

Ixodid tick infestations of wild birds and mammals on a game ranch in Central Province, Zambia

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ABSTRACT

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Ticks were collected at irregular intervals from December 1995 to November 1996 from wildlife on Mtendere Game Ranch in the Chisamba District of Central Province, Zambia. Total collections were made from two species of ground-nesting birds and 20 species of small and large mammals. Thirteen species/subspecies of ixodid ticks were recovered. *Rhipicephalus appendiculatus* was the most abundant, followed by *Boophilus decoloratus* and *Rhipicephalus evertsi evertsi*.

Small numbers of immature ticks of only a few species were collected from the birds and rodents. The lagomorphs carried large numbers of predominantly immature *R. appendiculatus*. Most of the ungulates harboured several tick species and had high infestations of *R. appendiculatus*. The seasonal abundances of *Amblyomma variegatum*, *B. decoloratus*, *R. appendiculatus* and *R. evertsi evertsi* were determined.

Keywords: Parasitic ixodid ticks, wildlife, Zambia

INTRODUCTION

Tick infestation is considered to be one of the constraints to successful game ranching (Horak 1980; Lightfoot & Norval 1981; Norval & Lightfoot 1982). Direct effects of ticks on their hosts include tick toxicosis, metabolic disturbances, anaemia and tick worry which can result in production losses or deaths (O'Kelly & Seifert 1969). Tick-bite wounds can become secondarily infected with bacteria or maggots (Lightfoot & Norval 1981). Several blood parasites are transmitted by ticks and have been incriminated as the cause of death in several wildlife species (Young & Basson 1973; Grobler 1981; Lightfoot & Norval 1981; Pandey, Minyoi, Hasebe & Mwase 1992). Although wild animals native to a specific region are

seldom adversely affected by the endemic tick-borne blood parasites, translocations of hosts and/or ticks into non-endemic areas can cause severe losses amongst susceptible animals (Lightfoot & Norval 1981; Meltzer 1993). Furthermore, stress can break down a host's inherent resistance to endemic parasites and these may then cause disease (O'Kelly & Seifert 1969).

Commercial game ranching in Zambia commenced in 1989 when the law pertaining to wildlife was amended. Severe tick infestations of wildlife on a game ranch in the Chisamba District of Central Province, Zambia, were reported by the owner in 1995. During a study of the free-living stages of ticks on this ranch (Zieger, Horak & Cauldwell 1998), the opportunity arose to investigate the tick burdens of various wild animal species as well. It was, impossible, however, to examine a number of wildlife species on a regular monthly or bi-monthly basis. Nevertheless, the results presented here portray the tick species that infest wild animals in this region of Zambia, their host ranges and preferences, the magnitude of the hosts' total tick burdens and the seasonal abundances of some ticks.

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Various birds and small mammals were included in this investigation as these may play an important role as hosts of the immature stages of certain ticks.

MATERIAL AND METHODS

Study area

The investigation was conducted on Mtendere Game Ranch (15°05'S, 28°16'E) in the Chisamba District of Central Province, Zambia. The altitude in this region ranges from 1 100–1 200 m above sea level. Mean annual rainfall is 850 mm (Hutchison 1974). Three distinct seasons can be distinguished. These are the warm rainy season from December to April, the cool dry season from May to August and the hot dry season from September to November. The monthly mean temperatures of January, July and October are 20,0°C, 15,0°C and 22,5°C, respectively (Ansell 1978). The major vegetation type is classified as miombo woodland, which is dominated by trees of the genera *Brachystegia* and *Julbernardia* (Trapnell 1953). Miombo woodland is typically interspersed with dambos. These are shallow, seasonally water-logged drainage lines. Dambos support open grasslands dominated by *Hyparrhenia*, *Brachiaria*, *Echinochloa* and *Setaria* spp.

The ranch has operated commercially since 1990. It is situated approximately 20 km north of Lusaka and encompasses an area of 960 ha. It was stocked with several species of wildlife during 1990 and 1991. 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 wildlife comprised 34 Burchell's zebra (*Equus burchellii*); 10 warthog (*Phacochoerus africanus*); 25 bushpig (*Potamochoerus larvatus*); 135 impala (*Aepyceros melampus*); 18 tsessebe (*Damaliscus lunatus lunatus*); 48 Lichtenstein's hartebeest (*Sigmoceros lichtensteini*); 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*). An unknown number of Sharpe's grysbok (*Raphicerus sharpei*) were also present.

All newly introduced animals were treated with the acaricide flumethrin (Drastic Deadline, Bayer Animal Health) prior to release. Five Duncan Applicators (Duncan & Monks 1992) were set up during the hot dry season (October 1996) and filled with a dicalcium-phosphate and coarse sodium-chloride salt mixture. The applicators themselves were charged

with the acaricide flumethrin (Drastic Deadline, Bayer Animal Health) from November 1996 onwards once animals had become attracted and accustomed to them.

Survey animals

The birds and mammals examined and their dates of collection are summarized in Table 1. Two species of ground-nesting birds and 20 mammal species were examined during the period December 1995 to November 1996. Most of the larger mammals were shot either for venison or as trophies. The Lichtenstein's hartebeest and one eland were killed because of leg injuries. The Sharpe's grysbok and the sable antelope, a juvenile, were found freshly dead. Two bushpigs were shot as trophies in September 1996 and only the skins of their backs and legs were available for tick recovery. Their tick burdens are included in Fig. 1, 3 and 4, as no other animals became available during that month, but are not listed in the tables. Two sable antelope bulls were shot as trophies in July 1996 and only the back and leg skins were available for examination. These animals are mentioned as hosts of certain ticks, but their tick counts are not included in any of the tables or figures. The birds and scrub hares (*Lepus saxatilis*) were shot for the study. Except for the dormouse (*Graphiurus* sp.) that was found injured, the mice were trapped for the study and were killed with chloroform.

Collection of ticks

The birds were processed for tick recovery as described by Horak & Williams (1986); the lagomorphs and rodents as described by Horak, Sheppey, Knight & Beuthin (1986); and the ungulates as described by Horak, Boomker, Spickett & De Vos (1992).

Presentation of data

Because of the overdispersed nature of parasitic ticks (Petney, Van Ark & Spickett 1990), the tick counts of various host animals were transformed logarithmically [$\ln(\text{number of ticks} + 1)$] before being pooled to illustrate the ticks' seasonal occurrences (Fig. 1–4). The number of larvae, nymphs and adults were pooled for the one-host tick *Boophilus decoloratus* (Fig. 2), and the number of larvae and nymphs were pooled for the two-host tick *Rhipicephalus evertsi evertsi* (Fig. 4).

RESULTS AND DISCUSSION

The number of tick species and mean total number of ticks collected per host species are summarized in Table 1. The species and/or subspecies of ixodid ticks recovered and their presence on birds, lagomorphs, rodents and ungulates are listed in Table 2.

TABLE 1 The mean total tick burdens and number of tick species infesting birds and mammals examined on Mtendere Game Ranch, Central Province, Zambia

Host species (Common name)	Number examined	Mean total tick burden	Number of tick spp.	Date examined
Birds				
<i>Numida meleagris</i> (Helmeted guineafowl)	2	15,5	2	Jun. 96; Nov. 96
<i>Francolinus swainsonii</i> (Swainson's francolin)	3	1,0	1	Jun. to Nov. 96
Lagomorphs				
<i>Lepus saxatilis</i> (Scrub hare)	4	1 251,0	6	Jun. to Sep. 96
Rodents				
<i>Saccostomus campestris</i> (Pouched mouse)	2	2,0	3	Jun. 96
<i>Aethomys chrysophilus</i> (Red veld rat)	1	4,0	1	Aug. 96
<i>Mastomys</i> sp. (Multimammate mouse)	6	2,0	3	Jun. to Aug. 96
<i>Pelomys fallax</i> (Grooved-toothed mouse)	10	2,1	3	Jun. to Sep. 96
<i>Graphiurus</i> sp. (Dormouse)	1	2,0	1	Sep. 96
Ungulates				
<i>Equus burchellii</i> (Burchell's zebra)	1	2 204,0	5	Jan. 96
<i>Potamochoerus larvatus</i> (Bushpig)	2	10 379,0	3	Apr. 96
<i>Aepyceros melampus</i> (Impala)	12	4 975,2	7	Dec. 95 to Nov. 96
<i>Damaliscus lunatus lunatus</i> (Tsessebe)	3	7 111,3	6	Jan. to Aug. 96
<i>Sigmoceros lichtensteinii</i> (Lichtenstein's hartebeest)	1	3 724,0	7	Dec. 95
<i>Raphicerus sharpei</i> (Sharpe's grysbok)	1	144,0	4	Jun. 96
<i>Taurotragus oryx</i> (Eland)	2	11 956,0	7	Dec. 95; Feb. 96
<i>Tragelaphus scriptus</i> (Bushbuck)	2	15 951,0	6	Jun. 96; Aug. 96
<i>Tragelaphus strepsiceros</i> (Greater kudu)	2	10 098,0	8	Feb. 96; Mar. 96
<i>Hippotragus niger</i> (Sable antelope)	1	4 119,0	5	Nov. 96
<i>Kobus ellipsiprymnus defassa</i> (Defassa waterbuck)	6	10 460,6	6	Dec. 95 to Nov. 96
<i>Kobus leche kafuensis</i> (Kafue lechwe)	2	1 074,0	5	Dec. 95; Nov. 96
<i>Kobus vardonii</i> (Puku)	1	8 458,0	3	Aug. 96
<i>Redunca arundinum</i> (Reedbuck)	1	17 608,0	3	Aug. 96

TABLE 2 Ixodid ticks (x) collected on Mtendere Game Ranch, Central Province, Zambia, from birds (B), lagomorphs (L), rodents (R) and ungulates (U)

Tick species	B	L	R	U
<i>Amblyomma variegatum</i>	x			x
<i>Boophilus decoloratus</i>				x
<i>Haemaphysalis leachi</i> group			x	
<i>Rhipicephalus appendiculatus</i>	x	x	x	x
<i>Rhipicephalus evertsi evertsi</i>		x		x
<i>Rhipicephalus kochi</i>				x
<i>Rhipicephalus lunulatus</i>		x	x	x
<i>Rhipicephalus punctatus</i>				x
<i>Rhipicephalus simus</i>			x	x
<i>Rhipicephalus sulcatus</i>		x		x
<i>Rhipicephalus supertritus</i>				x
<i>Rhipicephalus zambeziensis</i>		x		
<i>Rhipicephalus</i> sp.		x	x	x

The host records for each of the tick species and/or subspecies collected on Mtendere Game Ranch are summarized in Tables 3–8. The seasonal abundances of those ticks of which sufficient numbers had been collected are graphically illustrated in Fig. 1–4. The histograms are based on the pooled monthly mean numbers of ticks collected from those animals which

appeared to be suitable hosts for the particular tick species.

The birds and rodents were infested with only a few tick species and harboured small numbers of immature ticks only. The most prevalent and abundant tick on the birds was *Amblyomma variegatum*, while *Rhipicephalus appendiculatus* was the most prevalent, and *Rhipicephalus simus* the most abundant, on the rodents. The scrub hares harboured large numbers of immature *R. appendiculatus* and *R. evertsi evertsi*. *R. appendiculatus* was the most prevalent and most abundant tick on the ungulates. The largest number of ticks was collected from a defassa waterbuck with a total count of 30 718, followed by an impala with a total of 25 735 ticks.

***Amblyomma variegatum* (Table 3; Fig. 1)**

This tick was collected from birds and most ungulates, but was absent on lagomorphs and rodents. The birds were infested only with the immature stages. Bushpig, tsessebe, Sharpe's grysbok and reedbuck carried only immature ticks, Burchell's zebra only adults, and the other animals both immatures and adults. Larvae of *A. variegatum* were recovered from

TABLE 3 Host records of *Amblyomma variegatum* on Mtendere Game Ranch, Central Province, Zambia

Host	Number examined	Number infested	Mean number of ticks collected (+/- S.E.)				
			Larvae	Nymphs	Males	Females	Total
Helmeted guineafowl	2	2	10,5	1,0	0,0	0,0	11,5 (3,7)
Swainson's francolin	3	2	0,0	1,0	0,0	0,0	1,0 (1,0)
Burchell's zebra	1	1	0,0	0,0	10,0	8,0	18,0
Bushpig	2	2	64,5	0,0	0,0	0,0	64,5 (9,2)
Impala	12	7	20,8	1,4	0,7	0,2	23,1 (6,2)
Tsessebe	3	3	23,3	11,3	0,0	0,0	34,6 (5,6)
Lichtenstein's hartebeest	1	1	0,0	2,0	24,0	6,0	32,0
Sharpe's grysbok	1	1	1,0	0,0	0,0	0,0	1,0
Eland	2	2	0,0	2,0	30,0	13,0	45,0 (6,8)
Bushbuck	2	2	29,0	1,0	0,0	1,0	31,0 (6,4)
Greater kudu	2	2	44,0	0,0	0,0	2,0	46,0 (7,7)
Sable antelope	1	1	0,0	4,0	2,0	0,0	6,0
Defassa waterbuck	6	5	8,0	3,0	0,7	0,0	11,7 (4,2)
Kafue lechwe	2	2	0,0	5,0	5,0	5,0	15,0 (4,3)
Reedbuck	1	1	0,0	10,0	0,0	0,0	10,0

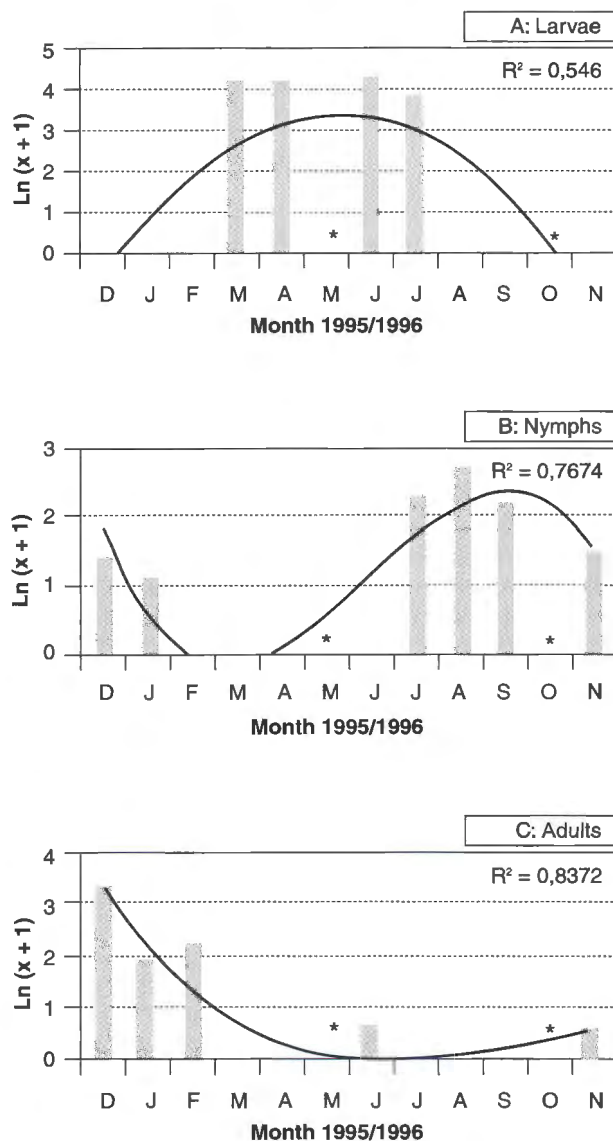


FIG. 1 The seasonal abundance of (A) larvae, (B) nymphs and (C) adults of *Amblyomma variegatum* on Burchell's zebra, bushpig, impala, tsessebe, eland, bushbuck, greater kudu and defassa waterbuck on Mtendere Game Ranch, Central Province, Zambia (* no collection)

March to July, nymphs in December and January and again from July to November, and adults mainly from December to February.

A. variegatum has been described from a wide variety of domestic and wild hosts in Africa (Petney, Horak & Rechav 1987). Cattle appear to be a major host of this tick. Adults are also found on medium to large wild herbivores, whereas immatures occur on a variety of hosts (Norval 1983; Petney *et al.* 1987; Walker 1991). Larvae and nymphs have been collected from ground-nesting birds (Theiler & Salisbury 1959; Walker 1974) and feed mostly on the birds' heads and upper necks. Colbo & MacLeod (1976) have recovered immatures in low numbers from several bird species in Zambia. Lagomorphs and rodents have also been listed as hosts of the immature stages of other *Amblyomma* spp. in Africa (Theiler 1962). Hares are good hosts of *Amblyomma hebraeum* and *Amblyomma marmoreum* (Horak & Fourie 1991) and Matthyse (1954) has reported large numbers of *A. variegatum* nymphs from hares in Zambia. Moderate numbers of nymphs of an *Amblyomma* sp. have also been collected from hares by MacLeod (1970) and Colbo & MacLeod (1976) in the latter country. It is therefore surprising that no *A. variegatum* larvae or nymphs were recovered from the scrub hares in the present study.

Except for puku, all the ungulates examined hosted *A. variegatum*. It is impossible to identify the preferred hosts of *A. variegatum* in this study because of the strictly seasonal occurrence of this tick. For several of the host species only one or a few individuals were

TABLE 4 Hosts records of *Boophilus decoloratus* on Mtendere Game Ranch, Central Province, Zambia

Host	Number examined	Number infested	Mean number of ticks collected (+/- S.E.)				
			Larvae	Nymphs	Males	Females	Total
Burchell's zebra	1	1	260,0	172,0	86,0	124,0	642,0
Impala	12	12	255,2	76,9	28,6	18,4	379,1 (15,8)
Tsessebe	3	3	245,3	29,3	4,0	4,0	282,6 (15,5)
Lichtenstein's hartebeest	1	1	242,0	1 364,0	678,0	376,0	2 660,0
Eland	2	2	1 301,0	1 790,0	1 672,0	388,0	5 151,0 (63,1)
Bushbuck	2	2	17,0	35,0	1,0	0,0	53,0 (7,6)
Greater kudu	2	2	2 216,0	788,0	307,0	188,0	3 499,0 (36,2)
Sable antelope	1	1	1 393,0	910,0	582,0	279,0	3 164,0
Defassa waterbuck	6	6	31,7	0,7	0,3	0,0	32,7 (5,7)
Kafue lechwe	2	2	30,0	21,0	29,0	7,0	87,0 (12,0)
Puku	1	1	10,0	0,0	2,0	2,0	14,0

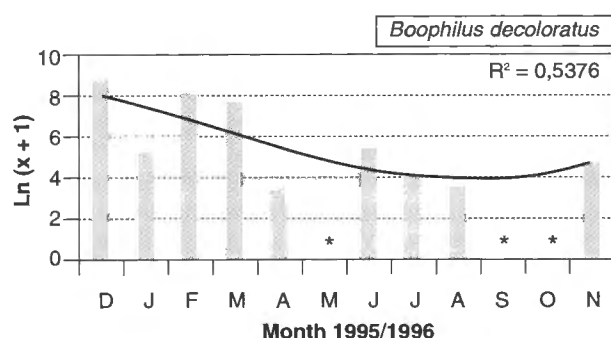


FIG. 2 The seasonal abundance of all stages of *Boophilus decoloratus* on impala, tsessebe, eland, bushbuck and greater kudu on Mtendere Game Ranch, Central Province, Zambia (* no collection)

available for tick collection and the time of examination may not have coincided with the tick's peak activity period. Impala were examined throughout the year and hosted all life stages but carried few adults. One of the three tsessebe was examined during the peak activity period of adult ticks. No adults were collected from this animal, indicating that tsessebe are possibly unsuitable hosts for this life stage. The greatest numbers of adults were present on the Lichtenstein's hartebeest and on eland. In previous studies in Zambia, Burchell's zebra, warthog, impala, eland, greater kudu, sable antelope and Kafue lechwe had been found to host this tick (Matthysse 1954; MacLeod 1970; Colbo 1973; Pandey *et al.* 1992).

A. variegatum occurs in semi-arid as well as humid regions and appears to require a minimum annual rainfall of 400 mm (Yeoman & Walker 1967). It completes one generation per year in regions with a single annual rainy season (Wilson 1950; Matthysse 1954). Adults are most abundant on cattle in Zambia from November to January (Matthysse 1954; MacLeod 1970; MacLeod, Colbo, Madbouly & Mwanuamo 1977), while larvae are most abundant on these animals from March to May and nymphs from

April to December (MacLeod & Colbo 1976). In the present study, all stages of this tick showed a pattern of seasonal occurrence similar to that recorded on cattle.

Boophilus decoloratus (Table 4; Fig. 2)

B. decoloratus was collected only from ungulates, but was absent on bushpig, Sharpe's grysbok and reedbuck. Large numbers were present on Lichtenstein's hartebeest, eland, greater kudu and sable antelope. It occurred throughout the year with a peak in abundance during the height of the rainy season (December to March).

B. decoloratus is primarily a tick of larger herbivores (Walker 1991). In South Africa it has been found in large numbers on Burchell's zebra, giraffe (*Giraffa camelopardalis*), greater kudu, nyala (*Tragelaphus angasi*), bushbuck, eland and impala (Horak, Potgieter, Walker, De Vos & Boomker 1983; Horak, De Vos & De Klerk 1984; Horak *et al.* 1992). In the present study the preferred hosts were Lichtenstein's hartebeest, eland, greater kudu and sable antelope. Burchell's zebra and impala were also good hosts, but mean tick numbers were not as high as they were on these animals in the Kruger National Park, South Africa (Horak 1995). Few ticks were collected from the other ungulates. Both the defassa waterbuck and the tsessebe can be considered virtual dead-end hosts for this one-host tick. This is indicated by the ratios of larvae to nymphs and nymphs to adults, of 105,7:2,3:1 and 30,6:3,7:1, respectively, implying a poor translation to adulthood, compared with 4,5:1,6:1 on the greater kudu, which are good hosts.

The smaller mammals and birds did not carry any *B. decoloratus* in this study. Colbo & MacLeod (1976) have collected some adults from hares and from a groove-toothed mouse (*Pelomys fallax*) in Zambia. With the exception of defassa waterbuck, Kafue lechwe and puku, the larger mammals reported here have previously been listed as hosts of *B. decoloratus*

in Zambia (Matthysse 1954; MacLeod 1970; Colbo 1973; MacLeod *et al.* 1977).

Reports on the seasonal abundance of this tick vary. Two main activity periods have been found on cattle in Zambia, namely the rainy season and the hot, dry season (MacLeod 1970; MacLeod *et al.* 1977). In South Africa, two or three peaks of abundance have been recorded (Baker & Ducasse 1967; Rechav 1982; Horak *et al.* 1992), while in Zimbabwe, Jooste (1966) speculated that four generations may occur in one year. Free-living *B. decoloratus* larvae collected from the vegetation of Mtendere Game Ranch showed two peaks of abundance, namely during the rainy season and the hot, dry season (Zieger *et al.* 1998). In the present study, *B. decoloratus* was most active during the rainy season from December to March. It is possible, however, that the second peak of abundance during the hot, dry season recorded on the ranch for free-living ticks (Zieger *et al.* 1998) was missed. The only animals that were examined in September were two bushpigs, and these did not host any *B. decoloratus*. No animals were available for tick collection in October.

Haemaphysalis leachi group (Table 8)

This group of ticks contains both *H. leachi* and *H. spinolusa*, of which the immature stages are extremely difficult to differentiate. In this survey, only one *Haemaphysalis* nymph belonging to this group was found on a pouched mouse (*Saccostomus campestris*). Adults of this group are typically parasites of domestic dogs and a variety of wild carnivores (Walker 1991). *H. leachi* has been reported from jackal (*Canis sp.*) and civets (*Civettictis sp.*) in Zambia (Colbo 1973;

MacLeod *et al.* 1977). As very few wild carnivores are present on Mtendere Game Ranch it is not surprising that the immature stages of the *H. leachi* group were not collected more frequently from rodents which are their preferred hosts (Walker 1991).

Rhipicephalus appendiculatus (Table 5; Fig. 3)

This tick occurred on all host groups. Small numbers of immatures only were collected from some of the birds and rodents while the scrub hares carried large numbers. Bushpigs, impala, tsessebe, Sharpe's grysbok, bushbuck, puku and reedbuck carried mostly or only immature ticks. Except for the Burchell's zebra, which carried only adults, the remaining animals carried both immature and adult ticks. Most larvae were recovered from February to September, nymphs from June to September and adults from December to March and again in November.

R. appendiculatus has an extremely wide host range (Walker 1991). Among wild animals its preferred hosts are Artiodactyla. All life stages generally occur on the same host species, but the smaller hosts are usually mostly infested with the immature stages (Horak 1982; Norval, Walker & Colborne 1982; Walker 1991). *R. appendiculatus* is the dominant tick on Mtendere Game Ranch. Its larvae accounted for 91,6% of all ticks collected from scrub hares. It also constituted 99,4% of all ticks present on bushpig, 88,5% on tsessebe, 93,8% on Sharpe's grysbok, 98,8% on bushbuck, 91,9% on defassa waterbuck and 98,4% on puku. Adults occurred in the greatest numbers on eland, greater kudu and defassa waterbuck which can all be considered preferred hosts. The partial counts of the two sable antelope bulls examined

TABLE 5 Host records of *Rhipicephalus appendiculatus* on Mtendere Game Ranch, Central Province, Zambia

Host	Number examined	Number infested	Mean number of ticks collected (+/- S.E.)				
			Larvae	Nymphs	Males	Females	Total
Helmeted guineafowl	2	1	4,0	0,0	0,0	0,0	4,0 (2,4)
Scrub hare	4	4	941,0	205,0	0,0	0,0	1 146,0 (37,5)
Multimammate mouse	6	3	1,0	0,0	0,0	0,0	1,0 (1,0)
Groove-toothed mouse	10	2	0,6	0,0	0,0	0,0	0,6 (1,3)
Dormouse	1	1	1,0	1,0	0,0	0,0	2,0
Burchell's zebra	1	1	0,0	0,0	746,0	400,0	1 146,0
Bushpig	2	2	10 243,0	43,0	12,0	14,5	10 312,5 (80,4)
Impala	12	12	3 079,8	653,1	12,3	5,8	3 751,0 (84,2)
Tsessebe	3	3	4 278,6	1 965,3	24,7	22,6	6 291,2 (76,6)
Lichtenstein's hartebeest	1	1	0,0	2,0	542,0	150,0	694,0
Sharpe's grysbok	1	1	127,0	8,0	0,0	0,0	135,0
Eland	2	2	942,0	5,0	3 292,0	1 456,0	5 695,0 (39,1)
Bushbuck	2	2	13 957,0	1 806,0	1,0	0,0	15 764,0 (20,9)
Greater kudu	2	2	3 554,0	14,0	866,0	892,0	5 326,0 (59,8)
Sable antelope	1	1	3,0	69,0	33,0	6,0	111,0
Defassa waterbuck	6	6	4 550,8	3 281,5	1 121,7	662,8	9 616,8 (113,4)
Kafue lechwe	2	2	1,0	48,0	247,0	68,0	364,0 (19,2)
Puku	1	1	3 956,0	4 370,0	0,0	0,0	8 326,0
Reedbuck	1	1	5 758,0	6 922,0	2,0	2,0	12 684,0

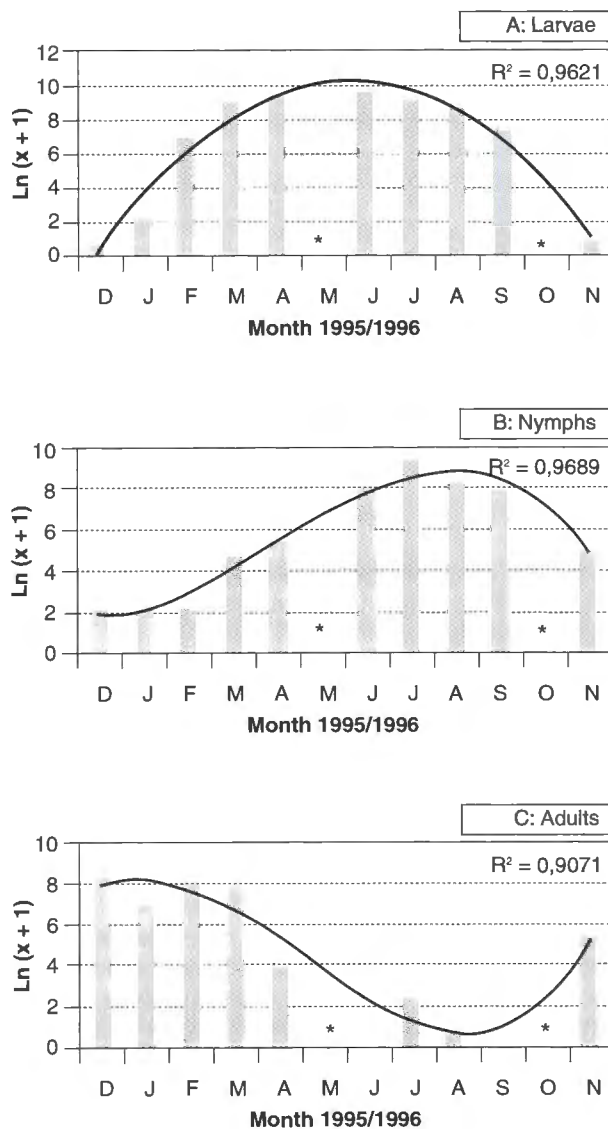


FIG. 3 The seasonal abundance of (A) larvae, (B) nymphs and (C) adults of *Rhipicephalus appendiculatus* on bushpig, impala, tsessebe, eland, bushbuck, greater kudu, defassa waterbuck, puku and reedbuck on Mtendere Game Ranch, Central Province, Zambia (* no collection)

in July revealed no fewer than 9 264 and 4 676 ticks respectively (numbers are not included in Table 1). The large number of adults collected from the Burchell's zebra, which is usually not considered to be a good host, probably reflects the superabundance of *R. appendiculatus* on the ranch.

R. appendiculatus has been recorded as one of the major ticks occurring on cattle in the Southern and Central Provinces of Zambia (MacLeod 1970; MacLeod *et al.* 1977; Pegram, Perry, Musisi & Mwanauo 1986). Most of the wildlife species previously examined in the same regions carried this tick, but only in small numbers (MacLeod 1970; Colbo 1973; MacLeod *et al.* 1977).

This three-host tick has a well-defined pattern of seasonal abundance reflecting the completion of a single generation per year. This pattern of abundance has been described in several African countries (Wilson 1946; Baker & Ducasse 1967; Matson & Norval 1977; Gallivan & Surgeoner 1995). In Zambia, MacLeod *et al.* (1977) found a distinct seasonal pattern with the highest numbers of adults present on cattle during the rainy season. Adults, however, were also present in low numbers throughout the year (Matthysse 1954; MacLeod *et al.* 1977), a phenomenon seen in the present study. The seasonal abundance of free-living *R. appendiculatus* collected from the vegetation of Mtendere Game Ranch revealed a pattern similar to that described on the host animals (Zieger *et al.* 1998). However, in that study adults disappeared from the vegetation during the dry months (July to November).

Rhipicephalus evertsi evertsi (Table 6; Fig. 4)

This tick was absent on birds and rodents, while all the scrub hares were infested with the immature stages. Except for the Sharpe's grysbok, all ungulates harboured *R. evertsi evertsi*, including one of the two bushpigs on which only partial counts were done. Bushbuck and puku hosted only immature stages. The number of immature ticks collected from the reedbuck far exceeded the counts on any of the other ungulates. All life stages were present throughout the year.

R. evertsi evertsi is widespread in Africa (Theiler 1962). It is a two-host tick whose adults do not usually occur in large numbers, except on zebra and eland (Horak *et al.* 1984; Horak, Fourie, Novellie & Williams 1991). These animals are also good hosts for all life stages, while other wild ruminants and scrub hares have been described as fair to good hosts of the immature stages (Horak & Knight 1986; Rechav, Zeederberg & Zeller 1987; Horak 1995). Bushpigs and bushbuck are new host records for this tick in Zambia. Burchell's zebra, Lichtenstein's hartebeest and eland were good hosts for the adults. Though results from single host collections must be interpreted with care, the translation of larvae to nymphs is apparently poor on impala, bushbuck, greater kudu and defassa waterbuck. This has also been observed on impala and greater kudu in South Africa (Horak *et al.* 1992; Horak 1995).

All life stages of this tick occurred throughout the year on Mtendere Game Ranch. No clear seasonal pattern of abundance was discernible, but adults appeared to be present in slightly larger numbers during the rainy season. Previous reports from Zambia indicate that larval abundance on cattle peaks in September and October (MacLeod 1970) and that, depending on climatic conditions, adults occur in two to three waves per year (MacLeod 1970, 1975). It is possible that, because of the irregular sampling of

TABLE 6 Host records of *Rhipicephalus evertsi evertsi* on Mtendere Game Ranch, Central Province, Zambia

Host	Number examined	Number infested	Mean number of ticks collected (+/- S.E.)				
			Larvae	Nymphs	Males	Females	Total
Scrub hare	4	4	56,0	32,3	0,0	0,0	88,3 (9,8)
Burchell's zebra	1	1	302,0	6,0	28,0	16,0	352,0
Impala	12	12	683,8	103,8	7,8	4,2	799,6 (28,6)
Tsessebe	3	3	364,7	126,6	5,3	4,7	501,3 (13,0)
Lichtenstein's hartebeest	1	1	80,0	140,0	34,0	12,0	266,0
Eland	2	2	634,0	147,0	97,0	32,0	910,0 (4,7)
Bushbuck	2	2	86,0	2,0	0,0	0,0	8,0 (4,7)
Greater kudu	2	2	1 142,0	62,0	8,0	7,0	1 219,0 (29,1)
Sable antelope	1	1	458,0	342,0	11,0	5,0	816,0
Defassa waterbuck	6	6	639,3	95,3	11,0	8,3	753,9 (31,2)
Kafue lechwe	2	2	391,0	165,0	17,0	12,0	585,0 (25,7)
Puku	1	1	90,0	28,0	0,0	0,0	118,0
Reedbuck	1	1	1 798,0	3 106,0	6,0	4,0	4 914,0

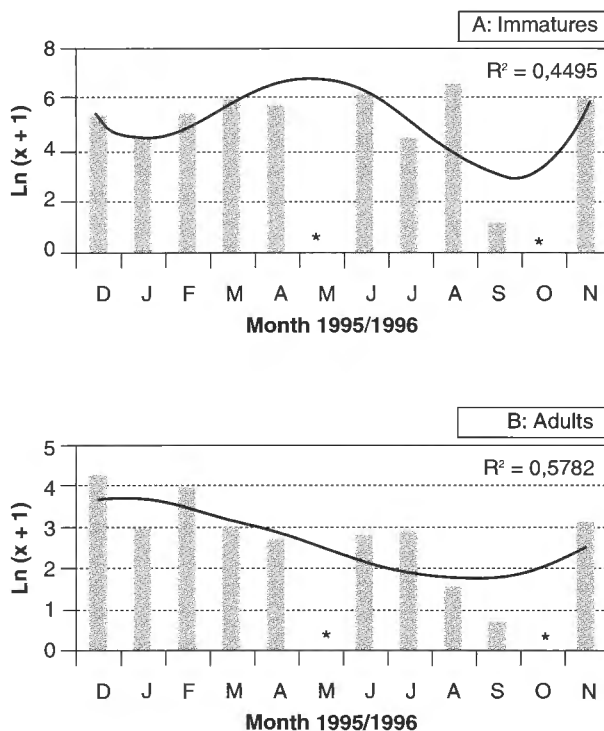


FIG. 4 The seasonal abundance of (A) immatures and (B) adults of *Rhipicephalus evertsi evertsi* on Burchell's zebra, bushpig, impala, tsessebe, eland, bushbuck, greater kudu, defassa waterbuck, puku and reedbuck on Mtendere Game Ranch, Central Province, Zambia (* no collection)

hosts in our study, the pattern of abundance was less clear than that on cattle.

Rhipicephalus kochi (Table 8)

This tick is widely distributed in East and Central Africa where it parasitizes a large variety of domestic and wild hosts (Clifford, Walker & Keirans 1983). It has been recorded from greater kudu in Zambia

(Pegram *et al.* 1986) and was present in small numbers on five of the ruminant species on Mtendere Game Ranch.

Rhipicephalus lunulatus (Table 7)

Nymphs were collected from one of the scrub hares and from two multimammate mice (*Mastomys* sp.) Most of the ungulates were infested, but harboured only adults. Nymphs were present in June, and the adults from December to March and again in November.

Adults of this tick appear to be non-specific in their choice of hosts (Walker 1991). The host range reported here is probably incomplete because of the limited number of animals examined during the main activity period of adult ticks. All ungulates examined on the ranch from December 1995 to March 1996 and during November 1996 carried adults. In many African countries, peaks of adult activity are associated with hot, wet conditions (Walker, Keirans, Pegram & Clifford 1988). Larvae and nymphs have been successfully reared under laboratory conditions (Colborne 1985) but their natural hosts were not identified. In the present study, *R. lunulatus* nymphs were collected for the first time from a scrub hare and two multimammate mice.

Rhipicephalus punctatus (Table 8)

Small numbers of adults were collected from an impala, the Lichtenstein's hartebeest and Sharpe's grysbok. The immature stages of this tick are unknown. However, the *Rhipicephalus* sp. immatures, which we collected from scrub hares, a groove-toothed mouse, an impala and a bushbuck (Table 8) and which we were unable to identify, may belong to this species. In previous surveys in Zambia, Colbo (1973) and MacLeod *et al.* (1977) found *R. punctatus* on a variety of wild animals.

TABLE 7 Host records of *Rhipicephalus lunulatus* on Mtendere Game Ranch, Central Province, Zambia

Host	Number examined	Number infested	Mean number of ticks collected (+/- S.E.)				
			Larvae	Nymphs	Males	Females	Total
Scrub hare	4	1	0,0	0,3	0,0	0,0	0,3 (0,7)
Multimammate mouse	6	2	0,0	0,8	0,0	0,0	0,8 (1,3)
Burchell's zebra	1	1	0,0	0,0	42,0	4,0	46,0
Impala	12	8	0,0	0,0	16,6	4,8	21,4 (5,9)
Tsessebe	3	1	0,0	0,0	0,7	0,0	0,7 (1,0)
Lichtenstein's hartebeest	1	1	0,0	0,0	42,0	14,0	56,0
Eland	2	2	0,0	0,0	109,0	24,0	133,0 (13,3)
Kudu	2	2	0,0	0,0	3,0	1,0	4,0 (0,0)
Sable antelope	1	1	0,0	0,0	18,0	4,0	22,0
Defassa waterbuck	6	4	0,0	0,0	28,3	17,0	45,3 (8,6)
Kafue lechwe	2	2	0,0	0,0	16,0	7,0	23,0 (4,6)

Rhipicephalus simus (Table 8)

The immature stages of this tick were collected only from the rodents. These animals are the preferred hosts of these stages (Norval & Mason 1981). They have previously been recorded on a variety of small mammals in Zambia (Colbo 1973; Colbo & MacLeod 1976). Adults were recovered from bushpigs and eland in the present study, whereas MacLeod (1970), Colbo (1973) and MacLeod *et al.* (1977) have recovered them from several wild animal species in Zambia.

Rhipicephalus sulcatus (Table 8)

In the present study, adults were collected from one scrub hare, from the Lichtenstein's hartebeest and one greater kudu. This tick is widely distributed in East and Central Africa (Pegram, Clifford, Walker & Keirans 1987). Adults are commonly found on dogs and hares, and less frequently on wild carnivores and antelopes (Pegram *et al.* 1987). The hosts of the immature stages are unknown (Walker 1991). Among Zambian wild ungulates it had previously been collected only from Lichtenstein's hartebeest and defassa waterbuck (MacLeod 1970; Colbo 1973).

Rhipicephalus supertritus (Table 8)

A few adults of this tick were collected from eland and greater kudu on the ranch. MacLeod (1970) also recovered small numbers of adults from eland and greater kudu in Zambia, while Colbo (1973) found adults also on Burchell's zebra. This tick is consistently present in large numbers on cattle in a small area south-east of Lusaka but is otherwise rare (Matthysse 1954; MacLeod *et al.* 1977). No explanation has been found for this phenomenon. The hosts of the immature stages are unknown.

Rhipicephalus zambeziensis (Table 8)

One larva only was collected from a scrub hare. Twenty-one larvae and a nymph were also collected

from the vegetation on the ranch (Zieger *et al.* 1998). This tick is closely related to *R. appendiculatus* and replaces the latter in the hot, dry, low-lying areas of south-eastern Africa (Norval *et al.* 1982). Their distributions overlap in the Southern Province of Zambia along the Zambezi Valley. Hosts of *R. zambeziensis* include numerous wild ungulates (Norval *et al.* 1982). Its low incidence on Mtendere Game Ranch indicates that the ranch is located near the limit of its distribution in this region.

GENERAL

The dominant tick on Mtendere Game Ranch is *R. appendiculatus*. It is followed by *B. decoloratus* and *R. evertsi evertsi*. These three species accounted for 99,2 % of all mean total tick counts. All the tick species/subspecies collected in this survey have already been recorded in Zambia (Matthysse 1954; Theiler & Robinson 1954; MacLeod 1970; Colbo 1973; MacLeod *et al.* 1977; Pegram *et al.* 1986). Though the tick collection techniques differed in each of these studies, none of the authors commented on a clear dominance of one or several tick species on the animals examined. However, a situation comparable to that on Mtendere Game Ranch was observed by MacLeod (1970) on cattle in the Southern Province of Zambia. Here the dominating frequency of *B. decoloratus*, *R. appendiculatus* and *R. evertsi evertsi* on intensely farmed cattle was thought to be 'not a necessary concomitant of cattle, but rather an effect of their ecologically unnatural density'. MacLeod (1970) concluded that the concentration of cattle under commercial ranching conditions, and possibly its consequent effect on the vegetation cover, had upset the balance between tick species.

The total tick burdens of wild animals on Mtendere Game Ranch appear to be heavy but are comparable to the burdens collected from animals in natural wildlife areas in South Africa. In the Kruger National

TABLE 8 Host records of the less common tick species on Mtendere Game Ranch, Central Province, Zambia

Tick and host	Number examined	Number infested	Mean number of ticks collected (+/- S.E.)				
			Larvae	Nymphs	Males	Females	Total
<i>Haemaphysalis leachi</i> group							
Pouched mouse	2	1	0,0	0,5	0,0	0,0	0,5 (0,8)
<i>Rhipicephalus kochi</i>							
Impala	12	1	0,0	0,0	0,2	0,0	0,2 (0,8)
Tsessebe	3	1	0,0	0,0	0,0	0,7	0,7 (1,1)
Sharpe's grysbok	1	1	0,0	0,0	2,0	3,0	5,0
Bushbuck	2	2	0,0	14,0	0,0	0,0	14,0 (3,8)
Greater kudu	2	1	0,0	0,0	2,0	0,0	2,0 (1,7)
<i>Rhipicephalus simus</i>							
Pouched mouse	2	2	1,5	0,0	0,0	0,0	1,5 (0,8)
Red veld rat	1	1	1,0	3,0	0,0	0,0	4,0
Multimammate mouse	6	1	0,0	0,2	0,0	0,0	0,2 (0,6)
Grooved-toothed mouse	10	2	0,6	0,7	0,0	0,0	1,3 (1,9)
Bushpig	2	2	0,0	0,0	0,5	1,5	2,0 (1,2)
Eland	2	2	0,0	0,0	7,0	0,0	7,0 (1,8)
<i>Rhipicephalus punctatus</i>							
Impala	12	1	0,0	0,0	0,0	0,2	0,2 (0,8)
Lichtenstein's hartebeest	1	1	0,0	0,0	2,0	2,0	4,0
Sharpe's grysbok	1	1	0,0	0,0	3,0	0,0	3,0
<i>Rhipicephalus sulcatus</i>							
Scrub hare	4	1	0,0	0,0	0,3	0,3	0,6 (0,8)
Lichtenstein's hartebeest	1	1	0,0	0,0	10,0	2,0	12,0
Greater kudu	2	1	0,0	0,0	1,0	0,0	1,0 (1,2)
<i>Rhipicephalus supertritus</i>							
Eland	2	1	0,0	0,0	15,0	0,0	15,0 (4,6)
Kudu	2	1	0,0	0,0	0,0	1,0	1,0 (1,2)
<i>Rhipicephalus zambeziensis</i>							
Scrub hare	4	1	0,3	0,0	0,0	0,0	0,3 (0,7)
<i>Rhipicephalus</i> sp.							
Scrub hare	4	3	4,3	11,5	0,0	0,0	15,8 (5,1)
Grooved-toothed mouse	10	1	0,1	0,0	0,0	0,0	0,1 (0,5)
Impala	12	1	0,7	0,0	0,0	0,0	0,7 (1,5)
Bushbuck	2	1	1,0	0,0	0,0	0,0	1,0 (1,2)

Park, South Africa, the mean tick burdens of Bur-chell's zebra, impala and greater kudu during several years of investigation were between 3000 and 5000 per animal (Horak *et al.* 1992; Horak 1995). Buffalo in the Hluhluwe Game Reserve carried close to 20000 ticks (Horak *et al.* 1983). With the exception of the Lichtenstein's hartebeest and one eland, which were both shot on the ranch because of leg injuries, and the sable antelope and Sharpe's grysbok which were found dead, all other animals were shot for venison or as trophies and were apparently in good condition. The year of investigation had been a year of good rainfall and, despite the high stocking den-

sity on the ranch, the overall food supply was adequate during the entire study period. The numbers of ticks collected therefore represent the normal burdens of healthy animals on the ranch.

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