Ectoparasite diversity on rodents at De Hoop Nature Reserve, Western Cape Province

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Fleas, lice, mites and ticks were collected from 41 *Rhabdomys pumilio* and seven *Otomys irroratus* at De Hoop Nature Reserve in the Western Cape Province of South Africa. The aims of the study were firstly to quantify parasite abundance and to record the species richness on the rodents. Secondly to record the parasite species that were shared between *R. pumilio* and *O. irroratus* and thirdly to compare the parasite abundance on *R. pumilio* between localities of varying antelope activity. Each rodent was individually examined under a stereoscopic microscope and its parasites were removed, counted and identified to species level. The parasite species included seven flea, one louse, nine mite and 10 tick species. Three undescribed mite species were also recovered and new locality records were obtained for six flea, two lice, two mite and one tick species. Several flea, mite and tick species were shared between *R. pumilio* and *O. irroratus*. Both the mean abundance of the total ectoparasite burdens and the mean tick abundance were significantly higher on *R. pumilio* individuals that were trapped in habitats preferred and occupied by large antelope species compared to habitats in which antelope were absent or rarely present.

Key words: fleas, lice, mites, ticks, rodents.

INTRODUCTION

South Africa has a considerable diversity of plant and animal species and especially so for small mammals (Skinner & Chimimba 2005). Small mammals such as members of the Muridae and Cricetidae often occur in large numbers and play an important role in maintaining ecosystems (Dickman 1999). Little is known about the diversity of ectoparasites, especially fleas, lice, and mites, associated with small mammals in the Western Cape Province (WCP). Most of the research conducted here to date, has been mainly descriptive, has focused on ticks and been biased by limited sampling (e.g. Horak *et al.* 1986; Horak & Boomker 1998; Petney *et al.* 2004). In an attempt to address the paucity of information Matthee *et al.* (2007) used an intensive sampling approach to record ectoparasite diversity on the four-striped mouse, *Rhabdomys pumilio* (Muridae) in the Cape Floristic Region. It is evident from the latter study that *R. pumilio* harbours a large variety of parasite species (more than 30) and is an important host for several of the parasites. In addition, several new mite and one new tick species were recorded in the study (Matthee & Ueckermann 2008, 2009; Apanaskevich *et al.*, in press). The substantial parasite diversity associated with this host may be due to its generalist nature and adaptability to anthropogenic activities in the region (Matthee, unpubl. data). A number of parasites that are found on *R. pumilio* are of importance in the etiology of zoonotic diseases in humans, and play an important role in the transmission of diseases of domestic and wild animals (Walker 1991; Norval & Horak 2004).

There are several other small mammal species that co-occur with *R. pumilio.* In particular vlei rats, *Otomys irroratus* (Cricetidae) are often trapped in the same area as *R. pumilio* in the Cape Floristic Region (Matthee, unpubl. data) while whistling rats, *Parotomys littledalei,* and bush karoo rats, *Otomys unisulcatus,* seem to co-occur with *R. pumilio* in the succulent Karoo (Schradin 2005, 2006). Several fleas, mites, ticks and a louse species are listed as

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potential parasites of *O. irroratus*, but the species lists are generally old and need to be updated (Zumpt 1961; Theiler 1962, Ledger 1980; Segerman 1995).

The present study focused on the ectoparasite species associated with *R. pumilio* and *O. irroratus* at De Hoop Nature Reserve (DHNR), WCP. The small rodents were trapped as part of a larger study that investigated the feasibility of using Strontium isotope analysis to determine large herbivore habitat preference, with the rodents providing a proxy for the bio-available $^{87}Sr/^{86}Sr$ ratio's of the respective habitat types within DHNR (Radloff 2008). The mammal species at DHNR include several large antelope species such as bontebok (*Damaliscus pygargus pygargus*) and eland (*Tragelaphus oryx*). Large antelopes (Bovidae) have their own ectoparasite assemblages (Zumpt 1961; Theiler 1962; Ledger 1980; Walker 1991). Certain ectoparasite taxa such as sucking lice have co-evolved with the hair diameter of their hosts and thus there is no sharing of species between large antelopes and small rodents. By contrast, certain tick species, for example *Hyalomma truncatum*, make use of rodents (for the immature stages) and large antelopes (for the adult stages) (Theiler 1962).

The aims of the study were firstly to make an inventory of the ectoparasite species associated with *R. pumilio* and *O. irroratus* at DHNR. This information will contribute to the existing literature on ectoparasite diversity on small mammals in the WCP and will provide data on the geographical distribution of species within the region. The second aim was to compare the parasite abundance on *R. pumilio* between localities that vary with respect to large antelope use in the reserve. We predict that the presence of bontebok and eland in a specific habitat will have a positive effect on the ectoparasite abundance, but that this effect will vary between ectoparasite taxa because of differences in life history patterns and association with hosts.

MATERIALS & METHODS

Study site

Rhabdomys pumilio (Sparrman) and *Otomys irroratus* (Brants) were trapped at 21 sites distributed between the five major habitat types of DHNR (34°26′S, 20°30′E) in the Western Cape Province (WCP) (Fig. 1). The Reserve has three distinct geological substrates: sandstones of the Table Mountain Group, marine-related limestones of the Bredasdorp Group and shales of the Bokkeveld Group (Coetzee 1993; Malan *et al.* 1994). The geological substrates support five major vegetation types: a) shale renosterveld, b) sandstone fynbos on the Potberg Mountain, c) limestone fynbos, d) limestone fynbos interspersed with sand filled karstic sinkhole depressions supporting grazing lawns, and e) sand fynbos and strandveld on highly leached sands in the valley at the base of the Potberg Mountain and on the dunes next to the coastline (Mucina *et al.* 2007). An aerial census during October 2006 provided the following large herbivore numbers for the reserve: 511 bontebok, 497 eland, 76 Cape mountain zebra (*Equus zebra*) and 460 ostriches (*Struthio camelus*) (Smith 2006).

Sampling protocol and data analysis

The project was approved by the Ethical Committee of the University of Stellenbosch and permits were issued by the Western Cape Nature Conservation Board. One hundred and two live traps (Sherman-type) were used for the study. The traps were baited with peanut butter and oats and set over 10 nights to trap *R. pumilio* and *O. irroratus* between 8 and 17 May 2006 (which corresponded with the onset of winter and generally characterized by cold and wet conditions). Adult male and female *R. pumilio* (mass ≥30 g) and *O. irroratus* individuals (males and females) weighing between 90 and 134 g were sampled during this period. The traps were set during the afternoon and checked every morning. Once trapped, the animals were identified and either killed with Fluothane (for *R. pumilio* and *O. irroratus*) or released at the trap site (any non-target species). Each rodent was individually placed in a pre-marked plastic bag and frozen for later thawing and examination. The entire thawed animal was systematically examined under a stereoscopic microscope, and forceps were used to remove ectoparasites.

All fleas, lice, mites and ticks were collected and counted. Where possible, the fleas, mites and ticks were identified to species level. Lice that were collected from *R. pumilio* were assumed to belong to a single species (*Polyplax arvicanthis* Bedford 1919) based on similar morphology, the fact that *P. arvicanthis* is host specific to this rodent (Ledger 1980) and previous studies conducted on *R. pumilio* in the Western and Northern Cape Provinces and Namibia have only recovered *P. arvicanthis* from *R. pumilio* (Matthee *et al.* 2007; Matthee *et al.*,

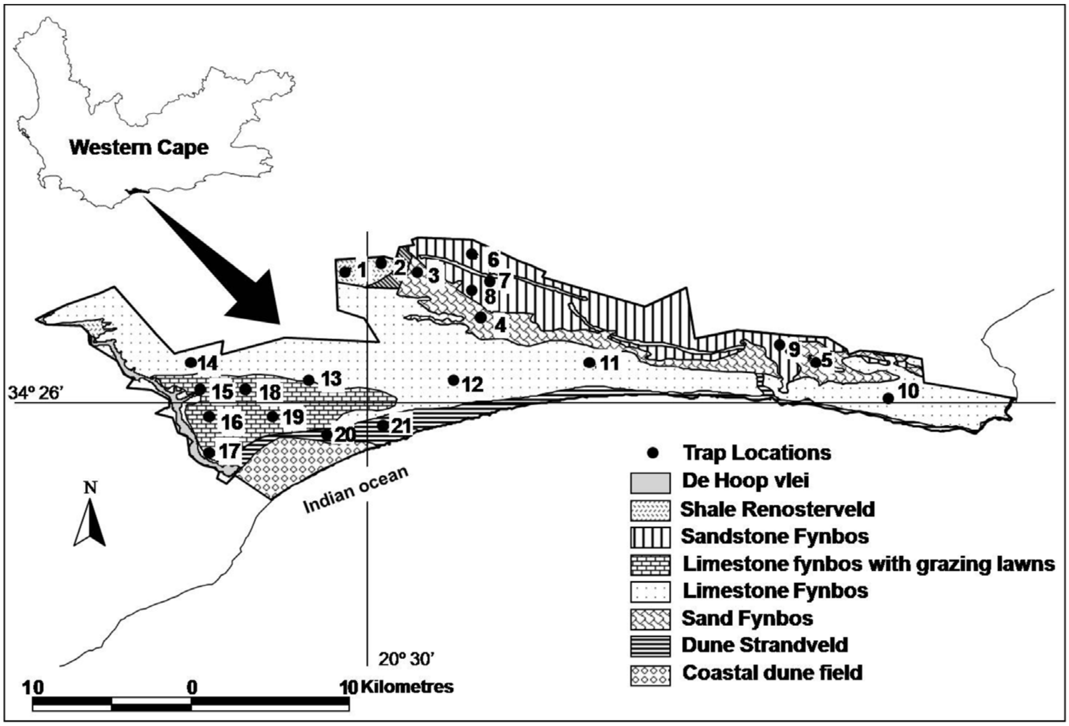

Fig. 1. The 21 trap locations in relation to the major vegetation types of De Hoop Nature Reserve as identified by Mucina *et al.* (2007).

unpubl. data). Lice collected from *O. irroratus* were also not identified, and were assumed to be *Polyplax otomydis* (Cummings 1921) based on Ledger (1980) and previous studies on *O. irroratus* in which *P. otomydis* was identified by L.A. Durden, an expert taxonomist (Matthee *et al.*, unpubl. data).

The habitat use of eland and bontebok in DHNR were assessed by surveying dung abundance in circular plots along set transects within each of the five habitat types during the summer months of 2006 and 2007. Transect placement was standardized for slope and distance from water within each of the habitat types. For more detail see Radloff (2008).

The mean abundance, standard error and prevalence were calculated for total parasite burdens, the four higher taxa and for individual parasite species. A Kruskal-Wallis analysis of variance, followed by a non-parametric multiple comparison test of mean ranks for all groups, were performed on the total parasite burdens and the four higher taxa between the five main habitat types. Statistica version 9, StatSoft© was used for the analyses.

RESULTS

Parasite diversity on rodents

Most *R. pumilio* and *O. irroratus* individuals were not reproductively active, and only a few males were scrotal (<30% for both). In total, 28 ectoparasite species were collected from 41 *R. pumilio* and 7 *O. irroratus* at DHNR. Ticks represented the largest number of species (36%) followed by mites (32%), fleas (25%) and sucking lice (7%) (Table 1). *Rhabdomys pumilio* and *O. irroratus* shared several tick (5), mite (2) and flea (5) species (Table 1).

Ten ixodid tick species, representing four genera, were recovered from *R. pumilio* and *O. irroratus* (Table 1). The highest proportion of tick life stages were larvae (90.5%), followed by nymphs (8.8%). The former also showed the highest prevalence (82.9%) compared to nymphs (48.8%) (Table 2). We were unable to identify the larvae of two *Ixodes* spp., and for convenience we refer to them as *Ixodes* sp. 1 and 2. Ticks of the *Rhipicephalus gertrudae* group were the most abundant (7.6 ± 2.3 and 2.4 ± 2, respectively) and prevalent (65.9% and 42.9%, respectively) on the two host species.

Table 1. Tick, mite, flea and lice species list for 41 *Rhabdomys pumilio* and seven *Otomys irroratus* at De Hoop Nature Reserve, Western Cape Province, South Africa, 8–17 May 2006.

Group	Suborder	Family	Subfamily/Species	*R. pumilio*	*O. irroratus*
Ticks	Ixodida	Ixodidae	Haemaphysalinae		
			Haemaphysalis elliptica (Koch 1844)	X	
			Hyalomminae		
			Hyalomma truncatum (Koch 1844)	X	
			Ixodinae		
			Ixodes sp. 1	X	X
			Ixodes sp. 2	X	
			I. elongatus?		X
			I. bakeri (Arthur & Clifford 1961)	X	X
			I. fynbosensis (Apanaskevich, Horak, Matthee & Matthee, in press)	X	
			I. pilosus (Koch 1844)	X	X
			Rhipicephalinae		
			Rhipicephalus follis (Dönitz 1910)	X	X
			R. gertrudae group	X	X
Mites	Mesotigmata	Laelaptidae	Laelaptinae		
			Androlaelaps dasymys (Radford 1939)	X	X
			A. fahrenholzi (Berlese 1911)	X	
			Laelaps sp. 1	X	X
			Laelaps sp. 2		X
			Laelaps sp. 3	X	
			Laelaps giganteus (Berlese 1918)	X	
	Astigmata	Atopomelidae	Atopomelinae		
			Listrophoroides womersleyi (Lawrence 1951)		X
	Trombidiformes	Trombiculidae	Trombiculinae		
			Uncertain genus 1	X	
			Uncertain genus 2		X
Fleas		Chimaeropsyllidae	*Chiastopsylla rossi* (Waterston 1909)	X	X
			Dinopsylla tenax (Jordan 1930)	X	X
			Hysopthalmus temporis (De Meillon 1940)	X	X
			Listropsylla agrippinae (Rothschild 1904)	X	X
			L. dorripae (Rothschild 1904)	X	X
			Xenopsylla hirsuta group		X
			X. sulcata (Ingram 1928)		X
Lice	Anoplura	Polyplacidae	*Polyplax arvicanthis* (Bedford 1919)	X	
			P. otomydis (Cummings 1912)		X

Ixodes sp. 2 and *Hyalomma truncatum* were the second and third most numerous ticks on *R. pumilio.* No clear separation could be made for *O. irroratus,* and both *Ixodes* sp. 1 and *Ixodes* sp. 2 were present.

Nine mite species representing at least three genera were collected (Table 1). *Laelaps giganteus* was the most numerous mite and was present on 73.2% of *R. pumilio. Androlaelaps dasymys* and *A. fahrenholzi* were the second and third most numerous mites on this host. By contrast, an unidentified *Laelaps* species (*Laelaps* sp. 1) was the most prevalent (71%) and abundant 3.4 (±1.6) mite on *O. irroratus. Androlaelaps dasymys* and *Listrophoroides womersleyi* were the second and third most numerous species on *O. irroratus.* Three undescribed mite species were recorded, *Laeplaps* sp. 1, *Laeplaps* sp. 2 and *Laeplaps* sp. 3, all of which will be described in a separate publication. Unidentified trombiculid (chigger) mites were found on three *R. pumilio* and one *O. irroratus* individuals. Female-biased sex ratios were recorded for all the mite species on *R. pumilio* (Table 2).

Seven flea species representing five genera were

Table 2. Mean abundance (± SE) and prevalence of tick, mite, and flea life stages and mean abundance (±SE) and prevalence for lice collected from 41 *Rhabdomys pumilio* at De Hoop Nature Reserve, Western Cape Province, South Africa (May 2006).

Group	Species	Mean abundance (±SE)					Prevalence (%)				
		Larvae	Nymphs	Males	Females	Total	Larvae	Nymphs	Males	Females	Total
Ticks		9.73 (±2.95)	0.95 (±0.19)	0	0.07 (±0.05)	10.76 (±2.96)	82.93	48.78	0	4.88	92.68
	H. elliptica	0.10 (±0.05)	0.10 (±0.06)	0	0	0.20 (±0.08)	9.76	7.32	0	0	14.63
	H. truncatum	0.71 ±0.61)	0.10 (±0.05)	0	0	0.81 (±0.63)	9.76	9.76	0	0	17.07
	Ixodes sp. 1	0.12 (±0.08)	0	0	0	0.10 (±0.08)	7.32	0	0	0	4.88
	Ixodes sp. 2	1.05 (±0.39)	0	0	0	1.07 (±0.39)	31.71	0	0	0	34.15
	I. bakeri	0.22 (±0.13)	0.12 (±0.06)	0	0.07 (±0.05)	0.42 (±0.15)	12.20	9.76	0	4.88	21.95
	I. fynbosensis	0	0.49 (±0.15)	0	0	0.49 (±0.15)	0	26.83	0	0	26.83
	I. pilosus	0.05 (±0.05)	0	0	0	0.05 (±0.05)	2.44	0	0	0	2.40
	R. follis	0	0.02 (±0.02)	0	0	0.02 (±0.02)	0	2.44	0	0	2.44
	R. gertrudae grp	7.49 (±2.29)	0.12 (±0.05)	0	0	7.61 (±2.29)	60.98	12.20	0	0	65.85
Mites			0.20 (±0.09)	0.07 (±0.04)	2.78 (±0.30)	3.32 (±0.36)		14.63	7.32	82.93	87.81
	A. dasymys		0.07 (±0.04)	0.07 (±0.04)	0.22 (±0.14)	0.44 (±0.18)		9.76	7.32	7.32	17.07
	A. fahrenholzi		0.01 (±0.01)	0	0.29 (±0.14)	0.44 (±0.19)		2.44	0	14.60	17.07
	Laelaps sp. 1		0.01 (±0.01)	0	0.17 (±0.08)	0.2 (±0.1)		2.44	0	12.20	12.19
	Laelaps sp. 3		0	0	0.05 (±0.05)	0.05 (±0.05)			0	2.44	2.44
	L. giganteus		0	0	2.05 (±0.27)	1.98 (±0.26)			0	73.20	70.73
Fleas				1.39 (±0.30)	1.56 (±0.40)	5.81 (±2.94)			56.10	53.66	70.73
	C. rossi			0.69 (±0.22)	0.60 (±0.21)	1.27 (±0.38)			34.15	24.39	43.90
	D. tenax			0.25 (±0.08)	0.05 (±0.03)	0.32 (±0.09)			19.51	4.88	26.83
	H. temporis			0.10 (±0.05)	0.42 (±0.16)	0.51 (±0.16)			9.76	24.39	34.15
	L. agrippinae			0.34 (±0.10)	0.51 (±0.17)	0.85 (±0.23)			26.83	21.95	34.15
	L. dorripae			0.02 (±0.02)	0	0.02 (±0.02)			2.44	0	2.44
Louse	*P. arvicanthis*					12.66 (±2.91)					65.85

Table 3. Comparison of the relative host density and mean abundance (±S.E.) for the combined ectoparasite abundance and the individual tick, mite, flea and louse burdens of *Rhabdomys pumilio* between different habitat types of De Hoop Nature Reserve, WCP. Different superscript letters denote significant differences between group means ($P < 0.05$).

Habitat type	Relative density of *R. pumilio**	Parasite abundance (mean ± S.E.)				
		Combined	Ticks	Mites	Fleas	Lice
Sandstone fynbos	0.06	10.40 (±1.86)[a]	2.40 (±0.68)[a]	3.40 (±1.08)[a]	0.40 (±0.25)[a]	4.2 (±2.2)[a]
Limestone fynbos	0.18	30.09 (±5.22)[ab]	6.73 (±1.34)[ab]	4.73 (±0.59)[a]	2.09 (±0.53)[a]	16.55 (±5.0)[a]
Sand fynbos	0.12	25.89 (±4.73)[ab]	5.89 (±1.93)[ab]	3.67 (±1.01)[a]	3.44 (±1.80)[a]	12.89 (±4.57)[a]
Limestone fynbos with grazing lawn	0.12	23.08 (±6.21)[ab]	7.42 (±2.78)[ab]	2.17 (±0.39)[a]	2.92 (±0.73)[a]	10.58 (±6.20)[a]
Shale renosterveld	0.18	81.25 (±38.19)[b]	53.25 (±19.92)[b]	2.00 (±1.15)[a]	7.75 (±3.96)[a]	18.25 (±17.59)[a]

*number of mice/trap.

recovered (Table 1). *Chiastopsylla rossi* was the most numerous and prevalent flea (43.9%) on *R. pumilio* (Table 2). *Dinopsylla tenax* was the most numerous flea on *O. irroratus* with a prevalence of 71.4%. Two flea species *Listropsylla agrippinae* and *Hysopthalmus temporis* alternated between second and third most numerous, respectively, on *R. pumilio* and *O. irroratus.*

Sucking lice were collected from both *R. pumilio* and *O. irroratus. Polyplax arvicanthis* was the most abundant taxon and species on *R. pumilio* with a prevalence of 65.9% and a mean abundance of 12.7 (±2.9). The louse *P. otomydis* was present on almost half of the *O. irroratus* (42.9%). The abundance of this louse was extraordinarily high ($n = 263$) on a single female; when this female specimen was excluded, mean abundance was 1.0 (±0.6).

Parasite abundance and antelope activity

Both total ectoparasite abundance and the individual abundances of fleas, lice and ticks were higher on *R. pumilio* individuals that were trapped in the shale renosterveld habitat compared to that of the sandstone fynbos. This pattern was significant for the combined ectoparasite abundance ($H_{4,41} = 10.38$, $P < 0.05$) and for the ticks ($H_{4,41} = 11.53$, $P < 0.05$) (Table 3).

DISCUSSION

A diverse assemblage of parasite species was collected from *R. pumilio* and *O. irroratus* at DHNR in the WCP. This study confirms previous reports that the four-striped mouse is host to a large number of parasite species (Matthee *et al.* 2007). In addition to the three undescribed mite species, new locality records were recorded for six flea species (*Chiastopsylla rossi, Dinopsylla tenax, Hysopthalmus temporis, Listropsylla dorripae, Xenopsylla hirsuta* group and *X. sulcata*) (Segerman 1995), a mite (*Listrophoroides womersleyi*; Zumpt 1961) and a tick species (*Ixodes fynbosensis*; Apanaskevich *et al.,* in press). This study also provides novel data on the ectoparasite species that are found on vlei rats in the WCP. Species lists for this host in South Africa include several potential flea (Segerman 1995), mite (Zumpt 1961) and tick species (Theiler 1962), while Ledger (1980) lists one louse species (*P. otomydis*). The present study adds to the current lists with new host records for two flea species (*L. dorippae* and *X. sulcata*), a mite (*Androlaelaps dasymys*) and four tick species (*Ixodes bakeri, Ixodes pilosus, Rhipicephalus follis* and *Rhipicephalus gertrudae* group) on *O. irroratus.* Ectoparasite species richness on *O. irroratus* was lower than that on *R. pumilio.* It is uncertain whether vlei rats generally have fewer parasites than striped mice as the current pattern may be an artefact of a smaller sample size (Walther *et al.* 1995; Feliu *et al.* 1997; Poulin & Morand 2004). A female-biased sex-ratio was recorded for several of the flea species, all the mites and a tick species (*I. bakeri*) on *R. pumilio.* On-host female-bias in parasite infestations seems to be common for ectoparasitic insects such as lice and fleas, while the specific reproductive systems of mites and the life history of *Ixodes* spp. may facilitate a female bias (Marshall 1981a; Norton *et al.* 1993; Sonenshine 1993; Matthee *et al.* 2007).

Ten ixodid tick species, representing four genera were recovered from *R. pumilio* and *O. irroratus.* Most of the ticks that were collected were larvae, followed by nymphs. The predominance of immature stages on small rodents is a common phenomenon (Walker 1991; Petney *et al.* 2004;

Matthee *et al.* 2007) and may be attributed to several factors such as host grooming (Gallivan & Horak 1997), the behaviour and microclimatic preference of different life stages (Short *et al.* 1989; Mejlon & Jeanson 1997), and the host preferences of tick species (Walker 1991). Seven of the nine tick species that were collected from *R. pumilio* had previously been recorded on this host (Horak *et al.* 1986; Horak & Boomker 1998; Matthee *et al.* 2007). The immature stages of *Haemaphysalis elliptica* commonly occur on rodents (Walker 1991), while the adults are associated with domestic dogs and large wild felids in South Africa (Horak *et al.* 1987, 2000; Horak & Matthee 2003). This tick is of medical and veterinary importance because of its role as a vector of several pathogens including the causative agents of canine babesiosis and human tick-bite fever (Walker 1991; Apanaskevich *et al.* 2007). In the present study *H. elliptica* was present in low numbers on *R. pumilio,* and was absent on *O. irroratus.* This is in accordance with a previous study on *R. pumilio* in the WCP in which it was present in low to moderate numbers (Matthee *et al.* 2007).

Hyalomma truncatum is widely distributed throughout South Africa and is the only one of the three southern African *Hyalomma* species that occurs in the coastal belt of the WCP (Howell *et al.* 1983). This tick is of veterinary and medical importance because of its role in the transmission of *Babesia caballi,* the causative agent of equine babesiosis in South Africa (De Waal 1990). It is also capable of producing a toxin that causes sweating sickness in cattle (Neitz 1954; Dolan & Newson 1980), and that can cause necrotic lesions on dogs around the bites of adult ticks (Burr 1983). *Hyalomma truncatum* was the second most abundant tick on *R. pumilio* in the present study. However, this was mainly due to the presence of numerous individuals (26) on a single scrotal male *R. pumilo.* The level of infestation was low (1–2 ticks) on six of the seven *R. pumilio* that were positive. The immature stages have a predilection for *Lepus* species (e.g Cape and scrub hares, *Lepus capensis* and *L. saxatilis*) (Horak & Fourie 1991), while various rodents can also act as hosts (Walker 1991). The presence of *H. truncatum* on *R. pumilio* supports a previous study in the WCP (Matthee *et al.* 2007). This species was absent on *O. irroratus.*

Six *Ixodes* species were recovered of which two are known species (*I. bakeri* and *I. pilosus*), one is a newly described species (*I. fynbosensis*) and the species identities of the remaining three are uncertain (*I. elongatus*?) or unknown (*Ixodes* sp. 1 and *Ixodes* sp. 2). The distribution of *I. bakeri* is restricted to South Africa and previous records list isolated localities in Gauteng, KwaZulu-Natal and WCP (Stellenbosch) (Walker 1991), and around Grahamstown in the ECP (Petney *et al.* 2004). The present study provides a new locality record for *I. bakeri* as no records exist along the coastal belt of South Africa. An interesting aspect of the life cycle of this tick is that both the immature and adult stages prefer rodents such as vlei rats and also shrews (*Crocidura mariquensis* and *Myosorex varius*) (Walker 1991). This is evident from the fact that a nymph and four female ticks were collected from four *Otomys* spp. individuals in the ECP (Petney *et al.* 2004), and from *R. pumilio* in the present study (a female tick) and previously in the WCP (predominantly female ticks, Matthee *et al.* 2007). The tick was present in moderate abundance on *R. pumilio* in the present study, while only a single tick was recorded on *O. irroratus. Ixodes fynbosensis* is a recently described species, whose immature stages are present in large numbers on *R. pumilio* in the Stellenbosch and Grabouw regions of the WCP (Matthee *et al.* 2007; Apanaskevich *et al.,* in press). Its presence in this study can thus be regarded as a new locality record for *I. fynbosensis.* It was present in moderate abundance on a quarter of the *R. pumilio* individuals. It was absent on *O. irroratus. Ixodes pilosus* seems to occur in the southern parts of KwaZulu-Natal as well as in parts of the WCP (Walker 1991). The tick has a wide host preference that includes antelope, small carnivores and scrub hares (Horak *et al.* 1986, 2000). The presence of a few individuals on a single *R. pumilio* and *O. irroratus* in the present study can thus be seen as accidental infestations. Based on morphological similarities we suggest that the single male tick that was recorded on *O. irroratus* is in fact *I. elongatus.* To date only adult females of this species have been described and illustrated and it is thus difficult to identify with certainty, hence we refer to this specimen as *I. elongatus*? *Ixodes elongatus* has a patchy distribution that includes localities in Gauteng and the ECP (Walker 1991). The present study represents a new locality record for this tick. Rats, mice (Muridae), shrews (Soricidae) and elephant shrews (Macroscelididae) are noted as potential hosts (Walker 1991). We were unable to identify the larvae of two *Ixodes* species that were also collected. *Ixodes* sp. 1 was present in low numbers (1–3) on two *R. pumilio* and on a single *O. irroratus.*

By contrast, *Ixodes* sp. 2 was the second most abundant (1.07 ± 0.39) and prevalent (34%) tick species on *R. pumilio.*

The genus *Rhipicephalus* was represented by larvae (60.9%) and nymphs (12.2%) belonging to the *R. gertrudae* group and nymphs of *R. follis.* Although the majority of larvae collected were *R. gertrudae,* other larvae similar in appearance to *R. gertrudae,* namely, *R. capensis, R. follis, R. lounsburyi* and *R. simus,* were possibly also present. The immature larval stages of these species were pooled due to the difficulty in distinguishing between them (Walker *et al.* 2000). In this paper detailed discussion will only focus on *R. gertudae* and *R. follis. Rhipicephalus gertrudae* is widely distributed in the WCP, in the Free State Province, NCP and parts of Namibia (Walker *et al.* 2000). Rodents seem to be preferred hosts for the immature stages (Walker 1991; Fourie *et al.* 1992; Matthee *et al.* 2007). In the present study ticks of the *R. gertrudae* group were the most abundant (7.6 ± 2.3) and prevalent (>60%) ticks on *R. pumilio.* This is in agreement with the study by Matthee *et al.* (2007). They were also the most abundant and prevalent on *O. irroratus. Rhipicephalus follis* is widely distributed in the eastern and southern regions of South Africa (Walker *et al.* 2000), and the immature stages prefer rodents (Petney *et al.* 2004). Only two nymphs were collected, one each on *R. pumilio* and *O. irroratus.*

Nine mite species were recorded on *R. pumilio* and *O. irroratus.* The mesostigmatid mites *A. dasymys, A. fahrenholzi* and *Laelaps giganteus* have a wide geographic range in South Africa and seem to have a preference for a large number of small rodent species (Zumpt 1961; Till 1963). The current geographic distribution of these mites is broadly listed as the Cape Province and it is uncertain whether DHNR represents a new locality record (Zumpt 1961; Till 1963). All three species have, however, previously been recorded on *R. pumilio* in the WCP (Matthee *et al.* 2007). In the latter study *A. fahrenholzi* was the most abundant and prevalent species, followed by *L. giganteus.* This is in contrast to the present study where *L. giganteus* was the most abundant mite on *R. pumilio. Androlaelaps dasymys* was the only mite of the three species that was recorded on *O. irroratus* in the present study. In addition three undescribed mite species (subfamily Laelapinae) were recorded of which one, *Laelaps* sp. 1 was the most abundant species on *O. irroratus.*

An astigmatid mite, *L. womersleyi,* was collected from *O. irroratus.* This record is interesting in that previous locality details only list the Drakensberg range and Pietermaritzburg, KwaZulu-Natal (Zumpt 1961). De Hoop Nature Reserve therefore represents a new locality record and the most southerly occurrence of the mite in South Africa. Its presence on *O. irroratus* supports previous data on its host preference (Zumpt 1961). Chigger mites (Trombiculidae, Prostigmata) are a diverse group in the Acari and only their larval stages are parasitic (Zumpt 1961). Trombiculids are of medical and veterinary importance because they can cause chigger dermatitis (Heyne *et al.* 2001) and for their role in the transmission of the causative agent of scrub typhus in humans (Roberts & Janovy 2000). Several species occur in South Africa and especially on small rodents. It seems that a number of trombiculid species, particularly in the *Otomyia*-group of the genus *Euschöngastia,* have been recorded on *R. pumilio* and *O. irroratus* (Zumpt 1961). Although chiggers have previously been collected from *R. pumilio* in the WCP, the identity of the mites is unknown (Matthee *et al.* 2007). Trombiculid mites were recovered from *R. pumilio* and on *O. irroratus* in the present study, but their identity is uncertain, chiefly because of the lack of taxonomic expertise.

Seven flea species representing five genera were recorded. Five of the species were found on *R. pumilio,* while seven species were recovered from *O. irroratus.* Most of the flea species recovered occur throughout South Africa with a few restricted to the WCP. *Chiastopsylla rossi* is widely distributed in South Africa and its distribution includes several localities along the southwestern coast of the WCP and along the coast of the Eastern Cape Province (ECP) (Segerman 1995). De Hoop Nature Reserve represents a new locality record for this species. Its host preference includes small rodents and more specifically the Highveld gerbil, *Tatera brantsii, R. pumilio* and also *O. irroratus* (Segerman 1995). It was the most abundant flea species on *R. pumilio* in the present study. This is in agreement with a previous study on *R. pumilio* in the Cape Floristic Region (CFR), WCP (Matthee *et al.* 2007). Although *C. rossi* was recorded on *O. irroratus* it was in low abundance (one and two fleas on two vlei rats).

Dinopsyllus tenax has a more restricted distribution and occurs in the southwestern part of the WCP (Segerman 1995; Matthee *et al.* 2007). It is completely absent in the rest of the country and DHNR represents a new locality record and its most eastern distribution. Segerman (1995) lists the bush karoo rat (*Otomys unisulcatus*), *O. irroratus* and *R. pumilio* as hosts, and *D. tenax* seems to specifically prefer the nests of these hosts. *Hysopthalmus temporis* is geographically restricted to the coast of the WCP and ECP and also occurs in the highlands of Lesotho and KwaZulu-Natal (Segerman 1995). Its distribution along the coast is disconnected and the presence of the flea at DHNR represents a new locality record. *Otomys irroratus* and *R. pumilio* are listed as the only principal hosts for this flea (Segerman 1995). This supports the fact that *H. temporis* was one of the flea species common to both hosts in the present study.

Listropsylla agrippinae has an extensive distribution in the WCP, ECP, NCP and Lesotho. Its widespread distribution suggests that it is not restricted by climatic factors (Segerman 1995). Its host preference includes *R. pumilio* and *O. unisulcatus,* but *O. irroratus* is also mentioned (Segerman 1995). According to Segerman (1995) *L. agrippinae* prefers hosts that make nests above ground level and is replaced by a congeneric species, *L. dorippae* on host species that use underground burrows as nests. *Otomys irroratus* mainly uses above ground nests and the presence of *L. agrippinae* confirms the suggestion by Segerman (1995). The nesting behaviour of *R. pumilio* is flexible and varies between geographic regions. Burrows (its own or those of other species), shallow nests under shrubs, and above ground nests with grass have all been recorded for this species (De Graaff 1981; Skinner & Chimimba 2005). *Listropsylla agrippinae* was the third most abundant flea on *R. pumilio* in the CFR and at DHNR and it is therefore possible that *R. pumilio* uses shallow or above-ground nests in these areas. *Listropsylla dorippae* is widely distributed throughout the interior regions of South Africa, with records in Botswana and Namibia. To date there are no records along the coastal belt of South Africa (Segerman 1995), and the present study therefore represents a new locality record for *L. dorippae.* Segerman (1995) notes that *L. dorippae* is a nest flea which may explain why it has a preference for host species such as gerbils (*Tatera brantsii, Tatera leucogaster* and the short-tailed gerbil, *Desmodillus auricularis,* as well as Brants' whistling rat, *Parotomys brantsii*) that live in burrows. According to Segerman (1995) it has previously been recorded on *R. pumilio,* but not on *O. irroratus.* Given the single fleas collected from an individual *R. pumilio* and the two from *O. irroratus,* and the nesting behaviour of these hosts, it is possible that the presence of *L. dorippae* on them represents accidental infestations.

The remaining two flea species belong to the genus *Xenopsylla.* Several species within this genus are regarded as key vector species for plague in southern Africa (Segerman 1995). The *X. hirsuta* group consists of six species that share a restricted geographic distribution in the southwestern part of the WCP. One species, *X. demeilloni* also occurs in the western part of the Northern Cape Province (Segerman 1995). In the present study a single specimen was identified as belonging to the *X. hirsuta* group mainly because of the taxonomic difficulty in identifying it to species level. Another specimen was identified as *X. sulcata.* Only two records exist for *X. sulcata* in the WCP, namely at Citrusdal and Vanrhynsdorp (Segerman 1995). Its recovery in the present study represents a new locality record in the WCP. The Cape gerbil, *Tatera afra,* and the hairy-footed gerbil, *Gerbillurus paeba* are the principal hosts of flea species within the *X. hirsuta* group (Segerman 1995). The presence of members of the *X. hirsuta* group on *O. irroratus* at DHNR can be considered as accidental.

The louse *P. arvicanthis* is host specific to *R. pumilio* and seems to be widely distributed in Africa (Ledger 1980). Although it is said to follow its host's distribution, little geographical information on its distribution in the WCP existed prior to the study by Matthee *et al.* (2007). The present study provides a new locality record for *P. arvicanthis.* It was the most abundant ectoparasite species on *R. pumilio,* and this is in agreement with the previous study on these animals (Matthee *et al.* 2007). *Polyplax otomydis* seems to be specific to the genus *Otomys* and is the only louse that has previously been recorded on *O. irroratus* (Ledger 1980; Matthee, unpubl. data). In this study it was present on almost half of the *O. irroratus* examined.

The study investigating eland and bontebok habitat use found that the more nutrient rich shale renosterveld and sinkhole interspersed limestone fynbos with grazing lawns were the two most heavily utilized habitat types, while they ignored the nutrient poor sandstone fynbos (Radloff 2008). The combined ectoparasite abundance on *R. pumilio* was significantly higher in the shale renosterveld compared to the sandstone fynbos. Interspecific comparisons between the parasite taxa revealed that fleas, lice and ticks were more abundant on *R. pumilio* in the shale renosterveld compared to those collected in the sandstone fynbos. This pattern was significant for ticks.

Several possible factors can contribute to this pattern. The relative density of *R. pumilio* was almost twice as high in the shale renosterveld as that in the sampling site in the sandstone fynbos. A high host density will result in an increase in contact between group members, which may facilitate the transmission of parasites that are closely associated with the host (Marshall 1981b; Krasnov 2008). This may partially explain the increase in the abundance of lice, fleas and the rodent specific tick *I. bakeri* on *R. pumilio* present in the renosterveld vegetation.

Bontebok and eland are also parasitized by lice, mites and ticks (Zumpt 1961; Theiler 1962; Ledger 1980; Walker 1991). As mentioned previously there are certain tick species that are shared between rodents and large antelopes. Besides *I. bakeri* and *Ixodes* sp. 2, there was an increase in the number of *R. gertrudae* group ticks in the present study. Previous studies have noted that bontebok and particularly eland can carry large burdens of the adults of *R. capensis*, *R. follis* and *R. gertrudae* (Horak *et al.* 1986, 1991; Golezardy & Horak 2007). The larvae and nymphs that were assigned to the *R. gertrudae* group in the present study are the progeny of one or more of these three tick species. Eland can also harbour particularly large burdens of adult *H. truncatum* (Horak *et al.* 1991; Golezardy & Horak 2007). Thus engorged female ticks detaching from bontebok and eland are a source of larvae that will infest *R. pumilio,* while engorged nymphs detaching from *R. pumilio* are a source of adult ticks that will infest bontebok and eland.

This investigation highlights the diversity of ectoparasite species that are associated with small mammals at DHNR. *Rhabdomys pumilio* is a broad niche species that is an important host to several flea, mite and tick species and a louse. Sympatric, closely related host species often share parasite species as is the case of *R. pumilio* and *O. irroratus.* Furthermore, this study provides current and baseline data on the ectoparasite species that are associated with *O. irroratus* in the WCP. It also endorses the importance of host density and host species composition to maintain parasite diversity and burdens on rodents.

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