The Effects of Bird Feeders on Lyme Disease Prevalence and Density of *Ixodes scapularis* (Acari: Ixodidae) in a Residential Area of Dutchess County, New York

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ABSTRACT The effects of bird feeders on local densities of *Ixodes scapularis* ticks and prevalence of Lyme disease were examined in residential areas of Dutchess County, NY. Ticks were collected, counted, and analyzed for *Borrelia burgdorferi* spirochetes in 2001–2002 on residential properties with and without bird feeders. Tick densities and infection prevalence were not significantly different on properties with and without bird feeders. Furthermore, analysis of a questionnaire, administered to 580 local residents in 2001, showed that bird feeders were not associated with the prevalence of Lyme disease. These observations suggest that bird feeders should not be considered a risk factor for Lyme disease in this residential setting.

KEY WORDS Birds, *Borrelia burgdorferi*, *Ixodes*, Lyme disease, risk factors

Lyme disease (etiological agent: *Borrelia burgdorferi*) is the most common vector-borne disease in the United States, with 17,730 cases reported in 2000 (Marshall et al. 2000). The principal vector for *B. burgdorferi* in the northeastern United States is the blacklegged tick, *Ixodes scapularis* (Burgdorfer et al. 1982). Adult blacklegged ticks primarily parasitize white-tailed deer (*Odocoileus virginianus*) (Piesman et al. 1979), whereas immature life stages of the tick parasitize a diversity of small- and medium-sized mammals (Mather et al. 1989) and birds (Rand et al. 1998). The white-footed mouse, *Peromyscus leucopus* is the principal reservoir of *B. burgdorferi* in the Northeast (Mather et al. 1989), but other small mammals, such as the eastern chipmunk (*Tamias striatus*) (Schmidt and Ostfeld 2001), and some avian species, such as American Robins (*Turdus migratorius*) and House Wrens (*Troglodytes aedon*) (Anderson et al. 1990) are competent reservoirs as well.

Epidemiological evidence suggests that nymphal ticks are responsible for the majority of Lyme disease cases (Piesman et al. 1987) with adults responsible for a small percentage (Benach and Coleman 1986). Much effort has been devoted to understanding the causes of variation in the abundance and infection prevalence of blacklegged ticks (Jones et al. 1998, Ostfeld et al. 2001). Falco and Fish (1988) demonstrated that most blacklegged tick bites are acquired on the victim's own property. Therefore, many recommendations have been published in the scientific and popular press to reduce the risk of encountering ticks on private properties.

One common recommendation in the popular press is to avoid, or limit the use of, bird feeders (e.g., Hodges-Griffin 1998, Burrascano 2000, Matsen 2001, Kelly 2001). Two studies have indicated that the presence of bird feeders may increase Lyme disease prevalence (Orloski et al.1998, Smith et al. 2001). Presumably, the underlying mechanism is that ticks are deposited by their avian or mammalian hosts as they visit the feeder, thereby increasing local densities of infected nymphs and adults. However, we are unaware of any research that rigorously examines the effect of bird feeders on the local density of *I. scapularis.*

In this study, we examined the relationship between bird feeders and both the prevalence and entomological risk of Lyme disease in a highly endemic area of Dutchess County, NY. We examined the relationship of bird feeders to Lyme disease prevalence by means of a telephone survey, and the impact of bird feeders on risk by means of monitoring tick densities on residential properties with and without bird feeders.

Materials and Methods

Study Sites. The field studies and survey were conducted within four study sites in the towns of LaGrange and Poughkeepsie, Dutchess County, NY. Lyme disease case information, derived from a computer-based geographical information system (GIS), was used to select the residential sites in the zip code with the largest number of reported Lyme disease

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cases in Dutchess County. Previous research at the Institute of Ecosystem Studies, ≈15 km from these sites, had demonstrated consistently high *I. scapularis* densities (≈0.5–2.0 nymphs m^{-2}) and infection prevalence (≈30–45% for nymphs) in the area (Ostfeld et al. 2001, Goodwin et al. 2001). The sites each consisted of a core area of 259 hectares (one square mile) and a surrounding area of 554.3 hectares (2.1 square miles). Within the core areas, the telephone surveys (discussed below) were conducted and tick sampling was more intensive. To systematically distribute sampling residences throughout the sites, we divided the core and surrounding area of each site into four quadrants. We randomly selected two residences from each quadrant, for a total of 64 residences. To boost sample size, an additional 18 residences were randomly selected within the core area of one site.

Permission to conduct field work was obtained either by door-to-door solicitation or by letters of request. Where possible, we avoided properties that used their own tick reduction techniques. For the two residences that did use pesticides, we avoided the areas that had been sprayed in our tick sampling. Two of the residences did not have lawns, and were excluded from our analyses. The remaining 80 residences had at least 100 m^2 of lawn.

Forest type on the residential properties was eastern deciduous, second-growth forest, >50 yr in age. Although forest patches varied in species composition, often containing ornamental species, the canopy was generally dominated by sugar maple (*Acer saccharum*), while the understory was dominated by Japanese barberry (*Berberis thunbergii*) and honeysuckle (*Lonicera morrowi*). Properties were categorized as to whether they either encompassed or were directly adjacent to a forest patch of any size, or had no forest, to assess the possible effects of setting on tick abundance.

Tick Sampling. To characterize risk of exposure to Lyme disease on each property, we collected and counted ticks from up to 100 square meters of forest, lawn, and ecotone (unmaintained forest edge) on each property. The actual area of each habitat type that was sampled was proportional to the area of coverage on each property. Ticks were collected by dragging a 1-m^2 white corduroy drag cloth through these habitats. Ticks were identified, counted, and removed from the drag cloths at 20 m intervals on lawns, and at 10 m intervals in forests and ecotones, where thick underbrush could dislodge ticks. Whenever possible, ecotones were sampled on the border of the change in vegetation (i.e., with half of the drag cloth on the lawn, and half in the adjacent forest). In the few cases when the topography made this impossible, we dragged either on the lawn directly adjacent to the edge, or in the forest within two meters of the edge. The transect lines were mapped, and the same lines were followed in each sampling period.

Ticks of all stages were collected during four sampling periods on 64 of the properties. These periods were approximately coincident with local periods of peak abundance for the different life stages of *I. scapularis* (Ostfeld et al. 1996). Nymphs were collected from 16 July through 2 August 2001 and 17 June through 8 July 2002; larvae were collected from 20 August though 10 September 2001; and adults were collected from 22 October through 1 November 2001 and 02 April through 16 April 2002. Nymphs were also collected from an additional 18 properties during the last sampling period (17 June through 8 July 2002).

To examine the effect of bird feeders on tick densities, we ran a two-way Analysis of Variance, using presence or absence of a bird feeder as one factor, and setting (presence or absence of forest on or adjacent to the property) as the second factor. The feeder x setting interaction was of interest given that feeders might enhance tick numbers only on properties in which forest-dwelling mammals and birds could be attracted to the feeder. We examined the effects of bird feeders on the average density (number/m^2) of nymphs, larvae, and nymphs plus adults on the lawn alone, where landowners presumably spend the most time outdoors on their property, and in all available habitats (lawn, forest, and ecotone). Because of low numbers of adults, we did not analyze them separately, but summed the two potentially infective life stages (adults and nymphs) in one analysis. To determine if feeders that were operated during summer months had a different effect on tick densities, we reanalyzed the data, including the "winter-only" feeders with the "no feeders" group. Life stages other than the targeted life stage collected in each sampling period were not included in these analyses because of small sample sizes.

Samples of adult and nymphal ticks were analyzed in the laboratory for infection with *B. burgdorferi* using direct immunofluorescence assay, as described in Ostfeld et al. (2001). Nymphs and adults for assay were selected randomly from the total collected in the last four sampling periods.

Bird Feeder Survey. To assess which of our sampling properties employed bird feeders, we administered telephone or email surveys to each landowner. Participants were first asked if they had an active, seed-distributing bird feeder. If not, they were asked how many years had passed since a feeder had been operated on their property. Participants with active feeders were asked for the number of years it had been operated, months of operation, and the type of food provided.

Bird Species List Survey. The species composition of birds that visit feeders are relevant to any potential impacts on Lyme disease risk because different species vary in their average body burdens of *I. scapularis* (i.e., the mean number of ticks per host species), as well as their reservoir competence. To generate a list of common birds found at feeders in the Poughkeepsie area, members of a local bird-watching club (the Ralph T. Waterman Bird Club) were emailed the following survey question:

> For a research project, we are polling area birders for their best guesses as to the most common birds visiting feeders in the Poughkeepsie

Table 1. Means and standard errors of ticks/100m^2 in properties with and without bird feeders on lawns and in all habitat types, in 2001-2002, in Dutchess County, NY

Life stage	Habitat	Feeder (yes/no)	Mean (SE)
Larvae	Lawn	yes	2.71 (0.20)
Larvae	Lawn	no	3.75 (0.77)
Larvae	All	yes	73.09 (34.97)
Larvae	All	no	63.03 (24.09)
Nymphs	Lawn	yes	0.38 (0.14)
Nymphs	Lawn	no	0.27 (0.07)
Nymphs	All	yes	1.77 (0.39)
Nymphs	All	no	1.71 (0.51)
Nymphs + Adults	Lawn	yes	0.58 (0.18)
Nymphs + Adults	Lawn	no	0.47 (0.10)
Nymphs + Adults	All	yes	2.75 (0.60)
Nymphs + Adults	All	no	3.42 (0.93)

area. Please list the top 10 birds (ranked in order of frequency of visits) that you would expect to see on or around a bird feeder in the following situation: A mixed-seed feeder in a grassy yard (with small patches of forest nearby, but not extensive forest), in midsummer, in an urban or suburban location in Poughkeepsie.

A list of the 10 most common birds was produced by summing the ranks of birds cited most frequently in the responses.

Lyme Disease Household Survey. In November of 2001, a community survey was conducted by the Dutchess County Department of Health. The specific goal of the survey was to measure people's knowledge, attitudes, and behaviors regarding Lyme disease. A local hospital's institutional review board approved the survey, and verbal informed consent was obtained from all participants. A national survey company was hired to randomly call people who lived within the core areas of each of the four study sites. Thus, the survey was conducted in the same residential area in which we monitored ticks, but did not necessarily include all of the residents on whose properties we sampled. Names of the respondents were kept anonymous, so we could not match responses to specific properties.

A list of 1,991 viable phone numbers, which included all listed numbers for residents in the study sites, was provided to the survey company. These numbers were then randomized within each study site by a computerized system and selected for participation in the survey. The only requirement for participation was that adults (over 18) familiar with the health and health-related behaviors of the household voluntarily complete the survey. Up to six calls were made to each household selected to secure a representative sample. In total, 580 people completed the questionnaire, which took ≈14 min. The number of surveys administered in each core area was proportional to the number of viable telephone numbers in that site.

Among the 23 questions on the survey, participants were asked the following, the results of which we use in this paper:

1. Do you feed birds on your property?
2. Have you ever been diagnosed by a health care professional as having Lyme disease?

Results

Bird Feeder Survey. Of the 82 properties at which we monitored tick numbers, 74 landowners participated in the bird feeder survey. In total, 30 (40.5%) of the residents operated seed-distributing bird feeders on their properties. Of these, 14 (46.7%) of the feeders were operated in winter only, 15 (50.0%) were operated all year, and one (3.3%) was operated during summer months only.

Species List of Common Feeder Birds. Seventeen birders provided lists of the most common birds that they observed at local bird feeders, and 22 species were reported. The 10 species reported with the greatest frequency were Blue Jays (*Cyanocitta cristata*), Black-capped Chickadees (*Poecile atricapilla*), Tufted Titmice (*Baeolophus bicolor*), House Finches (*Carpodacus mexicanus*), Mourning Doves (*Zenaida macroura*), Northern Cardinals (*Cardinalis cardinalis*), White-breasted Nuthatches (*Sitta carolinensis*), Downy Woodpeckers (*Picoides pubescens*), American Goldfinches (*Carduelis tristis*), and Red-bellied Woodpeckers (*Melanerpes carolinus*).

Tick Abundance and Infection Prevalence. We collected ticks from 73 of the 74 properties for which we had bird feeder survey data. We eliminated tick data from two properties that did not have lawns. Of the 71 properties for which we had valid tick data, 28 (39.4%) had feeders. Fifteen (53.6%) of these were operated year-round; 12 (42.9%) were winter only; and 1 (3.5%) was summer only. For property setting, 28 (39.4%) of the properties contained lawn habitat only, while 43 (60.6%) of the properties contained, or were adjacent to, forested habitat.

During the 2001 and 2002 nymphal peaks, 89 and 419 *I. scapularis* nymphs were collected, respectively. In the fall 2001 and spring 2002 adult peaks, 199 and 74 adults were collected, respectively. During the 2001 larval peak, 7,525 larval ticks were collected.

On average, 0.38 (0.14 SE) and 1.77 (0.39) nymphs/100m^2 were collected, respectively, from lawns and all habitats on properties with feeders, versus 0.27 (0.07) and 1.71 (0.51), respectively, from lawns and all habitats on properties without feeders (Table 1). Similarly, the total number of nymphs plus adults on lawns with feeders was 0.58 (0.18) compared with 0.47 (0.10) for lawns with no feeders; values for all habitats were 2.75 (0.60) for properties with feeders and 3.42 (0.93) for properties without feeders. Neither feeder nor setting had any significant effect on any of the life stages, and the setting x feeder interaction was not significant in any of the tests ($P > 0.05$) (Fig. 1). This was true both when all bird feeders were considered together, and when "winter-only" feeders were included in the "no feeders" group (Tables 2 and 3).

In total, 24 of 107 (22%) of the nymphs and 118 of 203 (58.1%) of adult ticks examined were infected with *B. burgdorferi.* There was no significant effect of

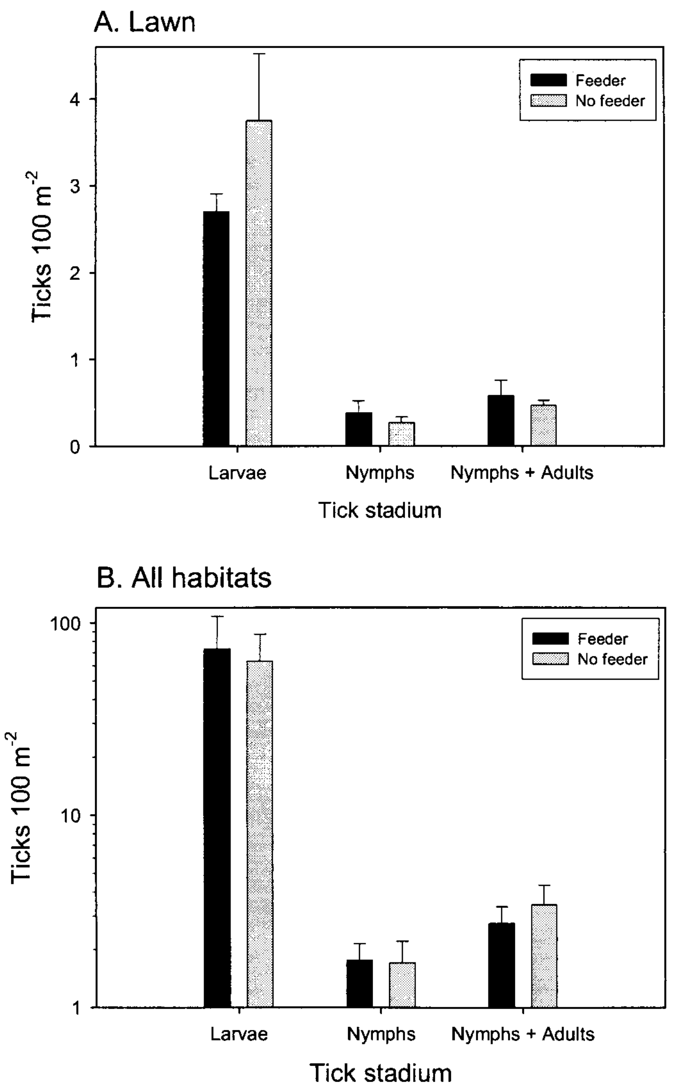

Fig. 1. The density (mean + 1SE) of different life stages of *I. scapularis* on properties with and without bird feeders, in lawns and in all habitat types. Data were collected in 2001–2002, in Dutchess County, NY.

bird feeders on either nymphal [Pearson χ^2 = 0.41, degrees of freedom (df) = 1, P = 0.52] or adult infection prevalence (Pearson χ^2 = 1.09, df = 1, P = 0.30). For nymphs, the trend was for infection prevalence to be higher on properties with feeders (25.6%) than on those without feeders (20.3%), but for adults the trend was for a lower percentage of infected ticks on properties with feeders (51.2%) than without feeders (60.0%).

Survey Results. In total, 580 people in our study sites completed the questionnaire. Two cases were eliminated from the data on the basis of the respondents' reported ages (7 and 17), resulting in a total of 578 valid responses.

A total of 224 (39%) people answered that they fed birds on their property. Fifteen percent of the respondents reported that they had been diagnosed with Lyme disease by a health-care professional. Of the respondents, 53 (15.0%) without bird feeders had been diagnosed with Lyme disease, while 34 (15.2%) with bird feeders had been diagnosed. There was no significant difference in Lyme disease prevalence for the respondents in households with and without bird feeders [odds ratio (OR): 1.02, 95% confidence interval (CI): 0.62–1.66].

Discussion

In this study, bird feeders did not appear to be a risk factor for Lyme disease. The presence of a bird feeder did not increase Lyme disease prevalence or local density of *I. scapularis* at any life stage. Bird feeders had no effect on tick densities on lawns, where most bird feeders are located, and where residents presum-

Table 2. Results of 2-way ANOVAs testing for the effects of bird feeders (including all feeders, regardless of season of operation) and setting (whether the property has lawn only or lawn plus forest) on densities of ticks. Data were collected in 2001-2002, in Dutchess County, NY

	Effect	df	*F*	*P*
Larvae (lawn)				
	Feeder	3	−0.94	0.35
	Setting	3	−0.74	0.47
	Feeder × setting	3	1.34	0.19
	Residual	52		
Larvae (all habitats)				
	Feeder	3	0.04	0.97
	Setting	3	0.85	0.40
	Feeder × setting	3	−0.07	0.94
	Residual	52		
Nymphs (lawn)				
	Feeder	3	0.38	0.70
	Setting	3	1.44	0.16
	Feeder × setting	3	−0.66	0.51
	Residual	67		
Nymphs (all habitats)				
	Feeder	3	0.04	0.97
	Setting	3	1.30	0.20
	Feeder × setting	3	−0.06	0.95
	Residual	67		
Adults + Nymphs (lawn)				
	Feeder	3	0.187	0.852
	Setting	3	1.488	0.143
	Feeder × setting	3	−0.457	0.650
	Residual	52		
Adults + Nymphs (all habitats)				
	Feeder	3	−0.211	0.834
	Setting	3	0.989	0.327
	Feeder × setting	3	0.330	0.743
	Residual	52		

Table 3. Results of 2-way ANOVAs testing for the effects of bird feeders operated in summer months and setting (whether the property has lawn only or lawn plus forest) on densities of ticks. Data were collected in 2001-2002, in Dutchess County, NY

	Effect	df	*F*	*P*
Larvae (lawn)				
	Feeder	3	−0.61	0.55
	Setting	3	−0.00	1.00
	Feeder × setting	3	0.44	0.66
	Residual	52		
Larvae (all habitats)				
	Feeder	3	0.62	0.56
	Setting	3	1.63	0.11
	Feeder × setting	3	−1.04	0.30
	Residual	52		
Nymphs (lawn)				
	Feeder	3	0.80	0.43
	Setting	3	1.61	0.11
	Feeder × setting	3	−1.00	0.32
	Residual	67		
Nymphs (all habitats)				
	Feeder	3	0.02	0.99
	Setting	3	0.92	0.36
	Feeder × setting	3	0.05	0.96
	Residual	67		
Adults + Nymphs (lawn)				
	Feeder	3	0.78	0.44
	Setting	3	1.95	0.06
	Feeder × setting	3	−1.16	0.25
	Residual	52		
Adults + Nymphs (all habitats)				
	Feeder	3	−0.01	1.00
	Setting	3	0.97	0.34
	Feeder × setting	3	0.03	0.98
	Residual	52		

ably spend the most time outdoors. Similarly, they had no effect when all habitat types found on suburban properties (lawn, forest, and ecotone) were considered. Moreover, bird feeders had no effect on *B. burgdorferi* infection prevalence for either nymphal or adult ticks.

The supposition that bird feeders would increase Lyme disease risk and prevalence near the vicinity of the feeder seems to be based on the following assumptions: (1) small mammals and birds attracted to the feeder will deposit fed ticks in the local area; (2) many of the ticks will be infected with *B. burgdorferi;* and (3) these ticks will survive, molt, and quest locally. The degree to which these assumptions are met would appear to be influenced by the following factors, which we discuss in turn: (1) the season in which feeders are operated; (2) the body burdens and reservoir competence of the common visitors of bird feeders; and (3) microhabitat in the vicinity of the feeders.

Feeder Seasonality. The potential for bird feeders to affect local tick populations will depend, in part, on season of operation. A large fraction (43%) of bird feeders in our study sites were operated only in winter months (approximately November through May). During these months, only adult *I. scapularis* are active (Fish 1993). Adults, which specialize on white-tailed deer and other large mammals (Piesman et al. 1979), generally do not parasitize small mammals and birds. Thus, small mammals and birds visiting feeders only during the winter months would not be infested with ticks, and therefore would not increase local tick densities.

It is possible that winter-operated feeders could attract white-tailed deer and their attached adult ticks. However, if engorged adults from these deer drop off and lay eggs that hatch in the vicinity of the feeder, we would expect the feeder properties to have higher densities of questing larval ticks, a result that did not materialize in our study.

The majority of feeders (57%), however, were operated in summer months as well as winter months. Immature *I. scapularis* are active during summer months, and parasitize many species of birds and small mammals. If engorged larvae and nymphs are deposited by these hosts in the vicinity of the feeder and successfully molt, we would expect elevated densities of questing nymphal and adult ticks on feeder properties. However, even when we considered summer-operated feeders alone, we observed no increase in tick densities.

Species Composition of Hosts. Not all of the species of birds common at bird feeders are likely to be parasitized by *I. scapularis.* Birds that do not associate with the ground have a much lower probability of infestation than do ground-foraging and ground-nesting birds (Stafford et al. 1995, Rand et al. 1998). Of the ten species most commonly reported at local feeders, six species (Black-capped Chickadees, Tufted Titmice, Downy and Red-bellied Woodpeckers, White-breasted Nuthatches, and American Goldfinches) are primarily bark- and foliage-gleaners (Ehrlich et al. 1988). Because their exposure to *I. scapularis* is limited, these species would be expected to make a relatively small contribution to local densities of *I. scapularis.* Little has been reported on the reservoir competence of any of the ten most common avian feeder species. However, when compared with the competent members of the mammalian community, songbirds, as a group, are known to have relatively low reservoir competence (Giardina et al. 2000, LoGiudice et al. 2003).

Although much attention has been devoted to birds as hosts capable of dispersing and sometimes infecting ticks, few of the species so identified commonly visit feeders. Perhaps more important is the attraction of small mammals, such as squirrels, mice, and chipmunks. The gray squirrel (*Sciurus carolinensis*), for example, is a mammal commonly observed at local bird feeders (A.T. and R.O., unpublished data). Although they have high body burdens of *I. scapularis*, gray squirrels are relatively poor reservoirs when compared with the white-footed mouse, the most competent reservoir of *B. burgdorferi* (LoGiudice et al. 2003). Unlike gray squirrels, white-footed mice are nocturnal and secretive, and thus, are not easily observed at bird feeders. To some extent, this important host may be discouraged from visiting bird feeders when feeders are located on mowed lawns, as mice prefer to forage in areas with a complex microhabitat (Dueser and Shugart 1978, Kaufman et al. 1983, Manson and Stiles 1998).

The effects of bird feeders on local activity, abundance, and species composition of seed-eating mammals would be worthy of study. Regardless of the exact density and species composition of hosts visiting bird feeders, however, no significant difference existed in infection prevalence on feeder versus no-feeder properties. This finding suggests that there is no net difference in overall reservoir competence of hosts on properties with and without bird feeders.

Bird Feeder Microhabitat. Despite the potential for increased host traffic on properties with bird feeders, we observed no increase in local tick densities. One possible reason may be feeder microhabitat. Although not quantified, we observed that many bird feeders were located on mowed lawns. In addition to acting as a deterrent for some small mammals (Dueser and Shugart 1978, Kaufman et al. 1983, Bowers et al. 1993, Manson and Stiles 1998), this microhabitat may also be an impediment for tick survival. Ixodid ticks have high humidity requirements (Maupin et al. 1991, Carroll et al. 1992, Yoder and Spielman 1992, Duffy et al. 1994, Stafford 1994) and are likely to experience high mortality on the sunny lawns. Thus, the potential for hosts to boost tick numbers on properties with bird feeders might be mitigated by low survivorship of ticks dropped onto lawns.

The results of our study differed from those of Orloski et al. (1998) and Smith et al. (2001), which found an increased prevalence of Lyme disease for residents with bird feeders on their properties. However, for Orloski et al., this effect was only marginally significant (OR 3.2, 95% CI 1.0–10.2). The sample size of our survey (n = 578 households) was smaller than that of Smith et al. (n = 743) but larger than that of Orloski et al. (n = 102), so the difference is apparently not because of lack of statistical power. Neither Orloski et al. nor Smith et al. looked at the potential mechanisms behind the increase in Lyme disease prevalence (e.g., tick densities on properties with and without feeders). It is possible that bird feeders did not cause an increase in local tick densities, but that feeding birds was associated with a risky behavior (e.g., time spent outside). Another possibility is that land use surrounding residential properties can influence the effect that bird feeders have on Lyme disease prevalence. Approximately 20% and 78% of respondents in the studies of Smith et al. and Orloski et al., respectively, reported that they lived in a rural environment, whereas all of the respondents in our study lived in an urban or suburban environment. Although we found no evidence that bird feeders increase risk or incidence of Lyme disease in urban and suburban settings, we suggest that variation in both human behavior and landscape features surrounding residences are worthy of further study.

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