Tick magnets: The occupational risk of tick-borne disease exposure in forestry workers in New York

Amanda Roome1,2 | Sugam Gouli1 | Ratdanai Yodsuwan1 | Jennifer Victory1 | Casie Collins3 | Paul Jenkins1,2 | Melissa Scribani1 | Nicole Krupa1 | Daniel Freilich1 | Anne Gadomski1

1Research Institute, Bassett Medical Center, Cooperstown, New York, USA
2Northeast Center for Occupational Health and Safety, Bassett Medical Center, Cooperstown, New York, USA
3HealthWorks, Bassett Medical Center, Cooperstown, New York, USA

Correspondence
Amanda Roome, Northeast Center for Occupational Health and Safety (NEC), 1 Atwell Road, Cooperstown, NY 13326, USA. Email: amanda.roome@bassett.org

Funding Information
E Donnall Thomas Resident Research Program; Friends of Bassett

Abstract

Background: Outdoor workers, such as forestry workers, are at an increased risk for contracting tick-borne diseases due to their prolonged time spent in tick habitats. Although well studied in Europe, no studies have been conducted with forestry workers in the Northeastern United States since 1990s.

Methods: Full-time forestry workers and two comparison groups (volunteer firefighter/first responders and indoor/healthcare workers) within New York State Department of Environmental Conservation Regions 3, 4, 5, 6, and 7 were recruited for this cross-sectional seroprevalence study. Blood draws were conducted to test for antibodies to Lyme, anaplasmosis, babesiosis, and ehrlichiosis. Surveys were administered to determine personal risk factors and protective behaviors.

Results: Between November 2020 and May 2021, 256 (105 forestry, 101 firefighter/first responder, and 50 indoor/healthcare) workers participated in this study. Forestry workers had a probability of testing positive nearly twice as high for any tick-borne disease (14%) compared to firefighter/first responders (8%) and to indoor workers (6%); however, this difference was not statistically significant (P = .140). Forestry workers were more likely to find embedded ticks on themselves (f = 33.26, P < .0001 vs both comparison groups) and to have been previously diagnosed with a tick-borne disease (P = .001 vs firefighter/first responders, P = .090 vs indoor/healthcare workers).

Conclusions: This pilot study suggests a higher proportion of tick-borne disease risk among forestry workers compared to firefighters/first responders and indoor/healthcare workers with lesser exposure. A larger study to confirm or refute this pilot data could help optimize mitigation/prevention strategies.

KEYWORDS
anaplasmosis, babesiosis, ehrlichiosis, forestry, Lyme disease, occupational health, occupational risk, prevention and prophylaxis, tick-borne disease
1 | INTRODUCTION

Vector-borne diseases have been emerging and re-emerging because of societal, demographic, and climate changes in the United States.1-3 Tick-borne diseases, including Lyme, anaplasmosis, and babesiosis, among others, constitute a specific group of emerging tick-borne infectious disease threats to humans and thus are of increasing public health concern.4-10 The pathogens that cause these tick-borne diseases are transmitted to humans by the bite of an infected deer tick, except for ehrlichiosis which is transmitted to humans by the bite of an infected Lone Star tick. These tick-borne diseases can lead to morbidity, time lost from work, hospitalization, long-term sequelae, or even death.11-13

Outdoor workers are at an increased risk for contracting tick-borne diseases due to their extended exposure within areas endemic for ticks, including worksites with woods, bushes, high grass, and leaf litter.14 Several studies have shown that the incidence and seroprevalence of Lyme disease is consistently higher in outdoor workers than in indoor workers.15-19 However, most of these studies were conducted outside of the United States, and those taking place within the United States date back to the 1990's. Outdoor workers remain at risk year-round, even during winter months, as mid-winter thaws have been occurring more frequently due to climate change, causing ticks to re-emerge and quest for a host more readily.20,21 Ticks do not die during winter, but rather overwinter underneath leaf litter and snowpack. In addition, climate change has influenced the geographic distribution of ticks, which can now live at latitudes farther north than they previously were able to.22

Forestry workers, who spend much of their time in wooded areas, are very likely to encounter ticks that may be carrying multiple pathogens.23 This exposure poses an occupational risk to forestry workers that is higher than individuals with indoor jobs, or loggers who often operate machinery with shielded cabs that reduce direct exposure to tick habitat.24-29 Recent studies have documented an increased occupational risk of Lyme disease in forestry workers in Europe.30-33 In Poland, forestry workers had a seroprevalence of 28.1% while blood donors had 6%.24 In the Netherlands, forestry workers had a seroprevalence of 28% compared to 5% among office workers.25 In Italy, the seroprevalence of Lyme disease was higher in forestry workers than farmers, rangers, soldiers, hunters, or fishermen.27 In Germany, forestry workers had a seroprevalence of 8% compared to 4% in the control group of healthy blood donors.28 However, the tick species in Europe differ from those in the United States and may exhibit different behaviors,34 therefore, these results, while suggestive, are not generalizable to the United States.

Tick-borne disease incidence is rapidly increasing throughout the United States, predominantly in the Northeast and Upper Midwest. Surprisingly, there have been no data published since 1995 on the occupational risk of tick-borne diseases for forestry workers in the Northeast United States, where the endemic risk of Lyme and other tick-borne diseases is high.35 An older study in New Jersey found the seroprevalence of B. burgdorferi, the causative agent of Lyme disease, in outdoor workers to be 3.8%, compared to 0.8% among indoor counterparts.16 In a 2015 study, numbers of confirmed Lyme cases reported at the county level between 1993 and 2012 were aggregated into 5-year intervals to define high risk counties based on observed vs expected number of cases. Relative risk was determined by the observed number of cases divided by the expected number of cases for a specific period and population and a relative risk greater than or equal to 2.0 defined a high-risk county. Between 1993 and 1997, 69 counties were defined as high risk, and between 2008 and 2012, 260 counties were defined as high risk, all within the Northeast and upper Midwest.20

Lyme, anaplasmosis and ehrlichiosis are usually treated with doxycycline, while babesiosis is typically treated with atovaquone and azithromycin.36 The use of doxycycline for chemoprophylaxis against Lyme and other tick-borne diseases has not yet been studied, although doxycycline is regularly used for malaria chemoprophylaxis.37 Chemoprophylaxis is also used to prevent sexually transmitted infections,38,39 and leptospirosis.40 Baseline seroprevalence data for tick-borne diseases is needed to inform potential public health interventions, such as a doxycycline chemoprophylaxis trial.

The Hudson River Valley and Central New York have had some of the highest incidence rates of Lyme disease in the nation, with cases increasing dramatically in the last several years.41 These regions are located within the New York State Department of Environmental Conservation’s (NYSDEC) Regions 3, 4, 5, 6 and 7 (Figure 1). By targeting this high-risk area in New York, this study aimed to (a) determine the seroprevalence of B. burgdorferi, A. phagocytophilum, B. microti, and E. chaffeensis among forestry workers and two comparison groups in order to identify the occupational risk of exposure, (b) identify the risk of exposure to B. burgdorferi, A. phagocytophilum, and E. chaffeensis in high risk occupations in order to assess the ethics, utility and design of a doxycycline chemoprophylaxis study, and (c) describe individual behavioral risk factors associated with tick encounters.

FIGURE 1 Map of New York State, highlighting in red the Department of Environmental Conservation (DEC) regions eligible for participation in the current study
2 | MATERIALS AND METHODS

2.1 | Study population and study sites

Full-time forestry workers within NYSDEC Regions 3, 4, 5, 6, and 7 who were employed in the industry for at least 1 year (range = 1.47, mean = 16.45, SD = 12.59) were recruited using convenience and chain referral sampling through publicly available email and phone lists, and e-newsletter announcements. To be eligible for the study, forestry workers were required to have a predominantly outdoor component to their work; however, due to fluctuating fieldwork schedules during the COVID-19 lockdown, minimum percentage time spent outdoors was not set. Full-time office-based forestry workers were excluded. Written informed consent was obtained from each participant. The study team met forestry workers between November 2020 and May 2021 at prearranged locations within healthcare facilities, NYSDEC locations, and/or private forestry operations. Two comparison groups of firefighters/first responders and indoor/healthcare workers within the same NYSDEC regions were recruited as well. Firefighters/first responders were recruited during regularly scheduled training sessions through the New York Center for Agricultural Medicine and Health. Indoor/healthcare workers at the Bassett Medical Center in Cooperstown, NY, were recruited using convenience and chain referral sampling through email, phone calls, and word of mouth. Firefighter/first responders may have had variable occupational risks depending on their primary occupation (some were outdoor workers) and were therefore conceptualized as having an intermediate occupational exposure. To better contrast occupational exposure, healthcare workers who work indoors and who have a low occupational exposure were added as a comparison group. However, the sample size for healthcare workers was limited due to financial constraints.

2.2 | Surveys

After consenting to participate in the project, participants completed a questionnaire on iPads, or by paper survey. Questions included basic demographic information, occupational activities, number of ticks removed (embedded or unattached) since May 2020, ticks bites since May 2020, tick-borne disease exposure, use of preventives, and outdoor recreational activities. Forestry workers were given a list of work related tasks and asked to rank the top three tasks they did most often. All participants across all occupations were given a list of recreational activities and asked to rank the top three activities they did most often.

2.3 | Antibody testing

Once the questionnaire was complete, a phlebotomist drew a 10 mL blood sample that was spun down. This sample was sent to Mayo Clinic Laboratories for serological testing using their Tick-Borne Disease Antibody Panel. This test detects antibodies to Lyme disease (ELISA, if positive an immunoblot test was run), Anaplasmosis (IgG IFA), Babesiosis (IgG IFA), and Ehrlichiosis (IgG IFA). Participants could opt to have their test results mailed to them during the consent process.

2.4 | Sample size calculation

An estimate of the expected seroprevalence of B. burgdorferi, A. phagocytophilum, B. microti, or E. chaffeensis was made based using data from Thorin et al.43 Thorin and colleagues reported a 14.1% seroprevalence rate of B. burgdorferi among forestry workers in France in 2003. Given that current serology data were not available in the Northeast, we conservatively estimated the seroprevalence of tick-borne diseases (any of the four pathogens) to be 15%. Data from Smith et al44 showed that the rate of tick-borne disease infection is five times greater in outdoor workers, so we estimated the seroprevalence to be 3% in firefighters/first responders and indoor/healthcare workers. Using a 2-tailed test, having 100 participants in each group (forestry workers and firefighters/first responders) would produce a power of 82%. It was not financially feasible to recruit 100 healthcare workers for this study, so 50 were recruited.

2.5 | Statistical analyses

Data from questionnaires and laboratory results were downloaded on the secure Research Electronic Data Capture (REDCap) server at the Bassett Research Institute. Data were analyzed using SAS 9.4 statistical software (Cary, NC). Demographics were compared across professions using chi-square for sex, Fisher’s Exact test for race, and the t-test for age. Questionnaire data collected in a categorical fashion, such as occupational activities, history of tick-borne disease, perceptions of risk for TBD, and use of preventives, were compared across professional groups using chi-square or Fisher’s Exact test as necessary. Self-reported numbers of ticks removed and embedded ticks were highly right-skewed, and therefore comparisons across professions were carried out using analysis of variance (ANOVA) with data converted to ranks, with pairwise comparisons using Scheffe’s test. One extreme outlier (a forester reporting 1000 ticks removed since May 2020) was removed from the analysis of ticks removed. Self-reported ticks removed and embedded ticks were compared according to use of preventive measures (DEET, Permethrin, any preventive) using the Wilcoxon Rank Sum test. Lab-derived seroprevalence rates (overall and specific diagnoses) were compared across professions using chi-square.

This study was approved by the host institution’s Institutional Review Board.

3 | RESULTS

Two hundred and fifty-six subjects participated in the study: 105 forestry workers, 101 firefighter/first responders, and 50 indoor/healthcare workers. Based on a denominator of 3941 employees in...
the forestry & logging industry in all of New York State, this study (in a smaller region of New York) represents 2.7% of this occupational group. Indoor/healthcare workers were older than forestry workers and firefighter/first responders, with a mean age of 47.3 (±12.9), 46.7 (±16.9), and 42.3 (±11.9), respectively (overall \( P = .043 \), pairwise comparisons not significant, \( f = 3.20 \), Table 1). Over 96% of participants across all occupations identified as White, with the majority of forestry workers and firefighters/first responders identifying as male (77.9% and 84.2%, respectively) (Table 1). The distribution of race and ethnicity in this sample is reflective of the population in this rural area. A significantly greater proportion of females was seen among indoor/healthcare workers (76.0%, \( P < .0001 \) vs forestry and \( P < .0001 \) vs firefighter/first responder). The male/female distribution in this sample is also representative of these occupations. No efforts were made to conduct targeted oversampling of particular demographic groups, as this was a pilot study that used convenience/referral sampling. One eligible forester actively refused participation due to a needle phobia.

Fourteen percent (\( n = 14 \)) of forestry workers tested positive for any tick-borne disease, while 8% (\( n = 8 \)) of firefighter/first responders and 6% (\( n = 3 \)) of indoor/healthcare workers tested positive (Table 2). Seroprevalence analyses included 49/50 indoor/healthcare workers as one test result came back unreadable. Forestry workers had a probability of testing positive for any tick-borne disease nearly two times higher than firefighters/indoor workers. However, this was not statistically significantly different from firefighters/first responders or indoor/healthcare workers (overall \( P = .176 \), forestry vs firefighter/first responder \( P = .140 \), forestry vs indoor/healthcare \( P = .137 \), firefighter/first responder vs indoor/healthcare \( P = .999 \) ) (Table 2). In subsequent analyses, babesia was removed in order to compare rates of tick-borne disease that can be treated with doxycycline (Lyme, anaplasma and ehrlichia). While there was no significant difference in seropositivity in the overall sample (\( P = .136 \), the difference between forestry workers and healthcare/office workers was marginally significant (\( P = .063 \)). Forestry workers had a higher prevalence of anaplasmosis (8.7%, \( n = 9 \)) compared to firefighters/first responders (6.9%, \( n = 7 \)) (overall \( P = .8435 \), Table 2). Indoor/healthcare workers had the highest prevalence of babesiosis seropositivity (4.1%, \( n = 2 \)), possibly explained by two of these participants reporting camping as a frequent recreational activity. Lyme seropositivity was relatively low across the sample, with 2.9% (\( n = 3 \)), 1.0% (\( n = 1 \)) and 2.0% (\( n = 1 \)) of forestry workers, firefighters/first responders, and indoor/healthcare workers, respectively (Table 2).

Survey data showed that forestry workers (71.4%, \( n = 75 \)) were significantly more likely than firefighter/first responders (17.0%,

---

**Table 1** Demographic characteristics by occupation

| Characteristic       | Forestry (FOR) | Firefighter/first responder (FF) | Healthcare worker (HWC) | Overall P value | Pairwise comparison P values |
|----------------------|---------------|---------------------------------|-------------------------|-----------------|-----------------------------|
| Mean Age (SD)        | 42.3 (11.9)   | 46.7 (16.9)                     | 47.3 (12.9)             | .0425 (\( f = 3.20 \)) | .10 FOR vs FF | .13 FOR vs HCW | .96 FF vs HCW |
| Male (%)             | 82 (78.1)     | 85 (84.2)                       | 12 (24.0)               | .0385           | .99 FOR vs FF | .0680 FF vs HCW | .0415       |
| Female (%)           | 23 (21.9)     | 16 (15.8)                       | 38 (76.0)               | .0001           | .267 FOR vs HCW | <.0001 FF vs HCW | <.0001       |
| White                | 102 (98.1)    | 100 (99.0)                      | 46 (92.0)               | .0385           | .99 FOR vs FF | .0680 FF vs HCW | .0415       |
| Black                | -             | -                               | 2 (4.0)                 | .0017           | .999 FOR vs HCW | .0680 FF vs HCW | .0415       |
| Asian                | 1 (1.0)       | 1 (1.0)                         | 1 (2.0)                 | .0017           | .999 FOR vs HCW | .0680 FF vs HCW | .0415       |
| Native American      | 1 (1.0)       | -                               | -                       | .0017           | .999 FOR vs HCW | .0680 FF vs HCW | .0415       |
| Other                | -             | -                               | 1 (2.0)                 | .0017           | .999 FOR vs HCW | .0680 FF vs HCW | .0415       |

**Table 2** Number and percentage of study sample testing positive for antibodies to Lyme, Anaplasma, Ehrlichia, Babesia, or any Tick-Borne Disease (TBD)

| Tick-Borne disease | Forestry (FOR) (\( n = 104 \)) | Firefighter/first responder (FF) (\( n = 101 \)) | Indoor/healthcare (HCW) (\( n = 49 \)) | Overall P value | Pairwise comparison P values |
|--------------------|-------------------------------|-----------------------------------------------|---------------------------------|-----------------|-----------------------------|
| Lyme (%)           | 3 (2.9)                       | 1 (1.0)                                      | 1 (2.0)\(^a\)                  | .8435           | .6216 FOR vs FF | .999 FOR vs HCW | .999 FF vs HCW |
| Anaplasma (%)      | 9 (8.7)                       | 7 (6.9)                                      | 0 (0.0)                         | .1192           | .6605 FOR vs FF | .0578 FOR vs HCW | .0965       |
| Ehrlichia (%)      | 1 (1.0)                       | 1 (1.0)                                      | 0 (0.0)                         | .999            | .999 FOR vs FF | .999 FOR vs HCW | .999 FF vs HCW |
| Babesia (%)        | 3 (2.9)                       | 0 (0.0)                                      | 2 (4.1)\(^b\)                 | .1434           | .2466 FOR vs HCW | .6555 FOR vs HCW | .1067       |
| Lyme, Anaplasma, Ehrlichia (%) | 12\(^c\) (11.5) | 8 (7.9)\(^d\) | 1 (2.0)\(^e\)                  | .136            | .3828 FOR vs HCW | .063 FOR vs HCW | .2723       |
| Any TBD            | 15 (14.4)\(^c\)              | 8 (7.9)\(^d\)                               | 3 (6.1)\(^e\)                 | .176            | .140 FOR vs FF | .137 FOR vs HCW | .999 FF vs HCW |

\(^a\)Female participant with no known tick exposure risk identified.

\(^b\)Both male participants with recreational exposures noted.

\(^c\)Coinfection in one participant; Lyme and Anaplasma.

\(^d\)Coinfection in one participant; Babesia.
n = 17) or indoor/healthcare workers (0%) to report feeling that they had a higher occupational risk of tick-borne disease exposure than other occupations (P < .0001 for overall sample and all occupational group pairwise comparisons) (Table 3). Forestry workers were also significantly more likely to check themselves for ticks after work (P < .0001 for overall sample and all pairwise comparisons) and find ticks on themselves while they were at work (P < .0001 for overall sample and all pairwise comparisons). Seventy-six percent of forestry workers (n = 79), 39.8% (n = 39) of firefighters/first responders, and 12.2% (n = 6) of indoor/healthcare workers reported that they check themselves for ticks after work and 51.4% (n = 54) of forestry workers, 3.1% (n = 3) of firefighters/first responders, and none of the indoor/healthcare workers reported finding ticks on themselves while at work (both P < .0001 for overall sample and all pairwise comparisons) (Table 3).

Because tick encounters can be used as a proxy for tick-borne disease risk, we compared the number of ticks removed across the study groups.46 Fire workers (95.2%, n = 99) were significantly more likely to have removed ticks from themselves (embedded or unattached) than firefighter/first responders (70.0%, n = 70) or indoor/healthcare workers (47.9%, n = 23) (overall P < .0001, forestry vs firefighter/first responder P < .0001, forestry vs indoor/healthcare P < .0001, firefighter/first responder vs indoor/healthcare P = 0.009) (Table 3). Forestry workers reported a significantly greater number of ticks removed since May 2020 ranging from 0 to 500 (mean: 23.22 ± 58.07, overall F = 89.90; P < .0001) than firefighter/first responders (mean: 3.25 ± 10.80, range: 0-100, pairwise t = 10.43; P < .0001) or indoor/healthcare workers (mean: 0.45 ± 1.32, range: 0-8, pairwise t = 11.98; P < .0001) (Table 3). Of the reported ticks removed, participants were asked how many of those were embedded. Forestry workers reported a significantly greater number of embedded ticks removed (mean: 1.85 ± 2.66, range: 0-20, overall F = 33.62, P < .0001) than indoor/healthcare workers (mean: 0.29 ± 1.10, range: 0-7, pairwise t = 7.26; P < .0001) and firefighters/first responders (mean: 0.52 ± 1.04, range: 0-6, pairwise t = 6.43; P < .0001) (Table 3). Through self-report, forestry workers (18.5%, n = 19) were significantly more likely to have been diagnosed with any tick-borne disease than firefighter/first responders (4.0%, n = 4, P = .001) and significantly more likely to report having been diagnosed with Lyme disease than firefighter/first responders (P = .017) (Table 3).

Forestry workers who reported walking in the woods (examining timber quality and value, harvest planning) as their most frequent task averaged more tick bites than other tasks (P = .0147) (Table 4). Across all occupations, gardening/lawn maintenance was the most frequently reported outdoor recreational activity, followed by hiking, hunting, and walking a dog/pet. There was no association between the primary recreational activity reported and reported tick bites (across the full sample or stratified by occupation) (Table 4).

Seroprevalence did not differ significantly across the occupations by self-reported use of preventives of any kind (P = .429). There was no association between reported permethrin use during work and reported tick bites (P = .75) (Table 5). Forestry workers were significantly more likely to use permethrin and DEET products while at work than firefighters/first responders (P < .001, P < .001, respectively) or
indoor/healthcare workers (P < .0001, P < .0001, respectively). They were also significantly more likely to use permethrin during recreational activities (foresters vs firefighters/first responders (P < .0001; foresters vs indoor/healthcare workers (P < .0001), but not DEET (P = .144 overall; P = .055 foresters vs firefighters/first responders, P = .253 foresters vs indoor/healthcare workers). Those who checked themselves for ticks “often” across all occupations reported a higher number of tick bites (P < .0001); however, among forestry workers, there was no significant difference in the number of tick bites whether they checked themselves for ticks or not. Across all occupations, those with positive serology results reported significantly higher numbers of tick bites (P = .006).

### TABLE 4  Recreational activity data by occupation with seropositivity for any of the four tick-borne diseases

| Occupation and recreational activities | n | Tick bites, Mean (SD) | P-value | Seropositive, n (%) | P-value |
|----------------------------------------|---|-----------------------|---------|---------------------|---------|
| All occupations                        |   |                       |         |                     |         |
| Most frequent recreational activity: Gardening/lawn maintenance | 79 | 0.84 (2.45) | .0926 | 6 (7.79) | .3967 |
| Most frequent recreational activity: Other than gardening/lawn maintenance | 177 | 1.11 (1.76) |       | 20 (11.30) | |
| Forestry workers                       |   |                       |         |                     |         |
| Most frequent recreational activity: Gardening/lawn maintenance | 24 | 1.91 (4.21) | .2141 | 2 (8.70) | .5124 |
| Most frequent recreational activity: Other than gardening/lawn maintenance | 81 | 1.90 (2.04) |       | 13 (16.1) | |
| Firefighters/first responders          |   |                       |         |                     |         |
| Most frequent recreational activity: Gardening/lawn maintenance | 37 | 0.47 (0.97) | .8500 | 2 (5.41) | .7069 |
| Most frequent recreational activity: Other than gardening/lawn maintenance | 64 | 0.55 (1.08) |       | 6 (9.38) | |
| Indoor/healthcare workers              |   |                       |         |                     |         |
| Most frequent recreational activity: Gardening/lawn maintenance | 18 | 0.28 (0.75) | .5034 | 2 (11.76) | .2731 |
| Most frequent recreational activity: Other than gardening/lawn maintenance | 32 | 0.29 (1.27) |       | 1 (3.13) | |
| Forestry workers (occupational)        |   |                       |         |                     |         |
| Most frequent occupational activity: Walking in woods | 23 | 1.61 (4.18) | .0147 | 3 (13.04) | .9999 |
| Most frequent occupational activity: Other than walking in woods | 82 | 1.99 (2.01) |       | 12 (14.81) | |

### TABLE 5  Prevention strategies and mean number of reported tick bites by occupation

| Prevention strategy | n | Forestry workers Mean (SD) | P-value | Firefighter/first responder Mean (SD) | P-value | Healthcare worker Mean (SD) | P-value |
|---------------------|---|---------------------------|---------|--------------------------------------|---------|-----------------------------|---------|
| Did not use permethrin at work | 39 | 1.78 (1.88) | .7457 | 56 | 0.54 (1.06) | .5294 | 50 | 0.29 (1.10) |
| Used permethrin at work | 66 | 1.97 (3.00) |       | 5 | 0.20 (0.45) |       | 0 |
| Did not use DEET at work | 48 | 1.82 (2.17) | .9999 | 70 | 0.45 (1.04) | .1937 | 48 | 0.28 (1.12) |
| Used DEET at work | 57 | 1.96 (3.00) |       | 31 | 0.68 (1.05) |       | 2 | 0.50 (0.71) |
| Did not use permethrin recreationally | 61 | 2.03 (2.11) | .0844 | 93 | 0.48 (0.97) | .2575 | 47 | 0.26 (1.12) |
| Used permethrin recreationally | 44 | 1.71 (3.26) |       | 8 | 1.00 (1.69) |       | 3 | 0.67 (0.58) |
| Did not use DEET recreationally | 48 | 1.77 (1.83) | .7083 | 33 | 0.47 (1.02) | .6608 | 18 | 0.33 (0.77) |
| Used DEET recreationally | 57 | 2.00 (3.16) |       | 68 | 0.54 (1.06) |       | 32 | 0.26 (1.26) |

### DISCUSSION

Due to the increasing prevalence and incidence of tick-borne diseases in New York State, we expected tick-borne disease to be an occupational hazard for forestry workers. However, the use of preventives and increased awareness of tick borne disease may have mitigated
the degree of seroprevalence we measured. The sample population for the current study included both NYSDEC and private forestry workers, but was heavily weighted toward DEC workers. Within the last few years, the NYSDEC has been issuing permethrin treated clothing to forestry workers who spend 80 to 100+ hours in the field per season (personal correspondence with NYSDEC employees). Though it is currently an optional, unofficial program, it is possible that this increase in permethrin use may have decreased the DEC forestry workers’ exposure to tick bites. Although the forestry workers in our study had an elevated seroprevalence relative to the comparison groups, the magnitude of seropositivity was higher in studies conducted in Europe (eg, twice as high at 28.1% in Poland).24,25,28 Additionally, the current study performed ELISA testing followed by running an immunoblot to confirm positivity, while the study in Poland did not confirm results using an immunoblot test. Likewise, a study in the Netherlands between 1989 and 1990 with Dutch forestry workers and male office workers showed a seroprevalence rate of 28% in forestry workers, and 5% in office workers by ELISA testing.25 Another study in the Netherlands with forestry workers and male office workers using IFA and Western Blot testing showed a seroprevalence rate of 19.7% in forestry workers and 6.3% in office workers, similar to the results in this study.26 Although the seroprevalence of tick-borne diseases in forestry workers is proportionally higher than in firefighters/first responders or indoor/healthcare workers, a larger, higher powered study is needed to determine the feasibility of a doxycycline chemoprophylaxis study.

Unsurprisingly, forestry workers noted that they felt their occupation had a higher risk of tick-borne disease exposure than other occupations. Outdoor occupations have consistently been cited as having a higher risk of tick-borne disease exposure.14 Many forestry workers cited what they refer to as “100 tick days” during peak tick season, where they count the number of ticks they pull off of themselves at work, and once they hit 100, they are done working for the day. Most cited going home by early to mid-morning. Given this information, removing 1000 ticks in a 1-year period does not seem unreasonable. It is likely that increased awareness prompts these workers to check themselves for ticks more often and find and remove ticks from themselves (especially at work) as well as use permethrin. As our data show, forestry workers are significantly more likely to use permethrin at work and during leisure activity than firefighters/first responders or indoor/healthcare workers.

Forestry workers were also significantly more likely to report a prior diagnosis of tick-borne disease, especially Lyme disease. This reporting may in part be due to an increased awareness of the occupational risk they face, potentially making them more likely to seek medical attention after a tick bite or when they begin to experience symptoms. Forestry workers who did not use preventives reported a higher proportion of reported tick bites, though this proportion was not significant compared to the other study groups. Consistent use of preventives most likely reduces the occupational risk of tick-borne disease exposure; however, clear guidelines on dosing, that is, how to apply or how often to apply preventives are not available for forestry workers.

Limitations of this study include a long data collection period (November 2020-May 2021). Ideally, the collection period would have ended in April as spring ticks start to reemerge; however, data collection ended before antibody responses to potential tick bites during spring 2021 would have been detectable. Study participants in the forestry industry were predominantly NYSDEC employees, introducing a potential bias given the NYSDEC’s recent inclusion of an opt-in permethrin treated clothing program for forestry workers. Additionally, self-selection bias may have led study participants who were most worried about or most aware of tick-borne disease exposure to enroll; however, the impact of this type of self-selection bias on seroprevalence results is unknown. Financial constraints limited the sample size of the study, thus this sample may not be representative of each occupation. Lastly, the type of tick reported in the survey could not be verified and therefore may have included ticks that do not transmit the tick-borne disease pathogens we studied.

Tick-borne diseases are a public health threat to those living in the Northeastern United States, especially those with outdoor occupations like forestry workers. This pilot study found doubling of seroprevalence rates of tick-borne diseases among forestry workers in comparison to firefighters/first responders and healthcare workers, although the difference was not statistically significant. These preliminary data should be leveraged to complete a properly powered study to confirm or refute seroprevalence rates. If confirmed, clinical trials to study novel prevention strategies, potentially including chemoprophylaxis, may be indicated.

ACKNOWLEDGMENTS
The authors would like to thank the Clinical Research Staff at the Bassett Research Institute: Peggy Cross, Melissa Huckabone, and Catherine Gilmore for their time and assistance in completing blood draws. The authors would also like to thank Kristopher Brown at the Watershed Agricultural Council and Jerry Carlson at the New York State Department of Environmental Conservation for their assistance with this project.

FUNDING
This research was supported by the E. Donnall Thomas Resident Research Program at the Bassett Research Institute and the Friends of Bassett, Bassett Medical Center, Cooperstown, New York.

AUTHOR CONTRIBUTIONS
Conceptualization: Amanda Roome, Sugam Gouli, Ratdanai Yodsuan, Paul Jenkins, Daniel Freilich, Anne Gadomski.
Data Curation: Amanda Roome, Jennifer Victory, Casie Collins.
Formal Analysis: Paul Jenkins, Melissa Scribani, Nicole Krupa.
Funding Acquisition: Amanda Roome, Sugam Gouli, Ratdanai Yodsuan.
Investigation: Amanda Roome.
Methodology: Amanda Roome, Jennifer Victory, Paul Jenkins, Melissa Scribani, Daniel Freilich, Anne Gadomski.
Project Administration: Amanda Roome, Anne Gadomski.
Writing – Original Draft Preparation: Amanda Roome.
Amanda Roome, Daniel Freilich, Anne Gadomski approved the final version of the manuscript.

Agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved: Amanda Roome, Anne Gadomski.

TRANSPARENCY STATEMENT
This manuscript is an honest, accurate, and transparent account of the study being reported; no important aspects of the study have been omitted; and any discrepancies from the study as planned (and, if relevant, registered) have been explained.

CONFLICT OF INTERESTS
The authors declare no conflicts of interest.

DATA AVAILABILITY STATEMENT
The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

ETHICS STATEMENT
All work was performed through the Bassett Research Institute under Institutional Review Board protocol # 1641407-7. Written informed consent was obtained from each participant.

ORCID
Amanda Roome https://orcid.org/0000-0002-0975-8788

REFERENCES
1. Kilpatrick AM, Randolph SE. Drivers, dynamics, and control of emerging vector-borne zoonotic diseases. Lancet. 2012;380(9846):4955.
2. Altizer S, Ostfeld RS, Johnson PT, Kutz S, Harvell CD. Climate change and infectious diseases: from evidence to a predictive framework. Science. 2013;341(6145):514-519.
3. Gubler DJ. Resurgent vector-borne diseases as a global health problem. Emerg Infect Dis. 1998;4(3):442-450.
4. DiMarcoantonio T. Incidence Rates of Certain Tick-Borne Diseases on the Rise in US. Infectious Disease News. RSS Healio. 2012. http://www.healthy.com/infectious-disease/news/print/infectious-disease-news/%7B4027118b-ba0a-48b6-be09-c657bde015387d/ incidence-rates-of-certain-tick-borne-diseases-on-the-rise-in-us
5. Ismail N, Bloch KC, McBride JW. Human Ehrlichiosis and Anaplasmosis. Clin Lab Med. 2010;30(1):261-292.
6. Jones KE, Patel NG, Levy MA, et al. Global trends in emerging infectious diseases. Nature. 2008;451(7181):990-994.
7. Parola P, Raoult D. Ticks and tick-borne bacterial diseases in humans: an emerging infectious threat. CID. 2001;32:897-928.
8. Parola P, Paddock CD, Raoult D. Tick-borne rickettsioses around the world: emerging diseases challenging old concepts. Clin Microbiol Rev. 2005;18:719-756.
9. Raoult D, Parola P. Rocky Mountain spotted fever in the USA: a benign disease or a common diagnostic error? Lancet. 2008;8:587-589.
10. Steere AC. Lyme disease. N Engl J Med. 2001;345(2):115-125.
11. Institute of Medicine. Chapter 8: Prevention. Critical needs and gaps in understanding prevention, amelioration, and resolution of Lyme and other tick-borne diseases: The short-term and long-term outcomes: Workshop report, Washington DC. pp. 155-176. 2011.
12. Kostic T, Momcilovic S, Pericic ZD, et al. Manifestations of Lyme carditis. Int J Cardiol. 2017;232:24-32.
13. Shadick NA, Phillips CB, Logigian EL, et al. The long-term clinical outcomes of Lyme disease. A population-based retrospective cohort study. Ann Intern Med. 1994;121:560-567.
14. Placentino JD, Schwartz BS. Occupational risk of Lyme disease: an epidemiologic review. Occup Environ Med. 2002;59(2):73-84.
15. Schwartz BS, Goldstein M. Lyme disease in outdoor workers: risk factors, preventive measure, and tick removal methods. Am J Epidemiol. 1990;131:877-885.
16. Bowen G, Schulze T, Hayne C, et al. A focus of Lyme disease in Monmouth County, New Jersey. Am J Epidemiol. 1984;120:387-394.
17. Ley C, Olshen E, Reingold A. Case-control study of risk factors for incident Lyme disease in California. Am J Epidemiol. 1995;142:S39-547.
18. Schwartz BS, Goldstein M, Childs J. Longitudinal study of Borrelia burgdorferi infection in NJ outdoor workers. Am J Epidemiol. 1994;139:504-512.
19. Oteo J, Artola M, Casas J, et al. Epidemiology and prevalence of seropositivity against Borrelia burgdorferi antigen in La Rioja, Spain rev. Epidemiol Sante Publique. 1999:40:85-92.
20. Kugeler KJ, Farley GM, Forrester JD, Mead PS. Geographic distribution and expansion of human Lyme disease, United States. Emerg Infect Dis. 2015;21(8):1455-1457.
21. Duffy DC, Campbell SR. Ambient air temperature as a predictor of activity of adult Ixodes scapularis (Acari: Ixodidae). J Med Entomol. 1994;31(1):179-180.
22. Brunner JL, Killilea M, Ostfeld RS. Overwintering survival of Nymphal Ixodes scapularis (Acari: Ixodidae) under natural conditions. J Med Entomol. 2014;49(3):981-987.
23. Rojko T, Ruzic-Sablic E, Stele F, Lotric-Furlan S. Prevalence and incidence of Lyme borreliosis among Slovene forestry workers during the period of tick activity. Middle Eur J Med. 2005;11(5-6):219-225.
24. Chmielewka-Badora J. Seroepidemiologic study on LB in the Lublin region. Ann Agric Environ Med. 1998;5:183-186.
25. Kuiper H, de Jongh B, Nauta A, et al. One year follow up study to assess the prevalence and incidence of Lyme borreliosis among Dutch forestry workers. Eur J Clin Microbiol Infect Dis. 1993;12:413-418.
26. Kuiper H, Dam A, van Charante M, et al. Lyme borreliosis among Dutch forestry workers. J Infect. 1991;23:279-286.
27. Nuti M, Amaddeo D, Crovatto M, et al. Infections in an alpine environment. Am J Trop Med Hyg. 1993;48:20-25.
28. Rath P, Ibershoff B, Mohnhaupt A, et al. Seroprevalence of Lyme borreliosis in forestry workers from Brandenburg, Germany. Eur J Clin Microbiol Infect Dis. 1996;15:372-377.
29. Van Charante M, Groen J, Osterhaus A. Risk of infections transmitted by arthropods and rodents in forestry workers. Eur J Epidemiol. 1994; 10:349-351.
30. Jahfari S, Herremans T, Platonov AE, et al. High seroprevalence of Borrelia miyamotoi antibodies in forestry workers and individuals suspected of human granulocytic anaplasmosis in The Netherlands. New Microbes New Infect. 2014;4(2):144-149.
31. Kurnatowski P, Warpechowska M, Kurnatowski AJ. Knowledge on Lyme disease among foresters. Int J Vector Borne Dis. 2011;4(5):144-149.
32. Lewandowska A, Kruba Z, Filip R. Epidemiology of Lyme disease among workers of forest inspectorates in Poland. J Vector Borne Dis. 2011;48:20-25.
33. Panczuk A, Tokarska-Rodak M, Koziol-Montewka M, Plewik D. The incidence of Borrelia burgdorferi, Anaplasma phagocytophilum and Babesia microti coinfections among foresters and farmers in eastern Poland. J Vector Borne Dis. 2016;53(4):348-354.
34. Arsnoe IM, Hickling GJ, Ginsberg HS, McElreath R, Tsao JI. Different populations of blacklegged tick nymphs exhibit differences in questing behavior that have implications for human Lyme disease risk. *PLoS One*. 2015;10(5):e0127450.

35. Schwartz AM, Kugeler KJ, Nelson CA, Marx GE, Hinckley AF. Use of commercial claims data for evaluating trends in Lyme disease diagnoses, United States, 2010–2018. *Emerg Infect Dis*. 2021;27(2):499-507. doi:10.3201/eid2702.202728

36. Center for Disease Control and Prevention. Tickborne Diseases of the United States: A Reference Manual for Healthcare Providers. Fifth Edition. 2018. https://www.cdc.gov/ticks/tickborne_diseases/TickborneDiseases-P.pdf

37. Tan KR, Magill AJ, Parise ME, Arquin PM. Doxycycline for malaria chemoprophylaxis and treatment: report from the CDC expert meeting on malaria chemoprophylaxis. *Am J Trop Med Hyg*. 2011;84(4):517-531.

38. Scott HM, Klausner JD. Sexually transmitted infections and pre-exposure prophylaxis: challenges and opportunities among men who have sex with men in the US. *AIDS Res Ther*. 2016;13(5):5. doi: 10.1186/s12981-016-0089-8

39. Grant JS, Stafylis C, Celum C, Granman T, et al. Doxycycline prophylaxis for bacterial sexually transmitted infections. *Clin Infect Dis*. 2020;70(6):1247-1253.

40. Takafuji ET, Kirkpatrick JW, Miller RN, et al. An efficacy trial of doxycycline chemoprophylaxis against leptospirosis. *N Engl J Med*. 1984;10(8):497-500.

41. Prusinski MA, Kokos JE, Hukey KT, Kogut SJ, Lee J, Backenson PB. Prevalence of *Borrelia burgdorferi* (Spirochaetales:Spirochaetaceae), *Anaplasma phagocytophilum* (Rickettsiales:Anaplasmataceae), and *Babesia microti* (Piroplasma: Babesiidae) in *Ixodes scapularis* (Acari: Ixodidae) collected from recreational lands in the Hudson Valley region, New York state. *J Med Entomol*. 2014;51:226-236.

42. Mayo Clinic. Tick-borne disease antibodies panel, Serum. 2021. https://www.mayocliniclabs.com/test-catalog/Performance/83265

43. Thorin C, Rigaud E, Capek I, et al. Seroprevalence of Lyme Borreliosis and tick-borne encephalitis in workers at risk, in eastern France. *Med Mal Infect*. 2008;38(10):533-542.

44. Smith PF, Benach JL, White DJ, Stroup DF, et al. Occupational risk of Lyme disease in endemic areas of New York state. *Ann N Y Acad Sci*. 1988;539:289-301.

45. Cavo M, Wagner J, Newman D. New York state Forest industry: An Economic Overview. 2014. https://woodproducts.ny.gov/economic-value-new-yorks-forests-resource

46. Hook SA, Nawrocki CC, Meek JI, et al. Human-tick encounters as a measure of tick-borne disease risk in Lyme disease endemic areas. *Zoonoses Public Health*. 2021;68(5):384-392.

**How to cite this article**: Roome A, Goulie S, Yodsuwan R, et al. Tick magnets: The occupational risk of tick-borne disease exposure in forestry workers in New York. *Health Sci Rep*. 2022;5:e509. doi:10.1002/hsr2.509