Ectoparasite fauna of rodents collected from two wildlife research centres in Saudi Arabia with discussion on the implications for disease transmission

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Highlights

- Ectoparasite data was collected from 161 rodents at two locations in Saudi Arabia.
- 771 ectoparasites were identified in 12 taxa.
- Results are discussed in the context of disease transmission for the region.

ABSTRACT

The majority of human pathogens are zoonotic and rodents play an important role as reservoirs of many of these infectious agents. In the case of vector-borne pathogens, rodent reservoirs not only act as a source of infection for vectors but also serve as hosts for the vectors themselves, supporting their populations. Current data on rodent-ectoparasite

relationships is limited in Saudi Arabia, however, this is needed to assess disease risk and the relative importance of different hosts for the maintenance of vector-borne pathogen cycles. In order to provide baseline data for the region that could be used to assess zoonotic disease risk, we collected and identified 771 ectoparasite specimens (ticks, fleas and mites) from 161 rodents at two wildlife research centres in Saudi Arabia and discuss our results in the context of possible zoonotic disease risk based on the hosts and vectors present.

Graphical abstract

Key words. fleas, mites, Saudi Arabia, rodents, ticks, zoonosis

1. Introduction

Of 1,415 human pathogens identified by Taylor et al. (2001), 868 (61%) are zoonotic and can be transmitted from animals to humans. Rodents are important reservoirs of zoonotic agents hosting a wide range of bacteria, protozoa and viruses of medical and veterinary importance. These pathogens can be transmitted either directly via exposure to rodent excreta (e.g. leptospirosis, hantavirus) or indirectly via arthropod vectors such as fleas, lice, mites and ticks (Meerburg et al., 2009). In the latter case, rodents propagate pathogen cycles both by being a source of infection for the vectors and by supporting vector populations themselves.

Knowledge of specific host-ectoparasite associations in an area can provide important insights into disease transmission. Moreover, the identification of ectoparasites and rodents that are known vectors and reservoirs of pathogens in other locations suggests that the pathogen could be present in local systems. If a particular disease cycle of medical or veterinary importance is identified, quantitative data on specific host-ectoparasite relationships can be used to facilitate control measures (e.g. vaccination or vector/rodent control) and can be used in models to identify proximate drivers of disease transmission or predict risk.

A few older studies (Lewis, 1964, 1982; Al-Kalifa et al., 2006) have presented data on rodent-ectoparasite relationships in Saudi Arabia, however, little new data has been collected in the last 20 years. In order to provide baseline data that could be used to assess zoonotic disease risk, we identified host-ectoparasite relationships of rodents at two wildlife breeding and research centres in Saudi Arabia and discuss results with reference to the implications for disease transmission for the region.

2. Materials and methods

2.1 Rodent capture

We collected and analysed ectoparasite data from 161 rodents captured within the grounds of the National Wildlife Research Centre (NWRC), Taif (21.253021, 40.699416) and the King Khalid Wildlife Research Centre (KKWRC), Riyadh (25.220649, 46.626471). Taif is situated at 1900m altitude with a mild desert climate and average summer daily temperatures of 28˚C and average winter temperatures of 15˚C. Riyadh is at an altitude of 600m with average summer temperatures of 33˚C and average winter temperatures of 15˚C. Both locations were dominated by bare, sandy substrate with sparse low level shrub vegetation, however, Taif had

a large amount of rocky outcrops at trapping locations which were almost completely absent from the Riyadh site. Rodents were trapped using locally available live rat traps with a hook and bait trigger system. Thirty traps were baited with bread and a peanut butter and oat mix and placed five metres apart near the entrances of rodent burrows located at the base of shrubs and also at the base of rocky outcrops. Traps remained set throughout the day and night and were checked every three hours from 6 am until 12 pm. Trap lines were moved to a new location ~50 m away from the previous line every two days in order to capture new hosts that had not yet been sampled. Traps were re-baited as required. Captured animals were removed from the trap, weighed, and the sex and species recorded. Rodent species were identified in the field based on morphological characteristics following Harrison and Bates (1991) and the identification of populations of *A. dimidiatus* and *G. nanus* found at the trapping locations were confirmed by genetic analyses (Bray et al., 2013). The body of each animal was searched by back-combing the fur and ectoparasites were removed with fine forceps and stored in 70% ethanol. After processing, a small amount of fur was clipped from the head of the animal as a mark to identify recaptures and then released at their point of capture. Animals that had already been captured and marked were not processed again. Traps were in place for a total of 28 days, from the 16th November until the 13th December 2011 with the first 10 days at KKWRC and the remaining 18 days at NWRC the in Saudi Arabia. These centres employ numerous staff that come into immediate contact with animals and their enclosures during general animal husbandry and veterinary procedures. In addition, the centres are involved in captive breeding programmes for species of conservation concern including Arabian oryx (*Oryx leucoryx*), sand gazelles (*Gazella marica*), Arabian gazelles (*Gazella arabica*) and Nubian ibex (*Capra nubiana*). Therefore, both humans and species of conservation concern may be at risk from rodent and vector-borne diseases at these locations.

2.2 Ectoparasite identification

Ectoparasites were identified by taxonomic specialists in their respective fields, either mounted or in ethanol, with reference to appropriate keys, descriptions and their own reference material. Mites were identified by E.U. (using Till, 1963; Baker, 1999), fleas by G.N.R. and M.W.H (using Hopkins and Rothschild, 1953; Lewis, 1982) and ticks by D.A.A. (using Filippova, 1997; Walker et al., 2000; Apanaskevich and Horak, 2009). Only generic identifications were possible for some ectoparasite specimens and although lice were also collected, they were not available for identification.

3. Results

3.1 Rodents

A total of 161 rodents were captured that belonged to four taxa consisting of 37 *Acomys dimidiatus*, 70 *Gerbillus nanus*, 41 *Meriones lybicus* and 13 *M. rex*. The majority of host species captured at KKWRC were *M. lybicus* (68.3% = 41/60 of the animals caught), followed by *G. nanus* (16, 26.7%) and *A. dimidiatus* (3, 5.0%). At NWRC, the majority of individuals captured were *G. nanus* (54, 53.4% of 101 animals), followed by *A. dimidiatus* (34, 33.7%) and *M. rex* (13, 12.9%). The mean mass of males and females ± 1 standard error of the mean and the proportion that are male for each species at KKWRC and NWRC are presented in Table 1.

Table 1. Species, sample size (*n*), sex ratio and mean body mass ± 1 standard error of the mean rodents captured at the King Khalid Wildlife Research Centre (KKWRC), Riyadh, and the National Wildlife Research Centre (NWRC), Taif, Saudi Arabia.

Site	Species	*n*	Male/Female (Proportion which are male)	Mean body mass Males (g)	Mean body mass Females (g)
KKWRC	*Acomys dimidiatus*	3	1/2 (0.33)	29.66 ± 0.00	27.66 ± 1.00
	Gerbillus nanus	16	6/10 (0.38)	19.46 ± 1.15	15.49 ± 1.80
	Meriones lybicus	41	21/20 (0.51)	130.16 ± 8.27	117.04 ± 6.30
NWRC	*Acomys dimidiatus*	34	19/15 (0.56)	40.94 ± 2.23	34.60 ± 1.47
	Gerbillus nanus	54	24/30 (0.44)	19.80 ± 0.45	18.98 ± 0.51
	Meriones rex	13	9/4 (0.69)	143.47 ± 26.87	129.55 ± 11.59

3.2 Ectoparasites

A total of 771 ectoparasites were collected and identified that comprised 151 mites in two taxa (*Androlaelaps tateronis* and *Ornithonyssus* spp.), 413 fleas in seven taxa (*Nosopsylla iranus theodori*, *Parapulex chephrensis*, *Synosternus cleopatrae cleopatrae*, *Synosternus cleopatrae* spp., *Xenopsylla conformis mycerini*, *Xenopsylla nubica* and *Xenopsylla* spp.) and 207 ticks in three taxa (*Hyalomma impeltatum*, *Rhipicephalus camicasi* and *Rhipicephalus* spp.). Host-ectoparasite data for KKWRC and NWRC are summarised in Tables 2 and 3, respectively.

3.3 Mites

The genus *Meriones* was the predominant host for the mite *Androlaelaps tateronis* with all stages found on *M. lybicus* comprising 92% of the 24 mites collected at KKWRC (Table 2). This mite species was not found on any other host at KKWRC. In contrast, mites of the genus *Ornithonyssus* were only found on *A. dimidiatus* which hosted the remaining 8% of mites collected at KKWRC. A similar pattern existed at the NWRC (Table 3) with *M. rex* hosting

all stages of *A. tateronis* (92.1% of 127 mites collected) but no *Ornithonyssus* spp. A single specimen of *Ornithonyssus* spp. was found on *A. dimidiatus*. Small numbers of juveniles of *A. tateronis* were also found on *G. nanus* and *A. dimidiatus* accounting for 7% of the mites collected.

3.4 Fleas

Meriones lybicus hosted the majority of fleas at KKWRC (93.5% of 167 fleas collected), followed by *G. nanus* (5.4%) and *A. dimidiatus* (1.2%) (Table 2). *Nosopsyllus iranus theodori* (29.9% of fleas collected) and another flea which could only be identified to the genus *Xenopsylla* (2.4%) were found only at KKWRC. *Nosopsyllus iranus theodori* was predominantly found on *M. lybicus* with smaller numbers found on *G. nanus*. Only three specimens of the flea identified as *Xenopsylla* spp. were found on *M. lybicus* and a single specimen on *A. dimidiatus*. The remaining flea species from KKWRC, *Synosternus cleopatrae cleopatrae*, *Xenopsylla conformis mycerini* and *Xenopsylla nubica*, were also found at NWRC (Table 3). *Synosternus cleopatrae cleopatrae* was generally scarce, found in small numbers (4.8% of fleas) on *M. lybicus* with a single specimen on *G. nanus*. Both *X. c. mycerini and X. nubica* were much more abundant at KKWRC and almost exclusively associated with *M. lybicus* making up 23.4% and 37.1% of fleas collected at this site while a single specimen of *X. nubica* was found on *G. nanus*. *Parapulex chephrensis* was found only at NWRC (6.5% of 246 fleas collected) and predominantly on *A. dimidiatus* with a single specimen found on *M. rex*. The flea identified to specific level as *S. cleopatrae* ssp. (8.9%) was also only found at NWRC on both *G. nanus* (7.3%) and *M. rex* (1.6%) but not on *A. dimidiatus*. The three flea species collected at both locations were most commonly found on *Meriones* spp. and on *G. nanus* at NWRC but were rarely found on *G. nanus* at KKWRC or on *A. dimidiatus*. Eleven per cent and 35.8% of fleas collected at NWRC were *S. c. cleopatrae* found on *M. rex* and *G. nanus* respectively with two specimens on *A. dimidiatus*.

Xenopsylla conformis mycerini was more abundant on *M. rex* (21.5%) than on *G. nanus* (4.1%), and four specimens (1.6%) were collected from *A. dimidiatus*. *Xenopsylla nubica* infesting *M. rex* and *G. nanus* comprised 2% and 7.3% of fleas collected at NWRC with one specimen collected from *A. dimidiatus.*

3.5 Ticks

Meriones lybicus was the main host for ticks at KKWRC, hosting 87% of the 40 ticks collected comprising the juvenile stages of *Hyalomma impeltatum* and the juvenile stages of a currently unknown *Rhipicephalus* spp. (Table 2). An additional 6 ticks belonging to this unknown species were also collected from *G. nanus*. Unfortunately, the juvenile stages of this tick could not be identified to species level when compared to specimens of any other members of the *Rhipicephalus* genus and as such it may represent a novel species. *H. impeltatum* was only collected from *G. nanus* at the NWRC but not from *Meriones* (table 3). The unidentified *Rhipicephalus* spp. was also present at NWRC with juvenile stages abundant on both *M. rex* (50.3% of the 161 ticks collected) and *G. nanus* (19.3%) with a single specimen observed on *A. dimidiatus*. Another *Rhipicephalus*, namely *R. camicasi*, was present at the NWRC and was only found on *A. dimidiatus* and represented 28% of ticks collected.

Table 2. Ectoparasites collected from rodents at the King Khalid National Wildlife Research Centre, Riyadh. Numbers in parenthese after host species names indicates the numbers of each host animal from which collections were made, life stage/sex codes for ectoparasites; L-Larva, N-Nymph, PN-Protonymph, DN-Deutonymph, M-Male, F-Female. No. indicates the number of specimens of that life stage/sex collected, % is the percentage of host individuals on which that life stage/sex was collected, the CV is the coefficient of variation and $\bar{\chi} \pm SE$ indicates the mean abundance plus/minus one standard error of the mean of that ectoparasite life stage/sex collected on the host.

			Meriones lybicus (n=41)				*Gerbillus nanus* (n=16)				*Acomys dimidiatus* (n=3)			
		Stage/ Sex	No.	$\bar{\chi} \pm SE$	%	CV	No.	$\bar{\chi} \pm SE$	%	CV	No.	$\bar{\chi} \pm SE$	%	CV
Mites (24)	*Androlaelaps tateronis*	PN	6	0.15 ± 0.12	4.9	4.3	-	-	-	-	-	-	-	-
		DN	5	0.12 ± 0.06	9.8	1.3	-	-	-	-	-	-	-	-
		M	4	0.10 ± 0.08	4.9	2.5	-	-	-	-	-	-	-	-
		F	7	0.17 ± 0.15	4.9	5.2	-	-	-	-	-	-	-	-
	Ornithonyssus spp.	DN	-	-	-	-	-	-	-	-	2	0.67± 0.67	33.3	2.0
Fleas (167)	*Nosopsyllus iranus theodori*	M	14	0.34 ± 0.11	22.0	1.6	1	0.06 ± 0.06	6.3	1.0	-	-	-	-
		F	28	0.68 ± 0.17	39.2	1.8	6	0.38 ± 0.20	25.0	1.7	1	0.34 ± 0.34	33.3	1.0
	Synosternus cleopatrae cleopatrae	M	4	0.1 ± 0.05	9.8	0.9	1	0.06 ± 0.06	6.3	1.0	-	-	-	-
		F	6	0.15 ± 0.07	12.2	1.2	-	-	-	-	-	-	-	-
	Xenopsylla spp.	M	2	0.05 ±0.03	4.9	1.0	-	-	-	-	1	0.33 ± 0.33	33.3	1.0
		F	1	0.02 ± 0.02	2.4	1.0	-	-	-	-	-	-	-	-
	Xenopsylla conformis mycerini	M	39	0.95 ± 0.19	48.8	1.7	-	-	-	-	-	-	-	-
		F	61	1.49 ± 0.33	51.2	3.0	1	0.06 ± 0.06	6.3	1.0	-	-	-	-
	Xenopsylla nubica	M	1	0.02 ± 0.02	2.4	1.0	-	-	-	-	-	-	-	-
Ticks (46)	*Hyalomma impeltatum*	L	3	0.07 ± 0.07	2.4	3.0	-	-	-	-	-	-	-	-
		N	3	0.07 ± 0.07	2.4	3.0	-	-	-	-	-	-	-	-
	Rhipicephalus spp.	L	17	0.41 ± 0.19	17.7	3.7	-	-	-	-	-	-	-	-
		N	17	0.41 ± 0.19	17.7	3.7	6	0.38 ± 0.38	6.3	6.0	-	-	-	-

Table 3. Ectoparasites collected from rodents at the National Wildlife Research Centre, Taif in the Kingdom of Saudi Arabia. Numbers in parentheses after host species names indicates the numbers of each host animal from which collections were made, life stage/sex codes for ectoparasites; L-Larva, N-Nymph, PN-Protonymph, DN-Deutonymph, M-Male, F-Female. No. indicates the number of specimens of that life stage/sex collected, % is the percentage of host individuals on which that life stage/sex was collected, the CV is the coefficient of variation and $\bar{\chi} \pm SE$ indicates the mean abundance plus/minus one standard error of the mean of that ectoparasite life stage/sex collected on the host.

			Meriones rex (n=13)				*Gerbillus nanus* (n=54)				*Acomys dimidiatus* (n=34)			
		Stage/ Sex	No.	$\bar{\chi} \pm SE$	%	CV	No.	$\bar{\chi} \pm SE$	%	CV	No.	$\bar{\chi} \pm SE$	%	CV
Mites (127)	*Androlaelaps tateronis*	PN	32	2.46 ± 1.34	38.5	9.5	-	-	-	-	5	0.15 ± 0.10	8.8	2.1
		DN	37	2.85 ± 1.54	3.8	10.9	3	0.06 ± 0.03	5.6	1.0	1	0.03 ± 0.03	2.9	1.0
		M	27	2.08 ± 0.89	61.5	4.9	-	-	-	-	-	-	-	-
		F	21	1.62 ± 0.82	38.5	5.4	-	-	-	-	-	-	-	-
	Ornithonyssus spp.	F	-	-	-	-	-	-	-	-	1	0.03 ± 0.03	2.9	1.0
Fleas (246)	*Parapulex chephrensis*	M	1	0.08 ± 0.08	7.7	1.0	-	-	-	-	3	0.09 ± 0.06	5.9	1.6
		F	-	-	-	-	-	-	-	-	12	0.35 ± 0.14	23.5	1.9
	Synosternus cleopatrae spp.	M	3	0.17 ± 0.10	7.7	3.0	9	0.17 ± 0.09	7.5	2.4	-	-	-	-
		F	1	0.08 ± 0.08	7.7	1.0	9	0.23 ± 0.23	5.6	3.6	-	-	-	-
	Synosternus cleopatrae cleopatrae	M	17	1.31 ± 0.47	61.5	2.2	44	0.81 ± 0.16	42.6	1.8	2	0.05 ± 0.04	5.9	1.0
		F	10	0.77 ± 0.23	53.8	0.9	44	0.81 ± 0.18	44.4	2.1	-	-	-	-
	Xenopsylla conformis mycerini	M	30	2.31 ± 0.87	61.5	4.3	8	0.15 ± 0.06	11.1	1.4	1	0.03 ± 0.03	2.9	1.0
		F	23	1.77 ± 0.50	76.9	1.8	2	0.03 ± 0.02	3.7	1.0	3	0.09 ± 0.05	8.8	0.9
	Xenopsylla nubica	M	2	0.15 ± 0.10	15.4	0.9	7	0.13 ± 0.05	11.1	1.2	-	-	-	-
		F	3	0.23 ± 0.17	15.4	1.6	11	0.20 ± 0.07	16.7	1.2	1	0.03 ± 0.03	2.9	1.0
Ticks (161)	*Hyalomma impeltatum*	L	-	-	-	-	1	0.02 ± 0.02	1.9	1.0	-	-	-	-
		N	-	-	-	-	2	0.04 ± 0.03	3.7	1.0	-	-	-	-
	Rhipicephalus spp.	L	64	4.92 ± 2.68	38.5	18.9	23	0.43 ± 0.16	18.5	3.2	1	0.03 ± 0.03	2.9	1.0
		N	17	1.31 ± 0.74	3.8	5.4	8	0.15 ± 0.07	11.1	1.6	-	-	-	-
	Rhipicephalus camicasi	L	-	-	-	-	-	-	-	-	41	1.21 ± 0.68	14.8	13
		N	-	-	-	-	-	-	-	-	4	0.12 ± 0.06	11.8	0.9

4. Discussion

Androlaelaps tateronis was first described when collected from *Tatera* spp. in Uganda (Radford, 1939) and has since been collected from other *Tatera* spp. and unidentified rodents in Sudan, Kenya and Cameroon (Till, 1963). Little information is provided in the literature since these early descriptions, however, the identification of this species in both locations in Saudi Arabia suggests the distribution of this mite extends much farther than previously thought. The abundance of this mite on *Meriones* spp. in the current study is consistent with previous host records that suggest that gerbilline rodents are a preferred host, however, we also found a number of specimens of this mite species on *A. dimidiatus*.

Unfortunately we could not confidently identify the other mite species found further than genus level, however, it is plausible that the species present on *A. dimidiatus* was *Ornithonyssus bacoti*. While a number of other species of *Ornithonyssus* have been described, many are associated with birds or are found in other locations (Baker, 1999) while *O. bacoti* has been collected previously from *M. rex* in Saudi Arabia (Morsy, et al., 2001). This mite species is important as it has been shown to experimentally transmit numerous pathogens such as *Rickettsia typhi* (murine typhus), *Coxiella burnetti* (Q-fever) and *Trypanosoma cruzi* (Chagas' disease) and is a suspected vector of many other pathogens (Baker, 1999; Moro et al., 2005). In addition, this mite readily bites humans causing severe dermatitis (Baker, 1999; Baumstark et al., 2007).

Nosopsyllus iranus theodori is a common ectoparasite of rodents across the north of the Arabian peninsula and has been collected previously from *M. lybicus* and *G. nanus* (as in the current study) and from *M. crassus, G. dasyurus* and *Jaculus jaculus* in northern Saudi Arabia (Lewis, 1964). The presence of this flea species on rodents near Riyadh is the most southerly record of the range of this flea species. There have been no studies on the disease

associations for this species and the status of this flea as a vector of pathogens is currently unknown.

Xenopsylla conformis mycerini is a common and widespread flea species found throughout the Middle East and North Africa and has been collected from a number of rodents including *M. lybicus*, *M. crassus*, *G. nanus*, *G. dasyurus* and *J. jaculus* at sites across northern Saudi Arabia (Lewis, 1964) and on *Rattus rattus rattus*, *R. r. frugivorus*, *R. r. alexandrinus* and *A. dimidiatus* in the Hail region in north central Saudi Arabia (Asiry and Fetow, 2014). In the current study, we also recorded this flea species on *G. nanus*, *A. dimidiatus*, *M. lybicus* and *M. rex*. The presence of this flea near Riyadh extends the known distribution of this flea further south from the Hail region (~550km NW of KKWRC). Currently, nothing is known regarding the vectorial capacity of *X. c. mycerini*. However, *Yersinia pestis*, the bacterium responsible for plague has been detected in north-west Saudi Arabia in both *M. lybicus* and *X. cheopis* collected from the corral of a camel from which five people contracted pharyngeal plague after consuming the meat (Bin Saeed et al., 2005) Moreover, the alternative subspecies of *X. c. mycerini*, *X. c. conformis*, is a known vector of plague in the South Caucasus mountains in eastern Europe where it maintains an enzootic plague cycle in *M. lybicus* (Bakanidze et al., 2003). Given the close relationship (genetically and geographically) between this flea species and known reservoirs and vectors of the plague bacterium, could be possible that this species is also involved in enzootic transmission cycles of *Y. pestis* in *M. lybicus* in Saudi Arabia.

The flea species *P. chephrensis* occurs from northeast Africa to the Arabian peninsula and is predominantly a parasite of spiny mice (*Acomys* spp.) but has also been recorded on *M. rex*, *M. crassus*, *R. rattus*, *J. jaculus* and *Procavia capensis* (Lewis, 1967; Lewis et al., 1982). Our findings are consistent with previous host records as the majority of our specimens were found on *A. dimidiatus* at NWRC. To our knowledge there are no studies that have implicated

this flea species as a disease vector, however, *A. dimidiatus* that were predominantly infested with *P. chephrensis* fleas in Egypt were infected with a wide range of blood-borne microparasites including *Bartonella*, *Hepatozoon* and *Trypanosoma* spp. (Bajer et al., 2006), suggesting that *P. chephrensis* may be a vector of some of these pathogens.

Synosternus cleopatrae cleopatrae is one of the most common fleas of gerbilline rodents occupying the more arid, sandy, areas of north Africa and the Middle East, including Saudi Arabia, (Lewis, 1964; 1982) and as expected it was found in relatively high abundance on both *G. nanus* and *Meriones* spp. in the current study. Another sub-species of *S. cleopatrae* (*S. c. pyramidis*) exists but it is thought to be restricted to the coastal regions of northern Africa and the Middle East, while *S. c. cleopatrae* is found further to the south and east (Lewis, 1967). Nothing is known regarding the pathogen associations of this flea species in Saudi Arabia, however, a number of *Bartonella* strains have been identified in *S. c. cleopatrae* in the Negev desert, Israel (Morick et al., 2010; Gutiérrez et al., 2014). This flea species is also recognised as an important vector of *Y. pestis* among gerbils (*G. gerbillus* and *G. nanus*) in Mauritania (Klein et al., 1975) and is capable of transmitting this pathogen to animals and humans (Dennis et al., 1999).

There are numerous records of *X. nubica* on rodent hosts in Africa (Lewis and Lewis, 1990), however, records from Morocco and Asia (Lewis, 1982) as well as northern Saudi Arabia (Lewis, 1964) are commonly from jerboas (a type of hopping desert rodent). We collected small numbers of this flea from all four rodent host species and from both sites; however, we did not capture any jerboas and so this host species was not available for comparison. Similar to *S. c. cleopatrae*, *X. nubica* is also a vector of *Y. pestis* in enzootic cycles involving jerboas at the Mauritania plague focus and can transmit this pathogen to animals and humans (Dennis et al., 1999).

The ixodid tick genus, *Rhipicephalus*, is primarily an African genus with a few species found outside the continent. To date only a few species of *Rhipicephalus* are thought to be found in Saudi Arabia including *R. sanguineus*, *R. turanicus*, *R. evertsi evertsi* and *R. camicasi* (Walker et al., 2000). While there have been a number of reports of *R. sanguineus*, *R. turanicus* and *R. evertsi evertsi* on both wild and domestic animals in Saudi Arabia (Al-Khalifa et al., 1987, 2006; Diab et al., 1987), *R. camicasi* has rarely been recorded in the country. Upon examining the juvenile stages of the ticks collected from rodents in the current study, we concluded that there were two distinct species of *Rhipicephalus* present, the first could not be identified to species while the other was identified as *R. camicasi*. The separation of these species was also supported by host associations; the unidentified *Rhipicephalus* spp. was almost exclusively associated with *G. nanus* and *Meriones* spp. at both sites whereas *R. camicasi* was only recovered from *A. dimidiatus* at NWRC. Given the wide geographic distribution of these tick species within the *Rhipicephalus* genus (and associated morphological variation) it is important that a full taxonomic study of this group be conducted across the region so that correct identification of these ticks can be determined. Ticks of the genus *Rhipicephalus* are vectors of a wide range of pathogens and the tick species present in Saudi Arabia that have been implicated in the transmission of members of the genera *Anaplasma*, *Babesia*, *Borrelia*, *Ehrlichia*, *Theileria* and of Q-fever (Walker et al., 2000), however, the disease associations of *R. camicasi* are currently unknown.

One other species of tick, *Hyalomma impeltatum*, was recovered from *M. lybicus* at KKWRC and from *G. nanus* at NWRC. This species is found in west, east and north Africa, Arabia and the Middle East. In Saudi Arabia, juvenile stages have been found on *A. dimidiatus*, *M. lybicus* and *M. rex* as well as the fat sand rat, *Psammomys obesus*, and the desert hedgehog, *Paraechinus aethopicus* (Al-Khalifa et al., 2006) and there are numerous records of adults of this tick species on domestic ungulates (Al-Khalifa et al., 1987, Diab et

al., 1987). *Hyalomma* spp. are well known vectors of numerous pathogens of humans and animals across Africa, Europe and Asia. In Saudi Arabia, both Sindbis and Dhori viruses (causing human febrile illnesses) have been identified in *H. impeltatum* (Al-Khalifa et al., 2007). This tick has also been confirmed as a vector of Crimean-Congo Hemorrhagic Fever Virus (Dohm et al., 1996) of which there was an outbreak in 1990 involving seven individuals in the west of Saudi Arabia (El-Azazy and Scrimgeour, 1997). *H. impeltatum* can also transmit *Theileria annulata* which is a widespread and often fatal pathogen of cattle (Mustafa et al., 1983). In addition it has also been implicated in the fatal transmission of *T. hirci* to sheep in Saudi Arabia (El-Azazy et al., 2001). Antibodies to *Rickettsia rickettsii* (Lange et al., 1992) and kinetes of a *Babesia* spp. (Dipeolu and Amoo, 1984) have also been detected in the haemolymph of *H. impeltatum*. Transmission of these pathogens to species within the research centres will negatively affect the success of captive breeding programmes and conservation efforts.

The current study highlights the paucity of information regarding the ectoparasites of rodents in Saudi Arabia and the lack of data on reservoir and vector capacity of rodents and their ectoparasites for pathogens of medical and veterinary importance in the region. Several flea species collected are known vectors of human pathogens and in some instances involved the same reservoir hosts that maintain enzootic infections elsewhere (for example, *X. c. mycerini* and *S. c. cleopatrae* transmitting *Y. pestis* to gerbils in Mauritania and South Caucasus). The ticks collected in this study are also known vectors of pathogens of medical and veterinary importance (e.g. Crimean-Congo Hemhorragic Fever Virus). That some of these pathogen cycles exist in Saudi Arabia and the vector potential of these ectoparasites and the reservoir hosts of these pathogens should be a priority for future research in Saudi Arabia.

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