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Ectoparasite diversity in the eastern rock sengis (*Elephantulus myurus*): the effect of seasonality and host sex

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Globally small mammals are important hosts of ectoparasite vectors of pathogens of medical, veterinary and economic importance. Insectivores are currently understudied as hosts of pathogen vectors. However, data are needed on the diversity of such vectors before we can investigate the underlying factors affecting ectoparasite distribution. Abiotic (e.g. temperature and rainfall) and biotic (e.g. host sex) factors have been identified as the main determinants of host–parasite interactions. The present study describes the ectoparasite community of insectivorous eastern rock sengis (*Elephantulus myurus*) in a nature reserve in the Gauteng province, South Africa, and how it varies with season and host sex. A total of 81 sengis were examined for the presence of ticks, mites, fleas and lice between April 2010 and April 2011. The ectoparasite assemblage comprised 11 groups of tick species, a single mite family, one louse and two flea species, with ticks and mites being the most numerous ectoparasites recovered. The prevalence and/or abundance of two commonly collected ticks (*Ixodes* spp. and *Rhipicephalus warburtoni/arnoldi*) and chigger varied with season. In addition, female-biased tick burdens were apparent for one ectoparasite species possibly due to reproductive investment. The mechanisms causing the observed patterns should be addressed in future studies.

Keywords: ectoparasites, host sex, Macroscelididae, seasonality

Introduction

Small mammals are hosts to numerous ectoparasite species, some of which are vectors of pathogens such as *Borrelia*, *Babesia* and *Anaplasma* causing disease in both humans and livestock (Labuda and Nuttall 2004; Morand and Krasnov 2006).Understanding the factors that regulate the distribution of ectoparasites among host populations could provide management solutions for such diseases. It has frequently been observed that parasites exhibit aggregated or over-dispersed patterns on or within their hosts, i.e. the majority of parasites infest few host individuals, whereas most host individuals harbour only a few or no parasites (Wilson et al. 2001; Poulin 2007). Such aggregation patterns may be caused by a number of drivers that can be abiotic (e.g. climate) or biotic factors (e.g. host reproductive activity) acting on the parasite and/or the host (Wilson et al. 2001). Abiotic factors, such as temperature and rainfall, can result in seasonal variation in parasite burdens. For example, high temperatures can reduce developmental times for arthropod parasites but at the same time may increase the risk of desiccation and hence mortality when humidity is low (Marshall 1981; Needham and Teel 1991; Benoit and Denlinger 2010). For arthropod parasites such effects may be closely linked to the

relationship between parasites and their hosts. Parasites such as ticks, which spend a substantial part of their life off-host, will be more strongly affected by climate factors than, for example, lice, which spend their entire life cycle on their hosts (Marshall 1981; Randolph 2004; Kim 2006).

Seasonal variation in temperature and rainfall can also influence a host's exposure and susceptibility to parasitic infection. For example, during cold seasons resources may be limited, while concurrently the energy demand for thermoregulation is high. If hosts have to increase their home range to cover their nutritional needs this may result in increased exposure to parasites during cold periods. Alternatively, but not mutually exclusive, hosts may have lower resistance to parasites during winter due to reduced resources available for parasite defence (Nelson et al. 2002; Martin et al. 2008). Parasite burdens may, however, also be increased during summer because the host diverts resources for parasite defences into reproductive activities (Altizer et al. 2006). Seasonal variation in ectoparasite burdens has been recorded by a number of studies carried out in different regions of Africa, including South Africa, and irrespective of whether those were carried out in summer or winter rainfall regions, rainfall patterns appeared to play

a major role in affecting these patterns (Fourie et al. 1992, 2005; Matthee et al. 2007; Lutermann et al. 2012a, 2012b). However, most of these studies have focused on ticks.

In addition to season, ectoparasite burdens are often influenced by the sex of the host. Sex-specific investment strategies in reproduction may account for gender biases in parasite burdens (Matthee et al. 2010; Kiffner et al. 2013). This could be due to differences in body size, behaviour and/or physiology between the sexes (Moore and Wilson 2002; Klein 2004). Males of many mammal species are often larger than their female counterparts, as a result of intrasexual competition, and this could translate into them representing a larger resource patch for parasites (Moore and Wilson 2002). In addition, males may greatly increase their home range during mating periods, concomitantly increasing their exposure to ectoparasites (Scantlebury et al. 2010; Boyer et al. 2010). Alternatively, higher levels of the male sex hormone testosterone have been shown to increase susceptibility to ectoparasites such as ticks (Hughes and Randolph 2001), whereas lowered immune defences during gestation can render female mammals more susceptible to ectoparasites (Christe et al. 2000; Lutermann et al. 2012b). However, sex-biased parasite burdens are not the rule and the degree of sex-bias may differ between different ectoparasite species parasitising the same host as well as for the same parasite on different host species (Krasnov and Matthee 2010; Scantlebury et al. 2010; Kiffner et al. 2013).

Despite the substantial ectoparasite burdens, particularly of ticks, that insectivores may sustain, host–parasite interactions have been studied less frequently on these small mammals than on rodent hosts (Harrison et al. 2012). Sengis or elephant shrews (order Macroscelidae) are insectivores comprising 17 species with a wide distribution across the African continent (Skinner and Chimimba 2005). No less than 27 tick species from six genera have been reported from sengis, including several of veterinary and economic importance (Fourie et al. 1992, 1995, 2002, 2005; Harrison et al. 2011). In addition, the tick burden of sengis may be 100 times greater than those of sympatric rodents (Fourie et al. 1992; Harrison et al. 2011). Besides ticks, eight mite species from five genera, 12 flea species from nine genera, including the plague vector *Xenopsylla brasiliensis*, as well as one louse species have been collected from sengis but currently only descriptive information for these parasite taxa is available (Fourie et al. 1995; Segerman 1995; Beaucournu et al. 2003).

The Eastern rock sengi (*Elephantulus myurus*) is restricted to southern Africa with a distributional range from Mozambique, throughout parts of Zimbabwe, eastern Botswana and most parts of north-east South Africa and western Swaziland (Skinner and Chimimba 2005). They prefer rocky habitats, specialise on ants and termites as food items and may be active during both the day and night with peaks at dusk and dawn (Skinner and Chimimba 2005). Breeding takes place during the warm, wet summer (September to March) (Medger et al. 2012). They may host a variety of ectoparasites, including the immature stages of at least 12 tick species belonging to seven genera (Fourie et al. 1995; Harrison et al. 2011; Horak et al. 2012). Of these, no less than three species (*Ixodes rubicundus*,

Rhipicentor nuttalli and *Rhipicephalus warburtoni*) have been implicated as causing paralysis in domestic animals, while *R. warburtoni* may also be infected with *Anaplasma bovis* (Fourie et al. 1992; Harrison et al. 2011). Rock sengis do not exhibit sexual dimorphism and body mass was not a significant predictor of *R. warburtoni* burden in a previous study (Lutermann et al. 2012b). Only two flea species from two genera (*Demeillonia granti* and *Macroscelidopsylla albertyni*), one laelapid mite (*Ornithonyssus capensis*) and one louse species (*Neolinognathus elephantuli*) have been recorded for *E. myurus* (Fourie et al. 1995; Beaucournu et al. 2003). In contrast to ticks, the seasonal or sex-dependent patterns of abundance of the latter ectoparasite species as well as their status as disease vectors are largely unknown. The present study had two main aims: first, to determine the ectoparasite community infesting eastern rock sengis in the summer rainfall region over an extended period and, second, to assess the patterns of prevalence and abundance of ectoparasite species on these animals and evaluate the role of seasonality and host sex in generating these patterns.

Materials and methods

Study area and capture plots
Eastern rock sengis were sampled at the Ezemvelo/Telperion Nature Reserve (25°41′ S, 28°56′ E) located on the border between Gauteng and Mpumalanga provinces, South Africa. The reserve is approximately 11 000 ha in size and the vegetation cover is described as Highveld grassland and savanna with large rocky outcrops present throughout the area (Swanepoel 2006). The reserve stocks a variety of large mammal species, including plains zebra, greater kudu, eland and waterbuck as well as smaller antelope species such as impala. Smaller mammals on the reserve include hares, red rock rabbits and rock hyraxes, all of which may act as hosts for the adult and/or immature stages of several tick species (Walker et al. 2000). Sampling took place five times from April 2010 until April 2011 in order to cover all seasons (April/May, July/August, October/November in 2010 as well as January/February and April/May in 2011). Sixteen plots comprising eight rocky outcrops and eight grasslands were selected for the study. This procedure was, however, not followed during the first visit, during which only five rocky outcrops and one grassland were sampled. Since the abundance of sengis was markedly higher on rocky outcrops, only the latter were sampled during the last trip (April/May in 2011).

Host species and trapping protocol
Animals were collected using 72 Sherman traps (HB Sherman Traps, Inc., Tallahassee, FL, USA) baited with a mixture of peanut butter and oats to attract animals. Traps were set in each plot in four parallel lines, approximately 10 m apart and each line consisted of 18 traps placed about 10 m apart. Traps were set in the late afternoon (around 18:00) for four consecutive nights and checked early each morning (around 05:00). They were closed during the day to limit trap related deaths as a result of environmental exposure and bedding was provided in the traps during winter.

Laboratory procedure

Animals were removed from the traps and placed in Ziplock bags and transferred to a field laboratory where they were processed immediately. They were removed from the bags and then restrained by hand and their sex was recorded. Thereafter, each sengi was carefully checked for ectoparasites with particular attention to the ear margins, legs and the base of the tail where ticks and mites aggregated (DMF pers. obs.). The rest of the body was searched by back-combing the fur for the presence of fleas and lice. Ectoparasites were removed using fine-tipped tweezers and stored in 70% ethanol for later identification to species level and counting. All sengis captured were marked with ear notches and subsequently released at their site of capture. Only the first capture of an individual during a capture period was included. Ticks were identified to species or genus level by IGH using descriptions provided by Theiler (1961), Arthur (1965), Walker et al. (2000) and Apanaskevich et al. (2007). Mites were identified to family level by EAU using Krantz and Walter (2009). Lice and fleas were identified by DMF with the help of an experienced taxonomist using the keys of Ledger (1980) and Segerman (1995), respectively. Mites, lice and fleas were mounted on glass slides for microscopic examination following standard techniques. The developmental stages of all parasite species encountered were recorded and counted.

Data analysis

Following Bush et al. (1997), species richness was defined as the number of ectoparasite species encountered on a host. In addition, prevalence was defined as the number of hosts infested with one or more individuals of a particular parasite species divided by the total number of hosts examined for that parasite species. Mean abundance was the total number of individuals of a parasite species collected, divided by the total number of hosts investigated. The effect of seasonality on variation in the species richness, prevalence and abundance of the various ectoparasite species was examined using generalised linear models (GLMs). None of the data were normally distributed and, consequently, a Poisson distribution with a log-link function was employed for species richness data, a binomial distribution with logit-link function was selected for prevalence data, and a negative-binomial distribution with a log-link function was chosen for abundance data. *Post-hoc* analyses were done with pairwise comparisons of all significant parameters using the least significant difference (LSD). Only the most prevalent parasite species (overall prevalence of >15%) were analysed in depth for prevalence and abundance. Only adult animals of a body mass exceeding 40 g were used in our analyses. Body mass did not differ significantly between the sexes (males, mean $\pm$ SE: 64.035 $\pm$ 6.400 g, females: 62.910 $\pm$ 11.778 g, $t = 0.567$, df = 75, $p = 0.600$). In contrast, male body length (measured from neck to base of the tail) was significantly greater for male than female sengis (males: 80.491 $\pm$ 7.640 mm, females: 76.251 $\pm$ 8.467 mm, *t*-test: $t = 2.216$, df = 69, $p = 0.030$). Given that body length is a better proxy for body size than body mass, we initially included body length as a covariate in these analyses. However, because this variable did not significantly affect any of the variables considered ($p \geq 0.185$), we only report the results for GLMs without body length. The prevalence of *R. warburtoni/arnoldi* was close to 100% (see Results section), hence we only carried out an analysis for the abundance of this species. All statistical analyses were conducted with IBM SPSS Statistics version 21 (IBM Corp., Boston, MA, USA). The study was approved by the animal ethics committee of the University of Pretoria (EC015-10) and permits were issued by the Gauteng Nature Conservation Board (permit no. CPF6-0041).

Results

A total of 81 individual sengis, of which 44 were males (54.3%) and 37 females (45.7%), were examined for ectoparasites. The number of sengis caught per trip and their sex is summarised in Table 1. We collected a total of 25 497 immature ticks (no adults were recovered), 11 584 mites, 62 lice and 32 fleas over the entire study period. Ticks (68.6%) represented by far the largest proportion of ectoparasites recovered, followed by mites (31.2%), lice and fleas (Table 2). The mean species richness observed was 2.88 $\pm$ 0.142 (range: 0–7). It varied significantly with season (Wald $\chi^2 = 17.034$, df = 4, $p = 0.002$; Figure 1a). *Post-hoc* analyses showed that it was significantly greater in April 2011 compared with all other seasons ($p \leq 0.034$) except January 2011 (LSD: $p = 0.424$). In addition, species richness tended to be greater in January 2011 compared with April 2010 (LSD: $p = 0.055$) and was significantly higher in January 2011 than in October (LSD: $p = 0.004$; Figure 1a). None of the remaining pairwise comparisons was significant ($p \geq 0.129$). Neither host sex (Wald $\chi^2 = 0.229$, df = 1, $p = 0.632$) nor the interaction between season and sex was significant (Wald $\chi^2 = 1.104$, df = 4, $p = 0.908$).

Ticks

A total of 11 ixodid tick species, representing four genera (*Ixodes*, *Haemaphysalis*, *Rhipicentor* and *Rhipicephalus*), were collected (Table 2). Large numbers of larvae and nymphs belonging to the *Rhipicephalus pravus* group of species (Walker et al. 2000) were collected. Some engorged nymphs from this group were allowed to moult to adults and these belonged to two tick species, namely *Rhipicephalus warburtoni* (referred to in earlier publications as *Rhipicephalus* near *R. pravus* and *Rhipicephalus* near *R. warburtoni*; Harrison et al. 2011; Lutermann et al. 2012a, 2012b), and *Rhipicephalus arnoldi*. The larvae and nymphs of these two species so closely resemble each other that it would have required individual specimens to be mounted on glass slides and examined under a

Table 1: *Elephantulus myurus* host individuals caught per season in the Ezemvelo/Telperion Nature Reserve

Season	Males (mean length $\pm$ SE; mm)	Females (mean length $\pm$ SE; mm)
April 2010	13 (80.52 $\pm$ 1.27)	10 (80.43 $\pm$ 1.63)
July 2010	9 (82.73 $\pm$ 4.48)	2 (90.62 $\pm$ 1.22)
October 2010	7 (70.08 $\pm$ 2.51)	10 (76.45 $\pm$ 5.09)
January 2011	8 (74.91 $\pm$ 4.51)	8 (80.44 $\pm$ 3.10)
April 2011	7 (76.88 $\pm$ 2.04)	7 (77.74 $\pm$ 1.33)

Table 2: Ectoparasite species collected and their infestation parameters on *Elephantulus myurus* in the Ezemvelo/Telperion Nature Reserve

Taxon	Species	Total numbers	Prevalence (%)	Mean abundance (±SE)
Ticks	*Rhipiciphalus appendiculatus*	654	2.5	8.07 ± 8.062
	Rhipiciphalus warburtoni/arnoldi	24 309	97.5	300.11 ± 23.827
	Rhipiciphalus arnoldi[a]	23	4.9	0.28 ± 0.179
	Rhipiciphalus warburtoni[a]	42	4.9	0.52 ± 0.301
	Rhipiciphalus distinctus	54	27.2	0.67 ± 0.252
	Rhipiciphalus decoloratus	2	2.5	0.02 ± 0.017
	Rhipiciphalus evertsi evertsi	7	6.2	0.09 ± 0.040
	Rhipicentor nuttalli	33	17.3	0.41 ± 0.139
	Haemaphysalis (*Rhipistoma*) spp.	11	9.9	0.14 ± 0.052
	Ixodes spp.	449	44.4	5.54 ± 1.915
	Ticks total	25 497	98.8	314.78 ± 24.0
Mites	Trombiculidae larvae (chiggers)	11 584	63.0	143.01 ± 33.017
Lice	*Neolinognathus elephantuli*	62	9.9	0.77 ± 0.405
Fleas	*Demeillonia granti*	29	3.7	0.36 ± 0.206
	Xenopsylla brasiliensis	3	3.7	0.04 ± 0.021
	Fleas total	32	8.6	0.41 ± 0.206

[a] Engorged nymphs were allowed to moult and gave rise to the adult ticks, which could be unambiguously identified
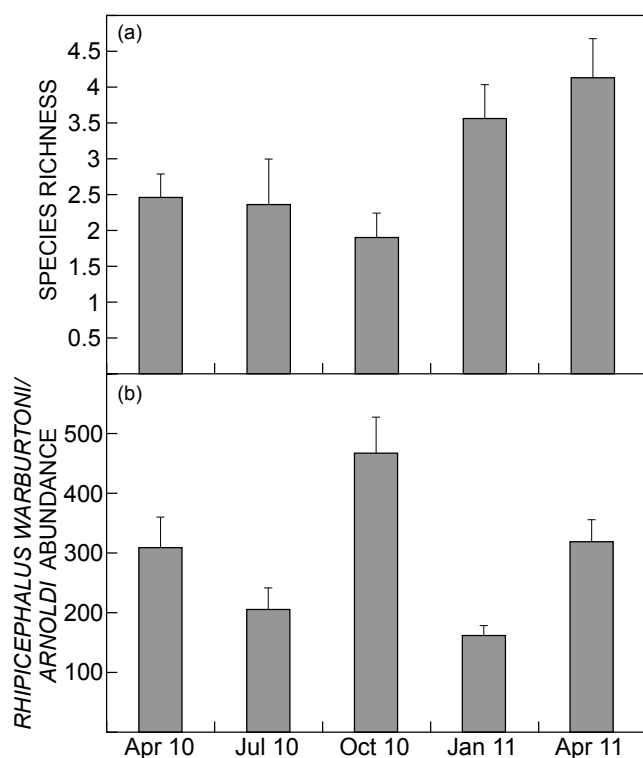

Figure 1: Seasonal variation in mean (±SE) (a) ectoparasite species richness and (b) *Rhipicephalus warburtoni/arnoldi* abundance found on eastern rock sengis in Ezemvelo/Telperion Nature Reserve

light microscope to determine their separate identities, a procedure that was not practical considering the thousands of immature ticks involved and that many of these were semi-engorged or engorged. We have therefore chosen to pool these immature ticks as *R. warburtoni/arnoldi*. The larvae and nymphs of two *Haemaphysalis* (*Rhipistoma*) species (*H. leachi* and *H. elliptica*) were also present and, as both of these species belonged to the subgenus

Rhipistoma and were difficult to distinguish, we have chosen to identify them as *Haemaphysalis* (*Rhipistoma*) spp. Similarly, the larvae and nymphs of two species within the genus *Ixodes* could only be identified with confidence to genus level, more particularly because the immature stages of several ticks within this genus in Africa have not been described (Arthur 1965). Engorged nymphs belonging to the genus *Rhipicentor* were allowed to moult and the ensuing adults were identified as *Rhipicentor nuttalli*. Ticks of the *Rhipicephalus warburtoni/arnoldi* grouping were the most prevalent and abundant, followed by *Ixodes* spp., *Rhipicephalus distinctus* and *Rhipicentor nuttalli* (Table 2).

The mean abundance of *R. warburtoni/arnoldi* varied significantly with season (Table 3, Figure 1b). *Post-hoc* analyses revealed that abundance was significantly greater in October 2010 compared to July 2010 (LSD: $P = 0.017$) and January 2011 (LSD: $P = 0.012$). None of the other pairwise comparisons were significant ($P \geq 0.053$). Neither host sex nor the interaction between season and sex were significant (Table 3).

None of the factors considered significantly affected the prevalence of *R. distinctus* (Table 3). Similarly, the abundance of *R. distinctus* did not vary significantly with season nor was the interaction between sex and season significant (Table 3). In contrast, *R. distinctus* abundance was significantly greater for females (1.11 ± 3.26) than for males (0.30 ± 0.59; Table 3).

The prevalence of *Ixodes* spp. varied significantly with season (Table 3, Figure 2a). *Post-hoc* tests showed that the prevalence of *Ixodes* spp. was significantly greater in April 2010 than in July 2010 (LSD: $P = 0.026$). In addition, *Ixodes* spp. prevalence was significantly lower in October 2010 compared with January 2011 (LSD: $P = 0.001$; Figure 2a). None of the remaining comparisons between consecutive months were significant ($p \geq 0.338$). Similarly, neither host sex nor the interaction between season and sex were significant (Table 3).

The mean abundance of *Ixodes* spp. varied significantly with season (Table 3, Figure 2b). *Post-hoc* analyses indicated that it was significantly higher in April 2010

Table 3: Results of GLMs for prevalence and abundance of common ectoparasite species collected from *Elephantulus myurus* in the Ezemvelo/Telperion Nature Reserve from April 2010 until April 2011. The *P*-values highlighted in bold indicate significant effects

Taxon		Season		Sex		Season*sex	
		Wald χ^2	*P*	Wald χ^2	*P*	Wald χ^2	*P*
Rhipicephalus warburtoni/arnoldi	Prevalence	–	–	–	–	–	–
	Abundance	11.725	**0.020**	0.796	0.372	1.014	0.908
Rhipicephalus distinctus	Prevalence	4.451	0.348	0.000	1.000	2.466	0.651
	Abundance	7.162	0.067	6.662	**0.010**	0.757	0.860
Rhipicentor nuttalli	Prevalence	0.194	0.996	0.000	1.000	0.546	0.969
	Abundance	4.542	0.209	0.573	0.449	1.251	0.263
Ixodes spp.	Prevalence	11.927	**0.018**	0.000	1.000	1.470	0.832
	Abundance	65.366	**<0.0001**	0.824	0.364	8.789	**0.032**
Chiggers	Prevalence	6.035	0.197	0.000	1.000	0.334	0.988
	Abundance	215.067	**<0.0001**	2.438	0.118	16.284	**0.003**

– No analyses were carried out for parasites with a prevalence of 100%

compared with July 2010 (LSD: *P* < 0.0001) and significantly lower in October 2010 than in January 2011 (LSD: *P* < 0.0001; Figure 2b). No other comparisons between successive months were significant (*P* ≥ 0.077). The interaction between season and sex was significant (Table 3, Figure 3a). *Post-hoc* analyses indicated that females carried a significantly greater number of *Ixodes* spp. in April 2010 than in July 2010 (LSD: *P* = 0.006) and in January 2011 than in April of the same year (LSD: *P* = 0.030; Figure 3a). Abundance increased significantly from October 2010 to January 2011 (LSD: *P* = 0.014). The numbers of *Ixodes* spp. on male sengis decreased significantly from April 2010 to July 2010 (LSD: *P* = 0.012) but increased significantly from October 2010 to January 2011 (LSD: *P* = 0.007; Figure 3a). None of the remaining comparisons between consecutive months were significant (*P* ≥ 0.340) for males nor were any of the comparisons between the sexes within a season significant (*P* ≥ 0.066). Neither the prevalence nor the abundance of *Rhipicentor nuttalli* was significantly affected by any of the factors considered (Table 3).

Mites
Only the larval stage (chiggers) of one family of mites (Trombiculidae) was recovered. Of all sengis captured, 51 (63%) were infested with chiggers, with the highest individual burden consisting of 1 850 mites. The prevalence of chiggers did not vary significantly with any of the factors considered (Table 3). In contrast, chigger abundance varied significantly with season (Table 3, Figure 4). *Post-hoc* analyses showed that it was significantly higher in April 2010 than in July 2010 and significantly lower in October 2010 compared with January 2011 (*P* < 0.0001 for both comparisons; Figure 4). In addition, the chigger abundance was significantly greater in January 2011compared with April 2011 (LSD: *P* = 0.023). Host sex had no significant effect on the abundance of chiggers (Table 3). However, the interaction between season and sex was significant (Table 3, Figure 3b). *Post-hoc* analyses indicated that the chigger abundance on male sengis in April 2010 was significantly greater than in July 2010 (LSD: *P* = 0.002) and in January 2011 compared with October 2010 (LSD: *P* = 0.005, Figure 3b). Chigger abundance decreased significantly on female sengis from July to
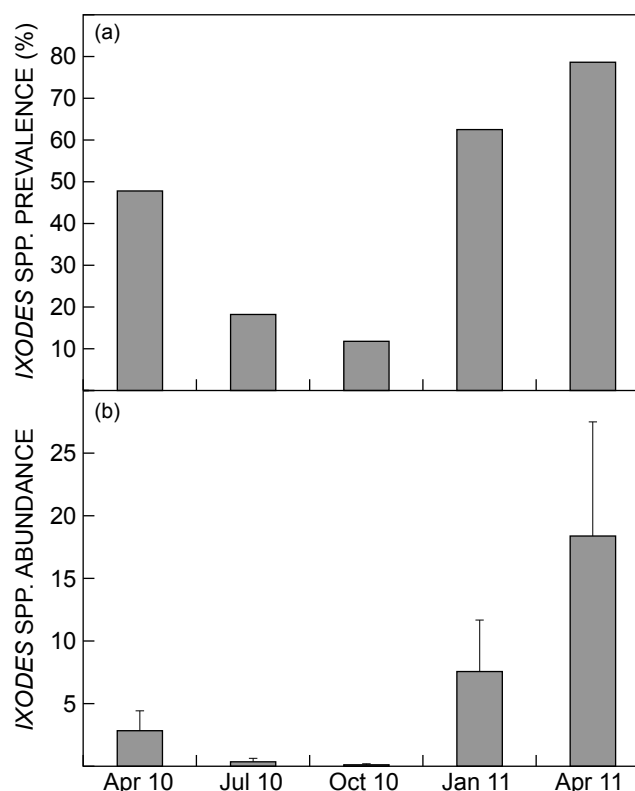
Figure 2: Seasonal variation of (a) prevalence and (b) mean abundance (±SE) of *Ixodes* spp. harboured by eastern rock sengis in the Ezemvelo/Telperion Nature Reserve

October 2010 (LSD: *P* = 0.003) and from January 2011 to April 2011 (LSD: *P* = 0.036). In contrast, the abundance of chiggers increased significantly from October 2010 to January 2011 (LSD: *P* = 0.005; Figure 3b). It was significantly lower for females compared with males in July (LSD: *P* = 0.004). None of the remaining pairwise comparisons was significant (*P* ≥ 0.055).

Lice
A total of 62 lice were collected and all were identified as *Neolinognathus elephantuli* (Table 2). Only eight animals
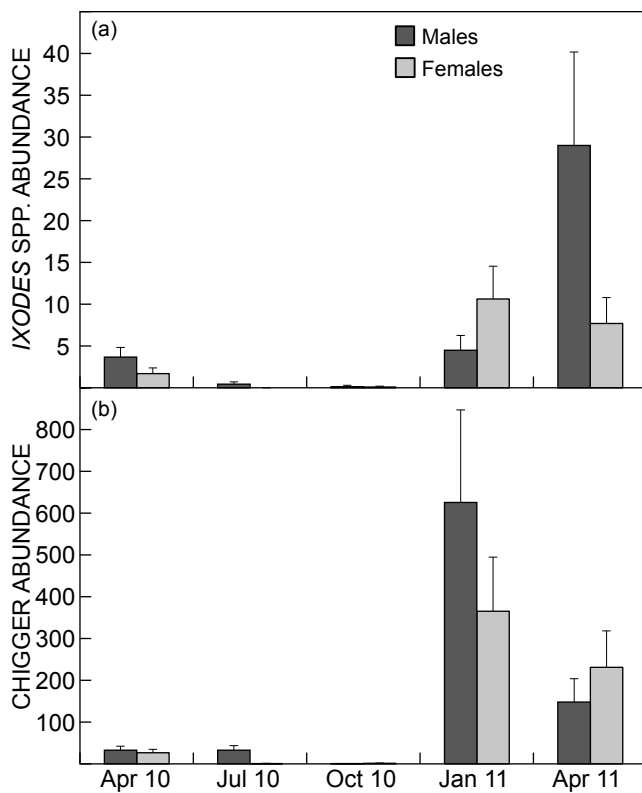
Figure 3: Variation of mean abundance (±SE) with sex and season for (a) *Ixodes* spp. and (b) chiggers on eastern rock sengis in Ezemvelo/Telperion Nature Reserve

Figure 4: Seasonal variation in the mean abundance (±SE) of chiggers found on eastern rock sengis in Ezemvelo/Telperion Nature Reserve

(9.9%) were infested and the highest individual burden consisted of 29 lice.

Fleas

A total of 32 fleas belonging to two species, namely *Demeillonia granti* and *Xenopsylla brasiliensis*, were collected from sengis in April 2011 (Table 2). Seven animals (8.6%) were infested and the highest individual burden was 11 fleas (Table 2). A total of 29 *Demeillonia granti* was collected from three individuals (two females and one male) and a single *Xenopsylla brasiliensis* was collected from each of three females.

Discussion

The present study recorded considerable ectoparasite species diversity on eastern rock sengis, a widely distributed small mammal in the southern African region. This is in agreement with the findings of previous studies, which indicated that eastern rock sengis were hosts for a large variety of parasite species, particularly ticks (Fourie et al. 1992, 1995; Beaucournu et al. 2003; Fourie et al. 2005; Harrison et al. 2011). Species richness was greatest in summer possibly because the rainfall and elevated temperatures favoured a number of the ectoparasite species encountered. The 11 tick species recovered in the present study represent the largest number of species recovered from eastern rock sengis at a single locality.
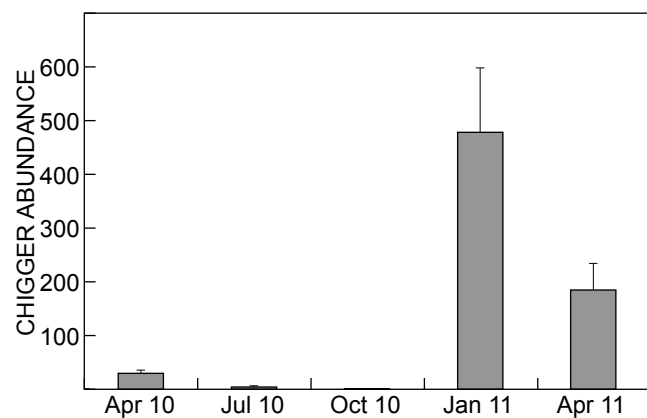
Sengis are amongst the preferred hosts of the immature stages of *R. arnoldi* and *R. warburtoni*, and virtually the sole hosts for the immature stages of *R. nuttalli* (Walker et al. 2000; Fourie et al. 2002, 2005). The prevalence of these ticks in the present study supports this fact. Sengis are also preferred hosts of the immature stages of *Ixodes rubicundus*, colloquially known as the Karoo paralysis tick, which was not recovered in this study. However, judging by the prevalence and abundance of the immature stages of the two *Ixodes* spp. that were collected, it would appear that sengis are preferred hosts for at least one *Ixodes* spp. The adults of *R. warburtoni* can induce paralysis in new-borne goat kids, those of *R. nuttalli* can cause paralysis in dogs, whereas the paralysis induced by the females of *I. rubicundus* has resulted in massive annual mortalities in sheep (Walker et al. 2000; Fourie et al. 2002, 2005). Hence, a better understanding of the factors driving the interaction between these tick species and sengis could provide valuable insights for disease management. The attachment rates and feeding success of the immature stages of *R. warburtoni* and *Ixodes rubicundus* are significantly higher on artificially infested eastern rock sengis than on similarly infested sympatric Namaqua rock mice (*Micaelamys namaquensis*) (Harrison et al. 2012). Sengis also appear to have little resistance to infestation by these ticks (du Toit et al. 1994; Harrison et al. 2012), highlighting the importance of this host for the population dynamics of these species.

The study site constitutes a new locality record for *R. appendiculatus*, a species for which all stages of development feed on large domestic and wild ruminants, particularly domestic cattle (Walker et al. 2000). With the exception of a single larva collected from a four-toed sengi (*Petrodromus tetradactylus*) in north-eastern KwaZulu-Natal (Horak et al. 2011), there are no records of *R. appendiculatus* on sengis. The presence of larvae and nymphs on sengis in this study indicates that this host–parasite association is possibly not rare, but has previously not been recorded because the localities at which the sengis were examined did not lie within the distribution range of the tick. This hypothesis is further supported by the observation that

large burdens of *Rhipicephalus muehlensi*, one of 11 tick species within the *R. appendiculatus* species group, have been collected from four-toed sengis (Horak et al. 2011).

All stages of development of *Rhipicephalus decoloratus* and *Rhipicephalus evertsi evertsi* infest large domestic and wild ruminants as well as equids (Horak et al. 1992; Walker et al. 2000). Sympatric habitat preferences of these hosts and rock sengis in the reserve, together with a likely large pool of free-living immature ticks, would account for the accidental infestations of a few larvae on the study species. Hyraxes are virtually the sole hosts of the adults of *R. distinctus*, with most collections coming from rock hyraxes (*Procavia capensis*) (Walker et al. 2000). The latter animals are plentiful on the rocky outcrops in the reserve. The immature stages of *R. distinctus* feed on murid rodents and those recovered from sengis are most likely stragglers from a large population of free-living immature ticks.

The immature stages of several ticks within the *Haemaphysalis* (*Rhipistoma*) spp. infest murid rodents and sengis are hence only accidental hosts, which may account for their low prevalence and abundance in the current study (Horak et al. 2005; Matthee et al. 2007; Apanaskevich et al. 2007).

The chiggers found in the current study constitute the first record of a trombiculid mite on eastern rock sengis. They may, however, be common on other sengi species (Fourie et al. 1995). We were unable to identify the species because of the lack of taxonomic expertise on this family of mites in South Africa. Trombiculidae (chiggers) are a large family with a worldwide distribution and are characterised by low host specificity (Shatrov and Kudryashova 2006). Only the larvae are parasitic and are known to cause skin irritations where their stylostomes pierce the host tissue and they may also transmit diseases such as scrub typhus (Shatrov and Kudryashova 2006).

Only one species of louse was found in the present study. Ledger (1980) described two species in the genus *Neolinognathus*, namely *N. elephantuli* and *N. prelautu*, both of which are specific to sengis. *Neolinognahtus elephantuli* has also been recorded from three other sengi species (*E. brachyrhynchus, E. rufescens* and *Petrodromys tetradactylus*) (Fourie et al. 1995), but its geographical distribution, biology and life cycle remain largely unknown.

Two flea species were recovered in this study, *Demeillonia granti* and *Xenopsylla brasiliensis*. Both members of the genus *Demeillonia*, *D. granti* and *D. miriamae*, are known to prefer sengis as hosts (Segerman 1995). *Demeillonia granti* has been reported from three other sengi species (*E. edwardii, E. rupestris* and *Macroscelides proboscideus*) as well as *M. namaquensis*, which share the same habitat (Zumpt 1966; Segerman 1995; Beaucournu et al. 2003). Fleas of the genus *Xenopsylla* are of medical importance as they are carriers of plague among wild rodents (Zumpt 1966; Segerman 1995). With the exception of *X. cheopis*, *X. brasiliensis*, also known as African flea, is the most widespread and efficient vector of plague in Africa. The usual host for *X. brasiliensis* is *Rattus rattus*, but it has also been recorded from murid rodents such as *Aethomys chrysophilus* and *Micaelamys namaquensis*, both of which may occur sympatrically with the study species (Zumpt

1966; Segerman 1995). With few exceptions this flea is commonly associated with nest-using rodents (Segerman 1995). In contrast, sengis do not use nests (Skinner and Chimimba 2005) and hence may not provide good environmental conditions for *X. brasiliensis*. Consequently, the infestation of sengis is likely accidental.

Three of the five main ectoparasite species of eastern rock sengis found in the study area showed marked seasonal patterns in prevalence and/or mean abundance. Since Acari spend most of their life cycle off-host and the risk of desiccation may be high during this time, this may be directly linked to climate factors, such as the seasonal variation in rainfall and temperature (Needham and Teel 1991; Benoit and Denlinger 2010). For example, the seasonal abundance of *R. warburtoni* has been linked to temperature as well as rainfall and was greater during cool dry months compared with hot wet months in a sengi population in the Limpopo province (Lutermann et al. 2012a). The seasonal pattern found in the current study appears to support this relationship. However, the peak in abundance of *R. warburtoni/arnoldi* in October was unexpected and may be linked to the onset of reproductive activity and the associated suppression of immune responses (Christe et al. 2000). This hypothesis is supported by a previous study in which the abundance of the immature stages of *R. warburtoni* on adult males and pregnant female eastern rock sengis was increased during the breeding season (August until March; Lutermann et al. 2012b).

It is likely that the seasonal variation in chigger abundance was also driven by increases in temperature and humidity (Marshall 1981) and, due to their smaller size, the risk of desiccation can be assumed to be higher for this species than for ticks. Increases in mite abundance with rainfall have previously been reported for several other mite species in South Africa irrespective of whether rainfall occurs during winter (Matthee et al. 2007; Archer et al. 2014) or summer (Viljoen et al. 2011) as in the current study. Unlike *R. warburtoni/arnoldi* the abundance of *Ixodes* spp. and chiggers was substantially lower in April 2010 than in April 2011. This may be a consequence of the former being much drier than the latter. The absence of marked seasonal patterns for the remaining two common tick species (*Rhipicephalus distinctus* and *Rhipicentor nuttalli*) could be linked to their generally low abundance. Indeed, *Rhipicentor nuttalli* never appears to be particularly abundant on sengis in other provinces of South Africa (Fourie et al. 1992, 2005).

Sex biases in abundance were found for three of the five most common ectoparasite species. The abundance of the *Ixodes* spp. and chiggers was male-biased during certain seasons. A similar bias has been reported for *I. rubicundus* in the Free State province of South Africa (Fourie et al. 1992). Due to the lack of body size effects and the monogamous mating system of sengis, we can largely exclude body or home range size as contributing factors towards the gender bias (Ribble and Perrin 2005; Lutermann et al. 2012b). In contrast, the male-bias could be explained by the increased susceptibility of males to Acari as a result of the immunosuppressive properties of testosterone (Hughes and Randolph 2001). It is surprising,

however, that this was not apparent for *R. warburtoni/ arnoldi* as higher *R. warburtoni* burdens have been recorded during the breeding season (August–March) on male sengis at other localities (Lutermann et al. 2012b). However, sex-biased parasitism is far from universal and may vary among parasite species infesting the same host as well as within the same parasite species when infesting different hosts (Krasnov and Matthee 2010; Scantlebury et al. 2010; Kiffner et al. 2013). Unexpectedly, the abundance of *R. distinctus* was female-biased and the causes for this are not immediately obvious. One potential explanation could be that pregnant females, but not breeding males, were particularly susceptible to this tick as has been shown for *R. warburtoni* (Lutermann et al. 2012b). The observation that the prevalence of *R. distinctus* was greater during the breeding season (38.3%) than during the non-breeding season (11.8%) would support this hypothesis. However, this remains currently speculative and further studies are needed to corroborate this hypothesis.

In conclusion, *E. myurus* is host to a large diversity of ectoparasitic arthropods at the study locality, the majority of which are ticks. At least eight of the 15 ectoparasite species collected appear to be either specific parasites of sengis or preferentially use them as hosts. The remaining seven species are most probably accidental infestations. Three of the five most common ectoparasite species collected exhibited seasonal patterns that are likely to be linked to climatic conditions. In addition, reproductive effort may contribute to this pattern for *R. warburtoni/arnoldi*, the most prevalent and abundant species. Both male- and female-biased parasite burdens were observed for several of the common species and we hypothesise that these may be linked to reproductive investment by the hosts. Future research is required to corroborate this hypothesis.

References

Altizer S, Dobson A, Hosseini P, Hudson P, Pascual M, Rohani P. 2006. Seasonality and the dynamics of infectious diseases. *Ecology Letters* 9: 467–484.

Apanaskevich A, Horak IG, Camicas JL. 2007. Redescription of *Haemaphysalis* (*Rhipistoma*) *elliptica* (Koch, 1844), an old taxon of the *Haemaphysalis* (*Rhipistoma*) *leachi* group from East and southern Africa, and of *Haemaphysalis* (*Rhipistoma*) *leachi* (Audouin, 1826) (Ixodida, Ixodidae). *Onderstepoort Journal of Veterinary Research* 74: 181–208.

Archer EK, Bennett NC, Ueckermann EA, Lutermann H. 2014. Ectoparasite burdens of the common mole-rat (*Cryptomys hottentotus hottentotus*) from the Cape Provinces of South Africa. *Journal of Parasitology* 100: 79–84.

Arthur DR. 1965. *Ticks of the genus Ixodes in Africa*. London: Athlone Press, University of London.

Beaucournu J-C, Horak IG, Fourie LJ. 2003. Fleas of elephant shrews (Mammalia, Macroscelididae), and a new host and locality record for *Macroscelidopsylla albertyni* De Meillon & Marcus, 1958 (Siphonaptera, Chimaeropsyllidae). *Onderstepoort Journal of Veterinary Research* 70: 251–253.

Benoit JB, Denlinger DL. 2010. Meeting the challenges of on-host and off-host water balance in blood-feeding arthropods. *Journal of Insect Physiology* 56: 1366–1376.

Boyer N, Réale D, Marmet J, Pisanu B, Chapuis J-L. 2010. Personality, space use and tick load in an introduced population of Siberian chipmunks *Tamias sibiricus*. *Journal of Animal Ecology* 79: 538–547.

Bush AO, Lafferty KD, Lotz JM, Shostak AW. 1997. Parasitology meets ecology on its own terms: Margolis et al revisited. *Journal of Parasitology* 83: 575–583.

Christe P, Arlettaz R, Vogel P. 2000. Variation in intensity of a parasitic mite (*Spinturnix myoti*) in relation to the reproductive cycle and immunocompetence of its bat host (*Myotis myotis*). *Ecology Letters* 3: 207–212.

du Toit JS, Fourie LJ, Horak IG. 1994. Sequential feeding of *Ixodes rubicundus* on its natural host, *Elephantulus myurus*: effects on tick mass and on engorgement and moulting success. *Onderstepoort Journal of Veterinary Research* 61: 143–147.

Fourie LJ, du Toit JS, Kok DJ, Horak IG. 1995. Arthropod parasites of elephant-shrews, with particular reference to ticks. *Mammal Review* 25: 31–37.

Fourie LJ, Horak IG, Kok DJ, van Zyl W. 2002. Hosts, seasonal occurrence and life cycle of *Rhipicentor nuttalli* (Acari: Ixodidae). *Onderstepoort Journal of Veterinary Research* 69: 177–87.

Fourie LJ, Horak IG, van den Heever JJ. 1992. The relative importance of rock elephant shrews *Elephantulus myurus* and Namaqua rock mice *Aethomys namaquensis* for economically important ticks. *South African Journal of Zoology* 27: 108–114.

Fourie LJ, Horak IG, Woodall PF. 2005. Elephant shrews as hosts of immature ixodid ticks. *Onderstepoort Journal of Veterinary Research* 72: 293–301.

Harrison A, Bown KJ, Horak IG. 2011. Detection of *Anaplasma bovis* in an undescribed tick species collected from the eastern rock sengi *Elephantulus myurus*. *Journal of Parasitology* 97: 1012–1016.

Harrison A, Robb GN, Bennett NC, Horak IG. 2012. Differential feeding success of two paralysis-inducing ticks, *Rhipicephalus warburtoni* and *Ixodes rubicundus* on sympatric small mammal species, *Elephantulus myurus* and *Micaelamys namaquensis*. *Veterinary Parasitology* 188: 346–354.

Horak IG, Anthonissen M, Krecek RC, Boomker J. 1992. Arthropod parasites of springbok, gemsbok, kudus, giraffes and Burchell and Hartman zebras in the Etosha and Hardap Nature Reserves, Namibia. *Onderstepoort Journal of Veterinary Research* 59: 253–257.

Horak IG, Fourie LJ, Braack LEO. 2005. Small mammals as hosts of immature ixodid ticks. *Onderstepoort Journal of Veterinary Research* 72: 255–261.

Horak IG, Lutermann H, Medger K, Apanaskevich DA, Matthee CA. 2012. Natural hosts of the larvae of *Nuttalliella* sp. (*N. namaqua*?) (Acari: Nuttalliellidae). *Onderstepoort Journal of Veterinary Research* 79: 405.

Horak IG, Welman S, Hallam SL, Lutermann H, Mzilikazi N. 2011. Ticks of four-toed elephant shrews and Southern African hedgehogs. *Onderstepoort Journal of Veterinary Research* 78(1): 243.

Hughes VL, Randolph SE. 2001. Testosterone depresses innate and acquired resistance to ticks in natural rodent hosts: a force for aggregated distributions of parasites. *Journal of Parasitology* 87: 49–54.

Kiffner C, Stanko M, Morand S, Khokhlova IS, Shenbrot GI, Laudisoit A, Leirs H, Hawlena H, Krasnov BR. 2013. Sex-biased parasitism is not universal: evidence from rodent-flea associations from three biomes. *Oecologia* 173: 1009–1022.

Kim KC. 2006. Blood-sucking lice (Anoplura) of small mammals: true parasites. In: Morand S, Krasnov BR, Poulin R (eds), *Micromammals and macroparasites: from evolutionary ecology to management*. Tokyo: Springer-Verlag. pp 141–160.

Klein SL. 2004. Hormonal and immunological mechanisms mediating sex differences in parasite infection. *Parasite Immunology* 26: 2472–2464.

Krantz GW, Walter ED. 2009. *A manual of acarology* (3rd edn). Lubbock: Texas Tech University Press.

Krasnov BR, Matthee S. 2010. Spatial variation in gender-biased parasitism: host-related, parasite-related and environment-related effects. *Parasitology* 137: 1527–1536.

Labuda M, Nuttall RA. 2004. Tick-borne viruses. *Parasitology* 129: S221–S245.

Ledger JA. 1980. *The arthropod parasites of vertebrates in Africa south of the Sahara, vol. IV: Phthiraptera (Insecta).* Johannesburg: South African Institute for Medical Research.

Lutermann H, Medger K, Horak IG. 2012a. Abiotic and biotic determinants of tick burdens in the eastern rock sengi (*Elephantulus myurus*). *Medical and Veterinary Entomology* 26: 255–262.

Lutermann H, Medger K, Horak IG. 2012b. Effects of life-history traits on parasitism in a monogamous mammal, the eastern rock sengi (*Elephantulus myurus*). *Naturwissenschaften* 99: 103–110.

Marshall AG. 1981. *The ecology of ectoparasitic insects*. London: Academic Press.

Martin LB, Weil ZM, Nelson RJ. 2008. Seasonal changes in vertebrate immune activity: mediation by physiological trade-offs. *Philosophical Transactions of the Royal Society B: Biological Sciences* 363: 321–339.

Matthee S, Horak IG, Beaucournu J-C, Durden LA, Ueckermann EA, Mcgeoch MA. 2007. Epifaunistic arthropod parasites of the four-striped mouse, *Rhabdomys pumilio*, in the Western Cape Province, South Africa. *Journal of Parasitology* 93: 47–59.

Matthee S, McGeoch MA, Krasnov BR. 2010. Parasite-specific variation and the extent of male-biased parasitism; an example with a South African rodent and ectoparasitic arthropods. *Parasitology* 137: 651–660.

Medger K, Chimimba CT, Bennett NC. 2012. Seasonal reproduction in the eastern rock elephant-shrew: influenced by rainfall and ambient temperature? *Journal of Zoology* 288: 283–293.

Moore SL, Wilson K. 2002. Parasites as a viability cost of sexual selection in natural populations of mammals. *Science* 297: 2015–2018.

Morand S, Krasnov BR, Poulin R (eds). 2006. *Micromammals and macroparasites: from evolutionary ecology to management*. Tokyo: Springer-Verlag.

Needham GR, Teel PD. 1991. Off-host physiological ecology of ixodid ticks. *Annual Review of Entomology* 36: 659–681.

Nelson RJ, Demas GE, Klein SL, Kriegsfeld LJ (eds). 2002. *Seasonal patterns of stress, immune function, and disease.* Cambridge: Cambridge University Press.

Poulin R. 2007. *Evolutionary ecology of parasites*. Princeton: Princeton University Press.

Randolph SE. 2004. Tick ecology: processes and patterns behind the epidemiological risk posed by ixodid ticks as vectors. *Parasitology* 129: S37–S65.

Ribble D, Perrin M. 2005. Social organization of the eastern rock elephant-shrew (*Elephantulus myurus*): the evidence for mate guarding. *Belgian Journal of Zoology* 135: 167–173.

Scantlebury M, Maher McWilliams M, Marks NJ, Dick JTA, Edgar H, Lutermann H. 2010. Effects of life-history traits on parasite load in grey squirrels. *Journal of Zoology* 282: 246–255.

Segerman J. 1995. *Siphonatera of southern Africa: a handbook for the identification of fleas*. Johannesburg: South African Institute for Medical Research.

Shatrov AB, Kudryashova NI. 2006. Taxonomy, life cycles and the origin of parasitism in trombiculid mites. In: Morand S, Krasnov BR, Poulin R (eds), *Micromammals and macroparasites: from evolutionary ecology to management*. Tokyo: Springer-Verlag. pp 119–140.

Skinner JD, Chimimba CT. 2005. *The mammals of the southern African subregion*. Cambridge: Cambridge University Press.

Swanepoel BA. 2006. The vegetation ecology of Ezemvelo Nature Reserve, Bronkhorstspruit, South Africa. MSc thesis, University of Pretoria, South Africa.

Theiler G. 1961. A contribution to the knowledge of African Ixodidae. The genus *Rhipicentor*. *Revue de Zoologie et de Botanique Africaines* 66: 297–308.

Viljoen H, Bennett NC, Ueckermann EA, Lutermann H. 2011. The role of host traits, season and group size on parasite burdens in a cooperative mammal. *PLoS ONE* 6: e27003.

Walker JB, Keirans JE, Horak IG. 2000. *The genus* Rhipicephalus *(Acari, Ixodidae): a guide to the brown ticks of the world*. New York: Cambridge University Press.

Wilson K, Bjørnstad ON, Dobson AP, Merler S, Poglayen G, Randolph SE, Read AF, Skorping A. 2001. Heterogeneities in macroparasite infections: patterns and processes. In: Hudson PJ, Rizzoli A, Grenfell BT, Heesterbeek H, Dobson AP (eds), *The ecology of wildlife diseases*. New York: Oxford University Press. pp 6–44.

Zumpt F. 1966. *The arthropod parasites of vertebrates in Africa south of the Sahara, vol. III (Insecta excl. Phthiraptera)*. Johannesburg: South African Institute of Medical Research.