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# Ticks and Tick-borne Diseases

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## Evaluating acarological risk for exposure to *Ixodes scapularis* and *Ixodes scapularis*-borne pathogens in recreational and residential settings in Washington County, Minnesota

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### ABSTRACT

The distribution of *I. scapularis*, the tick vector of the bacteria that cause Lyme disease, has been expanding over the last two decades in the north-central United States in parallel with increasing incidence of human cases of Lyme disease in that region. However, assessments of residential risk for exposure to ticks are lacking from this region. Here, we measured the density of host-seeking *I. scapularis* nymphs in two suburban and two rural public recreational sites located in Washington County, Minnesota as well as in nearby residential properties. We sought to compare tick densities across land use types and to identify environmental factors that might impact nymphal density. We also assessed the prevalence of infection in the collected ticks with Lyme disease spirochetes (*Borrelia burgdorferi* sensu stricto, *B. mayonii*), and other *I. scapularis*-borne pathogens including *B. miyamotoi*, *Babesia microti* and *Anaplasma phagocytophilum*. Similar to studies from the eastern United States, on residential properties, *I. scapularis* nymphal densities were highest in the ecotonal areas between the forest edge and the lawn. Residences with the highest densities of nymphs were more likely to have a higher percentage of forest cover, log piles, and signs of deer on their property. In recreational areas, we found the highest nymphal densities both in the wooded areas next to trails as well as on mowed trails. Among the 303 host-seeking *I. scapularis* nymphs tested for pathogens, *B. burgdorferi* sensu stricto, *A. phagocytophilum* and *B. miyamotoi* were detected in 42 (13.8%), 14 (4.6%), and 2 (0.6%) nymphs, respectively.

### 1. Introduction

Lyme disease is the most commonly reported vector-borne disease in the United States (Adams et al., 2014). In recent decades, counties reporting the presence of *Ixodes scapularis*, the primary vector of Lyme disease spirochetes (*Borrelia burgdorferi* sensu stricto and *B. mayonii*), and those classified as high incidence for Lyme disease have increased in number with the most notable expansion in the upper Midwest and in the Northeast (Eisen et al., 2016; Kugeler et al., 2015). Lyme disease prevention strategies have largely focused on 1) avoiding tick habitat, 2) reducing the risk of tick bites by using repellents on skin or clothing or wearing permethrin-treated clothing, 3) reducing the risk of tick-borne pathogen transmission through prompt detection and removal of ticks, and 4) reducing the abundance of infected ticks through landscape modification and/or use of chemical or biological controls on

tick-questing substrates or hosts (Eisen and Dolan, 2016). Success of these interventions relies, in part, on knowledge of where humans and zoonotic hosts are most likely to encounter ticks.

A limited number of studies from the northeastern United States that assessed where humans are most likely to encounter *I. scapularis* nymphs and adults implicated peridomestic settings for the majority of exposures, but also noted the importance of exposure to ticks in recreational settings (Carroll et al., 1992; Falco and Fish, 1989, 1988; Maupin et al., 1991; Stafford and Magnarelli, 1993). In an effort to better target prevention efforts, several studies aimed to identify where host-seeking nymphs and adults are most abundant in residential settings. Overall, the highest numbers of host-seeking ticks were typically found in the woods and in ecotones comprised of woods and lawn and less commonly in lawns that were distant from woodlands (Carroll et al., 1992; Maupin et al., 1991; Stafford and Magnarelli, 1993).

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Studies assessing where humans frequently encounter ticks or the distribution of host-seeking *I. scapularis* nymphs on residential properties and in comparison to nearby recreational sites are lacking for the north-central United States (Kitron and Kazmierczak 1997).

In this study, we measured the density of host-seeking *I. scapularis* in two suburban and two rural public recreational sites located in Washington County, Minnesota as well as in nearby residential properties. We used a stratified sampling approach to assess the distribution of host-seeking nymphs by land use type (e.g. forest, ecotone, lawn, and ornamental), and we used observational surveys and remotely sensed land cover data to collect additional information about environmental factors that might impact nymphal density. Our goals were to 1) statistically compare the density of host-seeking nymphs between land use types and residential properties and to describe patterns in nymphal density within recreational areas, 2) identify environmental predictors of elevated host-seeking *I. scapularis* nymphal density on residential properties, and 3) report the prevalence in nymphs of Lyme disease spirochetes (*Borrelia burgdorferi* sensu stricto, *B. mayonii*), and other *I. scapularis*-borne pathogens including *B. miyamotoi*, *Babesia microti* and *Anaplasma phagocytophilum*.

## 2. Materials and methods

### 2.1. Study site

This study took place in Washington County, Minnesota, which lies on the eastern edge of the Twin Cities metropolitan area (Fig. 1). The county population was almost 252,000 in 2015. Approximately 56% of the county land area is devoted to agriculture, 20% is residential development, 11% is designated as parks or recreational areas, 10% is covered by fresh water, and less than 5% is commercial or industrial development (Minnesota Metropolitan Council, 2010). Washington County forests are dominated by aspen, birch, maple, basswood, and oak, but there are considerable mixed conifer forests that host a variety of pine species intermingled with deciduous canopy trees (Almendinger, 1989). The eastern and southern edges of the county are bounded by the St. Croix and Mississippi rivers, respectively. We selected Washington County for this study because *I. scapularis* is established in the area (Eisen et al., 2016), much of the county contains suitable habitat for the tick vector (Johnson et al., 2016), and there is a high incidence of Lyme disease cases (36 cases/100,000 population between 2008 and 2013 compared to 22 cases/100,000 for the state over the same time period) reported to the Minnesota Department of Health (MN Department of Health Vectorborne Disease Program, 2016; Robinson et al., 2015).

### 2.2. Recreational site selection

We selected four recreational areas in Washington County for sampling (Fig. 1). We created the sampling frame for the recreational sites by extracting the boundaries of parks, recreational, and preserve areas from the Metropolitan Council Generalized Land Use dataset (Minnesota Metropolitan Council, 2010) and selecting land units that contained more than 20% forested area based on the USGS National Land Cover dataset (Homer et al., 2015) using ArcGIS 10.3 (ESRI, Redlands, CA). Next, we overlaid these recreational areas on a map of census block human population density (U.S. Census Bureau, 2010). We selected two recreational sites that were in or near suburban areas of high human population density and two recreational sites that were surrounded by lower density, more rural areas. Recreational sites surrounded by high population density urban areas were excluded from the site selection because the majority of the residential households in these areas did not meet the selection criteria described below, in particular the yards were too small and there was not sufficient tree cover for tick sampling.

The two suburban recreational sites were Lake Elmo Park Reserve

(LEPR) and Katherine Abbott Park (KAP). LEPR is 2165 acres with 80% of this area set aside for habitat preservation and restoration. The park contains prairie, wetlands, and tracts of mixed northern hardwoods, predominately oaks, elms, and maples (Washington County Parks and Open Spaces, 2010). KAP is a 76-acre community park comprised mostly of mixed oak forests, grassland, and several wetlands (City of Mahtomedi, 2013). The two rural recreational sites were William O'Brien State Park (WOSP) and St. Croix Bluffs Regional Park (SCBRP). WOSP is located on the St. Croix National Scenic Riverway, and is approximately 2200 acres (MN Department of Natural Resources, 2008). The land cover ranges from prairie, savanna, and wetlands to hardwood and floodplain forests. Prescribed burns and periodic flooding of the St. Croix River affect the plant communities in the park. SCBRP is 579 acres, bounded in the east by the St. Croix River, and contains upland prairies, mixed-conifer forests, and forested bluffs that descend to the river shoreline.

The tick sampling location in each recreational site was selected through discussion with the Minnesota Department of Health and the park management staff to identify a high-use trail near a forested area. Prior to field work, we used GoogleEarth to identify sampling transects in three land use types at each recreational site: on trail, next to trail (e.g., the 1 m wide drag is placed on the outside edge of the trail), and > 10 m off trail (in adjacent woods).

### 2.3. Residential site recruitment

After selecting the recreational sites, we overlaid the MetroGIS Regional Parcel Dataset (MetroGIS, 2016) and selected all parcels zoned as 1-unit residential properties within 5 km of the recreational sites. We retained parcels from 1 to 5 acres that contained some forest based on the USGS National Land Cover dataset (Homer et al., 2015) to ensure sufficient forested area for sampling. We extracted mailing addresses for all parcels that met these selection criteria and mailed a letter of invitation to participate in the study.

After a three week recruitment period, we mapped the location of households who responded to the letter and decided to focus our residential study around LEPR and WOSP. From those who responded to the recruitment letter and were located within 5 km of one of these recreational sites, we randomly selected 12 households for a total of 24 residential properties. Each selected household was contacted via telephone to schedule property visits and delineate property boundaries. Prior to field work, we identified four land use types on each property using GoogleEarth and Washington County aerial imagery (Washington County Public Works, 2014): forest (closed-canopy forest with leaf litter), ecotone (up to 5 m on either side of the intersection of forest with lawn), lawn (maintained cultivated grasses > 5 m from forest edge), and ornamental (area < 1 m from annual and perennial ground cover, flower gardens, shrubs, and hedges below chest height).

### 2.4. Tick sampling and observational surveys

We drag sampled all recreational sites twice and all residential sites once between 31 May and 20 June 2016. We chose these dates to coincide with expected peak *I. scapularis* nymphal activity based on previous phenological tick sampling conducted by the Minnesota Department of Health and on a time-lagged peak occurrence of reported Lyme disease cases in the state. We sampled for ticks by dragging a 1-m<sup>2</sup> cloth made of rubber-bonded cotton fabric with a rope attached to a 48" dowel inside the top edge. Weighted "fingers" were sewn to the bottom half of the drag to ensure sampling occurred near the ground. We dragged up to 750 m<sup>2</sup> in each land use type at the recreational sites and on each of the residential properties. If there was not 750 m<sup>2</sup> of area available in a particular land use type on a residential property, the entire land use type was sampled. Every 15 m, samplers stopped and removed all ticks from themselves and the drag to minimize the likelihood of ticks falling off the drag before being collected. Ticks were

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