

Rodents as reservoir hosts in the transmission of *Schistosoma mansoni* in Richard-Toll, Senegal, West Africa

J.M. Duplantier^{1,2} and M. Sène^{1,3*}

¹Programme 'Eau & Santé', IRD (ex ORSTOM), B.P. 1386, Dakar, Sénégal; ²Programme RAMSE, IRD B.P. 434, Antananarivo 101, Madagascar; ³Département de Biologie Animale, Faculté des Sciences et Techniques, Université Cheikh Anta Diop de Dakar, Sénégal

Abstract

More than 2000 animals belonging to six different rodent species and one insectivore species were examined for infection with schistosomes in the region of Richard-Toll, Senegal. Two murid rodents, *Arvicanthis niloticus* and *Mastomys huberti*, were found infected with *Schistosoma mansoni*. Prevalences were about 5% for both rodent species with a mean worm burden of about 20 worms per host. The sex-ratios of *S. mansoni* worms were always biased towards males. Prevalences and worm burdens, although similar in both male and female rodents, increased significantly with age. The highest prevalences and worm burdens were found near habitations and decreased significantly with the distance from the town of Richard-Toll. Eggs were also observed in the liver and faeces of the two naturally infected rodent species. The results suggest that rodents participate in the transmission of intestinal schistosomiasis in Richard-Toll but the human population is the main source of infection. The genetic resemblance between human and murine isolates of *S. mansoni* suggests that further epidemiological studies are needed in this region of Senegal.

Introduction

Intestinal schistosomiasis with *Schistosoma mansoni* occurs in Arabia, Africa, the West Indies and South America. The definitive host is usually man, but numerous other mammalian species have also been found infected by this parasite. Among these, rodents are the most common (Pitchford, 1977; Imbert-Establet, 1986).

Recently, an outbreak of intestinal schistosomiasis occurred in Richard-Toll, along the Senegal river (Talla *et al.*, 1990). Because of a high human prevalence (Talla *et al.*, 1991), significant infection levels in the intermediate hosts (*Biomphalaria pfeifferi*) (Diaw *et al.*, 1991; Talla *et al.*, 1991) and the widespread occurrence of rodent populations (Duplantier, 1990) a preliminary survey of rodents

was undertaken in this focus to elucidate whether or not they are involved in the epidemiology of intestinal schistosomiasis in Richard-Toll.

Long-term studies on the importance of rodents in transmitting intestinal schistosomiasis have been carried out in Guadeloupe Island (Combes *et al.*, 1975; Combes & Delattre, 1981) and in Brazil (Rey, 1993). However in Africa, apart from studies in South Africa by Pitchford (1959) and Pitchford & Visser (1962), little is known about the occurrence of *S. mansoni* in species of rodents. The eruption of a new focus in Senegal, at a considerable distance from the northern limit of this disease in West Africa as described by Sellin & Boudin (1981), provides an opportunity to follow the evolution of schistosomiasis amongst wild rodents from the outset: all previous studies were undertaken in foci whose age was unknown.

The aims of the present study therefore are to identify which rodent species are potential carriers of *S. mansoni* and to establish the distribution of *S. mansoni* among the various biotopes occupied by these rodents.

* Address for correspondence: Laboratoire de Paludologie, IRD (ex ORSTOM) Bel-Air, B.P. 1386 Dakar, Senegal.
Fax: 832 16 75
E-mail: senewade@metiasacana.sn



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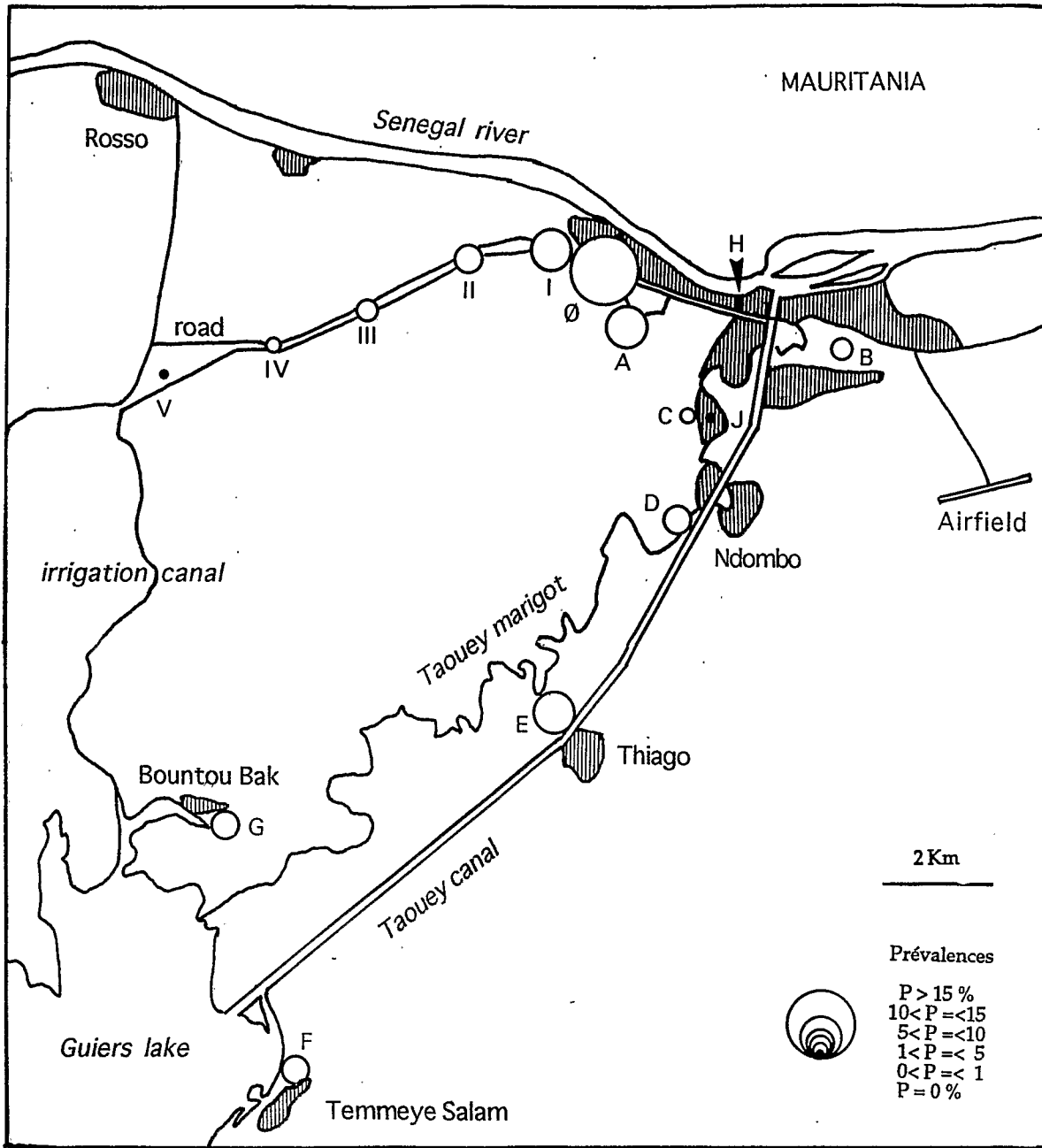


Fig. 1. A sketch map of Richard-Toll showing the location of the trapping sites in the western (O, I, II, III, IV and V) and southern (A, B, C, D, E, F and G) axes.

Material and methods

Study area

Bimonthly sampling of rodents was carried out from July 1990 to July 1993 around Richard-Toll, a town located in northern Senegal (16°27'N, 15°42'W). The hydrographic network is very dense (fig. 1) and composed of: (i) the Senegal river, along the northern limit of the town; (ii) the Taouey canal, built to connect the Senegal river directly to lake Guiers; (iii) the Taouey marigot, a previous link between the river and the lake; and (iv) the irrigation system of the 'Compagnie Sucrière Sénégalaise' (CSS). This company has been located in Richard-Toll since 1971 and cultivates thousands of hectares of sugarcane. The number of inhabitants in Richard-Toll increased from 6000 inhabitants in 1971 to 50000 in 1992 (Handschumacher *et al.*, 1992). Around the town and the sugarcane fields, farmers cultivate mainly rice during the wet season (July to December) and vegetables during the dry season.

A dam was built near the mouth of the Senegal river in 1986, to prevent salt water entering the river during the dry season. One year later, another dam was completed 600 km upstream, at Manantali in Mali, to regulate the flow of the Bafing River, a tributary of the Senegal River, and to generate hydroelectricity. Both dams have dramatically modified the ecology of the Senegal valley and particularly the environment of the Richard-Toll area, which now has permanent fresh water.

Trapping procedures

Rodents were collected with wire-meshed live-traps (Firobind and Manufrance models), baited with peanut butter. Lines of 20 traps with a 10 m interval between consecutive traps were set for two or three nights. Traps were set in the late afternoon and checked every morning. The different trapping areas (fig. 1) were sampled every two months. Trap lines were located along hedges around small gardens and orchards and along irrigation canals inside the ricefields. Some trapping was also carried out inside the town itself.

The first sampling axis was established from the town towards the West with a trap site every 2 km (stations I to IV) along the main irrigation canal. In May 1992, as human cases of schistosomiasis were discovered along the Guiers lake, it was decided to set up another sampling axis for rodents towards the South between the town of Richard-Toll and Guiers lake.

Recovery of *S. mansoni*

Rodents were brought back alive to the laboratory. Each rodent was killed by a pentobarbital injection, and then the body lengths, weights and sexual activity were recorded. Adult worms were recovered from the portal-mesenteric system as described by Duvall & Dewitt (1967). Worms were also searched for by visual examination of the mesenteric vein. The liver and lungs of rodents, which were found to be infected during perfusion, were also examined for the presence of schistosomes. Then a search for eggs was undertaken within the liver and the faeces by means of microscopic examinations.

Data analysis

Chi-square test and Student *t* tests were used to compare respectively prevalences and mean worm burdens. Relationships between prevalences or worm burdens and age, sex of rodents or the proximity of human habitations were calculated using the coefficient of correlation *R*.

Any increase in body weight does not cease when rodents become sexually mature, but continues throughout the life of the animal (Foulet, 1982; Duplantier, 1988). Thus, it is possible to correlate weight classes with age classes. The rodents have been sub-divided into five 30 g classes for *Arvicanthis niloticus* and into five 10 g classes for *Mastomys huberti*. The first two classes correspond to juveniles, the following three to adults.

Results

Prevalences and worm burdens of *S. mansoni* are presented according to the species, sex, age and spatial distribution of rodents. Mean worm burdens are calculated as the geometric means of the number of worms recovered after perfusion.

Species and sex of rodents

More than 2000 animals belonging to six different rodent species and one insectivore species have been examined (table 1). These included the following:

Three murids: *Arvicanthis niloticus* (the Nile rat), *Mastomys huberti* (one of the multimammate rats) and *Mus musculus* (the house mouse).

Two gerbils: *Taterillus pygargus* and *Taterillus gracilis*, sibling species were not distinguished here.

One squirrel: only one *Xerus erythropus* (the West African ground squirrel) was caught as the trap model that was used is usually too small for this species.

Some shrews belonging to the genus *Crocidura* were also analysed but none of them was infected.

Only two species, *A. niloticus* and *M. huberti*, were found to be infected with *S. mansoni*. Differences observed between *A. niloticus* and *M. huberti* are not significant.

No significant differences were observed between male and female hosts either for *A. niloticus* or for *M. huberti* (table 2).

Rodent age

For the two species under consideration, prevalence is zero for class I, and only one infected rodent belongs to class II (table 3). A strong correlation was observed between prevalence and host age and between worm burden and host age.

Spatial distribution of rodents

Prevalences of *S. mansoni* in the rodent species vary from 0% to almost 20% (table 4). On the sampling axis, located on the west side of the town, prevalences decrease regularly and significantly with increasing distance from the town ($r = 0.845$, $P < 0.05$). On the other hand, on the southern sampling axis, from the town to the Guiers lake (stations C to G), there is no gradient in prevalence values.

Table 1. Prevalence of rodent species naturally infected with *Schistosoma mansoni* in Richard-Toll.

	Number of individuals		Prevalence (%)
	examined	infected	
<i>Arvicanthis niloticus</i>	1387	77	5.5 ± 1.2
<i>Mastomys huberti</i>	861	39	4.5 ± 1.4
<i>Mus musculus</i>	18	0	0
<i>Taterillus</i> sp.	13	0	0
<i>Xerus erythropus</i>	1	0	0
<i>Crocidura</i> sp.	19	0	0
Total	2299	116	5 ± 0.9

As in the case of prevalences, worm burdens decrease significantly with the distance from the town on the western axis ($r = 0.858$, $P < 0.05$). The correlation between prevalence and worm burden is not significant ($r = 0.342$, $P > 0.05$).

Eggs in the liver and faeces of rodents

Three groups were identified among the 98 rodents examined according to the presence or absence of *S. mansoni* eggs in the liver or faeces. The first group passed eggs with their faeces and represented 34% of the infected rodents. The second group (24%) had solely encapsulated eggs within the liver and the third group (41%) had eggs neither in the liver nor faeces (table 5). The mean worm burden is significantly higher in the first group having eggs in liver and faeces than in the second ($t = 2.981$, $P < 0.01$) and third groups ($t = 2.019$, $P < 0.05$). Furthermore, the first group represents a more balanced sex-ratio of worms. The distribution of male and female *S. mansoni* is significantly different among the three groups of rodents ($\chi^2 = 6.3569$, $P < 0.02$).

Discussion

The survey undertaken around Richard-Toll has shown the existence of two rodent species (*A. niloticus* and *M. huberti*) naturally infected with *S. mansoni*. Various factors could explain the existence of *S. mansoni* worms in a rodent: life in humid areas, activity rhythms corresponding to emergence of cercariae and immunological compatibility.

Arvicanthis niloticus is a generalist rodent living in both humid and dry areas (Poulet, 1982). *Mastomys huberti* lives only in wet areas, marshes and ricefields (Duplantier & Granjon, 1988). *Arvicanthis niloticus* has been reported as a host of *S. mansoni* in Egypt (Mansour, 1978; Arafa & Massoud, 1990), in Sudan (Karoum & Amin, 1985) and

in Niger (Mbieleu-Nkouedeu, 1991), with prevalences ranging from 1.6% to 7.7%, but this is the first record of *S. mansoni* in *M. huberti*. The only available data concerning the genus *Mastomys* originate from a study in South Africa (Pitchford & Visser, 1962), in which a prevalence of 0.9% was recorded from more than 1000 *Mastomys natalensis* over three years.

The sample size of other rodent species examined is likely to be too small to produce positive parasitological results, although gerbils of the genus *Taterillus* live in very dry biotopes and are rarely trapped in humid zones: thus it is not surprising that none of them was infected with *S. mansoni* in Richard-Toll. The house mouse (*Mus musculus*) whose laboratory strains constitute the best experimental host for schistosomiasis is not naturally infected in Richard-Toll. In Senegal, *M. musculus* lives only inside habitations, and has no contact with water from rivers and canals. The shrews (*Crocidura* sp.) live in similar humid biotopes to *Mastomys huberti*. As *Crocidura* sp. have been found infected in other African countries, Zaire and Egypt (Stijns (1952) and Kuntz, (1958) in Pitchford (1977)) the hypothesis of an insufficient sample in this study has to be taken into account.

Arvicanthis niloticus is mainly diurnal, while *M. huberti* is only nocturnal (Duplantier & Granjon, 1990). Two hypotheses could explain the presence of *S. mansoni* worms within rodents with different patterns of activity, i.e. cercarial chronobiologic polymorphism and emergence at different periods is related to activity rhythms of *A. niloticus* and of *M. huberti* or cercarial densities are high enough to infect these diurnal and nocturnal rodents. The first hypothesis seems unlikely in Richard-Toll as this focus is very recent: the first human cases were reported in 1988 (Talla *et al.*, 1990). Théron *et al.* (1989) demonstrated that chronobiologic polymorphism is related to the ecological features of the focus, activity of the definitive hosts and genetic variations of the schistosomes. However, in Richard-Toll, Sène *et al.* (1997) reported that the genetic variations observed between human and murine isolates of *S. mansoni* are not significant and man is the main source of infection. Hence, the second hypothesis seems more likely.

Prevalence values in *A. niloticus* and *M. huberti* are lower than those observed for other rodents in Guadeloupe Island and South America. Prevalences of 52% for *Rattus rattus* and 37% for *R. norvegicus* have been reported in Guadeloupe (Combes & Delattre, 1981). In the same island, Imbert-Establet (1986) observed prevalences of 72% for *R. rattus* and 28% for *R. norvegicus*.

In Brazil, prevalences of about 50% have been recorded in several foci (Rey, 1993) and concerned mainly two

Table 2. Prevalence, worm burden and sex-ratio of *Schistosoma mansoni* in male and female naturally infected *Arvicanthis niloticus* and *Mastomys huberti*.

Rodent species	Sex	Number of rodents		Prevalence (%)	Worm burden		Sex-ratio of worms m:f
		examined	infected		mean	Max ^a	
<i>A. niloticus</i>	male	632	38	6	6.53	582	2.0:1.0
<i>A. niloticus</i>	female	755	39	5.2	5.06	299	1.4:1.0
<i>M. huberti</i>	male	472	22	4.7	6.15	102	1.6:1.0
<i>M. huberti</i>	female	389	17	4.4	5.75	204	1.2:1.0

^a Highest number of worm recovered.

Table 3. Prevalence and worm burden of *Schistosoma mansoni* in naturally infected *Arvicanthis niloticus* and *Mastomys huberti* relative to rodent age class.

	Age classes	Weight classes (g)	Number of rodents		Prevalence (%)	Mean worm burden	Coefficient of correlation (R)
			examined	infected			
<i>M. huberti</i>	I	< 20	63	0	0	0	0.954 ^a
<i>M. huberti</i>	II	20-29	209	1	0.5	2	(d.f.=3)
<i>M. huberti</i>	III	30-39	169	7	4.1	2.2	0.9148 ^b
<i>M. huberti</i>	IV	40-49	182	9	4.9	4.7	(d.f.=38)
<i>M. huberti</i>	V	> 50	238	22	9.2	9.6	
<i>A. niloticus</i>	I	< 30	55	0	0	0	0.882 ^a
<i>A. niloticus</i>	II	30-59	192	1	0.5	1	(d.f.=3)
<i>A. niloticus</i>	III	60-89	364	7	1.9	4.03	0.9544 ^b
<i>A. niloticus</i>	IV	90-119	392	18	4.6	4.04	(d.f.=75)
<i>A. niloticus</i>	V	> 120	384	51	13.3	7.1	

^a Prevalence; ^b worm burden.

rodents of the Sigmodontinae subfamily with aquatic habitats: *Nectomys squamipes* and *Holochilus brasiliensis*. In Africa only one study, carried out in Kenya, presented such high prevalences (Kawashima *et al.*, 1978), but only 41 *Felomys* sp. were analysed.

Several factors influence the global infection levels discussed above. The prevalence of *S. mansoni*, although independent of species and sex of the definitive host, increases significantly with the age of rodents, at least for the species studied here. Combes & Delattre (1981) have observed the same phenomenon for *R. rattus* and *R. norvegicus*. This can be explained by the fact that newborn rodents do not leave the nest before two weeks and after penetrating the definitive host, cercariae need four weeks to develop into adult worms. So it is highly unlikely that a two-month-old rodent could be infected. Despite the importance of rodent age in prevalence, this factor has not been taken into account in previous studies, except by Combes & Delattre (1981).

The decrease in prevalence relative to the distance from the town, on the western axis, and especially as this phenomenon has not been observed on the southern axis where all trapping sites are located near villages, except for site C, shows that in this focus, human beings are mainly responsible for transmission.

The biased sex-ratio in favour of male worms, whatever the rodent species, may be due to the greater aptitude of male cercariae to penetrate and develop in the definitive host, or to a greater number of male cercariae in the water. Bradley & May (1978) consider also that this observed difference could result in greater difficulty in recovering females during perfusion. This technical problem is real but not sufficient to explain this unbalanced sex-ratio. An unbalanced sex-ratio was also observed in wild *R. norvegicus*, naturally infected in Guadeloupe (Imbert-Establet, 1986) and in experimentally infected *A. niloticus* (Mbieleu-Nkouedeu, 1991).

In conclusion, the present study has shown that two different species of rodents are naturally infected with *S. mansoni* in Richard-Toll. Prevalences and worm burdens, observed in the field, are low and decrease significantly according to the distance from the human focus. These results show that, in Richard-Toll, the participation of rodents in the dynamic transmission of intestinal schistosomiasis is minor compared with humans being the main source of infection. However, several facts show that rodents should be taken into account in any future control programme. Sène (1996) observed that prevalences and worm burdens increase regularly and sharply during the three years of study. It was also demonstrated that

Table 4. Prevalence and worm burdens in rodents naturally infected with *Schistosoma mansoni* relative to trapping sites in the western (O, I, II, III, IV and V) and southern (A, B, C, D, E, F and G) axes.

Trapping sites	Number of rodents		Prevalence (%)	Number of <i>S. mansoni</i>	Mean worm burden
	examined	infected			
A	8	1	12.5	3	3
B	244	9	3.7	45	3.8
C	294	2	0.7	2	1
D	188	14	7.4	72	2.7
E	179	18	10	485	5.1
F	123	5	4.1	396	15.4
G	68	1	1.5	2	2
O	72	14	19.4	286	8.2
I	187	25	13.4	1488	13.4
II	281	16	5.7	304	6.4
III	425	10	2.4	28	2.1
IV	177	1	0.6	1	1
V	2	0	0	0	0

Table 5. Prevalence (in parentheses), worm burdens and sex-ratios of naturally infected rodents relative to the presence/absence of *Schistosoma mansoni* eggs in the liver and faeces.

	Eggs in the liver and faeces	Eggs in the liver only	No eggs
<i>Arvicanthus niloticus</i>	21 (32 %)	14 (22 %)	30 (46 %)
<i>Mastomys huberti</i>	8 (29 %)	7 (25%)	13 (46 %)
Mean worm load	31.55	5.50	2.05
Sex-ratio of worms (m:f)	1.3:1.0	2.2:1.0	4.0:1.0

m, male; f, female.

naturally infected *A. niloticus* and *M. huberti* pass viable and infective eggs in the faeces, indicating that these rodents are potential definitive hosts (Sène *et al.*, 1996). In addition, human and murine *S. mansoni* are phenotypically similar, as no significant genetic variation was observed between the two isolates (Sène *et al.*, 1997).

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