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William c. Scharf
Lake Superior State University, wcscharf@charter.net

Lisa Aukland
Texas A&M University

Gary W. Shugart
University of Puget Sound

Sarah A. Hamer
Texas A&M University

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1Department of Biology Lake Superior State University, present address 6241 Summit Ct., Traverse City, MI 49686. (e-mail: wcscharf@charter.net). 2 Department of Veterinary Integrative Biosciences, Texas A&M University, 4458 TAMU, College Station, TX, 77845. 3Slater Museum, University of Puget Sound, Tacoma, WA 98416 4 Schubot Center for Avian Health, Department of Veterinary Pathobiology, Texas A&M University, 4458 TAMU, College Station, TX, 77845.

Occurrence of Ticks (Acari: Ixodidae) on Birds in Northwestern Lower Michigan, 2011–2019

William C. Scharf [1,*], Lisa Aukland[2], Gary W. Shugart[3], and Sarah A. Hamer[2,4]

[1] Department of Biology Lake Superior State University, present address 6241 Summit Ct., Traverse City, MI 49686

[2] Department of Veterinary Integrative Biosciences, Texas A&M University, 4458 TAMU, College Station, TX, 77843

[3] Slater Museum, University of Puget Sound, Tacoma, WA 98416

[4] Schubot Center for Avian Health, Department of Veterinary Pathobiology, Texas A&M University, 4467 TAMU, College Station, TX, 77843

* Corresponding author: (e-mail: wcscharf@charter.net)

Abstract

Monitoring tick infestation of wildlife provides baseline tick occurrence data that may have human or animal health implications. We collected 312 ticks of four species from 5,122 birds of 93 species while monitoring bird migration during 15 fall and spring seasons between 2011 and 2019 in the northern Lower Peninsula of Michigan. Twenty-seven of 93 bird species hosted ticks with an overall prevalence (= at least one tick) of 3.6% (185/5,122). Median burden was one tick/per infested bird with a range of 1–16 ticks per infested bird. Tick species collected were primarily *Haemaphysalis leporispalustris* (Packard) and *Ixodes scapularis* Say, with smaller numbers of *Ixodes dentatus* Marx and a single *Ixodes brunneus* Koch. The prevalence of avian infestations by *I. scapularis* increased over the eight-year study period ($P = 0.046$) to a high of over 4.6% infestation by *I. scapularis* in 2019. Based on the migratory status of birds, our data suggest that birds transported ticks to our site from northern or southern areas. Additionally, based on bird recapture data during stop-over periods at our site, we detected new tick infestations in 27 of 437 birds that had ticks removed on initial capture. These reinfestations potentially reflect bird's local acquisition of ticks, such as *I. scapularis*. This indicates that *I. scapularis* is becoming established in the region, which appears to be on the leading edge of this tick's expanding range in the Lower Peninsula of Michigan. Birds may be contributing to the establishment by contributing and possibly introducing and maintaining the ticks. Birds may be transporting ticks and seeding them elsewhere.

Keywords: ticks, phenology, pathogen, vector, zoonotic, birds

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Surveys that focus on associations among tick vectors and avian hosts provide useful data complementing the studies focused on tick-borne pathogens and disease risk (Ogden et al. 2008, Hamer et al. 2011, Loss et al. 2016, Clow et al. 2017, Walter et al. 2017, CDC 2018, Sonenshine 2018). In these surveys, infestation prevalence and the number of ticks on birds (hereafter burden) have been related to factors such as host status (migrant, breeding resident, year-round resident), body size, foraging height or location, phenology of tick life stages, and vegetation structure (Ogden et al. 2008, Loss et al. 2016, Parker et al. 2017). We collected ticks from migrating birds in the NW Lower Peninsula of Michigan to provide an overview of all ticks encountered relative to characteristics of bird species that may influence tick prevalence and burden. We then examined changes in annual prevalence over the 9-year study for two tick species most common in the region. Human health concerns vary depending on tick species and pathogens (Nelder et al. 2016, Loss et al. 2016, CDC 2018, Sonenshine 2018, Scott et al. 2020), although most human-biting ticks and tick-borne pathogens are maintained in wildlife populations. Thus, ecological studies focused on documenting tick-host associations over time, especially in regions of tick range expansions, provide crucial information to complement epidemiological and disease-focused studies.

Materials and Methods

Study Site. From 2011–2019, we used 12 × 2.6 m mist nets, with a mixture of 32 mm and 36 mm mesh sizes, to capture birds.

Figure 1. Tick infested Indigo Bunting, *Passerina cyanea* (L.) from the Chippewa Run Natural Area in the northern Lower Peninsula of Michigan. photo by Alice Van Zoeren.

Ten nets were opened with reduction in number of nets in times of heavy flights. Nets were placed at the Chippewa Run Natural Area (44.81°N, 86.05°W), near Empire, Leelanau County, Michigan. Shrubby vegetation 0.5–2.5 m in height consists of Honeysuckle (*Lonicera tatarica* L.), willows (*Salix* sp.), and Red Osier Dogwood (*Cornus amomum* Mill.). The shrubs are interspersed with taller Paper Birch (*Betula papyrifera* Marsh.) and Pin Cherry (*Prunus serotina* Ehrh.). This shrub-woodland was bordered by a variety of grasses and forbs on the upland side and a cattail (*Typha latifolia* L.) marsh with flowing water on the lowland side. Mist nets were opened seven days per week at sunrise for 3–4 hours, weather permitting, for a total of 8,463.05 net hours for seven spring seasons and eight fall seasons. We netted, in most seasons, from 1 May through 31 May and from 15 August through 30 September. No data from 2012 were available for analysis because of laboratory mis-handling.

Bird Processing. Captured birds were aged, sexed, weighed, and banded with U.S. Geological Service bands. Each band is uniquely numbered to allow tracking of individuals. After search and removal of ticks, the birds were released. Following banding protocol, birds were aged as after hatch year (AHY) in the spring and hatch year (HY) or AHY in the fall using accepted criteria (Pyle 1997). Birds were released after searching for and removing any ticks. Federal and State of Michigan bird banding permits to Scharf allowed the work described here.

Bird species status was designated as migrant, breeding/migrant, or year-round non-migratory resident (see Chartier et al. 2011) because noting that status could be important in infestation by ticks (see Loss et al. 2016). Bird foraging height followed categories of Parker et al. (2017): designating canopy, or below the canopy, or ground foraging. Bird names in the Supplement follow the International Ornithological Congress (IOC) list which and includes authors (Gill et al. 2020).

Tick Collection. Each bird was closely examined for the presence of attached ticks, especially around the head and neck with particular attention to the ear region and eyelids (Fig. 1). A head-mounted magnifying loupe facilitated inspection and removal of ticks. Ticks were removed intact with

Table 1. Distribution of 312 ticks by life stage and season. Ticks were removed from birds captured during fall and spring seasons of 2011–2019 in the northeastern Lower Peninsula of Michigan.

Species and season		Adult	Larvae	Nymph	undetermined	Total
Haemaphysalis leporispalustris	Total		122	29		151
	fall		106	18		124
	spring		16	11		27
Ixodes brunneus	Total	1				1
	spring	1				1
Ixodes dentatus	Total		11	4		15
	fall		5	1		6
	spring		6	3		9
Ixodes scapularis	Total		62	80		142
	fall		57	8		65
	spring		5	72		77
Ixodes species	Total		1	1	1	3
	spring		1	1	1	3
Total		1	196	114	1	312

fine, straight forceps taking care to remove the entire tick for later identification.

Typically, during migration, birds stop along the route to replenish fat and energy stores (Kaiser 1999). Time between initial examination and recapture within a season provided a minimal estimate of stopover length of bird migrants. During stopover periods, banding, removing ticks when found, then inspecting recaptured birds for ticks, provided an indication that ticks were locally acquired.

All ticks removed from birds were preserved in labeled vials containing 70% ethanol. The ticks were identified by S. A. Hamer and L. Auckland at Texas A&M University to species and stage in 2013 - 2019. Dr. Jean Tsao of Michigan State University identified ticks from 2011. Tick specimens are deposited in the Texas A&M University tick collection.

Statistical Analysis. Data were analyzed using Minitab 19 (2020). Infestation prevalence was compared using Wilcoxon-Mann-Whitney two-sample signed rank tests (Zar 1999) tests with two-tailed probabilities, including tests of differences in infestation by season and bird age (Parker et al. 2017) and body size of bird (Marsot et al. 2012, Brinkerhoff et al. 2018).

Results

In total, 5,122 birds (includes recaptures) of 93 species were examined during fall and spring seasons between fall 2011 and fall 2019, excluding 2012 (Supplement). Ticks were collected from 29% (27/93) of bird species captured (Supplement). Of these tick bearing birds, only six were year-round non-migratory species and only one in this group, a Northern Cardinal (*Cardinalis cardinalis* [Linnaeus]), hosted a tick (Supplement). Excluding, 680 year-round residents and within season recaptures, the mean initial capture date in the spring was 17 May (N = 2,429 birds, SD = 8.0 days) and the mean capture date in the fall was 7 September (N = 2,013 birds, SD = 11.6 days). Based on these initial capture dates and status, 87% (4,442/5,122) of birds were migrants.

We collected 312 ticks from 2,382 and 2,740 birds from spring and fall, respectively. The overall infestation prevalence was 3.6% (185 of 5,122 birds hosted at least one tick) (Table 1). Tick burden ranged from 1-16 ticks, with a median of one tick/per infested bird (Fig. 2). For comparison to other studies (e.g., Loss et al. 2016), the mean for our study was 1.6 ticks/infested bird.

Bird species were categorized by foraging category of ground-understory or canopy (Loss et al. 2016, Parker et al. 2017) for species with more than 10 individuals sampled (see Loss et al. 2016, Brinkerhoff et al. 2018). Only 1 of 23 (4%) of canopy foraging species was infested (an American Redstart, *Setophaga ruticilla* (Linnaeus)), which was significantly fewer than 74% (23/31) ground-understory birds that hosted ticks (*Fisher's Exact Test* = 0.0000002).

To assess variation in the prevalence of infestation by season and age, we used the 25 bird species that were captured in both

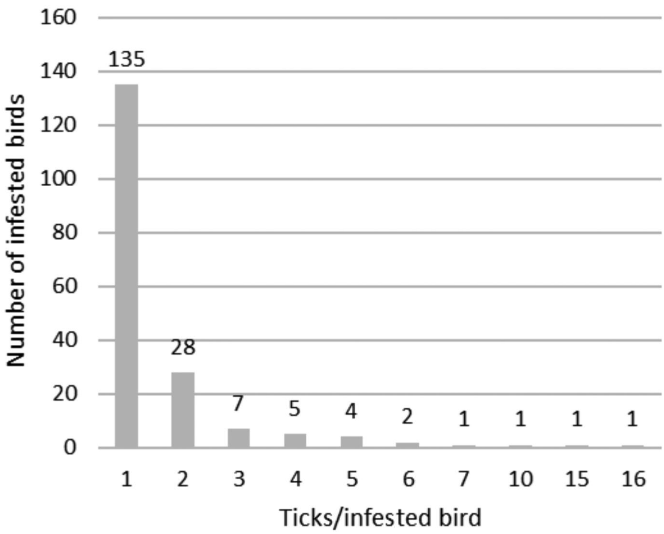

Figure 2. The distribution of 312 ticks on 185 bird hosts.

seasons and found no significant difference related to season (*Mann-Whitney-Wilcoxon* = 684; df = 25,25; $P = 0.369$) (Table 2) or age (*Mann-Whitney-Wilcoxon* = 563.5; df = 25,25; $P = 0.138$) (Table 2). To assess variation in the prevalence of infestation by bird weight, we used bird species that were infested and had 10 or more individuals sampled, for which our data showed no relationship ($R^2 = -0.078$, $P = 0.692$) (Fig. 3)

We collected four species of ticks: *Haemaphysalis leporispalustris* (Packard), *Ixodes brunneus* Koch, *Ixodes dentatus* Marx, and *Ixodes scapularis* Say. Tick species, percent of total ticks (n = 312), and percent of infested birds with the tick species in order were: *H. leporispalustris*, 48.4% (151/312) of ticks on 34.1% of infested birds, *I. scapularis,* 45.2% (142/312) of the ticks on 58.4% of infested birds; and *I. dentatus,* 4.8% (10/312) of ticks found on 5.4% of infested birds. We collected a single *I. brunneus* (Keith et al. 2015), and three *Ixodes* sp. ticks could not be identified to species (Table 1).

Two tick species, *I. scapularis* and *H. leporispalustris*, were numerous enough to provide assessments of phenology for larvae and nymphs. We found the overall number of *I. scapularis* were similar in fall and spring, but there were significantly more *I. scapularis* nymphs in the spring (*Chi-square* = 102.595; df = 1; $P < .00001$) and more larvae in the fall (Fig. 4A). In contrast, fewer *H. leporispalustris* were found in the spring than fall. In this species, larvae were more common than nymphs in both seasons, but similar to *I. scapularis*, there were significantly more larvae in the fall (Fig. 4B) (*Chi-square* = 9.827; df=1; $P = .00172$).

The annual prevalence of *I. scapularis* infestation increased from 1.5% to 4.85% at a rate given by the slope of the regression of 0.55% (Fig. 5) ($R^2 = 0.58$, $P = 0.046$). This regression was based on 2013 - 2019 when sampling was done in both fall and spring. In

Table 2. Summary values for percent prevalence of infestation for 25 (=N) bird species birds examined during fall and spring. Categories include All-Fall = AHY+HY, only AHY birds are encountered in spring. Means and SEs are provided for comparison to other studies. Q1 and Q3 refers to the first and third quartile about the median. Superscripts refer to comparisons (see text) that were not significantly different (p>.05).

Variable	N	Minimum	Q1	Median	Q3	Maximum	Mean	SE Mean
All-Fall[1]	25	0	1	5	13	100	13	4
AHY-Fall[2]	25	0	0	0	7	31	5	2
HY-Fall[2]	25	0	0	6	13	100	13	5
AHY-Spring[1]	25	0	0	5	11	20	6	1
Overall	25	0	2	5	10	20	6	1

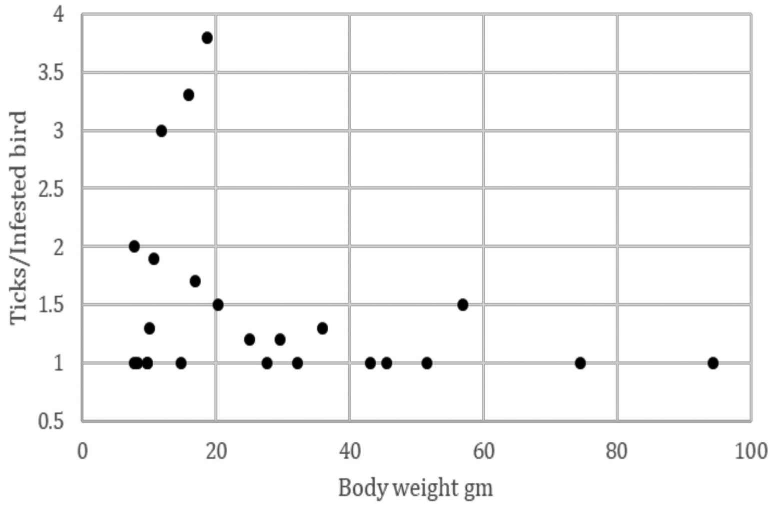

Figure 3. Average body weight relative to tick burden for bird species that had 10 or more individuals examined. See Supplement for species and sample sizes.

contrast, the annual *H. leporispalustris* infestation prevalence was relative unchanged across this period with approximately 1.2% infestation prevalence ($R^2 = 0.038$, $P = 0.673$) (Fig. 5). Percent data used in regressions did not deviate significantly from normality (*I. scapularis, Anderson-Darling* = 0.402, N = 7, *P* = 0.256; *H. leporispalustris, Anderson-Darling* = 0.250, N = 7, *P* = 0.618).

Of 27 bird species with ticks, 23 species hosted *I. scapularis* and 19 species hosted *H. leporispalustris* separately. Individual bird infestation by more than one species of tick at the same time occurred rarely, with five birds hosting both *I. scapularis* and *H. leporispalustris* and one bird hosting both *I. dentatus* and *I. scapularis*.

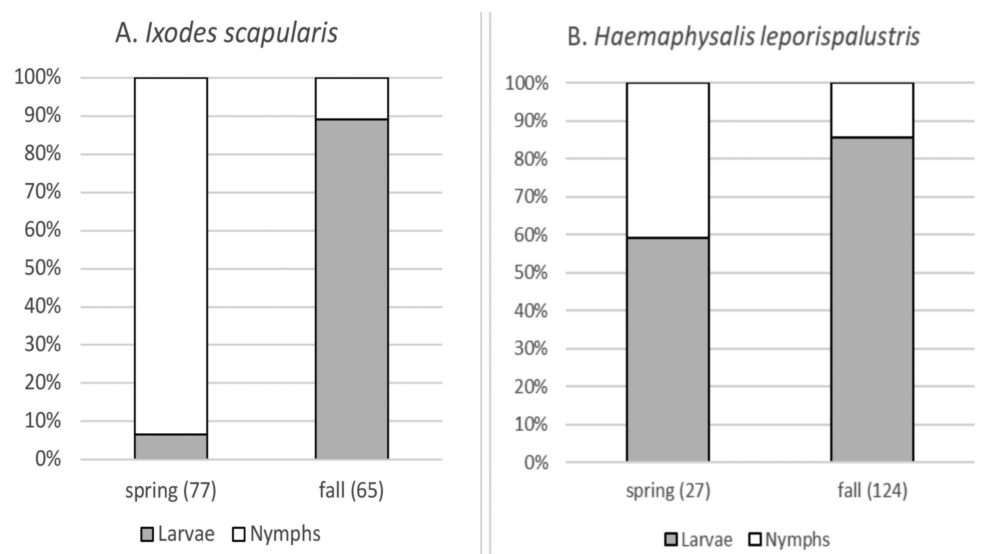

Figure 4. Percent of each life stage in relation to the total number of ticks removed from birds in spring versus fall, 2011–2019. Sample size of birds examined was 2,382 in the spring and 2,740 in the fall.

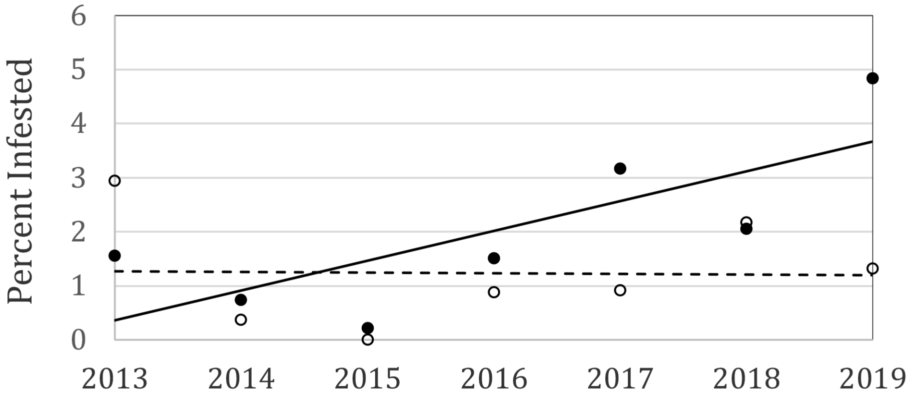

Figure 5. Prevalence of infestation on birds for *I. scapularis* (solid marker & solid trend line) and *H. leporispalustris* (open marker and dashed trend line) using years with fall and spring netting. *I. scapularis* increased, while *H. leporispalustris* was unchanged. Regression *I. scapularis* y = 0.5513x – 1109.4, *H. leporispalustris* y = –0.0121x + 25.704. Year-birds examined: 2013-577, 2014-538, 2015-461, 2016-793, 2017-979, 2018-826, 2019-681.

Origin of Ticks. Birds were categorized as migrants or migrants that breed locally with the exception of six non-migratory species that are year-round residents at the field site (Supplement). The analysis of within season recaptures of 437 birds allowed a conservative estimate of stopover length (Kaiser 1999) and local infestation. The median stopover length was four days (quartiles about median = two and eight days). Of these same-season recaptures, 6.2% (27/437) hosted ticks when recaptured (Table 3), including *I. scapularis* and *H. leporispalustris*, indicating that both these tick species could have been be acquired locally (Table 3).

The criteria used to designate an established tick population is either at least six or more individuals or two of more life stages identified in a single collection period (Dennis et al. 1998), with collection period further defined as a single year (Eisen et al. 2016). A simple tally of ticks removed from birds (Table 4) has limited utility in designating the establishment status of ticks at a field site, because ticks may be imported from other areas on migrants. However, analysis restricted to the new tick infestations on recaptured birds, during a time when avian movements outside of the study area are not expected, is useful in establishing the local origin of ticks (Table 5). Based on this restricted analysis, both *H. leporispalustris* and *I. scapularis* met criteria of established tick populations for three and four years within the eight years of study, respectively.

Discussion

We found 3.6% of birds captured during spring and fall migrations in 2011–2019 harbored ticks of four different species. *H. leporispalustris* and *I. scapularis* were most common. A systematic review of bird-tick publications from North America showed an overall infestation prevalence of 5.1% (Loss et al. 2016). Similar studies from the midwestern Unites States report overall infestation prevalence of 12.5% (Wisconsin, Nicholls and Callister 1996), 1.6% (Illinois, Hamer et al. 2012), 10.6% (Michigan, Hamer

Table 3. Tick species and stage found on 27 of 437 birds recaptured during stopover periods. No ticks were found on 410 recaptured birds. Birds are assumed to have remained in the study area during the stopover periods.

	Larvae		Nymphs		Total	
Tick species	Ticks found	Birds examined	Ticks found	Birds examined	Ticks found	Birds examined
Haemaphysalis leporispalustris	18	6	8	5	26	11
Ixodes dentatus	1	1			1	1
Ixodes scapularis	14	9	8	6	22	15
Totals	33	16	16	8	49	27

Table 4. Ticks found on all birds by year and season.

	Fall		Spring	
Year	Larvae	Nymph	Larvae	Nymph
Haemaphysalis leporispalustris				
2011	41	5		
2013	15	5	7	8
2014	3		1	
2016	6	3		
2017	14	1	1	2
2018	20	3		4
2019	7	1	3	1
Ixodes scapularis				
2011	5			
2013	4	4		8
2014				4
2015	1			
2016	5		2	6
2017	12	2		19
2018	4	2		18
2019	26		3	17

Table 5. Tick reinfestation of birds during migratory stopover. used to evaluate criteria for demonstrating the establishment of tick populations. Using Eisen et al.'s criteria, both tick species would be categorized as established.

	Fall		Spring	
Year	Larvae	Nymphs	Larvae	Nymphs
Haemaphysalis leporispalustris				
2011	5	4		
2013	4		3	1
2016		1		
2018	4	2		1
2019	1			
Ixodes scapularis				
2011	1			
2013	1	2		1
2016	2		1	2
2017	3			2
2018	1			1
2019	5			

et al. 2011), and 13.2% (Illinois, Parker et al. 2017). Tick burdens on birds varied from a median single tick in this study to two ticks/infested bird in Northcentral Wisconsin 1989-1992 (Nicholls and Callister 1996).

Haemaphysalis leporispalustris was the most abundant tick in our study, and accounted for 48% of the ticks. An overview of North American bird-tick data found that *H. leporispalustris* accounted for 30.1% of ticks on birds using data from across 11 studies (Loss et al. 2016). In netting studies like ours, there was wide variation in how common *H. leporispalustris* was on sampled birds. For example, this tick species accounted for 66.2% of bird ticks in Minnesota (Brinkerhoff et al. 2018), 45% of bird ticks in Illinois (Parker et al. 2017), 98% of bird ticks in Wisconsin (Nicholls and Callister 1996), 8.3% in Illinois (Hamer et al. 2012), and 13.4% in Michigan (Hamer et al. 2011). The widespread occurrence of this tick, which can harbor pathogens, may be of limited human health consequence since this species feeds almost exclusively on birds and rabbits and they rarely bite humans (Lane et al. 1991, Nicholls and Callister 1996, Hamer et al. 2011).

Ixodes scapularis comprised 45% of bird ticks in our study. This tick was the most commonly reported bird tick in systematic analysis of bird tick data from North America, accounting for 62% of ticks on birds (Loss et al, 2016). In contrast to our findings, at a study site in Michigan 260 km south of our site, *I. scapularis* accounted for less than 1% of ticks while *I. dentatus* accounted for 86.6% of ticks in 2004–2009 (Hamer et al. 2011). This difference could reflect geographic and habitat differences (Hamer et al. 2010, Parker et al. 2017), as *I. dentatus* was associated with inland areas while *I. scapularis* was found in coastal areas. However, the difference may also be explained in that *I. scapularis* has been undergoing a range expansion in Michigan with documented expansion in the Lower Peninsula, such that tick community compositions have likely changed over the last decade. For example, surveillance at a field site along the east shore of Lake Michigan only 12 km SW of our field site failed to detect *I. scapularis* for several years until a small number of *I. scapularis* were first detected on small mammals in 2008, representing a northward expansion into the region (Hamer et al. 2010). Our study indicates continued expansion of *I. scapularis,* which now accounts of half of the ticks encountered on birds.

Ticks may be carried into the area by migrating birds or of local origin. Using Eisen et al.'s (2016) criteria and specifically restricting our data analysis to ticks that were acquired on site (rather than those that arrive on migrating birds), we showed that *H. leporispalustris* met criteria of an established population in three of eight years at our study site. Similarly, *I. scapularis* met the criteria in four years of our study. Given that tick collection from birds is influenced by the search effort/sample size, it is likely that increased efforts in future years will continue to show establishment of these species at the site.

We found that foraging height was a significant factor related to tick prevalence or on bird hosts, which was expected (Loss et al. 2016, Parker et al. 2017, Brinkerhoff et al. 2018). A second expected relationship of tick burden to body mass was not confirmed by our data. Again, a lack of a relationship may reflect a different bird species profile of our sample in that there was not a dispersion of bird weights of infested birds (Supplement) similar to other studies (Marsot et al. 2012, Brinkerhoff et al. 2018).

Ground-foraging bird species, especially non-migratory ground foragers, were disproportionately likely to have high prevalence and burden of ticks (Mitra et al. 2010, Loss et al. 2016). However, most of the bird species we sampled were migrants with only 6.5% (6/93) of bird species non-migratory. Only one of these, Northern Cardinal, was a ground foraging species (Supplement). Accordingly, given the focus on migrants and a lack of ground foraging resident at northern latitudes, we were unlikely to find that ground foraging resident birds as being disproportionately infested with ticks. In regions where ground foraging resident species are rare, migratory birds maintain of the tick populations and concomitant the enzootic cycles.

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Literature Cited

Brinkerhoff, R. J., L. Dang, H. M. Streby, and M. Gimpel. 2018. Life history characteristics of birds influence patterns of tick parasitism, Infection Ecology & Epidemiology 9:1–8.

Centers for Disease Control and Prevention (CDC). 2018. Tickborne Diseases of the US: A Reference Manual for Health Care Providers, Fifth Edition (2018) [PDF – 52 pages]. https://www.cdc.gov/ticks/tickbornediseases/TickborneDiseases-P.pdf

Chartier, A.T., J. J. Baldy, and J. M. Brenneman. 2011. The Second Michigan Breeding Bird Atlas, 2002–2008. Kalamazoo Nature Center, Kalamazoo, MI.

Clow, K. M., P. A. Leighton, N. H. Ogden, L. R. Lindsay, P. Michel, D. L. Pearl, and C. M. Jardin. 2017. Northward range expansion of *Ixodes scapularis* evident over a short timescale in Ontario, Canada. PLoS ONE 12: 1–15. Available from: https://doi.org/10.1371/journal.pone.0189393

Dennis, D. T., T. S. Nekomoto, J. C. Victor, W. S. Paul, and J. Piesman. 1998. Reported distribution of *Ixodes scapularis* and *Ixodes pacificus* (Acari: Ixodidae) in the United States. Journal of Medical Entomology 35: 629–638.

Eisen, R.J., L. Eisen, and C. B. Beard. 2016. County-Scale Distribution of *Ixodes scapularis* and *Ixodes pacificus* (Acari: Ixodidae) in the Continental United States. Journal Medical Entomology 53: 349–386.

Gill, F., D. Donsker, and P. Rasmussen, P (Eds). 2020. IOC World Bird List (v 10.1). DOI 10.14344/IOC.ML.10.1. http://www.worldbirdnames.org/ (Accessed May 2020)

Hamer, S. A., J. I. Tsao, E. D. Walker, and G. J. Hickling. 2010. Invasion of the Lyme disease vector *Ixodes scapularis*: implications for *Borrelia burgdorferi* endemicity. EcoHealth 7: 47–63.

Hamer, S. A., G. J. Hickling, J. L. Sidge, M. E. Rosen, E. D. Walker, and J. I. Tsao. 2011. Diverse *Borrelia burgdorferi* Strains in a Bird-Tick Cryptic Cycle. Applied and Environmental Microbiology 77: 1999–2007.

Hamer, S. A., T. L. Goldberg, U. D. Kitron, J. D. Brawn, T. K. Anderson, S. R. Loss, E. D. Walker, and G. L. Hamer. 2012. Wild Birds and Urban Ecology of Ticks and Tick-borne Pathogens, Chicago, Illinois, USA, 2005–2010. Emerging Infectious Diseases 18:1589–1595.

Kaiser, A. 1999. Stopover strategies in birds: a review of methods for estimating stopover length, Bird Study 46:(supplement) S299–S308.

Keith, R. S., B. S. Keith, W. C. Scharf, and S. A. Hamer. 2015. *Ixodes brunneus* (Acari: Ixodidae) from two bird hosts: a new Michigan tick. Great Lakes Entomologist. 48: 201–204.

Lane, R. S., J. Piesman, and, and W. Burgdorfer. 1991. Lyme Borreliosis: Relation of Its Causative Agent to Its Vectors and Hosts in North America and Europe. Annual Review of Entomology 1991 36:1, 587–609. Available from https://doi.org/10.1080/00063659909477257

Loss, S. R., B. H. Noden, G. L. Hamer, and S.A. Hamer. 2016. A quantitative synthesis of the role of birds in carrying ticks and tick-borne pathogens in North America. Oecologia 182: 947–959.

Marsot, M., P. Y .Henry, G. Vourc'h, P. Gasqui, E. Ferquel, J. Laignel, M. Grysan, and J-L. Chapuis. 2012. Which forest bird species are the main hosts of the tick, *Ixodes ricinus*, the vector of *Borrelia burgdorferi* sensu lato, during the breeding season? International Journal of Parasitology 42: 781–788.

Minitab 19 Statistical Software. 2020. Computer software. State College, PA: Minitab, Inc. (www.minitab.com).

Mitra, S. S., P. A. Buckley, F. G. Buckley, and H. S. Ginsberg. 2010. Highly variable acquisition rates of *Ixodes scapularis* (Acari: Ixodidae) by birds on an Atlantic Barrier Island. Journal of Medical Entomology. 47:1019–1027.

Nelder, P., C. B. Russell, N. J. Sheehan, B. Sander, S. Moore, Y. Li, S. Johnson, S. N. Patel, and D. Sider. 2016. Human pathogens associated with the blacklegged tick *Ixodes scapularis*: a systematic review. Parasites & Vectors 9:265. Available from https://doi.org/10.1186.s13071-016-1529y

Nicholls, T. H., and S. M. Callister. 1996. Lyme disease spirochetes in ticks collected from birds in midwestern United States. Journal of Medical Entomology 33: 379–384.

Ogden, N.H., L.R. Lindsay, K. Hanincová, I.K. Barker, M. Bigras-Poulin, D. F. Charron, A. Heagy, C. M. Francis, C. J. O'Callaghan, I. Schwartz, and R. A. Thompson. 2008. Role of migratory birds in introduction and range expansion of *Ixodes scapularis* ticks and of *Borrelia burgdorferi* and *Anaplasma phagocytophilum* in Canada. Applied Environmental Microbiology 74(6): 1780–1790.

Parker, C. M, J. R. Miller, and B. F. Allan, 2017. Avian and Habitat Characteristics Influence Tick Infestation Among Birds in Illinois. Journal of Medical Entomology 54: 550–558.

Pyle, P. 1997. Identification guide to North American birds. Part 1: Columbidae to Ploceidae. Slate Creek Press Bolinas, CA.

Scott, J. D., E. L. Pascoe, M. S. Sajid, and J. E. Foley. 2020. Monitoring of Nesting Songbirds Detects Established Population of Blacklegged Ticks and Associated Lyme Disease Endemic Area in Canada. Healthcare 8: 59. Available from https://doi.org/10.3390/healthcare8010059

Sonenshine, D. E. 2018. Range Expansion of Tick Disease Vectors in North America: Implications for Spread of Tick-Borne Disease. International Journal of Environmental Research and Public Health 15(3): 478. Available from https://doi.org/10.3390/ijerph15030478

Walter, K. S., G. Carpi, A. Caccone, and M. A. Diuk-Wasser. **2017**. Genomic insights into the ancient spread of Lyme disease across North America. Nature Ecology & Evolution 1: 1569–1576.

Zar, J. H. 1999. Biostatistical Analysis, 4th ed. Prentice Hall, Upper Saddle River, NJ.

Supplement. Prevealance and abundance of ticks on birds species examined in fall 2011 and spring and fall 2013-2019. Status YR=year-round non migratory resident, MB=migrant or breeding, M=migrant Where typically found, categories: G-U = ground or understory, C=canopy Species names and authors follow International Congress of Ornithology. Gill, F., D. Donsker and P. Rasmussen, P (Eds). 2020. IOC World Bird List (v 10.1).

Species	Status	Birds examined	Birds with a tick	Prevalence (% of birds with at least 1 tick)	Total ticks	Ticks/ infested bird (tick load)	Where typically found	Number `weighed	Mean gm	IOC Scientific Name	Authority
Common Yellowthroat	MB	576	39	6.8	49	1.3	G-U	317	10.1	*Geothlypis trichas*	(Linnaeus, 1766)
Grey Catbird	MB	403	14	3.5	18	1.3	G-U	211	35.9	*Dumetella carolinensis*	(Linnaeus, 1766)
American Redstart	MB	332	4	1.2	4	1	Canopy	164	7.7	*Setophaga ruticilla*	(Linnaeus, 1758)
Swamp Sparrow	MB	252	22	8.7	72	3.3	G-U	119	16.0	*Melospiza georgiana*	(Latham, 1790)
American Goldfinch	MB	249	0	0	0		G-U	156	12.5	*Spinus tristis*	(Linnaeus, 1758)
Wilson's Warbler	M	213	1	0.5	2	2	G-U	92	7.7	*Cardellina pusilla*	(Wilson, A, 1811)
Black-capped Chickadee	YR	202	0	0	0		Canopy	131	11.6	*Poecile atricapillus*	(Linnaeus, 1766)
Song Sparrow	MB	185	23	12.4	34	1.5	G-U	98	20.4	*Melospiza melodia*	(Wilson, A, 1810)
American Yellow Warbler	MB	174	0	0	0		G-U	79	9.6	*Setophaga aestiva*	(Gmelin, JF, 1789)
Red-eyed Vireo	MB	165	0	0	0		Canopy	58	17.7	*Vireo olivaceus*	(Linnaeus, 1766)
White-throated Sparrow	M	137	11	8	13	1.2	G-U	66	25.1	*Zonotrichia albicollis*	(Gmelin, JF, 1789)
Nashville Warbler	MB	127	1	0.8	1	1	G-U	58	8.2	*Leiothlypis ruficapilla*	(Wilson, A, 1811)
Red-winged Blackbird	MB	120	2	1.7	3	1.5	G-U	40	57.0	*Agelaius phoeniceus*	(Linnaeus, 1766)
Ruby-crowned Kinglet	M	113	0	0	0		Canopy	53	6.2	*Regulus calendula*	(Linnaeus, 1766)
Myrtle Warbler	M	113	0	0	0		Canopy	69	11.4	*Setophaga coronata*	(Linnaeus, 1766)
House Wren	MB	111	16	14.4	30	1.9	G-U	79	10.7	*Troglodytes aedon*	Vieillot, 1809
Swainson's Thrush	M	108	6	5.6	7	1.2	G-U	57	29.6	*Catharus ustulatus*	(Nuttall, 1840)
White-crowned Sparrow	M	106	2	1.9	2	1	G-U	24	27.7	*Zonotrichia leucophrys*	(Forster, JR, 1772)
Lincoln's Sparrow	M	103	14	13.6	24	1.7	G-U	43	16.9	*Melospiza lincolnii*	(Audubon, 1834)
Palm Warbler	M	98	1	1	1	1	G-U	34	9.7	*Setophaga palmarum*	(Gmelin, JF, 1789)
Alder Flycatcher	MB	89	0	0			Canopy	34	12.7	*Empidonax alnorum*	Brewster, 1895
Northern Waterthrush	MB	86	4	4.7	4	1	G-U	38	32.1	*Parkesia noveboracensis*	(Gmelin, JF, 1789)
Least Flycatcher	MB	73	0	0	0		Canopy	37	17.3	*Empidonax minimus*	(Baird, WM & Baird, SF, 1843)
Cedar Waxwing	MB	61	0	0	0		G-U	44	12.9	*Bombycilla cedrorum*	Vieillot, 1808
Magnolia Warbler	M	59	0	0	0		Canopy	27	8.3	*Setophaga magnolia*	(Wilson, A, 1811)
Ovenbird	MB	59	2	3.4	2	1	G-U	18	18.7	*Seiurus aurocapilla*	(Linnaeus, 1766)
Chipping Sparrow	MB	46	0	0	0		G-U	35	12.0	*Spizella passerina*	(Bechstein, 1798)
Baltimore Oriole	MB	45	0	0	0		Canopy	23	35.1	*Icterus galbula*	(Linnaeus, 1758)
Brown Thrasher	MB	45	6	13.3	23	3.8	G-U	16	74.6	*Toxostoma rufum*	(Linnaeus, 1758)
Eastern Phoebe	MB	39	0	0	0		Canopy	30	18.9	*Sayornis phoebe*	(Latham, 1790)

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Species	Status	Birds examined	Birds with a tick	Prevalence (% of birds with at least 1 tick)	Total ticks	Ticks/ infested bird (tick load)	Where typically found	Number `weighed	Mean gm	IOC Scientific Name	Authority
Canada Warbler	M	39	0	0	0		Canopy	15	10.0	*Cardellina canadensis*	(Linnaeus, 1766)
Grey-cheeked Thrush	M	34	2	5.9	2	1	G-U	19	51.6	*Catharus minimus*	(Lafresnaye, 1848)
Rose-breasted Grosbeak	MB	33	1	3	1	1	G-U	15	45.6	*Pheucticus ludovicianus*	(Linnaeus, 1766)
Blackpoll Warbler	M	31	0	0			Canopy	21	11.6	*Setophaga striata*	(Forster, JR, 1772)
Mourning Warbler	MB	28	1	3.6	1	1	G-U	8	11.9	*Geothlypis philadelphia*	(Wilson, A, 1810)
Indigo Bunting	MB	28	3	10.7	9	3	G-U	13	14.8	*Passerina cyanea*	(Linnaeus, 1766)
Yellow-bellied Sapsucker	MB	27	0	0	0		Canopy	19	48.4	*Sphyrapicus varius*	(Linnaeus, 1766)
Tennessee Warbler	M	27	0	0	0		Canopy	22	9.1	*Leiothlypis peregrina*	(Wilson, A, 1811)
Common Grackle	MB	23	3	13	3	1	G-U	6	94.3	*Quiscalus quiscula*	(Linnaeus, 1758)
Northern Cardinal	YR	22	1	4.5	1	1	G-U	12	43.1	*Cardinalis cardinalis*	(Linnaeus, 1758)
Field Sparrow	MB	22	1	4.5	1	1	G-U	13	12.8	*Spizella pusilla*	(Wilson, A, 1810)
Warbling Vireo	MB	18	0	0	0		Canopy	8	13.3	*Vireo gilvus*	(Vieillot, 1808)
Pine Warbler	M	18	0	0	0		G-U	16	10.9	*Setophaga pinus*	(Linnaeus, 1766)
Orange-crowned Warbler	M	18	0	0	0		G-U	9	8.2	*Leiothlypis celata*	(Say, 1822)
Downy Woodpecker	YR	18	0	0	0		Canopy	14	26.4	*Dryobates pubescens*	(Linnaeus, 1766)
Hairy Woodpecker	YR	14	0	0	0		Canopy	9	40.6	*Leuconotopicus villosus*	(Linnaeus, 1766)
Blue Jay	YR	14	0	0	0		Canopy	7	83.3	*Cyanocitta cristata*	(Linnaeus, 1758)
Northern Flicker	MB	13	0	0	0		Canopy	7	70.3	*Colaptes auratus*	(Linnaeus, 1758)
Scarlet Tanager	MB	13	0	0	0		G-U	8	28.2	*Piranga olivacea*	(Gmelin, JF, 1789)
Yellow-bellied Flycatcher	MB	12	0	0	0		G-U	10	13.5	*Empidonax flaviventris*	(Baird, WM & Baird, SF, 1843)
Cape May Warbler	M	12	0	0	0		Canopy	3	11.9	*Setophaga tigrina*	(Gmelin, JF, 1789)
American Robin	MB	11	0	0	0		Canopy	4	74.3	*Turdus migratorius*	Linnaeus, 1766
Eastern Bluebird	MB	10	0	0	0		Canopy	7	17.2	*Sialia sialis*	(Linnaeus, 1758)
Chestnut-sided Warbler	MB	10	0	0	0		Canopy	3	9.3	*Setophaga pensylvanica*	(Linnaeus, 1766)
Savannah Sparrow	MB	9	0	0	0					*Passerculus sandwichensis*	(Gmelin, JF, 1789)
Red-breasted Nuthatch	MB	9	0	0	0			5	10.1	*Sitta canadensis*	Linnaeus, 1766
Pileated Woodpecker	YR	9	0	0	0			4	11.9	*Dryocopus pileatus*	(Linnaeus, 1758)
Black-throated Green Warbler	MB	7	0	0	0			4	15.4	*Setophaga virens*	(Gmelin, JF, 1789)
Veery	MB	7	2	28.6	2	1		4	7.9	*Catharus fuscescens*	(Stephens, 1817)
Red-bellied Woodpecker	MB	6	0	0	0			4	28.0	*Melanerpes carolinus*	(Linnaeus, 1758)

Purple Finch	MB	6	0	0	0		4	31.8	*Haemorhous purpureus*	(Gmelin, JF, 1789)
Black-and-White Warbler	MB	6	0	0	0		3	9.6	*Mniotilta varia*	(Linnaeus, 1766)
American Woodcock	MB	6	0	0	0				*Scolopax minor*	Gmelin, JF, 1789
Connecticut Warbler	M	5	0	0	0		3	13.3	*Oporornis agilis*	(Wilson, A, 1812)
Blue-headed Vireo	MB	5	0	0	0				*Vireo solitarius*	(Wilson, A, 1810)
Bay-breasted Warbler	M	5	0	0	0		3	30.1	*Setophaga castanea*	(Wilson, A, 1810)
Eastern Towhee	MB	5	1	20	1	1	3	12.2	*Pipilo erythrophthalmus*	(Linnaeus, 1758)
Golden-winged Warbler	MB	4	0	0	0		3	83.0	*Vermivora chrysoptera*	(Linnaeus, 1766)
Hermit Thrush	MB	4	2	50	2	1	3	137.8	*Catharus guttatus*	(Pallas, 1811)
Yellow-throated Vireo	MB	3	0	0	0		3	18.0	*Vireo flavifrons*	Vieillot, 1808
Philadelphia Vireo	M	3	0	0	0		2	77.5	*Vireo philadelphicus*	(Cassin, 1851)
Eastern Wood Pewee	MB	3	0	0	0		2	15.3	*Contopus virens*	(Linnaeus, 1766)
Eastern Kingbird	MB	3	0	0	0		2	20.4	*Tyrannus tyrannus*	(Linnaeus, 1758)
Blue-winged Warbler	M	3	0	0	0		2	51.8	*Vermivora cyanoptera*	Olson & Reveal, 2009
Brown-headed Cowbird	MB	3	0	0	0		1	42.1	*Molothrus ater*	(Boddaert, 1783)
Wood Thrush	MB	2	0	0	0		1	7.1	*Hylocichla mustelina*	(Gmelin, JF, 1789)
White-breasted Nuthatch	MB	2	0	0	0		1	11.1	*Sitta carolinensis*	Latham, 1790
Sharp-shinned Hawk	MB	2	0	0	0		1	79.3	*Accipiter striatus*	Vieillot, 1808
Grasshopper Sparrow	MB	2	0	0	0		1	38.1	*Ammodramus savannarum*	(Gmelin, JF, 1789)
Red Fox Sparrow	M	2	0	0	0		1	20.0	*Passerella iliaca*	(Merrem, 1786)
Clay-colored Sparrow	MB	2	0	0	0		1	31.4	*Spizella pallida*	(Swainson, 1832)
Brown Creeper	MB	2	0	0	0		1	17.5	*Certhia americana*	Bonaparte, 1838
Blackburnian Warbler	MB	2	0	0	0		1	9.8	*Setophaga fusca*	(Müller, PLS, 1776)
Black-billed Cuckoo	MB	2	0	0	0		1	24.8	*Coccyzus erythropthalmus*	(Wilson, A, 1811)
Vesper Sparrow	MB	1	0	0	0		1	24.2	*Pooecetes gramineus*	(Gmelin, JF, 1789)
Dark-eyed Junco	MB	1	0	0	0		1		*Junco hyemalis*	(Linnaeus, 1758)
Orchard Oriole	M	1	0	0	0		1		*Icterus spurius*	(Linnaeus, 1766)
Mourning Dove	MB	1	0	0	0		1		*Zenaida macroura*	(Linnaeus, 1758)
House Finch	MB	1	0	0	0		1		*Haemorhous mexicanus*	(Müller, PLS, 1776)
Great Crested Flycatcher	MB	1	0	0	0		1		*Myiarchus crinitus*	(Linnaeus, 1758)
Eastern Meadowlark	MB	1	0	0	0		1		*Sturnella magna*	(Linnaeus, 1758)
Black-throated Blue Warbler	MB	1	0	0	0		1		*Setophaga caerulescens*	(Gmelin, JF, 1789)
American Tree Sparrow	M	1	0	0	0		1		*Spizelloides arborea*	(Wilson, A, 1810)