Received: 7 September 2021 | Revised: 5 January 2022 | Accepted: 17 January 2022
DOI: 10.1002/hsr2.509

RESEARCH ARTICLE

Health Science Reports Open Access
WILEY

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

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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

Institution at which the work was performed: Bassett Research Institute.

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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.

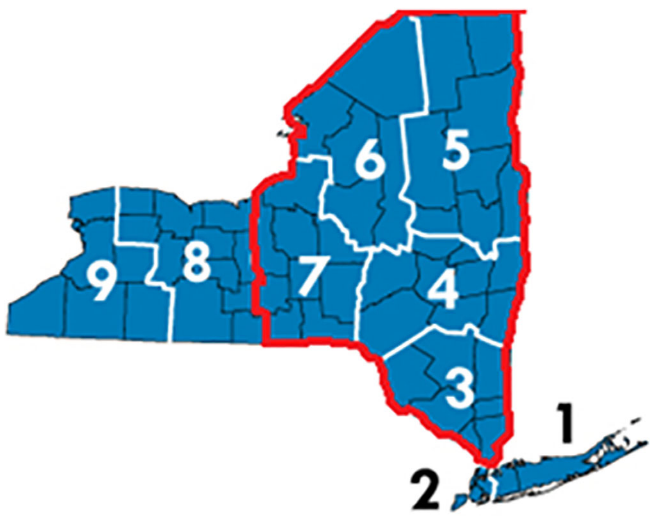

FIGURE 1 Map of New York State, highlighting in red the Department of Environmental Conservation (DEC) regions eligible for participation in the current study

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).[42] 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 al[44] 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 seroprevalance 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,[45] 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: FOR vs FF	FOR vs HCW	FF vs HCW
Mean Age (SD)	42.3 (11.9)	46.7 (16.9)	47.3 (12.9)	.0425 ($f = 3.20$)	.10	.13	.96
Male (%)	82 (78.1)	85 (84.2)	12 (24.0)	-	-	-	-
Female (%)	23 (21.9)	16 (15.8)	38 (76.0)	<.0001	.267	<.0001	<.0001
White	102 (98.1)	100 (99.0)	46 (92.0)	.0385	.99	.0680	.0415
Black	-	-	2 (4.0)	-	-	-	-
Asian	1 (1.0)	1 (1.0)	1 (2.0)				
Native American	1 (1.0)	-	-	-	-	-	-
Other	-	-	1 (2.0)	-	-	-	-

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: FOR vs FF	FOR vs HCW	FF vs HCW
Lyme (%)	3 (2.9)	1 (1.0)	1 (2.0)[a]	.8435	.6216	.999	.999
Anaplasma (%)	9 (8.7)	7 (6.9)	0 (0.0)	.1192	.6605	.0578	.0965
Ehrlichia (%)	1 (1.0)	1 (1.0)	0 (0.0)	.999	.999	.999	.999
Babesia (%)	3 (2.9)	0 (0.0)	2 (4.1)[b]	.1434	.2466	.6555	.1067
Lyme, Anaplasma, Ehrlichia (%)	12[c] (11.5)	8 (7.9)	1 (2.0)	.136	.3828	.063	.2723
Any TBD	15 (14.4)[c]	8 (7.9)[d]	3 (6.1)	.176	.140	.137	.999

[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; Anaplasma and Ehrlichia.

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] Forestry 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 $P < 0.0001$, 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 ($P = .129$). 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

TABLE 3 Survey data by occupation

Variable	Forestry (FOR) (%)	Firefighter/first responder (FF) (%)	Healthcare worker (HWC) (%)	Overall P value	Pairwise comparison P values: FOR vs FF	FOR vs HCW	FF vs HCW
Perceived higher risk of exposure at work (yes, often)	75 (71.4)	17 (17.0)	0 (0.0)	<.0001	<.0001	<.0001	<.0001
Ever removed ticks from oneself (yes)	99 (95.2)	70 (70.0)	23 (47.9)	<.0001	<.0001	<.0001	.009
Mean number of ticks removed (Nov 2020-May 2021)	3.25 ± 10.80	23.22 ± 58.07	0.45 ± 1.32	<.0001; $F = 89.90$	<.0001; $t = 10.43$	<.0001; $t = 11.98$	.002; $t = 3.52$
Range	0-100	0-500	0-8				
Mean number of ticks embedded (Nov 2020-May 2021)	1.85 ± 2.66	0.52 ± 1.04	0.29 ± 1.10	<.0001; $F = 33.62$	<.0001; $t = 6.43$	<.0001; $t = 7.26$	.126; $t = 2.04$
Range	0-20	0-6	0-7				
check oneself for ticks after work (yes, often)	79 (76.0)	39 (39.8)	6 (12.2)	<.0001	<.0001	<.0001	<.0001
Find ticks on oneself at work (yes, often)	54 (51.4)	3 (3.1)	0 (0.0)	<.0001	<.0001	<.0001	<.0001
Previously diagnosed with any tick-borne disease (self-report)	19 (18.5)	4 (4.0)	4 (8.0)	.003	.001	.090	.441
Previously diagnosed with Lyme disease (self-report)	14 (13.3)	4 (4.0)	3 (6.0)	.041	.017	.172	.685

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	n	Firefighter/first responder Mean (SD)	*P*-value	n	Healthcare worker Mean (SD)	*P*-value
Did not use permethrin at work	39	1.78 (1.88)	.7457	96	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)	.1377
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)	.0084
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)	.1324
Used DEET recreationally	57	2.00 (3.16)		68	0.54 (1.06)		32	0.26 (1.26)	

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 ($P = .006$).

4 | 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.

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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 was obtained from each participant.

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How to cite this article: Roome A, Gouli 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