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PARASITES OF SOUTH AFRICAN WILDLIFE. IV. HELMINTHS OF KUDU, *TRAGELAPHUS STREPSICEROS*, IN THE KRUGER NATIONAL PARK

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ABSTRACT

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During ongoing surveys of parasites of wild animals in the Kruger National Park, a total of 96 kudu, *Tragelaphus strepsiceros*, were culled in the southern part of the park at monthly intervals from April 1981 to March 1983. A single kudu was shot in the same area in November 1983. Two more kudu were obtained from Pafuri in the northern part of the Park during October 1981 and another from near Satara in the central part of the Park during October 1982. The helminths of all the kudu were collected and 2 trematode, 4 cestode and 18 nematode species recovered.

Amongst the helminths recovered, *Agriostomum gorgonis*, *Cooperia fuelleborni*, *Cooperia hungi*, *Cooperia yoshidai*, *Impalaia tuberculata*, a *Parabronema* sp., a *Setaria* sp., *Strongyloides papillosus*, *Trichostrongylus falculatus*, *Schistosoma mattheei*, an *Avitellina* sp., *Moniezia benedeni*, and *Echinococcus* sp. larvae appear to be new records for kudu. *Haemonchus vegliai*, which has been considered a rare nematode, was present in many animals. An amended list of the parasites of kudu is included, and the seasonal abundance of the major nematode species discussed and graphically illustrated.

INTRODUCTION

Kudu, *Tragelaphus strepsiceros*, are large antelope that are widely distributed in southern and East Africa. In South Africa their distribution coincides with Acocks' (1975) Tropical Woodland and Savannah veld types. They prefer dense bush or light forest (Ansell, 1971) and generally avoid open country (Dorst & Dandelot, 1972; Rautenbach, 1982). They usually live in small groups consisting of adult cows and their offspring. Young calves remain hidden for the first few months of life and join the cow groups when they are about 3 months old (Novellie, 1983). Bull calves leave the group when about 2 years old, while females remain with the group until fully mature (Novellie, 1983). Adult bulls join the cow groups occasionally, usually during the breeding season, and for the rest of the year they form bachelor groups (Novellie, 1983).

According to Dorst & Dandelot (1972), kudu are largely nocturnal, visiting the feeding grounds from the late afternoon to early morning. In the Kruger National Park (KNP), however, kudu are often seen feeding throughout the day (J. Boomker, unpublished data, 1982).

Kudu are browsers that consume the flowers, fruits, seeds, pods, leaves and twigs of a large variety of plants, many of which are poisonous to domestic stock (Wilson, 1965; Dorst & Dandelot, 1972; Hofmann, 1973). Brynard & Pienaar (1960) list 147 species of plants eaten by kudu in the KNP. Preliminary studies by Owen-Smith (1979) and detailed studies by Novellie (1983) indicate that, although the leaves and shoots of shrubs and trees are consumed throughout the year, they make up the bulk of the diet only from September to November, which is the time of year when low-growing forbs and herbs are scarce. Forbs and herbs make up the major part of the diet from December to May (Owen-Smith, 1979; Novellie, 1983). Novellie (1983) found that kudu near Tshokwane in the central part of the KNP spent 68 % of their time feeding on herbs and forbs during May–September, 17 % during September–December and 66 % during December–May. Grass is seldom eaten but may be taken after early rains (Wilson, 1965) or during droughts (Elizabeth Boomker, unpublished data, 1983). However, grass generally makes up an insignificant part of the diet (Novellie, 1983).

The helminth parasites of kudu from the African continent have been listed by Round (1968). Of these, 1 trematode, 1 *Cysticercus* sp. *(sic)* and 9 nematode species occur in South Africa (Round, 1968). Condy (1972) has listed the parasites from kudu in some Zimbabwean game reserves. Boomker (1982) added *Cooperia acutispiculum* to these lists and Boomker & Kingsley (1984) *Paracooperia devossi*, but other than these no further records could be found in the available literature.

MATERIALS AND METHODS

Study area

The main study area was situated in the southern part of the KNP, between the Shirimanthanga hills in the north, the James windmill in the south, the main dirt road from Skukuza to Malelane in the east and the main tarred road between the same camps in the west (Fig. 1). This area is about 195 km^2 in extent and is situated between latitude 25° 06′–25° 21′ S and longitude 31° 27′–31° 36′ E. The altitude varies from 200–350 m (Gertenbach, 1983).

The vegetation is classified as Lowveld (Acocks, 1975). However, it is diverse and 4 veld types are recognized, namely mixed *Combretum/Acacia* veld in the extreme north, mixed *Combretum* veld in the major portion, a narrow strip of *Acacia nigrescens/Sclerocarya birrhea* veld that roughly bisects the southern 2/3rds and *Terminalia/Dichrostachys*/Malelane mountain communities in the extreme south of the study area (Anon., 1984) (Fig. 2).

Some kudu were also obtained from Pafuri (23° 27′ S, 31° 19′ E) in the north of the Park, an area classified as Mopane veld by Acocks (1975) or as *Colophospermum mopane* shrub veld/sandveld communities (Anon., 1984). One kudu was shot at Satara (24° 23′ S, 31° 47′ E) in the centre of the Park, where the vegetation is classified as Arid Lowveld (Acocks, 1975) or as *Acacia nigrescens* and *Sclerocarya birrhea* on basalt and dolorite (Anon., 1984).

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FIG. 1 Map of the southern part of the Kruger National Park indicating the main study area

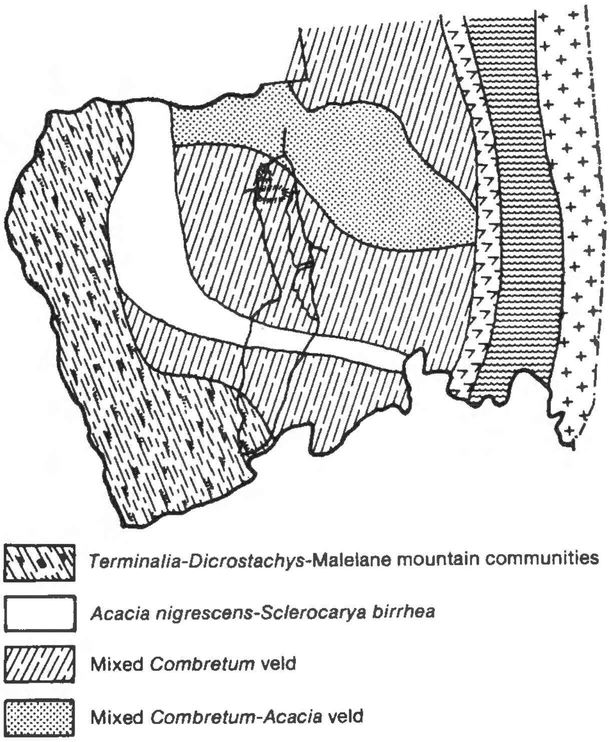


FIG. 2 Map of the southern part of the Kruger National Park indicating the vegetation of the study area

Climatological data

The days are warm to hot in summer and mild in winter and frost occurs occasionally. The mean monthly maximum and minimum temperature for the period April 1981–March 1983 is illustrated in Fig. 3.

The seasons are defined as follows: spring is from September to October, summer from November to March, autumn from April to May and winter from June to August.

The rainfall in the study area varies from 600–700 mm *per annum* and it usually falls in summer. The total monthly rainfall for the period April 1981–March 1983 was measured at the Stolznek ranger's post and at the Malelane and Skukuza tourist camps, which roughly form a triangle that encompasses the study area. The rainfall data are graphically illustrated in Fig. 4–6 (Gertenbach, 1980, in part).

Survey animals

Each month from April 1981 to March 1983, 4 kudu were shot in the study area. At each occasion an attempt was made to obtain 1 adult male, 1 adult female, 1 young adult male and 1 juvenile or calf of either sex. The animals were aged according to the criteria described by Simpson (1971). Collections were made not less than 3 weeks or more than 5 weeks apart, and a total of 96 kudu were examined. In addition a young adult male was obtained from the study area in November 1983. Two males were shot near Pafuri in October 1981 and a single male at Satara in October 1982. The latter animal was in a very poor condition because of the drought that prevailed at the time.

For statistical reasons, the animals were grouped according to age into calves, 0–12 months old (age group 1), juveniles, 13–24 months old (age group 2), young adults, 25–48 months old (age group 3) and prime or old adults, 49 months and older (age group 4).

Collection of parasites

As soon as an animal was shot, blood smears were made according to standard techniques (Schalm, Jain & Carroll, 1975). These were fixed in acid-free methyl alcohol, stained with 10 % Giemsa for 1 h and examined with the aid of a compound microscope and an oil immersion lens at 1 000 × magnification.

The kudu from the main study area and the 1 from Satara were transported to the laboratory at Skukuza where they were processed as described below. These procedures were performed in the field for the kudu from Pafuri.

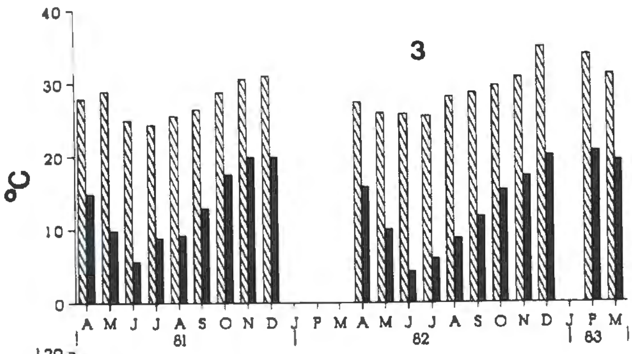
The carcass was skinned and opened and the entire gastro-intestinal tract, together with the heart, lungs and liver removed. The various organs were separated from each other and from the suspensory ligaments and placed individually in shallow plastic trays.

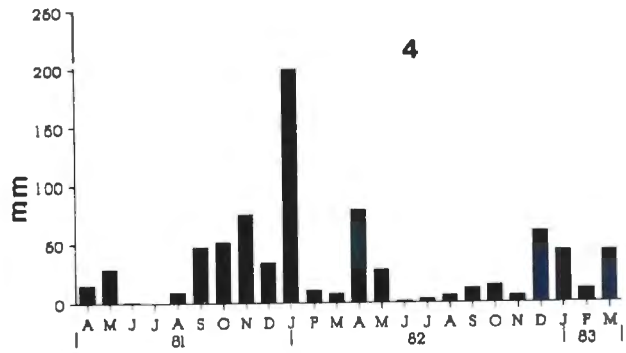
The heart was opened and the macroscopically visible parasites removed and placed in 70 % ethyl alcohol. Special attention was paid to the coronary vessels, where the adults of *Cordophilus sagittus* occur in aneurysms. The heart was then cut into slices approximately 10 mm thick and these were placed in a glass jar filled with normal saline.

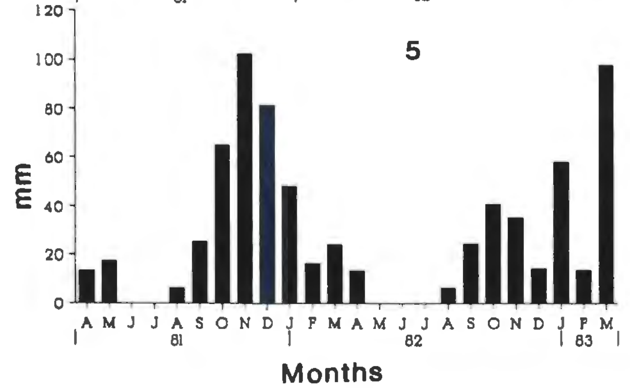
Five strips, each approximately 10 mm thick, were removed from 5 places over the entire width of the liver and placed in a glass jar with normal saline. The strips represented $\frac{1}{5}$th ± 50 g of the mass of the liver and thus represented a $\frac{1}{5}$th aliquot.

Only the right lung, which is the larger one, together with the trachea, were processed for parasite collection. The trachea and bronchi were opened, rinsed in running water and the washings collected over a sieve with 0,038 mm apertures. The pulmonary artery was opened, followed to its terminal arterioles in the diaphragmatic lobe and all *Cordophilus sagittus* collected and preserved in 70 % alcohol. The entire lung was washed again and then cut into 20 mm cubes and placed in a glass jar with normal saline.

The hearts, livers and lungs of the kudu from the main study area and those from the single kudu from Satara were incubated, in their saline solutions, in a water-bath at 38–42 °C for not less than 1,5 h and not more than 2,5 h. The same organs of the kudu from







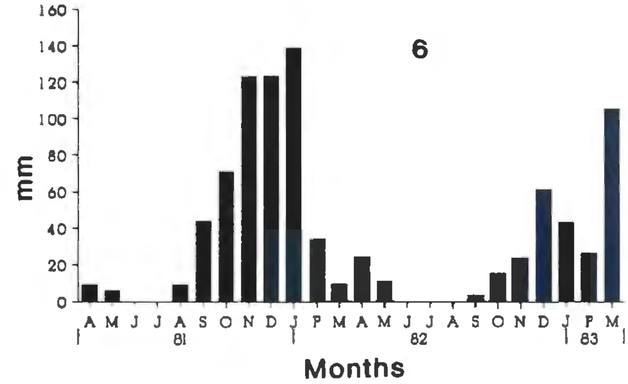


FIG. 3 The mean monthly maximum and minimum temperatures as measured at Skukuza. No readings were taken during January–March 1982 or during January 1983

FIG. 4 The total monthly rainfall at Skukuza

FIG. 5 The total monthly rainfall at Malelane

FIG. 6 The total monthly rainfall at the Stolznek ranger's post

Pafuri were placed near an open fire to reach the desired temperature. They were then moved away from the fire until the temperature dropped by 3–5 °C, after which they were shaken and the procedure repeated for the required time. After incubation, the various organs were thoroughly rinsed individually in running water and the washings, together with the saline in which each organ had been incubated, were sieved over a sieve with 0,038 mm apertures. The residues in the sieve were collected and separately preserved in 10 % formalin. The washings of the trachea and the bronchi were included with those of the lungs.

The digestive tract was divided into rumen and reticulum, omasum, abomasum, small intestine and large intestine. The latter included the caecum, but the distal part, i.e. from where the terminal gyrus centripetalis reflects upon itself, to and including the rectum, was discarded.

The rumen and reticulum were opened and their contents carefully removed. Visible paramphistomes were collected from the ingesta and placed either in 70 % alcohol or in 10 % formalin. The rumen wall was placed in a bucket with hot water to facilitate detachment of the flukes and those still attached after 15 min were removed manually. The contents of the bucket were sieved over a sieve with 0,150 mm apertures and preserved in 10 % formalin.

The abomasa and the small and the large intestines were opened in separate trays and the ingesta removed. Each organ was rinsed twice in a small quantity of water, which was added to the respective ingesta. The washed organs were retained for further processing.

The ingesta of each part of the gastro-intestinal tract were thoroughly mixed, and 2 aliquots, each representing ${}^{1}/_{25}$th of the total volume, were taken. Those of the abomasa and small intestines were sieved over a sieve with 0,038 mm apertures and those of the large intestines over a sieve with 0,150 mm apertures. The residues in the sieves were preserved separately in 10 % formalin.

The mucosae of the abomasa and of the small and the large intestines were removed by scraping with a knife or a glass slide, and were placed in separate glass jars of 1 ℓ capacity. Digesting fluid, consisting of 10 g of pepsin powder and 35 mℓ of technical hydrochloric acid per litre of normal saline, was added to the mucosae in the ratio of 4 parts digesting fluid to 1 part mucosa. The jars were incubated in a water-bath at 40–43 °C, and in the case of the kudu from Pafuri the same procedure as described for the hearts, lungs and livers of these animals was followed. The jars were shaken every 15–20 min to ensure breaking up of the mucosae and thus proper digestion. The process was continued until large pieces of mucosa were no longer visible, but not for longer than 3 h. When digestion was complete, each digest was sieved over a sieve with 0,038 mm apertures and the residues preserved separately in 10 % formalin.

The carcasses were examined for the presence of *Taenia* larvae by incising the masseter, the triceps and the ilio-psoas muscles. When larvae were found, they were preserved in 70 % alcohol.

In addition to the above procedures, nematode egg counts were done on rectal faeces, using Reinecke's (1961) modification of the McMaster technique of Gordon & Whitlock (1939).

Counting and identification of the parasites

The various aliquots of the ingesta and the entire digests and heart, lung and liver washings were examined in a perspex counting chamber using a stereoscopic microscope, and all the worms were collected. The nematodes were cleared in lactophenol,

TABLE 1 Amended list of the helminth parasites of kudu in the Republic of South Africa, the reference to the first record and the authors used to assist with the identification

Parasite	First record	Identification
Trematodes		
Paramphistomum cervi (Zeder, 1790) Fischoeder, 1901	Veglia, 1919	*
Paramphistomes	This paper	Eduardo, 1982
Schistosoma mattheei Veglia & Le Roux, 1929	This paper	Veglia & Le Roux, 1929
Cestodes		
Avitellina sp. Gough, 1911	This paper	Skrjabin & Spasski, 1963
Cysticercus sp. (*sic*)	Le Roux, 1930	Verster, 1969
Echinococcus sp. larvae	This paper	Wardle & McLeod, 1952
Moniezia benedeni (Moniez, 1879) Blanchard, 1891	This paper	Skrjabin & Spasski, 1963
Nematodes		
Agriostomum cursoni Mönnig, 1932	Ortlepp, 1961	*
Agriostomum gorgonis Le Roux, 1929 b	This paper	Le Roux, 1929 b
Cooperia acutispiculum Boomker, 1982	Boomker, 1982	Boomker, 1982
Cooperia fuelleborni Hung, 1926	This paper	Gibbons, 1981
Cooperia hungi Mönnig, 1931	This paper	Gibbons, 1981
Cooperia neitzi Mönnig, 1932	Mönnig, 1932	Gibbons, 1981
Cooperia pectinata Ransom, 1907	Ortlepp, 1961	*
Cooperia punctata (Von Linstow, 1906) Ransom, 1907	Ortlepp, 1961	*
Cooperia yoshidai Mönnig, 1939	This paper	Gibbons, 1981
Cordophilus sagittus (Von Linstow, 1907) Mönnig, 1926	Mönnig, 1926	Mönnig, 1926
Gaigeria pachyscelis Railliet & Henri, 1910	Ortlepp, 1961	*
Haemonchus contortus (Rudolphi, 1803) Cobb, 1989	Ortlepp, 1961	*
Haemonchus vegliai Le Roux, 1929 a	Le Roux, 1929 a	Gibbons, 1979
Impalaia tuberculata Mönnig, 1923	This paper	Boomker, 1977
Impalaia sp. females	Boomker *et al.*, 1986	Boomker, 1977
Parabronema sp. Baylis, 1921	This paper	Yorke & Maplestone, 1926
Paracooperia devossi Boomker & Kingsley, 1984	Boomker & Kingsley, 1984	Boomker & Kingsley, 1984
Setaria africana (Yeh, 1959) Ortlepp, 1961	Ortlepp, 1961	*
Setaria sp. Viborg, 1795	This paper	Yeh, 1959
Strongyloides papillosus (Wedl, 1856) Ransom, 1911	This paper	Ransom, 1911
Trichostrongylus falculatus Ransom, 1911	This paper	Ransom, 1911
Trichostrongylus deflexus Boomker & Reinecke, 1989	Boomker *et al.*, 1986	Boomker & Reinecke, 1989

* = After Round (1968). Not found in this survey

TABLE 2 The helminths recovered from 96 kudu from the main study area in the Kruger National Park

Helminth species	Numbers of worms recovered			Percentage of animals infested
	Larvae	Adults	Total	
Paramphistomes	*	3 052	3 052	32,0
Schistosoma mattheei	*	371	371	19,6
Avitellina sp.	*	17	17	2,1
Echinococcus sp. larvae	2	*	1	1,0
Moniezia benedeni	*	19	19	10,3
Taenia spp. larvae	24	*	24	11,3
Agriostomum gorgonis	0	2 143	2 143	33,0
Cooperia acutispiculum	†	27 448	27 448	77,3
Cooperia fuelleborni	†	357	357	4,1
Cooperia hungi	†	1 542	1 542	8,2
Cooperia neitzi	†	115 981	115 981	83,5
Cooperia yoshidai	†	118	118	1,0
Cooperia spp.	1 645	177	1 822	2,1
Cordophilus sagittus	0	1 036	1 036	68,0
Haemonchus vegliai	257	25 181	25 438	89,7
Impalaia tuberculata	357	5 681	6 038	25,8
Parabronema sp.	0	1	1	1,0
Paracooperia devossi	†	27	27	3,1
Setaria sp.	0	2	2	2,1
Strongyloides papillosus	38	4 454	4 492	6,2
Trichostrongylus falculatus	0	835	835	6,2
Trichostrongylus deflexus	0	28 243	28 243	43,3
Trichostrongylus spp.	0	415	415	5,2
Trichuris spp.	0	126	126	5,2

* = Not found in kudu
† = 4th stage larvae are indistinguishable at species level and all are regarded as being *Cooperia* spp.

examined with a compound microscope, counted and identified using the descriptions of the authors listed in Table 1, which also lists the helminths recovered from kudu to date.

Male nematodes were identified specifically, but the females, especially where 2 or more species of the same genus occurred in a single host, were identified to the generic level only and allocated to the various species in the same proportion as that in which the males occurred. Trematodes and cestodes were mostly identified to generic level.

RESULTS

Main study area

The species of helminths recovered, their totals and the percentage of animals infested with each are presented in Table 2.

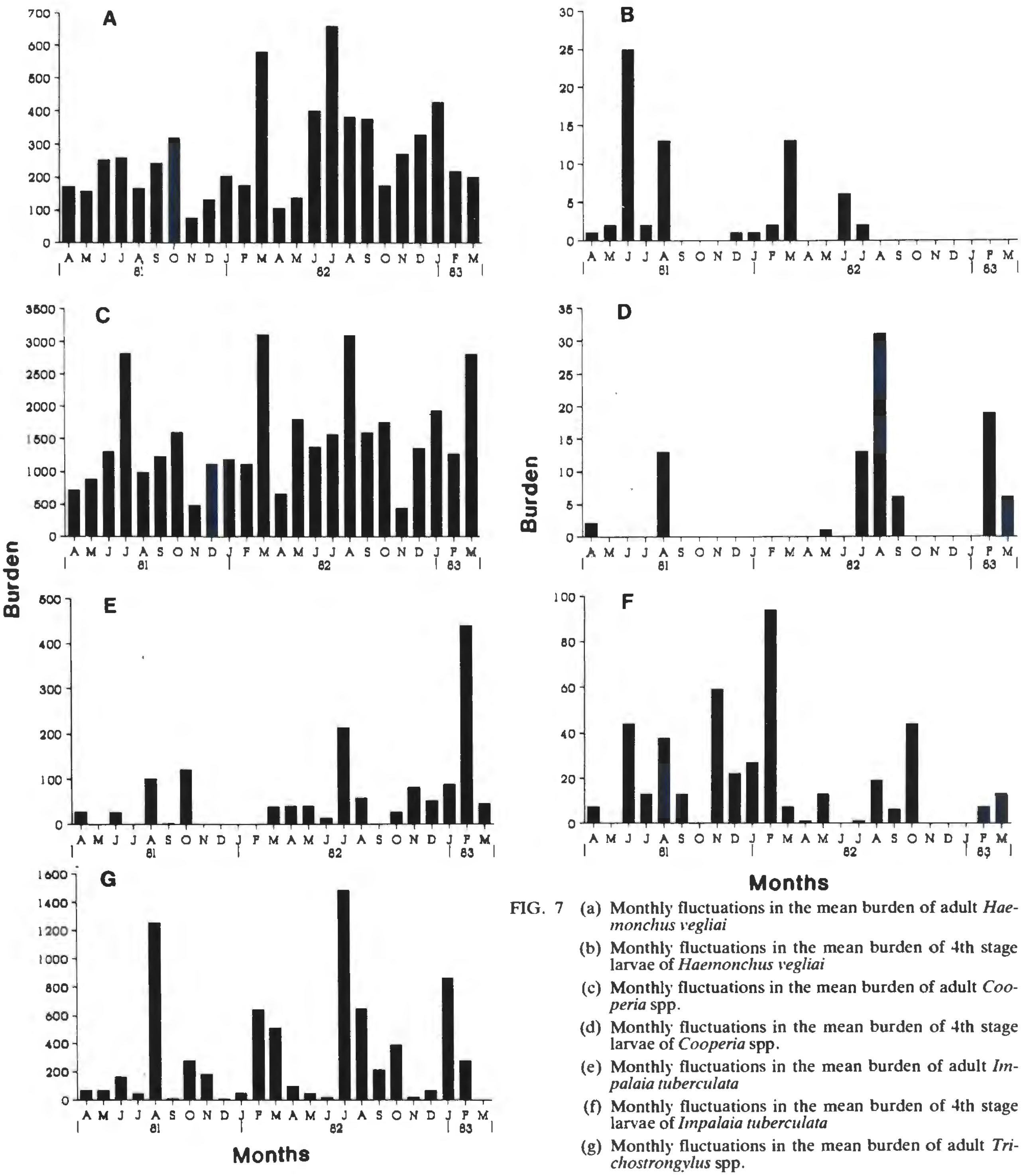


FIG. 7 (a) Monthly fluctuations in the mean burden of adult *Haemonchus vegliai*
(b) Monthly fluctuations in the mean burden of 4th stage larvae of *Haemonchus vegliai*
(c) Monthly fluctuations in the mean burden of adult *Cooperia* spp.
(d) Monthly fluctuations in the mean burden of 4th stage larvae of *Cooperia* spp.
(e) Monthly fluctuations in the mean burden of adult *Impalaia tuberculata*
(f) Monthly fluctuations in the mean burden of 4th stage larvae of *Impalaia tuberculata*
(g) Monthly fluctuations in the mean burden of adult *Trichostrongylus* spp.

Eighteen nematode species, 2 trematodes and 4 cestodes were recovered. *Agriostomum gorgonis*, *Cooperia fuelleborni*, *Cooperia hungi*, *Cooperia yoshidai*, *Impalaia tuberculata*, a *Parabronema* sp., a *Setaria* sp., *Strongyloides papillosus*, *Trichostrongylus falculatus*, *Schistosoma mattheei*, *Avitellina* sp., *Moniezia benedeni*, and *Echinococcus* sp. larvae appear to be new parasite records for kudu in this country.

The most prevalent nematode was *Haemonchus vegliai*, followed by *Cooperia neitzi*, *Cooperia acutispiculum*, and *Cordophilus sagittus*. The other helminths were present in fewer than 50 % of the animals examined. The most abundant worm was *Cooperia neitzi*, followed by *Trichostrongylus deflexus*, *Cooperia acutispiculum* and *H. vegliai*. The paramphistomes were the most numerous and most prevalent of the trematodes and *M. benedeni* was the most prevalent and most abundant adult cestode.

H. vegliai, *Cooperia acutispiculum*, *Cooperia neitzi* and *Trichostrongylus deflexus* were present in all 4 age groups, although few *Cooperia neitzi* were present in the calves. *Trichostrongylus falculatus* and *Cooperia fuelleborni* were present only in the calves while *Cooperia hungi* was present in 7 calves and 1 adult. *Cooperia yoshidai* was recovered from a single calf. A *Cooperia* sp., which is closely related to *Cooperia rotundispiculum* and is indistinguishable from a *Cooperia* sp. recovered from several antelope species from the KNP and some Natal nature reserves

TABLE 3 The total helminth burdens of each age group of male and female kudu from the main study area in the Kruger National Park

Date	Age group 1 (0–12 mths)		Age group 2 (13–24 mths)		Age group 3 (25–48 mths)		Age group 4 (48 mths and over)	
	M	F	M	F	M	F	M	F
Apr. 81	365	—	—	—	577	426	2 608	—
May 81	—	1 102	1 899	—	—	247	2 448	—
Jun. 81	—	478	—	—	—	—	3 130*	968
Jul. 81	—	—	—	—	2 999*	—	—	3 480
Aug. 81	—	4 223	2 921	—	1 954	—	—	1 290
Sep. 81	—	968	1 881	—	—	—	1 626	1 821
Oct. 81	1 235*	—	—	—	—	—	4 247	2 695
Nov. 81	921	—	493	—	—	—	1 028	746
Dec. 81	—	—	—	328*	1 434	—	—	3 378
Jan. 82	1 446	—	—	—	—	1 473	2 695	533
Feb. 82	2 007	—	1 383	—	3 212	—	—	1 796
Mar. 82	2 568	—	3 789	—	—	—	7 016	7 279
Apr. 82	—	690	—	—	2 897	—	127	437
May 82	—	852	—	—	—	922	2 425	5 012
Jun. 82	54	—	1 766	—	—	—	1 025	4 661
Jul. 82	4 778	1 072	—	—	—	—	8 043	2 412
Aug. 82	3 309	—	3 620	—	—	—	6 603	3 397
Sep. 82	488	—	4 021	—	—	—	1 403	2 969
Oct. 82	976	—	—	—	5 075	—	3 207	457
Nov. 82	733	—	1 216	—	—	—	487	1 161
Dec. 82	—	1 285	2 270	—	—	—	866	2 873
Jan. 83	—	5 143	3 741	—	—	—	3 116	1 494
Feb. 83	898	—	2 060	—	—	—	1 412	4 575
Mar. 83	483	—	690	—	5 763	—	—	5 534
Nov. 83	—	—	—	—	969	—	—	—
Mean burden	1 447	1 757	2 268	328	2 764	767	2 816	2 680

— = No animals of this age or sex culled
* = Average burden of 2 animals

(Boomker, Horak & De Vos, 1986; Boomker, Keep & Horak, 1987), was found in 1 calf and 1 juvenile kudu. *I. tuberculata* occurred in about equal numbers of calves and adult kudu (10 and 12 respectively), while only 3 juveniles and 3 young adults were infested. *Strongyloides papillosus* was present only in 6 calves, all of which were less than 6 months old. Four calves, 5 juveniles, 6 young adults and 26 adult kudu were infested with *Agriostomum gorgonis*, while *Paracooperia devossi* occurred in 3 adult kudu only. Two calves, 12 juveniles, 14 young adults and 38 adult kudu harboured the adults of *Cordophilus sagittus*. The *Setaria* sp. occurred in 2 adult kudu only.

Paramphistomes were present in 24 adult kudu, 4 young adults, 1 juvenile and 4 calves and *Schistosoma mattheei* in 4 calves, 2 juveniles, 3 young adults and 9 adults.

M. benedeni was recovered from 5 adults, 1 young adult, 4 juveniles and 3 calves, the *Avitellina* sp. from 1 adult and 1 calf and *Taenia* larvae from 7 adults, 2 young adults, 1 juvenile and 1 calf. The liver of a single adult kudu contained 2 hydatid cysts.

Peak burdens of adult *H. vegliai*, irrespective of the age of the antelope, occurred during March and July 1982 and January 1983, while 4th stage larvae peaked during June and August 1981 and March and June 1982 (Fig. 7 a & b). Adult *Cooperia* species occurred in peak numbers during July 1981, March and August 1982 and March 1983, while the 4th stage larvae were most abundant during June and November 1981 and February and October 1982 (Fig. 7 c & d). Small numbers of adult *I. tuberculata*

TABLE 4 The helminth burdens of the different age groups of kudu from the main study area in the Kruger National Park

Age group	Number of animals	Mean burden	Standard deviation	Standard error of mean
1	24	1 555	1 414.6	90.95
2	16	2 025	1 279.9	63.20
3	13	2 306	1 903.0	82.53
4	43	2 770	2 096.0	75.68
All	96	2 281	1 844.0	80.84

TABLE 5 Comparison of the helminth burdens of pregnant, lactating and quiescent adult female kudu from the main study area in the Kruger National Park

Kudu No.	Date	Helminth burden: Pregnant	Lactating	Quiescent
2	Apr. 81	—	—	426
5	May 81	247	—	—
12	Jun. 81	968	—	—
15	Jul. 81	325	—	—
16	Jul. 81	6 633	—	—
19	Aug. 81	—	—	1 289
23	Sep. 81	—	—	1 821
28	Oct. 81	2 695	—	—
31	Nov. 81	746	—	—
36	Dec. 81	3 378	—	—
41	Jan. 82	533	—	—
42	Jan. 82	—	—	1 473
43	Feb. 82	—	1 796	—
49	Mar. 82	—	7 279	—
53	Apr. 82	—	—	437
56	May 82	—	—	922
58	May 82	—	—	5 012
61	Jun. 82	—	—	4 661
63	Jul. 82	2 412	—	—
68	Aug. 82	—	—	3 397
73	Sep. 82	—	—	2 969
77	Oct. 82	—	—	457
81	Nov. 82	1 161	—	—
84	Dec. 82	2 873	—	—
91	Jan. 83	1 494	—	—
92	Feb. 83	—	4 575	—
97	Mar. 83	—	5 534	—
Mean burden		1 955	4 796	2 079

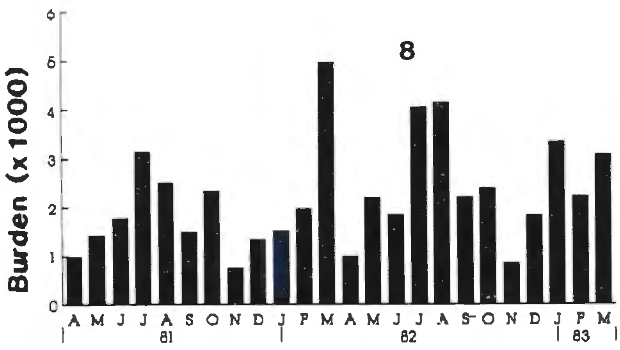


FIG. 8 Monthly fluctuations in the mean total nematode burdens

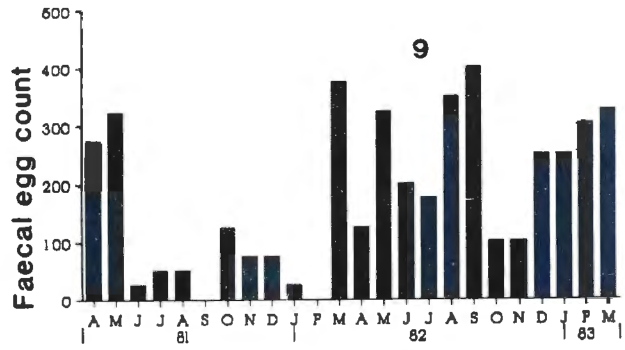


FIG. 9 Monthly fluctuations in the mean faecal nematode egg count per gram of faeces

occurred in August and October 1981, July 1982 and February 1983 (Fig. 7 e & f). Adult *Trichostrongylus* species occurred in peak numbers during August 1981 and July 1982, while minor peaks were observed during February and March 1982 and January 1983 (Fig. 7 g).

The total numbers of helminths recovered from male and female kudu of the various age groups are listed in Table 3.

Only in age group 1 did the female animals harbour more worms than the males. The most worms (8 043) were recovered from an adult male shot in July 1982 and the least (54) from a male calf shot in June 1982.

The mean total helminth burdens of kudu of various ages from the main study area are listed in Table 4.

The total worm burdens increased with the age of the animals and the overall mean burden was approximately that of the 3rd age group.

The numbers of helminths recovered from pregnant, lactating and reproductively inactive (quiescent) females of reproductive age (48 months +) are listed in Table 5.

The mean burden of quiescent females was 124 worms more than that of the pregnant females. The mean burden of lactating females, however, was more than double those of the other 2 female groups.

The fluctuations in the mean monthly total nematode burdens of the kudu are illustrated in Fig. 8 and the monthly fluctuations in the faecal nematode egg counts in Fig. 9.

The mean nematode burden fluctuated seasonally, with peaks occurring during the winters of 1981 and 1982, and the summers of 1982 and 1983. No seasonal pattern could be seen in the mean monthly faecal nematode egg counts.

Only once were 3 microfilariae found in a blood smear and that made from the peripheral blood of an adult male kudu. As part of this study, an adult female *Cordophilus sagittus* was dissected and one of the microfilariae expressed from the uterus is illustrated in Fig. 10. The measurements of 25 of these microfilariae show that they are 0,188–0,236 mm long, 0,006–0,008 mm wide, are sheathed and have a characteristically bent tail. The nuclei are distinct when stained with Giemsa. The nerve ring is situated approximately 0,057 mm from the anterior end and the *innenkorper* approximately 0,08 mm.

Pafuri and Satara

The species and numbers of worms recovered from these kudu are presented in Table 6.

Fewer worms and fewer species were recovered than from the kudu from the main study area, the largest burden being 2 902 from 1 kudu from Pafuri and 677 from the kudu from Satara.

TABLE 6 The helminths recovered from kudu from Pafuri and Satara in the Kruger National Park

Locality and helminth species	Number of adult worms recovered	Number of animals infested
Pafuri		
Cooperia neitzi	2 331	2
Cooperia spp.	1 800	2
Cordophilus sagittus	5	2
Haemonchus vegliai	582	2
Paracooperia devossi	78	1
Setaria sp.	1	1
Trichostrongylus deflexus	50	1
Satara		
Cooperia neitzi	602	1
Haemonchus vegliai	75	1

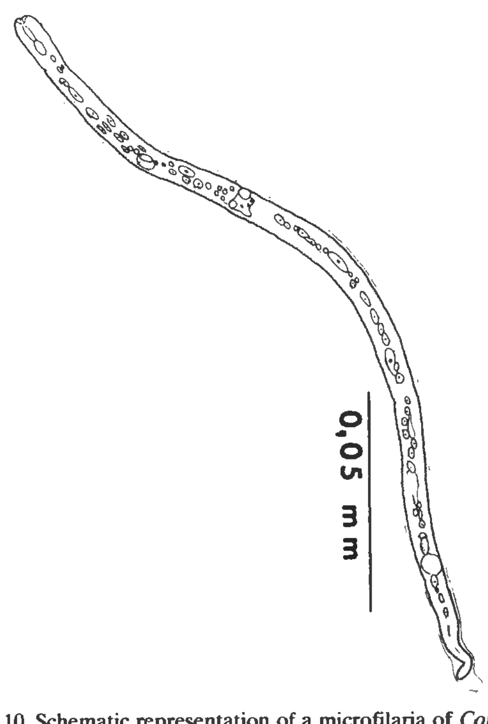


FIG. 10 Schematic representation of a microfilaria of *Cordophilus sagittus*

Discussion

Horak (1980) suggested that worms can be classified into definitive, occasional and accidental parasites of their respective hosts. According to his criteria, *H. vegliai, Cooperia neitzi, Cooperia acutispiculum, Cordophilus sagittus* and *Trichostrongylus deflexus* are definitive parasites of kudu, since they occur in a large percentage of the population and in large numbers. The paramphistomes, *Schistosoma mattheei, M. benedeni,* the *Taenia* spp. larvae, *I. tuberculata, Agriostomum gorgonis* and *Strongyloides papillosus* would be occasional parasites, since they are present in variable numbers in some of the population. The remainder can be considered accidental parasites, since they are present in small numbers in only a small percentage of the population.

The mean total helminth burdens, as listed in Table 4, should be considered the normal burdens of kudu in the KNP under the specific environmental conditions that prevailed at the time of the study. Out of the 96 kudu processed, 42 had burdens above and 54 burdens below the mean. The difference between the highest and lowest mean burdens was 1 214 worms and taking the species diversity into account, this difference is not thought to be detrimental to the host. The small burdens harboured by the females of age group 2 are probably not a true reflection of the actual situation, since only 2 females of this group were examined and both during the same month.

The effect of disease in the host on the numbers of worms recovered, as well as the effect of the parasites on the kudu seemed to be unimportant during this study. Kudu No. 16, an adult female that had small circumscribed lesions of what could be foot-and-mouth disease on the coronets and the tongue, had 6 633 worms, whereas kudu No. 64, an adult male in good health and prime condition had 8 043 worms. Nine kudu, shot during the drought that prevailed during the later part of 1982, were in poor condition but showed no effects that could be attributed to the worms. Other than these, the animals appeared to be in good health, as was evident from the autopsies performed on all the antelope, and in good condition as judged by the amount of kidney fat.

The difference in burdens between the lactating animals and the other female groups is probably the result of stress associated with terminal pregnancy, parturition, lactation and anxiety during the first few weeks of the new-born calf's life. That the stress associated with pregnancy and parturition can result in increased burdens is amply illustrated by the periparturient relaxation of resistance against *Haemonchus contortus* in sheep and goats (Van Rensburg, 1971; Gordon, 1973; Reinecke, 1983).

Two facts should be borne in mind when attempting to relate epidemiological trends in the parasites of wild antelope to those which are already known for domestic stock. Firstly, with the exception of goats in certain habitats, domestic ruminants are grazers, although cattle may also occasionally browse. Hence, one cannot really compare the epidemiology of the worms of domestic grazers with that of the helminths of wild browsers, since their hosts' feeding habits are entirely different. The ground-cover of the KNP consists mostly of grass, interspersed with herbs and forbs, and, because of its physical structure and relative abundance, more infective larvae will occur on the grass than on the forbs. This results in grazers having more worms than browsers, as is evident from previous studies on grazing antelope in the same locality (Horak, Boomker & De Vos, unpublished data, 1980).

Secondly, most of the epidemiological work on the helminths of wild ruminants has been done on the grazing species. The epidemiological trends of their parasites can probably be compared with those of domestic animals but not with those of the browsing antelope. Very little is known about the ecology of the free-living stages of the worms that normally occur in antelope. Many helminth species that infest wild ruminants do not occur in domestic animals and one cannot assume that the free-living stages of these worms behave in the same way as those of the same genus in domestic ruminants. Because the worms of antelope have evolved along with their hosts and therefore in the same habitat, there may be small but significant adaptations in their ability to survive and in the longevity of their free-living stages.

The infective larvae of *H. contortus* of domestic animals increase on the pastures in the summer rainfall areas of South Africa, which includes the KNP, from about October onwards. On the Transvaal Highveld, where the winters are severe, sheep and cattle acquire infestations from November onwards and peak adult burdens occur from the end of November to the end of February. Burdens of 4th stage larvae increase from March to August, with peak burdens during May and June. A spring rise in adult worm burdens and in faecal worm egg counts is often seen in October (Reinecke, 1983).

It appears that *H. vegliai* has no seasonal pattern of abundance in kudu in the southern part of the KNP. This is probably due to the mild winter temperatures.

Horak, De Vos & Brown (1983) recovered the largest numbers of *Haemonchus bedfordi* from blue wildebeest, *Connochaetes taurinus,* in the KNP during winter and spring and Boomker, Du Plessis & Boomker (1983) recovered the greatest numbers of *Haemonchus* spp. from grey duikers, *Sylvicapra grimmia,* from the central Transvaal during the same seasons. Horak *et al.* (1983), however, found that an age resistance to infestation with *H. bedfordi* developed in blue wildebeest, something that was not seen in the kudu in this study.

The *Cooperia* spp. present a problem in that a total of 6 species were recovered. The major species, *Cooperia neitzi* and *Cooperia acutispiculum,* followed a similar pattern of seasonal abundance and are combined in Fig. 7c. The other species occurred in negligible numbers.

Since the 4th stage larvae of the various *Cooperia* species cannot be specifically identified they are considered here as a group which includes the larvae of the minor species, as well as those of *Paracooperia devossi.* No clear pattern of seasonal abundance was evident for the larvae or the adult worms and the latter occurred throughout the year.

These findings do not corroborate those of Horak (1978 b) for *Cooperia* spp. in cattle in the northern Transvaal, where the worms occurred in large numbers during April to June and during December. They also differ from those of Horak *et al.* (1983) for *Cooperia connochaeti* in blue wildebeest in the KNP, where peak adult burdens occurred in April, May and October. The differences are possibly due to differences in climate during the times when the studies were undertaken, host specificity and the epidemiology of the *Cooperia* spp. concerned.

I. tuberculata parasitizes a wide range of antelope. In kudu in the main study area, the worm burdens were too small and variable to determine any pattern of seasonal abundance. Similar observations have been made in grey duikers in the central Transvaal (Boomker *et al.*, 1983). In impala, *Aepyceros melampus,* in the northern Transvaal, Horak (1978 a) found the parasites to be present in peak numbers from May to August and during December.

Trichostrongylus deflexus was the most abundant of the *Trichostrongylus* spp. recovered, the other species being present in negligible numbers. Peak adult *Trichostrongylus* burdens occurred in July and August with minor peaks in January and February. Peak burdens of *Trichostrongylus axei* were observed during the same time of year (August and January) in grey duikers from the central Transvaal (Boomker *et al.*, 1983).

The pattern of infestation of *S. papillosus* seems to indicate a milk-borne infestation, as seen in sheep and goats (Lyons, Drudge & Tolliver, 1970; Moncol & Grice, 1974). Similar observations have been made for impala in the northern Transvaal (Horak, 1978 a) and blue wildebeest in the KNP (Horak *et al.*, 1983).

Paracooperia devossi is a nematode recently described from bushbuck, *Tragelaphus scriptus,* from the KNP (Boomker & Kingsley, 1984), and as a total of only 27 worms were recovered from all the kudu, it must be assumed that it is an accidental parasite in this host.

Agriostomum gorgonis was present in about equal numbers in the kudu of different age groups and had no definite seasonal distribution. Only 42,3 % of kudu were infested as opposed to 80 % of blue wildebeest (Horak *et al.*, 1983). Assuming that *Agriostomum,* like the other hookworms of ruminants, infest their hosts percutaneously, and that their larvae occur in moist areas, such as around drinking places, we are of the opinion that because kudu occur in smaller herds and drink water less often, they are not subject to the same infestation levels as blue wildebeest.

A single *Parabronema* spp. female, which could not be identified to species level, was found in 1 of the kudu. We consider this an accidental parasite, originating either from the square-lipped rhinoceros, *Ceratotherium simum,* or giraffe, *Giraffa camelopardalis.*

Cordophilus sagittus is a common parasite of the tragelaphine antelope and has also been recorded from buffalo, bovines and eland (Mönnig, 1926; McCully, Van Niekerk & Basson, 1967; Keep, 1983; Newsholme & Coetzer, 1984).

During this survey, numerous bite marks were seen on the inner surfaces of the ear pinnae of all but the very young kudu. In a number of cases, unidentified tabanid flies were seen feeding on the ears. The bites appeared more numerous and more acute during the warmer months of the year, from September onwards.

A possible explanation for the low incidence of microfilariae in the blood smears of kudu is that the microfilariae exhibit a specific biorhythm, occurring in the peripheral blood during the warm part of day when the flies, which are suspected to be the intermediate hosts, are active. The majority of the kudu were shot early in the morning when the flies were not yet active. As mostly older kudu and only 2 calves between 10 and 12 months old were infested, we suggest that the life cycle takes at least 9 months to complete.

In his description of the morphology of *Cordophilus sagittus,* Turner (1925) mentioned that the 'embryos' *(sic)* are 0,245 mm long and 0,0075 mm thick, and that they are 'finely granular with faint suggestions of 2 cell outlines a little anterior to the middle'. Mönnig (1926) stated that improperly fixed larvae expressed from the uterus of a female measured 0,33 mm, but he did not mention any morphological characteristics. The larvae measured in this study are slightly shorter than those of Turner (1925) and considerably shorter than those of Mönnig (1926). We assume that fixation is responsible for these differences, and that microfilariae in blood smears may be slightly longer.

The remaining nematodes as well as the trematodes and cestodes displayed no distinct seasonal pattern of abundance.

Peak mean total adult worm burdens were observed during winter (June–August) and again during mid- to late summer (January–March), with the most worms occurring during March, July and August 1982 (Fig. 8).

The fluctuations in the faecal worm egg counts are unrelated to the seasonal abundance of the worms (Fig. 9). The linear correlation between (a) the number of adult trichostrongylid females and the faecal nematode egg count and (b) the total adult trichostrongylid burden and the faecal nematode egg count were determined by using the formula of Steel & Torrie (1960). The results of these calculations indicate that there is little correlation, 0,17 and 0,07 respectively, between faecal worm egg count and total female or total worm burdens. Furthermore, kudu harbouring small worm burdens sometimes had high faecal egg outputs, while others had large burdens without any eggs being present. We suggest that the size of nematode burdens in game should not be determined by means of faecal egg counts and that autopsy remains the best method, as advocated by Reinecke (1983) for domestic stock.

The minimum and maximum atmospheric temperatures (Fig. 3) and the rainfall during summer (Fig. 4–6) appear to be sufficient to prevent the faecal pellets of the kudu from drying out and to enable the larvae to escape from these pellets. The environmental conditions also seem favourable for the year-round survival of the free-living stages. This would corroborate the earlier observation that arrested development did not occur and that infestation took place throughout both years of the survey.

As part of the study, trichostrongylid worms were randomly collected from the kudu of all age groups and measured. The measurements of individual worms, both male and female, did not differ significantly and abnormally large or small spicules, reduced vulvar flaps or smaller eggs were not seen. We conclude that previous exposure to the various trichostrongylids did not affect subsequent infestations as is often the case in domestic ruminants (Michel, 1963; Keith, 1967), the reason being that the burdens in kudu are probably not large enough to stimulate immunity.

Pafuri and Satara

The definitive and occasional parasites of the kudu in the main study area were also present in the animals from Pafuri, but only 2 of the definitive parasites were present in the kudu from Satara. *Paracooperia devossi* was present in 1 of the kudu from Pafuri in larger numbers than in all the kudu from the main study area put together, but 3 bushbuck, the type host of the worm from the same locality, harboured none (Boomker *et al.*, 1986).

The small total worm burden of the animal from Satara is thought to be the result of the drought that prevailed at the time, creating unfavourable conditions for the survival of the free-living stages. Furthermore, during droughts the antelope are forced to cover greater distances in search of food, which limits their exposure to the infective larvae of their own worms.

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