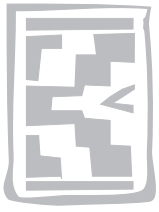

The comparative prevalence of five ixodid tick species infesting cattle and goats in Maputo Province, Mozambique

C. DE MATOS[1], C. SITOE[2], L. NEVES[3], J.O. NÖTHLING[4] and I.G. HORAK[5]*

ABSTRACT

DE MATOS, C., SITOE, C., NEVES, L., NÖTHLING, J.O. & HORAK, I.G. 2009. The comparative prevalence of five ixodid tick species infesting cattle and goats in Maputo Province, Mozambique. *Onderstepoort Journal of Veterinary Research*, 76:201–208

This study compares the prevalence of ixodid tick species on cattle and goats in Maputo Province. Adult ticks as well as the nymphs of three species, and only the adults of two species were collected from sets of five cattle at 21 localities throughout the province and compared with those collected from similar sets of goats at the same places. *Amblyomma hebraeum* adults and/or nymphs were present on cattle and on goats at all 21 localities, and 90 cattle and 22 goats were infested with adult ticks. *Rhipicephalus* (*Boophilus*) *microplus* adults and/or nymphs were collected from cattle at 20 and from goats at 15 localities, and 92 cattle and 34 goats were infested [Chi-square test (χ^2), $P < 0.001$]. The total length of several maturing female *R.* (*Boophilus*) *microplus* collected from cattle and goats exceeded 5 mm, indicating that they successfully engorge on both host species. *Rhipicephalus appendiculatus* adults and/or nymphs were present on cattle at 15 and on goats at 13 localities, but 28 cattle and only one goat were infested with adult ticks (χ^2, $P < 0.001$). Adult *Rhipicephalus evertsi evertsi* were recovered from cattle at 20 and from goats at 17 localities, and 74 cattle and 69 goats were infested. Adult *Rhipicephalus simus* were collected from cattle at 18 and from goats at 11 localities (Fisher's exact test, $P = 0.04$), and 60 cattle and 14 goats were infested (χ^2, $P < 0.001$). These findings underscore the advisability of including goats in acaricide application programmes designed for the control of tick-borne diseases in cattle at the same locality.

Keywords: *Amblyomma hebraeum*, cattle, goats, ixodid ticks, Maputo Province, Mozambique, *Rhipicephalus appendiculatus*, *Rhipicephalus* (*Boophilus*) *microplus*, *Rhipicephalus evertsi evertsi*, *Rhipicephalus simus*

INTRODUCTION

Seventeen species of ixodid ticks have been reported from cattle in Mozambique (Dias 1991). Amongst these *Amblyomma theilerae* has been synonymized with *Amblyomma hebraeum* (Camicas, Hervy, Adam & Morel 1998), and in our opinion the tick identified by Dias (1991) as *Rhipicephalus sanguineus*, is

* Author to whom correspondence is to be directed: E-mail: ivan.horak@up.ac.za

[1] Direcção de Ciências Animais, Instituto de Investigação Agrária de Mozambique, C.P. 1922, Maputo, Mozambique; and Department of Veterinary Tropical Diseases, Faculty of Veterinary Science, University of Pretoria, Private Bag X04, Onderstepoort, 0110 South Africa

[2] Direcção de Ciências Animais, Instituto de Investigação Agrária de Mozambique, C.P. 1922, Maputo, Mozambique

Accepted for publication 25 September 2008—Editor

[3] Faculdade de Veterinária, Universidade Eduardo Mondlane, C.P. 257, Maputo, Mozambique

[4] Department of Production Animal Studies, Faculty of Veterinary Science, University of Pretoria, Private Bag X04, Onderstepoort, 0110 South Africa

[5] Department of Veterinary Tropical Diseases, Faculty of Veterinary Science, University of Pretoria, Private Bag X04, Onderstepoort, 0110 South Africa; and Department of Zoology and Entomology, University of the Free State, P.O. Box 339, Bloemfontein, 9300 South Africa

more likely to be *Rhipicephalus turanicus*. Dias (1991) also lists five tick species that parasitize goats in Mozambique. These five ticks, namely *A. hebraeum, Rhipicephalus* (*Boophilus) microplus, Rhipicephalus appendiculatus, Rhipicephalus evertsi evertsi* and *Rhipicephalus simus* also infest cattle (Dias 1991). Although no surveys have been carried out on the tick species that infest sympatric cattle and goats in Mozambique, several such studies have been done in South Africa (Baker & Ducasse 1967, 1968; Rechav 1982; Nyangiwe & Horak 2007).

In KwaZulu-Natal Province, South Africa, Baker & Ducasse (1968) examined cattle at five localities at which goats were also present, and in the Eastern Cape Province Nyangiwe & Horak (2007) examined sets of five cattle and five goats at 72 communal cattle dip-tanks. The latter authors stated that there are no tick species that infest either of these hosts to the exclusion of the other in that region of the country. However, whereas cattle may harbour large numbers of both adult and immature ticks (Baker & Ducasse 1967), goats are often hosts of large numbers of immature ticks and fewer adults (Baker & Ducasse 1968; MacIvor & Horak 2003). Baker & Ducasse (1968) and Nyangiwe & Horak (2007) concluded that goats play an important role in maintaining infestations of ticks that normally infest cattle, and recommended that they should be included in tick control programmes designed for cattle on the same properties.

The objective of the present study was to compare the prevalence of infestation of the major ixodid tick species that infest sympatric cattle and goats in Maputo Province, Mozambique.

MATERIALS AND METHODS

Localities and animals

Thirty localities spread throughout Maputo Province were visually selected from a map of the province. Ticks were collected from cattle at each of these localities, and from goats at 25. However, the required numbers of five animals of both species were realized at only 21 of these sites, and consequently only the tick burdens of animals examined at the latter localities were compared for the purpose of this communication. The 21 localities at which ticks were collected are plotted in Fig. 1. It is most unlikely that cattle or goats at any of these localities had been treated with an acaricide during the 12 months preceding tick collection.

Tick collections

Ticks were collected from the ears, bodies, bellies, feet, tails and peri-anal regions of the cattle and goats on the single occasion that each locality was visited. The collections of ticks from each bovine or goat were not intended to be exhaustive, and focused on adult ticks, but several nymphs of *A.*

FIG. 1 Twenty-one localities in Maputo Province, Mozambique at which ticks were collected from cattle and goats for comparative purposes

hebraeum, *Rhipicephalus* (*Boophilus) microplus* and *R. appendiculatus* were also collected. The ticks were placed in 70 % ethyl alcohol in internally labelled vials and transported to a laboratory in Maputo or in Pretoria where they were identified and counted under a stereoscopic microscope.

Presentation of data

The chief comparison made was between the presence of adult ticks of four of the major tick species, namely *A. hebraeum, R. appendiculatus, R. e. evertsi* and *R. simus* on cattle and goats. However, because large numbers of nymphs of both *A. hebraeum* and *R. appendiculatus* were also incidentally collected their presence on cattle and goats was also separately compared. The fifth major tick species, *R.* (*B.*) *microplus,* is a one-host tick, with all stages of development present on the host at the same time. The adults and nymphs of this species were thus considered an entity and their presence was compared as such on the cattle and goats.

Because the collections of ticks from each animal were not complete, the actual numbers of ticks recovered from the cattle and goats cannot be compared. However, the presence or absence of a particular tick species on the two hosts, as well as at the various sampling localities, can be compared. These data are presented in tabular format together with similar data collected from cattle and goats in the Eastern Cape Province, South Africa.

The proportion of infested cattle pooled from all sampling sites was compared by means of a Chi-square (χ^2) test to the proportion of infested goats pooled from the same sampling sites. The proportion of localities at which infested cattle were present was compared to the proportion at which there were infested goats by means of Fisher's exact test. A paired t-test was used to compare the differences between the average numbers of infested cattle and infested goats at each dip-tank. If the differences were not normally distributed Wilcoxon's signed-rank test was used. The NCSS 2004 software package (www.NCSS.com) was used for all statistical analyses. The data are also presented graphically.

RESULTS

A significantly greater proportion (χ^2, $P < 0.001$) and average number ($P < 0.001$, paired t-test) of cattle than goats were infested with adult ticks (Table 1),

TABLE 1 The relative prevalence of adult ixodid ticks on 105 cattle and 105 goats examined in sets of five at 21 localities in Maputo Province, Mozambique

Tick and host species	No. (proportion) of animals infested with adult ticks	Average no. (± SD) of animals infested with adult ticks at each locality	No. (proportion) of localities positive for any life stage of each tick species
Amblyomma hebraeum			
Cattle	90 (85.7 %)[a]	4.3 (± 1.00)[a]	21 (100 %)
Goats	22 (21.0 %)[a]	1.0 (± 1.24)[a]	21 (100 %)
Rhipicephalus* (*Boophilus*) *microplus*[*]			
Cattle	92 (87.6 %)[a]	4.4 (± 1.43)[a]	20 (95.2 %)
Goats	34 (32.4 %)[a]	1.8 (± 1.51)[a]	15 (71.4 %)
Rhipicephalus appendiculatus			
Cattle	28 (26.7 %)[a]	1.3 (± 1.85)[a]	15 (71.4 %)
Goats	1 (0.9 %)[a]	0.05 (± 0.25)[a]	13 (61.9 %)
Rhipicephalus evertsi evertsi			
Cattle	74 (70.5 %)	3.5 (± 1.32)	20 (95.2 %)
Goats	69 (65.7 %)	3.3 (± 2.02)	17 (81.0 %)
Rhipicephalus simus			
Cattle	60 (57.1 %)[a]	2.9 (± 1.82)[a]	18 (85.7 %)[a]
Goats	14 (13.3 %)[a]	0.62 (± 0.67)[a]	11 (52.4 %)[a]

Pairs of figures in the same column, under the same species name and bearing the same superscript are significantly different ($P \leq 0.05$)

* = Nymphs and adults

TABLE 2 Ticks collected from cattle and goats in the Eastern Cape Province, South Africa and in Maputo Province, Mozambique

Province and tick species	Cattle			Goats		
	Total no. of ticks		No. of collections	Total no. of ticks		No. of collections
	Nymphs	Adults		Nymphs	Adults	
Eastern Cape, RSA[1]	Treated *ca.* 14 days previously			Untreated		
A. hebraeum	4	588	138	19	49	61
R. (*Boophilus*) *microplus*	960 (all stages)		242	236 (all stages)		113
R. appendiculatus	5	2 154	271	59	1 865	296
R. evertsi evertsi	31	1 926	316	41	2 210	334
Maputo, Mozambique[2]	Untreated			Untreated		
A. hebraeum	558	584	99	677	71	96
R. (*Boophilus*) *microplus*	4 932 (NN & Ads)		92	357 (NN & Ads)		34
R. appendiculatus	501	269	54	423	3	37
R. evertsi evertsi	12	368	74	78	346	69
R. simus	NA	250	60	NA	23	14

[1] Nyangiwe & Horak (2007)
[2] Present study

RSA = Republic of South Africa
NN & Ads = Nymphs and adults
NA = Not applicable, nymphs feed on rodents

and many more adult *A. hebraeum* were collected from cattle (584) than from goats (71) (Table 2, Fig. 2). *A. hebraeum* adults and/or nymphs were present on cattle and goats at all 21 sampling localities (Table 1, Fig. 2), and similar total numbers (99 vs. 96), and proportions (χ^2, P = 0.26), and average numbers were infested (Wilcoxon signed-rank test, P = 0.6). The total number of nymphs collected from the goats (677) was slightly greater than that from the cattle (558) (Table 2), and a significantly greater proportion of goats than cattle were infested with nymphs (χ^2, P < 0.01). There was, however, no significant difference between the average numbers of cattle (3.5 ± 1.69) and goats (4.3 ± 0.96) infested with nymphs at each dip tank (P = 0.08, paired t-test).

The proportion and average numbers of cattle infested with *R. (Boophilus) microplus* were significantly greater than the proportion and average numbers of infested goats (χ^2, P < 0.001, and paired t-test, P < 0.001, respectively). There was, however, no difference in the proportion of localities at which infested cattle and goats were present (Fisher's exact test, P = 0.18) (Table 1).

A total of 4 932 *R.* (*B.*) *microplus* was collected from the cattle compared to a total of 357 ticks from the goats (Table 2). Not all female *R.* (*B.*) *microplus* collected were available for measurement, but 33.9 % (151) out of a total of 445 female *R.* (*B.*) *microplus* collected from some of the cattle exceeded 5 mm in length, while 20.3 % (15) of a total of 74 females collected from some of the goats also exceeded this length.

Compared to goats, the proportion of cattle and the average numbers infested with adult *R. appendiculatus* at each locality were significantly greater (χ^2, P < 0.001, Wilcoxon signed-rank test, P < 0.01 respectively) (Table 1). The proportion of cattle infested with nymphs and adults was also significantly greater than the proportion of goats similarly infested (χ^2, P = 0.02). The average numbers of cattle and goats that were infested with *R. appendiculatus* nymphs and/or adults at each locality, and the proportion of localities at which infested cattle and goats were present did not differ significantly (paired t-test, P = 0.07, and Fisher's exact test, P = 0.74, respectively).

Few *R. evertsi evertsi* nymphs, but several hundred adults were collected from both cattle and goats. The proportions and average numbers of cattle and goats that were infested with adult ticks, and the proportion of localities at which infested cattle and goats were present were similar (χ^2, P = 0.46, paired t-test, P = 0.5, and Fisher's exact test, P = 0.34, respectively) (Table 1, Fig. 2).

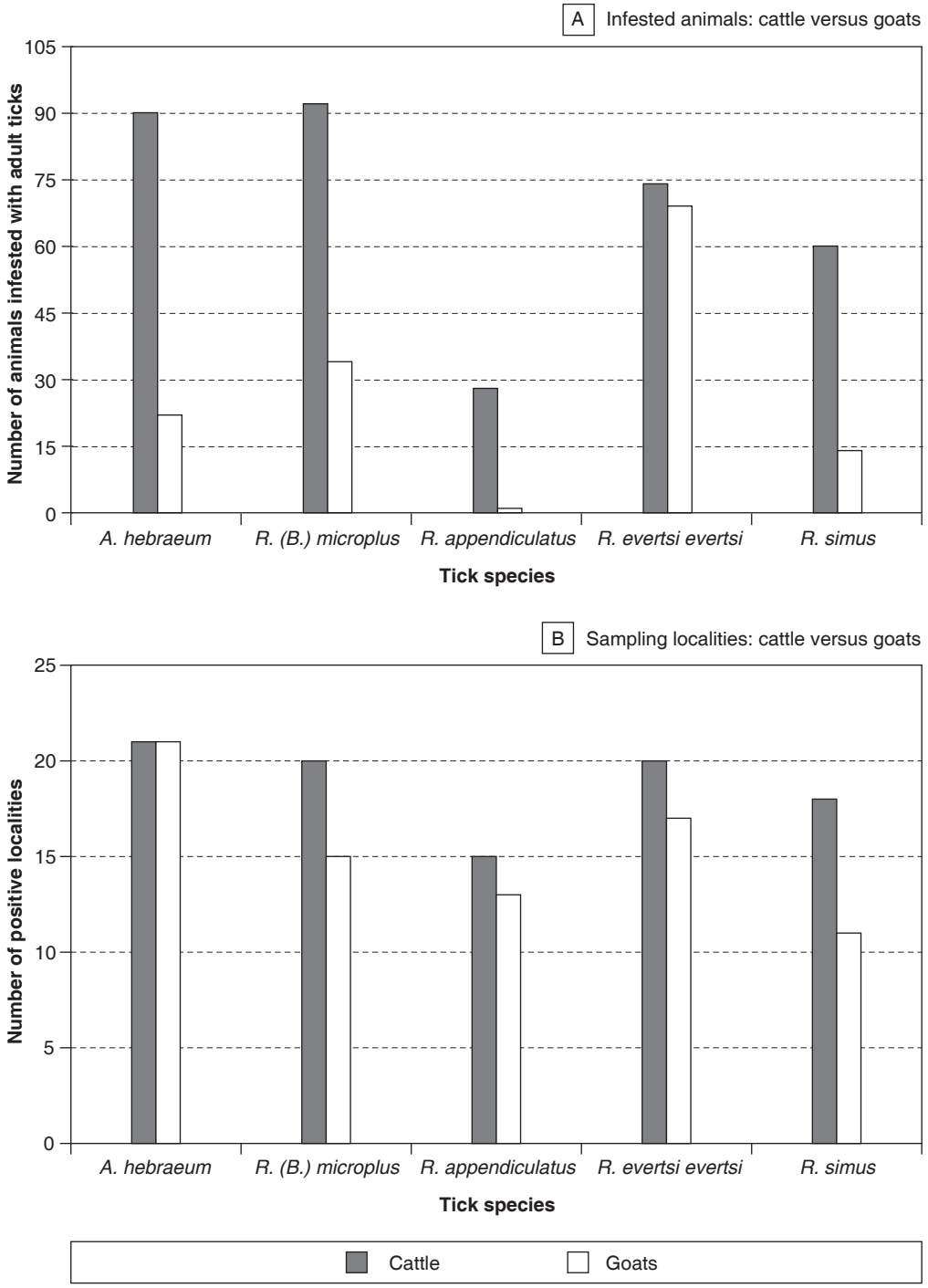

FIG. 2 The total numbers of (a) cattle and goats from which adult *Amblyomma hebraeum*, *Rhipicephalus* (*Boophilus*) *microplus* (adults and nymphs), *Rhipicephalus appendiculatus*, *Rhipicephalus evertsi evertsi* and *Rhipicephalus simus* were collected in Maputo Province, Mozambique and (b) localities at which adults, or adults and nymphs of these species were present

Only adult *R. simus* were collected from the cattle and goats. A significantly greater proportion of cattle than goats was infested (χ^2, $P < 0.001$), and infested cattle were present at a significantly greater proportion of localities than infested goats (Fisher's exact test, $P = 0.04$) (Fig. 2). The average number of infested cattle at each locality was also significantly greater than the average number of infested goats (Wilcoxon signed-rank test, $P < 0.001$) (Table 1).

DISCUSSION

Although it was not our intention to collect immature ticks, the fairly large numbers of nymphs of both *A. hebraeum* and *R. appendiculatus* that were collected contributed towards the results obtained for both tick species. Had only adult ticks been collected, fewer localities would have been recorded as being infested with either species.

Nyangiwe & Horak (2007) collected adult *A. hebraeum* from 138 of 360 cattle examined in the Eastern Cape Province, South Africa, and from 61 of 360 goats examined at the same localities as the cattle (Table 2). Although the proportion of goats infested with adult ticks in the current survey was reasonably similar to that conducted by Nyangiwe & Horak (2007), 20.9 % compared to 16.9 %, the proportion of infested cattle differed considerably, 85.7 % compared to 38.3 % (Table 2). Horak, MacIvor, Petney & De Vos (1987) concluded that the larger the host species the greater the likelihood that it would harbour adult *A. hebraeum*, and this was confirmed by the present findings.

Amblyomma hebraeum was present at every locality sampled in Maputo Province (Fig. 1), compared to only 54.2 % of 72 localities in the Eastern Cape Province (Nyangiwe & Horak 2007). This difference can probably be ascribed to the prevailing climate of Maputo Province as being more suitable for *A. hebraeum* than that of the eastern regions of the Eastern Cape Province.

Amblyomma hebraeum is the most important southern African vector of *Ehrlichia ruminantium*, the causative organism of heartwater in domestic and some wild ruminants (Norvall & Horak 2004). Goats are particularly susceptible, and according to Allsopp, Bezuidenhout & Prozesky (2004) up to 30 % of goats in some parts of the rural farming areas of South Africa become infected annually. Whereas, in the absence of challenge, immunity in cattle lasts for approximately 2 years after immunization, immunity in goats is extremely variable (Allsopp *et al*. 2004).

Rhipicephalus (*Boophilus*) *microplus* is a one-host tick that infests cattle, and is usually only found on other animals provided infested cattle are present at the same locality. As far back as 1943, Theiler, in her monograph on the ticks of domestic livestock in Mozambique, mentioned that the tick that she then referred to as *Boophilus* (*Uroboophilus*) *fallax*, and that is now accepted as *R.* (*B.*) *microplus* (Camicas *et al*. 1998), was found mostly on cattle, but that it could also occur on equines, ovines and caprines (Theiler 1943). Furthermore Dias (1991) listed both *Rhipicephalus* (*Boophilus*) *decoloratus* and *R.* (*B.*) *microplus* from cattle in Mozambique, but listed only *R.* (*B.*) *microplus* from goats. Baker & Ducasse (1968) recovered a total of 266 *R.* (*B.*) *microplus* in all stages of development in nine consecutive collections from a goat, while the total yield of nine collections each from two calves at the same locality in KwaZulu-Natal Province, South Africa, was 32 692 ticks. Nyangiwe & Horak (2007) recorded 242 collections of *R.* (*B.*) *microplus* from cattle and 113 collections from goats examined at the same localities in the Eastern Cape Province, South Africa (Table 2). They also noted that a large proportion of maturing female ticks collected from goats were 5 mm or more in length (standard females), indicating that they should complete their engorgement and detach within the following 24 h. Considering that this is a one-host species it is only necessary to show that engorged female ticks that detach from goats can lay fertile eggs to prove that *R.* (*B.*) *microplus* can complete its entire life cycle on these animals.

The recovery of *R.* (*B.*) *microplus* from goats at so many localities in the present study can partly be ascribed to the high prevalence of infestation on cattle at the same localities (Fig. 2). The presence of standard female ticks on many of the goats in this survey as well as that of Nyangiwe & Horak (2007) is a fair indication that in at least two regions of southern Africa *R.* (*B.*) *microplus* has adapted to feeding on goats, and may even be able to survive on these animals in the complete absence of cattle. Nyangiwe & Horak (2007) speculated that if *R.* (*B.*) *microplus* had indeed adapted to goats, a further adaptation to various wildlife species, particularly those that share much of their habitat with goats in the Eastern Cape Province, may be imminent. A similar risk does not seem to exist in Maputo Province, where most of the larger wildlife species were annihilated during the independence conflict of the 1980s. Subsequent human settlement and agricultural activities in the province, which is the most populous in Mozambique, have now decimated much of the remaining wildlife's natural habitat. With the possible exception of a few isolated localities it would seem as if the introduced *R.* (*B.*) *microplus* has completely displaced the indigenous *R.* (*B.*) *decoloratus* in Maputo Province.

Rhipicephalus (*B.*) *microplus* is the vector both of *Babesia bigemina* and the more virulent *Babesia bovis*, the organisms that cause of babesiosis or redwater in domestic cattle, whereas the indigenous

R. (*B.*) *decoloratus* transmits only *B. bigemina* (Norval & Horak 2004). According to De Vos, De Waal & Jackson (2004) several factors have led to redwater being recognized as one of the most important diseases of cattle in southern Africa since the latter part of the 20th century. These authors also state that there is little evidence to suggest that animals other than cattle are important reservoir hosts of these parasites. Hence goats are unlikely to play a role in the epidemiology of redwater should infected ticks feed on them, and their presence on pastures with cattle could perhaps even reduce the chance of the latter animals acquiring infection.

Domestic cattle and large wild herbivores such as greater kudus, *Tragelaphus strepsiceros*, eland, *Taurotragus oryx*, and African buffaloes, *Syncerus caffer*, are the hosts favoured by adult *R. appendiculatus* (Baker & Ducasse 1967; Horak, Boomker, Spickett & De Vos 1992; Horak, Golezardy & Uys 2007). These animals as well as many smaller domestic and wild herbivores can also all be heavily infested with the immature stages of this tick (Baker & Ducasse, 1967, 1968; Horak, Gallivan, Braack, Boomker & De Vos 2003; Horak *et al.* 2007). Contrary to the study of Baker & Ducasse (1968) in KwaZulu-Natal, in which slightly more adult *R. appendiculatus* were collected from cattle than from goats, and that of Nyangiwe & Horak (2007) in the Eastern Cape Province, in which slightly more goats than cattle were infested with adult ticks, only three adult ticks were recovered from a single goat in the present survey compared to 269 adult ticks from 28 cattle (Table 2, Fig. 2). One of the reasons for this anomaly can be that the collections by Nyangiwe & Horak (2007) were all made during the months January to May (mid-summer to autumn), the period of peak abundance of adult *R. appendiculatus* in the Eastern Cape Province (Horak 1999). This is also the period of peak adult abundance in the Kruger National Park, which lies immediately to the west of Maputo Province (Horak *et al.* 1992). In the Mozambican survey 12 of the 21 localities were sampled during June or July, months during which few adults are present, but in which large numbers of larvae and nymphs occur (Horak *et al*. 1992), as in the present case.

Rhipicephalus appendiculatus is the principal vector of *Theileria parva*, the causative organism of East Coast fever, one of the most devastating diseases of domestic cattle in East and southern Africa (Lawrence, Perry & Williamson 2004). *Theileria parva* is not infective to goats (Lawrence *et al*. 2004), and hence they will not act as reservoirs of the parasite. It might even be so that herding goats with cattle could slightly reduce the risk of the latter animals becoming infected.

Of all tick species that belong to the genus *Rhipicephalus* in Africa, *R. e. evertsi* has the most widespread distribution and also has one of the largest host ranges (Walker, Keirans & Horak 2000). The preferred hosts of its adult and immature stages are domestic and wild equids and eland (Norval 1981; Horak *et al.* 2007), but cattle, goats and sheep are also suitable hosts (Walker *et al*. 2000). Baker & Ducasse (1968) collected more adult ticks from untreated cattle than from goats at five localities in KwaZulu-Natal Province, whereas Nyangiwe & Horak (2007) collected adult ticks from slightly more goats than from cattle at their 72 sampling localities (Table 2).

Only adult *R. simus* were collected from both cattle and goats in the present study. This is not surprising as the immature stages infest rodents (Norval & Mason 1981; Rechav 1982). In the study conducted in the Eastern Cape Province by Nyangiwe & Horak (2007), no *R. simus* were collected from cattle or from goats, even though it was present on dogs sampled at the same localities (Nyangiwe, Horak & Bryson 2006). In the present study the majority of dogs examined concurrently with the cattle and goats were infested (De Matos, Sitoe, Neves, Bryson & Horak 2008). Judging by the number and the variety of hosts infested and the widespread occurrence of *R. simus* in Maputo Province, the prevailing climate and other environmental conditions are obviously favourable for its survival.

ACKNOWLEDGEMENTS

We are most grateful to the Directorate of Animal Science, Mozambique, for permitting C. de Matos and C. Sitoe to participate in this survey as part of their official duties. We also thank the various cattle and goat owners for permission to collect ticks from their animals and for their assistance with these collections. The finances for this study came mainly from a SIDA/SAREC-Joint INEVE-Eduardo Mondlane University Veterinary Faculty Research Project, No. # 27, while funds provided by the National Research Foundation contributed towards I.G. Horak's expenses.

REFERENCES

ALLSOPP, B.A., BEZUIDENHOUT, J.D. & PROZESKY, L. 2004. Heartwater, in *Infectious diseases of livestock*, edited by

J.A.W. Coetzer & R.C. Tustin. Oxford University Press: Cape Town.

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

BAKER, M.K. & DUCASSE, F.B.W. 1968. Tick infestation of livestock in Natal. The role played by goats as reservoirs of the economically important cattle ticks. *Journal of the South African Veterinary Medical Association,* 39:55–59.

CAMICAS, J.-L., HERVY, J.-P., ADAM, F. & MOREL, P.-C. 1998. *The ticks of the World (Acarida, Ixodida). Nomenclature, described stages, hosts, distribution.* Paris: Orstom Editions.

DE MATOS, C., SITOE, C., NEVES, L., BRYSON, N.R. & HORAK, I.G. 2008. Ixodid ticks on dogs belonging to people in rural communities and villages in Maputo Province, Mozambique. *Onderstepoort Journal of Veterinary Research*, 75:103–108.

DE VOS, A.J., DE WAAL, D.T. & JACKSON, L.A. 2004. Bovine babesiosis, in *Infectious diseases of livestock*, edited by J.A.W. Coetzer & R.C. Tustin. Oxford University Press: Cape Town.

DIAS, J.A., TRAVASSOS SANTOS. 1991. Some data concerning the ticks (Acarina-Ixodoidea) presently known in Mozambique. *Garcia de Orta, Séries Zoologica, Lisboa*, 18 (1993): 27–48.

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

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

HORAK, I.G. 1999. Parasites of domestic and wild animals in South Africa. XXXVII. Ixodid ticks on cattle on Kikuyu grass pastures and in Valley Bushveld in the Eastern Cape Province. *Onderstepoort Journal of Veterinary Research,* 66:175–184.

HORAK, I.G., GALLIVAN, G.J., BRAACK, L.E.O., BOOMKER, J. & DE VOS, V. 2003. Parasites of domestic and wild animals in South Africa. XLI. Arthropod parasites of impalas (*Aepyceros melampus*) in the Kruger National Park. *Onderstepoort Journal of Veterinary Research*, 70:131–163.

HORAK, I.G., GOLEZARDY, H. & UYS, A.C. 2007. Ticks associated with the three largest wild ruminant species in southern Africa. *Onderstepoort Journal of Veterinary Research*, 74: 231–242.

LAWRENCE, J.A., PERRY, B.D. & WILLIAMSON, S.M. 2004. East Coast fever, in *Infectious diseases of livestock*, edited by J.A.W. Coetzer & R.C. Tustin. Oxford University Press: Cape Town.

MACIVOR, K.M. DE F. & HORAK, I.G. 2003. Ixodid ticks of Angora and Boer goats, grysbok, common duikers, kudus and scrub hares in Valley Bushveld in the Eastern Cape Province. *Onderstepoort Journal of Veterinary Research*, 70: 113–120.

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

NORVAL, R.A.I. & HORAK, I.G. 2004. Vectors: ticks, in *Infectious diseases of livestock*, edited by J.A.W. Coetzer & R.C. Tustin. Oxford University Press: Cape Town.

NYANGIWE, N., HORAK, I.G. & BRYSON, N.R. 2006. Ixodid ticks on dogs in the eastern region of the Eastern Cape Province, South Africa. *Onderstepoort Journal of Veterinary Research*, 73:305–309.

NYANGIWE, N. & HORAK, I.G. 2007. Goats as alternative hosts of cattle ticks. *Onderstepoort Journal of Veterinary Research*, 74:1–7.

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

THEILER, GERTRUD. 1943. *Notes on the ticks of domestic stock from Portuguese East Africa.* Estação Anti-Malárica de Lourenço Marques: Imprensa Nacional de Moçambique.

WALKER, JANE B., KEIRANS, J.E. & HORAK, I.G. 2000. *The genus* Rhipicephalus *(Acari, Ixodidae): a guide to the brown ticks of the world.* Cambridge: Academic Press.