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Risk of Urban Lyme Disease Enhanced by the Presence of Rats

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To determine whether Norway rats contribute to the risk of human Lyme disease in a central European city park, densities of endemic rodents were compared as were feeding densities of vector ticks and prevalence of infection by the Lyme disease spirochete. Only Norway rats and yellow-necked mice were abundant, and three times as many mice as rats were present. More larval ticks fed on rats than on mice, and far more nymphs engorged on the rats. All rats but only about half of the mice infected ticks. Each rat was more infectious than each infectious mouse. Infected rats were distributed throughout the city. Spirochetes infected about a quarter of the questing nymphal ticks. The capacity of rats to serve as reservoir hosts for the Lyme disease spirochete, therefore, increases risk of infection among visitors to this and other urban parks.

Human Lyme disease due to *Borrelia burgdorferi* sensu lato (s.l.) is associated mainly with the forest edge, both in Europe and in North America. The woody plants that proliferate in these ecotonal situations support the seed-eating mice that generally perpetuate these pathogens and the browsing ungulates required by their vector ticks [1]. These spirochetes infect diverse hosts, including birds [2, 3] and reptiles [4]. In island situations, rats may contribute to the force of transmission [5, 6].

Although Lyme disease is generally associated with forests, infections may be acquired in parks in such urban centers as London [7], Prague, Brno (Slovakia) [8], Bridgeport, Connecticut [9], and Baltimore [10]. The reservoir hosts that support this pathogen in these locales, however, have not been identified. We learned of several human infections apparently originating in urban parks in Magdeburg, Germany (~120 km east of Hameln), where Norway rats, *Rattus norvegicus,* are abundant. The contribution of these rodents to the force of transmission of the Lyme disease spirochete, however, is unknown.

It may be that rats serve effectively as reservoir hosts for the Lyme disease spirochete. Accordingly, we compared the contributions of the locally abundant indigenous rodents to risk of human infection by comparing their abundance, the frequency with which the vector tick, *Ixodes ricinus,* parasitizes

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Table 1. Density of *Ixodes ricinus* ticks on *Rattus norvegicus* (Rn) and *Apodemus flavicollis* (Af) sampled in an urban park in the city of Magdeburg, Germany.

Host	Larvae		Nymphs		
Kind (*n*)	% of hosts infested	Mean/ host	% of hosts infested	Mean/ host	Larvae/ nymph
Rn (9)	100	153.6	100	18.0	8.5
Af (28)	100	35.4	32.1	0.6	61.9

them, and the prevalence of infection. In particular, we compared the components of reservoir capacity for each of the most abundant candidate reservoir hosts present in the Magdeburg study site.

Materials and Methods

Study site. The main study site was located in a lightly wooded recreational facility, Rotehorn Park, on an island in the Elbe River. Public buildings and homes are contiguous with this 200-ha park. Stands of trees are surrounded by brushy vegetation and interspersed with lawns and meadows. Secondary study sites were located within the city zoo, located ~5 km to the north, and in a part of town ~1 km east of the park. Several deer were present in Rotehorn Park, as were beavers, hedgehogs, foxes, and squirrels. The burrows of Norway rats, as well as the rats themselves, were ubiquitous, particularly near refuse collections and refreshment stands.

Sampling procedures. Small mammals were sampled in the Rotehorn Park from June through September 1994 in apple- and bread-baited Tomahawk traps and in Longworth traps baited with apple and rodent chow. Captured animals were caged over water until all ticks had detached. Engorged ticks were permitted to molt. A segment of the pinna of the ear was sampled from each animal. In April and May 1995, ticks were sampled by flagging vegetation. Spirochetal infection was detected by darkfield microscopy and by amplifying a fragment of the OspA gene [11].

Results

We determined the relative densities of the vertebrates that might enter traps in the Rotehorn Park site. Fourteen Tomahawk traps were set for 2 consecutive nights every 3 weeks for a total of 168 trap nights; 17 Longworth traps were similarly set, for a total of 204 trap nights. Norway rats and yellow-necked mice, *Apodemus flavicollis,* were most abundant (table 1). Animals that were only infrequently captured included 1 black-striped mouse, *Apodemus agrarius,* and 2 bank voles, *Clethrionomys glareolus;* a few subadult *I. ricinus* were present on each of these (data not shown). Although no squirrels entered these traps, we found hundreds of subadult ticks on a red squirrel, *Sciurus vulgaris,* that was found dead; few squirrels were seen. Norway rats and yellow-necked mice, which dominate in the fauna of this disturbed Magdeburg site, were present in a ratio of ~1:3.

Numerous *I. ricinus* ticks infested both the Norway rats and yellow-necked mice from the Rotehorn Park site. Although larvae were present on each of the 37 animals that were examined, more than four times as many were found on the rats than on the mice (table 1). Nymphs infested all rats but only a third of the mice. Their feeding density on rats exceeded that on mice by 30-fold. Larvae outnumbered nymphs by a far smaller increment (7-fold) on rats than on mice. Many more subadult vector ticks fed on rats in Magdeburg than on yellow-necked mice, and far more nymphs engorged on rats than on mice.

Spirochetal infectivity of rats for ticks was compared with that of mice captured in the study site. Thus, nymphs derived from engorged larvae that had detached from each field-derived rodent were analyzed for the presence of spirochetes. Whether by darkfield microscopy or by polymerase chain reaction (PCR), spirochetes were detected in about twice as many rats as mice (table 2). Although all rats produced infected ticks, some mice failed to do so. We note that the PCR method was somewhat more sensitive than darkfield microscopy. More Magdeburg rats infected ticks than did yellow-necked mice, and infectious rats infected more ticks than did infectious mice.

As an independent measure of the prevalence of spirochete infection in field-derived rats, we analyzed segments of the pinna of the ear of each trapped animal by PCR. These rats included 9 from the Rotehorn Park site, 2 from the zoo, and 4 from an abandoned farm. DNA characteristic of *B. burgdorferi* s.l. was amplified from each animal (data not shown). Spirochete-infected rats were widely distributed throughout Magdeburg.

We then estimated the prevalence of spirochetal infection in questing ticks sampled in Rotehorn Park. Nymphs were swept from vegetation throughout the site, and their gut contents were examined by darkfield microscopy. Of 144 such ticks, spirochetes were detected in 36. About a quarter of questing nymphal *I. ricinus* in this site were infected.

Table 2. Presence of Lyme disease spirochetes in nymphal *Ixodes ricinus* reared from larvae taken from naturally infested *Rattus norvegicus* (Rn) and *Apodemus flavicollis* (Af) sampled in an urban park in Magdeburg, Germany.

	Host	Infection in derived nymphs		% of hosts with ≥1 derived nymph infected
Examined by	Kind (*n*)	No. tested	%	
DF	Rn (6)	81	72.8	100
	Af (18)	152	33.6	50
PCR	Rn (5)	50	86.0	100
	Af (12)	72	47.2	75

NOTE. DF, darkfield microscopy; PCR, polymerase chain reaction.

Discussion

Although Lyme disease generally is acquired at the forest edge, risk may also occur in relatively urbanized environments. Spirochete-infected vector ticks infest London's Richmond Park, a recreational site in England visited by several million people each year [7]. Infected ticks are also present in parks in Prague and Brno [8]. In the United States, infected vector ticks infest urban parks in Bridgeport, Connecticut [9], and in Baltimore [10]. The abundant deer in these sites support the reproductive stages of the vector ticks. A human infection associated with the Baltimore park represents the only such documented urban infection. No reservoir hosts have been implicated in any of these urban situations.

Particular rodents serve as reservoir hosts for the agent of Lyme disease. The North American white-footed mouse, *Peromyscus leucopus* is one of the most effective of these hosts. They are abundantly parasitized by the local vector tick, *Ixodes dammini,* and infect ~90% of larvae that feed on them [12]. Similarly, the European edible dormouse, *Glis glis,* is frequently parasitized by subadult vector ticks and infects ~95% of larvae [13]. Another European reservoir, the black-striped mouse, *A. agrarius,* infects ~60% of ticks [1]. Each of these rodents is abundant and heavily infested by vector ticks. In addition to competence as a host to the Lyme disease spirochete, the capacity of an animal to perpetuate this pathogen depends on its competence as a host to larval and nymphal vector ticks and its local density.

Alternative candidate reservoir hosts for the Lyme disease spirochete include hedgehogs, birds, and lizards. Hedgehogs appear to be poorly competent, infecting only about a fifth of ticks [14]. Indeed, we failed to infect larval ticks on several of these animals that had previously served as host to infected vector ticks (unpublished data). Although certain birds appear incompetent [15], other birds [2, 3] and lizards [4] may become infected but sustain only transient infection and are so vagile that ticks that engorge on them may detach where development cannot proceed. Indeed, ticks tend to detach from birds and lizards after these hosts have become active [16]. Although these animals contribute some infected ticks to the transmission cycle, their presence may divert more spirochetal infections than they contribute.

Rats appear to perpetuate the Lyme disease spirochete on the islands of Madeira, Portugal [5], and Monhegan, Maine [6], but at a level that endangers few people. Spirochetes infect <50% of the black rats, *Rattus rattus,* in a tick-infested Madeiran valley. Although prevalence of infection in Norway rats on Monhegan remains undefined, few local residents are seropositive. Rats fulfill various of the capacity criteria that characterize effective reservoir hosts of the agent of Lyme disease: They are comparatively long-lived, persistently competent, frequently parasitized by nymphal and larval *I. ricinus,* and forage relatively far from their nests.

"An effective reservoir host for a vectorborne infection must be abundantly parasitized by the pathogen-receptive stage of the vector, it must be abundant and it must permit ready transfer of the pathogen to the vector" [1]. These components of a reservoir inoculation rate (RIR) provide a measure of the contribution of a potential reservoir host to the local risk of human infection. Our comparison of nymphal density on these putative reservoir hosts suggests that these ticks feed on Norway rats some 30 times as often as on yellow-necked mice. Rats are ~2.5 times less abundant than mice but are about twice as infective to ticks. Because superinfection contributes little to the force of transmission, biting density of nymphal ticks beyond some threshold value would be nonlinear. If we set that threshold at one infection per week per rat, the 3:1 RIR of these urban rats relative to that of yellow-necked mice then approximates the 2:1 RIR of sylvan dormice relative to that of the same mice in southern Germany [13]. A rat promotes transmission more than a mouse does.

The feeding density of nymphal *Ixodes* ticks in nature relative to that of larvae differs among hosts. The main North American reservoir of the agent of Lyme disease, *P. leucopus,* generally is infested by 3.5 times as many larvae as nymphs [17]. European mice, however, tend to harbor fewer nymphs; the larval to nymphal ratio is 14:1 on *A. agrarius* in northeast Germany and 39:1 on *A. flavicollis* near Berlin. Even fewer nymphs infected the Magdeburg *A. flavicollis* (ratio, 62:1). More nymphs feed on dormice (ratio, 5:1), and still more on spirochete-incompetent European sand lizards (ratio, 1.6:1). The ratio for Norway rats is 6:1, whether in North America [6] or Europe. The frequency of feeding of spirochete-infected nymphal vector ticks on reservoir hosts largely determines spirochete prevalence, and rats would, therefore, be infected earlier in life than would European mice.

Certain behavioral characteristics of Norway rats are consistent with that of a reservoir for a tickborne pathogen. They nest in underground sites where any *I. ricinus* that successfully parasitizes them is likely to detach. Such ticks detach from these nocturnally active hosts early in the afternoon (unpublished observations). The sheltered and humid environment of these burrows would favor their subsequent survival and development. The tendency of Norway rats to forage out of doors over several kilometers and in various kinds of habitat [18] may bring them into contact with numerous subadult ticks. If such vagile rats forage in the ecotone of nearby forests, they may serve as a bridge between forest and city, establishing urban enzootic foci of transmission of Lyme disease spirochetes. Then too, the prevalence of spirochetal infection would accumulate in rats over their usual 2-year life span. Their vagility, long life, nest-dwelling habit, and host competence for spirochetes and vector ticks contribute to the capacity of Norway rats as reservoir hosts for the agent of Lyme disease.

Although only 1 case of Lyme disease has previously been attributed to an urban focus of transmission [10], we know of 84 local cases of human infection (based on criteria adopted by the State of Sachsen-Anhalt) that were reported to the Magdeburg Hygiene Institute during 1993. Many of these people

would have been exposed to vector ticks in Rotehorn Park. Indeed, 1 of us became seroreactive (by Western blot) after a tick attached to him there. We know of 2 patients who report that this park was their sole site of relevant exposure. It seems likely that Norway rats contribute importantly to the risk of Lyme disease experienced by thousands of people who visit this park each year and to others who frequent comparable urban sites.

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