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PARASITES OF DOMESTIC AND WILD ANIMALS IN SOUTH AFRICA. XVII. ARTHROPOD PARASITES OF BURCHELL'S ZEBRA, *EQUUS BURCHELLI*, IN THE EASTERN TRANSVAAL LOWVELD

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ABSTRACT

HORAK, I. G., DE VOS, V. & DE KLERK, B. D., 1984. Parasites of domestic and wild animals in South Africa. XVII. Arthropod parasites of Burchell's zebra, *Equus burchelli*, in the eastern Transvaal Lowveld. *Onderstepoort Journal of Veterinary Research*, 51, 145–154 (1984).

Thirty-five Burchell's zebra, *Equus burchelli*, were shot for arthropod parasite recovery during the period November 1978—January 1982 in the Kruger National Park. Six species of gasterophilid larvae, 2 species of oestrid larvae, 2 louse species and 7 ixodid tick species were recovered. The distribution of the *Gasterophilus* spp. larvae within the gastrointestinal tract and their seasonal prevalence were determined. The seasonal prevalence of the oestrid larvae and 4 of the 7 ixodid tick species was also ascertained.

INTRODUCTION

The southern boundary of the distribution of Burchell's zebra, *Equus burchelli*, extends from southern Angola across northern South West Africa/Namibia, through southern Botswana and across the provinces of the Transvaal and Natal in the Republic of South Africa to the Indian Ocean. The northern boundary stretches from south-western Angola across Zaire to western Tanzania, up through Uganda, then across the southern Sudan, south-western Ethiopia, northern Kenya and southern Somalia to the sea (Ansell, 1971). It is not surprising that because of their widespread distribution many zebras have been shot and examined and consequently much is known about their parasites.

Zumpt (1965) has recorded the *Gasterophilus* spp. and *Rhinoestrus* spp. infesting Burchell's zebra. Several of the *Gasterophilus* spp. are the same as those encountered in domestic horses while others are peculiar to the zebra. Larvae of nasal bot flies of the genus *Rhinoestrus* have not been encountered in horses in South Africa but have been found in Burchell's zebra in this country (Zumpt, 1965). The lice recovered from Burchell's zebra are probably specific to this animal (Ledger, 1980), while several of the tick species found in South Africa on these animals are the same as those found on domestic horses and cattle (Theiler, 1962).

Although the seasonal prevalence of *Gasterophilus intestinalis* and *Gasterophilus nasalis* has been determined in horses in various surveys conducted in several countries (Kettle, 1974; Drudge, Lyons, Wyant & Tolliver, 1975; Hatch, McCaughey & O'Brien, 1976; Panitz, 1978), no such data are available for Burchell's zebra. Howard (1981) has determined the numbers of *Gasterophilus* spp. larvae infesting Burchell's zebra in the Lochinvar National Park in Zambia, but he could find no seasonal pattern of activity.

The seasonal prevalence of nasal bot flies, lice and ticks infesting Burchell's zebra has also not been determined. During surveys of the parasites of wild animals in the Kruger National Park, 35 Burchell's zebra were shot and this paper records the prevalence of arthropod parasites recovered from these animals. The internal parasite burdens of 10 of these zebras have been recorded in separate papers (Scialdo, Reinecke & De Vos, 1982; Scialdo-Krecek, 1983).

MATERIALS AND METHODS

The Kruger National Park is situated in the eastern Transvaal Lowveld. The zebra examined in this survey were obtained from a region within the park bounded by Satara (24°24'S, 31°47'E; Alt. 275 m) in the north and Lower Sabie (25°07'S, 31°55'E; Alt. 180 m) in the south. This region is described by Acocks (1975) as comprising Arid Lowveld and Lowveld. Atmospheric temperature and rainfall were measured at a weather station at Skukuza (24°58'S, 31°36'E; Alt. 262 m), situated to the west of the survey area within the park.

Zebra were shot at 3-month intervals from November 1978–August 1979; during September 1979; at month intervals from June 1980–July 1981, and from October 1981–January 1982. The culling procedure was so arranged that by the time the last animal had been shot at least 2 animals had been culled during each calender month, though not necessarily in the same year.

After the zebras had been shot they were exsanguinated and their carcasses were transported to the laboratory at Skukuza where they were processed for parasite recovery.

At necropsy *Rhinoestrus* spp. larvae and *Gastrophilus* spp. larvae were recovered by the methods described by Malan, Reinecke & Scialdo (1981). On some occasions mature *Rhinoestrus* spp. larvae present in the nasal passages or mature *Gasterophilus* spp. larvae in the recta were collected, placed in vermiculite in gauze-stoppered, wide-mouthed bottles and transported to the laboratory at Onderstepoort, where they were allowed to pupate.

The ticks and lice were collected by methods described by Horak, De Vos & Brown (1983), but only half of the animal was processed for ectoparasite recovery. These parasites were counted as described by Horak, Potgieter, Walker, De Vos & Boomker (1983).

In the graphs mean parasite burdens have been plotted when 2 animals were slaughtered at the same time, and total parasite burdens if only 1 animal had been shot.

RESULTS

The total numbers of the various arthropod parasites recovered and their prevalence are summarized in Table 1.

The larvae of 6 bot fly species and 2 nasal bot fly species, plus the immature and/or adult stages of 2 louse species and 7 ixodid tick species, were recovered.

Gasterophilus ternicinctus was the most numerous bot fly larva recovered; every zebra was infested with larvae of this fly plus those of *G. nasalis*. *Rhinoestrus usbekistanicus* was the commonest 3rd stage nasal bot fly larva recovered. A *Haematopinus* sp. was the most abundant and most prevalent louse. *Boophilus decoloratus* was the most numerous tick; all zebras were infested with this species and with *Amblyomma hebraeum* and *Rhipicephalus evertsi evertsi*.

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TABLE 1 The arthropod parasites recovered from Burchell's zebra in the Kruger National Park

Arthropod species	Total numbers of arthropods recovered						Percentage of animals infested
Zebra bot flies	1st stage larvae	2nd stage larvae	3rd stage larvae			Total	
Gasterophilus spp.	564	—	—			564	88,6
Gasterophilus haemorrhoidalis	—	718	1 702			2 420	97,1
Gasterophilus inermis	—	734	3 388			4 122	77,1
Gasterophilus meridionalis	—	787	1 949			2 736	91,4
Gasterophilus nasalis	—	3 014	5 118			8 132	100,0
Gasterophilus pecorum	—	1 361	3 148			4 509	94,3
Gasterophilus ternicinctus	—	1 808	6 837			8 645	100,0
Zebra nasal bot flies*							
Rhinoestrus spp.	1 409	53	—			1 462	84,8
Rhinoestrus steyni	—	—	24			24	24,2
Rhinoestrus usbekistanicus	—	—	109			109	36,4
Lice*		Nymphae	Adults			Total	
Damalinia sp.		342	197			539	30,3
Haematopinus sp.		752	469			1 221	51,5
Ixodid ticks*	Larvae	Nymphae	♂♂	♀♀		Total	
Amblyomma hebraeum	7 476	1 727	59	28	(4)	11 290	100,0
Boophilus decoloratus	35 321	13 222	7 924	3 834	(203)	60 301	100,0
Hyalomma truncatum	0	0	17	9		26	20,0
Rhipicephalus appendiculatus	—	5 968	—	—		5 968	75,8
Rhipicephalus appendiculatus/zambeziensis	6 328	—	178	117	(8)	6 623	87,9
Rhipicephalus evertsi evertsi	20 009	8 563	1 852	660	(20)	31 084	100,0
Rhipicephalus simus	0	0	284	97	(2)	381	60,6
Rhipicephalus zambeziensis	—	20	—	—		20	6,1

* Numbers based on 33 of the 35 animals

( ) Number of maturing female ticks, ie. *A. hebraeum* > 9,0 mm; *B. decoloratus* > 4,0 mm; *R. appendiculatus/zambeziensis* > 5,0 mm; *R. evertsi evertsi* > 6,0 mm; *R. simus* > 6,0 mm

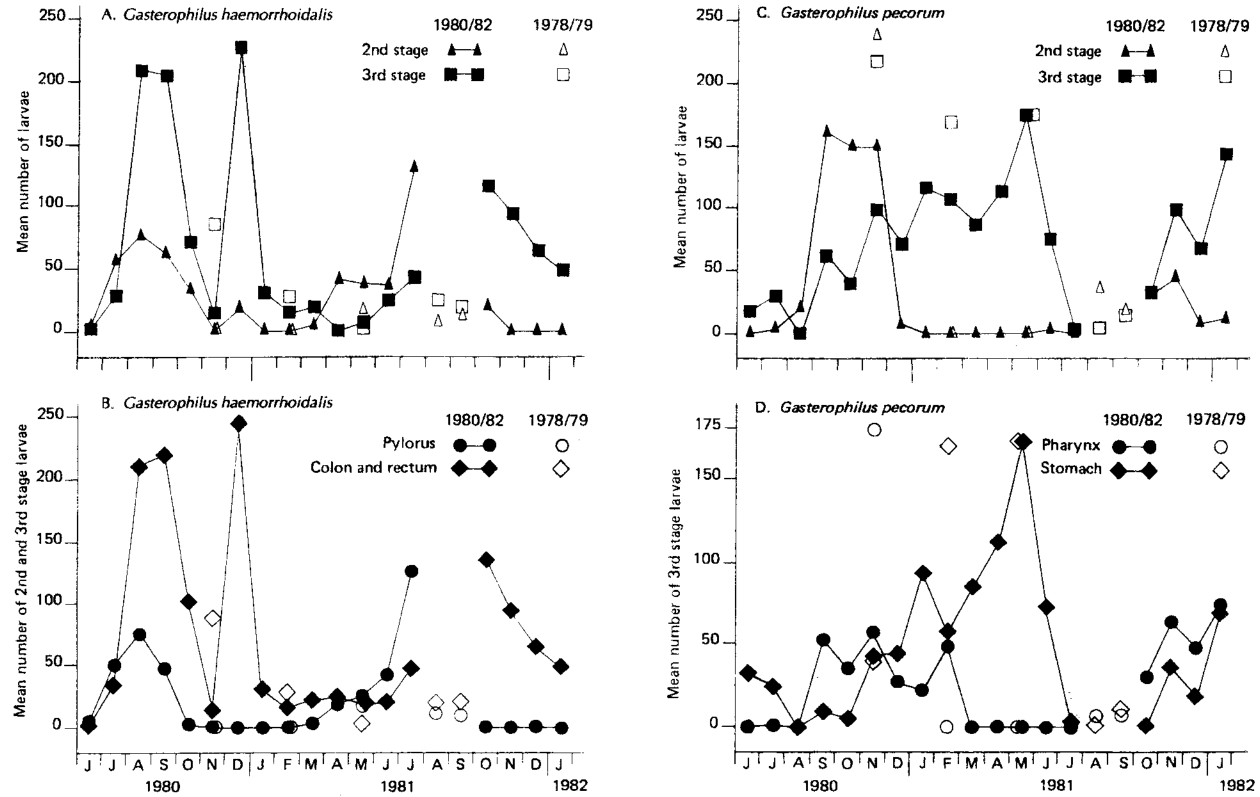


FIG. 1 The seasonal prevalence of the larvae of

A. *Gasterophilus haemorrhoidalis* and

C. *Gasterophilus pecorum* and

the seasonal migration of

B. 2nd and 3rd stage *Gasterophilus haemorrhoidalis* larvae from the pylorus to the colon and rectum and

D. 3rd stage *Gasterophilus pecorum* larvae from the pharynx to the stomach

in Burchell's zebra in the Kruger National Park

TABLE 2 The distribution of *Gasterophilus* spp. larvae in the gastrointestinal tracts of 35 Burchell's zebra

Gasterophilus spp.	Stage of development	Numbers (percentages) of larvae recovered: Tongue*	Peridontal spaces	Pharynx	Cardiac region of stomach	Pylorus and duodenum	Small intestine	Ventral and dorsal colon	Descending colon and rectum
Gasterophilus spp.	1st	38 (6,74)	**526 (93,26)**						
G. haemorrhoidalis	2nd		6 (0,84)		6 (0,84)	**479 (66,71)**	9 (1,25)	124 (17,27)	94 (13,09)
	3rd					67 (3,94)	2 (0,12)	**1 362 (80,02)**	271 (15,92)
G. inermis	2nd	1 (0,14)							**733 (99,86)**
	3rd							8 (0,24)	**3 380 (99,76)**
G. meridionalis	2nd		1 (0,13)		1 (0,13)	**700 (88,94)**	85 (10,80)		
	3rd				11 (0,56)	**1 876 (96,26)**	55 (2,82)	7 (0,36)	
G. nasalis	2nd		26 (0,86)		29 (0,96)	**2 878 (95,49)**	80 (2,66)		1 (0,03)
	3rd				24 (0,47)	**5 056 (98,79)**	35 (0,68)	2 (0,04)	1 (0,02)
G. pecorum	2nd	13 (0,96)	1 (0,07)	**1 336 (98,16)**	11 (0,81)				
	3rd			957 (30,40)	**2 172 (69,00)**	3 (0,09)		7 (0,22)	9 (0,29)
G. ternicinctus	2nd		192 (10,62)	3 (0,16)	**1 602 (88,61)**	11 (0,61)			
	3rd				**6 726 (98,38)**	24 (0,35)	1 (0,01)	19 (0,28)	67 (0,98)

* Tongues of 28 zebras examined

Bold print indicates preferred site of attachment from November–June. Two Zebra foals, approximately 6 months of age and shot during June 1980 and May 1981 respectively, harboured no 2nd or 3rd stage larvae.

The seasonal prevalence of the other *Gasterophilus* spp. larvae is graphically illustrated in Fig 2.

Gasterophilus inermis. The vast majority of 2nd and 3rd stage larvae attached in the descending colon and rectum (Table 2). Second stage larvae were generally more prevalent from April–August and 3rd stage from October–March (Fig. 2a).

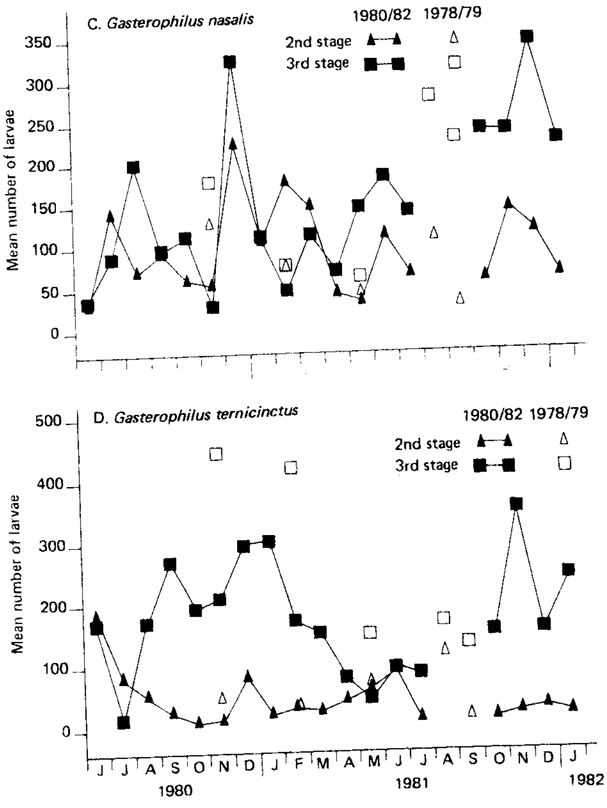
Gasterophilus meridionalis. Both 2nd and 3rd stage larvae preferred the pylorus and duodenum although some were found deeply embedded in the mucosa of the small intestines (Table 2). Peak activity occurred from August or October–December and from December–April for the 2nd and 3rd stage larvae respectively (Fig. 2 b).

Gasterophilus nasalis. The predilection site for both 2nd and 3rd stage larvae was the pylorus and duodenum (Table 2). No clear pattern of seasonal abundance could be determined (Fig. 2 c).

Gasterophilus ternicinctus. The cardiac region of the stomach was the preferred site of attachment for 2nd and 3rd stage larvae (Table 2). The 2nd stage larvae exhibited no clear pattern of seasonal prevalence, while the 3rd stage was usually most prevalent from August–March (Fig. 2 d). In the laboratory the pupal period of mature 3rd stage larvae collected during January 1981 was 23 and 24 days, while that for larvae collected during February 1981 ranged between 24 and 28 days.

Oestrids

The seasonal abundance of the *Rhinoestrus* spp. 1st stage larvae is graphically illustrated in Fig. 3.



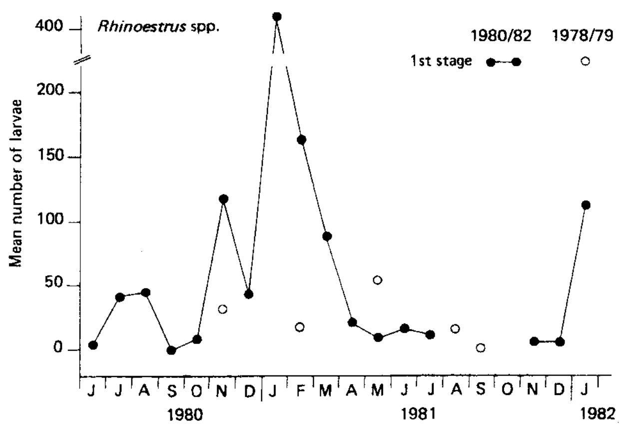


FIG. 3 The seasonal prevalence of 1st stage *Rhinoestrus* spp. larvae in the nasal passages of Burchell's zebra in the Kruger National Park

First stage larvae were generally present in the greatest numbers from November or January–March. Small numbers of 2nd stage larvae were present during February, May and August 1979, June–August 1980, January–April and June and July 1981. Third stage larvae of *Rhinoestrus steyni* were recovered in small numbers during May 1979, June and July 1980, March, April and June 1981. Small numbers of 3rd stage *R. usbekistanicus* larvae were present during May, August and September 1979, July and August 1980, March and May–July 1981.

The pupal period of *R. steyni* at room temperature in the laboratory at Onderstepoort was 55 days for a mature larva collected during July 1980 and ranged between 32 and 33 days for larvae collected during March 1981. The pupal period of *R. usbekistanicus* was 36 and 37 days for larvae collected on 13 and 14 August 1979, 55 days for a larva collected during July 1980 and 29 days for a larva collected on 21 August 1980.

Lice

Lice belonging to 2 genera, *Damalinia* and *Haematopinus*, were recovered but were not identified specifically.

No clear pattern of seasonal abundance could be established for either genus.

Ixodid ticks

The seasonal prevalence of the 4 most abundant tick species is graphically illustrated in Fig. 4. All stages of development of *B. decoloratus* are combined in the graph.

A. hebraeum. Peak numbers of larvae were recovered from July–September and during December 1980 and June 1981. Peak numbers of nymphae were present during September 1979 and August and September 1980. Few adults were recovered at any time and these are not included in the graph.

B. decoloratus. The percentages of ticks in the various stages of development on the heads and ears; necks, bodies, tails and upper legs; and lower legs and feet of 31 of the 35 zebras are summarized in Table 3.

The vast majority of *B. decoloratus* were recovered from the necks, bodies, tails and upper legs of the zebras. Higher percentages of these ticks were in the nymphal and adult stages of development than were those present on the heads and ears or lower legs and feet.

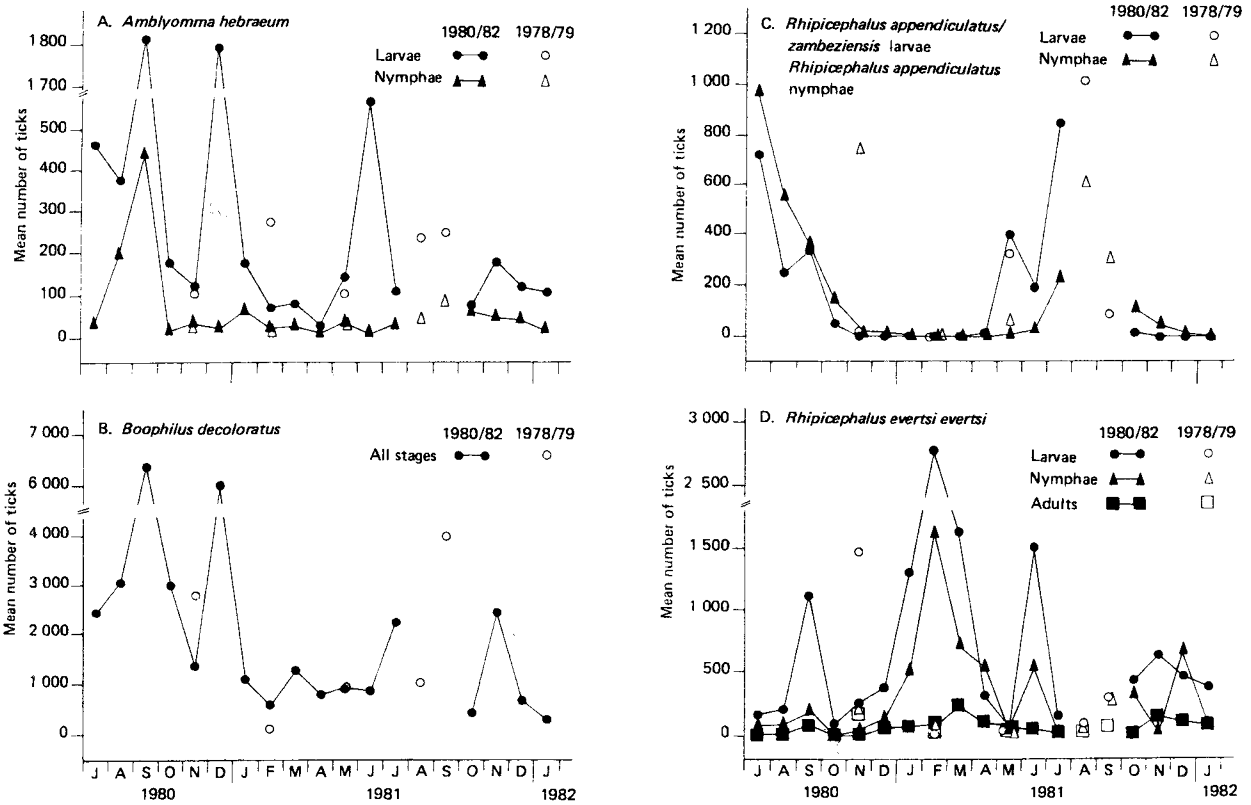


FIG. 4 The seasonal prevalence of
A. *Amblyomma hebraeum*
B. *Boophilus decoloratus*
C. *Rhipicephalus* spp. larvae and *Rhipicephalus appendiculatus* nymphae and
D. *Rhipicephalus evertsi evertsi*
on Burchell's zebra in the Kruger National Park

TABLE 3 The proportional distribution of the various stages of development of *Boophilus decoloratus* on 31 Burchell's zebra

Site	Total number of ticks recovered	Percentage in each stage of development			
		Larvae	Nymphae	Males	Females
Head and ears	5 348	76,20	13,44	7,55	2,81
Neck, body, tail and upper legs	49 768	56,13	23,20	13,88	6,79
Lower legs and feet	4 799	66,58	18,46	10,31	4,65

Burdens reached a peak during September 1979 and September and December 1980.

R. appendiculatus/zambeziensis. Larvae of this group were most numerous during August 1979, July 1980 and July 1981. Peak numbers of *R. appendiculatus* nymphae were present during November 1978, August 1979 and July 1980 and a peak also occurred during the period July–October 1981. Only 20 *R. zambeziensis* nymphae were recovered, and these came from an animal shot during July 1981 and another shot during January 1982. Few *R. appendiculatus/zambeziensis* adults were recovered and these are not included in the graph.

R. evertsi evertsi. Larvae and nymphae reached peaks during November 1979, September 1980, January–March and June 1981. Comparatively large numbers of adults were recovered during November 1978 and March and November 1981.

Rhipicephalus simus. Peak numbers of adults were present during February and May 1979, March 1981 and January 1982.

The monthly mean minimum and maximum atmospheric temperatures and monthly rainfall measured at Skukuza are graphically illustrated in Fig. 5.

With the exception of August 1981, mean maximum temperatures always exceeded 25 °C and, with the exception of July 1979, June and July 1980 and June 1981, mean minimum temperatures exceeded 5 °C. Most rain generally fell during the period September–April.

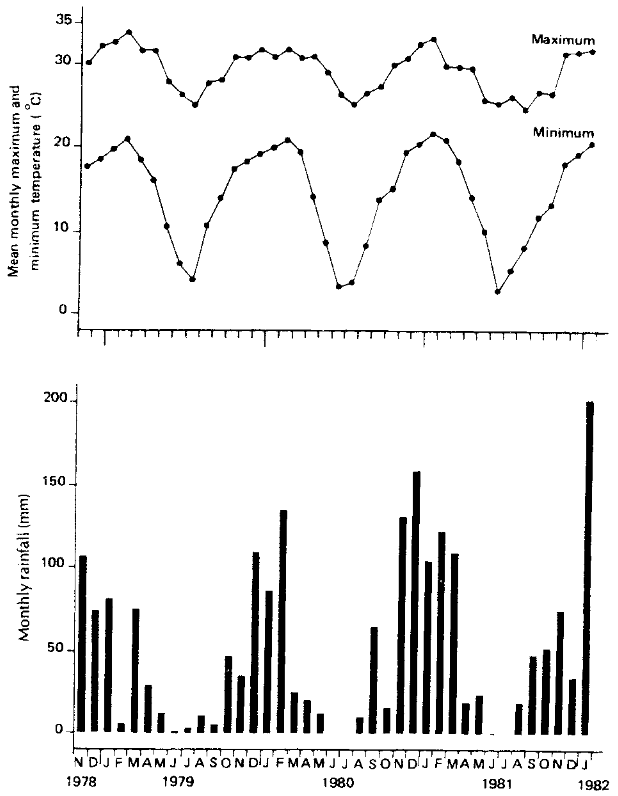


FIG. 5 The monthly mean minimum and maximum atmospheric temperatures and monthly rainfall at Skukuza from November 1978–January 1982

DISCUSSION

Gasterophilids

Of the 6 species of *Gasterophilus* larvae recovered *G. meridionalis* and *G. ternicinctus* are peculiar to Burchell's zebra, while *G. haemorrhoidalis, G. inermis, G. nasalis* and *G. pecorum* are also found in domestic horses (Zumpt, 1965). With the exception of *G. pecorum*, the same species were recovered by Howard (1981) from 34 Burchell's zebras he examined in and around Lochinvar National Park in Zambia.

The small number of 1st stage *Gasterophilus* spp. larvae recovered in the present study is possibly an indication of a poor recovery technique. It may also indicate that the larvae spend a comparatively short time in this stage of development compared with that spent in the later stages. Likewise, the smaller numbers of 2nd stage larvae recovered compared with the numbers of 3rd stage larvae are an indication of the comparative lengths of time spent in these stages.

Third stage larvae of *G. pecorum* and *G. ternicinctus* both occur in the cardiac region of the stomach (Table 2). However, they seem to avoid competition for space by the fact that *G. pecorum* reaches peak numbers from November–June and *G. ternicinctus* generally from August–March (Fig. 1c,2d). The larvae of *G. haemorrhoidalis, G. meridionalis* and *G. nasalis* attach in the pyloric region of the stomach and the anterior portion of the duodenum (Table 2). Competition between the former 2 seems to be avoided by the fact that *G. haemorrhoidalis* peaks in this site from April–September compared with December–April for *G. meridionalis* (Fig. 1b,2b). Large numbers of *G. nasalis* larvae may be present in the pyloric region of the stomach at any time of the year (Fig. 2c).

The localities from which the *Gasterophilus* spp. larvae were recovered and the seasonal occurrence of the 2nd and 3rd stage larvae allow one to speculate what their life cycles might be.

G. haemorrhoidalis. Eggs are probably deposited from February–June or July. First stage larvae moult to the 2nd stage from March–July or August and these moult to the 3rd stage from June–November. Third stage larvae leave the zebra to pupate from November–March.

Zumpt (1965) stated that the 2nd stage larvae moult to the 3rd stage in the stomach and duodenum before migrating to the rectum. In the present survey migration to the colon and rectum took place while the larvae were in the 2nd or 3rd stage. It did not appear as if a period spent in the stomach or duodenum was a prerequisite before migration to the colon and rectum took place. Those larvae that did attach in the stomach had all migrated to the colon and rectum by October or November (Fig. 1b). The majority of larvae were found in the ventral and dorsal colon (Table 2) and few were present in the descending colon and rectum, a site that Zumpt (1965) and Howard (1981) found was favoured by larvae of this species.

G. inermis. Eggs are probably deposited from February–May. First stage larvae moult to the 2nd stage from March–June and these to the 3rd stage from May–August. Third stage larvae leave the zebras to pupate from December–March.

G. meridionalis. Eggs are probably deposited from June–September. The fact that the 2 6-month-old zebras slaughtered during June 1980 and May 1981, respectively, harboured no 2nd and 3rd stage larvae of this species, while the 2 older zebras examined at the same time were infested, supports this suggestion. First stage larvae moult to the 2nd stage from August–October. These in turn moult to the 3rd stage from October–December and moulting is completed by January. The 3rd stage larvae leave the zebra to pupate from April–August. Only 1 life cycle per year seems possible in the Kruger National Park.

G. nasalis. The presence of 2nd and 3rd stage larvae throughout the year and the fluctuations in their numbers suggest either that more than 1 life cycle per year can be completed in the Kruger National Park or that the life cycle can continue uninterruptedly throughout the year.

In New Zealand Kettle (1974) found that *G. nasalis* adults were active from December–June and that this species probably overwintered as 3rd stage larvae. The incidence of infestation was 59% and the median number of larvae per horse was 14. In Kentucky, in the United States of America, Drudge *et al.* (1975) found that 80,7% of horses were infested with *G. nasalis* and the mean burden consisted of 52 larvae. They suggested that the horses in their study became infested only between May and November. Hatch *et al.* (1976) found that 28,6% of horses slaughtered at an abattoir near Dublin in Ireland were infested with *G. nasalis*, but at an abattoir near Belfast none were infested.

G. pecorum. Eggs are probably deposited from May—September. This supposition is supported by the fact that 2 6-month-old foals, slaughtered during June 1980 and May 1981, respectively harboured no 2nd or 3rd stage *G. pecorum* larvae, while the older zebras slaughtered at the same time were both infested. Both these foals had fairly large burdens of 1st stage larvae, which may either have been, or have included, *G. pecorum* larvae. The 1st stage larvae moult to the 2nd stage from July–October and the majority of these attach in the pharynx. Second stage larvae moult to the 3rd stage from September–December and these migrate from the pharynx to the cardiac region of the stomach from November–February (Fig. 1). The 3rd stage larvae leave the zebras and pupate from April–July. Zumpt (1965) states that in southern Africa adults hatch from February–May and again in August after a pupal period of 20–26 days. Only 1 generation per year seems likely.

G. ternicinctus. The presence of relatively large numbers of 2nd and 3rd stage larvae at all times suggests that the life cycle can continue throughout the year. This is further confirmed by Zumpt's observation (1965) that adults hatched in April and May and in November and December. In the present survey mature larvae were present during January and February 1981, and these gave rise to flies during February and March, respectively, after pupal periods lasting 23–28 days.

Oestrids

The large number of 1st stage *Rhinoestrus* spp. larvae recovered compared with the relatively small numbers of 2nd and 3rd stage larvae suggests that many larvae are lost during development. This is perhaps not surprising as, unlike *Oestrus ovis*, in which the 2nd and 3rd stage larvae inhabit the sinus cavities (Horak, 1977), 2nd and 3rd stage *R. steyni* and *R. usbekistanicus* are found in the posterior naso-pharyngeal region, and possibly they are more easily dislodged from there.

R. steyni. The seasonal incidence of larvae of this nasal bot fly in zebras in the Kruger National Park suggests that more than 1 life cycle can be completed annually. First stage larvae are presumably deposited in or around the nostrils from October–April or May. These moult to the 2nd stage from January and to the 3rd stage from March onwards. Mature 3rd stage larvae are already present in March and these leave the nostrils from March onwards until virtually all have left by July or August.

A pupal period of 32–33 days was recorded in the laboratory for 3rd stage larvae collected during March. If this finding is applicable to field conditions in the Kruger Park, which is still very warm during March (Fig. 5), it would be possible for a 2nd generation of 1st stage larvae to be deposited during April or May. These larvae would have to complete their development rapidly in order to have left the zebras by September.

R. usbekistanicus. The recovery of mature 3rd stage larvae during only July, August and September suggests that this fly completes a single life cycle per year in the Kruger National Park.

The mature larvae collected during August 1979 gave rise to flies between 18 and 20 September 1979. Those collected during July and August 1980 gave rise to flies on 17 and 19 September 1980, respectively. This synchronized hatching implies that post-winter infestation would take place from mid-September onwards, a fact confirmed by the present results.

Sumpt (1965) comments on the variable speed of development of *Rhinoestrus purpureus* in horses. He states that both in this species and in *R. usbekistanicus* 2 generations per year are possible.

The life cycles of the *Rhinoestrus* spp. in zebras in the Kruger National Park are not unlike that of *O. ovis* in sheep in colder climates. In these climates only 1 or 2 generations of *O. ovis* per year are possible and larvae are deposited in summer and autumn (Kettle, 1973). *O. ovis*, however, overwinters in the nasal passages as 1st stage larvae (Cobbett & Mitchell, 1941), whereas the *Rhinoestrus* spp. overwinter in the 2nd and 3rd larval stage.

Lice

No attempt was made to identify the lice specifically because, according to Ledger (1980), considerable controversy still exists about the *Damalinia* and *Haematopinus* spp. from equids. The largest number of the *Damalinia* sp. recovered from a single zebra, an adult animal slaughtered during November 1981, was 64 nymphae and 64 adults. An 18-month-old animal slaughtered during August 1980 harboured 432 nymphae and 288 adult *Haematopinus* sp. No seasonal prevalences could be determined for either of these lice.

Ixodid ticks

Horak, De Vos & Brown (1983) recovered a total of 38 305 ticks, belonging to the same species as those infesting the zebra, fron 47 blue wildebeest shot in the Kruger National Park from December 1977–November 1978. Of these ticks, 2 302 were adult, giving a ratio of 15,6:1 immature to adult ticks. The wildebeest harboured a total of 88 engorging female ticks, all of which

TABLE 4 The mean numbers of ticks recovered from Burchell's zebras and blue wildebeest in the Kruger National Park

Tick species	Mean numbers of ticks recovered									
	Burchell's zebra					Blue wildebeest				
	Larvae	Nymphae	♂♂	♀♀	Total	Larvae	Nymphae	♂♂	♀♀	Total
Amblyomma hebraeum	287	52	1,8	0,8	342	73	4	0,2	0,1	77
Boophilus decoloratus	1 070	401	240	116	1 827	420	81	27	20	548
Hyalomma truncatum	0	0	0,5	0,3	0,8	0	0	0,1	0,02	0,12
Rhipicephalus appendiculatus/zambeziensis	192	—	5,4	3,5	201	52	—	0	0	52
Rhipicephalus appendiculatus	—	181	—	—	181	—	86	0,04	0,02	86
Rhipicephalus zambeziensis	—	0,6	—	—	0,6	—	0,4	—	—	0,4
Rhipicephalus evertsi evertsi	606	260	56	20	942	46	1,5	0,8	0,6	49
Rhipicephalus simus	0	0	8,6	2,9	12	1,3	0	0	0	1,3

were *B. decoloratus*. The 33 zebra on which tick counts were done in the present survey harboured a total of 115 693 ticks. Of these 15 059 were adult, i.e. a ratio of 6,7:1 immature to adult ticks. The zebras harboured a total of 237 engorging females of 5 different species (Table 1).

The mean tick burdens of the blue wildebeest examined by Horak, De Vos & Brown (1983) and of the zebras examined in the present survey are summarized in Table 4.

With the minor exception of the larvae of *R. simus*, the zebras carried more ticks of every species in each stage of development than did the blue wildebeest. Although the majority of these animals were shot during different years they were shot within the same region of the park, and the differences in their tick burdens would be difficult to explain solely in terms of climatic variations between years. The 2 zebras shot during November 1978 had mean burdens of 5 565 ticks, while the 4 wildebeest examined during November 1978 had mean burdens of only 825 ticks. Burchell's zebras are therefore better hosts of the tick species infesting large herbivores within the Kruger National Park than are blue wildebeest.

Amblyomma hebraeum. With the possible exception of April, fairly large numbers of larvae were consistently present, which suggests that they hatch throughout the year and/or survive for a long time. The presence of nymphae in every collection, with a peak in September during 2 years of the survey, suggests that, although larvae moulted to nymphae throughout the year, some synchronous moulting of accumulated larvae must have occurred during August to give this nymphal peak. Small numbers of adults were recovered from individual animals in nearly every month of the year.

This year-round activity of the larvae and adults does not correspond with the more seasonal activity noted for this species in other surveys in South Africa. In these the greatest numbers of larvae were present in late summer and autumn and adults during summer (Baker & Ducasse, 1967; Rechav, 1982). It does, however, agree with that reported by Minshull (1981) in south-eastern Zimbabwe. The warm climate of the Kruger National Park (Fig. 5) probably makes development throughout the year possible.

The nymphal peak, however, suggests that, although conditions in general are always favourable, optimum conditions for the nymphae in the Kruger National Park prevail in early spring. In the eastern Cape Province Knight & Rechav (1978) recorded the greatest numbers of nymphae on greater kudu during November and December and in April, while Rechav (1982) recovered the greatest numbers of nymphae from cattle in early summer, with a 2nd peak during winter. In Natal, Baker & Ducasse (1967) found the greatest nymphal activity on cattle from May–September. The blue wildebeest from the Kruger National Park examined by Horak, De Vos & Brown (1983) harboured virtually no adult *A. hebraeum* and very few nymphae, while the larval numbers exhibited a short, sharp peak during October and November. As the wildebeest carried virtually no larvae at any other time of the year it is difficult to interpret this larval peak. Horak, De Vos & Brown (1983) suggested that, as this peak occurred at the time of the northward migration of the wildebeest, it might have indicated a greater exposure to larvae of this tick during migration. The 2 zebras shot during November 1978 carried mean burdens of 108 larvae compared with the mean burdens of 265 larvae harboured by the 4 wildebeest shot during November 1978.

In Zambia MacLeod & Colbo (1976) recovered larvae and nymphae of *Amblyomma variegatum* from cattle in the ratio 5:1 to 14:1. They concluded that cattle feed sufficient larvae of this tick to maintain their own loads of nymphal infestation. In the present survey the ratio of *A. hebraeum* larvae to nymphae was 5,5:1, indicating that the zebras were feeding sufficient larvae to maintain their level of nymphal infestation. The ratio of 19,9:1 nymphae to adults on the zebras suggests either a massive mortality before the nymphae reach adulthood or that some other host is preferred by the adult ticks. Horak, Potgieter, Walker, De Vos & Boomker (1983) have found that eland, buffalo and giraffe can carry large numbers of adult *A. hebraeum*. It is thus probable that the majority of nymphae that feed on zebras moult to adults which prefer to feed on these large herbivores.

Boophilus decoloratus. In Natal Baker & Ducasse (1967) recovered peak numbers of *B. decoloratus* from calves from November–June. In the eastern Cape Province Robertson (1981) recorded peak numbers on cattle from February–June and Rechav (1982) found peak numbers generally during the periods March/April and August/September. Horak, De Vos & Brown (1983) found peak numbers on blue wildebeest in the Kruger National Park from April or May–June or July with a 2nd higher peak occurring in October. The peaks on the wildebeest closely correspond to those noted by MacLeod, Colbo, Madbouly & Mwanaumo (1977) on cattle in the Central Province of Zambia. They found however, that the major peak occurred during May and the minor peak during October.

In the present survey peak numbers were recovered from the zebras during September 1979 and 1980 and December 1980. The September peaks correspond closely to the October peak recorded on blue wildebeest during 1978 by Horak, De Vos & Brown (1983). These spring peaks could be due to synchronous hatching of large numbers of larvae (Robertson, 1981) coupled with a decrease in host resistance brought about by poor nutrition during the preceding winter months.

A reduction in numbers of *B. decoloratus* occurred between the larval and nymphal stages on the zebras. Horak, De Vos & Brown (1983) recorded a proportionally even greater reduction on blue wildebeest in the Kruger National Park. One of the ways in which resistance to infestation with *Boophilus microplus* on cattle is manifested is by a considerable loss of ticks between the larval and nymphal stages (Wagland, 1979). As the reduction in numbers between these stages was not large on the Zebras, one can assume that these animals did not possess a high degree of resistance to infestation.

Possible resistance to infestation is not the only reason for a decrease in numbers between the larval and nymphal stages of *B. decoloratus* on the zebras. Larvae attached to the heads and ears and to the lower legs and feet of the zebras have less chance of developing to the nymphal stage than those attached to the neck, body, tail and upper legs (Table 3). This is possibly because the ticks are more exposed on the former sites and hence the larger nymphae are more likely to be dislodged than are the larvae. Newly moulted nymphae may also migrate to more favourable sites of attachment.

Apparently very little loss occurs during the transition from the nymphal to the adult stage (Tables 1 and 3). However, only 5,3 % of the female population on the zebras had reached a length of 4,0 mm. This length is only slightly less than the 4,5 mm given by Wharton & Utech (1970) for *B. microplus* females (which are larger than those of *B. decoloratus*) that will complete their engorgement and detach within the following 24 h. On hosts constantly exposed to reinfestation one would theoretically expect 14,3 % ($^1/_7$) of a female tick population, which spends approximately 7 days on the host, to have reached 4,0 mm during the previous 24 h before detaching. A reduction in the number of female ticks which reach 4,5 mm in length is a characteristic of resistance of cattle to *B. microplus* (Sutherst, Wharton, Cook, Sutherland & Bourne, 1979).

It would be interesting to know what role red-billed oxpeckers, which are common in the Kruger National Park, play in keeping the numbers of engorging female *B. decoloratus* low. This tick is one of the preferred foods of these birds (Bezuidenhout & Stutterheim, 1980).

Rhipicephalus appendiculatus/zambeziensis. The seasonal occurrence (May–September) of *R. appendiculatus/zambeziensis* larvae on the zebras is the same as that recorded for these larvae on blue wildebeest (Horak, De Vos & Brown, 1983). This is later than the March or April–July peak recorded for *R. appendiculatus* larvae on impala and cattle in the northern Transvaal by Horak (1982).

But for 1 zebra, which harboured a large number of *R. appendiculatus* nymphae during November 1978, most nymphae of this tick were recovered from July–October (Fig. 4). This is similar to the June–October peak recorded on blue wildebeest in the Kruger National Park (Horak, De Vos & Brown, 1983) and impala and cattle in the northern Transvaal (Horak, 1982). It is later than the April–September peak on cattle in Natal (Baker & Ducasse, 1967) and shorter than the May–November peak on cattle and Angora goats in the eastern Cape Province (Rechav, 1982).

Although, in general, few were recovered, adult *R. appendiculatus/zambeziensis* were present in the greatest numbers from January–March and during May.

The number of *R. appendiculatus/zambeziensis* larvae present could not possibly have given rise to the number of *R. appendiculatus* nymphae recovered as these were nearly equal (Table 1). The small number of adults recovered has already been mentioned. These findings indicate that, although the zebras were good hosts of *R. appendiculatus* nymphae, they were not as suitable for the larvae or adults of *R. appendiculatus/zambeziensis*. The wildebeest examined by Horak, De Vos & Brown (1983) were also relatively poor hosts of the larvae of these ticks and extremely poor hosts of the adults. Other animals such as impala, kudu and buffalo probably served as preferred hosts of these stages of development.

As in the case of the blue wildebeest (Horak, De Vos & Brown, 1983) the zebras carried very few nymphae of *R. zambeziensis*. Whether this was due to host preference or the region in which the zebras were grazing could not be determined in this survey.

Rhipicephalus evertsi evertsi. The several peaks of immature and adult activity recorded throughout the year can possibly be attributed to separate generations (Matson & Norval, 1977). This view that more than 1 generation can be completed within a year is further supported by the relatively short life cycle recorded for this 2-host tick in the laboratory (Rechav, Knight & Norval, 1977).

The large number of adults and larvae recovered and the high proportion of the latter that successfully developed into nymphae indicate that zebras are excellent hosts for all stages of development of this tick. This support the contention of Norval (1981) that the preferred hosts of *R. evertsi evertsi* are horses, donkeys and zebras.

Horak (1982) found that impala harboured fairly large numbers of both larvae and nymphae of this tick, but few adults. Baker & Ducasse (1967) recovered a total of 5 744 adult *R. evertsi evertsi* from cattle in Natal. When this number is compared with the 132 419 immature specimens they collected from the same animals, it is obvious that, although cattle may be considered good hosts, they are not as good as the zebras reported in the present survey.

Rhipicephalus simus. The preferred hosts of this tick in the Kruger National Park are zebras (this survey), large carnivores and warthogs (Horak & De Vos, unpublished data, 1982). In Zambia MacLeod *et al.* (1977) and MacLeod & Mwanaumo (1978) and in Zimbabwe Norval & Mason (1981) found warthog and lion to be amongst its preferred hosts and recovered few from zebras.

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