 2 polypropylene tubes serving as hiding places. The individuals were force-fed twice an week with pelleted food supplied by the eel farm.

A year later (360 d post-infection) 1 eel was killed by decapitation, and its swim bladder was opened and examined for adult and larval *Anguillicola papernai*. The second eel was killed on Day 415 post-infection (pi). The bottom of the aquarium where the eels were kept was inspected for L_2 of the parasite once a month by pipetting sediment into a Petri-dish, which was subsequently examined under a stereoscopic microscope. In the fifth month pi sufficient larvae were obtained from the aquarium to infect the copepods *Thermocyclops* cf. *crassus* (Fischer) and *Mesocyclops leuckarti* (Claus), collected from a pond in the Botanical Garden of the University of Karlsruhe and thus free of *A. crassus* or any other helminth infection. The copepods were placed in a 40 l aquarium and allowed to feed on the L_2 larvae collected from the aquarium the eels were kept in. From the 3rd day after adding the nematode larvae, the copepods were fed with suspended yeast and remained in the same aquarium at 20°C until they were used to infect eels, 30 d later. Three individuals were infected by stomach tube and kept in separate aquaria under conditions as described above. Eel 1 received an undetermined number of larvae, still inside the copepods, the second was given 20 larvae liberated from copepods, and 9 larvae were given to Eel 3. Eel 1 was killed 131 d post-infection (dpi) and Eel 2 on Day 275 pi Eel 3 died 7 dpi.

Adult *Anguillicola papernai* collected from experimentally infected European eels as well as larvae obtained from the laboratory cycle were prepared for measurements as described above.

The maintenance of eels and copepods infected with *Anguillicola papernai* in the laboratory in Germany as well as all related experiments were carried out under strict laboratory preventive measures. Water potentially containing L_2 larvae of the parasite was prevented from getting into the public sewage system.

RESULTS AND DISCUSSION

Field observations

Only 2 of the 14 long fin eels from the site 'Nahoon Farmland' were infected with 1 *Anguillicola papernai* each. Larvae could not be detected in the swim bladder wall (Table 1). Beside *A. papernai*, 3 other species of nematodes were recorded: *Paraquimperia africana* Moravec, Boomker & Taraschewski, 2000, inhabiting the small intestine, *Heliconema longissimum* Ortlepp, 1923 in the stomach, as well as *Contracaecum* spp., encapsulated on virtually all surfaces of the viscera (Table 1). *H. longissimum* was most prevalent and most abundant. The few data available did not permit any appreciable statistical analyses.

The 2 specimens of *Anguilla marmorata* also caught at this station in March (length 87 and 55 cm, weight 2001 and 287 g, respectively) harboured only *Contracaecum* larvae on the outer surfaces of their viscera.

At the second sampling site ('Nahoon Reservoir') in March and January the prevalence of adult *Anguillicola papernai* approximated 10% (2 eels out of 25 and 21, respectively, being infected). In January, however, the larval prevalence was 14% as opposed to the 0% in March at both the Nahoon sampling sites. The abundance of adult worms was as low as at the other Nahoon station. The dominant species, *Heliconema longissimum*, did not show the same high worm burdens as at the farmland station further downstream (Table 1) but this seemed to be due to the smaller average eel size below the dam. The lower abundance and intensity of *Paraquimperia africana* as well as of the anisakid larvae also might reflect the lower length of the eels at the Nahoon Reservoir compared to the farmland station.

Approximately 5 *Anguillicola papernai* were present in the swim bladder of about every second of the 10 individuals from the Kwalega River. The maximum intensity was 12 adult nematodes per eel. These preliminary infection data reveal a high degree of overdispersion in this river. In contrast to the Nahoon sites a strong presence of larvae was noted, especially in January. The occurrence of the 3 other helminth species resembled the situation in the Nahoon River (Table 1).

The difference in occurrence of *Anguillicola papernai* in the 2 rivers might reflect a specific habitat preference of the parasite, or its intermediate hosts. The Kwalega River is fast-flowing whereas the Nahoon has a weak current only, but the available data are too limited for a discussion of this nature. In addition, the data seem to suggest a certain seasonality in the occurrence of the parasite. At all 3 stations an increase of larvae, presumably due to new infections, was noted in January.

The prevalence, as well as the worm burden of *Anguillicola papernai*, resembles the situation which has been described for the other *Anguillicola* species in their indigenous eel hosts. In Queensland, Australia, the overall prevalence of *A. australiensis* in *Anguilla reinhardtii* (Steindachner) was 50% and reached 78% in 1 of 9 locations, but the intensity nowhere exceeded 10 worms per swim bladder (Kennedy 1994). Similar data are available for *Anguillicola globiceps* in *Anguilla japonica* from 2 sites in China and 1 in Japan. At the former locality the prevalence was 40 and 61%, respectively, and the intensity ranged between 1 and 12; in the latter a prevalence of 6% was found, and the incidence was mostly 3 or 4 (maximum 7) adult worms per swim bladder (Wang & Zhao 1980, Nagasawa et al. 1994). Even *Anguillicola crassus* in its indigenous host, *Anguilla japonica*, revealed a similar prevalence during different surveys (25, 40, 17.5, 56%) (Nagasawa et al. 1994). A maximum intensity of 11 adult worms was recorded. In East Asia it is only in cultured European eels that this species occasionally reaches a 100% prevalence and a maximum intensity exceeding 30 (Nagasawa et al. 1994).

After its introduction into Europe, infection rates of *Anguillicola crassus* reached almost 100% in European eels (Taraschewski et al. 1987, Kennedy & Fitch 1990, Thomas & Olivier 1992) with mean intensities of adult worms often above 20 (Thomas & Olivier 1992) and maximum worm burdens of 42 (Taraschewski et al. 1987) or 71 (Cardoso & Saraiva 1998) adults per individual. Similar data have been published concerning another phylogenetically young host–parasite relation, i.e. *A. novaezelandiae* in *Anguilla anguilla* in a lake near Rome where the nematode had been introduced from New Zealand in the early 1980s. Here the prevalence was 80%, the intensity 1 to 27 and the mean 11 (Moravec et al. 1994). In contrast, in its natural host *Anguilla australis* in New Zealand the prevalence ranged from 0 to 12 % (5 biotopes) with intensities of 1 or 2 adult worms (maximum: 5) (Lefèbvre et al. 2004).

Thus, the field data presented in this study suggests that *Anguilla mossambica* and *Anguillicola papernai* have come to a state of moderate host–parasite relations after long co-evolution.

The 2 other nematode species found as adults in the digestive tracts of African longfin eels and reported on in this paper are eel-specific, as is *Anguillicola papernai* (Moravec et al. 2000, Ogden 1969, Chabaud 1989). The stomach worm *Heliconema longissimum* was always the dominant species in *Anguilla mossambica*.

Low parasite diversity and high dominance as reported here from an African eel species are also known from populations of European eels (Kennedy et al. 1998, Sures et al. 1999) as well as from American eels *Anguilla rostrata* in Canada (Cone et al. 1993, Barker et al. 1996, Marcogliese & Cone 1996). So far, only a survey on macroparasites in and on *A. rein-*

Table 2. *Anguillicola papernai* from experimentally infected *Anguilla anguilla*. Measurements in mm of fixed adults. dpi = days post-infection

Criterion	Males, 131 dpi (n = 6)	Gravid females, 131 dpi (n = 4)	Gravid females, 275 dpi (n = 3)
Body length	14.24–20.66	13.70–14.86	20.40–24.07
Max. body width	1.17–1.43	1.30–3.33	2.24–2.58
Buccal capsule length	0.012–0.015	0.012	0.012
width	0.027	0.027–0.030	0.027–0.030
Cephalic end length	0.095–0.018	0.109–0.135	0.095
width	0.105–0.109	0.095–0.108	Not determined
Width of neck constriction	0.095–0.099	0.093–0.108	0.122–0.136
Oesophagus length	0.476–0.530	0.517–0.558	0.598–0.612
width	0.136–0.150	0.150–0.163	0.150–0.204
Ratio: oesophagus length to body length	1:30–39	1:25–28	1:33–37
Nerve ring	0.153–0.180	0.129–0.138	0.122–0.136
Vulva from posterior end	Not applicable	2.52–3.20	2.60–5.10
Length of tail	Not determined	0.299	0.245–0.299
Remarks	Not applicable	Numerous eggs, larvae not yet developed	Numerous eggs with developed L_2

hardtii in Queensland (tropical Australia) has revealed very rich parasite communities (Kennedy 1995). This study did not, however, determine whether the parasites were in a reproductive stage. In the study by Sures et al. (1999) about 50% of the helminths of *A. anguilla* in the Rhine River were neozoic species of non-European origin reflecting the enormous imports of non-European eels into Europe. In contrast, the very poor helminth communities of longfin eels in South Africa do not reveal any allochtonous impact. Among the adult helminth species recorded here from *A. mossambica*, only *Heliconema longissimum* was described from other eel species. However, the taxonomy of the genus *Heliconema* is confusing and is currently being revised by F. Moravec et al. (unpubl.).

Morphology of adult worms

The measurements of the 13 adult worms derived from experimental infections in the European eel (Table 2) closely resemble those presented in the original description of *Anguillicola papernai* based on 4 females and 1 male specimen from naturally infected longfin eels (Moravec & Taraschewski 1988). The range of measurements is wider in the present individuals.

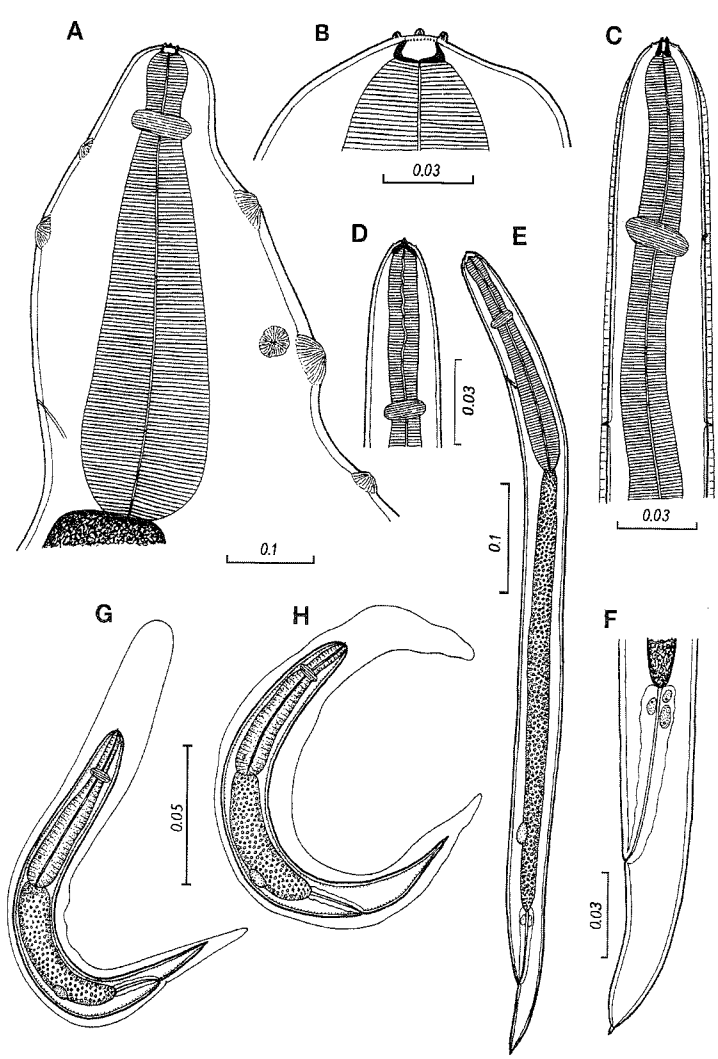

Fig. 1. Ink drawings of *Anguillicola papernai* Moravec & Taraschewski, 1988, from experimentally infected European eels and copepods. Scale bars in mm. (A, B) Gravid female. (A) Anterior end of body; (B) cephalic end. Note the knobs on the outer surface. (C–F) Third-stage larva from the copepod intermediate host. (C) Anterior end, dorso-ventral view; (D) same, lateral view; (E) general view of larva; (F) tail. (G, H) Free second-stage larvae

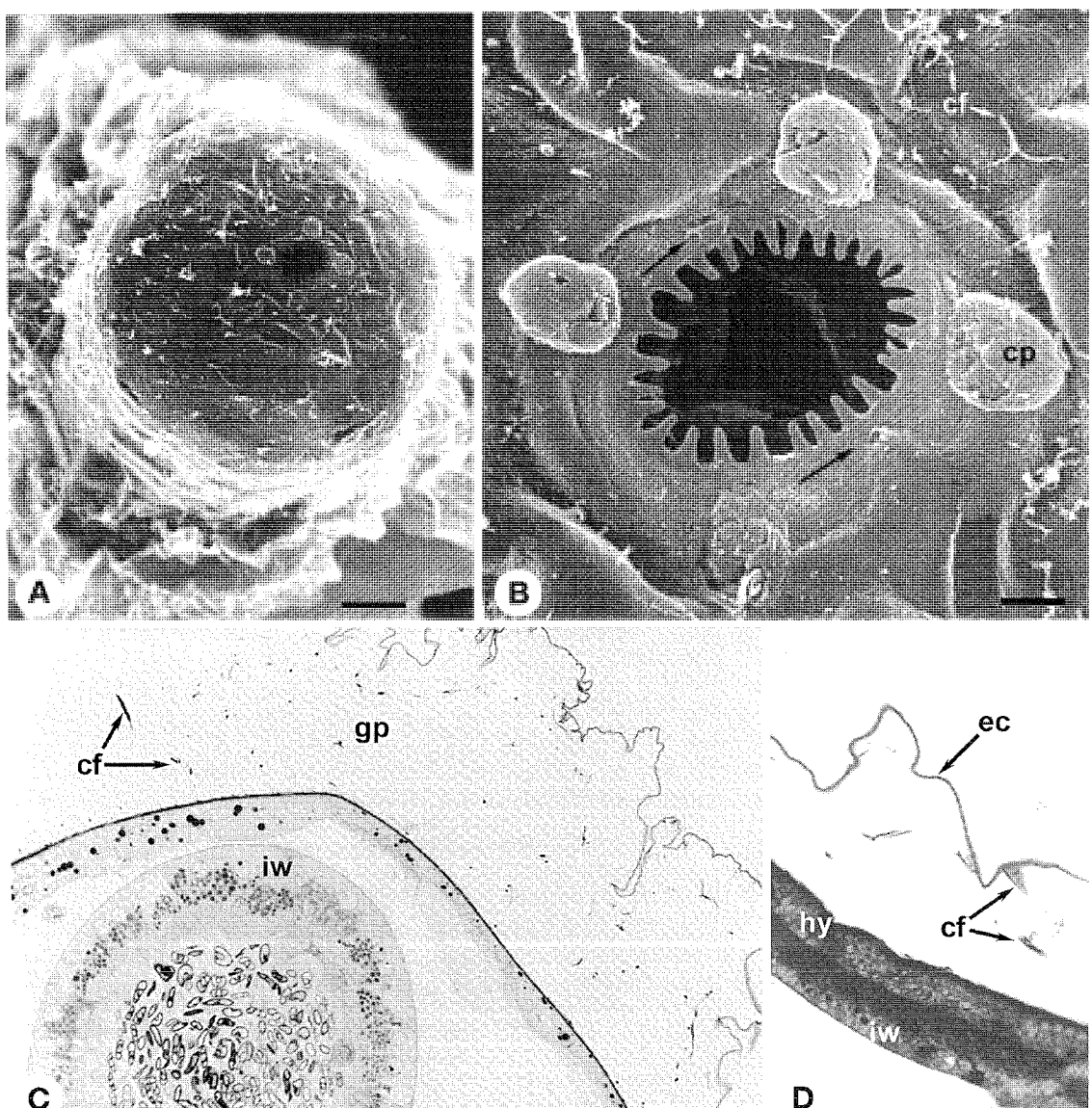

Fig. 2. *Anguillicola papernai* from naturally infected *Anguilla mossambica*. Micrographs showing external features of adult. (A,B) Scanning electron micrographs of the buccal (A) and oral (B) region. Note the 26 (27) oral teeth, and the large dorsolateral cephalic papillae (cp); the 2 lateral amphids (arrows) are very indistinct, also the filiform outgrowths (cf) of the hypodermis' outer surface, persisting on the surface after the gelatinous outer part of the cuticle was washed away during the SEM-preparation of the worm. Scale bars: (A) = 15 µm, (B) = 3 µm. (C) Semi-thin section through the body wall. At the mid and posterior part of the body the outer gelatinous part of the cuticle (gp) may be very thick and interspersed with filiform cords of fibres (cf); iw: intestinal wall. Scale bar 7 µm. (D) Semi-thin section of the intestinal wall (iw), hypodermis (hy) and cuticle. Note the medium-sized cord of fibers (cf) communicating with the epicuticle (ec) and obviously keeping the latter in position. Scale bar = 8 µm

The main difference is that the buccal capsule is not as deeply retracted into the body as in the type specimens (Figs. 1 & 2A,B); this probably has to do with the method of fixation. The surface structures named cuticular 'papilla-like excrescences of fibrous structure' (Fig. 1A) in the paper by Moravec & Taraschewski (1988) which are present on the narrower anterior and posterior parts of the worms, were again studied by light microscopy. In the present investigation, however, these structures appeared to be less numerous and less conspicuous which, again, may have to do with the method of fixation. When these structures, together with the cuticle, are viewed with the electron microscope, it is evident that most of the cuticle consists of a gelatinous matrix and that the 'excrescences' mark the points of attachment of thick cords of fibres that interconnect the epicuticle with the outer membrane of the hypodermis (Fig. 2D).

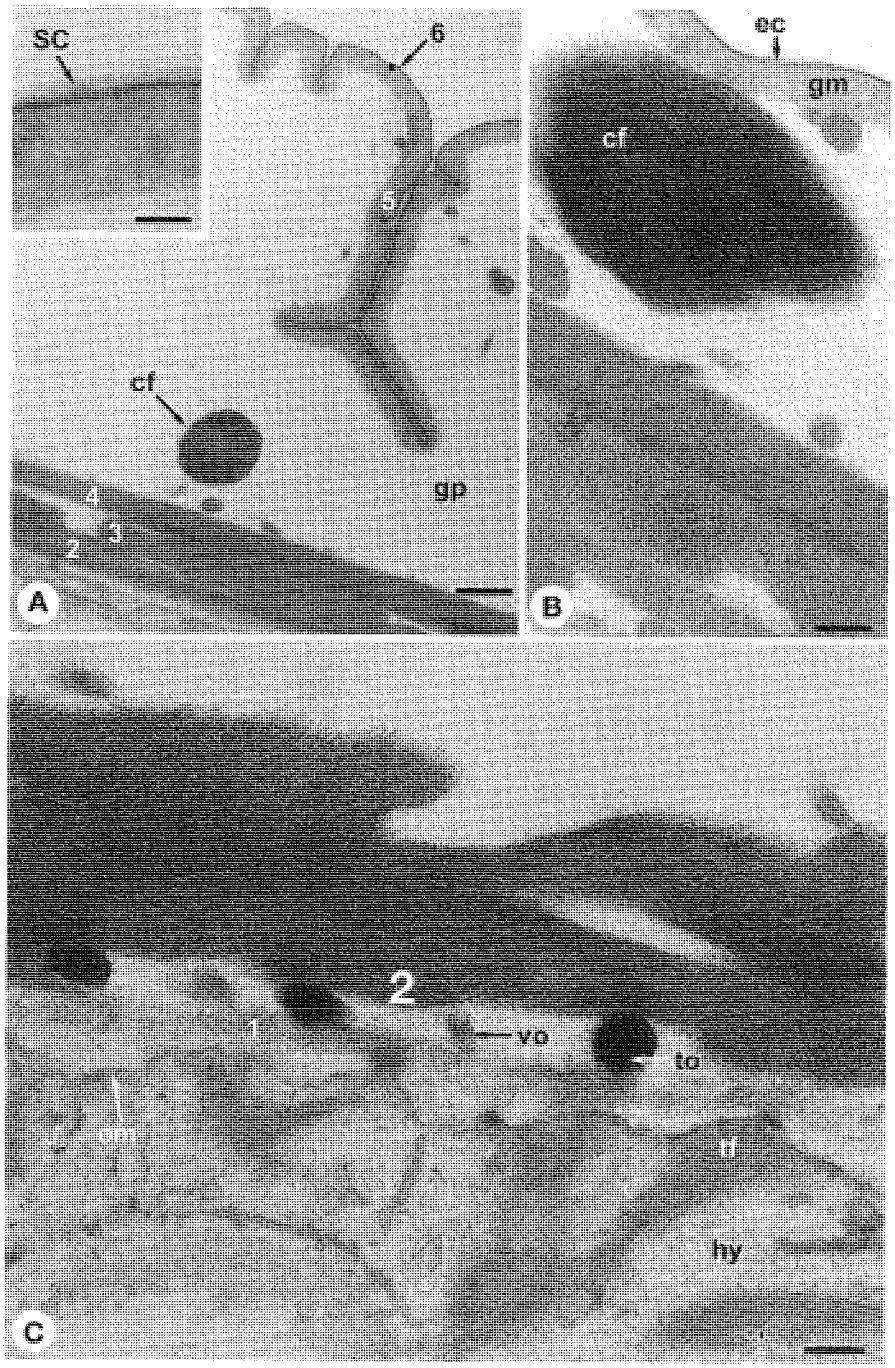

Fig. 3. *Anguillicola papernai* from naturally infected *Anguilla mossambica*. Transmission electron micrographs of cross sections through cuticles and hypodermes of adult. (A) Note the regular arrangement of 3 prominent layers of fibre cords (2–4) in the inner part of the cuticle. The innermost thin, less compact layer of fibres (1) cannot be seen well in (A). It can be discerned better in (C). In the gelatinous outer part of the cuticle (gp) a medium-sized filiform radially arranged cord of fibres (cf) can be seen. The epicuticle (6th electron-dense layer) is supported on its inner side by granular matter of a considerable thickness (Layer 5). Scale bar = 0.5 µm. Inset: higher magnification of the worm's outer surface (Layers 5 and 6) showing the fuzzy surface coat (sc). Scale bar = 0.15 µm. (B) Obliquely sectioned very thick rope (cf) inside the gelatinous layer of the cuticle. The attachment site of such a thick cord of filaments at the epicuticle (ec) is seen as a knob (compare Fig. 1A) when the worm is viewed by a light microscope; gm: granular matter underneath the epicuticle. Scale bar = 0.25 µm. (C) At high magnification a circularly oriented thin layer of loosely arranged fibers (1) between the hypodermis (hy) and the inner circularly oriented cord (2) of fibres can be discerned. This layer as well as the overlying 3 layers of differently oriented fibers (2–4, compare A) are interwoven by radially arranged, regularly set thin outgrowths (to) and very thin outgrowths (vo) of the hypodermis' outer membrane (om). The points of insertion at the outer membrane (om) are supported by tonofilaments (tf) inside the hypodermis. Scale bar = 0.2 µm

The cuticle may reach considerable thickness, especially at the mid and posterior part of the worm's body (Fig. 2C). Six layers of electron-dense matter can be distinguished in the gelatinous electron-lucent matrix that forms the major portion of the cuticula (Figs. 2C,D, 3). Close to the outer membrane of the hypodermis, 4 layers of fibrous matter, can be differentiated. The innermost one (Layer 1) is rather thin with loosely associated fibres that do not show a clear spatial orientation (Fig. 3C). Towards the exterior it is followed by 3 layers of compact fibre cords (Fig. 3). The inner one of these 3 (Layer 2) consists of strands which are ovoid in cross section and are arranged like circular belts around the worms. In the second one (Layer 3) the strands form a belt of longitudinally arranged cords. In the outermost layer (Layer 4) the cords show again the same arrangement and structure as in Layer 2. The fibres inside the cords reveal different orientations. Between the cords of each of the 3 fibrous belts the gelatinous matrix of the cuticle remains visible (Fig. 3). The outer lining of the cuticle is formed by a monolayered, osmiophilic epicuticle (Layer 6), which is interiorly supported by a thick layer (5th electron-dense layer) consisting of granular matter (Fig. 3). A surface coat (glycocalyx) can be figured out at higher magnification (Fig. 3A inset).

In addition to the epicuticle with its thick lamina and the layers of fibre cords in the inner part of the gelatinous cuticle, a system of more or less radially arranged cords of filaments contributes to the stability of the gelatinous cuticle (Figs. 2 & 3). These 'spokes' seem to keep the epicuticle in position. They originate from the outer membrane of the hypodermis and are supported by bundles of tonofilaments inside the hypodermis. It appears that each size group of cords follows a regular pattern of position on the surface of the hypodermis (Fig. 3C). They seem to be interwoven with the thin innermost layer of fibrous matter (Layer 1) and the thick 3-layered fibre belt (Layers 2 to 4) further outwards by passing through the open spaces between the cords of these layers. The diameter of these radially arranged 'spokes' may vary considerably, between about 0.02 µm and 1.4 µm.

At least the thin and very thin bundles of fibres seem to form a regular pattern along the hypodermis (Fig. 3C) while the few medium-sized (Fig. 3A) and thick ones (Fig. 3B) do not seem to follow a specific pattern. Accordingly, the points of their attachment at the epicuticle do not show a regular distribution and thus the knobs on the surface of the nematodes, as seen by light microscopy, do not follow a pattern (Fig. 1 and also see Fig. 7 of Moravec & Taraschewski 1988). In specimens of *Anguillicola papernai* that were prepared for scanning electron microscope (SEM) investigation, large portions of the gelatinous matter (as well as the epicuticle) were washed away, especially near the mouth opening where the cuticle is generally thin. At the surface of such worms the strings that formerly kept the epicuticle in position can still be discerned (Fig. 2A,B: thin or very thin strings are seen).

The knobs on the surface of *Anguillicola papernai* have not been described from the other *Anguillicola* species (Moravec & Taraschewski 1988), suggesting that the other species are not equipped with the thick cords of fibres described here. After fixation in alcohol, the gelatinous part of the cuticle seems to shrink, making the points of attachment of the thick cords appear as prominent excrescences. Cords of smaller diameter were shown in micrographs of 2 studies on *A. crassus* (Taraschewski et al. 1988, Kirk et al. 2002). In the ultra-thin sections of *A. papernai* studied here, the epicuticle is seen as a single osmiophilic, monolayered lamella. In contrast, the outer lining of *A. crassus* has been interpreted as a 'multilayered epicuticle' (Taraschewski et al. 1988) or as a 'multilayered network of filaments, overlying a densely stained osmiophilic membrane' (Kirk et al. 2002). However, in Fig. 2C of the latter paper the 'filaments' reveal the same thickness as the cuticle itself although they are less osmiophilic. This labyrinthine surface is probably useful in molecular mimicry or in resistance against the host's defense or the chemical environment inside the swim bladder. We do not know why the worms investigated in our study were lacking such an enlarged surface, but it appears unlikely that the labyrinth got lost during the shipment of the fixed nematodes from South Africa to Germany, since the epicuticle of these specimens still carried a surface coat. Such a glycocalyx rich in carbohydrates has been demonstrated from many parasitic nematodes (Dell et al. 1999).

Other morphological differences between *Anguillicola crassus* and *A. papernai* can be seen by SEM: in *A. papernai* the number of the circumoral teeth seems to be around 26 to 27 (Fig. 2B and see also Fig. 7F of the paper by Moravec & Taraschewski 1988) whereas *A. crassus* usually only possesses 22 or fewer, only exceptionally having up to 28 teeth. (Taraschewski et al. 1987, Moravec & Taraschewski 1988). The size of the buccal capsule in fully developed *A. crassus* is distinctly larger (20–27 × 40–63 µm) (but only 12–15 × 33–42 µm in juvenile forms) as compared to that of fully developed *A. papernai* (9–15 × 27–30 µm). Furthermore, the cephalic papillae seem to be considerably larger in *A. papernai* (Fig. 2B) than in *A. crassus* (Taraschewski et al. 1987: Fig. 3C; H. Taraschewski, J. Boomker, F. Moravec unpubl.).

Larval morphology

The larvae of *Anguillicola papernai* have not yet been described. The following descriptions were made from larvae obtained in the laboratory from experimental infections in *Anguilla anguilla* and in European copepods.

Free second-stage larvae

Free second-stage larvae are sheathed by the cuticle of the first moult. They are elongate, whitish to translucent, 0.177 to 0.192 mm long and 0.018 mm wide. The cuticular sheath is 0.030 to 0.033 mm wide. The cephalic end is armed with a minute dorsal conical cuticular tooth. The cuticle is very thin and smooth. The internal organization of the body is not clearly visible. The oesophagus is 0.051 to 0.075 mm long, with a somewhat expanded posterior part. The nerve ring encircles the oesophagus 0.021 to 0.027 mm from its anterior end. The excretory pore was not seen. The intestine is relatively wide, sparsely granulated; the rectum is a thin-walled, colourless tube. The tail is conical, sharply pointed, 0.039 to 0.060 mm long. A small, indistinct genital primordium is situated ventrally in the posterior part of the body (Fig. 1G,H).

Third-stage larvae

These are slender, whitish, 0.717 to 0.816 mm long and 0.036 mm wide. Their cuticle appears to be almost smooth under the light microscope. Two narrow (0.003 mm wide) cuticular alae extend along the entire body length. A pair of minute conical deirids is present 0.180 mm from the anterior extremity. The cephalic end is rounded and the mouth is provided with 2 small lateral, anteriorly directed sclerotized teeth. Behind each tooth is a sclerotized apparatus, which is situated at the level of the anterior end of the oesophagus and which appears bifurcate in lateral view. The apparatus is 0.012 mm long and 0.015 mm wide. Cephalic papillae are indistinct. The oesophagus is long, slender, distinctly broader at its posterior part, and is 0.222 to 0.228 mm long (27 to 32% of the whole body length) and 0.024 mm wide at the posterior part. The nerve ring and the excretory pore are 0.084 to 0.105 mm and 0.123 to 0.141 mm, respectively, from the anterior extremity. The intestine is straight and narrow and contains numerous granules. The rectum is a hyaline tube and rectal glands are indistinct. The tail is conical, 0.063 to 0.075 mm long, bearing a distinct small cuticular spike on its tip. The length of the tail represents 9% of the total body length. A small oval genital primordium is located ventrally, 0.231 to 0.240 mm from the posterior extremity (Fig. 1E).

The morphology of both the second- and third-stage larvae seems to be identical with that of the corresponding larval stages of other congeneric species (*Anguillicola crassus*, *A. novaezelandiae*, *A. globiceps*) (Wang and Zhao 1980, Petter et al. 1989, Moravec et al. 1993, 1994) but the measurements, especially those of the L_2, are slightly smaller. In the L_2 it may be partly because only fixed larvae (contracted) were measured. However, live L_2 of *A. papernai* appeared more slender, and they moved more 'elegantly' and vigorously than those of *A. crassus*.

Laboratory experiments with European eels and copepods

The first recorded intermediate hosts of *Anguillicola papernai* are the unidentified South African copepods used in this study and as well as the European copepods *Thermocyclops* cf. *crassus* and *Mesocyclops leuckarti*, all of which serve as suitable intermediate hosts as the nematode larvae develop to the infective stage. That the larvae are indeed infective was proven by infection and recovery of adult nematodes from the European eels. One of the 2 individuals infected with L_3 within the copepods from South Africa and killed at 360 dpi) turned out to be uninfected. The second, however, killed at 416 dpi, contained 3 dead worms (2♀, 1♂). In addition, in the fifth month pi L_2, which were infective to European copepods and then to eels as proven by transmission experiments, were found on the bottom of the aquarium in which these 2 individuals had been kept.

The usefulness of the European copepods as intermediate hosts has been proven by infecting an eel with experimentally infected copepods. At 131 dpi when the eel was killed, its swim bladder contained 5 gravid females, 4 male worms and numerous eggs (L_2). In a second experiment using the European copepods, 2 European eels were infected with known numbers of L_3 liberated from the copepods. One eel (No. 2) was infected with 20 larvae and another (No. 3), that died 7 d after infection, with 9 larvae. In this individual the larvae obviously had not yet reached the wall of the swim bladder and could not be found. The other one was killed 275 dpi and harboured 4 female worms, a single live male, a dead male and numerous L_2 (eggs).

It is theoretically possible that the nematodes, if introduced into Europe or North America, could spread through the eel populations following the colonization pattern of *Anguillicola crassus*. Thus far,

none of the 4 eel species occurring in southern and eastern Africa (Skelton 1993) is fished commercially, and probably no infected African eels have been brought to Europe or to other continents. In South Africa only a few fishermen fish for eel in the coastal parts of the rivers leading into the Indian Ocean. In addition, it is unknown whether all 4 African eel species may be suitable hosts of *A. papernai*. The 2 Madagascar mottled eels examined in this study were negative, but no conclusions should be drawn from this preliminary result. In Australia, *A. australiensis* only seems to parasitise in *Anguilla reinhardtii* while *Anguillicola novaezelandiae* has only been found in *Anguilla australis* (Moravec & Rohde 1992, Kennedy 1994), suggesting that, unlike *A. crassus*, some species of *Anguillicola* may be host-specific. *Anguillicola novaezelandiae* was introduced into Lake Bracciano in Italy in the early 1980s but did not spread. It was eventually replaced by *A. crassus* which had invaded the lake in the 1990s (Moravec et al. 1994). *A. novaezelandiae* has demonstrated that it is able to reproduce in *Anguilla anguilla* in a closed habitat but did not behave like a colonizing species and could not compete with *A. crassus* in this small lake. Similarly, despite being capable to parasitise and reproduce in European eels, *A. papernai* might also not be able to compete with *A. crassus* in the field. Moreover, the likelihood of becoming introduced into a water-body that is free from *A. crassus* is ever-decreasing due to the rapid and continuous colonization of the latter species (Barse & Secor 1999, Evans & Matthews 1999, Maamouri et al. 1999).

On the other hand, in South Africa, Mozambique and Madagascar attempts are currently being made to use the last untouched eel resources in the world for commercial fishing and aquaculture (L. Ter Morshuizen pers. comm.). In this context we would like to strongly recommend that no live eels from Europe, Asia or elsewhere should ever be imported to southern Africa. In addition to *Anguillicola crassus*, other pathogenic parasites and diseases of eels (see for instance, Buchmann et al. 1987) might be imported.

Acknowledgements: The help of Mr. Denzil Radloff, of East London, whose intimate knowledge of the local conditions and who caught eels when no eels were to be found, is gratefully acknowledged. Thanks are also due to Mrs. Bärbel Seufert-Dausmann, Mrs. Cornelia Haug, Mr. Frankie Thielen, Mr. Felix Reitze and Mr. W. Send and Mr. V. Zibat (Electron Microscopical Laboratory of the University Karlsruhe) for technical assistance. Dr. Bernd Sures has also supported the investigation by various activities. The study was funded by the Foundation for Research Development and the Medical University of Southern Africa, by the 'Deutsche Forschungsgemeinschaft', and partly by grant no. 524/03/0061 from the Grant Agency of the Academy of Sciences of the Czech Republic.

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Editorial responsibility: Wolfgang Körting, Hannover, Germany

Submitted: April 2, 2002; Accepted: September 8, 2004
Proofs received from author(s): January 21, 2005

PENTASTOMIDS

Onderstepoort Journal of Veterinary Research, 65:159–167 (1998)

Pentastomid infections in cichlid fishes in the Kruger National Park and the description of the infective larva of *Subtriquetra rileyi* n. sp.

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ABSTRACT

JUNKER, K., BOOMKER, J. & BOOYSE, D.G. 1998. Pentastomid infections in cichlid fishes in the Kruger National Park and the description of the infective larva of *Subtriquetra rileyi* n. sp. *Onderstepoort Journal of Veterinary Research*, 65:159–167

During 1995, studies were conducted on the pentastome fauna of the cichlid fishes *Tilapia rendalli* and *Oreochromis mossambicus* in the Kruger National Park. The prevalence of infective pentastome larvae was 40,5% in *T. rendalli* and 9,2% in *O. mossambicus*. Encapsulated nymphs of *Leiperia cincinnalis* were taken from the mesentery, while *Sebekia wedli* was either encapsulated or free-living in the swim bladder. The subtriquetrids moved about freely in the swim bladder. *L. cincinnalis* was present in 0,5% of *T. rendalli* and 0,8% of *O. mossambicus* and additional descriptions and measurements of the nymphs are presented. *S. wedli* was present in 2,5% of *O. mossambicus* and a new *Subtriquetra* species, for which the name *Subtriquetra rileyi* n. sp. is proposed, in 7,5%. This ratio in *T. rendalli* was 40,5% and 2,2%, respectively. Of the infected *T. rendalli*, 89% harboured one or two sebekiid larvae, while a single fish harboured eight. Fish infected with *S. rileyi* contained only one larva each.

The condition factor of infected *T. rendalli* was compared statistically to that of uninfected fish and no significant difference found. However, infected fish were significantly shorter and lighter than uninfected ones.

S. rileyi differs from the other three known *Subtriquetra* spp., *Subtriquetra subtriquetra*, *Subtriquetra megacephala* and *Subtriquetra shipleyi* in both hook size and annulus counts. Furthermore, *S. subtriquetra* occurs in South American crocodilians (Riley 1986), and *S. megacephala* and *S. shipleyi* in crocodilians in India (Fain 1961). This is the first record of the genus occurring in Africa and although adult specimens of *S. rileyi* n. sp. were not obtained, we assume that the new species is specific to Nile crocodiles.

Keywords: *Caiman sclerops*, cichlid fishes, crocodiles, *Crocodylus niloticus*, *Crocodylus palustris*, Kruger National Park, *Leiperia cincinnalis*, *Oreochromis mossambicus*, pentastomids, *Sebekia wedli*, *Subtriquetra rileyi*, *Tilapia rendalli*

INTRODUCTION

Pentastomes were first described in crocodiles more than a century ago and it was assumed from an early stage that fish were the intermediate hosts of these endoparasites. Rudolphi (1819, cited by Sambon 1922) was one of the first to report on crocodilian pentastomids found in the South American caiman, *Caiman sclerops*, and described them as *Pentastoma proboscideum*. Bremser (1824, cited by Sambon 1922) collected pentastomids from the mouth cavity of *Caiman sclerops*, which he thought to be identical to those described by Rudolphi. Sambon (1922) created the genera *Sebekia* and *Subtriquetra* to accommodate the specimens collected by Rudolphi (1819) and Bremser (1824) which were renamed *Sebekia*

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Accepted for publication 21 May 1998—Editor

oxycephala Sambon, 1922 and *Subtriquetra subtriquetra* Sambon, 1922, respectively. The nymphal form of the latter species was found in the intestine of the cichlid fish *Acara coscudo* by Natterer (cited by Sambon 1922).

Currently two families of crocodile pentastomes are known. These are the family Sebekidae which contains the genera *Sebekia*, *Leiperia* Sambon, 1922, *Alofia* Giglioli, 1922, *Selfia* Riley, 1994 and *Agema* Riley, Hill & Huchzermeyer, 1997, and the family Subtriquetridae, which contains the single genus *Subtriquetra* (Heymons 1935; Fain 1961; Riley 1994; Riley, Hill & Huchzermeyer 1997). To date, three species of *Subtriquetra* are known, namely *S. subtriquetra*, *Subtriquetra megacephala* and *Subtriquetra shipley*. In this article, we describe the infective larvae of a fourth species, which we believe to be endemic to Africa, and for which we propose the name *Subtriquetra rileyi* n. sp.

Little is known about the distribution of pentastome infections in freshwater fish in Africa. The existing data mainly refer to Central Africa and are mostly restricted to the naming of those fish that act as intermediate hosts for *Leiperia cincinnalis* Sambon, 1922 (Fain 1961).

This paper presents some of the results of a postgraduate study on pentastomes in South Africa (Junker 1996). As part of the study two cichlid species, Mozambique bream, *Oreochromis mossambicus* Peters, 1852 and red-breasted bream, *Tilapia rendalli swierstrai* Boulanger, 1896, were examined for the prevalence and intensity of pentastome infections. The aim was to assess the suitability of *O. mossambicus* and *T. rendalli* as intermediate hosts and to determine their pentastome fauna, as well as to investigate the biology of pentastomes in their intermediate hosts.

The fishes were chosen because they are common and widespread in the Kruger National Park (KNP) and occur in all the rivers in which Nile crocodiles, *Crocodylus niloticus*, are found. *O. mossambicus* inhabits the east coastal rivers of the lower Zambesi system down to the Bushman System in the Eastern Cape Region and is widespread in rivers of the Northern Province and KwaZulu-Natal. *O. mossambicus* prefers standing waters and does not occur in fast-flowing rivers. It is a mouth-breeder and due to a high tolerance of changes in salinity and temperatures can breed in saline as well as in fresh water. The diet of *O. mossambicus* consists mainly of algae, diatoms and detritus but insects and small invertebrates are readily taken by large individuals. *O. mossambicus* is an important species in aquaculture as well as in commercial and subsistence fisheries (Skelton 1993).

T. rendalli is present in the Cunene, Okavango and Zambesi Systems and is also found in Mozambique and Zaire. In South Africa, it occurs in the Lowveld of Mpumalanga and the Northern Province, and in KwaZulu-Natal. Like *O. mossambicus*, *T. rendalli* is euryhaline and eurythermic. Its preferred habitat is quiet, well-vegetated water along river littorals, backwaters, floodplains and swamps where it feeds mainly on water plants, algae and aquatic invertebrates and even small fish. *T. rendalli* is valued in aquaculture and fisheries, and as angling species (Skelton 1993).

MATERIALS AND METHODS

O. mossambicus (n = 119) and *T. rendalli* (n = 185) were caught with baited hand-lines in the Phabeni Dam in the KNP on two occasions during February 1995.

Fish were weighed to the nearest gram and the total length measured from the tip of the snout to the most distal tip of the caudal fin (Skelton 1993). After opening the fish by ventral incision, the surface of the viscera and tissues surrounding the gastro-intestinal tract were examined macroscopically for the presence of pentastome larvae. The swim bladders were removed and placed in separate vials in phosphate buffered saline (PBS). Within 4 h of collection, the swim bladders were examined under a stereoscopic microscope between two perspex slides while applying gentle pressure. Pentastomes were removed from the respective tissues by blunt dissection.

All pentastomes were transferred into PBS and either used for experimental infections or fixed in cold 70% ethanol and mounted in Hoyer's medium for identification. Measurements were taken from whole mounted specimens according to the methods described by Riley, Spratt & Winch (1990) (Fig. 1B, C).

Measurements of the oral cadre of four specimens of *S. rileyi*, in which this structure was slightly laterally orientated, correlated well with those taken from two oral cadres in frontal view. Annuli were counted either by including those annuli that were bordered anteriorly and posteriorly by a complete row of spines (Winch & Riley 1986b), or by counting the total number of annuli, including incomplete ones.

Prevalence and intensity (*sensu* Margolis, Esch, Holmes, Kuris & Schad 1982) of pentastome infections in the fish were determined and the condition factor (C) of the fish was calculated using the formula:

$$C = 100\ [\text{body mass (g)}] \div \text{total length (cm)}$$

In order to evaluate the impact of infection on the hosts, the independent, bilateral U-Test of Wilcoxon, Mann and Whitney was used to compare the body-mass, total length and condition factor of infected *T. rendalli* to those of uninfected ones. No biometrics were done with data of *O. mossambicus*, as we con-

sidered the number of infected fish ($n = 11$) to be too low to give reliable results.

RESULTS

The overall prevalence of pentastome infections in *T. rendalli* was 40,5% and 9,2% in *O. mossambicus*; both families of pentastomes were collected from both cichlid species.

All sebekiid larvae, with the exception of two nymphs of *L. cincinnalis*, were assigned to *Sebekia wedli* Giglioli, 1922, the identification of which was confirmed by experimental infection of final hosts (Junker 1996).

The larvae of *S. wedli* (Table 1) possess double hooks and the posterior half of each annulus carries a row of spines. The first 2–3 rows of spines are incomplete. Chloride cells are arranged in a line along the anterior edge of each annulus. The bud-shaped oral cadre is open anteriorly but fibrous material between the two prongs may make it to appear closed. Annulus counts vary from 71–79.

The main measurements of the encysted larvae of *L. cincinnalis* taken from the mesentery of *O. mossambicus* and *T. rendalli* are listed in Table 2. Their elongated, slender appearance, together with a distinctly rounded head and large double hooks, clearly distinguishes the larvae of *L. cincinnalis* from other sebekiid larvae. Chloride cells are distributed over the entire width of each annulus. Annuli are equipped with a row of minute spines on the posterior border. The heavily chitinized oral cadre resembles that of the genus *Alofia*: it is U-shaped with a peg-like extension into the oesophagus. The oral cadre appears very small. The hooks are double; the spike is slender and only slightly curved while the hook itself is robust and strongly curved.

The prevalence and intensity of larval *Sebekia* and *Subtriquetra* in *T. rendalli* and *O. mossambicus* are presented in Table 3. While *T. rendalli* was predominantly parasitized by *S. wedli* and only a few fish were

TABLE 1 The main characteristics of infective larvae of *Sebekia wedli* recovered from *Oreochromis mossambicus* and *Tilapia rendalli* out of the Phabeni Dam, Kruger National Park. All measurements in micrometres unless otherwise indicated

Specimen number	Number of annuli	Body length (mm)	Body width (mm)	Mouth dimensions			Hook length	Fulcrum length
				Overall length	Cadre length	Cadre width		
LM2	76,0	5,3	0,7	188,6	116,4	65,6	78,7	171,4
LM3	75,0	6,0	0,6	170,6	105,0	62,3	74,9	170,6
LM4	74,0	5,4	0,6	155,8	100,0	65,6	*n*	159,1
LM5	75,0	5,4	0,5	160,7	108,2	67,2	68,9	150,1
LM6	72,0	4,4	0,6	141,0	100,0	64,0	74,2	154,2
LM7	72,0	3,9	0,6	154,2	103,3	54,1	75,4	134,5
LM8	71,0	4,7	0,5	137,8	93,5	55,8	76,5	163,2
LM9	79,0	*n*	0,7	200,1	131,2	70,5	76,7	182,9
LM10	76,0	5,0	0,7	182,0	126,3	62,3	84,5	171,8
LM11	75,0	*n*	0,7	185,3	113,2	64,0	74,9	177,1
LM13	76,0	4,8	0,7	180,4	113,2	64,0	90,2	188,2
Mean	74,6	5,0	0,6	168,8	110,0	63,2	77,5	165,7
(SD)	(2,3)	(0,6)	(0,1)	(20,3)	(11,5)	(4,7)	(5,9)	(15,6)

n = not measured

TABLE 2 The main characteristics of infective larvae of *Leiperia cincinnalis* recovered from *Oreochromis mossambicus* (LM20) and *Tilapia rendalli* (LM19) out of the Phabeni Dam, Kruger National Park. All measurements in micrometres unless otherwise indicated

Specimen number	Number of annuli	Body length (mm)	Body width (mm)	Mouth dimensions			Hook length	Fulcrum length
				Overall length	Cadre length	Cadre width		
LM19	100	22,4	1	377,2	280,6	119,6	242,7	545,1
LM20	*n*	27,0	1	405,6	314,6	132,6	286,7	567,0

n = not measured

infected with *S. rileyi*, this ratio was reversed in *O. mossambicus*.

The intensity of infection in the fish examined was low. Of the 75 infected *T. rendalli*, 47 (63 %) harboured single sebekiid larvae and 20 (27 %) had two. The remaining eight of the fish had more than two larvae in the swim bladder, a single one harbouring eight. A total of 132 *S. wedli* larvae were recovered from the 75 infected fish. The four *T. rendalli* infected with *S. rileyi* each contained one larva.

Similar results were obtained for *O. mossambicus*. The three fish infected with *S. wedli* had one, two and eight larvae, respectively. All but one of those that were infected with *S. rileyi* had single larvae.

All sebekiid larvae, except for those of *L. cincinnalis*, which was encysted on the mesentery of both fish species, had invaded the swim bladder. Within *T. rendalli*, 77% of these larvae were encysted, whereas only 23% occurred free. Approximately the same ratio was found in *O. mossambicus* (64% and 36%, respectively). All larvae of *S. rileyi* were freely mobile in the swim bladders of both intermediate hosts.

The comparison of infected *T. rendalli* (n = 75) to uninfected fish (n = 110) showed that infected fish were significantly (P = 0,05) shorter and lighter than uninfected ones (63 g and 14 cm vs. 76 g and 15 cm). The condition factor, however, did not differ significantly between the two groups (45 and 51, respectively). No pathological examination was done on infected fishes but neither obvious lesions nor any signs of stress caused by the developing pentastomes were detected.

Description of *Subtriquetra rileyi* n. sp. (Table 4)

TYPE HOSTS AND LOCALITY

Oreochromis mossambicus and *Tilapia rendalli* from the Phabeni Dam (25°1′S, 31°15′0

.E), Kruger National Park, South Africa.

TYPE MATERIAL

Six syntype specimens, all mounted in Hoyer's medium, deposited in the collection of the British Museum (Natural History), No. BMNH 1998.71.1–6.

TABLE 3 Prevalence and intensity of *Sebekia wedli* and *Subtriquetra rileyi* n. sp. in *Tilapia rendalli* and *Oreochromis mossambicus* from the Phabeni Dam, Kruger National Park

Host	*Tilapia rendalli* (n = 185)				*Oreochromis mossambicus* (n = 119)			
Parasite	No. positive	Prevalence	Intensity		No. positive	Prevalence	Intensity	
		%	Mean	Range		%	Mean	Range
Sebekia wedli	75	40,5	1,8	1–8	3	2,5	3,7	1–8
Subtriquetra rileyi	4	2,2	1,0	1	9	7,5	1,1	1–2

TABLE 4 Main characteristics of the infective larvae of *Subtriquetra rileyi* n. sp. out of *T. rendalli* and *O. mossambicus* from the Phabeni Dam, Kruger National Park. All measurements in micrometres unless otherwise indicated

Specimen number	Number of annuli	Body length (mm)	Body width (mm)	Mouth dimensions			Hook length		Base length		Fulcrum length	
				Cadre	Overall	Width	Anterior	Posterior	Anterior	Posterior	Anterior	Posterior
3#6	28 (33)	2,7	0,8	193	221	–	–	329*	–	182*	–	–
4#6	28 (32)	2,9	1,0	209	246	76	317	336*	170	170*	–	–
5#6	28 (34)	3,4	0,9	207	242	78	362	362	189	192	–	–
6#6	28 (33)	3,0	1,1	196	230	74	324*	317*	175*	179*	557	511*
1#6	30 (36)	4,0	1,3	212	242	[106]	337	331	188	178	[616]	531
2#6	30 (35)	3,1	0,9	207	242	–	366*	–	179*	–	–	–
Mean	28,6	3,2	1,0	204	237	76	341	335	180	180	557	521
(SD)	(0,9)	(0,5)	(0,2)	(7,6)	(9,6)	(2,0)	(22,1)	(16,6)	(8,2)	(7,9)	–	(14,1)

Mouth dimensions of specimens 1#6 and 2#6 were taken from frontal view, the oral cadres of the remaining specimens were positioned slightly laterally

* Only a single feature measured
[ ] Data not included in mean and SD
( ) Total number of rows of spines, including incomplete ones

ETYMOLOGY

The species is named after Dr John Riley, University of Dundee, United Kingdom, in recognition of his extensive contribution to the knowledge of the pentastome parasites.

DESCRIPTION

The living infective larvae of the new species could be easily distinguished from the sebekiids by their bright red colour. The body is elliptical (Fig. 1A), ventrally flattened and dorsally convex. The dorsal vault is more pronounced anteriorly, reaching its maximum shortly before the cephalothorax and quickly sloping to a flattened anterior border. The margins of the body remain flat.

The anterior and posterior hooks are simple, slender and sharply pointed (Fig. 1B; 2A, B). The anterior hooks are slightly longer than the posterior ones. Their fulcra extend far into the cephalothorax and their surface appears finely granular (Fig. 1A; 2B). The hooks form a curved line in the centre of which lies the oval oral opening (Fig. 2A). The latter is supported by a heavily chitinized oral cadre (Fig. 1C), which is closed anteriorly. Deep longitudinal grooves mark the surface of the anterior prongs. In lateral view, the oral cadre has the shape of half a walnut shell. The almost parallel anterior prongs curve dorso-ventrally in such a way that the posterior and anterior ends point ventrally. The mouth is superficial.

The abdomen carries conspicuous rows of sharply pointed, projecting spines (Fig. 2A–C) but on the first two or three annuli, these are incomplete. The spines emerge in the mid-annular region. The total length of the spines is 52,6 µm, 37,2 µm of which are embedded in the cuticle, while 15,4 µm are free. Chloride cells are disposed in a single row in the anterior half of each annulus (Fig. 2D).

DISCUSSION

Little is known about the intermediate hosts of the pentastome parasites of crocodiles. In this study, *L. cincinnalis* was recovered from *O. mossambicus* and *T. rendalli*. Thus, both cichlid species must be added to the list of intermediate hosts of *L. cincinnalis* as given by Fain (1961).

The measurements of the infective larvae of *L. cincinnalis* from *O. mossambicus* and *T. rendalli* fit in well with the data provided for three double-hooked nymphs from *Pelamatochromis robustus* (Riley & Huchzermeyer 1996). At the same time they reflect some of the intraspecific variation of all the morphogical characteristics emphasized by the latter authors. The infective larvae we recovered from the fishes were only slightly smaller than those found in the aorta of *C. niloticus* (Junker 1996).

Adult *S. wedli* were mentioned by Wedl as early as 1861, establishing the Nile crocodile as its final host (Sambon 1922) but nothing is recorded as regards its intermediate hosts. *O. mossambicus* and *T. rendalli* are therefore the first intermediate host records for this parasite.

Annulus counts as well as hook- and mouth dimensions were used to distinguish *S. wedli* from the infective larvae of other sebekiids. The presence of double hooks and the annular rows of spines indicated that the larvae we recovered had reached the infective stage (Riley 1986; Winch & Riley 1986a). The identification of the larvae as *S. wedli* was later confirmed by experimentally infecting final hosts with encysted larvae recovered from *O. mossambicus* and *T. rendalli* (Junker 1996).

Both cichlid species are preyed upon by *C. niloticus* (Branch 1994). Both fish species are bottom feeders and therefore readily exposed to the pentastomes while feeding on detritus or water plants. The eggs of *S. wedli* containing the infective stages must be ingested, while the free-living primary larvae of *Subtriquetra* hook onto the fish and penetrate the skin (Vargas 1975; Winch & Riley 1986b). The prevalence of infection with *S. wedli* is markedly higher in *T. rendalli* than in *O. mossambicus* (40,5% and 9,2%, respectively). The opposite was true of *S. rileyi*.

From a physiological standpoint, both fish species are suitable intermediate hosts. It appears that behavioural differences, especially feeding behaviour, accounts for the higher intensity of *S. wedli* in *T. rendalli* and the higher intensity of *S. rileyi* in *O. mossambicus*. However, Winch & Riley (1986b) found *Tilapia zilli*, to be an unsuitable host for the development of *S. subtriquetra* and the primary larvae were all killed around the time of the first moult.

Nothing has yet been published on the prevalence of crocodile pentastomes in fish intermediate hosts in Africa. Low levels of infection have been reported for several intermediate hosts of *S. oxycephala*, a species present in South American crocodilians, by Winch & Riley 1986a who found one infective larva in each of four *Aequidens pulcher* and one *Tilapia* sp.. Boyce, Cardeilhac, Lane, Buergelt & King (1984) recorded a prevalence of 60% and a mean intensity of 9,1 *S. oxycephala* in mosquito fish, *Gambusia affinis*. Both the prevalence and the intensity of *S. oxycephala* in mosquito fish is considerably higher than that of *S. wedli* in *T. rendalli* and *O. mossambicus*. High pentastome burdens appear to be rare.

The infective larvae recovered from the fish show a high degree of site selection. *S. rileyi* was found exclusively in the swim bladder, which conforms to the

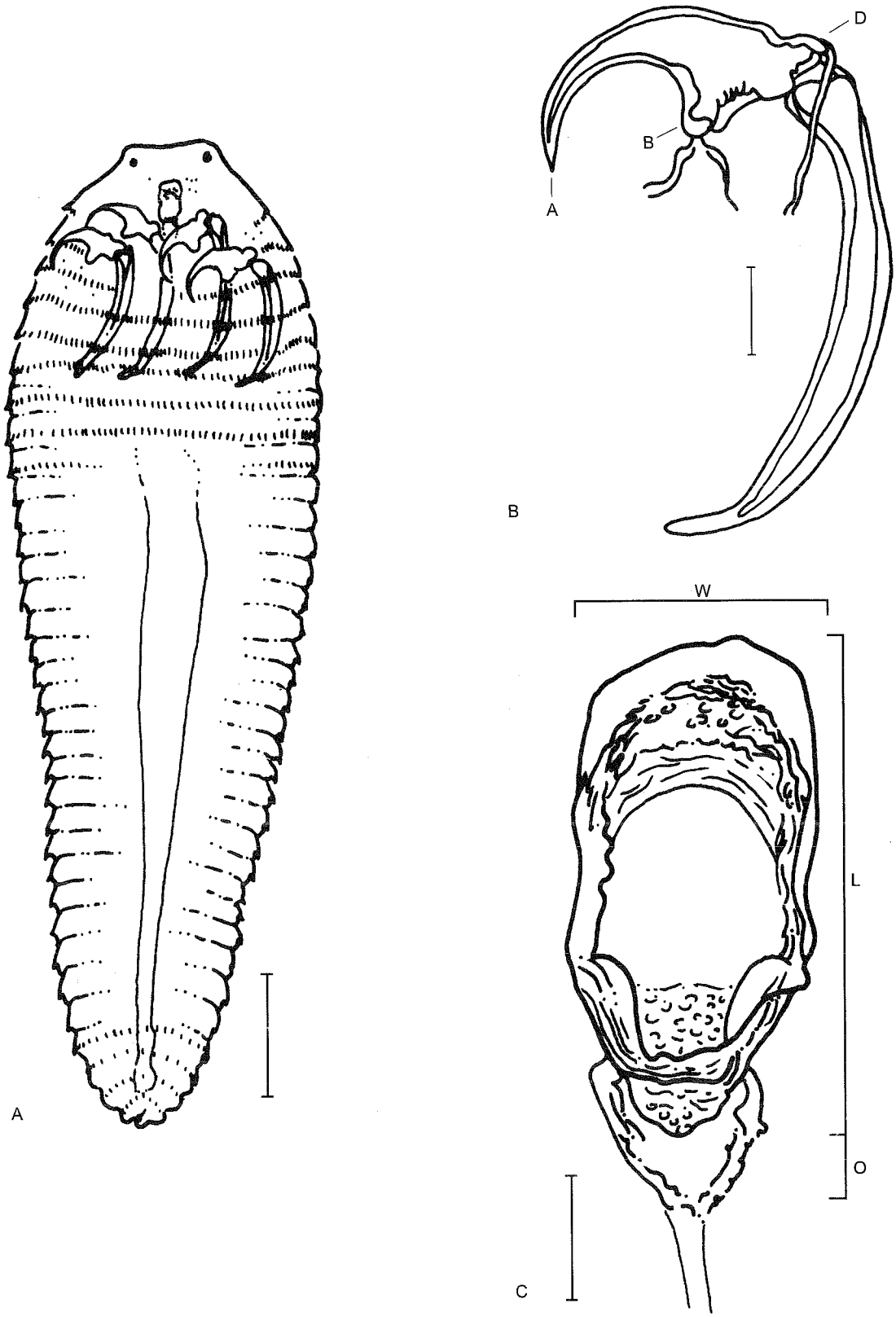

FIG. 1 A. Infective larva of *Subtriquetra rileyi* n. sp. Scale bar: 500 µm. B. Left posterior hook; length (AD) and base length (BD). Scale bar: 100 µm. C. Oral cadre. Cadre length (L), overall length (L + O) and width (W) as illustrated. Scale bar: 50 µm

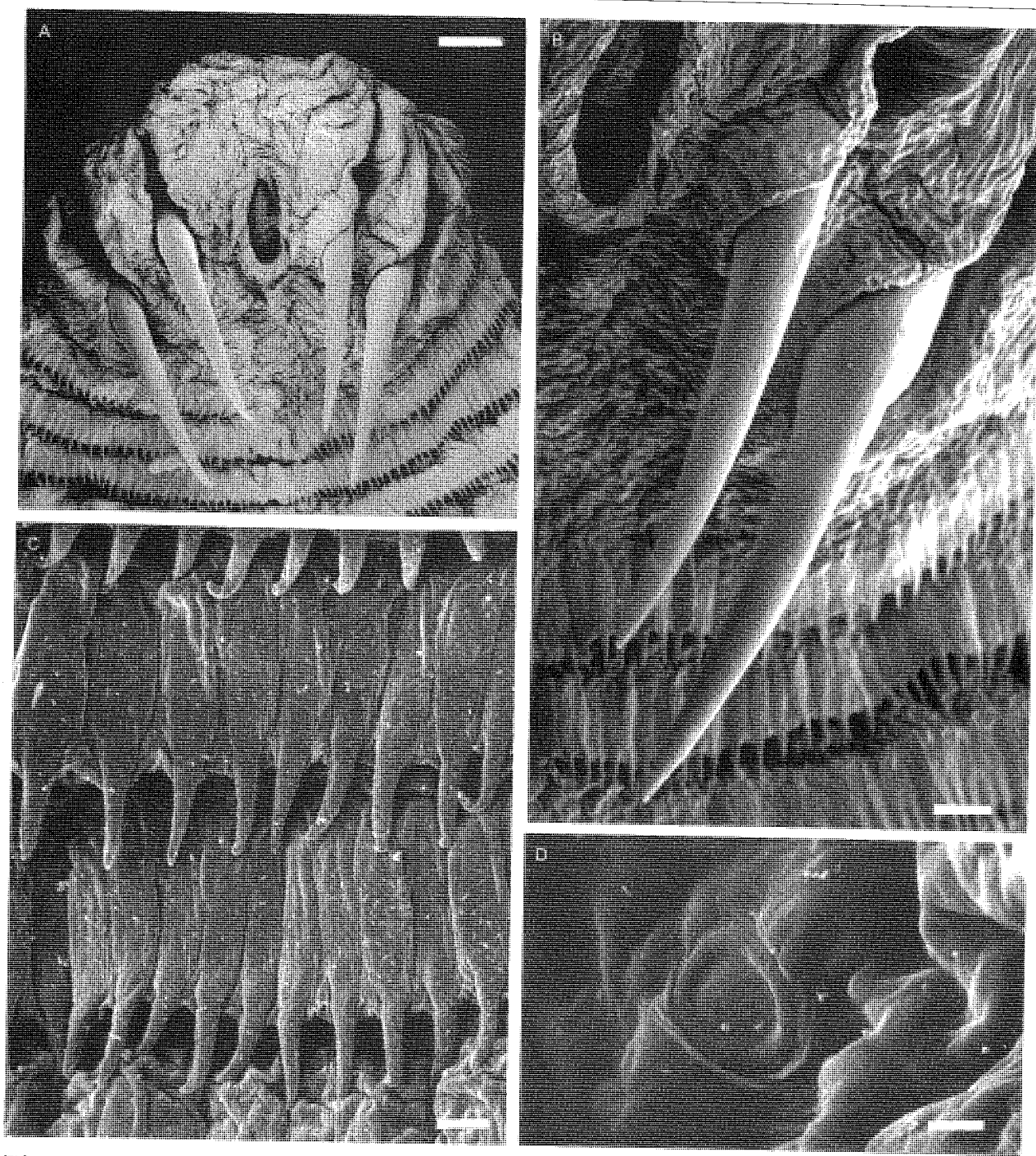

FIG. 2 A. Scanning electron micrograph of an infective larva of *Subtriquetra rileyi* n. sp. showing the oral cadre situated between the two pairs of single hooks and the rows of spines covering the annuli. Scale bar: 60 µm. B. Detail of the left hook pair. The surfaces of the hooks appear finely granular. Scale bar: 20 µm. C. Detail of the prominent annular spines. Scale bar: 9 µm. D. Detail of a chloride cell. Scale bar: 10 µm

findings of Vargas (1975) and Winch & Riley (1986b). The available information for *Sebekia* spp. indicates that larvae occur at a variety of sites, such as muscle, kidney, liver, mesentery, swim bladder or free in the abdominal cavity (Overstreet, Self & Vliet 1985; Boyce, Kazacos, Kazacos & Engelhardt 1987; Riley 1986). Infective larvae of *S. wedli* were typically encountered in the swim bladder, where they encyst without causing any apparent damage to the host tissue. The ratio of free-living to encysted *S. wedli* larvae in *T. rendalli* and *O. mossambicus* is similar to that found for *S. oxycephala* in experimentally

infected fish (Winch & Riley 1986a). These authors report that 80% of the infective larvae of *S. oxycephala* were contained in a cyst of host origin in the swim bladder of experimentally infected fish. The fact that only the last larval stage is encysted is considered typical for the genus *Sebekia* in fish (Winch & Riley 1986a).

Infected *T. rendalli* examined in this study were found to be significantly shorter and lighter than uninfected *Tilapia*. A possible explanation could be a negative effect of the pentastomes on the development of their intermediate hosts, slowing the growth rate of infected fish. Once ingested, the hatched primary larvae penetrate the intestinal wall and start migrating within the host (Esslinger 1962a,b; Self 1969; Winch & Riley 1986a). This, and the activity of subsequent developmental stages, could quite easily cause extensive damage to host tissues affecting their normal function (Boyce 1985; Boyce & Kazacos 1991). However, comparison of the conditional factors of the two fish species in this study gave no indication of retarded development in infected fish. This suggests the possibility that shorter body-length and lower mass are not a result of but rather the cause for the infection. If the susceptibility to pentastome infections varied in different age groups, juvenile fish would be more likely to become infected. Different behaviour and feeding habits of the fish, as well as the behaviour of the primary larva of *Subtriquetra* could account for this. The eggs of *S. wedli* need to be swallowed, whereas primary larvae of *Subtriquetra* only need to make contact with the skin. Young *T. rendalli* mainly feed on detritus (Skelton 1993), prefer quiet, well-vegetated areas and often remain in such areas for extended periods of time (Boomker 1980, personal observation). The young of *O. mossambicus* are more mobile and could have a better chance to come into contact with larger numbers of the primary larvae of *S. rileyi*.

Sebekia mississippiensis causes extensive damage in swordfish, *Xiphophorus helleri*, whereas only a mild inflammatory response was elicited in mosquito fish (Boyce *et al.* 1987). *S. subtriquetra* was highly pathogenic in small fish, but bigger fish were able to tolerate up to seven infective larvae (Winch & Riley 1986b). These findings emphasize that the pathology of pentastomid infections depends on several factors, such as intensity of infection, the size ratio of the host and parasite as well as previous infections (Self 1972). No macroscopically visible pathological lesions were evident in any of the fish examined in this study. When the size of the fish is compared to the size of the pentastomes, and considering the low intensity of infection, it seems feasible that the developing pentastome larvae do not seriously affect their hosts.

The conspicuous red coloration of *Subtriquetra* spp., which results from haemoglobin in the haemocoel, is considered a characteristic of this genus (Riley 1986). Studies on the larval development of *S. subtriquetra* conducted by Winch & Riley (1986b) show that the outer segmentation only becomes prominent in the last three larval stages and that only the last two larval stages carry simple hooks. Based on those findings, we conclude that our larvae actually represent the infective stage, since the annuli were well developed and the hooks simple. The conformity of the measurements also gave no indication of the presence of different developmental stages.

The comparison of the morphological characteristics of the proposed new species and infective larvae of *S. subtriquetra* (Winch & Riley 1986b) suggests that they belong to two different species (Table 3). This is even more likely since the findings indicate that the South American and African sebekiid pentastomes differ distinctly (Winch & Riley 1986b). The infective larvae of *S. rileyi* are bigger than those of *S. subtriquetra*, the body is longer (3,2 mm vs. 2,5 mm) as are the hooks and fulcra (338 ± 18,7 and 533 ± 23,1 µm vs. 232,8 ± 3 µm and 359,2 ± 3,5 µm, respectively), and the oral cadre length (204 µm vs. 163,3 µm).

There are no detailed descriptions of larval forms of the two other known species of *Subtriquetra*. Shipley (1898) re-examined an adult female of *S. megacephala* from *Crocodylus palustris* from India that had been described by Baird (1853) as *Porocephalus megacephalus* (synonym *Pentastoma megacephalum*). He counted from 40 to 50 annuli (Shipley 1898) and an illustration of the same specimen (Sambon 1922) shows 43 annuli before becoming diffuse in the anterior part of the drawing. Several pentastomids, including *S. subtriquetra*, attain the final number of annuli during the infective larval stage (Esslinger 1962a; Sachs, Rack & Woodford 1973; Riley, Spratt & Presidente 1985; Winch & Riley 1986a, b). In view of the difference between the number of annuli in *S. rileyi* and *S. megacephala* this criterion alone can discriminate between the two species.

The infective larvae isolated from cichlids in the KNP carry large hooks, whereas the hooks of adult *S. shipleyi* were described as relatively small and smaller than those of *S. subtriquetra* but measurements were not provided (Hett 1924).

To date there have been no reports of a *Subtriquetra* sp. from Africa and the presence of infective larvae of *Subtriquetra* in the two cichlid species indicates that *C. niloticus* may be a suitable final host. However, we did not find adult specimens in two crocodiles we examined (Junker 1996).

Comparison between adult pentastomes and infective larvae must be done with circumspection and we conclude that the genus *Subtriquetra* is represented on the African continent by a distinctive species.

ACKNOWLEDGEMENTS

We are indebted to the Board of Trustees, South African National Parks for placing the animals at our disposal, to Dr L.E.O. Braack for his help with organization and logistics and to Dr John Riley, University of Dundee, Scotland for his sustained interest and help with this project. Our special thanks to Miss Chantelle Baker for doing the scanning electron microscopy on the specimens.

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CHAPTER 2

Population dynamics

of

helminths of freshwater fishes

Introduction

The results of helminth surveys of fishes from the Hartbeespoort Dam, and several rivers in the KNP are reported in this chapter. This is exclusively my work and gives some insight into the non-seasonal distribution of helminth parasites in fishes. Most of the helminths make use of an intermediate host, and the seasonality is therefore not apparent, because of several generations of helminths developing at the same time in the same host. In addition, the prevalence of a parasite in a fish host is merely an indication of the abundance of the intermediate host.

The publications are listed in chronological order.

BOOMKER, J., 1982. Parasites of South African freshwater fish. I. Some nematodes of the catfish (*Clarias gariepinus* Burchell, 1822)) from the Hartbeespoort dam. *Onderstepoort Journal of Veterinary Research*, 49, 41 - 51.

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Onderstepoort J. vet. Res., 49, 41–51 (1982)

PARASITES OF SOUTH AFRICAN FRESHWATER FISH. I. SOME NEMATODES OF THE CATFISH [*CLARIAS GARIEPINUS* (BURCHELL, 1822)] FROM THE HARTBEESPOORT DAM

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ABSTRACT

BOOMKER, J., 1982. Parasites of South African freshwater fish. I. Some nematodes of the catfish [*Clarias gariepinus* (Burchell, 1822)] from the Hartbeespoort Dam. *Onderstepoort Journal of Veterinary Research*, 49, 41–51 (1982).

A seasonal study of the parasites of fish in the Hartbeespoort Dam was undertaken in 1979. This paper deals with 4 nematode species recovered from catfish, namely, *Paracamallanus cyathopharynx* (Baylis, 1923), *Procamallanus laeviconchus* (Wedl, 1862), *Contracaecum* sp. and *Skrjabinocara* sp. Total numbers of parasites recovered are tabulated and their seasonal variation illustrated diagrammatically. *Paracamallanus cyathopharynx* was recovered from 23 out of 43 catfish examined and *Procamallanus laeviconchus* from 13, while *Contracaecum* sp. larvae were present in all the catfish. *Skrjabinocara* sp. was recovered from 1 catfish only, but it is not regarded as being parasitic in fish, as it was also recovered from 1 out of 4 cormorant examined. *Paracamallanus cyathopharynx* and *Procamallanus laeviconchus* are illustrated and the measurements of the Hartbeespoort Dam material compared with those given by various authors who recovered the same parasites from other fish species elsewhere in Africa.

INTRODUCTION

Although the parasites of freshwater fish in Africa have already received considerable attention (Khalil, 1969, 1971), those of South African freshwater fish have not been studied in any great detail. Khalil (1971) lists *Contracaecum* sp. larvae as the only nematodes occurring in catfish. Ortlepp (1935), Price, McClellan, Druckenmiller & Jacobs (1969) and Lombard (1968) mention some parasites they found in fish, and Prudhoe & Hussey (1977) list a few species of parasites found in fish in the Transvaal, South Africa. Mashego (1977) recorded *Paracamallanus cyathopharynx* (Baylis, 1923), *Procamallanus Laeviconchus* (Wedl, 1862) and *Contracaecum* sp. larvae in catfish in Lebowa, South Africa, for the first time.

This paper deals with some nematodes found in catfish from the Hartbeespoort Dam, as well as their seasonal variation during 1979.

MATERIALS AND METHODS

The site

All the catfish utilized in this study were collected from the Hartbeespoort Dam, which is situated about 40 km to the west of Pretoria, Transvaal (S25°43′, E27°51′). The dam is 1167 m above sea level and has a total surface area of 2 000 ha when full (Dept. of Water Affairs, 1964, cited by Steijn, Toerien & Visser, 1975). The dam is highly eutrophic (Steijn *et al.*, 1975), nitrogen and phosphorus entering the dam mostly through the Crocodile River (Fig. 1).

Fish were collected from areas which, by a number of trial nettings, they were known to frequent (Fig. 1). Site No. 2 yielded most of the catfish, but some were also caught at sites Nos. 1 and 3.

Collection of fish

Usually fish were caught with seine nets, except in those cases when the quota could not be met. In such cases additional fish were caught with handlines.

An attempt was made to collect 5 specimens on each collecting trip over 13 consecutive months. During the coldest months, June and July, however, no fish were caught, because they moved to water that was too deep to be netted, and attempts to catch them with handlines also failed.

Received 9 November 1981—Editor

Collection of parasites

Immediately after being landed, fish were examined macroscopically for ectoparasites. All visible parasites were then collected in 70% ethyl alcohol and their sites of attachment noted.

Large fish were transported alive to the laboratory, where they were killed and smears were taken from the blood, gills and body. The fish were then scrubbed with a bristle brush under running water, and the washings sieved onto a sieve with apertures of 150 μm. The residue was collected and preserved in 10% formalin.

Small fish were killed at the collection sites and, after smears of the blood, gills and body were taken, they were placed individually in 50% ethyl alcohol. At the laboratory they were transferred to another container, scrubbed with water, and this water, together with the 50% alcohol in which they were transported, was sieved. The residue was preserved in 10% formalin.

The fish were opened ventrally with scissors, and the entire digestive tract, together with the liver and spleen, was removed. After the mesenterium, liver and spleen had been removed, the stomach and intestines were opened separately and thoroughly washed in normal saline. The washings were heated to 60 °C in a waterbath, after which they were sieved (38 μm aperture) and the residue fixed in 10% formalin.

The mucosae of the stomach and intestines of the large fish were removed by scraping with a knife or a glass slide and digested as described by Reinecke (1973).

In the case of small fish, or those with thin-walled stomachs and intestines, the entire organs were digested in pepsin and HCl (Reinecke, 1973).

As large numbers of *Contracaecum* larvae were found in all the catfish, the entire mesenterium was digested for ½–1 hour at room temperature. This resulted in the liberation of live larvae, which were then fixed in boiling alcohol-glycerine (approximately 60 °C) and preserved in alcohol-glycerine.

Blood smears were made according to standard techniques (Wintrobe, 1947). Gill smears were made by scraping the surface of the gills and smearing the resulting epithelium onto pre-cleaned glass slides. Body smears were made in the same way. Impression smears of the spleen and kidney were made according to the technique described by Ashley & Smith (1964). The various smears were fixed and stained, as described in an earlier paper (Boomker, 1980).

The livers of all the fish were examined macroscopically for parasites and thereafter cut into 0,5 cm cubes. These were kept in normal saline at 40 °C for 1–2 hours, after which the tissue was thoroughly washed and discarded. The saline and washings were sieved through a sieve with 38 μm apertures and the residue preserved in 10% formalin.

In addition to the above procedures, the gills, swim bladders, abdominal cavities and reproductive organs were examined macroscopically and then washed. The washings were sieved through a sieve with 38 μm apertures and fixed in 10% formalin.

Where organs showed distinct pathological lesions, tissue blocks were collected in 10% neutral buffered formalin for histological examination.

The various collections and residues were examined in a counting chamber with the aid of a stereoscopic microscope. Total counts were made, except in the case of very large fish or large volumes, when 1/10 aliquots were prepared and counted. In all cases, total counts of the *Contracaecum* larvae were done.

To determine the monthly incidence, the mean number of a parasite species was calculated by dividing the total number of that parasite collected during a month by the number of hosts caught during the same month.

Additional nematodes of the genera *Paracamallanus* and *Procamallanus* from Looss' collection from Egypt and Mashego's collection from Lebowa were loaned from the British Museum (Natural History) and compared with the Hartbeespoort Dam material.

For identification purposes, nematodes were cleared and examined in lactophenol. Drawings were made with the aid of a Nikon Optiphot microscope with Nomarski differential interference contrast illumination and a Sankei drawing tube.

RESULTS

Only 4 species of nematodes were recovered from the 43 catfish examined. They were *Paracamallanus cyathopharynx* (Baylis, 1923) and *Procamallanus laeviconchus* (Wedl, 1862) (Camallamidae), *Contracaecum* sp. larvae (Anisakidae) and *Skrjabinocara* sp. (Acuariidae). Of the last-named genus, only 1 female and 3 larvae were recovered.

The numbers of parasites recovered from each catfish are given in Table 1, and in Fig. 2–5 variation in their prevalence is graphically illustrated.

Paracamallanus cyathopharynx was found in the intestines, especially near the rectum of 53,5% (23) of the fish examined. *Procamallanus laeviconchus* occurred in the stomachs of only 30,2% (13) of the catfish while *Contracaecum* sp. larvae were found in the mesenterium of 100%. Some *Contracaecum* sp. larvae were also recovered from the stomach mucosa. *Skrjabinocara* sp. was found in the stomach of 1 catfish only.

The configuration of the buccal capsule and pharynx of *Paracamallanus cyathopharynx* (Fig. 6 & 7) sets it apart from other nematodes of fish. The spicules and tail of the male of the Hartbeespoort Dam material are illustrated in Fig. 8–10, and the female tail and vulvar region in Fig. 11 & 12, while the morphology of *Procamallanus laeviconchus* of catfish from the Hartbeespoort Dam is illustrated in Fig. 13–18. The 4th larval moults of both species are illustrated in Fig. 19–21.

Mashego (1977), who was the first to record *Paracamallanus cyathopharynx* and *Procamallanus laeviconchus* from catfish in South Africa, does not provide any measurements of the nematodes he collected. In Table 2 the measurements of 7 male and 8 female *Paracamallanus cyathopharynx* from the Hartbeespoort Dam catfish are compared with those of specimens identified by Baylis (1 male, 1 female ex coll. Looss, on loan from British Museum), as well as with measurements given by Baylis (1923) for material from *Clarias anguillaris* from Egypt, and that given by Moravec (1974) from material from *Clarias lazera* and *C. anguillaris*, also from Egypt.

The principal measurements of 6 male and 5 female *Procamallanus laeviconchus* of the Hartbeespoort Dam material are compared with those given by Baylis (1923) in Table 3, as well as those of 2 females from *Bagrus bayad* which Baylis identified as *Procamallanus laeviconchus*.

DISCUSSION

Yorke & Maplestone (1926) created the genus *Paracamallanus* for nematodes found in the clariid fish *Clarias anguillaris* (syn. *Heterobranchus anguillaris*) from Egypt. These nematodes were originally described as *Camallanus cyathopharynx* by Baylis (1923). Since then the parasites have been recorded from a number of clariid fishes from various countries (Vassiliades, 1970; Khalil, 1971; Moravec, 1974; Mashego, 1977).

Moravec (1974) redescribed *Paracamallanus cyathopharynx* and suggested that *Camallanus longitridentatus* Fernando & Furtado, 1963 from *Clarias batrachus* be transferred to the genus *Paracamallanus*. He also regarded *Paracamallanus senegalensis* Vassiliades, 1970 from *Clarias senegalensis* as synonymous with *Paracamallanus cyathopharynx* (Moravec, 1974).

The data in Table 2 indicate that the Hartbeespoort Dam material is considerably larger than the material from Looss' collection. However, the measurements given by Baylis (1923) and Moravec (1974) correspond well with those of the Hartbeespoort Dam material. From Table 2 it is also apparent that there is a considerable variation in the size of this nematode, a fact which could be attributed to the influence of the host in which it occurs.

Procamallanus laeviconchus (Wedl, 1862) was originally recorded from *Synodontis schaal* from Egypt and described as *Cucullanus laeviconchus* Wedl, 1862, but was subsequently transferred to the genus *Camallanus* (Railliet & Henry, 1915). Baylis (1923) compared material from *Bagrus bayad* from Egypt with that of Wedl (1862) and erected a new genus, *Procamallanus*, to which he assigned his own material as well as *Cucullanus laeviconchus* Wedl, 1862.

Moravec (1975) stated that *Procamallanus laeviconchus* is one of the most prevalent nematodes of fish, and that it has been recorded from fish belonging to the families Clariidae, Mormyridae, Characidae, Siluriidae, Tetraodontidae and Cichlidae. Until 1971, *Procamallanus brevis* (Kung, 1948) and *Procamallanus slomei* (Southwell & Kirschner, 1937) were the only species recorded in South Africa, and both occur in frogs (Ivashkin, Sobolev & Khromova, 1971). Mashego (1977) recorded *Procamallanus laeviconchus* from the catfish, *C. gariepinus* from Lebowa, South Africa, for the first time.

The *Procamallanus* sp. recovered from the Hartbeespoort Dam catfish resembles *Procamallanus laeviconchus* but differs from it in that only 1 spicule could be found, and that there is an additional pair of sub-lateral papillae on the tail of the male. Material collected by Mashego (1977) from the Olifants River was examined and found to be similar to that from Hartbeespoort Dam. Despite the differences mentioned above, the Hartbeespoort Dam material is assigned to *Procamallanus laeviconchus*.

Moravec (1974, 1975) studied the life cycle of *Paracamallanus cyathopharynx* and *Procamallanus laeviconchus* in Egypt and found that *Mesocyclops leukarti* (Copepoda) harbours the first 3 larval stages of both these nematodes. The copepod must then be ingested by the catfish to continue the life cycle. The only immature stages that were found in this study were the 4th stage larvae and 4th larval moults. The latter are illustrated in Fig. 19–21. This confirms the observations of Moravec (1974).

The numbers of *Paracamallanus cyathopharynx* and *Procamallanus laeviconchus* collected on a montly basis are given in Fig 2 & 3. In the case of *Paracamallanus cyathopharynx* a seasonal variation in parasite burdens seems to occur. Peak worm burdens were seen in February and again in November, which are 2 of the hottest months in this country. Between these 2 months the numbers of nematodes in the fish declined but were not completely absent. The surviving adult nematodes acted as source of infection for the copepods, which are more abundant during the summer months, thereby creating favourable conditions for the transmission of the parasites.

From Fig. 2 it can be seen that 4th stage larvae of *Paracamallanus cyathopharynx* were recovered from catfish that were caught during the warmer months, with the exception of November 1979 and January 1980. This indicates that the intermediate host is more abundant during these months and that catfish are seasonally infested.

Procamallanus laeviconchus seems to be non-seasonal in its infestation rate, as can be seen from Fig. 3. Although some 4th stage larvae were recovered (Table 1), their numbers were too small for any conclusion to be made as regards their life cycle and seasonal occurrence. The adult worms, however, were more often recovered during the summer months, and especially late summer (January to March). During these months more adults were collected than during all the other months together (Table 1). This is in agreement with the observations of Imam (1971) and Moravec (1975).

TABLE 1 The total worm burdens recoverd from *Clarias gariepinus* from Hartbeespoort Dam for the period January, 1979–January, 1980

Fish No.	Date collected	Sex	Length (cm)	*Contracaecum* sp.		*Paracamallanus cyathopharynx* (Baylis, 1923)			*Procamallanus laeviconchus* (Wedl, 1862)			Total recovered
				L_2	L_3	L_4	M	F	L_4	M	F	
A	Jan. '79	?	?	4	107			1			1	113
B*	Jan. '79	?	?	2	53							57
1	Jan. '79	M	73		169	1	4	4	1	3	4	186
2	Feb. '79	F	62,5	1	173	1		1				176
3	Feb. '79	M	88,5		270		4	9			3	286
4	Mar. '79	M	80,5		375						1	376
5	Mar. '79	M	86		342	2						344
6	Mar. '79	F	67		285						1	286
7	Mar. '79	M	82	3	354			1		1	2	361
8	Mar. '79	M	79,5	1	225	1	4	5		1		237
9	Apr. '79	M	89	2	443	2		1				448
10	Apr. '79	F	79		216							216
11	Apr. '79	M	115		117			3			1	121
12	Apr. '79	M	81	1	395		3	2	1	2		404
13	May '79	M	82		614							614
14	May '79	M	79	1	258							259
15	May '79	F	70		456		3					459
16	May '79	M	81		323		1	1				325
17	May '79	M	83		392		2					394
18	Aug. '79	F	70		392					1	1	394
19	Aug. '79	M	91		474		2	2				478
20	Sept. '79	M	73		279		1	1		1		282
21**	Sept. '79	M	82	1	422		4	1				433
22	Sept. '79	F	75		268	1						269
23	Oct. '79	M	72,5		334	1	2					337
24	Oct. '79	?	70,5		261	1	1			1		264
25	Nov. '79	M	86		407		5	2				414
26	Dec. '79	M	92		229							229
27	Dec. '79	M	80		144		2	3				149
28	Dec. '79	M	81		696	2						698
29	Dec. '79	M	95		721			5			1	727
30	Dec. '79	M	93		407	1		2				410
31	Dec. '79	M	107		364		11	11				386
32	Dec. '79	F	82		344							344
33	Dec. '79	M	102		691							691
34	Dec. '79	M	90		374		1					375
35	Dec. '79	F	88		605							605
36	Dec. '79	F	84		231							231
37	Jan. '80	M	110	8	775		1				1	785
38	Jan. '80	M	115	1	552		2	1				556
39	Jan. '80	F	87	2	330							332
40*	Jan. '80	M	77	1	313			6				322
41	Jan. '80	M	62	4	113			3				120

M=Male
L_2=2nd stage larvae
L_3=3rd stage larvae
L_4=4th stage larvae
F=Female

*Two unidentifiable nematodes found in each catfish
**One adult *Skrjabinocara* female, 3 fourth stage larvae and 1 unidentifiable nematode found in this catfish

TABLE 2 Comparative measurements of *Paracamallanus cyathopharynx from different hosts*+

Author	Baylis, 1923		Moravec, 1974		Specimens ex coll. Looss, this paper		This paper	
Host	*C. anguillaris*		*C. anguillaris* and *C. lazera*		*Host not given*		*C. gariepinus*	
	M	F	M	F	M	F	M	F
Length (mm)	5,9	9,2	2,04–6,54	5,81–13,75	3,76	4,93	4,13–5,45	11,42–12,52
Width	120	180	82–122	122–190	68	84	106,6–135,2	163,8–192,4
Oesophagus, length of muscular part	440–560	650–670	381–465	510–680	336	448	384,8–5,07	572–657,8
length of glandular part	490–540	630–650	420–681	525–844	444	564	587,6–780	863–977
Buccal capsule, length	*	*	60–69	81–99	46	—	57,2–65	72,8–83,2
width			63–75	90–162	52	—	52–67,6	70,2–88,4
Pharynx, length	*	*	33–42	54–69	34	—	39–46,8	59,8–65
width			51–60	72–87	48	—	49,4–62,4	72,8–83,2
Distance of nerve ring from anterior end	130–150	170–180	135–183	186–249	126	168	145,6–168,2	192,4–208
Distance of cervical papillae from anterior end	behind nerve ring		129–156	162–210	124	—	135,2–184,6	187,2–202,8
Trident, length of lateral part	—	—	51–66	69–99	28	—	41,6–57,2	59,8–70,2
length of median part	—	—			32	—	44,2–57,2	52–62,4
Distance of vulva–anus (mm)	—	—	—	—	—	—	—	4,25–4,86
Distance of anus–tail	—	350–430	—	228–570	—	230	—	395,2–496,6
Distance of vulva–tail (mm)	—	4,3	—	2,45–7,41	—	2,16	—	4,65–5,32
Right spicule, length	—	—	240–309	—	—	—	239,2–300,8	—
Left spicule, length	—	—	33–48	—	—	—	28,6–31,2	—
External spicular sheath, length	—	—	—	—	—	—	28,6–33,8	—
Distance of tail–cloaca	50–70	—	63–78	—	48	—	75,4–91	—

+ All measurements given as μm unless otherwise stated
* Combined length given as 100–130 μm by Baylis, 1923
M=Males
F=Females

TABLE 3 Comparative measurements of *Procamallanus laeviconchus* from different hosts*

Author	Baylis, 1923		Specimens ex collection Looss, this paper		This paper	
Host	*B. bayad*		*B. bayad*		*C. gariepinus*	
	M	F	M+	F	M	F
Length (mm)	3,65	15,5		11,37–15	3,77–5,38	7,02–8,93
Width	110	350		208–416	97,9–123,6	181–216
Buccal capsule length		67,5–70		96–104	67,6–72,8	83,2–96,2
width		42,5–60		60–88	44,2–50	59,8–70,2
Oesophagus, length of muscular part	400	470		376–492	309,4–413,4	410,8–491,4
length of glandular part	600	780		764–812	603,2–793	774,8–927
Distance of nerve ring from anterior end		175–200		208–220	169–200,2	208–226,3
Distance of cervical papillae from anterior end	—	—		116–232	201–221	252,8–262,2
Distance of vulva–anus (mm)	—	—		3,8–4,5	—	3,0–3,5
Distance of anus–tail	—	150		120–160	—	117–137,8
Distance of tail–vulva (mm)	—	—		3,9–4,6	—	3,1–3,6
Right spicule, length	150	—		—	106,6–137,8	—
Left spicule, length	50	—		—	not found	—
Caudal alae, length	—	—		—	182–243,2	—
Distance of tail–cloaca	37	—		—	52–59,8	—
Preanal papillae, No. of pairs	9 (8–10)	—		—	8 (9)	—
Post-anal papillae, No. of pairs	4–5	—		—	3+1	—
Adanal papillae, No. of pairs	1	—		—	1	—

* All measurements given in μm unless otherwise stated
M=Males
F=Females
+ No males available

During the warmer months, the intermediate hosts are also expected to increase, especially in an eutrophic dam such as the Hartbeespoort Dam. This increase usually takes place in the warmer, shallow water which catfish frequent during their spawning activities (Holl, 1968; Van der Waal, 1974) and where they no doubt also become infested by ingesting infested copepods. The species of copepod that acts as intermediate host for *Paracamallanus cyathopharynx* and *Procamallanus laeviconchus* in this country has yet to be determined.

Larval *Contracaecum* spp. were collected from all of the catfish examined, and the numbers recovered are given in Table 1. As it is impossible to assign the larvae to a species, a number of piscivorous birds have been collected and their intestinal parasites identified.

Thomas (1937) described some aspects of the life cycle of *Contracaecum spiculigerum*, under experimental conditions. He found that eggs were laid in a morulated stage and that the larvae moulted twice within the eggs without shedding their sheaths. Upon hatching they attach to the substrate by means of the loose anterior ends of the sheaths (Thomas, 1937). The larvae lost the sheaths only when ingested by a suitable fish host (Thomas, 1937).

Sprent (1954) postulated that the Ascarididoidea evolved through the marine arthropods and vertebrates. Because of a lack of host-specificity the 2nd stage larvae may enter the tissues of a wide variety of invertebrate and vertebrate hosts and may remain there for an indefinite period without any further development (Sprent,

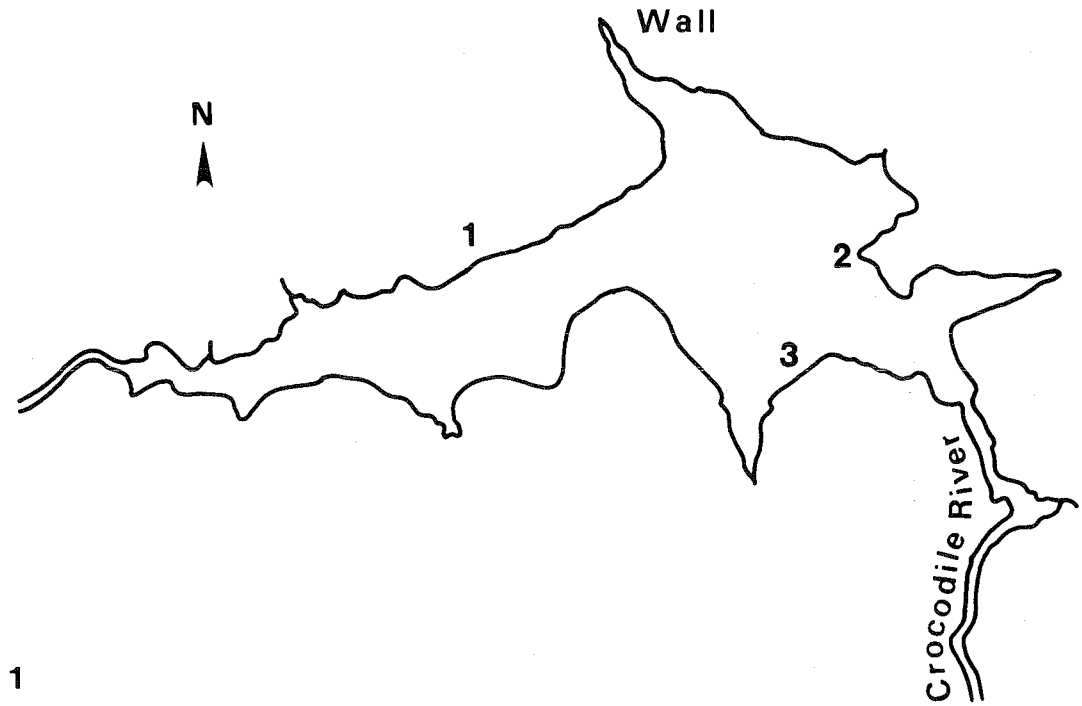


FIG. 1 Schematic representation of the Hartbeespoort Dam and the sites at which the catfish were caught

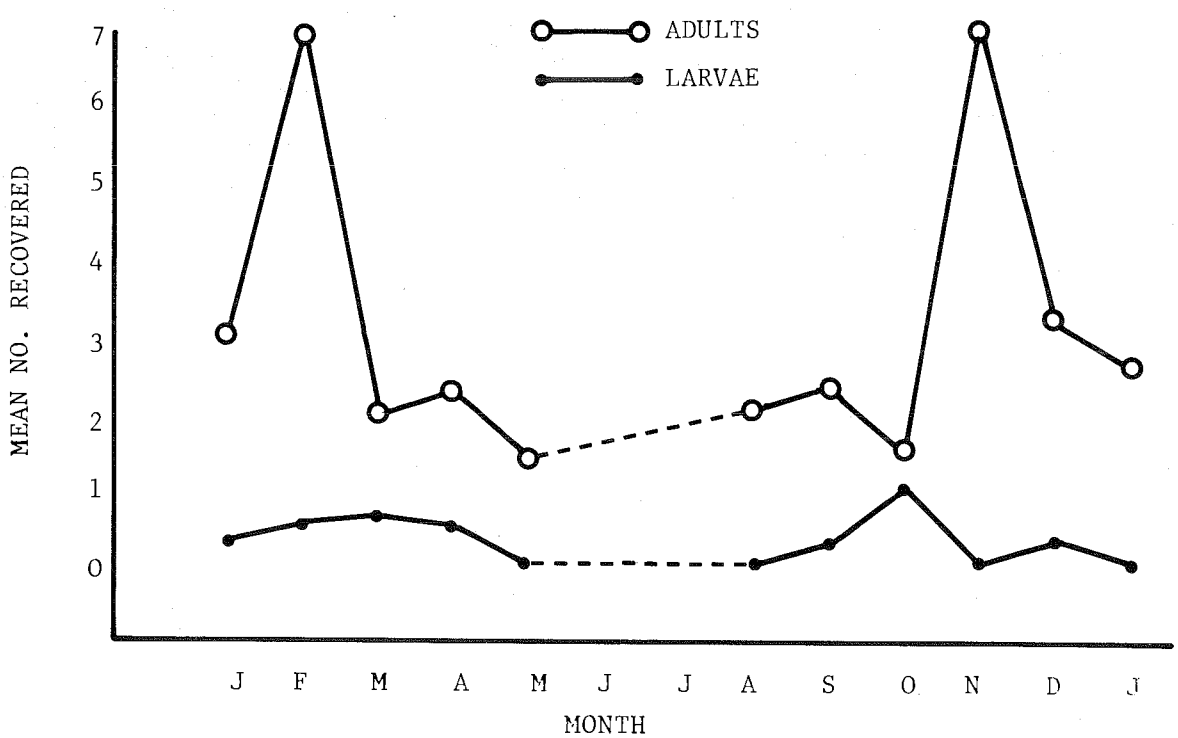


FIG. 2 Mean number of *Paracamallanus cyathopharynx* recovered each month

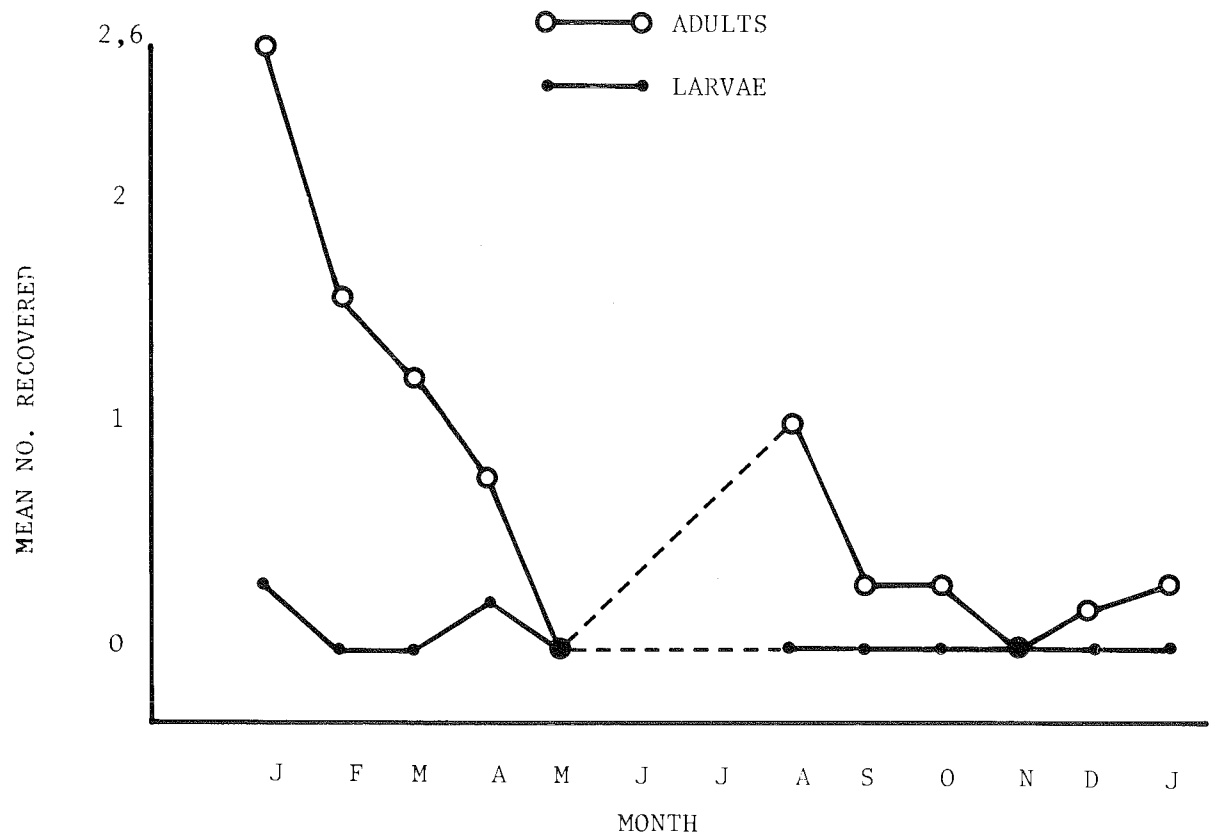


FIG. 3 Mean number of *Procammallanus laeviconchus* recovered each month

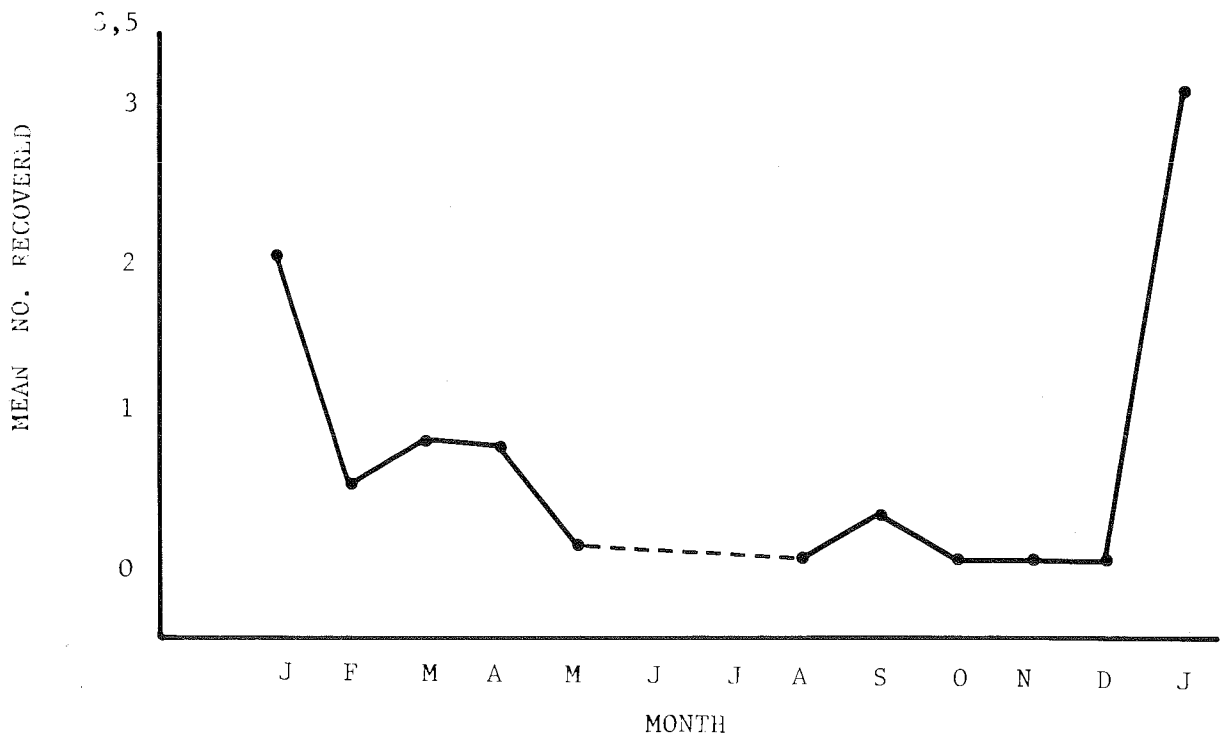


FIG. 4 Mean number of 2nd stage *Contracaecum* larvae recovered each month

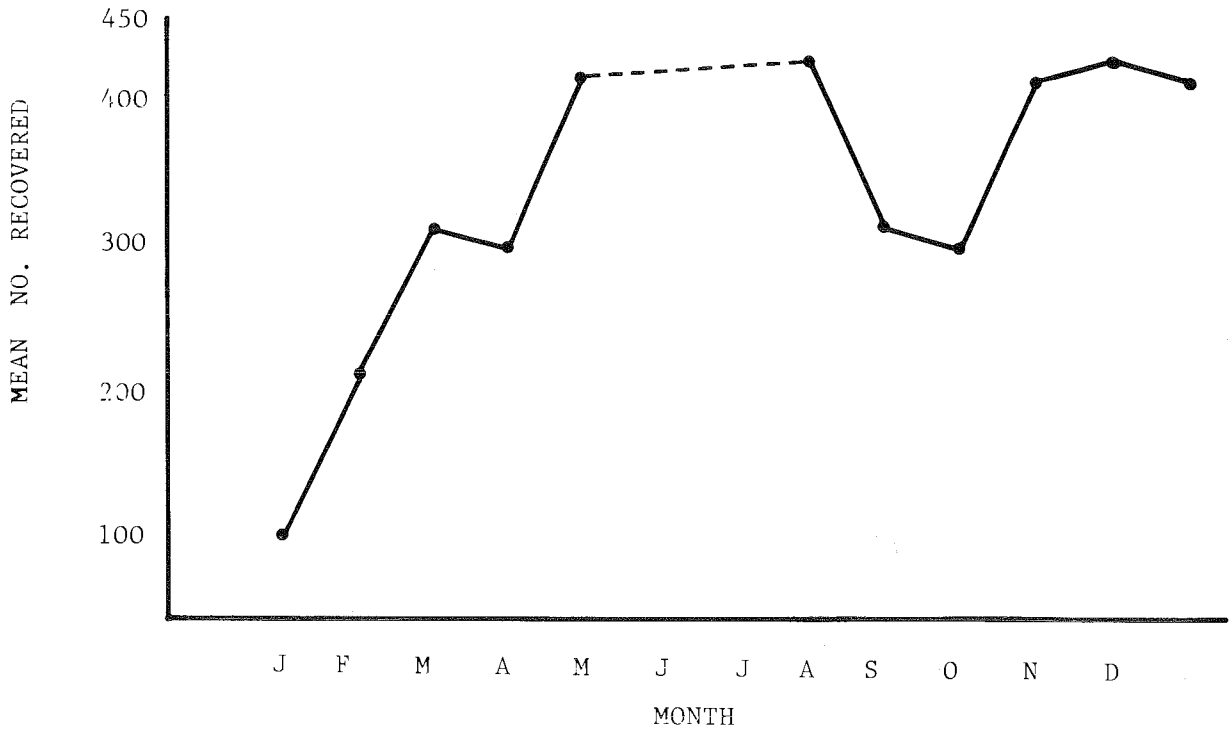


FIG. 5 Mean number of 3rd stage *Contracaecum* larvae recovered each month

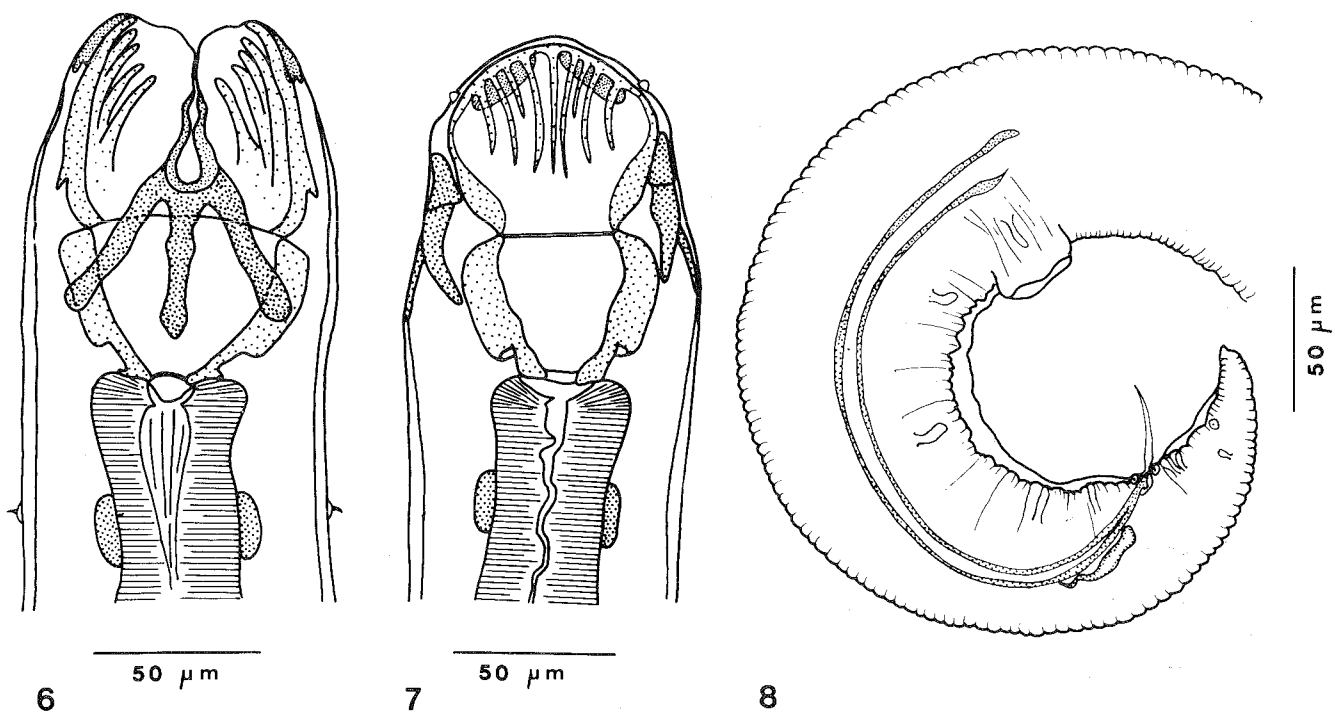


FIG. 6 Anterior extremity of *Paracamallanus cyathopharynx*, ventral view
FIG. 7 Anterior extremity of *Paracamallanus cyathopharynx*, lateral view
FIG. 8 Posterior extremity of *Paracamallanus cyathopharynx* male, lateral view

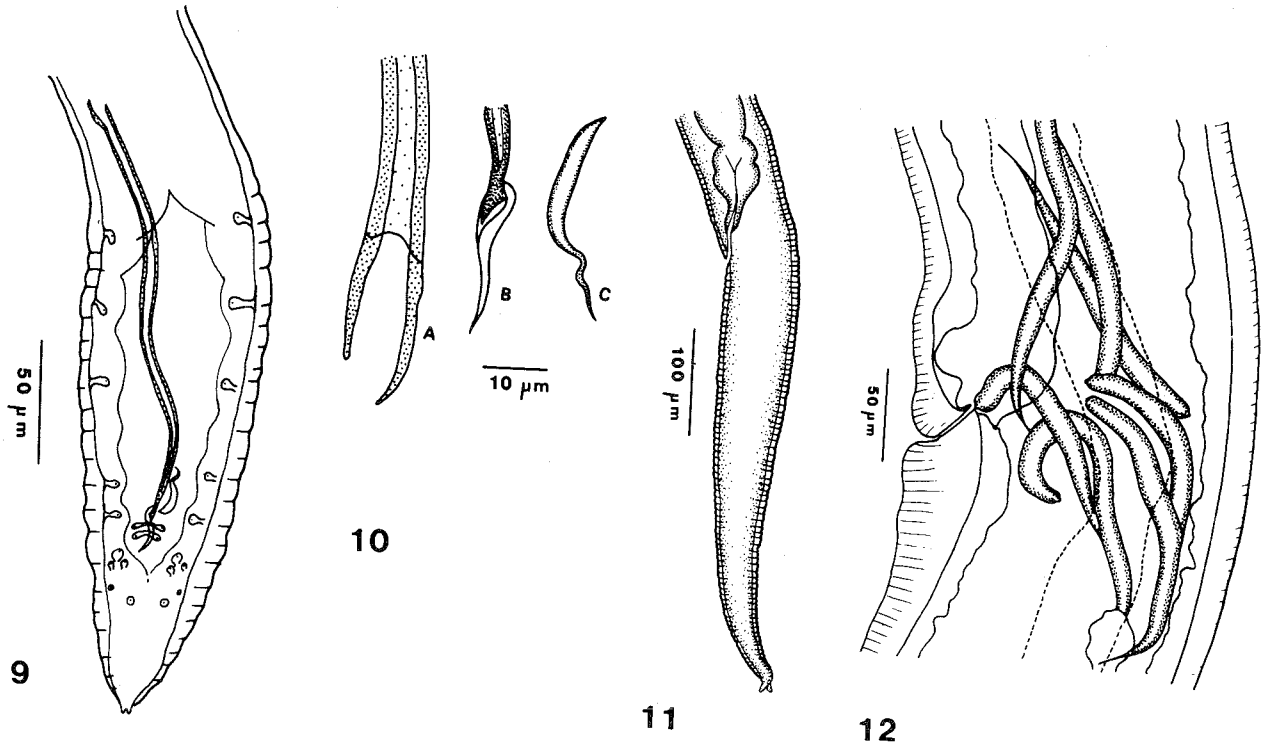


FIG. 9 Posterior extremity of *Paracamallanus cyathopharynx* male, ventral view
FIG. 10 *Paracamallanus cyathopharynx*, spicules; (A) proximal end of right spicule, (B) distal end of right spicule, (C) left spicule
FIG. 11 *Paracamallanus cyathopharynx*, posterior end of female
FIG. 12 *Paracamallanus cyathopharynx*, vulvar region of female

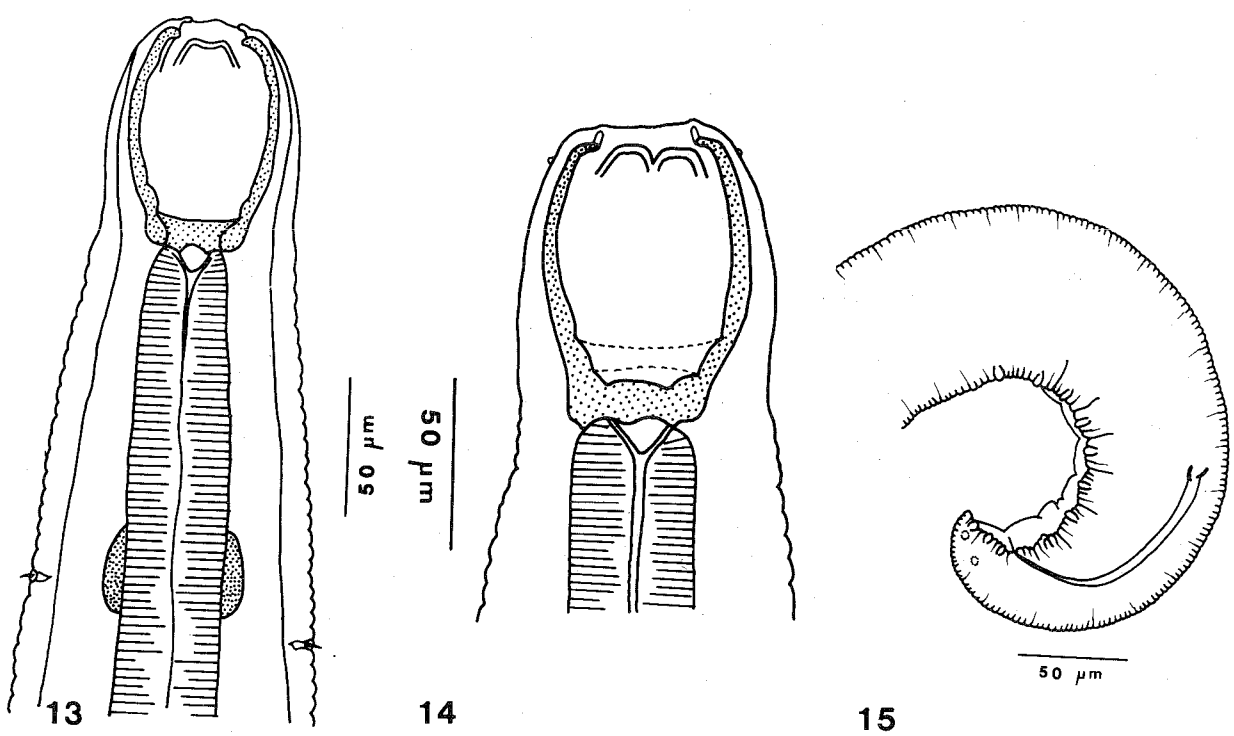
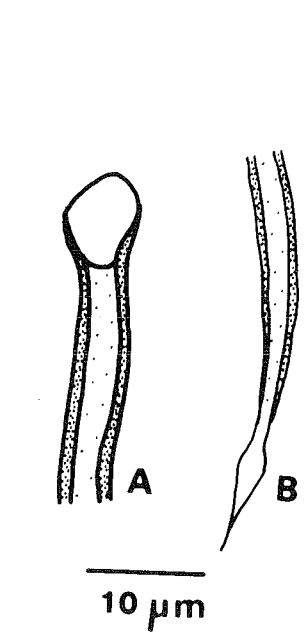


FIG. 13 Anterior extremity of *Procamallanus laeviconchus*, ventral view
FIG. 14 Anterior extremity of *Procamallanus laeviconchus*, lateral view
FIG. 15 Posterior end of *Procamallanus laeviconchus* male, lateral view



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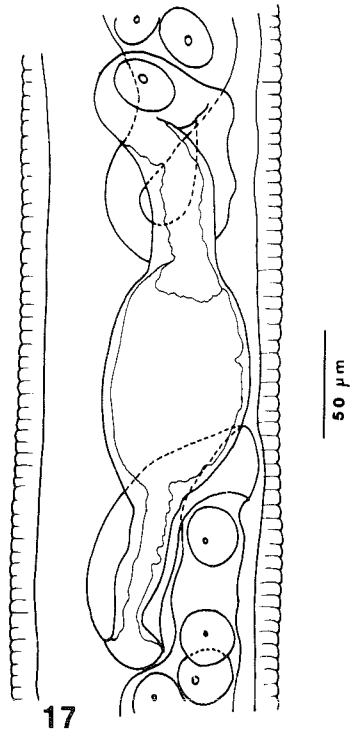

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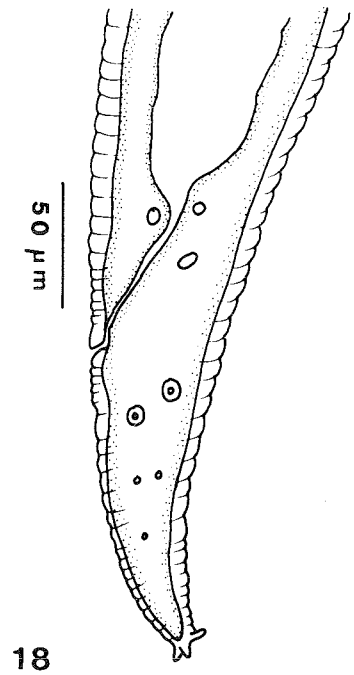

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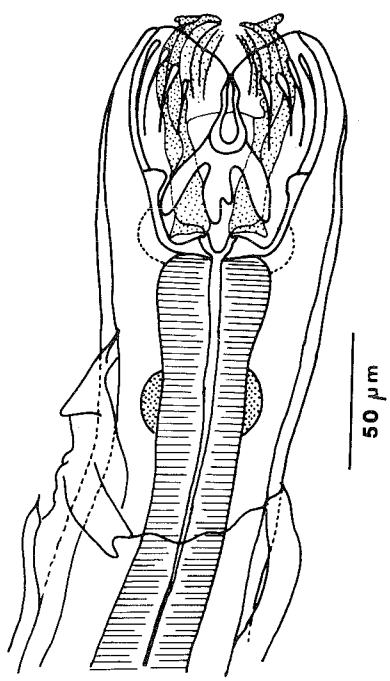
FIG. 16 *Procamallanus laeviconchus*, right spicule, (A) proximal and (B) distal ends
FIG. 17 *Procamallanus laeviconchus*, female uterus
FIG. 18 *Procamallanus laeviconchus*, tail of female, lateral view



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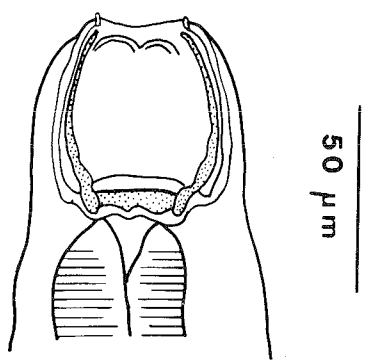

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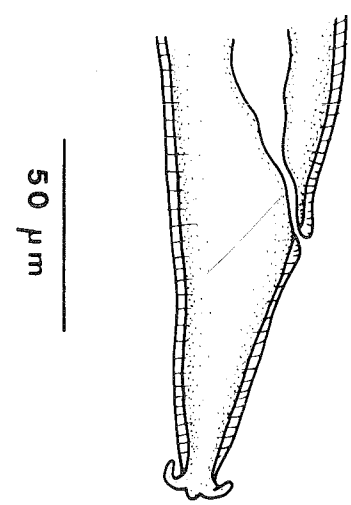

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FIG. 19 *Paracamallanus cyathopharynx*, 4th moult; shaded part is the buccal capsule of 4th stage larva, dorsal view
FIG. 20 Anterior end of *Procamallanus laeviconchus*, dorsal view of 4th moult. Shaded part is the buccal capsule of the 4th stage larva
FIG. 21 *Procamallanus laeviconchus*, tail of 4th moult, lateral view

1962). However, Thomas (1937) showed that domestic ducks and fowl are not susceptible to infection with *Contracaecum spiculigerum*, thereby implying a degree of host specificity where the final host is concerned.

A tentative scheme for life cycle patterns in the Ascarididoidea was given by Sprent (1954). He stated that larvae after hatching are ingested by an intermediate host, which in turn has to be eaten by the final host and used the life cycle of *Contracaecum spiculigerum* as an example of this type. A second type of life cycle involves the ingestion of embryonated eggs by an intermediate host. The larvae that hatch from these eggs remain in the tissues of the intermediate host until they are eaten by a second intermediate host or by the final host. It is only in the final host that the larvae will develop into 4th stage larvae and adult nematodes (Sprent, 1954). A nematode that has this type of life cycle is *Contracaecum microcephalum* (Sprent, 1954).

Hartbeespoort Dam supports a large number of water birds of which the white-breasted cormorant (*Phalacrocorax carbo*), the reed cormorant (*Phalacrocorax africanus*) and the darter (*Anhinga rufa*) are the most prevalent predators of fish. Various species of heron, egrets and occasionally the fish eagle (*Haliaetus vocifer*) also prey on fish, but these are regarded as being of lesser importance in the transmission of *Contracaecum* because they do not consume the same quantities of fish as the cormorants and are also not as numerous on Hartbeespoort Dam. A possible exception is the cattle egret (*Bubulcus ibis*) and the little egret (*Egretta garzetta*), which are found in large numbers. McLachlan & Liversidge (1978) record the food of both species as including fish, especially the smaller fish, such as Canary kurper (*Chetia flaviventris*), from which *Contracaecum* spp. larvae have also been recovered (Boomker, unpublished data). Egrets may therefore also play a role in the transmission of *Contracaecum*. This assumption is strengthened by observations of the feeding habits of catfish. During the summer months, large numbers of both species of cormorants and egrets mentioned above breed in the trees which stand in shallow water along the banks of the dam. Catfish move into the shallow water and avidly consume the bird droppings as well as bird eggs and chick that fall out of the nests. Sometimes as many as 20 birds nest in the same tree and on numerous occasions up to 8 catfish have been caught beneath these trees. During the months that the birds are not breeding, catfish will move in at night under the trees where the birds roost and consume their droppings (Boomker, unpublished data).

Malvestuto & Ogambo-Ongoma (1978) are of the opinion that the first intermediate host, usually a crustacean, is not needed in the life cycle of *Contracaecum*. The above-mentioned feeding behaviour of catfish seems to support their opinion, but because the eggs of the nematodes are shed in the faeces of the birds in a morulated stage, they must embryonate and hatch in the stomach of the fish intermediate host. Such a process has as yet not been shown to occur in the case of *Contracaecum*. One must also remember that the bird droppings are very fluid and disperse immediately after falling into the water. Catfish ingest only a small amount, that is sieved by the gill rakers which hold back only the larger undigested pieces. Therefore, most of the *Contracaecum* eggs are lost and the majority of the 3rd stage larvae probably result from the ingestion of either the crustacean intermediate host or the ingestion of smaller fish that harbour the parasites.

The presence of the large numbers of 3rd stage larvae is attributed to the constant intake of small numbers of either embryonated nematode eggs or infested intermediate hosts. As all the catfish examined in this study were large fish, over 60 cm long (Table 1), they have conceivably been exposed to infestation for a number of years. However, the numbers of larvae are probably not directly proportional to the number of infective stages ingested, as not all the larvae will develop into dormant 3rd stage larvae. One must consider that the immune mechanisms of the catfish, albeit slow in developing, may cause inhibition and later destruction of the infective stages in the stomach mucosa in a way similar to that seen with *Haemonchus* spp. in ruminants (Reinecke, personal communication, 1980). This mechanism, if present in catfish, will account for the few 2nd stage larvae recovered. Furthermore, the mortality rate of encapsulated 3rd stage larvae must also be considered, although very few dead larvae were recovered in this study. The method employed to liberate the larvae from their protective capsules worked very well, and 30 minutes after the infested mesenteria had been placed in the digesting fluid, larvae could already be seen moving about freely inside the container. This method resulted in the liberation of 100% of the larvae.

Ortlepp (1938) described *Contracaecum carlislei* from the oesophagus and stomach of *Microcarbo africana africanides* (= *Phalacrocorax africanus africanus*). Prudhoe & Hussey (1977) state that 3 species of *Contracaecum* commonly occur in African fish-eating birds, namely, *Contracaecum micropapillatum* (Stossich, 1890) in cormorants and pelicans, and *Contracaecum microcephalum* (Rudolphi, 1809) and *Contracaecum spiculigerum* (Rudolphi, 1809) usually in cormorants, pelicans and herons. The latter 2 parasites have been recorded from white pelican (*Pelecanus onocrotalis*) and white-breasted cormorants from lake St Lucia, Natal, by Whitfield & Heeg (1977). In the course of this study, 3 reed cormorants and 1 white-breasted cormorant were also examined and numerous adult *Contracaecum* spp. were recovered. Preliminary studies indicate that they are *C. spiculigerum* and *C. carlislei*. It therefore seems reasonable to assume that the *Contracaecum* larvae found in catfish belong to the species found in the birds.

Three 4th stage larvae and 1 female of a nematode belonging to the genus *Skrjabinocara* were found in 1 catfish only. Their occurrence in catfish seems to be erratic, as none of the 7 species of *Skrjabinocara* listed by Yamaguti (1961) occur in fish. *Skrjabinocara squamatum* (Von Linstow, 1883) has the widest distribution and has not only been found in *Phalacrocorax carbo* in Turkestan, the Volga Delta and Adelaide (Australia), but also in *Phalacrocorax auritus* from Cuba and *Phalacrocorax cristatellus* from Indochina (Yamaguti, 1961). One species, *Skrjabinocara buckleyi* Ali, 1957, has been found in *Phalacrocorax niger* from India and the others from various fish-eating birds in Russia (Yamaguti, 1961).

The fact that these nematodes have been found in only 1 of the 43 catfish examined has led to the opinion that they were ingested by the catfish after accidental regurgitation by white-breasted cormorant whilst feeding the chicks, and that they are not normally parasitic in fish. This view has been confirmed by the finding of adult male and female *Skrjabinocara* sp. from the gizzard and stomach of the white-breasted cormorant examined.

ACKNOWLEGEMENTS

The author wishes to express his gratitude to the Transvaal Department of Nature Conservation for placing the material at his disposal; to Messrs F. van der Merwe and A. Moolman, Provincial Fisheries, Hartbeespoort Dam, for assisting with the collections, and the Pretoria Spinfishing Society for providing some of

the material. A special word of thanks is due to Mesdames E. Visser and M. R. Brown and Mr I. L. de Villiers for their technical assistance, and to Dr D. Gibson, British Museum (Natural History), London for the loan of material from their collection.

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Onderstepoort Journal of Veterinary Research, 61:35–43 (1994)

Parasites of South African freshwater fish. VI. Nematode parasites of some fish species in the Kruger National Park

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ABSTRACT

BOOMKER, J. 1994. Parasites of South African freshwater fish. VI. Nematode parasites of some fish species in the Kruger National Park. *Onderstepoort Journal of Veterinary Research*, 61:35–43

The nematode parasites of 30 spot-tailed robbers, *Brycinus imberi*, five tiger-fish, *Hydrocynus vittatus*, 77 large-scaled yellowfish, *Barbus marequensis*, two mudsuckers, *Labeo molybdinus*, 114 catfish, *Clarias gariepinus*, 46 silver barbel, *Schilbe intermedius*, 66 squeakers, *Synodontis zambezensis*, three eels, *Anguilla* spp., 83 Mozambique bream, *Oreochromis mossambicus*, 81 red-breasted bream, *Tilapia rendalli swierstrae* and 32 large-mouthed bream, *Serranochromis meridianus*, caught in the Sabie, Crocodile and Olifants Rivers in the southern and central regions of the Kruger National Park, were collected, identified and counted.

A single *Camallanus* sp. male was recovered from one of the mudsuckers; *Capillaria* spp. from three catfish and one squeaker; philometrid nematodes from two silver barbel, 15 squeakers and a large-mouthed bream; *Paracamallanus cyathopharynx* from one tiger-fish, 80 catfish, 28 silver barbel and one squeaker; *Procamallanus laeviconchus* from a single catfish; *Rhabdochona esseniae* from six large-scaled yellowfish; *Rhabdochona versterae* from 14 spot-tailed robbers; *Rhabdochona* spp. from 20 catfish, 17 silver barbel, eight squeakers, two eels, one large-mouthed bream and two red-breasted bream; *Raillietnema synodontisi* from 33 squeakers; *Spinitectus petterae* from 37 catfish; *Spinitectus zambezensis* from 55 squeakers; *Spinitectus* spp. from one tiger-fish and four silver barbel, and *Spirocamallanus daleneae* and *Synodontisia thelastomoides* from 33 and 35 squeakers, respectively. Second- and third-stage *Contracaecum* spp. larvae were recovered from 26 spot-tailed robbers, five tiger-fish, one large-scaled yellowfish, 53 catfish and ten silver barbel and unidentified nematode larvae from two spot-tailed robbers, 57 large-scaled yellowfish, both mudsuckers, 105 catfish, 45 silver barbel, 58 squeakers, all three the eels, 29 Mozambique bream, 33 red-breasted bream and 26 large-mouthed bream.

Camallanus sp. in mudsuckers, *Capillaria* spp. in catfish and squeakers, *Rhabdochona* spp. in eels, catfish, silver barbel, squeakers, large-mouthed bream and red-breasted bream, *Spinitectus* spp. in tiger-fish and silver barbel, *Paracamallanus cyathopharynx* in silver barbel, tiger-fish and squeakers, *Raillietnema synodontisi* and *Synodontisia thelastomoides* in squeakers, constitute new parasite records for the respective hosts in South Africa.

With few exceptions, the fishes harboured more nematode larvae than adult nematodes but no pattern of seasonal abundance of either of the developmental stages was evident for any of the fish species examined.

Received 18 November 1993–Editor

INTRODUCTION

Despite the variety of freshwater fishes in South Africa, the nematode parasites infecting these fishes have been the subject of few papers. Several of these papers record incidental findings of nematodes in fishes (Lombard 1968; Prudhoe & Hussey 1977; Bruton 1979), while others are of a taxonomic nature (Mashego 1989; 1990; Boomker 1993a; b; Boomker & Petter 1993). The papers of Whitfield & Heeg (1977), Mashego & Saayman (1981), Mashego (1989) and Boomker (1982) record the results of surveys conducted in various areas in the country, while those of Khalil (1971) and Van As & Basson (1984) are the first to establish host-parasite lists for several of the fish species. Two papers deal with disease or mortalities caused by nematodes (Lombard 1968; Jackson 1978).

Surveys of the nematode parasites of freshwater fishes have been done outside the Park in the Olifants River that flows through the central region and the Limpopo and Levuvhu Rivers that flow through the northern region of the Kruger National Park (Mashego & Saayman 1981; Mashego 1989; 1990). Although the worms recovered by Mashego & Saayman (1981) and Mashego (1989; 1990) should and indeed do occur in the Kruger National Park, as is indicated in this study, no actual records of nematodes of fishes in the Park itself could be found in the literature.

The survey was undertaken to determine the species and numbers of parasites of fishes in two major rivers in the southern region of the Kruger National Park and also to determine the seasonal prevalence of these parasites. A previous paper (Boomker 1984) describes *Phyllodistomum bavuri* (Trematoda: Gorgoderinae) from the urinary bladders of catfish and discusses the trematode's seasonal prevalence. This paper deals with the numbers and species of nematodes of all the fish species collected during the survey and, where possible, indicates trends in the seasonal fluctuation of these nematodes.

MATERIALS AND METHODS

The survey was conducted from February 1980 to January 1981 in the Sabie and the Crocodile Rivers. These are the two major rivers in the southern part of the Kruger National Park. Both rivers form part of the eastern drainage system (Wellington 1955, cited by Jubb 1967) and both arise in the mountains of the eastern Transvaal escarpment. Both are major perennial sources of water in the Park and the water in both the rivers is extensively used by agricultural activities outside the Park. On a single occasion some fish species were also caught in the Olifants River in the central region of the Park.

The fishes were caught with baited handlines and their parasites collected as described by Boomker (1982). The nematodes were recovered and counted under a stereoscopic microscope and identified under a standard microscope with interference contrast illumination. Except for second- and third-stage *Contracaecum* spp., larvae were not specifically identified, and are grouped as unidentified nematode larvae.

The terms "prevalence" and "intensity" are used here in accordance with the definitions of Margolis, Esch, Holmes, Kuris & Schad (1982).

RESULTS AND DISCUSSION

A total of 539 fishes were processed, and the collection and morphometric data of the fishes, together with the mean intensities and prevalence of their larval and adult nematode burdens, are presented in Table 1. The nematode species recovered, their mean monthly intensities and mean total intensities, range and prevalence are listed in Tables 2–4.

The helminths

Enoplida: Trichuridae

A *Capillaria* sp. and *Capillaria fritschi*, both recovered from electric eels, *Malapterurus electricus*, as well as *Capillaria yamagutii*, found in *Bagrus bayad* (Campana-Rouget 1961; Tadros & Mahmoud 1968; Khalil 1971), are the only *Capillaria* spp. recorded from African fishes. Moravec (1974a), however, regarded all these nematodes as synonyms of *Capillaria fritschi*.

Only damaged specimens were recovered from the intestines of catfish and squeakers during this survey, and they could not be assigned to a species. This is the first record of *Capillaria* spp. in South Africa.

No *Capillaria* spp. were found in the fishes from the Olifants River and only catfish in the Crocodile River were infected. Catfish and squeakers in the Sabie River were infected with small numbers of the nematodes.

Oxyurida: Pharyngodonidae

Synodontisia thelastomoides are small nematodes originally described from the intestines of *Synodontis sorex* in Senegal and *Synodontis ocellifer* in Chad (Petter, Vassiliades & Troncy 1972). The genus *Synodontisia* shows morphological similarities to the genus *Cithariniella* but differs from it in the number and configuration of the cloacal papillae and in the configuration of the pharyngeal teeth. The genus *Cithariniella* has not yet been found in South Africa and this is the first record of *Synodontisia thelastomoides* in this country. In view of its prevalence in more than 50 % of the squeakers examined, it should be regarded as a definitive parasite.

TABLE 1 Collection data and nematode infection of fishes in the Kruger National Park

Fish species and locality	Sex of fishes and number examined				Length of fishes (cm)	Mean intensity of nematodes		Prevalence of nematodes	
	Undetermined	♂♂	♀♀	Total	(Mean ± SD)	Larvae	Adults	Larvae	Adults
Sabie River									
Brycinus imberi	1	10	12	23	16,0 ± 1,9	11	5	96	61
Barbus marequensis	9	42	9	60	26,3 ± 12,5	30	1	80	10
Clarias gariepinus	0	37	30	67	53,5 ± 13,5	40	5	99	88
Schilbe intermedius	5	14	22	41	23,7 ± 9,6	195	3	98	78
Synodontis zambezensis	7	13	31	51	15,1 ± 6,0	9	131	88	100
Anguilla spp.	2	0	0	2	84,0 ± 33,0	28	3	100	100
Oreochromis mossambicus	2	27	21	50	21,7 ± 5,9	6	0	44	0
Tilapia rendalli swierstrae	5	30	9	44	19,0 ± 8,2	4	1	36	2
Serranochromis meridianus	4	17	11	32	16,7 ± 6,5	15	2	81	9
Crocodile River									
Brycinus imberi	0	2	5	7	13,7 ± 1,3	2	0	51	0
Hydrocynus vittatus	0	1	2	3	37,5 ± 5,1	161	7	100	33
Barbus marequensis	0	11	6	17	41,5 ± 4,4	11	0	65	0
Labeo molybdinus	2	0	0	2	ND[a]	2	1	100	50
Clarias gariepinus	0	25	20	45	52,6 ± 11,8	50	10	93	76
Schilbe intermedius	0	2	1	3	17,3 ± 3,5	15	1	100	67
Synodontis zambezensis	0	4	9	13	19,7 ± 3,7	33	32	85	92
Anguilla sp.	1	0	0	1	125,0	73	0	100	0
Oreochromis mossambicus	3	18	12	33	21,2 ± 4,6	2	0	21	0
Tilapia rendalli swierstrae	2	24	11	37	21,3 ± 5,6	3	1	46	3
Olifants River									
Hydrocynus vittatus	0	2	0	2	42,8 ± 4,8	37	0	100	0
Clarias gariepinus	0	0	2	2	53,5 ± 1,5	12	17	100	100
Schilbe intermedius	0	2	0	2	30,3 ± 2,7	46	5	100	100
Synodontis zambezensis	0	1	1	2	20,5 ± 0,5	1	34	50	100

[a] ND = No data

The life cycle of this nematode is unknown, but embryonated eggs are laid. Most oxyurids have a direct life cycle, and since *Synodontis zambezensis* is a bottom-feeder, it is assumed the fishes are infected by ingesting the eggs of the nematodes with their food.

Synodontisia thelastomoides was recovered from all three localities and while the ranges varied greatly, the prevalence was 50–55 %.

Ascaridida: Cosmocercidae

The genus *Raillietnema* consists of about 21 species, of which *Raillietnema synodontisi* is the only one occurring in fishes and then only in the genus *Synodontis*. It was described from *Synodontis ocellifer* in Senegal by Vassiliades (1973) and has since been recovered from *Synodontis frontosus* in Chad (Vassiliades & Troncy 1974, cited by Moravec & Řehulka, 1975) and *Synodontis eupterus* in Czechoslovakia (Moravec & Řehulka 1987). In the latter case, it is suspected that the nematode was imported along with its host into Europe (Moravec & Řehulka 1987). This is the first record of *Raillietnema synodontisi* in a South African fish species. The nematodes were not found in any other fish species examined during this study and should be regarded as a definitive parasite of squeakers as they were present in large numbers in more than 50 % of the fishes examined.

The life cycle of this nematode is unknown but is presumed to be direct (Moravec & Řehulka 1987). Eggs are embryonated when laid (Vassiliades 1973) and infection possibly takes place when the eggs are ingested by the final host with its food.

Large numbers of *Raillietnema synodontisi* were recovered from 65 % of squeakers caught in the Sabie River, but only one nematode was found in one of the 13 squeakers in the Crocodile River and one in one of the two squeakers in the Olifants River. This may indicate either that the conditions for the survival of the embryonated eggs are better in the Sabie River, or that the population of *Synodontis*

TABLE 2 The mean monthly and mean total intensities of adult and larval nematodes of various fish species collected in the Sabie River, Kruger National Park, from February 1980 to January 1981

Host and parasite species	Mean monthly intensity												Mean total intensity		Range	Prevalence
	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Larvae	Adults		
Brycinus imberi (23 fish)																
Rhabdochona versterae	ND[b]	ND	ND	ND	ND	ND	ND	3	5	1	6	5	1	5	1–14	61
Contracaecum spp. larvae[a]	ND	ND	ND	ND	ND	ND	ND	12	6	10	1	16	11	–[c]	1–47	91
Unidentified nematode larvae	ND	ND	ND	ND	ND	ND	ND	0	0	1	1	0	2	–	1	9
Barbus marequensis (60 fish)																
Rhabdochona esseniae	2	0	0	0	1	3	2	0	0	0	0	0	1	1	1–4	10
Unidentified nematode larvae	6	2	7	5	132	9	23	28	37	9	4	70	30	–	1–412	80
Clarias gariepinus (67 fish)																
Capillaria sp.[a]	0	0	0	0	0	0	0	0	0	0	1	0	0	1	1	2
Rhabdochona spp.[a]	1	1	2	0	1	3	1	0	0	0	2	0	0	2	1–5	18
Paracamallanus cyathopharynx	2	3	7	5	3	4	2	3	4	2	3	4	2	6	1–16	79
Spinitectus petterae	1	2	0	3	3	0	13	2	3	0	2	0	2	5	1–35	24
Contracaecum spp. larvae	2	5	4	19	3	1	3	8	2	0	1	5	4	–	1–35	43
Unidentified nematode larvae	57	54	23	25	47	72	33	32	56	25	13	24	38	–	1–208	97
Schilbe intermedius (41 fish)																
Philometrid nematode	ND	0	0	0	1	ND	0	0	0	0	0	1	0	1	1	5
Rhabdochona spp.[a]	ND	9	4	0	0	ND	0	1	7	6	4	2	7	4	1–19	46
Spinitectus spp.[a]	ND	3	2	0	0	ND	0	1	0	0	0	0	3	1	1–4	10
Paracamallanus cyathopharynx[a]	ND	3	1	4	2	ND	1	8	3	1	1	3	8	2	1–6	59
Contracaecum spp. larvae	ND	0	1	0	0	ND	1	4	0	2	1	2	2	–	1–4	17
Unidentified nematode larvae	ND	52	170	141	381	ND	217	101	250	219	168	287	193	–	6–521	98
Synodontis zambezensis (51 fish)																
Philometrid nematode	2	0	0	0	2	ND	3	0	0	3	2	2	0	2	1–3	28
Capillaria spp.[a]	0	0	2	0	0	ND	0	0	0	0	0	0	0	2	2	4
Rhabdochona spp.[a]	0	1	1	0	0	ND	0	0	2	0	1	0	0	1	1–3	10
Raillietnema synodontisi[a]	20	212	100	57	11	ND	285	337	64	152	50	34	0	131	1–1 000	65
Spinitectus zambezensis	35	40	3	87	23	ND	31	59	35	35	22	24	9	31	1–220	88
Spirocamallanus daleneae	6	6	2	1	6	ND	6	4	11	14	18	8	7	5	1–28	61
Synodontisia thelastomoides[a]	10	22	9	27	21	ND	17	32	31	46	12	7	0	23	1–96	55
Unidentified nematode larvae	1	5	1	0	2	ND	1	3	0	1	0	3	2	–	1–11	33
Oreochromis mossambicus (50 fish)																
Unidentified nematode larvae	0	ND[b]	5	0	4	3	3	18	2	3	1	5	6	–[c]	1–63	44
Tilapia rendalli swierstrae (44 fish)																
Rhabdochona sp.[a]	0	0	0	0	1	ND	0	0	0	0	0	0	0	1	1	2
Unidentified nematode larvae	7	0	2	0	0	ND	4	3	2	0	0	0	4	1	1–11	39
Serranochromis meridianus (32 fish)																
Philometrid nematode	ND	ND	ND	0	0	0	0	1	0	0	0	ND	0	1	1	3
Rhabdochona spp.[a]	ND	ND	ND	0	0	0	2	0	0	2	0	ND	0	2	2	6
Unidentified nematode larvae	ND	ND	ND	25	11	18	6	3	31	5	22	ND	15	–	1–72	81
Anguilla spp.																
Rhabdochona spp.[a]	ND	ND	ND	ND	ND	ND	ND	7	ND	ND	ND	2	2	3	2–7	100
Unidentified nematode larvae	ND	ND	ND	ND	ND	ND	ND	50	ND	ND	ND	2	26	–	2–50	100

[a] New host record [b] ND = No data [c] – Not applicable

TABLE 3 The mean monthly and mean total intensities of adult and larval nematodes of various fish species collected in the Crocodile River, Kruger National Park, from February 1980 to January 1981

Host and parasite species	Mean monthly intensity												Mean total intensity		Range	Prevalence
	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Larvae	Adults		
Brycinus imberi (7 fish)																
Contracaecum spp. larvae[a]	ND[b]	ND	ND	ND	ND	ND	ND	2	1	ND	ND	ND	1	0	1–6	71
Hydrocynus vittatus (3 fish)																
Spinitectus sp.[a]	0	ND	ND	ND	ND	ND	ND	ND	ND	7	ND	ND	1	6	7	50
Paracamallanus cyathopharynx[a]	0	ND	ND	ND	ND	ND	ND	ND	ND	1	ND	ND	1	0	1	50
Contracaecum spp. larvae[a]	125	ND	ND	ND	ND	ND	ND	ND	ND	178	ND	ND	160	–[c]	90–266	100
Barbus marequensis (17 fish)																
Contracaecum sp. larvae	ND	ND	ND	1	ND	0	ND	0	0	0	ND	0	1	–	1	6
Unidentified nematode larvae	ND	ND	ND	11	ND	0	ND	0	12	19	ND	2	11	–	2–27	53
Labeo molybdinus (2 fish)																
Camallanus sp.[a]	ND	ND	ND	ND	ND	ND	ND	ND	ND	1	ND	ND	1	–	1	50
Unidentified nematode larvae	ND	ND	ND	ND	ND	ND	ND	ND	ND	4	ND	ND	2	–	1–3	100
Clarius gariepinus (45 fish)																
Capillaria sp.[a]	0	0	0	0	0	1	0	0	1	0	0	0	0	1	1	4
Rhabdochona spp.	1	1	1	5	0	1	0	0	0	0	1	0	0	2	1–5	13
Paracamallanus cyatho pharynx	3	11	1	1	5	2	2	1	4	3	6	14	5	4	1–16	56
Spinitectus petterae	4	29	1	15	7	55	4	6	1	2	0	40	3	12	1–101	47
Contracaecum spp. larvae	23	1	67	1	72	1	2	2	3	0	0	1	32	–	1–351	49
Unidentified nematode larvae	193	30	74	19	130	4	11	5	6	79	10	15	50	–	1–503	93
Schilbe intermedius (3 fish)																
Rhabdochona spp.[a]	ND	ND	ND	ND	0	ND	ND	ND	ND	ND	1	1	1	–	1	67
Contracaecum spp. larvae	ND	ND	ND	ND	1	ND	ND	ND	ND	ND	0	1	1	–	1	67
Unidentified nematode larvae	ND	ND	ND	ND	24	ND	ND	ND	ND	ND	8	12	16	–	8–24	100
Synodontis zambezensis (13 fish)																
Rhabdochona spp.[a]	ND	ND	ND	ND	0	ND	ND	1	0	ND	1	ND	0	1	1	15
Raillietnema synodontisi[a]	ND	ND	ND	ND	0	ND	ND	1	0	ND	0	ND	0	1	1	8
Spinitectus zambezensis	ND	ND	ND	ND	112	ND	ND	28	21	ND	33	ND	41	16	1–153	69
Spirocamallanus daleneae	ND	ND	ND	ND	2	ND	ND	2	2	ND	2	ND	2	2	1–4	69
Synodontisia thelastomoides[a]	ND	ND	ND	ND	0	ND	ND	18	0	ND	36	ND	0	23	1–39	54
Unidentified nematode larvae	ND	ND	ND	ND	7	ND	ND	2	0	ND	0	ND	4	–	1–14	38
Oreochromis mossambicus (33 fish)																
Unidentified nematode larvae	ND	0	0	ND	ND	0	2	ND	1	3	1	2	2	–	1–6	21
Tilapia rendalli swierstrae (37 fish)																
Rhabdochona sp.[a]	ND	0	0	0	ND	0	0	1	0	0	0	0	0	1	–	3
Unidentified nematode larvae	ND	2	1	0	ND	1	2	4	4	2	2	1	3	–	1–10	46
***Anguilla* sp.** (1 fish)																
Unidentified nematode larvae	ND	ND	ND	ND	ND	ND	ND	ND	ND	73	ND	ND	73	–	–	100

[a] New host record [b] ND = No data [c] – Not applicable

TABLE 4 The mean total intensity of larval and adult nematodes from various fish species caught in the Olifants River, Kruger National Park, during October 1980

Host and parasite species	Mean total intensity		Range	Prevalence
	Larvae	Adults		
Hydrocynus vittatus (2 fish)				
Contracaecum spp. larvae[a]	37	–[b]	31–42	100
Clarias gariepinus (2 fish)				
Rhabdochona spp.[a]	0	32	32	50
Paracamallanus cyathopharynx	2	1	1–2	100
Procamallanus laeviconchus	0	1	1	50
Contracaecum spp. larvae	2	–	2	100
Unidentified nematode larvae	9	–	3–15	100
Schilbe intermedius (2 fish)				
Paracamallanus cyathopharynx[a]	0	5	3–6	100
Contracaecum spp. larvae	1	–	1	50
Unidentified nematode larvae	45	–	15–75	100
Synodontis zambezensis (2 fish)				
Philometrid nematode	0	4	4	50
Rhabdochona spp.	0	36	36	50
Paracamallanus cyathopharynx[a]	0	1	1	50
Raillietnema synodontisi[a]	0	1	1	50
Spinitectus zambezensis	0	10	5–15	100
Spirocamallanus daleneae	0	1	1	50
Synodontisia thelastomoides[a]	0	4	4	50
Unidentified nematode larvae	1	–	1	50

[a] New host record [b] – Not applicable

zambezensis in this river is considerably higher than those in the other rivers, thus facilitating the spread of the nematodes.

Ascaridida: Anisakidae

Prudhoe & Hussey (1977) recovered *Contracaecum* spp. larvae from the bile ducts or cysts in the mesenteries and body wall of catfish from Swaziland and two localities in the Transvaal, and stated that these larvae are exceedingly common in African freshwater fishes. Whitfield & Heeg (1977) recorded the larval *Contracaecum* spp. from five species of marine fishes as well as from catfish and Mozambique bream in Lake St Lucia. Mashego & Saayman (1981) stated that *Contracaecum* spp. larvae occur in catfish, silver barbel and 14 *Barbus* spp. in Lebowa and Venda. Van As & Basson (1984) and Mashego (1989), however, list only five *Barbus* spp. as being infected and Van As & Basson (1984) did not include the record from silver barbel in their host-parasite check-list. Boomker (1982) recorded canary kurper, *Chetia flaviventris*, as yet another host, and spot-tailed robbers and tiger-fish are recorded here as new hosts for the nematodes.

As far as their intermediate and paratenic hosts are concerned, *Contracaecum* spp. larvae do not seem to be host specific and a variety of marine and freshwater fishes can be infected. However, Thomas (1937) was unable to recover adult *Contracaecum* spp. from experimentally infected domestic ducks and chickens, thereby implying a degree of specificity for the final host. Whitfield & Heeg (1977) also reported a certain degree of host specificity of the adult nematodes.

From this and previous surveys it would appear that larger fishes, such as catfish and tiger-fish, are major paratenic hosts of *Contracaecum* spp. larvae. The nematodes were recovered from 46,5% of all catfish examined in the Kruger National Park as opposed to the 57% and 100% recorded by Mashego & Saayman (1981) and Boomker (1982), respectively. The numbers of worms recovered from catfish range from 1–2860 (Mashego & Saayman 1981) to 53–775 (Boomker 1982) and 1–351 (this study). Similarly, the tiger-fish from the Crocodile River harboured 90–266 larvae and those from the Olifants River 31–42. This possibly indicates either that greater numbers of *Contracaecum* spp. larvae occur in water bodies which support large piscivorous bird populations (many of which could be the final hosts of the nematodes), or that the intermediate host is more plentiful in dams than in streams or rivers. In addition, infection with

Contracaecum spp. larvae seems to be cumulative, with larger (and therefore older) fishes having more worms.

Spirurida: Camallanidae

The single *Camallanus* sp. male recovered from *Labeo molybdinus* was badly damaged and could not be identified to species level. The genus appears to be uncommon in African freshwater fishes and only *Camallanus kirandensis* from a *Barbus* sp. in Tanzania, *Camallanus lacustris* from *Lucioperca sandra* in Egypt, *Camallanus ctenopomae* from *Ctenopoma kingsleyae* in Senegal and a female *Camallanus* sp. from *Barbus paludinosus* in South Africa, have thus far been recorded (Baylis 1923; Khalil 1971; Vassiliades & Petter 1972; Mashego 1989).

Paracamallanus cyathopharynx has previously been recorded in Africa only from the clariid fishes, *Clarias* and *Heterobranchus* (Khalil 1971; Moravec 1974a, b; Mashego & Saayman 1981; Boomker 1982; Van As & Basson 1984), and some aspects of its biology have been summarized by Mashego & Saayman (1981) and Boomker (1982). The former authors do not state the prevalence of infection in their study, but 70 % of all the catfish examined during this and a previous survey (Boomker 1982) were infected with the nematodes, indicating that the intermediate host is widespread in both rivers and dams. In this study nematodes were, for the first time in this country, recovered from tiger-fish, squeakers and silver barbel, indicating that the host range may be wider than has thus far been recorded. *Paracamallanus cyathopharynx* should be considered an accidental parasite of tiger-fish and squeakers, but a definitive parasite of catfish and silver barbel.

Although the genus *Procamallanus* contains many species, the only ones recorded from South Africa are *Procamallanus laeviconchus* in catfish (Mashego & Saayman 1981; Boomker 1982; Van As & Basson 1984), and *Procamallanus slomei* and *Procamallanus brevis* from toads (Ivashkin, Sobolev & Khromova 1971). *Procamallanus laeviconchus* is one of the most prevalent and widespread nematodes (Khalil 1971; Moravec 1975) and has been recorded from 23 species of fishes, most often siluroids (Khalil 1971; Moravec 1974a).

The occurrence of one nematode in only one of the catfish (0,9 %), from the Olifants River, is surprising as it was present in 9 % (range 1–23 worms) and 32,5 % (range 1–22 worms) of catfish examined by Mashego & Saayman (1981) and Boomker (1982), respectively. This probably indicates that the intermediate host may have a limited distribution or is more common in dams.

Spirocamallanus daleneae is a recently described nematode of squeakers (Boomker 1993a), and occurred in more than half of the fishes of this species examined from each of the three localities. *Spirocamallanus spiralis*, to which *Spirocamallanus daleneae* is closely related, has not been found in this country, but has been recorded from siluroid fish elsewhere in Africa (Khalil 1971).

The Camallanidae are all ovoviviparous, live larvae escaping with the faeces of the host. The intermediate host is attracted by their movement and consumes them, and further development takes place in this host. The life cycles of *Paracamallanus cyathopharynx* and *Procamallanus laeviconchus* have been described by Moravec (1974b; 1975), who found that copepods are the intermediate hosts. The intermediate host in South Africa is, however, unknown.

Spirurida: Philometridae

Two species of philometrid nematodes have been recorded from African freshwater fishes (Khalil 1971).

They are *Nilonema gymnarchi* from *Gymnarchus niloticus* and *Thwaitia bagri* from *Bagrus bayad* (Khalil 1960; 1965). The nematodes of this family recovered from silver barbel, squeakers and large-mouthed bream in the present survey could not be identified, because of extensive damage.

The life cycles of some of the *Philometra* spp. have been described by Furuyama (1934, cited by Khalil 1969), Molnár (1966) and Moravec (1977a). These authors found that gravid females leave the fishes through the skin, the mouth or the rectum and rupture in the water to release numerous larvae. The larvae are ingested by copepods in which further development takes place and the copepods are in turn ingested by fishes to complete the life cycle.

Spirurida: Rhabdochonidae

Rhabdochona esseniae was recorded from several *Barbus* species, including *Barbus marequensis*, in Lebowa and Venda, South Africa (Mashego 1989; 1990), but Mashego (1990), in his description of the new species, does not mention the type host. Mashego (1989) limited his studies to the north-western part of the Transvaal, with the Loskop Dam in the Olifants River, which forms part of the Limpopo drain-age system, as the most southern locality. *Barbus marequensis*, however, occurs wide-spread in the Transvaal Lowveld (Jubb 1967) and the recovery of *Rhabdochona esseniae* in large-scaled yellowfish in the Sabie River is therefore not unexpected. Although present in only 10 % of the *Barbus marequensis* from the Sabie River examined during this study and in 16 % of those examined by Mashego (1989), the nematode should be considered a definitive parasite of this host. Despite their low prevalence in *Barbus lineomaculatus* (2 %), *Barbus paludinosus* (1 %) and *Barbus trimaculatus* (11 %), the nematodes should also be regarded as a definitive parasite of these hosts.

Rhabdochona versterae is a recently described nematode of spot-tailed robbers in the Sabie River (Boomker & Petter 1993). In view of its occurrence in 61 % of these fishes in this river, it should be considered a definitive parasite of this host. The nematodes were, however, not found in spot-tailed robbers in the Crocodile River.

With the exception of Mozambique bream, *Rhabdochona* spp. were recovered from all the other fish species examined in the Sabie River and only from catfish, silver barbel and squeakers in the Crocodile River, and catfish and squeakers in the Olifants River. The range and prevalence of the *Rhabdochona* spp. in catfish and squeakers in the Sabie and Crocodile Rivers were approximately the same, but considerably more worms were recovered from the small numbers of these hosts examined in the Olifants River. A few worms were recovered from some redbreasted bream from the Sabie and Crocodile Rivers, but many silver barbel in these rivers were infected.

Moravec (1972a) revised the African species of the genus and described the life cycle of *Rhabdochona ergensi* and *Rhabdochona phoxini* in Czechoslovakia (Moravec 1972b, 1977b). In both cases the intermediate hosts were found to be the nymphae of mayflies (Ephemeroptera). The life cycles of the South African species, however, are not known.

Spirurida: Cystidicolidae

Both *Spinitectus petterae* and *Spinitectus zambezensis* are recently described nematodes of catfish and squeakers, respectively (Boomker 1993b). Catfish in the Crocodile River harboured more of these nematodes and more were infected than those in the Sabie River. The two catfish examined in the Olifants River were not infected. In the Sabie River, squeakers harboured more *Spinitectus zambezensis* and more fish were infected than was the case in the Crocodile River. The two squeakers examined in the Olifants River had small burdens. The differences in the intensity and prevalence of infection could be due to the distribution of the intermediate host.

The *Spinitectus* spp. recovered from one of the tigerfish and four of the silver barbel could not be assigned to any known species. Both, however, are closely related to *Spinitectus petterae* in the configuration of the lips, and the number of caudal papillae in the males.

The life cycles of the *Spinitectus* spp. are poorly known and only brief notes on their developmental stages have been published (Moravec 1972b). It appears that *Spinitectus* spp. in Europe utilize mayfly and caddis-fly (Trichoptera) nymphae, as well as freshwater shrimps (Gustafson 1939; Johnson 1966). To the best of my knowledge, no attempt has been made to elucidate the life cycles of any of the *Spinitectus* spp. in Africa and none of the intermediate hosts is known.

Remarks

The determination of the seasonal occurrence of the various nematodes was to a large extent, probably, precluded because not all the fish species were represented during each month of the survey. However, despite some of the fish species being represented monthly, no seasonal pattern of abundance was evident even in these fishes, and nematodes were continuously present, with only minor fluctuations in their numbers.

ACKNOWLEDGEMENTS

The author wishes to thank the Board of Trustees, National Parks Board for making the fishes available, and Drr V. de Vos and L.E.O. Braack for the logistical arrangements. Professor I.G. Horak of the Faculty of Veterinary Science, University of Pretoria, and the staff of the Division Nature Conservation, Skukuza, Kruger National Park, are thanked for assisting with the collections, and Messrs D. Booyse, N. Jonker and J. Sithoi for their excellent technical assistance.

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Onderstepoort Journal of Veterinary Research, 61:197–199 (1994)

RESEARCH COMMUNICATION

Parasites of South African freshwater fish. VII Nematodes of some scaled fishes from the Hartbeespoort Dam, Transvaal

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ABSTRACT

BOOMKER, J. 1994. Parasites of South African freshwater fish. VII. Nematodes of some scaled fishes from the Hartbeespoort Dam, Transvaal. *Onderstepoort Journal of Veterinary Research*, 61:197–199

The nematode parasites of 16 large-scaled yellowfish, *Barbus marequensis*, six silverfish, *Barbus mattozi*, six small-scaled yellowfish, *Barbus polylepis*, 52 canary kurper, *Chetia flaviventris*, 11 carp, *Cyprinus carpio*, 45 Mozambique bream, *Oreochromis mossambicus* and a single-banded bream, *Tilapia sparrmani*, caught in the Hartbeespoort Dam, Transvaal, were collected, identified and counted.

Contracaecum spp. larvae were recovered from one *O. mossambicus*, 40 *Chetia flaviventris*, three *Cyprinus carpio*, one *B. marequensis* and five *B. mattozi*, *Rhabdochona esseniae* from five *B. marequensis*, *Rhabdochona* spp. from one *O. mossambicus* and four *Cyprinus carpio*, and unidentified nematode larvae from two *O. mossambicus*, three *Chetia flaviventris*, two *Cyprinus carpio* and from the single *T. sparrmani*. Burdens in the infected fishes were generally small, and small-scaled yellowfish did not harbour any worms.

Only Mozambique bream and canary kurper were caught at regular intervals, but even in these species no pattern of seasonal prevalence of the nematodes was evident.

INTRODUCTION

The nematode parasites of freshwater fishes in South Africa are poorly known and only a few papers dealing with incidental findings, surveys, taxonomy and diseases or mortalities caused by these worms, have appeared (Lombard 1968; Whitfield & Heeg 1977; Jackson 1978; Bruton 1979; Mashego & Saayman 1981; Mashego 1989, 1990; Boomker 1982, 1993a, b; Boomker & Petter 1993). Host-parasite lists for many of the fish species were first established by Khalil (1971) and Van As & Basson (1984).

Received 24 March 1994—Editor

The nematodes recovered from catfish examined in a survey conducted in the Hartbeespoort Dam, Transvaal, during 1979 have previously been reported (Boomker 1982). The present paper records the species and numbers of nematodes present in the scaled fish species collected at the same time.

MATERIALS AND METHODS

All the fishes were caught in the Hartbeespoort Dam (25°42'–25°45'S; 27°48'–27°54'E), which is situated about 40 km to the west of Pretoria, Transvaal. All were collected at the same time and sites, and in the same manner as previously reported for catfish (Boomker 1982).

A total of 137 fishes, comprising 16 large-scaled yellowfish, *Barbus marequensis*, six silverfish, *Barbus mattozi*, six small-scaled yellowfish, *Barbus polylepis*, 52 canary kurper, *Chetia flaviventris*, 11 carp, *Cyprinus carpio*, 45 Mozambique bream, *Oreochromis mossambicus* and one banded bream, *Tilapia sparrmani*, were collected and examined. All the nematodes were removed, identified and counted with the aid of a compound microscope with interference contrast illumination.

With the exception of July 1979 (*O. mossambicus*) and July and August 1979 (*Chetia flaviventris*), *O. mossambicus* and *Chetia flaviventris* were caught during every month of the survey. The parasites of the other fish species were collected as the fish became available.

RESULTS AND DISCUSSION

No helminths were recovered from *B. polylepis*. The nematodes recovered from the other fish species are listed in Table 1. The terms "intensity" and "prevalence" are used here in accordance with the definitions given by Margolis, Esch, Holmes, Kuris & Schad (1982).

Contracaecum spp. have been recorded from a large variety of freshwater and marine fishes (Prudhoe & Hussey 1977; Whitfield & Heeg 1977; Mashego & Saayman 1981; Boomker 1982, 1994; Van As & Basson 1984). These nematodes were recovered from *O. mossambicus* for the first time by Whitfield & Heeg (1977) who found a prevalence of 15 %. In this study, a single *O. mossambicus* harboured one *Contracaecum* sp. larva, while none of the 83 *O. mossambicus* examined in a separate survey in the Kruger National Park were infected (Boomker 1994).

Mashego (1989) recovered *Contracaecum* spp. larvae from five *Barbus* spp. in Lebowa and Venda, and recorded a prevalence of 13 % and 50 % in *B. marequensis* and *B. mattozi*, respectively. In this study both the prevalence and intensity of these nematodes in *B. marequensis* were lower than those recorded by Mashego (1989). The prevalence in *B. mattozi*, however, was considerably higher, while the intensity was almost the same as that noted by Mashego (1987).

Chetia flaviventris has previously been mentioned as a host for *Contracaecum* spp. larvae (Boomker 1982). After *B. mattozi* these fishes had the highest incidence and prevalence of these larvae, which is rather surprising, when one considers the relatively small size of the fish (159 ± 34 mm as opposed to 330 ± 109 mm for *B. mattozi*).

The *Rhabdochona* spp. recovered from *O. mossambicus* and *Cyprinus carpio* in this study could not be identified to species level. Those recovered from

TABLE 1 The mean total intensities, range and prevalence of larval and adult nematodes of scaled-fish species in the Hartbeespoort Dam, Transvaal

Host and parasite species	Mean total intensity		Range	Prevalence
	Larvae	Adults		(%)
Oreochromis mossambicus (45 fish)				
Contracaecum sp.	1	–	–	2,2
Rhabdochona sp.	0	1	–	2,2
Unidentified nematode larvae	5	–	1–4	4,4
Chetia flaviventris (52 fish)				
Contracaecum spp.	6	–	1–15	76,9
Unidentified nematode larvae	1	–	1–2	5,8
Tilapia sparrmani (1 fish)				
Unidentified nematode larva	1	–	–	100,0
Cyprinus carpio (11 fish)				
Contracaecum spp.	5	–	1–12	27,3
Rhabdochona spp.	0	4	1–5	36,4
Unidentified nematode larva	1	–	–	18,2
Barbus marequensis (16 fish)				
Contracaecum spp.	7	–	–	9,1
Rhabdochona esseniae	–	2	1–7	31,3
Rhabdochona sp.	–	1	–	9,1
Barbus mattozi (6 fish)				
Contracaecum spp.	14	–	6–28	83,3

– Not applicable

B. marequensis, however, were identified as *R. esseniae*, a nematode recently described from several *Barbus* spp. (Mashego 1989, 1990). Mashego (1989) found 16 % of *B. marequensis* in Venda and Lebowa to be infected with this nematode and Boomker (1994), 20 % of the same host in the Kruger National Park. The prevalence in the present study was considerably higher. The mean intensity of nematodes was slightly higher than that recorded by Boomker (1994), but lower than that reported by Mashego (1989) for this host.

The differences in the mean intensities and prevalences in the various fish species are thought to be due to differences in their feeding habits. *O. mossambicus* and *T. sparrmani* feed mostly on vegetable matter, while *Cyprinus carpio* are mainly bottom-feeders. The *Barbus* species and *Chetia flaviventris* are predatory, feeding on a variety of aquatic arthropods. From this and previous studies, it appears that the small *Barbus* spp., as well as *B. marequensis* and *B. mattozi*, and *Chetia flaviventris,* could be highly predatory. Thus the possible high ingestion rate of the intermediate hosts of the *Contracaecum* spp. larvae resulted in the high infection rates.

ACKNOWLEDGEMENTS

The Transvaal Department of Nature Conservation is thanked for placing the material at my disposal. Messrs F. van der Merwe and A. Moolman, Provincial Fisheries, Hartbeespoort, assisted with the collections and Mrs Evelyn Visser and Mr I.L. de Villiers provided technical assistance. This study was partly funded by the Council for Scientific and Industrial Research.

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CONCLUSION

The past 40 years have been exceptional years for me as regards the numerous pleasant hours spent in equally numerous lovely places in South Africa, the opportunity to examine an unprecedented number of hosts and their parasites, helminth, arthropod or pentastomid, the number of new species described or revised, and last, but certainly not least, the number of pleasant people that I have had the honour to work with.