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Arthropod parasites of elephant-shrews, with particular reference to ticks

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ABSTRACT
Elephant-shrews from sub-Saharan Africa are infested by a large variety of arthropod parasites including ticks, mites, fleas, lice and the larvae of a calliphorid fly. Lists of the ectoparasites recorded from these animals are presented. Of particular importance are the ixodid ticks infesting elephant-shrews, as several of these can cause toxicosis, particularly paralysis in domestic animals, while others serve as important vectors of disease. Twenty-seven ixodid tick species belonging to six genera recorded from elephant-shrews are listed. Both host- and tick-dependent factors must be examined in order to determine the ecology of ticks infesting elephant-shrews and their relationship to disease in domestic and wild animals.

INTRODUCTION
The exact meaning of the term parasitism is controversial and difficult to define precisely. We prefer the definition of Kim (1985) which states that a parasite is a symbiont that lives, throughout a part or the entire period of its life, in or on the host from which its food and other biological necessities are derived.

Although many parasitological studies have concentrated on domestic livestock, investigations on wild animals, particularly on small mammals, are also important. First, they broaden our understanding of the ecology of zoonotic and veterinary diseases (Sonenshine, 1975; Fourie, Horak & Van den Heever, 1992). In this respect intensive studies on various small mammals which serve as hosts for the ticks capable of transmitting the Lyme disease agent (*Borrelia burgdorferi*) serve as a good example (Matuschka *et al.* 1991; Galbe & Oliver, 1992). Second, small mammals also act as reservoir hosts for many tick-transmitted diseases (Balashov, 1972). Consequently quantitative and qualitative data on the status of small mammals as hosts for medically and veterinary important parasites are essential. Third, there is a constant search for new and better animal models for biomedical research and small mammals should be considered (Stunkard *et al.*, 1975).

Elephant-shrews could serve as excellent subjects for the investigation of parasite–host interrelationships. Unfortunately there is a paucity of information on the parasites of these mammals. This paper deals with the diversity of ectoparasites which infest elephant-shrews, with particular emphasis on ticks. Some guidelines for future parasitological research on these animals are provided.

DIVERSITY OF PARASITES
Elephant-shrews are hosts of a variety of macroparasites. Although little is known about the endoparasites, acanthocephalans encysted in the body cavity and large intestine, have been recorded from *Elephantulus myurus* (D.J. Kok, J.S. Du Toit & L.J. Fourie, unpublished data), *Rhynchocyon chrysopygus* and *Petrodromus tetradactylus* (Rathbun, 1976). Various nematode

species and cestodes have also been recovered from either the stomach, large intestine or the caecum of *E. myurus* (D.J. Kok, J.S. Du Toit & L.J. Fourie, unpublished data), *R. chrysopygus* and *P. tetradactylus* (Stunkard *et al.*, 1975; Rathbun, 1976). A variety of mites, lice and fleas have also been recorded from elephant-shrews and these are summarized in Table 1. Unfortunately no quantitative data on any of these ectoparasites are available.

Table 1. Host–parasite list of non-ixodid arthropod ectoparasites of various elephant-shrews. * Indicates typical elephant-shrew parasites. An asterisk followed by a question mark indicates that the parasite may typically occur on elephant-shrews but too few specimens have been found, not only on elephant-shrews, to be conclusive

Host	Parasite	Reference
Elephantulus		
E. brachyrhynchus	*Leptotrombidium subquadrata* (Acari: Trombiculidae)	Zumpt (1961)
	*?*Schöngastia katangae* (Acari: Trombiculidae)	Zumpt (1961)
	**Schoutedenichia dureni* (Acari: Trombiculidae)	Zumpt (1961)
	**Schoutedenichia nasilionis* (Acari: Trombiculidae)	Zumpt (1961)
	Ctenocephalides felis (Siphonaptera: Pulicidae)	Zumpt (1966)
	Xenopsylla brasiliensis (Siphonaptera: Pulicidae)	Zumpt (1966)
	Dinopsyllus ellobius (Siphonaptera: Hystrichopsyllidae)	Zumpt (1966)
	Dinopsyllus lypusus (Siphonaptera: Hystrichopsyllidae)	Zumpt (1966)
	**Neolinognathus elephantuli* (Anoplura: Neolinognathidae)	Ledger (1980)
E. fuscipes	**Schoutedenichia dureni* (Acari: Trombiculidae)	Zumpt (1961)
	Echidnophaga gallinacea (Siphonaptera: Pulicidae)	Zumpt (1966)
	Ctenocephalides felis (Siphonaptera: Pulicidae)	Zumpt (1966)
E. myurus	**Ornithonyssus capensis* (Acari: Laelaptidae)	Shepherd & Narro (1983)
	**Neolinognathus elephantuli* (Anoplura: Neolinognathidae)	Ledger (1980)
E. rufescens	**Neolinognathus praelautus* (Anoplura: Neolinognathidae)	Ledger (1980)
E. rupestris	**Euschöngastia (?) annulata* (Acari: Trombiculidae)	Zumpt (1961)
	Echidnophaga gallinacea (Siphonaptera: Pulicidae)	Zumpt (1966)
	Ctenocephalides felis (Siphonaptera: Pulicidae)	Zumpt (1966)
	Xenopsylla brasiliensis (Siphonaptera: Pulicidae)	Zumpt (1966)
	Dinopsyllus lypusus (Siphonaptera: Hystrichopsyllidae)	Zumpt (1966)
	Listropsylla prominens (Siphonaptera: Hystrichopsyllidae)	Zumpt (1966)
	Epirimia aganippes (Siphonaptera: Chimaeropsyllidae)	Zumpt (1966)
	**Demeillonia granti* (Siphonaptera: Chimaeropsyllidae)	Zumpt (1966)

E. rupestris (as *E. vandami*)†	*Xenopsylla brasiliensis* (Siphonaptera: Pulicidae)	Zumpt (1966)
	**Demeillonia miriamae* (Siphonaptera: Chimaeropsyllidae)	Zumpt (1966)
	**Macroscelidopsylla albertyni* (Siphonaptera: Chimaeropsyllidae)	Zumpt (1966)
Macroscelides		
M. proboscideus	*Echidnophaga gallinacea* (Siphonaptera: Pulicidae)	Zumpt (1966)
	Xenopsylla occidentalis (Siphonaptera: Pulicidae)	Zumpt (1966)
	**Demeillonia granti* (Siphonaptera: Chimaeropsyllidae)	Zumpt (1966)
Petrodromus		
P. tetradactylus	*?*Schöngastia howdadi zanzi* (Acari: Trombiculidae)	Zumpt (1961)
	*?*Schoutedenichia oyei* (Acari: Trombiculidae)	Zumpt (1961)
	Echidnophaga gallinacea (Siphonaptera: Pulicidae)	Zumpt (1966)
	Ctenocephalides felis (Siphonaptera: Pulicidae)	Zumpt (1966)
	**Neolinognathus elephantuli* (Anoplura: Neolinognathidae)	Ledger (1980)
P. tetradactylus (as *P. sultan*)†	**Chimaeropsylla haddowi* (Siphonaptera: Chimaeropsyllidae)	Zumpt (1966)
	**Chimaeropsylla potis* (Siphonaptera: Chimaeropsyllidae)	Zumpt (1966)
Rhynchocyon		
R. chrysopygus	**Chimaeropsylla haddowi* (Siphonaptera: Chimaeropsyllidae)	Zumpt (1966)
	**Chimaeropsylla potis* (Siphonaptera: Chimaeropsyllidae)	Zumpt (1966)
R. cirnei	*Cordylobia rodhaini* (Diptera: Calliphoridae)	Zumpt (1966)
	**Chimaeropsylla potis* (Siphonaptera: Chimaeropsyllidae)	Zumpt (1966)
R. cirnei (as *R. stuhlmanni*)†	*Cordylobia rodhaini* (Diptera: Calliphoridae)	Zumpt (1966)
	**Chimaeropsylla potis* (Siphonaptera: Chimaeropsyllidae)	Zumpt (1966)
R. petersi	*Ctenocephalides felis* (Siphonaptera: Pulicidae)	Zumpt (1966)
	**Chimaeropsylla haddowi* (Siphonaptera: Chimaeropsyllidae)	Zumpt (1966)
	**Chimaeropsylla potis* (Siphonaptera: Chimaeropsyllidae)	Zumpt (1966)

† The following synonyms are recognized (Corbet, 1974; Meester *et al.*, 1986): *Elephantulus rupestris* (= *E. vandami*); *Petrodromus tetradactylus* (= *P. sultan*); *Rhynchocyon cirnei* (= *R. stuhlmanni*).

Particularly noticeable, especially to those who have captured elephant-shrews, are their tick infestations. Depending on the species and developmental stage, the ticks infesting elephant-shrews commonly attach to the head, including the ear margins, base of the tail and the tail itself (Rathbun, 1976; Du Toit, 1993). Twenty-seven ixodid tick species, belonging to six genera, have been recorded from elephant-shrews (Table 2). Except for some adult tick species belonging to the genus *Ixodes*, elephant-shrews serve mainly as hosts for immature ticks. The immature stages of non-nidicolous two- and three-host ticks commonly feed on small mammals (Balashov, 1972; Oliver, 1989).

Table 2. Ixodid ticks recorded on various elephant-shrew species (A, adult, I, immature, L, larva, N, nymph)

Host	Tick	Reference
Elephantulus		
Elephantulus sp.	*Amblyomma sparsum* (I)	Theiler (1962)
	Haemaphysalis leachi leachi (I)	Theiler (1962)
	Hyalomma rufipes (I)	Theiler (1962)
	Ixodes sp. (I)	Theiler (1962)
	Ixodes alluaudi (I)	Theiler (1962)
	Rhipicephalus appendiculatus (I)	Theiler (1962)
	R. oculatus (A,I)	Theiler (1962)
	R. pravus (I)	Theiler (1962)
	R. sanguineus (I)*	Theiler (1962)
E. brachyrhynchus	*Ixodes* sp.	Theiler (1962)
	Rhipicephalus evertsi (I)	Theiler (1962)
	R. oculatus (I)	Theiler (1962)
	R. pravus (I)	Theiler (1962)
	R. punctatus (L, N)	Colbo & MacLeod (1976)
	R. sanguineus (I)	Theiler (1962)
	R. simus (I)	Theiler (1962)
E. fuscipes	*Rhipicephalus pravus* (I)	Theiler (1962)
E. intufi	*Rhipicephalus pravus* (I)	Theiler (1962)
E. myurus	*Amblyomma marmoreum* (L)	Fourie *et al.* (1992)
	Haemaphysalis leachi/spinulosa (L, N)	Fourie *et al.* (1992)
	Hyalomma marginatum rufipes (N)	Fourie *et al.* (1992)
	Ixodes rubicundus (L, N)	Fourie *et al.* (1992)
	Rhipicephalus arnoldi (L, N)	Fourie *et al.* (1992)
	R. distinctus (N)	Fourie *et al.* (1992)
	R. punctatus (L, N)	Fourie *et al.* (1992)
	Rhipicentor nuttalli (L, N)	Du Toit (1993)
E. edwardii	*Haemaphysalis leachi/spinulosa* (L, N)	Fourie & Horak (unpublished)
	Ixodes rubicundus (L, N)	Fourie & Horak (unpublished)
	Rhipicephalus gertrudae (L, N)	Fourie & Horak (unpublished)
	R. punctatus (L, N)	Fourie & Horak (unpublished)
E. rufescens	*Rhipicephalus evertsi* (I)	Theiler (1962)
	R. pravus (A, I)	Theiler (1962)
	R. sanguineus (I)	Theiler (1962)
E. rupestris	*Amblyomma marmoreum* (I)	Theiler (1962)
	Haemaphysalis leachi leachi (I)	Theiler (1962)
	H. leachi mühsami (I)	Theiler (1962)
	Ixodes sp. (I)	Theiler (1962)
	I. alluaudi (I)	Theiler (1962)
	I. rubicundus (I)	Theiler (1962)
	I. pilosus (I)	Theiler (1962)
	Rhipicephalus appendiculatus (I)	Theiler (1962)
	R. capensis (I)	Theiler (1962)
	R. oculatus (I)	Theiler (1962)
	R. pravus (I)	Theiler (1962)
Macroscelides		
Macroscelides sp.	*Rhipicephalus sanguineus* (I)	Theiler (1962)
M. proboscideus	*Haemaphysalis leachi leachi* (I)	Theiler (1962)
	Rhipicephalus evertsi (I)	Theiler (1962)
	R. oculatus (I)	Theiler (1962)

Petrodromus		
Petrodromus sp.	*Ixodes* sp. (I)	Theiler (1962)
	I. nchisiensis (A)	Theiler (1962)
	Rhipicephalus appendiculatus (I)	Theiler (1962)
	R. kochi	Clifford *et al.*(1983)
	R. pravus (I)	Theiler (1962)
	R. oculatus (I)	Theiler (1962)
P. tetradactylus	*Ixodes nchisiensis* (A)	Colbo & MacLeod (1976)
	I. rhabdomysae (N)	MacLeod (1970)
	Rhipicephalus appendiculatus (L, N)	MacLeod (1970)
	R. oculatus (I)	Theiler (1962)
	R. punctatus (L, N)	MacLeod (1970)
	R. pravus (L, N)	MacLeod (1970)
	R. sanguineus group (L, N)	MacLeod (1970)
	R. simus group (L)	MacLeod (1970)
	R. tricuspis (N)	MacLeod (1970)
P. tetradactylus	*Rhipicephalus pravus* (I)	MacLeod (1970)
(= *P. rovumae*)†	*R. sanguineus* (I)	MacLeod (1970)
P. tetradactylus	*Haemaphysalis leachi leachi* (I)	MacLeod (1970)
(= *P. sultan*)†	*Ixodes* sp. (I)	MacLeod (1970)
	Rhipicephalus appendiculatus (I)	MacLeod (1970)
	R. pulchellus (I)	MacLeod (1970)
	R. sanguineus (I)	MacLeod (1970)
	R. simus (I)	MacLeod (1970)
Rhynchocyon		
Rhynchocyon cirnei	*Ixodes rasus* group (A)	Colbo & MacLeod (1976)
R.. chrysopygus	*Rhipicephalus appendiculatus* (I)	Theiler (1962)
R.. petersi	*Haemaphysalis parmata* (I)	Theiler (1962)
	Ixodes vanidicus (A)	Theiler (1962)
	Rhipicephalus simus (I)	Theiler (1962)

* The records listed by Theiler (1962) as *Rhipicephalus sanguineus* may actually refer to *R. tupanicus*, a species not then known to occur in the Afrotropical region (Walker, 1991).
† The following synonyms are recognized (Corbet, 1974; Meester *et al.*, 1986): *Petrodromus tetradactylus* (= *P. rovumae*; = *P. sultan*).

In those cases for which quantitative data on tick infestations of elephant-shrews are available it is evident that these animals have the potential to carry very large burdens (MacLeod, 1970; Colbo & MacLeod, 1976; Fourie *et al.*, 1992). An examination of *E. myurus* and *Aethomys namaquensis*, which occur sympatrically in the southern Orange Free State of South Africa, has shown that the 132 elephant-shrews examined harboured a mean total burden of 121 ticks, compared to a mean of four for the 321 Namaqua mice (Fourie *et al.*, 1992). Similar observations have been made on elephant-shrews and rodents studied in Zambia (Colbo & MacLeod, 1976). It is not uncommon to record a total tick burden in excess of 400 on *E. myurus*. This species has been used in the laboratory on a routine basis to feed the larvae and nymphs of *Ixodes rubicundus*, the Karoo paralysis tick (Du Toit, 1993).

SIGNIFICANCE OF TICK INFESTATIONS

Many of the tick species that infest elephant-shrews are known to cause either tick toxicosis, including tick paralysis, or to transmit a diversity of pathogens such as viruses, bacteria, rickettsias, spirochaetes and protozoans to man and animals (Balashov, 1972). Because there is a lack of sound quantitative and qualitative data on tick infestations of elephant-shrews in general, the exact status of these animals as hosts for veterinary and medically important ticks remains uncertain. Although a total of seven ixodid tick species were recorded from *E. myurus*, two paralysis-inducing tick species, *I. rubicundus* and *Rhipicephalus punctatus*, accounted for 99% of the ticks recovered (Fourie *et al.*, 1992). The first mentioned species is of major economic importance in South Africa because adult females are capable of causing paralysis, and consequently mortalities, amongst domestic stock (Fourie *et al.*, 1989) and wild artiodactyls (Fourie & Horak, 1987; Fourie & Vrahimis, 1989). *Elephantulus myurus* is a major host of the immature stages of this tick and large numbers have also been collected from *Elephantulus edwardii* (Stampa, 1959).

To assess the complex phenomenon of tick–host–disease relationships, detailed and simultaneous studies, generating data at the various levels of the interactions, are required. Individual interactions between ticks and their hosts may be governed by host-dependent and tick-dependent factors. Host-dependent factors include abundance, home-range size, seasonal and daily activity patterns and habitat selection. All these factors have a direct influence on the hosts' patterns of habitat utilization and hence tick–host contact. Furthermore, host-dependent factors may also include age (i.e. size) and sex-related differences in the above-mentioned factors, the ability of the host to acquire protective immunity to ticks and its susceptibility to tick-transmitted pathogens. Tick-dependent factors include parameters such as predilection (host specificity) or opportunism (indiscriminate acceptance of all hosts), the temporal and spatial distribution of the tick and appetence response (Arthur, 1973; Sonenshine, 1975).

Several of these aspects pertaining to the interaction between *I. rubicundus* (Karoo paralysis tick) and *E. myurus*, such as effect of tick feeding on the host (Du Toit, 1993), detachment rhythms (Du Toit, Fourie & Horak, 1994), abundance, spatial distribution and activity patterns of the host, have already been investigated (Du Toit, 1993). The data gained have contributed in a major way towards our understanding of interrelationships between the tick and its host and stress the importance of a holistic approach in research design. For example, factors within an agro-ecosystem which contribute towards changes in the density of *E. myurus* within the habitat may markedly affect the population dynamics of *I. rubicundus*. Alternatively, colonization of new areas by the Rock Elephant-Shrew may also contribute towards the expansion of the geographic distribution range of the tick and the disease it causes. The detailed and simultaneous study of the many complex interactions pertaining to tick–host–disease interactions constitutes a major effort. Advances in the computer modelling of such interactions have been made recently (Haile, Mount & Cooksey, 1990) and this represents a useful tool in our understanding of these processes.

In the past, few attempts have been made to understand and quantify the nutritional, ecological and physiological implications of parasitic infestations on wild hosts. The reasons for this may be diverse, but are probably related to the fact that in domesticated or laboratory animals, the effects of parasitism are more readily determined and economic considerations often dictate the choice of subject animals. In this respect elephant-shrews are promising subject animals when taking into account the diversity and quantity of parasites that infest them and the ease with which they can be maintained as laboratory animals. To support this contention the guidelines listed below for future parasitological research on elephant-shrews are suggested.

1 The status of various elephant-shrew species as hosts for medical and veterinary important ticks should be determined.

2 The ability of elephant-shrews to maintain tick-transmitted pathogens should, as a matter of urgency, receive attention.

3 Habitat requirements of elephant-shrews and factors which may contribute towards the expansion of their distribution should be investigated. This together with the relevant data on tick ecology will make it possible to delineate the area of influence of particular tick vectors.

4 Data on the prevalence and seasonality of both elephant-shrews and ticks infesting them should be obtained, analysed and incorporated into predictive models.

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