

BEST PRACTICES FOR URBAN PLANNING IN THE CONTEXT OF CLIMATE CHANGE AND EMERGING TICK-BORNE DISEASES ("UPTick-PHASE II")

© Manisha A. Kulkarni

THE UPTick PROJECT

A project undertaken by the INSIGHT Research Lab, School of Epidemiology & Public Health, University of Ottawa, with funding from the Public Health Agency of Canada's Infectious Diseases & Climate Change Fund.

2023-2026 Narrative Report

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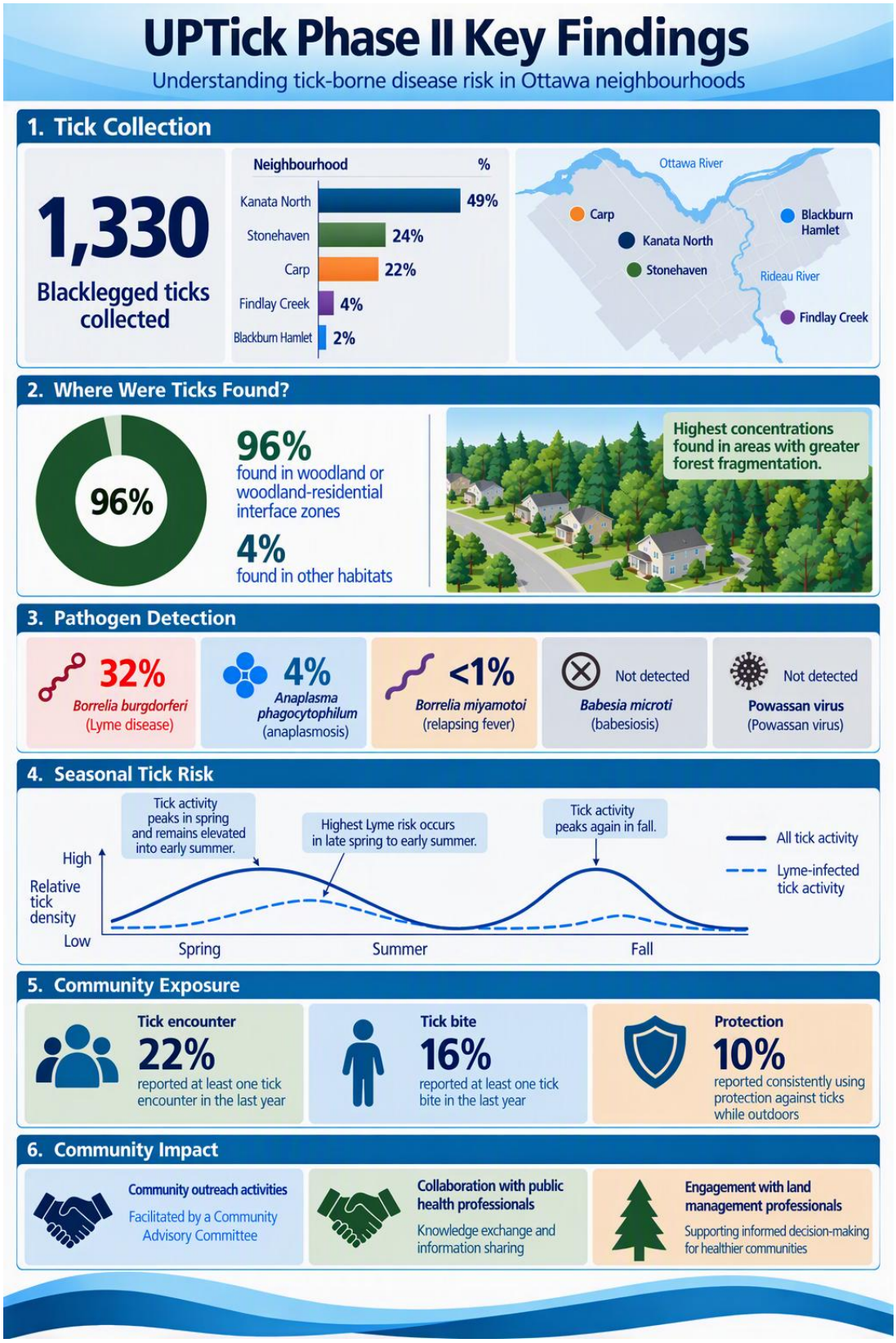
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PREFACE

This report presents the results of the three-year research project (2023–2026), "Best Practices for Urban Planning in the Context of Climate Change and Emerging Tick-Borne Diseases (UPTick-Phase II)", led by the University of Ottawa's INSIGHT Lab with funding from the Public Health Agency of Canada's Infectious Diseases and Climate Change Fund. The project monitored changes in tick populations and tick-borne disease risk in Ottawa neighbourhoods to enhance knowledge and awareness amongst public health stakeholders and local residents. Preliminary project results are outlined in this report and will be reported in greater detail in forthcoming open-access scientific publications.

SUMMARY OF RESULTS



BACKGROUND

Basis for the project:

Lyme disease is caused by the spirochete bacterium *Borrelia burgdorferi*, which is maintained in nature in a transmission cycle between *Ixodes* ticks (e.g. blacklegged ticks, *I. scapularis*, in eastern North America) and small mammals (e.g. white-footed mice).[1] Humans can be infected when bitten by a tick carrying *B. burgdorferi*.[2] Eastern Ontario is considered a hotspot of Lyme disease emergence with some of the highest rates of Lyme disease incidence in the country,[3] and evidence of recent northward tick expansion into new areas placing more Canadians at risk.[4,5]

In Ottawa, cases of human Lyme disease have increased markedly since 2010: from 7 cases in 2010 [0.8 per 100,000 population] to 72 cases in 2015 [7.5 per 100,000 population], and more than doubling to 191 in 2017 [18.8 per 100,000 population].[6] Due to this, the city of Ottawa was declared an at-risk area for Lyme disease for the first time in 2017. Recent case counts have increased further despite inter-annual variations, with 416 and 440 reported cases in 2024 and 2025, respectively.[6] Along with *B. burgdorferi*, blacklegged ticks are potential vectors for several other tick-borne pathogens, such as *B. miyamotoi*, *Anaplasma phagocytophilum*, *Babesia microti* and Powassan virus.[7,8] The expansion of blacklegged tick populations in the Ottawa region therefore presents additional emerging health threats.

Issue being addressed:

The city of Ottawa, with a population of over 1 million inhabitants, is experiencing ongoing growth and expansion. Population growth and land use change are occurring at an accelerated rate alongside warming temperatures due to climate change, compounding the health risks due to vector-borne diseases.[9] While warming temperatures are facilitating the expansion and growth of tick populations in areas with suitable habitat[1,5], urban expansion, including the encroachment of subdivisions into zones with enzootic transmission of tick-borne pathogens, is increasing the number of people at risk of infection with Lyme disease and other tick-borne infections. This is reflected in the increasing number of Lyme disease cases that were acquired locally in Ottawa in recent years, with ~30-40% of all Lyme disease cases in Ottawa residents in 2017-2019[10] and 2022[11] being acquired locally. More than half of the reported local exposures occurred within 5km of the patient's home reflecting residential or recreational exposures.[10] Given these trends, and with more than 80% of the Canadian population living in urban centres, there is an urgent need to identify the factors driving risk of tick-borne disease transmission in Canadian cities, such as Ottawa.

The 2016 Pan Canadian Framework on Clean Growth and Climate Change expressed the need "to advance the science and understanding of health risks and best practices to adapt".[12] Current climate change adaptation strategies include initiatives that promote the expansion of green and blue infrastructure (e.g. urban tree cover projects and urban bodies of water, respectively) in urban centres, as a means to mitigate the effects of heat on human health[13,14] and contribute to carbon sequestration.[15] However, alongside numerous benefits to citizens' quality of life and public health, green and blue infrastructure has the potential to create unexpected, undesirable,

side-effects for health.[13] For example, greening activities to address urban heat island effects can generate habitat for arthropod vectors and wildlife hosts, creating the potential for enzootic pathogen transmission and spillover to human populations.[13,16]

The role of urban greenspace on vector-borne disease risk is complex and may depend on the type of greenspace in question, which can range from urban vegetation and parks to conserved natural areas surrounding cities (e.g. greenbelt zones).[17] For Lyme and other tick-borne diseases, endemic areas may be found in parks, conservation areas and recreational trails, and often border suburban or peri-urban neighbourhoods.[18,19] In these areas, people entering wooded areas for recreational and occupational activities, or those with yards adjacent to wooded areas, are at increased risk of tick encounter.[20] Residence in an endemic area is considered the principal risk factor for Lyme disease in North America, largely based on findings from studies in the US,[21,22] with some recent studies by our team at the University of Ottawa highlighting similar findings in southern and eastern Ontario.[10,23] In an Ottawa-wide web survey conducted by our team in 2020, 8% and 11% of respondents from suburban zones in east and west Ottawa, respectively, reported that they had ever experienced a tick bite[24]; however, residents in these regions had only moderate knowledge of ticks and Lyme disease, demonstrating the need for additional studies on risk factors to inform mitigation strategies in these settings.

A better understanding of the influence of forest fragmentation and the interface between built and natural environments on the proliferation of ticks and wildlife hosts in suburban residential areas is needed. However, in Canada, tick surveillance data are noticeably lacking in residential zones, with efforts to date largely focused on public-access woodlands such as provincial parks and conservation areas.[25–27] The UPTick Phase I project aimed to fill critical knowledge gaps on the impacts of urban development and greening on tick populations and tick-borne disease transmission in peri-urban neighbourhood settings, with important findings to date (see below)[28]. UPTick Phase II was initiated recognizing the need for further research to generate robust and generalizable findings to inform public health action and adaptation strategies for Canadian cities.

Results of previous studies – UPTick Phase I:

The UPTick Phase I project revealed differences in blacklegged tick density and infection rates between and within four western Ottawa neighbourhoods. In general, the suburban neighbourhoods of Kanata North and Stonehaven, which both border the Greenbelt wooded zone, had higher tick densities than the more rural neighbourhoods of Carp and Stittsville. For example, through monthly sampling between May to October 2020 and bi-weekly sampling between May and October 2021 (covering an area of 1800 m^2 per neighbourhood per sampling period) that collected a total of 537 blacklegged ticks, the project team collected 290 (54%) and 138 (27%) blacklegged ticks in Kanata North and Stonehaven compared to 66 (12%) in Carp and 43 (8%) in Stittsville. Interestingly, 62% of all collected ticks were found in the woodland zones of neighbourhoods, i.e. trail networks in forested areas adjacent to the neighbourhood, and 37% of ticks were found in the interface zones, i.e. trails directly bordering residential properties adjacent to woodlands, with only ~1% of ticks detected along residential pathways. Tick densities and infection rates in woodland and interface zones were similar within a given neighbourhood.

In total, 28% of collected ticks were infected with *B. burgdorferi* and <1% were infected with *A. phagocytophilum*. This result strongly indicated the presence of exposure risk to ticks and tick-borne pathogens for people accessing recreational trails and wooded areas within or adjacent to their neighbourhoods, including residents whose properties interface with wooded greenspaces.

Similar to the UPTick Phase I findings regarding tick populations, results from small mammal trapping revealed interesting patterns in the abundance of *Peromyscus* spp. mice and their prevalence of infection with *B. burgdorferi*. Of the 812 mice that were sampled in 2020 and 2021, 564 (69%) were *P. leucopus* (white-footed mice) while 217 (38%) were *P. maniculatus* (deer mice); however, approximately 70% of mice in residential and interface zones were *P. leucopus* while this species represented 79% of sampled mice in woodland zones. Importantly, *P. leucopus* comprised more than 90% of the mice infected with *B. burgdorferi*, with infection rates ranging from 5-35% across neighbourhoods. Infection rates in mice differed significantly between zone types, ranging from 0-5% in residential zones to 10-36% and 7-46% in interface and woodland zones, respectively. These results support the finding that enzootic transmission of *B. burgdorferi* is largely concentrated in the interface and woodland zones. Combined with the results of tick surveillance, the UPTick Phase I project highlighted the exposure risk posed to residents who access recreational pathways and trail networks surrounding their neighbourhoods and in nearby wooded greenspaces.

OVERVIEW OF PROJECT

PROJECT PURPOSE:

The main goal of the "UPTick Project – Phase II" was to enhance knowledge and strengthen capacity by characterizing and monitoring changes in tick populations and tick-borne disease risk in the context of climate change and urban planning using a One Health approach, building on the findings of "UPTick – Phase I".

The project aimed to (1) expand our knowledge on landscape factors that drive environmental risk for tick-borne diseases in peri-urban settings. Further to this, we aimed to (2) address knowledge gaps regarding the factors driving human exposure to ticks and tick-borne diseases in peri-urban environments and the preventive behaviours that populations have adopted to reduce their risk of infection, generating results that are applicable to the Canadian context.

To achieve these aims, we characterized environmental conditions in selected sites and monitored changes in tick populations, wildlife reservoir host populations, and pathogen infection rates (including *Borrelia burgdorferi*, *B. miyamotoi*, *Anaplasma phagocytophilum*, *Babesia microti*, and Powassan virus). This enabled us to refine risk models that were developed as part of the UPTick Phase I project to improve their precision and generalizability. We also conducted a cross-sectional survey of Ottawa residents, and engaged with community members via the UPTick Community Advisory Committee, to understand factors influencing human exposure to ticks, and the barriers and enablers to implementation and adoption of preventive measures at the individual and community levels.

STUDY LOCATION:

The project was carried out in the city of Ottawa, given recent increases in Lyme disease incidence in this region and our previous research that characterized Lyme disease environmental risk[1]. The project was implemented in three of the neighbourhoods that were included in the UPTick Phase I project (Kanata North, Stonehaven, Carp), which are situated in western Ottawa, as well as in two new study neighbourhoods in the eastern and southern regions of Ottawa (Orleans and Findlay Creek, respectively) (Figure 1). These neighbourhoods were selected to reflect different levels of forest fragmentation and landscape change, taking into consideration areas with blacklegged tick populations. The latter was informed by an ecological niche model of tick population establishment for the city of Ottawa[29] and active tick surveillance conducted by our team from 2017 to 2019.[25]

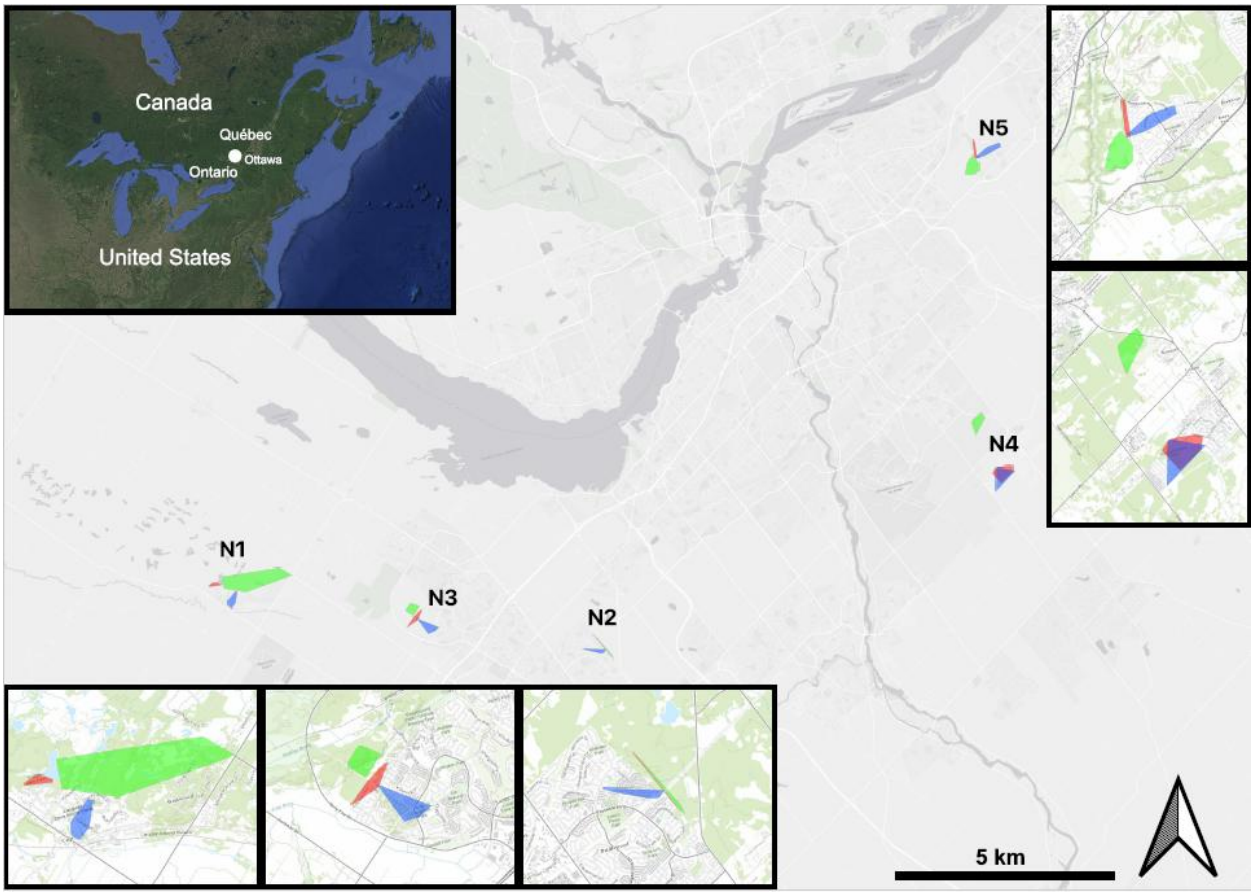


Figure 1. Map showing the locations of five UPTick Project – Phase II study neighbourhoods: N1 (Carp), N2 (Stonehaven), N3 (Kanata North), N4 (Findlay Creek), N5 (Blackburn Hamlet). Coloured lines reflect tick sampling zones within each neighbourhood: green=woodland, red=interface, blue=residential.

[1] Lyme disease environmental risk is a measure of acarological hazard, often expressed as the density of infected ticks (DIT) or density of infected nymphs (DIN) in a given area.

PROJECT OBJECTIVES:

The project aims were accomplished through four specific objectives and their associated activities between April 1, 2023 – March 31, 2026:

Objective 1 - One Health surveillance: To monitor ticks, wildlife hosts, pathogen infection rates and environmental factors over three years in five Ottawa neighbourhoods through field sampling and laboratory analyses.

Objective 2 – Environmental risk analysis: To assess changes in tick-borne disease environmental risk associated with urban development, and develop risk models to identify drivers of tick-borne disease environmental risk, through statistical and spatial modelling.

Objective 3 – Population survey: To assess human exposure to ticks and the use of preventive measures in different communities.

Objective 4 - Community and stakeholder engagement: To engage communities and stakeholders for improved understanding of tick-borne disease risks and preventive strategies by the general public, public health professionals, and urban planning authorities, through tailored knowledge mobilization approaches.

METHODS

Objective 1.0: One Health Surveillance

In each of the five study neighbourhoods, sampling sites were situated along a gradient of urban development, including the following three "zones": (1) natural wooded zones (e.g. Greenbelt or conservation areas), (2) established residential/woodland interface, (3) within-neighbourhood parks, pathways and trails, for a total of fifteen surveillance sites across the city.

Tick sampling and identification

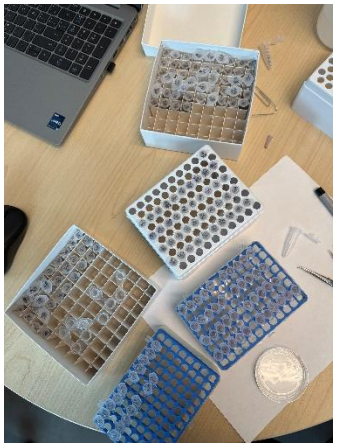
Tick sampling was conducted on biweekly basis between May and October of 2023, 2024 and 2025. A standard field dragging protocol was employed in which a one-meter squared white flannel cloth sheet was dragged along surface vegetation and the forest floor for a total of 1000 meters squared for each zone, totalling 3000 meters squared for each neighbourhood. The drag sheets and surveyors' clothes were checked for ticks every 25 meters. Latitude and longitude coordinates were recorded for each sample location using a hand-held Garmin GPS unit. All larval, nymphal, and adult ticks found in the field were collected in specimen tubes and brought to the INSIGHT Lab for species identification under a microscope using standard taxonomic keys.



Small mammal sampling

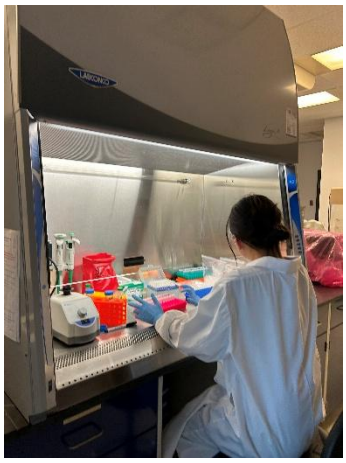


Small mammal trapping was conducted for two rounds of two consecutive nights in the interface and residential zones of each neighbourhood between June and August of 2023 and 2024, during the peak period of mouse activity. In each year, a sampling grid with 150 small folding aluminum Sherman traps was utilized with two sampling rounds of two consecutive nights per site (600 trap-nights/site) with adjustment of trapping effort. In the first sampling round, teams deployed 150 traps for 2 nights in each sampling zone, while in the second round, the number of trap-nights was reduced in sites where the target number of animals was reached, in compliance with our approved animal care protocols. Target species included the white-footed mouse (*Peromyscus leucopus*) and deer mouse (*Peromyscus maniculatus*). We followed approved animal care protocols to collect ear punch tissue biopsies from small mammals for subsequent pathogen testing.



Pathogen testing

Biopsy punches from mice, and adult and nymphal ticks were tested for *Borrelia burgdorferi* and other tick-borne pathogens using quantitative polymerase chain reaction (qPCR) assays. In this procedure, total genomic DNA was extracted from the majority of specimens using the QIAamp mini kit (QIAGEN Inc., Mississauga, Ontario, Canada). To facilitate viral pathogen screening, a proportion of specimens (10-15%) from each site was randomly selected for RNA extraction using the RNeasy mini kit (QIAGEN Inc., Mississauga, Ontario, Canada). A duplex qPCR screening assay was used targeting the 23S rRNA gene for *Borrelia* species and msp2 gene for *Anaplasma phagocytophilum*. In samples positive for *Borrelia* spp., we confirmed the presence of *B. burgdorferi* or *B. miyamotoi* by targeting the ospA and flaB genes, respectively. Detection of *Babesia microti* and *Babesia odocoilei* was performed using a qPCR assay targeting the 18S rRNA gene. For viral pathogen screening, RNA nucleic acids were tested for Powassan virus using a qPCR assay targeting the NS5 gene (POW NS5 screen). Amplification was carried out using the BioRad CFX96 Real-Time PCR Detection System (BioRad, Mississauga, Ontario, Canada), and analysis was performed using the CFX Maestro software (BioRad, Mississauga, Ontario, Canada). All assays were performed under optimized cycling conditions with positive and negative controls to ensure assay specificity and sensitivity.



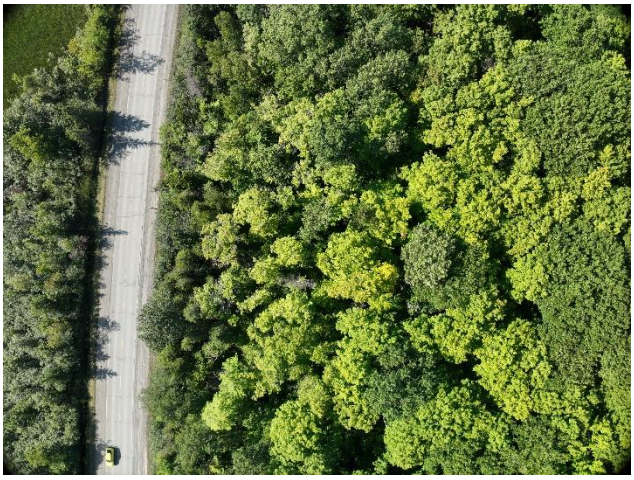


Environmental characterization

We characterized each neighbourhood with regards to key environmental factors that are known to affect ticks and tick-borne disease transmission through their impacts on arthropod vector and wildlife host populations: temperature, vegetation index (a proxy for moisture), land cover (forest/tree cover and type, forest edge and patch size, agricultural land area), and built infrastructure (roads, buildings, housing density). To this end, we used Geographic Information Systems (GIS) software alongside publicly available satellite imagery data and spatial data on urban structures to derive high-resolution maps of each neighbourhood. We also collected annual field data on environmental factors that are known to influence tick populations (e.g. litter depth, soil moisture, canopy cover) from all tick sampling locations following protocols that were established during UPTick Phase I.

Objective 2.0 – Environmental risk analysis

We analyzed data on environmental factors, tick and wildlife host populations, and infection rates in ticks and small mammals, using statistical software. We conducted annual descriptive analysis of surveillance data to calculate blacklegged tick density and infection rates, including density of infected nymphs (DIN) as an indicator of Lyme disease environmental risk, within neighbourhoods (i.e. woodland/interface/residential zones) and between neighbourhoods. In the final project year, we conducted a multi-year analysis to identify ecological factors associated with elevated environmental risk indices within and across neighbourhoods. Specifically, we used mixed effects regression models to identify factors associated with overall tick density and DIN, accounting for interannual variations, repeated measures over time and spatial autocorrelation. We examined factors relevant to *I. scapularis* tick and *B. burgdorferi* ecology at different spatial scales from broader-scale, abiotic factors that often do not vary greatly over larger distances (>1km), such as climate averages and soil characteristics, to regional-scale landscape factors such as land cover and forest fragmentation indices, or local-scale microhabitat factors, such as land surface temperature, vegetation indices and local land cover metrics, that may vary widely at finer spatial resolutions (<1km or <100m). To generate variables for statistical analyses, we



accessed publicly available satellite remote sensing datasets from 2023-2025 at the finest spatial and temporal resolution available along with soil data from 2010 and population density data from 2020.

Objective 3.0 – Population survey

To assess factors associated with human exposure to ticks and the use of preventive measures in different communities, and to understand enablers and barriers to adoption of preventive behaviours and control strategies, using a mixed methods approach, we implemented a structured, web-based cross-sectional survey of Ottawa residents in year 2 of the project. The survey was distributed in November 2024. Stratified sampling was used to ensure geographic representativeness and coverage of the UPTick study neighbourhoods, including urban core, suburban west/south/east, and rural areas. The survey utilized validated questionnaires to collect data from a sample of 200 people/stratum (target sample size 1000) on demographic factors, knowledge of tick-borne diseases, history of tick encounter/bite, use of preventive measures, and perceptions surrounding tick-borne disease prevention strategies (i.e. acceptability and feasibility). Respondents aged 18 or older were sampled using a survey company web panel (e.g. Leger360) to ensure representativeness and maximize the response rate. We obtained informed consent from participants for collection of data; ethical approval for this study was received from the University of Ottawa Health Sciences and Science Research Ethics Board (file number H-11-22-8400). Survey data on reported tick exposures and the use and acceptability of preventive measures among residents of study neighbourhoods were analyzed using descriptive statistics. Regression models were used to identify population factors associated with increased risk of tick encounter and/or use of preventive measures. Data on the acceptability and feasibility of Lyme disease preventive measures was analyzed separately and will be presented in a forthcoming scientific publication (Ost et al, in preparation).

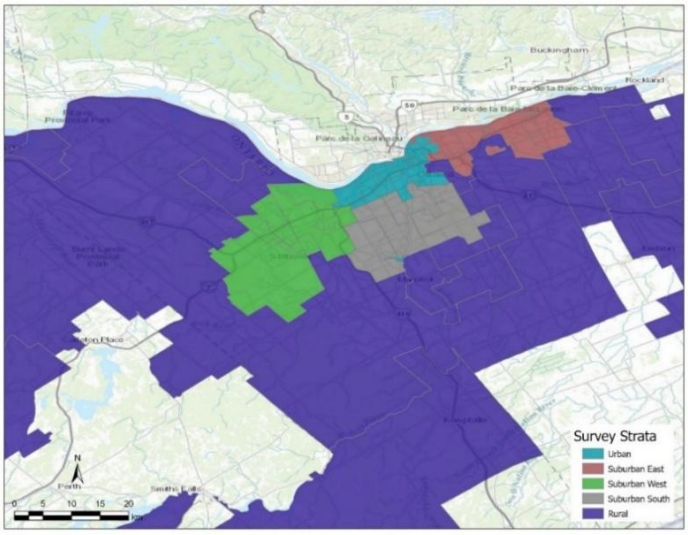


Figure 2. Classification of Ottawa neighbourhoods by postal code for survey distribution across five sampling strata: Green-Suburban West, Blue-Urban, Grey-Suburban South, Red-Suburban East and Purple-Rural.

Objective 4.0 - Community and stakeholder engagement

In the first year of the project, we established the UPTick Community Advisory Committee, comprised of 10 members representing community associations from each study neighbourhood. The UPTick Community Advisory Committee was engaged and consulted in year 1 of the project and annually thereafter to share project findings and inform the implementation of project outreach activities via traditional/social media, the project website (www.uptickproject.ca) and special community events during the spring-to-fall tick season to increase public engagement and enhance knowledge on tick-borne disease risks in peri-urban settings.

PROJECT OUTCOMES

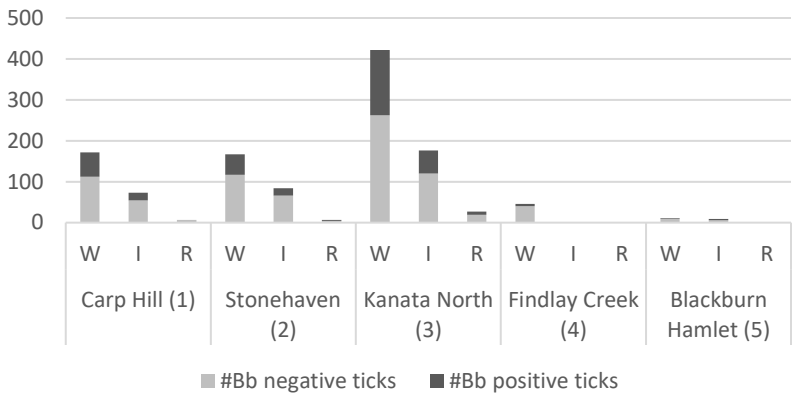
Objective 1.0 – One Health surveillance

***Tick sampling and testing*.** Across the three field surveillance seasons in 2023, 2024 and 2025, we collected 1330 *I. scapularis* ticks of all life stages. The highest number of ticks was collected from Kanata North (n=652; 49%) followed by Stonehaven (n=322; 24%), Carp (n=287; 22%), Findlay Creek (n=48; 4%) and Blackburn Hamlet (n=21; 2%). Of the collected ticks across the five neighbourhoods, 922 (69%) were found in woodland zones, 360 (27%) in interface zones and 48 (4%) in residential zones (Figures 3a and 3b). Over the 13 bi-weekly sampling periods, this reflects a mean density of adult ticks per 1000m^2 ranging from 3.4 in woodland zones to 1.3 in interface zones and 0.2 in residential zones. Mean nymphal density was lower in the woodland, interface, and residential zones of 0.9, 0.5 and 0.0 nymphs per 1000m2, respectively. However, there was notable seasonal variation in tick density (see p.14).

Over the three sampling years, 1202 adult and nymphal ticks were tested for tick-borne pathogens via qPCR. Overall, 384 (31.9%) ticks were infected with *B. burgdorferi* across three years. Across all five neighbourhoods, *B. burgdorferi* infection rates from woodland zones ranged from 9-38% while in interface zones, the infection rate ranged from 0-33% and in residential zones between 0-43% (note: infection rates in residential zones should be interpreted with caution due to low sample sizes).

For other tick-borne pathogens, a total of 8 ticks (0.6%) were positive for *B. miyamotoi*, while 48 (4.0%) were positive for *A. phagocytophilum;* all specimens infected with these pathogens were collected from the three western neighbourhoods. We also detected 80 (8.2%) positive ticks for the white-tailed deer pathogen, *Babesia odocoilei,* from the three western neighbourhoods and Blackburn Hamlet. No ticks tested positive for *Babesia microti* or Powassan virus.

Figure 3a. Total number of *Borrelia burgdorferi* negative and positive ticks by neighbourhood and zone, May-Oct 2023, 2024 and 2025, collected via bi-weekly drag sampling of 1000m^2 per zone per sampling period (13 sampling weeks per year).



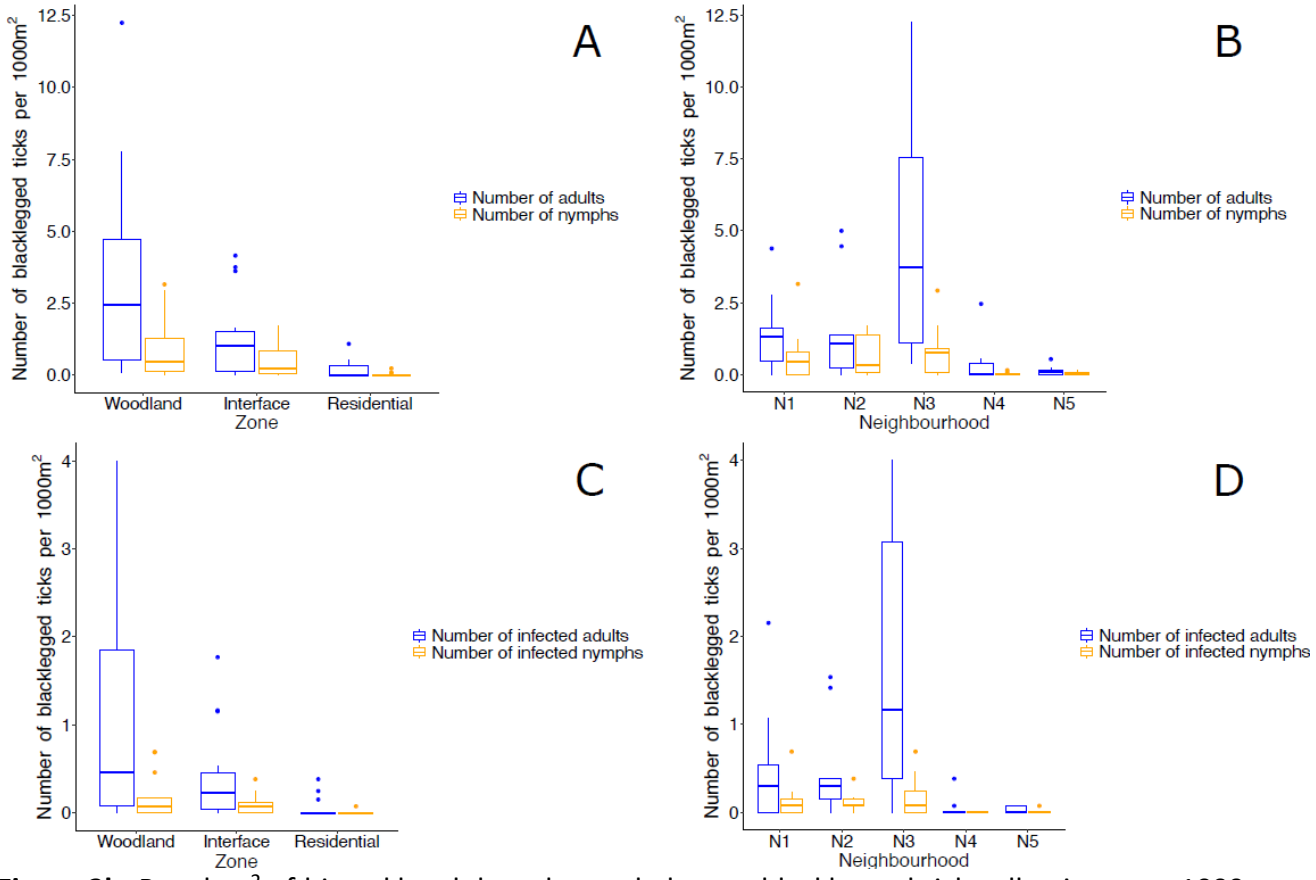


Figure 3b. Boxplots[2] of biweekly adult and nymphal stage blacklegged tick collection over 1000 m^2, by sampling zone and neighbourhood of total blacklegged ticks (A and B), and blacklegged ticks infected by *Borrelia burgdorferi* (C and D), in study neighbourhoods from 2023-2025. N1-Carp, N2-Stonehaven, N3-Kanata North, N4-Findlay Creek, N5- Blackburn Hamlet.

[2] Boxplots show the median value (middle line) and interquartile range (IQR; bottom and top of rectangle denote 25% and 75% percentile values, respectively). Whiskers denote maximum and minimum values; dots show outliers.

The number of collected ticks varied by sampling week, with two observed peaks of adult tick activity in the spring and fall. Two smaller peaks of nymphal tick activity were observed during the same period. Overall, we detected the highest density of *B. burgdorferi*-infected adult and nymphal ticks in the early summer peaking in June, with fewer infected ticks collected during the mid-summer and fall periods (Figure 4).

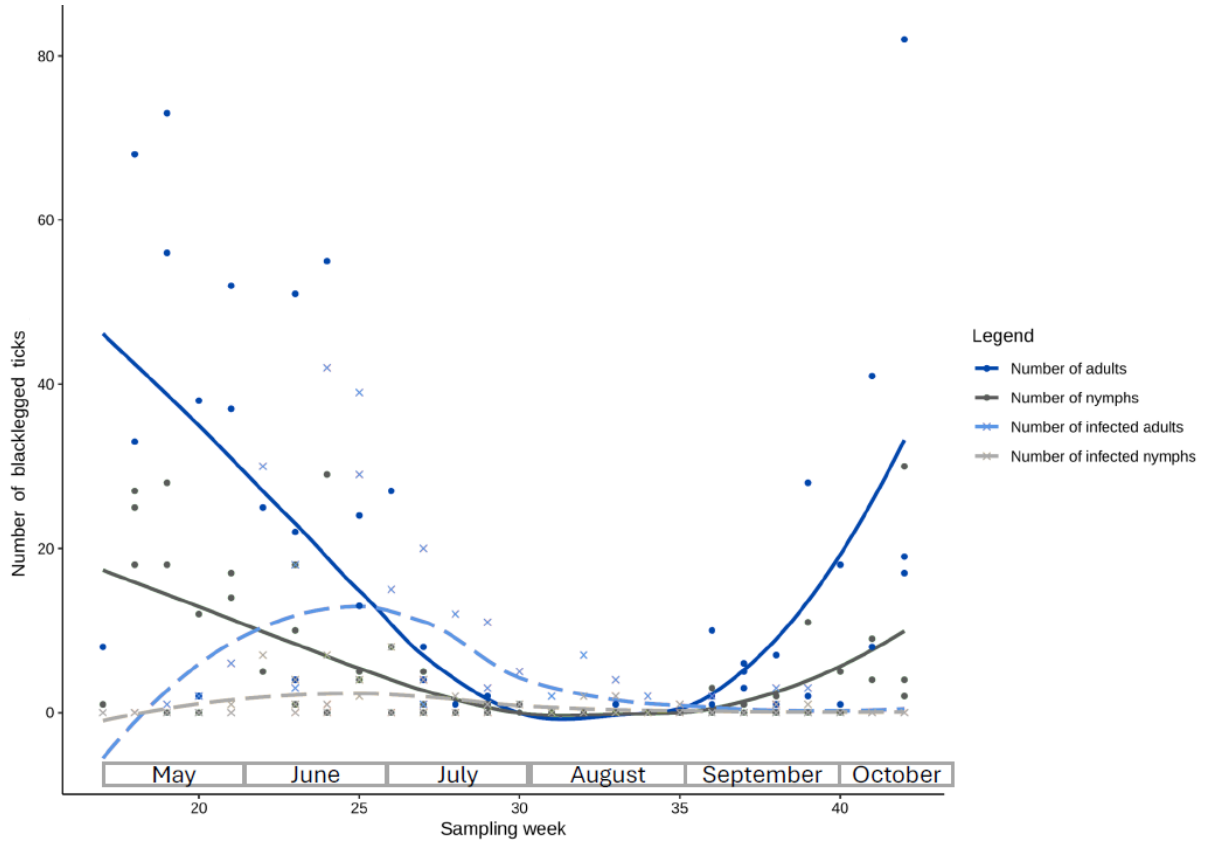


Figure 4. Seasonal variation in the number of blacklegged ticks and *Borrelia-burgdorferi*-infected ticks collected via drag sampling by sampling week and life stage (adults and nymphs) in the five study neighbourhoods, 2023-2025.

***Small mammal sampling and testing*.** White-footed mouse trapping was conducted in July/August 2023 and 2024 in woodland and interface zones of all five neighborhoods. During the two sampling seasons we trapped 195 *Peromyscus* species mice: 94 *Peromyscus* spp. (71 *P. leucopus* and 23 *P. maniculatus*) in 2023 and 101 *Peromyscus* spp. (74 *P. leucopus*, 18 *P. maniculatus* and 9 *Peromyscus* hybrid mice) in 2024. We detected infected mice in both woodland and interface zones of the three western neighbourhoods (Stonehaven, Kanata North and Carp), while in Findlay Creek and Blackburn Hamlet, infected mice were only detected in the woodland and interface zones, respectively (Figure 5).

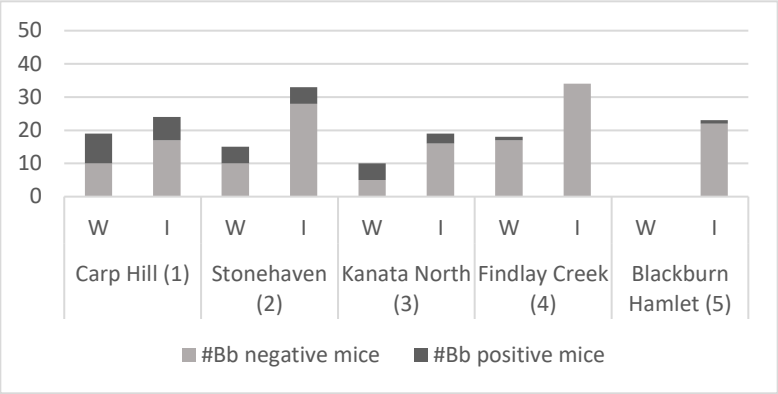


Figure 5. Number of *B. burgdorferi* negative and positive mice sampled from the woodland and interface zones of five neighbourhoods, July-August, 2023 and 2024. The total sampling effort comprised 600 trap-nights per zone per year.

Objective 2.0 – Environmental risk analysis.

Tick density was associated with ecological factors at both the local and regional scales. Areas with smaller forest patches, less non-forest landcover (e.g. consisting of more built-up, barren, or other types of vegetation), and more built-natural environment interface at the regional scale, as well as higher vegetation index (a proxy for greenness or moisture) at the local scale, were associated with a higher abundance of blacklegged ticks in our study setting. In addition, areas with smaller forest patches at the regional scale and higher local forest cover at the local scale were associated with higher density of adult and nymphal stage ticks infected with *B. burgdorferi*.

Objective 3.0 – Population survey and consultation.

A total of 1015 Ottawa residents participated in the survey. Participants were broadly balanced by gender, with 52.4% identifying as women and 46.7% as men, and a small proportion identifying as non-binary or other genders. Using the 2021 Ottawa Census as a reference, we found survey respondents to be generally representative of the census population in terms of geographic region, with slight overrepresentation of the urban versus rural population (Table 1). Sociodemographic characteristics were broadly balanced across categories. Most respondents fell within the 25-34 age group (18.2%), and the fewest in the 75 and older group (8.5%). Respondents were also more likely to identify as white (73.3%), speak English as primary language (82.7%), report annual household incomes between $80,000 and $99,999 (16%), and be university educated or more (58.5%).

Table 1. Sociodemographic characteristics of survey participants.

Characteristic	***Category***	***Number of Respondents***		
		n	**%**	**(95% CI)**
		1015		
Gender	Woman	532	52.4	(49.3, 55.5)
	Man	474	46.7	(43.6, 49.8)
	Non-Binary	8	0.8	(0.3, 1.4)
	Other	1	0.1	(0.0, 0.3)

Age	18 to 24	128	12.6	(10.6, 14.6)
	25 to 34	185	18.2	(15.8, 20.6)
	35 to 44	180	17.7	(15.4, 20.1)
	45 to 54	153	15.1	(12.9, 17.3)
	55 to 64	168	16.6	(14.3, 18.9)
	65 to 74	115	11.3	(9.4, 13.3)
	75 or older	86	8.47	(6.8, 10.2)
Ethnicity	white	744	73.3	(70.5, 76.0)
	Indigenous	59	5.8	(4.4, 7.3)
	Other	192	18.9	(16.5, 21.3)
	NA	20	2.0	(1.1, 2.8)
Region	Urban	347	34.2	(31.3, 37.1)
	Suburban E	195	19.2	(16.8, 21.6)
	Suburban S	197	19.4	(17.0, 21.9)
	Suburban W	139	13.7	(11.6, 15.8)
	Rural	137	13.5	(11.4, 15.6)
Residence in Canada	Less than 1 year	13	1.28	(0.6, 2.0)
	1-5 years	45	4.43	(3.2, 5.7)
	6-10 years	37	3.65	(2.5, 4.8)
	10+ years **	920	90.64	(88.8, 92.4)
Income	< $20,000	51	5.0	(3.7, 6.4)
	$20,000 to $39,999	72	7.1	(5.5, 8.7)
	$40,000 to $59,999	102	10.1	(8.2, 11.9)
	$60,000 to $79,999	125	12.3	(10.3, 14.4)
	$80,000 to $99,999	162	16.0	(13.8, 18.3)
	$100,000 to $119,000	141	13.9	(11.8, 16.0)
	$120,000 or more	276	27.2	(24.5, 29.9)
	NA	86	8.5	(6.8, 10.2)
Education	Highschool or less	130	12.8	(10.8, 14.9)
	College	288	28.4	(25.7, 31.2)
	University or higher	594	58.5	(55.5, 61.6)
	Other/ NA	3	0.3	(0.0, 0.7)
Primary Language	English	839	82.7	(80.4, 85.0)
	French	137	13.5	(11.4, 15.6)
	Other	39	3.8	(2.7, 5.0)

Overall, 29% of respondents reported knowing someone with an LD diagnosis and 3% reported having received a diagnosis of LD at some point, 22% and 16% of respondents reported having at least one tick encounter or tick bite in the last year respectively, and only 10% reported consistently using some sort of protection against ticks while outdoors (Table 2). The most

preferred method for personal protection against ticks was clothing protection (long pants, long sleeves, tucking pants into socks), mentioned by 43% of respondents, while 27% preferred repellent spray, 15% preferred tick checks, and 5% preferred to shower immediately after time outside.

The majority of respondents did not use tick prevention around their homes or did not have a yard. Of the 220 out of 1015 respondents who reported using one or more tick prevention methods around their property, 53% used landscaping techniques, 45% used fencing to keep deer out, 41% used spraying, and 26% used tick prevention for wildlife (e.g. tick tubes for mice).

Respondents who were male or in the youngest age group (ages 18-24 years) were more likely to report experiencing one or more tick encounters or tick bites in the previous year. After adjusting for age and sex, a higher frequency of reported tick encounter (1 or more times per year) or tick bite (1 or more times per year) was associated with higher reported household income (>=$60,000/year) and increased frequency of forest use (>=10 times/year). Residence in the Suburban West region was also associated with higher frequency of tick bites.

Younger respondents (ages 18-24 years) were more likely to often or always use personal protective measures against ticks while outdoors while no sex-based differences were observed. After adjusting for age and sex, a higher frequency of using personal protection (often or always use protection outside) was associated with higher income (>=$60,000/year) and increased frequency of forest use (>=10 times/year), while no significant differences were observed between regions.

Amongst those who reported visiting a forested area 10 or more times per year, the use of personal protection 'sometimes', 'often' or 'always' was associated with lower frequency of reported tick bites or encounters compared to those who indicated that they 'never' used personal protective measures. However, due to the cross-sectional nature of the data, which was collected at a single point in time, it is not possible to attribute causal relationships.

Table 2. Risk and exposure factors of survey participants (N=1015)

Risk or exposure variable	***Category***	***N Respondents***	***% Respondents***	***(95%CI)***
Tick encounter frequency	Never	782	77.0	(74.4, 79.5)
	1-2 times per year	183	18.0	(15.8, 20.5)
	3+ times per year	50	4.9	(3.8, 6.4)
Tick bite frequency	Never	848	83.5	(81.1, 85.7)
	1-2 times per year	148	14.6	(12.5, 16.9)
	3+ times per year	19	1.9	(1.2, 2.9)
Ever thought they had LD	Yes	48	4.7	(3.6, 6.2)
	No	967	95.3	(93.8, 96.4)
Ever diagnosed with LD	Yes	33	3.3	(2.4, 4.7)
	No	967	95.3	(93.8, 96.4)
	I don't know	14	1.4	(0.8, 2.3)
Know someone with LD	Yes	293	28.9	(26.2, 31.7)

	No	678	66.8	(63.8, 69.6)
	I don't know	44	4.3	(3.2, 5.8)
Frequency of personal tick protection use	Never	313	30.8	(28.1, 33.8)
	Sometimes	358	35.3	(32.4, 38.3)
	Often	228	22.5	(20.0, 25.1)
	Always	97	9.6	(7.9, 11.5)
	I don't know	19	1.9	(1.2, 2.9)
Yard access and maintenance	No access	171	16.8	(14.7, 19.3)
	Access but no maintenance	250	24.6	(22.1, 27.4)
	Access and maintenance	594	58.5	(55.5, 61.5)
Yard tick prevention use	Yes, yard prevention use	220	21.7	(19.2, 24.3)
	No yard prevention use	618	60.9	(57.8, 63.8)
	No yard/No maintenance	120	11.8	(10.0, 14.0)
	I don't know	57	5.6	(4.4, 7.2)
Forest use frequency	25+times per year	145	14.3	(12.3, 16.6)
	11-24 times per year	226	22.3	(19.8, 24.9)
	3-10 times per year	302	29.8	(27.0, 32.6)
	2 or less times per year	231	22.8	(20.3, 25.4)
	Never	111	10.9	(9.2, 13.0)
Pet ownership	Yes	393	38.7	(35.8, 41.8)
	No	622	61.3	(58.2, 64.2)
Pet tick or LD protection frequency	Never	91	9.0	(7.4, 10.9)
	Sometimes	95	9.4	(7.7, 11.3)
	Often	138	13.6	(11.6, 15.8)
	Always	195	19.2	(16.9, 21.8)
	No pet/ Don't know	496	48.9	(45.8, 52.0)

Objective 4.0 - Community and stakeholder engagement.

Members of the UPTick Community Advisory Committee were identified and invited through outreach to community associations in each of the five study neighbourhoods, including Bridlewood, Kanata Lakes, Huntley, Findlay Creek and Blackburn Hamlet Community Associations as well as the Friends of Carp Hills. The UPTick project PI (Dr. Kulkarni) and Coordinator (Dr. McKay) gave presentations to share project results and answered questions during town hall meetings for the Blackburn Hamlet Community Association in February 2023, Bridlewood Community Association in April 2024 and April 2025, Kanata Lakes Community Association in May 2025, and Queen's University Biological Station (QUBS) in August 2024 and 2025. The town halls were organized with the input and support of the UPTick Community Advisory Committee. The town hall meetings engaged members of neighbourhood community associations and other community groups (e.g. recreational and business associations, nature conservation associations, youth organizations, schools) and members of the general public that reside in study neighbourhoods. The project also engaged with local media outlets to raise awareness of trends in rising tick populations and prevention strategies, including West Carleton Online, Ottawa Citizen and CTV News.

CONCLUSION

The UPTick-Phase II project highlighted the presence of tick-borne disease risks in Ottawa neighbourhoods associated with the ecological characteristics of surrounding greenspaces, including the interface between woodlands and residential areas. The project identified wide variation in the density of blacklegged ticks and Lyme disease environmental risk (measured as the density of *B. burgdorferi*-infected ticks) between neighbourhoods, with highest overall tick densities and environmental risk observed in the three western neighbourhoods. Of these western neighbourhoods, Kanata North had the highest overall densities of ticks and infected ticks, which were roughly double the densities of ticks and infected ticks found in both Stonehaven and Carp. Overall, lower tick densities were observed in Findlay Creek in the south and Blackburn Hamlet in the east. These findings are consistent with previous studies that have identified emerging tick populations in the southern and eastern regions of Ottawa, which are characterized by lower densities of ticks in the environment, while tick populations in the western region of Ottawa are well-established.[25]

There was notable seasonal variation in tick densities and Lyme disease environmental risk; while tick activity peaked in the spring and fall, the density of infected ticks was highest in the late spring to early summer period, reflecting the peak period of Lyme disease risk for people. Infected ticks were detected along trails within forested areas as well as forest-edge trails directly adjacent to residential properties that are easily accessed by local residents, highlighting the need for public awareness and use of personal protective measures in these settings. Interestingly, very low densities of ticks or infected ticks were observed in the residential zones in two of the western neighbourhoods, while no ticks or infected ticks were observed in the residential zones of other neighbourhoods. This suggests that residential pathways and trails are not major sources of Lyme disease environmental risk in these settings, although a non-negligible level of risk may be present in residential areas of highly endemic regions, which warrants public awareness.

Interestingly, the project identified that tick density and Lyme disease environmental risk were both associated with indices of forest fragmentation at the regional and local scales, highlighting the need to better understand the role of urban development and its interface with forested greenspaces in driving tick-borne disease risks. Furthermore, this highlights the importance of targeting interventions to the built-natural environment interface within fragmented landscapes to reduce environmental risk and/or human-tick exposure.

While the survey identified that 22% and 16% of respondents reported having at least one tick encounter or tick bite in the last year, respectively, only 10% reported consistently using some sort of protection against ticks while outdoors, and 22% reported using tick prevention in their yard. Greater awareness and adoption of preventive measures to avoid tick bites is important to reduce population risks of tick-borne diseases. This is particularly important in regions of higher environmental risk in western Ottawa, and for population groups reporting a higher frequency of tick encounters (e.g. younger adults, men, and forest users), which may be related to recreational or occupational exposures.

NEXT STEPS

The information shared with public health authorities and local communities in Ottawa has helped to raise awareness of tick-borne disease risks to inform preventive strategies; however, ongoing surveillance of tick populations and risk communication is needed to optimize tick-borne disease prevention. This is especially important given the rising trends in Lyme and other tick-borne diseases in the Ottawa region, where peri-urban greenspaces may have negative consequences for tick-borne disease risks, despite the importance of these natural areas for climate change adaptation and biodiversity conservation.

Alongside this surveillance work, the INSIGHT Lab's research program has focused on translating evidence from the UPTick project on emerging risk into locally relevant prevention and control strategies. This has included a field-based evaluation of environmental interventions, such as woodchip barriers used along recreational trail systems[30,31]; research examining public acceptability of prevention approaches (paper in preparation); and evidence synthesis to identify which strategies have most consistently shown effectiveness, contributing to prevention efforts in these spaces[32]. The lab is also reviewing evidence on the impact of urban green infrastructure on tick-borne disease risks to identify promising urban planning and land management strategies for risk mitigation. However, further research is still needed to identify tick management strategies in urban settings that balance public health, climate adaptation, conservation, and land management priorities. Continued monitoring of ticks and tick-borne disease risks in peri-urban areas in Ottawa is also key to tracking evolving risks that are increasing due to climate change and other socioecological changes, and identifying entry points for disease prevention and control.

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