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ABSTRACT: Wild turkeys are increasing in abundance and distribution in eastern North America, but their potential role as hosts for ticks, or as predators on ticks, is unknown. We performed two experiments, one to determine whether juvenile black-legged ticks (*Ixodes scapularis*) feed successfully on turkeys, and the other to determine if turkeys depredate adult black-legged ticks in forest habitats. Of 550 larval ticks placed directly on 5 captive wild turkeys, none engorged and only 7 (1.3%) were recovered; the remainder apparently were consumed during preening. Of 165 nymphal ticks placed on the turkeys, 5 engorged and 8 unengorged ticks were collected; 152 (93.3%) were apparently consumed. Of 250 adult ticks introduced into forest enclosures exposed to turkey foraging, 89.5% were recaptured, which was not significantly different from the 92.2% recaptured in control enclosures from which turkeys were excluded. We conclude that wild turkeys are unlikely to host juvenile black-legged ticks in nature, and that turkey foraging is unlikely to reduce local density of adult ticks.

Keyword Index: Host, Lyme disease, parasite-host interactions, vector.

INTRODUCTION

Historically, the wild turkey (*Meleagris gallopavo*) was an abundant member of vertebrate communities within forests and grasslands of eastern and central North America (Healy 1992). However, this species was decimated throughout its historical range during the 18th through early 20th centuries as a result of hunting and habitat destruction (Kennamer et al. 1992). Regrowth of forests following deforestation, combined with reintroductions, transplantations, and subsequent population growth and dispersal of the birds, has resulted in rapid increases in both density and range of this species. Between about 1930 and 1990, the turkey population in the eastern United States and southeastern Canada increased from extreme scarcity to more than 2.5×10^6 individuals, which may equal or exceed the abundance they maintained in precolonial times (Kennamer et al. 1992).

Regrowth of eastern forests and the consequent expansion of populations of other vertebrates, most notably white-tailed deer (*Odocoileus virgianus*) and white-footed mice (*Peromyscus leucopus*), have resulted in the emergence of Lyme disease, a zoonotic disease transmitted by tick vectors (*Ixodes* spp.) (Barbour and Fish 1993, Ostfeld 1997). Forest floor vertebrates play key roles in the Lyme-disease epizootic both as hosts for ticks and as sources from which feeding ticks obtain the bacterium (*Borrelia burgdorferi*) that causes the disease (Lane et al. 1991, Piesman and Gray 1994). Because wild turkeys are abundant, large, and active on the forest floor where ticks seek hosts, this species may interact strongly with *Ixodes* ticks. If turkeys serve as hosts for ticks or as reservoirs of Lyme-disease bacteria, they may enhance the density and infection prevalence of the ticks, thus increasing risk of human exposure to Lyme disease. Alternatively, if turkeys consume the ticks they encounter while foraging, they may reduce tick density and hence disease risk. We are not aware of any studies on trophic interactions between turkeys and *Ixodes* ticks. To evaluate the possibility that turkeys may influence the abundance or infection prevalence of ticks, we undertook a study to determine experimentally whether and how these species interact.

In summer and autumn 1998, we conducted two experiments on trophic interactions between turkeys and black-legged ticks (*Ixodes scapularis* — formerly *I. dammini*), the primary vector of Lyme disease in eastern and central North America. In the first experiment, we sought to determine whether turkeys are suitable hosts for juvenile ticks. If so, our intention was to determine whether turkeys are a competent reservoir for *Borrelia burgdorferi*. In the second experiment, we asked whether turkeys depredate unfed adult ticks and consequently reduce their abundance within local areas.

MATERIALS AND METHODS

Experimental Animals

Five yearling female eastern wild turkeys were obtained in June 1998 from Quattro's Game Birds in Pleasant Valley, NY. The breeding stock consisted of 10th generation turkeys originating from wild-caught birds native to Wisconsin, and was bred periodically with wild stock captured in Massachusetts. These birds were hatched in incubators and raised in large groups. We housed the five birds together in a 2m wide by 5m long by 2m high coop made of welded wire on a wood frame and containing a wooden perch and rain shelter. The coop was placed in a native old-field at the Institute of Ecosystem Studies in Millbrook, NY, ~500m from the experimental forest plots (see below). Turkeys were supplied with commercial turkey feed, scratch grain, and water ad lib.

Host-seeking ticks (*Ixodes scapularis*) were obtained for both experiments by dragging a 1 m^2 piece of white corduroy cloth in a forested site ~3 km from the experimental site. Ticks were placed in glass vials with moistened plaster of paris, and were used within five days of collection. The same collection and maintenance procedure in prior experiments resulted in high feeding success of larval ticks on two species of *Peromyscus* mice (Hazler and Ostfeld 1995).

Experiment I - Turkeys as Hosts for Ticks

The primary purpose of this experiment was to determine whether juvenile (larval and nymphal) black-legged ticks can feed successfully on turkeys. In the initial phase, we used nymphal ticks known from our prior studies at this site to have a 30-40% infection prevalence with Lyme-disease bacteria (R. S. Ostfeld, unpublished data). If nymphal ticks fed successfully, our secondary purpose was to determine using xenodiagnosis the probability that uninfected larval ticks feeding two weeks later would acquire the bacteria.

In August 1998, we placed 27 nymphal *I. scapularis* ticks on each of the five turkeys. While the birds were restrained, ticks were placed on the nape of the turkeys' necks with a fine brush. The nape of the neck was used to reduce the possibility that turkeys would immediately remove ticks by preening. The turkeys were then held individually for five days (125 hours) in wire-mesh cages (40 cm wide by 56 cm long by 80 cm high) that were suspended over tubs of water. Cages were covered by plastic tarps for protection and shading. The turkeys had ad lib access to food and water through a 10 cm by 15 cm opening in the front of each cage. The tubs of water beneath cages were examined for fed or unfed ticks once each day for five days. We used a five-day criterion because juvenile ticks may require up to a day to attach and typically remain attached to hosts for about three days (Lane et al. 1991, Ostfeld 1997). After a two-week resting period, we placed 110 larval and 6 nymphal *I. scapularis* on each turkey (again, on the nape of the neck), returned the turkeys to their individual cages, and repeated the daily collection procedure for seven days (168 hours).

Experiment II - Turkeys as Predators on Ticks

The purpose of this experiment was to evaluate the effectiveness of turkeys as predators on adult *I. scapularis* in a natural forest habitat. We used adult ticks because this largest life stage (ca 2 mm long in *I. scapularis*) is the most likely to be visible and attractive to turkeys as food. To this end, we established six 10 m by 10 m enclosures in a mature oak forest site about 500 m from the turkey coop. The oak forest sites are described thoroughly in Ostfeld et al. (1995, 1996a). Enclosures were arranged as three blocks with 30-100 m between blocks and 15 m between the two enclosures within each block. Enclosures were constructed of plastic snow-fencing 2.5 m high that was supported at the corners by stapling the fence to tree trunks. For each pair of enclosures within a block, we used a coin toss to determine which would be the experimental (with turkeys) and control (no turkeys) unit.

We performed a pilot experiment in October 1998, in which we introduced 50 adult ticks (1:1 sex ratio) into the center of one of the experimental enclosures and allowed them to acclimate for 15 hours. We then introduced two turkeys into the enclosure and left them undisturbed for eight hours. The turkeys were then placed individually in cages suspended over water for 48 hours (see methods for Experiment 1) to determine whether any of the ticks had parasitized the turkeys. We then estimated the number of ticks that remained in the forest plots using a standard drag-sampling technique (e.g., Falco and Fish 1992). We exhaustively sampled the forest floor of both experimental and control enclosures by dragging a 1 m^2 corduroy cloth in concentric circles, checking the cloth for ticks every 10 paces. Because recovery rates were low, we followed the pilot experiment with an additional experiment using carbon dioxide-baited tick traps (Falco and Fish 1992) in addition to drag-sampling.

We performed the full experiment in early to mid November, 1998, which is the time of peak activity of adult ticks at our sites (Ostfeld et al. 1996a,b). We placed 100 adult ticks (1:1 sex ratio) in the center of each of the six enclosures and allowed them to acclimate for 15 hours. We then released two turkeys into each of the three experimental enclosures and left them undisturbed for 8 hours per day for the following two days (16 hours total). Immediately following the 16 hours of foraging, the birds were placed in individual cages suspended over water for 48 hours to collect any ticks having parasitized the turkeys. The morning after turkey removal, three CO_2-baited tick traps were placed 2.5 m from the center of each enclosure, with at least 4.5 m between adjacent traps. Each trap was charged with ~1 kg of dry ice and was checked after seven hours. Immediately after the traps were checked, we drag-sampled the entire plots to collect any remaining ticks. We also drag-sampled the outer perimeter of the enclosures to determine whether any ticks had escaped. The following day the tick traps were recharged and the trapping and dragging procedures were repeated. We repeated this entire process in all six enclosures one week later. To be conservative in our analysis, we did not consider the repetitions of the tick introductions to be experimental replicates. Instead, we used a paired t-test with the presence or absence of turkeys as the independent variable, the experimental and control enclosure within a block comprising the pairs (N = 3 pairs), and the total number of ticks recovered in the two introductions as the dependent variable.

RESULTS

Experiment I - Turkeys as Hosts for Ticks

Very few larval or nymphal *Ixodes scapularis* ticks were recovered from the turkeys. Of the initial 27 nymphs placed on each of the five turkeys (135 ticks altogether), only six (4.4%) were recovered. On average, 1.20 (0.74 (SE; range 0-4) ticks per bird were recovered after 125 hours. Of the six nymphs that were recovered, four were engorged and two were unfed; the four engorged nymphs all came from one of the birds.

Of the 110 larvae and six nymphs placed on each turkey in phase two (580 ticks altogether), only 15 ticks (2.6%) were recovered after 168 hours. None of the 550 larvae engorged; all seven of the larvae recovered were unfed (mean = 1.40 ± 1.17 larvae per bird). Of the eight nymphs that were recovered, only one was engorged (TABLE 1). A thorough visual examination of one of the turkeys immediately following the seven days over water pans revealed no ticks. Because of the low success rate in feeding nymphs to repletion on the birds, and because no engorged larvae were recovered, we could not conduct a xenodiagnosis to test for the reservoir competence of wild turkeys.

Experiment II - Turkeys as Predators on Ticks

Turkeys were ineffective predators on adult *I. scapularis* ticks. On average, 179 adult ticks were recovered from the three forest enclosures in which turkeys foraged, compared to 184 ticks in the control enclosures (paired t-test, $t = -0.23$, $P = 0.84$; Fig. 1). The proportion of introduced ticks recovered after 16 hours of access by turkeys was 89.5% in experimental enclosures (with turkeys) and 92.2% in the turkey-free controls. No ticks were recovered from the turkeys during the 48 hours they were held over water immediately following the experiments.

DISCUSSION

Results of Experiment I suggest that wild turkeys are a poor host for juvenile *Ixodes scapularis* ticks, and are likely to be parasitized only rarely in nature. In the first phase, only four (3.0%) of 135 nymphs placed on turkeys fed to repletion, and in the second phase, only

TABLE 1. Recovery of juvenile *Ixodes scapularis* ticks placed on five captive wild turkeys held individually over collecting pans of water.

Tick Life Stage	Number of Ticks Introduced	Number (%) of Engorged Ticks Recovered	Number (%) of Unengorged Ticks Recovered	Total Number (%) of Ticks Recovered
Larval	550	0 (0)	7 (1.3)	7 (1.3)
Nymphal	30	1 (3.3)	7 (23.3)	8 (26.7)

one (3.3%) of 30 nymphs and none of 550 larvae fed to repletion. The low recovery rates for ticks in either an engorged or unengorged state strongly suggest that the ticks we placed on turkeys were preened off and swallowed by the hosts. The ticks had no other route of escape. Casual observations revealed that the turkeys commonly autopreened and allopreened while housed in the coop; however, observations of the birds while they were held in individual cages were prevented by protective tarps surrounding the cages. Grooming behavior is known or suspected to be responsible for reductions in infestation rates by ixodid ticks on other hosts (Ostfeld et al. 1993, Sonenshine 1993).

Ixodes scapularis ticks are known to parasitize dozens of species of vertebrate hosts, including several species of ground-dwelling songbirds (reviewed by Lane et al. 1991, Fish 1993, Tälleklint 1996). However, we are not aware of any studies reporting *I. scapularis* parasitizing *M. gallopavo*. Davidson and Wentworth (1992) reviewed studies of ectoparasites on turkeys, and reported the occurrence of three species of other ixodid ticks and one species of argasid on wild turkeys in the southeastern United States. The poor performance of these ticks on turkeys, and the likelihood that they were consumed during autopreening, suggests that continued range expansion and population growth of wild turkeys will not increase the number of feeding opportunities for questing *I. scapularis*.

Captive wild turkeys in our forest enclosures did not reduce abundance of adult *I. scapularis*, nor did the ticks parasitize the turkeys during their foraging bouts. Prior studies with the same individual turkeys in the same forest enclosures revealed that the turkeys spent much of their time in the enclosures feeding, and that they consumed substantial numbers of tree seeds experimentally introduced into the enclosures (F. Keesing, E. Brownold, and R. Ostfeld, unpublished data). In both prior and current studies, turkeys began pecking and scratching at the forest floor within several minutes of being introduced into enclosures (D. Lewis and R. Ostfeld, pers. obs.). Therefore, the lack of removal of adult ticks was not caused by a lack of foraging effort. We tentatively conclude that natural populations of turkeys are unlikely to reduce population size of questing adult *I. scapularis* through predation. Because both turkeys and ticks occur naturally in aggregations (Ostfeld et al. 1996a, Lewis and Ostfeld, pers. obs.), it remains possible that turkey flocks may encounter and depredate clumps of ticks.

Natural enemies of ticks appear to be common (Carroll 1995, Hu et al. 1993, Samish and Rehacek 1999, Zhioua et al. 1995), although their impacts on tick populations are poorly understood. Duffy et al. (1992) found that helmeted guineafowl (*Numida meleagris*) reduced abundance of adult *I. scapularis* ticks on grass lawns. However, this species of tick is substantially more abundant in forests than on lawns (Adler et al. 1992, Maupin et al. 1991, Ostfeld et al. 1995). Although >40 species of birds are reported to feed on ticks, evidence suggesting regulation of tick populations by birds is scarce (Samish and Rehacek 1999). Further studies of the regulatory capacity of birds and other predators and pathogens on ticks are warranted.

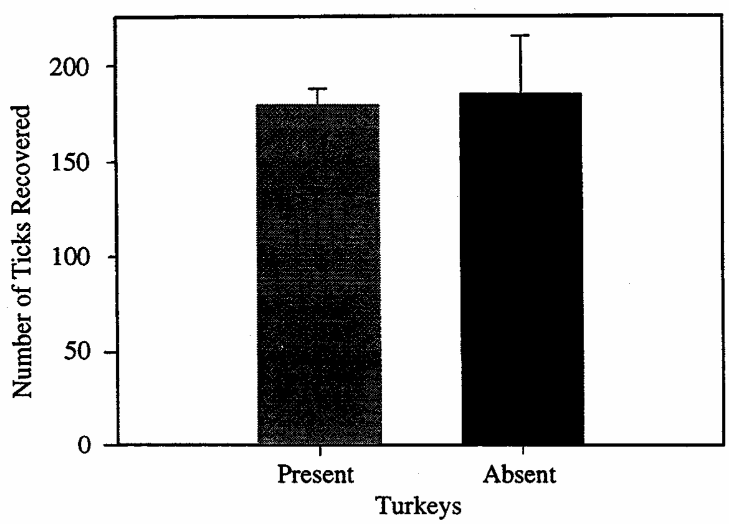

Figure 1. Number (+1 SE) of adult *Ixodes scapularis* ticks recovered using CO_2-baited traps and cloth drag-sampling inside 10m by 10m forest enclosures. Three replicates (experimental enclosures) had turkeys present for 16 hours over two days, and three (controls) had no turkeys.

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