Ixodid tick diversity on wild mammals, birds, and reptiles in and around Etosha National Park, Namibia

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Introduction

There have been several surveys of the tick species that infest wildlife and domestic animals in various regions of Namibia. Horak et al. (1983) collected ticks from warthogs, Horak et al. (1984) from mountain zebras and horses, Brain and Bohrmann (1992) examined baboons, Horak et al. (1992) sampled plains and mountain zebras, giraffes, kudus, gemsbok and springbok, Fourie et al. (2005) collected ticks from elephant shrews, Horak et al. (2010) examined cheetahs, lions and a leopard, and Pascucci et al. (2011) sampled African buffaloes. Biggs and Langenhoven (1984) and Nyangiwe et al. (2013) examined cattle and Matthee et al. (2010) dogs. A total of 19 species of ixodid ticks were collected in these surveys, many of which infest both wild and domestic species.

The last tick survey in Etosha National Park (ENP) was conducted in the mid-1980s, and seven species of mammalian herbivores were examined, with seven tick species recovered (Horak et al., 1992). In the present follow-up study, conducted from 2008-2010, we opportunistically sampled wild mammals, birds and reptiles in and around ENP, Namibia, to determine the ticks present in the area and their host-parasite associations.

Material and Methods

This study was conducted primarily in ENP, a 22,915km^2 semi-arid savanna ecosystem in northern Namibia, located between 18˚30'-19˚30'S and 14˚15'-17˚10'E. Additional sampling occurred in other areas of Namibia, including Windpoort Farm, Lake Oponono, Swakopmund, Hardap National Park and from a roadkill along the B1 highway (Figure 1). Sampling locations for each host species are provided in Table 1.

Plains zebra, black-backed jackal, African elephant and springbok were captured, sampled and many fitted with collars for other studies in ENP (sampling centered roughly around Okaukuejo camp: S 19.11988, E 15.91439) using methods detailed in Bellan et al. (2012), Cizauskas et al. (2014a), Cizauskas et al. (2014b), and Kamath et al. (2014). While animals were immobilized, they were examined for ticks (details below). Whenever possible, elephants, springbok, and jackals, recaptured for collar removal, were re-sampled; recaptures of zebras were attempted every six months over 2-3 years, in order to sample in wet and dry seasons. Sampling of zebras

Table 1. Host species screened for ticks in Namibia and their sampling locations. Some locations are broadly defined, when the spatial extent of sampling was large (e.g. elephants were sampled throughout ENP); others are more specific, if the species was sampled at a single location. GPS coordinates for specific locations are Okaukuejo (S 19.17652, E 15.91736), Windpoort Farm (S 19.34143, E 15.45380), Lake Oponono (S 18.16886, E 15.75748), Swakopmund (S 23.01484, E 14.45340), Gemsbokvlakte (S 19.21870, E 16.05936), and Leeubron (S 19.07430, E 15.81057).

Scientific name	Common name	N sampled	N infested	Sampling location
birds				
Accipiter badius	Little Banded Goshawk	1	1	Okaukuejo, ENP
Amadina erythrocephala	Red-headed Finch	6	0	Okaukuejo/Windpoort Farm
Apus affinis	Little Swift	7	0	Okaukuejo, ENP
Charadrius pecuarius	Kittlitz's Plover	17	0	Lake Oponono
Cinnyris mariquensis	Marico Sunbird	9	0	Okaukuejo, ENP
Creatophora cinerea	Wattled Starling	4	2	Okaukuejo, ENP
Crithagra atrogularis	Black-throated Canary	36	1	Okaukuejo, ENP
Dicrurus adsimilis	Fork-tailed Drongo	2	1	Okaukuejo, ENP
Glaucidium perlatum	Pearl-spotted Owlet	5	0	Okaukuejo, ENP
Gyps africanus	White-backed Vulture	18	0	central ENP
Halcyon leucocephala	Grey-headed Kingfisher	1	1	Okaukuejo, ENP
Lamprotornis nitens	Cape glossy Starling	48	6	Okaukuejo, ENP
Melierax canorus	Southern Pale Chanting Goshawk	2	1	Okaukuejo, ENP
Monticola brevipes	Short-toed Rock Thrush	5	0	Windpoort Farm
Passer diffusus	Southern Grey-headed Sparrow	30	0	Okaukuejo, ENP
Philetairus socius	Sociable Weaver	225	0	Okaukuejo, ENP
Plocepasser mahali	White-browed Sparrow-weaver	25	1	Okaukuejo/Windpoort Farm
Ploceus intermedius	Lesser Masked Weaver	7	0	Okaukuejo/Windpoort Farm
Ploceus velatus	Southern Masked Weaver	22	1	Okaukuejo/Windpoort Farm
Pterocles bicinctus	Double-banded Sandgrouse	5	0	Windpoort Farm
Pycnonotus nigricans	Red-eyed Bulbul	45	1	Okaukuejo/Windpoort Farm
Pytilia melba	Green-winged Pytillia	5	0	Okaukuejo/Windpoort Farm
Quelea quelea	Red-billed Quelea	27	0	Okaukuejo/Windpoort Farm
Rhinoptilus africanus	Double-banded Courser	7	0	central ENP/ Windpoort Farm
Spilopelia senegalensis	Laughing Dove	7	0	Okaukuejo/Windpoort Farm

Sterna hirundo	Common Tern	8	0	Swakopmund
Torgos tracheliotos	Lappet-faced Vulture	9	1	central ENP
Tricholaema leucomelas	Pied Barbet	5	0	Okaukuejo/Windpoort Farm
mammals				
Diceros bicornis	black rhino	12	12	central-western ENP/Hardap NP
Equus quagga	plains zebra	139	132	central ENP
Giraffa camelopardalis	giraffe	2	2	central-eastern ENP
Loxodonta africana	African elephant	45	8	ENP
Panthera leo	lion	3	3	central ENP
Canis mesomelas	black-backed jackal	99	17	central ENP
Antidorcas marsupialis	springbok	13	2	central ENP
Hippotragus niger	sable antelope	1	1	Khoabendes, ENP
Otocyon megalotis	bat-eared fox	1	1	Okaukuejo, ENP
Crocuta crocuta	spotted hyena	2	1	central ENP
Mellivora capensis	honey badger	1	1	Gemsbokvlakte, ENP
Xerus inauris	ground squirrel	3	3	central ENP
Proteles cristata	aardwolf	1	1	B1 highway north of Okahandja
reptiles				
Boaedon capensis	brown house snake	1	1	Okaukuejo, ENP
Naja nigricincta	zebra snake	1	1	Okaukuejo, ENP
Naja sp.	cobra (subadult)	1	1	Okaukuejo, ENP
Psammophis leopardalis	leopard sand snake	1	1	Okaukuejo, ENP
Stigmochelys pardalis	leopard tortoise	1	1	Leeubron, ENP
Varanus albigularis	rock monitor	3	3	central ENP

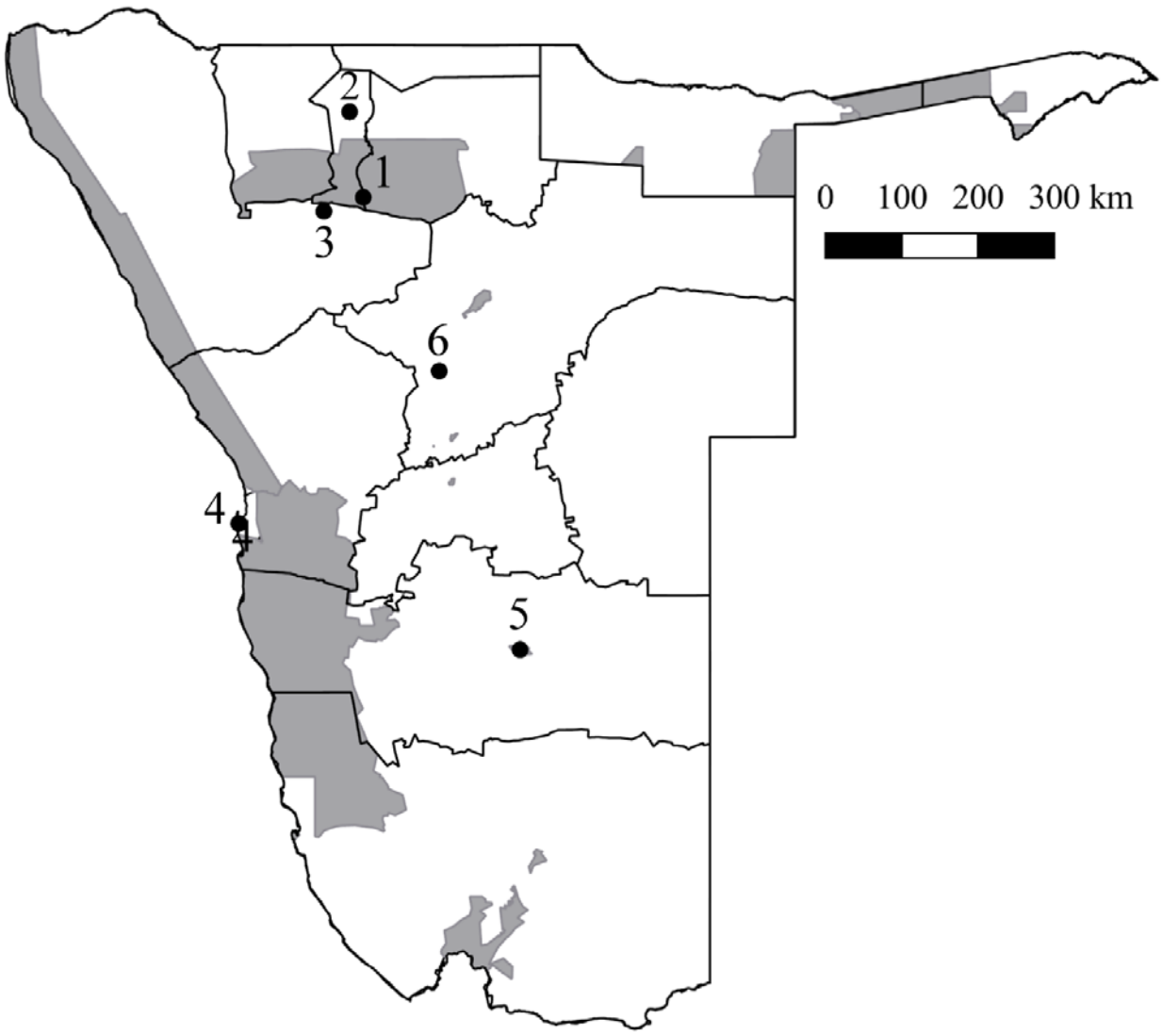

Figure 1. Tick collection sites in northern and central Namibia. 1. Etosha National Park (the circle shows the location of Okaukuejo in central Etosha), 2. Lake Oponono, 3. Windpoort Farm, 4. Swakopmund, 5. Hardap National Park, 6. B1 Highway, located approximately 100km north of Okahandja. Black lines indicate administrative regions of Namibia, gray polygons are government protected areas.

took place from March 2008-August 2010, jackals from January 2009-June 2011, elephants from October 2008-July 2010 (sampling in dry seasons only), and springbok from August 2009-April 2010. Here we present tick infestation data from 139 zebra immobilizations (from 68 unique individuals), 99 black-backed jackal immobilizations (96 unique individuals), 45 elephant immobilizations (33 unique individuals) and 13 springbok immobilizations (11 unique individuals).

Bird sampling was conducted by W.V. from June 2008-May 2009. Vulture chicks were sampled as part of an ongoing monitoring program conducted by the Ministry of Environment and Tourism, where nests in ENP were monitored for breeding activity during the year. Vulture courtship commences in April; egg laying occurs between April and August (Brown et al., 2015) and banding of chicks in the nest took place in September-November. These localities were scattered throughout ENP depending on where the vultures nested and as the colonies moved. In addition, an adult Lappet-faced vulture was sampled as part of the study by Speigel et al. (2013). All other birds were sampled by mist-netting. Standard mist-netting and bird-banding procedures and data reporting protocols were followed as specified by SAFRING, and ticks were collected while processing the bird.

Captured mammals (described above) were handled under IACUC R217-0509B (University of California, Berkeley), and captured birds under ringing licenses to W.V. from the Ministry of Environment and Tourism and SAFRING (No. 1119). All other sampled species were collected opportunistically, from road kills or animals captured, handled or destroyed by the staff of the Ministry of Environment and Tourism in the course of their duties.

Ticks were collected by examining each individual for approximately two minutes. The search areas varied by taxon: these included for mammals the ears, the tip of the tail, the thin skin at the base of the legs and around the groin and anus; for birds the top of the head, around the ear opening, and on the dorsal surface of the neck; and for reptiles the ear and body scales (snakes) or the ear and nose (other reptiles). Upon collection, ticks were stored in 70% ethanol at room temperature. All specimens were identified by I.G.H. Estimates of prevalence were made only if

two criteria were met: i) sampling records detailed all animals thoroughly examined for ticks, including those with none found, and ii) sample size was >5 host individuals.

Results and Discussion

We examined 917 animals for ticks, consisting of 28 bird species (*N*=587 individuals), 13 mammal species (*N*=322 individuals), and six reptile species (*N*=8 individuals) (Table 1). We recovered 981 ticks comprising a total of 12 species in the genera *Amblyomma*, *Hyalomma*, *Rhipicentor* and *Rhipicephalus* (Table 2).

Amblyomma exornatum

The 'leguan tick' infests monitor lizards in southern Africa, and the rock monitor and the water monitor are its preferred hosts (Horak et al., 2006). *Amblyomma exornatum* has previously been documented in north and central Namibia, including ENP (Walker, 1991) and we recovered nymphs and adults from rock monitors in the park.

Amblyomma latum

The 'snake tick' infests several species of snakes, only incidentally other reptiles or mammals, and is widely distributed in the Afrotropical region (Walker, 1991, Horak et al., 2006). It has previously been recorded in central Namibia around Okahandja and Gobabis (Walker, 1991). The present study expands its documented range to include ENP. We recovered a larva from a brown house snake, a nymph from a zebra snake and adults from a leopard sand snake and a sub-adult cobra.

Amblyomma marmoreum

The 'southern African tortoise tick' infests reptiles, most commonly tortoises, and has been recorded sporadically in the central and southern regions of Namibia (Walker, 1991). A single tick was recovered from a leopard tortoise in ENP, but demographic data for the tick were not recorded. This is the first record of *A. marmoreum* north of Outjo (Walker, 1991).

Table 2. Tick infestations on Namibian wildlife. All specimens were collected in Etosha National Park unless otherwise noted.

Tick-host associations	Host common name	Hosts infested/ sampled	Prev. (%)	Total number of ticks recovered				
				Larvae	Nymphs	Males	Females	Total
Amblyomma exornatum								
Varanus albigularis	rock monitor	3/3	-	0	3	6	2	11
Amblyomma latum								
Boaedon capensis	brown house snake	1/1	-	1	0	0	0	1
Naja nigricincta	zebra snake	1/1	-	0	1	0	0	1
Naja sp.	cobra (subadult)	1/1	-	0	0	1	1	2
Psammophis leopardalis	leopard sand snake	1/1	-	0	0	1	1	2
Amblyomma marmoreum								
Stigmochelys pardalis	leopard tortoise	1/1	-	-	-	-	-	1
Hyalomma rufipes								
Diceros bicornis	black rhino	3/6	-	0	0	5	0	5
Diceros bicornis[1]	black rhino	5/6	-	0	0	7	5	12
Equus quagga[2]	plains zebra	16/139	11.5	0	0	12	5	17
Giraffa camelopardalis	giraffe	2/2	-	0	0	2	0	2
Accipiter badius	Little Banded Goshawk	1/1	-	0	1	0	0	1
Creatophora cinerea	Wattled Starling	2/2	-	0	2	0	0	2
Crithagra atrogularis	Black-throated Canary	1/1	-	0	1	0	0	1
Dicrurus adsimilis	Fork-tailed Drongo	1/1	-	0	3	0	0	3
Halcyon leucocephala	Grey-headed Kingfisher	1/1	-	0	3	0	0	3
Plocepasser mahali[3]	White-browed Sparrow-weaver	1/25	4.0	0	1	0	0	1

Ploceus velatus[3]	Southern Masked Weaver	1/22	4.5	0	1	0	0	1
Pycnonotus nigricans[3]	Red-eyed Bulbul	1/45	2.2	0	1	0	0	1
Lamprotornis nitens	Cape Glossy Starling	6/48	12.5	2	6	0	0	8
Hyalomma truncatum								
Diceros bicornis	black rhino	5/6	-	0	0	31	16	47
Diceros bicornis[1]	black rhino	5/6	-	0	0	14	7	21
Equus quagga[2]	plains zebra	28/139	20.1	0	0	41	17	58
Giraffa camelopardalis	giraffe	2/2	-	0	0	55	20	75
Loxodonta africana[2]	African elephant	8/45	17.8	0	0	8	4	12
Panthera leo	lion	2/3	-	0	0	4	1	5
Torgos tracheliotus[4]	Lappet-faced Vulture	1/9	-	0	0	1	0	1
Rhipicentor bicornis								
Panthera leo	lion	1/3	-	0	0	1	0	1
Rhipicentor nuttalli								
Canis mesomelas[2]	black-backed jackal	1/99	1.0	0	0	0	1	1
Rhipicephalus evertsi mimeticus								
Equus quagga[2]	plains zebra	127/139	91.4	0	1	469	108	578
Antidorcas marsupialis[2]	springbok	2/13	15.4	0	2	0	1	3
Hippotragus niger	sable antelope	1/1	-	0	14	0	0	14
Otocyon megalotis	bat-eared fox	1/1	-	0	4	0	0	4
Rhipicephalus gertrudae								0
Diceros bicornis[1]	black rhino	5/6	-	0	0	28	12	40
Rhipicephalus sulcatus								
Equus quagga[2]	plains zebra	1/139	0.7	0	0	0	1	1
Canis mesomelas[2]	black-backed jackal	11/99	11.1	0	0	13	4	17
Crocuta crocuta	spotted hyena	1/2	-	0	0	1	3	4
Rhipicephalus theileri								

Mellivora capensis	honey badger	1/1	-	-	-	-	-	3
Xerus inauris	ground squirrel	3/3	-	0	1	0	2	3
Rhipicephalus turanicus								
Canis mesomelas[2]	black-backed jackal	7/99	7.1	0	0	8	2	10
Equus quagga[2]	plains zebra	1/139	0.7	0	0	0	1	1
Melierax canorus	Southern Pale Chanting Goshawk	1/1	-	0	0	1	1	2
Otocyon megalotis	bat-eared fox	1/1	-	0	0	2	0	2
Panthera leo	lion	1/3	-	0	0	1	1	2
Proteles cristata[5]	aardwolf	1/1	-	0	0	0	1	1

[1]sampled in Hardap National Park, Namibia

[2]includes some re-sampling of marked individuals, see Methods for details

[3]individuals sampled were either from Okaukuejo in ENP or from Windpoort Farm located south of ENP

[4]infested individual was an adult, all others sampled were chicks in the nest

[5]roadkill sampled on the B1 highway in the Otjozondjupa region of Namibia

Hyalomma rufipes

The adults of *H. rufipes* infest a diversity of domestic and wild ungulates (Walker, 1991, Espinaze et al., 2015, Horak et al., 1992), while the immature stages commonly feed on birds and particularly on hares (Horak and Fourie, 1991, Van Niekerk et al., 2006). We recovered adult *H. rufipes* from large mammalian herbivores, including plains zebras (11.5% prevalence), black rhinos, and giraffe, and nymphs from the Little Banded Goshawk, Wattled Starling, Black-throated Canary, Fork-tailed Drongo, Grey-headed Kingfisher, White-browed Sparrow-weaver (4.0% prevalence), Southern Masked Weaver (4.5% prevalence), and Red-eyed Bulbul (2.2% prevalence), and nymphs and larvae from Cape Glossy Starling (12.5% prevalence). With the exception of Red-eyed Bulbul, the other birds are new records for the immature stages of *H. rufipes* in southern Africa (Hasle et al., 2009, Van Niekerk et al., 2006). Including southern Africa, this tick is widely distributed in the Afrotropical region (Apanaskevich and Horak, 2008a).

Hyalomma truncatum

Like *H. rufipes*, the adults of *H. truncatum* primarily infest wild and domestic ungulates, while the immature stages infest hares and murid rodents (Apanaskevich and Horak, 2008b). We recorded adult ticks on large mammals, including plains zebras (20.1% prevalence), black rhinos, African elephants, giraffe and lions. This is the first record of *H. truncatum* on African elephants, and 17.8% of elephants sampled in ENP were infested. In keeping with the host patterns documented in Apanaskevich and Horak (2008b), we recovered no immature stages from any of the 28 bird species examined. However, a single adult tick was collected from an adult Lappet-faced Vulture, which it likely acquired from feeding on an ungulate carcass. *Hyalomma truncatum* is widely distributed throughout Africa (Apanaskevich and Horak, 2008b).

Rhipicentor bicornis

Wild and domestic carnivores, including several species of canids, felids, and genets are the preferred hosts of *R. bicornis* adults (Walker, 1991, Horak et al., 2010). Including northern Namibia, it is present from South Africa to central Africa (Walker, 1991). We collected a single adult tick from a lion in ENP.

Rhipicentor nuttalli

The adults of *R. nuttalli* infest hedgehogs, porcupines, leopards, other wild carnivores, and domestic dogs and cats (Matthee et al., 2010, Horak et al., 2010, Walker, 1991). This tick is distributed across southern and central Africa (Walker, 1991). We recovered a single adult tick on a black-backed jackal in central ENP, representing a prevalence of 1.0% on this host species.

Rhipicephalus evertsi mimeticus

Various domestic and wild herbivores are hosts of *R. e. mimeticus* with most collections from equids and greater kudu (Walker et al., 2000, Horak et al., 1992, Horak et al., 1984). *Rhipicephalus e. mimeticus* is present in the western region of south-central Africa from southern Namibia through Angola to the western tip of the Democratic Republic of the Congo, with introductions documented in South Africa (Walker et al., 2000). We found this species primarily on plains zebra (91.4% prevalence), while several individuals were also collected from springbok (15.4% prevalence), a sable antelope and a bat-eared fox. Although nymphs were collected from all four host species, most ticks collected were adults on zebras. *Rhipicephalus e. mimeticus* has not previously been recorded on sable or bat-eared fox. The sable population in ENP has been introduced, and the natural distribution of sable does not overlap that of *R. e. mimeticus.*

Rhipicephalus gertrudae

Adults of this species tend to parasitize larger herbivores (Walker, 1991). However, several collections have been made from domestic dogs and some from domestic cats and caracals (Horak and Matthee, 2003, Horak et al., 2010, Matthee et al., 2010). Walker et al. (2000) plot locality records across Namibia and south-central South Africa. In the survey of several herbivore species conducted by Horak et al. (1992), *R. gertrudae* was not recovered from any of the hosts examined in ENP or Hardap Nature Reserve. We recovered adult ticks from five of six black rhinoceroses examined in the Hardap Nature Reserve, but not from animals in ENP (including black rhinos). This is the first recorded association between *R. gertrudae* and black rhino (Walker et al., 2000).

Rhipicephalus sulcatus

We recorded adult ticks on black-backed jackal, spotted hyena, and plains zebra. Excluding the records on several non-specific “jackals” summarized in Walker et al. (2000), none of these

species has previously been reported in association with this tick. We collected a single adult tick from a zebra representing 0.7% prevalence. Prevalence on black-backed jackals on the other hand, was 11.1%. With the exception of the southern parts of Namibia and South Africa, this species has a wide distribution throughout sub-Saharan Africa (Walker et al., 2000).

Rhipicephalus theileri

Yellow mongoose, meercat and Cape ground squirrel are the preferred hosts of *R. theileri* and its distribution in southern Africa coincides with the distribution of these small mammals (Walker et al., 2000). We found a nymph and two adults on ground squirrels. We also found three ticks on a honey badger, a new host association, but no demographic information was recorded for these ticks.

Rhipicephalus turanicus s.l.

This species name is used for a tick which differs in taxonomic features depending on the continent or sub-continent in which it is collected and for which a specific identity has yet to be assigned to the southern African specimens (Guglielmone et al., 2014). In sub-Saharan Africa, the preferred wild hosts include several meso- to large carnivores, hares and various ground-feeding birds (Walker et al., 2000). We collected adult ticks from black-backed jackal (7.1% prevalence), and a single plains zebra (0.7% prevalence), lion, aardwolf, bat-eared fox, and Southern Pale Chanting Goshawk. All these mammals have previously been reported in association with this tick; however, the Southern Pale Chanting Goshawk, on which we found two adult ticks, represents a new host association (Walker et al., 2000, Hasle et al., 2009, Van Niekerk et al., 2006).

Conclusion

Twelve ixodid tick species were collected from mammals, birds and reptiles in central and northern Namibia. The numbers collected from individual animals were generally low and with some exceptions the prevalence of infestation low. The recorded infestation rates are well below those reported in other parts of southern Africa (e.g., Horak et al., 2000), but are consistent with those previously reported in our study area (e.g., Horak et al., 1992).

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