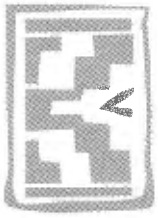

Dynamics of free-living ixodid ticks on a game ranch in the Central Province, Zambia

U. ZIEGER[1], I.G. HORAK[2]* and A.E. CAULDWELL[1]

ABSTRACT

ZIEGER, U., HORAK, I.G. & CAULDWELL, A.E. 1998. Dynamics of free-living ixodid ticks on a game ranch in the Central Province, Zambia. *Onderstepoort Journal of Veterinary Research,* 65:49–59

Free-living ixodid ticks were collected at monthly intervals from January to December 1996 by drag-sampling the vegetation of Mtendere Game Ranch in the Chisamba District of the Central Province, Zambia. Ticks belonging to 11 species were recovered. *Rhipicephalus appendiculatus* was most abundant, comprising 90 % of the total number collected. All life stages of this tick showed a definite seasonal pattern of activity. The adults were present mainly during the rainy season (February and March), the larvae during the cool and dry season (May to August), and the nymphs during the hot and dry season (August to October). Adults were most abundant in the wooded areas and nymphs in the open grasslands. Larvae of *Amblyomma variegatum* were only found from May to September, while larvae of *Boophilus decoloratus* were present throughout the year with peaks of abundance from January to February and again from August to November. *Rhipicephalus evertsi evertsi* larvae occurred throughout the year. Recent burning of the vegetation did not seem to affect the number of ticks collected. A possible burning regime to achieve a degree of tick control is discussed.

Keywords: Central Province, Zambia, drag-sampling, free-living ixodid ticks

INTRODUCTION

Ticks have been incriminated as a contributing factor to wildlife losses on some game ranches in southern Africa (Lightfoot & Norval 1981; Norval & Lightfoot 1982). The effects of heavy tick burdens on wild animals can include tick toxicosis, anaemia, metabolic disturbances and tick worry (O'Kelly & Seifert 1969; Seebuck, Springel & O'Kelly 1971). Secondary bacterial infections and myiasis of tick-bite wounds are also common (Howell, Walker & Nevill 1978). Blood parasites, such as *Theileria* spp, *Babesia* spp, *Anaplasma* spp, *Cytauxzoon* spp and *Cowdria ruminantium* can all be transmitted by ticks (Howell *et al.* 1978). Although endemic wild animals are usually not affected by these blood parasites, translocation of hosts and/or ticks into non-endemic areas can cause severe losses amongst susceptible animals (Lightfoot & Norval 1981; Meltzer 1993).

Commercial game ranching is a new and developing industry in Zambia. Many of the present game ranches are small, covering areas of less than 1 000 ha. Overstocking with wildlife is common, leading to a situation that lends itself to the build-up of high tick numbers (Horak 1980; Gallivan, Culverwell, Girdwood & Surgeoner 1995). Heavy tick infestations on wildlife on a game ranch in the Chisamba District of the Central Province of Zambia had previously been reported by the owner. In the present study the abundance of free-living ticks on this ranch was investigated. Data were collected concerning the tick species present on the ranch, their seasonal occurrence and abundance on the vegetation, their vegetation type preferences and the effects of recent burning of certain areas of the ranch on their subsequent numbers. The total tick burdens of a variety of large and small mammals and some birds on the

* Author to whom correspondence should be addressed

[1] Centre for Wildlife Management, University of Pretoria, Pretoria, 0002 South Africa

[2] Faculty of Veterinary Science, University of Pretoria, Onderstepoort, 0110 South Africa

Accepted for publication 19 December 1997—Editor

ranch were also ascertained. However, the results of the latter studies will be published separately.

MATERIAL AND METHODS

Study area

The survey was conducted on Mtendere Game Ranch (15°05´S, 28°16´E), approximately 20 km north of Lusaka in the Chisamba District of the Central Province of Zambia. The altitude in this region varies from 1 100–1 200 m above sea level, and the annual rainfall from 800–900 mm (Hutchison 1974). Three distinct seasons occur. They are the warm and wet rainy season from December to April, the cool and dry season from May to August and the hot and dry season from September to November. The monthly mean temperatures are 20,0 °C in January, 15,0 °C in July and 22,5 °C in October (Ansell 1978). The vegetation of this region is classified as miombo woodland. It is dominated by trees of the genera *Brachystegia* and *Julbernardia* (Trapnell 1953). Miombo woodlands are typically interspersed with shallow, seasonally waterlogged drainage lines called dambos.

The ranch is 960 ha in size and has operated as a commercial game ranch since 1990. In January 1996 it contained some 570 larger ungulates. This is equivalent to 205 large stock units at a stocking rate of one large stock unit per 4,7 ha. The game included 34 Burchell's zebra *Equus burchellii;* ten warthog *Phacochoerus africanus;* 25 bushpig *Potamochoerus larvatus;* 135 impala *Aepyceros melampus;* 18 tsessebe *Damaliscus lunatus lunatus;* 48 Lichtenstein's hartebeest *Sigmoceros lichtensteinii;* four oribi *Ourebia ourebi;* 22 eland *Taurotragus oryx;* 35 bushbuck *Tragelaphus scriptus;* two sitatunga *Tragelaphus spekii;* 43 greater kudu *Tragelaphus strepsiceros*; 20 common duiker *Sylvicapra grimmia;* four roan antelope *Hippotragus equinus;* 30 sable antelope *Hippotragus niger;* 62 defassa waterbuck *Kobus ellipsiprymnus defassa;* 20 Kafue lechwe *Kobus leche kafuensis*; 36 puku *Kobus vardonii*; and 22 reedbuck *Redunca arundinum.*

Selection of sites

Ticks were collected monthly at eight sites. One site was situated in each of the four major vegetation types of the ranch: a grassland, a dambo, a miombo woodland and a munga woodland. The grassland area had been planted to Rhodes grass *Chloris gayana* in 1990 and is currently classified according to Edwards (1983) as a short closed grassland with a grass height of 0,5–1,0 m, and a tree and shrub crown cover of less than 0,1 %. The dambo site is dominated by *Setaria incrassata, Echinochloa colona* and *Hyparrhenia* spp. It is classified as a tall closed grassland with a grass height of 1,0–2,0 m and a tree and shrub crown cover of less than 0,1 %. The miombo woodland is dominated by the tree *Brachystegia spiciformis* and the grass *Andropogon gayanus.* This vegetation type is classified as a tall closed woodland with a total tree crown cover of 10,0–75,0% and a canopy height of 10,0–20,0 m. The munga woodland is typically found between dambo and miombo vegetation. It is dominated by grasses of the genera *Brachiaria*, *Stereochlaena* and *Setaria,* which are interspersed with *Combretum fragrans* trees. It is classified as a tall, closed woodland with a crown canopy cover of 1,0–10,0 % and a mean tree height of 11,0 m. None of these sites, subsequently called control sites, has been manipulated by the application of fire or bush clearing during the past 6 years. In addition, ticks were collected at four matching sites. In these matching sites, the vegetation had been manipulated previously. They are a grassland site that had been burnt in December 1995; a dambo site that had been burnt in October 1995; a miombo woodland site that had been burnt in August 1994 and in which undergrowth had regularly been cleared with heavy machinery during the 1980's; and a munga woodland site that had been burnt in August 1994.

Tick collection

Ticks questing on the vegetation were collected by drag-sampling (Londt & Whitehead 1972; Rechav 1982; Zimmerman & Garris 1985). The method used is described in detail by Spickett, Horak, Braack & Van Ark (1991). In addition, a 95-mm steel rod was sewn into the distal end of each flannel strip to keep it down on the vegetation while dragging. At each site, three replicate drags of 250 m each were done at monthly intervals. After each drag all the ticks present were removed from the flannel strips and stored in vials containing 70 % ethyl alcohol for later identification and counting. Drags were done during the first week of every calendar month from January 1996 to December 1996.

Rainfall

During the course of the study the total monthly rainfall was recorded using a standard rain gauge. This was located in the approximate centre of the ranch.

Presentation of data

The ticks collected each month from the three replicate drags per site were pooled. Because of the overdispersed nature of free-living ticks, all counts had to be transformed for statistical analysis (Petney, Van Ark & Spickett 1990). The natural logarithm [ln (number of ticks + 1)] of the raw data was found to be the best transformation, as the variance to mean ratio after transformation approximated the value of one, indicating a random distribution. Statistical tests

were done using the paired *t*-test on the transformed data only.

RESULTS

Rainfall

The monthly rainfall recorded during 1995/1996 is illustrated in Fig.1. Total rainfall for the 1995/1996 rainy season was 763 mm, which is slightly less than the modal variation of 800–900 mm (Hutchison 1974).

Tick species and abundance

The tick species recovered and their total numbers collected on Mtendere Game Ranch during the 12-month monitoring period are summarized in Table 1.

Ticks belonging to 11 species were recovered. By far the most abundant was *Rhipicephalus appendiculatus*, which constituted 90,0 % of the 39 713 ticks collected. This was followed by *Boophilus decoloratus* (5,6 %), *Rhipicephalus evertsi evertsi* (3,7 %) and *Amblyomma variegatum* (0,5 %). The other ticks were collected in small numbers only.

Amblyomma variegatum

The monthly total numbers of larvae collected from the four control sites are illustrated graphically in Fig. 2A.

Larvae were only found from May to September. The total number of larvae collected during the 12-month period from each of the four control sites and their respective manipulated sites are illustrated in Fig. 3A.

Although the number of larvae collected from the grassland and dambo control sites was higher than that from the miombo and munga woodland control sites, these differences were not statistically significant. Furthermore, no statistically significant differences in larval numbers were found between any of the control sites and their respective manipulated sites.

Boophilus decoloratus

Larvae were present throughout the year (Fig. 2B). They were most abundant from January to February and again from August to November. No statistically significant differences in the total numbers of larvae were found between the four vegetation types (Fig. 3B). However, the miombo woodland control site had a significantly higher number of larvae than the manipulated miombo woodland site ($P < 0,01$). Significantly more larvae were recovered from the vegetation of the manipulated munga woodland site than from the control site ($P < 0,05$).

Rhipicephalus appendiculatus

The monthly total numbers of larvae, nymphs and adults collected from the four control sites are illustrated in Fig. 4.

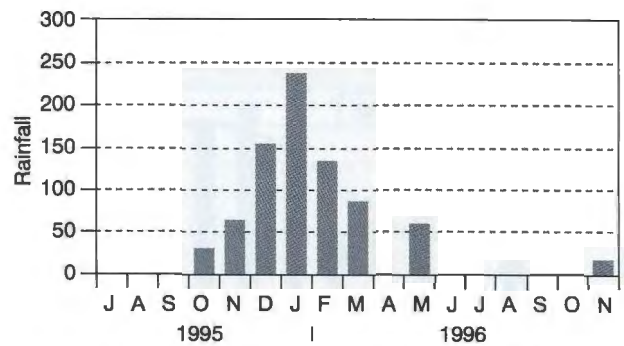

FIG. 1 The monthly rainfall (mm) recorded on Mtendere Game Ranch in the Central Province of Zambia from July 1995 to November 1996

TABLE 1 The species and number of ticks collected by monthly drag-sampling eight vegetation sites on Mtendere Game Ranch in the Central Province of Zambia during 1996

Tick species	Number of ticks collected				
	Larvae	Nymphs	Males	Females	Total
Amblyomma sp.	9	0	0	0	9
Amblyomma variegatum	192	2	0	0	194
Boophilus decoloratus	2 209	0	0	0	2 209
Hyalomma marginatum rufipes	2	0	0	0	2
Rhipicephalus appendiculatus	32 629	2 930	102	87	35 748
Rhipicephalus evertsi evertsi	1 481	0	0	1	1 482
Rhipicephalus lunulatus	0	0	10	5	15
Rhipicephalus sp. (like *R. pravus*)	23	0	0	0	23
Rhipicephalus sulcatus	0	0	4	4	8
Rhipicephalus turanicus	0	0	0	1	1
Rhipicephalus zambeziensis	21	1	0	0	22
Total number	36 566	2 933	116	98	39 713

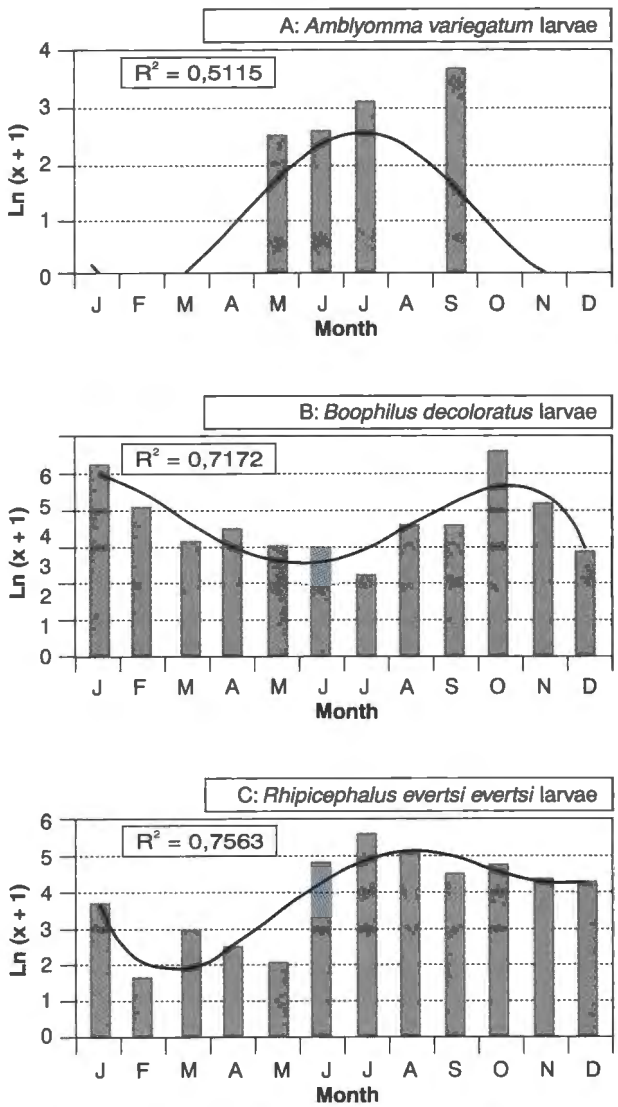

FIG. 2 The monthly number [Ln (x + 1)] of (A) *Amblyomma variegatum*, (B) *Boophilus decoloratus* and (C) *Rhipicephalus evertsi evertsi* larvae collected by drag-sampling the vegetation of four control sites on Mtendere Game Ranch in the Central Province of Zambia in 1996

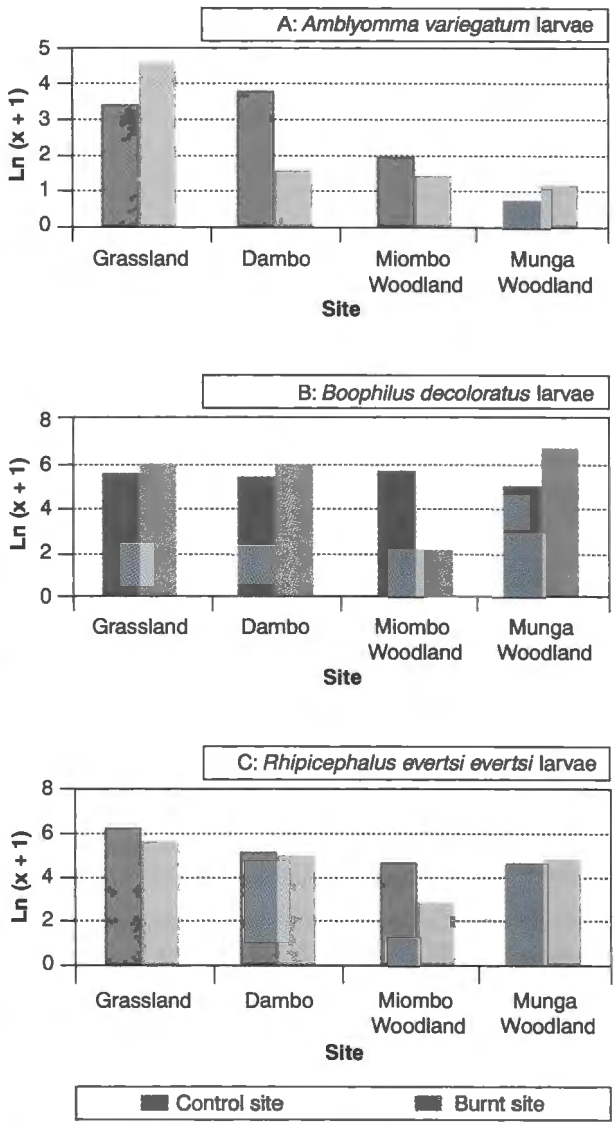

FIG. 3 The total number [Ln (x + 1)] of (A) *Amblyomma variegatum*, (B) *Boophilus decoloratus* and (C) *Rhipicephalus evertsi evertsi* larvae collected by drag-sampling the vegetation of control and burnt sites in four vegetation types on Mtendere Game Ranch in the Central Province of Zambia in 1996

Larvae were most active from May to August. Thereafter their numbers declined and they disappeared from the vegetation during December (Fig. 4A). Nymphs were most abundant from August to October (Fig. 4B). No nymphs were collected in March. Adults were recovered from January to June, with a peak in abundance during February and March (Fig. 4C), and total disappearance from the vegetation in July.

No statistically significant differences in larval abundance were found between the four vegetation types (Fig. 5A). Consistently lower numbers of larvae were recovered from the burnt dambo site than from its control site ($P < 0,01$). The number of larvae collected from the burnt munga woodland was twice as high as the number collected from its control site, although this difference was not statistically significant. There was a significant difference in the abundance of nymphs (Fig. 5B) between the grassland and the munga woodland sites ($P < 0,05$), between the dambo and the miombo woodland sites ($P < 0,05$) and between the dambo and the munga woodland sites ($P < 0,01$). Nymphs were more abundant in the burnt munga woodland than in the control munga woodland ($P < 0,05$). The total number of adults collected from the grassland site (Fig. 5C) was significantly lower than that collected from the three other

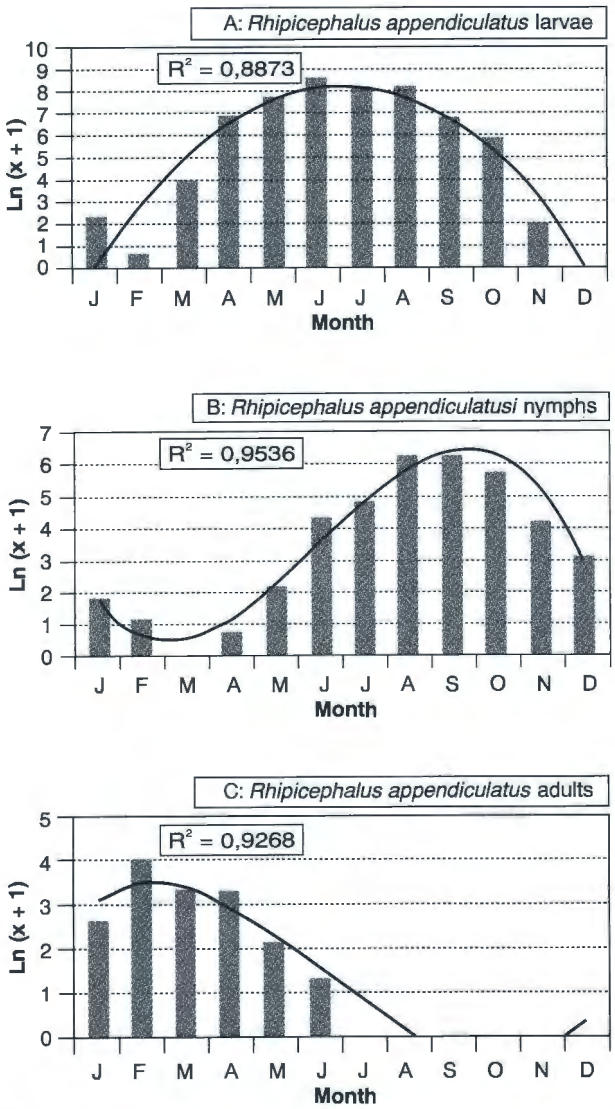

FIG. 4 The monthly number [Ln (x + 1)] of (A) larvae, (B) nymphs and (C) adults of *Rhipicephalus appendiculatus* collected by drag-sampling the vegetation of four control sites on Mtendere Game Ranch in the Central Province of Zambia in 1996

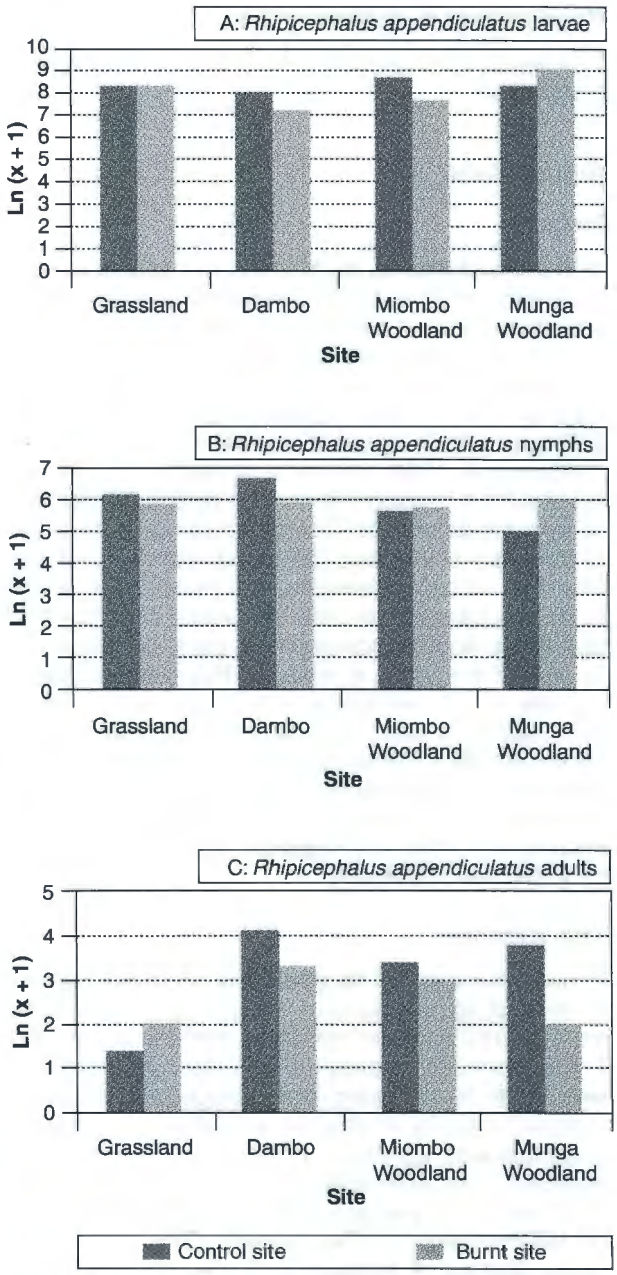

FIG. 5 The total number [Ln (x + 1)] of (A) larvae, (B) nymphs and (C) adults of *Rhipicephalus appendiculatus* collected by drag-sampling the vegetation of control and burnt sites in four vegetation types on Mtendere Game Ranch in the Central Province of Zambia in 1996

vegetation types ($P < 0,05$). No significant differences were found in the abundance of adults between the control and their respective manipulated sites.

Rhipicephalus evertsi evertsi

Larvae were collected throughout the year (Fig. 2C). They were more abundant during the dry period from June to November than at other times of the year. Significantly more larvae were recovered from the grassland site than from both the munga and the miombo woodland sites ($P < 0,01$). The burnt grassland site had significantly fewer larvae than its control site ($P < 0,05$).

Rhipicephalus lunulatus

Only 15 adults were recovered. One was collected in January, and the rest in December.

Rhipicephalus sp. (like *R. pravus*)

Larvae resembling those of *R. pravus* were found from May to September only.

Rhipicephalus zambeziensis

The few larvae collected were present from April to September.

DISCUSSION

Ticks

To our knowledge no study of this kind has previously been conducted in Zambia. However, similar surveys have been done in the south-eastern lowveld of Zimbabwe (Colborne 1988) and in the Eastern Cape Province (Rechav 1982) and in the Kruger National Park of South Africa (Spickett, Horak, Van Niekerk & Braack 1992; Spickett, Horak, Heyne & Braack 1995; Horak 1998). In none of these surveys was there such a marked dominance by one tick species as was the case with *R. appendiculatus* in this one. In his study in Zambia, MacLeod (1970) concluded that high stocking densities with cattle led to a shift in the tick composition and frequency on cattle. This shift favoured *B. decoloratus*, *R. appendiculatus* and *R. evertsi evertsi.* It is possible that the high stocking rate and the wildlife spectrum present on Mtendere Game Ranch have specifically favoured *R. appendiculatus*. If this were so, the tick species composition and the number of parasitic ticks present on the hosts should reflect the same trend. This aspect is currently under investigation, and the results will be published separately.

Tick numbers

A mean number of 138 ticks were recovered per individual drag per month. Horak (1998) collected a mean of 168 ticks per individual monthly drag over a 7-year period in an area of the Kruger National Park which, with the exception of *A. variegatum,* which was replaced there by *Amblyomma hebraeum,* contained a comparable spectrum of ticks. In Horak's study, however, ticks were collected not only from the flannel strips of the drag apparatus but also from the flannel leggings worn by the operator. Ticks of the three major species (*A. hebraeum, B. decoloratus* and *R. appendiculatus*) collected from the leggings, contributed approximately 28,0 % to the total number of ticks recovered (Horak, unpublished data 1992). When the ticks collected from the leggings are excluded from the counts, a mean number of 121 ticks were collected per drag-sample in the Kruger National Park. Although this comparison does not take the environmental differences between the two regions into account, the number of ticks questing on the vegetation on Mtendere Game Ranch is similar to that found in a natural South African wildlife area.

Amblyomma variegatum

In regions with a single annual rainy season *A. variegatum* completes one generation per year (Wilson 1950; Matthysse 1954). Adults are most active during the rainy season, with a peak of abundance on cattle in Zambia from November to January (Matthysse 1954; MacLeod 1970; MacLeod, Colbo, Madbouly & Mwanaumo 1977). All these reports, however, indicate that adults are always present, albeit in low numbers. With 65 days elapsing from the time of detachment of engorged females to the hatching of larvae (Walker 1956, cited by Petney, Horak & Rechav 1987), it is surprising that larvae were recovered only from May onwards in the present study. Most larvae are found on cattle in Zambia from March to May and the life cycle of this tick appears to be controlled by the time of oviposition (MacLeod & Colbo 1976; Pegram, Perry, Musisi & Mwanaumo 1986). In a normal rainfall year this means that the first larvae hatch in March. Total rainfall in the study area was normal during the 1995/1996 rainy season, but it was a rather cool and prolonged season with rains falling as late as May. It is possible therefore that these cool and wet climatic conditions may have led to a delay in the hatching of larvae.

Amblyomma variegatum has been reported from a wide variety of habitat types, particularly those with a good tree and/or bush or tall grass cover (Yeoman & Walker 1967; Yeoman 1968). In our study, however, hardly any larvae were recovered from the woodland areas. Burning of the dambo and grassland sites in October and December 1995 respectively did not significantly influence the number of larvae collected from the vegetation during the subsequent season of larval activity.

Boophilus decoloratus

This is a one-host tick and thus with rare exceptions, only larvae are recovered from the vegetation. Larvae were present throughout the year, with peaks of abundance during the height of the rainy season, and again during the hot and dry season. A similar seasonal pattern of abundance has been reported by MacLeod (1970) and MacLeod *et al.* (1977), who found peak numbers of adult *B. decoloratus* on cattle in the Southern and Central Provinces of Zambia during the rainy season, and again during the hot and dry season. In the Eastern Cape Province of South Africa, Rechav (1982) found two or three peaks of larval abundance on the vegetation. Based on Londt's (1977) results that at low temperatures the pre-oviposition period is long and egg development slow, Rechav (1982) concluded that the larval periodicity of *B. decoloratus* depended upon the prevailing ambient temperatures, and that this could lead to varying numbers of generations per annum. In Zimbabwe, Jooste (1966) speculated that four generations of *B. decoloratus* occurred per year, whereas in the KwaZulu-Natal and Mpumalanga Provinces of South Africa two peaks of abundance are usually recorded (Baker & Ducasse 1967; Horak, Boomker, Spickett & De Vos 1992).

No preference for vegetation type could be found in our study. The literature on this issue is, however, inconclusive. Rechav (1982) and Spickett *et al.* (1991) recovered greater numbers of larvae from open grassland than from other vegetation sub-zones, while Londt & Whitehead (1972) reported that *B. decoloratus* preferred the more protected types of vegetation. Neither burning of the grassland, nor of dambo sites 1 and 3 months respectively before the commencement of this study, influenced the numbers of larvae collected subsequently. This is consistent with the findings of Spickett, Horak, Van Niekerk & Braack (1992) who recorded a reduction in larval numbers immediately after a burn, to be followed by a rapid recovery and a subsequent period of overcompensation. In the present study few larvae were collected from the miombo woodland site, which was cleared of underbrush and which had been burnt regularly during the 1980's and again in 1994. The grass layer of this site is now dominated by unpalatable grasses such as *Zonotriche inamoena* and *Tristachia superba*. Lacking both palatable grazing and cover, this area is used infrequently by game. In contrast, more larvae were present in the munga woodland site that had been burnt in 1994, than in the unburned control site. The vegetation composition and structure of the latter two sites do not differ much. However, the burnt site was more heavily utilized by game, particularly so by a large breeding herd of sable antelope and a herd of Lichtenstein's hartebeest, both of which probably contributed to the larger number of ticks collected.

Rhipicephalus appendiculatus

All the developmental stages of *R. appendiculatus* showed a strict pattern of seasonal abundance, which reflects a single generation per annum. Adults were most abundant during the height of the rains, larvae during the cool and dry winter months, and nymphs at the end of the winter and during the hot and dry months. In this study adults disappeared completely from the vegetation for 6 months. This 1-year cycle has been well documented for several southern African countries: Malawi (Wilson 1946); Zimbabwe (Matson & Norval 1977; Short & Norval 1981; Colborne 1988); Zwaziland (Gallivan & Surgeoner 1995) and South Africa (Baker & Ducasse 1967; Horak 1982; Rechav 1982). In the Central Province of Zambia, MacLeod *et al.* (1977) found a distinct seasonal pattern with the highest numbers of adult *R. appendiculatus* occurring on cattle from December to March. However, smaller numbers of adults were present throughout the remainder of the year, as in the study of Matthysse (1954). It is unfortunate that MacLeod *et al.* (1977) pooled their results from the various farms, which they surveyed, thus making it impossible to determine in which region of the Central Province they had collected adult ticks all year round. The mean annual rainfall within this province varies from 1 100 mm in the north to 600 mm in the south along the lower Kafue River (Trapnell 1953). Pegram *et al.* (1986) also report that one generation of *R. appendiculatus* per year occurs in Zambia, with some inactive adults present on the vegetation during the dry months. These results indicate that *R. appendiculatus* generally completes a single life-cycle per annum in Zambia, but that at some localities adult ticks may be active throughout the year as in parts of East Africa (Yeoman & Walker 1967; McCulloch, Kalaye, Tungaraza, Suda & Mbasha 1968). The life cycle of *R. appendiculatus* is regulated by the adult life stage (Short & Norval 1981). Depending upon the prevailing climatic conditions, unfed adults may enter diapause and become active only when the combined influences of temperature, humidity and daylength are suitable. Four factors which initiate the activity period of *R. appendiculatus* adults have been proposed (Short & Norval 1981):

- > 10 mm of rainfall per month
- mean monthly minimum temperature of > 15 °C
- mean monthly maximum temperature of < 30 °C or > 30 °C only if rainfall exceeds 20 mm per month
- daylength of > 11 h of sunlight

On Mtendere Game Ranch the first condition was not met from June to the beginning of December 1996. Although the ambient temperatures were not recorded, it is likely that the second condition was not met from June to July and the third condition during November.

Free-living *R. appendiculatus* depend on adequate vegetation cover for their survival (Theiler 1949; Rechav 1982). The tick's spatial distribution within its preferred habitat is largely reliant upon the availability of suitable hosts and their distribution (Minshull & Norval 1982). In our study fewer adult *R. appendiculatus* were collected from the grassland site than from the three other vegetation types. Although this might be attributed to the sparse tree cover and short grasses in the grassland site, it seems more likely that the drop-off rhythm of the ticks and their hosts' behaviour influenced their distribution (Minshull & Norval 1982). Nymphs were most abundant during the hot and dry months of September and October. During this period most ungulates seek shade in woodland areas or in tall grass in the hot daytime hours. As engorged nymphs detach mainly between 12:00 and 18:00 (Minshull 1982), they would drop in these more shaded areas and moult there to the adult life stage. The opposite was observed for free-living nymphs in that more were collected from the grassland and the dambo areas than from the woodland vegetation types. Ungulates utilize the open areas throughout the daylight hours during the cold winter months when the larvae are most active. As engorged larvae detach from their hosts mainly between 10:00 and 14:00 (Minshull 1982), many would

drop in the grassland areas and moult there to nymphs. No distribution pattern related to vegetation type was observed for the larvae. This indicates that the various vegetation zones of the ranch were utilized evenly by ungulates during the rainy season, which coincides with the peak activity period of the preceding generation of adult ticks.

Fewer *R. appendiculatus* larvae were collected from the burnt dambo site than from its control. The dambo site was burnt in October 1995 during the period of peak abundance of free-living nymphs, and it is likely that the burn affected their numbers. However, there were no differences between the number of adults collected from the burnt and the unburned sites. It is generally believed that a burn causes direct mortalities among ticks, and that burning also makes the microclimate less favourable for their survival. These effects seem to be offset by the subsequent high concentration of host animals, which are attracted to the resprouting grasses in the freshly burnt area and thus introduce fresh infestation. This can lead to an increased number of ticks in the subsequent life stage at this site (Minshull & Norval 1982; Spickett *et al.* 1992). In the present study it appears likely that heavy rains caused the reduced number of larvae recovered from the burnt dambo site. This site, which is situated close to the middle of the drainage line, was waterlogged for a longer period than the control site. It is therefore possible that the egg batches and/or the newly hatched larvae had a lower chance of survival in the burnt dambo site than in its control.

Burning of the grassland site in December 1995 apparently had no effect on the number of ticks recovered subsequently. The direct effect of fire on ticks at this time is probably low, as the number of questing nymphs is declining rapidly and few adults are active. Two years after the August 1994 burn in the munga woodland, more larvae and nymphs were recovered from the burnt site than from the unburned site. As in the case of *B. decoloratus*, this is probably related to the subsequent heavy utilization of this area by game.

Rhipicephalus evertsi evertsi

All life stages of this tick are generally present throughout the year, but reports on its seasonality vary. Spickett *et al.* (1992) found no seasonal pattern for the free-living larvae in the Mpumalanga Lowveld of South Africa, but noted a 2-month cycle of high and low larval numbers. In the Eastern Cape Province of South Africa, Rechav (1982) recorded two peaks of larval abundance both for those questing on the vegetation and those on hosts. These peaks occurred from July to August and again from January to March. Collection of adult ticks from cattle in Zambia indicates peaks of abundance from March to May and again from September to October. There also is a single peak of larval abundance from September to October (MacLeod 1970). Adults occur in three waves per year in Zambia, or four waves per year in Zimbabwe (MacLeod 1975; Matson & Norval 1977). Larval numbers in our study were high during the cool and dry and during the hot and dry months. This seems to agree with MacLeod's (1970) results for ticks on cattle in Zambia. It appears that *R. evertsi evertsi* requires 2 months to complete a single generation under optimal climatic conditions (Rechav, Knight & Norval 1977). In contrast, a generation is completed in 6 months at winter temperatures (Matson & Norval 1977). Climatic variation will therefore influence the seasonal occurrence of this tick markedly, not only regionally but also between years (Rechav 1982). In our study larvae were more numerous in the open grassland area than in the other vegetation types. Similarly in Rechav's 1982 study this species was more abundant in open areas than in bushy habitat. On Mtendere Game Ranch the distribution of this tick possibly reflects the habitat preferences of the zebra, which clearly favoured the grassland areas of the ranch to the woodland ones. Zebra are the preferred hosts of all life stages of this tick (Horak, De Vos & De Klerk 1984; Horak 1998). Many engorged females consequently detach in the grassland and this subsequently leads to high larval numbers on the vegetation.

Consistently fewer larvae were collected from the burnt grassland site than from the control one. As larvae are active during December when this site was burnt, it is likely that they were affected directly. Zebra utilized this area extensively after the burn and it can therefore be assumed that many engorged females would have dropped here. This should have led to an increase in larval numbers. That this was not the case, is possibly because the plant litter had been removed by the burn and that the grasses were kept so short by heavy grazing that the microclimate had become unfavourable for the survival of these ticks (Gray 1961).

Rhipicephalus lunulatus

Only a few *R. lunulatus* adults were recovered. They were present in December and January. Pegram *et al.* (1986) recovered adult *R. lunulatus* from Zambian cattle only during the rainy season. No larvae or nymphs were collected from the vegetation in the present study.

Rhipicephalus sp. (like *R. pravus*)

These ticks are present on Mtendere Game Ranch in low numbers only. In the literature, *R. kochi, R. punctatus* and *R. pravus* are frequently referred to as the '*R. pravus* group' of ticks, as they are morphologically so similar, that differentiation between them is often very difficult. Both *R. neavei* (now known as *R. kochi)* and *R. punctatus* have previously been

recorded from cattle in the Central Province of Zambia. However, *R. pravus* has not yet been found (MacLeod *et al.* 1977). The seasonal occurrence of larvae seems to be restricted to the dry season.

Rhipicephalus zambeziensis

Rhipicephalus zambeziensis is closely related to *R. appendiculatus*, and their morphology and host related ecology are similar but their distributions differ (Norval, Walker & Colborne 1982). *R. zambeziensis* replaces *R. appendiculatus* in the hot, dry, low-lying areas of south-eastern Africa. Their distributions overlap where a gradual transition occurs between wet, high-lying and dry, low-lying areas. Such conditions occur in the Southern Province of Zambia, which borders the Zambezi Valley. *R. zambeziensis* does not appear to build up to such large numbers as does *R. appendiculatus*. The small number of *R. zambeziensis* larvae collected during the present study compared to the large number of *R. appendiculatus* larvae, indicates that the study site is probably situated at the northernmost limit of the distribution of the former tick along the Zambezi Valley. It also appears that the Chisamba District is more suited to *R. appendiculatus* than to *R. zambeziensis*. No *R. zambeziensis* adults were found on cattle in the Northern, Northwestern and Western Provinces of Zambia, whereas they were present in low numbers in the Central, Eastern and Southern Provinces (Pegram *et al.* 1986).

Control of ticks

Effect of burning

A grassland and a dambo site were burnt 1 and 3 months respectively before the start of our study in an attempt to control tick numbers. This objective was not achieved. The only tick that was reduced in numbers on the burnt grassland site was *R. evertsi evertsi,* which is a minor tick on the ranch. The burn did not affect populations of *R. appendiculatus*, the major tick species on the ranch. Although the efficiency of burning as a means of tick control has been questioned (Minshull & Norval 1982; Spickett *et al.* 1992), much of Zambia's vegetation requires periodic burning to remove moribund material. If these fires could be timed properly and if appropriate post-burn management could be applied, then it should be possible to effect a degree of tick control by burning the vegetation. To achieve a direct effect on questing ticks, a burn should, however, coincide with the peak activity period of the particular tick. For *R. appendiculatus* this would be from June to August to affect larvae and September or October to affect the nymphs. Whether burns at these times of year are ecologically advisable, will depend upon the type and condition of the vegetation and its moisture content. The influx of potential host animals into a recently burnt area tends to offset the initial reduction of tick numbers (Minshull & Norval 1982; Spickett *et al.* 1992). A long-term reduction in tick numbers can only be expected if animal concentrations in the burnt area can be avoided. On a game ranch, where rotational grazing such as that commonly employed with domestic animals cannot be applied easily, an overall low stocking rate can attempt to achieve this. In addition, if particular areas on a game ranch were to be burnt, these should be so large that the subsequent influx of animals does not lead to a high concentration of game on these burnt areas. A staggered burning programme, where fires are set in several areas at 2- to 3-week intervals, would also dilute host animal numbers and should result in a pattern of rotational grazing. If artificial watering points were in use, then those in the vicinity of the burnt areas can be closed to force game to move away (Du Toit 1996).

The use of cattle

The spatial and temporal distribution of *R. appendiculatus* can be exploited for tick control. In the present study, adults of this tick were most numerous in the woodland areas, whereas the nymphs were more abundant in the grassland and dambos. Cattle that are regularly treated with an acaricide are an efficient means of reducing the numbers of free-living ticks on the vegetation and parasitic ticks on game (Petney & Horak 1987; Mackie & Clarke 1992). If cattle were to be used for tick control on Mtendere Game Ranch, it is advocated that they be herded into the woodland areas during the rainy season and onto the grassland and dambo areas during the hot and dry season provided that sufficient grazing is available at these times. Cattle are excellent hosts of adult *R. appendiculatus* (MacLeod *et al.* 1977; Horak 1982) and should pick up large numbers of these ticks during the rainy season. These ticks will be killed each time that the cattle are treated with an acaricide.

ACKNOWLEDGEMENTS

We wish to express our sincere thanks to Prof. J. du P. Bothma for initiating this study and for his valuable criticism of our manuscript. We thank Mr A.M. Spickett for his advice on the statistical analysis of our data. We are grateful to Mr and Mrs M. O'Donnell who provided accommodation on their game ranch and permitted us to undertake this work. The assistance of Mr P. Phiri with the fieldwork is also greatly appreciated.

REFERENCES

ANSELL, W.F.H. 1978. *The mammals of Zambia*. Chilanga: National Parks and Wildlife Service.

BAKER, MAUREEN K. & DUCASSE, F.B.W. 1967. Tick infestation of livestock in Natal. I. The predilection sites and seasonal variations of cattle ticks. *Journal of the South African Veterinary Medical Association*, 38:447–453.

COLBORNE, J.R.A. 1988. The role of wild hosts in maintaining tick populations on cattle in the southeastern lowveld of Zimbabwe. M. Phil. thesis, University of Zimbabwe.

DU TOIT, J.G. 1996. Water for game, in *Game ranch management,* 3rd ed., edited by J. du P. Bothma. Pretoria: J.L. van Schaik Publishers: 95–108.

EDWARDS, D. 1983. A broad-scale structural classification of vegetation for practical purposes. *Bothalia*, 14:705–712.

GALLIVAN, G.J. & SURGEONER, G.A. 1995. Ixodid ticks and other ectoparasites of wild ungulates in Swaziland: regional, host and seasonal patterns. *South African Journal of Zoology*, 30: 169–177.

GALLIVAN, G.J., CULVERWELL, J., GIRDWOOD, R. & SURGEONER, G.A. 1995. Ixodid ticks of impala (*Aepyceros melampus*) in Swaziland: effect of age class, sex, body condition and management. *South African Journal of Zoology*, 30: 178–186.

GRAY, W.J. 1961. *Rhipicephalus evertsi*: notes on free-living phases. *Bulletin of Epizootic Diseases in Africa*, 9:25–27.

HORAK, I.G. 1980. The control of parasites in antelope in small game reserves. *Journal of the South African Veterinary Association,* 51:17–19.

HORAK, I.G. 1982. Parasites of domestic and wild animals in South Africa. XV. The seasonal prevalence of ectoparasites on impala and cattle in the northern Transvaal. *Onderstepoort Journal of Veterinary Research*, 49:85–93.

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

HORAK, I.G., BOOMKER, J., SPICKETT, A.M. & DE VOS, V. 1992. Parasites of domestic and wild animals in South Africa. XXX. Ectoparasites of kudus in the eastern Transvaal Lowveld and eastern Cape Province. *Onderstepoort Journal of Veterinary Research*, 59:259–273.

HORAK, I.G. 1998. The relationship between ticks, hosts and the environment in the Kruger National Park, South Africa. *Proceedings of the 2nd International Conference on tick-borne pathogens at the host-vector interface (THPI), Skukuza, Kruger National Park, 1995.*

HOWELL, C.J., WALKER, JANE B. & NEVILL, E.M. 1978. Ticks, mites and insects infesting domestic animals in South Africa 1. Descriptions and biology [Pretoria:] Department of Agricultural Technical Services, Republic of South Africa. *Science Bulletin; no.* 393.

HUTCHISON, P. 1974. *The climate of Zambia*. Lusaka: Zambia Geographical Association (Occasional study; no. 7).

JOOSTE, KATE F. 1966. A two-year study on the seasonal occurrence of adult ticks on a herd of red-poll cows. *Rhodesian Agricultural Journal*, 63:97–99.

LIGHTFOOT, C.J. & NORVAL, R.A.I. 1981. Tick problems in wildlife in Zimbabwe. 1. The effects of tick parasitism on wild ungulates. *South African Journal of Wildlife Research*, 11:41–45.

LONDT, J.G.H. & WHITEHEAD, G.B. 1972. Ecological studies on ticks in South Africa (Acarina: Ixodidae). *Parasitology*, 65: 469–490.

LONDT, J.G.H. 1977. Oviposition and incubation in *Boophilus decoloratus* (Koch, 1844) (Acarina: Ixodidae). *Onderstepoort Journal of Veterinary Research,* 44:13–20.

MACKIE, A.J. & CLARKE, FRANCOISE. 1992. Sable antelope influencing tick populations on game farms in the lowveld. *Proceedings of the International Conference of the South African Veterinary Association, Wildlife Group, on The Sable Antelope as a Game Ranch Animal, Onderstepoort, 1992:* 60–63.

MACLEOD, J. 1970. Tick infestation patterns in the southern province of Zambia. *Bulletin of Entomological Research*, 60:253–274.

MACLEOD, J. 1975. Apparent host selection by some African tick species. *Oecologia,* 19:359–370.

MACLEOD, J. & COLBO, M.H. 1976. Ecological studies of ixodid ticks (Acari: Ixodidae) in Zambia. I. Cattle as hosts of larvae of *Amblyomma variegatum* (F.) and *Rhipicephalus appendiculatus* Neum. *Bulletin of Entomological Research*, 66:65–74.

MACLEOD, J., COLBO, M.H., MADBOULY, M.H. & MWANAUMO, B. 1977. Ecological studies of ixodid ticks (Acari: Ixodidae) in Zambia. III. Seasonal activity and attachment sites on cattle, with notes on other hosts. *Bulletin of Entomological Research,* 67: 161–173.

MATSON, B.A. & NORVAL, R.A.I. 1977. The seasonal occurrence of adult ixodid ticks on cattle on a Rhodesian highveld farm. *Rhodesian Veterinary Journal*, 8:2–6.

MATTHYSSE, J.G. 1954. *Report on tick-borne diseases*. Department of Veterinary Services, Lusaka, Northern Rhodesia: Government Printer.

MCCULLOCH, B., KALAYE, W.J., TUNGARAZA, R., SUDA, B.Q.J. & MBASHA, E.M.S. 1968. A study of the life history of the tick *Rhipicephalus appendiculatus*—the main vector of East Coast fever—with reference to its behaviour under field conditions and with regard to its control in Sukumaland, Tanzania. *Bulletin of Epizootic Diseases in Africa*, 16:477–500.

MELTZER, D.G.A. 1993. Historical survey of disease problems in wildlife populations: southern Africa mammals. *Journal of Zoo and Wildlife Medicine*, 24:237–244.

MINSHULL, JACQUELINE I. 1982. Drop off rhythms of engorged *Rhipicephalus appendiculatus* (Acarina: Ixodidae). *Journal of Parasitology*, 68:484–489.

MINSHULL, JACQUELINE I. & NORVAL, R.A.I. 1982. Factors influencing the spatial distribution of *Rhipicephalus appendiculatus* in Kyle Recreational Park, Zimbabwe. *South African Journal of Wildlife Research*, 12:118–123.

NORVAL, R.A.I. & LIGHTFOOT, C.J. 1982. Tick problems in wildlife in Zimbabwe. Factors influencing the occurrence and abundance of *Rhipicephalus appendiculatus*. *Zimbabwe Veterinary Journal*, 13:11–20.

NORVAL, R.A.I., WALKER, JANE B. & COLBORNE, J. 1982. The ecology of *Rhipicephalus zambeziensis* and *Rhipicephalus appendiculatus* (Acarina: Ixodidae) with particular reference to Zimbabwe. *Onderstepoort Journal of Veterinary Research,* 49: 181–190.

O'KELLY, J.C. & SEIFERT, G.W. 1969. Relationship between resistance to *Boophilus microplus*, nutritional status, and blood composition of Shorthorn x Hereford cattle on high and low planes of nutrition. *Australian Journal of Biological Science*, 22: 1497–1506.

PEGRAM, R.G., PERRY, B.D., MUSISI, F.L. & MWANAUMO, B. 1986. Ecology and phenology of ticks in Zambia: seasonal dynamics on cattle. *Experimental and Applied Acarology,* 2:25–45.

PETNEY, T.N., HORAK, I.G. & RECHAV, Y. 1987. The ecology of the African vectors of heartwater, with particular reference to *Amblyomma hebraeum* and *Amblyomma variegatum*. *Onderstepoort Journal of Veterinary Research,* 54:381–395.

PETNEY, T.N. & HORAK, I.G. 1987. The effect of dipping on parasitic and free-living populations of *Amblyomma hebraeum* on a farm and on an adjacent nature reserve. *Onderstepoort Journal of Veterinary Research,* 54:529–533.

PETNEY, T.N., VAN ARK, H. & SPICKETT, A.M. 1990. On sampling tick populations: the problem of overdispersion. *Onderstepoort Journal of Veterinary Research*, 57:123–127.

RECHAV, Y., KNIGHT, M.M. & NORVAL, R.A.I. 1977. Life cycle of the tick *Rhipicephalus evertsi evertsi* under laboratory conditions. *Journal of Parasitology*, 63:575–579.

RECHAV, Y. 1982. Dynamics of tick populations (Acari: Ixodidae) in the eastern Cape Province of South Africa. *Journal of Medical Entomology*, 19:679–700.

SEEBUCK, R.M., SPRINGEL, P.H. & O'KELLY, J.C. 1971. Alterations in host metabolism by the specific and anorectic effects of the cattle tick (*Boophilus microplus*). 1. Food intake and body weight growth. *Australian Journal of Biological Science*, 24:373–380.

SHORT, N.J. & NORVAL, R.A.I. 1981. The seasonal activity of *Rhipicephalus appendiculatus* Neumann 1901 (Acarina: Ixodidae) in the highveld of Zimbabwe. *Journal of Parasitology*, 67:77–84.

SPICKETT, A.M., HORAK, I.G., BRAACK, L.E.O. & VAN ARK, H. 1991. Drag-sampling of free-living ixodid ticks in the Kruger National Park. *Onderstepoort Journal of Veterinary Research*, 58:27–32.

SPICKETT, A.M., HORAK, I.G., VAN NIEKERK, ANDREA & BRAACK, L.E.O. 1992. The effect of veld-burning on the seasonal abundance of free-living ticks as determined by drag-sampling. *Onderstepoort Journal of Veterinary Research*, 59: 285–292.

SPICKETT, A.M., HORAK, I.G., HEYNE, HELOISE & BRAACK, L.E.O. 1995. The effect of severe drought on the abundance of ticks on vegetation and on scrub hares in the Kruger National Park. *Koedoe*, 38:59–63.

THEILER, GERTRUD. 1949. Zoological Survey of the Union of South Africa. Tick Survey. II. Distribution of *Rhipicephalus appendiculatus*, the brown ear tick. *Onderstepoort Journal of Veterinary Science and Animal Industry*, 22:269–284.

TRAPNELL, C.G. 1953. *The soils, vegetation and agriculture of North-Eastern Rhodesia*. Lusaka, Northern Rhodesia: Government Printer.

WILSON, S.G. 1946. Seasonal occurrence of Ixodidae on cattle in Northern Province, Nyasaland. *Parasitology*, 37:118–125.

WILSON, S.G. 1950. A check-list and host list of ixodidae found in Nyasaland with descriptions and biological notes on some of the rhipicephalids. *Bulletin of Entomological Research*, 41: 415–428.

YEOMAN, G.H. & WALKER, JANE B. 1967. *The ixodid ticks of Tanzania*. London: Commonwealth Institute of Entomology.

YEOMAN, G.H. 1968. Field vector studies of epizootic East Coast fever. VI. The occurrence of *Amblyomma variegatum* and *A. lepidum* in the East Coast fever zones. *Bulletin of Epizootic Diseases of Africa*, 16:183–203.

ZIMMERMAN, R.H. & GARRIS, G.I. 1985. Sampling efficiency of three dragging techniques for the collection of nonparasitic *Boophilus microplus* (Acari: Ixodidae) larvae in Puerto Rico. *Journal of Economic Entomology*, 78:627–631.