

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 led 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.

HELMINTHS

- BOOMKER, J., 1984. Parasites of South African freshwater fish. II. Redescription of the African species of the genus *Phyllodistomum* Braun, 1899 (Trematoda: Gorgoderidae) and the description of a new species. *Onderstepoort Journal of Veterinary Research*, 51, 129 - 139.
- BOOMKER, J., 1993. Parasites of South African freshwater fish. III. *Rhabdochona* (*Rhabdochona*) *versterae* n. sp. (Nematoda: Rhabdochonidae) from the spot-tailed robber, *Alestes imber* Peters, 1852. *Onderstepoort Journal of Veterinary Research*, 60, 23 - 27.

- BOOMKER, J., 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 *Spirocamallanus spiralis* (Baylis, 1923). *Onderstepoort Journal of Veterinary Research*, 60, 131 - 137.
- 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.
- BOOMKER, J. & PUYLEAERT, F.A., 1994. Eight new *Spinitectus* species with a key to the members of the genus in the Region. *Onderstepoort Journal of Veterinary Research*, 61, 127 - 142.
- MORAVEC, F., BOOMKER, J. & TARASCHEWSKI, H. 2000. *Paraquimperia africana* n. sp. (Nematoda: Quimperidae), a new intestinal parasite of the eel *Anguilla mossambica* Peters, in South Africa. *Journal of Parasitology*, 86, 113 – 117.
- TARASCHEWSKI, H., BOOMKER, J., KNOPF, K. & MORAVEC, F. 2005. *Anguillicola papernai* (Nematoda: Anguillicolidae) and other helminths parasitizing the African longfin eel *Anguilla mossambica*. *Diseases of Aquatic Organisms*, 63, 185-195.

PENTASTOMIDS

- JUNKER, K., BOOMKER, J. & BOOYSE, D.G. 1998. Pentastomid infections in cichlid fishes in the Kruger National Park and the description of the infective larvae of *Subtriquetra rileyi* n. sp. *Onderstepoort Journal of Veterinary Research*, 65, 159 – 167.

HELMINTHS

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 tributary 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

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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 $\frac{1}{3}$ 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 $\frac{1}{3}$ 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 $\frac{1}{3}$ 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 $\frac{1}{3}$ 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 $\frac{1}{3}$ 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 $\frac{1}{4}$ 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 $\frac{1}{3}$ 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.

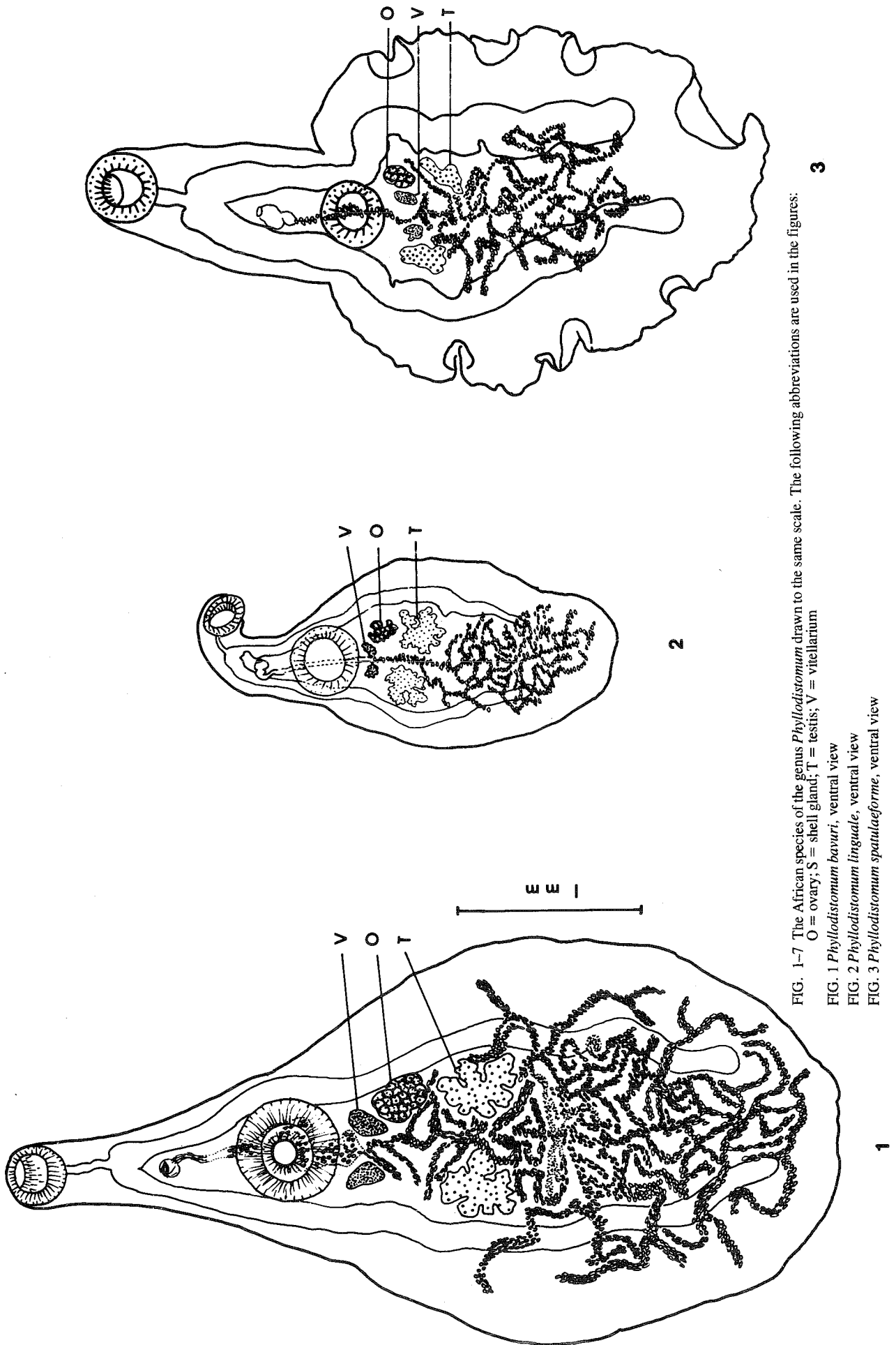
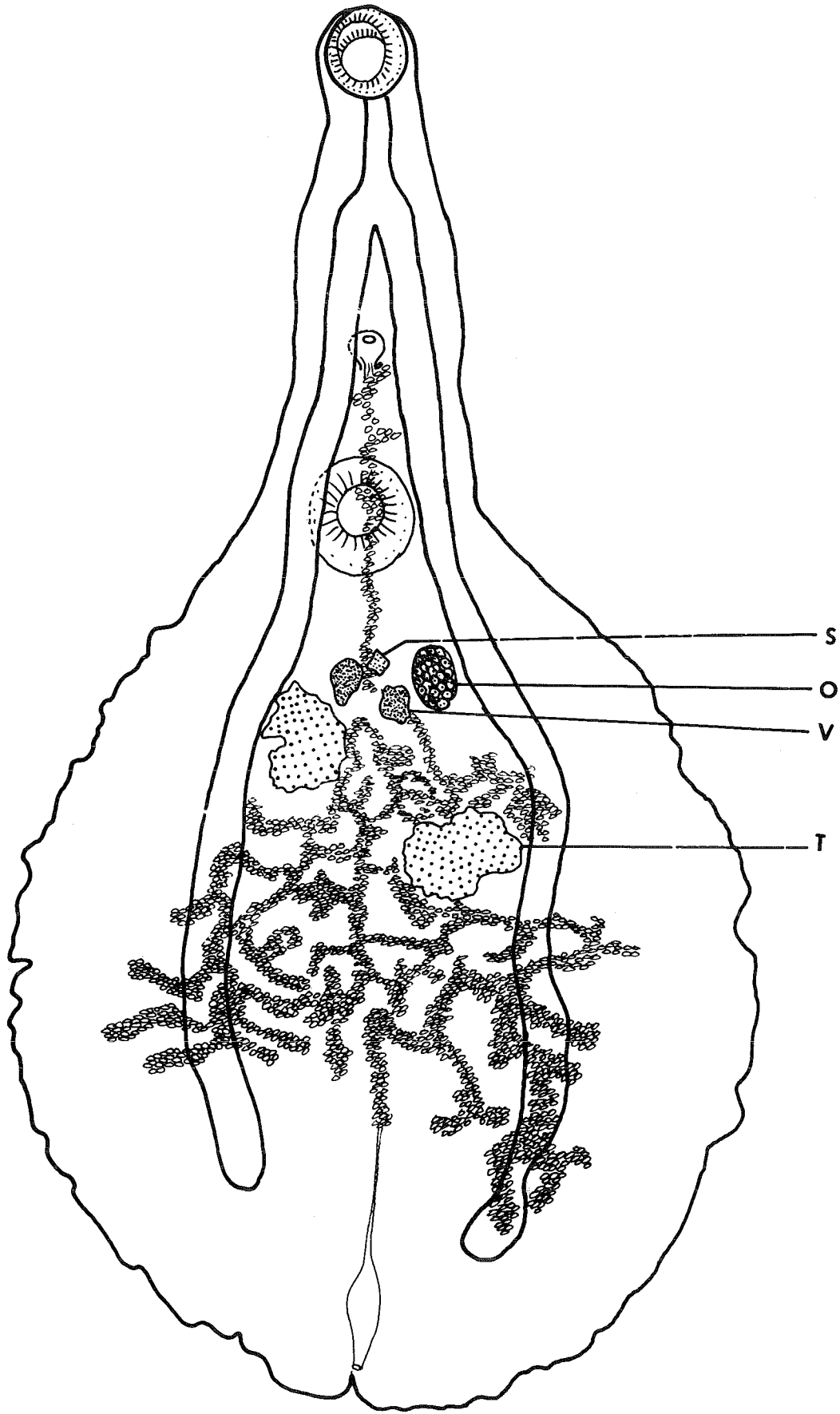


FIG. 1-7 The African species of the genus *Phyllodistomum* drawn to the same scale. The following abbreviations are used in the figures:
O = ovary; S = shell gland; T = testis; V = vitellarium

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

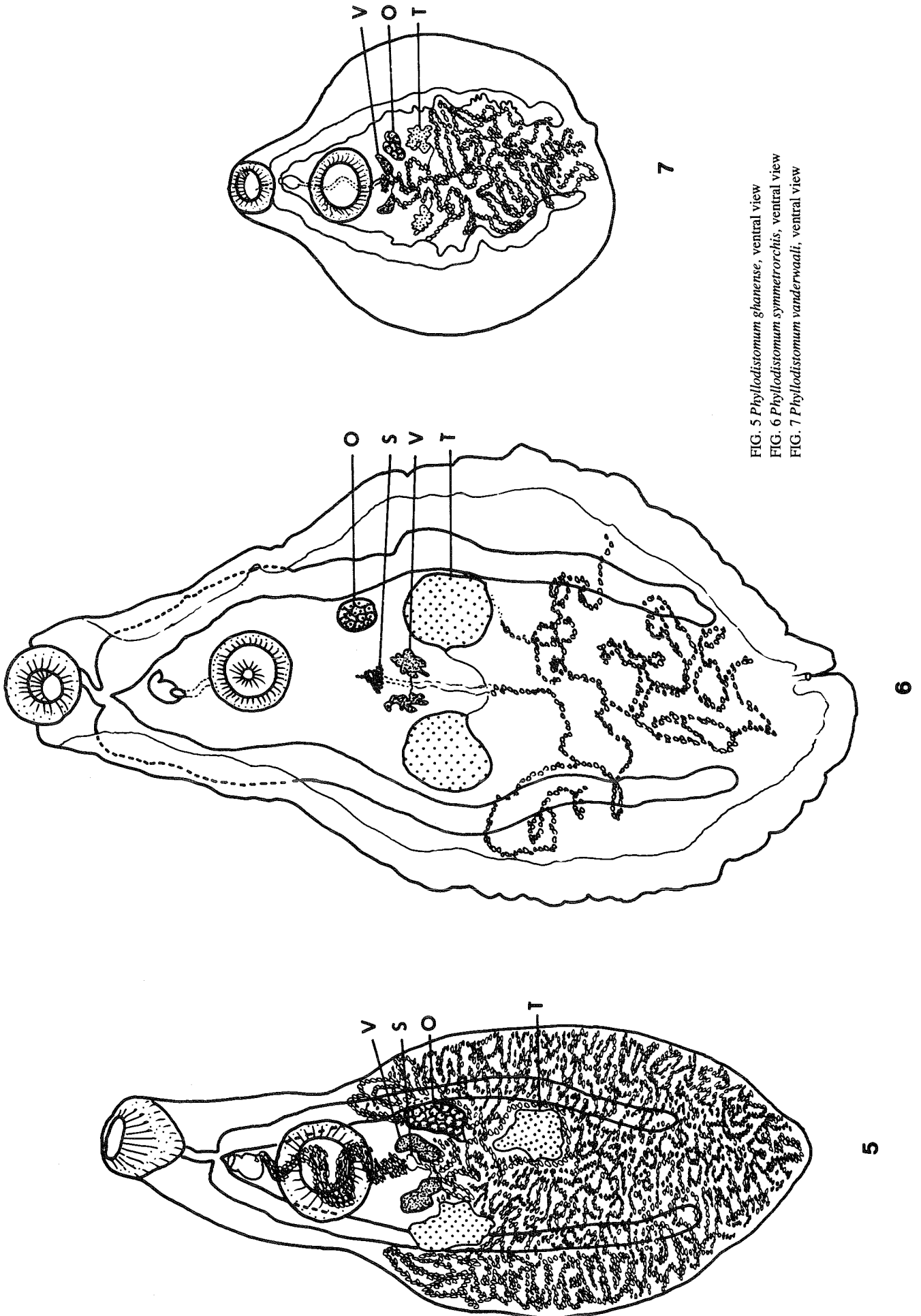


FIG. 5 *Phyllodistomum ghanense*, ventral view
FIG. 6 *Phyllodistomum symmetrorchis*, ventral view
FIG. 7 *Phyllodistomum vanderwaali*, ventral view

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
<i>P. bavuri</i>	—	3,49–5,18	0,99–2,54	0,27–0,36	0,41–0,63	0,99–1,71
<i>P. linguale</i>	Odhner, 1902	5,30	2,30	0,43	0,73	—
	Lewis, 1935	5,36	2,35	0,43	0,73	—
	This paper	2,99	1,48	0,18	0,41	0,78
<i>P. spatulaeforme</i>	Odhner, 1902	4,75	2,80	0,35	0,40	—
	Lewis, 1935	4,75	2,80	0,35	0,40	—
	This paper	4,05	2,20	0,40	0,40	1,25
<i>P. spatula</i>	Odhner, 1902	5,0–5,75	3,3–3,6	0,48	0,52	—
	Lewis, 1935	5,0–5,75	3,3–3,6	0,48	0,52	—
	This paper	5,31–6,35	3,19–3,42	0,36–0,38	0,49	2,07–2,16
<i>P. ghanense</i>	Thomas, 1958	3,65	1,50	0,39	0,50 × 0,53*	—
	This paper	3,69	1,53	0,41	0,54	1,04
<i>P. symmetrorchis</i>	Thomas, 1958	4,34–4,35	2,16–2,69	0,37–0,40 × 0,38–0,42*	0,41–0,45 × 0,41–0,43*	—
	This paper	4,40	2,39	0,40	0,45	1,08
<i>P. vanderwaali</i>	Prudhoe & Hussey, 1977	1,9–2,5	1,3–1,6	0,23–0,25	0,35–0,40	—
	This paper	1,82–2,27	0,63–1,65	0,22–0,25	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		
<i>P. bavuri</i>	—	0,33–0,67	0,21–0,47	0,31–0,61	0,16–0,43	0,19–0,38	0,15–0,32
<i>P. linguale</i>	Odhner, 1902 Lewis, 1935 This paper	— 1–1,5 times size of ovary** 0,27	— 0,30	— 0,25	— 0,26	— 0,285 0,14	— 0,212 0,18
<i>P. spatulaeforme</i>	Odhner, 1902 Lewis, 1935 This paper	— 1–2 times size of ovary** 0,27	— 0,18	— 0,31	— 0,13	— 0,22 0,20	— 0,163 0,14
<i>P. spatula</i>	Odhner, 1902 Lewis, 1935 This paper	— 2–3 times size of ovary** 0,52–0,54	— 0,38–0,43	— 0,49–0,61	— 0,36–0,41	— 0,562 0,27–0,29	— 0,462 0,20–0,25
<i>P. ghanense</i>	Thomas, 1958 This paper	0,42 0,49	0,30 0,32	0,50 0,45	0,40 0,27	0,40 0,40	0,27 0,20
<i>P. symmetrorchis</i>	Thomas, 1958 This paper	0,43–0,49** 0,47	0,40–0,41** 0,43	— 0,47	— 0,47	0,01–0,21 0,22	0,14–0,18 0,20
<i>P. vanderwaali</i>	Prudhoe & Hussey, 1977 This paper	— 0,11–0,27	— 0,09–0,15	— 0,09–0,16	— 0,09–0,15	0,12–0,17 0,13–0,15	0,08–0,12 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		
<i>P. bavuri</i>	—	0,13–0,25	0,08–0,16	0,13–0,23	0,08–0,16	0,036–0,043	0,018–0,032
<i>P. linguale</i>	Odhner, 1902	—	—	—	—	0,033	—
	Lewis, 1935	½–⅓ 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
<i>P. spatulaeforme</i>	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
<i>P. spatula</i>	Odhner, 1902	—	—	—	—	0,030	—
	Lewis, 1935	¼–½ 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
<i>P. ghanense</i>	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
<i>P. symmetrorchis</i>	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	—	—
<i>P. vanderwaali</i>	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			<i>P. bavuri</i> 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 2/3 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 immedi-

ately 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*.

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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 moravecii* 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 pre-cloacal 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 moravecii* 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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**DESCRIPTION OF RHABDOCHONA
(RHABDOCHONA) VERSTERAE**

Type host

Alestes imber 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. imber* 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

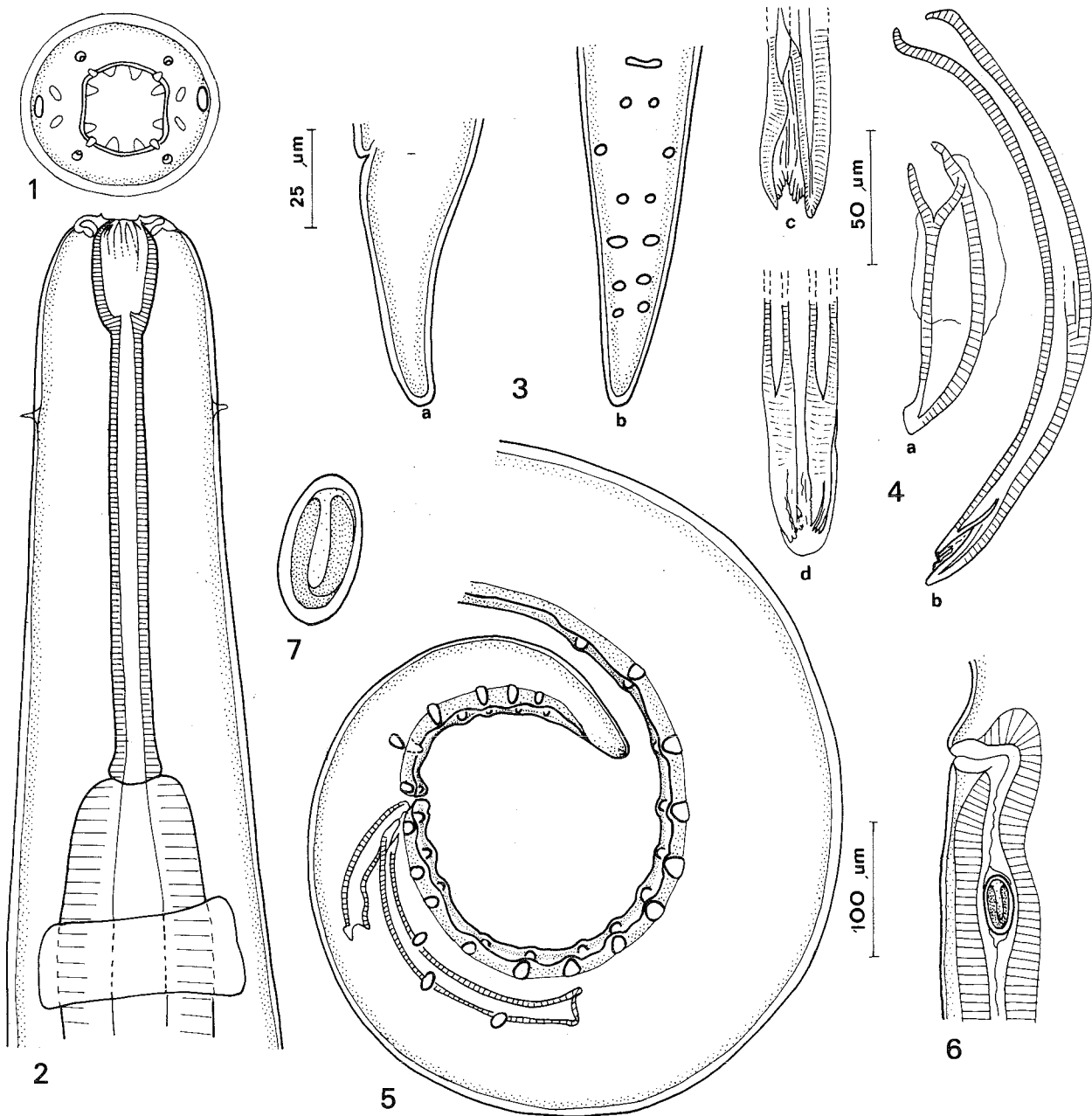


FIG. 1–7 *Rhabdochona versterae* n. sp.

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 of *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. moravecii* 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. moravecii* 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. moravecii* 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.

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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

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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 pericloacal 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					
	<i>Clarias anguillaris</i>	<i>Synodontis eupterus</i>	<i>Synodontis eupterus</i>		<i>Synodontis tessmanni</i>	<i>Synodontis haugi</i>
	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	**
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

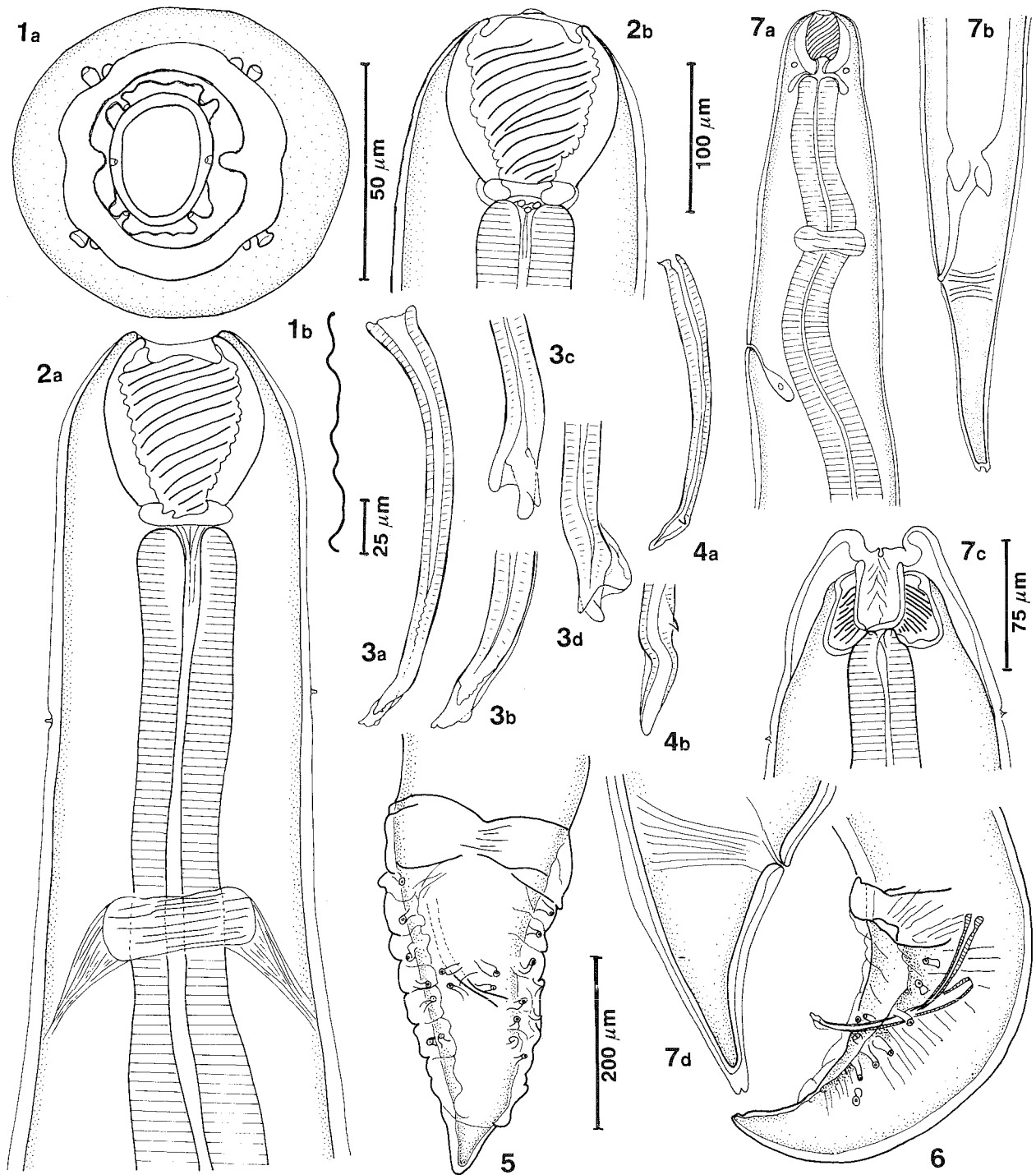


FIG. 1–7 *Spirocamallanus daleneae* from *Synodontis zambezensis*

- 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, mucrons 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* Raillet & 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

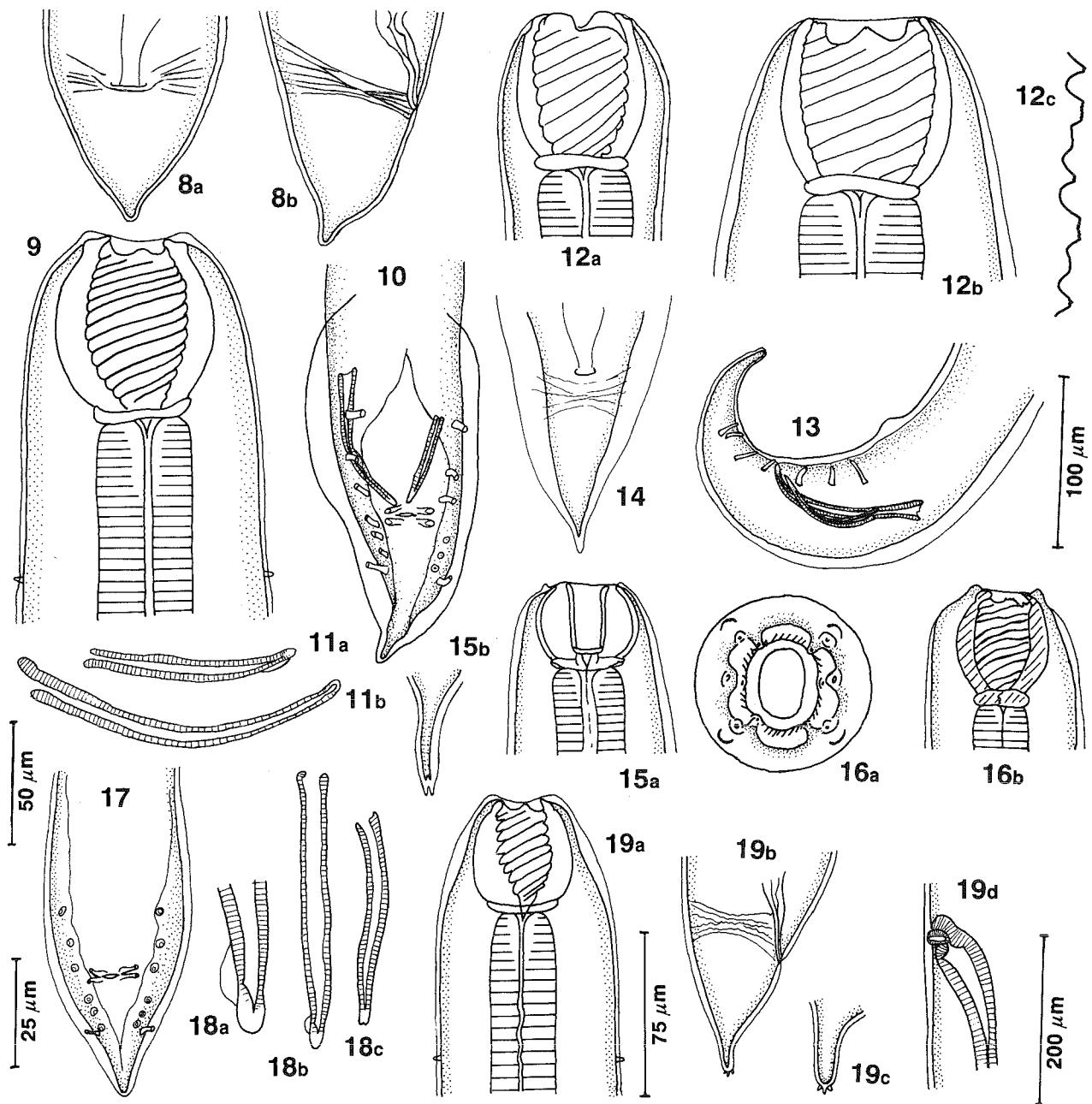


FIG. 8 *Spirocamallanus daleneae* from *Synodontis zambezensis*. Tail of a female in (a) ventral and (b) lateral views

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 μ m—FIG. 18a

50 μ m—FIG. 16a, 16b

75 μ m—FIG. 12a, 12b, 18b, 18c

100 μ m—FIG. 9, 11a, 11b, 15a, 15b, 19a, 19c

200 μ m—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 lato* 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

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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* FOURMONT, 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

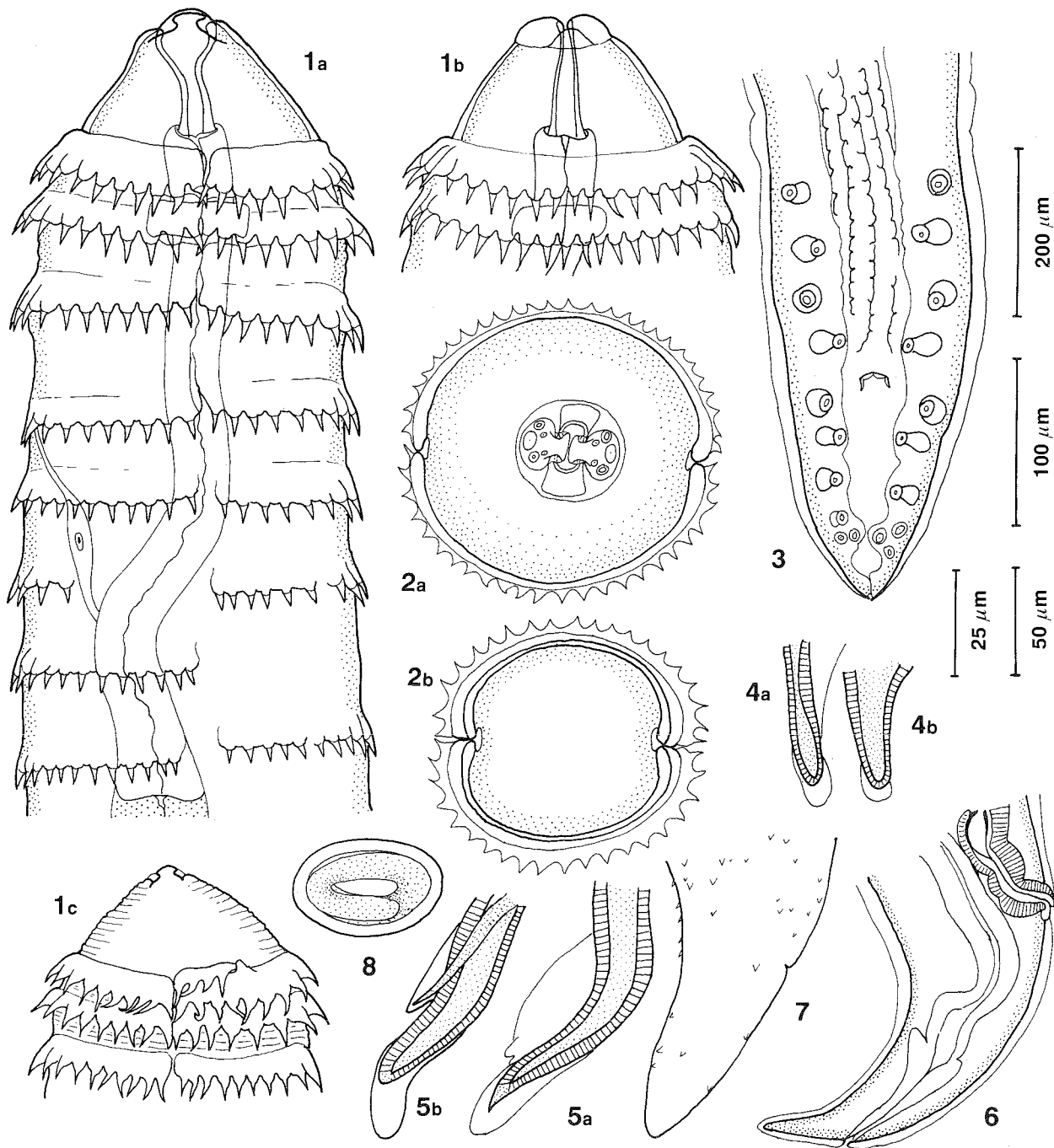


FIG. 1–8 *Spinitectus petterae*

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–

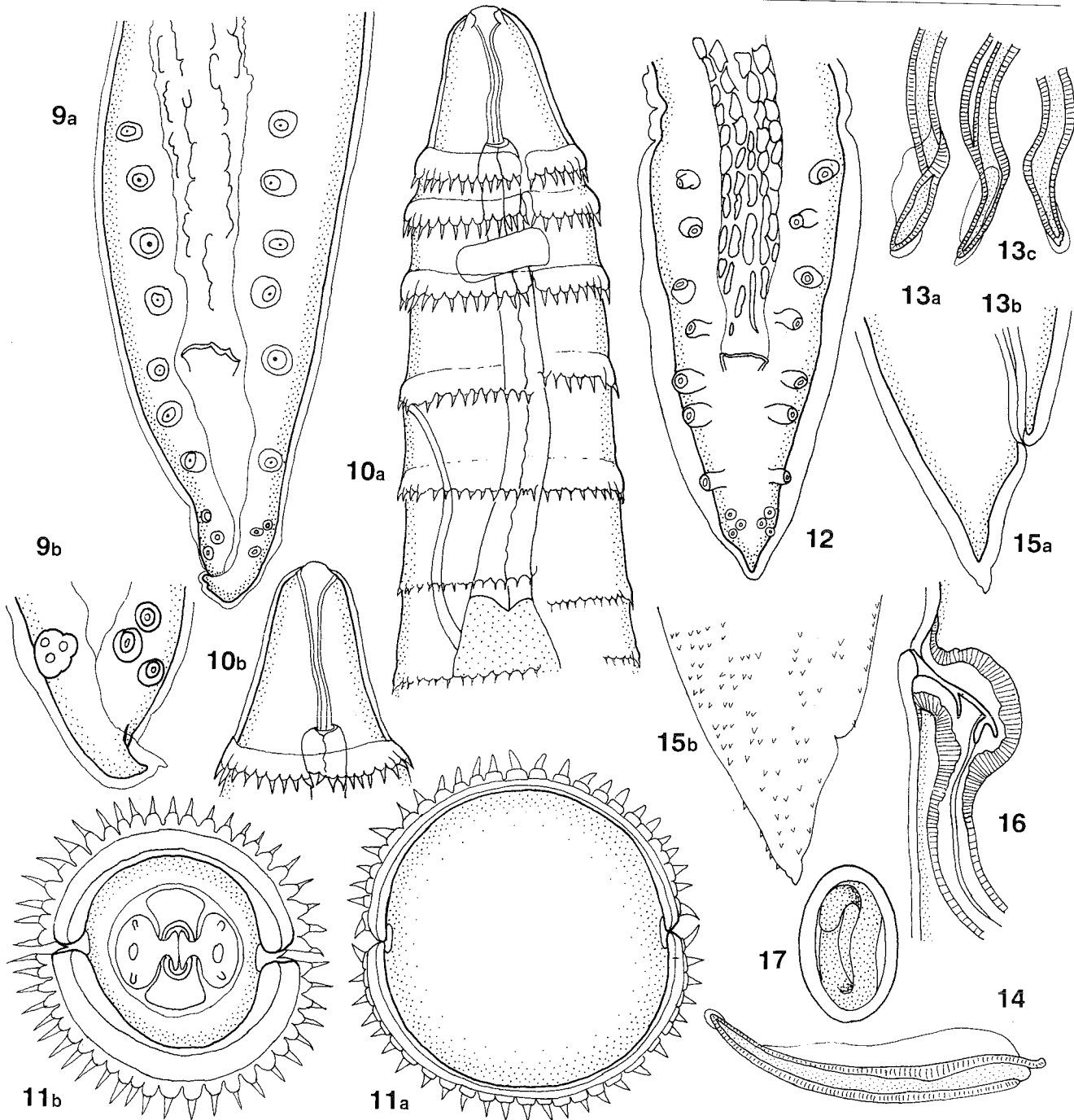


FIG. 9 Abnormalities in the configuration of the caudal papillae; (a) papilla 6 on the left side absent and (b) fusion of papillae 8—10 on the right side

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

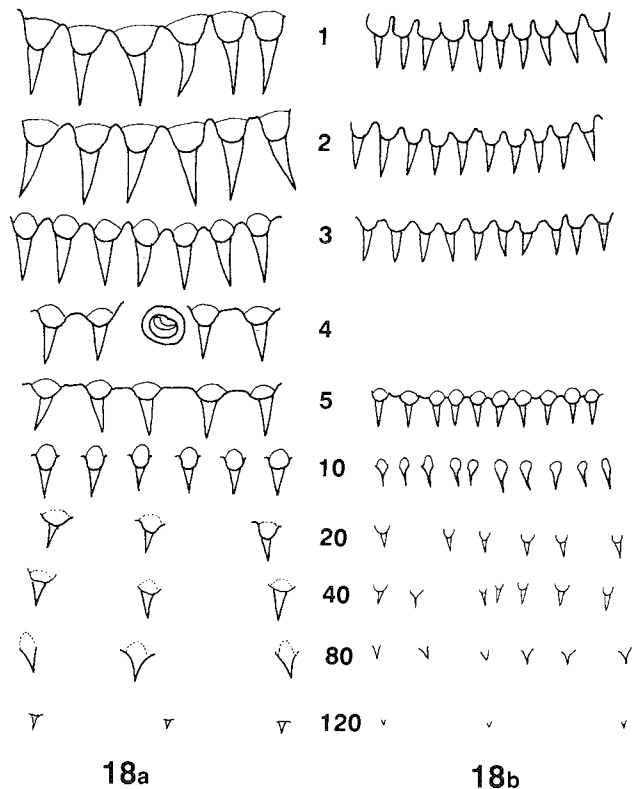


FIG. 18 Spinulation of the holotype males of (a) *Spinitectus petterae* and (b) *Spinitectus zambezensis* drawn to the same scale. Row numbers are indicated, as is the large excretory pore between the spines of row 4 of *Spinitectus petterae*

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

Eight new Afrotropical *Spinitectus* spp. (Nematoda: Cystidicolidae) from freshwater fishes with a key to the members of the genus in the Region

J. BOOMKER¹ and F.A. PUYLEAERT²

ABSTRACT

BOOMKER, J. & PUYLEAERT, 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 maleficus* 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. maleficus*, 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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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 Musée 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. micropectum 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

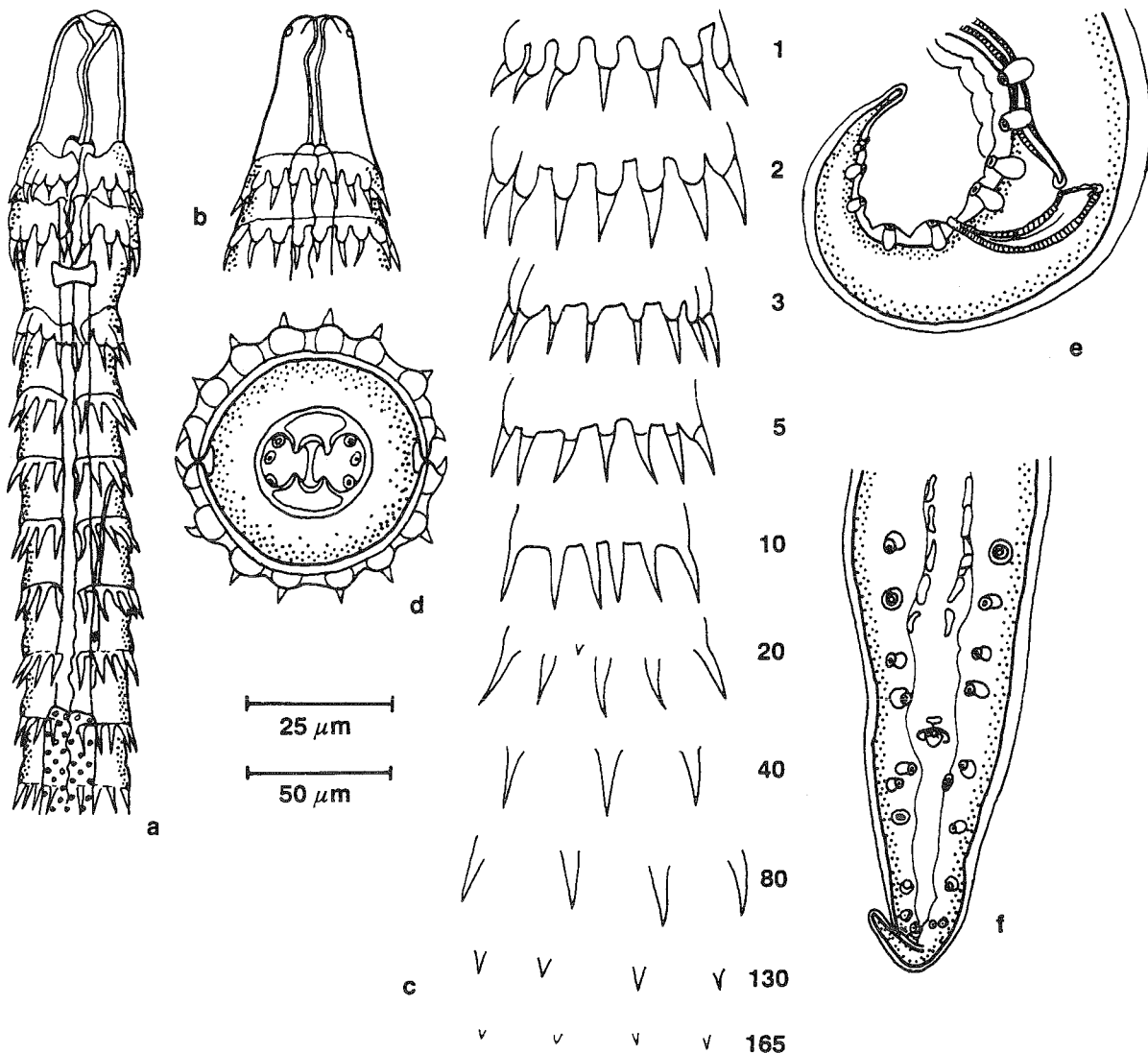


FIG. 1 *Spinitectus micropectum*: a. Anterior end of a paratype male, lateral view. b. Head, holotype male, dorsal view. c. Spines, holotype male, row number indicated. d. Apical structures and cross-section of first row of spines. e. Posterior end, holotype male. f. Posterior end, ventral view, paratype 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

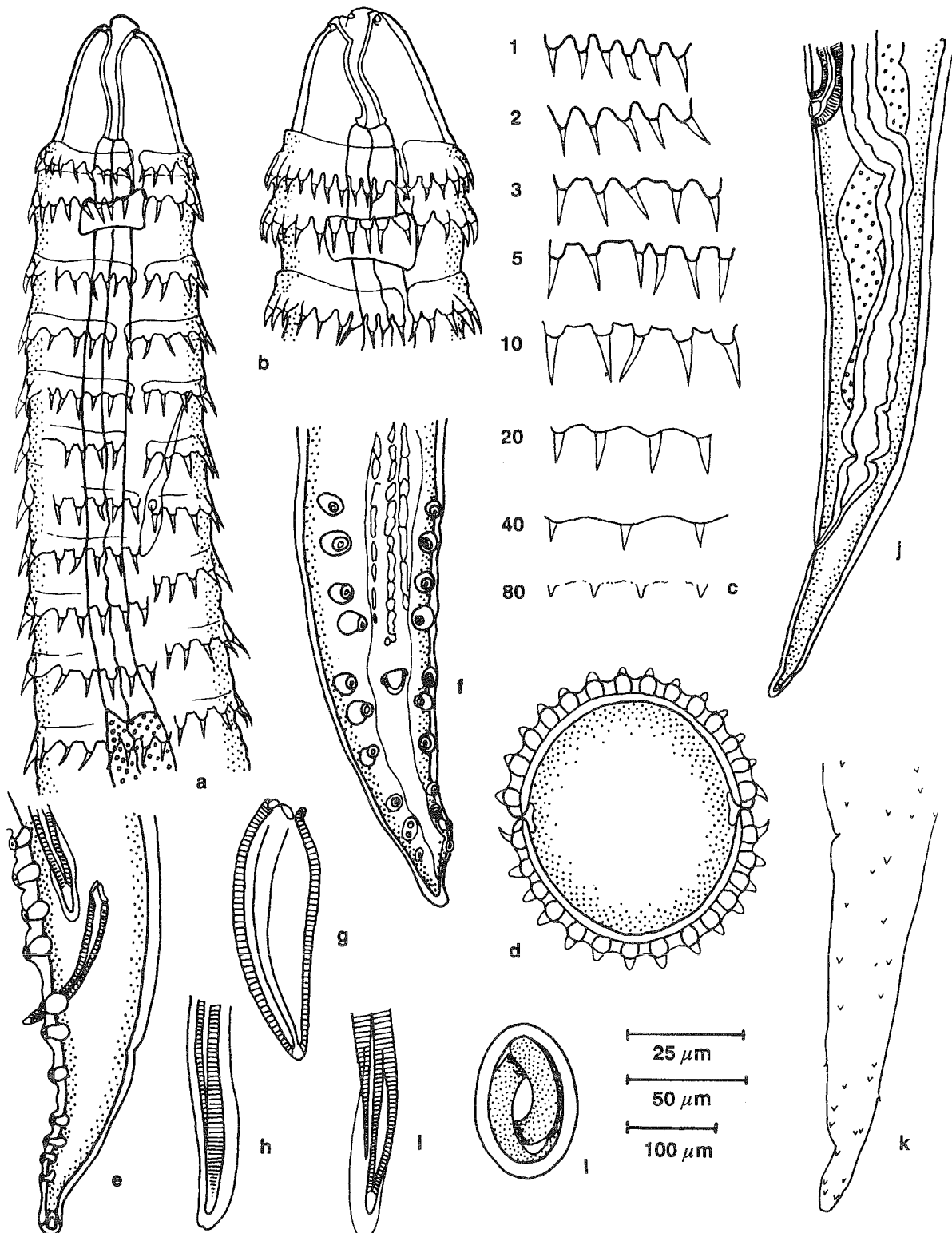


FIG. 2 *Spinitectus maleficus*: a. Anterior end of the holotype male, lateral view. b. Head, lateral view, allotype female. c. Spines, holotype male, row number indicated. d. Anterior row of spines of a male in cross-section. e, f. Lateral and ventral views, male posterior end. g. Right spicule, ventral 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

Eight new Afrotropical *Spinitectus* spp. from freshwater fishes

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 en-

closed 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

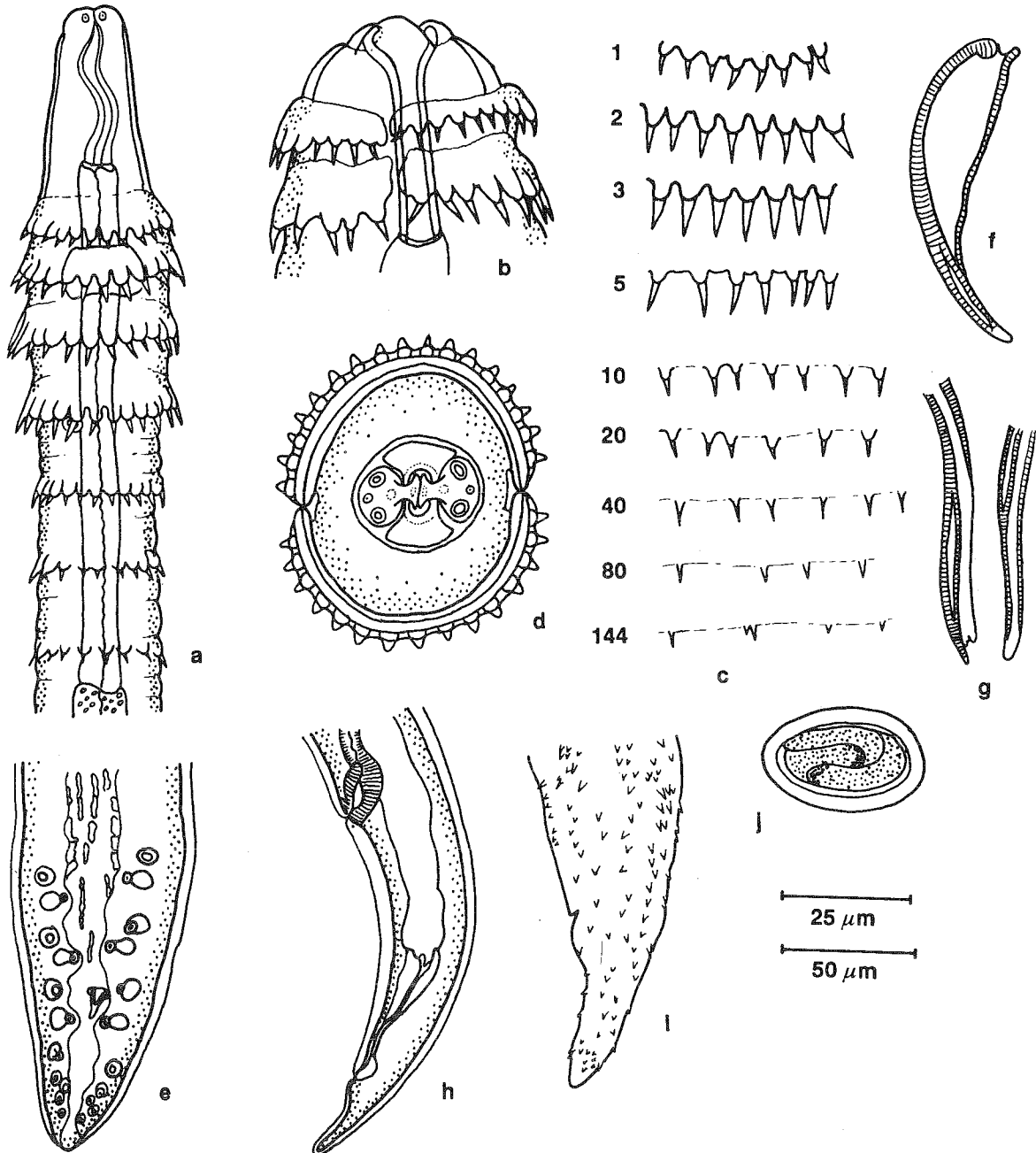


FIG. 3 *Spinitectus macilentus*: a. Dorsal view of anterior end of the allotype female. b. Head, lateral view, holotype male. c. Spines of holotype male, row number indicated. d. Apical structures and cross-section of first row of spines. e. Posterior end, holotype male, ventral view. f. Right spicule, 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.

Eight new Afrotropical *Spinitectus* spp. from freshwater fishes

TYPE HOST

Heterobranchus isoferus (Clariidae).

two females, MRAC 34.784, from *Clarias vanderhorsti*, Zoquin, Ivory Coast, 20.iii.69.

HABITAT

Mucosa of stomach.

ETYMOLOGY

The species is named for its size.

TYPE MATERIAL

Holotype and allotype female, MRAC 34.679, Zoquin, Ivory Coast, date not given. Paratypes, two males and

COMMENTS

S. minusculus differs from *S. macilentus* and *S. maleficus* in having six post-cloacal papillae instead

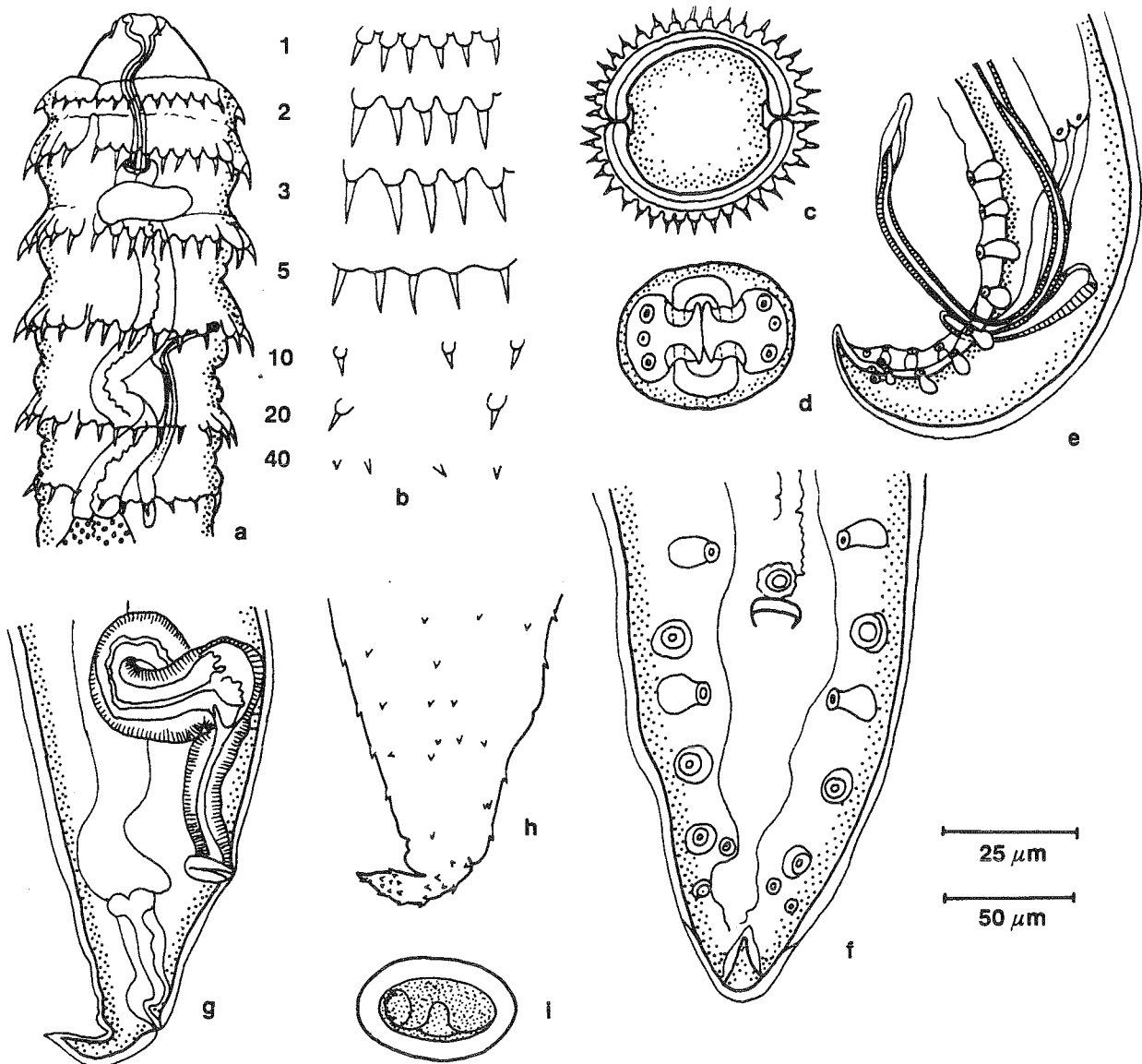


FIG. 4 *Spinitectus minusculus*: a. Lateroventral view of anterior end of the holotype male. b. Spines of holotype male, row number indicated. c. Cross-section of first row of spines of a female. d. Apical structures. e. Posterior end, holotype male, lateral view. f. Ventral view, male posterior end. 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. moravecii* 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. moravecii*, 120–237 in *S. macilentus* and 309–486 in *S. maleficus*).

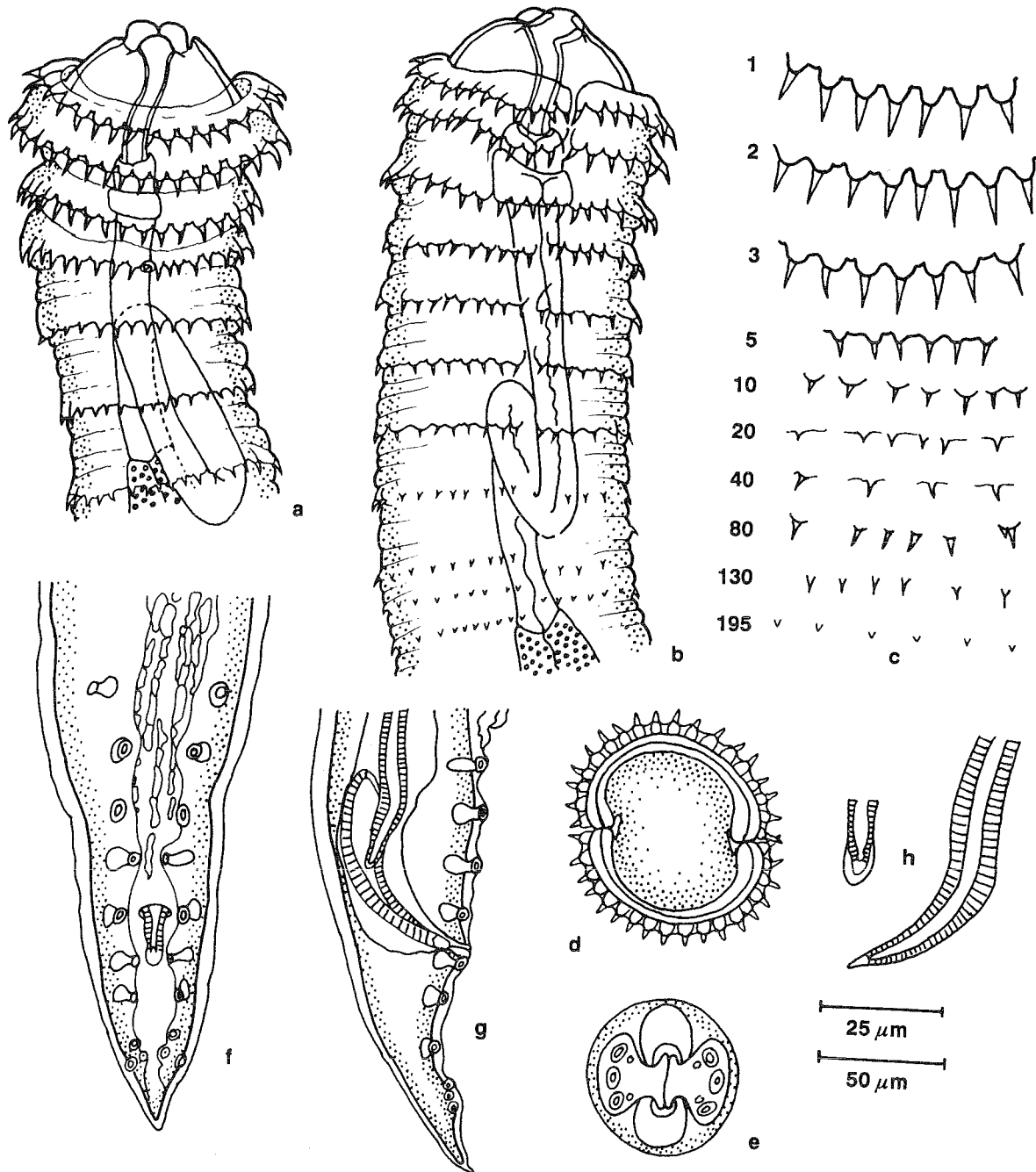


FIG. 5 *Spinitectus macherius*: a. Ventral view of anterior end of the holotype male. b. Lateral view of the anterior part of a paratype male. c. Spines of holotype male, row number indicated. d. Cross-section of the first row of spines of a male. e. Apical structures. f, g. Male posterior end, ventral 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. maleficus* 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

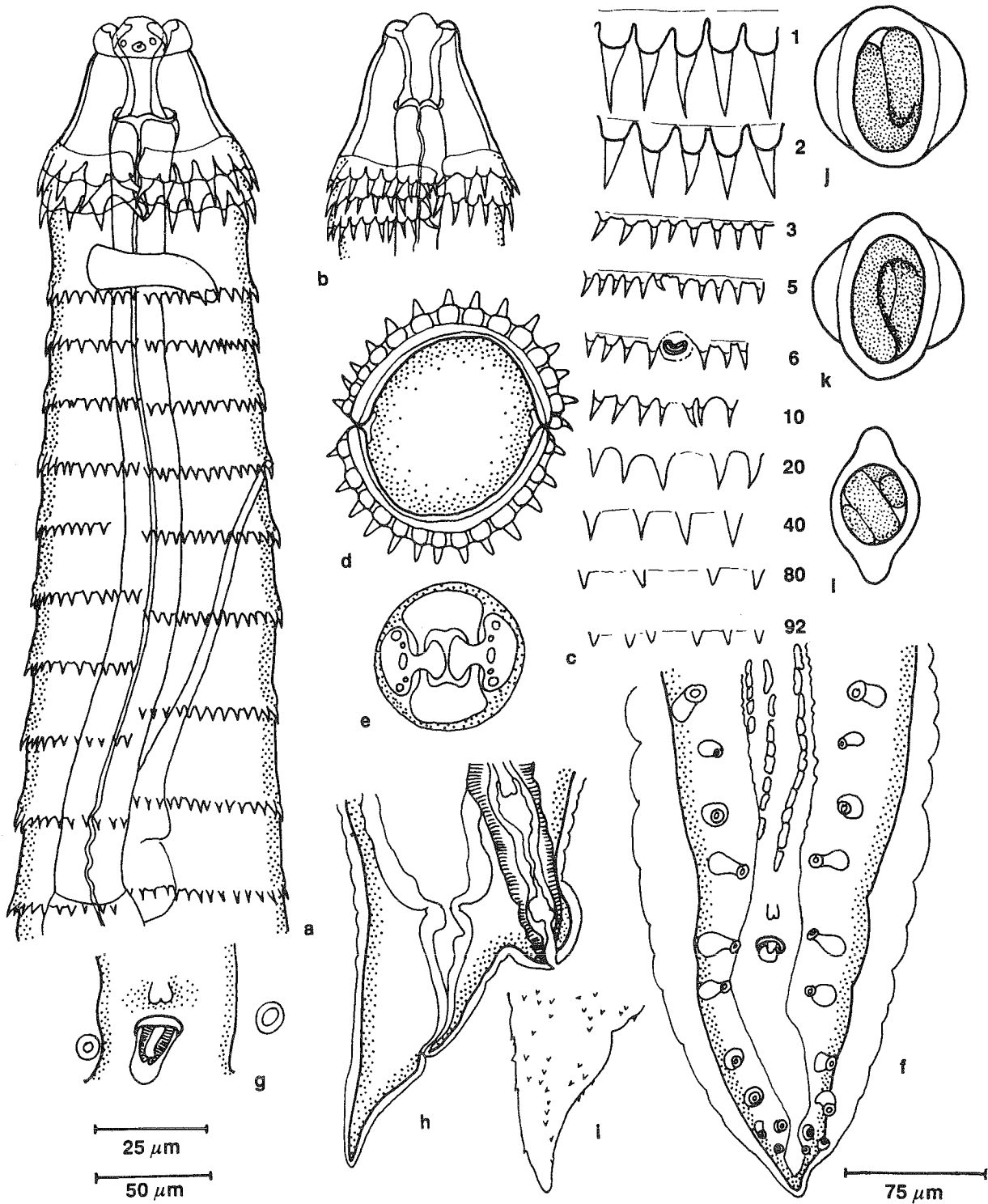


FIG. 6 *Spinitectus mucronatus*: a. Lateral view of anterior end of a paratype male. b. Lateral view of a male showing additional semi-circle of spines. c. Spines of holotype male with row number indicated. d. Cross-section at level of first row of spines. e. Apical structures. f. Male posterior end, 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 zancloirostris*, all others from specimens from *Mormyrops delicosus*

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 zancloirostris*, MRAC 35.740, Libange, Zaire, no date given.

OTHER MATERIAL

Several males and females from *Mormyrops deliciosus*, MRAC 35.759, Doko, 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 semi-circle 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 moravecii 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. maleficus* 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

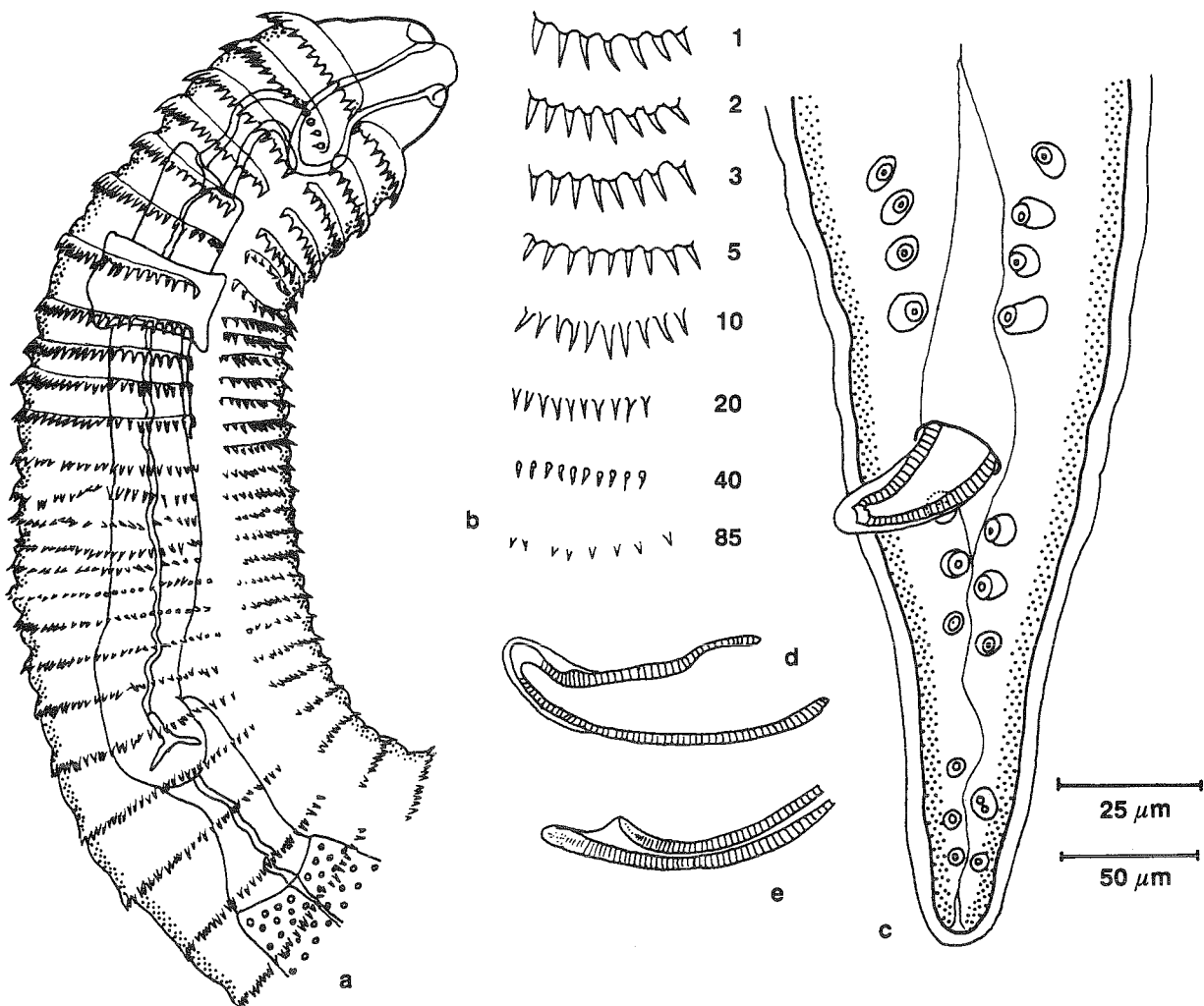


FIG. 7 *Spinitectus monstrosus*: Holotype male. a. Lateral view. b. Spines with row number indicated. c. Ventral view of caudal end. d. Right spicule, lateral view. e. Tip of left spicule, lateral view

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. maleficus*, *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. maleficus* 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 *Mormyrus* 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 *SPINICTECTUS* FOURMONT, 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*, Lake Tanganyika, 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 maleficus*
- 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 oeso-

phagus 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*

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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 phasmsids). 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.

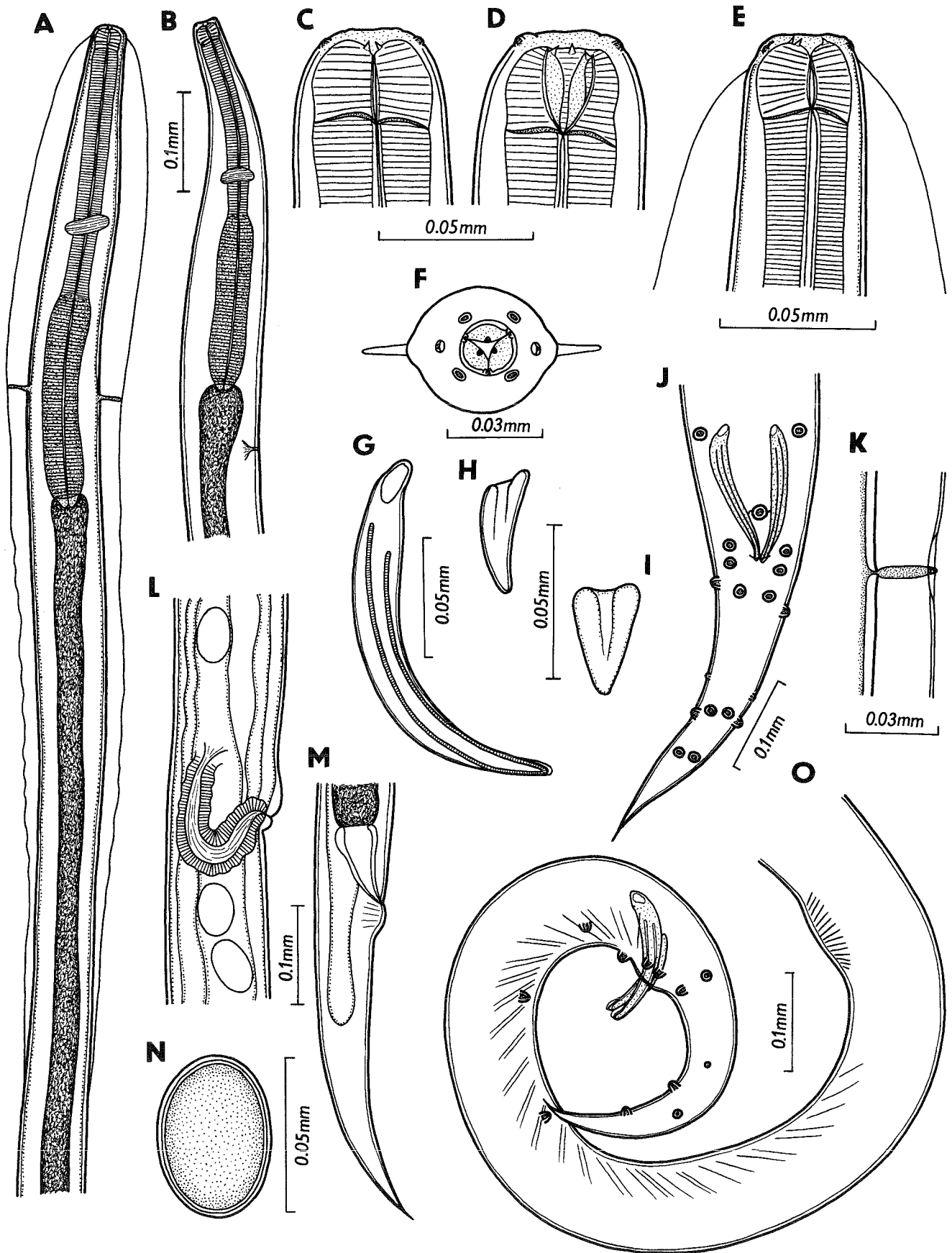
Type locality: Nahoon River, East London, South Africa (27°55'E, 33°10'S) (collected 2 February 1995).

Prevalence and intensity: Sixty-six percent (27 fishes infected/41 fishes examined); 1–10 (mean 4) nematodes per fish.

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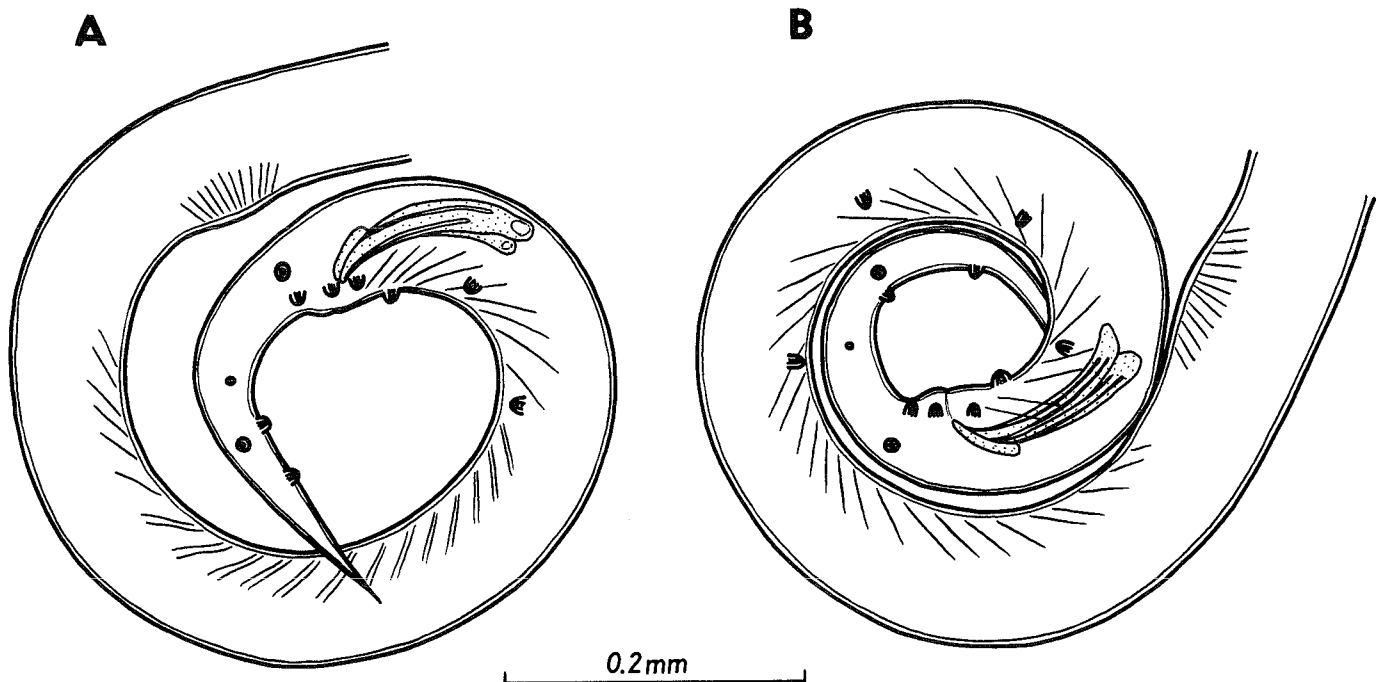


FIGURE 2. *Paraquimperia africana* n. sp., male caudal ends with different numbers of subventral preanal papillae. A. With 3 pairs. B. With 5 pairs.

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. *Paraquimperia 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

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.

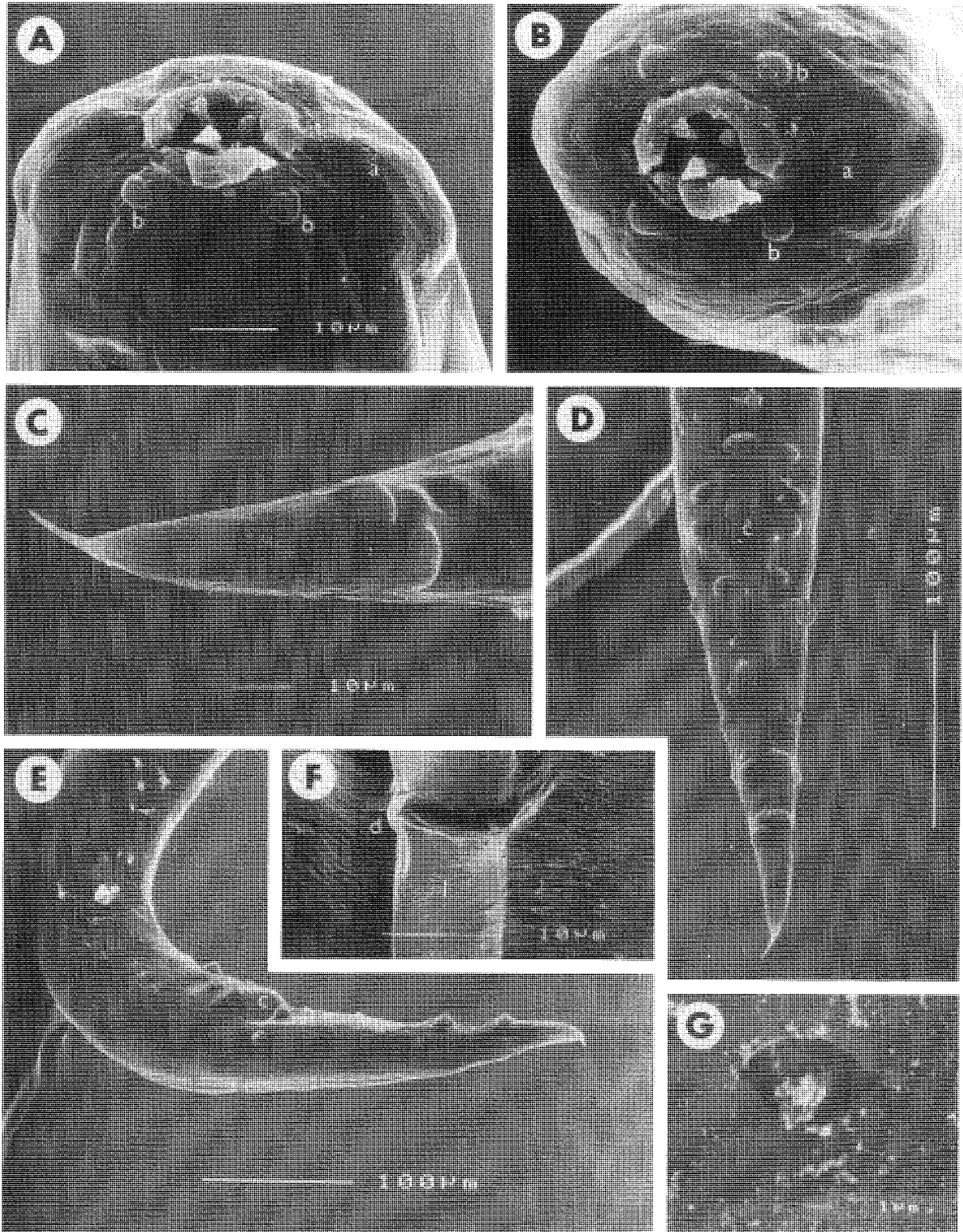


FIGURE 3. *Paraquimperia africana* n. sp., scanning electron micrographs. **A, B.** Cephalic end, dorsoventral and apical views. **C.** Posterior end of male tail, ventral view. **D, E.** Tail of male, ventral and lateral views. **F.** Deirid. **G.** Excretory pore. Abbreviations: **a.** Amphid. **b.** 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.

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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

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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)
<i>Anguillicola papernai</i> 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)
<i>Anguillicola papernai</i> 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)
<i>Paraquimperia africana</i>	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
<i>Heliconema longissimum</i>	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 (<i>Contracaecum</i> 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 *Contraecum* 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 *Contraecum* 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 allochthonous 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.

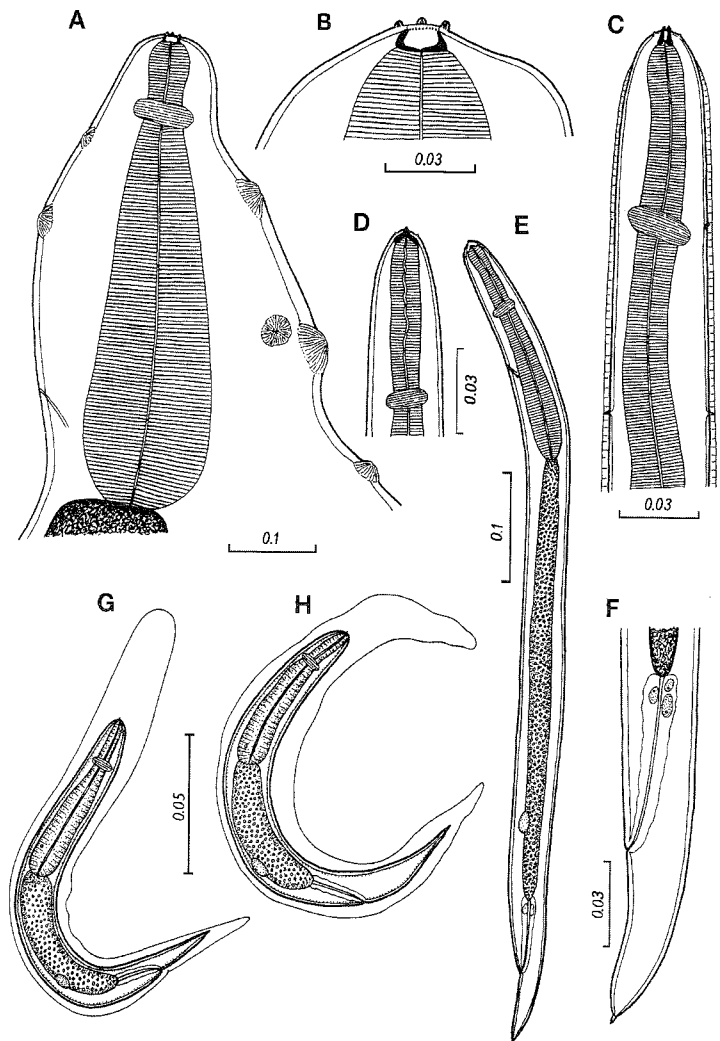


Fig. 1. Ink drawings of *Anguillicola papernai* Moravec & Taraschewski, 1988, from experimentally infected European eels and copepods. Scale bars in mm. (A, B) Gravid female. (A) Anterior end of body; (B) cephalic end. Note the knobs on the outer surface. (C–F) Third-stage larva from the copepod intermediate host. (C) Anterior end, dorso-ventral view; (D) same, lateral view; (E) general view of larva; (F) tail. (G, H) Free second-stage larvae

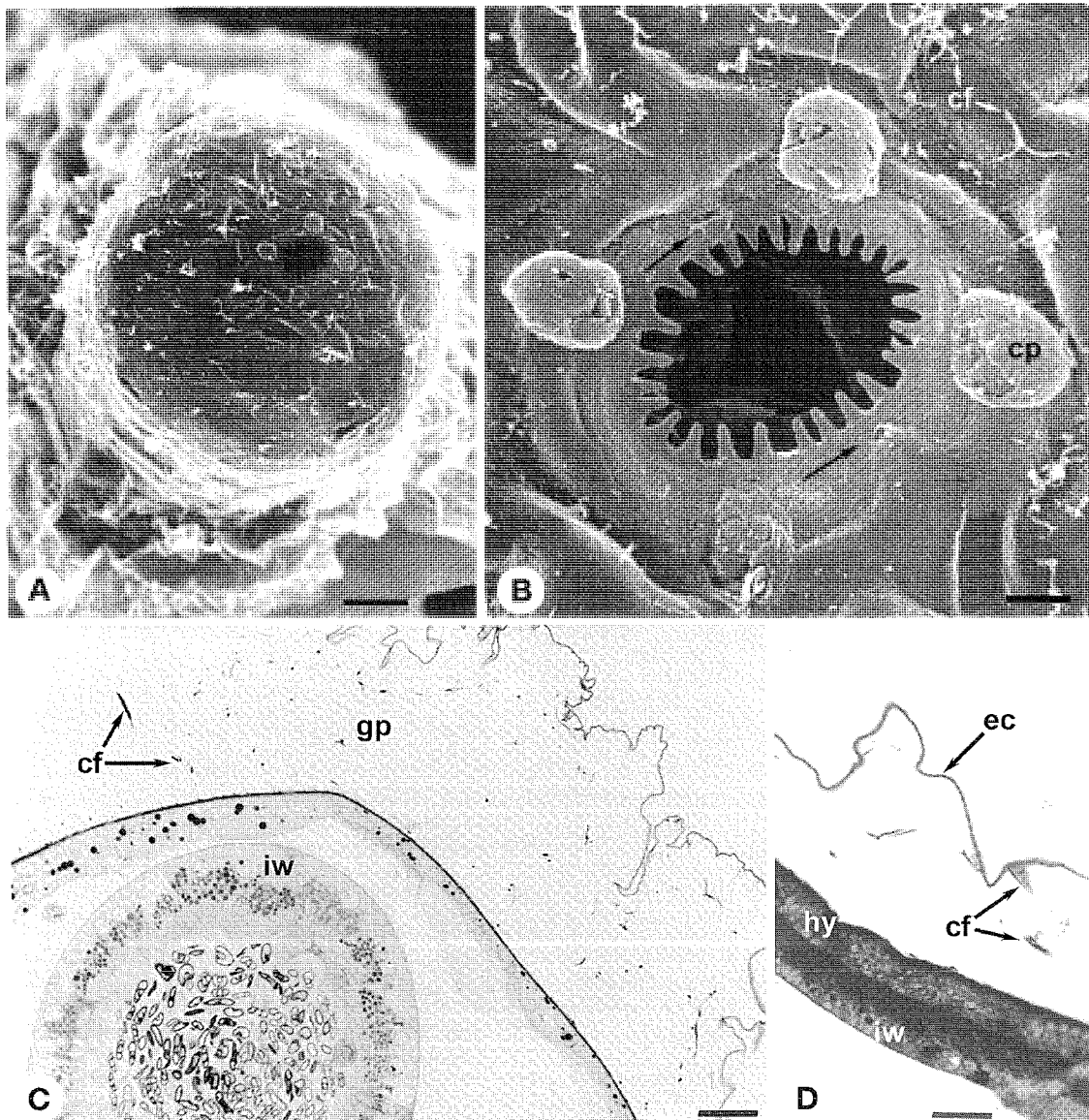


Fig. 2. *Anguillicola papernai* from naturally infected *Anguilla mossambica*. Micrographs showing external features of adult. (A,B) Scanning electron micrographs of the buccal (A) and oral (B) region. Note the 26 (27) oral teeth, and the large dorsolateral cephalic papillae (cp); the 2 lateral amphids (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 μ m, (B) = 3 μ m. (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 μ m. (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 μ m

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 investiga-

tion, 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).

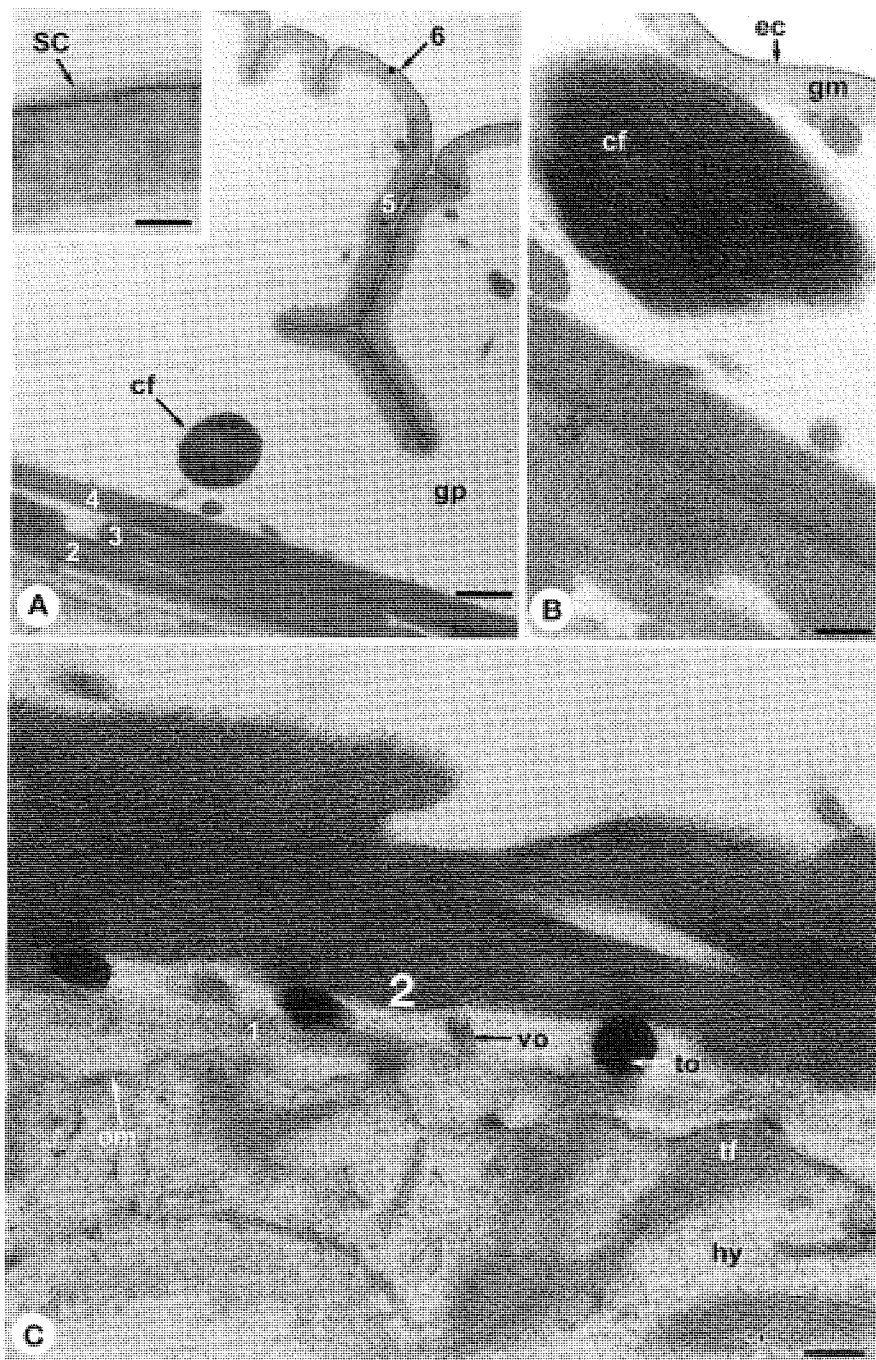


Fig. 3. *Anguillicola papernai* from naturally infected *Anguilla mossambica*. Transmission electron micrographs of cross sections through cuticles and hypodermes of adult. (A) Note the regular arrangement of 3 prominent layers of fibre cords (2–4) in the inner part of the cuticle. The innermost thin, 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 \times 40–63 μm) (but only 12–15 \times 33–42 μm in juvenile forms) as compared to that of fully developed *A. papernai* (9–15 \times 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 L₂, are slightly smaller. In the L₂ it may be partly because only fixed larvae (contracted) were measured. However, live L₂ 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 L₃ 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 L₂, 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 (L₂). In a second experiment using the European copepods, 2 European eels were infected with known numbers of L₃ 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 L₂ (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 novaezealandiae* 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 novaezealandiae* 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. novaezealandiae* 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.

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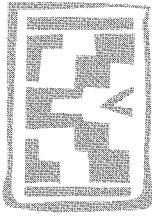
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PENTASTOMIDS



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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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 post-graduate study on pentastomes in South Africa (Juncker 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	<i>n</i>	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	<i>n</i>	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	<i>n</i>	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	<i>n</i>	27,0	1	405,6	314,6	132,6	286,7	567,0

n = not measured

Pentastomid infections in cichlid fishes in the Kruger National Park

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	<i>Tilapia rendalli</i> (n = 185)				<i>Oreochromis mossambicus</i> (n = 119)			
	No. positive	Prevalence	Intensity		No. positive	Prevalence	Intensity	
		%	Mean	Range		%	Mean	Range
<i>Sebekia wedli</i>	75	40,5	1,8	1-8	3	2,5	3,7	1-8
<i>Subtriquetra rileyi</i>	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 morphological 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

Pentastomid infections in cichlid fishes in the Kruger National Park

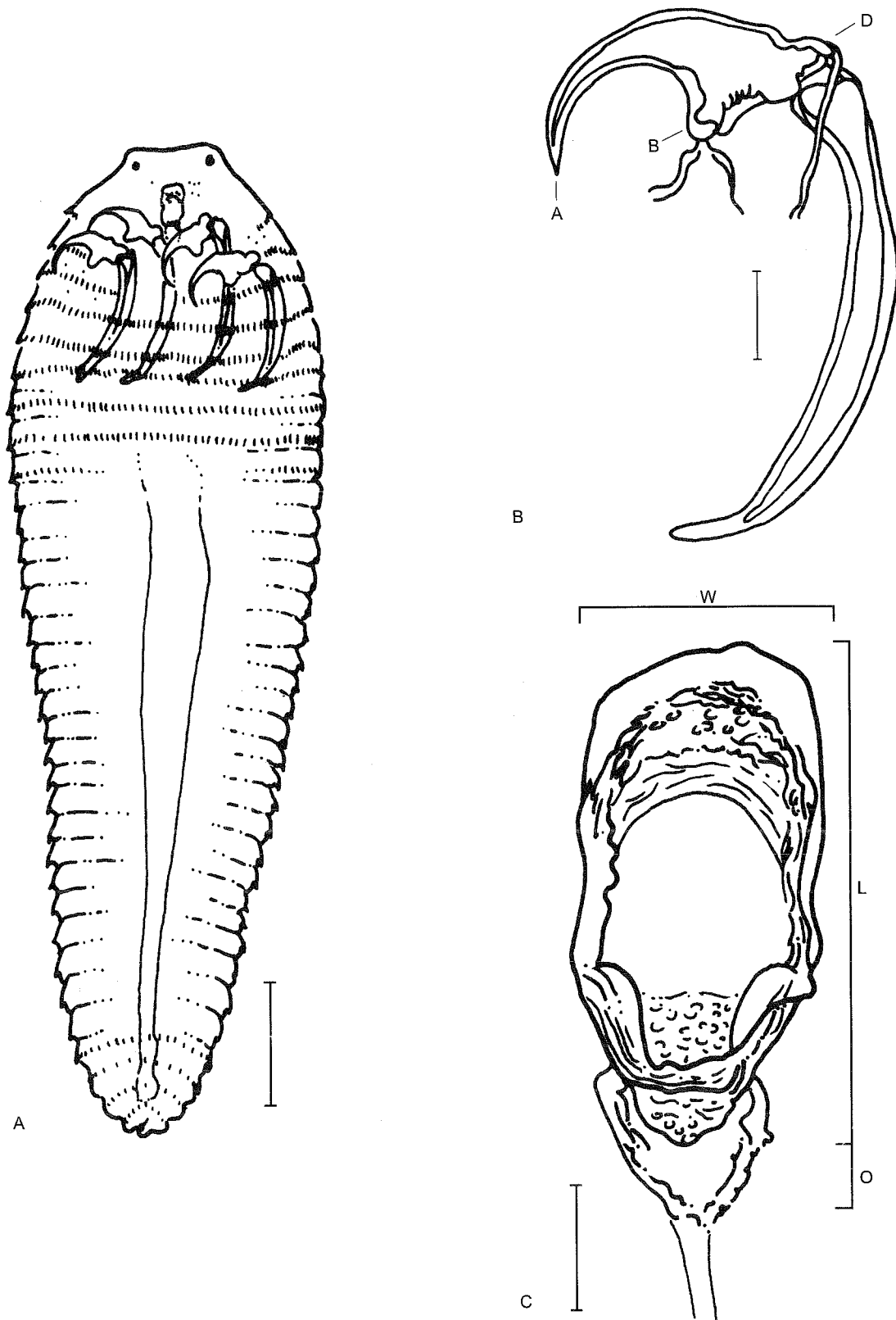


FIG. 1 A. Infective larva of *Subtriquetra rileyi* n. sp. Scale bar: 500 μ m. B. Left posterior hook; length (AD) and base length (BD). Scale bar: 100 μ m. C. Oral cadre. Cadre length (L), overall length (L + O) and width (W) as illustrated. Scale bar: 50 μ m

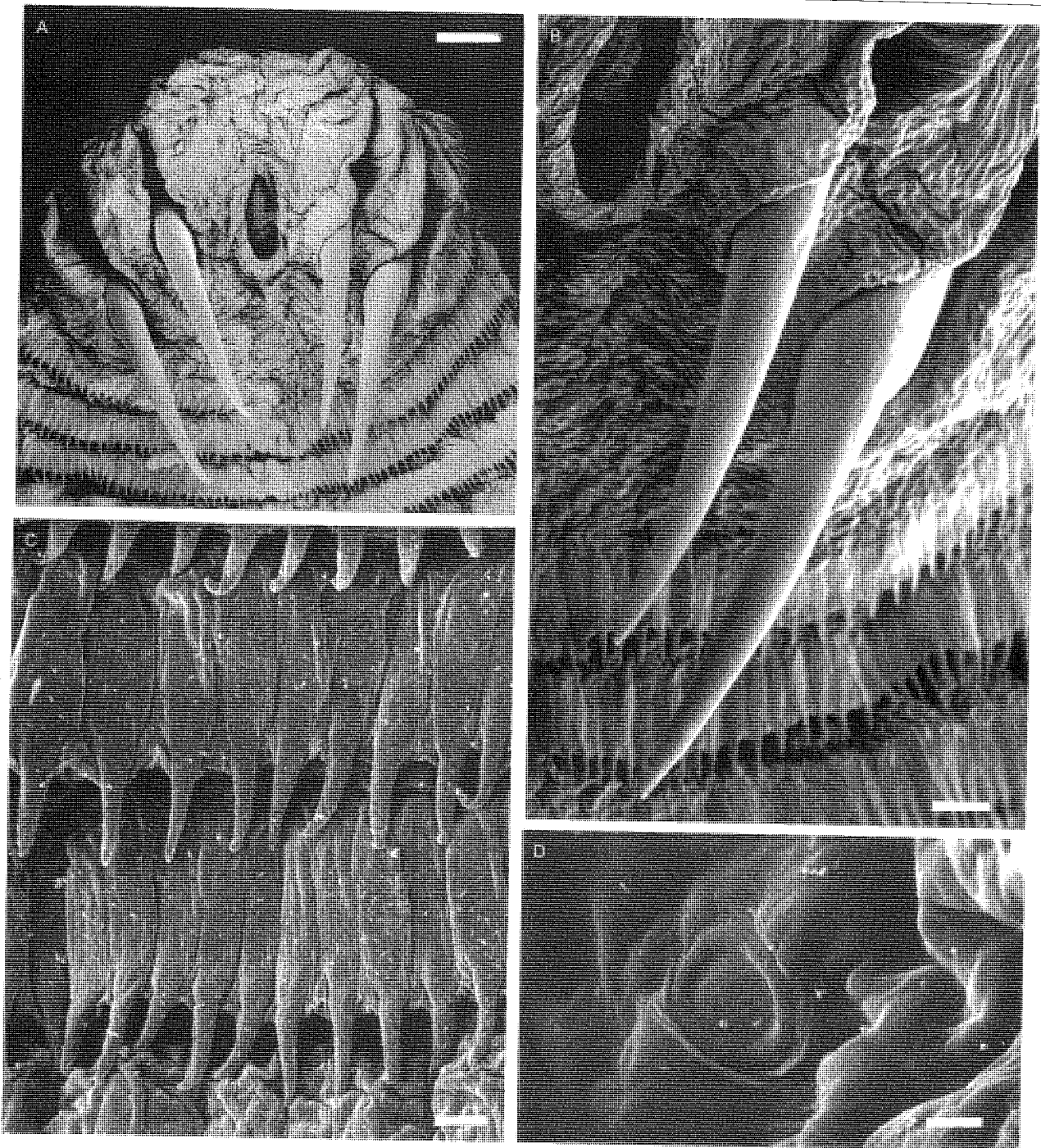


FIG. 2 A. Scanning electron micrograph of an infective larva of *Subtriquetra rileyi* n. sp. showing the oral cadre situated between the two pairs of single hooks and the rows of spines covering the annuli. Scale bar: 60 µm. B. Detail of the left hook pair. The surfaces of the hooks appear finely granular. 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 ($338 \pm 18,7$ and $533 \pm 23,1$ μm vs. $232,8 \pm 3$ μm and $359,2 \pm 3,5$ 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

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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.

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.

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.

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 laeiconchus* (Wedl, 1862), *Contraecaecum* 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 laeiconchus* from 13, while *Contraecaecum* 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 laeiconchus* 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 *Contraecaecum* sp. larvae as the only nematodes occurring in catfish. Ortlepp (1935), Price, McClellan, Druckemiller & 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 laeiconchus* (Wedl, 1862) and *Contraecaecum* 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.

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 μ m. 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 water-bath, after which they were sieved (38 μ m 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 *Contraecaecum* 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 *Contraecum* 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 laeiviconchus* (Wedl, 1862) (Camallanidae), *Contraecum* 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 laeiviconchus* occurred in the stomachs of only 30,2% (13) of the catfish while *Contraecum* sp. larvae were found in the mesenterium of 100%. Some *Contraecum* 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 laeiviconchus* 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 laeiviconchus* 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 laeiviconchus* 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 laeiviconchus*.

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 laeiviconchus (Wedl, 1862) was originally recorded from *Synodontis schaal* from Egypt and described as *Cucullanus laeiviconchus* 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 laeiviconchus* Wedl, 1862.

Moravec (1975) stated that *Procamallanus laeiviconchus* is one of the most prevalent nematodes of fish, and that it has been recorded from fish belonging to the families Clariidae, Mormyridae, Characidae, Siluridae, 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 laeiviconchus* from the catfish, *C. gariepinus* from Lebowa, South Africa, for the first time.

The *Procamallanus* sp. recovered from the Hartbeespoort Dam catfish resembles *Procamallanus laeiviconchus* 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 laeiviconchus*.

Moravec (1974, 1975) studied the life cycle of *Paracamallanus cyathopharynx* and *Procamallanus laeiviconchus* 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 laeiviconchus* collected on a monthly 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 laeiviconchus 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 recovered from *Clarias gariepinus* from Hartbeespoort Dam for the period January, 1979–January, 1980

Fish No.	Date collected	Sex	Length (cm)	<i>Contracaecum</i> sp.		<i>Paracamallanus cyathopharynx</i> (Baylis, 1923)			<i>Procamallanus laeiviconchus</i> (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

L₂=2nd stage larvae

L₃=3rd stage larvae

L₄=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	<i>C. anguillar</i>		<i>C. anguillar</i> and <i>C. lazera</i>		Host not given		<i>C. gariepinus</i>	
	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 *Procammallanus laeviconchus* from different hosts*

Author	Baylis, 1923		Specimens ex collection Looss, this paper		This paper	
Host	<i>B. bayad</i>		<i>B. bayad</i>		<i>C. gariepinus</i>	
	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 *Procammallanus 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 Ascaridoidea 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,

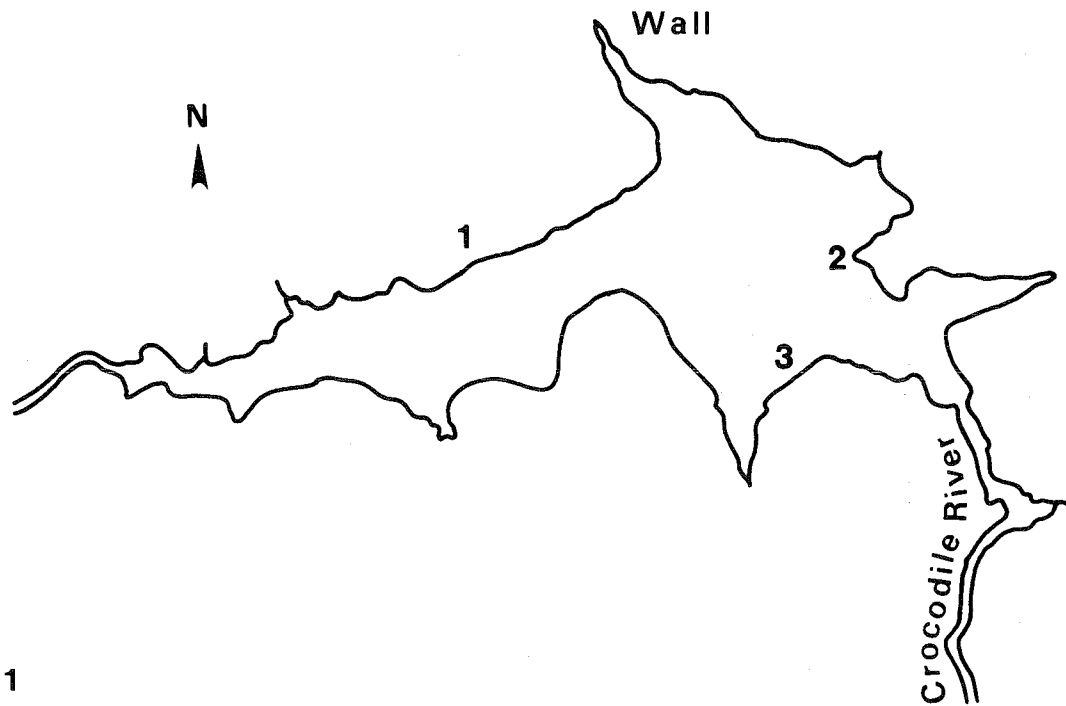


FIG. 1 Schematic representation of the Hartbeespoort Dam and the sites at which the catfish were caught

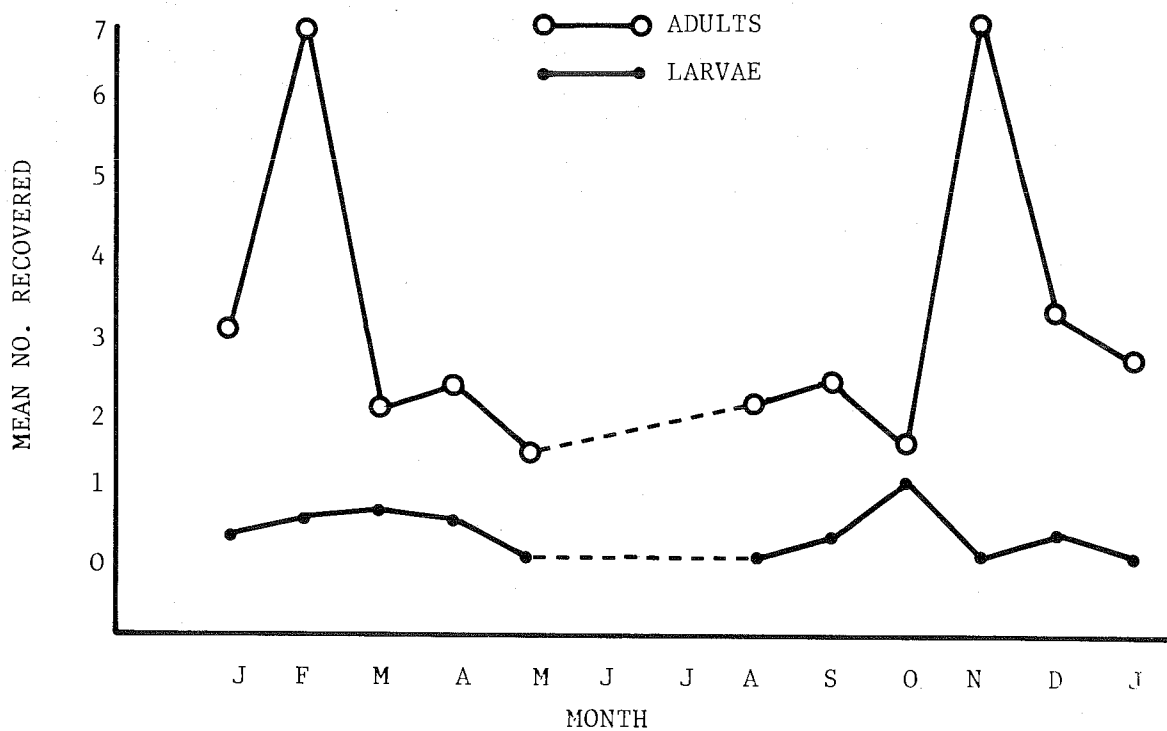


FIG. 2 Mean number of *Paracamallanus cyathopharynx* recovered each month

PARASITES OF SOUTH AFRICAN FRESHWATER FISH. I.

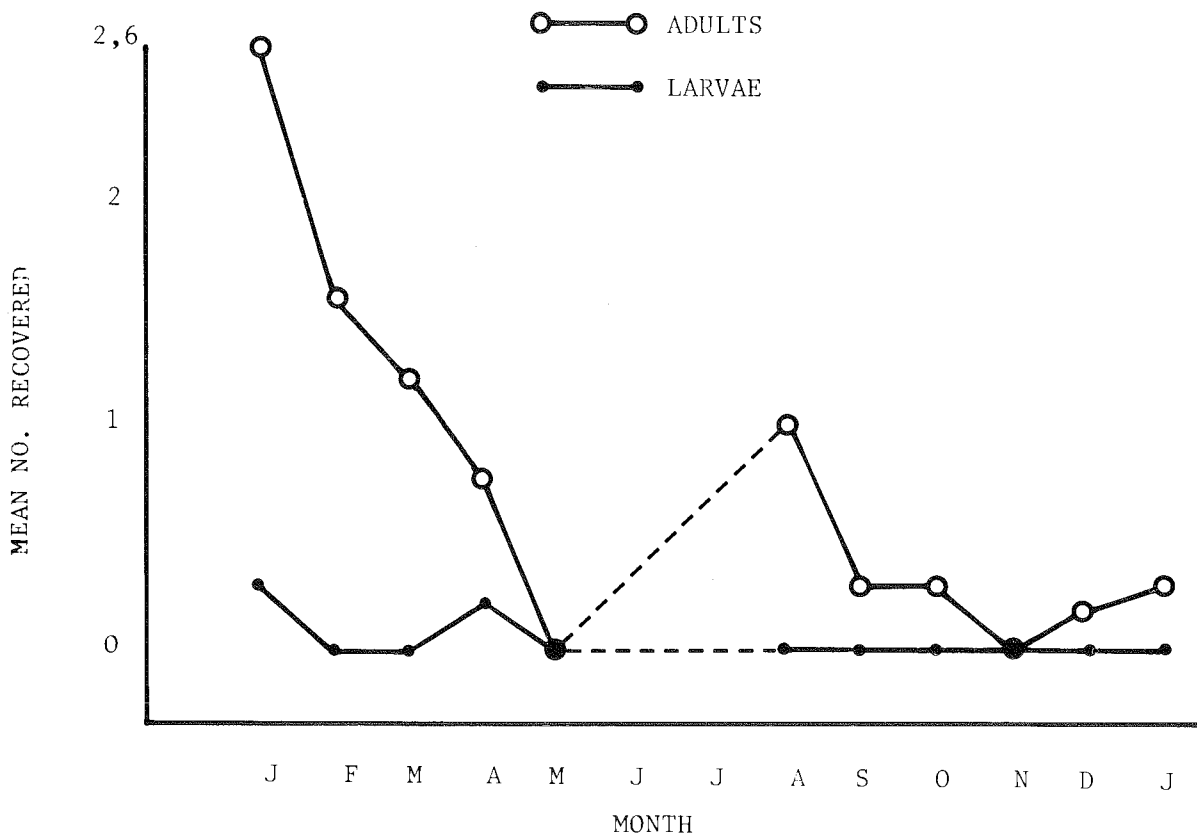


FIG. 3 Mean number of *Procammallanus laeviconchus* recovered each month

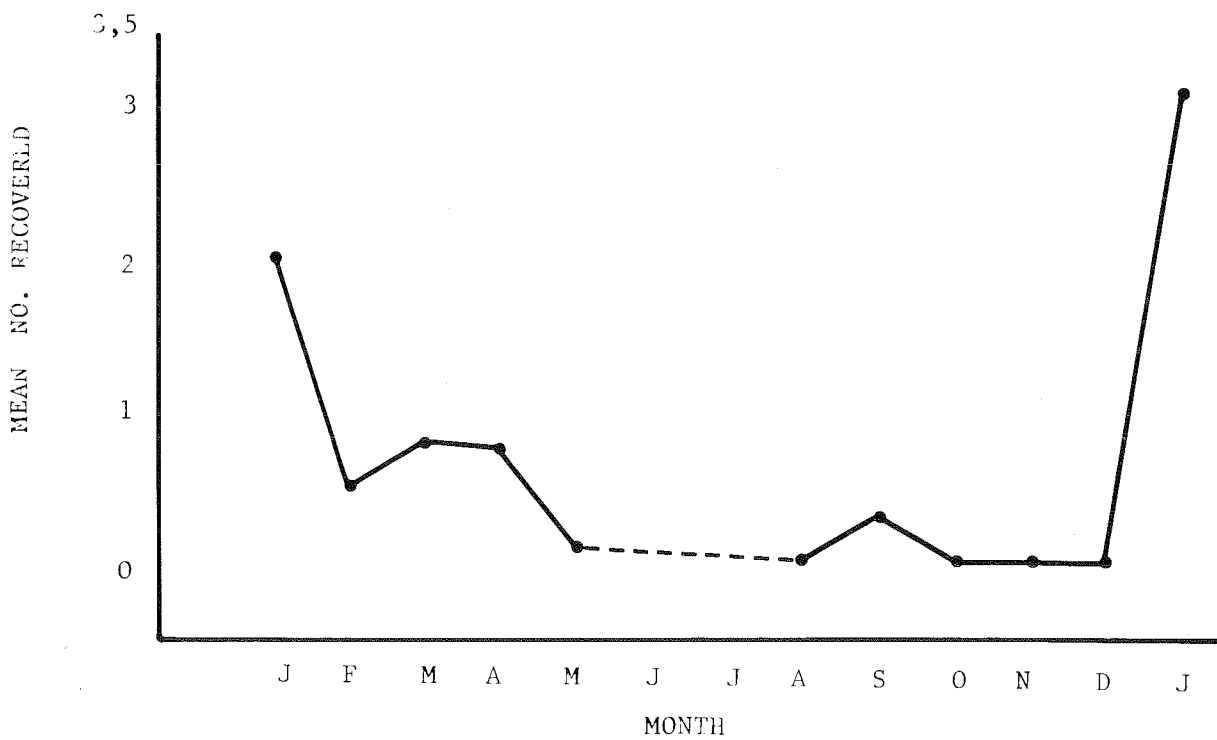


FIG. 4 Mean number of 2nd stage *Contracaecum* larvae recovered each month

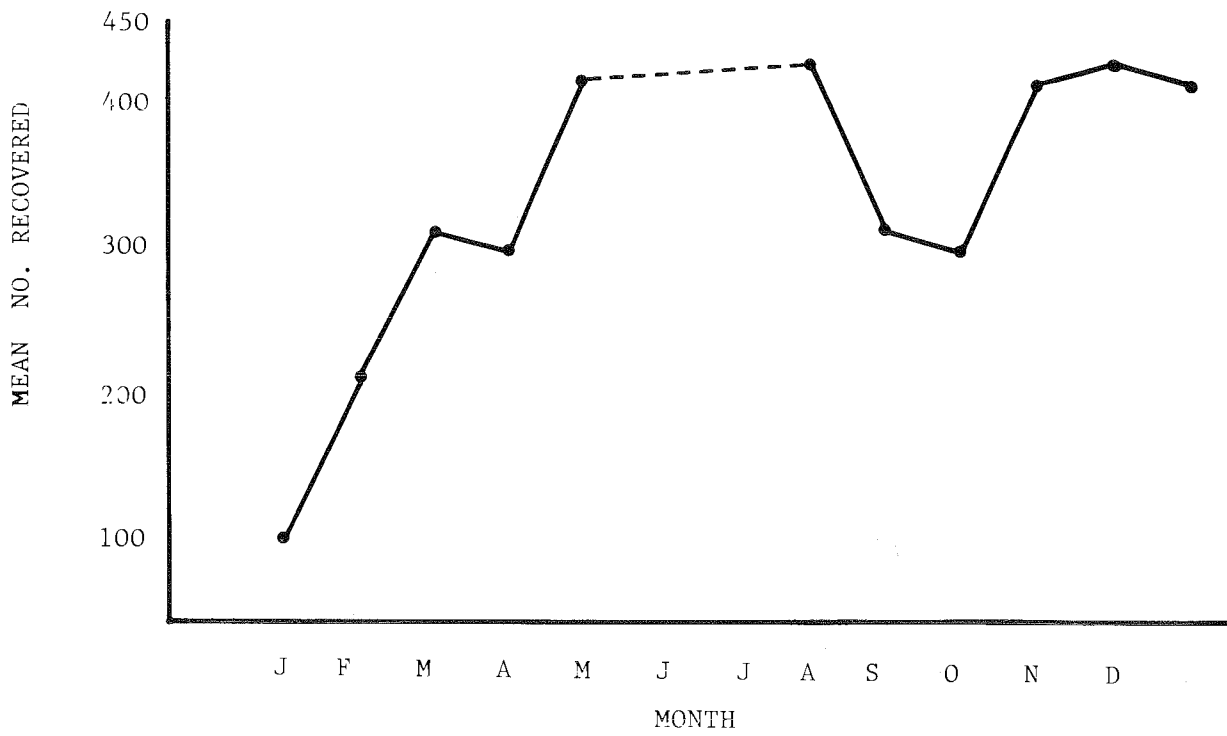


FIG. 5 Mean number of 3rd stage *Contracaecum* larvae recovered each month

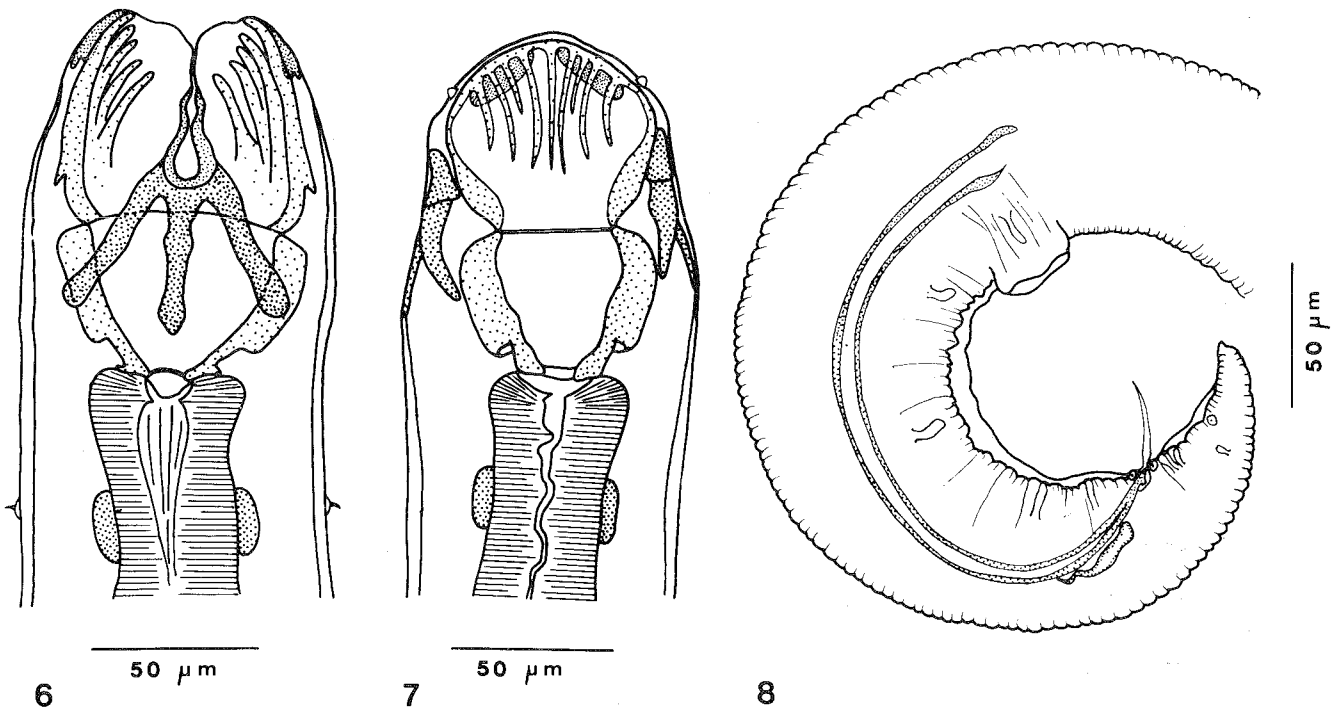


FIG. 6 Anterior extremity of *Paracamallanus cyathopharynx*, ventral view

FIG. 7 Anterior extremity of *Paracamallanus cyathopharynx*, lateral view

FIG. 8 Posterior extremity of *Paracamallanus cyathopharynx* male, lateral view

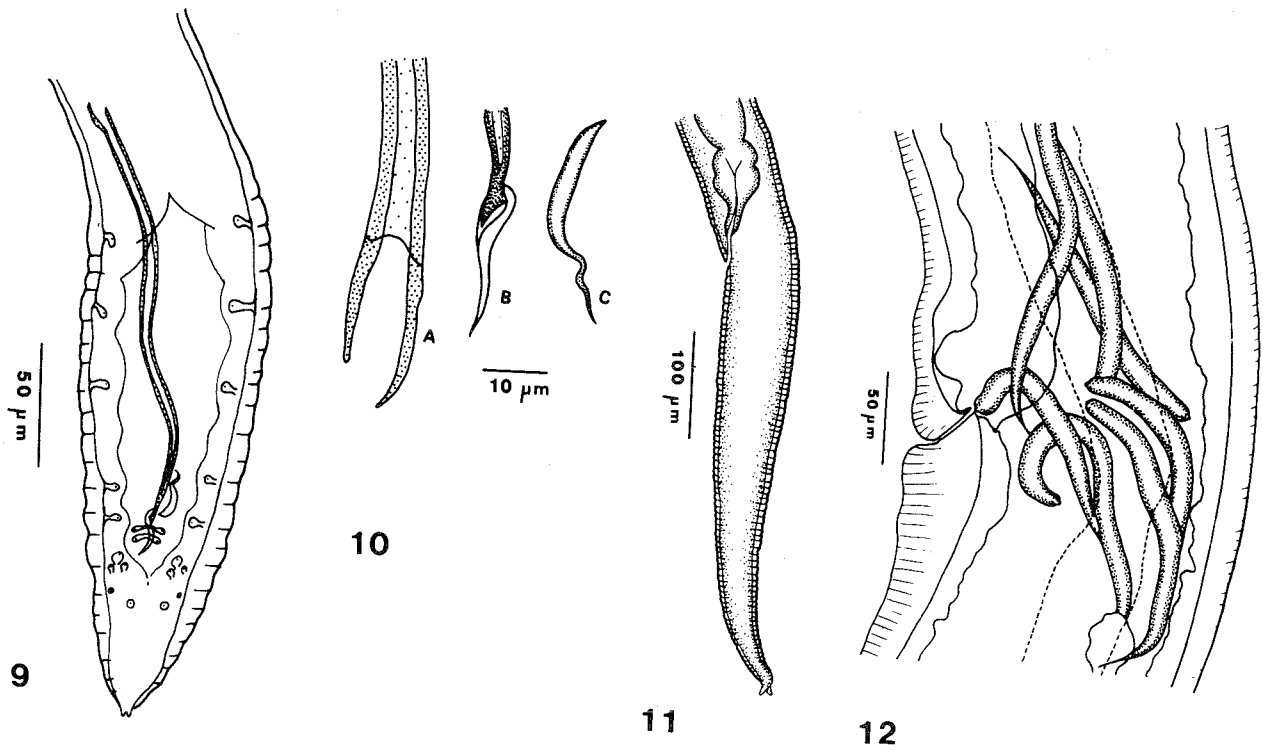


FIG. 9 Posterior extremity of *Paracamallanus cyathopharynx* male, ventral view

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

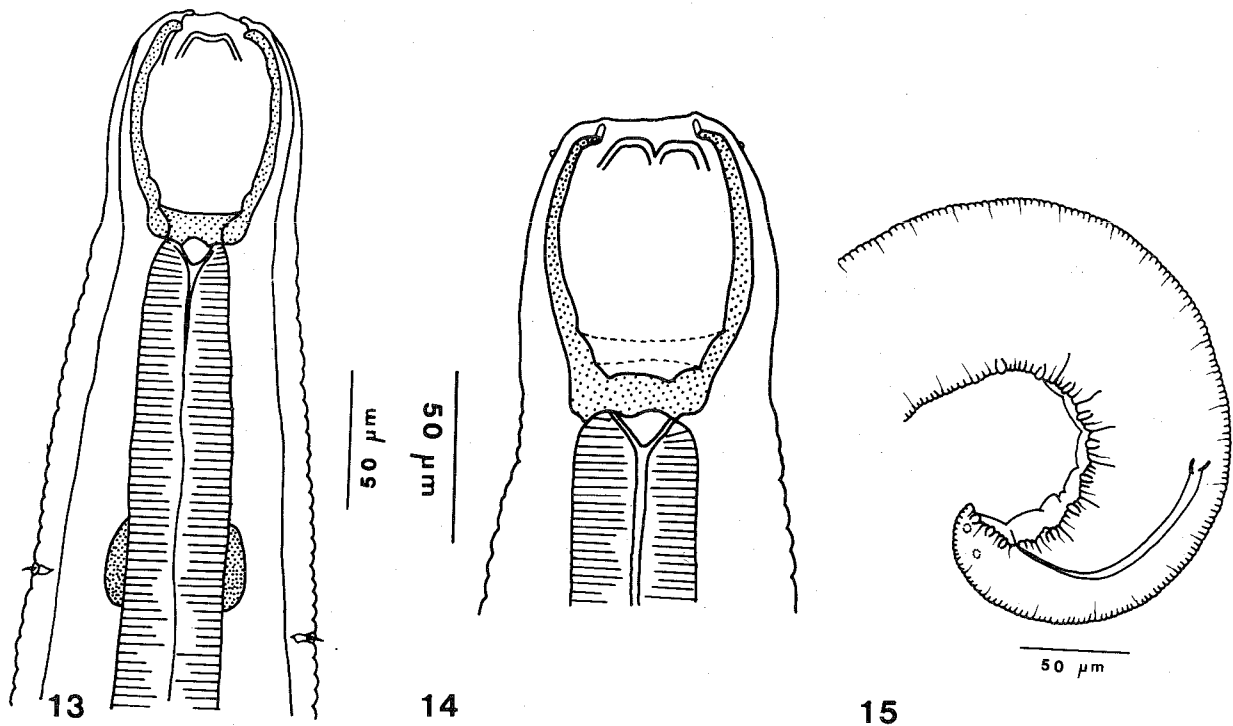


FIG. 13 Anterior extremity of *Procamallanus laeiconchus*, ventral view

FIG. 14 Anterior extremity of *Procamallanus laeiconchus*, lateral view

FIG. 15 Posterior end of *Procamallanus laeiconchus* male, lateral view

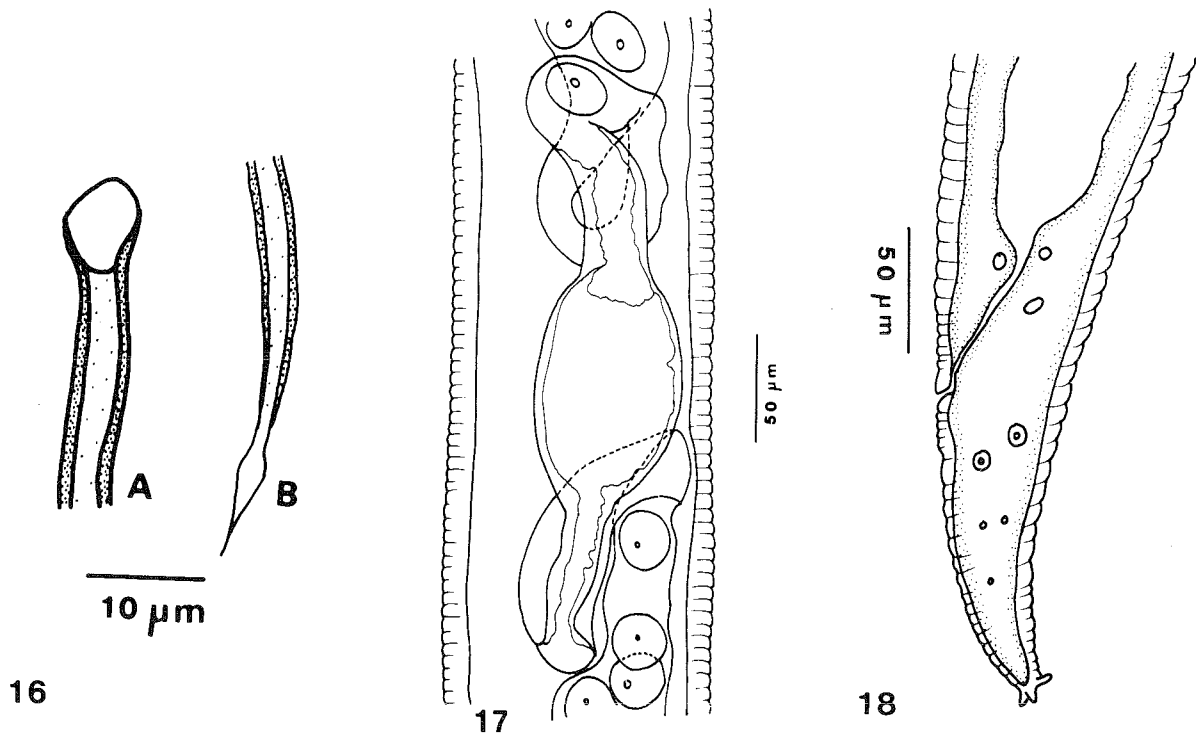


FIG. 16 *Procamallanus laeiconchus*, right spicule, (A) proximal and (B) distal ends
 FIG. 17 *Procamallanus laeiconchus*, female uterus
 FIG. 18 *Procamallanus laeiconchus*, tail of female, lateral view

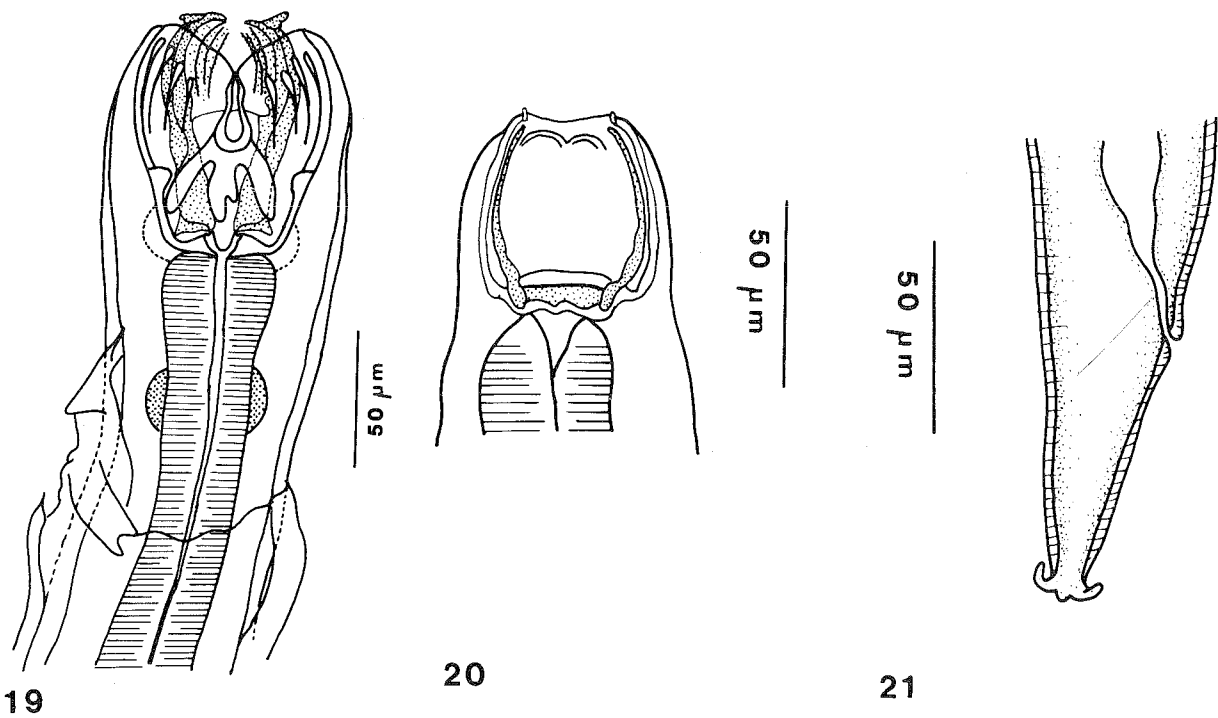


FIG. 19 *Paracamallanus cyathopharynx*, 4th moult; shaded part is the buccal capsule of 4th stage larva, dorsal view
 FIG. 20 Anterior end of *Procamallanus laeiconchus*, dorsal view of 4th moult. Shaded part is the buccal capsule of the 4th stage larva
 FIG. 21 *Procamallanus laeiconchus*, tail of 4th moult, lateral view

1962). However, Thomas (1937) showed that domestic ducks and fowl are not susceptible to infection with *Contraecum spiculigerum*, thereby implying a degree of host specificity where the final host is concerned.

A tentative scheme for life cycle patterns in the Ascaridoidea 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 *Contraecum 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 *Contraecum 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 (*Haliaeetus vocifer*) also prey on fish, but these are regarded as being of lesser importance in the transmission of *Contraecum* 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 *Contraecum* spp. larvae have also been recovered (Boomker, unpublished data). Egrets may therefore also play a role in the transmission of *Contraecum*. 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 *Contraecum*. 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 *Contraecum*. 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 *Contraecum* 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 interme-

mediate 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 *Contraecum carlislei* from the oesophagus and stomach of *Microcarbo africana africanides* (= *Phalacrocorax africanus africanus*). Prudhoe & Hussey (1977) state that 3 species of *Contraecum* commonly occur in African fish-eating birds, namely, *Contraecum micropapillatum* (Stossich, 1890) in cormorants and pelicans, and *Contraecum microcephalum* (Rudolphi, 1809) and *Contraecum 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 *Contraecum* spp. were recovered. Preliminary studies indicate that they are *C. spiculigerum* and *C. carlislei*. It therefore seems reasonable to assume that the *Contraecum* 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.

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Parasites of South African freshwater fish. VI. Nematode parasites of some fish species in the Kruger National Park

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ABSTRACT

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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 *Contraecaecum* 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.

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 *Contra-caecum* 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 ± SD)	Mean intensity of nematodes		Prevalence of nematodes	
	Undetermined	♂♂	♀♀	Total		Larvae	Adults	Larvae	Adults
Sabie River									
<i>Brycinus imberi</i>	1	10	12	23	16,0 ± 1,9	11	5	96	61
<i>Barbus marequensis</i>	9	42	9	60	26,3 ± 12,5	30	1	80	10
<i>Clarias gariepinus</i>	0	37	30	67	53,5 ± 13,5	40	5	99	88
<i>Schilbe intermedius</i>	5	14	22	41	23,7 ± 9,6	195	3	98	78
<i>Synodontis zambezensis</i>	7	13	31	51	15,1 ± 6,0	9	131	88	100
<i>Anguilla</i> spp.	2	0	0	2	84,0 ± 33,0	28	3	100	100
<i>Oreochromis mossambicus</i>	2	27	21	50	21,7 ± 5,9	6	0	44	0
<i>Tilapia rendalli swierstrae</i>	5	30	9	44	19,0 ± 8,2	4	1	36	2
<i>Serranochromis meridianus</i>	4	17	11	32	16,7 ± 6,5	15	2	81	9
Crocodile River									
<i>Brycinus imberi</i>	0	2	5	7	13,7 ± 1,3	2	0	51	0
<i>Hydrocynus vittatus</i>	0	1	2	3	37,5 ± 5,1	161	7	100	33
<i>Barbus marequensis</i>	0	11	6	17	41,5 ± 4,4	11	0	65	0
<i>Labeo molybdinus</i>	2	0	0	2	ND ^a	2	1	100	50
<i>Clarias gariepinus</i>	0	25	20	45	52,6 ± 11,8	50	10	93	76
<i>Schilbe intermedius</i>	0	2	1	3	17,3 ± 3,5	15	1	100	67
<i>Synodontis zambezensis</i>	0	4	9	13	19,7 ± 3,7	33	32	85	92
<i>Anguilla</i> sp.	1	0	0	1	125,0	73	0	100	0
<i>Oreochromis mossambicus</i>	3	18	12	33	21,2 ± 4,6	2	0	21	0
<i>Tilapia rendalli swierstrae</i>	2	24	11	37	21,3 ± 5,6	3	1	46	3
Olifants River									
<i>Hydrocynus vittatus</i>	0	2	0	2	42,8 ± 4,8	37	0	100	0
<i>Clarias gariepinus</i>	0	0	2	2	53,5 ± 1,5	12	17	100	100
<i>Schilbe intermedius</i>	0	2	0	2	30,3 ± 2,7	46	5	100	100
<i>Synodontis zambezensis</i>	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*

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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				
<i>Brycinus imberi</i> (23 fish)																		
<i>Rhabdochona versterae</i>	ND ^b	ND	ND	ND	ND	ND	ND	3	5	1	6	5	1	5	1-14	61		
<i>Contracaecum</i> 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		
<i>Barbus marequensis</i> (60 fish)																		
<i>Rhabdochona esseniae</i>	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		
<i>Clarias gariepinus</i> (67 fish)																		
<i>Capillaria</i> sp. ^a	0	0	0	0	0	0	0	0	0	0	1	0	0	1	1	2		
<i>Rhabdochona</i> spp. ^a	1	1	2	0	1	3	1	0	0	0	2	0	0	2	1-5	18		
<i>Paracamallanus cyathopharynx</i>	2	3	7	5	3	4	2	3	4	2	3	4	2	6	1-16	79		
<i>Spinitectus petterae</i>	1	2	0	3	3	0	13	2	3	0	2	0	2	5	1-35	24		
<i>Contracaecum</i> 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		
<i>Schilbe intermedius</i> (41 fish)																		
Philometrid nematode	ND	0	0	0	1	ND	0	0	0	0	0	1	0	1	1	5		
<i>Rhabdochona</i> spp. ^a	ND	9	4	0	0	ND	0	1	7	6	4	2	7	4	1-19	46		
<i>Spinitectus</i> spp. ^a	ND	3	2	0	0	ND	0	1	0	0	0	0	3	1	1-4	10		
<i>Paracamallanus cyathopharynx</i> ^a	ND	3	1	4	2	ND	1	8	3	1	1	3	8	2	1-6	59		
<i>Contracaecum</i> 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		
<i>Synodontis zambezensis</i> (51 fish)																		
Philometrid nematode	2	0	0	0	2	ND	3	0	0	3	2	2	0	2	1-3	28		
<i>Capillaria</i> spp. ^a	0	0	2	0	0	ND	0	0	0	0	0	0	0	2	2	4		
<i>Rhabdochona</i> spp. ^a	0	1	1	0	0	ND	0	0	2	0	1	0	0	1	1-3	10		
<i>Raillietiema synodontisi</i> ^a	20	212	100	57	11	ND	285	337	64	152	50	34	0	131	1-1000	65		
<i>Spinitectus zambezensis</i>	35	40	3	87	23	ND	31	59	35	35	22	24	9	31	1-220	88		
<i>Spirocamallanus daleneae</i>	6	6	2	1	6	ND	6	4	11	14	18	8	7	5	1-28	61		
<i>Synodontisia thelastomoides</i> ^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		
<i>Oreochromis mossambicus</i> (50 fish)																		
Unidentified nematode larvae	0	ND ^b	5	0	4	3	3	18	2	3	1	5	6	— ^c	1-63	44		
<i>Tilapia rendalli swierstrae</i> (44 fish)																		
<i>Rhabdochona</i> 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		
<i>Serranochromis meridianus</i> (32 fish)																		
Philometrid nematode	ND	ND	ND	0	0	0	0	1	0	0	0	ND	0	1	1	3		
<i>Rhabdochona</i> 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		
<i>Anguilla</i> spp.																		
<i>Rhabdochona</i> 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		
<i>Brycinus imberi</i> (7 fish) <i>Contracaecum</i> spp. larvae ^a	ND ^b	ND	ND	ND	ND	ND	ND	2	1	ND	ND	ND	1	0	1-6	71
<i>Hydrocynus vittatus</i> (3 fish) <i>Spinitectus</i> sp. ^a <i>Paracamallanus cyathopharynx</i> ^a <i>Contracaecum</i> spp. larvae ^a	0	ND	ND	ND	ND	ND	ND	ND	ND	7	ND	ND	1	6	7	50
	0	ND	ND	ND	ND	ND	ND	ND	ND	1	ND	ND	1	0	1	50
	125	ND	ND	ND	ND	ND	ND	ND	ND	178	ND	ND	160	— ^c	90-266	100
<i>Barbus marequensis</i> (17 fish) <i>Contracaecum</i> sp. larvae Unidentified nematode larvae	ND	ND	ND	1	ND	0	ND	0	0	0	ND	0	1	—	1	6
	ND	ND	ND	11	ND	0	ND	0	12	19	ND	2	11	—	2-27	53
<i>Labeo molybdinus</i> (2 fish) <i>Camallanus</i> sp. ^a Unidentified nematode larvae	ND	ND	ND	ND	ND	ND	ND	ND	ND	1	ND	ND	1	—	1	50
	ND	ND	ND	ND	ND	ND	ND	ND	ND	4	ND	ND	2	—	1-3	100
<i>Clarius gariepinus</i> (45 fish) <i>Capillaria</i> sp. ^a <i>Rhabdochona</i> spp. <i>Paracamallanus cyathopharynx</i> <i>Spinitectus petterae</i> <i>Contracaecum</i> spp. larvae Unidentified nematode larvae	0	0	0	0	0	1	0	0	1	0	0	0	0	1	1	4
	1	1	1	5	0	1	0	0	0	0	1	0	0	2	1-5	13
	3	11	1	1	5	2	2	1	4	3	6	14	5	4	1-16	56
	4	29	1	15	7	55	4	6	1	2	0	40	3	12	1-101	47
	23	1	67	1	72	1	2	2	3	0	0	1	32	—	1-351	49
	193	30	74	19	130	4	11	5	6	79	10	15	50	—	1-503	93
<i>Schilbe intermedius</i> (3 fish) <i>Rhabdochona</i> spp. ^a <i>Contracaecum</i> spp. larvae Unidentified nematode larvae	ND	ND	ND	ND	0	ND	ND	ND	ND	ND	1	1	1	—	1	67
	ND	ND	ND	ND	1	ND	ND	ND	ND	ND	0	1	1	—	1	67
	ND	ND	ND	ND	24	ND	ND	ND	ND	ND	8	12	16	—	8-24	100
<i>Synodontis zambezensis</i> (13 fish) <i>Rhabdochona</i> spp. ^a <i>Raillietnema synodontisi</i> ^a <i>Spinitectus zambezensis</i> <i>Spirocamallanus daleneae</i> <i>Synodontisia thelastomoides</i> ^a Unidentified nematode larvae	ND	ND	ND	ND	0	ND	ND	1	0	ND	1	ND	0	1	1	15
	ND	ND	ND	ND	0	ND	ND	1	0	ND	0	ND	0	1	1	8
	ND	ND	ND	ND	112	ND	ND	28	21	ND	33	ND	41	16	1-153	69
	ND	ND	ND	ND	2	ND	ND	2	2	ND	2	ND	2	2	1-4	69
	ND	ND	ND	ND	0	ND	ND	18	0	ND	36	ND	0	23	1-39	54
	ND	ND	ND	ND	7	ND	ND	2	0	ND	0	ND	4	—	1-14	38
<i>Oreochromis mossambicus</i> (33 fish) Unidentified nematode larvae	ND	0	0	ND	ND	0	2	ND	1	3	1	2	2	—	1-6	21
<i>Tilapia rendalli swierstrae</i> (37 fish) <i>Rhabdochona</i> sp. ^a Unidentified nematode larvae	ND	0	0	0	ND	0	0	1	0	0	0	0	0	1	—	3
	ND	2	1	0	ND	1	2	4	4	2	2	1	3	—	1-10	46
<i>Anguilla</i> 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		
<i>Hydrocynus vittatus</i> (2 fish) <i>Contracaecum</i> spp. larvae ^a	37	— ^b	31–42	100
<i>Clarias gariepinus</i> (2 fish) <i>Rhabdochona</i> spp. ^a	0	32	32	50
<i>Paracamallanus cyathopharynx</i>	2	1	1–2	100
<i>Procamallanus laeviconchus</i>	0	1	1	50
<i>Contracaecum</i> spp. larvae	2	—	2	100
Unidentified nematode larvae	9	—	3–15	100
<i>Schilbe intermedius</i> (2 fish) <i>Paracamallanus cyathopharynx</i> ^a	0	5	3–6	100
<i>Contracaecum</i> spp. larvae	1	—	1	50
Unidentified nematode larvae	45	—	15–75	100
<i>Synodontis zambezensis</i> (2 fish) Philometrid nematode	0	4	4	50
<i>Rhabdochona</i> spp.	0	36	36	50
<i>Paracamallanus cyathopharynx</i> ^a	0	1	1	50
<i>Raillietnema synodontisi</i> ^a	0	1	1	50
<i>Spinitectus zambezensis</i>	0	10	5–15	100
<i>Spirocamallanus daleneae</i>	0	1	1	50
<i>Synodontisia thelastomoides</i> ^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

Contraecum 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 laevis* in catfish (Mashego & Saayman 1981; Boomker 1982; Van As & Basson 1984), and *Procamallanus slomei* and *Procamallanus brevis* from toads (Ivashkin, Sobolev & Khromova 1971). *Procamallanus laevis* 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 laevis* 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: Rhabdochoniidae

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 red-breasted 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.

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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.

Contraecaecum 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).

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).

Contraecaecum 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 *Contraecaecum* 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 *Contraecaecum* 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 *Contraecaecum* 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		
<i>Oreochromis mossambicus</i> (45 fish)				
<i>Contraecaecum</i> sp.	1	—	—	2,2
<i>Rhabdochona</i> sp.	0	1	—	2,2
Unidentified nematode larvae	5	—	1-4	4,4
<i>Chetia flaviventris</i> (52 fish)				
<i>Contraecaecum</i> spp.	6	—	1-15	76,9
Unidentified nematode larvae	1	—	1-2	5,8
<i>Tilapia sparrmani</i> (1 fish)				
Unidentified nematode larva	1	—	—	100,0
<i>Cyprinus carpio</i> (11 fish)				
<i>Contraecaecum</i> spp.	5	—	1-12	27,3
<i>Rhabdochona</i> spp.	0	4	1-5	36,4
Unidentified nematode larva	1	—	—	18,2
<i>Barbus marequensis</i> (16 fish)				
<i>Contraecaecum</i> spp.	7	—	—	9,1
<i>Rhabdochona esseniae</i>	—	2	1-7	31,3
<i>Rhabdochona</i> sp.	—	1	—	9,1
<i>Barbus mattozi</i> (6 fish)				
<i>Contraecaecum</i> spp.	14	—	6-28	83,3

— Not applicable

B. marequensis, however, were identified as *R. eseniae*, 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.

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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.