

ORIGINAL ARTICLE

Parasites of the Nile rat in rural and urban regions of Sudan

Dina M. FAGIR and El-Amin EL-RAYAH

Department of Zoology, University of Khartoum, Khartoum, Sudan

Abstract

In this investigation on endoparasites (helminths) and ectoparasites of the Nile rat (*Arvicanthis niloticus* Desmarest, 1822), a total of 220 Nile rats were trapped from different regions of Sudan during the period January 2003–January 2006. Examination of different tissues, identification of parasites, effect of these parasites on the organs, the prevalence and intensity of infestation of the parasites and their relation to the habitat of the host, and sex-related infestations were considered. Results showed that the variation among helminth species was wide, especially in those that are transferred by arthropods. No protozoan parasites or distortion in the infected tissues were observed. No examination for *Toxoplasma gondii* was carried out. Two species of cestodes (*Hymenolepis nana*, *Hymenolepis diminuta*), two genera (*Raillietina* sp. I, *Raillietina* sp. II) and one unidentified Hymenolepididae were reported. The most prevalent species of cestodes was *Raillietina* sp. And for nematodes only one species and one genus were recovered (*Monanema nilotica* and *Streptopharagus* sp.). Investigation of skin revealed that 83.8% of rats were infested with one or more of ectoparasites; namely, insects and arachnids. This survey also revealed that fleas and lice were the most common ectoparasites that infested the Nile rat. Synanthropic rodents, particularly those living in close association with man, play a significant role in human health, welfare and economy. It has to be stressed that their arthropod ectoparasites are important vectors of pathogenic microorganisms and they can also be important reservoirs for parasitic zoonoses, like trichinellosis and capillariosis. No doubt, the increase in rodent populations could be followed by an increase in zoonotic diseases (Stojcevic *et al.* 2004, Durden *et al.* 2000). Rats and mice (commensal and wild) play an important role in public health, being carriers or reservoirs for infectious diseases that can be transmitted to humans (zoonoses). *Xenopsylla cheopis* is the most important vector of plague and the rickettsial infection murine typhus (Gratz 1999). Man can also acquire the infection through direct contact with infected animals' tissues (WHO 1987). *Arvicanthis niloticus*, *Mastomys natalensis* and *Rattus rattus* are probably the most important and widespread reservoirs of plague in Kenya: 10 percent of all *Rattus rattus* tested were found to be positive as compared to 12% of the *Arvicanthis niloticus* (Gratz 1999).

Key words: *Arvicanthis*, fleas, lice, mites, Nile rat, Sudan, ticks.

INTRODUCTION

The parasitic fauna of rodents have been widely stud-

ied as rodents often act as intermediate hosts and reservoirs of several helminthic and protozoan diseases (Smyth 1981). In Sudan, there is high risk from diseases spread by rats because of socioeconomic factors typical of developing countries. The unstriped Nile grass rat (*Arvicanthis niloticus*) is a common rodent species in Sudan and, in particular, the most common species detected along the cultivated banks of the Nile. This rodent is a herbivorous

Correspondence: Dina M. Fagir, Department of Zoology, University of Khartoum, Khartoum 11115, Sudan.
Email: d_fagir@hotmail.com

murine species inhabiting dry savannah, woodlands and grasslands across tropical Africa (Rosevear 1969) and is primarily diurnal (Delany & Kansimeruhanga 1970; Rabiou & Fisher 1989). Despite the large distribution of this animal and its affinity for human-altered landscapes, little research has been conducted on the parasites of this important reservoir for parasites and disease.

Previous work relating to rodent-borne parasites in Sudan has focused on the role of rodents as reservoirs of helminth parasites and ectoparasites. Apart from a few dated studies, very little work has been done on protozoan parasites of the unstriped Nile grass rat. Abdel Ghaffar (1985) investigated the protozoan parasites of the Nile rat and detected no coccidian parasites, and no intercellular or intracellular parasites from thin blood films and impression smears made from the liver, spleen, body muscle, tongue and brain. However, Abdel Ghaffar did find embryos of hexacanth in fecal smears, adult cestodes in the small intestine, and nematode eggs and adults in the intestine. Other studies have included *A. niloticus* as a focal species, but have also failed to detect the prevalence of protozoan parasites (see Tawil 1998; Fadl 1996).

Sharief (1995) studied the reservoir hosts of *Leishmania donovani* in Gadaref State. In his screening of the domestic animals suspected to be reservoir hosts he included donkeys, cows, sheep, goats, dogs, camels and wild rats. Sharief reported that only 3 *A. niloticus* out of 73 had significant leishmania agglutinating antibodies, but that no parasites were isolated from the skin, spleen or bone marrow.

The most recent work relating to helminth parasites of the Nile rats in the Sudan is that of Fadl (1996) and Fagir (2006). Fadl reported three species of cestodes: *Hydatigera taeniaeformis* (strobilocercus larva), *Hydatigera laticollis* (strobilocercus larva) and *Raillietina* sp. Fadl also reported 4 nematode species: *Monanema nilotica* (adult, skin and blood microfilariae), *Physaloptera* sp., *Streptopharagus* sp. and *Rictularia* sp. Fagir (2006) described 2 species of cestodes (*Hymenolepis nana* and *Hymenolepis diminuta*), 2 genera (*Raillietina* sp. I, *Raillietina* sp. II), 1 unidentified Hymenolepididae, and 1 nematode species (*Monanema nilotica*) and genus (*Streptopharagus* sp.). In Sudan, few nematode species have been described in rats: Shawgi (1985) reported 3 nematodes belonging to the subclass Secernentea, a species in the genus *Monanema* (*Monanema nilotica*), and 2 species from the genus *Rictularia* (*Rictularia affinis* and *Rictularia* sp.). In other rodent species, Tawil (1988) reported 4 genera of nematodes, *Pterygodermatites* (family: Rictulariidae) and *Streptopharagus* (family: Spirocercidae) from *Rattus rattus*, *Aspiculuris* (family: Heteroxynematidae) from *Mus*

musculus and *Oxyurid* (family: Oxyuridae) from *Gerbillus pyramidum*.

Here, we determine the occurrence of key endoparasites of the blood and internal organs and major ectoparasites of the Nile rat. This account will be discussed in the context of the effects of these parasites on the organs of this species and the broader public health importance of zoonotic species in Sudan.

MATERIALS AND METHODS

Clean traps were baited with onion, tomato, cucumber or bread and placed in the vicinity of Nile rat burrows. Most rat burrows occurred in clayey soil under bushy hedges and near farms producing vegetables, fruits, dura (*Sorghum bicolor*) and barseim (*Trifolium alexandrinum*), and containing pigs, sheep, cows and dogs. Traps were set in the early morning or before sunset and left for 3–4 days. Captured animals ($N = 220$) were removed from traps and transferred to cages for transport to the Sudan Natural Museum. At the time of collection, the mass and sex of each animal was recorded. Chloroform or ether was used to kill animals.

To survey for endoparasites, blood, bone marrow, fecal and liver smears were prepared and then investigated for the presence of protozoans or different stages of helminths. Fecal samples were further subjected to the floatation technique and samples were also mixed with potassium dichromate (2.5%) to allow for sporulation of any oocysts (Maegraith *et. al.* 1961). This was done because sporulated oocysts might be used for other experiments, and the infectivity of the sporulated oocysts lasts longer than that of unsporulated oocysts. All smears were fixed in absolute methanol for 15 min, then stained with Giemsa's stain. Internal organs (digestive tract, heart, liver, lungs and kidneys) were separated into different Petri dishes and then examined in normal saline under a dissecting microscope. The heart was cut open and examined for nematode worms. Intestines were opened longitudinally and examined for cestode worms. Encountered helminth parasites were left for some time to stretch out. They were then counted and their number, location and density were recorded. Small pieces (between 4 and 6 mm) of liver, small intestine and heart of infected rats were taken and preserved in formal saline for histological examination. For morphological studies, the specimens were first examined microscopically while still alive. Subsequently, microscopic identification of fixed stained specimens was carried out to determine their diagnostic characteristics. Significance of difference in prevalence rates of infection was evaluated using the χ^2 -test. Classi-

Table 1 Frequency of infection by different groups of endoparasites across different collection sites

Parasite		Prevalence (%)			
		Khartoum	Tuti	Sbaloka	Duiem
Cestodes	<i>Hymenolepis nana</i>	12.5	—	7.1	—
	<i>Hymenolepis diminuta</i>	1.3	—	—	—
	<i>Hymenolepis</i> spp.	1.3	—	—	—
	<i>Raillietina</i> sp. (I)	14	—	3.6	—
	<i>Raillietina</i> sp. (II)	51	80	57.1	—
Nematodes	<i>Monanema nilotica</i>	1.5	32	18	—
	<i>Streptopharagus</i> sp.	—	4	—	—

Collection sites: Khartoum State, 151 (Geraif West, 45; Shambat, 19; Soba, 26; Halfayia, 36 and Droshab, 25); Tuti Island, 27; Sabaloka Cataract, 31; Duiem Town, 11).

fication of cestodes was based on Wardle and McLeod (1968) and Soulsby (1978), and that of nematodes was based on Yamagutti (1959).

To survey for ectoparasites, rats ($N = 220$) were put in a bottle containing water and soap and then transferred to water only. A toothbrush was used to comb each rat; this was repeated several times until all ectoparasites had been confidently removed. Parasites were sorted using a finer-scale brush and preserved in labeled specimen tubes containing 70% alcohol for subsequent dehydration and mounting in DPX (The British Drug Houses, Poole, UK). The total number of ectoparasites (fleas, lice, mites and ticks) was carefully calculated. Subsequently, microscopic identification of fixed specimens was made to determine their diagnostic characteristics. Photographs were taken from slides using a Wild MPS 11 camera, mounted on a Leitz dialux 20 microscope (Leitz Wetzlar, Germany) with magnification 10 \times , 25 \times and 50 \times for endoparasites (helminths); and 4 \times and 10 \times for ectoparasites. Significance of difference in prevalence rates of infection was evaluated using the χ^2 -test. The classification of fleas and lice was based on Chandler and Read (1961), Noble and Noble (1971) and Smith (1973). Classification of mites and ticks were based on www.visualsunlimited.com, Chandler and Read (1961) Burgess (1981), Younis *et al.* (1995).

RESULTS

The majority of rats (198 from 220 rats sampled) had some type of infection; infection among male rats was

86.3% and in female rats was 94.1%. Percentage of infection with endoparasites was 70% (155 from 220 rats) and with ectoparasites was 83.8% (166 from 220 rats). The parasites found are listed in Tables 1 and 2.

Examination of smears from blood and bone marrow and impression smears from liver tissue did not reveal any protozoan parasites or life cycle stages of helminths. No histopathological changes were detected in sections taken from intestine, liver and heart of infected animals. Internal examination revealed 2 species, 2 genera (from the small intestine) and 1 unidentified sample (from the lungs) of cestode, and 1 species and 1 genus (from the heart) of nematodes.

Rats collected around Khartoum showed the highest prevalence of infection (see Tables 1 and 2). Rats collected from Tuti Island were infected with only 1 species of cestode and rats collected from Duiem Town were free from endoparasites. Overall infection with cestodes (70.2%) was by far higher than nematodes (8%). *Raillietina* sp. (II) had the highest overall prevalence rate (53%). No sex-related infection was observed ($P > 0.05$), except in the case of *Monanema nilotica*, where more female rats were infested than male rats ($P < 0.05$).

Some variations were encountered in the overall prevalence of infection and the relative frequencies of the different arthropod parasites. Fleas and lice were the most common ectoparasites that infested the Nile rat. Mites were absent in rats from Tuti Island. As for prevalence of infec-

Table 2 Frequency of infection by different groups of ectoparasites across different collection sites

Parasite		Prevalence (%)			
		Khartoum	Tuti	Sbaloka	Duiem
Insects	<i>Xenopsylla cheopis</i>	32.3	4	21.4	78
	<i>Polyplax spinulosa</i>	50	60	25	100
	<i>Polyplax abyssinica</i>	50	64	21.4	89
	<i>Polyplax serrata</i>	1.3	—	—	—
	<i>Lipeurus</i> spp.	2.2	—	—	—
Mites	<i>Trombicula</i> sp.	3.7	—	—	—
	<i>Dermanyssus</i> sp. (I).	15	—	14.3	56
	<i>Dermanyssus</i> sp. (II)	10.3	—	3.6	11.1
	<i>Dermanyssus gallinae</i>	16.2	—	7.1	44.4
	<i>Ornithonyssus bacoti</i>	9	—	7.1	33.3
	<i>Laelaps</i> sp.	1.3	—	—	11.1
Ticks	<i>Rhipicephalus</i> sp.	—	4	—	—

Collection sites: Khartoum State, 151 (Geraif West, 45; Shambat, 19; Soba, 26; Halfayia, 36 and Droshab, 25); Tuti Island, 27; Sabaloka Cataract, 31; Duiem Town, 11).

tion by ectoparasites, 30.3% of the Nile rats were infected with fleas, 77.2% with lice, 29.2% with mites, and 1.01% with ticks.

Polyplax spinulosa and *Polyplax abyssinica* (50 and 49.5%, respectively) showed the highest prevalence rates, followed by *Xenopsylla cheopis* (30.3%), *Dermanyssus gallinae* (14.1%) and *Dermanyssus* sp. (I) (15%). As for intensity of infection, *Polyplax abyssinica* showed the widest range in intensity (1–333) followed by *Polyplax spinulosa* (1–227) and *Xenopsylla cheopis* (1–134).

DISCUSSION

Most rodent species are reservoir hosts for many serious zoonotic diseases, such as plague, murine typhus fever, trichinosis, toxoplasmosis, leishmaniasis, hymenolepiasis, rat bite fever, rabies, spirochaetosis and Lyme's disease. These diseases are often transmitted from rodents to humans and other animals by ectoparasites (Younis *et al.* 1995). Here, we detected an array of endoparasites and ectoparasites infecting 220 Nile rats in

Sudan. Most of the animals tested were apparently healthy with no skin ulcers, hair loss or other clinical symptoms. The endoparasite fauna consisted of cestodes and nematodes. The higher infection of *A. niloticus* in Khartoum area (in particular Gerief West area) might be due to the richer insect and other arthropod fauna in this area. Animals collected from Duiem Town were not infected with endoparasites, possibly because these animals feed mainly on stored food material.

No protozoan blood parasites were detected, which is consistent with a study on Nile rats in Egypt by Samaha and Otify (1991); however, protozoan parasites have been reported in *A. niloticus* inhabiting other parts of the world. The absence of protozoans from the sample in the present study might be explained by a low intensity of infection, although Hoogstraal and Heynemann (1969) examined more than 500 impression smears of liver and spleen of rodents from visceral leishmaniasis endemic areas in southern Sudan and all were found negative. Another reason might be that infections with some protozoan parasites are age-specific, and in the present study most of the ani-

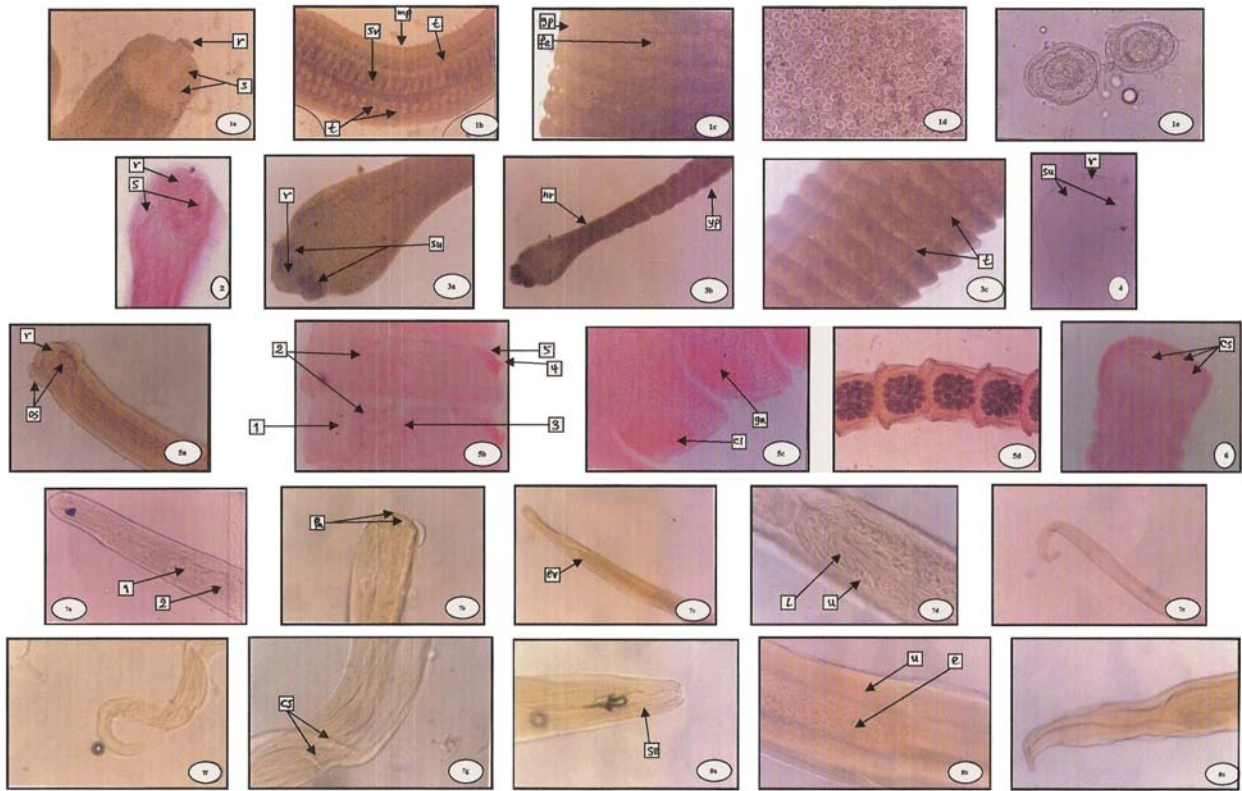


Figure 1 (a) Cestoda, *Hymenolepis nana*: showing scolex with armed rostellum (r) and four suckers (s) ($\times 25$). (b) Cestoda, *Hymenolepis nana*: showing mature proglottids (mp), testes (t) and seminal viscle (sv). ($\times 10$). (c) Cestoda, *Hymenolepis nana*: showing gravid proglottids (gp), with fertilized eggs (fe) ($\times 10$). (d) Cestoda, *Hymenolepis nana*: eggs ($\times 10$). (e) Cestoda, *Hymenolepis nana*: magnified eggs 50x, showing characteristic bipolar filaments.

Figure 2 Cestoda, *Hymenolepis diminuta*: showing scolex with unrmied rostellum (r) and four suckers (s) ($\times 10$)

Figure 3 (a) Cestoda, *Hymenolepis* sp.: showing scolex with rostellum (r) and suckers (su) ($\times 25$). (b) Cestoda, *Hymenolepis* sp.: showing neck region (nr) with young proglottids (yp). (c) Cestoda, *Hymenolepis* sp.: showing mature proglottids, showing four testes (t) ($\times 10$).

Figure 4 Cestoda, *Hymenolepis* sp.: showing larval form; (r) rostellum and (su) suckers ($\times 25$).

Figure 5 (a) Cestoda, *Raillietina* sp. (I): showing scolex with rostellum (r), oval suckers (os) and hooks (($\times 25$). (b) Cestoda, *Raillietina* sp. (I): mature proglottids. Showing: 1. excretory canal; 2. testes; 3. ovary; 4. unilateral genital atrium; 5. cirrus sac ($\times 10$). (c) Cestoda, *Raillietina* sp. (I): mature proglottids. Showing: genital atrium (ga) and cirrus (ci). (d) Cestoda, *Raillietina* sp. (I): gravid proglottids ($\times 10$).

Figure 6 Cestoda, *Raillietina* sp. (II): showing scolex with four circular suckers (cs) and armed rostellum ($\times 25$).

Figure 7 (a) Nematoda, *Monanema nilotica*: The anterior tip of the female: showing vulva close to the head: 1. vagina loop; 2. vulva ($\times 25$). (b) Nematoda, *Monanema nilotica*: showing the anterior tip of the female with papillae (pa) ($\times 50$). (c) Nematoda, *Monanema nilotica*: showing the excretory pore (ev) ($\times 10$). (d) Nematoda, *Monanema nilotica*: larvae (l) in the uterus (u) ($\times 50$). (e) Nematoda, *Monanema nilotica*: showing the posterior end of the female (spatulate). (f) Nematoda, *Monanema nilotica*: showing the posterior end of the male with papillae. (g) Nematoda, *Monanema nilotica*: the posterior end of the male showing the compulatory spicules (cs) ($\times 50$).

Figure 8 (a) Nematoda, *Streptopharagus* sp.: the anterior tip of the female, showing the s-shaped esophagus (se) ($\times 25$). (b) Nematoda, *Streptopharagus* sp.: showing fully embryonated eggs (e) in the uterus (u) ($\times 25$). (c) Nematoda, *Streptopharagus* sp.: the posterior end of the female ($\times 10$).

Figure 9 (a) *Xenopsylla cheopis* (female). (b) *Xenopsylla cheopis* (gravid female). (c) *Xenopsylla cheopis* (male).

Figure 10 (a) *Polyplax spinulosa* (female). (b) *Polyplax spinulosa* (male).

Figure 11 (a) *Polyplax abyssinica* (female). Hair confined to midline or dorsal surface (h). (b) *Polyplax abyssinica* (male). Showing the two long bristles (b) in posterior end.

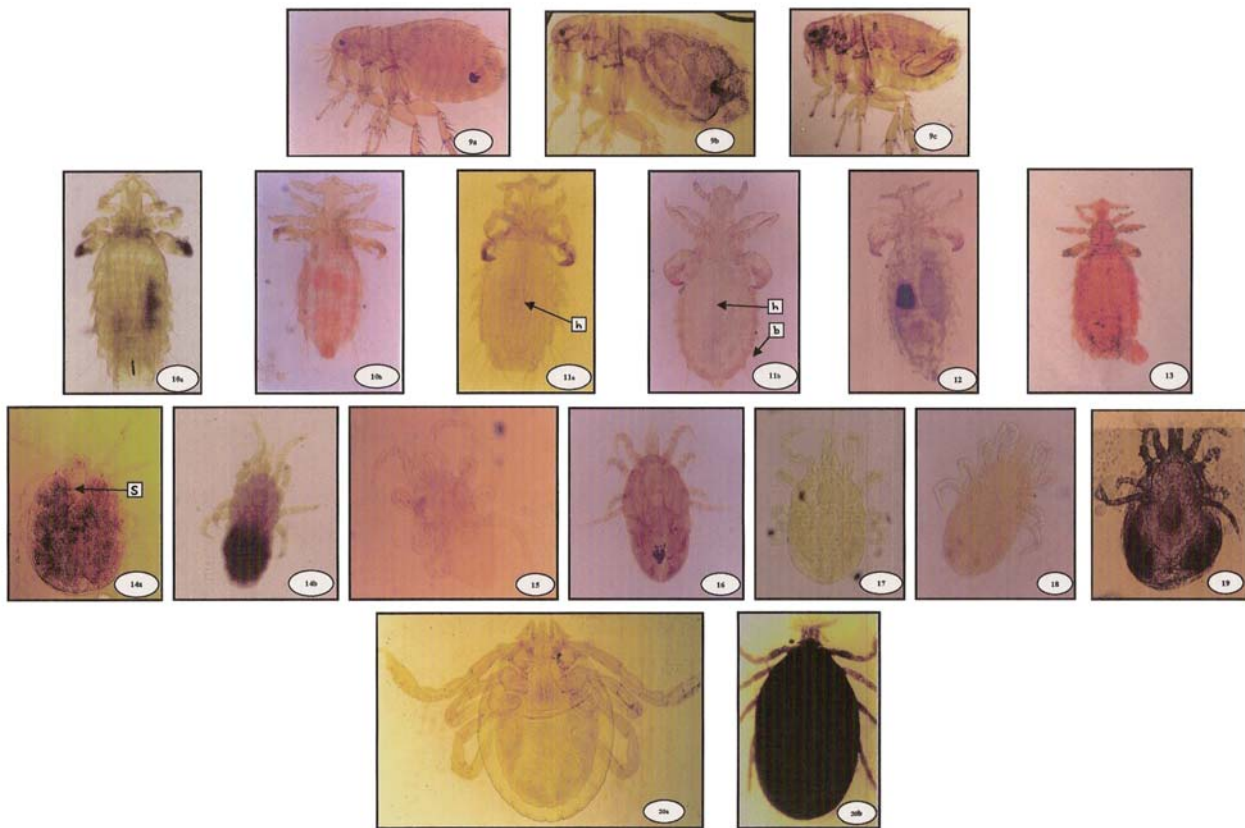


Figure 12 *Polyplax serrata*. Note the abdomen is serrated (sr).

Figure 13 *Lipeurus* spp. (female).

Figure 14 (a) *Trombicula* spp., the parasitic larva, showing rectangular shield (s). (b) *Trombicula* spp., quiescent imago-chrysalis stage.

Figure 15 *Dermanyssus* sp. (I).

Figure 16 *Dermanyssus* sp. (II).

Figure 17 *Dermanyssus gallinae*.

Figure 18 *Ornithonyssus bacoti* (the tropical rat mite).

Figure 19 *Laelaps* sp.

Figure 20 (a) *Rhipicephalus* sp., larva ($\times 4$). (b) *Rhipicephalus* sp., adult ($\times 4$).

imals examined were adults (181 adults, 39 juveniles). The susceptibility of younger rats and the increasing resistance to infection of old rats is demonstrated by Dobson (1962).

Histopathological investigations of the heart tissue revealed no inflammatory reactions in cardiopulmonary tissues, where adult worms of *M. nilotica* normally reside. The overall rate of infection by cestodes was 70.2%. *Raillietina* sp. was the most commonly detected. Various species in this genus have also been recorded from rodents throughout Africa, such as *Mus musculus* and *Rhabdomys* sp. (Yamagutti 1959). Two species of *Raillietina* were found and the predilection site for these cestodes was the

first-third of the small intestine. This might be explained by the availability of food: in heavy infection, cestodes were distributed along the whole length of the intestine, which indicates that competition forced some of them to occupy less-preferred regions of the intestine. Although the life cycle of the majority of these worms is unknown, it is suggested that the cysticercoids develop in insects (Wardle & McLeod 1968), and this might explain the high rate of infection (65%) in rats collected from the Khartoum: an area likely to contain a higher density of intermediate hosts. Abu Madi *et al.* (2001) suggested that these insects might come into contact with rat feces or feed on the same food sources as rats. The direct life cycle and,

alternatively, the presence of this intermediate host with a high prevalence, might account for the equally high prevalence of this cestode *H. nana*. Contamination of the food of rats with rat feces might account for the continuity of infection. In Sudan, there are high rates of *H. nana* infection among schoolchildren. The direct life cycle, the completely mature eggs in feces of rats, and the high degree of resistance of eggs to climate and chemicals account for such widespread infection.

For nematodes, a low overall rate of infection (8%) was observed during this survey. *Streptopharagus* sp. was isolated from the alimentary canal of *A. niloticus*, with a low prevalence of 4%, and only in the Tuti Island group. Species in this genus have also been recovered from *Rattus* sp., *Gerbillus* sp., *Acomys cahirinus* and *Meriones libycus* in Egypt (Myers 1954) and from *R. rattus*, *R. norvegicus*, *A. niloticus* and *Gerbillus gerbillus* (Mohamed *et al.* 1993). However, *Streptopharagus sudanensis* has been described from *G. gerbillus* in Sudan by Baylis as early as (1923). In this work, no males of *Streptopharagus* sp. were available; therefore, complete classification was not possible and comparison with *S. sudanensis* was also not possible. The other nematode recovered was *Monanema nilotica* (El-Bihari *et al.* 1977). *M. nilotica* infection was found to be quite specific to *A. niloticus*, as total absence of infection was reported in rodents of *Acomys* sp. and *Tatera* sp. (El-Bihari *et al.* 1977). Here, I found a low prevalence from Khartoum (1%), but a high prevalence from Tuti Island (32%). This indicates that the blood-sucking arthropod vector must prefer the moist environments of Tuti Island; however, this vector has not yet been identified. In addition, *M. nilotica* occurred more in female rats than in male rats. Generally, animal onchocerciasis does not cause serious damage to the health of infected animals (Nelson 1970, Englekirk *et al.* 1982).

In Sudan, there is a paucity of information on the ectoparasites of rats. Much of our understanding of infection in rodents comes from studies in Egypt. We found that the ectoparasites of *A. niloticus* from my sample could be organized into two groups: insects (e.g. *X. cheopis*, *P. spinulosa*, *P. abyssinica*, *P. serrata* and *Lipeurus* spp.) and arachnids (e.g. *Trombicula* sp., *Dermanyssus* sp. (I), *Dermanyssus* sp. (II), *D. gallinae*, *O. bacoti*, *Laelaps* sp and *Rhipicephalus* sp.)

Although many ectoparasitic ticks, mites, lice and fleas were isolated from *A. niloticus*, only 1 species of flea (*X. cheopis*) was recovered. Previous work (Khalid *et al.* 1992) in Egypt has found that *A. niloticus* has the second highest number of fleas, and in rats collected from fields an

overall infection rate of 60%. We similarly detected a high incidence of infestation in rats collected near fields (mainly Duiem Town site). We also found a higher prevalence of female fleas, which might be a result of female fleas more frequently seeking hosts for blood meals to compensate for egg laying and for fluid loss during other activities.

Six common mite species or genera were recovered from the host: *Trombicula gallinae*, *Dermanyssus gallinae* (I), *Dermanyssus* sp. (II), *D. gallinae*, *O. bacoti* and *Laelaps* sp. *Dermanyssus* sp (I) and *D. gallinae* were the most dominant species infesting the Nile rat. *D. gallinae* is an economically-important ectoparasite affecting poultry and many birds (WHO 1986). It feeds on blood and might become a serious pest, causing irritation and anaemia and, in some cases, even death of its host. In this survey, a 22% prevalence was detected on the skin of *A. niloticus* from Khartoum collection sites. Although this parasite is most commonly found on the skin of gallinaceous birds, the often close association between rodents and avian agriculture (pigeons and chickens) must result in many rodents becoming infested. This parasite is naturally infected with the encephalitis virus and might act as a vector for its infection (Soulsby 1978). *O. bacoti* is parasitic on rats and people all over the world. People employed in grainaries, food stores, stockyards and other places frequented by rats are greatly annoyed and discomforted by rat mites (Bishop 1923). *Ornithonyssus bacoti* transmits many diseases, such as plague, Q fever, murine typhus and *Rickettsia akari*. It is also the intermediate host of the filarial nematode *Litomosoides carinii* of rodents (Zeese *et al.* 1990). *Laelaps nuttalli*, an ectoparasite in rodents, has been reported in Egypt by many authors. El-Kammah *et al.* (1994) identified a new species of *Laelaps* (*Laelaps Sinai*) from Sinai Peninsula.

Here, we recorded only one genus of tick namely, *Rhipicephalus* sp. *Rhipicephalus* sp. is mainly found on dogs, but it has been recorded on rodents (see Shoukry *et al.* 1993). Larval and nymphal stages of the tick *Rhipicephalus simus* and *Haemaphysalis* sp. are known to feed on rodents. *Rhipicephalus sanguineus* is the most widely distributed tick species in the world and this cosmopolitan tick infests domestic and wild mammals, and, incidentally, humans. Immature *R. sanguineus* infest rodents and other small mammals (Hoogstraal 1985). It is suspected to be the vector of *Monanema nilotica* (El-Bihari *et al.* 1977). Rodents serve as hosts to the immature stages of many of the tick species; furthermore, rodent burrows would seem to provide a more suitable microhabitat of higher humidity and buffered temperature extremes for Ixodid ticks (Logan *et al.* 1993).

ACKNOWLEDGMENTS

The authors would like to thank Dr Saadia A. Younis of the University of Khartoum for her invaluable help in the identification of helminths. Thanks are also due to Mr Sayed Yousif of the Electronic Microscope Unit, University of Khartoum, for assistance with photography.

REFERENCES

- Abdel Ghaffar A (1985). Detection of coccidian parasites in the Nile rat *Arvicanthis niloticus testicularis* (Honours dissertation). University of Khartoum, Sudan.
- Abu Madi MA, Lewis JW, Mikhail M, El-Nagger ME, Behnke JM (2001). Monospecific helminth and arthropod infections in an urban population of brown rat from Doha, Qatar. *Journal of Helminthology* **75**, 313–20.
- Baylis HA (1923). Report on a collection of parasitic nematodes, mainly from Egypt. Part I. Ascaridae and Heterakidae. Part II. Oxyuridae, Part III. Camallanidae ...etc. with a note on a Prostomayria and an appendix on Acanthocephala. *Parasit* **15**, 1–2, 14–23, 24–38.
- Bishop FC (1923). The rat mite attacking man. Washington DC Department of Agriculture, No. 249.
- Burgess NRH (1981). *Arthropods of Medical Importance*. Noble Books, London.
- Chandler AC, Read CP (1961). *Introduction to Parasitology*. Tenth edition. Toppan Printing, Japan.
- Darwish M, Hoogstraal H (1981). Arboviruses infecting humans and lower animals in Egypt. *Journal of Egyptian Public Health Association* **56**, 1–112.
- Delany MJ, Kansiiimeruhanga WDK (1970). Observations of the ecology of rodents from a small arable plot near Kampala, Uganda. *Review of Zoology and Botany in Africa* **81**, 417–25.
- Dobson C (1962). Certain aspects of the host parasite relationship of *Nematospiroides dubius* (Baylis). IV. The effect of the host's age on experimental infections in the mouse and rat. *Journal of Parasitology* **52**, 31–40.
- Durden LA, Hu R, Oliver JH Jr, Clilek JE (2000). Rodent ectoparasites from two locations in Northern Florida. *Journal of Vector Ecology* **25**, 222–8.
- El-Bihari S, Hussein HS, Muller R (1977). *Monanema nilotica* n. sp. (Nematoda: Onchocercidae) a cardiopulmonary parasite of the Nile rat in Sudan. *Journal of Helminthology* **51**, 317–21.
- El-Kady GA, Shoukry A, Ragheb DA, El-Said AM, Habib KSM, Morsy TA (1995). Mites (Acari) infesting commensal rats in Suez Canal Zone, Egypt. *Journal of Egyptian Society of Parasitology* **25**, 417–25.
- El-Kammah KM, Oyoun LMI, El-Kady GA (1994). *Laelaps sinai* sp. nov. (Laelapinae, Laelapidae). A parasite of *Gerbillus pyramidum* in El-Arish, North Sinai, Egypt. *Journal of the Egyptian Society of Parasitology* **24**, 167–71.
- Engelkirk PG, Williams GM, Schmidt G, Lied RW (1982). Zoonotic onchocerciasis. In: Schultz MG, ed. *CRC Handbook Series in Zoonoses, Section C: Parasitic Zoonoses Vol. II*. CRC Press, Boca Raton, Florida, USA, pp. 225–50.
- Fadl MA (1996). Parasitic fauna of the Nile rat (*Arvicanthis niloticus*) with emphasis on the Onchocercoid nematode *Monanema nilotica* (Masters thesis). University of Khartoum, Sudan.
- Fagir DM (2006). Parasitological survey of the Nile rat *Arvicanthis niloticus* (Desmarest, 1822) Lesson, 1842 (Mammalia, Muridae) in some rural and urban regions of Sudan (Masters thesis). University of Khartoum, Sudan.
- Gratz NG (1999). Rodent reservoirs and flea vectors of natural foci of plague. In: Dennis DT, Gage KL, Gratz NG, Poland JD, Thikhomirov E, eds. *Plague manual: Epidemiology, distribution, surveillance and control*. World Health Organisation, Geneva, pp. 63–96.
- Haeselbarth E, Segerman J, Zumpt FKE (1966). The arthropod parasites of vertebrates in Africa South of the Sahara (Ethiopian region). V. III (Insecta exd. Phthiraptera). *Publications of South African Institute of Medical Research* **13**, 283.
- Hass GE, Tomich PO (1973). The fleas (Siphonaptera) of Egypt. Early records from mammals. *Journal of Egyptian Public Health Association* **48**, 1–17.
- Hoogstraal H (1985). Ticks. In: Gaafar SM, ed. *Animal Population Handbook* (World Animal Science) Vol. 21 (parasite, pest and predators), Elsevier Science, Amsterdam, Netherlands, pp. 347–69.
- Hoogstraal H, Heynmann D (1969). Leishmaniasis in the Sudan Republic. Final epidemiological report. *American Journal of Tropical Medicine and Hygiene* **18**, 1091–210.
- Khalid MLM, Morsy TA, El-Shennawy SFA, Farrag AMM K, Sabry AHA, Mostafa HAA (1992). Studies on flea fauna in El-Fayoum Governorate. *Journal of*

- the *Egyptian Society of Parasitology* **22**, 783–99.
- Logan TM, Wilson ML, Cornet JP (1993). Association of ticks (Acari: Ixodoidea) with rodent burrows in Northern Senegal. *Journal of Medical Entomology* **30**, 799–801.
- Maegraith BG, Kershaw WE, Dagnall D (1961). *Techniques in Tropical Medicine*. Oliver and Boyd, Edinburgh, London.
- Mohamed, Wanas QA, Shehata KK, Rashed AA (1993). Studies on the nematode parasites from Egyptian rodents. I. Spirurid nematodes. *Journal of the Egyptian Society of Parasitology* **23**, 851–63.
- Myers BJ (1954). Helminth parasites of birds and mammals. 1. *Streptopharagus kuntzi* from rodents with a review of the genus. *Canadian Journal of Zoology*. **25**, 366–74.
- Nelson GS (1970). Onchocerciasis. In: Daves B, ed. *Advances in Parasitology*, Vol. 8. Academic Press, London and New York, pp. 173–210.
- Noble ER, Noble GA (1971). *Parasitology. The Biology of Animal Parasitology*. Lea and Febiger, Philadelphia, USA.
- Okereke TA (1971). On the distribution of wood-sucking gamasid mites (Acari: Mesostigmata) on small mammalian hosts in Western Nigeria. *Bulletin of Entomological Society of Nigeria* **3**, 50–5.
- Paperna I, Furman DP, Rothstein N (1970). The parasite fauna of rodents from urban and suburban areas of Accra-Tema, South Ghana. *Revue de Zoologie et de Botanique Africaines* **81**, 330–6.
- Rabiu S, Fisher M (1989). The breeding season and diet of *Arvicanthis niloticus* in Northern Nigeria. *Journal of Tropical Ecology* **5**, 375–86.
- Rifaat MA, Mahdi AH, Arafa MS (1969). Helminthic infection of the climbing rat *Rattus rattus* Linnaeus 1758, in the U.A.R. *J. Egypt Pub. Health Ass.* **44**, 119–25.
- Rosevear DR (1969). *The Rodents of West Africa*. Trustees of the British Museum (Natural History), London, UK.
- Samaha H, Otify Y (1991). Role of rodents as reservoir hosts of some enteric parasites. *Assuit Veterinary Medical Journal* **24**, 171–5.
- Sharief AH (1995). Identification of possible reservoir hosts of *Leishmania donovani* in two villages in Gadaref State, Eastern Sudan (Masters thesis). University of Khartoum, Sudan.
- Shawgi S (1985). Studies on the helminth parasites of *Arvicanthis niloticus testicularis* (Honours dissertation). Department of Zoology, University of Khartoum, Sudan.
- Shoukry A, El-Kady GA, Morsy TA, Salama MMI (1993). Rodents and their arthropods ectoparasites in South Sinai Governorates. *Journal of the Egyptian Society of Parasitology* **23**, 775–83.
- Smith KGV (1973). *Insects and Other Arthropods of Medical Importance*. The Trustees of the British Museum (Natural History) London.
- Smyth JD (1981). *Introduction to Animal Parasitology*. Hodder and Stoughton Educational. London, U.K.
- Soulsby EJJ (1978). *Helminths, Arthropods and Protozoa of Domesticated Animals*, 6th edn. The English Language Book Society and Bailliere Tindal and Cassall, London.
- Stojcevic D, Mihaljevic Z, Marinculic A (2004). Parasitological survey of rats in rural regions of Croatia. *Veterinary Medicine – Czech* **49**, 70–4.
- Tawil SAM (1988). Study on some aspects of ecology and parasites of four rodent species from Khartoum and Kordofan (Masters thesis). University of Khartoum, Sudan.
- Wardle RA, McLeod JA (1968). *The Zoology of Tapeworms*. Hafner Publishing, New York and London.
- World Health Organization (1986, 1987). Mites. Training and information guide. Vector Control Series. World Health Organization, Vector Biology and Control Division.
- Yamagutti S (1959). *Systema Helminthum, Vol. II. The Cestodes of Vertebrates*. Interscience publishers, New York and London.
- Younis TA, Fayad ME, El-Hariry MA, Morsy TA (1995). Interaction between Acari ectoparasites and rodents in Suez Governorate, Egypt. *Journal of Egyptian Society of Parasitology* **25**, 377–94.
- Zeese W, Khalaf SA, Abou El-Ela RG, Morsy TA (1990). Rodents and their ectoparasites in Sharkia Governorate, Egypt. *Journal of Egyptian Society of Parasitology* **20**, 827–35.