EAR TAGGING INCREASES TICK (*IXODES DAMMINI*) INFESTATION RATES OF WHITE-FOOTED MICE (*PEROMYSCUS LEUCOPUS*)

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The white-footed mouse (*Peromyscus leucopus*) is an important host of the deer tick (*Ixodes dammini*), and the principle reservoir for the spirochete (*Borrelia burgdorferi*) known to cause Lyme disease. In summer and autumn 1991, we uniquely marked small rodents, including *P. leucopus*, with metal ear tags. The presence of ear tags increased rates of infestation by larval ticks on mice by 50 to 100%, probably because the tags reduced grooming efficiency. Because larval deer ticks acquire the Lyme disease spirochete more efficiently from *P. leucopus* than from other mammalian and avian hosts, increasing the numbers of ticks parasitizing mice may cause a higher percentage of ticks to carry Lyme disease.

Key words: ***Ixodes dammini*, *Peromyscus leucopus*, ear tags, Lyme disease, ticks**

The spirochete, *Borrelia burgdorferi*, that causes Lyme disease in humans, uses ticks, especially *Ixodes dammini* and *I. pacificus* as a vector (Burgdorfer et al., 1982; Lane et al., 1991; Miller, 1987). Larval ticks typically are free of *B. burgdorferi* upon hatching, but may obtain the spirochete during their first blood meal, usually taken from a mammal, bird, or lizard (Anderson, 1988; Lane et al., 1991). Among mammalian hosts of *Ixodes* ticks, white-footed mice (*Peromyscus leucopus*) are the most competent reservoir for these spirochetes (Davidar et al., 1989; Donahue et al., 1987; Fish and Daniels, 1990; Levine et al., 1985; Mather et al., 1989). After a blood meal, larval ticks molt and become nymphs. The abundance of nymphal *Ixodes* ticks infected with *B. burgdorferi* is the predominant risk factor in human exposure to Lyme disease (Falco and Fish, 1989).

Although it has not been demonstrated, we suspect that the proportion of larval ticks able to feed on *P. leucopus*, compared to other hosts that are less competent as spirochete reservoirs, will determine the proportion of nymphal ticks infected with *B. burgdorferi*. Thus, any factor that increases the likelihood that a larval tick will obtain its first blood meal from a white-footed mouse probably will increase local risk to humans of contracting Lyme disease. Here we report that a commonly used field technique for individually marking small mammals, namely ear tagging, markedly increases the number of larval *Ixodes* ticks infesting *P. leucopus*.

MATERIALS AND METHODS

In July 1991, we began a long-term study of the effects of small mammals on structure and function of forest ecosystems. We established two live-trapping grids on the grounds of the Mary Flagler Cary Arboretum in Millbrook, Dutchess Co., New York. High abundance of *I. dammini* and high infection rates of ticks with *B. burgdorferi* have been documented at this site since 1984 (D. Fish and R. Winchcombe, pers. comm.). The two grids, Tea House Grid and Henry Farm Grid, are 1.5 km apart. Each grid consists of 121 trap stations in an 11 by 11 array, with 15 m between stations. Including a 7.5-m boundary strip, each grid covers 2.48 ha. At both study sites, the canopy is dominated by red oak (*Quercus rubra*) and chestnut oak (*Q. prinus*), whereas the predominant understory species is sugar maple (*Acer saccharum*). The Henry Farm Grid also

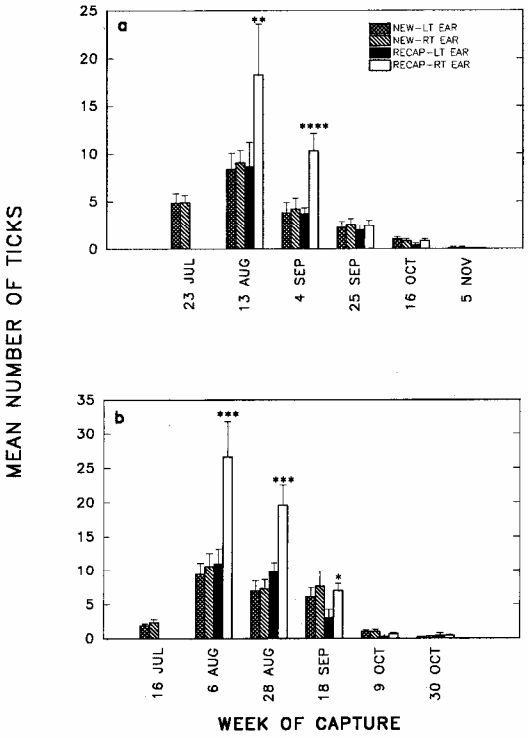

FIG. 1.—Mean number (±1 *SE*) of larval ticks attached to the ears of *Peromyscus leucopus* at Tea House Grid (a) and Henry Farm Grid (b), Dutchess Co., New York. "New" refers to previously untagged individuals, and "Recap" refers to recaptured, tagged individuals. Ear tags always were placed in the right ear. For "Recap" individuals, statistically significant differences between means for left and right ear for any given trapping session are indicated by * ($P < 0.05$), ** ($P < 0.01$), *** ($P < 0.001$), and **** ($P < 0.0001$). No differences were detected between left and right ears of "New" mice.

has many white pines (*Pinus strobus*) in the canopy.

We set one large (7.6 cm by 8.9 cm by 22.9 cm) and one small (5.1 cm by 6.4 cm by 15.2 cm) Sherman trap at each station for 3 consecutive nights every 3 weeks between July and December 1991. Traps were baited with crimped oats and covered with boards; during cold periods they also were supplied with sunflower seeds and cotton batting. Traps were closed during the day and between trapping sessions. We marked all small mammals (except shrews) upon first capture with uniquely numbered metal ear tags (size 1 Monel fish fingerling tags; National Band and Tag Company, Newport, KY). We recorded tag number, sex, age class, reproductive status, mass, and capture location of each individual upon capture. In addition, upon first capture during each trapping session, we removed all ticks from the face and auditory pinnae (the primary site of attachment—Main et al., 1982) and preserved them in 70% ethanol for later identification. On subsequent captures within each trapping session, we counted, but did not remove, ticks to monitor reinfestation. To facilitate removal of ticks, we lightly anaesthetized rodents with metofane (methoxyflurane; Pitman-Moore, Trenton, NJ). All rodents recovered completely within 2–3 min and were released at the point of capture.

RESULTS

Peromyscus leucopus was the most abundant species of small mammal at both sites. Density (minimum number alive) of white-footed mice averaged 19.9 and 21.0 individuals/ha on Tea House Grid and Henry Farm Grid, respectively, during the course of the study. Other small mammals captured, in decreasing order of abundance, were *Tamias striatus, Blarina brevicauda, Sorex cinereus, Glaucomys volans, Cleth-rionomys gapperi,* and *Microtus pennsylvanicus.*

White-footed mice were heavily infested with ticks, >99% of which were larval *Ixodes dammini.* Of all ticks on the heads of mice, 92.5% were attached to the pinnae. Rates of infestation by ticks peaked on both grids in August (monthly mean = 9.7 ticks/ear for untagged mice) and declined until late October, after which mice were free of ticks (Fig. 1). This seasonal pattern of infestation closely paralleled the seasonal abundance of host-seeking larval ticks as determined from transect drag sampling (M. C. Miller, J. Schnurr, and R. S. Ostfeld, in litt.). Thus, our study period incorporated the primary period during the annual cycle of *I. dammini* when *P. leucopus* is vulnerable to infestation by larval ticks. The only other species of small mammal for which we obtained reasonable samples (≥5 individuals/month) was *T. striatus.* It had, on average, 8.0, 7.2,

0, and 0.2 ticks per individual in July, August, September, and October, respectively.

During August and early September, tagged mice had approximately twice as many ticks on their tagged right ear as on their untagged left ear (Fig. 1). On each grid, the difference between numbers of ticks on tagged and untagged ears was statistically significant throughout this period (2-tailed paired t-tests—Tea House Grid: 13 August, $t = 3.15$, $P = 0.006$; 4 September, $t = 4.40$, $P = 0.0001$. Henry Farm Grid: 6 August, $t = 4.10$, $P = 0.0006$; 28 August, $t = 4.06$, $P = 0.0005$; 18 September, $t = 2.68$, $P = 0.018$). However, no significant differences in abundance of ticks existed between left and right ears for newly captured (untagged) mice at either site (paired t-tests, $P > 0.05$; Fig. 1). Ear tagging was associated with a 50–100% increase in total abundance of ticks on mice. The difference in total numbers of ticks on tagged and untagged mice was statistically significant throughout August and early September (one-way analysis of variance, 1 *d.f.*, $P < 0.05$).

The approximate doubling of abundance of ticks on tagged compared to untagged ears was observed even after 24-h intervals within trapping sessions. In August and September, mice on Tea House Grid obtained, on average, 0–0.8 ticks on the untagged left ear and 0.6–1.8 ticks on the tagged right ear within 1 day. On Henry Farm Grid, mice acquired, on average, 0–1.7 ticks on the left ear and 2.0–4.3 on the right ear.

Discussion

The presence of an ear tag approximately doubled the number of ticks attached to the ears of white-footed mice, causing tagged mice to have a significantly greater number of ticks than untagged mice. The effect of an ear tag was obvious even after 24-h intervals within trapping sessions, when marked mice from which all ticks had been removed were recaptured. After 3-week intervals between trapping sessions, numbers of ticks on mice apparently had stabilized, as indicated by the similarity between counts of ticks on untagged left ears of unmarked and previously marked individuals (Fig. 1). Thus, ear tags probably caused chronically higher rates of infestation by ticks.

We suspect that the presence of an ear tag reduces grooming efficiency by mice, thus hindering removal of ticks and enhancing infestation by ticks. However, the trauma of perforating the pinna to attach the tag may cause inflammation that attracts ticks to the tagged ear.

Elevated numbers of ticks following ear tagging may have important consequences to the ecology of Lyme disease. Larval *I. dammini* preferentially attach to small and medium-sized mammals and birds (Anderson, 1988; Lane et al., 1991), which differ in their likelihood of transmitting *B. burgdorferi* to the ticks (Davidar et al., 1989; Donahue et al., 1987; Fish and Daniels, 1990; Levine et al., 1985; Mather et al., 1989). Our results suggest that many more larval *I. dammini* attempt to attach to *P. leucopus* than actually are successful in doing so, and that grooming by the mice is responsible for removing substantial numbers of ticks. Removed ticks may then seek another host. Removal of larval ticks that have obtained only a partial blood meal might be responsible for the occurrence of larval ticks infected with *B. burgdorferi* (Piesman, 1991), which previously had been ascribed to transovarial acquisition of spirochetes (Magnarelli et al., 1987).

Since *P. leucopus* is the most effective mammal yet studied in transmitting *B. burgdorferi* to *I. dammini* (Lane et al., 1991), any action that increases success rates of ticks at attaching to these mice and obtaining a full meal is likely to increase the proportion of immature ticks infected with *B. burgdorferi*. Infection rate of immature ticks is a primary determinant of risk to humans of contracting Lyme disease (Falco and Fish, 1989). Currently, we are using ear tags to test the hypothesis that increased numbers of larval ticks on *P. leucopus* elevates the proportion of nymphal ticks that are infected with *B. burgdorferi*. Infestation by

ixodid ticks dramatically increased mortality rates in a population of *Clethrionomys rufocanus* (Viitala et al., 1986); therefore, ear tagging also may affect demography of populations of the white-footed mouse.

Our trapping effort began after the seasonal peak in abundance of host-seeking nymphal *I. dammini* (June—Spielman et al., 1985); therefore, we do not know the effects of ear tags on infestation with nymphs. Infected nymphs primarily are responsible for transmitting spirochetes to mice (Donahue et al., 1987). Therefore, if ear tags also cause elevated numbers of nymphal ticks on mice, then the ear-tagging technique may increase the proportion of mice infected with *B. burgdorferi.* Moreover, since infection with *B. burgdorferi* can cause systematic disease in captive *P. leucopus* (Burgess et al., 1990), demography of mice may be further influenced by the ear-tagging technique.

In conclusion, we believe that ear tagging will prove a useful technique for improving our understanding of the ecology of Lyme disease by uncovering the relationships between rates of infestation by ticks, rates of infection of spirochetes in both ticks and mice, and demography of mice. For research programs in which Lyme disease-vaccinated mice (Fikrig et al., 1992) are released into the wild, ear tagging may be a useful technique for preferentially attracting ticks to vaccinated mice. Vaccinated mice would be much less likely than unvaccinated mice to transmit *B. burgdorferi* to larval ticks. However, for mammalian ecologists working in tick-infested habitats who do not want to artificially elevate numbers of ticks, we recommend alternative methods of individually marking animals.

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