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THE EFFECT OF VELD-BURNING ON THE SEASONAL ABUNDANCE OF FREE-LIVING IXODID TICKS AS DETERMINED BY DRAG-SAMPLING

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ABSTRACT

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A supervised veld-burn in the *Sclerocarya caffra/Acacia nigrescens* Savanna landscape zone in the south-eastern region of the Kruger National Park was carried out during September 1988. The effect of the fire on the free-living tick population was determined by comparing the numbers of ticks collected by monthly drag-sampling in the burnt zone with those collected in an adjacent unburnt zone over a 2-year period. A total of 13 ixodid tick species were involved.

Tick numbers were reduced after the burn but rose again after varying periods of time. The length of these periods depended upon a number of variables. These included tick species, patterns of seasonal abundance, and host preferences. The original reduction in numbers seemed to result in subsequent cyclical population fluctuations and in some instances overcompensation was noted.

Veld-burning as a control technique may be effective with tenuously adapted tick species or reduced populations and may be enhanced by the exclusion of major hosts for a critical period after the fire.

INTRODUCTION

The value of veld-burning as a means of controlling tick populations has mostly been a matter of conjecture and its use to date mainly haphazard. Theiler (1959, 1969), theorized that veld-burning does not destroy the developing stages but rather increases environmental exposure, resulting in shortened developmental periods. Minshull & Norval (1982) found that fire affected the distribution of all tick stages because of the increased density of grazing herbivores on recently burnt areas. Traditional winter burning practised by farmers to encourage new growth, does not coincide with the seasonal activity periods of the questing stages of most ixodid ticks (Norval, 1977). This, coupled with the environmental harm caused by winter burning according to agronomists, has resulted in the practice generally being considered an unsuccessful biological control measure for ticks (Galun, 1978).

The scientifically planned, routine, supervised veld-burning of certain regions in the Kruger National Park, eastern Transvaal Lowveld, presented an opportunity to monitor the long-term effect of fire on the questing stages of ticks compared to those on an adjacent unburnt area.

MATERIALS AND METHODS

Study site

The study was carried out in the extreme south of the *Sclerocarya caffra/Acacia nigrescens* Savanna zone (Landscape Zone 17 of Gertenbach, 1983) of the Kruger National Park. A full description of the geomorphology, climate, soil and vegetation patterns of this region has been provided by Gertenbach (1983). Generally it is an open, tree savanna with a moderate shrub and dense grass layer. The study site lies within an area described as tropical with an above average rainfall for this zone, i.e. the long term average for the nearest station, Crocodile Bridge, is 599,6 mm. The study site encompassed an area approximately 20 × 10 km in extent (25° 10′–25° 21′ S and 32° 02′–32° 05′ E), along the Nhlowa tourist road, between Crocodile Bridge in the south and Lower Sabie in the north. The southern portion of this area, immediately to the west of the road, was subjected to a total veld-burn during the second week of September 1988. The northern portion of the area, to the east of the road, was utilized as the unburnt control zone. The burnt and unburnt zones displayed no obvious differences in topography or vegetation.

Tick collection

Ticks questing on the vegetation were collected by drag-sampling (Zimmerman & Garris, 1985; Petney & Horak, 1987). A detailed description of our collection method is given in Spickett, Horak, Braack & Van Ark (1991). In addition a 95 mm long steel rod was sewn into the end of each flannel drag strip to aid in keeping these down on the vegetation while dragging, and flannel leggings were also worn. The latter consisted of 2 flannel strips, sewn together at the waist, and covering the front of the drag operator from the waist to the ankles. The leggings were tied to the operator at the waist, knees and ankles and provided an additional surface for the attachment of questing ticks while the drag strips were being pulled through the vegetation.

Three drags were performed in each of 3 representative subzones within both the burnt and unburnt zones. These subzones were open grassland, gully and woodland. The collections were usually made on the same day in the first week of each calendar month, commencing in August 1988,

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TABLE 1 The total number of ticks recovered over a 2-year monitoring period from the vegetation of a burnt and an unburnt zone in the Kruger National Park

	Larvae	Nymphs	Males	Females	Total
Burnt zone					
Amblyomma hebraeum	10 979	13	0	0	10 992
Amblyomma marmoreum	11	0	0	0	11
Boophilus decoloratus	5 395	0	0	0	5 395
Haemaphysalis leachi	14	0	22	12	48
Rhipicephalus appendiculatus	2 810	87	9	6	2 912
Rhipicephalus evertsi evertsi	1 233	0	0	0	1 233
Rhipicephalus simus	1	2	6	11	20
Rhipicephalus turanicus	0	0	2	4	6
Rhipicephalus zambeziensis	229	5	0	0	234
Totals	20 672	107	39	33	20 851
Unburnt zone					
Amblyomma hebraeum	27 608	11	0	0	27 619
Amblyomma marmoreum	58	1	0	0	59
Boophilus decoloratus	5 405	0	0	0	5 405
Haemaphysalis leachi	7	1	9	8	25
Haemaphysalis sp.	1	0	0	0	1
Hyalomma truncatum	4	0	0	0	4
Ixodes sp.	0	1	0	0	1
Rhipicephalus appendiculatus	7 477	93	6	5	7 581
Rhipicephalus evertsi evertsi	352	0	0	0	352
Rhipicephalus maculatus	0	1	0	0	1
Rhipicephalus simus	1	0	13	21	35
Rhipicephalus turanicus	0	0	6	2	8
Rhipicephalus zambeziensis	116	20	0	0	136
Totals	41 029	128	34	36	41 227

for a period of 2 years. A controlled, hot veld-burn of the designated zone, to burn off the existing dense vegetation layer, was supervised by National Parks Board staff after the September 1988 drags had been completed in both study areas.

Ticks collected monthly in the subzones from the flannel drag strips plus the leggings were identified and totalled separately for the burnt and unburnt zones. These counts were transformed [Log $_{10}$ (x + 1)] and, where applicable, differences between monthly collections were analysed using the non-parametric Wilcoxon paired observation test (Petney, Van Ark & Spickett, 1990). Each monthly total therefore represents questing ticks recovered from 9 drags in each zone.

RESULTS

The collection method used favours the recovery of larvae (Spickett *et al.,* 1991) although nymphs and/or adults of some species were consistently recovered. The tick species and total numbers recovered from the vegetation of the burnt and unburnt zones of the study area during the 2-year monitoring period are summarized in Table 1.

In total, 13 tick species were collected, the unburnt zone yielding small numbers of 4 species not recovered in the burnt zone. These were *Haemaphysalis* sp. (1 larva), *Hyalomma truncatum* (4 larvae), *Ixodes* sp. (1 nymph) and *Rhipicephalus maculatus* (1 nymph). Of the remaining 9 species, 6 were more numerous in the unburnt zone than in the burnt zone, some significantly so and others only marginally. The 3 species which were more numerous in the burnt than in the unburnt zone were *Haemaphysalis leachi, Rhipicephalus evertsi evertsi* and *Rhipicephalus zambeziensis.*

In the burnt zone the order of predominance of the species (and developmental stage recovered) was, *Amblyomma hebraeum* (larvae) followed by *Boophilus decoloratus* (larvae), *Rhipicephalus appendiculatus* (larvae), *R. evertsi evertsi* (larvae), *R. zambeziensis* (larvae), *H. leachi* (adults), *Rhipicephalus simus* (adults), *Amblyomma marmoreum* (larvae) and *Rhipicephalus turanicus* (adults). In the unburnt zone this order was *A. hebraeum* (larvae), *R. appendiculatus* (larvae), *B. decoloratus* (larvae), *R. evertsi evertsi* (larvae), *R. zambeziensis* (larvae), *H. leachi* (adults), *A. marmoreum* (larvae), *R. simus* (adults) and *R. turanicus* (adults). The burnt zone yielded about half the total number of ticks recovered in the unburnt zone.

The monthly total numbers of ticks (irrespective of species) collected from the burnt and unburnt zones are graphically illustrated in Fig. 1. An initial drop in

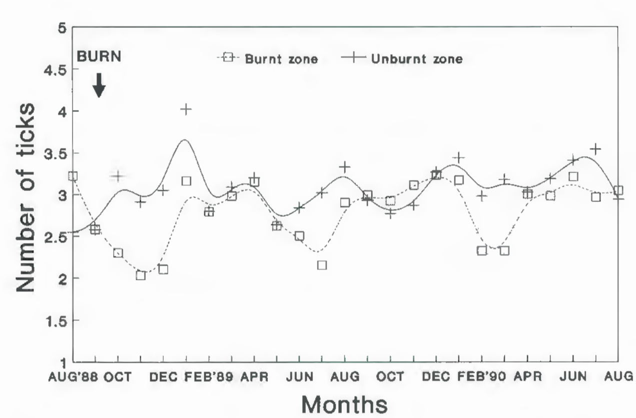

FIG. 1 The monthly total numbers of ticks [Log_{10} (x+1)] recovered by means of drag-sampling from a burnt and unburnt zone in the Kruger National Park. The burn took place in September 1988, after the second monthly drag

numbers occurred in the burnt zone immediately after the fire. These started to increase 4 months later and reached levels similar to those in the unburnt zone 5 months after the burn. However, cyclic declines in tick numbers in the burnt zone occurred at 10 and 17 months and a marginal overcompensation at 13 months after the burn. Paired analysis of monthly collections showed the total number of ticks collected in the burnt zone to be significantly less than in the unburnt zone (P=0,005; T=52,0).

The numbers of *A. hebraeum* larvae recovered are illustrated in Fig. 2. No change in numbers was recorded in the burnt zone 1 month after the fire, while those in the unburnt zone rose sharply. Thereafter the fluctuations in larval numbers paralleled each other with the totals in the 2 zones being nearly equal 6 and 7 months after the burn. This was followed by 4 sharp declines in larval numbers interspersed by short periods of recovery in the burnt zone. The initial reduction in numbers coupled with these declines resulted in less than half the number of *A. hebraeum* larvae being recovered from the burnt zone than from the unburnt zone (Table 1). Paired analysis of monthly collections indicated larval numbers in the burnt zone to be significantly less than in the unburnt zone (P=0,009; T=65,0).

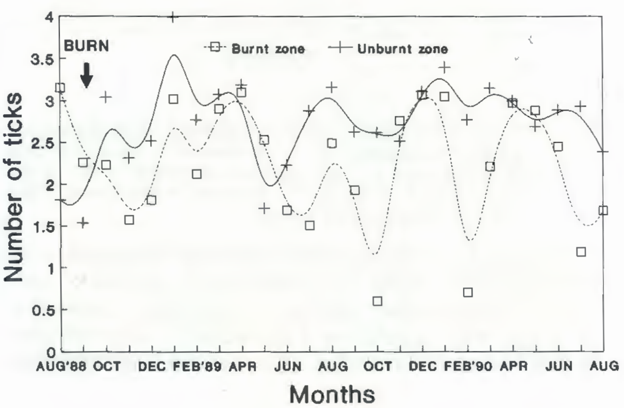

FIG. 2 The monthly total numbers of *Amblyomma hebraeum* larvae [Log_{10} (x+1)] recovered by means of drag-sampling from a burnt and unburnt zone in the Kruger National Park. The burn took place in September 1988, after the second monthly drag

In the burnt zone, *A. marmoreum* larvae were recovered in August 1988 before the burn and only again in January, April and June 1990, 16–21 months after the burn. In the unburnt zone larvae were active from March–September 1989 and from March–June 1990 (Fig. 3). The numbers of larvae recovered from the burnt zone during the 2-year monitoring period were significantly less than in the unburnt zone on paired analysis of monthly collections (P=0,021; T=9,5).

B. decoloratus larvae declined sharply in the burnt zone immediately after the burn and increased equally rapidly to nearly equal the number of those in the unburnt zone within only 4 months (Fig. 4). A 3

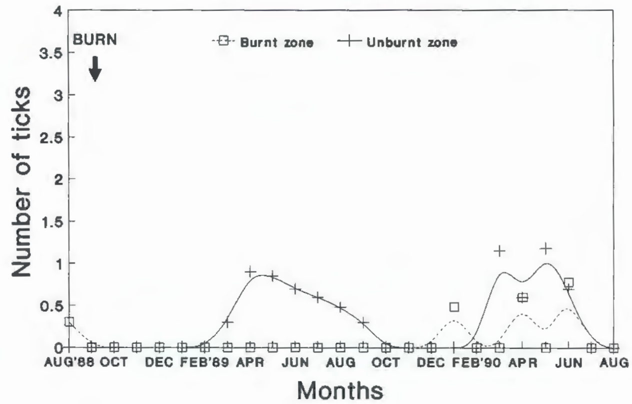

FIG. 3 The monthly total numbers of *Amblyomma marmoreum* larvae [Log_{10} (x+1)] recovered by means of drag-sampling from a burnt and unburnt zone in the Kruger National Park. The burn took place in September 1988, after the second monthly drag

month period of overcompensation followed this recovery in the burnt zone, while larval numbers in the unburnt zone underwent a seasonal decline. The subsequent decline in larval numbers in the burnt zone reached its lowest level 4 months after that in the unburnt zone. The increase in larval numbers following this decline was more rapid in the burnt than in the unburnt zone. Overcompensation resulted in peak abundance 2 months prior to that in the unburnt zone. After this, larval numbers in both zones stabilized and for approximately 6 months remained similar though fewer were recovered in the burnt zone. Larvae in the latter zone displayed another peak during June 1990, 21 months after the burn had taken place. A total of only 10 fewer *B. decoloratus* larvae were recovered from the vegetation of the burnt zone than that of the unburnt zone (Table 1). Despite the fluctuations in the numbers recovered monthly (Fig. 4), paired analysis showed no significant difference between the burnt and unburnt zones (P=0,542; T=139,5).

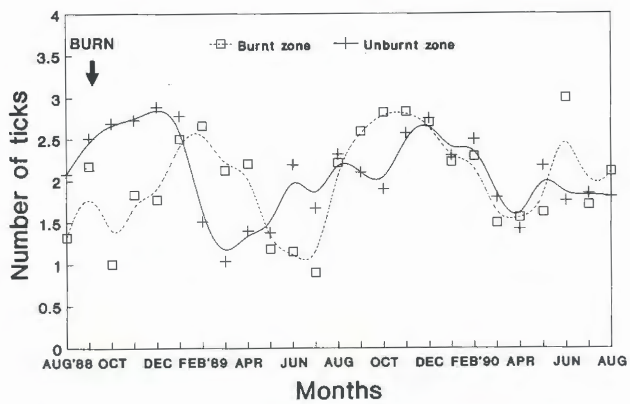

FIG. 4 The monthly total numbers of *Boophilus decoloratus* larvae [Log_{10} (x+1)] recovered by means of drag-sampling from a burnt and unburnt zone in the Kruger National Park. The burn took place in September 1988, after the second monthly drag

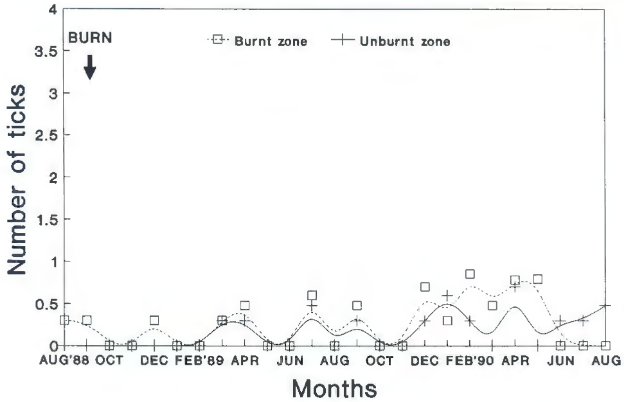

FIG. 5 The monthly total numbers of *Haemaphysalis leachi* adults [Log_{10} (x+1)] recovered by means of drag-sampling from a burnt and unburnt zone in the Kruger National Park. The burn took place in September 1988, after the second monthly drag

Cyclic variations in the small numbers of adult *H. leachi* recovered were evident in both the burnt and unburnt zones (Fig. 5). Slightly more adults were recovered in the burnt zone, especially during the second year of observation. These numbers were considered too small for meaningful analysis.

The larvae of *R. appendiculatus* were in a seasonal population decline at the time of the burn and no effect on larval numbers or seasonal activity was evident (Fig. 6). In both burnt and unburnt zones the larval activity period spanned 8 months, from April to November 1989. Peak abundances were recorded during May or June to August 1989, and activity commenced again in March or April 1990 and peaked in July. The numbers of larvae recovered from the burnt zone were consistently, as well as significantly less than those from the unburnt zone (P=0,0028; T=16,5).

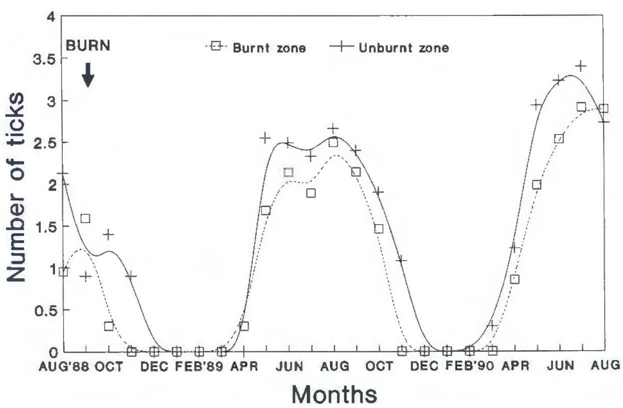

FIG. 6 The monthly total numbers of *Rhipicephalus appendiculatus* larvae [Log_{10} (x+1)] recovered by means of drag-sampling from a burnt and unburnt zone in the Kruger National Park. The burn took place in September 1988, after the second monthly drag

Small numbers of *R. appendiculatus* nymphs were recovered from both burnt and unburnt zones (Table 1). A marked decline in nymphal numbers was evident immediately after the burn in the burnt zone. However, nymphal activity in this zone continued for 2 months thereafter and ended only 2 months prior to that in the unburnt zone (Fig. 7). Subsequent resumption of nymphal activity occurred marginally sooner in the burnt zone than in the unburnt zone and reached slightly higher numbers, but with a shorter period of peak abundance. The unburnt zone yielded only 6 more nymphs in total than the burnt zone and paired analysis of monthly collections indicated no significant difference in the numbers recovered (P=0,465; T=76,5).

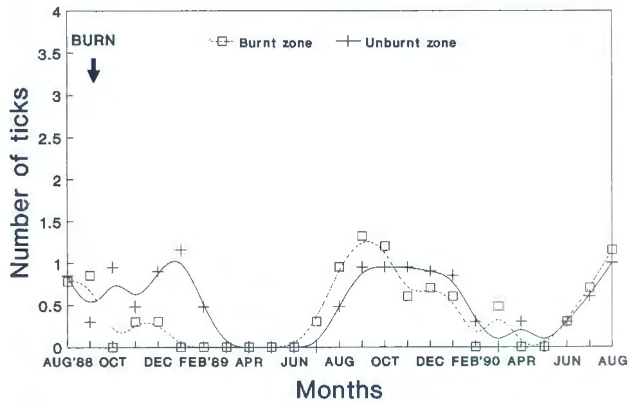

FIG. 7 The monthly total numbers of *Rhipicephalus appendiculatus* nymphs [Log_{10} (x+1)] recovered by means of drag-sampling from a burnt and unburnt zone in the Kruger National Park. The burn took place in September 1988, after the second monthly drag

R. appendiculatus adults, although present in the unburnt zone, were not collected in the burnt zone until 7 months after the burn had taken place (Fig. 8). Thereafter adults were collected in low numbers in this zone for 2 months only, before their seasonal

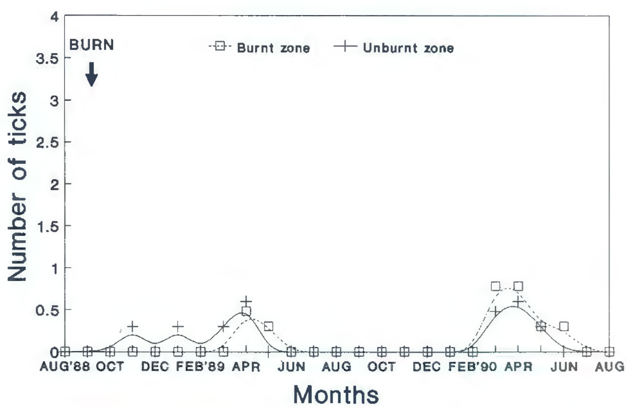

FIG. 8 The monthly total numbers of *Rhipicephalus appendiculatus* adults [Log_{10} (x+1)] recovered by means of drag-sampling from a burnt and unburnt zone in the Kruger National Park. The burn took place in September 1988, after the second monthly drag

decline in June 1989. Adult activity resumed in both zones from March to May or June of the next year. The numbers collected were too low for meaningful analysis of differences.

R. evertsi evertsi displayed cyclic activity throughout the monitoring period with no definite pattern of seasonal abundance (Fig. 9). No larvae were recovered in the burnt zone in September 1988 immediately preceding the burn. Their numbers increased thereafter to reach numbers similar to those in the unburnt zone within 4 months. A cyclic 2-month pattern of high and low numbers followed, similar to that in the unburnt zone but with larger fluctuations. Consistently higher numbers of larvae were recovered from the burnt than from the unburnt zone during the period September 1989 to January 1990 (12 to 16 months after the burn) and again from April 1990 to August 1990 (19 to 23 months after the burn) (Fig. 9). This resulted in approximately 4 times more *R. evertsi evertsi* larvae being recovered from the burnt than from the unburnt zone (Table 1). Paired analysis of monthly collections, however, showed no significant differences in larval numbers between the 2 zones (P=0,200; T=114,5).

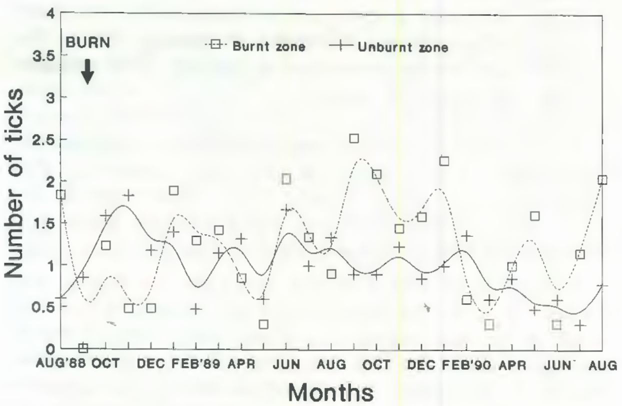

FIG. 9 The monthly total numbers of *Rhipicephalus evertsi evertsi* larvae [Log_{10} (x+1)] recovered by means of drag-sampling from a burnt and unburnt zone in the Kruger National Park. The burn took place in September 1988, after the second monthly drag

Low numbers of *R. simus* adults were present from December or January to May in both years, in both the burnt and unburnt zones (Fig. 10). The burn seemed to have some effect in that no adults were collected in the burnt zone during the earlier portion of the first activity period (up to 7 months after the burn). The second activity period (16 months after the burn) appeared to be shorter in the burnt than in the unburnt zone. The numbers of adults collected were too low for meaningful analysis.

The numbers of adult *R. turanicus* recovered in both zones were too low to permit meaningful analysis.

The larval population of *R. zambeziensis* was in a period of seasonal decline at the time of the burn (Fig. 11). The burn therefore had very little effect

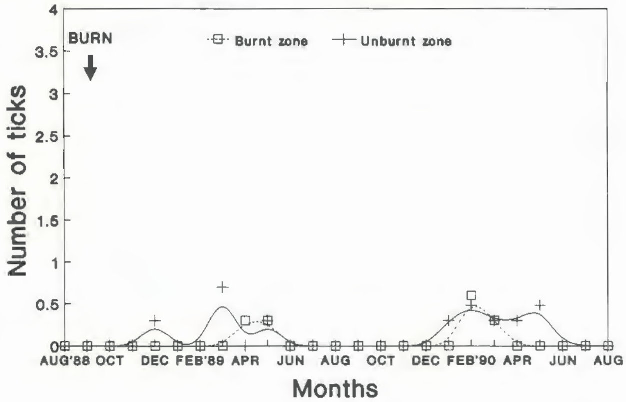

FIG. 10 The monthly total numbers of *Rhipicephalus simus* adults [Log_{10} (x+1)] recovered by means of drag-sampling from a burnt and unburnt zone in the Kruger National Park. The burn took place in September 1988, after the second monthly drag

except perhaps that larval activity was less pronounced during the subsequent activity period May 1989 to September 1989 (8 to 12 months after the burn). Larval numbers had stabilized by the next season, in which activity commenced during May 1990 (20 months after the burn) and lasted till the end of the monitoring period. Paired analysis of monthly collections revealed no significant difference in larval numbers between the 2 zones (P=0,726; T=24,0).

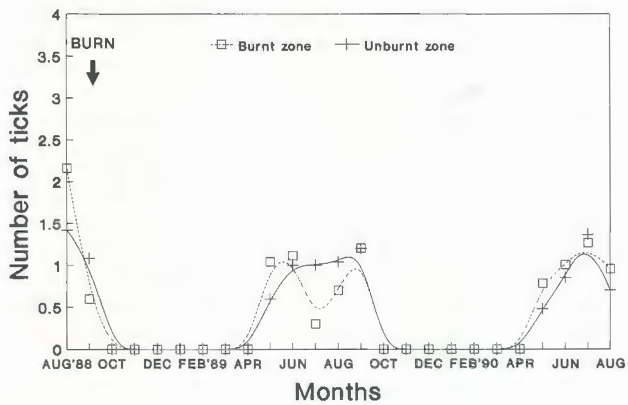

FIG. 11 The monthly total numbers of *Riphicephalus zambeziensis* larvae [Log_{10} (x+1)] recovered by means of drag-sampling from a burnt and unburnt zone in the Kruger National Park. The burn took place in September 1988, after the second monthly drag

R. zambeziensis nymphs were recovered from the burnt zone before and in the month immediately after the burn (Fig. 12). Thereafter none were found for the remainder of the monitoring period. In contrast, *R. zambeziensis* nymphs recovered from the unburnt zone, albeit in low numbers, displayed activity over the winter and spring months, from August to November 1989. Although adults of *R. zambeziensis* have previously been collected in other land-

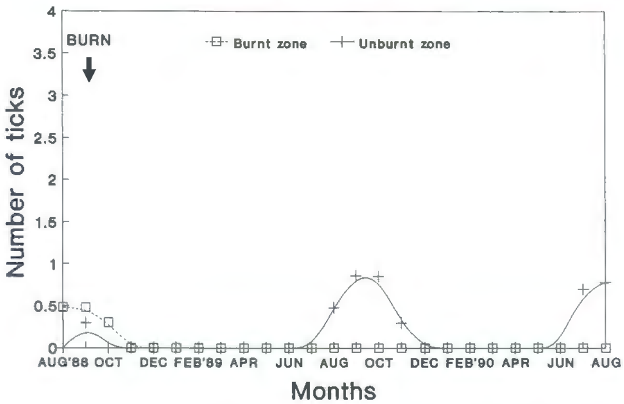

FIG. 12 The monthly total numbers of *Rhipicephalus zambeziensis* nymphs [Log_{10} (x+1)] recovered by means of drag-sampling from a burnt and unburnt zone in the Kruger National Park. The burn took place in September 1988, after the second monthly drag

scape zones using the same sampling technique (Spickett *et al.*, 1991), no adults were recovered in this study from the burnt or unburnt zones.

DISCUSSION

It could be expected that a hot veld-fire would destroy virtually all free-living tick stages present at the time. However, even the first drags after the burn, which were conducted after a 3-week interval, yielded ticks from the vegetation of the burnt zone. The larvae present on these first drags must have survived the burn or have hatched within the 3-week interval from eggs that were present at the time of the burn. The relatively short period of 4–5 months for the recovery of the free-living tick population as a whole in the burnt zone, after its initial decline, also indicates that some eggs and perhaps even engorged females had survived the effects of the fire. The initial reduction caused by the burn did, however, affect overall tick numbers in that 2 further cyclic declines were evident in the burnt zone, 10 and 17 months after the fire, resulting in significantly fewer ticks being recovered from this zone than from the unburnt zone.

The effects of the burn on the total tick population are largely a reflection of its effects on the 3 major species viz., *A. hebraeum, B. decoloratus* and *R. appendiculatus.* These and *R. evertsi evertsi* and *A. marmoreum,* were the most drastically affected in respect of numbers recovered or seasonal activity. The increase in larval numbers of *A. hebraeum* and *B. decoloratus,* after their initial decline in the burnt zone, is probably a result of exposure of their eggs to higher temperatures after removal of the vegetation layer and hence more rapid hatching. The overcompensation in the number of *B. decoloratus* larvae exhibited in the fifth to seventh month after the burn, is most likely due to the relatively early hatch of eggs from engorged females, detached from hosts which had been attracted to the burnt zone by new growth, 2 to 5 months previously. Because of the absence of vegetation cover, soil surface temperatures would have been higher and oviposition and egg hatch could have been completed within the space of 2 months (Robertson, 1981; Spickett & Heyne, 1990). The continued attraction of herbivores to the new growth in this zone during the following months would have contributed more engorged female *B. decoloratus.* The increased protection afforded to these females by the developing vegetation cover, as well as the onset of winter would delay oviposition and consequently egg development. The synchronous hatching of these eggs in spring (Robertson, 1981; Spickett & Heyne, 1990), could account for the next period of overcompensation in larval numbers from September to November 1989, 12 months after the burn.

The same host attraction effect is evident in the higher numbers of *R. evertsi evertsi* recovered from the burnt zone during the latter portion of the monitoring period. Grazers utilizing long grass would have frequented the burnt zone only after an extended period of recovery of the vegetation layer. The increased presence of these animals and particularly zebras, which are the preferred hosts of *R. evertsi evertsi* (Horak, De Vos & De Klerk, 1984), in the burnt zone some time after the fire would have resulted in many engorged females being dropped and consequently an increase in larvae during the second half of the monitoring period. The greater number of adult *H. leachi* in the burnt zone compared with the unburnt zone during the latter portion of the monitoring period can possibly be ascribed to carnivores, which are the preferred hosts of this stage (Horak, Jacot Guillarmod, Moolman & De Vos, 1987), following the grazers into the zone with the development of new growth in the previous year.

An opposite effect of the burn on the hosts and hence on tick numbers is clearly illustrated in the case of *A. marmoreum.* Larvae were recovered in the burnt zone for the first time 16–21 months after the burn, whereas activity occurred in the unburnt zone 4–10 months earlier and also during the 18–21 month period after the burn had taken place. The preferred hosts of *A. marmoreum* adults are tortoises (Norval, 1975). Many of these were probably destroyed in the fire and, judging by larval activity, only moved back into the zone approximately 10–12 months later. These is, however, another explanation for this phenomenon. All parasitic stages of *A. marmoreum* may spend several months on their tortoise hosts (Dower, Petney & Horak, 1988), and hence the life-cycle may be longer than 1 year. Any disruption of this life-cycle, such as the destruction of the free-living stages by fire, might therefore result in a period of a year or more for the cycle to be rectified.

The normal seasonal fluctuations of the various life stages of the tick populations at the time of the burn also played a role in the direct or long-term effect of the fire. In contrast to *A. hebraeum* and *B. decoloratus,* the larval populations of both *R. appendiculatus* and *R. zambeziensis* were in a state of seasonal decline at the time of the burn. The fire to a small extent accellerated this decline and also indirectly reduced larval numbers of *R. appendiculatus* during the subsequent activity periods. However, the onset of the subsequent larval activity period of both species was not affected. The effect of the burn on the nymphs of the latter 2 ticks was direct at the time of the burn. This and the direct effect on the larvae at the same time affected both subsequent nymphal activity and numbers and the nymphs of *R. zambeziensis* disappeared entirely from the burnt zone. The absence of adult *R. appendiculatus* during their normal activity period after the burn was probably a consequence of the free-living nymphs being destroyed by the fire. No adult *R. zambeziensis* were collected from either zone during the monitoring period.

The large numbers of *R. appendiculatus* compared to the small numbers of *R. zambeziensis* recovered from both burnt and unburnt zones, indicate that the former species is ecoclimatically favoured in this landscape zone, while the presence of the latter is tenuous. The fire thus affected the less secure species to a greater extent resulting in the disappearance of *R. zambeziensis* nymphs from the burnt zone. Adult *R. simus*, like adult *R. appendiculatus*, appear to be affected only directly after the burn with a minimal, if any, effect on numbers during the second activity period. The virtual absence of the immature stages of both *R. simus* and *H. leachi* on the drags can be ascribed to their questing behaviour. Both prefer rodents during these stages of development (Norval, 1984: Hussein & Mustafa, 1985) and would hence be unlikely to quest from vegetation.

The presence of 4 additional tick species in the unburnt zone is probably unrelated to the effects of veld-burning. The recovery of only 4 *H. truncatum* larvae, despite their occurrence in large numbers on scrub hares in the Park (Horak & Spickett, unpublished data), confirms the inability of the sampling technique employed to adequately monitor this species (Spickett *et al.*, 1991). The collection of a nymph of *R. maculatus* is surprising as its distribution is confined to the coastal regions of northern Natal (Walker, 1991). This species could have been introduced into the Kruger National Park with hosts transferred to the Park from Zululand. Its subsequent establishment in the Park has been confirmed by the recent recovery of a male and an engorged female from an elephant in the Park (L.E.O. Braack, unpublished data).

The temporary and generally short-lived reductions in tick populations recorded after the fire in the present study, indicate little practical benefit from veld-burning during spring as a method of tick control. The effects of fire are influenced by the developmental status of the tick population at the time of the burn, subsequent host influx or exclusion from the burnt area, and the ecoclimatic suitability of the region for tick species. The technique may, however, be effective if aimed at specific tick species, either tenuously adapted to an area or with populations already reduced by chemical control. Efficacy could be enhanced by the exclusion of major hosts for a critical period after the burn to prevent or delay population recovery, a strategy advocated by Minshull & Norval (1982).

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REFERENCES

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.

GALUN, RACHEL, 1978. Research into alternative arthropod control measures against livestock pests (Part 1) *In:* THOMPSON, K. C. (ed.). *Proceedings of a Workshop on Ecology and Control of Ectoparasites on Bovines in Latin America*, C. I. A. T., 25-30 August 1975, 155–169.

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

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., JACOT GUILLARMOD, AMY, MOOLMAN, L. C. & DE VOS, V., 1987. 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.

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

MINSHULL, JAQUELINE 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., 1975. Studies on the ecology of *Amblyomma marmoreum* Koch, 1844 (Acarina: Ixodidae). *Journal of Parasitology*, 61, 737–742.

NORVAL, R. A. I., 1977. Ecology of the tick *Amblyomma hebraeum* Koch in the eastern Cape Province of South Africa. I. Distribution and seasonal activity. *Journal of Parasitology*, 63, 734–739.

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

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.

ROBERTSON, WENDY, D., 1981. A four year study of the seasonal fluctuations in the occurrence of the blue tick *Boophilus decoloratus* (Koch) in the coastal regions of Eastern Cape. *Proceedings of an International Conference on Tick Biology and Control*, Rhodes University, Grahamstown, 27–29 January, 1981, 199–204.

SPICKETT, A. M. & HEYNE, HELOISE, 1990. The prehatch period and larval survival of *Boophilus decoloratus* (Koch, 1844) (Acarina: Ixodidae) under natural conditions in the Transvaal, South Africa. *Onderstepoort Journal of Veterinary Research,* 57, 95–98.

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.

THEILER, GERTRUD, 1959. Ticks: Their biology and distribution. *Journal of the South African Veterinary Medical Association,* 30, 195–204.

THEILER, GERTRUD, 1969. Factors influencing the existence and the distribution of ticks. The biology and control of ticks in southern Africa. *Proceedings of a Symposium on the Biology and Control of Ticks in Southern Africa,* Rhodes University, Grahamstown, 1–3 July, 1969, 17–36.

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

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.

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