Onderstepoort Journal of Veterinary Research, 60:163–174 (1993)

Parasites of domestic and wild animals in South Africa. XXXII. Ixodid ticks on scrub hares in the Transvaal

I.G. HORAK[1], A.M. SPICKETT[2], L.E.O. BRAACK[3] and B.L. PENZHORN[1]

ABSTRACT

HORAK, I.G., SPICKETT, A.M., BRAACK, L.E.O. & PENZHORN, B.L. 1993. Parasites of domestic and wild animals in South Africa. XXXII. Ixodid ticks on scrub hares in the Transvaal. *Onderstepoort Journal of Veterinary Research*, 60:163–174

A total of 264 scrub hares (*Lepus saxatilis*) were examined for ixodid ticks at various localities in the Kruger National Park, eastern Transvaal Lowveld. Thirteen tick species were recovered from these hares. The seasonal abundances of the immature stages of *Amblyomma hebraeum, Amblyomma marmoreum, Hyalomma truncatum, Rhipicephalus appendiculatus, Rhipicephalus evertsi evertsi, Rhipicephalus simus* and *Rhipicephalus zambeziensis* and all stages of a *Rhipicephalus* sp. (near *R. pravus*) were determined.

Three scrub hares, examined in the north-western Transvaal Bushveld, were infested with five ixodid tick species. Ten hares examined in the eastern Transvaal Highveld harboured three species.

A total of 15 ixodid tick species were recovered from the scrub hares examined in the three regions of the Transvaal. No haematozoa were found in blood smears made from the hares examined in the southern region of the Kruger National Park.

INTRODUCTION

The ixodid tick species infesting hares in South Africa have been recorded in several studies (Horak & Knight 1986; Horak, Sheppey, Knight & Beuthin 1986; Rechav 1986; Horak & MacIvor 1987; Rechav, Zeederberg & Zeller 1987; Horak & Fourie 1991; Horak, Fourie, Novellie & Williams 1991a). These surveys indicated that scrub hares (*Lepus saxatilis*) are good hosts of the immature stages of *Amblyomma hebraeum*, *Amblyomma marmoreum*, *Hyalomma marginatum rufipes*, *Hyalomma marginatum turanicum*, *Hyalomma truncatum*, *Rhipicephalus appendiculatus*, *Rhipicephalus evertsi evertsi* and *Rhipicephalus glabroscutatum*. In addition, they are good hosts of all stages of *Ixodes pilosus*, *Rhipicephalus nitens*, *Rhipicephalus oculatus* and *Rhipicephalus punctatus,* as well as the adults of a *Rhipicephalus* sp. (near *R. oculatus*). The seasonal abundances of these ticks on the scrub hares were also determined. With the exception of the survey conducted by Rechav *et al.* (1987), which was carried out in the south-western Transvaal, the other South African studies were done in the Cape Province and in the Orange Free State.

Scrub hares may serve as reservoir hosts of the virus of Crimean-Congo haemorrhagic fever (Hoogstraal 1979; Swanepoel, Struthers, Shepherd, McGillivray, Nel & Jupp 1983). Furthermore, they are the

[1] Department of Veterinary Tropical Diseases, Faculty of Veterinary Science, University of Pretoria, Onderstepoort, 0110 South Africa

[2] Onderstepoort Veterinary Institute, Onderstepoort, 0110 South Africa

[3] Scientific Services, Kruger National Park, Skukuza, 1350 South Africa

Received 7 May 1993–Editor

preferred hosts of the immature stages of the three *Hyalomma* ticks present in South Africa (Horak & MacIvor 1987; Rechav *et al.* 1987; Horak & Fourie 1991). The virus has been isolated from two of these ticks, namely *H. marginatum rufipes* and *H. truncatum*. *Hyalomma marginatum rufipes* has also been proven to be a vector of the virus (Swanepoel *et al.* 1983). The hares are therefore vitally important in the epidemiology of the disease.

It has recently been shown that scrub hares can be infected experimentally with *Cowdria ruminantium*, the causative organism of heartwater in cattle, sheep and goats, by intravenous injection of infected sheep blood (Bezuidenhout 1988). At the same time it was demonstrated that *A. hebraeum* larvae, placed on one of these hares 7–9 d later, picked up the infection and transmitted it to sheep during the nymphal and adult stage (Bezuidenhout 1988). As scrub hares are good hosts of the immature stages of *A. hebraeum* and *A. marmoreum* (Horak & Fourie 1991)—both of which are proven experimental vectors of *C. ruminantium* (Bezuidenhout 1987)—the hares could potentially play a role in the epidemiology of this important stock disease.

The present paper records the presence and seasonal abundance of ixodid ticks on scrub hares at various localities in the Transvaal, and compares these with the results of surveys conducted elsewhere in South Africa.

MATERIALS AND METHODS

Survey animals

A total of 277 scrub hares were examined—264 from the Kruger National Park (KNP), three from the north-western Transvaal bushveld, and ten from the eastern Transvaal Highveld. They were shot at night, using a spotlight and a single-shot, small-calibre rifle or a .410 shotgun. An attempt was made to shoot only adult animals, but this was not always possible.

Tick recovery

The hares were processed for tick recovery as described by Horak *et al.* (1986) and Horak & Fourie (1991). The ticks were identified and counted under a stereoscopic microscope, and the length of the idiosoma of maturing females was measured. The minimum length assigned to each species is that length which we estimate the maturing female tick would reach 24 h before detaching.

Non-ixodid arthropod parasites recovered from the hares, as well as the helminths recovered from many of the animals and the morphometric measurements of the hares in the south of the KNP, will be reported separately.

Thin blood smears were made from all the hares shot in the south of the KNP. These were fixed in methanol, stained with 10 % Giemsa stain, and examined for haematozoa under oil immersion at 1000 x magnification. At least 50 fields were examined on each smear.

Climate

Monthly mean maximum and minimum temperatures and the total monthly rainfall were recorded at Skukuza, KNP.

SURVEY LOCALITIES AND RESULTS

Kruger National Park (KNP)

This nature reserve, which is about two million ha in extent, is situated in the north-eastern Transvaal Lowveld along the South African border with Mozambique. The localities at which the various surveys were done are listed from north to south.

Pafuri (23°27'S, 31°19'E)

Three scrub hares were shot between February and April 1990 in this region in the far north-east of the KNP. The vegetation here is classified as Mixed Bushveld (Acocks 1988) and the landscape described as Limpopo/Levubu Floodplains by Gertenbach (1983). The species and numbers of ixodid ticks recovered from these hares are summarized in Table 1. They were infested with seven tick species, of which the immature stages of *H. truncatum* were the most numerous.

Shingwedzi (23°07'S, 31°26'E)

The vegetation in this northern section of the KNP is classified as Mopani Veld (Acocks 1988) and the landscape described by Gertenbach (1983) as Alluvial Plains with *Salvadora angustifolia* tree-savanna. A total of 18 scrub hares were shot in groups of three at 2-monthly intervals from June 1989 to April 1990, within a 5-km radius of the Shingwedzi rest camp. The ticks recovered from these hares and the seasonal abundances of *H. truncatum* and a *Rhipicephalus* sp. (near *R. pravus*), are presented in Table 2 and Fig. 1, respectively.

A total of six tick species were recovered from the hares, of which the *Rhipicephalus* sp. (near *R. pravus*) was the most numerous. (We have assumed that the immature stages which we recovered, and which resemble the immature stages of *R. punctatus*, belong to the former tick.) The largest numbers of larvae were recovered during June, and the largest numbers of nymphs during June and August. Adults were always present, but few were recovered in April. *H. truncatum* is a two-host tick, and the greatest numbers of larvae and nymphs

TABLE 1 Ixodid ticks recovered from three scrub hares examined near Pafuri in the far north-east of the Kruger National Park

Tick species	Total numbers recovered					No. of hares infested
	Larvae	Nymphs	Males	Females	Total	
Amblyomma hebraeum	1	3	0	0	4	3
Hyalomma truncatum	178	101	0	0	279	2
Rhipicephalus appendiculatus	0	1	0	0	1	1
Rhipicephalus evertsi evertsi	0	3	0	0	3	2
Rhipicephalus kochi	5	1	4	3	13	2
Rhipicephalus sp. (near *R. pravus*)	4	0	11	5 (1)	20	1
Rhipicephalus zambeziensis	2	1	0	0	3	2

( ) = Number of maturing female ticks, i.e. idiosoma of *R. kochi* and of *Rhipicephalus* sp. (near *R. pravus*) > 5,5 mm in length

TABLE 2 Ixodid ticks recovered from 18 scrub hares from near Shingwedzi in the north of the Kruger National Park

Tick species	Total numbers recovered					No. of hares infested
	Larvae	Nymphs	Males	Females	Total	
Amblyomma hebraeum	3	51	0	0	54	13
Amblyomma marmoreum	0	2	0	0	2	2
Hyalomma truncatum	222	169	0	0	391	15
Rhipicephalus evertsi evertsi	2	6	0	0	8	5
Rhipicephalus sp. (near *R. pravus*)	713	125	163	48 (8)	1 049	18
Rhipicephalus zambeziensis	17	20	0	0	37	6

( ) = Number of maturing female ticks, i.e. idiosoma of *Rhipicephalus* sp. (near *R. pravus*) > 5,5 mm in length

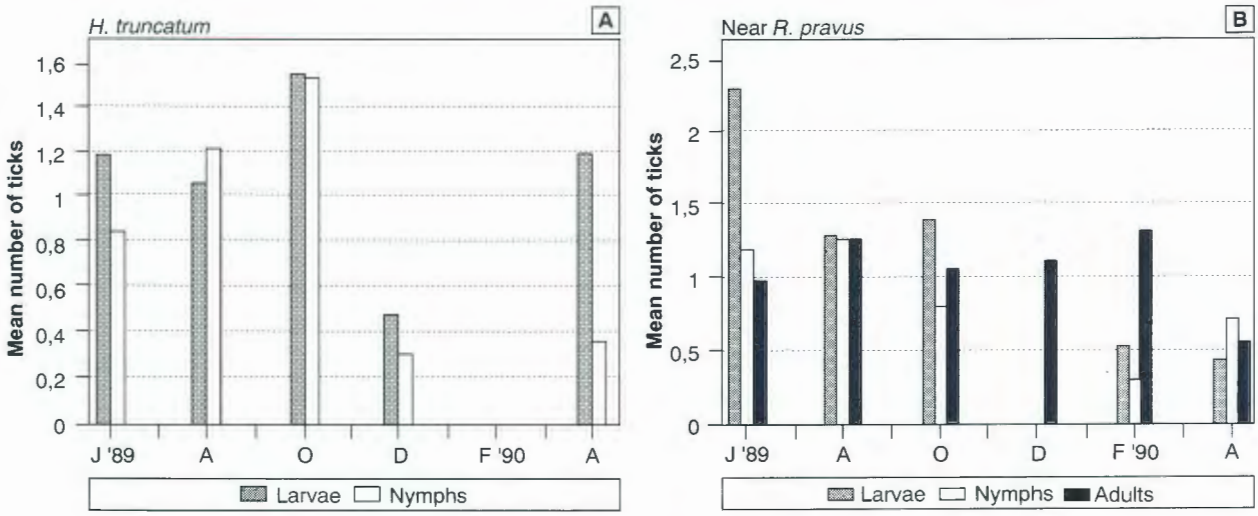

FIG. 1 The seasonal abundance of (A) *Hyalomma truncatum* and (B) *Rhipicephalus* sp. (near *R. pravus*) on scrub hares around Shingwedzi, Kruger National Park

were present from June to October 1989 and during April 1990.

Skukuza (24°58'S, 31°36'E)

This camp is situated in the south of the KNP in a landscape zone described as Thickets of the Sabie and Crocodile Rivers (Gertenbach 1983), and classified as Lowveld by Acocks (1988). At about monthly intervals for a period of 4 years (from August 1988 to July 1992), sets of five scrub hares were shot within a 25-km radius of Skukuza. A total of 240 hares were collected in this way. The species and numbers of ticks collected from these hares are summarized in Table 3.

TABLE 3 Ixodid ticks recovered from 240 scrub hares from near Skukuza in the south of the Kruger National Park

Tick species	Total numbers recovered					No. of hares infested
	Larvae	Nymphs	Males	Females[a]	Total	
Amblyomma hebraeum	2 354	2 497	0	1	4 852	236
Amblyomma marmoreum	522	250	0	0	772	149
Boophilus decoloratus	22	0	3	0	25	10
Haemaphysalis leachi	74	16	1	0	91	21
Haemaphysalis sp.	8	5	0	0	13	2
Hyalomma truncatum	23 421	7 064	0	0	30 485	188
Rhipicephalus appendiculatus	35	76	0	0	111	37
Rhipicephalus evertsi evertsi	2 033	2 003	1	0	4 037	199
Rhipicephalus sp. (near *R. pravus*)	0	3	17	2	22	10
Rhipicephalus simus	342	38	0	0	380	39
Rhipicephalus turanicus	0	0	1	3	4	4
Rhipicephalus zambeziensis	7 864	4 541	3	1	12 409	166

[a] No maturing female ticks were recovered

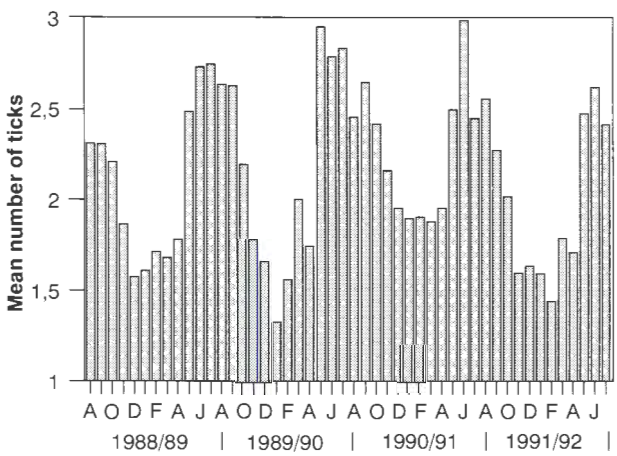

FIG. 2 Mean total numbers of ticks of all species recovered at monthly intervals from scrub hares around Skukuza, Kruger National Park from August 1988 to July 1992

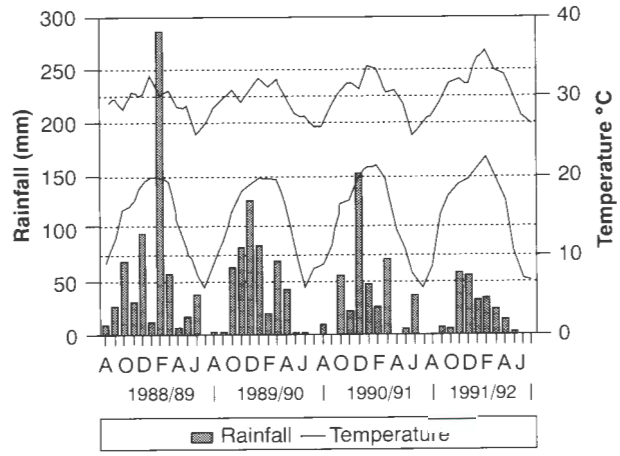

FIG. 3 Mean monthly maximum and minimum atmospheric temperature and total monthly rainfall at Skukuza, Kruger National Park from August 1988 to July 1992

The hares harboured 12 ixodid tick species, of which the immature stages of *H. truncatum* and *Rhipicephalus zambeziensis* were the most abundant, and *A. hebraeum* and *R. evertsi evertsi* the most prevalent.

The mean total numbers of ticks of all species recovered from the hares at monthly intervals during the survey period are shown graphically in Fig. 2. The maximum and minimum atmospheric temperatures and the total monthly rainfall at Skukuza are recorded in Fig. 3.

Significantly fewer ticks were recovered during the period August 1988 to July 1989 than during the corresponding period in 1990/91 (Wilcoxon T = 10; P = 0,05). Significantly more ticks were recovered during these periods in 1989/90 and 1990/91 than during the corresponding period in 1991/92 (t = 0,997; t = 4,391; P = 0,05).

Comment: The low rainfall experienced during the 1991/92 season (Fig. 3) could have been responsible for the lower total numbers of ticks recovered during this period. The highest mean total numbers of ticks were recovered during May and June of each year, corresponding to the peak seasonal abundance of the two main species collected—*H. truncatum* and *R. zambeziensis*. These peaks occurred during periods in which the lowest minimum and maximum temperatures and rainfall were recorded. However, detailed analysis of climatic parameters is beyond the scope of this paper.

The seasonal abundances of *A. hebraeum*, *A. marmoreum*, *H. truncatum*, *R. appendiculatus*, *R. evertsi*

evertsi, *Rhipicephalus simus* and *R. zambeziensis* on the hares are illustrated in Fig. 4 and 5.

No clear pattern of seasonal abundance for *A. hebraeum* or *R. evertsi evertsi*, which is a two-host tick, was evident. The larvae of *A. marmoreum* were generally present from January to July, August or September, while no clear pattern of seasonal abundance was evident for the nymphs. The larvae and nymphs of *H. truncatum* were most numerous from

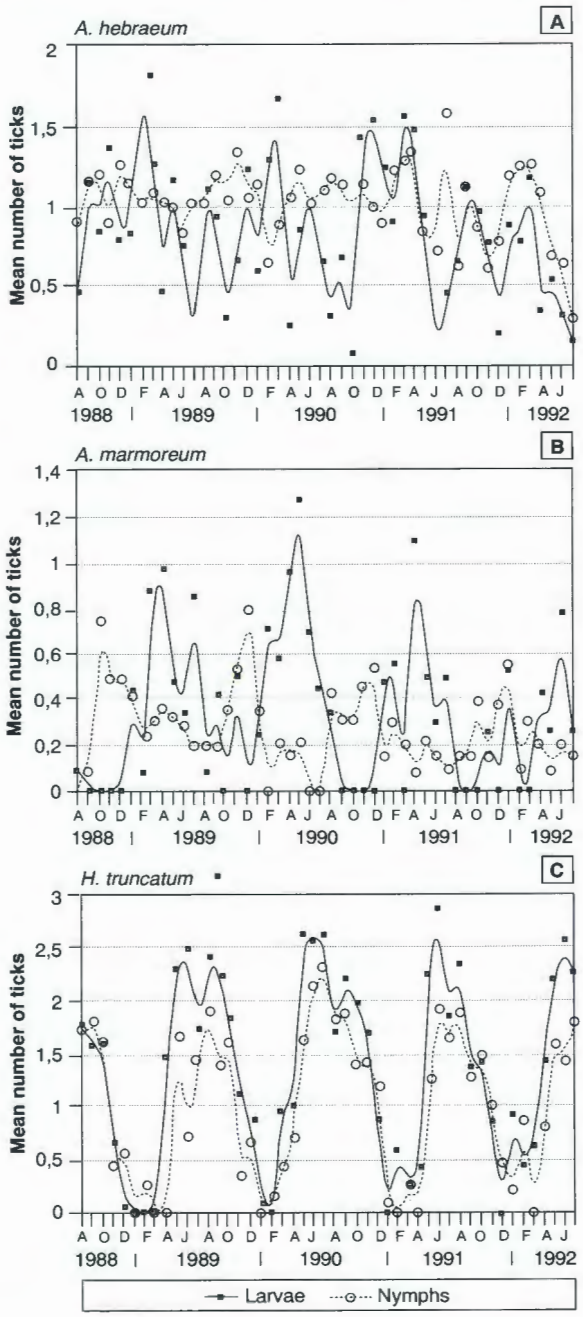

FIG. 4 The seasonal abundance of (A) *Amblyomma hebraeum*, (B) *Amblyomma marmoreum*, and (C) *Hyalomma truncatum* on scrub hares around Skukuza, Kruger National Park

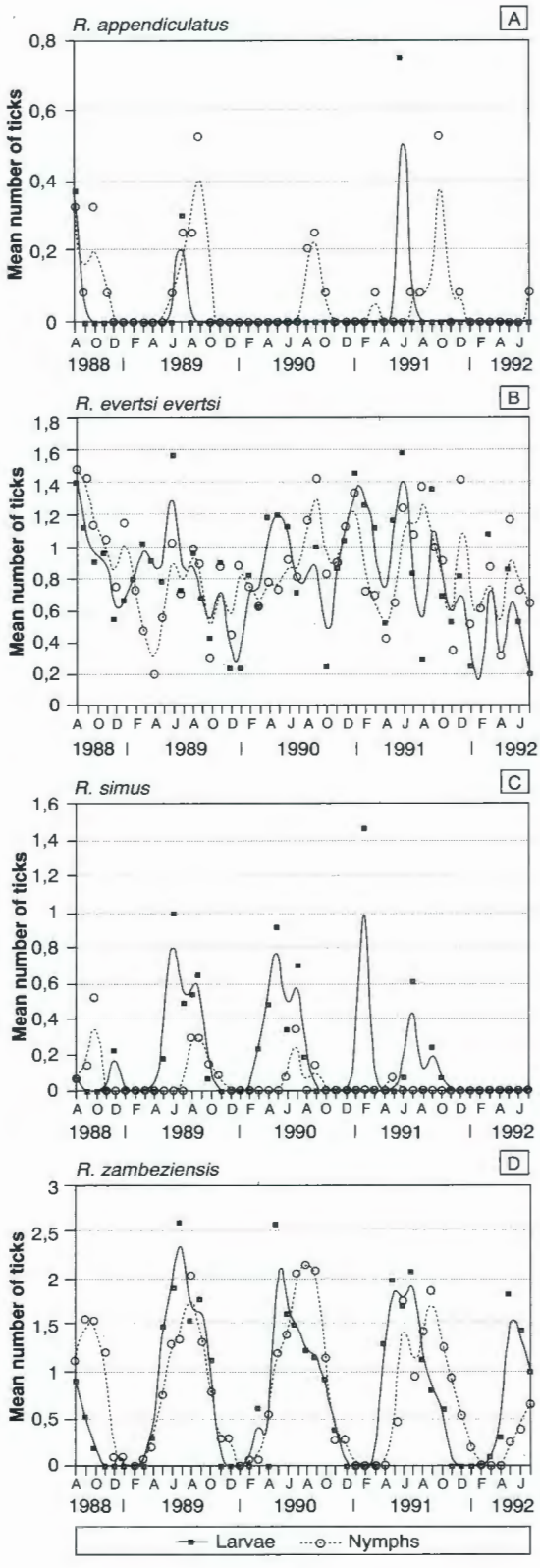

FIG. 5 The seasonal abundance of (A) *Rhipicephalus appendiculatus*, (B) *Rhipicephalus evertsi evertsi*, (C) *Rhipicephalus simus* (D) and *Rhipicephalus zambeziensis* on scrub hares around Skukuza, Kruger National Park

May to October. The nymphs of *R. appendiculatus* were usually present during the period June to September or October. With some exceptions, the larvae of *R. simus* were present during the months March to October, and the nymphs during the months August to October. The greatest numbers of *R. zambeziensis* larvae were recovered during the period May to July, and nymphs during the period August to October.

No haematozoa were found in blood smears from hares collected near Skukuza.

Pretoriuskop (25°10′S, 31°16′E)

The vegetation surrounding this camp, which is located in the south-west of the KNP, is classified as Lowveld Sour Bushveld and Lowveld (Acocks 1988), and the landscape described as Lowveld Sour Bushveld of Pretoriuskop (Gertenbach 1983). During June 1989 three scrub hares were shot within a radius of 6 km of Pretoriuskop. The numbers of ticks recovered from these animals are summarized in Table 4.

Seven tick species were recovered from the hares, of which *R. appendiculatus* was the most numerous.

No haematozoa were found in blood smears from the hares collected at Pretoriuskop.

Eastern Transvaal Highveld

Ermelo (26°32′S, 29°59′E)

Ten scrub hares were shot during June 1989 on three farms to the west of this town. Acocks (1988) has classified the vegetation of this region as Themeda Veld (Turf Highveld). The tick species and numbers harboured by the hares are summarized in Table 5.

A total of three tick species were recovered, of which the immature stages of *R. evertsi evertsi* were the most abundant.

North-western Transvaal

Marken (23°35′S, 28°21′E)

The farm "Mooimeisiesfontein" lies about 10 km to the south of the town Marken. The vegetation is classified as Mixed Bushveld (Acocks 1988). Three scrub hares were shot on the farm during November 1988. The numbers of ticks recovered from these animals are summarized in Table 6.

The hares were infested with five ixodid tick species, of which a *Rhipicephalus* sp. (near *R. pravus*) was the most numerous.

DISCUSSION

Horak & Fourie (1991) listed 13 ixodid ticks for which they considered the scrub hare to be a good, preferred or definitive host. To that list can be added the immature stages of *H. marginatum turanicum*, for which hares in the Mountain Zebra National Park are the preferred hosts (Horak *et al.* 1991a), and the immature stages of *R. zambeziensis*, for which hares in the present study were good hosts. Two of the three hares examined near Pafuri were infested with both immature and adult *Rhipicephalus kochi* (Table 1), and scrub hares may yet prove to be good hosts of this tick. With the exception of the animals at Pretoriuskop and Ermelo, hares at each locality were infested with immature and adult ticks of the *Rhipicephalus* sp. (near *R. pravus*), and appear to be a preferred host of this tick. Although only four hares in the present survey were infested with adults of *R. turanicus* (Table 3), further studies may indicate that they are good hosts of this tick. In their ecological observations on *R. turanicus*, Pegram, Clifford, Walker & Keirans (1987a) record more collections from hares (*Lepus* spp.) than from any other wild hosts.

Horak & Fourie (1991) stated that, in all, 25 ixodid tick species had been recovered from scrub hares in recent surveys in South Africa. The present study has added *Boophilus decoloratus*, the immature stages of an unidentified *Haemaphysalis* sp. and an *Ixodes* sp. which all should be considered accidental infestations, as well as *R. kochi*, *Rhipicephalus* sp. (near *R. pravus)*, *R. turanicus* and *R. zambeziensis*. The number of tick species identified to specific or subspecific level on the scrub hares in these studies now totals 28, with the immature stages of a further four identified only to generic level. However, scrub hares probably serve as hosts of the immature stages of several more of the 83 species of ixodid ticks listed by Walker (1991) as occurring in South Africa. The widespread distribution of the hares and their preference for scrub-type vegetation, combined with their persistence in agriculturally developed areas (Skinner & Smithers 1990), ensure that their habitat overlaps those of most of the ticks occurring on domestic livestock and wild animals in this country.

Although scrub hares may harbour large tick burdens, it would appear that, with the exception of the *Hyalomma* spp., they suffer little irritation from the ticks. At the height of the immature *Hyalomma* spp. infestations, in mid-winter, the necks of hares, where these ticks attach, are frequently nearly hairless, presumably because of continuous scratching.

Amblyomma hebraeum

The distribution area of this tick in the Transvaal lies roughly north and west of the Highveld region of this province (Howell, Walker & Nevill 1978). With the exception of the hares examined near Ermelo in the Highveld, a total of 257 of the 267 animals examined at all the other localities were infested with the immature stages of *A. hebraeum*. One animal

TABLE 4 Ixodid ticks recovered from three scrub hares from near Pretoriuskop in the south-east of the Kruger National Park

Tick species	Total numbers recovered					No. of hares infested
	Larvae	Nymphs	Males	Females	Total	
Amblyomma hebraeum	39	44	0	0	83	3
Amblyomma marmoreum	34	1	0	0	35	2
Hyalomma truncatum	46	11	0	0	57	2
Rhipicephalus appendiculatus	91	32	0	0	123	3
Rhipicephalus evertsi evertsi	8	1	0	0	9	2
Rhipicephalus simus	6	4	0	0	10	2
Rhipicephalus zambeziensis	4	0	0	0	4	1

TABLE 5 Ixodid ticks recovered from ten scrub hares on three farms near Ermelo, eastern Transvaal Highveld

Tick species	Total numbers recovered					No. of hares infested
	Larvae	Nymphs	Males	Females	Total	
Hyalomma marginatum rufipes	1	7	0	0	8	5
Ixodes sp.	4	0	0	0	4	1
Rhipicephalus evertsi evertsi	73	69	0	0	142	9

TABLE 6 Ixodid ticks recovered from three scrub hares on a farm near Marken, north-western Transvaal

Tick species	Total numbers recovered					No. of hares infested
	Larvae	Nymphs	Males	Females	Total	
Amblyomma hebraeum	18	3	0	0	21	2
Hyalomma marginatum rufipes	2	5	0	0	7	2
Hyalomma truncatum	15	47	0	0	62	2
Rhipicephalus evertsi evertsi	4	42	0	0	46	3
Rhipicephalus sp. (near *R. pravus*)	34	10	100	31 (12)	175	3

( ) = Number of maturing female ticks, i.e. idiosoma of *Rhipicephalus* sp. (near *R. pravus*) > 5,5 mm in length

examined near Skukuza was also infested with an adult tick, but this must be considered an accidental infestation. The preferred hosts of the adults are very large herbivores such as cattle, eland, buffaloes, giraffes and rhinoceroses. The immature stages can be found in large numbers on these animals, as well as on a variety of smaller mammal species and helmeted guineafowls (Theiler 1962; Horak, MacIvor, Petney & De Vos 1987a).

The ratio of larvae to nymphs on 42 scrub hares shot at about monthly intervals in the Andries Vosloo Kudu Reserve in the eastern Cape Province was 3,05:1 (Horak & Fourie 1991). The mean burdens of these hares were 46,4 larvae and 15,2 nymphs. In the Skukuza region in the present survey the mean burdens were 9,8 larvae and 10,4 nymphs, with a ratio of 0,94:1. The higher burdens of the hares in the eastern Cape are possibly a reflection of the higher overall stocking density in that reserve than in the Kruger National Park (Horak, Boomker, Spickett & De Vos 1992b). The high ratio of nymphs to larvae compared to that on other animals, indicates that hares are better hosts of the former than the latter stage of development (Horak *et al.* 1987a).

During the same 25 months in which the first 125 scrub hares were examined in the Skukuza region of the KNP, 118 helmeted guineafowls were similarly examined for ticks in the southern part of the KNP (Horak, Spickett, Braack & Williams 1991b). These birds harboured mean burdens of 184,9 larvae and

16,7 nymphs of *A. hebraeum*. This represents a ratio of 11,1:1, indicating a preference of larvae for guineafowls.

No pattern of seasonal abundance could be discerned on the scrub hares in the KNP. This is in agreement with the findings of Horak *et al.* (1991b), Horak *et al.* (1992b) and Spickett, Horak, Van Niekerk & Braack (1992) on helmeted guineafowls, kudus and on the vegetation in the KNP.

Amblyomma marmoreum

This tick is more widely distributed in South Africa than is *A. hebraeum* (Walker 1991). Large numbers of adults and immatures may be found on one of its preferred hosts, the mountain tortoise (Dower, Petney & Horak 1988). Warm-blooded animals are seldom infested with adults, and never harbour the same numbers of immature stages of *A. marmoreum* as they do of *A. hebraeum* where the habitats of the ticks overlap (Horak *et al.* 1987a).

The fact that no hares were infested at some localities included in the present survey, possibly reflects either the small number of animals examined or the seasonality of the immature stages of the tick.

A total of 149 (62,1 %) of the 240 scrub hares examined around Skukuza were infested with *A. marmoreum*. The hares harboured mean burdens of 2,18 larvae and 1,04 nymphs, with a ratio of 2,09:1. Of the 118 helmeted guineafowls examined simultaneously with the first 125 scrub hares, 75,4 % were infested, and the overall mean burdens consisted of 19,4 larvae and 0,9 nymphs, with a ratio of 22,2:1 (Horak *et al.* 1991b). The guineafowls therefore appear to be better hosts of the larvae of this tick than are scrub hares.

The presence of larvae on the hares during the first 7–9 months of each year corresponds with the observations made on guineafowls and on the vegetation in the KNP (Horak *et al.* 1991b; Spickett *et al.* 1992). As in the case of the guineafowls, no pattern of seasonal abundance was evident for the nymphs.

Boophilus decoloratus

Although *Boophilus* sp. larvae have been recovered from scrub hares examined in the eastern and southwestern Cape Province and in the central Orange Free State, no specific diagnosis was made (Horak & Fourie 1991). Only *B. decoloratus* has been recovered in the KNP (Walker 1991). The scrub hares in the present survey harboured a total of three males and 22 larvae. No females or nymphs were recovered. We believe that these are accidental infestations and that the larvae would not complete their development on the hares.

Despite the fact that this is a one-host tick, males that have fallen from a host are occasionally collected from the vegetation during drag-sampling (Horak & Spickett, unpublished data 1992). They are possibly questing for a second host. It is probably such males that were recovered from the hares examined around Skukuza, not adults that had matured on the hares from larvae.

Haemaphysalis leachi /spinulosa

We were unable to differentiate between the immature stages of these ticks and hence have considered them together. Both tick species occur widespread in South Africa (Howell *et al.* 1978; Horak, Jacot Guillarmod, Moolman & De Vos 1987b). Present indications are that, provided the climate is not extreme, the existence of a satisfactory rodent and carnivore host complex will ensure the survival of the ticks (Norval 1984).

Adult *H. leachi* prefer carnivores such as domestic dogs and cats and the larger wild canids and felids, while adult *H. spinulosa* prefer the small carnivores (Norval 1984; Horak *et al.* 1987b). However, Clifford, Flux & Hoogstraal (1976) recorded a total of 167 adults of the *Haemaphysalis leachi* group on 397 hares they examined in Kenya.

In South Africa Horak & Fourie (1991) recovered a single female of *H. spinulosa* from 189 scrub hares examined in the Cape Province and the Orange Free State. In the present survey we collected one male *H. leachi* from the 277 hares shot in the Transvaal. The immature stages of these ticks prefer rodents (Norval 1984; Hussein & Mustafa 1985; Fourie, Horak & Van Heerden 1992), but hares may also play a role (Table 3) (Clifford *et al.* 1976; Horak & Fourie 1991).

Hyalomma marginatum rufipes

Except in the north-eastern Lowveld, this tick occurs throughout the Transvaal (Howell *et al.* 1978). Its absence on the hares in the KNP and its presence on those near Ermelo and Marken confirm this distribution pattern.

Scrub hares and Cape hares are the preferred hosts of the immature stages, while ground-frequenting birds, including helmeted guineafowls, may also play a role (Rechav *et al.* 1987; Horak & Fourie 1991). Large animals such as cattle, zebras, eland and giraffes are the preferred hosts of the adults (Horak 1982; Rechav *et al.* 1987; Horak, Anthonissen, Krecek & Boomker 1992a).

Hyalomma truncatum

This tick is found throughout the Transvaal, except for the Highveld, and possibly a small region in the south-west of the province (Howell *et al.* 1978). Its absence on the hares from around Ermelo is in agreement with this distribution pattern. As for *H.*

marginatum rufipes, scrub hares and Cape hares are the preferred hosts of the immature stages (Rechav *et al.* 1987; Horak & Fourie 1991). However, rodents may also be infested (Horak *et al.* 1991a). Large animals such as cattle, eland, zebras and giraffes are the preferred hosts of the adults (Horak 1982; Rechav *et al.* 1987; Horak *et al.* 1991a; Horak *et al.* 1992a).

As this is a two-host tick, the larvae and nymphs are simultaneously present on the host. The 18 scrub hares examined at regular intervals at Shingwedzi in the north of the KNP harboured a total of 222 larvae and 169 nymphs. This represents a ratio of 1,31:1 and a successful translation of larvae to nymphs. The 240 scrub hares shot at monthly intervals in the south of the KNP, where infestation levels were considerably higher, carried a total of 23 421 larvae and 7 064 nymphs. The ratio here was 3,32:1, indicating a considerable loss of nymphs, during or after the moult. The irritation caused by these large numbers of ticks possibly resulted in increased scratching by the hares, causing selectively greater loss of the larger nymphs.

The fairly clearly defined period of maximum seasonal abundance of immatures on the hares from May to October, and their virtual absence from January to March, is an indication that probably only one life cycle per year is completed in the KNP. This differs from the findings of Rechav *et al.* (1987) in the south-western Transvaal and Horak & Fourie (1991) in the northern Cape Province. At both the latter localities the immature stages reached peak abundance during autumn or winter, and again during summer.

Rhipicephalus appendiculatus

The distribution of this tick in the Transvaal was illustrated by Howell *et al.* (1978). To the west of Pretoria it is generally present north of latitude 26°00'S; in the east it is present north and east of the eastern Transvaal Highveld. More recently, this distribution pattern has been modified to exclude the central and northern parts of the KNP, with the exception of a salient of bushveld extending into the northern portion of the Park at Pafuri (Walker 1991).

The preferred hosts of all stages of development, but more particularly of the adults, are the larger members of the Artiodactyla, both domestic and wild (Norval, Walker & Colborne 1982). Although the smaller animals of this group will also harbour adult ticks, they are better hosts of the immature stages (Theiler 1962; Norval *et al.* 1982; Walker 1991). *Lepus crawshayi* in Kenya and *L. saxatilis* in South Africa are efficient hosts of the immature stages (Clifford *et al.* 1976; Horak & Fourie 1991). In the present study those scrub hares examined during the period April or May to October (the time of maximal immature abundance) proved to be an excellent indication of the presence or absence of the tick at a particular locality:

- In the bushveld salient extending into the north of the KNP at Pafuri, *R. appendiculatus* was present (albeit on only one of three hares).
- At Shingwedzi in the north of the KNP, but south of this salient, *R. appendiculatus* was absent.
- At Skukuza in the south, where *R. appendiculatus* occurs in small numbers on the vegetation, but is dominated by *R. zambeziensis* (Horak, Spickett & Braack, unpublished data 1992), an identical pattern was reflected on the scrub hares.
- In the west, at Pretoriuskop, where the converse is true, the burdens of the hares confirmed this.
- No ticks of this species were recovered from the hares examined on the Transvaal Highveld.
- The hares examined in the north-western Transvaal were shot outside the period of maximum abundance.

As mentioned above, the Skukuza region of the KNP is not an ideal habitat for *R. appendiculatus*—a fact reflected by the small numbers of ticks and particularly larvae of this species recovered from the hares examined here. Despite this, the nymphs were most numerous from July or August to September or October. This corresponds to the periods June to October on blue wildebeest, July to October on Burchell's zebras, June to September on warthogs, July to September or November on kudus, and August or September to November or December observed on the vegetation in the KNP (Horak, De Vos & Brown 1983b; Horak, De Vos & De Klerk 1984; Horak, Boomker, De Vos & Potgieter 1988; Horak *et al.* 1992b; Spickett *et al.* 1992). In the eastern Cape Province the largest numbers of nymphs were present on scrub hares from May or June to October (Horak & Fourie 1991).

According to Short & Norval (1981) the pattern of seasonal abundance of *R. appendiculatus* depends mainly on the period of activity of the adults. This in turn is regulated by the combined effects of humidity, temperature and the length of day. Horak *et al.* (1992b) recorded peak adult activity on kudus in the KNP from February to May, while Rechav (1981) and Horak *et al.* (1992a) recovered the largest numbers of adults on cattle and kudus in the eastern Cape Province from December to February. This would probably account for the earlier nymphal activity on scrub hares in the latter region than in the KNP.

Rhipicephalus evertsi evertsi

The biographic distribution of this tick includes the whole of the Transvaal (Howell *et al.* 1978). This pattern was confirmed by the fact that scrub hares examined at each locality in the present survey were infested.

Although scrub hares and other hares never carry very large burdens of immature ticks, they must, because of the high proportion infested, be considered good hosts for these stages of development (Clifford *et al.* 1976; Rechav *et al.* 1987; Horak & Fourie 1991; Horak *et al.* 1991a). The largest number of immature ticks recovered from a single hare in the present survey was 122 larvae and 44 nymphs. Large, wild herbivores such as zebras and eland are the preferred hosts for all stages of development (Horak *et al.* 1984; Horak *et al.* 1991a), while horses, donkeys and cattle probably fulfil this role amongst domestic stock (Norval 1981; Horak 1982).

R. evertsi evertsi is a two-host tick, and the larvae and nymphs occur simultaneously on the host. The 240 hares examined around Skukuza harboured a total of 2 033 larvae and 2 003 nymphs. The larva to nymph ratio of 1,01:1 indicates successful translation with little loss from one stage to the next.

Matson & Norval (1977) have suggested that this tick may complete several life cycles annually, an observation confirmed by the absence of seasonality in the occurrence of the immature stages on the scrub hares examined around Skukuza. Clifford *et al.* (1976) found the percentage of Cape hares (*Lepus capensis*) infested with immature stages to decline on a cattle ranch in Kenya during the season of long rains. In the south-western Transvaal Rechav *et al.* (1987) recorded a clear peak in the abundance of immature stages on Cape and scrub hares from spring to autumn.

Rhipicephalus kochi

In South Africa this tick has as yet been recorded only at Pafuri, while on the rest of the continent it is found south of the Equator in parts of eastern, central and southern Africa (Clifford, Walker & Keirans 1983).

The recorded hosts of the nymphs are four-toed elephant shrews, while those of the nymphs and probably also larvae, are kudus, nyalas and bushbuck (Clifford *et al.* 1983; Horak, Potgieter, Walker, De Vos & Boomker 1983a). Scrub hares may now be added to this list. The adults have been recovered from hares, including scrub hares (Clifford *et al.* 1983) and from numerous artiodactylid hosts.

Rhipicephalus sp. (near *R. pravus*)

Walker (1991), who recently attempted to clarify the taxonomic status of *Rhipicephalus punctatus* in South Africa, included the western, northern and north-eastern Transvaal in its range of distribution. However, it would now appear that the tick occurring in these regions is not *R. punctatus,* but a related *Rhipicephalus* sp. (near *R. pravus*). Further taxonomic studies are, therefore, necessary to clarify this problem. In this connection an observation by Warburton as long ago as 1912, concerning the genus *Rhipicephalus*, seems apposite: "The identification of species of *Rhipicephalus* is likely to give more trouble than that of any other genus of Ixodidae."

One of the hares examined at Pafuri and all the hares from near Marken and around Shingwedzi were infested with this tick. Only a few from around Skukuza harboured ticks of this species, and these were all animals shot to the north of the rest camp.

Adults, including engorging females, were found attached to the ears of the hares examined at the various localities.

Horak & Fourie (1991) could not discern any clear pattern of seasonal abundance for *R. punctatus* on the scrub hares they examined in the central Orange Free State. They suggested that this might be due to the close association between the tick and the hare within the latter's form, where warmth and moisture would be supplied by the hare. In the present study the only hares examined at regular intervals within the distribution range of the *Rhipicephalus* sp. (near *R. pravus*) were those at Shingwedzi. As in the case of *R. punctatus* on the hares in the Orange Free State, larvae were most numerous in June (Horak & Fourie 1991), while most nymphs were recovered in August. Except in April, adult ticks were always present in fairly substantial numbers. Large numbers of adult ticks were recovered from the three scrub hares examined in the north-western Transvaal during November, but as no other hares were shot at this locality, no seasonal comparisons could be made.

Rhipicephalus simus

Theiler (1962) indicated that this species was present in the western, central, north-eastern and eastern Transvaal. Only the hares examined around Skukuza and Pretoriuskop in the south and south-west of the KNP, respectively, were infested.

The preferred hosts of the immature stages are rodents (Norval & Mason 1981; Pegram, Walker, Clifford & Keirans 1987b), but the present results show that hares may also play a minor role. In the KNP large, monogastric animals such as Burchell's zebras, the larger carnivores and warthogs are the preferred hosts of the adults (Horak *et al.* 1984, 1987a, 1988).

The recovery of larvae from the hares, mainly from March to October, and of nymphs, from August to October, is in keeping with the finding that the largest adult burdens on warthogs in the southern KNP were from January to April (Horak *et al.* 1988). This would also seem to indicate that only one life cycle per year is probable at this locality.

Rhipicephalus turanicus

The taxonomic status of this tick and other ticks belonging to the *Rhipicephalus sanguineus* group has been clarified by Pegram *et al.* (1987a). Walker (1991) lists it as being present in scattered localities in the Transvaal. *R. turanicus* has a wide range of hosts, including hares, carnivores, ungulates and ground-feeding birds (Walker 1991). The recovery of the tick from scrub hares at Skukuza, albeit in very low numbers, supports the host status of these animals.

Rhipicephalus zambeziensis

In South Africa this tick has to date been found only in the Transvaal, mainly on farms in the west of the province and in the northern and southern regions of the KNP in the east (Norval *et al.* 1982). Within the southern regions of the KNP there are localities at which the distributions of *R. zambeziensis* and *R. appendiculatus* overlap, and others where one or the other is present nearly exclusively (Horak *et al.* 1992b; Spickett *et al.* 1992). We have been drag-sampling the vegetation around Skukuza for ticks at monthly intervals for the past four years and have recovered virtually only *R. zambeziensis*. The burdens of the hares from Skukuza examined over the same period mirror this finding.

Apparently *R. zambeziensis* has the same host preferences as *R. appendiculatus* (Norval *et al.* 1982; Horak *et al.* 1983b, 1984, 1988, 1992b). Although the Cape hare, *Lepus capensis*, has previously been found to be infested (Norval *et al.* 1982), the scrub hare is a new host record for the immature stages. Judging by the numbers of ticks recovered and the proportion of hares infested, it is an efficient host. The single adults recovered from some of the hares are probably accidental infestations and a reflection of the large numbers of ticks questing from the vegetation.

On kudus examined over a 2-year period in a region of the KNP slightly west and south of Skukuza, in which *R. zambeziensis* and *R. appendiculatus* occur in approximately equal numbers, the largest numbers of *R. zambeziensis* larvae were present from April or May to August or September, and the largest numbers of nymphs from July to November or December (Horak *et al.* 1992b). The seasonal abundances of *R. zambeziensis* larvae and nymphs on the scrub hares fall within these periods.

ACKNOWLEDGEMENTS

This study is part of the Wildlife Research Programme of the Faculty of Veterinary Science, University of Pretoria.

We thank the National Parks Board of Trustees, Mr E. Kadish of Ermelo and Mr J.W. Gey van Pittius of Marken for placing the hares in the Kruger National Park and on their farms, respectively, at our disposal.

Messrs I. de Beer, A. Louw, N. Mostert, J. Simon, L. Serfontein, S. Whitfield, L. Viljoen, P. Duigan, E. Kadish and J. Gey van Pittius were responsible for shooting the hares. Misses Heloise Heyne and Andrea van Niekerk and Messrs D. de Klerk, J. Sithole, A. Nkuna, O. Mathebula and S. Monareng processed the hares for tick recovery, and Mrs S. Meyer, Miss M.L. Horak and Mr J.P. Louw collected and counted the ticks from the processed material. Miss Andrea van Niekerk drew the graphs.

This research was funded by the Foundation for Research Development, the Department of Agricultural Development, the Agricultural Research Council and Bayer Animal Health.

REFERENCES

ACOCKS, J.P.H. 1988. Veld types of South Africa with accompanying veld type map. 3rd ed. *Memoirs of the Botanical Survey of South Africa*, 57:146.

BEZUIDENHOUT, J.D. 1987. Natural transmission of heartwater. *Onderstepoort Journal of Veterinary Research*, 54:349–351.

BEZUIDENHOUT, J.D. 1988. Sekere aspekte van hartwateroordraging, voorkoms van die organisme in bosluise en *in vitro* kweking. D.V.Sc.-proefskrif, Universiteit van Pretoria.

CLIFFORD, C.M., FLUX, J.E. & HOOGSTRAAL, H. 1976. Seasonal and regional abundance of ticks (Ixodidae) on hares (Leporidae) in Kenya. *Journal of Medical Entomology*, 13:40–47.

CLIFFORD, C.M., WALKER, JANE B. & KEIRANS, J.E. 1983. Clarification of the status of *Rhipicephalus kochi* Dönitz, 1905 (Ixodoidea, Ixodidae). *Onderstepoort Journal of Veterinary Research*, 50:77–89.

DOWER, KATHY M., PETNEY, T.N. & HORAK, I.G. 1988. The developmental success of *Amblyomma hebraeum* and *Amblyomma marmoreum* on the leopard tortoise, *Geochelone pardalis*. *Onderstepoort Journal of Veterinary Research*, 55:11–13.

FOURIE, L.J., HORAK, I.G. & VAN HEERDEN, J.J. 1992. The relative host status of rock elephant shrews *Elephantulus myurus* and Namaqua rock mice *Aethomys namaquensis* for economically important ticks. *South African Journal of Zoology*, 27: 108–114.

GERTENBACH, W.P.D. 1983. Landscapes of the Kruger National Park. *Koedoe*, 26:9–121.

HOOGSTRAAL, H. 1979. The epidemiology of tick-borne Crimean-Congo hemorrhagic fever in Asia, Europe and Africa. *Journal of Medical Entomology*, 15:307–417.

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., POTGIETER, F.T., WALKER, JANE B., DE VOS, V. & BOOMKER, J. 1983a. The ixodid tick burdens of various large ruminant species in South African nature reserves. *Onderstepoort Journal of Veterinary Research*, 50:221–228.

HORAK, I.G., DE VOS, V. & BROWN, MOIRA R. 1983b. Parasites of domestic and wild animals in South Africa. XVI. Helminth and arthropod parasites of blue and black wildebeest

(*Connochaetes taurinus* and *Connochaetes gnou*). *Onderstepoort Journal of Veterinary Research*, 50:243–255.

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.

HORAK, I.G. & KNIGHT, M.M. 1986. A comparison of the tick burdens of wild animals in a nature reserve and on an adjacent farm where tick control is practised. *Journal of the South African Veterinary Association*, 57:199–203.

HORAK, I.G., SHEPPEY, K., KNIGHT, M.M. & BEUTHIN, C.L. 1986. Parasites of domestic and wild animals in South Africa. XXI. Arthropod parasites of vaal ribbok, bontebok and scrub hares in the western Cape Province. *Onderstepoort Journal of Veterinary Research*, 53:187–197.

HORAK, I.G. & MACIVOR, K.M. DE F. 1987. The scrub hare, a reliable indicator of the presence of *Hyalomma* ticks in the Cape Province. *Journal of the South African Veterinary Association*, 58:15–19.

HORAK, I.G., MACIVOR, K.M. DE F., PETNEY, T.N. & DE VOS, V. 1987a. Some avian and mammalian hosts of *Amblyomma hebraeum* and *Amblyomma marmoreum* (Acari: Ixodidae). *Onderstepoort Journal of Veterinary Research*, 54:397–403.

HORAK, I.G., JACOT GUILLARMOD, AMY, MOOLMAN, L.C. & DE VOS, V. 1987b. Parasites of domestic and wild animals in South Africa. XXII. Ixodid ticks on domestic dogs and on wild carnivores. *Onderstepoort Journal of Veterinary Research*, 54:573–580.

HORAK, I.G., BOOMKER, J., DE VOS, V. & POTGIETER, F.T. 1988. Parasites of domestic and wild animals in South Africa. XXIII. Helminths and arthropod parasites of warthogs, *Phacochoerus aethiopicus*, in the eastern Transvaal Lowveld. *Onderstepoort Journal of Veterinary Research*, 55:145–152.

HORAK, I.G. & FOURIE, L.J. 1991. Parasites of domestic and wild animals in South Africa. XXIX. Ixodid ticks on hares in the Cape Province and on hares and red rock rabbits in the Orange Free State. *Onderstepoort Journal of Veterinary Research*, 58:261–271.

HORAK, I.G., FOURIE, L.J., NOVELLIE, P.A. & WILLIAMS, E.J. 1991a. Parasites of domestic and wild animals in South Africa. XXVI. The mosaic of ixodid tick infestations on birds and mammals in the Mountain Zebra National Park. *Onderstepoort Journal of Veterinary Research*, 58:125–136.

HORAK, I.G., SPICKETT, A.M., BRAACK, L.E.O. & WILLIAMS, E.J. 1991b. Parasites of domestic and wild animals in South Africa. XXVII. Ticks on helmeted guineafowls in the eastern Cape Province and eastern Transvaal Lowveld. *Onderstepoort Journal of Veterinary Research*, 58:137–143.

HORAK, I.G., ANTHONISSEN, M., KRECEK, R.C. & BOOMKER, J. 1992a. Arthropod parasites of springbok, gemsbok, kudus, giraffes and Burchell's and Hartmann's zebras in the Etosha and Hardap Nature Reserves, Namibia. *Onderstepoort Journal of Veterinary Research*, 59:253–257.

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

HOWELL, C.J., WALKER, JANE B. & NEVILL, E.M. 1978. *Ticks, mites and insects infesting domestic animals in South Africa. Part 1. Descriptions and biology*. Pretoria: Department of Agricultural Technical Services, Republic of South Africa: 69 (Science Bulletin; no. 393).

HUSSEIN, S.H. & MUSTAFA, B.E. 1985. *Haemaphysalis spinulosa* and *Rhipicephalus simus* (Acari: Ixodidae): seasonal abundance of immature stages and host range in the Shambat area, Sudan. *Journal of Medical Entomology*, 22:72–77.

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.

NORVAL, R.A.I. 1981. The ticks of Zimbabwe. III. *Rhipicephalus evertsi evertsi*. *Zimbabwe Veterinary Journal*, 12:31–35.

NORVAL, R.A.I. & MASON, C.A. 1981. The ticks of Zimbabwe. II. The life cycle, distribution and hosts of *Rhipicephalus simus* Koch, 1844. *Zimbabwe Veterinary Journal*, 12:2–9.

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.

NORVAL, R.A.I. 1984. The ticks of Zimbabwe. IX. *Haemaphysalis leachi* and *Haemaphysalis spinulosa*. *Zimbabwe Veterinary Journal*, 15:9–17.

PEGRAM, R.G., CLIFFORD, C.M., WALKER, JANE B. & KEIRANS, J.E. 1987a. Clarification of the *Rhipicephalus sanguineus* group (Acari, Ixodoidea, Ixodidae). I. *R. sulcatus* Neumann, 1908 and *R. turanicus* Pomerantsev, 1936. *Systematic Parasitology*, 10:3–26.

PEGRAM, R.G., WALKER, JANE B., CLIFFORD, C.M. & KEIRANS, J.E. 1987b. Comparisons of populations of the *Rhipicephalus simus* group: *R. simus, R. praetextatus,* and *R. muhsamae* (Acari: Ixodidae). *Journal of Medical Entomology*, 24: 666–682.

RECHAV, Y. 1981. Ecological factors affecting the seasonal activity of the brown ear tick *Rhipicephalus appendiculatus*. *Proceedings of the International Conference on Tick Biology and Control, Grahamstown, South Africa, 27–29 January 1981*:187–191.

RECHAV, Y. 1986. Seasonal activity and hosts of the vectors of Crimean-Congo haemorrhagic fever in South Africa. *South African Medical Journal*, 69:364–368.

RECHAV, Y., ZEEDERBERG, M.E. & ZELLER, D.A. 1987. Dynamics of African tick (Acari: Ixodoidea) populations in a natural Crimean-Congo hemorrhagic fever focus. *Journal of Medical Entomology*, 24:575–583.

SHORT, N.J. & NORVAL, R.A.I. 1981. Regulation of seasonal occurrence in the tick *Rhipicephalus appendiculatus* Neumann, 1901. *Tropical Animal Health and Production*, 13:19–26.

SKINNER, J.D. & SMITHERS, R.H.N. 1990. The mammals of the southern African subregion. Pretoria: University of Pretoria.

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 ixodid ticks as determined by drag-sampling. *Onderstepoort Journal of Veterinary Research*, 59:285–292.

SWANEPOEL, R., STRUTHERS, J.K., SHEPHERD, A.J., MCGILLIVRAY, G.M., NEL, M.J. & JUPP, P.G. 1983. Crimean-Congo hemorrhagic fever in South Africa. *American Journal of Tropical Medicine and Hygiene*, 32:1407–1415.

THEILER, GERTRUD 1962. The Ixodoidea parasites of vertebrates in Africa south of the Sahara (Ethiopian Region). Project S. 9958. *Report to the Director of Veterinary Services, Onderstepoort*. Mimeographed.

WALKER, JANE B. 1991. A review of the ixodid ticks (Acari, Ixodidae) occurring in southern Africa. *Onderstepoort Journal of Veterinary Research*, 58:81–105.

WARBURTON, C. 1912. Notes on the genus *Rhipicephalus*, with the description of new species, and the consideration of some species hitherto described. *Parasitology*, 5:1–20.