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FORUM

Ticks (Acari: Ixodidae) Associated with Wildlife and Vegetation of Haller Park along the Kenyan Coastline

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ABSTRACT This artcile describes the results obtained from a tick survey conducted in Haller park along the Kenyan coastline. The survey aimed at evaluating tick–host associations, assessing tick population density, and providing baseline information for planning future tick control and management in the park. Ticks (2,968) were collected by handpicking from eight species of wildlife and by dragging in 14 selected sites within the park. A considerable proportion of ticks were also collected from leaves, stems, and bark of most dominant trees, namely, *Casuarina equisetifolia* L. (Forst. & Forst.), *Cocos nucifera* L., *Adansonia digitata* L., *Musa paradisiaca* L., and *Azadiracta indica* Adr. Juss. Dragging was conducted in sites predominantly occupied by *Cynodon dactylon* L. (Pers.), *Cenchrus ciliaris* L., *Stenotaphrum dimidiatum* L. (Kuntze.) Brongn., and *Brachiaria xantholeuca* Hack. Ex Schinz Stapf. and *Loudetia kagerensis* K. Schum. Hutch. Eight tick species were identified, and the collection included *Rhipicephalus pravus* Dönitz 1910, *Rhipicephalus pulchellus* Gerstäcker 1873, *Hyalomma marginatum rufipes* Koch 1844, *Amblyomma gemma* Dönitz 1910, *Amblyomma hebraeum* Koch 1844, *Amblyomma sparsum* Neumann 1899, *Amblyomma nuttalli* Dönitz 1909, and *Boophilus decoloratus* Koch 1844. Given that the identified tick species are known to parasitize humans as well as livestock, there exist risks of emergence of zoonotic infections mediated by tick vectors. In the recreational environment of Haller park, where tick vectors share habitats with hosts, there is a need to develop sustainable and effective tick control and management strategies to minimize economic losses that tick infestation may cause.

KEY WORDS ticks, ectoparasites, Haller park wildlife, hosts, tick-host associations

Haller park, along the Kenyan coastline, is an alluring, tourism-based recreational ecosystem with an admirable and considerable amount of biodiversity. It is a newly created and protected park undergoing rehabilitation and transformation processes geared toward achieving ecological diversity, stability, and an economically self-sustaining ecosystem. Each year, a considerable number of both local and international tourists spend their holidays at the park, thus contributing to Kenya's gross domestic product (Moran 1994; Emerton 1997; Emerton 1998a, b; Odunga 2005). However, one of the most serious problems recently noted at the park has been livestock tick infestation on both humans and animals (unpublished data).

In humans, livestock ticks cause paralyzes and toxicoses, irritation and allergy, wounds, and hemorrhage, and they are vectors of a broad range of viral, bacterial, and protozoan pathogens (Estrada-Péna and Jongejans 1999). Disease such as Crimean-Congo hemorrhagic fever caused by *Nairovirus* (Bunyaviridae) and transmitted by ixodid ticks (*Rhipicephalus pulchellus* Gerstäcker 1873, *Hyalomma marginatum rufipes* Koch 1844, *Amblyomma hebraeum* Koch 1844, *Boophilus decoloratus* Koch 1844, *Amblyomma variegatum* F. 1794, *Hyalomma anatolicum anatolicum* Koch 1844, *Hyalomma impeltatum* Schulze & Schlottke 1930, and *Hyalomma truncatum* Koch 1844) is likely to be encountered (Anonymous 1993, Walker et al. 2003). Another disease is the African tick typhus caused by *Rickettsia conorii* Brumpt 1932 and *Rickettsia africae* Kelly et al. 1996 that are transmitted by *Hyalomma* spp. and *Rhipicephalus* spp., and *A. hebreaum*, respectively (Anonymous 1993, Walker et al. 2003). And recently, rickettsiae of unknown pathogenicity and two new ehrlichiae of the *Ehrlichia canis* Donatien and Lestoquard 1935 group have been identified in *Hyalomma* spp., *Amblyomma* spp., and *Rhipicephalus* spp. in Africa (Parola et al. 2001). Transmission of these pathogens by ticks occurs mostly in a zoonotic cycle involving an interaction of wildlife, domestic animals, and humans, with wildlife and ticks as reservoir hosts (Pereira et al. 2000, Bechara et al. 2002, Bianchi and De Garine-Wichatitsky 2002). Because of the variety of pathogens ticks transmit and

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physical damage they cause on hosts (Balashov 1972, Jones et al. 1992), their harmful effects may take many different forms, some going unnoticed, whereas others take long periods to manifest (Aeschlimann 1991). This, coupled with limited knowledge on ticks involved in human parasitism and zoonotic infections (Michel 2002), is currently causing fear that the ever-growing interaction of wild animals with domestic animals and humans at the park may lead to the emergence of new tick–host relationships and to the exchange of pathogens between hosts and tick vectors (Hoogstraal 1981). To avert the occurrence of zoonotic epidemics that may affect tourism activities at the park, increased understanding of hosts, tick vectors, and pathogens as well as their associations is necessary. It was on this basis that a tick survey was initiated at the park with the goals of 1) identifying tick species present within the park; 2) analyzing the identified tick species in terms of their distribution, abundance, prevalence, and tick–host associations; and 3), using the generated information to plan for future tick control and management at the park. This article describes a survey of tick species in Haller park and their association with animal hosts and vegetation.

Materials and Methods

Study Area. The study area is located along the coastline of Kenya, ≈10 km northwest of Mombasa town (3° 59 S, 39° 42 E). The area was divided into north and south quarries, both of which are being transformed from a barren limestone quarry to an ecologically diverse and self-sustaining ecosystem. Selection of 14 sampling sites was based on wildlife–human interaction and biodiversity restoration state.

South Quarry (SQ) (150 ha). Selected sites were 1) ziwa la ng'ombe (primary grassland interspersed with *Cocos nucifera* L., has never been mined, and has shallow black cotton soil); 2) chai banda [secondary *Casuarina equisetifolia* L. (Forst. & Forst.) forest on sand/clay soil]; 3 banana plantation (disused *Musa paradisiaca* L. plantation on sand/clay, overgrown with scattered *C. equisetifolia* and interspersed with *C. nucifera*); 4) SQ grassland (open spacious reserve land for quarrying); 5) main gate; 6) snake park; 7) reception; and 8) fish farm. Sites 4–8 consist of mainly grass lawns.

North Quarry (NQ) (300 ha). Selected sites were 1) reception (grass lawns); 2) baobab tree (grass with *Adansonia digitata* L.); 3) maweni (primary grassland that has never been mined); 4) great lake (secondary grassland in quarry land; 5) boma [enclosure in which eland (*Taurotragus oryx* Pallas, 1766) and fringe-eared oryx (*Oryx gazella callotis* de Blainville 1816) spend the night]; 6) western water bodies (secondary *C. equisetifolia* forest interspersed with water bodies of varying sizes).

Because of the high level of interaction between humans and the ecosystem in the southern part of the park, eight sites in SQ were systematically selected for sampling compared with six sites in the NQ.

Tick Sample Collection. A 1 by 1-m^2 flannel cloth was dragged on the ground along a line transect for a distance of 20 m, five times. Each dragging time, ticks found on leaves, stems, and bark of trees along the line transect were collected. Ticks picked off of the drag cloth were immediately placed in 70% isopropyl alcohol for preservation until identification (Pereira et al. 2000, Kollars and Oliver 2003). Tick density was obtained by dividing the total number of ticks by the total area (square meters) dragged, excluding ticks collected from animal hosts. Sites with more than two ticks per square meter were considered targets for tick control.

Wild Animal Hosts. Animals in the park consist of freely roaming wild species whose movement is restricted within the boundaries of the park, whereas the semidomesticated group is confined in localized areas and cared for by park personnel. In many cases, ticks were observed and counted at their feeding predilection sites on animal hosts, and some ticks were handpicked using the expertise of game ranchers. Tick collections from animal hosts were similarly treated.

Tick Identification. Tick identification was conducted at Lafarge Eco Systems and at the International Centre for Insect Physiology and Ecology (ICIPE),

Table 1. Species of adult ticks identified and collected from animal hosts in Haller park during the survey (n = 885)

Tick species	Total no. of adult ticks collected		Animal host(s) from which adult ticks were collected	
	Male (486)	Female (399)	Principal animal host[a,b]	Other animal host(s)
Rh. pravus	0	0	—[c]	—
Rh. pulchellus	177	176	Maasai giraffe (353)	—
H. m. rufipes	0	0	—	—
Am. gemma	19	3	Fringe-eared oryx (18)	Aldabra giant tortoise
Am. hebraeum	5	12	Aldabra giant tortoise (17)	—
Am. sparsum	187	128	Aldabra giant tortoise (198)	Maasai giraffe, fringe-eared oryx, and eland
Am. nuttalli	9	31	Aldabra giant tortoise (27)	Maasai giraffe and eland
Bo. decoloratus	91	47	African rock python (85)	Maasai giraffe, fringe-eared oryx, eland, African buffalo, aldabra giant tortoise, and African eagle owl

[a] An animal host from which either all or more than half the total number of ticks for a given species was collected during the survey.
[b] Figures in parentheses represent the number of ticks collected from the principal animal host.
[c] Tick(s) not found on animal hosts.

Table 2. Species of adult ticks collected from vegetation by handpicking and dragging in Haller park during the survey ($n = 2{,}083$)

Tick species	Total no. of adult ticks collected		Host-seeking adult ticks collected from vegetation[a]
	Male (990)	Female (1093)	
Rh. pravus	155	58	Long grass/scrub/casuarina forest (213)
Rh. pulchellus	210	485	Scrub/long grass areas (695)
H. m. rufipes	55	149	Short grass areas (204)
Am. gemma	101	90	Scrub/casuarina forest/long grass (191)
Am. hebraeum	19	120	Long grass/casuarina forest (139)
Am. sparsum	135	159	Long grass/casuarina forest (294)
Am. nuttalli	134	31	Long grass/scrub (165)
Bo. decoloratus	181	1	Casuarina forest/long grass/scrub/marshes (182)

[a] Figures in parentheses represent the total number of ticks collected for each tick species.

Nairobi, Kenya. Ticks were identified following the descriptions of Hoogstraal (1956), Matthysse and Colbo (1987), Okello-Onen et al. (1999), and Walker et al. (2003).

Results

In total, 2,968 adult tick specimens (1,492 females and 1,476 males), from eight tick species, were collected from eight wildlife species and from vegetation within the park (Tables 1 and 2). The animal species observed and found infested with ticks included 41 eland (*T. oryx*), 70 fringe-eared oryx (*O. g. callotis*), 38 waterbuck (*Kobus ellipsyprymnus* Ogilby 1833), four Maasai giraffe (*Giraffa camelopardis tippelskirchi* Mtsch. 1898), three African buffalo (*Syncerus caffer* Sparrman 1779), one African rock python (*Python sebae sebae* Gmelin 1789), 12 aldabra giant tortoise (*Dipsochelys dussumieri* Gray 1831), and three African eagle owl (*Bubo africanus* Temminck 1821).

The number of tick species collected and the associated animal hosts and vegetation are shown in Tables 1 and 2. A high number of immature tick stages were observed, collected, and identified (Table 3); however, because their tiny size and large quantity, the immature ticks could not be easily quantified. Tick species found in the greatest numbers were the zebra tick (*Rh. pulchellus*), followed by large reptile tick (*Amblyomma sparsum* Neumann 1899), blue tick (*Bo. decoloratus*), small reptile tick (*Amblyomma nuttalli* Dönitz 1909), African bont tick, (*Amblyomma gemma* Dönitz 1910), convex-eyed tick (*Rhipicephalus pravus* Dönitz 1910), hairy or coarse-legged tick (*H. m. rufipes*), and bont tick (*Am. hebraeum*), in that order. All the eight species collected were found both in host-seeking and attached state except *Rh. pravus* and *H. m. rufipes,* which were only found in host-seeking state (Tables 1 and 2). The *G. c. tippelskirchi, D. dussumieri, P. s. sebae,* and *O. g. callotis* were the most heavily infested animals, in decreasing order, whereas *T. oryx, S. caffer,* and *Bu. africanus* had the lowest infestation rate (Table 1). The *P. s. sebae* harbored only *Bo. decoloratus,* whereas *D. dussumieri* harbored all the tick species collected except *Rh. pravus, Rh. pulchellus,* and *H. m. rufipes.* Most of the ticks (70.18%) were collected while in the state of seeking their respective hosts from grass of mixed species or sometimes from marshes, scrub, and *Ca. equisetifolia* forests (Table 2). Only 29.82% (885) of the total number of ticks (2,968 ticks) were collected from their respective animal hosts while in attached state and were assumed to be feeding (Tables 1 and 3). Of those that were attached, 399 were females and 486 were males (Tables 1 and 3), whereas 1,093 females and 990 males were in nonattached state (Table 2).

More ticks were collected from the SQ (2,777) than the NQ (191). In SQ, ziwa la ng'ombe site had the highest tick density (22.06 ticks per square meter),

Table 3. Distribution of tick species on the body of their respective animal hosts ($n = 885$)

Location on host body	*Am. nuttalli*			*Rh. pravus*			*H. m. rufipes*			*Rh. pulchellus*			*Am. gemma*			*Am. hebraeum*			*Am. sparsum*			*Bo. decoloratus*			Total adults
	M	F	I	M	F	I	M	F	I	M	F	I	M	F	I	M	F	I	M	F	I	M	F	I	
Nose/eyes/horn base/ears	—	—	—	—	—	—	—	—	—	—	—	—	9	8	—	—	—	—	—	—	—	9	11	Y	37
Neck and belly	4	2	Y	—	—	—	—	—	—	50	96	—	5	—	—	2	—	—	35	30	Y	12	8	—	244
Head	—	—	Y	—	—	—	—	—	—	107	20	Y	—	—	—	3	5	—	32	25	Y	13	7	—	212
Forelegs	1	—	Y	—	—	—	—	—	—	13	10	Y	—	—	—	3	1	—	21	15	Y	5	9	Y	78
Hump region	—	—	—	—	—	—	—	—	—	25	21	—	—	—	—	—	—	—	—	—	—	—	—	—	46
Back	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	17	2	Y	19
Hind legs	2	—	—	—	—	—	—	—	—	6	5	—	—	—	—	1	2	Y	14	10	Y	3	2	—	45
Cloaca/anus	17	4	Y	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	22	43	Y	5	15	—	106
Tail	10	—	Y	—	—	—	—	—	—	—	—	—	—	—	Y	—	—	—	26	42	—	14	6	—	98
Subtotals	34	6	Y	0	0	—	0	0	—	201	152	Y	14	8	Y	9	8	Y	150	165	Y	78	60	Y	885
Grand total[b]	40		Y	0		—	0		—	353		Y	22		Y	17		Y	315		Y	138		Y	

F, female; I, immature; M, male; Y, observed, identified, however not quantified.
[a] tick(s) not observed at the site on the host body.
[b] Sum of male and female adult ticks.

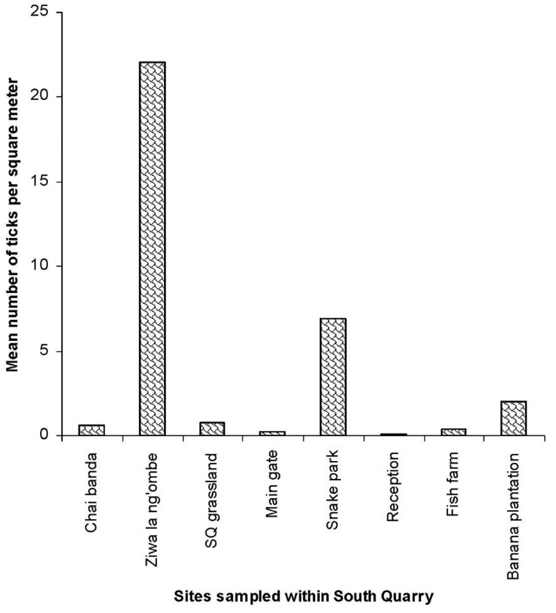

Fig. 1. Adult tick density in eight sampled area sites within the South Quarry of Haller park (n = 2,777).

whereas the reception area and the main gate sites had the lowest densities (0.1 and 0.2 ticks per square meter, respectively) (Fig. 1). Tick density in the NQ was generally lower, with the highest density, 1.8 ticks per square meter, in the animal boma, whereas some sites such western water bodies and the reception were tick free (Fig. 2). It was observed that, with the exception of *H. m. rufipes,* all the tick species were consistently collected from long grass (Table 2). The sites dragged were predominantly occupied by the following grass species: *Cynodon dactylon* L. (Pers.), *Cenchrus ciliaris* L., *Stenotaphrum dimidiatum* L. (Kuntze.) Brongn., *Brachiaria xantholeuca* Hack. Ex Schinz Stapf., and *Loudetia kagerensis* K. Schum. Hutch. A considerable proportion of ticks also were collected from leaves, stems, and bark of the most dominant trees such as *Ca. equisetifolia, Co. nucifera, Ad. digitata, M. paradisiacal,* and *Azadiracta indica* Adr. Juss.

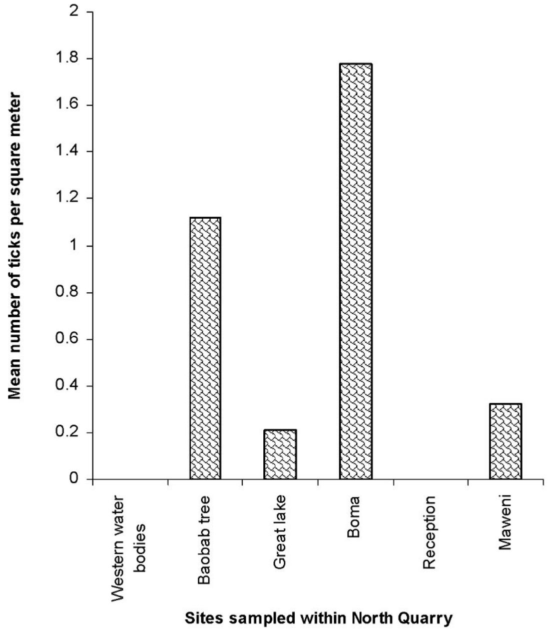

Fig. 2. Adult tick density in six sampled area sites within the North Quarry of Haller park (n = 191).

Discussion

Haller park is an attractive recreational ecosystem undergoing rehabilitation and transformation processes, particularly in the northern part, where biodiversity restoration has not fully commenced. This is in fact manifested in the overall tick density. The density is lower in the north than in the south ex-quarry, which is a more or less stable ecosystem with a considerable amount of biodiversity. In the NQ, ecosystems are at different stages of restoration, and in some areas, excavation is still in progress. As a tourist attraction and recreational ecosystem, there are implications of the possible wildlife–livestock–human interactions and the sharing of the same habitat. Such interactions may play a significant role in the epidemiology of tick and tick-borne diseases (Norval et al. 1992).

From our tick–host association survey results, more ticks (females) were collected while in a nonattached state than in an attached state. This in fact shows how ticks, particularly females, spend more time off-host than on-host (Jongejans and Uilenberg 1994). This phenomenon is, however, a result of the nature of ticks' life cycle involving some physiological processes, which favor off-host situation (such as molting and oviposition). This has been demonstrated in *Amblyomma* spp. (Jongejans and Uilenberg 1994). On preferred host animals, ticks show preference for feeding sites as described previously in *Rh. appendiculatus* and *Rh. evertsi* (Wanzala et al. 2004). Because more ticks were found on vegetation than on host animals, humans who are exposed to the same habitats during recreation are likely to be infested by ticks. Ticks are known vectors of many debilitating and often fatal zoonotic infectious agents, such as viruses and bacteria (Anonymous 1993, Chomel 2001, Parola et al. 2001, Walker et al. 2003). In a suitable wildlife–livestock/human interface such as the Haller park, zoonotic epidemics are likely to develop (Parola et al. 2001, Frölich et al. 2002, Aiello and Mays 2003) if appropriate pathogens exist and effective tick control measures are lacking.

It is worthwhile noting that several parasitological and epidemiological aspects of ticks involved in human parasitism remain poorly studied, albeit there are valid reports that diseases such as African tick typhus, encephalitis, hemorrhagic fevers, Lyme disease, tick-born rickettsioses, and human ehrlichial diseases cause considerable morbidity and mortality to humans (Anonymous 1993, Chomel 2001, Parola et al. 2001, Walker et al. 2003). In Haller park, with the exception of three species (*Am. gemma, Am. Sparsum,* and *Am. nuttalli*), the rest, in particular *Am. hebreaum* and *H. m. rufipes,* are frequently found parasitizing humans and are implicated in the transmission of the above-mentioned tick-borne diseases (Estrada-Pena and Jongejans 1999, Parola and Raoult 2001). Future studies at the park will therefore aim at establishing the existence of the pathogens.

Considering the risks of zoonotic disease transmission and the number and diversity of tick species collected from the animal hosts and vegetation in the park, there is a need to initiate effective tick control interventions. However, it is challenging to select the most appropriate, sustainable, and effective tick control interventions applicable to a fragile environment, such as Haller park. Although integrated tick control methods may be suitable, with the exception of unsustainable synthetic chemical control methods, they require extensive study before use. This option is currently being pursued.

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