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A LONGITUDINAL SURVEY OF *BORRELIA CROCIDURAE* PREVALENCE IN RODENTS AND INSECTIVORES IN SENEGAL

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Abstract. We report results of a longitudinal survey designed to determine the importance and the dynamics of *Borrelia crocidurae*, the spirochete responsible for tick-borne relapsing fever in West Africa in rodents and insectivores in a rural area of northern Senegal. A total of 954 animals were caught during bimonthly capture sessions over a two-year period. Positive thick blood smears were recorded in 17.6% of the 740 rodents and 7.3% of the 55 musk shrews tested. Variations of prevalence were analyzed in *Arvicanthis niloticus* and *Mastomys huberti*, which represented 62.7% and 28.3%, respectively, of the animals captured, and 65.7% and 27.6%, respectively, of the animals found infected. *Borrelia crocidurae* prevalence was significantly different between captures and fluctuated separately for each species. Age-specific prevalence of *B. crocidurae* showed distinct patterns, decreasing with age from 50% in younger juveniles to 3% in older adults for *A. niloticus*, while increasing with age from 8% to 23% for *M. huberti*. No relationship was observed with animal abundance or with the season of the year for either species. These findings suggest that the diversity of the population dynamics of host-vector-parasite associations in the Sahel region of Senegal may be a key factor for the relative stability of the borreliosis reservoir.

The spirochete *Borrelia crocidurae* was first described in 1917 by Leger[1] from the blood of a musk shrew from Dakar, Senegal, and it was later found in various rodent species.[2–4] Mathis demonstrated that relapsing fever in West Africa was due to *B. crocidurae*[5] and Durieux discovered the tick vector, *Alectorobius sonrai* (formerly *Ornithodorus erraticus sonrai*).[6] The frequent occurrence of relapsing fever in Senegal was first suspected in the mid-1930s.[7] However, since diagnosis is difficult because of the frequent low density of *B. crocidurae* in patients' blood,[4] case reports were rare and the disease has remained poorly studied. Recently, high prevalence rates were found in rodents from several regions of Senegal and studies of clinic outpatients have suggested that borreliosis is a major cause of morbidity in many rural areas of this country.[4]

The present paper reports results from a longitudinal study designed to determine the importance and the dynamics of the borreliosis animal reservoir in a rural area of northern Senegal where documented cases of relapsing fever in humans were recently reported.[4]

MATERIALS AND METHODS

Richard-Toll (16°27'N, 15°42'W) is located at the eastern limit of the Senegal River delta. The climate is sahelian with a short wet season from July to October, yielding an average annual rainfall of 230 mm for the last 30 years. In 1990 and 1991 (the period covered by the study), rainfall was 137 mm and 158 mm, respectively. The main economic activity is irrigated sugar cane cultivation.

Rodents and insectivores were captured in fields and gardens around Richard-Toll in March 1990 and every two months from July 1990 to January 1992. Animals were trapped alive with lattice-work traps (Manufrance, Saint Etienne, France) baited with peanut butter. We adopted the method of trap lines for captures, with a 10-meter space between traps. A limited number of captures were also made inside houses.

Trapped rodents were taken to our laboratory in Dakar, where they were identified, weighed (except in March 1990), and tested for *B. crocidurae*. Blood samples were taken by cutting the tail tip or by intracardiac tapping. Thick blood smears were stained with Giemsa and 200 oil immersion fields (1,000×) were systematically examined for *B. crocidurae* (equivalent to approximately 0.5 μl of blood).

TABLE 1

Prevalence of Borrelia crocidurae *in rodents and insectivores at Richard-Toll, Senegal*

Species	No. analyzed	No. positive	% positive
Arvicanthis niloticus	476	88	18.5
Mastomys huberti	234	37	15.8
Mus musculus	21	5	23.8
Taterillus sp.	9	0	0.0
Crocidura sp.	55	4	7.3
Total	795	134	16.9

RESULTS

Small mammals captured and prevalence of B. crocidurae

During the two years of the study, 899 rodents and 55 insectivores belonging to five species were caught: 599 *Arvicanthis niloticus* (Nile rat), 270 *Mastomys huberti* (Hubert's multimamate rat), 21 *Mus musculus* (house mouse), nine *Taterillus sp.* (Taterilline gerbil), and 55 *Crocidura sp.* (musk shrew). All animals were trapped outside habitations, except *Mus musculus,* which were trapped inside.

A total of 740 rodents and 55 insectivores were tested for *B. crocidurae* (others died after trapping, mainly because of high daytime temperatures). Positive thick blood smears were observed in 17.6% of the rodents and 7.3% of the musk shrews ($P < 0.05$, by chi-square test). Results by species are shown in Table 1. The average prevalences for *A. niloticus* (18.5%) and *M. huberti* (15.8%) were not significantly different ($P > 0.7$, chi-square test).

Variations in prevalence during follow-up

Borrelia crocidurae–infected animals were captured during each survey, with a minimum prevalence of 7.3% in March 1991 and a maximum prevalence of 30.4% in November 1990. Bimonthly variations in prevalence were studied in the two predominant species, *A. niloticus* and *M. huberti,* which represented 62.7% and 28.3%, respectively, of the animals captured, and 65.7% and 27.6%, respectively, of the positive thick blood smears. Results of bimonthly captures are shown in Table 2. *Borrelia crocidurae* prevalence was significantly different among captures, both for *A. niloticus* ($P < 0.01$, by chi-square test) and *M. huberti* ($P < 0.05$, by chi-square test), and variations of prevalence evolved independently for these two species (Spearman rank correlation test: $z = -0.116$, $P = 0.91$ [not significant]). No relation was observed between prevalence and animal abundance or the season or the time of year.

Variations in prevalence according to age and sex

Since weight in *A. niloticus*[8] and *M. huberti* (Duplantier J-M, 1988, Biologie Evolutive des Populations du Genre *Mastomys* au Senegal. Thesis, University of Montpellier, Montpellier, France) is a function of age because of contin-

TABLE 2

Bimonthly variations of Arvicanthis niloticus *and* Mastomys huberti *abundance and* Borrelia crocidurae *prevalence in tested animals*

Months	No. of trap-nights	*Arvicanthis niloticus* No. captured	No. tested	No. (%) of positive smears	*Mastomys huberti* No. captured	No. tested	No. (%) of positive smears
Mar 1990	120	52	52	12 (23.1)	7	7	0 (0.0)
Jul 1990	370	72	53	16 (30.2)	13	13	2 (15.4)
Sept 1990	579	35	26	2 (7.7)	18	11	1 (9.1)
Nov 1990	440	67	53	17 (32.1)	8	3	0 (0.0)
Jan 1991	510	72	42	11 (26.2)	44	40	12 (30.0)
Mar 1991	695	109	88	6 (6.8)	29	28	3 (10.7)
May 1991	660	37	37	0 (0.0)	23	23	4 (17.4)
Jul 1991	650	33	27	7 (25.9)	15	13	2 (15.4)
Sept 1991	660	31	28	5 (17.9)	26	24	6 (25.0)
Nov 1991	571	24	20	4 (20.0)	22	22	1 (4.5)
Jan 1992	410	67	50	8 (16.0)	65	50	6 (12.0)
Total	5,665	599	476	88 (18.5)	270	234	37 (15.8)

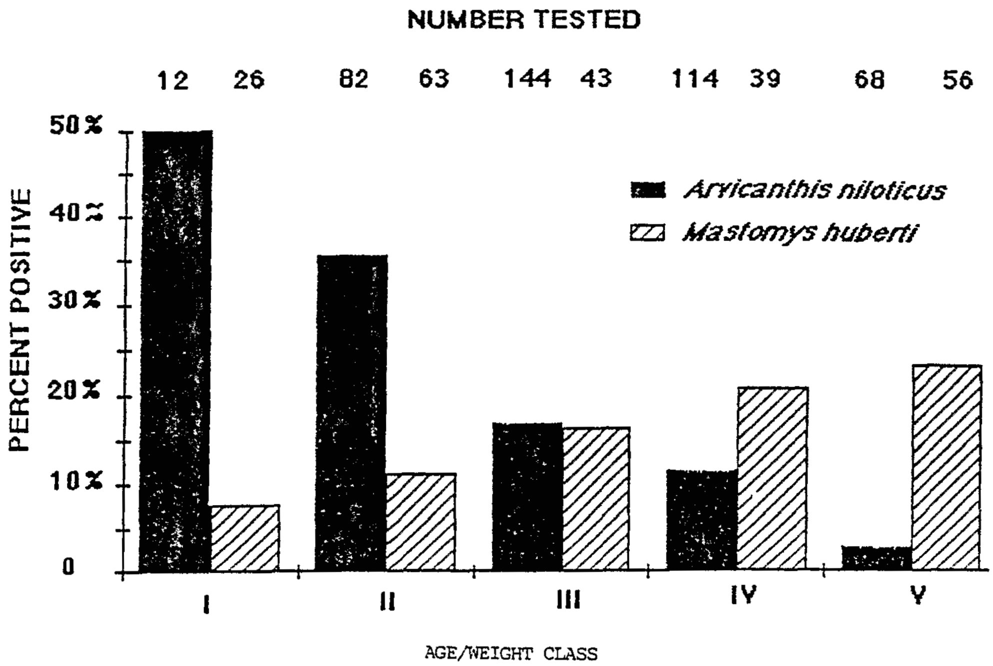

FIGURE 1. Prevalence of *Borrelia crocidurae* in *Arvicanthis niloticus* and *Mastomys huberti* according to weight and age. Weight classes I to V are of 30-gram intervals (from < 30 to ≥ 120 grams) for *A. niloticus* and of 10-gram intervals (from < 20 to ≥ 50 grams) for *M. huberti.* Classes I and II represent juveniles (i.e., before sexual maturity) and classes III, IV, and V represent adults.

uous growth during life, it was possible to study the age-specific prevalence of *B. crocidurae* in these two species. Animals were distributed into five weight classes, with the two smaller classes representing juveniles (i.e., before sexual maturity) and the other classes representing adults. The two species of rodents showed two distinct patterns of *B. crocidurae* prevalence (Figure 1). Prevalence in *A. niloticus* decreased with age from 50% to 2.9% ($P < 0.001$, by extended Mantel-Haenszel test), while prevalence in *M. huberti* increased with age from 7.7% to 23.2% ($P < 0.001$, by extended Mantel-Haenszel test). For each age group and species, prevalence rates in males and females were not significantly different (by chi-square test).

DISCUSSION

Our findings show that rodents and insectivores are a permanent reservoir for *B. crocidurae* in northern Senegal. Although a high proportion or animals were found infected during each survey, true prevalence was probably higher since animals were tested only by direct thick blood smears, a method that is less sensitive than the intraperitoneal inoculation of white mice.[4] *Borrelia crocidurae* was observed in each species collected except *Taterillus sp.*, but the number of animals captured of this species was low. Other investigations in Senegal indicate that *Taterillus sp.* is frequently infected (Godeluck B and others, unpublished data). The lower prevalence observed in shrews compared with rodents may be due to the fact that shrews in the study area burrow almost exclusively in wet grounds, near irrigation canals. We have not studied the relative abundance of the vector tick *A. sonrai* according to burrow characteristics, but studies in the Nile River valley of the closely related species *Ornithodoros erraticus* have shown that this species is rare in humid biotopes.[9,10] Among the species that were collected, *A. niloticus* and *M. huberti* were predominant and represented 93% of the reservoir of *B. crocidurae.* It is interesting to note the absence of *Mastomys erythroleucus* in Richard-Toll. This species is the most important reservoir of *B. crocidurae* in most other rural regions studied in Senegal (Godeluck B and others, unpublished data), but is replaced by *M. huberti* in wet areas such as the banks of the Senegal River.[11]

The diversity of the population dynamics of host-vector-parasite associations in the study area may be responsible for the relative stability of the reservoir for infection over the two-year period covered by the study. The variations in

B. crocidurae prevalence in *A. niloticus* and *M. huberti* could not be correlated with any climatic parameter, nor to variations in abundance of the two species. In contrast, it is striking that *B. crocidurae* prevalences were inversely age-dependent for the two species, decreasing with age from 50% to 2.9% for *A. niloticus* and increasing with age from 7.7% to 23.2% for *M. huberti*. We have no clear explanation for this observation, which may reflect different patterns of disease exposure and transmission in the two species, the evolution of disease, and/or the development of immunity. However, because of the important differences in the ecology of the two species, exposure to the vector tick *A. sonrai* is probably different. *Mastomys huberti* is associated strictly with wet environments and burrows in heavy, moist clay, while *A. niloticus* inhabits both wet and dry environments. Furthermore, the latter species is not a true burrower, but builds its nests in fencing, grass, and bushes or makes superficial burrows in road and channel embankments. Since vector ticks are probably much rarer in the burrows of *M. huberti* than in those of *A. niloticus*, this may explain the differences in *B. crocidurae* prevalence (for *M. huberti*, low risk in young animals and increasing risk with age because of wider roaming habits; for *A. niloticus*, high risk in all age groups, acquired immunity in adults). Clearly, there is a need for further studies on the ecology of the vector tick *A. sonrai* and the age-dependent factors governing the course of infection for the different rodent species. It would also seem important to investigate the incidence of relapsing fever in the population of the study area, since *B. crocidurae* prevalence in small mammals appears to be much higher than in other areas of Senegal where relapsing fever is a major cause of morbidity.

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