

Lyme Disease and Migrating Birds in the Saint Croix River Valley

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During a study of migrating land birds in 1987, we examined over 9,200 individual birds representing 99 species from the Saint Croix River Valley, a Lyme disease-endemic area of east central Minnesota and northwestern Wisconsin. We found that 250 deer tick (*Ixodes dammini*) larvae and nymphs infested 58 birds from 15 migrant species; 56 ticks (22.4%) were positive for the Lyme disease spirochete *Borrelia burgdorferi*. Five ground-foraging migrant bird species favoring mesic habitats, veery (*Catharus fuscescens*), ovenbird (*Seiurus aurocapillus*), northern waterthrush (*S. novaboracensis*), common yellowthroat (*Geothlypis trichas*), and swamp sparrow (*Melospiza georgiana*), accounted for nearly three-quarters of parasitized individuals. Nearly half of the spirochete-positive ticks were removed from migrating birds taken in a riparian floodplain forest. Recaptured migrants with infected ticks indicate that they transmit *B. burgdorferi* to hexapod larvae. We suggest that birds may be both an important local reservoir in the upper Mississippi Valley and long-distance dispersal agents for *B. burgdorferi*-infected ticks to other regions of the continent.

Land birds that migrate for long distances may travel seasonally up to 7,000 km from their breeding habitats in the middle and high latitudes of North America to their wintering areas in the neotropics. Many migrants travel through a variety of habitats and regions during their seasonal passage, stopping at some to rest and replenish nutrient reserves before continuing (15, 19). While stopped at a resting site, the birds may acquire locally abundant cysts, seeds, spores, larvae, or other propagules, which may be subsequently dispersed days or weeks later. For example, spores of pathogenic fungi common on agricultural crops have been isolated from 63 species of land birds migrating from Mexico to the Central Plains (G. Warner, Ph.D. dissertation, University of Minnesota, Minneapolis, 1976). Similar studies of both resident and migrant birds inhabiting the conifer forests of central North America demonstrated that the birds were important vectors in dispersing dwarf mistletoe (*Arceuthobium* spp.) seeds (20, 21). In North Africa, 40 species of autumn-migrating land birds were found to transport ticks, including *Ixodes ricinus* (14), a European vector for the Lyme disease pathogen, *Borrelia burgdorferi* (5). Recent studies in North America on winter and summer bird populations show that birds serve as hosts for *I. dammini*, one of several known acaridan vectors for *B. burgdorferi* (2, 3, 7). Although birds are not the only vertebrate hosts, they offer a ready means of widespread dispersal of ticks infected with *Borrelia* spp. (3, 7, 24, 25). This cosmopolitan prevalence of *B. burgdorferi* (2, 25) provides an opportunity to explore its web of relationships with diverse arthropod vectors, their hosts, and the natural environments in which these complex interactions take place.

During a study of habitat use by migrating birds in 1986, ectoparasites found on captured birds were removed and preserved for later study. Examination of the ixodid ticks removed showed that a majority were deer ticks (*I. dammini*). Ixodid ticks were again collected from migrating birds during the continuing habitat study in 1987, and these ticks were examined for the spirochete *B. burgdorferi*.

MATERIALS AND METHODS

Migrating birds were captured in nylon mist nets located at Sandrock Cliffs, Saint Croix National Riverway, river km 145.8, near Grantsburg, Wis. Twelve 30-mm mesh mist nets (12 by 3 m) were placed 30 m apart in each of five habitats: an alder swale, a conifer bog, an island floodplain forest, a pine barren forest, and a sedge fen. Hence, a total of 60 nets were used. The nets were open from dawn to dusk daily for six consecutive weeks each spring and fall, for totals of 28,617 and 33,072 net hours, respectively. Each captured bird was examined both visually and manually while a series of measurements and observations were recorded. The birds were banded with U.S. Fish & Wildlife Service bands and then released, usually within 0.5 h of capture. Ixodid ticks were removed manually with microdissecting forceps during examination of the birds. The ticks were placed alive in 4-ml glass vials with moistened filter paper and kept in portable coolers until transported to the laboratory.

I. dammini was identified in the laboratory, where the midgut tissues of these ticks were excised aseptically and placed on glass slides for fixation. The prepared slides were examined for *B. burgdorferi* under a Leitz Laborlux 12 fluorescent microscope. All spirochete isolates were distinguished serologically by reacting polyclonal rabbit (*Oryctolagus cuniculus*) antisera prepared to *B. burgdorferi* isolate 297 (26) and murine (*Mus musculus*) monoclonal antibodies (H5332). These were directed against the *B. burgdorferi* B31 31-kilodalton surface protein by using the indirect immunofluorescence antibody assay (6).

RESULTS

Deer ticks infested 15 of 99 migrating land bird species taken during the 1987 study period at Sandrock Cliffs. However, infested birds represented about 1% of all 5,131 individuals of the 15 species captured. Five species, veery (*Catharus fuscescens*), ovenbird (*Seiurus aurocapillus*), northern waterthrush (*S. novaboracensis*), common yellowthroat (*Geothlypis trichas*), and swamp sparrow (*Melospiza georgiana*), accounted for nearly 75% of the parasitized

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TABLE 1. Occurrence of *I. dammini* parasitizing avian migrants in the Saint Croix River Valley during spring and autumn migration 1987

Host species ^a	No. of birds infested/no. captured (%)	No. of ticks ^b	
		Larvae	Nymphs
<i>Catharus fuscescens</i> (veery)	10/97 (10.3)	21 (19.1)	3 (66.6)
<i>Dumetella carolinensis</i> (gray catbird)	1/67 (1.5)	1 (0)	0
<i>Vermivora ruficapilla</i> (Nashville warbler)	3/699 (0.4)	14 (21.4)	1 (0)
<i>Dendroica coronata</i> (yellow-rumped warbler)	1/1,618 (0.1)	2 (50.0)	0
<i>Setophaga ruticilla</i> (American redstart)	1/251 (0.4)	2 (0)	0
<i>Seiurus aurocapillus</i> (ovenbird)	12/434 (2.8)	73 (28.9)	1 (0)
<i>Seiurus noveboracensis</i> (northern waterthrush)	10/407 (2.5)	60 (16.7)	2 (50.0)
<i>Oporornis agilis</i> (Connecticut warbler)	1/10 (10.0)	8 (0)	0
<i>Oporornis philadelphia</i> (mourning warbler)	1/64 (1.6)	15 (6.7)	0
<i>Geothlypis trichas</i> (common yellowthroat)	7/852 (8.2)	14 (50.0)	4 (50.0)
<i>Wilsonia pusilla</i> (Wilson's warbler)	1/49 (2.0)	0	1 (100.0)
<i>Wilsonia canadensis</i> (Canada warbler)	2/69 (2.9)	5 (0)	0
<i>Melospiza melodia</i> (song sparrow)	2/176 (1.1)	0	2 (50.0)
<i>Melospiza georgiana</i> (swamp sparrow)	4/123 (3.3)	2 (100.0)	2 (50.0)
<i>Zonotrichia albicollis</i> (white-throated sparrow)	2/215 (0.9)	16 (0)	1 (0)
Total (15 spp.)	58/5,131 (1.1)	233 (21.5)	17 (47.1)

^a Scientific and common names conform to the American Ornithologists' Union Check-list of North American Birds (1).

^b Numbers in parentheses are percentages of ticks infested with *B. burgdorferi*.

tized individuals (Table 1). Two species, veery and mourning warbler (*Oporornis philadelphia*), exhibited a 10% infestation frequency for captured individuals, whereas among the remaining species less than 3% of the individuals were tick infested. The remaining 10 species exhibited lower infestation rates, although gray catbird (*Dumetella carolinensis*) and common yellowthroat show high deer tick infestation rates elsewhere (3, 4).

No adult deer ticks were obtained from migrant birds, although adult ticks were plucked regularly from the field personnel who traversed the habitats where the birds were captured. However, 250 immature *I. dammini* were collected from captured migrants; 94% of these ticks were hexapod larvae, and the remainder were octopod nymphs. All attached ticks were removed from the head, where they were concentrated about the eyes, ears, and rictus. These areas of the body are not easily reached by bill preening. The 58 infested birds averaged 4.3 deer ticks per animal, with a range of 26 (1 to 27) ticks.

A total of 56 of the 250 deer ticks (22.4%) were positive for *B. burgdorferi*. Of these, 49 were larvae infesting eight bird species and 7 were nymphs parasitizing five species (Tables 1 and 2). Wilson's warbler (*Wilsonia pusilla*) and song sparrow (*M. melodia*) were the only tick-infested birds taken during the spring migration. We removed spirochete-positive larvae from two ovenbirds taken in the floodplain forest (U.S. Fish & Wildlife Service band numbers 2030-18250 and 2030-18271) at their first capture on 19 and 23 August, respectively. We next recaptured them 7 and 15 days later in the same habitat and again collected *B. burgdorferi*-positive hexapod larvae from each.

The relative frequency of ticks collected from migrating birds shows that nearly 50% of the deer ticks collected were taken from birds captured in one habitat, the island floodplain forest. The remainder of the ticks were collected from birds captured in the other four habitats (Table 3). The floodplain forest habitat had both the largest number of individual birds infested with ticks and the largest number of ticks. However, the actual frequency of tick-infested birds occurring in any of the five habitats was low, although all habitats produced some tick-infested birds (Table 2). Only infested veerys were found in all five habitats. Four infested

TABLE 2. Frequency of *I. dammini*-infested migrating birds in five habitats at Sandrock Cliffs in spring and autumn 1987

Host species	No. of parasitized birds/1,000 net hours ^a									
	Alder swale		Pine forest		Floodplain forest		Conifer bog		Sedge fen	
	Spring	Autumn	Spring	Autumn	Spring	Autumn	Spring	Autumn	Spring	Autumn
<i>Catharus fuscescens</i> ^b	—	0.151	—	0.603	—	0.303	—	0.151	—	0.303
<i>Dumetella carolinensis</i>	—	—	—	—	—	—	—	—	—	0.152
<i>Vermivora ruficapilla</i> ^b	—	0.151	—	—	—	—	—	0.151	—	0.152
<i>Dendroica coronata</i> ^b	—	—	—	—	—	0.152	—	—	—	—
<i>Setophaga ruticilla</i>	—	—	—	0.151	—	—	—	—	—	—
<i>Seiurus aurocapillus</i> ^b	—	0.302	—	0.301	—	1.365	—	—	—	—
<i>Seiurus noveboracensis</i> ^b	—	0.151	—	—	—	1.061	—	—	—	0.152
<i>Oporornis agilis</i>	—	—	—	—	—	0.152	—	—	—	—
<i>Oporornis philadelphia</i> ^b	—	—	—	0.151	—	—	—	—	—	—
<i>Geothlypis trichas</i> ^b	—	0.302	—	—	—	0.152	—	—	—	0.606
<i>Wilsonia pusilla</i> ^b	0.175	—	—	—	—	—	—	—	—	—
<i>Wilsonia canadensis</i>	—	—	—	—	—	—	—	0.151	—	0.152
<i>Melospiza melodia</i> ^b	0.175	—	—	—	—	—	—	—	0.175	—
<i>Melospiza georgiana</i> ^b	—	0.302	—	—	—	—	—	—	—	0.152
<i>Zonotrichia albicollis</i>	—	0.151	—	—	—	—	—	—	—	0.152

^a 1 net hour = 1 net open for 1 h. Dashes indicate that no tick-infested birds were taken.

^b *B. burgdorferi* positive ticks present.

TABLE 3. Proportion of *I. dammini* collected from migrating birds in five habitats in the Saint Croix River Valley in spring and autumn 1987

Type (no.) of <i>I. dammini</i>	Proportion of ticks in following habitat ^a :									
	Alder swale		Pine forest		Floodplain forest		Conifer bog		Sedge fen	
	Spring	Autumn	Spring	Autumn	Spring	Autumn	Spring	Autumn	Spring	Autumn
Hexapod larvae (233)										
<i>B. burgdorferi</i> -positive	—	0.056	—	0.020	—	0.096	—	0.004	—	0.020
<i>B. burgdorferi</i> -negative	—	0.201	—	0.080	—	0.373	—	0.024	—	0.064
Octopod nymphs (17)										
<i>B. burgdorferi</i> -positive	0.008	—	—	0.004	—	0.008	—	—	—	0.008
<i>B. burgdorferi</i> -negative	—	0.004	—	0.008	—	—	—	0.004	0.004	0.012
Adult ticks (0)	—	—	—	—	—	—	—	—	—	—

^a Dashes indicate that no ticks were found on the birds examined.

species (Nashville warbler, ovenbird, northern waterthrush, and common yellowthroat) were found in three habitats. The remaining species exhibited infestations at lower capture frequencies and in only one or two habitats.

The floodplain forest had the highest incidence of deer tick-infested birds, with *Seiurus* warblers being the most commonly parasitized birds taken from this river island habitat (Table 3). Two other habitats, the alder swale and the sedge fen, produced nine infested species each, but these species showed lower frequencies than did those infested birds captured in the floodplain. The pine forest and the conifer bog had even fewer infested species, although half of the infested birds in the pine forest were *C. fuscescens*.

DISCUSSION

Earlier studies have shown that birds migrating for long distances may be parasitized at relatively low frequencies by ixodid ticks during the seasonal passage between their summer and winter habitats in Africa, Asia, and Europe (13, 14). These studies indicate that the greatest infestations occur during the autumn migration. Our data, from central North America, show a similar low frequency of ixodids parasitizing migrating birds and show that birds migrating in the autumn appear to be more heavily infested than those migrating in the spring. These data suggest that migrating birds are able to transport ticks over long distances. If the ticks are infected with a pathogen, migrating birds can be a factor in the long-distance dispersal of that pathogen (e.g., *B. burgdorferi*). It should be noted that the North American distribution of Lyme borreliosis—on the Atlantic seaboard, on the central West Coast, and from north central Minnesota to southeastern Wisconsin (10, 11)—parallels known bird migration routes (15, 23). The north-south linearity of this originally patchy distribution exhibits a pattern, on a continental scale, similar to that presented for bird-dispersed plant pathogens (20, 21).

An avian reservoir for the Lyme borreliosis pathogen has been suggested by the isolation of *B. burgdorferi* from the hepatic tissue of a nonmigrating veery and culturing spirochetes from ticks infesting other nonmigrating birds (2). Although that study is not comparable to ours in sample size or season, together they provide complementary evidence that migratory birds serve as a reservoir for *B. burgdorferi*. In addition, our study shows apparent spirochete transmission from ovenbirds to tick larvae under field conditions. The probability of transovarial transmission of *B. burgdorferi* in the larval ticks seems to be low (17).

The three bird species with the highest infestation frequencies at Sandrock Cliffs, i.e., veery, ovenbird, and northern

waterthrush, are exclusively ground-nesting and ground-foraging species that are common in the mesic woodlands of the north central area and the eastern seaboard of the United States. These three species migrate south and east to southern Central America and northern South America. The fourth species with a high incidence of infestation, common yellowthroat, is more widely distributed in North America. It prefers brushy marshes and fens for nesting and foraging, and it winters in Central America (7, 9, 23). All four species are essentially ground-dwelling animals that occupy and traverse the same general geographic regions, where they are readily available to questing *I. dammini*. The ticks, once attached, may be carried about for several days before dropping off (18, 22), allowing time for transfer of the spirochetes from one organism to the other. If ticks are acquired during migration, several days of flying may be converted into hundreds of kilometers during the time between migration rest stops (15, 24). We found that ticks infest 0.6% of our migrating bird sample, and we conservatively estimate that 10 billion birds migrate seasonally across North America (4, 19). Hence, it seems likely that avian migrants account for the wide dispersal of ticks (and spirochetes) over broad geographical areas. The potential dispersal role of migrating birds is a function of the distance traveled, the speed of travel, the time spent traveling, the routes traveled, the number of migratory stopovers, and the time spent at each stopover.

Our data corroborate previous observations that migratory birds are important agents in the dispersal of tick-borne diseases (13, 14, 24) and support the suggestion (2, 7) that the widespread distribution of *B. burgdorferi* is a function of dispersal by tick-infested birds.

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