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Assessing strategies for the prevention and control of emerging tick-borne diseases in urban and peri-urban settings.

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Abstract

Lyme disease (LD) is the most rapidly emerging vector-borne disease in Canada. LD risk is expanding into urban and peri-urban areas due to landscape and climatic changes, along with increasing human use of wildlife habitats. Integrative interventions are needed to maximize the effectiveness of LD prevention and control.

The *objective* of my thesis was to assess the effectiveness and acceptability of interventions to reduce LD risk in urban and peri-urban settings, using the city of Ottawa as the study site.

I first (1) conducted a systematic literature review and data synthesis of studies on LD prevention and control options comparable to the Canadian context. I then (2) investigated the comparative efficacy of two environmental tick control interventions, by conducting a two-year intervention study in two peri-urban recreational trails in Ottawa. Finally, I (3) assessed the acceptability and feasibility of LD prevention practices used to reduce LD exposure and risk amongst residents of Ottawa using a mixed methods study.

The systematic review summarized effectiveness and utility measures of tick and LD control options. The most common intervention domain in this study was host-targeted interventions, while the synthesis showed that chemical control approaches were the most consistently effective. However, reporting on social acceptability, environmental impact, cost, and feasibility, was inconsistent despite their potential impact on intervention uptake. Field study results found that both treated and untreated woodchips significantly reduced *I. scapularis* adult and nymphal

tick density (incidence rate ratio (IRR) = 0.01, 95 % CI: 0.001–0.08 and IRR = 0.52, 95 % CI: 0.34–0.78) respectively, relative to controls, demonstrating that modifying trailside ecotones with these interventions significantly reduces tick density. The mixed-methods analysis indicated that personal protection strategies and landscape strategies were the most comparably acceptable intervention types in the context of the Ottawa region; furthermore, acceptability was more consistently associated with sociodemographic factors than with risk and exposure variables.

Overall, this thesis evaluated LD prevention options relevant to a Canadian peri-urban context and examined their acceptability and feasibility in Ottawa, generating evidence to inform further development of evidence-based and publicly acceptable LD risk reduction strategies in Canada.

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List of Abbreviations

AIC	Akaike Information Criterion
B. burgdorferi	*Borrelia burgdorferi*
CI	Confidence interval
CLyDRN	Canadian Lyme Disease Research Network
DAG	Directed Acyclic Graphs (DAGs)
DIN	Density of Infected Nymphs
EM	Erythema migrans
FSA	Forward Sortation Area
GRADE	Grading of Recommendations, Assessment, Development, and Evaluations
IRR	Incidence Rate Ratio
ITM	Integrated tick management
I. scapularis	*Ixodes scapularis*
KAP	Knowledge, Attitudes, Practices
KII	Key informant interview
LD	Lyme disease
ROB2.0	Risk-Of-Bias tool for randomized trials
ROBINS-I	Risk Of Bias In Non-randomised Studies - of Interventions
TBD	Tick-borne disease
TBP	Tick-borne pathogen
TE	Translational Ecology

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1. Introduction

Ticks and tick-borne diseases (TBDs) have been recognized as a threat to public health in North America, primarily in the United States, for over a century. However, Lyme disease (LD) emerged more clearly as a threat in both the United States and Canada in the 1970s and 1980s, when the tick species *Ixodes scapularis* (previously known as *Ixodes dammini*) was first recognized as the primary vector of *Borrelia burgdorferi* sensu stricto (s.s.), the bacteria that causes Lyme disease (LD), as well as *Babesia microti*, the parasite responsible for human babesiosis (1,2). Although this recognition is relatively recent, genomic research has revealed that *Borrelia burgdorferi s.s.* has been circulating in the region for more than 20,000 years, indicating that its more modern emergence as a threat to human health is largely driven by environmental change and human land-use factors (3).

In recent years, these ecological shifts have coincided with a marked increase in LD incidence and geographic expansion of *I. scapularis*. LD is responsible for 75% of all vector-borne disease cases in the United States with increasing numbers of cases reported to the CDC each year, and is experiencing rapid northward spread of the bacteria and vector tick through North America (1,4,5). In Canada, similar trends have been noted, with the first locally acquired case of LD reported in the 1980s, and surveillance of the disease documenting a rapid increase in tick populations and human cases (1,6,7). These trends have prompted calls for coordinated national strategies to address the growing risk to human and animal health in Canada and the United States (8,9).

Calls for national strategies to address the growing threat of TBDs face several difficulties, first of which is the need to better understand TBD ecology and distribution as the geographic ranges of tick species and populations are expanding and emerging. This requires knowledge of the range of environments, habitats, and tick biology to adequately identify TBD risk areas. Different tick species have different biological characteristics and therefore occupy different ecological niches. For example, *Dermacentor variabilis* is more often found in open grassland or shrub-dominated areas and this species is more resistant to desiccation, whereas *I. scapularis* prefers deciduous forest canopies, abundant leaf litter, and generally more humid microclimates, as this species is more prone to desiccation, and also depends on wildlife hosts that thrive in these habitats (10). This ecological complexity in vector tick, host, and environmental components of tick-borne disease transmission complicates the design of national-level control strategies, since interventions may not effectively address multiple tick vector species across their range of habitats. Additionally, there is currently a limited toolkit of effective interventions, and a growing need for the continued evaluation of new potential tools and their contextual appropriateness, as the success of TBD control programs depends not only on the efficacy of a product or method in reducing risk of transmission, but also on a range of environmental and social considerations (11).

Leading to a third challenge, many control strategies face barriers to meeting contextual needs due to environmental concerns, including the measured or suspected negative impacts on non-target arthropods, broader environmental effects, or unintended consequences for wildlife host populations. Social acceptability, the potential for vector or bacterial resistance, environmental impact, feasibility, and cost are all factors to consider when selecting the most appropriate, and locally relevant strategy (11). Furthermore, a case study by Tiffin et al. (2022) emphasized the importance of cross-border collaboration in vector-borne disease control programs to maximize their effectiveness and long-term sustainability (12).

Local and national tick and TBD prevention and control strategies will therefore need to incorporate local ecological and social contexts, and consider the corresponding risk of exposure, while prioritizing integrated tick control approaches - this issue can therefore be addressed using a One Health approach, which recognizes the interconnected nature of environment, human, and animal health (13,14). The aim of my thesis is to advance understanding of the efficacy and utility of tick and TBD control programs, including their feasibility and acceptability, and to evaluate a novel integrated tick management method. In doing so, this work seeks to produce findings that are contextually relevant to the Ottawa, Canada, municipal region while contributing to broader discussions of TBD prevention and control strategies at larger scales. Lyme disease (LD), as the dominant TBD in North America, provides a clear case through which to examine these relationships and challenges in more depth. Although the next sections focus primarily on LD, the challenges and intervention considerations described here may also be informative for other integrated control approaches targeting other human and animal TBDs transmitted by the tick species, *I. scapularis*.

1.1 Organization of the Thesis

Chapter 1: Introduction

This chapter provides an overview of the historical significance of Lyme disease as a public health concern in North America and summarizes some of the recent trends in its epidemiology. The growing relevance of Lyme disease across both the United States and Canada underscore the need for unified strategies to combat this health issue. This section also reviews some of the central challenges that tick and Lyme disease control programs currently face.

Chapter 2: Background

This chapter provides a comprehensive review of the literature, expanding on the overview presented in Chapter 1. This section examines the epidemiology and health significance of Lyme disease in greater detail, including the ecological dynamics of vector ticks, their wildlife hosts, and the environmental factors influencing transmission. It also reviews approaches to tick and tick-borne disease management, while keeping this discussion at a summarized level, as these strategies are systematically evaluated in a dedicated chapter later in the thesis. Together, this background establishes the evidence base and rationale for the research questions, and methods that drive the following chapters.

Chapter 3: Methods

This section describes aspects of study design, data collection, or statistical analysis that are not found in the thesis research articles presented in chapters 4-6, and helps to further frame certain aspects of methodology through a One Health lens.

Chapter 4-6: Articles

Chapter 4 presents a systematic review of vector tick and Lyme disease control interventions, published in *BMC Infectious Diseases*. This work synthesized evidence on the effectiveness of diverse approaches and contributes to the thesis framework for evaluating and implementing holistic, integrated, and One Health oriented solutions. Chapter 5 presents an integrated experimental field study. This study evaluated the effectiveness of trailside ecotone modification using woodchip borders, with and without acaricidal spray, compared to standard maintenance. Chapter 6 presents a mixed-methods study conducted in Ottawa, Ontario. This study combined key informant interviews with a population-level survey to assess the feasibility and acceptability of various Lyme disease prevention strategies.

Chapter 7: Discussion

This chapter integrates findings across the preceding thesis chapters, summarizing the individual research objectives and their key results, and situating them in the existing literature on tick and Lyme disease control. It highlights some of the themes identified throughout the work, discusses the methodological strengths and limitations of the thesis, outlines some contributions it has made to policy and practice, as well as identifying some future research priorities related to this work.

1.2 Thesis Objectives and Conceptual Framework

1.2.1 Thesis objectives

With increasing incidence of Lyme disease (LD) in North America, there is an urgent need for novel integrative interventions to prevent human-tick encounters and LD infection that target multiple aspects of the disease transmission cycle, to maximize effectiveness of disease prevention and control programs (13). In the US, where LD has been established since the 1970's, tick control options are numerous compared to the Canadian context, where there is strict environmental regulation and lower public acceptance of chemical applications in the environment (15). Studies are urgently needed to assess promising LD interventions that are adapted to and acceptable within the local context. **My thesis investigates current scientific knowledge on intervention strategies for LD prevention in urban and peri-urban areas to inform locally adapted, acceptable, and feasible disease prevention and control strategies.**

My thesis research consists of three interrelated studies that together apply an interdisciplinary approach to understanding LD prevention and control strategies in the Canadian context. **Objective 1** aimed to synthesize the evidence base on LD prevention interventions, which was achieved through a systematic review and data synthesis. **Objective 2** aimed to evaluate an integrated environmental management strategy to reduce the density of questing ticks, which was achieved using a field-based intervention study in a recreational setting. Finally, **Objective 3** aimed to evaluate the feasibility and acceptability of the identified interventions from the first two objectives in the local context of the city of Ottawa by using an exploratory mixed methods analysis.

This research was carried out in collaboration with several external partners and stakeholders to ensure relevance to policy, practice, and local decision-making organizations. Objective 1 was conducted in partnership with the Canadian Lyme Disease Research Network (CLyDRN), specifically Pillar II (Prevention and Risk Reduction), and in coordination with the network's Innovation Working Group, along with collaboration from several members of the Public Health Agency of Canada's (PHAC) evidence synthesis team. I completed Objective 2 in collaboration with the National Capital Commission (NCC), a federal Crown corporation responsible for managing the Ottawa, Greenbelt lands where the intervention study was implemented. Objective 3 was integrated within the UPTick research project and its Community Advisory Committee, which supports community-engaged LD research priorities in the Ottawa region, through the INSIGHT lab at the University of Ottawa.

1.2.2 Conceptual model and framework

My conceptual model (Figure 1) illustrates how LD intervention methods can be understood and evaluated at their core through a **One Health lens**, recognizing the connections between humans, animals, and the environment. It emphasizes that interventions never operate in isolation but are situated within broader social and environmental contexts. One Health models can be used to better understand ecological relationships, disease risk, and intervention prioritization and integration. This lens is increasingly acknowledged for its importance in preventing and controlling zoonotic diseases, such as LD (16).

The complementary **socioecological model** in my theoretical framework is also critical to our understanding of LD interventions, as it emphasizes how individual, interpersonal, community, and structural factors shape health behaviours and intervention uptake. The socioecological model conceptualizes health behaviours as being shaped by micro-level (individual), meso-level (community/organizational), and macro-level (policy/structural) factors (17). When integrated with a One Health perspective, it highlights how human behaviour, along with the broader environmental and social contexts, influence the feasibility and acceptability of tick control and LD prevention interventions (Figure 1.1).

Figure 1.1:Thesis conceptual model integrating One Health, socioecological, and acceptability perspectives in Lyme disease and tick control.

Within this combined framework, **acceptability** of TBD and LD interventions is critical for the long-term implementation and sustainability of control programs, and is inherently context dependent (15,18,19). For example, small mammal acaricidal baits to control tick populations may be acceptable in woodland settings, but not in public parks, while habitat modification might be more acceptable in a wider range of settings. Intervention acceptability is shaped by many personal and societal considerations, including social norms, perceived risk, financial and policy considerations, environmental suitability, and perceived benefits, all of which shape whether interventions are feasible, effective, and likely to be implemented into practice and policy. Previous research on the acceptability of health intervention implementation has shown that acceptability and feasibility influence the scalability and sustainability of healthcare interventions (20). The Theoretical Framework of Acceptability (TFA) outlines several key individual-level constructs that contribute to these judgements, including affective attitude, burden, ethicality, intervention coherence, opportunity cost, perceived effectiveness, and self-efficacy (21). Related frameworks and measurement tools have been adapted and applied globally to assess the acceptability of diverse health interventions across different disciplines and contexts (22–24).

Building on these considerations of feasibility, acceptability, and socioecological factors, it is important to situate LD interventions within the broader One Health framework. Canadian studies have demonstrated the value of integrating LD risk analysis and prevention approaches to deepening our understanding of LD risk in communities, and therefore should also be adopted in order to maximize the efficacy of intervention programs (14,25). Interventions can be targeted at each of these One Health components: personal protection and health promotion for human and social considerations, host-targeted strategies for wildlife, or environmentally applied measures such as habitat modification. Importantly, framing these interventions in the context of an ecological system suggests that integrative strategies would benefit from incorporating multiple facets of the One Health model (13).

In relation to this thesis, the model provides a framework for situating each of the three research objectives presented previously. The systematic review (Objective 1) identifies types of interventions and their demonstrated effectiveness across these domains in context dependent study environments. The studies captured in this chapter reflect a comprehensive list of intervention options which correspond to the domains of the One Health framework. Furthermore, the review considers many acceptability factors such as feasibility, cost, and social opinions, as well as environmental suitability as a secondary objective of the research.

The experimental intervention study (Objective 2) directly tests an integrated strategy (ecotone modification with or without chemical application) in a recreational peri-urban context, in an effort to reduce the density of questing (i.e. host-seeking) ticks along the trails. This is embedded within the One Health framework; addressing landscape (environmental) determinants of tick density, as well as a modified application of an acaricidal treatment strategy with the aim of reducing tick density in several recreational settings in the Ottawa Greenbelt, where humans and companion animal exposure may occur..

Finally, the mixed methods evaluation (Objective 3) more intentionally examines the feasibility and acceptability of intervention domains shown in the conceptual framework, considering how social and environmental contexts influence intervention perception on the part of key stakeholders and the broader public. This is achieved through key informant stakeholder interviews (KIIs) with members of the public, LD patients, and recreational group members, as well as medical, animal, and environmental health experts. This was combined with a subsequent survey of the broader Ottawa public using a modified acceptability metric applied to the local context, where questionnaire development was informed by the KIIs.

Building on this framework, my thesis also integrates components of the socioecological health model, which highlights the layered influence of individual, community, and broader ecological factors on health behaviours and outcomes (26–28). By combining concepts of One Health, socioecological systems, and principles of acceptability, this conceptual diagram offers a comprehensive guide to informing locally adapted, acceptable, and integrated Lyme disease control strategies. Below I have summarized my thesis objectives and a general description of data sources included, outcome(s) of interest and the general analytic approach (Table 1.1).

Table 1.1:Summary of data sources, outcomes of interest, and analytic approaches for each of the thesis objectives

Objective	Data sources	Outcome of interest	Analytic approach
1	Systematic search, data extraction from included articles	Effectiveness and utility of tick and tick-borne pathogen (i.e. *Borrelia burgdorferi*) control	Systematic review and data synthesis of most comparable effectiveness results (i.e. Density of

		programs applicable in the Canadian context	Infected *I. scapularis* Nymphs; DIN)
2	Experimental field trial, active tick surveillance throughout experiment, environmental measures along trailside	Effect of each intervention group compared to the control group on overall tick density, and effect of interventions on *I. scapularis* adult and nymphal density	Negative binomial regression model to identify the effect of the interventions on tick density outcomes
3	Key informant interviews and survey of Ottawa adults	Feasibility and acceptability of different interventions, and category of interventions according to key informants and the general public	Qualitative thematic analysis and quantitative logistic regression analysis of acceptability scores by intervention category

2. Background

2.1: Tick-borne diseases

2.1.1 Tick-borne diseases in Canada

There are several tick-borne diseases (TBDs) recognized as emerging or established in Canada. The primary TBDs of concern include Lyme disease, anaplasmosis, babesiosis, and Powassan virus disease. While there are over 40 species of ticks documented in the country, only a subset are known to be competent vectors of human pathogens (29). The principal tick vector species of public health concern include *Ixodes scapularis* (blacklegged tick) in central and eastern Canada, *Ixodes pacificus* (western blacklegged tick) in British Columbia, *Dermacentor variabilis* (American dog tick), *Dermacentor andersoni* (Rocky Mountain wood tick), and, more recently, *Amblyomma americanum* (lone star tick) (Table 2.1) (30,31). In addition, there is increasing concern regarding the potential of *Haemaphysalis longicornis* (Asian longhorned tick) to continue its northward expansion into Canada from the United States, as it is known for rapid establishment and public health significance as a competent vector for multiple pathogens elsewhere (32). All of these tick vector species have unique host and environmental ecologies (30,31).

Table 2.1: Tickborne Pathogens of concern in Canada; Adapted from Bouchard et.al. (2019).

Tickborne Pathogen	**Principal tick vector(s)**	**Principal reservoir host species**	**Geographic distribution in Canada** Provinces with known **endemic transmission are in bold**

Anaplasma phagocytophilum	*Ixodes scapularis, Ixodes pacificus*	Rodents	BC, AB, SK, **MB**, **ON**, **QC**, **NB**, NL, **NS**, PEI
Babesia microti	*Ixodes scapularis*	Mice	**MB**, **ON**, QC, **NB**, NS
Borrelia burgdorferi	*Ixodes scapularis, Ixodes pacificus*	Rodents	**BC**, AB, SK, **MB**, **ON**, **QC**, **NB**, **NS**, NL, PEI
Borrelia hermsii	*Ornithodoros hermsi*	Rodents and rabbits	**BC**
Borrelia mayonii/ Borrelia mayonii-like	*Ixodes scapularis, Ixodes angustus*	Rodents	ON, BC
Borrelia miyamotoi	*Ixodes scapularis, Ixodes pacificus*	Mice	BC, AB, MB, ON, QC, NB, NS, NL, PEI
Colorado tick fever virus	*Dermacentor andersoni*	Golden mantled squirrels, deer mice and rabbits	SK, AB
Ehrlichia chaffeensis	*Amblyomma americanum*	White-tailed deer	---
Ehrlichia ewingii	*Amblyomma americanum*	White-tailed deer	---
Ehrlichia muris-like agent	*Ixodes scapularis/ Ixodes muris*	Mice	MB
Francisella tularensis	*Dermacentor variabilis, Dermacentor andersoni, Amblyomma americanum*	Rabbits, hares, and rodents	**Canada wide**
Heartland virus	*Amblyomma americanum*	White-tailed deer	---
Lineage I Powassan virus	*Ixodes cookei, Ixodes marxi, Ixodes spinipalpis*	Small and medium-sized woodland mammals (woodchucks)	**ON**, **QC**, **NB**, PEI
Lineage II Powassan virus	*Ixodes scapularis, Dermacentor andersoni*	Mice	**MB**, ON, NS
Rickettsia rickettsii	*Dermacentor variabilis, Dermacentor andersoni, Rhipicephalus sanguineus*	Variety of wild mammals including rodents	**BC**, **AB**, **SK**, **ON**, NS

Rows shaded in grey indicate diseases transmitted by *Ixodes scapularis* in Canada.

Ixodes scapularis (*I. scapularis*) is a three-host tick with a two-year lifecycle consisting of larval, nymphal, and adult stages (33). Larva may acquire *Borrelia burgdorferi (B. burgdorferi)* through feeding on competent reservoir hosts, particularly small mammals like the white-footed mouse (33). Nymphs and adult *I. scapularis* ticks are then capable of transmitting infection to humans. A more detailed description of *I. scapularis* and *B. burgdorferi* transmission dynamics is provided in Section 2.2.

2.1.2 Lyme disease in Canada and Ontario

The incidence of Lyme disease (LD) and other tick-borne illnesses is increasing in Canada due to ongoing climatic and environmental changes that have expanded the geographic range of LD vector ticks (*Ixodes scapularis* in eastern Canada and *Ixodes pacificus* in British Columbia) and brought them into closer proximity with human populations (5,34–36). Climatic variables, particularly warming temperatures, have facilitated the northward expansion of both vector ticks and their wildlife hosts, amplifying opportunities for transmission (37,38). Eastern Ontario exhibits some of the highest rates of LD incidence in the country, supported by extensive woodland habitat that favours tick survival and reproduction, as well as diverse wildlife hosts that carry the Lyme disease pathogen (*Borrelia burgdorferi s.s.*). Within this region, the risk of LD is expanding in many urban and peri-urban environments, including Ottawa and surrounding areas, where incidence rose from 1.2 to 12.3 cases per 100,000 population between 2010 and 2016 (39), and continued to rise substantially over the past decade, increasing from 7.7 to 37 cases per 100,000 population between 2015 and 2024 (40). This rise reflects multiple interacting factors, including urbanization, landscape fragmentation, and population growth (39,41,42). The combination of environmental suitability, urban expansion, and habitat fragmentation has created conditions conducive to sustained disease transmission extended the period of tick activity beyond historical tick season (43–45).

2.1.3 The economic cost of tick-borne diseases and Lyme disease

At a global level, tick-borne diseases impose substantial public health and economic burdens, with LD representing the most common VBD in temperate regions. A review of the cost effectiveness of LD interventions in the U.S. and Europe by Mac et al. (2019) found that three of the seven studies including cost analyses for LD emphasized the need for further research, particularly prioritizing preventive interventions (46). The same review estimated the economic burden of LD in the United States at approximately USD 292 million, which is comparable in magnitude to other vector-borne diseases such as West Nile virus and Zika (46). In Canada, the health and economic consequences of LD are increasingly recognized, with rising case numbers and healthcare costs; one study estimated that the projected annual cost of LD in Canada could reach CA$0.5 billion to $2.0 billion a year by 2050 under varying climate change projections and vector tick expansion (46,47).

2.2: Vector and pathogen ecology

2.2.1 Human Lyme disease bacterial pathogens

The *Borrelia burgdorferi* sensu lato (s.l.) complex is comprised of a group of over 20 closely related spirochete bacteria genospecies, several of which can cause Lyme disease in humans. Although the distribution of genospecies varies geographically, some key members, such as *B. burgdorferi* sensu stricto (s.s.), *B. afzelii,* and *B. garinii*, are recognized as being the primary human pathogens throughout the northern hemisphere including North America, Europe, and parts of Northern and Western Asia (Table 2.2) (48,49).

Table 2.2: Members of the *Borrelia burgdorferi* s.l. complex, their suspected reservoir host, vector Ixodes spp. And distribution. Adapted from Steinbrink et.al. 2022 (49)

***Borrelia* species**	**Reservoir hosts *suspected host**	**Suspected vector *Ixodes* spp.**	**Distribution**
B. afzelii	Rodents, insectivores	*I. ricinus, I. persulcatus, I. hexagonus*	Asia, Europe
B. bavariensis	Rodents	*I. ricinus, I. persulcatus*	Asia, Europe
***B. burgdorferi* s. s.**	Birds, rodents, insectivores, carnivores	*I. ricinus, I. scapularis, I. affinis, I. pacificus, I. minor, I. hexagonus*	Europe, North America
B. garinii	Birds	*I. ricinus, I. persulcatus, I. uriae*	Asia, Europe
B. mayonii	Rodents*	*I. scapularis*	North America
B. spielmanii	Rodents	*I. ricinus, I. hexagonus*	Europe

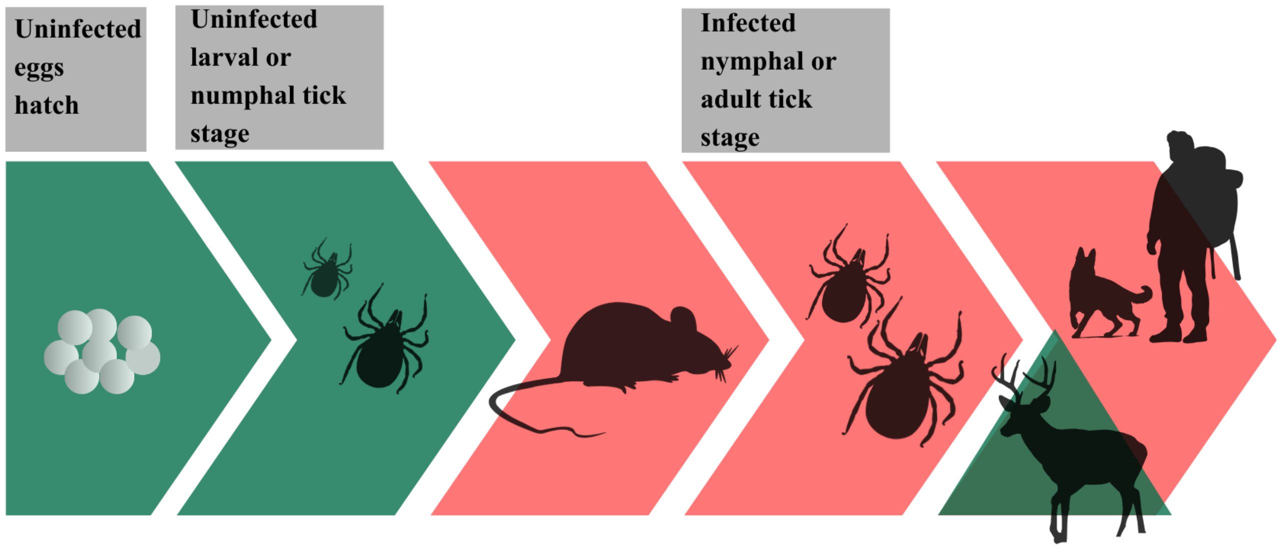
2.2.2 Vector ticks for *Borrelia burgdorferi*

The main vectors of the spirochete bacterium *Borrelia burgdorferi* in North America are *Ixodes scapularis* in central and eastern regions and *Ixodes pacificus* in western regions. In Canada, established *I. scapularis* populations now occur in the provinces of Manitoba, Ontario, Quebec, New Brunswick, and Nova Scotia, though there are several provinces and territories where these ticks are found, but not yet considered to be endemic (50). The *I. scapularis* tick species has a bimodal seasonal pattern of adult activity, with peaks in spring and fall, and a single peak of nymphal activity in the early to mid-summer (June-July) (51,52). The species completes its lifecycle over a period of two years and feeds upon multiple hosts throughout its lifecycle (53).

2.2.3 *Ixodes scapularis* lifecycle, and environmental & host ecology

Ixodes scapularis ticks transition (molt) through several stages from egg to larva, from larva to nymph, and from nymph to adult. These ticks seek bloodmeals from small or medium mammals, such as mice, chipmunks, or racoons in their larval and nymphal stages. In the adult stage, additional bloodmeals are sought from larger mammals (22,23). The most significant reservoir in the transmission of the LD-causing bacteria is thought to be the white-footed mouse (*Peromyscus leucopus*), which can pass *B. burgdorferi* to uninfected ticks during their bloodmeals (Figure 2.1) and is both a highly competent reservoir of *B. burgdorferi*, and abundant in landscapes with high risk of bacteria transmission to humans (24). In addition to the white-footed mouse, *I. scapularis* can acquire *B. burgdorferi* from other small wildlife hosts, including several rodent species, ground-foraging birds, and, in some regions, lizards. Vertical transmission of *B. burgdorferi* from infected female ticks to their offspring is negligible, therefore pathogen acquisition occurs during blood feeding on infected hosts. Ticks can also acquire the LD bacterium through co-feeding, a process in which the infected and uninfected ticks feed in close proximity on the same host (54). Recent studies have shown that ticks infected via co-feeding are highly infectious to rodents, when exposed to the *Borrelia afzelii* strain (one of the Lyme disease-causing genospecies) (55). White-tailed deer (*Odocoileus virginianus*) are the primary reproductive hosts of *I. scapularis* ticks; they do not contribute to the disease amplification cycle, as they are not suitable reservoirs for *B. burgdorferi*, however they do play an important role in the transportation and amplification of the reproduction cycle of ticks (25,26).

Figure 2.1: Transmission of *B. burgdorferi* from infected small mammal hosts to human host infection pathway

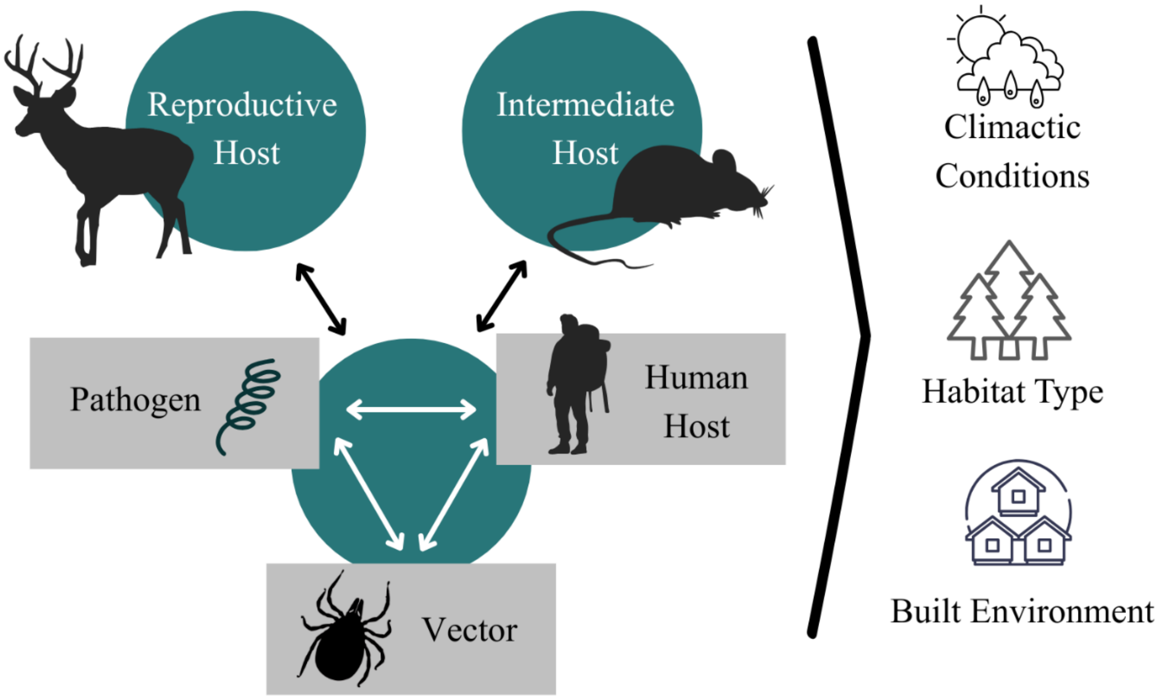


Green arrows indicate ticks or hosts that are uninfected, while red arrows represent those infected with *Borrelia burgdorferi*. Eggs hatch into larval ticks that seek small mammal hosts. When an uninfected larva or nymph feeds on an infected small mammal, it can acquire *B. burgdorferi* and retain the infection through subsequent nymphal and/or adult life stages. Infected nymphs or adults may then transmit the bacteria to incidental human hosts during feeding. In the final adult stage, ticks often feed on deer, which serve as important reproductive hosts but are incompetent reservoirs and do not become infected.

Furthermore, deciduous forests, which are common in Ontario and the greater Ottawa area, are important to the survival of ticks, as leaf litter, low vegetation, and shrubs help ensure protective conditions for *I. scapularis* ticks, as well as their wildlife hosts (27,28). It is expected that a combination of environmental suitability, landscape fragmentation, and a warming climate will continue to drive the expansion of tick populations northward (56). Additionally, a study on environmental suitability predicted that *I. scapularis* populations could continue to establish in more northern woodland types than their current environmental preferences suggest (57). Within the province of Ontario a recent modeling study identified high *I. scapularis* habitat suitability in eastern Ontario, with suitability in Southwestern Ontario, along the Great Lakes-U.S. border, as well as Kawartha region, and Georgian Bay; the predicted suitability for *B. burgdorferi* tick infection followed a similar pattern. These models were found to have strong performance when verified using active and passive surveillance techniques (58).

As demonstrated above, LD and other TBDs are shaped by factors which exist at different scales, from global climate change to local habitat and host features and recognizing this multi-level complexity is essential for designing effective prevention and control strategies (Figure 2.2). These factors shape not only where ticks can survive, but also the intensity and distribution of human activity and exposure, highlighting the need for prevention and control strategies that integrate climate, ecological, and social factors in alignment with One Health principles.

Figure 2.2: Multi-scale factors influencing the ecology and transmission of Lyme disease (adapted from Ostfeld, Richard S. *Lyme Disease: The Ecology of a Complex System*. Oxford University Press, 2011; page 6)



2.3: Lyme disease: description and risk factors

2.3.1 Clinical significance

Lyme disease in North America is caused by the spirochete *Borrelia burgdorferi* sensu stricto *(*s.s.*)* (2). The disease typically progresses through three clinical stages. The first stage, early localized LD, occurs 1–4 weeks after primary infection and is characterized by flu-like symptoms, with an erythema migrans (EM) rash appearing in 70–80% of cases (59). Early disseminated infection develops within 1–3 months of primary infection and may present with EM, limb pain and weakness, problems with concentration and memory, joint pain and swelling, and/or cardiovascular complications. Late disseminated LD, which occurs three or more months after initial infection, can persist for months or years and is associated with musculoskeletal and neurological complications affecting joints, nerves, and the brain (59). In Canada, from 2016 to

2019, 51% of cases were detected in early localized stages, 18.4% in early disseminated stage, and 30.6% in late disseminated stage, though the proportions varied throughout the provinces and territories, with Central provinces (Ontario) having an 3.5 higher odds of being diagnosed in late disseminated stage when compared to the Atlantic provinces (60).

2.3.2 Treatment and long-term prognosis

LD infection is treatable with oral antibiotics like doxycycline in its early stages, while intravenous therapy may be required when infection involves the central nervous system, heart, or joints (61). A meta-analysis of randomized control trials demonstrated that a single dose of antibiotics can be effective as post-exposure prophylaxis, reducing the risk of infection when administered within 72 hours of a tick bite (RR: 0.29, 95% CI: 0.14–0.60) (62). Despite generally effective treatment, a subset of patients experience persistent post-treatment symptoms, known as post-treatment Lyme disease syndrome (PTLDS) (63). Currently, no proven therapy exists for PTLDS, underscoring the importance of preventing initial infection (64). Furthermore, social determinants of health, such as lower socioeconomic status, reduced access to healthcare, and being a member of a racial minority, have been shown to be significantly associated with diagnosis of disseminated LD or complications arising from delayed diagnosis of LD infection in the United States (65–67).

2.3.3 Diagnosis and detection challenges

Standard laboratory diagnosis of Lyme disease (LD) uses a two-tier serologic algorithm: an initial, more sensitive ELISA (sensitivity of 54%; specificity of 97% in early LD stage) followed by a confirmatory Immunoblot (IgM/IgG) (sensitivity of 61%; specificity 97% in early LD stage) (68). During the first stage of LD infection a systematic review showed this testing ranges from 46.3%

sensitivity and increases to 89.7-99.4% in the second and third stages of LD infection, corresponding to the increase in specific antibodies in later infection stages (68). Although non-standard commercial assays are available, differing positivity thresholds and testing cutoff criteria can reduce reliability and risk misclassification. Lower specificity increases the likelihood of false positives, potentially inflating case counts, while lower sensitivity results in false negatives and missing an important proportion of true cases (69,70). Having appropriate diagnostics poses a major challenge to LD detection and subsequent treatment; these limitations underscore the importance of prevention while clinical research continues to refine diagnostic tools and strategies.

2.4 Risk factors, sociodemographic profile and measuring risk

2.4.1 Defining and measuring Lyme disease risk

Lyme disease risk factors have been studied extensively in the United States and to a lesser extent in Canada. Factors contributing to risk of Lyme disease infection are largely related to exposure to tick infested areas, or duration of tick attachment. Overall, incidence has been found to be higher in areas of the United States with higher proportions of White and more highly educated populations, who often live in more affluent communities, which is related to housing type and location (71). Housing type – specifically single family homes with larger property size – points to a connection between disease risk, land use, and land cover as higher-risk communities are more likely to be situated in areas with greater forest fragmentation due to residential expansion into natural areas and woodlands, placing residents at greater risk of LD infection (72). Odds of infection have also been shown to be higher amongst young children (0-5 years) and those aged 50-70 years, and among those living in rural, low-density population areas (73,74). Age is hypothesized to put individuals at higher risk of LD because of activities that increase contact with ticks (0-5 years) or reduced ability to detect and/or remove attached ticks (75). Pet ownership was also found to be positively associated with LD infection risk, given the potential to bring loose ticks into the home or into closer contact with their owners (73). Finally, occupational and recreational activities are associated with an increased incidence of LD, such as outdoor jobs, hiking, gardening, yard work, or playing outdoors (13). Several studies (76,77) point to a large proportion of cases being associated with high-risk activities such as play and yard or garden work in residential areas, which may increase the risk of tick exposure.

The nymphal and adult stages of the *I. scapularis* lifecycle represent the main periods of risk to humans and domestic animals. Notably, *I. scapularis* ticks in nymphal stages represent the greatest risk to humans as they are most active in the summer when people are outdoors. Furthermore, they are less visible and can go unnoticed more easily, with an average size of 2 mm (78). Studies in the United States found that bites from nymphal ticks were twice as likely to show signs of prolonged attachment when compared with adult stages (75,79). Tick bites are often painless, and *I. scapularis* ticks need to be attached to their host for an average of 24-48 hours to transmit *B. burgdorferi* to their host (80,81). As such, studies have found prompt tick removal to be an important factor in the prevention of LD transmission (82,83).

Risk of LD transmission in a given area can be measured in several ways (Table 2.3); and while modern studies most often opt to select a combination of measurements to evaluate LD and TBD risk, one of the mostly commonly used is by measuring the density of infected nymphs (DIN) or the density of infected ticks, defined as the density of host-seeking nymphs or ticks multiplied by the proportion infected with *B. burgdorferi*. This risk measure is useful, as it combines data for abundance of nymphs, or abundance of ticks of medical importance, with data on the likelihood of infection, which is a better predictor of LD incidence than either of these measures on their own (84,85). Furthermore, another available measure, number or frequency of self-reported tick bites, was found to underestimate the true risk of LD because many tick bites resulting in LD may go unnoticed (84). However it is important to note that the density of ticks, or density of infected ticks is not linearly correlated with Lyme disease risk, and one recent residential study in particular found that a 69% reduction in questing nymphs did not result in reduced numbers of tick bites or cases of LD at an individual scale, however these reductions do seem to result in reduced LD incidence over several years at the community level (84,86).

Table 2.3: Summary of indicators used to measure Lyme disease and tick-borne disease risk (87).

Measurement category	Description
Density of questing ticks	Density of questing: larvae, nymphs, adults, or a combination of stages per measurement unit (e.g. 100m^2)
	Questing tick encounter: larvae, nymphs, adults, or a combination of stages
Percent per plot	Percent of study ticks found per sampling plot: larvae
	Percent of study ticks found per sampling plot: nymphs
	Percent of study ticks found per sampling plot: adults
Infection prevalence in questing ticks	*Borrelia burgdorferi* infection prevalence in questing nymphs, adults, or a combination of stages
Acarological risk (density × prevalence)	Density of infected questing nymphs, adults, or a combination of stages
Infection prevalence in host or feeding ticks	*B. burgdorferi* infection prevalence in host (blood or tissue)
	Seroprevalence of host (e.g., anti-OspA antibodies following oral vaccination)
	B. burgdorferi infection prevalence in feeding: larvae, nymphs, adults, or a combination of stages collected from host
Host infestation metrics	Host infestation by larval, nymphal, adult, or a combination of tick stages: prevalence (number infested ÷ total hosts)
	Host infestation by larval, nymphal, adult, or a combination of tick stages: density (ticks per host, all hosts)

	Host infestation by larval, nymphal, adult, or a combination of tick stages: intensity (ticks per infested host)
Tick encounter or LD incidence in humans	Lyme disease cases in humans
	Lyme disease seroprevalence in humans
	Lyme disease incidence in humans
	Tick encounter (attached or unattached) in humans
	Tick bite (attached ticks only) in humans
Tick encounter or LD incidence in pets	Lyme disease cases in pets
	Lyme disease seroprevalence in pets
	Lyme disease incidence in pets
	Tick encounter (attached or unattached) in pets
	Tick bite (attached ticks only) in pets
Tick survival or fitness	Tick survival: percent larvae, nymph, adult, or a combination of tick stages surviving
	Tick fitness: fecundity and body mass (all stages)

Larval stage *I. scapularis* ticks are not implicated in LD risk to humans since there is no transovarial transmission of *B. burgdorferi.* However, larval abundance may serve as an indicator of local tick population establishment and future nymphal density.

2.5: Brief overview of Lyme disease prevention and control options

Tick and Lyme disease prevention and control options can be grouped into four main categories, or families, throughout this thesis; host-targeted interventions, environmentally applied interventions (chemical, natural alternative, or biological control options), landscape modification strategies, and personal protection measures, along with a fifth category of integrated interventions that combine elements across these domains (Table 2.4). In this section, I will briefly introduce these categories, as detailed descriptions and evaluations are provided in

Chapter 4 (objective 1). Clinical prevention strategies are not included in this thesis, as there are currently no widely available human vaccines or comparable clinical tools, though there are several currently in development. Due to this lack of available clinical options, there is an ongoing need to advance and assess the more "upstream" prevention efforts that rely on vector-targeted, environment, wildlife hosts, and behavioral interventions, or a combination of these options.

Table 2.4: Categories of Lyme disease and tick control strategies with examples of interventions

Category	List of possible activities and interventions
Host-targeted management of wildlife parasitism, infection, movement, and density	● Deer Management ○ Deer exclusion (fencing) ○ Deer reduction (culling; birth control) ○ Deer parasitism suppression (4-Poster [topical acaricide treatment], oral vaccine bait) ● Small mammal management ○ Rodent parasitism and pathogen infection suppression ■ Acaricide-treated nesting material ■ Bait boxes (deliver oral or topical acaricides, or prophylaxis) ○ Rodent reduction ○ Oral vaccine bait
Chemical insecticides, and natural tick control products applied to the environment	● Chemical control ○ Organophosphates ○ Carbamates ○ Pyrethroids ● Natural products ○ Botanically derived chemical alternatives ○ Natural enemies ■ Wolf spiders etc. ○ Biological agents ■ Entomopathogenic bacteria ■ Entomopathogenic fungi ■ Nematodes

Landscape management	• Vegetation clearing (e.g. Japanese barberry) • Vegetation burning • Barrier approaches (e.g. ecotone modification, substrates, woodchip borders, hardscaping))
Personal protection	• Community-targeted communication or empowerment involving: ○ Permethrin treated clothing/uniforms ○ Application of spray repellents to skin or clothing ○ Exposure and preventive behaviors or individual behavior changes ■ Habitat avoidance ■ Checking for ticks ■ Showering/bathing

2.5.1 Wildlife host-targeted tick and disease control options

Wildlife host targeted *I. scapularis* and *B. burgdorferi* control options can be divided into strategies focused on small mammals and those targeting white-tailed deer. The aim of small mammal-focused approaches is to reduce tick parasitism and pathogen infection prevalence in reservoir hosts, such as the white-footed mouse (*Peromyscus leucopus*), using tools like treated nesting materials or bait boxes containing treated nesting materials, or fipronil, fluralaner, permethrin, or antibiotic formulations (88–90). The effectiveness of these methods is heavily influenced by host abundance and movement and is influenced by the density and consistency of intervention placement (91,92).

White-tailed deer (*Odocoileus virginianus*) oriented prevention activities most often include the use of 4-poster devices, which use bait to encourage deer to put their heads through a set of rollers which apply a fipronil based acaracide treatment onto the fur of the deer. The goal of this device is to kill any ticks on the deer, as this is the reproductive host for *I. scapularis* (93,94). Other options include deer reduction (through controlled hunts, often using sharp shooting activities), or deer exclusion (deer fencing) (95–98). Deer population reduction is intended to decrease the availability of the primary host used by adult ticks during their final feeding and reproduction stage, while deer exclusion serves to keep deer from bringing ticks into areas with high human use patterns (99). Many targeted deer activities face controversy over ethical concerns and social resistance (18).

2.5.2 Environmentally applied chemical, natural, and biological control options

Environmentally applied strategies incorporate options that can applied as a spray or granular formulation with the aim of killing or repelling ticks in a defined area. These can consist of traditional chemical acaricides (such as synthetic pyrethroids and carbamates) which are highly effective at reducing questing tick populations (86,100). However, there is growing concern in communities about their unintended consequences for pollinators and other non-target arthropods, and the potential for acaricidal resistance in tick populations. Alternatives to these methods include naturally derived acaricides such as nootkatone (a compound derived from grapefruit and cedar), other essential oil mixes, or garlic concentrate (often sold as a spray to repel mosquitoes) (101–105). These are often thought to have lower toxicity to non-target species and have an advantage as many can be purchased and applied as a “DIY” solution by homeowners, but they often face issues with shorter residual activity periods, often requiring multiple applications timed to seasonal tick activity peaks (104,106). The final option in this control category is the use of biological control agents which include entomopathogenic fungi and bacteria, nematodes, or natural predators (107–110). These are often more environmentally sustainable and more specific to ticks or closely-related mite species, but can face challenges in finding the most effective dose, application method and application rate (106,107).

2.5.3 Landscape and environmental modification control strategies

Landscape and environmental modification control strategies include any activity which reduces or controls landscape habitats conducive to ticks and their wildlife hosts. These strategies are most often targeted to areas of higher human use, and most examples have been studied in a residential context. These activities can include what many people think of as standard yard maintenance like vegetation thinning, tree canopy management, lawn mowing, and leaf litter removal, which all serve to lower the microclimate humidity, reduce materials that ticks can actively quest on, and remove habitat for both ticks and small mammal hosts (111,112). Vegetation clearing and controlled burning can also serve similar purposes. Vegetation clearing can be chemical or manual, and usually targets patches of particularly tick-friendly species, such as the Japanese barberry (*Berberis thunbergii*) (113,114). Controlled burns are typically employed for other forestry management activities but can have a secondary effect of reducing tick abundance, though this effect appears to be temporary in most field and modelling studies (115–117). There are also hardscaping activities, such as ecotone modification, where the line between the forest and human use area (such as residential space, park, or trail) can be altered by placing a substrate such as woodchips or gravel (112,118). This targets transitional habitats where ticks are more likely to engage in questing activity and further helps delineate spaces into tick safe and tick risky habitat areas.

2.5.4 Personal protection strategies

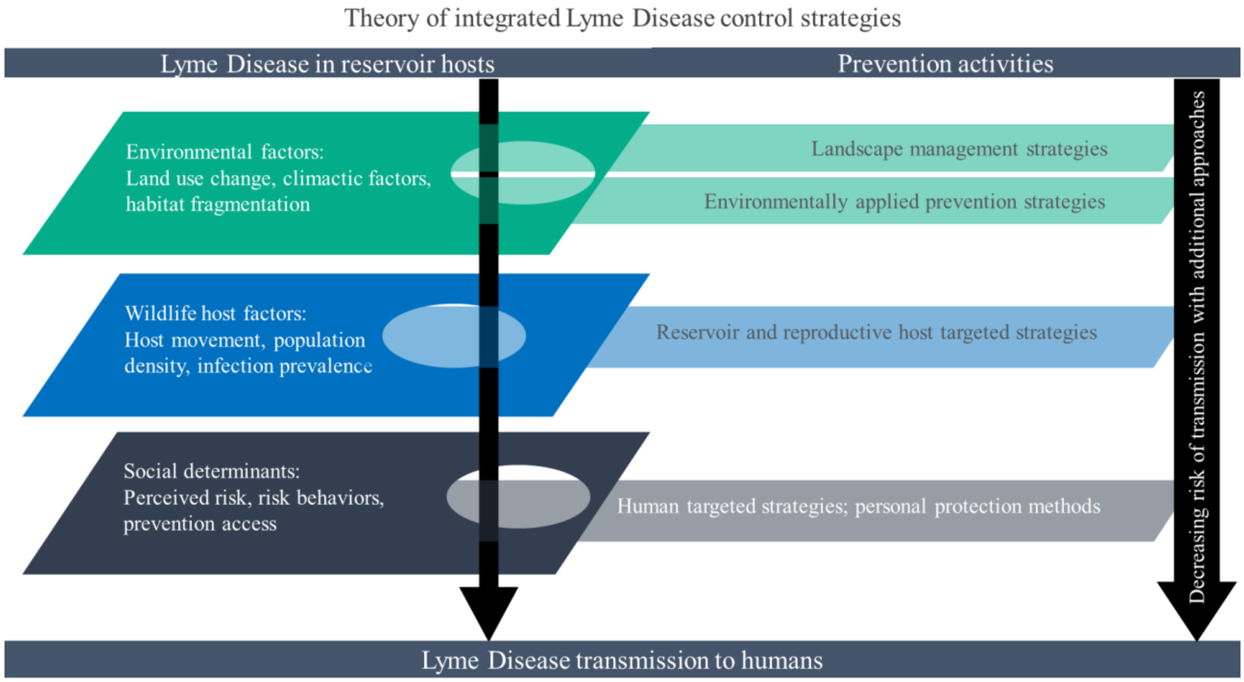
Personal protection strategies are often the target of many community campaigns to reduce TBD and LD. These strategies can broadly be split into two overarching goals; 1) to encourage people to use insect repellents on their skin and clothing (such as sprays containing DEET or icaridin), or permethrin-treated clothing, and 2) encouraging behaviours that reduce tick encounters or bites (119). The latter included measures such as wearing long pants and shirts, with pants tucked into socks, avoiding tick habitat and remaining in the center of trails and walkways, and checking for ticks on skin or clothing after time spent outdoors following by prompt removal of attached ticks (119). Additionally, showers and baths can help individuals detect attached ticks quickly or wash away ticks that are not yet attached to their skin. Together these strategies are consistently the most immediate and accessible strategies for individuals. The success of these options, as in many public health behaviour campaigns, hinges on individual and community risk perception, social norms, and overall knowledge as they depend on consistent use over time (120–123).

2.5.5 One Health oriented and integrated tick control strategies

Although individual tick and LD control strategies offer important strengths, each has limitations and none completely reduce risk in a way that meets the criteria of being feasible, acceptable, and effective. Therefore, combining strategies in these categories is a more effective way to reduce LD risk in human populations. LD and tick control strategies are increasingly being framed within a One Health lens, recognizing the interdependence of human, animal, and environmental health. The One Health High-Level Expert Panel (OHHLEP) defines One Health as “An integrated, unifying approach that aims to sustainably balance and optimize the health of people, animals, and ecosystems. It recognizes the health of humans, domestic and wild animals, plants, and the wider environment (including ecosystems) are closely linked and interdependent” (124) . In the context of TBDs, this framework is particularly relevant, as transmission dynamics are shaped by interactions between wildlife hosts, vector ecology, climate, land use, and human behaviour. This approach supports the integration of control strategies, while also accounting for social acceptability, ecological sustainability, and long-term feasibility.

Integrated LD prevention and tick control approaches may combine multiple interventions within a single category (e.g. combining multiple personal protection strategies at an individual level or multiple forms of landscape management) or they can span several tick and LD control categories (e.g. combining a chemical control strategy with one or more wildlife host control strategies) (11,13). These types of interventions align with a One Health perspective, which emphasizes that effective control requires coordinated action that addresses human, animal, and environmental factors (Figure 2.3). Furthermore, integrated approaches are recommended as tick abundance and population dynamics can vary considerably within and between regions due to fine-scale environmental variations. Consequently, single interventions rarely result in reliable reductions in LD risk across different ecological contexts, even within relatively small areas. Though integrated strategies tend to be more consistent and successful, they require a greater level of stakeholder collaboration and can face additional feasibility and sustainability challenges.

Figure 2.3: The theory of integrated Lyme Disease control strategies through a One Health lens, adapted from layered defense models (125).



2.4.1 Clinical prevention options

There are several human clinical prevention options currently in development. There is currently a human vaccine (VLA15) in Phase 3 clinical trials, however its uptake will depend on the social factors discussed previously such as perceived LD risk (balanced against perceived LD vaccine risk), public trust, cost, and ultimately the establishment of safety and efficacy data (126–128). Additionally, there is a tick pre-exposure prophylaxis treatment in Phase 2a trial, which is an oral treatment that aims to kill ticks that attach to humans (129). Currently available, there is a post-exposure prophylaxis option that can be taken when a tick bite is detected (where the tick has likely been attached for over 24 hours) to reduce the likelihood of LD transmission, however it depends on the individual to detect the tick bite in the first place, and to be aware of the prophylaxis option which needs to be taken within 72 hours of the bite (130). Finally, there is ongoing research on improving diagnostics and early detection which would support treatment in the early phase of LD, particularly if there is no erythema migrans to prompt an individual to act. Having more streamlined detection options would help physicians in screening LD out as a possible cause of vague patient symptoms (131). All these options will be instrumental in individual-level prevention but will not replace the more upstream activities described in this section.

Overall, the complexity of LD and vector tick ecology, surveillance and risk ascertainment, combined with the limitations in current clinical prevention, diagnosis, and treatment options reinforce the need for adaptable, locally tailored tick and tick-borne pathogen control strategies. Proactive, upstream interventions that integrate human, animal, and environmental considerations offer the most promising strategy to combat this issue.

3. Methods

Overview

This chapter provides an overview of the methodological approach in this thesis and situates the three research objectives within a One Health framework. While each study is presented in detail in subsequent chapters, this section offers additional context on study design choices, and sampling strategies. The three thesis objectives were designed to be complementary, reflecting the complex landscape of tick and LD control. The systematic review synthesized evidence on the effectiveness and utility of prevention strategies across several geographic, environmental, and social settings, providing a foundation for the subsequent objectives.

The systematic review (Objective 1) evaluated the effectiveness and utility of LD prevention measures in Canada, the United States, and Europe. The methodology for this review is fully described in Chapter 4 and in the corresponding registered protocol (PROSPERO: CRD42022335612). All materials used during screening, data extraction, and quality assessment were included in the manuscript appendices, ensuring transparency and reproducibility.

The experimental field study conducted in Ottawa's Greenbelt (Objective 2) explicitly tested an integrated environmental intervention, ecotone modification using untreated woodchips, deltamethrin-treated woodchips, and untreated control trail segments, in a peri-urban recreational setting in Ottawa, as a strategy for reducing tick density along high use, high tick density trails. The design of the field study was informed by a previous one-year pilot study by McKay et al., 2020, but was implemented over two study years, with extended sampling periods and multiple trail sites to improve temporal and spatial coverage(118).

Finally, Objective 3 situated the interventions examined in the first two objectives using an acceptability lens in a local context, addressing considerations that cannot be captured through effectiveness measures alone, while complementing some of the utility aspects of Objective 1. The study followed a sequential mixed methods approach. Qualitative data were collected through semi-structured interviews, allowing the study to address predefined research questions while retaining flexibility for participants to raise issues they felt were important. Qualitative reflexivity: The interviewer was a female, able-bodied PhD student working in the field of tick control and LD prevention. This positionality informed the interpretation of the data by bringing subject matter expertise to the analysis, while reflexive practices were used to ensure that participant perspectives remained central to the analysis. Findings from the qualitative data analysis informed the development and refinement of a survey tool which was distributed to a geographically stratified quota sample of the Ottawa public. These geographic strata were informed by previous local research linking landscape and environmental characteristics to tick density and LD risk patterns in the Ottawa region (43,132,133); and were intended as practical proxies for potential ecological and exposure risk. Survey-based acceptability outcomes were analyzed using logistic regression models to examine associations between intervention categories and the likelihood of high vs. low acceptability scores.

Across all of the thesis objectives, this research is grounded in a One Health perspective, recognizing aspects of human, animal, and environmental conditions that shape LD risk. The systematic review evaluated interventions across all the One Health domains, while the experimental field trial targeted the tick hazard component of LD risk that influences human-tick encounters, and the mixed-methods study captured the social and human factors that influence the success of interventions. When combined, this reflects a balanced, and context appropriate approach to LD and tick control approaches.

Conclusion

Together, the three methodological approaches used in this thesis were designed to address complementary components of LD prevention using a One Health framework. The systematic review synthesized evidence on the effectiveness and contextual reporting of intervention strategies spanning environment, human, and animal intervention targets and outcomes. The environmental field trial produced local evidence on the effectiveness of selected interventions in a peri-urban recreational setting. Finally, the mixed-methods study examined the acceptability and feasibility of these interventions in a local context. This integrated design allowed for the triangulation of data on effectiveness, feasibility, and acceptability across a range of intervention options in order to inform future interconnected One Health systems and interventions appropriate to a local setting.

4. A systematic review of the effectiveness and utility of Lyme disease prevention measures in Canada, the United States, and Europe (Objective 1)

Article Preface

The following article was developed through a collaborative effort between the University of Ottawa INSIGHT lab, Université de Montréal, the Public Health Agency of Canada systematic review team, and the Canadian Lyme Disease Research Network (CLyDRN) Innovation Working Group. Within the context of my thesis, this work contributes to advancing knowledge on vector tick and Lyme disease (LD) control options by synthesizing evidence on several intervention approaches. The systematic review also forms a foundational component of my broader research framework, which is focused on evaluating and implementing holistic, integrated, and One Health oriented solutions to the problem of LD emergence in Canada.

My specific contributions to this article include drafting the study protocol and screening materials, leading all phases of data screening and extraction, as well as the analysis and interpretation of findings. I also provided training to several team members involved in the review process, conducted primary data analysis, and was responsible for drafting the initial manuscript and responding to subsequent rounds of revision.

One of the key methodological challenges encountered in this work was the inability to perform a traditional meta-analysis due to the heterogeneity in study designs and reported outcomes. To address this, we developed an alternative approach that enabled interpretation of intervention effectiveness data in a manner that was less statistically robust but still provided meaningful comparability across intervention groups. This methodological adaptation represents one of the core contributions of the study and highlights the needs for context-appropriate approaches when synthesizing complex and heterogeneous evidence.

Because this systematic review only involved secondary data, and did not involve any human subjects, ethics approval was not required to complete this research.

Author contribution statement:

K.O. wrote the main manuscript text and prepared all figures and tables. K.O., A.D., T.C., L.W., K.Z., J.P.R., C.B., C.A., and M.K., were involved in the conceptualization and methodology for this project. K.O., M.N., A.D., R.S, C.D., and O.F., were responsible for the analysis. A.K., C.F., and M.K. supervised the project and contributed to the conceptualization. All authors reviewed and edited the manuscript.

Ethics approval: Not applicable, use of secondary data only

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Article Content

Title: A systematic review of the effectiveness and utility of Lyme disease prevention measures in Canada, the United States, and Europe

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Abstract:

Background: This systematic review aimed to assess the effectiveness of interventions which reduce human-tick encounters, prevent tick bites, and reduce the risk of *Borrelia burgdorferi* transmission, and to evaluate knowledge on the cost, environmental impact, social impact and acceptability, and public health impact of these interventions.

Methods: The search was conducted in Medline, Embase, Global Health, CAB Abstracts, Cochrane CENTRAL, Scopus, and Econlit for relevant literature in March 2022 and was updated in November 2024 and followed PRISMA guidelines for systematic reviews. Inclusion was applied at citation and full text, after which articles were assessed for risk of bias and data was extracted by two independent reviewers. Studies were summarized by intervention type (landscape management, host animal parasitism and movement, chemical/natural/botanical applications, personal protection) and a multi-study synthesis of tick suppression effects was conducted for interventions that reported the density of infected nymphs as the primary outcome.

Results: One hundred and twenty-seven studies published between 1977 and 2024 were included in this systematic review. Most studies (n=62) were classified as host-targeted interventions. Twenty-five studies were included in the multi-study synthesis of tick suppression effects, which suggested that chemical tick control methods are the most effective and consistent intervention type with 93.8% mean suppression of questing nymphs.

Conclusion: While some strategies such as chemical acaricides were shown to have greater effectiveness, factors such as social acceptability and resistance, environmental impact, cost, and feasibility should be considered when selecting the most appropriate intervention to maximize the utility of the intervention.

1. Introduction:

LD is the most common vector-borne disease in the northern hemisphere with the risk of transmission to humans intensifying and expanding as vector tick populations for *B. burgdorferi* spirochetes expand their geographic range (1–4). Lyme disease (LD) is caused by several bacterial genospecies belonging to the *Borrelia burgdorferi* sensu lato (s.l.) complex, including *Borrelia burgdorferi* sensu stricto (s.s.), *Borrelia mayonii*, *Borrelia afzelii,* and *Borrelia garinii, (B. burgdorferi)* that are transmitted to humans by several species of *Ixodes* ticks found in the Northern Hemisphere, particularly in the North America (primarily United States and Canada), Central and Eastern Europe, as well as Asia (including parts of China, Japan, and Russia) (5). In its early stage, LD is associated with febrile illness and rash which, if untreated, may progress to neurologic and myocardial abnormalities (6). Untreated patients with late-stage symptoms may present with arthritis and chronic central nervous system abnormalities, which may also manifest after clinically successful treatment of the early stage (6). Changing climactic conditions along with factor such as urbanization, landscape fragmentation, and population growth have contributed to this increasing risk of disease transmission in recent years (7–11).

In North America, including Canada, LD is primarily caused by the genospecies *Borrelia burgdorferi* sensu stricto (s.s.) (12). The main vector ticks of the *B. burgdorferi* spirochetes in North America are *Ixodes scapularis* and *Ixodes pacificus* (12). Across Canada, active and passive surveillance efforts have revealed variations in the distribution of the two species: *Ixodes scapularis* is found primarily in central and eastern Canada, while *Ixodes pacificus is mainly confined* to British Columbia (13). In the United States, current data indicate that *Ixodes scapularis* is widely established across all four cardinal regions, whereas *Ixodes pacificus* is predominantly reported in the Pacific Coast states (14). The incidence of LD in Canada has increased to 8.2 cases per 100,000 people in 2021 from 0.8 cases per 100,000 in 2011; with the majority of these cases (95.6%) from the provinces of Ontario, Nova Scotia, and Quebec (15). The incidence of LD in the United States was 18.8 per 100,000 in 2022 after the implementation of a new (more sensitive) case definition, and LD incidence is primarily focused in the Northeast and parts of the Midwestern region of the country. In both Canada and the United States, there is significant under-reporting of LD due to i) under-ascertainment, and ii) under-diagnosis (16,17). *Ixodes scapularis* and *I. pacificus* complete their life cycle over two and three-year periods, respectively (18). *Ixodes scapularis* ticks, the primary vector of interest, seek bloodmeals from small or medium-sized mammals or birds, in their first two life stages, with the white footed mouse (*Peromyscus leucopus*) often considered as the primary reservoir of *B. burgdorferi*. Adult *I. scapularis and I.ricinus* ticks actively seek out their primary reproductive host, the white-tailed deer in North America (*Odocoileus virginianus)* and roe deer (*Capreolus capreolus*) in Europe which play an important role in the establishment and growth of tick populations (19). Forested areas with deciduous trees and higher levels of leaf litter, or low-lying vegetation and shrubs, promote the survival of vector ticks and constitute suitable habitats for many of their wildlife hosts, such as deer, small mammals, and birds (20,21). Furthermore, ecotones between forested areas and other habitat types have been identified as high-risk areas for tick-host interactions (22).

The complex ecology and life cycle of the vector tick and the bacteria causing LD calls for a diverse and multifaceted approach when it comes to controlling LD spread and transmission. Existing strategies can be broadly divided into four approaches: 1) landscape management; 2) host-targeted management of wildlife parasitism, infection, movement, and density; 3) chemical insecticides, biological control agents, natural tick control products applied to the environment; and 4) personal protection methods. With increasing rates of LD in Canada, there is a need for efficacious and locally relevant control strategies for both the LD bacterium and its vector. Furthermore, there is increasing evidence to support the use of multiple strategies in an integrated approach to tick control and LD transmission, despite there being relatively few studies on these combined approaches (23).

Landscape management strategies aim to reduce landscape features which either support the growth of tick populations (like invasive barberry and deep leaf litter), or successful tick questing opportunities (such as long grasses and other low-lying shrubs) (24). Landscape management can consist of strategies feasible and accessible to many home and property owners such as mowing long grasses and leaf litter removal, or more involved strategies such as woodland ecotone modification using substrates, controlled burns, or vegetation clearing using manual or chemical strategies (24).

Chemical insecticides, biological control agents, and naturally derived tick control products are typically applied to the environment in areas of tick habitat. Chemical insecticides like organophosphates, carbamates, and pyrethroids have been successfully applied in many vector control research studies in the past and present (24), however due to concerns on environmental sustainability and their impact on non-target species, there is growing demand for natural alternatives (25). Biological control and natural products include many plant-derived products such as garlic (Mosquito Barrier ©) and Alaskan cedar (Nootkatone) (26). Other control measures are natural or biological control agents such as entomopathogenic fungi, bacteria, and nematodes (26). Both plant-derived products, and biologic agents are either used to reduce tick survival or fitness to quest for a bloodmeal and reproductive capabilities (27). Additionally, there have also been some studies examining the impact of natural predators, namely wolf spiders *Lycosidae spp.* on tick activity and survival (28,29).

Strategies that incorporate host-targeted management of wildlife parasitism, infection, movement, and density can function through several pathways. These strategies can reduce tick population density through targeting their primary reproductive hosts, white-tailed or roe deer (*Odocoileus virginianus or Capreolus capreolus* respectively), with products aimed to kill attached ticks, reducing the number of ticks that successfully reproduce. Host-targeted strategies often use bait methods, such as 4-Poster devices that allow deer to self-treat with topical acaricide while feeding at the device (30). For rodent reservoirs, primarily the white footed mouse (*Peromyscus leucopus*), strategies often utilize bait boxes that deliver oral or topical acaricides to small mammals that cause/induce mortality in attached ticks (31,32). Treated nesting materials are often used in studies to reduce tick abundance on small mammals, accomplished through permethrin-treated cotton placed in cardboard applicator tubes referred to as tick tubes. This cotton material is collected by rodents and brought back to their nests, allowing for the transfer of a topical dose of acaricide, killing ticks that are present in the nesting environment (32). Additionally, there are some approaches in this category that reduce enzootic transmission without impacting tick populations through prophylaxis treatments (such as doxycycline) or vaccination (oral or injectable) of small mammal reservoirs. Finally, restriction of host movement or host reduction strategies target deer using fencing to restrict deer movement through areas where humans often encounter ticks such as gardens and personal property. Other host reduction strategies are often accomplished through controlled hunting programs for white-tailed deer (26).

Personal protection strategies consist of actions taken on an individual level to protect oneself from either tick encounters, tick bites, or disease transmission. These include measures such as avoiding tick habitat areas, checking oneself for ticks after time spent outdoors, making certain clothing choices, or using a government-approved insect repellent effective on ticks (e.g. icardin or DEET) designed for use on either an individual's skin or clothing (33).

In North America, most research to date on LD and its associated tick vectors has been concentrated in the Northeast United States. While many environmental and ecological factors that are suitable for the establishment of tick populations are comparable between the Northeast United States and Eastern Canada (34), there are some differences in policy and public acceptability that need to be considered when implementing novel tick control strategies, specifically regarding control of wildlife populations, and environmental acaricide application (25). The objective of this systematic review was to perform a comprehensive assessment of the effectiveness of interventions, in countries where there is known transmission of LD, that are most applicable to a Canadian setting (i.e. most similar host animals) which reduce human-tick encounters, prevent tick bites and reduce the risk of LD and to evaluate the current state of knowledge on the economic cost, environmental impact, social impact and acceptability, as well as public health impacts of these interventions. This assessment will identify which global interventions have been shown to be effective and where knowledge gaps exist to inform LD and tick control options that may be applicable to both the natural and political environment in Canada.

2. Methods:

This systematic review adheres to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses for systematic reviews (PRISMA) (35). The protocol was developed *a priori* and is registered with PROSPERO: CRD42022335612.

2.1 Review question and eligibility criteria

The primary objective of our review was to address the question: "What is the effectiveness of interventions to reduce human-tick encounters, prevent tick bites and reduce the risk of LD in a global context, that are most applicable to a Canadian setting?". The secondary objective was to evaluate the current state of knowledge on the economic cost, environmental impact, social impact and acceptability, as well as public health impacts of these interventions. Articles included in the data extraction phase met the following inclusion criteria: 1. Studies focused on LD bacteria vector ticks (ticks who are competent vectors of *Borrelia burgdorferi* (s.l.) or LD focused interventions (including landscape management, management of host parasitism and movement, chemical/biological/natural control agents, or community or population level interventions aiming at increasing personal protective behaviors)), 2. Were written in French or English languages, and 3. Were published in any year.

We excluded case reports, case series, and single-cross-sectional study designs to increase the robustness of causality hypothesis and clearly attribute the risk reduction to the intervention via temporality. Studies that were conducted in a laboratory setting and were not field applied were excluded from the study to optimize our results for interventions that have been field tested. We also excluded LD interventions that did not focus on wildlife hosts applicable to the Canadian context (i.e. wildlife hosts not found in Canada such as lizards), or which only addressed LD prevention in livestock or domestic animals and did not also have an aim of protecting human populations in their proximity. Finally, we excluded studies that medically or pharmaceutically targeted human populations to prioritize upstream prevention activities that aimed to reduce environmental tick indices or *B. burgdorferi* bacterial infection rates in ticks or reservoir hosts, or activities to reduce human-tick encounters or promote the detection and removal of encountered/attached ticks.

2.2 Search strategy

The search strategy was developed in consultation with librarians from the University of Ottawa and the Public Health Agency of Canada and was implemented in March 2022 and updated in November of 2024. We completed our electronic query of seven databases including Medline, Embase, Global Health, CAB Abstracts, Cochrane CENTRAL, Scopus, and Econlit using the following general keywords: tick*, Ixodes scapularis, Ixodes pacificus, Ixodes ricinus, blacklegged tick, deer tick, tickborne disease*, tick bite, Lyme Disease, LD, Borrelia burgdorferi, Borrelia mayonii, intervention*, implementation, control program*, control practice*, tick reduction. The detailed search strategy can be found in Appendix 8.1.1. We verified our search strategy using backwards and forwards citation searching as well as reviewing the citations of previous relevant systematic reviews. We used Covidence, a systematic review management application to review studies and remove duplicates (36).

2.3 Selection of studies

Studies identified through the search algorithm were imported into Covidence, where the reviewers (KO, MN, AD, CD, OF, TC) then assessed the relevance of each title and abstracts followed by full texts in duplicate to verify that each article met the inclusion criteria using a predefined and piloted screening tool (Appendix 8.1.2). Any discordance in the inclusion or exclusion of studies was discussed among all reviewers and if no consensus was reached an additional reviewer was consulted. The screening tools are outlined in detail in Appendix 8.1.2.

2.4 Study characteristics and data extraction

We developed the extraction form *a priori* in Covidence which was then independently tested by all reviewers. Data were extracted from the included studies in Covidence and verified by a second reviewer. Conflicts were reviewed as a team to achieve consensus. We extracted data on descriptive characteristics of the study (title, author, year, location of study, targeted tick species and/or *B. burgdorferi* bacteria, intervention setting, type of intervention (Table 4.1), and outcome measures associated with intervention effectiveness, such as reduction of questing ticks, or reduced infection prevalence in hosts or ticks etc.) and key information on the feasibility, impact, and acceptability of interventions along with any cost effectiveness data available (Appendix 8.1.2).

In addition, we captured data on integrated tick control approach implementation if applicable, whether implicitly or explicitly. This was defined as a study that used multiple tick control products or approaches within or between intervention classifications.

Table 3.1: Classification of different tick control strategies

Landscape management	**Host-targeted management of wildlife parasitism, infection, movement, and density**

● Vegetation clearing (e.g. Japanese barberry)
● Vegetation burning
● Barrier approaches (e.g. ecotone modification, substrates, woodchip borders, hardscaping))
	● Deer Management
	  ○ Deer exclusion (fencing)
	  ○ Deer reduction (culling; birth control)
	  ○ Deer parasitism suppression (4-Poster [topical acaricide treatment], oral vaccine bait)
	● Small mammal management
	  ○ Rodent parasitism and pathogen infection suppression
	    ■ Acaricide-treated nesting material
	    ■ Bait boxes (deliver oral or topical acaricides, or prophylaxis)
	  ○ Rodent reduction
	  ○ Oral vaccine bait

Chemical insecticides, and natural tick control products applied to the environment	**Personal protection (at a community or population level)**

● Chemical control
  ○ Organophosphates
  ○ Carbamates
  ○ Pyrethroids
● Natural products
  ○ Botanically derived chemical alternatives
  ○ Natural enemies
    ■ Wolf spiders etc.
  ○ Biological agents
    ■ Entomopathogenic bacteria
    ■ Entomopathogenic fungi
    ■ Nematodes
	● Community-targeted communication or empowerment involving:
	  ○ Permethrin treated clothing/uniforms
	  ○ Application of spray repellents to skin or clothing
	  ○ Exposure and preventive behaviors or individual behavior changes
	    ■ Habitat avoidance
	    ■ Checking for ticks
	    ■ Showering/bathing

2.5 Multi-study synthesis of nymphal tick suppression effects

Recognizing the wide heterogeneity across studies in terms of design and reporting of outcomes that limited our potential to undertake a meta-analysis, we performed a multi-study synthesis on a subset of studies that reported on the most commonly occurring outcome type, density of questing nymphs, that spanned a breadth of intervention types. This was determined after data extraction was complete. Studies were included if they contained comparable information with regards to two main criteria: (1) timing of the measurements (post-intervention), and (2) density calculations (performed per distance in m^2, rather than density per time unit). This was done to ensure the results between included studies were comparable in terms of the reported effect size. We organized the primary outcome synthesis results into five intervention groupings (chemical acaricide, natural acaricide, deer fencing, 4-Poster devices, and tick tubes) (Table 2) ensuring each category had at least two studies which met the inclusion criteria. In assessing studies and outcome measurements for inclusion, we accounted for differences in intervention timelines which typically vary by intervention type (i.e. our time-range for synthetic or natural acaricides (9-15 days vs 14-21 days post application respectively) differs from host-targeted interventions which have a much longer time of treatment or post-intervention time lag before effectiveness of the intervention on nymphal tick suppression can be measured (deer fence 1 year, 4-Poster 4 years, tick tubes 1-2 years)).

2.6 Risk of bias appraisal and certainty of evidence for multi-study synthesis

For the muti-study synthesis based on a subset of comparable studies, we performed a risk of bias assessment using ROBINS-I and ROB 2.0 for non-randomized studies and randomized control trials, respectively (37,38). These are preferred tools to be used in Cochrane reviews for non-randomized and randomized studies to evaluate comparative effectiveness of interventions, they are primarily designed for healthcare studies but are readily adaptable to other contexts (38,39). This was followed by an appraisal of the certainty of the evidence using GRADE (Grading of Recommendations, Assessment, Development, and Evaluations), for the outcomes in our data synthesis and summarized in a GRADE table (40,41). The GRADE tool is also a preferred tool for Cochrane reviews to evaluate the certainty of the evidence using a validated domain-based tool that considers study design, risk of bias, publication bias, as well as the inconsistency, indirectness and imprecision of included effect estimates (42). These appraisal tools help to assess limitations of the studies included in systematic reviews and inform interpretation of the strength of review conclusions (35). All tools were pretested by all reviewers prior to proceeding with appraisals performed by a single reviewer and verified by a second. All conflicts were resolved between reviewers; if consensus was not achieved, a third reviewer was included in the discussion to achieve consensus.

2.7 Multi-study synthesis analysis

For the multi-study synthesis on a subset of comparable studies, where necessary we calculated a percent reduction estimate for those studies that did not already provide one, and which had results available for before and after intervention implementation at comparable time points. We completed the multi-study synthesis of tick suppression effects in Excel as an overall summary of the various effect sizes by summarizing the data in a forest plot using percent reduction in density of questing nymphs as the most comparable outcome present in the literature.

$$Percent\ reduction = \left[\frac{pre\ intervention\ density - post\ intervention\ density}{pre\ intervention\ density}\right] * 100$$

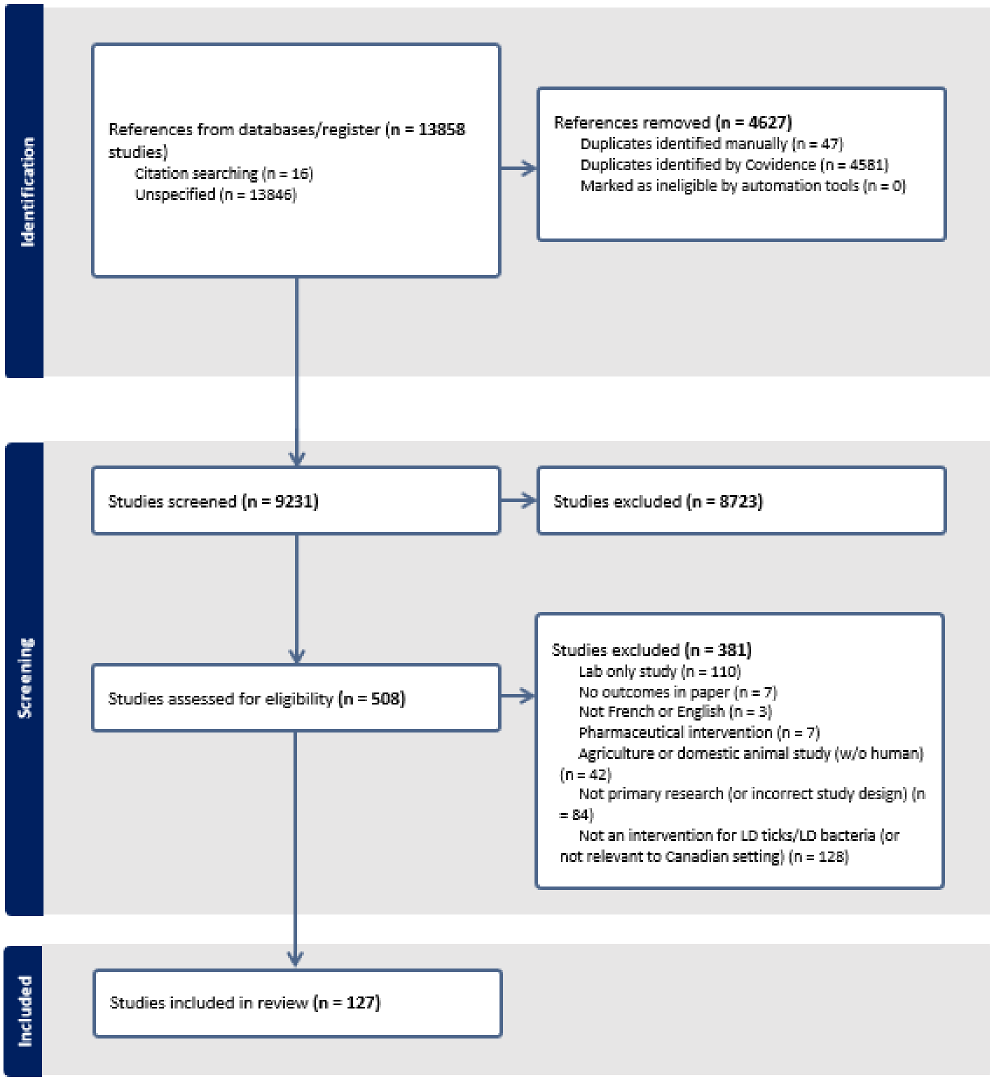
Since 95% confidence intervals for percent reduction or percent change are not often presented in the literature, we only used effect sizes in our synthesis to best reflect the data available in the literature. The risk of bias and GRADE tools were used by the team to inform the overall confidence in the evidence for the main outcome of interest to evaluate effectiveness. For other outcomes a narrative synthesis was performed, and effectiveness outcomes were tabulated in Table 2 using study by study conclusions on effectiveness at a $p<0.05$ level.

3 Results:

3.1 Characteristics of included studies:

Our search strategy identified 9,231 studies which were screened for relevance. A total of 127 studies were deemed eligible for inclusion in the main review, data extraction and risk of bias assessment (Figure 4.1). Included articles spanned the years 1977 to 2024 and were all written in English. Most of the studies used an experimental study design (n=120) followed by observational (n=6) and mixed methods (n=1) study designs (Table 4.2). Most studies were conducted in North America (n=114), of which only four studies were from Canada and the rest were from the United States (43–46). The remaining 13 studies were conducted in Europe (47–59).

Figure 3.1: PRISMA diagram for selection of relevant articles for data extraction



Most studies targeted LD vector ticks, either in the environment or on parasitizing wildlife hosts (n=94), rather than the bacteria (n=6) or a combination of the two (n=28). The majority of the studies were focused on reducing LD vector ticks or bacteria via host targeted strategies (n=62), followed by environmentally applied acaricides (chemical and naturally derived options, n=49), landscape targeted intervention studies (n=21), and personal protection strategies (n=7). Some of these studies crossed multiple classifications using integrated intervention strategies so the total N does not equal 127 studies (Figure 4.2).

Figure 3.2: Descriptive characteristics of the included studies (N=127)

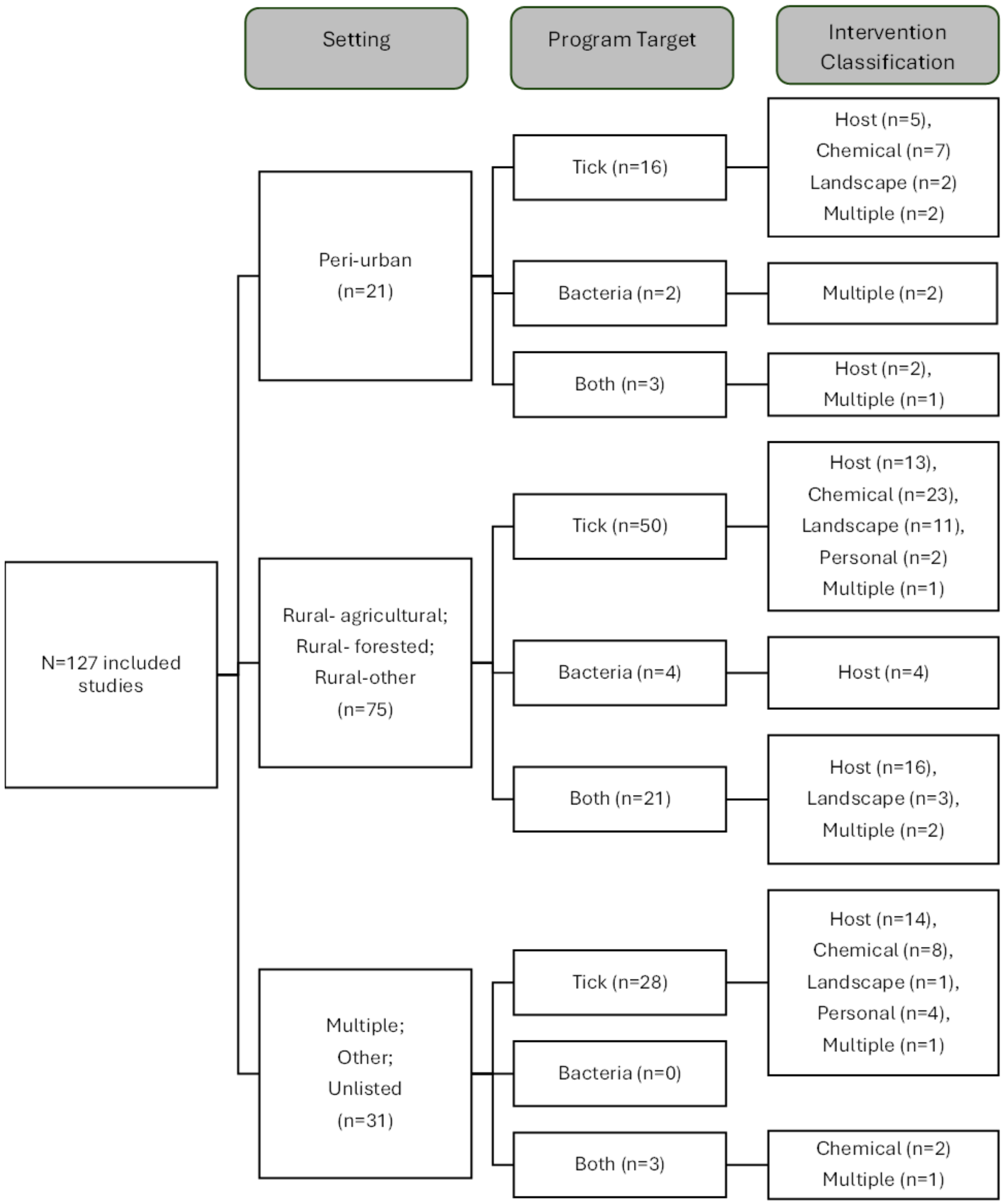


Figure 4.2 legend: Program targets include 'Tick' defined as programs which aim to reduce or repel LD vector tick species, 'Bacteria' is defined as programs which aim to eliminate or reduce bacteria amplification or transmission, and 'Both' which are programs that target both LD vector

ticks and bacteria simultaneously. *Chemical studies include the study classification of chemical and natural control interventions. **Multiple classification includes integrative studies spanning multiple classification types, see Table 1 for more information on classifications.

Of the included studies, 107 measured at least one entomological outcome (e.g. questing tick density, tick infection prevalence, etc.), of which 84 reported reductions in questing tick density, while 45 included at least one host-related outcome (e.g. host parasitism or *B. burgdorferi* host seroprevalence, etc.) and 12 investigated other outcomes such as qualitative or human outcomes.

3.2 Primary objective: effectiveness for all study types and outcome measures

Studies featuring chemical strategies had the greatest proportion of effective strategies (91%) according to study results and conclusions reported by the authors. Amongst host targeted strategies, deer targeted 4-Poster strategies had the greatest proportion of studies that reported effective strategies (89%) when compared to tick tubes, oral treatments and deer exclusion or deer reduction (Table 4.2). Host and landscape targeted strategies had the most variation in reported effectiveness with 16% with no effectiveness and 23% with mixed effectiveness within the host targeted strategies, and 25% with no effectiveness and 25% mixed effectiveness in landscape targeted strategies (Table 4.2). Information on the study-by-study effectiveness results, and the various included outcome types for all 127 studies can be found in Appendix 8.1.3.

Table 3.2: Overall effectiveness of the included study outcomes (all types) by intervention categories, according to authors' study conclusions (informed by outcome significance p-value <0.05)

Intervention	**Overall effectiveness of the program on all outcomes available in study** (questing ticks (any stage), host or human parasitism, tick mortality, or entomological/ etiologic risk)*	**List of studies included, and design** Experimental (non-RCT)** Experimental (RCT)[a] Observational [b] Other [c] ***All un-annotated studies are non-randomized experimental design*
Management of wildlife host parasitism, movement, and density		
Tick tubes	Yes	Mather 1988, Mejlon 1995, Tiffin 2024
	No	Leprince 1996, Hornbostel 2005
	Mixed results	Mather 1987, Daniels 1991, Stafford 1991
Bait box	Yes	Lane 1998, Dolan 2004, Barrile 2005, Dolan 2011, Schulze 2017, Pelletier 2022
	No	Hinckley 2021[a], Pelletier 2024
	Mixed results	*No studies applicable*
4-Poster	Yes	Solberg 2003, Carrol 2009 (1)[a], Carrol 2009 (2), Daniels 2009[b], Hoen 2009, Miller 2009, Schulze 2009, Stafford 2009
	No	*No studies applicable*
	Mixed results	Greer 2014
Deer or rodent removal	Yes	Delinger 1993[b], Wilson 1998
	No	Jordan 2007, Kiran 2024[a]
	Mixed results	Stafford 2003, Rand 2004, Martin 2023[b]
Oral antibiotic treatments/ Oral or injection host vaccine/ Other	Yes	Tsao 2004, Richer 2014, Contreras 2020[a], Stafford 2020[a], Vanier 2022
	No	*No studies applicable*
	Mixed results	Rand 2000
Deer exclusion (deer fencing)	Yes	Daniels 1993[b], Fabbro 2015
	No	Perkins 2006
	Mixed results	Stafford 1993, Daniels 1995
Chemical/natural/botanical		
Chemical	Yes	Rupes 1977, Schulze 1987, Schulze 1991, Stafford 1991, Schulze 1992, Curran 1993, Schulze 1994, Schulze 1995, Monsen 1999, Schulze 2000, Schulze 2001(1), Schulze 2001(2), Schulze 2005, Schulze 2008, Jurisic 2010, Jordan 2017, Bron 2020, Schulze 2020[a], Jurisic 2023, Williams 2024[a]
	No	*No studies applicable*
	Mixed results	Stafford 1990, Hinckley 2016[a]

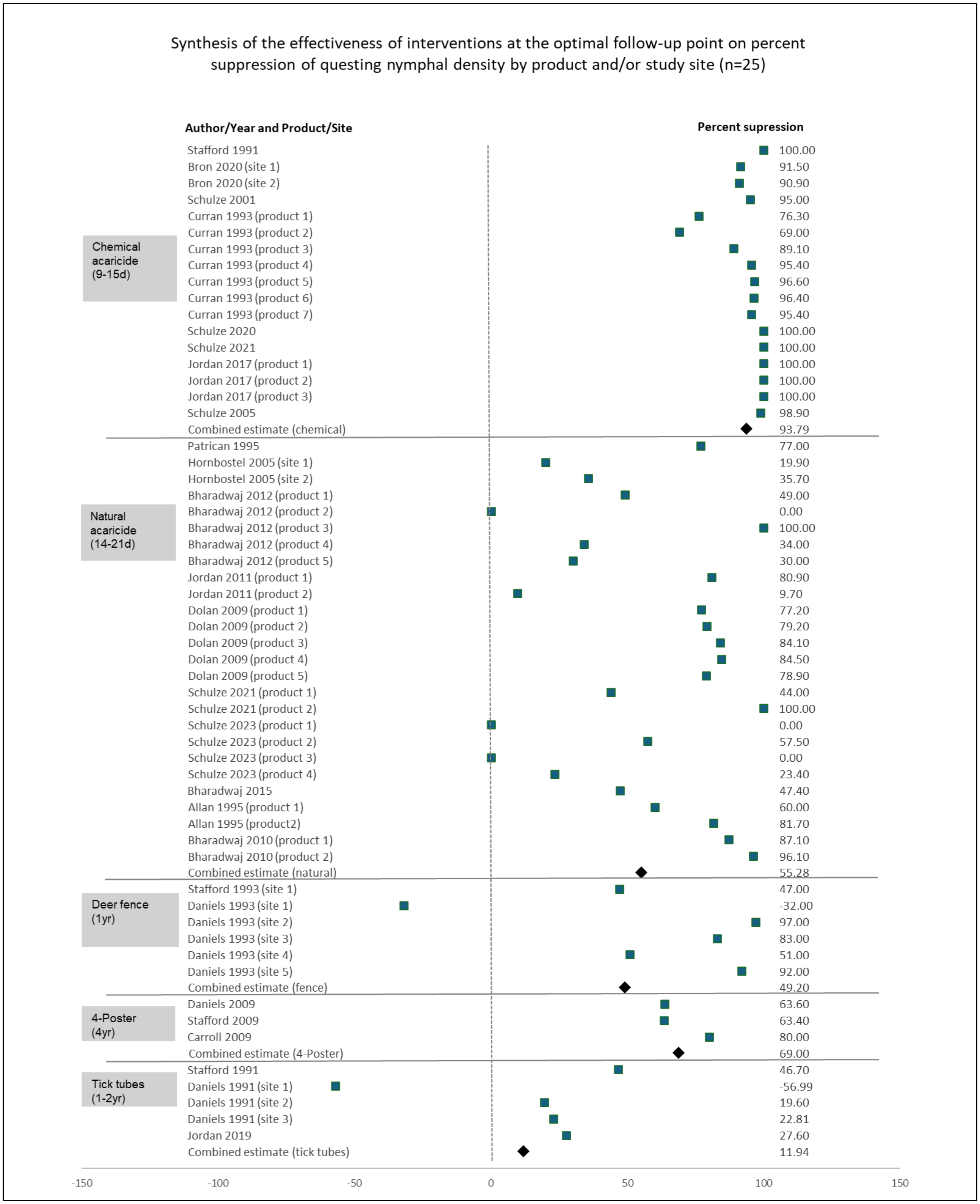
Botanical/ Fungal	Yes	Patrican 1995[a], Benjamin 2002[a], Hornbostel 2004[a], Dolan 2009, Greengarten 2011, Elias 2013
	No	Hornbostel 2005[a], Schulze 2023
	Mixed results	Allan 1995, Bharadwaj 2010, Bharadwaj 2015[a]
Landscape Management		
Vegetation clearing	Yes	Wilson 1986, Schulze 1995, Hubalek 2006, Williams 2009, Williams 2010, Williams 2017, Conte 2021
	No	Tack 2013, Elias 2024[a], Lee 2023
	Mixed results	Linske 2018, Jordan 2020
Vegetation burning	Yes	*No studies applicable*
	No	Padgett 2009
	Mixed results	Mather 1993, Stafford 1998
Barrier approaches (ecotone modification etc)	Yes	Mckay 2020[a]
	No	*No studies applicable*
	Mixed results	*No studies applicable*
Personal Protection		
Permethrin clothing or repellent program	Yes	Faulde 2015, Nadolny 2024[b]
	No	*No studies applicable*
	Mixed results	Staub 2002[a], Miller 2011[a], Richards 2015
Behaviour change program	Yes	Potes 2023[c]
	No	*No studies applicable*
	Mixed results	Beaujean 2016
Integrated Tick Control		
Integrated program or multiple classifications (within or between classification categories) *	Yes	Deblinger 1991, Schulze 2007, Dolan 2009, Rand 2010[a], Jordan 2011, Bharadwaj 2012, Gilbert 2012, Del Fabbro 2015, Burtis 2017[ac,] Dolan 2017, Williams 2017, Dolan 2018, Fischhoff 2018[a], Jordan 2019, Williams 2018[a], Potes 2023[c]
	No	Linske 2021[a], Mandli 2021, Ostfeld 2023[a], Linske 2024
	Mixed results	Stafford 2010, Garnett 2011, Little 2020, Dyer 2021[a], Schulze 2021[a], Keesing 2023[a], Ostfeld 2023[a], Ostfeld 2024[a]

Table 4.2 legend: See more information on integrated tick control combinations and classifications in table 4.4. *Effectiveness was determined by study results on their presented outcomes. Yes= intervention was effective on all outcomes measured. No= the intervention was not effective on outcomes measured. Mixed results= the intervention was effective on some of the outcomes measured but not all. Studies with many outcome measurement types may be more likely to be classified as ‘mixed’ effectiveness than studies with one or two key outcome measurements.

3.3 Multi-study synthesis of questing nymphal density

We included 25 studies that evaluated the effectiveness of interventions against questing nymphal stage ticks in the data synthesis. Of these studies, 8 evaluated a chemical acaricide, 10 evaluated a natural acaricide, 2 evaluated deer fencing, 3 evaluated 4-Poster devices, and 3 evaluated tick tubes (Figure 4.3). All of the included studies within each category reported a comparable timing of the outcome measurements (post-intervention), as well as comparable density calculations (performed per distance in m^2, rather than density per time unit).

Figure 3.3: Data synthesis of the effectiveness of the intervention on percent suppression of questing nymphal density (n=25).



Specific products and site descriptions of chemical acaracide study classifications:
Stafford 1991: Carbaryl (1-naphthyl-N-methycarbamate) was mixed at a rate of 1.20 g (AI)/liter of spray [single site estimate]
Bron 2020: Synthetic pyrethroid (granular formulation spectracide triazicide insect killer for lawns) containing 0.05% gamma-cyhalothrin [Two peri-urban/ suburban sites; site 1- 'EC' agricultural and woodland, site 2- 'SC' woodland]

Schulze 2001: Granular deltamethrin (DeltaGard G Insecticide Granule, 0.1% [AI], Aventis Environmental Science USA LP, Montvale, NJ) was applied at a rate of 0.15 kg/ha) [single site estimate]
Curran 1993: Carbaryl emulsifiable concentrate (EC) at 1.1 kg (#1) or 0.6 (#2) Al/ha, Granular (GR) carbaryl (7.15%) at 4.5 kg (#3) Al/ha, chlorpyri-fos wettable powder (WP) at 1.1 kg (#4) or 0.6 (#5) Al/ha, granular chlorpyrifos (2.3%) at 1.1 kg (#6) Al/ha, and cyfluthrin EC at 0.1 kg (#7) Al/ha. [Seven products, products and formulations assigned to balance treatment types between two neighborhoods]
Schulze 2020: Talstar P (bifethrin)
Schulze 2021: Talstar P (bifethrin)
Jordan 2017: product 1: Bayer Advanced (imidacloprid;beta-cyfluthrin) (0.72%;0.36%); product 2- Spectracide (lambda-cyhalothrin) (0.5%); product 3- Ortho Bug-B-Gon (bifenthrin/zeta-cypermethrin) (0.3%) [3 products reported, multiple formulations of prduct 1].
Schulze 2005: granular deltamethrin [single site estimate, single product reported].

Specific products and site descriptions of natural and botanical acaracide study classifications:
Patrican 1995: Drione, 40% amorphous silica gel (24.4 kg [AI]/ha),10% piperonyl butoxide (6.10 kg [AI]/ha), and 1% pyrethrins (0.60 kg [AI]/ha) [single site estimate]
Hornbostel 2005: Metarhizium anisopliae (Deuteromycetes) 109 spores/ml Bio-Blast + DI water suspension [Two rural sites (site 1- SR 44A) (site 2- ST Farm)]
Bharadwaj 2012: (product 1- [EC] 4.4 liters of 89.6% synthetic nootkatone, 1.9 liters of 93% d-limonene, a solvent extracted from orange peels, and 1.9 liters of E-Z-Mulse, at a ratio of 2:1:1) (product 2- EC + Fungus 0.4 liters of the nootkatone oil with 0.2 liters each of d-limonene and E-Z-Mulse at the same 2:1:1 ratio in combination with an oil-based formulation of M.brunneum). The following are all encapsulated formulations of nootkatone prepared by the National Center for Agricultural Utilization Research, Agricultural Research Service, USDA (product 4-[Lingin processing method 2009] 17.9% nootkatone wt:wt) (product 5- [Lingin processing method 2010] 20.7% nootkatone wt:wt]) (product 6- [Maillard processing method] 22.5% nootkatone wt:wt)
Jordan 2011: (product 1- [Nootkatone] 98.5% nootkatone crystals in 93% d-limonene, added to spray tank 95% EZ-Mulse, and 11.4 liters (3 gal) of water) (product 2- [Eco Trol T&O] carvacrol-EcoTrol: 95% carvacrol and 92% Calamide C, The EcoTrol T&O formulations, consisting of 10% rosemary oil, 2% peppermint oil, and 0.5% sodium lauryl sulfate, with wintergreen oil, vanillin, lecithin, and butyl lactate)

Dolan 2009: (product 1- Nootkatone 2006 formulation-98.5% nootkatone crystals dissolved in 93% d-limonene added to the spray tank con-taining water and 95% EZ-Mulse) (product 2- Nootkatone 2007 formulation-98.5% nootkatone crystals dissolved in 93% d-limonene added to the spray tank con-taining water and 95% EZ-Mulse) (product 3- Carvacrol applied 95% carvacrol and 92% Calamide C, prepared from highly refined coconut oil), (product 4 Nootkatone 2008 formulation- core specific location- an emulsified formulation containing nootkatone and food grade corn oil using a 1:1ratio of the surfactants transcutol and cremephor EL (Polyoxyl 35 Castor Oil ([USP/NF]) mixed in a 1:5 (cornoil/cosurfactant) ratio), (product 5 Nootkatone 2008 formulation- border specific location- an emulsified formulation containing nootkatone and food grade corn oil using a 1:1ratio of the surfactants transcutol and cremephor EL (Polyoxyl 35 Castor Oil ([USP/NF]) mixed in a 1:5 (corn oil/cosurfactant) ratio)
Schulze 2021: product 1- Met52 EC; product 2-Essentria IC3
Schulze 2023: product 1- Essentria IC3 high pressure application; product 2 Essentria IC3 low pressure application; product 3- Entomopathogenic fungal acaricide BotaniGard ES high pressure application; product 4 Entomopathogenic fungal acaricide BotaniGard ES low pressure application. [multiple products and application effect estimates reported]
Bharadwaj 2015:product 5- Botanical acaricide garlic concentrate Mosquito Barrier. [single product/single site effect estimates reported]
Allan 1995: product 1-Safer's insecticidal soap (3.9%); product 2- Drione amorphous silica gel, piperonyl butoxide, pyrethrins. [multiple product effect estimates reported]
Bharadwaj 2010: product 1- Entomopathogenic fungi M.anisopliae F52 application rate 1: 3.2x10^5 spores/cm^2; product 2- Entomopathogenic fungi M.anisopliae F52 application rate 2: 1.3X10^6 spores/cm^2. [multiple product effect estimates reported]

Specific products and site descriptions of deer fencing study classifications:
Stafford 1993: [single site estimate reported]
Daniels 1993: [site 1- Hudson Pines, site 2- Near Archives, site 3- Cemetery, Site 4- Far Archives, site 5- Park Estate]

Specific products and site descriptions of deer targeted 4-Poster study classifications:
Daniels 2009: 2% pour-on formulation of Amitraz. Initial application of 20 mL of Point-Guard to each roller once per week; increased to 40 mL Point-Guard per roller three times per week by end of study [single overall site estimate reported]
Stafford 2009: Point-Guard (2%amitraz) initially applied at 25mL per roller per week, increased to 40mL/roller in the later years of the study. [single site estimate reported]
Carroll 2009: 2% amitraz applied weekly from March to mid-December. Each roller received 2.5 mL acaricide for 9.2 kg corn consumed, increasing by 2.5 mL=roller for each additional 4.5 kg increment of corn consumed up to 70.5 kg. For every additional 11.4 kg corn consumed above 70.5 kg, an additional 5 mL of acaricide per roller was applied. [single site estimate reported]

Specific products and site descriptions of rodent targeted tick tube study classifications:
Stafford 1991: tubes containing cotton treated with 7.4% wt/wt permethrin [single site estimate reported]
Daniels 1991: tubes containing permethrin treated cotton [site 1= woodland, site 2= recreational, site 3= residential]

<u>Jordan 2019:</u> tubes containing cotton treated with 7.4% wt/wt permethrin [single site estimate reported]

3.4 Risk of bias and certainty of the evidence for studies in the multi-study synthesis

Our risk of bias assessment revealed that most studies had either moderate to serious risk of bias; and that studies often suffered from issues related to potential sources of confounding that were not appropriately controlled for (n=24) (Figure 4.4). The source of many of these study limitations were either restrictions placed on the studies by the resources available, or the environment itself.

Figure 3.4: Risk of Bias results from ROBINS-I and ROB2.0: studies reporting most common outcome (questing nymphal density)

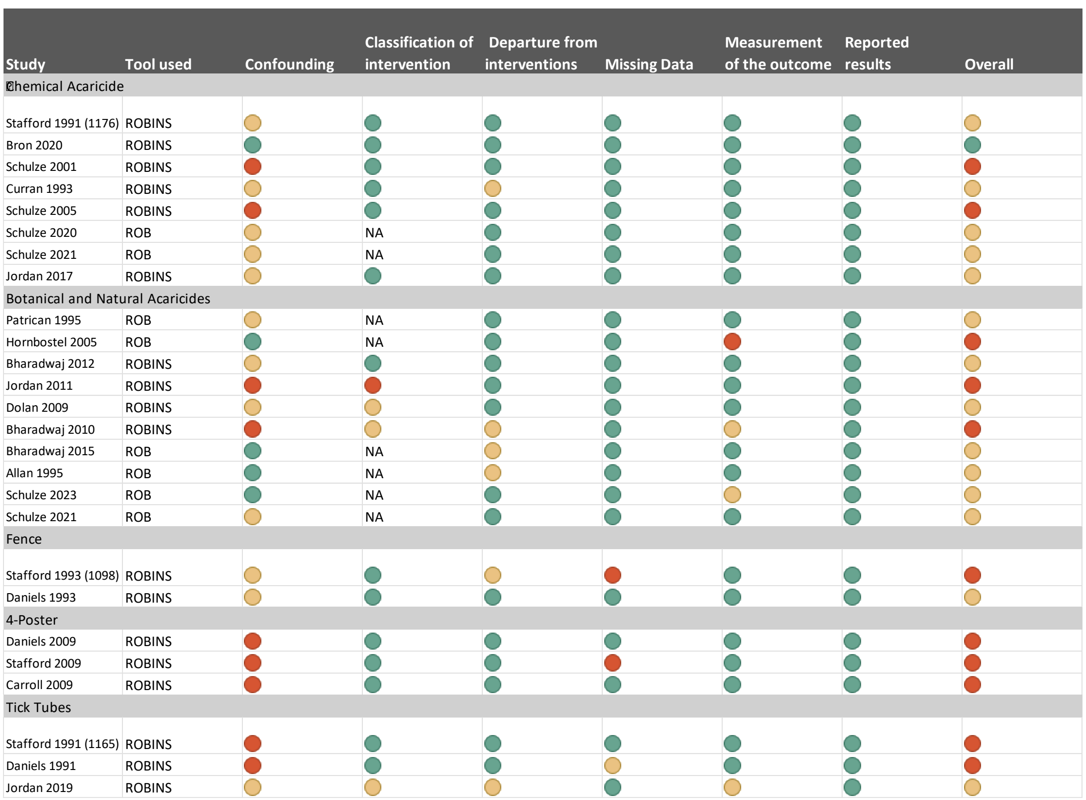


Figure 4.4 legend: Color coding represents different levels of bias risk, green= low risk of bias, yellow= some concerns and red= high risk of bias for each of the assessment tools.

Grading of the evidence of studies in this multi-study synthesis revealed that most study classifications (i.e. intervention types) had low or very low certainty of evidence with the exception of the effectiveness of environmentally broadcasted chemical acaricides against questing nymphal stage ticks (Table 4.3). Though this intervention classification also suffered from limitations in the risk of bias assessment, it was graded up for large effect sizes (percent reduction of questing nymphal tick density) and had no detected inconsistency or indirectness according to the GRADE guidelines (60) (Table 4.3). All the other intervention classifications suffered from limitations due to the risk of bias across studies, and inconsistency of the results (Table 4.3).

Table 3.3: GRADE table- The effectiveness of the intervention on the density of questing nymphs. Overall confidence in the estimates of effects

No. of studies	**Risk of Bias (ROB 2.0, ROBINS-I)**	**Inconsistency**	**Indirectness**	***Imprecision**	**Publication Bias**	**Other Considerations**	**Certainty of Evidence**
The effectiveness of chemical acaricides against questing nymphal stage ticks							
8 (6/8 non-randomized)	Serious	None detected	None detected	*NA*	None detected	+1 (upgrade for large effect sizes)	High (++++)
The effectiveness of natural acaricides against nymphal stage ticks							
10 (4/10 non-randomized)	Very serious	Very serious	None detected	*NA*	None detected	+1.5 (upgrade for randomized studies, confounding present likely underestimated the true effect size)	Low (++)
The effectiveness of deer fencing against questing nymphal stage ticks							

2 (2/2 non-randomized)	Very serious	Serious (-1.5)	None detected	*NA*	None detected	None	Very low (+)
The effectiveness of 4-Poster devices against questing nymphal stage ticks							
3 (3/3 non-randomized)	Serious	Moderate (-0.5)	None detected	*NA*	None detected	None	Low (++)
The effectiveness of rodent host targeted tick tubes against questing nymphal stage ticks							
3 (3/3 non-randomized)	Very serious	Very serious	None detected	*NA*	None detected	None	Very low (+)

*Unable to Grade based on imprecision due to lack of confidence intervals in the study results included in the multi-study synthesis of tick suppression effects, none of the included studies were Graded down based on imprecision. GRADING should be interpreted with caution due to the heterogeneity of methods found within intervention classifications.

3.5 Multi-study synthesis analysis

In the multi-study synthesis of 25 studies, despite the wide variety of products and formulations used in the chemical tick control studies, which often used varied approaches between sites of a single study, the results had consistently strong effect sizes. This finding suggests that these approaches remain the most consistently reliable of all tick control methods included in this analysis. 4-Poster interventions also had high certainty of evidence, as well as relatively consistent effect sizes (63.4-80% reduction in density of questing nymphs) when measured at the 4-year mark of study measurement. Natural and botanical approaches, deer fencing, and tick tubes all had lower certainty of evidence as well as inconsistent effect sizes among the included studies (Figure 3). These findings are consistent with the descriptive portion of this systematic review which suggested that most studies in the corresponding intervention classifications reduced some measure of LD risk with most mixed or negative results being present in the literature relating to tick tubes (Table 2).

3.6 Secondary outcome: host-targeted management of wildlife parasitism, infection, movement, and density

Of 62 articles which featured host targeted strategies, 56.5% and 40.3% were set in rural and residential settings, respectively. Within this classification, 25 were deer targeted, 33 were rodent targeted, and four were mixed (largely a combination of deer removal and rodent bait boxes) (Table 4.2). Fifteen of the studies indirectly addressed environmental impact, most (n=9) of these presented their host targeted approach as a way to reduce reliance on environmentally broadcasted acaricides and impact on non-target species; none of these studies performed direct measurements of environmental impact (48,56,61–67).

Ten studies (44,56,63,65,68–73) indirectly addressed the social acceptability of the intervention, but only one study that used permethrin tick tubes included an anecdotal measurement by noting complaints by visitors to the study area became rare after treatment (65). Eight studies considered social resistance of the intervention which were mostly captured in studies of deer targeted interventions, which faced concerns over the implications of attracting deer with supplemental feedings (74–76). Additionally, one study removed several 4-Poster devices during their study during a conflict with landowners (77), while another faced concerns from divided stakeholders over deer culling (48). Rodent targeted studies faced concerns that there could be unintentional non-target animal ingestion of the treated material (61,78), and one study anticipated public pushback over the delayed effect of host targeted strategies (79). None of the studies presented any direct measurement of social resistance or acceptability. Many (33.9%) of the host targeted studies anecdotally reported on feasibility. Using rodent targeted bait boxes and other interventions using rodent applied acaricides had mixed conclusions; five studies identified the level of human resources needed was a barrier to making these approaches highly feasible interventions (50,64,68,80,81); two other studies faced challenges with bait predation from non-target species (61,82). The deer reduction programs noted the programs were highly labor intensive (61,70,74). Similarly, all of the articles that used 4-Poster devices or corn feed and discussed feasibility excluding (63) noted challenges faced by the staff who were sometimes required to walk long distances to refill feed stations or perform maintenance on the 4-Poster devices (61,76,83,84). There were three studies which addressed deer fencing; one of which assigned high feasibility to the intervention and its scalability to small treatment areas (56), the other two faced challenges with human resources, fence placement, or the lag time needed between installation and effect (48,69). Finally, two studies focusing on rodent targeted oral vaccines noted high feasibility compared to injection vaccines (71,85), while the other noted challenges faced to ensure proper dosage of orally delivered vaccines (86).

Three studies considered the development of tick or bacterial resistance to the product used in their intervention. In one study, the team first tested the lowest concentration of doxycycline laden rodent-targeted bait needed to achieve complete spirochete suppression before deployment of their intervention (87). After which they found that the use of the same doxycycline bait could be controversial due to the potential for the development of bacterial resistance in an antibiotic commonly used in human populations (88). Another study justified their use of a bio-control agent, *Metarhizium anisopliae*, by noting an advantage of bio-control agents in reducing likelihood of resistance development, since there is often competition between the agent and target in the evolutionary process (66).

Six studies presented explicit information on cost; the most recently published studies used tick tubes ($75 for 24 tick tubes) and bait boxes ($40 and $45 per bait box), all of which were rodent targeted strategies (68,72,81). Three other studies also included some cost estimates for their deer targeted strategies including the cost of corn and 4-Poster device initiation (61,84,89). Additionally, one study provided cost estimates for sharpshooting services for a deer reduction strategy of $600 USD per deer (90). Sixteen other studies provided the product name and concentration, and five studies mentioned cost as a possible limitation of the approach (48,63,74,75,85).

3.7 Secondary objectives: chemical insecticides, biological control agents, natural tick control products

Our search resulted in 49 studies that focused on chemical insecticides, biological control agents, and natural tick control products of which 19 and 25 were set in residential or rural settings, respectively. Of the 49 studies, 49% evaluated chemical acaricides like carbaryl, 47% evaluated natural alternative acaricides like Metarhizium based products (i.e., Met 52) or Nootkatone, one of which also included a chemical comparison (91), and 4% evaluated biological control measures (e.g., natural predators such as wolf spiders). Twenty-four studies addressed environmental impacts in the text (49,52,55,61,62,64,69,91–107). Many of these studies justified their use of natural or botanical acaricide approaches to reduce impact on the environment or non-target arthropods. Three of these natural or botanical studies indirectly stated there were still concerns over impacts on non-target organisms or a possible need for more research on environmental impact (96,99,108). Two studies directly measured impacts on non-target organisms, finding that *Metarhizium brunneumin* spores did yield considerable yellow-mealworm mycosis after application (94,108). Additionally, three studies measured the impact of their intervention on non-target species abundance and diversity. The first found that their use of Eco-Exempt IC2 (a plant-derived acaricide) temporarily reduced some non-target species, but they rebounded within a few weeks (97). The other two studies found that their use of granular Carbaryl had detectable effects on non-target species over the study period (91), while the use of granular deltamethrin only had a temporary effect on non-target species before rebound (102). We found six studies which addressed public or social acceptability, most of which cited a higher acceptance of natural or botanical products over chemical products due to health or environmental concerns (91,92,95,96,109,110). We found only one study, which studied the effectiveness of Nootkatone (a natural tick control product derived from Alaskan yellow cedar (*Cupressus nookatensis*)), that directly addressed public or social acceptability which found that many residents in the study area would consider using a natural 'alternative' acaricide to control ticks if they were more available (92). Two of these studies provided indirect measurements of acceptability by referring to previous studies that provided direct acceptability measurements (109,110). Similarly, seven studies indirectly addressed potential social resistance, many of which focused on synthetic acaricides citing environmental or health concerns (61,73,101,103,106,111,112), while one of these faced social resistance when it came to cost and availability (112). Seven studies addressed concerns surrounding the feasibility of their proposed intervention relating to acaricides; two stated the natural products used in their study were easily purchased making them an accessible and minimal risk option for tick control (95,111), and another made sure that the fungal product they chose to test was able to be easily cultured in a laboratory setting to increase real world feasibility (93). Most others mentioned the cost and availability of the products to be potential barriers to their approach being feasible (61,96,103). Finally, one study mentioned that their demonstrated use of bifethrin outside its typical application season increased the feasibility of their design (104). Two of the 49 studies in this intervention category indirectly addressed the potential for tick or bacterial resistance to their proposed product use citing the need for products with strong residual activity, or improved efficacy and selectivity (49,55).

Seven studies included information on the cost of acaricides, six of these studies provided direct measurements. The first stated that, at the time of the study, the cost of the intervention was roughly 26$/backyard application of granular acaricide, Spectracide Triazicide, featuring Gamma-cyhalothrin as the active ingredient (113). Similarly, another study found that applications of synthetic granular formulations: $25-125/0.20 ha (0.5 acres) of tick habitat while applications of liquid formulations: $75-185/0.20 ha (0.5 acres) of tick habitat (109). Two other studies listed acaricide application costs between $325-350 (61,103). Another noted the cost of Nootkatone during the study was $3,481/kg of product (93). Finally, one study cited a previous survey which found most companies would charge between ($100-200 per application per 0.4ha) (91).

3.8 Secondary objectives: landscape management

We identified a total of 21 studies that focused on landscape management to reduce tick or LD risk to humans. Five were set in recreational settings, three were in residential settings, and others were either unlisted or in generally forested areas (n=13). Seven studies framed their interventions as part of a tick control approach which would reduce environmental impact. Of these, one assessed the effects of fencing and vegetation mowing as an environmentally low risk intervention to reduce ticks in high density areas (56), whereas another used active forest management techniques to control ticks as part of an environmentally sound strategy (114). Two others used vegetation management and/or ecotone modification to control questing ticks (115,116). Additionally, four studies mentioned the importance of this type of intervention in reducing the presence of invasive barberry and its effects on both forest health and tick populations (117–120). Finally, two studies mentioned concerns that their landscape approach may in fact have unintended consequences for the environment through potentially increasing deer populations during controlled burns (121) or reducing overwintering habitat for pollinators by removing leaf litter (122).

Only two studies mentioned social acceptability or resistance as justification for their type of intervention, one of which proposed fencing and vegetation mowing as a more acceptable intervention when compared to area wide application of acaricides (56), while the other cited a growing interest in non-chemical options to tick control according to a previous telephone survey study (110). Five of the 21 studies attempted to address feasibility indirectly, often as part of the rationale supporting the use of their tick suppression approach. One suggested vegetation removal is an approachable “do it yourself” friendly strategy to tick reduction (82), while another used ecotone modification using materials (woodchips) from an existing forest management program in the Ottawa area (45), a third study mentioned fencing and mowing are easily scalable approaches (56), and finally one study hoped their Japanese barberry approach would be a low cost option compared to other landscape approaches (117). Two other studies had concerns over feasibility, one faced study challenges removing decayed leaf litter layers (122), the other mentioned that their approach to vegetation management in control segments may in fact reduce the effectiveness of their sampling technique reducing study feasibility (116). None of the studies in this classification mentioned tick or bacterial resistance as a concern or benefit of their intervention approach.

We found that two studies directly provided cost estimates for their intervention in this classification. The first provided the cost for some components of their integrative approach (tick tubes) at $75/24 tick tubes (82), and the second listed their overall cost at $3800/50m^3 of woodchips, used to treat 500 m of trail, primarily occurred for transportation and labor costs (45). Finally, one study indirectly addressed cost, by mentioning that removing all layers of leaf litter in order to reduce tick habitat was very labor intensive and could be quite costly if the approach was scaled up (122).

3.9 Secondary objectives: personal protection

Seven studies were included for analysis that focused on personal protection strategies at a community level. Most (n=4) of these studies examined the effectiveness of permethrin treated clothing or uniforms in reducing tick encounter or tick bites. Three of these studies focused on occupational exposure (57,123,124), while the other focused on a program for a high-risk community in Rhode Island (125). One study in Canada, used a repeated cross-sectional mixed methods design to evaluate a motivational interviewing technique to increase personal protection measures in a high-risk community, combined with a rodent-targeted strategy (44). Another study from Switzerland examined the effectiveness of a spray repellent containing DEET and

EBAAP (both of which are commonly used insect repellents) in forestry workers (53). The final study from the Netherlands used randomized study design to compare education strategies using leaflets or video games, compared to controls, to increase knowledge, attitudes, and practices surrounding ticks and LD (126). None of these studies focused on the environmental impacts or benefits of their strategy.

Two of these studies mentioned social acceptability or resistance, one of which applied specific methods to ascertain the social acceptability of their strategy and community engagement; they found that participants with higher engagement in the program found it to be more efficacious and acceptable than those who didn't participate. They also noted that qualitative outcomes suggested that the participant and research team collaboration was well received (44). The other study mentioned that during participant recruitment, negative perceptions of permethrin-treated clothing contributed to lack of interest in the program (124). Three studies measured feasibility or complexity of their intervention. To this end, the first study noted the importance of treating all layers of clothing with permethrin, as untreated outer layers seemed to reduce the effectiveness of the intervention (57). While the other study found that community building activities were complicated by disruptions due to the COVID-19 (25). The research team noted that longer periods of study are required to evaluate the long-term feasibility and sustainability of this intervention type (44). The final study noted that effectiveness may increase if the method of intervention was tailored to individual preferences and outcome measures may have been more accurate if they had included a separate survey for parents (126). One of the studies mentioned that there was some concern over tick species resistance to the lethal effects of permethrin (123). Finally, none of the seven studies included information on cost.

3.10 Secondary objectives: integrated tick control:

Integrated tick control strategies were strongly supported by the literature. Of the included studies, we found that 40 studies either used or called for an integrated approach to tick control, while 28 of these used an integrated approach (Table 4.4). Most of the studies which used integrated approaches that spanned multiple intervention classifications (n=13) used a combination of host targeted interventions with chemical or natural tick control strategies. Only five of the studies involved landscape management or personal protection approaches. Of the strategies that used multiple tactics within the same intervention classification (n=15), most (n=7) used a combination of host targeted approaches, while the remaining studies used chemical, biological, or natural tick control strategies (Table 4.4).

Table 3.4: Studies using an integrated tick control strategy by classification (N=28)

Author	Study/ intervention target strategy	Description
Integrated effort occurred across multiple intervention classifications (n=13)		
Burtis 2017	1. Landscape management; 2. Chemical, biological, natural tick control	Biological control (natural predator) with landscape management (vegetation removal)
Del Fabbro 2015	1. Management of host parasitism & movement (Deer targeted); 2. Landscape management	Deer exclusion with vegetation mowing
Keesing 2023	1. Management of host parasitism & movement (Rodent targeted); 2. Chemical, biological, natural tick control	Natural acaricide -environment (entomopathogenic fungi) and rodent targeted acaricide (bait box)
Little 2020	1. Management of host parasitism & movement (Rodent and deer targeted); 2. Chemical, biological, natural tick control	Deer removal, natural acaricide-environment (Met52), and rodent targeted acaricide (bait boxes)

Mandli 2021	1. Landscape management; 2. Management of host parasitism & movement	Vegetation removal and rodent targeted acaricide (tick tubes)
Ostfeld 2023 (1)	1. Management of host parasitism & movement (Rodent targeted); 2. Chemical, biological, natural tick control	Rodent targeted acaricide application (bait box- fipronil); natural acaricide-environment (Met52)
Ostfeld 2023 (2)	1. Management of host parasitism & movement (Rodent targeted); 2. Chemical, biological, natural tick control	Rodent targeted acaricide application (bait box); natural acaricide- environment (Met52)
Ostfeld 2024	1. Management of host parasitism & movement (Rodent targeted); 2. Chemical, biological, natural tick control	Rodent targeted acaricide application (bait box- fipronil); natural acaricide-environment (Met52)
Potes 2023	1. Management of host parasitism & movement (Rodent targeted); 2. Personal protection (population level)	Rodent targeted acaricide (fluralaner) and personal protection -community targeted
Schulze 2007	1. Management of host parasitism & movement (Rodent and deer targeted); 2. Chemical, biological, natural tick control	Deer targeted acaricide application (4-Poster); Rodent targeted acaricide application (bait box); chemical acaricide- environment (granular deltamethrin)
Stafford 2010	1. Landscape management; 2. Chemical, biological, natural tick control	Natural acaricide- environment (entomopathogenic fungi *Beauveria bassiana*), with or without woodchip borders
Williams 2017 (1)	1. Management of host parasitism & movement (Rodent and deer targeted); 2. Chemical, biological, natural tick control	Natural acaricide- environment (Met52), rodent-targeted bait boxes (fipronil), deer removal
Williams 2018 (2)	1. Management of host parasitism & movement (Rodent and deer targeted) 2. Chemical, biological, natural tick control	Deer removal; natural acaricide- environment (Met52); rodent targeted bait boxes-topical acaricide
Integrated effort occurred within the same intervention classification (n=15)		
Bharadwaj 2012	Chemical, biological, natural tick control	Natural acaricide- environment (Met52, Nootkatone)

Deblinger 1991	Management of host parasitism & movement (Rodent and deer targeted)	Rodent and deer targeted host interventions
Dolan 2009	Chemical, biological, natural tick control	Multiple chemical acaricides - environment
Dolan 2017	Management of host parasitism & movement (Rodent targeted)	Rodent targeted- topical fipronil and oral doxycycline
Dolan 2018	Management of host parasitism & movement (Rodent targeted)	Rodent targeted- topical fipronil and antibiotic (ATB) treatment against infection
Dyer 2021	Chemical, biological, natural tick control	Natural and chemical acaricide- environment (multiple products)
Fischhoff 2018	Chemical, biological, natural tick control	Natural acaricide application- environment (entomopathogenic fungi) and natural predator control- environment
Garnett 2011	Management of host parasitism & movement (Deer targeted)	Deer removal and deer targeted acaricide application (4-Poster)
Gilbert 2012	Management of host parasitism & movement (Deer targeted)	Deer exclusion and deer removal
Jordan 2011	Chemical, biological, natural tick control	Multiple natural acaricides- environment
Jordan 2019	Management of host parasitism & movement (Rodent targeted)	Rodent targeted acaricide (bait boxes and tick tubes)
Linske 2024	Landscape management	Vegetation management and ecotone modification
Linske 2021	Management of host parasitism & movement (Rodent targeted)	Bait-boxes (fipronil), 4-Poster treatment (permethrin), bait-boxes (Met 52)
Rand 2010	Chemical, biological, natural tick control	Natural acaricide- environment, and chemical acaricide -environment
Schulze 2021	Chemical, biological, natural tick control	Natural and chemical acaricide- environment (multiple products)

4 Discussion:

This systematic review of tick and LD prevention strategies provides an overview of the main categories of interventions that have been evaluated in field studies to date and the effectiveness of these strategies against a wide range of outcomes. Our review highlights that most of the 127 included studies evaluated host targeted strategies, followed by chemical/natural/botanical acaricide approaches, landscape management, and personal protection strategies, respectively. A minority of the studies (n=28) employed an integrative approach to tick control, despite support in the literature for increasing the number of tick control studies using a multifaceted approach (127). Indeed, the authors of 12 of the included studies called for increased adoption of integrative approaches to tick control in the future, highlighting a need for more research conducted in this area.

Overall, the reporting of entomological outcomes (e.g. questing tick density, tick infection prevalence, etc.) was most common across studies, while fewer studies reported host-related outcomes (e.g. host parasitism or *B. burgdorferi* host infection prevalence, etc.), and a minority of studies investigated other outcomes such as qualitative or human outcomes. The most commonly reported outcome across all tick and LD prevention studies was the density of questing nymphal ticks, allowing some synthesis of effectiveness results for this outcome, despite wide variability in study design and reporting, in addition to varied outcome definitions and assessment methods.

According to the data synthesis, chemical tick abatement using varied products and formulations yielded the most efficacious and consistent results in reducing questing nymphal tick density and this effect was consistent at different scales and in different settings. This was followed by 4-Poster devices in their efficacy and consistency. All other interventions included in the data synthesis had varied results and outcomes, although most did have positive tick suppression effects. Amongst host targeted strategies, deer targeted 4-Poster strategies had the greatest proportion of studies with effective strategies according to study conclusions when compared to tick tubes, oral treatments and deer exclusion or deer reduction. Host and landscape targeted strategies had the most variation in effectiveness with 16% and 25% of studies in these categories, respectively, reporting no effectiveness, and roughly a quarter in both categories with mixed effectiveness. This suggests that while chemical abatement strategies may be the most consistently successful programs in reducing the density of questing nymphal ticks, depending on the local context and environment of the intervention, other available options could be considered to reduce LD risk depending on the feasibility, social acceptability, and cost needs of implementation in a given community.

Importantly, because of the environmentally dependent nature and other contextually important factors that influence study design choices for tick and LD prevention studies, the measurement and reporting of results across these studies is highly heterogeneous. This prevents functional synthesis of the data in a robust meta-analysis and is an issue that warrants consideration in future studies. Specifically, our systematic review identified variations in dosage, number of treatments, timing of treatments and measurement ascertainment, and delays between interventions and evaluation. Future research in this field may benefit from the development of guidance on standards for collection of data and reporting of results in published literature in order to optimize comparability with other studies, and consequently uptake of the intervention in other contexts. This could take the form of new or adapted reporting guidelines and quality assessment tools for tick-borne disease intervention studies, which offer flexibility depending on study context. Furthermore, future review studies aiming to conduct a meta-analysis would benefit from the development of guidance on the most appropriate way to synthesize heterogeneous data in this field of study, considering different outcome definitions and assessment timepoints.

In addition to evaluating the effectiveness of tick and LD control initiatives, this review summarized evidence on a range of secondary outcomes such as environmental impact, social acceptability, social resistance, feasibility, tick or biological resistance, and cost. Aside from the overall effectiveness of these studies in reducing LD risk, these factors are essential in determining successful selection, implementation, and scalability of these approaches across a variety of risk settings, and varying community needs. While these are certainly important outcomes to consider, we found that a majority of the included studies lacked information on these outcomes and that most of the included information was provided indirectly (i.e. there were no measurements of these factors) in a descriptive manner.

Few of the included studies explicitly measured the environmental impact of an intervention despite this being the chief concern that arose surrounding social acceptability or social resistance. Studies evaluating chemical, biological, and natural tick control approaches were the most likely to feature information on environmental impact, with almost half of papers in this category including some discussion or measurement of this secondary outcome. Most of this information was presented in an indirect manner, citing environmental concerns as justification for a certain approach to product application, or the use of a non-synthetic alternative. This category of control was also the most likely to directly measure environmental impact using non-target species evaluation, or an analysis of residual products found in the environment (94,97,102,128). One third of landscape management studies and a quarter of studies on host targeted approaches also provided some discussion on environmental impacts of their interventions, however none of these studies provided direct measurements such as those found in the chemical/natural/botanical acaricide studies.

There were very few direct or indirect discussions regarding social acceptability or social resistance in any of the reviewed studies, with landscape management studies being the least likely to feature any discussion on these elements. Host targeted strategies were the most likely to highlight issues surrounding social acceptability of their programs, while personal protection strategies were most likely to discuss both social acceptability and resistance in their papers. Feasibility was mentioned most consistently across all intervention categories, in the form of discussion of challenges authors faced over the course of the study, or issues that arose regarding cost, scalability, and accessibility of the products or approaches they used. Almost half of the personal protection strategy studies included discussion of feasibility; followed by one third of studies evaluating host targeted strategies, which often faced challenges with non-target animal predation of their products (such as bait boxes), and difficulty maintaining the systems (often referring to 4-Poster devices) (61,76). Issues surrounding the feasibility of 4-Poster devices were examined in more depth in another recent study where the authors found that operation was feasible, with strategies available to minimize maintenance time (129).

While acaracide resistance is a growing concern in many vector control programs, very few reviewed studies included a discussion of this issue. A recent review which investigated tick resistance to common acaricides as it relates to both agricultural and pathogen transmission research, found widespread challenges to efficacy for all available acaracides due to the development of tick resistance (130). The study highlighted a range of products, many that were featured in this systematic review within the chemical/botanical/natural acaricides category, and host targeted category; primarily concerning topical application acaricides (including products like fipronil, organophosphates, pyrethroids etc.). Despite this issue being highlighted as an important issue in the literature, studies on personal protection approaches were most likely to mention this topic, while studies on host targeted and chemical strategies were unlikely to mention issues surrounding tick or bacterial resistance to their products.

Furthermore, most studies did not include any information on the cost of the intervention, hampering the ability to make any strong conclusions on the feasibility of these methods moving forward with scalable community programming. However cost information was provided, this often included direct measurements within the context of the study. Our findings are consistent with findings from a recent study which found that most articles related to tick or LD control programs lacked cost estimates (131). In addition, the authors conducted key informant interviews of pest control and landscape firms in their study area (Monmouth County, New Jersey) investigating the cost of some tick control products that could be applied on a residential scale. They found that most of the tick control options in their area exceeded the $100-150 that homeowners are willing to spend per year to treat their residential property (131). Increasing direct measurement or including more explicit discussion within future studies regarding factors such as feasibility, social acceptability, social resistance, environmental impacts, cost, and biological resistance potential would help inform the uptake of these interventions by decision makers looking for relevant and feasible tick or LD control programs for their jurisdictions.

4.3 Strengths and limitations

While our search strategy was developed in collaboration with a library specialist, it is possible that even with a comprehensive search strategy some relevant studies may not have been identified. While the search was conducted in English, there were no limits placed on the search and no relevant studies were excluded due to language. In addition to measures of intervention effectiveness we included a wide range of outcomes on environmental impact, social acceptability, social resistance, feasibility, tick or bacterial resistance to the intervention, and cost. It is important to note that different categories of intervention are typically implemented on different scales, however this information was not consistently provided in the included studies which somewhat limits the comparability of factors such as cost and protective effect.
Because this systematic review included only personal prevention strategies that were distributed at a community or population level and it excluded studies which were single cross-sectional in their design, there were a limited number of studies in this intervention classification. These findings are consistent with a previous systematic review examining personal protective behaviors in the context of a widespread campaign (132). This review, published in 2012, identified very few (n=9) studies which met their inclusion criteria while including any study design, only three of which used a randomized design (132).

Risk of bias tools were applied to studies included in the data synthesis, which focused on studies with the most commonly reported outcome measure (density of questing nymphal ticks). ROBINS-I and ROB2.0, while robust tools, are designed to measure the risk of bias of studies with clinical or human outcomes, therefore they may not have been ideal instruments to assess studies in this systematic review; however, there is a lack of tools available for use on primarily environmental outcomes. To improve the applicability of these tools in our context, we followed recommendations from Bilotta et.al. and the modified ROBINS-I and ROB2.0 tools, as well as GRADE, were applied to our largely environmental outcomes (133).

This systematic review identified a lack of homogeneity in the way that results of tick and LD interventions were presented across different studies. This is consistent with previous reviews that have noted challenges in conducting meta-analyses related to this topic due to the heterogeneity of methods and outcome measures used in this field of study (134). Paired with the differences in field implementation, variety, density, and formulation of products and methods used, the quantitative data synthesis and effectiveness results should be interpreted with caution and may be most useful for descriptive purposes to compare the effects between intervention categories, not for the purpose of direct comparison of specific products or approaches. This is reflected in both the overall evaluation of effectiveness using paper-by-paper outcomes as well as the synthesis presented in this paper. In the data synthesis, we analyzed data on the most comparable outcomes between studies and the most comparable time points; therefore, some studies were excluded from the analysis because the outcomes were not sufficiently similar to the included studies in that intervention classification. We chose to retain site-specific estimates in the synthesis, rather than using mean estimates to retain environmental variation as an important factor in tick control methods. This means that sample sizes in the site-by-site estimates should be interpreted with caution given potential reductions in study power for these estimates. Additionally, although the use of the density of questing nymphs provides a good method for comparing interventions, this metric is only one component of acarological risk; some risk mitigation strategies which may be effective at reducing infection prevalence and which were not highlighted in our synthesis could also contribute to LD risk reduction. Notably, because most comparable studies reported the percent reduction or percent suppression of questing nymphs as the main outcome, there were no included confidence intervals presented in the articles, limiting our ability to use the GRADE tool to its full potential.

5 Conclusion:

Overall, this systematic review included studies with a wide range of interventions and outcome types relating to tick or LD risk reduction that were applicable to a Canadian context with regards to wildlife hosts and environmental factors. While some strategies such as chemical acaricides were shown to have greater effectiveness, factors such as social acceptability and resistance, environmental impact, cost, and feasibility should be considered when selecting the most appropriate intervention. The consideration of these contextual factors is important to maximize the utility of the intervention for reducing LD risk in different settings.

6 List of abbreviations

LD: Lyme disease; GRADE: Grading of Recommendations, Assessment, Development, and Evaluations; ROBINS-I: Risk Of Bias In Non-randomised Studies - of Interventions; ROB2.0: risk-of-bias tool for randomized trials

7 Declarations:

Ethics approval and consent to participate:

Not applicable

Consent for publication:

Not applicable.

Availability of data and material:

All included studies and data were extracted from an online query and extraction guide. These materials are provided in the supplemental materials of this article.

Competing interests:

Authors have no competing interests or conflicts of interest to declare.

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Author contribution statement:

K.O. wrote the main manuscript text and prepared all figures and tables. K.O., A.D., T.C., L.W., K.Z., J.P.R., C.B., C.A., and M.K., were involved in the conceptualization and methodology for this project. K.O., M.N., A.D., R.S, C.D., and O.F., were responsible for the analysis. A.K., C.F., and M.K. supervised the project and contributed to the conceptualization. All authors reviewed and edited the manuscript.

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5. Reducing tick density along recreational trails in Ottawa, Canada: results from an ecotone modification study using treated and untreated woodchips. (Objective 2)

Article Preface

This chapter is based on an experimental field study evaluating the effectiveness of untreated woodchips or acaricide-treated woodchip ecotone modification for reducing tick density along recreational trails in Ottawa's Greenbelt, as one possible way to help reduce human-tick encounters in these spaces. The study was designed collaboratively with my primary supervisor, with methodological guidance informed by previous work on this type of intervention conducted by Dr. Kulkarni's research group (McKay et al. 2020). I was responsible for identifying and scouting appropriate trail segments, coordinating intervention application with the land management organization, and supporting data collection during the first year. Standardized tick dragging protocols were applied consistently across study sites, as described in the detailed methods section, and the manuscript that follows. I was also primarily responsible for data cleaning and structuring, as well as conducting the statistical analysis, and manuscript drafting. Co-authors and members of my Thesis Advisory Committee provided analytical guidance and feedback throughout the process. This study did not require research ethics approval, as it did not involve human participants. Land access permits were obtained from the National Capital Commission, who also provided funding support and resources for intervention applications. At the time of submission of this thesis, the manuscript is accepted with revisions at the journal:

Ticks and Tick-borne Diseases. This chapter reproduces a manuscript prepared for journal submission and is therefore presented in the citation and formatting style required by the journal.

Article Content

Title: Reducing tick density along recreational trails in Ottawa, Canada: results from an ecotone modification study using deltamethrin-treated and untreated woodchips.

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Abstract:

Expanding tick populations and increasing Lyme disease incidence in Ottawa, Ontario, highlight the need for effective strategies to reduce human exposure in recreational areas. Ixodes scapularis is the primary tick vector of Borrelia burgdorferi sensu stricto (s.s.), the causative agent of Lyme disease in this region. We conducted a two-year experimental field trial (2022–2023) in Ottawa's Greenbelt to evaluate whether modifying trailside ecotones with woodchip borders could reduce questing tick density. Twenty 50-m trail segments across two sites were randomly assigned to intervention groups: untreated woodchip borders, deltamethrin-treated woodchip borders, and ten assigned to untreated controls. Pre-treatment tick drags were conducted at the start of each study year, and environmental variables (canopy cover, canopy type, soil moisture, leaf litter depth) were recorded. Post-intervention sampling was performed weekly for six weeks during peak nymphal activity (June–July). The effects of deltamethrin-treated or untreated woodchip borders on tick density compared to controls were analyzed using mixed-effects negative binomial regression accounting for study design. A total of 440 ticks were collected, including 322 adult and nymphal I. scapularis. Of 293 ticks tested, 34.5 % were positive for B. burgdorferi. Treated woodchips reduced I. scapularis adult and nymph density by 99 % (incidence rate ratio (IRR) = 0.01, 95 % CI: 0.001–0.08) relative to controls, while untreated woodchips achieved a 48 % reduction (IRR = 0.52, 95 % CI: 0.34–0.78). This study demonstrates that modifying trailsides with woodchip borders, deltamethrin-treated or untreated, substantially reduces questing tick density, offering a tool for integrated tick management in recreational settings.

Keywords: Intervention study, ecotone modification, tick control, recreational exposure

Highlights:

- **Field-based evidence:** A two-year experimental trial in Ottawa's Greenbelt demonstrated that modifying trailside ecotones with both untreated, and acaricide treated woodchip substrates can effectively reduce *Ixodes scapularis* tick densities.
- **Understudied context:** This study contributes on integrated and landscape-based tick control in recreational environments.
- **Public health relevance:** Findings support the inclusion of ecotone modification as a potential component of integrated tick management strategies in public recreational areas.

1. Introduction

In recent years, there has been an increase in the demand for integrated tick control efforts to combat the growing problem of Lyme and other tick-borne diseases in North America (Stafford, Williams and Molaei, 2017a; Eisen and Stafford, 2021). The incidence of Lyme disease (LD) cases has increased in central and eastern regions of North America and Canada due to the establishment and expansion in the habitable range for *Ixodes scapularis* ticks, the primary vector species for the *Borrelia burgdorferi* bacterium which causes Lyme disease (Piesman and Gern, 2004; Ogden *et al.*, 2008; Clow *et al.*, 2017). This expansion of tick populations can be attributed to a number of interrelated factors such as changes in climate, land use, and host reservoir populations (Simon *et al.*, 2014; Halsey, Allan and Miller, 2018; Talbot *et al.*, 2019a). In Canada the number of human reported LD cases has risen from 682 in 2013 to 4785 in 2023 and remains subject to underreporting due to misdiagnosis or issues surrounding case detection (Lloyd and Hawkins, 2018; Public Health Agency of Canada, 2025).

The regions of Canada experiencing the highest LD incidence include the Atlantic province of Nova Scotia, and southern portions of the central provinces of Manitoba, Ontario, and Quebec. In particular, the eastern Ontario region, situated on the north side of the St. Lawrence River across from upstate New York, has reported an exponential increase in LD cases since 2010 associated with ongoing expansion and establishment of *Ixodes scapularis* ticks (Kulkarni *et al.*, 2019). In the nation's capital city of Ottawa, situated in eastern Ontario, there has been a sustained increase in reported human Lyme disease cases following the spread and establishment of tick populations; between the year 2010 and 2016, LD incidence determined through reportable disease surveillance rose from 0.2 to 6.5 cases per 100,000 population, and this has risen further to 8 cases per 100,000 population by 2024 (Kulkarni *et al.*, 2019; Ottawa Public Health, 2025). A case-control study from this region reported that Lyme disease cases were associated with key indicators suggesting residence in rural or less densely populated areas with elevated environmental risk of tick encounter (Slatculescu *et al.*, 2022). Studies in the geographic area of Ottawa-Gatineau have reported high infection prevalence of *B. burgdorferi* in adult and nymphal *I. scapularis* ticks (>30%) comparable to other established Lyme disease risk areas identified by national surveillance efforts (Canada, 2020). Recent surveillance in Ottawa has shown high tick densities and *Borrelia burgdorferi* infection rates, with several sites within the Greenbelt identified as having the highest density of infected ticks across all city surveillance sites (Kulkarni *et al.*, 2018; Talbot *et al.*, 2019a; Burrows *et al.*, 2021; Logan *et al.*, 2024). While some US studies suggest high TBD risk in residential areas, wooded recreational spaces like the Greenbelt, where nymphal tick densities are up to 15 times higher than in residential zones, remain important targets for integrated tick control efforts (Fischhoff, Keesing and Ostfeld, 2019; Burrows *et al.*, 2021; Slatculescu *et al.*, 2022; Logan *et al.*, 2024). Examining options for integrated tick control programs in these wooded recreational areas is an important step in reducing tick exposure and LD risk of not only residents in the area, but also visitors to Canada's capital city.

Previous research in the Ottawa Greenbelt established that landscape management using woodchip xeric substrates (dry, well-drained materials such as mulched wood) along trailside ecotones, the interface zones between forest and more open habitat or trail networks, can be an effective way to reduce ticks along recreational trails with the potential to reduce questing tick density by up to 75% over the course of a single season of treatment (McKay *et al.*, 2020). In a laboratory setting, certain types of woodchips were found to effectively reduce tick migration across this substrate toward more favorable locations that could offer better cover to suit tick survival, supporting the use of this substrate type in keeping ticks off of recreational trails (Piesman, 2006). Additionally, chemical treatment options were found to be the most consistently effective tick management option in a recent systematic review (Schulze *et al.*, 2001; Bron, Lee Xia and Paskewitz, 2020; Schulze and Jordan, 2020, 2021; Ost *et al.*, 2025). Furthermore, there is growing demand for more studies investigating integrative tick control as a multi-faceted and potentially more effective approach to tackling the issue of LD in areas of emerging tick populations (Stafford, Williams and Molaei, 2017b; Burrows *et al.*, 2021). While a recent review identified studies demonstrating that integrated vegetation management, acaricide application, and host management to control *Amblyomma americanum* populations achieved 89-96% reduction in questing tick density, few studies have examined the effect of these combined strategies on *I. scapularis* (Bloemer *et al.*, 1990; Stafford, Williams and Molaei, 2017b). Despite the interest in these approaches, very few studies have combined xeric substrates and chemical control approaches in either a residential or recreational setting.

This study aimed to evaluate the effectiveness of woodchip substrates alone or combined with targeted chemical acaricide (deltamethrin) spraying to reduce the density of adult and nymphal *I. scapularis* ticks, the principal vectors of *B. burgdorferi*, and the density of *B. burgdorferi*-infected ticks over the course of a two-year period (McKay *et al.*, 2020). We hypothesized that while landscape management will continue to be a promising way to reduce tick density along these trails, both untreated woodchips, and chemically treated woodchips as an integrated tick management approach, will have increased effectiveness when compared to standard trail maintenance practices.

2. Methods

2.1 Study area

This study took place in the National Capital Commission (NCC) Greenbelt in the city of Ottawa, which is comprised of approximately 20,000 hectares of horseshoe-shaped green space, stretching from west to east just south of Ottawa's urban core, and divided into six main sectors (National Capital Commission, 2025). We selected two recreational trail study sites, one in each of the eastern and western greenbelt regions, based on data from previous tick monitoring demonstrating the presence of emerging or established tick populations. In the eastern region, the Mer Bleue sector has experienced an increase in tick populations in recent years (Logan *et al.*, 2024). In the western region, the Stoney Swamp sector is an area of known risk, with established *I. scapularis* tick populations and a stable (30-40%) *B. burgdorferi* infection prevalence

(Burrows *et al.*, 2021). The Jack Pine trail (Stony Swamp sector) has a total length of 1.7km, while the Dewberry trail (Mer Bleue sector) extends 1.0 km (National Capital Commission, 2021). The selected trails were approximately 1-metre wide, primarily composed of compacted soil with areas of exposed rock, and maintained by the NCC by cutting a 1.0-1.5-meter strip of vegetation along each side of the trail at the forest ecotone every two to three weeks, with vegetation cut to a height of 10 cm (McKay *et al.*, 2020). The study segments at both sites were assigned using a block-randomized experimental approach. Both sites consisted mainly of deciduous tree canopies commonly including maple (*Acer spp*.), birch (*Betula spp*.), and oak (*Quercus spp*.) species that are favourable to tick population establishment (Talbot *et al.*, 2019b), with some mixed deciduous tree stands and meadows. The understory along consisted primarily of leaf litter, low herbaceous vegetation, and sparse shrubs. Permission to conduct field research at these sites was provided by the NCC.

2.2 Interventions and outcomes

We evaluated the effectiveness of two woodchip-based environmental management interventions: (1) untreated woodchip borders (1 metre width x 5 cm depth), and (2) deltamethrin-treated woodchip borders (1 metre width x 5 cm depth; sprayed once with at a rate of 12mL of deltamethrin (Bayer DeltaGard® SC) dilute per 100m^2, in a minimum of 8L of water per 100 m^2) by a licensed contractor using standard handheld spray equipment in accordance with product label instructions ("DeltaGard SC: Product Information Sheet," 2022). Each intervention group was compared to a control group with no intervention. The primary outcome was the density of questing adult and nymphal *I. scapularis* ticks measured by weekly standardized drag sampling using a 1-square-meter white flannel cloth during the early summer peak of tick activity, over two seasons of intervention (see details in section 2.4) (Russell and Jain-Sheehan, 2015). We also evaluated the effect of the interventions on two secondary outcomes: density of all tick species and stages; and *B. burgdorferi s.s.*- infected *I. scapularis* density.

Intervention and control groups each consisted of multiple 50-meter-long trail segments which were distributed equally across the two study sites (i.e. thirty trail segments in each site including control segments; see details on study design below). In the intervention trail segments, we distributed woodchip borders along each side of the trail using an all-terrain vehicle (ATV) pulling a modified broadcast style top dresser, where the spinner attachment was removed to allow the conveyor to drop the material directly onto the ecotone section, the chips were then manually spread to specifications (1meter wide and 5cm deep) with a light top-up of woodchips applied at the start of the second year; in control segments we did not distribute woodchip borders (McKay *et al.*, 2020). All trails in treatment groups were managed by the NCC following standard trail maintenance practices, with the mowing height allowing sufficient clearance over the woodchip borders to avoid disturbing the intervention placements. This ensured that any emergent vegetation along the sides of the trails was cut to a similar height across all intervention and control segments during the study period. The deltamethrin-treated woodchip intervention group involved targeted spraying of the woodchip borders following their distribution in the specified segments, with spraying repeated at the start of the second season, rather than spraying that targets ecotonal vegetation, as is commonly performed by operators (Hinckley *et al.*, 2016; Ginsberg *et al.*, 2017; Eisen and Stafford, 2021). Our single annual-application, woodchip-targeted, treatment approach aimed to minimize impacts on non-target species in accordance with recommendations for restricted spray applications to trail or leaf litter, avoiding flowering species in order to minimize pollinator exposure to potentially harmful pesticides (Ginsberg *et al.*, 2017). Additionally, trail selection for this study was coordinated with the NCC's biology team to help protect natural waterways from the effects of synthetic acaricides. The woodchips used were primarily sourced from ash trees made readily available through the NCC's forest management program. (McKay *et al.*, 2020).

2.3 Sample size and study design

We calculated that twenty intervention trail segments, each 50 meters in length and sampled on both sides of the trail (total drag distance of 100 meters per segment) with ten intervention segments at each of the two trail locations, were sufficient to detect a 50% reduction in questing *I. scapularis* adult and nymphal tick density in each intervention group compared to the control group, assuming an average of 10 ticks per 1000m of sampling in the control group based on previous research (McKay *et al.*, 2020), with 80% power and a 95% significance level (sample size calculation completed in G*Power software (Faul *et al.*, 2007)). At each site we designated ten control segments, ten woodchip segments, and ten deltamethrin-treated woodchip segments using a stratified block randomized design to control for any environmental differences among the trails; furthermore, we left a 10-metre buffer distance between each trail segment to limit cross contamination of the treatment products between randomized segments. Intervention and control group segment assignments were maintained throughout the entire duration of the study to prevent residual contamination of the original assignment into the following season. Trails assigned to a treatment arm were retreated with woodchips, or woodchips and deltamethrin spray, according to their assigned intervention, at the beginning of the second year of the study.

2.4 Measurement

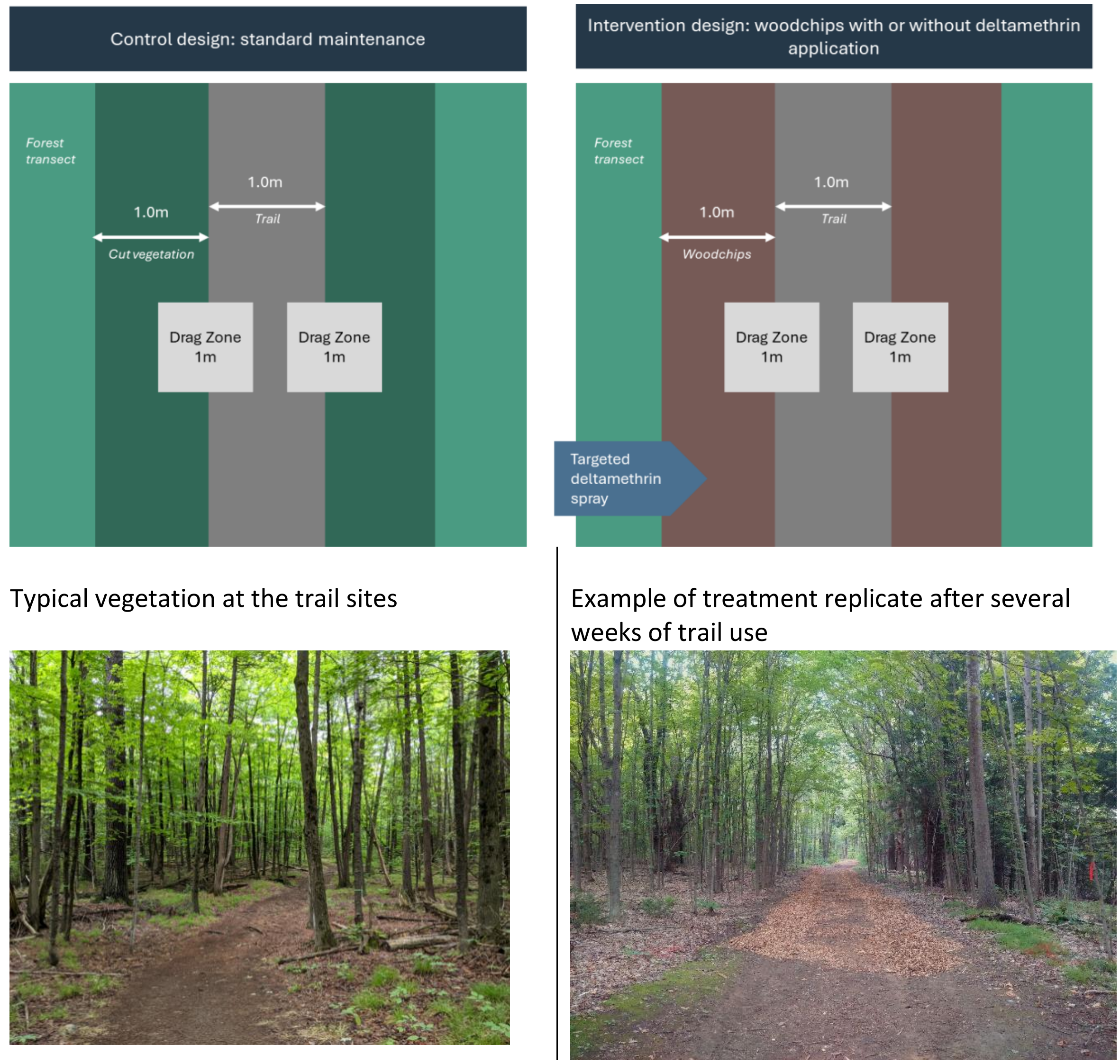
To capture any differences in questing tick density across experimental trail segment (replicates) prior to intervention, we conducted pre-treatment tick dragging using standardized drag sampling methods (Russell and Jain-Sheehan, 2015) at the beginning of each season. In 2022, pre-treatment sampling occurred before in mid-June, followed by treatment application in early July and six consecutive weeks of post-treatment sampling. In 2023, pre-treatment sampling was conducted the week prior to treatment application in mid-June, followed by six weeks of subsequent sampling, beginning the following week. We also collected data on environmental variables from the central point of each replicate during the pre-treatment period each year to assess baseline comparability of sampling replicates across the three treatment arms prior to the intervention: soil moisture, measured using a soil moisture meter (3-in-1 multi-purpose moister plant meter, light and pH acidity tester©, Panacea brand), canopy coverage, measured using a handheld gridded mirror (spherical densiometer, type convex, Forestry Suppliers) to calculate percent of sky covered by vegetation at each measurement point, canopy type (percent deciduous, coniferous, or mixed) and leaf litter depth, measured using a ruler inserted vertically (Table 5.1). We also collected information on the cost per intervention replicate including the costs of contracting personnel, equipment, DeltaGard, and signage for the public.

Table 5.1: Environmental data collected during study

Environmental variables	
Soil moisture	Wet/ Moist/ Fresh/ Dry (continuous; average of both trail sides per trail segment)
Canopy coverage	Percent Open/Tree/Shrub coverage (continuous; average percent coverage between both trail sides)
Canopy type	Percent Deciduous/ Coniferous/ Mixed (categorical)
Leaf litter depth	Depth in cm (continuous)

Post-treatment tick drags were conducted weekly for six weeks continuously throughout the months of July and part of August in 2022; and mid-June through July in 2023, during the period of peak nymphal activity (Wilson *et al.*, 2022). We completed tick collection along each replicate using a 1-square-meter flannel cloth along trail margins of each segment stopping every 10m to check the flannel and researcher clothing for ticks (Figure 5.1). Sampling was conducted sequentially along trail segments in their physical order and used separate tick dragging flannels for each treatment group and for the control group to avoid contamination between groups. Ticks were placed alive in plastic vials and transported on ice to a laboratory at the University of Ottawa for identification of species, and pathogen testing.

Figure 5.1: Study design trail segments



2.5 Laboratory analysis

The study team identified ticks to species, life stage, and sex using standard taxonomic keys (Clifford, Anastos and Elbl, 1961; Keirans and Litwak, 1989; Keirans *et al.*, 1996; Lindquist *et al.*, 2016; Egizi *et al.*, 2019). We tested adult and nymphal *I. scapularis* ticks for *B. burgdorferi* s.s., *Borrelia miyamotoi*, and *Anaplasma phagocytophilum* following standard laboratory protocols (Courtney *et al.*, 2004; Dibernardo *et al.*, 2014; McKay *et al.*, 2020). Ticks were dissected and total genomic DNA was extracted using the QIAamp DNA mini kit (QIAGEN Inc., Mississauga, Ontario, Canada). A duplex qPCR assay targeting the 23S rRNA and the msp2 gene was used to identify *Borrelia* species and *A. phagocytophilum*, respectively. We then confirmed *B. burgdorferi* s.s. and *B. miyamotoi* DNA in positive samples by targeting their ospA and glpQ genes, respectively. Amplification was carried out using the BioRad CFX96 Real-Time PCR Detection System (BioRad, Mississauga, Ontario, Canada). After amplification and real-time data acquisition, analysis of real time PCR data was performed using the CFX Maestro software (BioRad, Mississauga, Ontario, Canada).

2.6 Analysis

We first compared pre-treatment tick counts among treatment groups in the first year, before any interventions were applied, to verify that block randomization adequately controlled for unmeasured confounding factors. Baseline differences in pre-treatment tick counts were summarized descriptively and assessed using negative binomial models. To estimate the relative number per replicate per sampling week of adult and nymphal *I. scapularis* ticks (primary outcome) in each of the intervention groups when compared to the control group, we employed mixed-effects negative binomial regression models, which estimated effect sizes using the Incidence Rate Ratio (IRR) as a model coefficient with a significance level of $p<0.05$. This model type was selected due to detected overdispersion of the outcome data, determined with a dispersion parameter significantly greater than zero, in addition to showing improved fit based on Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) values when compared to Poisson and Zero-inflated models. Because sampling area and effort were identical across all treatment groups and time points, no offset term was required in the negative binomial models; inclusion of an offset did not improve model fit based on AIC/BIC comparisons. For both the primary and secondary outcomes, random effects were included to account for the repeated measures across weeks and for clustering within intervention and control replicates, reflecting the nested structure of segments within and across trail sites.

Model structures were guided by a priori conceptual frameworks, and final model selection was informed by AIC and BIC statistical measures. Environmental variables were initially assessed through bivariate analysis to identify significant associations ($p<0.05$) and to help screen for multicollinearity. Variables found to introduce collinearity or not improving model fit (AIC/BIC) by at least two points were excluded from the final models. Fixed effects in the models included intervention type, year, and trail site (Table 5.2). Additional fixed effects were incorporated to adjust for pre-treatment tick density and relevant environmental variables. We also explored any potential effect modification between sampling week and intervention type in order to identify any modification of treatment effect(s) over time. Model coefficients were reported as incidence rate ratios (IRRs), representing relative differences in tick counts between groups.

Table 5.2. Variables included in the analysis

Variable	Description
Intervention	Intervention Type (categorical)
Pre-treatment density of I. scapularis ticks	Number ticks per $100m^2$ replicate (continuous)
Post-treatment density of I. scapularis ticks	Number ticks per $100m^2$ replicate (continuous)
Date	Week 1-6 (categorical)
Year	2022 or 2023

Trail	Mer Bleue / Stonehaven (categorical)
Randomized block	1-10 per trail site randomized to intervention or control groups
Environmental variables*	Soil moisture, canopy coverage

*Soil moisture and canopy coverage were retained in the final models based on bivariate significance ($p < 0.05$), assessment of collinearity, and model fit criteria (AIC/BIC).

Similarly, to evaluate the effect of the interventions on the density of all tick species and stages, as well as *B. burgdorferi*-infected *I.scapularis* ticks (secondary outcomes) we applied similar mixed effects negative binomial models, using the number of all tick species and stages as well as *B. burgdorferi* positive *I. scapularis* ticks per replicate per sampling week as the outcome (dependent) variables for each respective model. When the analysis was restricted to *B. burgdorferi* infected *I. scapularis* ticks, model power was reduced; thus, to evaluate the effect of any treatment on the density of infected ticks, we combined treatment arms in an additional model using the same covariates.

A severe storm in late May 2022 rendered both of the trail sites inaccessible while fallen trees and debris were being cleared. As a result, the intervention treatment and subsequent data collection were delayed by three weeks in the first year of the study. After these three weeks the study team and contractors were able to conduct pre-treatment tick dragging, woodchip dispersal, and deltamethrin applications at both trail sites in order to begin the study. To assess the potential impact of this delay on our results, we conducted a sensitivity analysis by stratifying model outcomes by year. All analyses were performed in STATA v.16.1 (Stata Corp.,USA).

3 Results

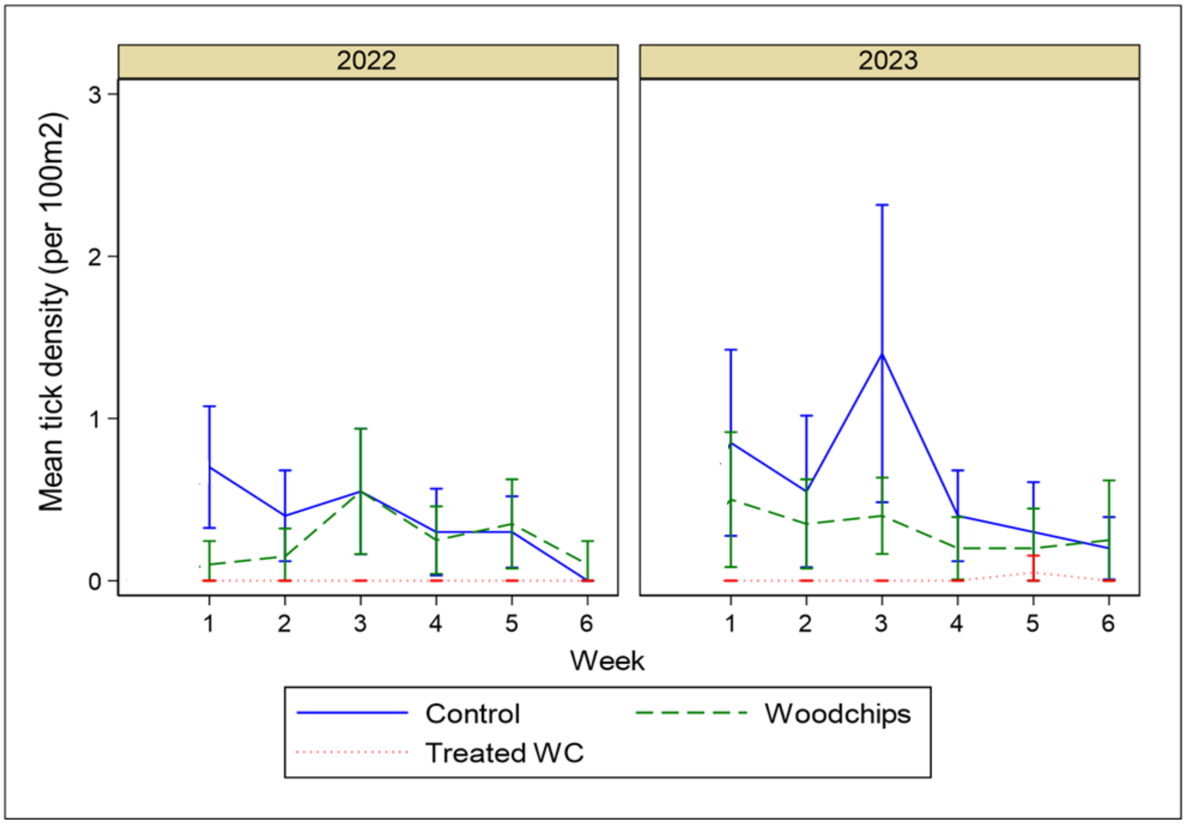
3.5 Descriptive analysis and tables (field sampling)

We completed field sampling for seven consecutive weeks each of the intervention years, with week 1 comprising the pre-treatment assessment of tick density, and the following six weeks representing post-treatment sampling. Throughout the study period we found 355 ticks at the Stonehaven (established tick population) site, of these ticks 78 were *Haemaphysalis leporispalustris* larvae or nymphs and the remaining 277 ticks were *I. scapularis spp.* (all stages) (Table 3). We found a total of 85 ticks at the Mer Bleue (emerging tick population) site, all of which were *I. scapularis* nymphs or adults (Table 5.3). The mean density of adult and nymphal *I. scapularis* ticks per 100m^2 was 0.43 (95% CI: -0.89, 1.74) in the control group compared to 0.24 (95% CI: -0.12, 0.61) in the untreated woodchip group and 0.004 (95% CI: -0.04, 0.05) in the deltamethrin-treated woodchip group. Differences in mean overall tick density over the six-week sampling period between 2022 and 2023 can be seen in Figure 5.2. In total, we tested 293 *I. scapularis* nymphs and adults and detected a mean 34.5% *B. burgdorferi* infection prevalence throughout the course of the study period. None of the tested ticks were positive for *Borrelia miyamotoi*, or *Anaplasma phagocytophilum.* Numbers of ticks collected per segment and the percentage of *B. burgdorferi* positive ticks can be found in Appendix 8.2.2.

Table 5.3. Mean and standard deviation (SD) for questing tick density per 100m^2 trail segment by intervention groups (excluding pre-intervention tick drag) and year, for two tick species (*Haemaphysalis leporispalustris* and *Ixodes scapularis*) combined and individually, *I. scapularis* nymphs/adults.

	Tick species and stage	# per 100m Control Mean (SD)	# per 100m Woodchip Mean (SD)	# per 100m Treated woodchip Mean (SD)	Total (SD)
Total	All tick stages and species	0.58 (0.06)	0.46 (0.18)	0.01 (0.01)	0.35 (1.57)
	Adult and nymphal *I. scapularis*	0.43 (0.15)	0.24 (0.04)	0.004 (0.005)	0.22 (0.62
	B. burgdorferi s.s.- infected *I. scapularis*	0.14 (0.49)	0.09 (0.30)	0.00 (0.00)	0.08 (0.33)
2022	All tick stages and species	0.54 (0.62)	0.33 (0.24)	0.00 (0.00)	0.29 (1.43)
	Adult and nymphal *I. scapularis*	0.32 (0.26)	0.21 (0.19)	0.00 (0.00)	0.18 (0.47)
	B. burgdorferi s.s.- infected *I. scapularis*	0.09 (0.29)	0.09 (0.31)	0.00 (0.00)	0.06 (0.25)
2023	All tick stages and species	0.62 (0.53)	0.59 (0.80)	0.01 (0.04)	0.41 (1.69)
	Adult and nymphal *I. scapularis*	0.53 (0.47)	0.27 (0.16)	0.01 (0.01)	0.27 (0.75)
	B. burgdorferi s.s.- infected *I. scapularis*	0.19 (0.62)	0.09 (0.28)	0.00 (0.00)	0.09 (0.40)

Figure 5.2: Mean density of *I. scapularis* nymphs and adults per 100m transect, stratified by intervention group and year (2022–2023), across six weekly sampling periods with 95% Confidence Intervals.



3.6 Primary outcome: effect of the interventions on questing adult and nymphal *I. scapularis* tick density

The results indicated no statistically significant difference in mean tick abundance between intervention or control groups during the pre-intervention period (incidence rate ratio (IRR)=1.28, 95%CI 0.74, 2.23, p=0.38) and (IRR=0.93, 95%CI 0.51, 1.69, p=0.81) for woodchips and deltamethrin treated woodchips respectively when controlling for group, trail site, and year. The mixed effects negative binomial models with the lowest AIC and BIC included treatment group, trail site, year, and the environmental variables soil moisture and canopy coverage as fixed effects, as well as randomization block and week as random effects. Inclusion of pre-treatment tick density did not improve model fit so this variable was not included in the final models.

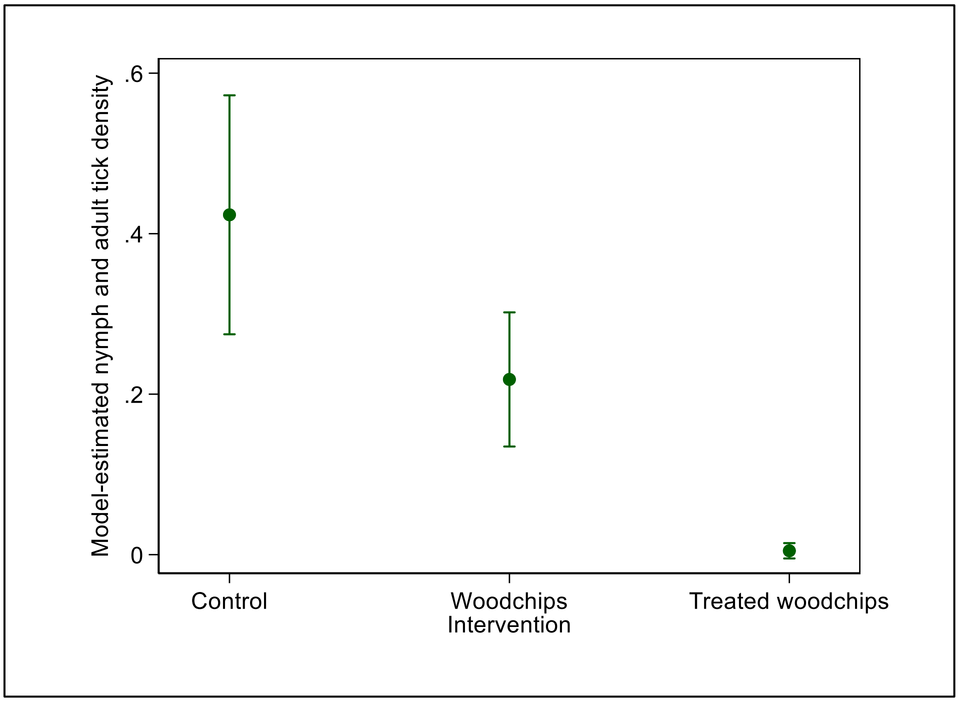
The primary analysis revealed that woodchips treated with deltamethrin achieved a 99% (IRR=0.01, 95% CI: 0.001-0.08) reduction in adult and nymphal *I. scapularis* tick density, while untreated woodchips achieved a 48% (IRR=0.52, 95% CI: 0.34-0.78) reduction (Table 5.4). We also included model estimates for the marginal effect of the intervention group on mean density of adult and nymphal *I.scapularis* ticks per intervention segment (Figure 5.3).

Table 5.4: Model coefficients from mixed effects negative binomial regression analysis of density of adult and nymphal *I.scapularis*, controlling for treatment, trail site, year, environmental variables soil moisture and canopy coverage as fixed effects and randomization block and week as random effects.

Response variable	**Explanatory variable**	**IRR**	**95%CI**	**P-value**
Density of adult and nymphal *I. scapularis*	Woodchip (W) intervention	0.52	0.34, 0.78	0.02
	Deltamethrin treated woodchip (DW) intervention	0.01	0.001, 0.08	<0.001

*Reference category for intervention = Control (no intervention). IRR < 1 indicates lower expected tick density relative to Control; IRR > 1 indicates higher density.

Figure 5.3: Average marginal effect of intervention group on mean density of adult and nymphal *I. scapularis* per $100m^2$ intervention segment



*Model-based predicted mean density of adult and nymph Ixodes scapularis per 100 m² by intervention group (Control, Woodchips, Deltamethrin-treated woodchips). Points show marginal means from a mixed-effects negative binomial model adjusted for trail site, year, soil moisture, and canopy cover; random intercepts were included for block and week. Error bars indicate 95% confidence intervals.

3.7 Secondary outcomes: effect of the interventions on all tick species and stages, and Borrelia *burgdorferi* infected *Ixodes scapularis* ticks.

There was a similar effect of interventions on all tick species and stages, with regression models detecting a 48% reduction in tick density in woodchip treatment groups (IRR = 0.52; 95% CI, 0.32–0.82; $p = 0.006$), and a 99% reduction in tick density in treated woodchip treatment groups (IRR = 0.01; 95% CI, 0.003–0.06; $p < 0.001$) (Table 5.5).

Although the regression models for the secondary outcomes were underpowered to detect changes in the density of infected ticks by individual treatment group, combining the treatment arms into an “any treatment” category showed a 68% reduction in tick density (IRR = 0.32; 95% CI: 0.19–0.55)

(Table 5.5).

Table 5.5: Model coefficients from mixed effects negative binomial regression analysis of density of infected ticks and relative risk of tick infection by intervention, controlling for treatment, trail, environmental variables soil moisture and canopy coverage as fixed effects and randomization block and week as random effects.

Response variable	**Explanatory variable**	**IRR**	**95%CI**	**P-value**
Total tick density	Woodchip (W) intervention	0.52	0.32,0.82	0.006
	Deltamethrin treated woodchip (DW) intervention	0.01	0.003,0.06	<0.001
B. burgdorferi s.s.- infected *I. scapularis* density	Woodchip (W) intervention	0.63	0.315, 1.28	0.20
	Deltamethrin treated woodchip (DW) intervention*	NA	NA	NA
B. burgdorferi s.s.- infected *I. scapularis* density	Any intervention**	0.32	0.19,0.55	<0.001
*Model could not be performed because no infected ticks were detected in the DW arm. **To address sparse counts, we additionally fit a model comparing Control vs. Any intervention (W or DW).				

3.8 Sensitivity analysis; year by year results

Our year-stratified sensitivity analysis revealed that effect sizes were consistent with the overall analysis, though model power was lower in 2022 when assessing the impact of the intervention on *Ixodes scapularis* nymph and adult densities. We also used a likelihood ratio test to assess whether the impact of treatment varied over time. Comparing the full model, which included an interaction term between treatment group and continuous study week, to a reduced model without the interaction term, we found no statistically significant improvement in model fit (χ^2 = 6.57, p = 0.087), suggesting limited evidence of an interaction between treatment and time. Additionally, stratified model results by year did not differ significantly from the full models (Table 5.6).

Table 5.6: Year sensitivity analysis for regression models of effect sizes for 2022 and 2023 to reflect differential timing of intervention application and sampling.

Density of adult and nymphal *I. scapularis*						
	Study Year 1 (2022)			Study Year 2 (2023)		
Explanatory variable	IRR	95%CI	P-value	IRR	95%CI	P-value
Woodchips (W)	0.59	0.34, 1.06	0.08	0.48	0.27, 0.85	0.012
Deltamethrin-treated woodchips (DW)*	NA	NA	NA	0.017	0.002, 0.13	<0.001
Any intervention**	0.33	0.19,0.58	<0.001	0.25	0.15, 0.44	<0.000
All tick species and stages						
	Study Year 1(2022)			Study Year 2 (2023)		
Explanatory variable	IRR	95%CI	P-value	IRR	95%CI	P-value
Woodchips (W)	0.51	0.27, 0.97	0.04	0.51	0.27, 0.95	0.04
Deltamethrin-treated woodchips (DW)*	NA	NA	NA	0.02	0.004, 0.10	<0.001
Any intervention**	0.25	0.13,0.47	<0.001	0.25	0.14, 0.46	<0.001
*No model estimated for Year 1 DW because no ticks were detected in that arm. ** To address sparse counts, we also fit a comparison of Control vs. Any intervention (W or DW).						

Incidence rate ratios (IRR) with 95% confidence intervals (CI) for intervention effects on tick density outcomes, stratified by year (2022 = Year 1; 2023 = Year 2). Models adjust for trail site, soil moisture, and canopy cover; random intercepts for block and week. Reference category: Control.

3.9 Other outcomes - intervention cost

As the woodchips used in this study were readily available, and diverted from landfill, the costs associated with this intervention were restricted to contracting personnel, equipment, the cost of the DeltaGuard, and signage for the public. The total cost of implementing the entire intervention study came to \$2.74CAD per m^2 or a total of \$16,453.69 CAD for all of the sixty trail replicates before local taxes. The cost of the woodchip intervention segments was \$3.79CAD per m^2 whereas the treated woodchips were \$4.44CAD per m^2 (Table 5.7).

Table 5.7: Cost per intervention segment in CAD

Items	Control (2000m^2)	Woodchip (2000m^2)	Treated woodchips (2000m^2)	Total (cost/m^2) where intervention was applied
Woodchip associated cost (equipment and personnel)	NA	7578.84 (3.79/m^2)	7578.84 (3.79/m^2)	15,157.68 (3.79/m^2)
DeltaGuard associated costs (equipment, personnel, product)	NA	NA	1296.01 (0.65/m^2)	1296.01 (0.65/m^2)
Total	NA	7578.84 (3.79/m^2)	8874.85 (4.44/m^2)	16453.69

4 Discussion

Our two-year experimental field study of environmental management interventions to reduce tick density along recreational trails in a setting endemic for Lyme disease demonstrated promising results for ecotonal woodchip borders. Both treated and untreated woodchip interventions significantly reduced the density of adult and nymphal *I. scapularis* ticks, the primary vectors of Lyme disease in eastern North America, with the deltamethrin-treated woodchips achieving a 99% (IRR=0.01, 95% CI: 0.001-0.08) reduction over two seasons of intervention. Both interventions also reduced the density of all tick species and stages, suggesting that woodchips may impact other species of ticks that may serve as vectors of disease in these settings. While the greatest results were found in the deltamethrin-treated woodchip group, the untreated woodchip intervention also achieved 48% (IRR=0.52, 95% CI: 0.34-0.78) reduction in outcome measures, suggesting that a range of intervention approaches, including those with or without targeted acaricide treatment, may meaningfully contribute to reductions in tick populations and human-tick encounters in similar environmental and/ or trail management conditions.

While numerous integrated control studies of *I. scapularis* ticks have been published, the majority do not incorporate ecotone modification or xeric substrates. Our findings align with results from our team's previous study conducted in the Ottawa Greenbelt, where the application of xeric substrates, such as woodchips, used as ecotone modification resulted in significant (68.4-75%) reductions in all tick and adult and nymph stage *I. scapularis* tick density respectively over one season (McKay *et al.*, 2020). The present study that expanded the study area to two sites with differing stages of tick establishment, and over two consecutive years, provides more robust evidence to support the effectiveness of these interventions. Our study findings are similar to a study conducted in Maryland USA, which used ecotone landscape modification to a mowed pasture or forest substrate (silt fence barrier), comparing sites untreated to those treated in a later study year with cyfluthrin. The study found significantly lower tick densities, depending on tick life stage, in the treated pasture that was intended to protect from tick encroachment (Carroll and

Schmidtmann, 1996). Despite variation in study design, environmental context, and effect magnitude, the overall consistency across these studies strengthens the evidence that certain environmental modifications, such as ecotonal border substrates or physical barriers, may serve as effective, low-impact/low-cost tick control strategies in peri-urban green spaces.

One of the key strengths of this study lies in the sustainable use of a local by-product. Ash trees preventatively removed from the area to reduce the risk of invasive species infestation were repurposed as chipped wood substrate, offering a solution to landfill diversion while supporting an environmentally conscious intervention approach. The use of woodchips, a natural and biodegradable material, represents a low-impact alternative to chemical-based vector control strategies. However, there is concern that their efficacy likely diminishes over time as the material degrades. We assessed the possibility that the relationship between intervention and tick density was modified over time, but these interaction variables were not significant. The use of ecotonal woodchip borders may also be a cost-effective solution, with the total cost of intervention between CAD3.80-4.40 per square meter of trail length; notably, the addition of deltamethrin spraying only increased the total cost by CAD0.60 per square meter of trail length. It is important to note that environmental concerns may restrict the application of acaricide-treated substrates to certain locations, such as those at least 10m from waterbodies, following the requirements of the responsible regulatory authority or organization. This is due to the potential for contamination through accidental drift of acaricide product during spraying or potential runoff of chemical compounds from intervention sites, and toxic effects of synthetic pyrethroids on aquatic organisms (Ranatunga, Kellar and Pettigrove, 2023). In the current study, intervention locations were situated away from waterbodies for this reason. However, further research would be useful to assess the concentration of chemicals that may leach out of treated woodchips, given that pyrethroids are known to adhere to soil particles and organic matter, and thus have a low potential to be washed away or move into groundwater (Health Canada, 2024). These findings suggest that treated and untreated xeric substrates such as woodchips hold promise for reducing the reducing opportunities for human exposure to ticks in recreational trail settings, such as the Ottawa Greenbelt. To better inform long-term tick management, further assessment is needed to determine the durability and sustainability of intervention effect. Future research should explore the longevity of efficacy in laboratory settings as well as duration of effectiveness (in field settings) in the absence of annual reapplication and investigate the threshold at which degradation leads to loss of impact. Understanding this timeline will be crucial for assessing the cost-effectiveness and sustainability of biodegradable interventions at scale. Furthermore, understanding the impact of targeted acaracide treatments to a xeric substrate, and its effect on non-target pollinators, compared to more traditional application approaches would help inform its environmental impact moving forward. Comparative assessment of acaricide-treated woodchips with direct acaricide-only applications would also be valuable, as they could identify additional cost-effective strategies where direct application is feasible. Treated woodchips remain a practical intervention to evaluate, considering that applied management strategies would apply continuous woodchip borders where possible, and restricting acaricide use to areas where there is high tick encounter risk, and lower risk to the environment.

4.5 Strengths and limitations

While this study achieved strong results in tick reduction, we must highlight several limitations. First, the study team faced several logistical challenges in terms of distributing the woodchips alongside the natural trail system. This intervention is limited by the type of recreational trail suitable for both intervention types, constrained by physical access for equipment and the movement of the trail care team. Furthermore, cost considerations may limit the scalability of this kind of intervention involving xeric substrates, like woodchips, especially in areas where implementation would require extensive coverage or upkeep. Additionally, application of deltamethrin is limited by proximity to waterways and weather conditions on day of application, which could pose a challenge in terms of feasibility and generalizability of this integrated intervention.

Additionally, environmental conditions influenced the feasibility and consistency of the intervention. A severe storm early in the first year significantly disrupted both the implementation of the woodchip treatment and the timing of post-treatment data collection. We performed a sensitivity analysis by year to assess the impact on overall study effect sizes and found negligible effect on the overall effect size and statistical significance. Weather events like these underscore the need to account for climate variability in the implementation of tick control programs, as this may be an increasing concern with ongoing climate change. It should also be noted that seasonal or daily fluctuations in tick activity may not have been fully captured, which could contribute to unmeasured confounding in the analysis. Furthermore, environmental variable measurement was only conducted pre-intervention, limiting our ability to evaluate post-treatment environmental effects. Finally, because this study was conducted alongside active recreational trails, tick sampling was conducted without replacement; however, control segments were sampled using the same approach, minimizing the potential for systematic bias.

Despite some operational challenges, the intervention achieved a notable reduction of questing ticks in both intervention types. This suggests that the use of integrated tick management strategies could be used to account for some of the challenges to the feasibility and trail suitability of each application type when applied in the context of a recreational tick control program.

5 Conclusion

Overall, our findings provide evidence that both acaricide treated and untreated woodchip interventions can effectively reduce tick populations in a recreational context. When considered alongside previous work, these results support the potential for scalable, tick control strategies to contribute meaningfully to integrated tick management programs in peri-urban settings.

Disclosures etc

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6. Evaluating the Acceptability of Lyme Disease Prevention Strategies in Ottawa: A Mixed-Methods Approach (Objective 3)

Article Preface

This chapter is a mixed-methods study evaluating the feasibility and acceptability of selected tick and LD prevention and control interventions in the Ottawa region. The study was co-designed with my thesis supervisor and co-supervisor, informed by existing acceptability frameworks. I conducted all qualitative key informant interviews and was responsible for adapting and refining an existing survey instrument in both English and French, which was reviewed and verified by additional contributors, as described in the manuscript. I then led qualitative data cleaning and coding, working alongside a co-coder. I performed all quantitative analysis and was responsible for drafting the manuscript. Members of my Thesis Advisory Committee provided guidance on analytical decisions and contributed feedback during manuscript development. At the time of submission of the thesis, the manuscript is in preparation for submission to a peer-review journal. This study obtained ethical approval from the University of Ottawa Health Sciences and Science Research Ethics Board (file number H-11-22-8400).

Article Content:

Title: Evaluating the Acceptability of Lyme Disease Prevention Strategies in Ottawa, Canada: A Mixed-Methods Study

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Abstract:

Introduction: In recent years, the province of Ontario has reported one of the highest Lyme disease incidence rates in Canada due to the abundance of habitat that favours the survival and reproduction of ticks and wildlife species that carry the LD pathogen (*Borrelia burgdorferi*). The aim of this study was to understand the acceptability and feasibility of various methods for LD prevention in the context of peri-urban settings in Ottawa, where LD is an emerging problem.

Methods: This research used an exploratory sequential mixed methods design. We conducted 12 semi-structured key informant interviews with public health practitioners, land management officials, and community members to identify the most locally acceptable and feasible LD interventions. We used themes that emerged during the interviews to develop and refine a previously validated questionnaire and implement a population-representative cross-sectional survey to evaluate public acceptability and feasibility, which applied a 9-point acceptability scale to this context. The survey also collected information on frequency of tick bites, uptake of LD

prevention behaviours, and explanatory variables including demographic information, property type and characteristics, and engagement with occupational or recreational outdoor activities. We distributed the survey to the Ottawa public via a web panel in 2024. **Results:** A total of 1015 participants responded to the survey. Findings from both key informant interviews and the population survey indicated higher acceptability of personal protection strategies and landscape management strategies. Twenty-nine (29) percent of survey respondents reported knowing someone with an LD diagnosis and 3% reported having received a diagnosis of LD at some point, while 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 methods of protection against ticks while outdoors. Acceptability of interventions was more consistently associated with respondents' sociodemographic characteristics than with their risk and exposure indices, which varied greatly in their contribution to acceptability across intervention types.
Conclusions: In our study, participants generally found host-targeted and chemical strategies to be the least acceptable type of intervention to prevent LD, while personal prevention strategies, land management, and natural alternatives to chemicals were found to be the most acceptable in the Ottawa context. The factors associated with higher acceptability varied by intervention type. This information will be helpful in producing high quality, targeted messaging to promote the uptake of different LD interventions. Overall, these findings will help to better inform policy on feasible and acceptable LD prevention practices that respond to local population preferences and context.

Ethics: 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).

1. Introduction

Lyme disease (LD) is a tick-borne disease caused by the bacteria *Borrelia burgdorferi s.l.* and is a growing public health threat in Canada, with reported cases rising from 682 to 4,785 between 2013 and 2023 (1). In Ottawa, the national capital city, the incidence of LD has grown from 7.7 to 37 cases per 100,000 people between 2015 and 2024 (2). Previous studies in Ottawa have identified several hot spots of LD risk due to the city's particular combination of land use, urban expansion, and climatic/ecological suitability, and presence of the primary vector tick in this region (*Ixodes scapularis*) (3–6).

Strategies to prevent LD can be broadly categorized into four groups. The first group comprises environmentally applied strategies, which include chemical, biological, and natural tick control strategies. These products are most commonly applied to the ground or vegetation as a spray or pellet formulation with the end goal of killing or repelling tick vector species in a certain area (7–12). The second group are host-targeted strategies, which may target the reproductive host of *I. scapularis* ticks, the white-tailed deer (*Odocoileus virginianus*), in an effort to reduce the overall population of ticks, or prevent the deer from moving through human use areas and transporting ticks into these spaces (8,13). These strategies may also target the disease amplification hosts, primarily the white footed mouse (*Peromyscus leucopus*), with the primary aim of reducing the prevalence of the *B. burgdorferi* bacteria infection in ticks and their hosts (14,15). The third group includes landscape modification strategies, which comprise options like ecotone modification and vegetation management to reduce tick habitat around human use areas (7). Finally, the focus of many LD prevention campaigns is on personal protection methods, such as using repellent sprays containing DEET or picaridin on the skin, permethrin-treated clothing, or wearing long clothing and tucking pants into socks etc. (16).

Knowledge, Attitudes, and Practices (KAP) surveys are commonly used in cross-sectional studies to assess what populations know about a disease, how they perceive associated risks, and which preventive behaviours they adopt (17). In Ottawa, a KAP survey was previously conducted to examine residents' awareness and perceptions of ticks and Lyme disease, as well as the strategies they use to prevent tick encounters and tick bites, and some of their risk behaviours (18). Though KAP surveys provide valuable insight into awareness and behaviours, there is continued need to understand how a given community would respond to specific disease prevention or control interventions to inform the implementation of effective public health strategies. As a next step, this acceptability and feasibility study focused directly on the conditions required for successful and sustainable interventions, recognizing that public acceptability plays an important role in the uptake of health and social interventions. Although several studies have examined acceptability of tick control or LD prevention activities in other contexts, evidence shows that acceptability is context-dependent and changes over time (19–21). This reinforces the need to further assess and understand acceptability, and its drivers, locally, in cities like Ottawa where LD is a growing public health concern.

Our overarching study aim was to assess the acceptability and feasibility of tick control and Lyme disease prevention options in Ottawa, Canada. The qualitative phase sought to explore important themes surrounding key informants' understanding of public and organizational acceptability with regards to the interventions, which informed the development and refinement of a survey questionnaire. The quantitative phase then assessed the comparative acceptability of tick control and LD prevention options in a population-based sample using a cross-sectional survey and identified important sociodemographic and factors associated with high acceptability across intervention categories. We integrated both phases using an exploratory sequential mixed methods approach to provide a comprehensive understanding of the relative acceptability of LD prevention strategies amongst Ottawa residents in the current socioecological context.

2. Methods

2.1 Ethics

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). This study employed an exploratory mixed-methods research design combining key informant interview (KIIs) and a population level cross-sectional survey administered through an online web panel by the online survey and analytics company Leger 360, which has expertise in collecting representative survey data in the greater Ottawa area (22). Key informants participated in a 1:1 verbal consenting conference with the researcher prior to the beginning of the interview, while survey participants consented through an online form.

2.2 Study design

We used an exploratory sequential mixed methods approach to measure acceptability for several tick control and LD prevention interventions in Ottawa. Phase 1 of the study included qualitative key informant interviews (KIIs), followed by Phase 2, a quantitative approach that included the development and refinement of an existing survey, and distribution of a cross-sectional survey targeting a representative sample of adults in the city of Ottawa using a stratified sampling design.

2.3 Phase 1- Key informant interviews

We conducted 12 semi-structured key informant interviews to assess the feasibility and acceptability of LD prevention and control approaches in the local Ottawa context and modify the subsequent questionnaire. These KIIs included participants from a variety of fields, areas of expertise and roles who were recruited using a purposive sampling frame (23). The sampling frame included field scientists, public health professionals, healthcare professionals, individuals with lived experiences of LD (including patient representatives and caregivers), and community members with experiences living or recreating in environments where tick exposure may occur. We collected information on participants' personal or professional acceptability of various tick or Lyme disease control options, and their perceived barriers, feasibility, and public concerns (Appendix 8.3.4). Recruitment was ongoing to the point of thematic saturation, and for each interview we collected an audio file and verbatim transcript (23). Data were analyzed in NVivo Qualitative Data Analysis Software (v 14) by two researchers, who independently coded three transcripts to ensure interrater reliability and expand the codebook. The final codebook was applied to the remaining nine transcripts (24).

We used a combination of inductive and deductive coding on our transcripts. We aimed to capture overarching (inductive) themes of drivers of acceptability and feasibility (or the lack of). We also used a deductive approach, using predefined codes that identified data specifically relevant to the four pre-defined tick control and LD prevention categories (i.e. environmentally applied, host targeted, landscape management, and personal tick protection strategies). Furthermore, results emerging from the interviews informed the refinement of an existing questionnaire previously used by Logan et al. 2024, to better capture data on the acceptability of interventions that population members had direct control over, and acceptability of interventions that survey respondents would or would not find acceptable if they were implemented by a governmental body or other kind of organization (18).

2.4 Phase 2.1- Questionnaire adaptation and design

We modified the questionnaire used in the study by Logan et al. to include a brief description of each category of tick control or LD prevention strategies and incorporated an infographic to improve intervention understanding and respondent comprehension regarding each of the acceptability domains. We also used the thematic analysis of KIIs to refine the acceptability domains used in the survey. The initial domains included personal protection, landscape management, host-targeted interventions, and environmentally applied strategies. Based on interview feedback, several categories were subdivided: personal protection was separated into behavioural and chemical strategies; host-targeted interventions were divided into deer-targeted and small mammal targeted approaches; and environmentally applied strategies were classified as natural alternatives to chemical acaricides, biological control options, or chemical acaricide control options, while landscape management remained unchanged. This ultimately resulted in eight acceptability domain measures.

For each of the domain measures, we used a 9-item composite acceptability score which was adapted from the Intervention Rating Profile tool and previously used to evaluate the acceptability of public health interventions across multiple cultural and global health contexts, and modified this to the local context and public health issue of LD (Table 6.1) (25–27). This composite scale assesses perceived effectiveness, personal approval, willingness to use and/or recommend the intervention, and perceived community benefit. Scores were calculated by summing the values of the nine indicators, each of which are graded by participants on a 4-point Likert scale without the neutral option (25). On a summed score from a minimum of 9 to a maximum of 36, 22.5 is considered the threshold of acceptability as the median score (25).

Table 6.1: Nine indicator acceptability metric adapted from Krentel et al 2021 (25)

Number	*Indicator*
1	The strategies in this category work against ticks
2	The strategies in this category work against Lyme disease
3	I would use the strategies in this category on my own property (or if I had a property)
4	I would like the strategies in this category to be used in public spaces
5	I would recommend the strategies in this category to friends or family
6	I would be willing to change the way I take care of my property (or if I had a property) to incorporate the strategies in this category
7	I like the strategies in this category
8	The strategies in this category are a good way to improve health and prevent illness caused by ticks and tick-borne diseases
9	Overall, these strategies will help my community

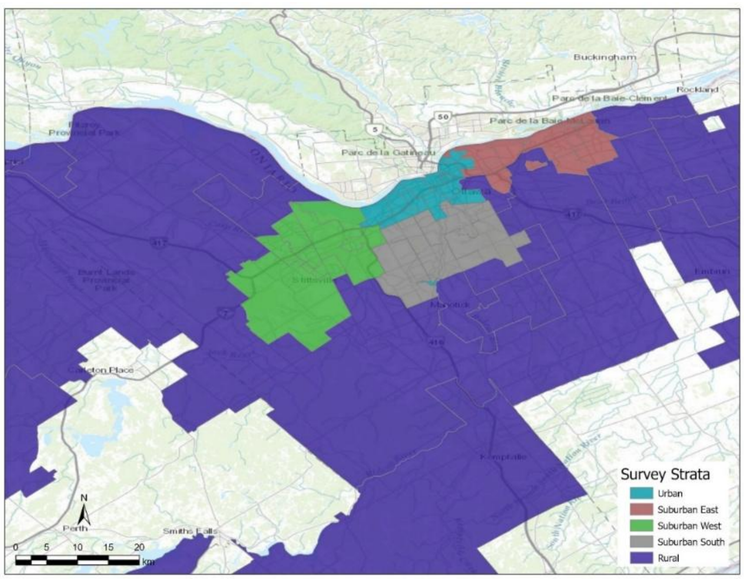
Modified from (Krentel et al. 2021) (25)
Participants answered along the continuum of disagree a lot, disagree, agree, agree a lot.

The survey was piloted by five individuals (three research assistants, and two members of the public). Two of these individuals (one public member and one researcher) validated the translation into French. The survey was then pre-tested with a sample of 15 web panel members to assess response functionality, and data capture prior to full questionnaire deployment. The cross-sectional online survey of adults residing in Ottawa, Canada was distributed in November 2024 through Leger 360, an online survey and analytics company. Leger invited a representative sample of participants from their panel of Ottawa residents using a recruitment script developed by the research team. Respondents were able to complete the survey in either English or French, the two official languages of the region.

We used a stratified sampling strategy to ensure geographic representation across Ottawa's major residential zones (Urban, Rural, Suburban West, Suburban South, and Suburban East (Figure 6.1), similar to the sampling approach used by Logan et al. 2024 (28). These strata definitions were created from the previous study using population density, walkability, and car-commuting rates from the Ottawa Neighbourhood Study (ONS), and are described in detail by Logan et al. 2024 (28). Furthermore, the original stratification used the Ottawa Greenbelt, which separates the urban core from surrounding suburban zones, as a geographic divider. In our study, we applied the same general stratification concept by assigning participants to strata based on the Forward Sortation Areas (FSAs) of their home postal code. This allowed us to map individuals to the five settlement types and maintain balanced sampling across urban, rural, and suburban neighbourhoods. We aimed to collect 200 responses per strata in order to allow us to estimate at least 1.67 odds of Ottawa respondents having high acceptability of each intervention with 80% power, 95% confidence and 5% margin of error (calculated in G*Power 3.1)(29).

The questionnaire captured data on sociodemographic variables (sex, gender, age, ethnicity, region of residence, length of residence in Canada, income, education), and risk and exposure variables (occupation - outdoor or indoor, suspected or confirmed previous LD diagnosis, yard maintenance requirements - whether participants had access to a yard and whether they were responsible for its upkeep, forest visitation frequency, pet ownership, tick encounter frequency, and tick bite frequency). The questionnaire also collected data on perceived cost, feasibility, and opinions on who should be responsible for intervention implementation.

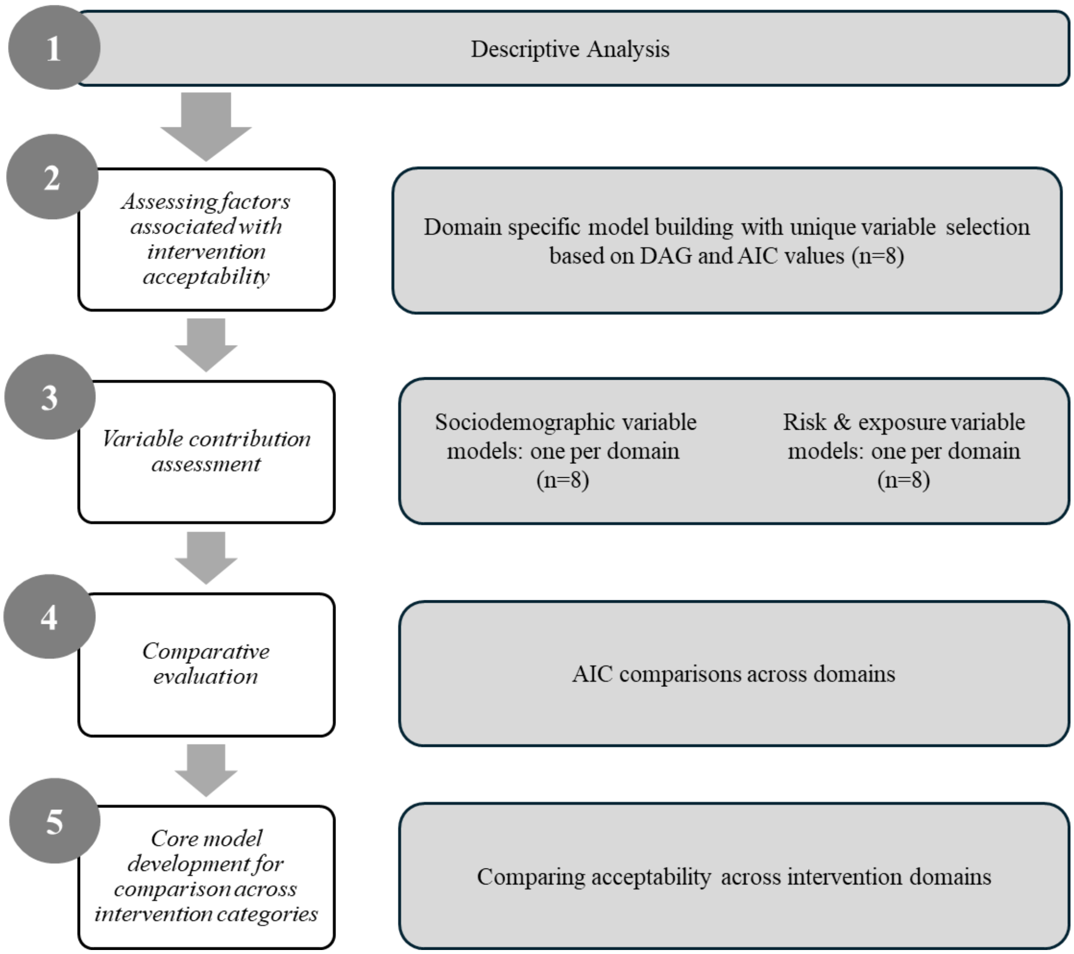
Figure 6.1: Classification of Ottawa neighborhood by postal code for survey distribution across five sampling strata: Green-Suburban West, Blue-Urban, Grey-Suburban South, Red-Suburban East and Purple-Rural (28).



2.5 Phase 2.2- Population survey statistical analysis

To evaluate predictors of intervention acceptability, we used a staged analytical aproach that combined descriptive analyses, domain-specific model development, and AIC-based model comparison. The overal analytical framework guiding this process is illustrated in Figure 6.2.

Figure 6.2: Analytical strategy for acceptability model development and analysis of intervention acceptability



Descriptive analysis

We first generated descriptive summaries to assess the number and proportion of respondents corresponding to the included variable categories for each section of the questionnaire. No missing data were possible for closed-ended survey items used in this analysis, as responses were required. Write in "other" responses were reviewed and reclassified into existing categories where appropriate. "Don't know" responses were retained as a separate category or grouped with "not applicable" where conceptually appropriate. Data on ethnicity were initially collected using detailed categorical options and subsequently collapsed into a three-level variable (White, Indigenous, Other) for comparability with previous work in this region (28). Data were collected on sex and gender; however, due to collinearity between these variables, only gender was retained in the analysis. We compared survey respondent characteristics with the 2021 Ottawa Census to assess sample representativeness and identify potential sources of selection bias using the 2021 Ottawa Census as a reference. The primary analysis subsequently focused on estimating the overall acceptability scores based on the 9-item composite acceptability score described previously and identifying factors associated with high acceptability for each of the eight primary intervention categories. Because acceptability scores were expressed as binary outcomes (e.g., acceptable >=22.5 vs. low acceptability <22.5), we fit separate multivariable logistic regression models for each intervention domain.

Assessing factors associated with intervention acceptability

Variable inclusion for each intervention specific model was guided by a conceptual diagram of hypothesized relationships amongst exposure and outcome variables. The conceptual diagram informed the set of justified covariates, including key sociodemographic variables retained a priori. Akaike's Information Criterion (AIC) was applied to compare candidate model specifications within this framework and assess variable contribution. To assess factors associated with high acceptability for each intervention, we compared the full model with a series of reduced models using a leave-one-out AIC approach, in which variables were removed one at a time from the full model to evaluate their relative contribution to model fit based on changes in AIC (30). We developed separate models using either sociodemographic factors (e.g.

gender, age, ethnicity, region of residence, length of residence in Canada, income, education level, and primary language) or risk and exposure factors (e.g. tick encounter or bite frequency, outdoor occupation, suspected or diagnosed LD, yard access and maintenance, forest visitation frequency, pet ownership) to reduce potential confounding, with cluster robust standard errors calculated, accounting for region of residence for all models (i.e., Urban, Suburban East, Suburban South, Suburban West, and Rural) (Figure 1)(31).

Contribution of sociodemographic and risk/exposure variables

In order to explore the relative contribution of sociodemographic or risk and exposure variables to model fit, we compared changes in AIC values across sixteen models (two per intervention domain) consisting of a sociodemographic only model, and a risk and exposure variable only model. Within each model set, variables were dropped in a "leave one out" method to assess their relative contribution to the model's fit. We classified predictors associated with an increase in AIC of 2 - 4 points as having a moderate contribution to model fit, and those associated with an increase of <2 points as having minimal impact on model fit (30). Lower AIC values indicate better relative model fit, while increases in AIC following variable removal indicate a greater contribution of that variable to model fit (30).

Core model development for comparison across intervention categories

The conceptual diagram and AIC comparisons were subsequently applied across the sixteen intervention-specific models (two models per domain) to inform the development of a "core" model. This model consisted of a common set of variables across the models that improved model fit by at least two AIC units and were supported by the conceptual diagram structure. We applied these core variables to a generalized estimating equation (GEE) model to allow direct comparison of the models across intervention categories. All analyses were performed in Stata (version 18.5).

Sensitivity analysis

The acceptability cutoff score of 22.5 has been used in several previous studies as threshold for acceptability, as it is midpoint of the score range from 9-36, low to positive acceptability (25,26). Recognizing the novel application of this acceptability tool to LD and the need to examine the suitability of this cutoff score, we performed a sensitivity analysis focused on more strict thresholds (≥23.5 and ≥25) to assess whether relative patterns of acceptability were robust to these definitions (Appendix 8.3.1). Lower thresholds were not explored further, as values below this midpoint would classify low acceptability as “high”, limiting conceptual interpretability. We found that most variables kept their relative acceptability classification, with the exception of environmentally applied chemicals, which had a more bimodal distribution of acceptability scores compared to the other acceptability domains; we therefore opted to apply the 22.5 cutoff threshold in our analysis. In addition, the score of 22.5 and the relative acceptability of the domains was supported by our qualitative results, indicating that this cutoff was appropriate for this analysis.

3. Results

3.1 Qualitative phase

3.1.1 Characteristics of Key informants

We included twelve key informants in our study and concluded recruitment once no additional themes were generated through interviews, indicating thematic saturation (23). Key informants were from a range of backgrounds and included program managers in environmental and public health programs, as well as community members and representatives from recreational organizations (Table 6.2). There was a relatively even distribution of men (5) and women (7) represented amongst the key informants, and ages ranged from 20s-70s. All interviews were conducted in English.

Table 6.2: Key informant participant characteristics, including sector, role type, and relevant expertise

ID	Sector	Role Type	Relevant Expertise
KI1	Natural sciences and environmental policy	Program manager	Wildlife systems, staff exposure concerns, communications
KI2	Natural resource management	Scientist	Staff exposure concerns, ecological concerns and communications
KI3	Recreational organization	Executive board member	Member exposure concerns
KI4	Health	Program manager	Communications
KI5	Environmental conservation organizations	Founder and volunteer	Communication, community exposure concerns
KI6	Community association	Volunteer	Environmental work, community exposure concerns

KI7	Community association	Board member	Environmental communications, community exposure concerns
KI8	Recreational organization	Founder and volunteer	Member exposure concerns
KI9	Health research	Researcher and LD patient	Patient community communications
KI10	Health professional, member of public	Pediatric health professional and member of public	Family exposure concerns
KI11	Health research	Social science researcher	Family exposure concerns
KI12	Wildlife research	Scientist, LD patient	Research team exposure concerns, wildlife host behaviour and wellbeing

3.1.2 Qualitative thematic findings

We identified six themes (two inductive and four deductive) that emerged from the key informant interview coding process: unintended consequences, personal or external control, environmentally applied strategy acceptability, host targeted control acceptability, landscape management strategy acceptability, and personal protection strategy acceptability. These themes, subthemes, and example quotes are shown in Table 6.3.

Table 6.3: Themes and subthemes from key informant interviews

Themes and subthemes (inductive or deductive)	Example quote
Unintended consequences (inductive) • Concerns regarding environmental impact • Concerns regarding non-target species (e.g., pollinators) • Concerns regarding risks to pets and children	"I actually do mow to keep, some of my grass down. I probably mow more than I would otherwise to try to make sure I'm not brushing against tick stuff like leaf litter, so, from a rural landowner, maybe around the house if you're told from an ecological perspective and everything else to leave it for the bees and the things. But if you wanted to remove it away from your house… you could do that." [Environmental conservation organization]

Personal or external control and scale (inductive) • Acceptability framed by personal vs. external control • Feasibility influenced by implementation context • Scale dependent perceptions of intervention feasibility	"Can I give you answers from two different perspectives?... One group that we do interact with quite a bit and [community organization name] are the landowners up in the [peri-urban town]…We're talking rural, often multiple acres. They [rural residences] have a house. So, I think that's one group. And the other group would be the peri- rural [residences]. …they're backing onto a natural area…so I can see there being kind of two different answers depending. Is that OK to kind of give you two different answers or would you prefer I answer for one group?" [Environmental conservation organization] "For landscape management as a solution for a community… so for public spaces or for my space at home… so generally the biggest issue, and it's a little bit like when you look at climate changes generally it's you have all these stakeholders and you want them all to do the same thing. Just managing all of that [stakeholder coordination] is such a huge level of work, and because they all have their own policies and own reasons for doing stuff, and then they may not all agree. So just I think that's overarching comment for all of the solutions." [Community association].
Environmentally applied strategy acceptability (deductive) • Low acceptability of chemical control options • Greater acceptability of natural or biological alternatives • Perceived high feasibility of environmental application compared to other approaches • Concerns regarding frequency of reapplication and maintenance	"I don't like the chemical control. It just doesn't sound great for the environment and like for us breathing it in, but like I also probably don't know that much about it either. The natural alternative sounds nice." [member of public-medical professional] "I like more the more the more natural ways, the plant-based pest control and the natural enemies because as for the chemical control… we have been told in university that... their effect is usually bigger than what we expect and so yeah, I'm more comfortable with natural solutions than chemicals." [Natural sciences and environmental policy]. "I mean probably they're all similarly feasible. I don't, except for obviously the natural enemies being the least feasible, but probably in terms of applying something to the environment, whether you apply [product]- like if they have to be reapplied or so I don't know enough about that."[Health researcher]
Host targeted control acceptability (deductive) • Anticipated social resistance to deer targeted strategies	"Deer management is a hot button topic and, we, it was discussed probably 15-20 years ago, more in terms of impacts on vegetation, and there is no appetite to talk about deer exclusion, deer reduction… And certainly, deer reduction/controlled hunts, that would be a huge public controversy." [Natural sciences and environmental policy].

- Interest in small mammal-targeted approaches - Uncertainty regarding function and feasibility of small mammal interventions	"I don't see that [bait boxes] as being a big a big issue. But you know people will be concerned. They would have questions- Are kids going to find these, pick them up, play with them? Those are usually the issues that come." [Wildlife scientist]
Landscape management strategy acceptability (deductive) - High acceptability of most landscape management approaches - Perceived compatibility with existing recreational space management priorities - Concerns regarding scalability and feasibility for individual implementation - Low acceptability of vegetation burning	"On wood chips [substrates], I'm going to assume they're not treated and they're just generally wood chips. I see people being super on board…What we've really discussed in the past, I think is more the vegetation clearing along the edges. So, trimming back trails so that people are not brushing up against vegetation when they're going along those trails, that's, I think the most feasible thing…. And then, we have in some cases talked about barrier approaches. So, putting down a woodchip trail instead of just a natural trail." [Natural sciences and environmental policy]. "I mean, I'm thinking about it in the terms of like our farm, and what's possible there, like we do try and mow the fields where we walk through, not all but some of the fields when we go, we have a pond but try and keep that mowed for that very reason. That's probably feasible. And it's certainly, I like it. It's acceptable to me when it's done." [Health researcher].
Personal tick or LD protection strategy acceptability (deductive) - High overall acceptability of personal tick or LD protection strategies - Variation in the preference across specific tick or LD prevention behaviours	"Probably they'd [our members] be more likely to use you know OFF or Deep Woods, like something with DEET because they're familiar with it. They might have a hesitancy towards permethrin… like if we can get our hands on it and it's readily available and not too expensive, providing that at the trail day, so people can apply it if they want." [Recreational organization board member] "I don't like spraying Permethrin on my clothing that I wear every day or I will dedicate a pair of pants for it. So that's what I recommend to my students as well. I do not like applying DEET or other products to my skin, directly to my skin... I would rather use protective clothing. That barrier for mosquitoes and ticks and other things than use DEET directly on my skin. I will spray it sometimes on my clothes." [Natural sciences and environmental policy].

Across intervention types, participants expressed concern about unintended consequences, such as the impact of interventions on the environment, non-target species (like pollinators), pets, and children when it came to many of the interventions. Acceptability was frequently related to perceived ecological safety.

A second cross-cutting theme concerned control and responsibility over a given intervention strategy, in addition to scale and context. Participants evaluated both feasibility and acceptability based on whether an intervention fell within their direct control vs. requiring external coordination and implementation (municipal, provincial etc.). Perceived feasibility was closely tied to implementation scale and the context of responsibility.

Within deductively coded intervention categories, chemical control strategies were generally viewed unfavourably and associated with low acceptability, whereas natural or biological alternatives were viewed as being more acceptable, though participants still brought up concerns regarding environmental safety. Environmentally applied strategies were often perceived as feasible, but there were some questions regarding reapplication frequency and maintenance over time.

Similarly host-targeted interventions, specifically deer targeted strategies, face challenges in terms of both perceived feasibility and acceptability. Both professionals working in wildlife and environmental sciences, as well as public policy, anticipated substantial public resistance. In contrast, small mammal strategies were interesting to participants, but participants were unclear on how they function and unsure of the feasibility.

Landscape management strategies were broadly perceived as acceptable and feasible, with the exception of vegetation burning. Ecotone modification was viewed as being well aligned with recreational space management priorities, though there were some reservations about the potential feasibility of scaling these projects to large spaces, and implementing them in a residential space.

Finally, personal protection strategies were consistently rated as acceptable; however, preferences varied across specific protective behaviours, reflecting differences in perceived personal burden, practicality, or personal health concerns.

3.2 Quantitative phase

3.2.1 Descriptive statistics

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 6.4). 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 (8.47%). 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 6.4: Sociodemographic characteristics of survey participants compared with the 2021 Ottawa Census

Characteristic	**Category**	**Ottawa, Ontario Census (2021)** (32)		**Survey**		
		n	**% ***	**n**	**% (95% CI)**	
		1,017,449	100	1015		
Gender	Woman	496,045	48.8	532	52.4	(49.3, 55.5)
	Male	521,405	51.2	474	46.7	(43.6, 49.8)
	Non-Binary	NA	NA	8	0.8	(0.3, 1.4)
	Other	NA	NA	1	0.1	(0.0, 0.3)
Age	18 to 24	131,170	12.9	128	12.6	(10.6, 14.6)
	25 to 34	143,020	14.1	185	18.2	(15.8, 20.6)
	35 to 44	135,410	13.3	180	17.7	(15.4, 20.1)
	45 to 54	133,505	13.1	153	15.1	(12.9, 17.3)
	55 to 64	135,260	13.3	168	16.6	(14.3, 18.9)
	65 to 74	97,730	9.6	115	11.3	(9.4, 13.3)
	75 or older	74,415	7.3	86	8.47	(6.8, 10.2)
Ethnicity	white	665,960	65.5	744	73.3	(70.5, 76.0)
	Indigenous	26,395	2.6	59	5.8	(4.4, 7.3)
	Other	324,960	31.9	192	18.9	(16.5, 21.3)
	NA	NA*	NA	20	2.0	(1.1, 2.8)
Region	Urban	262,187	23.3	347	34.2	(31.3, 37.1)
	Suburban E	205,776	18.2	195	19.2	(16.8, 21.6)
	Suburban S	249,938	22.2	197	19.4	(17.0, 21.9)
	Suburban W	161,625	14.3	139	13.7	(11.6, 15.8)
	Rural	248,044	22.0	137	13.5	(11.4, 15.6)
Residence in Canada	Less than 1 year	NA*	NA	13	1.28	(0.6, 2.0)
	1-5 years	47,415	37.6	45	4.43	(3.2, 5.7)
	6-10 years	78,715	62.4	37	3.65	(2.5, 4.8)
	10+ years **	NA**	NA	920	90.64	(88.8, 92.4)
Income	< $20,000	17,525	4.3	51	5.0	(3.7, 6.4)
	$20,000 to $39,999	39,695	9.7	72	7.1	(5.5, 8.7)
	$40,000 to $59,999	44,940	11.0	102	10.1	(8.2, 11.9)
	$60,000 to $79,999	49,280	12.1	125	12.3	(10.3, 14.4)

	$80,000 to $99,999	46,895	11.5	162	16.0	(13.8, 18.3)
	$100,000 to $119,000	50,875	12.5	141	13.9	(11.8, 16.0)
	$120,000 or more	158,040	38.8	276	27.2	(24.5, 29.9)
	NA	NA	NA	86	8.5	(6.8, 10.2)
Education	Highschool or less	284,135	34.1	130	12.8	(10.8, 14.9)
	College	187,210	22.4	288	28.4	(25.7, 31.2)
	University or higher	225,720	27.1	594	58.5	(55.5, 61.6)
	Other/ NA	137,075	16.4	3	0.3	(0.0, 0.7)
Primary Language	English	824,560	81.9	839	82.7	(80.4, 85.0)
	French	141,555	14.1	137	13.5	(11.4, 15.6)
	Other ***	40,850	4.1	39	3.8	(2.7, 5.0)

*2021 Census data did not include 95%CI's

**2021 Census categories for residence duration do not align directly with survey categories.

***2021 Census data for this cell are for a combination of English and French, or other language as the primary language spoken in the household

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 6.5).

Table 6.5: Risk and exposure factors of 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)

3.2.2 Acceptability domain-specific models

Individual models assessing factors associated with high acceptability of each intervention category varied in terms of variables most strongly associated with acceptability. For the 'environmentally applied - chemical control' category of interventions, men had 2.36 higher odds of finding chemical environmental application acceptable than women (95% CI 1.97, 2.82, p-value <0.001). All included age groups had lower (OR: 0.34 to 0.67) odds of acceptability of environmentally applied strategies when compared to 18–24-year-olds (p-values all <0.002). The acceptability differed in terms of participants' region of residence, with the Suburban East area, and rural locations having higher odds of acceptability compared urban areas (OR: 1.77, 95% CI: 1.64, 1.92, p-value <0.0001; and OR: 1.26, 95% CI:1.09, 1.45, p-value <0.001), respectively. Self-reported tick bite frequency also increased odds of chemical product acceptability with individuals with 1-2 bites in the last year having 3.54 (95% CI: 2.19, 5.71; p-value <0.001) higher odds of acceptability and those with more than 3 bites in the last year having 4.73 (95% CI: 1.25, 17.81; p-value <0.05) higher odds of acceptability when compared to those who did not have a self-reported tick bite. For 'environmentally applied - natural product' use, all age groups had lower (OR: 0.33 to 0.61) odds of acceptability when compared to 18-24-year-olds (p-values all <0.02). Indigenous respondents had higher odds (OR: 1.62) of acceptability of natural environmentally applied products (95% CI: 1.23, 2.15; p-value <0.001) compared to white participants. Respondents living outside of the urban center all had lower odds of acceptability for these interventions compared to urban respondents, with Suburban South, Suburban West, and rural locations having significantly lower odds (OR: 0.84: 95% CI 0.77, 0.91; p-value <0.001, OR: 0.71; 95% CI 0.66, 0.77; p-value <0.001, OR: 0.76; 95%CI 0.62, 0.93 p-value <0.05), respectively. When asked about 'environmentally applied - biological' interventions, similarly, all age groups had significantly lower odds of acceptability when compared to 18-24-year-olds (p-values <0.001) except for 75 years and older respondents. Region of residence was also significantly associated with odds of acceptability; respondents residing in the Suburban South and rural areas had ORs of 0.74 and 0.72 respectively (95% CI: 0.64, 0.87; p-value <0.001; and 95% CI: 0.54, 0.96; p-value<0.05) when compared to the urban region (Table 6.6).

With regards to landscape management strategies, Indigenous respondents had higher odds of finding them to be acceptable when compared to white respondents (OR: 2.92; 95% CI: 1.33, 6.42; p-value <0.05). Individuals residing in the Suburban West area had 1.31 higher odds of acceptability when compared to those in the Urban center (95% CI: 1.12, 1.53; p-value<0.001). Respondents who had access to a yard and were responsible for maintaining it had higher odds of acceptability when compared to those with no access to a yard (OR: 1.69; 95% CI: 1.18, 2.42; p-value<0.001). Similarly, those without pets had higher acceptability of these strategies (OR: 1.93; 95% CI: 1.32, 2.84; p-value <0.001) (Table 6.6).

With regards to host-targeted strategies, Indigenous respondents had higher odds of finding small mammal targeted strategies to be acceptable (OR: 1.75; 95% CI: 1.27, 2.40; p-value <0.001) when compared to white respondents. Most individuals living outside of the Urban center (excluding Suburban East) had significantly lower acceptability, with ORs ranging from 0.75 to 0.85 (p-values all <0.05). Similarly for deer targeted strategies, region played an important role in acceptability with those residing in Suburban South, Suburban West, and Rural areas having lower acceptability of deer targeted strategies (OR: 0.91; 95% CI: 0.82, 0.99; p-value <0.05, OR: 0.85; 95% CI: 0.76, 0.94; p-value<0.001, OR: 0.55, 95% CI: 0.49, 0.62; p-value <0.001) respectively, and those living in Suburban East having slightly higher odds of acceptability (OR:

1.14; 95% CI: 1.05, 1.24; p-value<0.001). Individuals with higher education above a college level also had higher odds of acceptability for deer targeted interventions with ORs ranging from 1.71 for those who attended college (95% CI: 1.35, 2.17; p-value<0.001) to 1.67 for those with a university degree or more (95% CI: 1.14, 2.46; p-value<0.05), when compared to those with a high school degree or less (Table 6.6).

Men found behavioural personal prevention strategies to be significantly less acceptable than women (OR 0.35, 95% CI: 0.19, 0.67, p-value<0.001). Individuals living in Suburban East had 2.52 times higher odds of high acceptability when compared with those living in the urban center (95%CI: 2.13, 2.97; p-value<0.001) and those living in Suburban South had lower odds of high acceptability (OR: 0.67, 95% CI: 0.51, 0.86; p-value< 0.001) compared to the urban region. Individuals who were primarily French speaking had significantly lower odds of high acceptability compared to English speakers (OR: 0.25, 95% CI: 0.12, 0.51; p-value <0.001). Finally, individuals with more than one tick bite in the last year had lower odds (OR: 0.17 to 0.06) of finding behavioural prevention strategies acceptable, and individuals with more than one tick encounter had significantly higher (ORs of 11.17 to 37.84) acceptability of these strategies. Chemical personal prevention strategies were more acceptable to individuals residing in Suburban East and Suburban South areas (OR: 1.83; 95% CI: 1.64, 2.04; p-value <0.001 and OR: 1.39; 95% CI: 1.12, 1.73, p-value <0.001) respectively, when compared to those living in the urban center. Similarly to behavioural strategies French speakers had lower odds of finding personal control strategies involving chemicals to be acceptable when compared to English speakers (OR: 0.46; 95% CI: 0.28, 0.76; p-value <0.001). Finally, individuals with more tick encounters had higher odds of acceptability compared to respondents with no tick encounters in the last year (OR: 1.74; 95% CI: 1.23, 2.48; p-value <0.001 and OR: 6.40; 95% CI: 1.49, 27.53; p-value<0.05) respectively (Table 6.6).

Table 6.6: Multivariable Logistic regression models for predictors significantly associated with high acceptability of Lyme Disease prevention or tick control interventions, with number of respondents in each category, and proportion of respondents finding the intervention to be acceptable (full models in Appendix 8.3.2). Variable categories showing statistically significant associations (p-value<0.05) are highlighted in green.

Environmentally Applied: Chemical Acceptability					
	Category	**No. respondents in category**	**Proportion of respondents with high acceptability [95%CI]**	**OR [95%CI]**	**p-value**
Gender	Woman	532	47.7 [0.43, 0.52]	Reference	.
	Male	474	67.1 [0.63, 0.71]	2.36 [1.97, 2.82]	<0.001
	Non-Binary	8	50.0 [0.16, 0.84]	1.12 [0.47, 2.69]	0.8
	Other	1	0.0 [0.00, 0.98]	.	.
Age	18 to 24	128	75.0 [0.67, 0.82]	Reference	.
	25 to 34	185	55.7 [0.48, 0.63]	0.52 [0.37, 0.73]	<0.001
	35 to 44	180	57.2 [0.50, 0.65]	0.45 [0.33, 0.62]	<0.001
	45 to 54	153	53.6 [0.45, 0.62]	0.42 [0.25, 0.72]	<0.001
	55 to 64	168	47.6 [0.40, 0.55]	0.34 [0.22, 0.54]	<0.001
	65 to 74	115	53.9 [0.44, 0.63]	0.55 [0.33, 0.92]	0.02
	75 or older	86	58.1 [0.47, 0.69]	0.67 [0.51, 0.89]	0.01
Region	Urban	347	56.2 [0.51, 0.61]	Reference	.
	Suburban E	195	67.2 [0.60, 0.74]	1.77 [1.64, 1.92]	<0.001
	Suburban S	197	50.3 [0.43, 0.57]	0.79 [0.69, 0.91]	<0.001
	Suburban W	139	53.2 [0.45, 0.62]	1.11 [0.95, 1.3]	0.18
	Rural	137	56.2 [0.47, 0.65]	1.26 [1.09, 1.45]	<0.001
Income	< $20,000	51	45.1 [0.31, 0.60]	Reference	.
	$20,000 to $39,999	72	56.9 [0.45, 0.69]	2.03 [0.69, 5.99]	0.2
	$40,000 to $59,999	102	58.8 [0.49, 0.68]	2.21 [1.18, 4.15]	0.01
	$60,000 to $79,999	125	54.4 [0.45, 0.63]	1.30 [0.57, 2.94]	0.53
	$80,000 to $99,999	162	66.0 [0.58, 0.73]	1.77 [0.92, 3.43]	0.09
	$100,000 to $119,000	141	57.4 [0.49, 0.66]	1.45 [0.71, 2.97]	0.31

	$120,000 or more	276	56.2 [0.50, 0.62]	1.82 [1.03, 3.22]	0.04
	NA	86	47.7 [0.37, 0.59]	1.70 [0.9, 3.24]	0.1
Tick bite	Never	848	51.3 [0.48, 0.55]	Reference	.
	1-2 times	148	83.8 [0.77, 0.89]	3.54 [2.19, 5.71]	<0.001
	3+ times	19	89.5 [0.67, 0.99]	4.73 [1.25, 17.81]	0.02
Environmentally Applied: Natural Acceptability					
	Category	**No. respondents in category**	**Proportion of respondents with high acceptability [95%CI]**	**OR [95%CI]**	**p-value**
Gender	Woman	532	85.9 [0.83, 0.89]	Reference	.
	Male	474	85.0 [0.81, 0.88]	1.08 [0.78, 1.49]	0.65
	Non-Binary	8	75.0 [0.35, 0.97]	0.20 [0.1, 0.41]	<0.001
	Other	1	100.0 [0.03, 1.00]	.	.
Age	18 to 24	128	93.8 [0.88, 0.97]	Reference	.
	25 to 34	185	88.1 [0.83, 0.92]	0.48 [0.38, 0.62]	<0.001
	35 to 44	180	84.4 [0.78, 0.89]	0.36 [0.28, 0.46]	<0.001
	45 to 54	153	85.0 [0.78, 0.90]	0.41 [0.26, 0.64]	<0.001
	55 to 64	168	80.4 [0.74, 0.86]	0.33 [0.19, 0.55]	<0.001
	65 to 74	115	80.0 [0.72, 0.87]	0.37 [0.16, 0.83]	0.02
	75 or older	86	87.2 [0.78, 0.93]	0.61 [0.28, 1.37]	0.24
Ethnicity	white	59	84.3 [0.81, 0.87]	Reference	.
	Indigenous	192	91.5 [0.81, 0.97]	1.62 [1.23, 2.15]	<0.001
	Other	744	88.5 [0.83, 0.93]	1.11 [0.83, 1.48]	0.5
	NA	20	80.0 [0.56, 0.94]	0.56 [0.12, 2.51]	0.44
Region	Urban	347	88.5 [0.85, 0.92]	Reference	.
	Suburban E	195	84.6 [0.79, 0.89]	0.92 [0.8, 1.06]	0.27
	Suburban S	197	85.8 [0.80, 0.90]	0.84 [0.77, 0.91]	<0.001
	Suburban W	139	82.7 [0.75, 0.89]	0.71 [0.66, 0.77]	<0.001
	Rural	137	81.0 [0.73, 0.87]	0.76 [0.62, 0.93]	0.01
Income	< $20,000	51	92.2 [0.81, 0.98]	Reference	.
	$20,000 to $39,999	72	88.9 [0.79, 0.95]	1.00 [0.37, 2.74]	1
	$40,000 to $59,999	102	85.3 [0.77, 0.92]	0.70 [0.25, 1.91]	0.48
	$60,000 to $79,999	125	85.6 [0.78, 0.91]	0.63 [0.34, 1.16]	0.14
	$80,000 to $99,999	162	82.7 [0.76, 0.88]	0.47 [0.24, 0.93]	0.03
	$100,000 to $119,000	141	86.5 [0.80, 0.92]	0.64 [0.33, 1.26]	0.2
	$120,000 or more	276	82.6 [0.78, 0.87]	0.55 [0.24, 1.27]	0.16
	NA	86	90.7 [0.82, 0.96]	1.23 [0.39, 3.82]	0.73

Forest	25+ per year	145	89.7 [0.84, 0.94]	Reference	.
	11-25 per year	226	87.6 [0.83, 0.92]	0.77 [0.4, 1.48]	0.44
	2-10 per year	302	87.1 [0.83, 0.91]	0.72 [0.41, 1.26]	0.25
	2/year	231	80.5 [0.75, 0.85]	0.47 [0.31, 0.73]	<0.001
	never	111	81.1 [0.73, 0.88]	0.47 [0.21, 1.05]	0.06
Environmentally Applied: Biological Acceptability					
	Category	**No. respondents in category**	**Proportion of respondents with high acceptability [95%CI]**	**OR [95%CI]**	**p-value**
Gender	Woman	532	74.6 [0.71, 0.78]	Reference	.
	Male	474	81.0 [0.77, 0.84]	1.32 [0.92, 1.89]	0.14
	Non-Binary	8	37.5 [0.09, 0.76]	0.17 [0.09, 0.32]	<0.001
	Other	1	100.0 [0.03, 1.00]	.	.
Age	18 to 24	128	86.7 [0.80, 0.92]	Reference	.
	25 to 34	185	74.6 [0.68, 0.81]	0.37 [0.2, 0.7]	<0.001
	35 to 44	180	75.6 [0.69, 0.82]	0.35 [0.27, 0.46]	<0.001
	45 to 54	153	76.5 [0.69, 0.83]	0.41 [0.29, 0.59]	<0.001
	55 to 64	168	75.0 [0.68, 0.81]	0.38 [0.23, 0.61]	<0.001
	65 to 74	115	76.5 [0.68, 0.84]	0.41 [0.23, 0.72]	<0.001
	75 or older	86	80.2 [0.70, 0.88]	0.47 [0.2, 1.07]	0.07
Region	Urban	347	79.8 [0.75, 0.84]	Reference	.
	Suburban E	195	83.6 [0.78, 0.88]	1.33 [1, 1.75]	0.05
	Suburban S	197	73.1 [0.66, 0.79]	0.74 [0.64, 0.87]	<0.001
	Suburban W	139	73.4 [0.65, 0.81]	0.78 [0.59, 1.03]	0.08
	Rural	137	72.3 [0.64, 0.80]	0.72 [0.54, 0.96]	0.03
Income	< $20,000	51	68.6 [0.54, 0.81]	Reference	.
	$20,000 to $39,999	72	83.3 [0.73, 0.91]	2.68 [1.41, 5.07]	<0.001
	$40,000 to $59,999	102	77.5 [0.68, 0.85]	1.80 [0.61, 5.36]	0.29
	$60,000 to $79,999	125	75.2 [0.67, 0.82]	1.35 [0.72, 2.51]	0.35
	$80,000 to $99,999	162	83.3 [0.77, 0.89]	1.76 [0.64, 4.82]	0.27
	$100,000 to $119,000	141	80.9 [0.73, 0.87]	1.68 [0.58, 4.81]	0.34
	$120,000 or more	276	76.1 [0.71, 0.81]	1.50 [0.92, 2.45]	0.11
	NA	86	67.4 [0.56, 0.77]	1.13 [0.49, 2.64]	0.77
Education	Highschool or less	130	73.1 [0.65, 0.80]	Reference	.
	College	288	78.8 [0.74, 0.83]	1.42 [0.81, 2.49]	0.22
	University +	594	77.6 [0.74, 0.81]	1.30 [1.05, 1.6]	0.02

	Other/ NA	3	66.7 [0.09, 0.99]	1.11 [0.13, 9.4]	0.93
Language	English	839	76.0 [0.73, 0.79]	.	.
	French	137	85.4 [0.78, 0.91]	1.90 [1.04, 3.47]	0.04
	Other	39	76.9 [0.61, 0.89]	0.96 [0.66, 1.41]	0.85
Occupation	Indoors	591	76.1 [0.72, 0.80]	Reference	.
	Mixed	128	79.7 [0.72, 0.86]	0.81 [0.44, 1.48]	0.49
	Outdoors	37	81.1 [0.65, 0.92]	0.80 [0.54, 1.18]	0.26
	Other	259	78.4 [0.73, 0.83]	1.25 [1.11, 1.4]	<0.001
Tick encounter	Never	782	73.8 [0.71, 0.77]	Reference	.
	1-2 times	183	89.6 [0.84, 0.94]	2.25 [1.12, 4.5]	0.02
	3+ times	50	88.0 [0.76, 0.95]	1.47 [0.33, 6.62]	0.61
Landscape Management Acceptability					
	Category	**No. respondents in category**	**Proportion of respondents with high acceptability [95%CI]**	**OR [95%CI]**	**p-value**
Ethnicity	white	59	87.1 [0.84, 0.89]	Reference	.
	Indigenous	192	93.2 [0.84, 0.98]	2.92 [1.33, 6.42]	0.01
	Other	744	82.8 [0.77, 0.88]	0.81 [0.62, 1.05]	0.11
	NA	20	60.0 [0.36, 0.81]	0.19 [0.05, 0.68]	0.01
Region	Urban	347	85.6 [0.81, 0.89]	Reference	.
	Suburban E	195	88.2 [0.83, 0.92]	1.09 [0.91, 1.3]	0.37
	Suburban S	197	82.7 [0.77, 0.88]	0.65 [0.61, 0.71]	<0.001
	Suburban W	139	89.9 [0.84, 0.94]	1.31 [1.12, 1.53]	<0.001
	Rural	137	85.4 [0.78, 0.91]	0.84 [0.73, 0.96]	0.01
Income	< $20,000	51	68.6 [0.54, 0.81]	Reference	.
	$20,000 to $39,999	72	80.6 [0.70, 0.89]	1.85 [0.84, 4.05]	0.13
	$40,000 to $59,999	102	91.2 [0.84, 0.96]	5.00 [1.94, 12.9]	<0.001
	$60,000 to $79,999	125	88.0 [0.81, 0.93]	3.06 [1.51, 6.19]	<0.001
	$80,000 to $99,999	162	86.4 [0.80, 0.91]	2.04 [0.67, 6.24]	0.21
	$100,000 to $119,000	141	88.7 [0.82, 0.93]	2.58 [1.17, 5.7]	0.02
	$120,000 or more	276	85.1 [0.80, 0.89]	1.75 [1.09, 2.81]	0.02
	NA	86	90.7 [0.82, 0.96]	3.98 [1.52, 10.45]	0.01
Yard	No access	171	83.6 [0.77, 0.89]	Reference	.
	Access, no maintenance	250	81.2 [0.76, 0.86]	0.91 [0.67, 1.23]	0.53
	Access and maintenance	594	88.9 [0.86, 0.91]	1.69 [1.18, 2.42]	<0.001
Pet	Yes	393	83.2 [0.79, 0.87]	Reference	.

	No	622	87.9 [0.85, 0.90]	1.93 [1.32, 2.84]	<0.001
Host Targeted Methods: Small Mammal Acceptability					
	Category	**No. respondents in category**	**Proportion of respondents with high acceptability [95%CI]**	**OR [95%CI]**	**p-value**
Ethnicity	white	59	83.1 [0.71, 0.92]	Reference	.
	Indigenous	192	76.0 [0.69, 0.82]	1.75 [1.27, 2.4]	<0.001
	Other	744	74.9 [0.72, 0.78]	1.12 [0.88, 1.41]	0.36
	NA	20	75.0 [0.51, 0.91]	1.06 [0.74, 1.53]	0.75
Region	Urban	347	77.5 [0.73, 0.82]	Reference	.
	Suburban E	195	76.9 [0.70, 0.83]	0.94 [0.78, 1.12]	0.48
	Suburban S	197	73.1 [0.66, 0.79]	0.82 [0.77, 0.87]	<0.001
	Suburban W	139	72.7 [0.64, 0.80]	0.75 [0.65, 0.87]	<0.001
	Rural	137	75.2 [0.67, 0.82]	0.85 [0.72, 1]	0.05
Residence in Canada	Less than 1 year	13	92.3 [0.64, 1.00]	Reference	.
	1-5 years	45	68.9 [0.53, 0.82]	0.20 [0.05, 0.73]	0.02
	6-10 years	37	83.8 [0.68, 0.94]	0.56 [0.06, 5.23]	0.61
	10+ years	920	75.3 [0.72, 0.78]	0.38 [0.12, 1.16]	0.09
Education	Highschool or less	130	68.5 [0.60, 0.76]	Reference	.
	College	288	76.4 [0.71, 0.81]	1.63 [1.03, 2.57]	0.04
	University +	594	76.8 [0.73, 0.80]	1.54 [1, 2.37]	0.05
	Other/ NA	3	66.7 [0.09, 0.99]	0.55 [0.04, 7.88]	0.66
Language	English	839	74.5 [0.71, 0.77]	Reference	.
	French	137	77.4 [0.69, 0.84]	1.18 [0.85, 1.63]	0.33
	Other	39	92.3 [0.79, 0.98]	3.85 [1.44, 10.33]	0.01
Tick encounter	Never	782	72.8 [0.69, 0.76]	Reference	.
	1-2 times	183	86.3 [0.80, 0.91]	2.63 [1.36, 5.09]	<0.001
	3+ times	50	80.0 [0.66, 0.90]	1.48 [0.4, 5.52]	0.56
Host Targeted Methods: Deer Acceptability					
	Category	**No. respondents in category**	**Proportion of respondents with high acceptability [95%CI]**	**OR [95%CI]**	**p-value**
Gender	Woman	532	63.7 [0.59, 0.68]	Reference	.
	Male	474	65.4 [0.61, 0.70]	0.98 [0.67, 1.43]	0.93
	Non-Binary	8	87.5 [0.47, 1.00]	3.93 [2.01, 7.71]	<0.001
	Other	1	0.0 [0.00, 0.98]	.	.
Ethnicity	white	59	79.7 [0.67, 0.89]	Reference	.
	Indigenous	192	64.1 [0.57, 0.71]	2.05 [0.91, 4.61]	0.08
	Other	744	64.0 [0.60, 0.67]	0.96 [0.67, 1.39]	0.84

	NA	20	50.0 [0.27, 0.73]	0.59 [0.43, 0.8]	<0.001
Region	Urban	347	67.7 [0.63, 0.73]	Reference	.
	Suburban E	195	69.7 [0.63, 0.76]	1.14 [1.05, 1.24]	<0.001
	Suburban S	197	64.5 [0.57, 0.71]	0.90 [0.82, 0.99]	0.03
	Suburban W	139	61.9 [0.53, 0.70]	0.85 [0.76, 0.94]	<0.001
	Rural	137	52.6 [0.44, 0.61]	0.55 [0.49, 0.62]	<0.001
Education	Highschool or less	130	54.6 [0.46, 0.63]	Reference	.
	College	288	66.7 [0.61, 0.72]	1.71 [1.35, 2.17]	<0.001
	University +	594	65.8 [0.62, 0.70]	1.67 [1.14, 2.46]	0.01
	Other/ NA	3	66.7 [0.09, 0.99]	1.62 [0.15, 17.93]	0.69
Forest	25+ per year	145	60.0 [0.52, 0.68]	Reference	.
	11-25 per year	226	66.4 [0.60, 0.73]	1.20 [1.04, 1.38]	0.01
	2-10 per year	302	67.9 [0.62, 0.73]	1.46 [0.98, 2.16]	0.06
	2/year	231	62.8 [0.56, 0.69]	1.21 [0.81, 1.81]	0.35
	never	111	62.2 [0.52, 0.71]	1.30 [0.69, 2.44]	0.42
Tick encounter	Never	782	62.0 [0.59, 0.65]	Reference	.
	1-2 times	183	75.4 [0.69, 0.81]	1.85 [1.46, 2.34]	<0.001
	3+ times	50	66.0 [0.51, 0.79]	1.10 [0.3, 4]	0.88
Personal Prevention: Behavioral Acceptability					
	Category	**No. respondents in category**	**Proportion of respondents with high acceptability [95%CI]**	**OR [95%CI]**	**p-value**
Gender	Woman	532	96.8 [0.95, 0.98]	Reference	.
	Male	474	92.4 [0.90, 0.95]	0.35 [0.19, 0.67]	<0.001
	Non-Binary	8	100.0 [0.63, 1.00]	.	.
	Other	1	100.0 [0.03, 1.00]	.	.
Region	Urban	347	94.5 [0.92, 0.97]	Reference	.
	Suburban E	195	96.9 [0.93, 0.99]	2.52 [2.13, 2.97]	<0.001
	Suburban S	197	91.9 [0.87, 0.95]	0.67 [0.51, 0.86]	<0.001
	Suburban W	139	95.7 [0.91, 0.98]	0.82 [0.42, 1.59]	0.55
	Rural	137	95.6 [0.91, 0.98]	1.06 [0.65, 1.74]	0.82
Language	English	839	95.5 [0.94, 0.97]	Reference	.
	French	137	89.8 [0.83, 0.94]	0.25 [0.12, 0.51]	<0.001
	Other	39	97.4 [0.87, 1.00]	2.26 [0.42, 12.24]	0.35
Tick bite	Never	848	95.2 [0.93, 0.97]	Reference	.
	1-2 times	148	93.9 [0.89, 0.97]	0.17 [0.05, 0.65]	0.01
	3+ times	19	84.2 [0.60, 0.97]	0.06 [0.02, 0.19]	<0.001
Tick encounter	Never	782	94.1 [0.92, 0.96]	Reference	.
	1-2 times	183	96.7 [0.93, 0.99]	11.17 [1.5, 83.29]	0.02

	Category	No. respondents in category	Proportion of respondents with high acceptability [95%CI]	OR [95%CI]	p-value
	3+ times	50	98.0 [0.89, 1.00]	37.84 [1.12, 1275.63]	0.04
Personal Prevention: Chemical Acceptability					
	Category	**No. respondents in category**	**Proportion of respondents with high acceptability [95%CI]**	**OR [95%CI]**	**p-value**
Age	18 to 24	128	96.1 [0.91, 0.99]	Reference	.
	25 to 34	185	87.6 [0.82, 0.92]	0.34 [0.09, 1.33]	0.12
	35 to 44	180	87.2 [0.81, 0.92]	0.29 [0.07, 1.2]	0.09
	45 to 54	153	85.6 [0.79, 0.91]	0.26 [0.07, 0.97]	0.05
	55 to 64	168	84.5 [0.78, 0.90]	0.20 [0.06, 0.68]	0.01
	65 to 74	115	82.6 [0.74, 0.89]	0.16 [0.05, 0.51]	<0.001
	75 or older	86	94.2 [0.87, 0.98]	0.51 [0.08, 3.43]	0.49
Region	Urban	347	86.5 [0.82, 0.90]	Reference	.
	Suburban E	195	90.3 [0.85, 0.94]	1.83 [1.64, 2.04]	<0.001
	Suburban S	197	89.3 [0.84, 0.93]	1.39 [1.12, 1.73]	<0.001
	Suburban W	139	85.6 [0.79, 0.91]	0.81 [0.64, 1.02]	0.07
	Rural	137	87.6 [0.81, 0.93]	1.21 [0.96, 1.53]	0.12
Language	English	839	88.6 [0.86, 0.91]	Reference	.
	French	137	81.8 [0.74, 0.88]	0.46 [0.28, 0.76]	<0.001
	Other	39	92.3 [0.79, 0.98]	2.30 [0.83, 6.4]	0.11
Tick encounter	Never	782	86.1 [0.83, 0.88]	Reference	.
	1-2 times	183	92.3 [0.87, 0.96]	1.74 [1.23, 2.48]	<0.001
	3+ times	50	98.0 [0.89, 1.00]	6.40 [1.49, 27.53]	0.01
Lyme disease diagnosis	Yes	34	91.2 [0.76, 0.98]	Reference	.
	No	967	87.9 [0.86, 0.90]	1.17 [0.73, 1.89]	0.51
	Unknown	14	71.4 [0.42, 0.92]	0.16 [0.06, 0.44]	<0.001

3.2.3 Synthesis across intervention specific models

Figure 6.3 summarizes the patterns in variables that were most consistently included and significantly associated with intervention acceptability. Across intervention-specific models, region, gender, and age were the significant sociodemographic predictors of acceptability that were most consistently retained following conceptual diagram and AIC based model refinement, with length of residence in Canada, and language being less likely to be retained or significant in the models (Figure 3). Risk and exposure variables showed greater variability across interventions, with occupation and tick encounter frequency being the most frequently retained and associated with acceptability, whereas both suspected and confirmed Lyme disease diagnosis were never, or rarely included in the models.

Figure 6.3: Overview of Variables Included in Each Multivariable Model and Their Statistical Significance Across Eight Acceptability Domains

	Sociodemographic Variables								Risk and Exposure Variables							
Prevention Strategy	Gender	Age	Ethnicity	Region	Residence in Canada	Income	Education	Language	Occupation	Suspected Lyme Disease	Lyme Disease Diagnosis	Yard Access and Maintenance	Forest Use Frequency	Pet Ownership	Tick Bite Frequency	Tick Encounter Frequency
Environmentally Applied: Chemical	✓	✓	✗	✗	✗	✗	✗	✗	✗			✗			✓	
Environmentally Applied: Natural	✓	✓	✓	✓	✗	✓	✗		✗				✓	✗	✗	✗
Environmentally Applied: Biological	✓	✓	✗	✓	✗	✓	✓	✓	✓			✗	✗		✗	✓
Landscape Management	✗	✗	✓	✓		✓	✗	✗	✗			✓		✓		✗
Host: Small Mammal	✗	✗	✓	✓	✓	✗	✓	✓	✗				✗			✓
Host: Deer	✓	✗	✓	✓		✗	✓						✓	✗		✓
Personal Prevention: Behaviour	✓	✓	✗	✓	✗	✗	✗	✓	✓			✗		✗	✓	✓
Personal Prevention: Chemical	✗	✓	✗	✓	✗		✗	✓	✗		✓	✗	✗	✗		✓

Green check marks indicate that variables were included, and statistically significant, red crosses indicate that they were included but not statistically significant, and boxes that are blank are variables that were not included based on AIC and conceptual diagram criteria.

3.2.4 Domain-specific model comparison using AIC of factors associated with high acceptability of intervention categories

Sixteen domain-specific models (two per acceptability domain: sociodemographic-only and risk/exposure-only) were estimated to compare relative contributions to model fit**.** Across interventions, patterns of AIC change differed between sociodemographic and risk and exposure models, suggesting that the relative contribution of variables to model fit varies by intervention type. This approach identified sociodemographic factors as being more consistently associated with acceptability of interventions compared to risk and exposure factors. In particular, the sociodemographic factors related to gender, region of residence, age, and income were the most frequently associated with moderate to high model fit contributions. Among risk and exposure variables, occupation, yard management, forest visitation, pet ownership, and tick encounters, contributed to better model fit most consistently (Table 6.7).

Table 6.7: Change in Akaike's Information Criterion (ΔAIC) when individual predictors are removed from sociodemographic-only and risk and exposure-only models, across intervention categories.

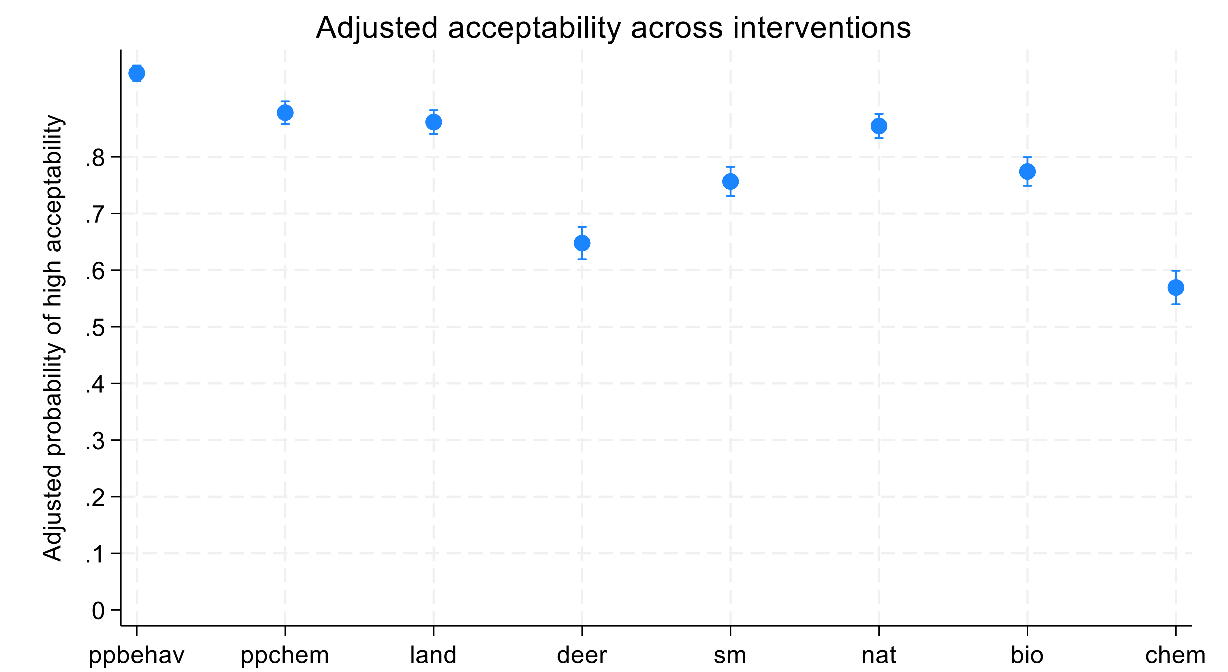
Sociodemographic-only models								
	Gender	Age	Ethnicity	Region of residence	Length of residence in Canada	Income	Education	Language
Chemical	44.05	31.61	6.16	15.43	5.01	9.00	5.76	1.04
Natural	3.20	12.44	1.69	1.77	4.22	7.49	4.64	0.04
Biological	12.36	13.45	3.62	7.61	4.61	9.43	2.21	4.47
Land Management	0.42	3.64	13.38	4.81	0.05	15.35	4.91	2.26
Small Mammal	1.62	3.08	2.66	1.95	4.32	8.73	4.42	6.61
Deer	3.66	6.39	6.66	9.54	0.79	8.73	7.10	0.45
Personal Protection: Behaviour	9.80	8.78	3.82	6.89	2.70	4.80	1.90	12.28
Personal Protection: Chemical	4.27	21.64	2.70	6.72	6.17	7.28	2.07	8.11
Risk and exposure-only models								
	Occupation	Lyme disease (suspected)	Lyme disease (diagnosis)	Yard access and maintenance	Forest visitation	Pet ownership	Tick bite frequency	Tick encounter frequency
Chemical	7.10	0.13	1.02	6.46	0.00	0.00	22.99	1.04
Natural	4.59	1.49	0.38	1.11	8.07	3.56	4.51	2.29
Biological	3.79	0.26	0.47	4.44	8.12	0.37	2.17	7.65
Land Management	7.30	0.10	1.92	10.60	3.20	8.99	0.21	2.22
Small Mammal	11.54	0.08	1.60	1.07	3.85	0.04	0.87	11.95
Deer	1.67	0.23	0.16	1.65	2.97	2.58	1.79	6.11

Personal Protection: Behaviour	6.61	0.56	0.15	4.11	0.84	4.58	12.50	17.61
Personal Protection: Chemical	2.17	0.59	2.65	4.46	11.11	2.01	0.25	8.48
Red text indicates variables that changed the model AIC by less than 2 points when dropped Yellow text indicates variables that changed the model AIC by less than 2-4 points when dropped, indicating moderate impact								

3.2.5 Core Generalized estimating equation (GEE) model results

Variables included in the forced core model were variables that changed the AIC by more than two points in more than three of the models or were informed by the conceptual diagram. This process resulted in the final inclusion of sociodemographic variables (gender, age group, ethnicity, region of residence, length of residence in Canada, income and education level) and risk or exposure variables (outdoor occupation, tick encounter frequency in the last year, and forest visitation frequency) in the Generalized estimating equation (GEE) model. Both personal prevention approaches (behavioural approach and chemical approach) had the highest probability of having high acceptability (0.95, 95% CI: 0.93, 0.96, p-value<0.001, and 0.88, 95% CI: 0.86, 0.90, p-value<0.001), respectively (Figure 4). Deer targeted interventions and environmentally applied chemical strategies had the lowest probability of acceptability (0.65, 95% CI: 0.62, 0.68, p-value <0.001) and 0.57%, 95% CI: 0.54, 0.60, p-value <0.001), respectively (Figure 6.4).

Figure 6.4: Model-adjusted probability of high acceptability across Lyme disease prevention and tick control interventions



Interventions are ordered as follows: personal prevention (behaviour), personal prevention (chemical), land management, deer management, small mammal management, natural, biological, chemical control strategies

Each point on the plot represents a GEE model-adjusted probability that participants rated a given intervention as "acceptable (>22.5)", holding included sociodemographic variables (gender, age group, ethnicity, region of residence, length of residence in Canada, income and education level) and risk or exposure variables (outdoor occupation, tick encounter frequency in the last year, and forest visitation frequency) constant.

For example, an estimated value of 0.57 for the chem intervention indicates that, after adjustment, approximately 57% of the population would be expected to consider this intervention acceptable.

4. Discussion

In the context of increasing incidence of LD infections in Ottawa, identifying prevention and control strategies that are both effective and socially acceptable are central to increasing the uptake and sustainability of interventions (33). This exploratory sequential mixed methods study demonstrated that overall levels of acceptability of Lyme disease prevention and tick control interventions among Ottawa adults was high, with the proportion reporting high acceptability ranging from 57% to 95% across eight intervention types. Acceptability varied across these intervention types. Personal protection strategies (both chemical and behavioural) were consistently rated as highly acceptable according to both the key informant interviews (KIIs) and survey results, whereas chemical control approaches and deer targeted host management strategies were among the least acceptable. Landscape management strategies were generally acceptable, with the exception of vegetation burning, as identified in the KIIs. Importantly, patterns of acceptability were not uniform across the population.

Region of residence was the most consistently retained sociodemographic predictor. Residents of the Suburban East were more likely to have high acceptability scores for most interventions when compared to urban residents. This pattern was observed across all intervention types, except for small mammal-targeted strategies and natural alternatives to synthetic acaricides. Furthermore, we observed differences in acceptability across gender, age, ethnicity, and language groups. While direct comparisons are limited by differences in measurement approaches, our findings contrast with acceptability patterns in other Canadian contexts, underscoring the importance of local context in shaping public support for LD prevention strategies (20). Tick encounter frequency was the risk and exposure variable most frequently retained in the individual models and was tick encounter frequency. Individuals with one to two self-reported tick encounters in the last year had higher odds of having high acceptability of interventions compared to individuals with no self-reported tick encounter. This association was the strongest for chemical and behavioural personal prevention strategies. Tick bite frequency, forest use frequency, and occupation, were also frequently included in individual models, however they were less likely to be associated with acceptability than sociodemographic variables. This may suggest that acceptability may depend more on social and geographic context than by individual risk exposure alone.

Importantly, these findings also highlight important differences between knowledge, attitudes, and practices and acceptability, even within the same regional context. In a previous KAP study conducted in Ottawa, older age, yard characteristics, exposure index, and knowing someone with LD were key drivers of knowledge, while prevention practices were most strongly associated with non-Indigenous racialized identity, yard access, previous LD or tick exposure, and occupation (indoor versus outdoor) (28). In contrast, our findings suggest that the acceptability of tick and LD interventions is more consistently associated with sociodemographic factors compared to risk or exposure characteristics. These differences are important to consider in the design of implementation strategies and public outreach surrounding interventions. While previous studies have identified risk and exposure variables such as occupation, recreational activities, outdoor space use, pet ownership, and home or yard characteristics, and tick encounters or bites have been widely documented as contributors to LD risk, their influence on acceptability in our study was more intervention specific (34). This suggests that perceived risk alone may not consistently translate into support for all prevention strategies, and that acceptability is shaped by how individuals perceive feasibility and consequences of specific interventions in context. These findings were also supported by our qualitative findings, which indicated that individuals considered a wide range of factors while thinking about acceptability of a given intervention, and were particularly concerned with feasibility, and unintended consequences of choosing a certain intervention type (35,36).

The qualitative phase of this study was instrumental in shaping both the survey instrument and the interpretation of quantitative findings. Key informant interviews highlighted themes such as those mentioned above, along with responsibility for implementation, and the scale of the intervention, which informed the refinement of survey questions to ensure clarity and consistent interpretation by the general public. These interviews also underscored the importance of providing brief educational explanations for each intervention; we therefore opted to include brief infographic-style descriptions in the survey to help establish a base understanding of these interventions in a quick and digestible way, with the aim of increasing comprehension and reducing misinterpretation of potentially unfamiliar intervention options. Additionally, qualitative findings consistently supported our quantitative findings, as many of the themes from the key informants were also represented in the quantitative results, and the relative acceptability of the interventions was also echoed between the interview and survey results. This convergence of data was a strength of this study and the alignment between methods increased confidence that the survey was capturing locally meaningful patterns of acceptability while using an acceptability scale novel to this context and use.

In terms of preventive behaviours in our study population in Ottawa, Ontario, although respondents reported a high level of tick encounters and bites (22% and 16% respectively), only 10% consistently used personal prevention measures, and 21.7% reported using yard or environmental controls. In contrast, previous research in another high risk locale in the United States noted that 99% of survey respondents reported using personal protective behaviours, and 65% reported using environmental tick controls (21). Our findings for personal protection are more consistent with other research performed in the neighbouring province of Quebec, where authors found that while tick exposure in the past year ranged from 3.4 to 21.9% (defined as reported encounter of at least one tick in the last year), personal preventive behaviours varied from 27.0% to 30.1% (37). Differences in environmental conditions, exposure patterns, and population familiarity with interventions all contribute to variations in acceptability across settings, highlighting the need for context specific evaluations when informing decision making for this health issue.

There were several limitations that should be considered when interpreting these findings. We examined distributions of summed acceptability scores to assess their overall shape and range. Although distributions of summed acceptability scores were approximately normal, analysis focused on a binary high versus low acceptability outcome to support interpretation in an implementation context. While dichotomization of the outcome variables may oversimplify the complexity of these relationships, it facilitates interpretation by stakeholders and enabled consistent comparison across intervention types. Additionally, we performed a sensitivity analysis using alternative thresholds, which resulted in similar patterns, supporting the robustness of the primary results, and threshold score.

This study uses a novel approach to acceptability scoring within the context of LD prevention and tick control, which limits more direct comparability with some prior studies. However, the mixed methods nature of the study design provided validation of the score's relevance for this field. The measures we included in the survey primarily focused on interventions over which individuals had some element of control over, rather than an external party.

Finally, the cross-sectional nature of this study prevents us from establishing a causal relationship between variables associated with high acceptability in the survey results. Data were collected through an online panel, and although the sample sociodemographic characteristics were descriptively compared to the most recent Canadian census data for Ottawa across age, sex, education, and income distributions, participation through a membership-based survey platform may introduce some element of selection bias, whereby the associations observed in the study may not fully reflect those in the target population.

Overall, these findings provide important insight into public support for LD prevention and tick control strategies across a range of urban classifications within a Canadian context and highlight the value of combining qualitative and quantitative approaches to inform feasible and contextually appropriate intervention planning, with high acceptability.

Recent cross-Canada qualitative research found that LD and tick bite prevention and adaptation efforts can influence mental health, outdoor recreation, interaction with nature, and views on pet ownership (38). These findings emphasize the importance of increasing education surrounding acceptable intervention options for control of this issue, while being cognizant of the stress and burden that tick-related risk can place on individuals and communities. Balancing risk with maintaining participation in outdoor spaces is challenging, but as shown by this, and previous studies performed in the Ottawa area, is critical to protecting human physical and mental health

(38). Findings from this study indicate that personal prevention behaviours are highly acceptable and represent an accessible entry point for increased education and promotion of protective behaviours. However, there was also a high level of interest in landscape management options and environmentally applied natural alternatives to spraying chemicals to reduce tick abundance in human use areas. Together, these results provide a range of intervention options that can be implemented at both the individual and organizational or stakeholder level in the region.

5. Conclusion

In this study we linked key informant interview data with population level survey data. This study identified context specific factors that shape public acceptability of tick control and LD prevention interventions, providing data to better inform socially acceptable, feasible, and context relevant prevention strategies in the city of Ottawa.

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7. Integrated discussion and conclusions

7.1 Overview and synthesis of key findings

Lyme disease (LD) continues to be a significant and rapidly expanding vector-borne disease (VBD) in Canada, with implications for human health and healthcare systems (47,136–138). Ongoing challenges related to diagnosis, treatment limitations, as well as research challenges in addressing post-treatment or long-term symptoms underscore the importance of tick control strategies as prevention, in absence of a vaccine. While provincial and national LD incidence rates highlight the scale of this disease as a public health problem, LD risk is ultimately shaped at finer spatial scales due to the complex relationships between vector ticks, wildlife hosts, human behaviour, and landscape alterations.

In response to this growing public health issue in Canada, there have been increased efforts to coordinate interdisciplinary research through initiatives such as the Canadian Lyme Disease Research Network (CLyDRN) (139). Furthermore, global shift towards One Health approaches for addressing zoonotic diseases, like those outlined in the World Health Organization's Quadripartite: One Health High-Level Expert Panel (OHHLEP) and the Lancet One Health Commission, reflect a growing recognition that effective prevention strategies are integrative, and combine aspects to address human, animal, and environmental health, and finally, are adaptable to a local context (140,141). This is important to peri-urban settings like Ottawa, where factors such as environmental suitability and urban expansion continue to shape LD risk (43,133,142).

This thesis examined the effectiveness, utility, and acceptability of LD prevention and tick control strategies using a multi-method and One Health informed approach. By integrating evidence from a systematic review, a field-based environmental intervention study, and a mixed-methods acceptability study, the findings highlight the various strengths and limitations of existing LD vector control options. Results from all three of the included thesis objectives consistently identified the importance of context and program integration in shaping intervention implementation and potential utility for LD prevention. These findings contribute to a better understanding of how tick control and LD prevention strategies may be adapted and implemented in similar peri-urban, recreational and public health contexts, in settings with similar tick ecology, using Ottawa as a case study.

The overarching goal of this thesis was to **investigate the scientific knowledge on intervention strategies for LD prevention in urban and peri-urban areas to inform locally adapted, acceptable, and feasible disease prevention and control strategies**. This was achieved through three interrelated sub-aims which were: 1. To synthesize the evidence base on LD prevention interventions; 2. To evaluate an integrated environmental management strategy to reduce LD risk in recreational settings; and 3. To evaluate the feasibility and acceptability of the interventions from the first two objectives in Ottawa. This was achieved through the three corresponding thesis projects, which were designed with a One Health lens that acknowledges the contextual factors of acceptability and socioecological frameworks.

The first objective synthesized the existing literature on LD prevention interventions across Canada, the United States, and Europe, identifying patterns in effectiveness, implementation challenges, and gaps in the current evidence base. Ultimately the 127 studies included in this review revealed that chemical acaricides were the most consistently effective intervention category but often faced concerns with social acceptability. The systematic review provided a foundation for understanding which intervention approaches show promise under different ecological and social conditions, through extraction of several "utility" measures. Furthermore, it identified additional areas where more research is needed to inform intervention relevance to specific contexts.

While the systematic review (Objective 1) identified intervention categories with demonstrated effectiveness, it also revealed inconsistencies in the contextual reporting (via the secondary utility objectives), limited evidence specific to recreational spaces, as well as calls for more research evaluating integrative approaches in the included literature. In response to the gaps identified in the systematic review, Objective 2 strengthened evidence in a local context through an experimental field trial that evaluated an integrated landscape management strategy in Ottawa's Greenbelt. Treated woodchips reduced *I. scapularis* nymph and adult tick density by 99 % (incidence rate ratio (IRR) = 0.01, 95 % CI: 0.001–0.08) relative to standard trail maintenance, while untreated woodchips achieved a 48 % reduction (IRR = 0.52, 95 % CI: 0.34–0.78) during the study period. This study found that while woodchip borders were effective as an ecotone modification strategy, their combination with deltamethrin treatment was highly effective, resulting in an almost complete elimination of questing ticks along trails. This study successfully generated site-specific evidence on how ecotone modification can reduce tick density in recreational settings, adding to the list of evidence-backed LD control options for use in peri-urban recreational settings.

Bridging evidence of effectiveness with contextual factors, the mixed methods approach used in Objective 3 addressed gaps identified in the systematic review (Objective 1), particularly the inconsistencies in reporting of utility measures. It further evaluated interventions identified in both the review and in the local field trial, in terms of their acceptability and feasibility within the Ottawa context. To complement the effectiveness evidence generated in Objectives 1 and 2, Objective 3 explicitly examined the acceptability of multiple interventions, capturing key informants' and public perspectives that inform real world implementation readiness. Overall, we found that personal LD protection and landscape management strategies had higher acceptability than chemical and wildlife host targeted strategies. The sociodemographic and risk or exposure variable associations with acceptability, varied by intervention type.

Together, these three studies triangulate evidence across complementary methodological approaches, while situating LD prevention within a One Health framework, and incorporating considerations of acceptability and socioecological context. Collectively, the findings advance a more comprehensive understanding of how LD prevention and tick control strategies can be designed to be more contextually appropriate and support implementation within real-world settings. The following discussion is organized around themes that emerge across the three thesis manuscripts and situates these findings within the current literature on LD prevention and tick control.

7.2 Integrated effectiveness of tick control strategies

Findings from all three studies in this thesis support the overall conclusion that there are limitations to single-intervention approaches to LD prevention and tick control. This is consistent with a growing body of literature suggesting that integrated approaches are more effective than single strategy interventions.

In the systematic review, we identified that studies with an integrative component (within or across intervention categories) were likely to have positive results according to study conclusions (n=16) or mixed results (n=8), as opposed to no positive study results (n=4) for reducing entomological or human outcomes used to measure risk for LD. Many of these studies combined some aspects of a host-targeted strategy, chemical, or natural tick control strategy. It is important to note that several of the host-targeted and natural strategies had high variability in study results when used independently, and therefore, using them in conjunction with other approaches may result in a higher likelihood of intervention success.

The importance of integrated approaches for LD prevention and tick control is not only supported by the studies included in this thesis, but in the scientific literature as well. Notably, a review of the literature by Stafford et al. (2017) concluded that integrative strategies are likely to be the most successful in reducing TBD risk in endemic areas. While this review primarily provided an overview of integrated tick management approaches, it referenced several trials conducted in Connecticut, which reported significant reductions in measures of acarological risk(13,143,144). These field trials, by Williams et al. (2018), found that when comparing four treatment combination options (control vs. deer removal, fipronil bait boxes and *Metarhizium* *anisopliae*, or deer removal combined with both fipronil bait boxes and *M. anisopliae*), combining fipronil bait boxes and broadcast application of *M. anisopliae* (an entomopathogenic fungi) achieved a 78-95% reduction in nymphal density over the study period of 3 years (143). The systematic review that was conducted as part of this thesis found that although there was demand for more integrative strategies, with 40 of the 127 included studies stating this need as a future research direction or in practice, only 28 of the studies engaged in an integrative approach. Furthermore, only 13 of the studies employed an approach that used multiple intervention categories, rather than multiple approaches within the same intervention category.

The experimental field study in this thesis provides further support for integrative approaches by demonstrating stronger effects when ecotone modification (a landscape modification strategy) was combined with targeted acaricide application (an environmental application strategy). In this study, the woodchips functioned via two theoretical pathways: 1. Reducing the amount of questing material available to ticks near the pathway, and 2. Incorporating a substrate that ticks do not migrate across as successfully compared to control segments with no woodchip borders. The latter pathway is supported by the pilot study completed in 2021 (Appendix 8.2.1), as well as work by Piesman (2006) who found that in laboratory conditions, Alaska Yellow Cedar wood products reduced nymphal tick crossing for up to one month (145). However, evidence examining the mechanistic effects of woodchip barriers in natural field settings remains limited. This area of research would benefit from future studies to evaluate how woodchip composition, depth, and maintenance influence tick movement, survival, or questing behaviour in a natural setting.

The observed reductions in questing tick density resulting from the experimental field study in this thesis are consistent with previous findings from Bloemer et al. (1990), who found that landscape management strategies (vegetation management) combined with acaricide applications of chlorpyrifos reduced the density of all stages of *Amblyomma americanum* ticks by 94% in a recreational setting in the U.S. (146). Furthermore, a prior study by McKay et al. (2020), in Ottawa, found that an ecotone modification strategy using woodchip borders reduced questing ticks near recreational trails by up to 75% over the course of the cumulative six sampling weeks during the study period (118). The addition of acaricide applications in Objective 2 of this thesis reflect an effort to increase the effectiveness of woodchips through combining landscape and environmentally applied synthetic chemicals, in a way that limits the potential effect of chemicals on non-target arthropods. This was achieved by limiting spray application specifically to the woodchips themselves, in alignment with recommendations from Ginsberg et al., 2017 (147). While additional research is needed to evaluate the non-target effects of this approach, these findings collectively support the value of combining these two approaches in an integrated and context appropriate way.

Recreational spaces remain an understudied and under-implemented area for tick control interventions. A recent review has emphasized that peri-urban TBD risk remains a blind spot in research and public health programming, despite the potential for human exposure in these novel ecosystems, with recreational spaces mentioned as an important exposure setting (142). The experimental field trial presented in this thesis represents one of the few integrated tick management studies conducted in a peri-urban recreational setting to date, although additional research is emerging from Quebec (25,148). Recent evidence from Burtis et al. (2026) further supports recreational TBD interventions as a research gap; the authors reported that only 10% of surveyed public land managers (n=129) across four U.S. states had implemented tick control strategies, despite high-use spaces in these settings being identified as promising targets for future publicly-funded vector control programs (149). However, 40% of managers expressed interest in adopting tick control methods, with an emphasis on landscape management approaches (149).

In the public land settings studied by Burtis et al., personal prevention education was the main intervention offered by land managers, however, the effectiveness of educational interventions in such settings likely requires further research to optimize user uptake (149). For example, a study by Hassett et al., 2022 which combined KAP survey responses of park users with ecological risk surveys, found that respondents identified parks as their primary location for tick exposure. Despite this, respondents had minimal individual perceived risk, and therefore reported limited engagement in tick checks (150). This highlights the importance of integrating ecological data on risk areas, information on human use of parks and individual risk perception to inform targeted interventions. This is demonstrated in a recent study in Quebec which combined ecological risk and human park use data to inform the prioritization of interventions in park hot spots (151). Study conclusions estimated that by strategically applying interventions to 11% of the park they could impact risk throughout 41-43% of the park areas, increasing the feasibility of such interventions (151). Together, these findings suggest that the predominant personal prevention education approaches currently used in parks may not fully align with the ecological and behavioural LD risk factors. Although integrated tick management practices were not specifically assessed in the survey of land managers, the interest expressed in landscape strategies may support this as a feasible option for future integrated strategies (149).

7.3 Acceptability, feasibility, and implementation

Although many tick control and LD prevention interventions have successfully demonstrated efficacy or effectiveness in experimental settings, fewer studies have considered contextual factors such as social acceptability or resistance, feasibility, cost, and environmental concerns, all of which influence the likelihood that the studied interventions will be implemented into practice. This was consistently demonstrated in the systematic review (Objective 1) thesis manuscript, which revealed a lack of reporting of these secondary outcomes in an explicitly measured way. A similar finding was highlighted in a review by Stafford (2017), which identified gaps in information on the real-world performance of tick control interventions, including data such as intervention cost, acceptance, and consistent use of tools (13). Subsequent work by Eisen and Stafford (2021) has similarly noted that evidence gaps persist around determinants of uptake and implementation (11). Factors such as cost and scalability in integrated tick management programs limit the real-world applicability of interventions, even when they demonstrate effectiveness (11). The authors further concluded that programs in the U.S. need to both improve the tick and pathogen prevention options available, and strengthen public health workforces that are supporting tick control at various levels of implementation (11).

In addition to knowledge gaps on factors related to intervention uptake and implementation, studies have also demonstrated consistent gaps in the feasibility considerations of integrated control programs, with a need to reconcile factors like cost and residential willingness to pay. One study in New Jersey, US, on the modeled costs of integrative tick control programs, identified a substantial gap between integrated tick management cost and what people were willing to pay. It found that programs could cost anywhere between US$508 and US$3,192 annually per household, depending on the combination of interventions used, whereas residents were only willing to pay US$100-150 (152). This article also discussed how long-term community-wide planning for integrated tick management (ITM) could reduce the cost of treatments over time for individual households, without any governmental or health authority contribution, and discussed various combinations and scenarios and their associated costs (152). Finally, another study from the Midwest of the US found that cross-sectional survey respondents were only willing to pay US$52 annually for a community-based program, and that respondents preferred landscaping and natural alternatives to synthetic acaricides as their options for tick control (153).

The findings from the experimental field trial in this thesis (Objective 2) demonstrated that the feasibility and acceptability of effective tick control interventions are context dependent. In this study, we were able to use recycled woodchips from the municipal ash tree removal program, diverting waste from the landfill and reducing material costs. The intervention was relatively inexpensive to deploy, with most costs attributable to human resources. The cost of untreated woodchips was approximately CAD $3.79 per square meter whereas the cost of acaricide-treated woodchips was approximately CAD $4.44 per square meter, supporting the potential for this kind of program in contexts where materials can be recycled on site, such as recreational areas with strong land management programs. However, despite these advantages, this is not a guarantee that the intervention will translate into public acceptability or stakeholder feasibility within recreational settings. This efficacy-implementation gap, is a well-recognized phenomenon in implementation science and translational ecology literature (154,155). In practice, the study in Objective 2 reflected core principles of translational ecology by engaging stakeholders and decision makers throughout the project and maintaining collaborative partnerships beyond the study period to support evidence-informed decision making (154). Nevertheless, real world deployment of this intervention required the adaptation of intervention design choices to the realities of working in a natural setting, accounting for factors such as distance from waterways, which limited our ability to apply acaricides in certain areas, and walkways that were not suitable for heavy machinery. These considerations underscore the importance of evaluating not only efficacy, but also context and scalability when developing practice-ready tick prevention strategies, which was identified as a knowledge gap in the thesis systematic review (Objective 1).

Finally, these findings on feasibility and acceptability for implementation were reinforced by the mixed methods thesis chapter (Objective 3). Key informants in this study cited concerns about the effect of acaricide use on non-target species and environmental impact, which were reinforced by lower acceptability scores among the survey respondents when compared to other intervention options (57%; 95%CI 54-60%, p-value<0,001). These findings echo a 2020 nationwide evaluation of awareness and confidence in pesticide regulatory systems in Canada, which evaluated markers of acceptability on general pesticide use (156). In this study 2,029 Canadians (in the regions of British Columbia, Alberta, Saskatchewan/Manitoba, Ontario, Quebec, and Atlantic Canada) were surveyed, paired with six focus groups (in Toronto, Montreal, and Calgary) (156). The survey results identified that, while acceptability was generally high (48%-59%) for general pesticide use in commercial vs. residential settings respectively, it declined from 2016 to 2020, with focus groups citing health-related, environmental (e.g. unintended impacts on flora and fauna, non-target species etc.), and usage concerns (e.g. residential vs. agricultural) (156). This usage-dependent pattern of acceptability resonates with findings from the key informant interviews in the thesis study, where participants often had different assessments of acceptability and feasibility of interventions depending on implementation scale and context (e.g. residential vs. municipal scale). There was also an interest in natural or biological alternatives to these synthetic chemical approaches echoed in both the qualitative and quantitative components of the mixed-methods study (Objective 3), as well as in the Health Canada report (156). The report stated that two thirds of the survey respondents (n=1,359) agreed that they would rather use a homemade/natural/organic pest control option than a registered pesticide (156). Finally, a Quebec study in Montérégie found different results for the acceptability of acaricide use, with a lower percentage of respondents finding this to be an acceptable intervention (29%, 95 % CI: 25–34%). This study also found that biological control measures had high acceptability scores (86% of respondents with high acceptability (95 % CI: 82–89)) (15). However, it should be noted that the measurement of acceptability in the Canada-wide survey and Quebec study differed from the methodology used in the thesis manuscript (Objective 3). Both the Canada-wide survey and Quebec study employed a similar 5-point Likert scale, ranging from strongly unacceptable to strongly acceptable. In contrast, this thesis research employed a 9-point acceptability scale based on a validated framework, which allowed for a finer assessment across multiple acceptability domains (24). This difference in scales poses a challenge for comparing results across studies.

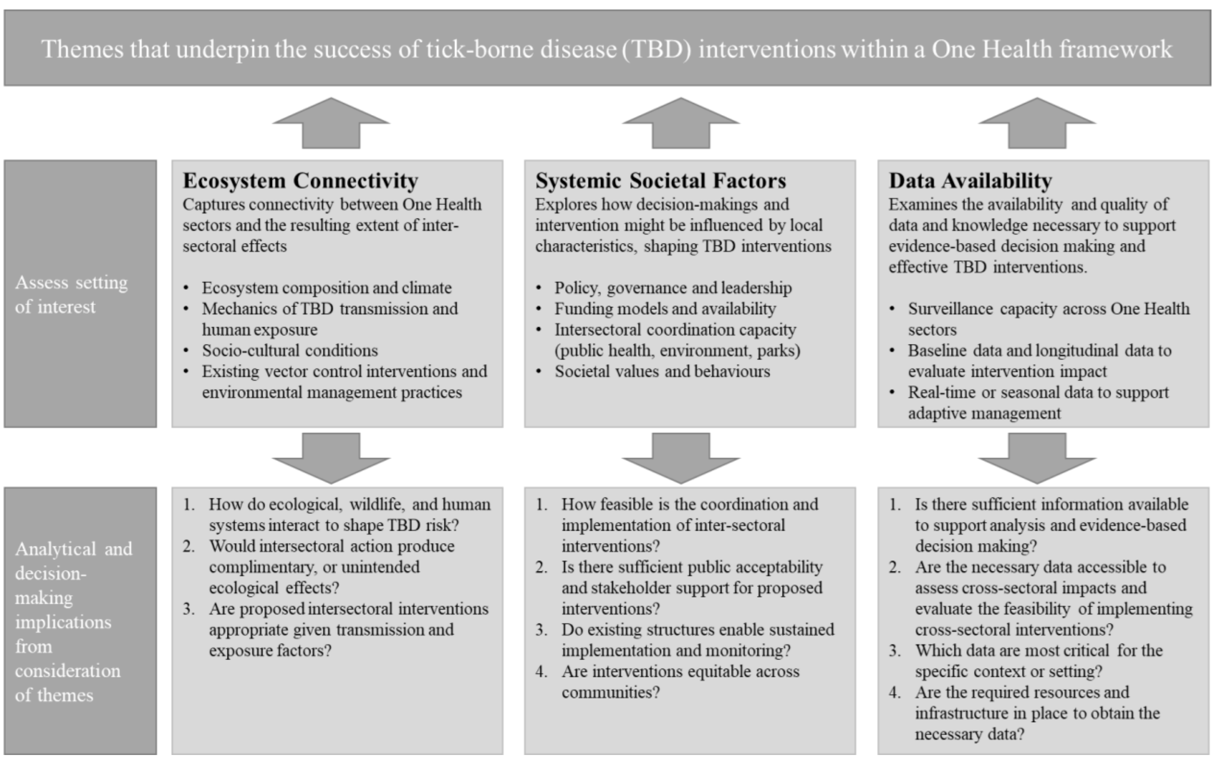
Expanding on previous research in Ottawa on knowledge, attitudes, and practices (KAP) related to LD, findings from the acceptability survey in the third thesis manuscript showed that acceptability was more consistently associated with sociodemographic characteristics, as opposed to respondents' KAP scores which were more strongly associated with a range of risk and exposure variables (157). This pattern also differed from findings from a tick control acceptability study by Aenishaenslin et al. (2016), where higher perceived LD risk and perceived intervention efficacy were associated with greater acceptability in some models (15). The divergence between some of these studies highlights the importance of evaluating acceptability to better understand intervention readiness, and potential for implementation, and may warrant further examination of which embedded constructs (e.g., perceived efficacy and community benefit) most strongly influence overall acceptability scores.

7.4 Value of integrated and One Health approaches

As demonstrated above, no single intervention strategy is sufficient to address the ecological and implementation-related complexity underlying LD risk. The results of this thesis support the value of integrative One Health oriented approaches that combine complementary strategies across human, animal, and environmental health domains, when adapted to local ecological and social contexts. These interventions are well positioned to balance issues of effectiveness and acceptability in real world settings, though feasibility and scale of implementation should be considered when selecting appropriate strategies. There is a growing body of work to support decision-making through a One Health lens. For example, Aluzaite et al. (2025) developed a framework, originally applied to antimicrobial resistance, to assess how the intersectoral effects (i.e., "indirect consequences that an intervention in one sector may have on others within a One

Health system" p.4) may influence effectiveness, cost-effectiveness, feasibility across contexts, and decision making (158). Frameworks like this are relevant to the development of tick-borne disease (TBD) and LD control programs, as they incorporate contextual factors that determine program success and sustainability. The themes in this framework (Figure 7.1) closely align with gaps identified in the systematic review (Objective 1) regarding contextual factor reporting (i.e., the secondary outcomes), the feasibility and implementation challenges encountered in the field study (Objective 2), and the acceptability considerations identified through the mixed methods study (Objective 3).

Figure 7.1: One Health themes influencing tick-borne disease interventions (adapted from antimicrobial resistance framework (158)).



Furthermore, One Health approaches are increasingly being applied to TBD research, particularly in the areas of surveillance and risk mapping. Recent work by Bouchard et al. (2023) demonstrated the utility of a One Health approach to TBD risk mapping in Quebec to inform prevention planning in the future (14). This study integrated social-behavioural and ecological approaches to generate risk maps for intervention prioritization and examine the contribution of various risk factors of LD risk (14). While there are some initiatives underway to increase the use of One Health approaches in TBD intervention studies (148), to date, it has been less frequently applied to the design and evaluation of intervention trials. However, many integrated tick management strategies described in the literature, and in the previous sections of this thesis chapter, align with the principles of One Health, as they often recognize the interconnectedness of the environmental, animal, and human factors that shape TBD and LD risk.

The findings of this thesis support the practical value of a One Health approach to tick control and LD prevention. Integrated management is a key component of these programs and acknowledges that TBDs like LD have complex ecology, which requires a multifaceted approach to address this public health issue. Initiatives developed with a One Health and integrative lens recognize the distinct strengths and weaknesses of each intervention type and provide a wide range of options that are customizable to contextual and utility factors as discussed throughout this thesis.

7.5 Methodological contributions and limitations

A key strength of this thesis is the triangulation of evidence across three study designs, which together provide a more comprehensive understanding of the effectiveness, acceptability, and contextual factors related to LD prevention and tick control strategies. By integrating a systematic review, an environmental field trial, and mixed methods research, this work addresses tick control options from both ecological and social perspectives. This approach helps bridge the gap between intervention development and generating options that are more practice ready in a local context.

Several limitations should also be acknowledged. The systematic review (Objective 1) identified heterogeneity across study designs, measurements, and contexts, which limited the ability to directly compare effectiveness in a meta-analysis. Furthermore, there were a wide variety of products and application techniques used in some of the study categories, such as chemical control measures, or natural alternatives. This variation limits the direct comparability of effect estimates. Additionally, there was variability in the outcome measurements provided in the published literature (e.g., tick density vs. host infection seropositivity prevalence vs. diagnosed human cases), as well as some of the measurement techniques used, limiting the number of studies comparable in a synthesis. While the review synthesis provides insights into patterns of effectiveness and utility, the findings should be interpreted with caution and serve as a general rather than robust guide to comparing intervention categories. Finally, the included studies were inconsistent in accounting for possible confounders such as host density, habitat composition, or other ecological considerations, which may have influenced the observed intervention effects.

The environmental field study (Objective 2) focused on two locations within Ottawa that represent high risk and emerging risk zones. While this design strengthens the evidence on the use of integrative and landscape modification approaches in a recreational setting, there are several limitations to the study design. Tick density outcomes were measured using standardized drag sampling; however, there may be information bias via detection, as sampling success may vary systematically between the materials on which dragging occurred. For example, in control segments where the research team sampled partially on the compacted soil trail, and partially on cut vegetation trailside, it is possible that tick detection may be somehow systematically different from intervention segments, where we sampled partially on the compacted soil trail, and partially on the woodchip substrate. This potential issue is not well documented in the literature, however a recent study that found that drag sampling may introduce downward bias to nymphal abundance or density estimates, as the sampling efficiency of this method is generally low on vegetation (<10-12% of active nymphal ticks collected in some study settings) (159). Measurement was also affected by weather variability, including a major storm, which disrupted implementation and measurement schedules of the study in its first year, limiting the amount of data collection the study team was able to conduct before the end of peak nymphal season. Additionally, the two-year study period, although longer than previous trials, remains relatively short in relation to the life and reproductive cycle of the *I. scapularis* tick species, potentially limiting the ability to evaluate whether observed reductions due to the intervention were sustained across natural population fluctuations that occur over multi-year intervals. Finally, this study may have limited generalizability beyond similar peri-urban recreational trail settings with comparable ecological and landscape characteristics, and should be piloted in other settings.

The mixed-methods study (Objective 3) consisted of key informant interviews and a cross-sectional, population-based survey. This study design may have been subject to selection bias, given that individuals participating in a member-based survey response platform, which the survey was hosted on, may somehow be systematically different from the more general population. Specifically, individuals participating in this survey on the Leger response platform may be more or less likely to have existing knowledge or interest in LD when compared to the rest of the population. Ultimately, participation through a member-based online survey panel may have resulted in systematic differences between respondents and the broader population, with respect to digital access and literacy, or pre-existing knowledge of the topic area. In addition, because the survey collected self-reported measures of tick exposure and prevention behaviours, the study may be subject to recall or desirability bias. Although multivariable models adjusted for key sociodemographic and exposure variables, residual confounding may be present in the results. Furthermore, the cross-sectional survey component of Objective 3 does not permit assessment of temporality and therefore limits our ability to establish causal inference and would benefit from repeated survey distribution or a longitudinal design to strengthen these results. While the survey and analytics company was able to recruit a representative sample according to the Canadian census, it was not based on an Ottawa-specific population structure, though it was ultimately well balanced when compared to the Ottawa census. Minor deviations between characteristics of the study sample and the Ottawa population census were present in terms of sampling region, with slight over sampling of the urban strata. This may have affected the population-level estimates of intervention acceptability, resulting in more conservative estimates for some intervention types, although this was adjusted for in the regression analyses. Finally, the regional strata used for this study were previously established as context-specific operational proxies for potential exposure risk and were informed by previous local studies on ecological and risk evidence and were not developed as transferable ecological-risk categories (43,132,133).

Findings from the qualitative component of Objective 3 may have been influenced by the composition of the participants, and certain stakeholder perspectives may have been over or underrepresented. Furthermore, interviews were conducted by a single researcher (KO), who has a background in Health Services, and expertise in LD, which enhanced consistency but may have influenced the direction of probing and interpretation. Deductive codes were informed by findings from Objectives 1 and 2 and may introduce the possibility of confirmation bias. However, two coders worked to develop the code book, and the research team used inductive analysis and transcript coder discussion to enhance analytic reflexivity. Findings from the key informant interviews reflect the political and social context of Ottawa, and findings should be interpreted within the specific geographic and regulatory context in which the study was conducted.

7.6 Implications for future policy, practice, and future research

The findings of this thesis underscore the importance of systematically incorporating contextual factors into tick and LD intervention research. While tick or LD reduction efficacy is a critical component of an intervention, the results from the mixed-methods study in this thesis demonstrated that interventions perceived as effective may still face barriers to adoption and uptake. There is a need for greater transparency and consistency in reporting on acceptability and feasibility, or utility metrics, to improve the contextual relevance of intervention studies. This was evident in the systematic review, where many studies reported reductions in entomological outcomes, but provided limited information on factors such as cost, feasibility, social acceptability or resistance and environmental impact (87). Furthermore, the experimental field trial encountered several feasibility concerns that limit it to certain types of recreational trails, reenforcing the finding that some of these key utility factors will be useful to future researchers if more transparently reported.

Findings from the mixed methods acceptability analysis also highlight the need to better understand drivers of intervention acceptability across sociodemographic and spatial contexts within the 9-point acceptability tool. Investigating key drivers within the acceptability tool may help highlight key differences between interventions that could help explain some of the differences we found in sociodemographic group acceptability between interventions. Results from the analysis suggest that sociodemographic variables were more consistently associated with acceptability scores when compared to risk and exposure variables. Acceptability varied not only by intervention category, but also geographic location within Ottawa, with models improving significantly when cluster robust standard errors, accounting for region of residence, were incorporated in our analysis. Different sociodemographic profiles were associated with acceptability across intervention categories, suggesting that there needs to be further outreach and education incorporated into future interventions. These interventions should also be tailored to residence type and location, as well as key sociodemographic characteristics. Efforts to increase implementation will benefit from an intervention specific approach, focusing on location of residence as a consistently important determinant of acceptability. These findings on location are consistent between the mixed methods study in this thesis, as well as the previous study on KAP by Logan et al. (2024) (132).

From a practice-oriented perspective, future research should explore decision support tools, similar to the multi-criteria decision analysis tools developed in Quebec to help understand risk in order to prioritize One Health interventions in the future (160,161). These tools could be applied to aid land managers and decision makers in balancing feasibility, conservation priorities, and intervention effectiveness across diverse landscape types and recreational or occupational use patterns. Finally, the challenges encountered in synthesizing intervention effectiveness across heterogeneous study designs in the systematic review highlight a need for methods innovation in evidence synthesis approaches for TBD intervention studies. These should include approaches to better support the heterogeneous nature of intervention application and reporting in this field of study. Rigorous meta-analysis requirements may discourage researchers from including data synthesis in their reviews, where some elements of data comparison or pattern recognition may help improve intervention designs (162–164).

7.7 Conclusion

In conclusion, my thesis emphasizes the need for the ongoing development of novel One Health and integrated tick control strategies to tackle the growing problem of TBDs. Though the systematic review identified several categories, such as wildlife host and synthetic chemicals to be most consistently effective, these approaches were not found to be acceptable in the mixed methods study. This disconnect reveals a critical implementation gap and reinforces the need for strategies that bridge acceptability and effectiveness to better align with public values and local feasibility considerations. Integrated strategies will have greater potential to reduce tick density, or TBD transmission in these peri-urban areas like Ottawa, and support sustainable, realistic implementation efforts.

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8. Appendices

8.1 (Objective 1)

8.1.1 Search strategy

Lyme Disease Prevention Search Summary

SEARCH COMPLETED BY ON MARCH 15, 2022
UPDATED NOVEMBER 19 2024

PHAC Update - November 2024- Search update Request

Summary of results

Database	# of results up to March 15 2022 with additional search terms	# of New results for previous time period with additional terms	# of New results from previous time period with additional terms (duplicates removed)	# of results March 2022 - Nov 19 2024	# of results March 2022 -Nov 192024 (duplicates removed)
Medline	2217	1140	1134	523	520
Embase	2100	1076	172	494	112
Global Health	3474	2151	1582	413	0
CAB Abstracts	5683	4362	1883	575	335
Cochrane Central	52	29	14	6	0
Scopus	3247	740	710	463	462
Econlit	5	0	0	1	1
Total	16778	9498	5495	2476	1430

Search Strategies

Medline

Ovid MEDLINE(R) ALL <1946 to November 18, 2024>		
#	Searches	Results
1	ixodidae/ or Ixodid/ or ixodes/	8982
2	(ixodidae or (tick adj hard*) or deer tick? or black?legged tick? or castor bean tick? or ixode or ixodes or I scapularis or I pacificus or I ricinus).tw,kf.	11994
3	(tick? adj2 (bites or drag* or encounter or repel or against)).tw,kf.	2900
4	or/1-3	16543
5	exp lyme disease/ or exp Borrelia burgdorferi Group/	14532
6	((lyme adj (infect* or disease)) or ((Borrelia or Borreliella or b) adj (burgdorferi or afzelii or garinii or japonica or lusitaniae or mayonii))).tw,kf.	15447
7	((tickborne or tick-borne) adj disease?).tw,kf.	4510
8	(abundance or suppress* or (Tick? adj2 control) or ((reduc* or tick? or nymph*) adj2 densit*)).tw,kf.	1099858
9	or/5-8	1119975
10	Tick control/ or Pest control/ or insect control/ or Pest Control, Biological/	25304
11	(prevent* or interven* or control* or biocontrol*).tw,kf.	7401448
12	(((landscape? or forest? or vegetation or environment*) adj2 (manage* or control*)) or ((vegetation or forest?) adj2 (clear* or burn*))).tw,kf.	31882
13	((deer? or rodent* or mice or mouse or squirrel? or chipmunk? or mammal* or peromyscus or odocoileus or sciurus or tamias or eutamias or neotamias or host? or wildlife?) adj3 (manage* or reduc* or excul* or control*)).tw,kf.	103983
14	(((Bait or feed) adj box*) or (tick adj2 tube?) or Damminx or four poster? or 4 poster? or TickBot or vaccine* or immuniz* or immunis* or barrier*).tw,kf.	895708
15	acaricides/ or insecticides/ or insect repellent/ or deet/ or pesticides/	84454
16	(Insecticide? or Acaricide? or pesticide? or repellent? or ((chemical* or biological* or natural*) adj (agent? or control*))).tw,kf.	143242
17	(deet or diethyltoluamide or autan or deltamide or detamide or flypel or metadelphene or muscol).tw,kf.	1509
18	Permethrin/ or doxycycline/ or Pyrethrins/ or Metarhizium/ or Beauveria/ or Bacillus thuringiensis/ or Plant Growth Regulators/ or exp Nematoda/ or Organophosphates/ or Chlorpyrifos/ or Diazinon/ or Carbamates/ or Carbaryl/	164063
19	(Permethrin? or acticin or ambush or armol or atroban or biomopedicul or dronol or ectiban or ectomethrin or elimite or expar or fmc 33297 or fmc33297 or gamabenceno plus or gamaderm or gepescab or infectomite or infectopedicul or klinits or loxazol or lyclear or mite-x or nedax plus or new-nok or nia-33297 or nittifor or nix or novo-herklin 2000 or nrdc 143 or nrdc 147 or nrdc-143 or nrdc-147 or oms 1821 or perigen or permanone or permectrin or permicren or permite or piopel or pounce or pp 557 or s-3151 or sarcop or scabianil or scabmite or stockade or stockate or wl 43479 or zalvor or zehu-ze).tw,kf.	7021
20	(Doxycycline or adoxa or amermycin or atrax or azudoxat or bactidox or banndoclin or basedillin or bassado or biocolyn or biodoxi or bronmycin or calcium doxycycline or cloran or cyclidox or dentistar or deoxycycline or deoxymycin dispersal or deoxymykoin or deoxyoxytetracycline or desoxy oxytetracycline or desoxycycline or doinmycin or dosil or dotur or doxaciclin or doxacycline or doxat or doxatet or doxibiotic or doxicycline or doxilin or doximed or doximycin or doxin or doxine or doxi-sergo or doxocycline or doxsig or doxy or doxybiocin or doxycen or doxycen retard or doxychel or doxycin or doxycyclin or doxylag or doxylin or doxymycin or doxypuren or doxytec or doxytrim or dumoxin or duracycline or esdoxin or etidoxina or	18535

	gewacyclin or gs 3065 or ibralene or idocyclin or idocyklin or interdoxin or investin or longamycin or lydox or magdrin or medomycin or mespafin or mildox or miraclin or monodox or nordox or nsc 56228 or oracea or paldomycin or pernox gel or radox or remycin or respidox or roximycin or serodoxy or servidoxine or servidoxyne or siadocin or siclidon or sigadoxin or spanor or supracyclin or supramycina or tenutan or tolexine or torymycin or tsurupioxin or unidox or veemycin or viadoxin or vibra s or vibrabiotic or vibracina or vibradox* or vibramicina or vibramycin or vibramycine or vibraveineuse or vibravenos or vibravet or wanmycin or zadorin or zenavod).tw,kf.	
21	(Organophosphate? or Organopyrophosphate? or phosphoester? or (organic adj phosphate?) or ("Phosphoric Acid" adj (Ester? or derivative? or diester?))).tw,kf.	16085
22	(Chlorpyrifos or dursban or lorsban or chloropyrifosor chlorpyriphos).tw,kf.	6666
23	(Diaz#non or Bazudine or Dimpylate or Neocidol or Neotsidol or basudin or gimpet or sarolex).tw,kf.	2346
24	(Carbamate? or ((Carbamate? or aminoformic) adj acid?) or dicarbamate? or phenylcarbamate?).tw,kf.	12386
25	(Carbaryl or aclimostat or albendazole or aldicarb or amelubant or aminocarb or Antigale or asunaprevir plus beclabuvir plus daclatasvir or avoralstat or barban or batefenterol or bendiocarb or benomyl or bromosporine or carbamic acid or carbamoyl phosphate or carbanilic acid derivative or Carbaril or carbofuran or carbosulfan or Carbyl or carisbamate or carisoprodol or Carylderm or cenobamate or chlorpropham or cloforex or "Concentrat VO 18" or daclatasvir or darunavir or dibutoline sulfate or Dog-Net Insecticide Poudre or elbasvir or elbasvir plus grazoprevir or emylcamate or encorafenib or etacizine or ethinamate or ethiofencarb or etiguanfacine or felbamate or fenbendazole or fenobucarb or fenoxycarb or "Fido's Free-Itch" or flubendazole or flupirtine or formetanate or G-Wizz or hexapropymate or indoxacarb or ipazilide or isoprocarb or Joseph Lyddy or ledipasvir or mebendazole or mebutamate or methiocarb or methocarbamol or methomyl or mivobulin or mivobulin isethionate or moracizine or nelociguat or netobimin or nocodazole or Ocecoxil or odalasvir or ombitasvir or oxamyl or oxfendazole or oxibendazole or oxyfenamate or parbendazole or pentacaine or phenmedipham or phenprobamate or pibrentasvir or pirimicarb or plocabulin or polyurethan or Poudre insecticide or Poutic or propoxur or pumaprazole or pyricarbate or pyridostigmine or razuprotafib or relenopride or revefenacin or rislenemdaz or rivastigmine or ronidazole or ruzasvir or samatasvir or Sepou or Sevin or Skatta Tick Flea Louse Powder or sofosbuvir plus velpatasvir or solriamfetol or styramate or tarafenacin or thiophanate or Tigal or urethan or velpatasvir or velufenacin or venglustat).tw,kf.	37424
26	(Fipronil or fiprex or regent or Frontline or TopSpot or Fiproguard or Flevox or PetArmor or Tri-Act or Spot-On or barricade or Easyspot or Effipro or Sentry Fiproguard or Parastar or Pronyl OTC or Spectra Sure).tw,kf.	20397
27	(Isoxazoline? or Fluralaner or bravecto or exzolt or Afoxolaner or frontpro or nexgard or Simparica or sarolaner or Credelio or lotilaner).tw,kf.	1254
28	(Pyrethrin? or Pyrethroid? or ipevet or ipevetex or pyrethrasin).tw,kf.	9808
29	(Nootkatone or "4674-50-4").tw,kf.	239
30	(Carvacrol or "2 hydroxy para cymene" or "2 methyl 5 isopropylphenol" or "2 para cymenol" or "isopropyl ortho cresol").tw,kf.	3196
31	(Metarhizium or Metschnikoff or Entomophthora anisopliae or Isaria anisopliae or Penicillium anisopliae or met52 or met 52).tw,kf.	2274

32	(Beauv#ria or Botrytis bassiana or Cordyceps bassiana or Penicillium bassianum or Spicaria bassiana or Tritirachium shiotae or Vuillemin or Hypocrea lixii).tw,kf.	2765
33	(Plant Growth Regulator? or Phytohormone? or Plant Hormone?).tw,kf.	21826
34	(Entomopathogenic bacteri* or Entomopathogenic fung*).tw,kf.	3596
35	((Bacillus adj2 thuringiensis) or Bacilan or Dipel or Thuricide).tw,kf.	8886
36	(Penicillium soppii or Penicillium matris-meae or Penicillium meleagrinum or Penicillium shearii or Penicillium rolfsii or Penicillium michaelis).tw,kf.	15
37	(Nematode? or Adenophorea or Nematoda or round worm? or roundworm? or Secernentea).tw,kf.	53519
38	Protective clothing/ or Gloves, Protective/ or baths/	13949
39	(clothing or clothes or shirt? or pant? or short? or boot? or shoe? or sneaker? or sandal? or sock? or jacket? or glove? or hat?).tw,kf.	1072431
40	(((personal or measur*) adj2 protect*) or ((avoid* or limit* or refrain*) adj5 (habitat* or environment* or wood* or forest* or terrain* or grass*))).tw,kf.	46493
41	((tick? adj3 (check* or inspect* or examin* or search*)) or shower* or bath* or wash*).tw,kf.	214730
42	((behavior* or behaviour* or attitude* or belief* of believe*) adj3 (chang* or alter* or educat* or shift*)).tw,kf.	133270
43	edge plot?.tw.	13
44	or/10-43	9269541
45	4 and 9 and 44	2860
46	limit 45 to (english or french)	2740
47	(202203* or 202204* or 202205* or 202206* or 202207* or 202208* or 202209* or 202210* or 202211* or 202212* or 2023* or 2024*).dt,dp.	4339172
48	46 and 47 [Time period update with additional terms]	523
49	1 or 2	14558
50	5 or 6	18324
51	or/10-42	9269531
52	49 and 50 and 51 [Original search terms -no time limit]	1357
53	47 and 52	214
54	52 not 53 [Original search terms -before March 2022]	1143
55	46 not 48 [Updated search terms-up to March 15 2022]	2217
56	55 not 54 [New results with additional search terms up to March15 2022]	1140

Embase

Embase <1974 to 2024 November 18>		
#	Search	Results
1	*ixodidae/ or exp *ixodes/	4264
2	(ixodidae or (tick adj hard*) or deer tick? or black?legged tick? or castor bean tick? or ixode or ixodes or I scapularis or I pacificus or I ricinus).tw,kw.	12046
3	(tick? adj2 (bites or drag* or encounter or repel or against)).tw,kw.	3425
4	or/1-3	15137
5	exp *lyme disease/ or *Borrelia burgdorferi/	15231
6	((lyme adj (infect* or disease)) or ((Borrelia or Borreliella or b) adj (burgdorferi or afzelii or garinii or japonica or lusitaniae or mayonii))).tw,kw.	17890
7	((tickborne or tick-borne) adj disease?).tw,kw.	4197
8	(abundance or suppress* or (Tick? adj2 control) or ((reduc* or tick? or nymph*) adj2 densit*)).tw,kw.	1326385

9	or/5-8	1348971
10	*Tick control/ or *Pest control/ or *insect control/ or *biological pest control/ or *chemical pest control/ or *environmental management/	21364
11	(prevent* or interven* or control* or biocontrol*).tw,kw.	9651611
12	(((landscape? or forest? or vegetation or environment*) adj2 (manage* or control*)) or ((vegetation or forest?) adj2 (clear* or burn*))).tw,kw.	34724
13	((deer? or rodent* or mice or mouse or squirrel? or chipmunk? or mammal* or peromyscus or odocoileus or sciurus or tamias or eutamias or neotamias or host? or wildlife?) adj3 (manage* or reduc* or excul* or control*)).tw,kw.	159518
14	(((Bait or feed) adj box*) or (tick adj2 tube?) or Damminx or four poster? or 4 poster? or TickBot or vaccine* or immuniz* or immunis* or barrier*).tw,kw.	1068535
15	*acaricide/ or *insecticide/ or *insect repellent/ or *diethyltoluamide/ or *pesticide/	48715
16	(Insecticide? or Acaricide? or pesticide? or repellent? or ((chemical* or biological* or natural*) adj (agent? or control*))).tw,kw.	157260
17	(deet or diethyltoluamide or autan or deltamide or detamide or flypel or metadelphene or muscol).tw,kw.	1716
18	*Permethrin/ or *doxycycline/ or *pyrethroid/ or *Metarhizium/ or exp *Beauveria/ or *Bacillus thuringiensis/ or *phytohormone/ or exp *Nematode/ or *Organophosphate/ or *Chlorpyrifos/ or *dimpylate/ or *carbamic acid derivative/ or *Carbaril/	102766
19	(Permethrin? or acticin or ambush or armol or atroban or biomopedicul or dronol or ectiban or ectomethrin or elimite or expar or fmc 33297 or fmc33297 or gamabenceno plus or gamaderm or gepescab or infectomite or infectopedicul or klinits or loxazol or lyclear or mite-x or nedax plus or new-nok or nia-33297 or nittifor or nix or novo-herklin 2000 or nrdc 143 or nrdc 147 or nrdc-143 or nrdc-147 or oms 1821 or perigen or permanone or permectrin or permicren or permite or piopel or pounce or pp 557 or s-3151 or sarcop or scabianil or scabmite or stockade or stockate or wl 43479 or zalvor or zehu-ze).tw,kw.	7252
20	(Doxycycline or adoxa or amermycin or atrax or azudoxat or bactidox or banndoclin or basedillin or bassado or biocolyn or biodoxi or bronmycin or calcium doxycycline or cloran or cyclidox or dentistar or deoxycycline or deoxymycin dispersal or deoxymykoin or deoxyoxytetracycline or desoxy oxytetracycline or desoxycycline or doinmycin or dosil or dotur or doxaciclin or doxacycline or doxat or doxatet or doxibiotic or doxicycline or doxilin or doximed or doximycin or doxin or doxine or doxi-sergo or doxocycline or doxsig or doxy or doxybiocin or doxycen or doxycen retard or doxychel or doxycin or doxycyclin or doxylag or doxylin or doxymycin or doxypuren or doxytec or doxytrim or dumoxin or duracycline or esdoxin or etidoxina or gewacyclin or gs 3065 or ibralene or idocyclin or idocyklin or interdoxin or investin or longamycin or lydox or magdrin or medomycin or mespafin or mildox or miraclin or monodox or nordox or nsc 56228 or oracea or paldomycin or pernox gel or radox or remycin or respidox or roximycin or serodoxy or servidoxine or servidoxyne or siadocin or siclidon or sigadoxin or spanor or supracyclin or supramycina or tenutan or tolexine or torymycin or tsurupioxin or unidox or veemycin or viadoxin or vibra s or vibrabiotic or vibracina or vibradox* or vibramicina or vibramycin or vibramycine or vibraveineuse or vibravenos or vibravet or wanmycin or zadorin or zenavod).tw,kw.	29584
21	(Organophosphate? or Organopyrophosphate? or phosphoester? or (organic adj phosphate?) or ("Phosphoric Acid" adj (Ester? or derivative? or diester?))).tw,kw.	18119

22	(Chlorpyrifos or dursban or lorsban or chloropyrifosor chlorpyriphos).tw,kw.	7493
23	(Diaz#non or Bazudine or Dimpylate or Neocidol or Neotsidol or basudin or gimpet or sarolex).tw,kw.	2868
24	(Carbamate? or ((Carbamate? or aminoformic) adj acid?) or dicarbamate? or phenylcarbamate?).tw,kw.	14365
25	(Carbaryl or aclimostat or albendazole or aldicarb or amelubant or aminocarb or Antigale or asunaprevir plus beclabuvir plus daclatasvir or avoralstat or barban or batefenterol or bendiocarb or benomyl or bromosporine or carbamic acid or carbamoyl phosphate or carbanilic acid derivative or Carbaril or carbofuran or carbosulfan or Carbyl or carisbamate or carisoprodol or Carylderm or cenobamate or chlorpropham or cloforex or "Concentrat VO 18" or daclatasvir or darunavir or dibutoline sulfate or Dog-Net Insecticide Poudre or elbasvir or elbasvir plus grazoprevir or emylcamate or encorafenib or etacizine or ethinamate or ethiofencarb or etiguanfacine or felbamate or fenbendazole or fenobucarb or fenoxycarb or "Fido's Free-Itch" or flubendazole or flupirtine or formetanate or G-Wizz or hexapropymate or indoxacarb or ipazilide or isoprocarb or Joseph Lyddy or ledipasvir or mebendazole or mebutamate or methiocarb or methocarbamol or methomyl or mivobulin or mivobulin isethionate or moracizine or nelociguat or netobimin or nocodazole or Ocecoxil or odalasvir or ombitasvir or oxamyl or oxfendazole or oxibendazole or oxyfenamate or parbendazole or pentacaine or phenmedipham or phenprobamate or pibrentasvir or pirimicarb or plocabulin or polyurethan or Poudre insecticide or Poutic or propoxur or pumaprazole or pyricarbate or pyridostigmine or razuprotafib or relenopride or revefenacin or rislenemdaz or rivastigmine or ronidazole or ruzasvir or samatasvir or Sepou or Sevin or Skatta Tick Flea Louse Powder or sofosbuvir plus velpatasvir or solriamfetol or styramate or tarafenacin or thiophanate or Tigal or urethan or velpatasvir or velufenacin or venglustat).tw,kw.	52668
26	(Fipronil or fiprex or regent or Frontline or TopSpot or Fiproguard or Flevox or PetArmor or Tri-Act or Spot-On or barricade or Easyspot or Effipro or Sentry Fiproguard or Parastar or Pronyl OTC or Spectra Sure).tw,kw.	28985
27	(Isoxazoline? or Fluralaner or bravecto or exzolt or Afoxolaner or frontpro or nexgard or Simparica or sarolaner or Credelio or lotilaner).tw,kw.	1811
28	(Pyrethrin? or Pyrethroid? or ipevet or ipevetex or pyrethrasin).tw,kw.	11343
29	(Nootkatone or "4674-50-4").tw,kw.	271
30	(Carvacrol or "2 hydroxy para cymene" or "2 methyl 5 isopropylphenol" or "2 para cymenol" or "isopropyl ortho cresol").tw,kw.	3889
31	(Metarhizium or Metschnikoff or Entomophthora anisopliae or Isaria anisopliae or Penicillium anisopliae or met52 or met 52).tw,kw.	2210
32	(Beauv#ria or Botrytis bassiana or Cordyceps bassiana or Penicillium bassianum or Spicaria bassiana or Tritirachium shiotae or Vuillemin or Hypocrea lixii).tw,kw.	2727
33	(Plant Growth Regulator? or Phytohormone? or Plant Hormone?).tw,kw.	19200
34	(Entomopathogenic bacteri* or Entomopathogenic fung*).tw,kw.	3485
35	((Bacillus adj2 thuringiensis) or Bacilan or Dipel or Thuricide).tw,kw.	9166
36	(Penicillium soppii or Penicillium matris-meae or Penicillium meleagrinum or Penicillium shearii or Penicillium rolfsii or Penicillium michaelis).tw,kw.	14
37	(Nematode? or Adenophorea or Nematoda or round worm? or roundworm? or Secernentea).tw,kw.	50334
38	*Protective clothing/ or exp *Gloves/ or *bath/	10046

39	(clothing or clothes or shirt? or pant? or short? or boot? or shoe? or sneaker? or sandal? or sock? or jacket? or glove? or hat?).tw,kw.	1358002
40	(((personal or measur*) adj2 protect*) or ((avoid* or limit* or refrain*) adj5 (habitat* or environment* or wood* or forest* or terrain* or grass*))).tw,kw.	52119
41	((tick? adj3 (check* or inspect* or examin* or search*)) or shower* or bath* or wash*).tw,kw.	279067
42	((behavior* or behaviour* or attitude* or belief* of believe*) adj3 (chang* or alter* or educat* or shift*)).tw,kw.	163352
43	edge plot?.tw.	9
44	or/10-43	11829259
45	4 and 9 and 44	2752
46	limit 45 to (english or french)	2594
47	("20220316" or "20220317" or "20220318" or "20220319" or "20220320" or "20220321" or "20220322" or "20220323" or "20220324" or "20220325" or "20220326" or "20220327" or "20220328" or "20220329" or "20220330" or "20220331" or 202204* or 202205* or 202206* or 202207* or 202208* or 202209* or 202210* or 202211* or 202212* or 2023* or 2024*).dc,dp.	5640302
48	46 and 47 [updated terms after March 2022]	494
49	46 not 48 [updated terms up to March15 2022]	2100
50	1 or 2	12573
51	5 or 6	20963
52	or/10-42	11829252
53	50 and 51 and 52	1294
54	limit 53 to (english or french)	1214
55	47 and 54 [Original search terms March 2022-present]	190
56	54 not 55 [Original search terms up to March 2022]	1024
57	49 not 56 [New results-up-toMarch 15 2022 with additional terms]	1076

Global Health

Global Health <1973 to 2024 Week 46>		
#	Search	Results
1	ixodidae/ or exp ixodes/	17557
2	(ixodidae or (tick adj hard*) or deer tick? or black?legged tick? or castor bean tick? or ixode or ixodes or I scapularis or I pacificus or I ricinus).tw,id.	17763
3	(tick? adj2 (bites or drag* or encounter or repel or against)).tw,id.	2858
4	or/1-3	19195
5	lyme disease/ or Borrelia burgdorferi/	13733
6	((lyme adj (infect* or disease)) or ((Borrelia or Borreliella or b) adj (burgdorferi or afzelii or garinii or japonica or lusitaniae or mayonii))).tw,id.	14234
7	((tickborne or tick-borne) adj disease?).tw,id.	24748
8	(abundance or suppress* or (Tick? adj2 control) or ((reduc* or tick? or nymph*) adj2 densit*)).tw,id.	155326
9	or/5-8	181435
10	Tick control/ or Pest control/ or insect control/ or biological control/ or chemical control/ or pest management/ or environmental management/ or habitat management/	29816
11	(prevent* or interven* or control* or biocontrol*).tw,id.	1565481
12	(((landscape? or forest? or vegetation or environment*) adj2 (manage* or control*)) or ((vegetation or forest?) adj2 (clear* or burn*))).tw,id.	10070

13	((deer? or rodent* or mice or mouse or squirrel? or chipmunk? or mammal* or peromyscus or odocoileus or sciurus or tamias or eutamias or neotamias or host? or wildlife?) adj3 (manage* or reduc* or excul* or control*)).tw,id.	23530
14	(((Bait or feed) adj box*) or (tick adj2 tube?) or Damminx or four poster? or 4 poster? or TickBot or vaccine* or immuniz* or immunis* or barrier*).tw,id.	265645
15	acaricides/ or insecticides/ or insect repellents/ or diethyltoluamide/ or pesticides/	58721
16	(Insecticide? or Acaricide? or pesticide? or repellent? or ((chemical* or biological* or natural*) adj (agent? or control*))).tw,id.	103262
17	(deet or diethyltoluamide or autan or deltamide or detamide or flypel or metadelphene or muscol).tw,id.	1654
18	Permethrin/ or doxycycline/ or Pyrethrins/ or Metarhizium/ or Beauveria/ or Bacillus thuringiensis/ or exp Plant Growth Regulators/ or exp Nematoda/ or organophosphorus compounds/ or Chlorpyrifos/ or Diazinon/ or Carbamates/ or Carbaryl/	117273
19	(Permethrin? or acticin or ambush or armol or atroban or biomopedicul or dronol or ectiban or ectomethrin or elimite or expar or fmc 33297 or fmc33297 or gamabenceno plus or gamaderm or gepescab or infectomite or infectopedicul or klinits or loxazol or lyclear or mite-x or nedax plus or new-nok or nia-33297 or nittifor or nix or novo-herklin 2000 or nrdc 143 or nrdc 147 or nrdc-143 or nrdc-147 or oms 1821 or perigen or permanone or permectrin or permicren or permite or piopel or pounce or pp 557 or s-3151 or sarcop or scabianil or scabmite or stockade or stockate or wl 43479 or zalvor or zehu-ze).tw,id.	4652
20	(Doxycycline or adoxa or amermycin or atrax or azudoxat or bactidox or banndoclin or basedillin or bassado or biocolyn or biodoxi or bronmycin or calcium doxycycline or cloran or cyclidox or dentistar or deoxycycline or deoxymycin dispersal or deoxymykoin or deoxyoxytetracycline or desoxy oxytetracycline or desoxycycline or doinmycin or dosil or dotur or doxaciclin or doxacycline or doxat or doxatet or doxibiotic or doxicycline or doxilin or doximed or doximycin or doxin or doxine or doxi-sergo or doxocycline or doxsig or doxy or doxybiocin or doxycen or doxycen retard or doxychel or doxycin or doxycyclin or doxylag or doxylin or doxymycin or doxypuren or doxytec or doxytrim or dumoxin or duracycline or esdoxin or etidoxina or gewacyclin or gs 3065 or ibralene or idocyclin or idocyklin or interdoxin or investin or longamycin or lydox or magdrin or medomycin or mespafin or mildox or miraclin or monodox or nordox or nsc 56228 or oracea or paldomycin or pernox gel or radox or remycin or respidox or roximycin or serodoxy or servidoxine or servidoxyne or siadocin or siclidon or sigadoxin or spanor or supracyclin or supramycina or tenutan or tolexine or torymycin or tsurupioxin or unidox or veemycin or viadoxin or vibra s or vibrabiotic or vibracina or vibradox* or vibramicina or vibramycin or vibramycine or vibraveineuse or vibravenos or vibravet or wanmycin or zadorin or zenavod).tw,id.	7599
21	(Organophosphate? or Organopyrophosphate? or phosphoester? or (organic adj phosphate?) or ("Phosphoric Acid" adj (Ester? or derivative? or diester?))).tw,id.	7147
22	(Chlorpyrifos or dursban or lorsban or chloropyrifosor chlorpyriphos).tw,id.	4341
23	(Diaz#non or Bazudine or Dimpylate or Neocidol or Neotsidol or basudin or gimpet or sarolex).tw,id.	1589
24	(Carbamate? or ((Carbamate? or aminoformic) adj acid?) or dicarbamate? or phenylcarbamate?).tw,id.	3926
25	(Carbaryl or aclimostat or albendazole or aldicarb or amelubant or aminocarb or Antigale or asunaprevir plus beclabuvir plus daclatasvir or avoralstat or barban or batefenterol or bendiocarb or benomyl or bromosporine or carbamic acid or	17154

	carbamoyl phosphate or carbanilic acid derivative or Carbaril or carbofuran or carbosulfan or Carbyl or carisbamate or carisoprodol or Carylderm or cenobamate or chlorpropham or cloforex or "Concentrat VO 18" or daclatasvir or darunavir or dibutoline sulfate or Dog-Net Insecticide Poudre or elbasvir or elbasvir plus grazoprevir or emylcamate or encorafenib or etacizine or ethinamate or ethiofencarb or etiguanfacine or felbamate or fenbendazole or fenobucarb or fenoxycarb or "Fido's Free-Itch" or flubendazole or flupirtine or formetanate or G-Wizz or hexapropymate or indoxacarb or ipazilide or isoprocarb or Joseph Lyddy or ledipasvir or mebendazole or mebutamate or methiocarb or methocarbamol or methomyl or mivobulin or mivobulin isethionate or moracizine or nelociguat or netobimin or nocodazole or Ocecoxil or odalasvir or ombitasvir or oxamyl or oxfendazole or oxibendazole or oxyfenamate or parbendazole or pentacaine or phenmedipham or phenprobamate or pibrentasvir or pirimicarb or plocabulin or polyurethan or Poudre insecticide or Poutic or propoxur or pumaprazole or pyricarbate or pyridostigmine or razuprotafib or relenopride or revefenacin or rislenemdaz or rivastigmine or ronidazole or ruzasvir or samatasvir or Sepou or Sevin or Skatta Tick Flea Louse Powder or sofosbuvir plus velpatasvir or solriamfetol or styramate or tarafenacin or thiophanate or Tigal or urethan or velpatasvir or velufenacin or venglustat).tw,id.	
26	(Fipronil or fiprex or regent or Frontline or TopSpot or Fiproguard or Flevox or PetArmor or Tri-Act or Spot-On or barricade or Easyspot or Effipro or Sentry Fiproguard or Parastar or Pronyl OTC or Spectra Sure).tw,id.	5050
27	(Isoxazoline? or Fluralaner or bravecto or exzolt or Afoxolaner or frontpro or nexgard or Simparica or sarolaner or Credelio or lotilaner).tw,id.	235
28	(Pyrethrin? or Pyrethroid? or ipevet or ipevetex or pyrethrasin).tw,id.	12510
29	(Nootkatone or "4674-50-4").tw,id.	139
30	(Carvacrol or "2 hydroxy para cymene" or "2 methyl 5 isopropylphenol" or "2 para cymenol" or "isopropyl ortho cresol").tw,id.	3376
31	(Metarhizium or Metschnikoff or Entomophthora anisopliae or Isaria anisopliae or Penicillium anisopliae or met52 or met 52).tw,id.	710
32	(Beauv#ria or Botrytis bassiana or Cordyceps bassiana or Penicillium bassianum or Spicaria bassiana or Tritirachium shiotae or Vuillemin or Hypocrea lixii).tw,id.	840
33	(Plant Growth Regulator? or Phytohormone? or Plant Hormone?).tw,id.	6843
34	(Entomopathogenic bacteri* or Entomopathogenic fung*).tw,id.	3590
35	((Bacillus adj2 thuringiensis) or Bacilan or Dipel or Thuricide).tw,id.	4498
36	(Penicillium soppii or Penicillium matris-meae or Penicillium meleagrinum or Penicillium shearii or Penicillium rolfsii or Penicillium michaelis).tw,id.	12
37	(Nematode? or Adenophorea or Nematoda or round worm? or roundworm? or Secernentea).tw,id.	80859
38	Protective clothing/ or Gloves/	5155
39	(clothing or clothes or shirt? or pant? or short? or boot? or shoe? or sneaker? or sandal? or sock? or jacket? or glove? or hat?).tw,id.	141096
40	(((personal or measur*) adj2 protect*) or ((avoid* or limit* or refrain*) adj5 (habitat* or environment* or wood* or forest* or terrain* or grass*))).tw,id.	15572
41	((tick? adj3 (check* or inspect* or examin* or search*)) or shower* or bath* or wash*).tw,id.	52799
42	((behavior* or behaviour* or attitude* or belief* of believe*) adj3 (chang* or alter* or educat* or shift*)).tw,id.	33339
43	edge plot?.tw.	2
44	or/10-43	1940014

45	4 and 9 and 44	4459
46	limit 45 to (english or french)	3900
47	remove duplicates from 46	3887
48	("20220316" or "20220317" or "20220318" or "20220319" or "20220320" or "20220321" or "20220322" or "20220323" or "20220324" or "20220325" or "20220326" or "20220327" or "20220328" or "20220329" or "20220330" or "20220331" or 202204* or 202205* or 202206* or 202207* or 202208* or 202209* or 202210* or 202211* or 202212* or 2023* or 2024*).dp.	370177
49	47 and 48 [updated search terms After March2022]	413
50	47 not 49 [updated search terms Before March2022]	3474
51	1 or 2	17763
52	5 or 6	14234
53	or/10-42	1940012
54	51 and 52 and 53	1582
55	limit 54 to (english or french)	1430
56	48 and 55	103
57	55 not 56 [Original search terms up to March 2022]	1327
58	50 not 57 [New results only-up to March 15 2022]	2151

CAB Abstracts

CAB Abstracts <1973 to 2024 Week 46>		
#	Searches	Results
1	ixodidae/ or exp ixodes/	32753
2	(ixodidae or (tick adj hard*) or deer tick? or black?legged tick? or castor bean tick? or ixode or ixodes or I scapularis or I pacificus or I ricinus).tw,id.	33032
3	(tick? adj2 (bites or drag* or encounter or repel or against)).tw,id.	3768
4	or/1-3	34644
5	lyme disease/ or Borrelia burgdorferi/	13398
6	((lyme adj (infect* or disease)) or ((Borrelia or Borreliella or b) adj (burgdorferi or afzelii or garinii or japonica or lusitaniae or mayonii))).tw,id.	14002
7	((tickborne or tick-borne) adj disease?).tw,id.	34402
8	(abundance or suppress* or (Tick? adj2 control) or ((reduc* or tick? or nymph*) adj2 densit*)).tw,id.	429542
9	or/5-8	464455
10	Tick control/ or Pest control/ or insect control/ or biological control/ or chemical control/ or pest management/ or environmental management/ or habitat management/	298401
11	(prevent* or interven* or control* or biocontrol*).tw,id.	2922934
12	(((landscape? or forest? or vegetation or environment*) adj2 (manage* or control*)) or ((vegetation or forest?) adj2 (clear* or burn*))).tw,id.	155065
13	((deer? or rodent* or mice or mouse or squirrel? or chipmunk? or mammal* or peromyscus or odocoileus or sciurus or tamias or eutamias or neotamias or host? or wildlife?) adj3 (manage* or reduc* or excul* or control*)).tw,id.	54251
14	(((Bait or feed) adj box*) or (tick adj2 tube?) or Damminx or four poster? or 4 poster? or TickBot or vaccine* or immuniz* or immunis* or barrier*).tw,id.	301768
15	acaricides/ or insecticides/ or insect repellents/ or diethyltoluamide/ or pesticides/	243501
16	(Insecticide? or Acaricide? or pesticide? or repellent? or ((chemical* or biological* or natural*) adj (agent? or control*))).tw,id.	551863

17	(deet or diethyltoluamide or autan or deltamide or detamide or flypel or metadelphene or muscol).tw,id.	1786
18	Permethrin/ or doxycycline/ or Pyrethrins/ or Metarhizium/ or Beauveria/ or Bacillus thuringiensis/ or exp Plant Growth Regulators/ or exp Nematoda/ or organophosphorus compounds/ or Chlorpyrifos/ or Diazinon/ or Carbamates/ or Carbaryl/	576415
19	(Permethrin? or acticin or ambush or armol or atroban or biomopedicul or dronol or ectiban or ectomethrin or elimite or expar or fmc 33297 or fmc33297 or gamabenceno plus or gamaderm or gepescab or infectomite or infectopedicul or klinits or loxazol or lyclear or mite-x or nedax plus or new-nok or nia-33297 or nittifor or nix or novo-herklin 2000 or nrdc 143 or nrdc 147 or nrdc-143 or nrdc-147 or oms 1821 or perigen or permanone or permectrin or permicren or permite or piopel or pounce or pp 557 or s-3151 or sarcop or scabianil or scabmite or stockade or stockate or wl 43479 or zalvor or zehu-ze).tw,id.	9643
20	(Doxycycline or adoxa or amermycin or atrax or azudoxat or bactidox or banndoclin or basedillin or bassado or biocolyn or biodoxi or bronmycin or calcium doxycycline or cloran or cyclidox or dentistar or deoxycycline or deoxymycin dispersal or deoxymykoin or deoxyoxytetracycline or desoxy oxytetracycline or desoxycycline or doinmycin or dosil or dotur or doxaciclin or doxacycline or doxat or doxatet or doxibiotic or doxicycline or doxilin or doximed or doximycin or doxin or doxine or doxi-sergo or doxocycline or doxsig or doxy or doxybiocin or doxycen or doxycen retard or doxychel or doxycin or doxycyclin or doxylag or doxylin or doxymycin or doxypuren or doxytec or doxytrim or dumoxin or duracycline or esdoxin or etidoxina or gewacyclin or gs 3065 or ibralene or idocyclin or idocyklin or interdoxin or investin or longamycin or lydox or magdrin or medomycin or mespafin or mildox or miraclin or monodox or nordox or nsc 56228 or oracea or paldomycin or pernox gel or radox or remycin or respidox or roximycin or serodoxy or servidoxine or servidoxyne or siadocin or siclidon or sigadoxin or spanor or supracyclin or supramycina or tenutan or tolexine or torymycin or tsurupioxin or unidox or veemycin or viadoxin or vibra s or vibrabiotic or vibracina or vibradox* or vibramicina or vibramycin or vibramycine or vibraveineuse or vibravenos or vibravet or wanmycin or zadorin or zenavod).tw,id.	8189
21	(Organophosphate? or Organopyrophosphate? or phosphoester? or (organic adj phosphate?) or ("Phosphoric Acid" adj (Ester? or derivative? or diester?))).tw,id.	17769
22	(Chlorpyrifos or dursban or lorsban or chloropyrifosor chlorpyriphos).tw,id.	16477
23	(Diaz#non or Bazudine or Dimpylate or Neocidol or Neotsidol or basudin or gimpet or sarolex).tw,id.	6617
24	(Carbamate? or ((Carbamate? or aminoformic) adj acid?) or dicarbamate? or phenylcarbamate?).tw,id.	10813
25	(Carbaryl or aclimostat or albendazole or aldicarb or amelubant or aminocarb or Antigale or asunaprevir plus beclabuvir plus daclatasvir or avoralstat or barban or batefenterol or bendiocarb or benomyl or bromosporine or carbamic acid or carbamoyl phosphate or carbanilic acid derivative or Carbaril or carbofuran or carbosulfan or Carbyl or carisbamate or carisoprodol or Carylderm or cenobamate or chlorpropham or cloforex or "Concentrat VO 18" or daclatasvir or darunavir or dibutoline sulfate or Dog-Net Insecticide Poudre or elbasvir or elbasvir plus grazoprevir or emylcamate or encorafenib or etacizine or ethinamate or ethiofencarb or etiguanfacine or felbamate or fenbendazole or fenobucarb or fenoxycarb or "Fido's Free-Itch" or flubendazole or flupirtine or formetanate or G-	63738

	Wizz or hexapropymate or indoxacarb or ipazilide or isoprocarb or Joseph Lyddy or ledipasvir or mebendazole or mebutamate or methiocarb or methocarbamol or methomyl or mivobulin or mivobulin isethionate or moracizine or nelociguat or netobimin or nocodazole or Ocecoxil or odalasvir or ombitasvir or oxamyl or oxfendazole or oxibendazole or oxyfenamate or parbendazole or pentacaine or phenmedipham or phenprobamate or pibrentasvir or pirimicarb or plocabulin or polyurethan or Poudre insecticide or Poutic or propoxur or pumaprazole or pyricarbate or pyridostigmine or razuprotafib or relenopride or revefenacin or rislenemdaz or rivastigmine or ronidazole or ruzasvir or samatasvir or Sepou or Sevin or Skatta Tick Flea Louse Powder or sofosbuvir plus velpatasvir or solriamfetol or styramate or tarafenacin or thiophanate or Tigal or urethan or velpatasvir or velufenacin or venglustat).tw,id.	
26	(Fipronil or fiprex or regent or Frontline or TopSpot or Fiproguard or Flevox or PetArmor or Tri-Act or Spot-On or barricade or Easyspot or Effipro or Sentry Fiproguard or Parastar or Pronyl OTC or Spectra Sure).tw,id.	11896
27	(Isoxazoline? or Fluralaner or bravecto or exzolt or Afoxolaner or frontpro or nexgard or Simparica or sarolaner or Credelio or lotilaner).tw,id.	743
28	(Pyrethrin? or Pyrethroid? or ipevet or ipevetex or pyrethrasin).tw,id.	36598
29	(Nootkatone or "4674-50-4").tw,id.	259
30	(Carvacrol or "2 hydroxy para cymene" or "2 methyl 5 isopropylphenol" or "2 para cymenol" or "isopropyl ortho cresol").tw,id.	5576
31	(Metarhizium or Metschnikoff or Entomophthora anisopliae or Isaria anisopliae or Penicillium anisopliae or met52 or met 52).tw,id.	7340
32	(Beauv#ria or Botrytis bassiana or Cordyceps bassiana or Penicillium bassianum or Spicaria bassiana or Tritirachium shiotae or Vuillemin or Hypocrea lixii).tw,id.	10509
33	(Plant Growth Regulator? or Phytohormone? or Plant Hormone?).tw,id.	197286
34	(Entomopathogenic bacteri* or Entomopathogenic fung*).tw,id.	30061
35	((Bacillus adj2 thuringiensis) or Bacilan or Dipel or Thuricide).tw,id.	23081
36	(Penicillium soppii or Penicillium matris-meae or Penicillium meleagrinum or Penicillium shearii or Penicillium rolfsii or Penicillium michaelis).tw,id.	39
37	(Nematode? or Adenophorea or Nematoda or round worm? or roundworm? or Secernentea).tw,id.	245038
38	Protective clothing/ or Gloves/	2998
39	(clothing or clothes or shirt? or pant? or short? or boot? or shoe? or sneaker? or sandal? or sock? or jacket? or glove? or hat?).tw,id.	374049
40	(((personal or measur*) adj2 protect*) or ((avoid* or limit* or refrain*) adj5 (habitat* or environment* or wood* or forest* or terrain* or grass*))).tw,id.	45785
41	((tick? adj3 (check* or inspect* or examin* or search*)) or shower* or bath* or wash*).tw,id.	117792
42	((behavior* or behaviour* or attitude* or belief* of believe*) adj3 (chang* or alter* or educat* or shift*)).tw,id.	43745
43	edge plot?.tw.	79
44	or/10-43	4097574
45	4 and 9 and 44	7228
46	limit 45 to (english or french)	6258
47	("20220316" or "20220317" or "20220318" or "20220319" or "20220320" or "20220321" or "20220322" or "20220323" or "20220324" or "20220325" or "20220326" or "20220327" or "20220328" or "20220329" or "20220330" or "20220331" or 202204* or 202205* or 202206* or 202207* or 202208* or 202209* or 202210* or 202211* or 202212* or 2023* or 2024*).dp.	736603

48	46 and 47 [Updated search terms After March 2022]	575
49	46 not 48 [Updated Search terms BeforeMarch2022]	5683
50	1 or 2	33032
51	5 or 6	14002
52	or/10-42	4097523
53	50 and 51 and 52	1577
54	limit 53 to (english or french)	1425
55	47 and 54	104
56	54 not 55 [Original search terms-Before Mar-2022]	1321
57	49 not 56 [New results only-up-to March 2022 with updated search terms]	4362

Scopus

Search	Results
TITLE-ABS-KEY (ixodidae OR (tick W/1 hard*) OR "deer tick*" OR "black*legged tick*" OR "castor bean tick*" OR ixode OR ixodes OR "I scapularis" OR "I pacificus" OR "I ricinus" OR "tick bite*" OR (tick* W/2 against) OR (tick* W/2 repel) OR (tick* W/2 drag*) OR (tick* W/2 encounter))) AND (TITLE-ABS-KEY ((lyme W/1 (infect* OR disease)) OR ((borrelia OR borreliella OR "b") W/1 (burgdorferi OR afzelii OR garinii OR japonica OR lusitaniae OR mayonii) OR (tick-borne W/2 disease*) OR ((reduc* OR tick? OR nymph*) W/2 densit*) OR abundance OR suppress*))) AND (TITLE-ABS-KEY (prevent* OR interven* OR control* OR biocontrol*) OR (TITLE-ABS-KEY (((landscape* OR forest* OR vegetation OR environment*) W/2 (manage* OR control*)) OR ((vegetation OR forest*) W/2 (clear* OR burn*))))) OR (TITLE-ABS-KEY ((deer* OR rodent* OR mice OR mouse OR squirrel* OR chipmunk* OR mammal* OR peromyscus OR odocoileus OR sciurus OR tamias OR eutamias OR neotamias OR host* OR wildlife*) W/3 (manage* OR reduc* OR excul* OR control*))) OR (TITLE-ABS-KEY (((bait OR feed) W/1 box*) OR (tick W/2 tube*) OR damminx OR "four poster*" OR "4 poster*" OR tickbot OR vaccine* OR immuniz* OR immunis* OR barrier*)) OR (TITLE-ABS-KEY (insecticide* OR acaricide* OR pesticide* OR repellent* OR ((chemical* OR biological* OR natural*) W/1 (agent* OR control*))))) OR (TITLE-ABS-KEY (deet OR diethyltoluamide OR autan OR deltamide OR detamide OR flypel OR metadelphene OR muscol)) OR (TITLE-ABS-KEY (permethrin* OR acticin OR ambush OR armol OR atroban OR biomopedicul OR dronol OR ectiban OR ectomethrin OR elimite OR expar OR "fmc 33297" OR fmc33297 OR "gamabenceno plus" OR gamaderm OR gepescab OR infectomite OR infectopedicul OR klinits OR loxazol OR lyclear OR "mite-x" OR "nedax plus" OR "new-nok" OR "nia-33297" OR nittifor OR nix OR "novo-herklin 2000" OR "nrdc 143" OR "nrdc 147" OR "nrdc-143" OR "nrdc-147" OR "oms 1821" OR perigen OR permanone OR permectrin OR permicren OR permite OR piopel OR pounce OR "pp 557" OR "s-3151" OR sarcop OR scabianil OR scabmite OR stockade OR stockate OR "wl 43479" OR zalvor OR "zehu-ze")) OR (TITLE-ABS-KEY (doxycycline OR adoxa OR amermycin OR atrax OR azudoxat OR bactidox OR banndoclin OR basedillin OR bassado OR biocolyn OR biodoxi OR bronmycin OR "calcium doxycycline" OR cloran OR cyclidox OR dentistar OR deoxycycline OR "deoxymycin	3694

dispersal" OR deoxymykoin OR deoxyoxytetracycline OR "desoxy oxytetracycline" OR desoxycycline OR doinmycin OR dosil OR dotur OR doxaciclin OR doxacycline OR doxat OR doxatet OR doxibiotic OR doxicycline OR doxilin OR doximed OR doximycin OR doxin OR doxine OR doxi-sergo OR doxocycline OR doxsig OR doxy OR doxybiocin OR doxycen OR "doxycen retard" OR doxychel OR doxycin OR doxycyclin OR doxylag OR doxylin OR doxymycin OR doxypuren OR doxytec OR doxytrim OR dumoxin OR duracycline OR esdoxin OR etidoxina OR gewacyclin OR "gs 3065" OR ibralene OR idocyclin OR idocyklin OR interdoxin OR investin OR longamycin OR lydox OR magdrin OR medomycin OR mespafin OR mildox OR miraclin OR monodox OR nordox OR "nsc 56228" OR oracea OR paldomycin OR "pernox gel" OR radox OR remycin OR respidox OR roximycin OR serodoxy OR servidoxine OR servidoxyne OR siadocin OR siclidon OR sigadoxin OR spanor OR supracyclin OR supramycina OR tenutan OR tolexine OR torymycin OR tsurupioxin OR unidox OR veemycin OR viadoxin OR "vibra s" OR vibrabiotic OR vibracina OR vibradox* OR vibramicina OR vibramycin OR vibramycine OR vibraveineuse OR vibravenos OR vibravet OR wanmycin OR zadorin OR zenavod)) OR (TITLE-ABS-KEY (organophosphate* OR organopyrophosphate* OR phosphoester* OR (organic W/1 phosphate*) OR ("Phosphoric Acid" W/1 (ester* OR derivative* OR diester*))))) OR (TITLE-ABS-KEY (chlorpyrifos OR dursban OR lorsban OR "chloropyrifosor chlorpyriphos")) OR (TITLE-ABS-KEY (diaz?non OR bazudine OR dimpylate OR neocidol OR neotsidol OR basudin OR gimpet OR sarolex)) OR (TITLE-ABS-KEY (carbamate* OR ((carbamate* OR aminoformic) W/1 acid*) OR dicarbamate* OR phenylcarbamate*)) OR (TITLE-ABS-KEY (carbaryl OR aclimostat OR albendazole OR aldicarb OR amelubant OR aminocarb OR antigale OR "asunaprevir plus beclabuvir plus daclatasvir" OR avoralstat OR barban OR batefenterol OR bendiocarb OR benomyl OR bromosporine OR "carbamic acid" OR "carbamoyl phosphate" OR "carbanilic acid derivative" OR carbaril OR carbofuran OR carbosulfan OR carbyl OR carisbamate OR carisoprodol OR carylderm OR cenobamate OR chlorpropham OR cloforex OR "Concentrat VO 18" OR daclatasvir OR darunavir OR "dibutoline sulfate" OR "Dog-Net Insecticide Poudre" OR elbasvir OR "elbasvir plus grazoprevir" OR emylcamate OR encorafenib OR etacizine OR ethinamate OR ethiofencarb OR etiguanfacine OR felbamate OR fenbendazole OR fenobucarb OR fenoxycarb OR "Fido's Free-Itch" OR flubendazole OR flupirtine OR formetanate OR "G-Wizz" OR hexapropymate OR indoxacarb OR ipazilide OR isoprocarb OR "Joseph Lyddy" OR ledipasvir OR mebendazole OR mebutamate OR methiocarb OR methocarbamol OR methomyl OR mivobulin OR "mivobulin isethionate" OR moracizine OR nelociguat OR netobimin OR nocodazole OR ocecoxil OR odalasvir OR ombitasvir OR oxamyl OR oxfendazole OR oxibendazole OR oxyfenamate OR parbendazole OR pentacaine OR phenmedipham OR phenprobamate OR pibrentasvir OR pirimicarb OR plocabulin OR polyurethan OR "Poudre insecticide" OR poutic OR propoxur OR pumaprazole OR pyricarbate OR pyridostigmine OR razuprotafib OR relenopride OR revefenacin OR rislenemdaz OR rivastigmine OR ronidazole OR ruzasvir OR samatasvir OR sepou OR sevin OR "Skatta Tick Flea Louse Powder" OR "sofosbuvir plus velpatasvir" OR solriamfetol OR styramate OR tarafenacin OR thiophanate OR tigal OR u	

rethan OR velpatasvir OR velufenacin OR venglustat)) OR (TITLE-ABS-KEY (fipronil OR fiprex OR regent OR frontline OR topspot OR fiproguard OR flevox OR pet armor OR "Tri-Act" OR "Spot-On" OR barricade OR easyspot OR effipro OR "Sentry Fiproguard" OR parastar OR "Pronyl OTC" OR "Spectra Sure")) OR (TITLE-ABS-KEY (isoxazoline* OR fluralaner OR bravecto OR exzolt OR afoxolaner OR frontpro OR nexgard OR simparica OR sarolaner OR credelio OR lotilaner)) OR (TITLE-ABS-KEY (pyrethrin* OR pyrethroid* OR ipevet OR ipevetex OR pyrethrasin)) OR (TITLE-ABS-KEY (nootkatone OR "4674-50-4")) OR (TITLE-ABS-KEY (carvacrol OR "2 hydroxy para cymene" OR "2 methyl 5 isopropylphenol" OR "2 para cymenol" OR "isopropyl ortho cresol")) OR (TITLE-ABS-KEY (metarhizium OR metschnikoff OR "Entomophthora anisopliae" OR "Isaria anisopliae" OR "Penicillium anisopliae" OR "met52" OR "met 52")) OR (TITLE-ABS-KEY (beauv?ria OR "Botrytis bassiana" OR "Cordyceps bassiana" OR "Penicillium bassianum" OR "Spicaria bassiana" OR "Tritirachium shiotae" OR vuillemin OR "Hypocrea lixii")) OR (TITLE-ABS-KEY ("Plant Growth Regulator*" OR phytohormone* OR "Plant Hormone*")) OR (TITLE-ABS-KEY ("Entomopathogenic bacteri*" OR "Entomopathogenic fung*")) OR (TITLE-ABS-KEY ((bacillus W/2 thuringiensis) OR bacilan OR dipel OR thuricide)) OR (TITLE-ABS-KEY ("Penicillium soppii" OR "Penicillium matris-meae" OR "Penicillium meleagrinum" OR "Penicillium shearii" OR "Penicillium rolfsii" OR "Penicillium michaelis")) OR (TITLE-ABS-KEY (nematode* OR adenophorea OR nematoda OR "round worm*" OR roundworm* OR secernentea)) OR (TITLE-ABS-KEY (clothing OR clothes OR shirt* OR pant* OR short* OR boot* OR shoe* OR sneaker* OR sandal* OR sock* OR jacket* OR glove* OR hat OR hats)) OR (TITLE-ABS-KEY (((personal OR measur*) W/2 protect*) OR ((avoid* OR limit* OR refrain*) W/5 (habitat* OR environment* OR wood* OR forest* OR terrain* OR grass* OR "edge plot*")))) OR (TITLE-ABS-KEY ((tick* W/3 (check* OR inspect* OR examin* OR search*)) OR shower* OR bath* OR wash*)) OR (TITLE-ABS-KEY ((behavior* OR behaviour* OR attitude* OR "belief* of believe*") W/3 (chang* OR alter* OR educat* OR shift*))))) AND LANGUAGE (english OR french)	
AND (PUBDATETXT ("March 2022" OR "April 2022" OR "May 2022" OR "June 2022" OR "July 2022" OR "August 2022" OR "September 2022" OR "October 2022" OR "November 2022" OR "December 2022") OR PUBYEAR > 2022)	463
New results from scopus up to March 2022 with additional search terms	740

Cochrane CENTRAL

EBM Reviews - Cochrane Central Register of Controlled Trials <October 2024>		
#	Search	Results
1	ixodidae/ or Ixodid/ or ixodes/	35
2	(ixodidae or (tick adj hard*) or deer tick? or black?legged tick? or castor bean tick? or ixode or ixodes or I scapularis or I pacificus or I ricinus).tw,kw.	49
3	(tick? adj2 (bites or drag* or encounter or repel or against)).tw,kw.	68
4	or/1-3	111
5	exp lyme disease/ or exp Borrelia burgdorferi Group/	195
6	((lyme adj (infect* or disease)) or ((Borrelia or Borreliella or b) adj (burgdorferi or afzelii or garinii or japonica or lusitaniae or mayonii))).tw,kw.	229

7	((tickborne or tick-borne) adj disease?).tw,kw.	38
8	(abundance or suppress* or (Tick? adj2 control) or ((reduc* or tick? or nymph*) adj2 densit*)).tw,kw.	37536
9	or/5-8	37810
10	Tick control/ or Pest control/ or insect control/ or Pest Control, Biological/	132
11	(prevent* or interven* or control* or biocontrol*).tw,kw.	1537760
12	(((landscape? or forest? or vegetation or environment*) adj2 (manage* or control*)) or ((vegetation or forest?) adj2 (clear* or burn*))).tw,kw.	1977
13	((deer? or rodent* or mice or mouse or squirrel? or chipmunk? or mammal* or peromyscus or odocoileus or sciurus or tamias or eutamias or neotamias or host? or wildlife?) adj3 (manage* or reduc* or excul* or control*)).tw,kw.	739
14	(((Bait or feed) adj box*) or (tick adj2 tube?) or Damminx or four poster? or 4 poster? or TickBot or vaccine* or immuniz* or immunis* or barrier*).tw,kw.	58898
15	acaricides/ or insecticides/ or insect repellent/ or deet/ or pesticides/	763
16	(Insecticide? or Acaricide? or pesticide? or repellent? or ((chemical* or biological* or natural*) adj (agent? or control*))).tw,kw.	2134
17	(deet or diethyltoluamide or autan or deltamide or detamide or flypel or metadelphene or muscol).tw,kw.	53
18	Permethrin/ or doxycycline/ or Pyrethrins/ or Metarhizium/ or Beauveria/ or Bacillus thuringiensis/ or Plant Growth Regulators/ or exp Nematoda/ or Organophosphates/ or Chlorpyrifos/ or Diazinon/ or Carbamates/ or Carbaryl/	3196
19	(Permethrin? or acticin or ambush or armol or atroban or biomopedicul or dronol or ectiban or ectomethrin or elimite or expar or fmc 33297 or fmc33297 or gamabenceno plus or gamaderm or gepescab or infectomite or infectopedicul or klinits or loxazol or lyclear or mite-x or nedax plus or new-nok or nia-33297 or nittifor or nix or novo-herklin 2000 or nrdc 143 or nrdc 147 or nrdc-143 or nrdc-147 or oms 1821 or perigen or permanone or permectrin or permicren or permite or piopel or pounce or pp 557 or s-3151 or sarcop or scabianil or scabmite or stockade or stockate or wl 43479 or zalvor or zehu-ze).tw,kw.	496
20	(Doxycycline or adoxa or amermycin or atrax or azudoxat or bactidox or banndoclin or basedillin or bassado or biocolyn or biodoxi or bronmycin or calcium doxycycline or cloran or cyclidox or dentistar or deoxycycline or deoxymycin dispersal or deoxymykoin or deoxyoxytetracycline or desoxy oxytetracycline or desoxycycline or doinmycin or dosil or dotur or doxaciclin or doxacycline or doxat or doxatet or doxibiotic or doxicycline or doxilin or doximed or doximycin or doxin or doxine or doxi-sergo or doxocycline or doxsig or doxy or doxybiocin or doxycen or doxycen retard or doxychel or doxycin or doxycyclin or doxylag or doxylin or doxymycin or doxypuren or doxytec or doxytrim or dumoxin or duracycline or esdoxin or etidoxina or gewacyclin or gs 3065 or ibralene or idocyclin or idocyklin or interdoxin or investin or longamycin or lydox or magdrin or medomycin or mespafin or mildox or miraclin or monodox or nordox or nsc 56228 or oracea or paldomycin or pernox gel or radox or remycin or respidox or roximycin or serodoxy or servidoxine or servidoxyne or siadocin or siclidon or sigadoxin or spanor or supracyclin or supramycina or tenutan or tolexine or torymycin or tsurupioxin or unidox or veemycin or viadoxin or vibra s or vibrabiotic or vibracina or vibradox* or vibramicina or vibramycin or vibramycine or vibraveineuse or vibravenos or vibravet or wanmycin or zadorin or zenavod).tw,kw.	2413
21	(Organophosphate? or Organopyrophosphate? or phosphoester? or (organic adj phosphate?) or ("Phosphoric Acid" adj (Ester? or derivative? or diester?))).tw,kw.	161
22	(Chlorpyrifos or dursban or lorsban or chloropyrifosor chlorpyriphos).tw,kw.	20

23	(Diaz#non or Bazudine or Dimpylate or Neocidol or Neotsidol or basudin or gimpet or sarolex).tw,kw.	4
24	(Carbamate? or ((Carbamate? or aminoformic) adj acid?) or dicarbamate? or phenylcarbamate?).tw,kw.	131
25	(Carbaryl or aclimostat or albendazole or aldicarb or amelubant or aminocarb or Antigale or asunaprevir plus beclabuvir plus daclatasvir or avoralstat or barban or batefenterol or bendiocarb or benomyl or bromosporine or carbamic acid or carbamoyl phosphate or carbanilic acid derivative or Carbaril or carbofuran or carbosulfan or Carbyl or carisbamate or carisoprodol or Carylderm or cenobamate or chlorpropham or cloforex or "Concentrat VO 18" or daclatasvir or darunavir or dibutoline sulfate or Dog-Net Insecticide Poudre or elbasvir or elbasvir plus grazoprevir or emylcamate or encorafenib or etacizine or ethinamate or ethiofencarb or etiguanfacine or felbamate or fenbendazole or fenobucarb or fenoxycarb or "Fido's Free-Itch" or flubendazole or flupirtine or formetanate or G-Wizz or hexapropymate or indoxacarb or ipazilide or isoprocarb or Joseph Lyddy or ledipasvir or mebendazole or mebutamate or methiocarb or methocarbamol or methomyl or mivobulin or mivobulin isethionate or moracizine or nelociguat or netobimin or nocodazole or Ocecoxil or odalasvir or ombitasvir or oxamyl or oxfendazole or oxibendazole or oxyfenamate or parbendazole or pentacaine or phenmedipham or phenprobamate or pibrentasvir or pirimicarb or plocabulin or polyurethan or Poudre insecticide or Poutic or propoxur or pumaprazole or pyricarbate or pyridostigmine or razuprotafib or relenopride or revefenacin or rislenemdaz or rivastigmine or ronidazole or ruzasvir or samatasvir or Sepou or Sevin or Skatta Tick Flea Louse Powder or sofosbuvir plus velpatasvir or solriamfetol or styramate or tarafenacin or thiophanate or Tigal or urethan or velpatasvir or velufenacin or venglustat).tw,kw.	5019
26	(Fipronil or fiprex or regent or Frontline or TopSpot or Fiproguard or Flevox or PetArmor or Tri-Act or Spot-On or barricade or Easyspot or Effipro or Sentry Fiproguard or Parastar or Pronyl OTC or Spectra Sure).tw,kw.	1825
27	(Isoxazoline? or Fluralaner or bravecto or exzolt or Afoxolaner or frontpro or nexgard or Simparica or sarolaner or Credelio or lotilaner).tw,kw.	73
28	(Pyrethrin? or Pyrethroid? or ipevet or ipevetex or pyrethrasin).tw,kw.	271
29	(Nootkatone or "4674-50-4").tw,kw.	0
30	(Carvacrol or "2 hydroxy para cymene" or "2 methyl 5 isopropylphenol" or "2 para cymenol" or "isopropyl ortho cresol").tw,kw.	45
31	(Metarhizium or Metschnikoff or Entomophthora anisopliae or Isaria anisopliae or Penicillium anisopliae or met52 or met 52).tw,kw.	12
32	(Beauv#ria or Botrytis bassiana or Cordyceps bassiana or Penicillium bassianum or Spicaria bassiana or Tritirachium shiotae or Vuillemin or Hypocrea lixii).tw,kw.	21
33	(Plant Growth Regulator? or Phytohormone? or Plant Hormone?).tw,kw.	27
34	(Entomopathogenic bacteri* or Entomopathogenic fung*).tw,kw.	3
35	((Bacillus adj2 thuringiensis) or Bacilan or Dipel or Thuricide).tw,kw.	32
36	(Penicillium soppii or Penicillium matris-meae or Penicillium meleagrinum or Penicillium shearii or Penicillium rolfsii or Penicillium michaelis).tw,kw.	0
37	(Nematode? or Adenophorea or Nematoda or round worm? or roundworm? or Secernentea).tw,kw.	196
38	Protective clothing/ or Gloves, Protective/ or baths/	861
39	(clothing or clothes or shirt? or pant? or short? or boot? or shoe? or sneaker? or sandal? or sock? or jacket? or glove? or hat?).tw,kw.	128103

40	(((personal or measur*) adj2 protect*) or ((avoid* or limit* or refrain*) adj5 (habitat* or environment* or wood* or forest* or terrain* or grass*))).tw,kw.	1360
41	((tick? adj3 (check* or inspect* or examin* or search*)) or shower* or bath* or wash*).tw,kw.	44722
42	((behavior* or behaviour* or attitude* or belief* of believe*) adj3 (chang* or alter* or educat* or shift*)).tw,kw.	21936
43	edge plot?.tw.	0
44	or/10-43	1588141
45	4 and 9 and 44	55
46	limit 45 to (english or french)	55
47	limit 46 to yr="2022 -Current"	6
48	1 or 2	57
49	5 or 6	272
50	44 and 48 and 49	25
51	limit 50 to yr="2023 -Current"	2
52	50 not 51 [Original search terms up to 2023]	23
53	limit 46 to yr="2023 -Current"	3
54	46 not 53	52
55	54 not 52 [New results up to 2023 with additional search terms]	29

Econlit

Econlit <1886 to November 11, 2024>		
#	Searches	Results
1	((lyme adj (infect* or disease)) or ((Borrelia or Borreliella or b) adj (burgdorferi or afzelii or garinii or japonica or lusitaniae or mayonii))).af.	6
2	limit 1 to yr="2022 -Current"	1

8.1.2 Screening and extraction guides

Abstract Relevance Screening Form:

Question	**Options**	**Definitions/additional notes**
Level 1 Screening (Title and Abstract) We will screen title and abstracts to evaluate the relevance of each study		
Does this study evaluate an intervention(s) or control methods which aims to prevent Lyme Disease through targeting either the borrelia burgdorferi (s.l.) bacteria or its vector ticks?	● Yes □ Include ● No □ Exclude	*Err on the side of inclusion at abstract screening stage* **Lyme Disease bacteria sub-types:** ● LD (Borrelia): Borrelia burgorferi ● *Borrelia sensu lato (s.l.) subtypes of interest:* ● B. afzelii, B. bavariensis, B. garinii, B. japonica, B. lusitaniae, B. sinica, B. spielmanii, B. tanukii, B. turdi, B. valaisiana, and B. yangtze) ● B. americana, B. andersonii, B. californiensis, B. carolinensis, and B. kurtenbachii ● *B. burgdorferi sensu stricto (s.s.), B. bissettii, and B. carolinensis*

		Lyme Disease Vector Ticks: ● *TICKS (Ixodes): I.scapularis, I.pacificus, I.ricinus.* ● *Less often mentioned: Ixodes: I.affinis, I.angustus, I.hexagonus, I.minor, I.muris, I.spinipalpis* <u>Include:</u> ● Any studies which evaluate an LD intervention ● Studies where relevance is unclear or if you suspect if could be relevant <u>Exclude:</u> ● Literature that does not evaluate an LD intervention or prevention program. ● Literature that is only focused on laboratory studies without a field-testing component ● Agricultural studies aimed at reducing tick density or LD bacteria in agricultural animals.

Full Text Relevance Screening Form:

Question	Options	Definitions/additional notes
Level 2 Screening (Full Text) For these questions we will evaluate the full text for its inclusion for data extraction Overall aim: we would like to extract data from articles and study types that have a primary prevention role in tick bites/LD.		
Is this a study **that evaluates an intervention(s)** which aims to prevent Lyme Disease through targeting either the borrelia burgdorferi (s.l.) bacteria or its vector ticks, **and is relevant to an applied Canadian setting?** ***does not necessarily mean applied in Canada, just relevant (wildlife)**	● Yes □ Include (if it meets criteria defined) ● No □ Exclude	**Prevention (Program or Intervention Types):** <u>Include</u>: ● Landscape Management ● Management of host parasitism (and LD infection) and movement ● Chemical insecticides, biological control agents, natural tick control products ● Personal protection (humans) including educational or community programs (must feature population/community level program) ● Interventions targeted at protecting domestic animals from ticks. <u>Exclude:</u> ● Studies which only focus on *wildlife hosts* which are not the main reservoirs of LD in the Canadian context (i.e., are not small mammals and deer) for example, lizards

		● Studies which only focus on LD or tick prevention *in livestock* ● Studies which are *medically/ pharmaceutically targeted* (i.e., prophylactic treatment, LD vaccine for human or domestic animal use). Note that prophylaxis and vaccination targeting relevant wildlife hosts is to be included. ● Personal protection interventions done at an individual level (does not test the effect of a community/population level campaign or education)
Is this a **relevant primary research** study that evaluates an intervention(s) which aims to prevent Lyme Disease through targeting either the borrelia burgdorferi (s.l.) bacteria or its vector ticks?	<u>Include:</u> ● Journal Article ● Thesis ● Grey literature with primary data ● Expert opinion or letter to the editor with primary data ● Conference proceeding with sufficient detail ● Preprint <u>Exclude:</u> ● Case reports ● Case series ● Single-cross-sectional designs/ prevalence study ● Reviews ● Opinion	****Special Note: Please remember to continue to include laboratory based studies** **Journal article:** Peer-reviewed primary literature. **Thesis:** a paper, essay, or dissertation involving primary research performed to obtain a university degree. **Grey literature:** materials and research produced by organizations outside of the traditional commercial or academic publishing (e.g. government reports or programs with an evaluation piece) **Conference proceeding:** include abstract or report of research presented by participants at conferences (if they have sufficient detail to extract) <u>Exclude</u>: Case series/ reports: In depth evaluation of 1+ cases and their clinical history/background/outcomes. Single cross-sectional designs: One set of observations collected at a single point in time to examine prevalence of exposures/risk/outcome. <u>Exclude:</u> *Conference proceedings: with no presentation or inclusion primary data collection or evaluation of an intervention, or insufficient data to extract

		*Grey literature: with no primary data collection or evaluation of an intervention *Thesis: with no primary data collection or evaluation of an intervention **Do not automatically exclude these unless there is not enough data in the full text to perform adequate extraction*
Does this study investigate the effectiveness, utility, cost, or acceptability of an LD intervention and report on one of the following outcome(s)? (Check all that apply)	● Tick exposure ● Density of ticks ● Density of nymphs ● Density of infected ticks ● Density of infected nymphs ● Lyme disease cases (count, prevalence, incidence) ○ IGg screening ○ IGm screening ○ Western blot screening ○ Self-reported diagnosis ○ A combination ● Cost of an intervention (per unit, per area) ● Acceptability of an intervention (qual/quant (score)) ● Uptake of an intervention (% change, point change) ● Positive or Negative environmental outcomes ● Other:	NA These should be pretty clear and well stated in the paper. *This is more of a guiding question rather than exclusion, if there are outcomes in the paper of any type, please include them.*
Is the study in French or English	● Yes: Include ● No: Exclude	

General Extraction Items (Summary):

Extraction Category	Specific Extraction Items

Descriptive Factors	● Title/ Year/ Author
	● Location (provincial/state)
	● Intervention Setting (residential/ recreational/ occupational/ other)
	● Geographic Setting (urban, peri-urban, rural)
	● Target (environment, host, chemical/bio/natural, human) **note if acaracide or product is applied to host population it falls under host parasitism not chemical/biological control**
	    ○ List specific approach (Landscape Management/ Management of host parasitism and movement/ Chemical, biological, natural tick control products/ Personal protection, population education)
	    ○ Describe approach *note if acaracide or product is applied to host population it falls under host parasitism not chemical/biological control*
	● Integration (is it an integrated project with multiple approaches)
	    ○ If so list
	    ○ If so describe
	● Outcome measures (DIT, DIN, LD cases, Tick encounters, Host-infection-prevalence, other)
	    ○ If other, list:

Feasibility/ Impact/ Acceptability	*Describe any considerations included* ● Environmental impact ● Acceptability ● Complexity ● Potential social resistance ● Potential for dev. of tick resistance to intervention

Cost and Effectiveness	● Cost of the intervention
	    ○ Cost per bait/intervention
	    ○ Bait/intervention density
	    ○ Treatment/intervention frequency
	    ○ Duration of treatment
	● Effectiveness (do one of these apply to the intervention outcomes?)
	    ○ Reduction in density of feeding/ questing ticks
	    ○ Reduction in infection prevalence in ticks
	    ○ Reduction in acarological risk (density *prevalence)
	        ▪ Describe:
	    ○ Reduction in infection prevalence in rodents/ hosts
	        ▪ Describe:
	    ○ Reduction in incidence in LD incidence risk
	    ○ Reduction in incidence of tick encounter
	    ○ Reduction in incidence of tick bites
	        ▪ Describe:
	    ○ Other:
	        ▪ Describe:

Full Extraction Guide:

#	Question	Options	Comments
Extraction Part 1: General (descriptive information)			
!!	Is this a laboratory only study (aka is not applied in a field setting?)	Mult. ● Yes ● No	If yes, only complete items 1-3 *These are included, but do not need a full data extraction.*
1	What is the publication year of this article?	__TXT___	Include the publication year only (YYYY).
2	What is the article publication language?	Mult. ● English ● French ● Other: Specify__(exclude)	Select relevant language, exclude if other.
3	Who is the first author?	__TXT___	Please write the last name of the first author as listed in the paper itself (This will help us correct for issue with Embase) (LAST)
4	What is the study design? (Check all that apply)	Mult. ● Observational ○ Cohort ○ Case control ○ Surveillance report ○ Longitudinal study ○ Repeated cross-sectional ○ Other: Specify____ ● Experimental study design ○ Randomized controlled trial (RCT) ○ Non-randomized controlled trial (or quasi-randomized controlled trial) ○ Controlled before-and-after study ○ Uncontrolled before-and-after ○ Other: Specify ____ ● Other ○ Predictive Model ○ Qualitative study	**Observational study:** assignment of subjects into a treated group versus a control group is natural (outside the control of the investigator). ● **Cohort study**: a study in which one or more groups of individuals with differing exposures to a suspected risk factor/predictor are observed and followed through time for occurrence of an outcome. ● **Case-control study**: compares exposure to the risk factor/predictor in subjects who have an outcome ('cases') with those who don't have the outcome, but are otherwise similar ('controls') and drawn from the same sampling frame. ● **Surveillance/monitoring program:** the on-going sampling from a defined representative sample of the target population to evaluate changes over time. ● **Longitudinal study**: two or more sets of observations of the same variables

		○ Mixed Methods study ○ Economic analysis ○ Risk assessment ○ Other: Specify____	for each individual over a period of time. (Matched) ● **Repeated cross-sectional:** one set of observations is collected at several time points to examine prevalence of exposures, risk factors or disease. Ideally the sample is representative of the target population. (Matched or Unmatched)
5	What is the study region?	Mult/TXT ● North America ○ List Country ○ List Province (if applicable) ● Europe ○ List Country ○ List Province (if applicable) ● Asia ○ List Country ○ List Province (if applicable) ● Other ○ List Country ○ List Province (if applicable) ○ List Special Note:__	LD is present in countries in North America, Europe, and Asia. If a country is listed outside of these continents, please add a special note with any information on concern for emergence or other relevant information for why they conducted this research.
6	What is the study/intervention setting?	Mult. ● Residential ● Recreational ● Occupational ● Other: Specify___ ● Unlisted/Not Applicable	Residential: studies which take place on personal property, or in residential spaces Recreational: studies which take place on public lands used for recreational activities such as hiking, biking, hunting, fishing etc. Occupational: studies which aim to prevent occupational exposures, often studies focused on military training grounds, forestry workers or other outdoor occupations.

			Other: is there another setting included in a study? e.g.: general forested area or general grasslands that are targeted to reduce general LD infection prevalence in ticks or wildlife hosts
7	What is the geographic setting of the study/intervention?	Mult. ● Urban ● Peri-urban ● Rural ● Other: Speficy___ ● Unlisted/Note Applicable	Urban: city centers and surrounding areas Peri-urban: suburban and peri-urban centers Rural: Farm, forested, and other rural settings *Note: list as mentioned in text
8	What was the study/ intervention target?	Mult./TXT ● Landscape Management ○ Describe:___ ● Management of host parasitism and movement ○ Describe:___ ● Chemical, biological, natural tick control products ○ Describe:___ ● Personal protection, population education ○ Describe:___ ● Companion animal (treatment applied to a dog or cat) ○ Describe:___	*Please refer to Table 1 for list of classification
9	Did the study/intervention use an integrated approach?	Mult./TXT ● Yes, across multiple intervention classifications ○ Describe:___ ● Yes, but within the same intervention classification ○ Describe:__ ● Unclear ● No	Integrated approaches use multiple interventions or programs within one study to evaluate the effect of combining programs to combat ticks/LD. <u>Examples:</u> [**Across multiple intervention classifications**]: A host targeted strategy (like deer bait stations) combined with a landscape management strategy, like a barrier approach.

			[**Within the same intervention classification**]: Host targeted (a deer bait station, paired with a nesting tube intervention for mice) *Please see table 1 for a more detailed list of classifications/classification types.
10	What type of tick was targeted with this intervention?	Mult./TXT ● Only the LD bacteria was targeted ● A LD carrying tick(s) was targeted ○ List: ________	**Lyme Disease Vector Ticks:** ● *TICKS (Ixodes): I.scapularis, I.pacificus, I.ricinus.* ● *Less often mentioned: Ixodes: I.affinis, I.angustus, I.hexagonus, I.minor, I.muris, I.spinipalpis*
11	What strain of borrelia was targeted with this intervention?	Mult./TXT ● Only the tick was targeted ● A strain of borrelia was targeted ○ List: ________	**Lyme Disease bacteria sub-types:** ● LD (Borrelia): Borrelia burgorferi ● *Borrelia sensu lato (s.l.) subtypes of interest:* ● B. afzelii, B. bavariensis, B. garinii, B. japonica, B. lusitaniae, B. sinica, B. spielmanii, B. tanukii, B. turdi, B. valaisiana, and B. yangtze) ● B. americana, B. andersonii, B. californiensis, B. carolinensis, and B. kurtenbachii ● *B. burgdorferi sensu stricto (s.s.), B. bissettii, and B. carolinensis*

Table 1: Intervention Classification

Landscape management	**Management of wildlife host parasitism, movement, and density**	**Chemical insecticides, biological control agents, natural tick control products**	**Personal protection (at a community or population level)**
Vegetation clearing Vegetation burning Barrier approaches (e.g. Japanese barberry, woodchips)	Deer Management ● Deer exclusion (fencing) ● Deer reduction ● Deer parasitism suppression (4 poster	Chemical control ● Organophosphates ● Carbamates ● Pyrethroids · Natural products · Biocontrol	Human: Community communication or empowerment involving: ● Permethrin treated clothing/uniforms

	[topical treatment], vaccine) Small mammal management ● Rodent parasitism and pathogen infection suppression ○ Acaracide-treated nesting material ○ Bait Boxes ○ Rodent reduction ○ Oral vaccine bait ○ Animal host vaccines	· Natural enemies · Biological agents ● Entomopathogenic bacteria ● Entomopathogenic fungi ● Nematodes	● Application of spray repellents to skin or clothing ● Exposure and preventive behaviors or individual behavior changes ○ Habitat avoidance ○ Checking ○ Showering/ Bathing Domestic Animal (One-Health): Topical acaracides (flea and tick drops) Flea and tick collars Flea and tick oral treatments

#	Question	Options	Comments
Extraction Part 2: Feasibility/ Impact/ Acceptability			
12	Did the study address or measure environmental impact, and how?	Mult./TXT ● No ● Yes ○ Describe and list outcome measures if any:____ ○ If outcome measures: list relevant results	These may vary if reported depending on the context of the study, this extraction item will feel more descriptive/qualitative in nature most often if present.
13	Did the study address or measure acceptability, and how?	Mult./TXT ● No ● Yes ○ Describe and list outcome measures if any:____	This may be addressed in the discussion based on other studies If measured in the study, these often take the form of qualitative or survey-

		○ If outcome measures: list (or describe if qual) relevant results	type results Survey results: list any results ● e.g. % of intervention with high/low acceptability Qualitative results: list any main themes or findings from interviews or focus groups
14	Did the study address or measure feasibility/complexity, and how?	Mult./TXT ● No ● Yes ○ Describe and list outcome measures if any:____ ○ If outcome measures: list (or describe if qual) relevant results	This may be addressed in the discussion based on other studies If measured in the study, these often take the form of qualitative or survey-type results according to those implementing or organizing an intervention If mentioned, the no. people engaged in field work and the no. years needed for the study results to be obtained Survey results: list any results ● e.g. % of intervention with high/low feasibility Qualitative results: list any main themes or findings from interviews or focus groups
15	Did the study address or measure any potential resistance?	Mult./TXT ● No ● Yes ○ Describe and list outcome measures if any:____ ○ If outcome measures: list relevant results	This may be close to acceptability/feasibility, focus this section on any direct measurement or mention of any challenges faced during the intervention with regards to social resistance. This may be addressed in the discussion based on other studies If measured in the study, these often take the form of qualitative or survey-type results according to those

			implementing or organizing an intervention Survey results: list any results Qualitative results: list any main themes or findings from interviews or focus groups
16	Does the intervention have any potential for the development of tick resistance, and did the study involve measurement of this?	Mult./TXT ● No ● Yes ○ Describe and list outcome measures if any:____ ○ If outcome measures: list relevant results	

#	Question	Options	Comments
Extraction Part 3: Cost and Effectiveness			
17	What was the cost of the intervention?	Mult./TXT ● Cost was not given ● Cost was given (either explicitly or otherwise) ○ Describe any of the following provided_____ ■ Cost per bait/intervention ■ Bait/intervention density ■ Treatment/intervention frequency ■ Duration of treatment	These should be pretty clearly stated (even if not explicitly listed as cost, please look for these items)
18	Effectiveness (do one of these	Mult. ● Reduction in density of feeding/ questing ticks	*Some other possible

<table>
<tr><td></td><td>apply to the intervention outcomes?)</td><td>● Reduction in infection prevalence in ticks
● Reduction in acarological risk (density *prevalence)
● Reduction in infection prevalence in rodents/ hosts
● Reduction in incidence in LD incidence risk
● Reduction in incidence of tick encounter
● Reduction in incidence of tick bites
● Other:
    ○ Describe:</td><td>outcomes are listed below</td></tr>
<tr><td>19</td><td>Effectiveness outcome / result extraction</td><td>TXT. (please enter the relevant outcome results)
● Reduction in density of feeding/ questing ticks
● Reduction in infection prevalence in ticks
● Reduction in acarological risk (density *prevalence)
● Reduction in infection prevalence in rodents/ hosts
● Reduction in incidence in LD incidence risk
● Reduction in incidence of tick encounter
● Reduction in incidence of tick bites
● Other:
    ○ Describe:</td><td>*Some other possible outcomes are listed below</td></tr>
<tr><td colspan="4">*Possible other outcomes:
● Tick exposure
● Density of ticks
● Density of nymphs
● Density of infected ticks
● Density of infected nymphs
● Lyme disease cases (count, prevalence, incidence)
    ○ IGg screening
    ○ IGm screening
    ○ Western blot screening
    ○ Self-reported diagnosis
    ○ A combination
● Uptake of an intervention (% change, point change)</td></tr>
</table>

8.1.3 Supplemental table 1: Study-by-study effectiveness

First author and year	Title	Brief description of intervention	If a product was used what was the concentration?	Was the intervention effective on outcomes measured in study?	Outcome measures *codebook in supplemental table 4b
Chemical, biological, natural tick control					
Rupes 1977	Effectiveness of fenitrothion for area control of ticks Ixodes ricinus (L.)	acaricide application-environment	MeYestation P-5 (dust) 5% fenitrothion Metation E-50 (spray) 50% fenitrothion	Yes	DensQN; DensQL; TickSurvPN
Schulze 1987	Effectiveness of two insecticides in controlling Ixodes dammini (Acari: Ixodidae) following an outbreak of Lyme disease in New Jersey.	acaricide application-environment	Carbaryl applied to block 1 at a rate of 0.84 kg (AI)/ha; diazinon was applied at a rate of 1.68 kg (AI)/ha to block	Yes	DensQA; DensQT
Stafford 1990	Insecticides applied near homes reduces tick bite risks	acaricide application-environment	Carbaryl- 1 to 2 pounds of active ingredient per acre.	Mixed	DensQL; DensQN; DensQA
Schulze 1991	Effectiveness of selected granular acaricide formulations in suppressing populations of Ixodes dammini (Acari: Ixodidae): short-term control of nymphs and larvae.	acaricide application-environment	[Granular formulas]; Diazinon applied to plot 2 at a rate of 4.5 kg (AI)/ha; Chlorpyrifos was applied to plot 3 at a rate of 1.1 kg (AI)/ha, and carbaryl applied to plot 4 at a rate of 8.3 kg (AI)/ha	Yes	InfesIntFL; InfesIntFN
Stafford 1991	Effectiveness of carbaryl applications for the control of Ixodes dammini (Acari: Ixodidae) nymphs in an endemic residential area.	acaricide application-environment	Carbaryl (1-naphthyl-N-methycarbamate) mixed at a rate of 1.20 g (AI)/liter of spray	Yes	DensQL; DensQN; DensQA
Schulze 1992	Effectiveness of an aerial application of carbaryl in controlling Ixodes dammini (Acari: Ixodidae) adults in a high-use recreational area in New Jersey.	acaricide application-environment	Carbaryl – applied at rate of 1.12 kg (Al) in 93.5 1 of water/ha	Yes	DensQA
Curran 1993	Reduction of nymphal Ixodes dammini (Acari: Ixodidae) in a residential suburban landscape by area application of insecticides.	acaricide application-environment	Carbaryl emulsifiable concentrate at 0.6 or 1.1 kg Al/ha; Granular carbaryl (7.15%) at 4.5 kg Al/ha; Chlorpyrifos wettable powder at 0.6 or 1.1 kg Al/ha; Granular chlorpyrifos (2.3%) at 1.1 kg Al/ha, and Cyfluthrin EC at 0.1 kg Al/ha.	Yes	DensQN
Schulze 1994	Suppression of Ixodes scapularis (Acari: Ixodidae) nymphs in a large residential community.	acaricide application-environment	Carbaryl was applied to Lake Drive NE quadrant at a rate of 8.8 kg	Yes	InfesIntFT; InfesIntFN

			(AI)/ha and to the Lake Drive NW and SE quadrants at a rate of 6.8 kg (AI)/ha		
Allan 1995	Reduction of immature Ixodes scapularis (Acari: Ixodidae) in woodlots by application of desiccant and insecticidal soap formulations	botanical/natural acaricide-environment	Drione- 40% amorphous silica gel (24.4 kg [AI]/ha), 10% piperonyl butoxide (6.10 kg [AI]/ha), and 1% pyrethrins (0.60 kg [AI]/ha). Safer's insecticidal soap- 3.9% (39 ml concentrate per liter of water).	Mixed	DensQL; DensQN
Patrican 1995	Application of desiccant and insecticidal soap treatments to control Ixodes scapularis (Acari: Ixodidae) nymphs and adults in a hyperendemic woodland site.	botanical/natural acaricide-environment	Drione, 40% amorphous silica gel (24.4 kg [AI]/ha), 10% piperonyl butoxide (6.10 kg [AI]/ha), and 1% pyrethrins (0.60 kg [AI]/ha) and insecticidal soap, 40% potassium salts of fatty acids and 0.2% pyrethrins- formulated with and without isopropyl alcohol	Yes	DensQN; DensQA
Schulze 1995	Potential influence of leaf litter depth on effectiveness of granular carbaryl against subadult Ixodes scapularis (Acari: Ixodidae)	acaricide application-environment	Granular carbaryl (Sevin 7 G, 7.15%) applied at the lowest rate recommended on the label (4.5 kg/ha)	Yes	DensQN
Monsen 1999	Experimental and field evaluations of two acaricides for control of I. pacificus (Acari: Ixodidae) in northern California.	acaricide application-environment	Chlorpyrifos (unlisted); Carbaryl (unlisted); both mixed with water applied a labeled dosage rate of 1.1kg/ha"	Yes	DensQA
Schulze 2000	Effects of granular carbaryl application on sympatric populations of Ixodes scapularis and Amblyomma americanum (Acari: Ixodidae) nymphs	acaricide application-environment	Granular carbaryl applied at a rate of 4.5 kg/ha	Yes	DensQN
Schulze 2001	Efficacy of granular deltamethrin against Ixodes scapularis and Amblyomma americanum (Acari: Ixodidae) nymphs	acaricide application-environment	Granular deltamethrin applied at a rate of 0.15 kg/ha along the woodland/ lawn interface	Yes	DensQN
Schulze 2001	Effects of an application of granular carbaryl on nontarget forest floor arthropods	acaricide application-environment	Granular Crbaryl 4.5kg/ha	Yes	DensQN
Benjamin 2002	Laboratory and field evaluation of the entomopathogenic fungus Metarhizium anisopliae (Deuteromycetes) for controlling questing adult Ixodes scapularis (Acari: Ixodidae)	botanical/natural acaricide-environment	Met52- Metarhizium anisopliae suspension containing 4x 10e9 spores per milliliter.	Yes	DensQA; TickSurvPA
Hornbostel 2004	Sublethal effects of Metarhizium anisopliae (Deuteromycetes) on engorged larval, nymphal, and adult Ixodes scapularis (Acari: Ixodidae)	botanical/natural acaricide-environment	Metarhizium anisopliae spores (10^8 M. anisopliae strain ESC1 spores per milliliter	Yes	TickFitT

Hornbostel 2005	Pathogenicity of Metarhizium anisopliae (Deuteromycetes) and permethrin to Ixodes scapularis (Acari: Ixodidae) nymphs	botanical/natural acaricide-environment	Metarhizium anisopliae 10^9 spores/ml Bio-Blast + DI water suspension	No	DensQN; TickSurvPN
Schulze 2005	Effects of barrier application of granular deltamethrin on subadult Ixodes scapularis (Acari: Ixodidae) and nontarget forest floor arthropods	acaricide application-environment	Granular deltamethrin 0.15kg/ha	Yes	DensQN; DensQL
Schulze 2008	Suppression of Ixodes scapularis (Acari: Ixodidae) following annual habitat-targeted acaricide applications against fall populations of adults	acaricide application-environment	Deltamethrin 0.09kg/ha	Yes	DensQT; DensAQ
Dolan 2009	Ability of two natural products, nootkatone and carvacrol, to suppress Ixodes scapularis and Amblyomma americanum (Acari: Ixodidae) in a Lyme disease endemic area of New Jersey.	botanical/natural acaricide-environment	2006 and 2008: 98.5% nootkatone crystals dissolved in 93%d-limonene, an all-natural, biodegradable solvent ex-tracted from orange peels and added to the spray tank containing water and 95% EZ-Mulse. 2008: emulsion formulation containing nootkatone and food grade corn oil by using a 1:1 ratio of the surfactants transcutol (also known ascarbitol or diethylene glycol monoethyl ether and cremephor EL (Polyoxyl 35 Castor Oil ([USP/NF]) mixed in a 1:5 (cornoil/cosurfactant) ratio 2006 and 2007: Carvacrol applied 95% carvacrol and 92% Calamide C.	Yes	DensQN
Bharadwaj 2010	Evaluation of Metarhizium anisopliae strain F52 (Hypocreales: Clavicipitaceae) for control of Ixodes scapularis (Acari: Ixodidae)	botanical/natural acaricide-environment	M.anisopliae F52 application rate 1: 3.2x10^5 spores/cm^2 application rate 2: 1.3X10^6 spores/cm^2	Mixed	TickSurvPN; DensQN
Jurisic 2010	The application of lambda-cyhalothrin in tick control	acaricide application-environment	Lambda-cyhalothrin; pesticide was suspended in diesel fuel (ratio 1:2) as a carrier	Yes	DensQN, PrevQT
Rand 2010	Trial of a minimal-risk botanical compound to control the vector tick of Lyme disease.	botanical/natural acaricide-environment; acaricide application-environment	Adjuvant-free IC2 (118 ml/3.8 l, 15 l/93 m^2), bifenthrin (7.9% solution diluted to 0.06% concentrate as SPECKoZ, 28.5 ml/93 m^2)	Yes	DensQL; DensQN; DensQA

Greengarten 2011	Occurrence of soil- and tick-borne fungi and related virulence tests for pathogenicity to Ixodes scapularis (Acari: Ixodidae).	botanical/natural acaricide-environment	Hypocrea lixii suspension (1.3 x 107 spores/ml) and 10 treatment plots with a Penicillium soppii suspension (1.1 x 107 spores/ml).	Yes	TickSurvT
Jordan 2011	Suppression of host-seeking Ixodes scapularis and Amblyomma americanum (Acari: Ixodidae) nymphs after dual applications of plant-derived acaricides in New Jersey.	botanical/natural acaricide-environment	Nookatone: 98.5% nootkatone crystals in 93% d-limonene, added to spray tank 95% EZ-Mulse, and 11.4 liters (3 gal) of water Carvacrol-EcoTrol: 95% carvacrol and 92% Calamide C, The EcoTrol T&O formulations; 2009 and 2010, the concentrations were 6 oz/gal and 10 oz/gal.	Yes	DensQN
Bharadwaj 2012	Efficacy and environmental persistence of nootkatone for the control of the blacklegged tick (Acari: Ixodidae) in residential landscapes.	botanical/natural acaricide-environment	2008 prepared by mix-ing; 4.4 liters of 89.6% synthetic nootkatone (mix of 95and 86% nootkatone products, 1.9 liters of 93% d-limonene, a solvent extracted from orange peels, and 1.9 liters of E-Z-Mulse, a proprietary nonionic surfactant blend to emulsify citrus terpenes and other natural oils; a ratio of2:1:1. This produced a formulation product with 44.8%wt:wt of nootkatone; 2008: combinations with M. brunneum prepared by mixing 0.4 liters of the nootkatone oil with 0.2 liters each of d-limonene and E-Z-Mulse at the same 2:1:1 ratio; 2009 and 2010: 2009 and 2010 nootkatone used for these formulations was 50% active ingredient (AI) in oil.	Yes	DensQN
Elias 2013	Effect of a botanical acaricide on Ixodes scapularis (Acari: Ixodidae) and nontarget arthropods	botanical/natural acaricide-environment	Eco-Exempt IC2 (4 oz/gal)- 10% rosemary oil, 2% peppermint oil, 88% other ingredients (wintergreen oil, mineral oil, and vanillin).	Yes	DensQL; DensQN; DensQA
Bharadwaj 2015	Effectiveness of Garlic for the Control of Ixodes scapularis (Acari: Ixodidae) on Residential Properties in Western Connecticut	botanical/natural acaricide-environment	Mosquito Barrier (garlic 99.3%, citric acid 0.5%, and potassium sorbate 0.2%) Rate 0.2g/AI/m^2)	Mixed	DensQN
Hinckley 2016	Effectiveness of Residential Acaricides to Prevent Lyme and Other Tick-borne Diseases in Humans	acaricide application-environment	bifenthrin 7.9%	Mixed	DensQT; TickEncoH; LDCaseH
Jordan 2017	Ability of Three General-Use Pesticides To Suppress Nymphal Ixodes scapularis and Amblyomma americanum (Acari: Ixodidae)	acaricide application-environment	Liquid Bayer Advanced Complete Insect Killer (0.72% imidacloprid/ 0.36% beta-cyfluthrin) Liquid Spectracide Triazicide Insect Killer (0.5% lambda-cyhalothrin)	Yes	DensQN

			Liquid Ortho Bug-B-Gon (0.3% bifenthrin/0.075 zeta-cypermethrin) Granular Bayer Advanced Complete Insect Killer (0.15% imidacloprid/ 0.05% beta-cyfluthrin) Granular Spectracide Triazicide Insect Killer (0.05% gamma-cyhalothrin) Granular Ortho Bug-B-Gon (0.115% bifenthrin)		
Fischhoff 2018	Tritrophic interactions between a fungal pathogen, a spider predator, and the blacklegged tick.	botanical/natural acaricide-environment	9 ounces (266 ml) of Met52- Metarhizium anisopliae in 12 gallons (45.4 L) of water per 1000 square feet (93 square meters).	Yes	DensQN
Bron 2020	Do-it-yourself tick control: granular gamma-cyhalothrin reduces Ixodes scapularis (Acari: Ixodidae) nymphs in residential backyards.	acaricide application-environment	Synthetic pyrethroid (granular formulation spectracide triazicide) containing 0.05% gamma-cyhalothrin.	Yes	DensQN
Schulze 2020	Early Season Applications of Bifenthrin Suppress Host-seeking Ixodes scapularis and Amblyomma americanum (Acari: Ixodidae) Nymphs	acaricide application-environment	Talstar P Professional Insecticide (7.9% bifenthrin)	Yes	DensQN
Dyer 2021	Evaluating the Effects of Minimal Risk Natural Products for Control of the Tick, Ixodes scapularis (Acari: Ixodidae)	botanical/natural acaricide-environment	Biopesticides EcoPCO: EC-X Pyrethrins 25.71 ml/m2 (2012) Met52 EC: Metarhizium anisopliae 0.96 ml/m2 (2012); 1.02 ml/m2 (2013) Botanical oils CedarCide PCO Choice: Texas red cedar oil 25.71 ml/m2 (2013) EcoEXEMPT IC2 (w. EcoADJUVANT): Rosemary oil, peppermint oil 25.71 ml/m2 EcoEXEMPT IC2, 6.43 ml/m2 EcoADJUVANT (2013) EcoSMART Organic Insecticide: Clove oil, thyme oil 24.41 g/m2 (2015) Essentria IC3: Rosemary oil, peppermint oil, geraniol 25.71 ml/m2 (2012, 2013); 19.28 ml/m2 (2014) Nootkatone (w. d-Limonene and EZ-Mulse): concentration 1: 1.02 ml/m2 nootkatone; concentration 2: 0.96 ml/m2 d-Limonene, EZ-Mulse (2013)	Mixed	DensQN

			Abrasives Private Label 1: Rosemary oil, peppermint oil, geraniol 16.07 ml/m2 (2015) Private Label 2: Rosemary oil, peppermint oil, geraniol 6.43 ml/m2 (2015) Tick Killz: Cedarwood oil 0.64 ml/m2 (2014) Tick Stop: Organic fertilizer 45.25 g/m2 (2014)		
Schulze 2021	Synthetic Pyrethroid, Natural Product, and Entomopathogenic Fungal Acaricide Product Formulations for Sustained Early Season Suppression of Host-Seeking Ixodes scapularis (Acari: Ixodidae) and Amblyomma americanum Nymphs	acaricide application-environment; botanical/natural acaricide-environment	Talstar P Professional Insecticide (7.9% bifenthrin), Essentria IC3 (10% rosemary oil, 5% geraniol, and 2% peppermint oil), and Met52 EC Bioinsecticide (11% Metarhizium anisopliae Strain F52)	Mixed	DensQN
Jurisic 2023	Bio-efficacy of permethrin/tetramethrin and lambda-cyhalothrin treatments in habitats of hard ticks (Acari, Ixodidae) populations with confirmed Borrelia spp. infection	acaricide application-environment	Perme PlusÂ® (producer: ORMA SRL, Tro-farello (TO), permethrin (15.2%) and tetramethrin (0.95%), with the synergist piperonyl butoxide (5.2%); and IconÂ® 10CS	Yes	DensQN; DensQA
Schulze 2023	Relative efficacy of high-pressure versus backpack sprayer applications of 2 natural product-based acaricides for control of host-seeking Ixodes Scapularis and Amblyomma americanum nymphs	botanical/natural acaricide-environment	Essentria IC^3 (10% rosemary oil, 5% geraniol, 2% peppermint oil) Entomopathogenic fungal acaricide BotaniGard ES (11.3% Beauveria bassinana Strain GHA)	No	DensQN
Williams 2024	Late fall synthetic acaricide application is effective at reducing host-seeking adult and nymphal Ixodes scapularis (Ixodida: Ixodidae) abundances the following spring	acaricide application-environment	Demand products (Lambda-cyhalothrin); Demand CS for liquid delivery and Demand G for granular.	Yes	DensQN; DensQA;
Landscape management					
Wilson 1986	Reduced abundance of adult Ixodes dammini (Acari: Ixodidae) following destruction of vegetation	vegetation management	NA/ unlisted	Yes	DensQA
Mather 1993	An unexpected result from burning vegetation to reduce Lyme disease transmission risks.	vegetation management	NA/ unlisted	Mixed	DensQN; PrevQN
Schulze 1995	Suppression of subadult Ixodes scapularis (Acari: Ixodidae) following removal of leaf litter	vegetation management	NA/ unlisted	Yes	DensQN; DensQL
Stafford 1998	Impact of controlled burns on the abundance of Ixodes scapularis (Acari: Ixodidae)	other landscape modification	NA/ unlisted	Mixed	DensQL; DensQN; DensQA

Hubalek 2006	Effect of forest clearing on the abundance of Ixodes ricinus ticks and the prevalence of Borrelia burgdorferi s.l.	vegetation management	NA/ unlisted	Yes	DensQA; DensQN; PrevQN; PrevQA
Williams 2009	Managing Japanese barberry (Ranunculales: Berberidaceae) infestations reduces blacklegged tick (Acari: Ixodidae) abundance and infection prevalence with Borrelia burgdorferi (Spirochaetales: Spirochaetaceae).	vegetation management	NA/ unlisted	Yes	DensQA; DensQN; InfesIntFL; PrevQT
Padgett 2009	Effect of prescribed fire for tick control in California chaparral.	other landscape modification	NA/ unlisted	No	InfesIntFT; InfesIntFI; DensQI; DensQT
Williams 2010	Effects of Japanese barberry (Ranunculales: Berberidaceae) removal and resulting microclimatic changes on Ixodes scapularis (Acari: Ixodidae) abundances in Connecticut, USA.	vegetation management	NA/ unlisted	Yes	DensQA; PrevQA
Tack 2013	Shrub clearing adversely affects the abundance of Ixodes ricinus ticks	vegetation management	NA/ unlisted	No	DensQL; DensQN; DensQA
Williams 2017	Long-term effects of Berberis thunbergii (Ranunculales: Berberidaceae) management on Ixodes scapularis (Acari: Ixodidae) abundance and Borrelia burgdorferi (Spirochaetales: Spirochaetaceae) prevalence in Connecticut, USA.	vegetation management	NA/ unlisted	Yes	DensQA; PrevQA
Linske 2018	Indirect effects of Japanese barberry infestations on white-footed mice exposure to borrelia burgdorferi	vegetation management	NA/ unlisted	Mixed	InfesIntFT; PrevH
Jordan 2020	Artificial Accumulation of Leaf Litter in Forest Edges on Residential Properties via Leaf Blowing Is Associated with Increased Numbers of Host-Seeking Ixodes scapularis (Acari: Ixodidae) Nymphs	vegetation management	NA/ unlisted	Mixed	DensQN
McKay 2020	Woodchip borders at the forest ecotone as an environmental control measure to reduce questing tick density along recreational trails in Ottawa, Canada.	ecotone modification	NA/ unlisted	Yes	DensQN; DensQA; DensQT; PrevQN; PrevQA; PrevQT

Conte 2021	Active Forest Management Reduces Blacklegged Tick and Tick-Borne Pathogen Exposure Risk	vegetation management	NA/ unlisted	Yes	DensQL; DensQN; DensQA; PrevFT
Lee 2023	Single Mowing Event Does Not Reduce Abundance of Ixodes scapularis (Acari: Ixodidae) and Dermacentor variabilis (Acari: Ixodidae) on Recreational Hiking Trails	vegetation management	NA/ unlisted	No	DensQT; DensQA; DensQN
Elias 2024	Partial trailside Japanese barberry (Ranunculales: Berberidaceae) removal did not reduce the abundance of questing blacklegged ticks (Acari: Ixodidae)	vegetation management	NA/ unlisted	No	DensQT; DensQA; DensQN
Linske 2024	Evaluation of landscaping and vegetation management to suppress host-seeking Ixodes scapularis (Ixodida: Ixodidae) nymphs on residential properties in Connecticut, USA	vegetation management; ecotone modification	NA/ unlisted	No	DensQN
Landscape management; Chemical, biological, and natural tick control					
Stafford 2010	Field applications of entomopathogenic fungi Beauveria bassiana and Metarhizium anisopliae F52 (Hypocreales: Clavicipitaceae) for the control of Ixodes scapularis (Acari: Ixodidae)	ecotone modification; botanical/natural acaracide-environment	Naturals T&O strain ATCC 74040 7.16% BotaniGard ES strain GHA 11.3%	Mixed	DensQN; PrevQN
Burtis 2017	Interactions between soil-dwelling arthropod predators and Ixodes scapularis under laboratory and field conditions.	vegetation management; biological control	NA/ unlisted	Yes	TickSurvPN
Management of host parasitism & movement					
Mather 1987	Lyme disease and babesiosis: acaricide focused on potentially infected ticks.	tick tubes	Permethrin 40% (50g/kg cotton)	Mixed	InfesPrevFI; InfesDensFI; DensQN
Wilson 1988	Reduced abundance of immature Ixodes dammini (Acari: Ixodidae) following elimination of deer.	deer removal	NA/ unlisted	Yes	DensQN; DensQL
Mather 1988	Reducing transmission of Lyme disease spirochetes in a suburban setting.	tick tubes	Permethrin 7.4%	Yes	InfesDensFI; DensQN; DensIN; PrevQN

Deblinger 1991	Efficacy of a permethrin-based acaricide to reduce the abundance of Ixodes dammini (Acari: Ixodidae).	tick tubes	Permethrin NR%	Yes	InfesPrevFI; InfesDensFL; InfesDensFN; DensQN
Stafford 1991	Effectiveness of host-targeted permethrin in the control of Ixodes dammini (Acari: Ixodidae).	tick tubes	Permethrin 7.4%	Mixed	InfesPrevFI; InfesDensFL; InfesDensFN; PrevH; PrevFI; DensQN; DensQA; PrevQN; PrevQA
Daniels 1991	Evaluation of host-targeted acaricide for reducing risk of Lyme disease in southern New York State.	tick tubes	Permethrin NR%	Mixed	DensQN; InfesDensFL; InfesPrevFL; PrevQN
Stafford 1992	Third-year evaluation of host-targeted permethrin for the control of Ixodes dammini (Acari: Ixodidae) in southeastern Connecticut.	tick tubes	Tubes containing the cotton (7.4% wt/wt permethrin)	No	InfesPrevFL; InfesIntFL; InfesPrevFN; InfesIntFN; InfesPrevFA; PrevFL; PrevFN; PrevQN; PrevQA; DensQN; DensQA
Daniels 1993	Reduced abundance of Ixodes scapularis (Acari: Ixodidae) and Lyme disease risk by deer exclusion.	fence	NA/ unlisted	Yes	DensQL; DensQN
Stafford 1993	Reduced abundance of Ixodes scapularis (Acari: Ixodidae) with exclusion of deer by electric fencing.	fence	NA/ unlisted	Mixed	DensQL; DensQN; DensQA; InfesPrevFL; InfesIntFL; InfesPrevFN; InfesIntFN; PrevQN
Deblinger 1993	Reduced abundance of immature Ixodes dammini (Acari: Ixodidae) following incremental removal of deer.	deer removal	NA/ unlisted	Yes	InfesDensFL; InfesDensFN
Daniels 1995	Effect of deer exclusion on the abundance of immature Ixodes scapularis (Acari: Ixodidae) parasitizing small and medium-sized mammals	fence	NA/ unlisted	Mixed	DensQT; DensQL DensQN; InfesDensFL
Mejlon 1995	Evaluation of host-targeted applications of permethrin for control of Borrelia-infected Ixodes ricinus (Acari: Ixodidae).	tick tubes	Permethrin 7.4%	Yes	InfesDensFL; DensQN; DensIN

Leprince 1996	Evaluation of permethrin-impregnated cotton balls as potential nesting material to control ectoparasites of woodrats in California.	tick tubes	Permethrin 7.5%	No	InfesDensFL; InfesDensFN; PrevH
Sonenshine 1996	A self-medicating applicator for control of ticks on deer	4-poster	Permethrin 1%	Yes	InfesPrevFT
Lane 1998	Modified bait tube controls disease-carrying ticks and fleas.	bait boxes-topical acaricide	Permethrin 1.250%; pyrethrins 0.125%; piperonyl butoxide 10.000%; inert ingredients 88.625%	Yes	InfesPrevFT; InfesDensFT
Rand 2000	Attempt to control ticks (Acari: Ixodidae) on deer on an isolated island using ivermectin-treated corn.	treated corn	10 mg ivermectin per 0.45 kg of corn	Mixed	DensQL; DensQN; DensQA; InfesDensFL; InfesDensFN; InfesDensFA
Stafford 2003	Reduced abundance of Ixodes scapularis (Acari: Ixodidae) and the tick parasitoid Ixodiphagus hookeri (Hymenoptera: Encyrtidae) with reduction of white-tailed deer.	deer removal	NA/ unlisted	Mixed	DensQN; DensQL; InfesPrevFL; InfesPrevFN
Solberg 2003	Control of Ixodes scapularis (Acari: Ixodidae) with topical self-application of permethrin by white-tailed deer inhabiting NASA, Beltsville, Maryland	4-poster	Permethrin (15ml) was applied to each roller, 5 d/wk, for the first month of treatment. After one month, we switched to a higher percentage of permethrin formulation (10% permethrin).	Yes	InfesDensFA; InfesDensFN; InfesDensFL; DensQA; DensQN; DensQL
Tsao 2004	An ecological approach to preventing human infection: vaccinating wild mouse reservoirs intervenes in the Lyme disease cycle.	injection RTV (rodent targeted vaccine)	Immunogen- 10 micro-g at first immunization and 5 at second	Yes	PrevQN; PrevH
Dolan 2004	Control of immature Ixodes scapularis (Acari: Ixodidae) on rodent reservoirs of Borrelia burgdorferi in a residential community of Southeastern Connecticut.	bait boxes-topical acaricide	Fipronil (phenylpyrazole) 0.43-0.75%	Yes	InfesDensFI; DensQA; PrevQA; PrevH
Hornbostel 2005	Effectiveness of Metarhizium anisopliae (Deuteromycetes) against Ixodes scapularis (Acari: Ixodidae) engorging on Peromnyscus leucopus.	nest boxes- fungus	Metarhizium anisopliae 10 ml of 10e8 spores/ml	No	InfesDensFL; InfesDensFN; DensQN; PrevQN
Rand 2004	Abundance of Ixodes scapularis (Acari: Ixodidae) after the complete removal of deer from an isolated offshore island, endemic for lyme disease	deer removal	NA/ unlisted	Mixed	DensQA; DensQL;DensQN; PrevQA; InfesDensFL; InfesDensFN

Barile 2005	A novel tick management system and its role in reducing the incidence of Lyme Disease.	bait boxes-topical acaricide	Fipronil 0.70%	Yes	InfesDensFT; DensQA; PrevQN
Perkins 2006	Localized deer absence leads to tick amplification	fence	NA/ unlisted	No	InfesIntFL; InfesIntFN; InfesIntFA; SeroprevH
Jordan 2007	Effects of reduced deer density on the abundance of Ixodes scapularis (Acari: Ixodidae) and Lyme disease incidence in a northern New Jersey endemic area.	deer removal	NA/ unlisted	No	DensQA; DensQN; DensQL; LDInciH
Hoen 2009	Effects of tick control by acaricide self-treatment of white-tailed deer on host-seeking tick infection prevalence and entomologic risk for Ixodes scapularis-borne pathogens.	4-poster	NA/ unlisted	Yes	PrevQN; PrevQA;
Schulze 2009	Effectiveness of the 4-Poster passive topical treatment device in the control of Ixodes scapularis and Amblyomma americanum (Acari: Ixodidae) in New Jersey.	4-poster	Point-Guard 2% amitraz; increased twice during the study; initial 20 mL Point-Guard/roller (80 mL Point-Guard/4-Poster) to 30 mL Point-Guard/roller(120 mL Point-Guard/4-Poster) in September 1998, and to 40 mL Point-Guard/roller (160 mL Point-Guard/4-Poster)in mid-August 1999; additionally, in mid-August 1999, a second application at the 40 mL Point-Guard/roller rate was added 3 to 4 days after the initial treatment each week to all 4-Posters. During the final 3 years of the treatment phase of the study was 80 mL Point-Guard/roller (320 mL Point-Guard/4-Poster).	Yes	DensQL; DensQN; DensQA
Daniels 2009	Acaricidal treatment of white-tailed deer to control Ixodes scapularis (Acari: Ixodidae) in a New York Lyme disease-endemic community.	4-poster	2% Amitraz (Point-Guard). Initial treatment regimen involved applying 20 mL of Point-Guard to each roller once per week; 1999 increased to 40 mL Point-Guard per roller three times weekly.	Yes	DensQA; DensQN; DensQL; InfesIntFT
Stafford 2009	Topical treatment of white-tailed deer with an acaricide for the control of Ixodes scapularis (Acari: Ixodidae) in a Connecticut Lyme borreliosis hyperendemic community.	4-poster	Point-Guard (2% amitraz) initially applied at 25mL per roller per week, increased to 40mL/roller in the later years of the study.	Yes	PlotPL; DensQN; DensQL; PrevQN
Carroll 2009	Sustained control of Gibson Island, Maryland, populations of Ixodes scapularis and Amblyomma americanum (Acari: Ixodidae) by community-administered 4-Poster deer self-treatment bait stations.	4-poster	2% amitraz replenished weekly. Each roller received 2.5 mL acaricide for 2.3 per 9.2 kg corn consumed, increasing by 2.5 mL=roller for each additional 4.5 kg increment of corn consumed up to 70.5 kg. For every additional 11.4 kg corn	Yes	DensQN

			consumed above 70.5 kg, an additional 5 mL of acaricide=roller was applied.		
Carroll 2009	The impact of 4-Poster deer self-treatment devices at three locations in Maryland.	4-Poster	Pour-on formulation of 2% amitraz applied to the rollers on the 4-posters	Yes	DensQT; DensQL; DensQN; DensQA
Miller 2009	Evaluating a deer-targeted acaricide applicator for area-wide suppression of blacklegged ticks, Ixodes scapularis (Acari: Ixodidae), in Rhode Island.	4-poster	Point-Guard was initially applied to each device at a rate of 25 mL per roller per week, 1999 roller size was increased to accommodate 40 mL of acaricide per week	Yes	DensQL; DensQN; DensQA
Dolan 2011	Elimination of Borrelia burgdorferi and Anaplasma phagocytophilum in rodent reservoirs and Ixodes scapularis ticks using a doxycycline hyclate-laden bait.	bait boxes-ATB (antibiotic)	Doxycycline 500 mg/kg	Yes	PrevH; PrevQN; PrevQA
Garnett 2011	Evaluation of deer-targeted interventions on lyme disease incidence in Connecticut.	deer removal; 4-poster	NA/ unlisted	Mixed	LDCaseH
Gilbert 2012	The effect of deer management on the abundance of Ixodes ricinus in Scotland	fence; deer removal	NA/ unlisted	Yes	DensQL; DensQN; DensQN
Grear 2014	The effectiveness of permethrin-treated deer stations for control of the Lyme disease vector Ixodes scapularis on Cape Cod and the islands: a five-year experiment.	4-poster	Permethrin acaricide added to rollers at a rate of 7.5 ml per 50 lbs (23 kg) of corn consumed	Mixed	DensQA; DensQN; DensQL
Richer 2014	Reservoir targeted vaccine against borrelia burgdorferi: A new strategy to prevent lyme disease transmission	oral RTV (rodent targeted vaccine)	200 mg of E. coli expressing OspA/bait	Yes	SeroprevH; PrevQN
Schulze 2017	Evaluation of the SELECT Tick Control System (TCS), a host-targeted bait box, to reduce exposure to Ixodes scapularis (Acari: Ixodidae) in a Lyme disease endemic area of New Jersey.	bait boxes-topical acaricide	Fipronil (0.75%)	Yes	InfesPrevFL; InfesIntFL; InfesPrevFN; InfesIntFN; DensQN
Dolan 2017	Evaluation of doxycycline-laden oral bait and topical fipronil delivered in a single bait box to control Ixodes scapularis (Acari: Ixodidae) and reduce Borrelia burgdorferi and Anaplasma phagocytophilum infection in small mammal reservoirs and host-seeking Ticks	bait boxes-per os acaricide ATB (antibiotic); bait boxes-topical acaricide	0.70% topical fipronil wick, and 0.05% doxycycline hyclate-impregnated oral bait	Yes	DensQL; DensQN; DensQA; PrevQN; PrevQA; InfesPrevFL; InfesDensFL; InfesPrevFN; InfesDensFN
Williams 2018	Integrated control of nymphal Ixodes scapularis: effectiveness of white-tailed deer reduction, the entomopathogenic	deer removal; botanical/natural acaricide-environment; bait	11% w/w of M. anisopliae or 5.5 x 10e9 CFU/g; bait boxes: 0.7% fipronil	Yes	DensQN; PrevQN

	fungus Metarhizium anisopliae, and fipronil-based rodent bait boxes.	boxes-topical acaricide			
Jordan 2019	Ability of Two Commercially Available Host-Targeted Technologies to Reduce Abundance of Ixodes scapularis (Acari: Ixodidae) in a Residential Landscape	bait boxes-topical acaricide; tick tubes	Tick tube: 7.4% permethrin; bait box: fipronil-treated felt wick	Yes	InfesPrevFL; InfesPrevFN; InfesIntFL; InfesIntFN; DensQN
Brown 2020	Tick tubes reduce blacklegged tick burdens on white-footed mice in Pennsylvania, USA.	tick tubes	Permethrin 7.5%	Yes	InfesDensFN
Contreras 2020	Control of tick infestations in wild roe deer (Capreolus capreolus) vaccinated with the Q38 Subolesin/Akirin chimera	injection DTV (deer targeted vaccine)	100 ug Q38 per dose	Yes	InfesDensFA
Stafford 2020	Field evaluation of a novel oral reservoir-targeted vaccine against Borrelia burgdorferi utilizing an inactivated whole-cell bacterial antigen expression vehicle.	oral-RTV (rodent targeted vaccine)	OspA-vectored E. coli BL21(DE3) pLysS employing the T7 inducible expression system	Yes	PrevH; PrevFL
Hinckley 2021	Prevention of Lyme and other tickborne diseases using a rodent-targeted approach: a randomized controlled trial in Connecticut	bait boxes-topical acaricide	Fipronil 0.70%	No	DensQN; PrevQN; TickEncoH; TickBiteH; LDCaseH
Linske 2021	Integrated Tick Management in Guilford, CT: Fipronil-Based Rodent-Targeted Bait Box Deployment Configuration and Peromyscus leucopus (Rodentia: Cricetidae) Abundance Drive Reduction in Tick Burdens.	bait boxes-topical acaricide	NA/ unlisted	No	InfesDensFT
Vanier 2022	Deployment of a Reservoir-Targeted Vaccine Against Borrelia burgdorferi Reduces the Prevalence of Babesia microti Coinfection in Ixodes scapularis Ticks	oral RTV (rodent targeted vaccine)	NA/ unlisted	Yes	PrevQN; PrevH
Martin 2023	Deer management generally reduces densities of nymphal Ixodes scapularis, but not prevalence of infection with Borrelia burgdorferi sensu stricto	deer removal	NA/ unlisted	Mixed	DensQN; PrevQN; DensIN
Kiran 2024	Effects of rodent abundance on ticks and Borrelia: results from an experimental and observational study in an island system	rodent removal (capture)	NA/ unlisted	No	DensQN; PrevQN; SeroprevH; InfesDensFN; InfesIntFN;

					InfesDensFL; InfesIntFL
Pelletier 2024	The effect of fluralaner treatment of small mammals on the endemic cycle of Borrelia burgdorferi in a natural environment	bait boxes-per os acaricide	Fluralaner 4.8 mg per gram of bait.	Mixed	InfesPrevFT; DensQN; PrevQN
Tiffin 2024	Maximizing and sustaining the efficacy of tick tubes for management of Ixodes scapularis through optimized deployment strategies	tick tubes	Unlisted- acaricide treated nesting cotton	Yes	InfesDensFT
Management of host parasitism & movement; Chemical, biological, natural tick control					
Schulze 2007	Integrated use of 4-Poster passive topical treatment devices for deer, targeted acaricide applications, and Maxforce TMS bait boxes to rapidly suppress populations of Ixodes scapularis (Acari: Ixodidae) in a residential landscape	4-poster ; bait boxes-topical acaricide; acaracide application-environment	4-poster: 2% amitraz- Point Guard- applied by roller Bait Box; 0.70% fipronil	Yes	DensQN; InfesDensFL; InfesDensFN
Williams 2018	Integrated control of juvenile Ixodes scapularis parasitizing Peromyscus leucopus in residential settings in Connecticut, United States.	deer removal; bait boxes-topical acaricide; botanical/natural acaricide-environment 1) rodent finopril bait box and Met52 2) deer removal 3) deer removal, rodent finopril, and Met52	Met52: 11% w/w of Metarhizium anisopliae	Yes	EncoQN; EncoQL, PrevQT
Little 2020	Evaluating the effectiveness of an integrated tick management approach on multiple pathogen infection in Ixodes scapularis questing nymphs and larvae parasitizing white-footed mice.	bait boxes-topical acaricide; deer removal; botanical/natural acaricide-environment	Fipronil 0.7%; 11% (5.5 10e9 CFU/g) Metarhizium anisopliae	Mixed	DensQN; PrevQN; PrevFI; InfesDensFI;
Pelletier 2022	Fluralaner Baits Reduce the Infestation of Peromyscus spp. Mice (Rodentia: Cricetidae) by Ixodes scapularis (Acari:	bait boxes-per os acaricide	Fluralaner concentration of 4.8 mg per g of bait.	Yes	InfesIntFL; InfesIntFN

	Ixodidae) Larvae and Nymphs in a Natural Environment				
Keesing 2023	Effects of Tick-Control Interventions on Tick Abundance, Human Encounters with Ticks, and Incidence of Tickborne Diseases in Residential Neighborhoods	bait boxes-topical acaricide; botanical/natural acaricide-environment	Fipronil: not specified; Met52- Metarhizium anisopliae: 2.22 L/378.5 L	Mixed	DensQN; TickEncoH; LDCaseH; LDCaseP; TickEncoP; InfesIntFL; InfesIntFN
Ostfeld 2023	Effects of Neighborhood-Scale Acaricidal Treatments on Infection Prevalence of Blacklegged Ticks (Ixodes scapularis) with Three Zoonotic Pathogens	botanical/natural acaracide-environment; bait boxes-topical acaricide	Bait boxes: fipronil; Met52 unspecified (assume applied according to manufacturer recs)	Mixed	PrevQN
Ostfeld 2023	Impacts Over Time of Neighborhood-Scale Interventions to Control Ticks and Tick-Borne Disease Incidence	bait boxes-topical acaricide; botanical/natural acaracide-environment	Met52: product concentration 2.22 L per 378.5 L of water	No	InfestIntFT; TickEncoH; LDCaseH; TickEncoP; LDCaseP; DensQN
Ostfeld 2024	Effects of residential acaricide treatments on patterns of pathogen coinfection in blacklegged ticks	botanical/natural acaracide-environment; bait boxes-topical acaricide	M. brunneum- recommended application concentration applied at 175-200psi	Mixed	PrevQN
Management of host parasitism & movement; Landscape management					
Del Fabbro 2015	Fencing and mowing as effective methods for reducing tick abundance on very small, infested plots.	fence, vegetation management	NA/not listed	Yes	DensQN; DensQA
Mandli 2021	Integrated tick management in south central Wisconsin: impact of invasive vegetation removal and host-targeted acaricides on the density of questing Ixodes scapularis (Acari: Ixodidae) nymphs.	tick tubes; vegetation management	Permethrin 10%	No	EncoQL; DensQN; DensIN
Management of host parasitism & movement; Personal protection (population level)					
Potes 2023	Evaluation of a community-based One Health intervention to reduce the risk of Lyme disease in a high-incidence municipality	personal protection-motivational; bait boxes-per os acaricide	Fluralaner: not specified	Yes	Qual- TickBiteH
Personal protection (population level)					
Staub 2002	Effectiveness of a repellent containing DEET and EBAAP for preventing tick bites	personal protection-repellent	ParapicTick-Repellent 15% DEET, 15% EBAAP, and isopropanol	Mixed	TickEncoH; TickBiteH

Miller 2011	Tick bite protection with permethrin-treated summer-weight clothing	personal protection-permethrin	0.5% permethrin aerosol spray applied to shoes worn by participants; Other applications unspecified	Mixed	TickBiteH
Faulde 2015	Pilot study assessing the effectiveness of factory-treated, long-lasting permethrin-impregnated clothing for the prevention of tick bites during occupational tick exposure in highly infested military training areas, Germany.	personal protection-permethrin	Polymer-coated with permethrin concentration 1300+- 300mg a.i./m^2	Yes	TickBiteH; DensQT; PrevQT
Richards 2015	Effectiveness of permethrin-treated clothing to prevent tick exposure in foresters in the central Appalachian region of the USA	personal protection-permethrin	NA/not listed	Yes	TickBiteH; TickEncoH
Nadolny 2024	Effects of permethrin-treated uniforms on tick submissions to a military passive tick surveillance program	personal protection-permethrin	NA/not listed	Yes	TickBiteH

8.1.4 Supplemental table 2: Codebook for outcome measures

Density questing ticks	
DensQL	Density questing ticks: Questing larvae
DensQN	Density questing ticks: Questing nymphs
DensQI	Density questing ticks: Questing immature ticks (larvae and nymphs)
DensQA	Density questing ticks: Questing adults
DensQT	Density questing ticks: Questing ticks (all stages counted together)
EncoQL	Questing tick encounter: larvae
EncoQN	Questing tick encounter: nymphs
EncoQI	Questing tick encounter: immatures
EncoQA	Questing tick encounter: adults
EncoQT	Questing tick encounter: all stages together
Infection prevalence in questing ticks	
PrevQN	Infection prevalence in questing ticks: Bb prevalence in questing nymphs
PrevQA	Infection prevalence in questing ticks: Bb prevalence in questing adults

PrevQT	Infection prevalence in questing ticks: Bb prevalence in questing ticks (all stages counted together)
Acarological risk (density*prevalence)	
DensIN	Acarological risk (density*Bb prevalence): Density of infected questing nymphs
DensIA	Acarological risk (density*Bb prevalence): Density of infected questing adults
DensIT	Acarological risk (density*Bb prevalence): Density of infected questing ticks
Infection prevalence in host/ feeding ticks	
PrevH	Infection prevalence in host/ feeding ticks: B. burgdorferi infection prevalence in host (blood or tissue)
SeroprevH	Seroprevalence of host (ex: to a specific protein, when the host is treated by oral vaccination, anti-OpsA seropositivity etc.)
PrevFL	Infection prevalence in host/ feeding ticks: B. burgdorferi infection prevalence in feeding larvae collected from host
PrevFN	Infection prevalence in host/ feeding ticks: B. burgdorferi infection prevalence in feeding nymphs collected from host
PrevFA	Infection prevalence in host/ feeding ticks: B. burgdorferi infection prevalence in feeding adults collected from host
PrevFI	Infection prevalence in host/ feeding ticks: B. burgdorferi infection prevalence in feeding immature (larvae and nymphs) collected from host
PrevFT	Infection prevalence in host/ feeding ticks: B. burgdorferi infection prevalence in feeding ticks (all stages together) collected from host
Host infestation	
InfesPrevFL	Host infestation by larval ticks: Infestation **prevalence** (no. of infested hosts/total no. of hosts)
InfesDensFL	Host infestation by larval ticks: Infestation **density** (no. ticks per host, all individual hosts included)
InfesIntFL	Host infestation by larval ticks: Infestation **intensity** (no. ticks per infested host)
InfesPrevFN	Host infestation by nymphal ticks: Infestation **prevalence** (no. of infested hosts/total no. of hosts)
InfesDensFN	Host infestation by nymphal ticks: Infestation **density** (no. ticks per host, all individual hosts included)
InfesIntFN	Host infestation by nymphal ticks: Infestation **intensity** (no. ticks per infested host)
InfesPrevFA	Host infestation by adult ticks: Infestation **prevalence** (no. of infested hosts/total no. of hosts)
InfesDensFA	Host infestation by adult ticks: Infestation **density** (no. ticks per host, all individual hosts included)
InfesIntFA	Host infestation by adult ticks: Infestation **intensity** (no. ticks per infested host)
InfesPrevFI	Host infestation by immature ticks: Infestation **prevalence** (no. of infested hosts/total no. of hosts)
InfesDensFI	Host infestation by immature ticks: Infestation **density** (no. ticks per host, all individual hosts included)
InfesIntFI	Host infestation by immature ticks: Infestation **intensity** (no. ticks per infested host)
InfesPrevFT	Host infestation by any tick stage: Infestation **prevalence** (no. of infested hosts/total no. of hosts)
InfesDensFT	Host infestation by any tick stage: Infestation **density** (no. ticks per host, all individual hosts included)
InfesIntFT	Host infestation by any tick stage: Infestation **intensity** (no. ticks per infested host)
Tick encounter or LD incidence in humans	
LDCaseH	Tick encounter or LD incidence in humans: Lyme disease cases
LDPrevH	Tick encounter or LD incidence in humans: Lyme disease prevalence

LDInciH	Tick encounter or LD incidence in humans: Lyme disease incidence
TickEncoH	Tick encounter or LD incidence in humans: Tick encounter (finding a tick attached or not attached)
TickBiteH	Tick encounter or LD incidence in humans: Tick bite (ticks attached only)
Tick encounter or LD incidence in pets	
LDCaseP	Tick encounter or LD incidence in pets: Lyme disease cases
LDPrevP	Tick encounter or LD incidence in pets: Lyme disease prevalence
LDInciP	Tick encounter or LD incidence in pets: Lyme disease incidence
TickEncoP	Tick encounter or LD incidence in pets: Tick encounter (finding a tick attached or not attached)
TickBiteP	Tick encounter or LD incidence in pets: Tick bite (ticks attached only)
Tick survival or Fitness	
TickSurvPL	Tick survival: percent larval ticks
TickSurvPN	Tick survival: percent nymphal ticks
TickSurvPA	Tick survival: percent adult stage ticks
TickSurvT	Tick survival: percent all stages
TickFitT	Tick fitness: all stages (fecundity and body mass)
Other	
LDCaseH	Tick encounter or LD incidence in humans: Lyme disease cases
Qual	Qualitative results on intervention effectiveness
Percent per Plot	
PlotPL	Percent of study ticks found per sampling plot: larval ticks
PlotPN	Percent of study ticks found per sampling plot: nymphal ticks
PlotPA	Percent of study ticks found per sampling plot: adult ticks
PlotPT	Percent of study ticks found per sampling plot: all stages ticks

8.2 (Objective 2)

8.2.1 Additional Methods: Manuscript 2- Experimental field study of tick control interventions

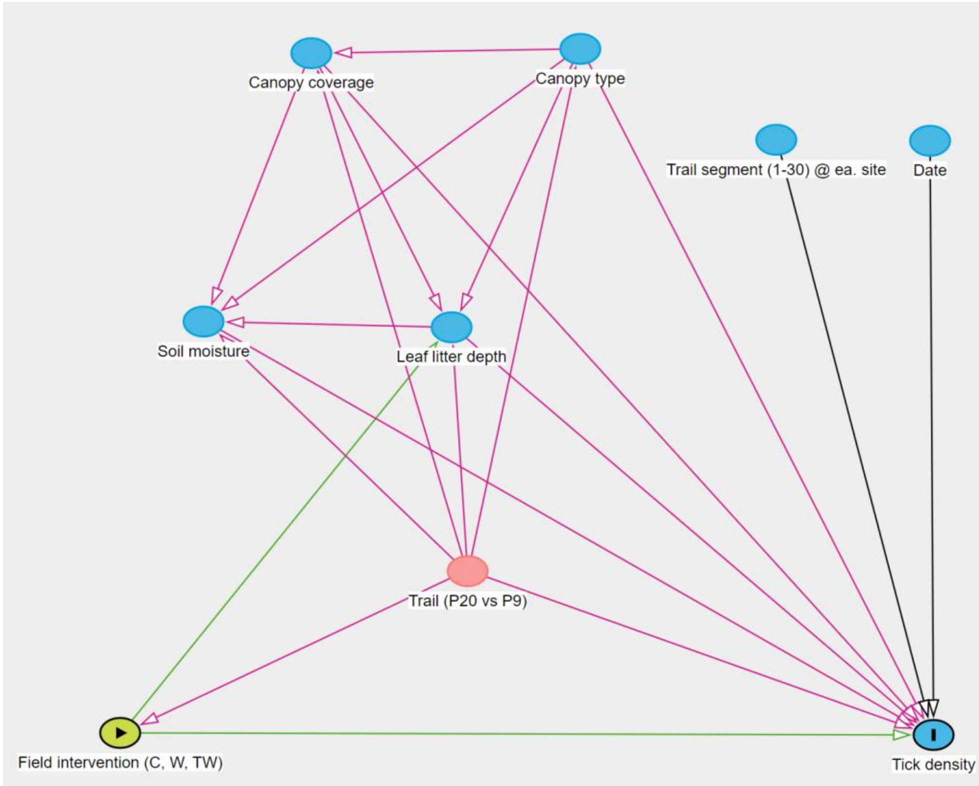
For this study sample size calculations were conducted to ensure sufficient power to detect reductions in the primary outcome (questing *I. scapularis* tick density, defined as the number of *I. scapularis* adult and nymphal ticks per $100m^2$ of drag sampling); the calculations are presented in the manuscript. Standard tick-dragging protocols were used throughout, and separate flannels were employed for each intervention type to prevent cross-contamination, as detailed in the manuscript (134). In consultation with project partners at the National Capital Commission, we made several changes from the previous study methods to improve the feasibility of this kind of intervention on a larger scale. These included the use of heavy machinery for woodchip distribution, which led us to remove the grass strip that existed between the trails and woodchip borders in the previous study. Study sites were selected to represent both an emerging risk zone in eastern Ottawa (Mer Bleue) and a well-established high-risk area in western Ottawa (Stony Swamp) based on previous tick surveillance in Ottawa, which allowed intervention performance to be evaluated in several contexts (43).

To evaluate the impact of the intervention on post-treatment tick density, a series of regression models were fitted to the collected field data. To assess the presence of overdispersion, both Poisson and negative binomial models were fitted and compared. A likelihood-ratio test comparing the Poisson and negative binomial models (testing H_0: $\alpha=0$) was statistically significant ($chibar^2(01) = 9.42$, $p = 0.001$), indicating the presence of overdispersion and supporting the use of a negative binomial model. This result is consistent with the expected spatial heterogeneity of tick populations, where spatial clustering of ticks is commonly observed across sampled environments.

Model selection was guided by Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) values to evaluate and improve initial model fit. Variable inclusion was informed by both statistical criteria and *a priori* causal assumptions using a directed acyclic graph (DAG) (Figure 3.1), ensuring that theoretically important confounders were retained regardless of AIC or BIC changes. Both AIC and BIC supported inclusion of week, year, trail, and group as predictors that improved model fit relative to the base model.

To account for repeated sampling and clustering, a mixed-effects negative binomial regression model was fitted. Sampling group was specified as the higher-level clustering variable, with week nested within group to reflect the longitudinal sampling structure (repeated sampling). Pre-treatment tick density was not included as an offset due to sparse data; however, it was retained as a covariate in the final models to help control for any baseline differences across sampling segments. This analytic approach allowed for formal comparison of intervention and control segments across ecological contexts.

Figure 8.1: Directed acyclic graph (DAG) of variables for consideration in negative binomial models.



** The line between Trail (P20 vs P9) and exposure (Field intervention) does not necessarily exist. If the site influenced the type of habitat where we could lay the intervention type (e.g. bodies of water where we can't spray deltamethrin) this is a potential biasing pathway. Since this was evaluated on site a priori and no issues were found, this is well controlled for.*

Additionally, we performed a pilot gradient tick dragging study prior to the study season to assess the effect of woodchips on the spatial distribution of tick density at the forest ecotone. These exploratory results, presented in Appendix 8.2.1, suggest a gradient pattern in tick density, decreasing from the forest edge to the centre of the trail; no statistically significant difference in the distribution of ticks was observed ($\chi^2(2) \approx 4.7$, $p \approx 0.09$) between control and woodchip intervention segments, though a higher proportion of ticks were observed in the forest ecotone under intervention conditions.

8.2.2 Pilot Study: Gradient tick dragging report

The Greenbelt Tick Study:

A uOttawa INSIGHT lab collaboration with the NCC to reduce tick density on trails, Annual report 2021

Background:

The incidence of Lyme disease (LD) and other tickborne illnesses are increasing in the region of eastern Ontario due to changes in climate and environment, which have expanded the habitable range in which LD vector ticks (*Ixodes scapularis)* are found, and their proximity to human populations (1–4). Eastern Ontario now has some of the highest rates of LD incidence in Canada posing a growing threat to the health and wellbeing of human populations in urban and peri-urban areas, including the capital city of Ottawa (5–7). Studies by Ogden et al have predicted that the expansion of *Ixodes scapularis* tick habitat will only continue in coming years, leading to an increase in the density of ticks and potential for transmission of LD to human populations(8,9).

This project aims to develop and evaluate environmental management strategies for tick control along National Capital Commission (NCC) recreational trails situated in the Ottawa Greenbelt through a series of experimental field studies. This work builds upon the pilot study by McKay et al that tested the effectiveness of woodchip borders placed along forest ecotones to reduce questing tick density along recreational trails (10). The project will also develop and evaluate educational strategies to improve knowledge of Lyme disease risks and the uptake of preventive behaviours among trail users. This project is a vital step in developing an integrative tick control approach with high acceptability in the Ottawa, ON region of Canada.

The 2021 field season was the first sampling year out of a 3-year planned partnership between the University of Ottawa and the National Capital Commission, which will use a two-pronged approach involving environmental control strategies and an educational component to increase the knowledge of LD risk and prevention of tick bites amongst recreational trail users.

Objective:

In the first year of this project (2021) we aimed to:

1) Assess woodchip border intervention mechanism on tick dispersal and tick questing along trail segments using an experimental design – this allowed us to better understand the mechanism by which woodchips work to reduce the density of questing ticks near recreational trails;

2) Evaluate the effects of natural products on the density of ticks and non-target arthropods on experimental plots to compare natural and synthetic acaracides' effect on the density of questing ticks, non-target arthropods, and pollinators. This aim was consisted of 3 sub aims:

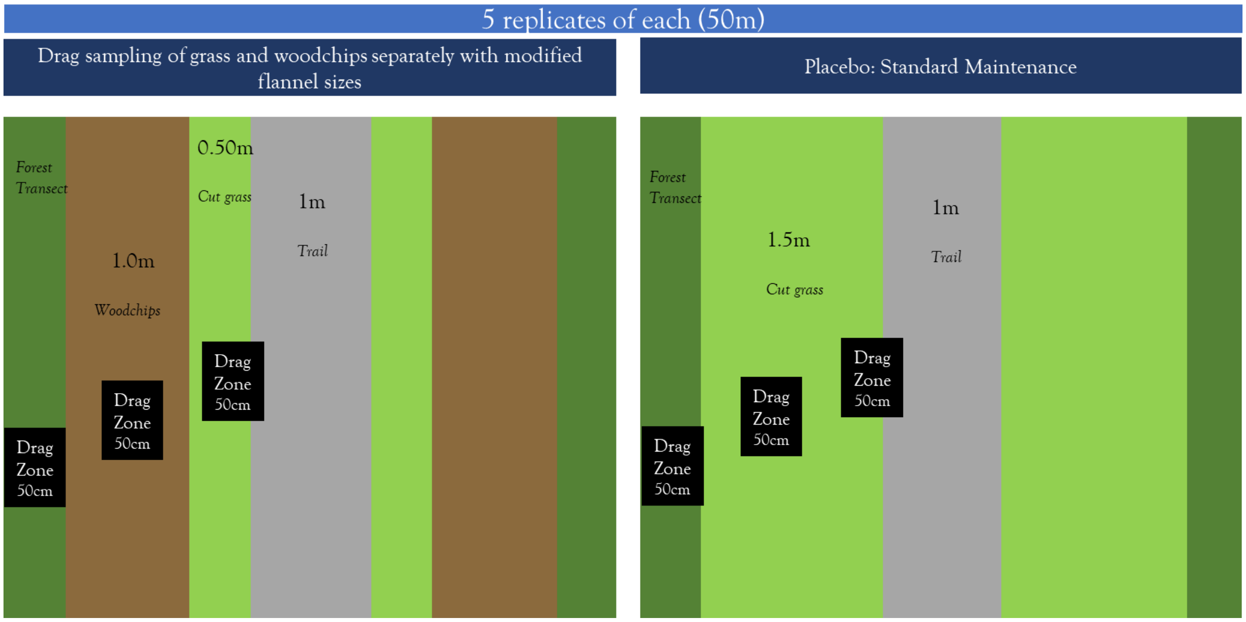
a) To assess the effectiveness of a synthetic acaracide, deltamethrin, in decreasing tick density in experimental plots;
b) To assess the effectiveness of the natural alternative garlic juice-based sprays, like mosquito barrier, in decreasing tick density in experimental plots;
c) To assess the impact of garlic juice-based spray and deltamethrin on non-target arthropods and pollinators.

Location:
Under Aim 1, ten trail segments of 50 m were created in west Ottawa (NCC P4, Timm Drive) to measure the gradation of tick density between the forest ecotone and trail margin on intervention and control segments (5 replicates each).

Under Aim 2 a set of experimental plots was used to compare the effects of a natural product and a synthetic acaracide on questing tick density and non-target arthropods (including pollinators). The experimental plots were constructed in west Ottawa (NCC P4, Timm Drive) and south Ottawa (NCC P16). Six plots were located at P4 and six plots at P16.

Procedures:
Aim 1 (Woodchip trail segments). To assess questing tick density along a gradient between the forest ecotone and trail margin, we used standard tick dragging protocols with modified flannel sizes of 50cm. In each trail replicate, three transects were sampled representing the forest, woodchip/cut grass, and trail margin (Figure 1).

Figure 1: Illustration of tick dragging methods used in 2021 to investigate tick dispersal



Aim 2 (Natural Alternative/ Integrated Strategy Justification). To test the impact of natural or chemical acaricides on tick density and non-target arthorpods we allocated 4 plots to each treatment group: (1) deltamethrin, (2) garlic spray, and (3) control. In each location (NCC P4 and P16) we have constructed two 4m x 8m plots per group for a total of 6 plots per location (total 12 plots). Plots were sprayed either Garlic Spray (Mosquito Barrier), deltamethrin, or placebo (water) treated. Each 4m x 8m plot were included a 4m x 4m area of mown meadow, next to a 4m x 4m of forest ecotone or vegetation.

Aim 2a (deltamethrin): *To assess the effectiveness of a synthetic acaracide (deltamethrin) in decreasing tick density in experimental plots.*
We performed tick dragging using 1m- wide flannels on four 4 x 8m experimental plots sprayed with deltamethrin and four 4 x 8m control plots (sprayed with water). Each plot was sampled 1 week prior to spraying, and 1 week post spraying.

Aim 2b (Garlic Juice): *To assess the effectiveness of the natural alternative garlic juice-based sprays (mosquito barrier) in decreasing tick density in experimental plots.*
We conducted tick dragging using 1m- wide flannels on four 4 x 8m experimental plots sprayed with mosquito barrier and four 4 x 8m control plots (sprayed with water) 1 week prior to spraying and 1 week post spraying.

Aim2c (Pollinator impact assessment): *To assess the impact of garlic juice-based spray and deltamethrin on non-target arthropods and pollinators.*
We conducted bulk sampling of soil and litter within the corresponding plot to collect ground-dwelling arthropods. We collected flying insects and pollinators using elevated pan traps by placing 3 pan replicate traps in each of our 12 (4m x 8m) replicate plots where our bulk sampling

was occurred. Sampling was performed 1 week prior to application of Garlic Spray and deltamethrin, and 1 week after, maintaining power to detect changes in non-target arthropods and pollinators.

Treatment effects was assessed by comparing the results from plots sprayed with natural product (mosquito barrier), and a synthetic acaracide (deltamethrin) versus the control plots.

Results:

Aim1: *Assess woodchip border intervention mechanism on tick dispersal and tick questing along trail segments*

From June 18th to July 16th 2021, we conducted four weekly tick drags along trail segments at the P4 location. The final date was adjusted due to unsuitable weather for collection of ticks. We collected a total of 161 ticks, 70.8% (n=114) of which were classified as medically important ticks (i.e., *Ixodes scapularis* nymphs and adults, which are responsible for the largest proportion of tick borne disease transmission in the region) (Table 1).

Table 1: Ticks found by date of drag, species, and stage

Tabulate: Date and Species/ Stage 2021						
Date	*I.scap larva*	*I.scap nymph*	*I.scap adult*	*Haem. larva*	*Haem. nymph*	Total
June 18th	0	22	19	1	0	42
June 25th	1	28	6	7	1	43
July 2nd	6	22	3	25	6	62
July 16th	0	11	3	0	0	14
Total	7	83	31	33	7	161

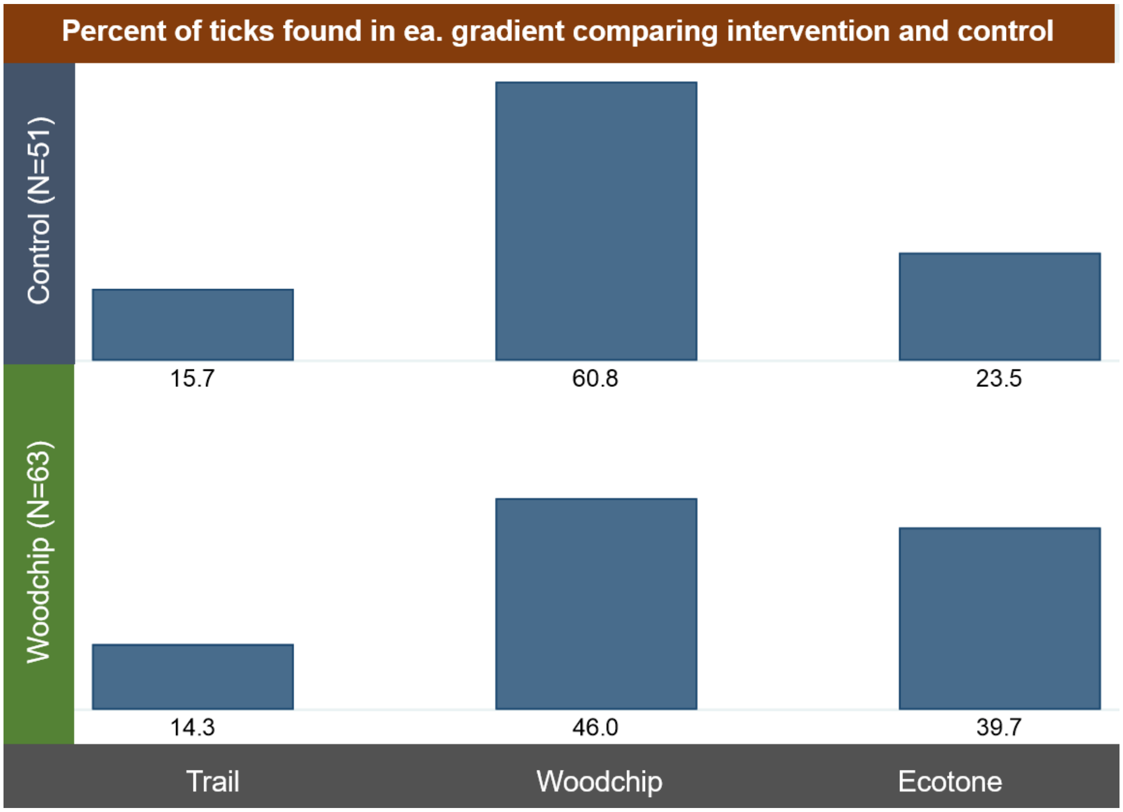
We found a total 44.7% (n=51) ticks on the untreated trails, and 55.3% (n=63) ticks on the woodchip trails (Table 2). Due to the amount of suitable trail space at P4, we were unable to randomize treatment and control trails, which reduced our ability to control for the influence of environmental factors like type of vegetation and tree coverage on tick density.

Table 2: Number of medically important ticks found by trail replicate and drag gradient

Tabulate: Trail Replicate and Gradient 2021					
C (1-5) = control **W (1-5) = woodchip**	Trail	Woodchip	Ecotone	Total	
C1	1	10	5	16	*Total ticks found in control replicates:* **51**
C2	4	6	2	12	
C3	0	4	0	4	
C4	3	8	3	14	
C5	0	3	2	5	
W1	0	0	3	3	*Total ticks found in treatment replicates:* **63**
W2	2	5	1	8	
W3	0	6	7	13	
W4	3	7	5	15	
W5	4	11	9	24	
Total	17	60	37	**114**	

On the treated trails we found a higher proportion of ticks in the forest ecotone, furthest from the trailside, compared to the untreated trails (39.7% and 23.5%, respectively), while the proportion of ticks on the trail margin was lower on treated trails. On the untreated trails, a higher proportion of ticks were found on the trailside vegetation compared to the proportion of ticks found on the on the woodchip substrate on treated trails (60.8% and 46% respectively) (Figure 2). These results suggest that woodchips could reduce migration of ticks from the forest ecotone to the immediate trailside and/or suppress tick questing in the zone of application.

Figure 2: Percent of ticks found in each gradient (treatment vs control replicates)



A chi-square test comparing the distribution of ticks across gradient locations between control and woodchip sites was not statistically significant ($\chi^2(2) \approx 4.7$, $p \approx 0.09$), although a greater proportion of ticks were observed in the ecotone (forest edge) within the woodchip sites than the control.

2a: *To assess the effectiveness of a synthetic acaracide, deltamethrin, in decreasing tick density in experimental plots;* and 2b *To assess the effectiveness of the natural alternative garlic juice-based sprays, like mosquito barrier, in decreasing tick density in experimental plots*

For the whole period of the field experiment we have detected only four Ixodes scapularis ticks in plots located at the P4 site. This number is low and doesn't provide us relevant data on assessing decreasing tick density by using either synthetic acaracide or natural product in experimental plots, in comparison with control sections (Table 3).

Table 3: Ticks found in experimental plots

Site	**Date (Pre or Post Spray)**	**Plot (Product Spray)**	**Number of Ticks**	**Species- Stage**
P4	NA	1 (Deltamethrin)	0	NA

P4	NA	2 (Garlic)	0	NA
P4	June 22, 2021 (Pre-Spray)	3 (Placebo)	1	Ixodes Scapularis, Female
P4	June 25, 2021 (Pre-Spray)	4 (Garlic)	1	Ixodes Scapularis, Male
P4	June 25, 2021 (Pre-Spray)	5 (Placebo)	1	Ixodes Scapularis, Female
P4	July 5, 2021 (Post-Spray)	5 (Placebo)	1	Ixodes Scapularis, Female
P4	NA	6 (Deltamethrin)	0	NA
P16*	*No ticks were found in the P16 plots			

2c: *To assess the impact of garlic juice-based spray and deltamethrin on non-target arthropods and pollinators*

Arthropod samples were obtained from 144 bulk samples (6 per 12 total plots per 2 collection periods) and 72 pan traps (3 per 12 total plots per 2 collection periods). Bulk sample collection was inconclusive. Pan trap results can be found below.

Table 4: Number of non-target arthropods found from pan traps (Pre and Post Spray)

	Pre-Spray	Post-Spray	Total
P4 Placebo	44	43	87
P4 Garlic	21	41	62
P4 Deltamethrin	44	42	86
P4 Total	**109**	**126**	**235**
P16 Placebo	171	49	220
P16 Garlic	86	69	155
P16 Deltamethrin	81	62	143
P16 Total	**338**	**180**	**518**

All Plots Total	**447**	**306**	**753**

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9. Ogden NH, St-Onge L, Barker IK, Brazeau S, Bigras-Poulin M, Charron DF, et al. Risk maps for range expansion of the Lyme disease vector, Ixodes scapularis, in Canada now and with climate change. Int J Health Geogr. 2008 May 22;7:24. doi:10.1186/1476-072X-7-24 PubMed PMID: 18498647; PubMed Central PMCID: PMC2412857.

10. McKay R, Talbot B, Slatculescu A, Stone A, Kulkarni MA. Woodchip borders at the forest ecotone as an environmental control measure to reduce questing tick density along recreational trails in Ottawa, Canada. Ticks Tick-Borne Dis. 2020 Mar;11(2):101361. doi:10.1016/j.ttbdis.2019.101361 PubMed PMID: 31874797.

8.2.3 Supplemental table 1: Total number of collected ticks by species and stage per 100m2, with nymphal and all-stage Borrelia burgdorferi infection prevalence by treatment and year, for before and after treatment implementation, over two sampling seasons (total 14 weeks).

Trail site	Treatment	No. Adults (% Infected)	No. Nymphs (% Infected)	Larvae	Total *I.scapularis*	*No. Haemaphysalis leporispalustris*
Stonehaven (P9)	Pre-treatment	55 (16/40)	67 (20/65)	2	124	4
	Control	22 (12/22)	46 (17/46)	26	94	17
	Woodchip (W) intervention	13 (4/13)	42 (17/42)	0	55	60
	Deltamethrin treated woodchip (DW) intervention	0 (na)	0 (na)	0	0	1
	Post-treatment Total	35 (16/35)	88 (34/88)	26	149	78
Mer Bleue (P20)	Pre-treatment	6 (0/6)	13 (0/13)	0	19	0
	Control	13 (4/13)	39 (7/38)	0	52	0
	Woodchip (W) intervention	3 (1/3)	10 (3/10)	0	13	0
	Deltamethrin treated woodchip (DW) intervention	1 (1/1)	0(na)	0	1	0
	Post-treatment Total	17 (5/17)	49 (10/48)	0	66	0

- * % BB positive values represent the number of positive tick specimens out of the total number that successfully amplified in qPCR

8.3 (Objective 3)

8.3.1 Additional Methods: Manuscript 3- Mixed methods study of LD intervention acceptability

The final chapter (Objective 3) employed a mixed methods approach to evaluate the feasibility and acceptability of selected tick and LD control interventions. Qualitative data analysis followed a hybrid inductive-deductive coding approach, with initial deductive codes informed by the study objectives, alongside inductive codes to capture any unanticipated emerging themes (135).

The survey distribution followed methods from Logan et al. (2024), which evaluated LD knowledge, attitudes, and practices (KAP) among Ottawa residents in late 2020. In the KAP study, Leger, a Canadian survey and analytics company, randomly invited participants from web panels of recruited Ottawa residents, using recruitment quotas to achieve a representative panel of a Canadian population (132). For consistency, we followed a similar survey sampling approach in this acceptability study, with participants stratified across five geographic regions: the urban center, rural, suburban west, suburban south, and suburban east. These five strata were defined using the same statistical estimates from the Logan et. al. (2024) study, which used estimates of population density, walkability, and car commuting rates calculated by the Ottawa Neighborhood study (ONS) and grouped according to the first three digits of their Forward Sortation Areas (FSA) (132). The following table (3.1) included a more detailed description of the data sources and uses that were employed in the Logan et al. (2024) study, which we have also used for this thesis chapter.

Table 8.1: Data sources and definitions used in Logan et al. (2024) and applied in the present acceptability study (132).

Data Source	**Definition**	**Use**	**Reference**
Statistics Canada; population density	Urban: greater than people per square kilometer Rural: less than people per square kilometer	Used to identify natural neighborhoods for urban and rural areas of residence	Statistics Canada. Population Centre and Rural Area Classification 2016. 2017.
Ottawa neighborhood study (ONS)	Natural neighbourhoods where car commuter rates were above the City of Ottawa average of (69%), or where ONS walkability scores implied moderate care dependance (score 20-50)	Used to define areas from above that fell into an "in between" or more of a suburban area of residence	Airgood-Obrycki W, Rieger S. Defining Suburbs: How Definitions Shape the Suburban Landscape. Cambridge, MA; 2019.
Ottawa Greenbelt spatial considerations	Protected green spaces that partially encircle the main city area of Ottawa	Used to help define and subdivide the suburban areas into east, south, and west	(132)
Forward Sortation Area (FSA)	First three digits of FSA were collected from survey respondents	Used to recruit appropriate number per stratum, and group respondents to one of the five neighborhoods	(132) Appendix 8.3.7

8.3.2 Supplemental table 1: Sensitivity analysis of cutoff score for acceptability

Score and justification	

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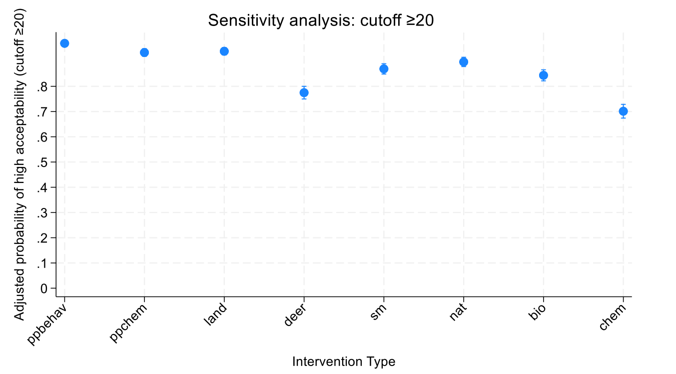
<td>Score equal or greater than 20: Scores range from 9-36, this would be below the midpoint, and therefore does not make sense to use as a threshold for acceptability</td>
<td>
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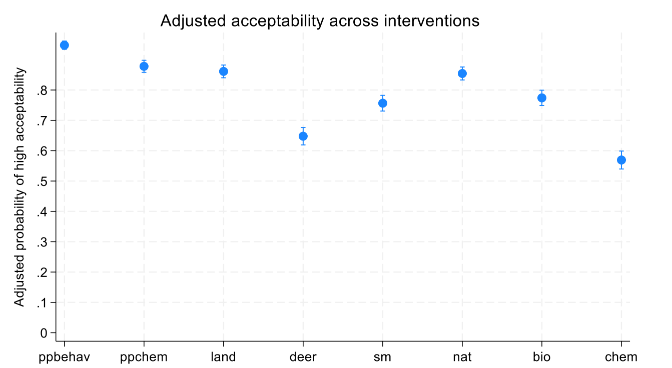
<tr>
<td>Original cutoff score of greater than 22.5: this is the midpoint of the score range indicating neutral acceptability.</td>
<td>
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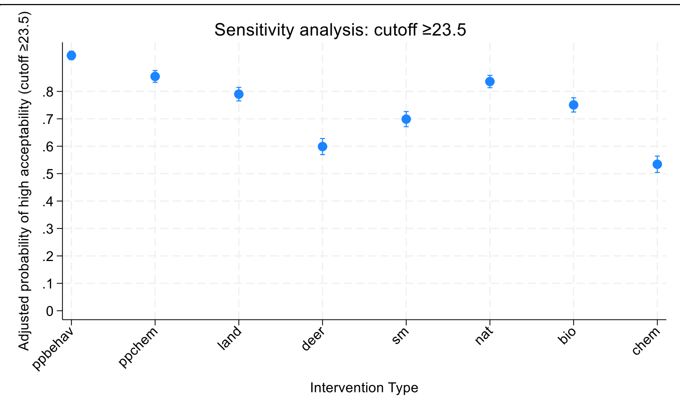
<td>Score of equal to or greater than 23.5: this score still indicates relatively neutral acceptability, relative acceptability of the interventions remains true to the qualitative findings, and are not significantly different from the original cutoff score.</td>
<td>
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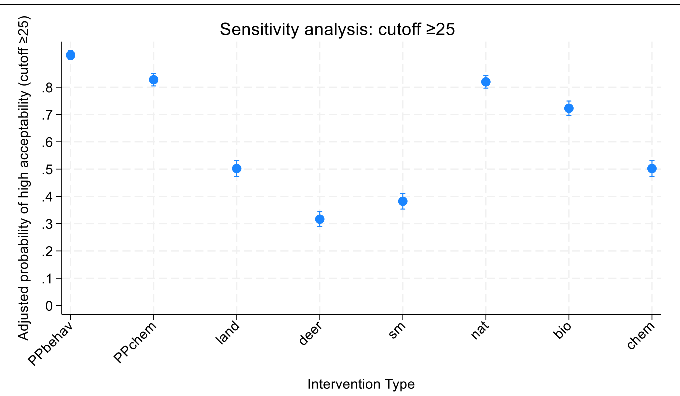
<td>Score of equal to or greater than 25: This threshold starts to diverge in terms of the relative acceptability of the interventions, however it is no longer true to the qualitative findings, and a score of 25 indicates very high acceptability, rather than more positive neutral agreement.</td>
<td>
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8.3.3 Supplemental table 2: Multivariable Logistic regression models for high acceptability for all Lyme Disease prevention or tick control interventions, with number of respondents in each category, and proportion of respondents finding the intervention to be acceptable. With full variable lists.

Environmentally Applied: Chemical Acceptability					
	Category	**No. respondents in category**	**Proportion of respondents with high acceptability [95%CI]**	**OR [95%CI]**	**p-value**
Gender	Woman	532	47.7 [0.43, 0.52]	Reference	.
	Male	474	67.1 [0.63, 0.71]	2.36 [1.97, 2.82]	0
	Non-Binary	8	50.0 [0.16, 0.84]	1.12 [0.47, 2.69]	0.8
	Other	1	0.0 [0.00, 0.98]	.	.
Age	18 to 24	128	75.0 [0.67, 0.82]	Reference	.
	25 to 34	185	55.7 [0.48, 0.63]	0.52 [0.37, 0.73]	0
	35 to 44	180	57.2 [0.50, 0.65]	0.45 [0.33, 0.62]	0
	45 to 54	153	53.6 [0.45, 0.62]	0.42 [0.25, 0.72]	0
	55 to 64	168	47.6 [0.40, 0.55]	0.34 [0.22, 0.54]	0
	65 to 74	115	53.9 [0.44, 0.63]	0.55 [0.33, 0.92]	0.02
	75 or older	86	58.1 [0.47, 0.69]	0.67 [0.51, 0.89]	0.01
Ethnicity	White	59	54.6 [0.51, 0.58]	Reference	.
	Indigenous	192	76.3 [0.63, 0.86]	0.85 [0.59, 1.22]	0.38
	Other	744	60.4 [0.53, 0.67]	0.63 [0.37, 1.08]	0.09
	NA	20	45.0 [0.23, 0.68]	0.47 [0.12, 1.88]	0.29
Region	Urban	347	56.2 [0.51, 0.61]	Reference	.
	Suburban E	195	67.2 [0.60, 0.74]	1.77 [1.64, 1.92]	0
	Suburban S	197	50.3 [0.43, 0.57]	0.79 [0.69, 0.91]	0
	Suburban W	139	53.2 [0.45, 0.62]	1.11 [0.95, 1.3]	0.18
	Rural	137	56.2 [0.47, 0.65]	1.26 [1.09, 1.45]	0
Residence in Canada	Less than 1 year	13	53.8 [0.25, 0.81]	Reference	.
	1-5 years	45	60.0 [0.44, 0.74]	1.23 [0.28, 5.42]	0.78
	6-10 years	37	78.4 [0.62, 0.90]	2.61 [0.31, 21.83]	0.38
	10+ years	920	55.8 [0.52, 0.59]	1.33 [0.32, 5.63]	0.7
Income	< $20,000	51	45.1 [0.31, 0.60]	Reference	.
	$20,000 to $39,999	72	56.9 [0.45, 0.69]	2.03 [0.69, 5.99]	0.2
	$40,000 to $59,999	102	58.8 [0.49, 0.68]	2.21 [1.18, 4.15]	0.01
	$60,000 to $79,999	125	54.4 [0.45, 0.63]	1.30 [0.57, 2.94]	0.53

	$80,000 to $99,999	162	66.0 [0.58, 0.73]	1.77 [0.92, 3.43]	0.09
	$100,000 to $119,000	141	57.4 [0.49, 0.66]	1.45 [0.71, 2.97]	0.31
	$120,000 or more	276	56.2 [0.50, 0.62]	1.82 [1.03, 3.22]	0.04
	NA	86	47.7 [0.37, 0.59]	1.70 [0.9, 3.24]	0.1
Education	Highschool or less	130	58.5 [0.49, 0.67]	Reference	.
	College	288	61.5 [0.56, 0.67]	1.15 [0.67, 1.97]	0.61
	University +	594	54.0 [0.50, 0.58]	0.80 [0.51, 1.26]	0.34
	Other/ NA	3	66.7 [0.09, 0.99]	2.30 [0.28, 18.77]	0.44
Language	English	839	56.7 [0.53, 0.60]	Reference	.
	French	137	59.1 [0.50, 0.67]	1.19 [0.92, 1.54]	0.18
	Other	39	48.7 [0.32, 0.65]	0.76 [0.5, 1.15]	0.19
Occupation	Indoor	591	55.3 [0.51, 0.59]	Reference	.
	Outdoor	128	68.8 [0.60, 0.77]	1.21 [0.73, 1.99]	0.47
	Mixed	37	78.4 [0.62, 0.90]	1.72 [0.76, 3.89]	0.19
	Other	259	51.0 [0.45, 0.57]	0.71 [0.42, 1.2]	0.2
Yard	No access	171	56.7 [0.49, 0.64]	Reference	.
	Access, no maintenance	250	49.6 [0.43, 0.56]	0.72 [0.51, 1.01]	0.05
	Access and maintenance	594	59.8 [0.56, 0.64]	1.08 [0.76, 1.54]	0.68
Tick bite	Never	848	51.3 [0.48, 0.55]	Reference	.
	1-2 times	148	83.8 [0.77, 0.89]	3.54 [2.19, 5.71]	0
	3+ times	19	89.5 [0.67, 0.99]	4.73 [1.25, 17.81]	0.02
Environmentally Applied: Natural Acceptability					
	Category	**No. respondents in category**	**Proportion of respondents with high acceptability [95%CI]**	**OR [95%CI]**	**p-value**
Gender	Woman	532	85.9 [0.83, 0.89]	Reference	.
	Male	474	85.0 [0.81, 0.88]	1.08 [0.78, 1.49]	0.65
	Non-Binary	8	75.0 [0.35, 0.97]	0.20 [0.1, 0.41]	0
	Other	1	100.0 [0.03, 1.00]	.	.
Age	18 to 24	128	93.8 [0.88, 0.97]	Reference	.
	25 to 34	185	88.1 [0.83, 0.92]	0.48 [0.38, 0.62]	0
	35 to 44	180	84.4 [0.78, 0.89]	0.36 [0.28, 0.46]	0
	45 to 54	153	85.0 [0.78, 0.90]	0.41 [0.26, 0.64]	0
	55 to 64	168	80.4 [0.74, 0.86]	0.33 [0.19, 0.55]	0
	65 to 74	115	80.0 [0.72, 0.87]	0.37 [0.16, 0.83]	0.02
	75 or older	86	87.2 [0.78, 0.93]	0.61 [0.28, 1.37]	0.24

Ethnicity	White	59	84.3 [0.81, 0.87]	Reference	.
	Indigenous	192	91.5 [0.81, 0.97]	1.62 [1.23, 2.15]	0
	Other	744	88.5 [0.83, 0.93]	1.11 [0.83, 1.48]	0.5
	NA	20	80.0 [0.56, 0.94]	0.56 [0.12, 2.51]	0.44
Region	Urban	347	88.5 [0.85, 0.92]	Reference	.
	Suburban E	195	84.6 [0.79, 0.89]	0.92 [0.8, 1.06]	0.27
	Suburban S	197	85.8 [0.80, 0.90]	0.84 [0.77, 0.91]	0
	Suburban W	139	82.7 [0.75, 0.89]	0.71 [0.66, 0.77]	0
	Rural	137	81.0 [0.73, 0.87]	0.76 [0.62, 0.93]	0.01
Residence in Canada	Less than 1 year	13	100.0 [0.75, 1.00]	Reference	.
	1-5 years	45	88.9 [0.76, 0.96]	0.98 [0.41, 2.36]	0.97
	6-10 years	37	94.6 [0.82, 0.99]	2.47 [0.75, 8.09]	0.14
	10+ years	920	84.7 [0.82, 0.87]	.	.
Income	< $20,000	51	92.2 [0.81, 0.98]	Reference	.
	$20,000 to $39,999	72	88.9 [0.79, 0.95]	1.00 [0.37, 2.74]	1
	$40,000 to $59,999	102	85.3 [0.77, 0.92]	0.70 [0.25, 1.91]	0.48
	$60,000 to $79,999	125	85.6 [0.78, 0.91]	0.63 [0.34, 1.16]	0.14
	$80,000 to $99,999	162	82.7 [0.76, 0.88]	0.47 [0.24, 0.93]	0.03
	$100,000 to $119,000	141	86.5 [0.80, 0.92]	0.64 [0.33, 1.26]	0.2
	$120,000 or more	276	82.6 [0.78, 0.87]	0.55 [0.24, 1.27]	0.16
	NA	86	90.7 [0.82, 0.96]	1.23 [0.39, 3.82]	0.73
Education	Highschool or less	130	81.5 [0.74, 0.88]	Reference	.
	College	288	87.2 [0.83, 0.91]	1.57 [0.93, 2.67]	0.09
	University +	594	85.4 [0.82, 0.88]	1.39 [0.79, 2.46]	0.26
	Other/ NA	3	100.0 [0.29, 1.00]	.	.
Occupation	Indoors	591	85.8 [0.83, 0.89]	Reference	.
	Mixed	128	90.6 [0.84, 0.95]	1.29 [0.64, 2.58]	0.48
	Outdoors	37	89.2 [0.75, 0.97]	0.98 [0.29, 3.27]	0.97
	Other	259	81.5 [0.76, 0.86]	0.82 [0.62, 1.09]	0.17
Forest	25+ per year	145	89.7 [0.84, 0.94]	Reference	.
	11-25 per year	226	87.6 [0.83, 0.92]	0.77 [0.4, 1.48]	0.44
	2-10 per year	302	87.1 [0.83, 0.91]	0.72 [0.41, 1.26]	0.25
	2/year	231	80.5 [0.75, 0.85]	0.47 [0.31, 0.73]	0
	never	111	81.1 [0.73, 0.88]	0.47 [0.21, 1.05]	0.06
Pet	Yes	393	84.0 [0.80, 0.87]	Reference	.
	No	622	86.3 [0.83, 0.89]	1.26 [0.79, 2.01]	0.33

Tick bite	Never	848	85.3 [0.83, 0.88]	.	.
	1-2 times	148	84.5 [0.78, 0.90]	0.57 [0.27, 1.17]	0.13
	3+ times	19	100.0 [0.82, 1.00]	.	.
Tick encounter	Never	782	84.8 [0.82, 0.87]	Reference	.
	1-2 times	183	85.8 [0.80, 0.91]	1.04 [0.45, 2.37]	0.93
	3+ times	50	94.0 [0.83, 0.99]	2.28 [0.88, 5.88]	0.09
Environmentally Applied: Biological Acceptability					
	Category	**No. respondents in category**	**Proportion of respondents with high acceptability [95%CI]**	**OR [95%CI]**	**p-value**
Gender	Woman	532	74.6 [0.71, 0.78]	Reference	.
	Male	474	81.0 [0.77, 0.84]	1.32 [0.92, 1.89]	0.14
	Non-Binary	8	37.5 [0.09, 0.76]	0.17 [0.09, 0.32]	0
	Other	1	100.0 [0.03, 1.00]	.	.
Age	18 to 24	128	86.7 [0.80, 0.92]	Reference	.
	25 to 34	185	74.6 [0.68, 0.81]	0.37 [0.2, 0.7]	0
	35 to 44	180	75.6 [0.69, 0.82]	0.35 [0.27, 0.46]	0
	45 to 54	153	76.5 [0.69, 0.83]	0.41 [0.29, 0.59]	0
	55 to 64	168	75.0 [0.68, 0.81]	0.38 [0.23, 0.61]	0
	65 to 74	115	76.5 [0.68, 0.84]	0.41 [0.23, 0.72]	0
	75 or older	86	80.2 [0.70, 0.88]	0.47 [0.2, 1.07]	0.07
Ethnicity	White	59	84.7 [0.73, 0.93]	Reference	.
	Indigenous	192	78.1 [0.72, 0.84]	1.22 [0.64, 2.32]	0.54
	Other	744	77.0 [0.74, 0.80]	1.24 [0.85, 1.82]	0.27
	NA	20	60.0 [0.36, 0.81]	0.45 [0.19, 1.06]	0.07
Region	Urban	347	79.8 [0.75, 0.84]	Reference	.
	Suburban E	195	83.6 [0.78, 0.88]	1.33 [1, 1.75]	0.05
	Suburban S	197	73.1 [0.66, 0.79]	0.74 [0.64, 0.87]	0
	Suburban W	139	73.4 [0.65, 0.81]	0.78 [0.59, 1.03]	0.08
	Rural	137	72.3 [0.64, 0.80]	0.72 [0.54, 0.96]	0.03
Residence in Canada	Less than 1 year	13	92.3 [0.64, 1.00]	Reference	.
	1-5 years	45	73.3 [0.58, 0.85]	0.15 [0.02, 1.39]	0.1
	6-10 years	37	89.2 [0.75, 0.97]	0.52 [0.05, 5.57]	0.59
	10+ years	920	76.8 [0.74, 0.80]	0.27 [0.04, 1.74]	0.17
Income	< $20,000	51	68.6 [0.54, 0.81]	Reference	.
	$20,000 to $39,999	72	83.3 [0.73, 0.91]	2.68 [1.41, 5.07]	0
	$40,000 to $59,999	102	77.5 [0.68, 0.85]	1.80 [0.61, 5.36]	0.29

	$60,000 to $79,999	125	75.2 [0.67, 0.82]	1.35 [0.72, 2.51]	0.35
	$80,000 to $99,999	162	83.3 [0.77, 0.89]	1.76 [0.64, 4.82]	0.27
	$100,000 to $119,000	141	80.9 [0.73, 0.87]	1.68 [0.58, 4.81]	0.34
	$120,000 or more	276	76.1 [0.71, 0.81]	1.50 [0.92, 2.45]	0.11
	NA	86	67.4 [0.56, 0.77]	1.13 [0.49, 2.64]	0.77
Education	Highschool or less	130	73.1 [0.65, 0.80]	Reference	.
	College	288	78.8 [0.74, 0.83]	1.42 [0.81, 2.49]	0.22
	University +	594	77.6 [0.74, 0.81]	1.30 [1.05, 1.6]	0.02
	Other/ NA	3	66.7 [0.09, 0.99]	1.11 [0.13, 9.4]	0.93
Language	English	839	76.0 [0.73, 0.79]	.	.
	French	137	85.4 [0.78, 0.91]	1.90 [1.04, 3.47]	0.04
	Other	39	76.9 [0.61, 0.89]	0.96 [0.66, 1.41]	0.85
Occupation	Indoors	591	76.1 [0.72, 0.80]	Reference	.
	Mixed	128	79.7 [0.72, 0.86]	0.81 [0.44, 1.48]	0.49
	Outdoors	37	81.1 [0.65, 0.92]	0.80 [0.54, 1.18]	0.26
	Other	259	78.4 [0.73, 0.83]	1.25 [1.11, 1.4]	0
Yard	No access	171	80.1 [0.73, 0.86]	Reference	.
	Access, no maintenance	250	73.6 [0.68, 0.79]	0.61 [0.36, 1.04]	0.07
	Access and maintenance	594	78.1 [0.75, 0.81]	0.77 [0.34, 1.76]	0.54
Forest	25+ per year	145	82.8 [0.76, 0.89]	Reference	.
	11-25 per year	226	84.1 [0.79, 0.89]	0.98 [0.36, 2.63]	0.96
	2-10 per year	302	75.5 [0.70, 0.80]	0.59 [0.3, 1.18]	0.14
	2/year	231	74.0 [0.68, 0.80]	0.65 [0.35, 1.19]	0.16
	never	111	68.5 [0.59, 0.77]	0.49 [0.2, 1.22]	0.13
Tick bite	Never	848	74.9 [0.72, 0.78]	Reference	.
	1-2 times	148	90.5 [0.85, 0.95]	1.39 [0.52, 3.72]	0.52
	3+ times	19	84.2 [0.60, 0.97]	0.77 [0.45, 1.3]	0.32
Tick encounter	Never	782	73.8 [0.71, 0.77]	Reference	.
	1-2 times	183	89.6 [0.84, 0.94]	2.25 [1.12, 4.5]	0.02
	3+ times	50	88.0 [0.76, 0.95]	1.47 [0.33, 6.62]	0.61
Landscape Management Acceptability					
	Category	**No. respondents in category**	**Proportion of respondents with high acceptability [95%CI]**	**OR [95%CI]**	**p-value**
Gender	Woman	532	85.7 [0.82, 0.89]	Reference	.
	Male	474	86.5 [0.83, 0.89]	1.04 [0.54, 2.02]	0.9

	Non-Binary	8	87.5 [0.47, 1.00]	1.69 [0.8, 3.56]	0.17
	Other	1	100.0 [0.03, 1.00]	.	.
Age	18 to 24	128	82.0 [0.74, 0.88]	Reference	.
	25 to 34	185	84.3 [0.78, 0.89]	1.05 [0.51, 2.15]	0.9
	35 to 44	180	87.8 [0.82, 0.92]	1.15 [0.51, 2.58]	0.74
	45 to 54	153	88.9 [0.83, 0.93]	1.42 [0.84, 2.39]	0.2
	55 to 64	168	88.1 [0.82, 0.93]	1.46 [0.61, 3.51]	0.4
	65 to 74	115	85.2 [0.77, 0.91]	0.96 [0.34, 2.76]	0.95
	75 or older	86	84.9 [0.76, 0.92]	0.83 [0.28, 2.53]	0.75
Ethnicity	White	59	87.1 [0.84, 0.89]	Reference	.
	Indigenous	192	93.2 [0.84, 0.98]	2.92 [1.33, 6.42]	0.01
	Other	744	82.8 [0.77, 0.88]	0.81 [0.62, 1.05]	0.11
	NA	20	60.0 [0.36, 0.81]	0.19 [0.05, 0.68]	0.01
Region	Urban	347	85.6 [0.81, 0.89]	Reference	.
	Suburban E	195	88.2 [0.83, 0.92]	1.09 [0.91, 1.3]	0.37
	Suburban S	197	82.7 [0.77, 0.88]	0.65 [0.61, 0.71]	0
	Suburban W	139	89.9 [0.84, 0.94]	1.31 [1.12, 1.53]	0
	Rural	137	85.4 [0.78, 0.91]	0.84 [0.73, 0.96]	0.01
Income	< $20,000	51	68.6 [0.54, 0.81]	Reference	.
	$20,000 to $39,999	72	80.6 [0.70, 0.89]	1.85 [0.84, 4.05]	0.13
	$40,000 to $59,999	102	91.2 [0.84, 0.96]	5.00 [1.94, 12.9]	0
	$60,000 to $79,999	125	88.0 [0.81, 0.93]	3.06 [1.51, 6.19]	0
	$80,000 to $99,999	162	86.4 [0.80, 0.91]	2.04 [0.67, 6.24]	0.21
	$100,000 to $119,000	141	88.7 [0.82, 0.93]	2.58 [1.17, 5.7]	0.02
	$120,000 or more	276	85.1 [0.80, 0.89]	1.75 [1.09, 2.81]	0.02
	NA	86	90.7 [0.82, 0.96]	3.98 [1.52, 10.45]	0.01
Education	Highschool or less	130	79.2 [0.71, 0.86]	Reference	.
	College	288	87.2 [0.83, 0.91]	1.39 [0.62, 3.11]	0.42
	University +	594	87.0 [0.84, 0.90]	1.52 [0.75, 3.11]	0.25
	Other/ NA	3	100.0 [0.29, 1.00]	.	.
Language	English	839	85.6 [0.83, 0.88]	Reference	.
	French	137	89.8 [0.83, 0.94]	1.45 [0.89, 2.36]	0.14
	Other	39	84.6 [0.69, 0.94]	0.79 [0.39, 1.61]	0.52
Occupation	Indoors	591	87.1 [0.84, 0.90]	Reference	.
	Mixed	128	85.9 [0.79, 0.91]	0.97 [0.51, 1.85]	0.93
	Outdoors	37	67.6 [0.50, 0.82]	0.27 [0.06, 1.18]	0.08
	Other	259	86.5 [0.82, 0.90]	0.85 [0.42, 1.73]	0.65

Yard	No access	171	83.6 [0.77, 0.89]	Reference	.
	Access, no maintenance	250	81.2 [0.76, 0.86]	0.91 [0.67, 1.23]	0.53
	Access and maintenance	594	88.9 [0.86, 0.91]	1.69 [1.18, 2.42]	0
Pet	Yes	393	83.2 [0.79, 0.87]	Reference	.
	No	622	87.9 [0.85, 0.90]	1.93 [1.32, 2.84]	0
Tick encounter	Never	782	85.3 [0.83, 0.88]	Reference	.
	1-2 times	183	90.2 [0.85, 0.94]	1.68 [0.91, 3.1]	0.1
	3+ times	50	84.0 [0.71, 0.93]	0.77 [0.28, 2.15]	0.62
Host Targeted Methods: Small Mammal Acceptability					
	Category	**No. respondents in category**	**Proportion of respondents with high acceptability [95%CI]**	**OR [95%CI]**	**p-value**
Gender	Woman	532	74.4 [0.71, 0.78]	Reference	.
	Male	474	77.0 [0.73, 0.81]	1.05 [0.67, 1.62]	0.85
	Non-Binary	8	62.5 [0.24, 0.91]	0.63 [0.34, 1.15]	0.13
	Other	1	100.0 [0.03, 1.00]	.	.
Age	18 to 24	128	73.4 [0.65, 0.81]	Reference	.
	25 to 34	185	73.0 [0.66, 0.79]	1.18 [0.42, 3.3]	0.76
	35 to 44	180	76.7 [0.70, 0.83]	1.31 [0.49, 3.49]	0.59
	45 to 54	153	77.1 [0.70, 0.84]	1.47 [0.62, 3.5]	0.38
	55 to 64	168	74.4 [0.67, 0.81]	1.18 [0.41, 3.42]	0.76
	65 to 74	115	79.1 [0.71, 0.86]	1.68 [0.73, 3.9]	0.22
	75 or older	86	76.7 [0.66, 0.85]	1.34 [0.67, 2.67]	0.41
Ethnicity	White	59	83.1 [0.71, 0.92]	Reference	.
	Indigenous	192	76.0 [0.69, 0.82]	1.75 [1.27, 2.4]	0
	Other	744	74.9 [0.72, 0.78]	1.12 [0.88, 1.41]	0.36
	NA	20	75.0 [0.51, 0.91]	1.06 [0.74, 1.53]	0.75
Region	Urban	347	77.5 [0.73, 0.82]	Reference	.
	Suburban E	195	76.9 [0.70, 0.83]	0.94 [0.78, 1.12]	0.48
	Suburban S	197	73.1 [0.66, 0.79]	0.82 [0.77, 0.87]	0
	Suburban W	139	72.7 [0.64, 0.80]	0.75 [0.65, 0.87]	0
	Rural	137	75.2 [0.67, 0.82]	0.85 [0.72, 1]	0.05
Residence in Canada	Less than 1 year	13	92.3 [0.64, 1.00]	Reference	.
	1-5 years	45	68.9 [0.53, 0.82]	0.20 [0.05, 0.73]	0.02
	6-10 years	37	83.8 [0.68, 0.94]	0.56 [0.06, 5.23]	0.61
	10+ years	920	75.3 [0.72, 0.78]	0.38 [0.12, 1.16]	0.09
Income	< $20,000	51	78.4 [0.65, 0.89]	Reference	.

	$20,000 to $39,999	72	79.2 [0.68, 0.88]	0.87 [0.51, 1.48]	0.6
	$40,000 to $59,999	102	77.5 [0.68, 0.85]	0.72 [0.22, 2.36]	0.59
	$60,000 to $79,999	125	68.0 [0.59, 0.76]	0.42 [0.17, 1.02]	0.06
	$80,000 to $99,999	162	76.5 [0.69, 0.83]	0.58 [0.25, 1.31]	0.19
	$100,000 to $119,000	141	80.1 [0.73, 0.86]	0.69 [0.36, 1.32]	0.27
	$120,000 or more	276	75.7 [0.70, 0.81]	0.61 [0.27, 1.4]	0.25
	NA	86	69.8 [0.59, 0.79]	0.53 [0.15, 1.86]	0.32
Education	Highschool or less	130	68.5 [0.60, 0.76]	Reference	.
	College	288	76.4 [0.71, 0.81]	1.63 [1.03, 2.57]	0.04
	University +	594	76.8 [0.73, 0.80]	1.54 [1, 2.37]	0.05
	Other/ NA	3	66.7 [0.09, 0.99]	0.55 [0.04, 7.88]	0.66
Language	English	839	74.5 [0.71, 0.77]	Reference	.
	French	137	77.4 [0.69, 0.84]	1.18 [0.85, 1.63]	0.33
	Other	39	92.3 [0.79, 0.98]	3.85 [1.44, 10.33]	0.01
Occupation	Indoors	591	74.3 [0.71, 0.78]	Reference	.
	Mixed	128	82.0 [0.74, 0.88]	1.24 [0.49, 3.13]	0.66
	Outdoors	37	59.5 [0.42, 0.75]	0.38 [0.07, 1.95]	0.25
	Other	259	77.6 [0.72, 0.83]	1.24 [0.61, 2.52]	0.56
Forest	25+ per year	145	78.6 [0.71, 0.85]	Reference	.
	11-25 per year	226	77.9 [0.72, 0.83]	0.90 [0.59, 1.37]	0.62
	2-10 per year	302	73.8 [0.68, 0.79]	0.78 [0.5, 1.2]	0.25
	2/year	231	77.1 [0.71, 0.82]	1.00 [0.51, 1.99]	0.99
	never	111	68.5 [0.59, 0.77]	0.67 [0.33, 1.38]	0.28
Tick encounter	Never	782	72.8 [0.69, 0.76]	Reference	.
	1-2 times	183	86.3 [0.80, 0.91]	2.63 [1.36, 5.09]	0
	3+ times	50	80.0 [0.66, 0.90]	1.48 [0.4, 5.52]	0.56
Host Targeted Methods: Deer Acceptability					
	Category	**No. respondents in category**	**Proportion of respondents with high acceptability [95%CI]**	**OR [95%CI]**	**p-value**
Gender	Woman	532	63.7 [0.59, 0.68]	Reference	.
	Male	474	65.4 [0.61, 0.70]	0.98 [0.67, 1.43]	0.93
	Non-Binary	8	87.5 [0.47, 1.00]	3.93 [2.01, 7.71]	0
	Other	1	0.0 [0.00, 0.98]	.	.
Age	18 to 24	128	71.9 [0.63, 0.79]	Reference	.
	25 to 34	185	62.7 [0.55, 0.70]	0.80 [0.54, 1.18]	0.26
	35 to 44	180	63.9 [0.56, 0.71]	0.80 [0.47, 1.36]	0.41

	45 to 54	153	63.4 [0.55, 0.71]	0.92 [0.62, 1.37]	0.68
	55 to 64	168	58.9 [0.51, 0.66]	0.81 [0.48, 1.37]	0.44
	65 to 74	115	65.2 [0.56, 0.74]	1.07 [0.74, 1.53]	0.72
	75 or older	86	72.1 [0.61, 0.81]	1.42 [0.69, 2.93]	0.34
Ethnicity	White	59	79.7 [0.67, 0.89]	Reference	.
	Indigenous	192	64.1 [0.57, 0.71]	2.05 [0.91, 4.61]	0.08
	Other	744	64.0 [0.60, 0.67]	0.96 [0.67, 1.39]	0.84
	NA	20	50.0 [0.27, 0.73]	0.59 [0.43, 0.8]	0
Region	Urban	347	67.7 [0.63, 0.73]	Reference	.
	Suburban E	195	69.7 [0.63, 0.76]	1.14 [1.05, 1.24]	0
	Suburban S	197	64.5 [0.57, 0.71]	0.90 [0.82, 0.99]	0.03
	Suburban W	139	61.9 [0.53, 0.70]	0.85 [0.76, 0.94]	0
	Rural	137	52.6 [0.44, 0.61]	0.55 [0.49, 0.62]	0
Income	< $20,000	51	62.7 [0.48, 0.76]	Reference	.
	$20,000 to $39,999	72	63.9 [0.52, 0.75]	1.00 [0.52, 1.92]	0.99
	$40,000 to $59,999	102	63.7 [0.54, 0.73]	0.98 [0.61, 1.56]	0.92
	$60,000 to $79,999	125	66.4 [0.57, 0.75]	1.01 [0.41, 2.51]	0.98
	$80,000 to $99,999	162	66.7 [0.59, 0.74]	0.95 [0.43, 2.1]	0.9
	$100,000 to $119,000	141	74.5 [0.66, 0.81]	1.48 [0.67, 3.25]	0.33
	$120,000 or more	276	59.4 [0.53, 0.65]	0.80 [0.39, 1.66]	0.55
	NA	86	61.6 [0.51, 0.72]	0.90 [0.38, 2.15]	0.82
Education	Highschool or less	130	54.6 [0.46, 0.63]	Reference	.
	College	288	66.7 [0.61, 0.72]	1.71 [1.35, 2.17]	0
	University +	594	65.8 [0.62, 0.70]	1.67 [1.14, 2.46]	0.01
	Other/ NA	3	66.7 [0.09, 0.99]	1.62 [0.15, 17.93]	0.69
Forest	25+ per year	145	60.0 [0.52, 0.68]	Reference	.
	11-25 per year	226	66.4 [0.60, 0.73]	1.20 [1.04, 1.38]	0.01
	2-10 per year	302	67.9 [0.62, 0.73]	1.46 [0.98, 2.16]	0.06
	2/year	231	62.8 [0.56, 0.69]	1.21 [0.81, 1.81]	0.35
	never	111	62.2 [0.52, 0.71]	1.30 [0.69, 2.44]	0.42
Pet	Yes	393	62.3 [0.57, 0.67]	Reference	.
	No	622	66.1 [0.62, 0.70]	1.18 [0.97, 1.43]	0.09
Tick encounter	Never	782	62.0 [0.59, 0.65]	Reference	.
	1-2 times	183	75.4 [0.69, 0.81]	1.85 [1.46, 2.34]	0
	3+ times	50	66.0 [0.51, 0.79]	1.10 [0.3, 4]	0.88
Personal Prevention: Behavioral Acceptability					

	Category	No. respondents in category	Proportion of respondents with high acceptability [95%CI]	OR [95%CI]	p-value
Gender	Woman	532	96.8 [0.95, 0.98]	Reference	.
	Male	474	92.4 [0.90, 0.95]	0.35 [0.19, 0.67]	0
	Non-Binary	8	100.0 [0.63, 1.00]	.	.
	Other	1	100.0 [0.03, 1.00]	.	.
Age	18 to 24	128	94.5 [0.89, 0.98]	Reference	.
	25 to 34	185	95.1 [0.91, 0.98]	1.39 [0.26, 7.32]	0.7
	35 to 44	180	93.9 [0.89, 0.97]	0.69 [0.28, 1.73]	0.43
	45 to 54	153	94.1 [0.89, 0.97]	1.00 [0.47, 2.14]	1
	55 to 64	168	97.0 [0.93, 0.99]	1.58 [0.69, 3.63]	0.28
	65 to 74	115	90.4 [0.84, 0.95]	0.43 [0.24, 0.76]	0
	75 or older	86	98.8 [0.94, 1.00]	3.28 [0.33, 32.79]	0.31
Ethnicity	White	59	91.5 [0.81, 0.97]	Reference	.
	Indigenous	192	93.2 [0.89, 0.96]	0.54 [0.17, 1.73]	0.3
	Other	744	95.4 [0.94, 0.97]	0.53 [0.26, 1.08]	0.08
	NA	20	95.0 [0.75, 1.00]	0.55 [0.13, 2.31]	0.41
Region	Urban	347	94.5 [0.92, 0.97]	Reference	.
	Suburban E	195	96.9 [0.93, 0.99]	2.52 [2.13, 2.97]	0
	Suburban S	197	91.9 [0.87, 0.95]	0.67 [0.51, 0.86]	0
	Suburban W	139	95.7 [0.91, 0.98]	0.82 [0.42, 1.59]	0.55
	Rural	137	95.6 [0.91, 0.98]	1.06 [0.65, 1.74]	0.82
Residence in Canada	Less than 1 year	13	100.0 [0.75, 1.00]	Reference	.
	1-5 years	45	95.6 [0.85, 0.99]	1.49 [0.23, 9.51]	0.68
	6-10 years	37	91.9 [0.78, 0.98]	1.16 [0.42, 3.23]	0.77
	10+ years	920	94.8 [0.93, 0.96]	.	.
Income	< $20,000	51	96.1 [0.87, 1.00]	Reference	.
	$20,000 to $39,999	72	95.8 [0.88, 0.99]	1.37 [0.48, 3.94]	0.56
	$40,000 to $59,999	102	95.1 [0.89, 0.98]	1.16 [0.36, 3.8]	0.81
	$60,000 to $79,999	125	91.2 [0.85, 0.96]	0.58 [0.08, 4.39]	0.6
	$80,000 to $99,999	162	93.8 [0.89, 0.97]	0.83 [0.24, 2.91]	0.77
	$100,000 to $119,000	141	95.0 [0.90, 0.98]	0.70 [0.26, 1.88]	0.48
	$120,000 or more	276	94.9 [0.92, 0.97]	0.88 [0.11, 6.86]	0.91
	NA	86	98.8 [0.94, 1.00]	3.17 [0.23, 43.88]	0.39
Education	Highschool or less	130	93.1 [0.87, 0.97]	Reference	.

	College	288	94.1 [0.91, 0.97]	1.13 [0.3, 4.2]	0.86
	University +	594	95.5 [0.93, 0.97]	1.67 [0.67, 4.15]	0.27
	Other/ NA	3	100.0 [0.29, 1.00]	.	.
Language	English	839	95.5 [0.94, 0.97]	Reference	.
	French	137	89.8 [0.83, 0.94]	0.25 [0.12, 0.51]	0
	Other	39	97.4 [0.87, 1.00]	2.26 [0.42, 12.24]	0.35
Occupation	Indoors	591	94.8 [0.93, 0.96]	Reference	.
	Mixed	128	96.1 [0.91, 0.99]	1.32 [0.38, 4.56]	0.66
	Outdoors	37	81.1 [0.65, 0.92]	0.32 [0.07, 1.46]	0.14
	Other	259	96.1 [0.93, 0.98]	1.43 [0.94, 2.19]	0.1
Yard	No access	171	95.9 [0.92, 0.98]	Reference	.
	Access, no maintenance	250	92.0 [0.88, 0.95]	0.54 [0.27, 1.09]	0.09
	Access and maintenance	594	95.6 [0.94, 0.97]	1.39 [0.44, 4.34]	0.58
Pet	Yes	393	93.1 [0.90, 0.95]	Reference	.
	No	622	95.8 [0.94, 0.97]	2.21 [0.97, 5.02]	0.06
Tick bite	Never	848	95.2 [0.93, 0.97]	Reference	.
	1-2 times	148	93.9 [0.89, 0.97]	0.17 [0.05, 0.65]	0.01
	3+ times	19	84.2 [0.60, 0.97]	0.06 [0.02, 0.19]	0
Tick encounter	Never	782	94.1 [0.92, 0.96]	Reference	.
	1-2 times	183	96.7 [0.93, 0.99]	11.17 [1.5, 83.29]	0.02
	3+ times	50	98.0 [0.89, 1.00]	37.84 [1.12, 1275.63]	0.04
Personal Prevention: Chemical Acceptability					
	Category	**No. respondents in category**	**Proportion of respondents with high acceptability [95%CI]**	**OR [95%CI]**	**p-value**
Gender	Woman	532	85.9 [0.83, 0.89]	Reference	.
	Male	474	89.7 [0.87, 0.92]	1.36 [0.93, 2]	0.11
	Non-Binary	8	100.0 [0.63, 1.00]	.	.
	Other	1	100.0 [0.03, 1.00]	.	.
Age	18 to 24	128	96.1 [0.91, 0.99]	Reference	.
	25 to 34	185	87.6 [0.82, 0.92]	0.34 [0.09, 1.33]	0.12
	35 to 44	180	87.2 [0.81, 0.92]	0.29 [0.07, 1.2]	0.09
	45 to 54	153	85.6 [0.79, 0.91]	0.26 [0.07, 0.97]	0.05
	55 to 64	168	84.5 [0.78, 0.90]	0.20 [0.06, 0.68]	0.01
	65 to 74	115	82.6 [0.74, 0.89]	0.16 [0.05, 0.51]	0
	75 or older	86	94.2 [0.87, 0.98]	0.51 [0.08, 3.43]	0.49
Ethnicity	White	59	89.8 [0.79, 0.96]	Reference	.
	Indigenous	192	89.1 [0.84, 0.93]	0.75 [0.39, 1.44]	0.39

	Other	744	87.6 [0.85, 0.90]	1.01 [0.48, 2.13]	0.98
	NA	20	75.0 [0.51, 0.91]	0.42 [0.13, 1.33]	0.14
Region	Urban	347	86.5 [0.82, 0.90]	Reference	.
	Suburban E	195	90.3 [0.85, 0.94]	1.83 [1.64, 2.04]	0
	Suburban S	197	89.3 [0.84, 0.93]	1.39 [1.12, 1.73]	0
	Suburban W	139	85.6 [0.79, 0.91]	0.81 [0.64, 1.02]	0.07
	Rural	137	87.6 [0.81, 0.93]	1.21 [0.96, 1.53]	0.12
Residence in Canada	Less than 1 year	13	100.0 [0.75, 1.00]	Reference	.
	1-5 years	45	80.0 [0.65, 0.90]	0.52 [0.23, 1.15]	0.1
	6-10 years	37	91.9 [0.78, 0.98]	0.92 [0.16, 5.44]	0.93
	10+ years	920	87.8 [0.86, 0.90]	.	.
Income	< $20,000	51	88.2 [0.76, 0.96]	Reference	.
	$20,000 to $39,999	72	81.9 [0.71, 0.90]	0.86 [0.42, 1.79]	0.69
	$40,000 to $59,999	102	89.2 [0.82, 0.94]	1.53 [0.27, 8.68]	0.63
	$60,000 to $79,999	125	82.4 [0.75, 0.89]	0.68 [0.15, 3.03]	0.61
	$80,000 to $99,999	162	91.4 [0.86, 0.95]	1.62 [0.63, 4.17]	0.32
	$100,000 to $119,000	141	89.4 [0.83, 0.94]	1.16 [0.3, 4.53]	0.83
	$120,000 or more	276	88.0 [0.84, 0.92]	1.18 [0.28, 5.08]	0.82
	NA	86	88.4 [0.80, 0.94]	1.36 [0.24, 7.77]	0.73
Education	Highschool or less	130	88.5 [0.82, 0.93]	Reference	.
	College	288	85.8 [0.81, 0.90]	0.80 [0.29, 2.25]	0.68
	University +	594	88.6 [0.86, 0.91]	0.95 [0.43, 2.08]	0.9
	Other/ NA	3	100.0 [0.29, 1.00]	.	.
Language	English	839	88.6 [0.86, 0.91]	Reference	.
	French	137	81.8 [0.74, 0.88]	0.46 [0.28, 0.76]	0
	Other	39	92.3 [0.79, 0.98]	2.30 [0.83, 6.4]	0.11
Occupation	Indoors	591	86.6 [0.84, 0.89]	Reference	.
	Mixed	128	93.0 [0.87, 0.97]	1.56 [0.82, 2.98]	0.18
	Outdoors	37	89.2 [0.75, 0.97]	1.24 [0.42, 3.69]	0.7
	Other	259	87.6 [0.83, 0.91]	1.27 [0.72, 2.26]	0.41
Yard	No access	171	87.7 [0.82, 0.92]	Reference	.
	Access, no maintenance	250	84.0 [0.79, 0.88]	0.84 [0.5, 1.4]	0.51
	Access and maintenance	594	89.4 [0.87, 0.92]	1.38 [0.78, 2.43]	0.27
Forest	25+ per year	145	82.8 [0.76, 0.89]	Reference	.

	11-25 per year	226	88.1 [0.83, 0.92]	1.31 [0.65, 2.61]	0.45
	2-10 per year	302	92.4 [0.89, 0.95]	2.56 [0.9, 7.3]	0.08
	2/year	231	86.1 [0.81, 0.90]	1.29 [0.63, 2.66]	0.49
	never	111	84.7 [0.77, 0.91]	1.46 [0.79, 2.71]	0.23
Pet	Yes	393	87.0 [0.83, 0.90]	Reference	.
	No	622	88.3 [0.85, 0.91]	1.49 [0.83, 2.66]	0.18
Tick encounter	Never	782	86.1 [0.83, 0.88]	Reference	.
	1-2 times	183	92.3 [0.87, 0.96]	1.74 [1.23, 2.48]	0
	3+ times	50	98.0 [0.89, 1.00]	6.40 [1.49, 27.53]	0.01
Lyme disease diagnosis	Yes	34	91.2 [0.76, 0.98]	Reference	.
	No	967	87.9 [0.86, 0.90]	1.17 [0.73, 1.89]	0.51
	Unknown	14	71.4 [0.42, 0.92]	0.16 [0.06, 0.44]	0

8.3.4 Key informant consent form

Consent Form

Investigating the Feasibility and Acceptability of Lyme Disease Interventions in Ottawa

Katarina Ost; MPH

PhD Candidate; Faculty of Medicine, School of Epidemiology and Public Health

Doctoral Thesis under the supervision of Dr. Manisha Kulkarni

Manisha Kulkarni; PhD BSc

Associate Professor; Faculty of Medicine, School of Epidemiology and Public Health

Funding: CIHR-CGS [476872]

Invitation to Participate: I am invited to participate in the abovementioned research study conducted by Katarina Ost and Manisha Kulkarni, as a part of Ms. Ost's PhD thesis.

Purpose of the Study: The purpose of the study is to learn more about my views and opinions on the acceptability and feasibility of certain interventions used to prevent tick bites and tick-borne diseases like Lyme disease. The researchers will use this information to help organizations, and the general public better understand the range of interventions options available to them, as well as inform the design and distribution of a survey which will gauge the public acceptability of the interventions, we find to be the most highly feasible as a result of these interviews.

Participation: My participation will consist of a one-on-one interview with a member of our study team which should take 45-60 minutes. This kind of interview is called a semi-structured interview. During this interview I will be asked to provide my views on the feasibility and acceptability of certain Lyme disease prevention activities, and provide my insight into how the organization I work with affects and/or is affected by these activities. The research team will also ask me to rank certain prevention activities in terms of high or low feasibility. I understand that this interview is being conducted independently from the organization I work or volunteer with. My interview will be recorded and transcribed by the research team to help them get the most information from the interview as possible.

Risks: My participation in this study will entail that I answer questions about my experiences and opinions. Though risks are minimal, I do not have to answer any question that makes me feel uncomfortable. I have received assurance from the researchers that every effort will be made to minimize these risks of discomfort and I am aware that I may leave the interview at any time if I do not want to participate anymore.

Benefits: My participation in this study will not directly benefit me, but it will contribute to a better understanding of the best, most acceptable methods of tick control and Lyme disease prevention in the Ottawa area.

Confidentiality: I have received assurance from the researchers that the information I will share will remain strictly confidential. I understand that the contents will be used only for research purposes and that my identity will be protected. I understand that the study team will not use my title and organization in the dissemination of findings, but rather a general description of the type of organization I work or volunteer for

Conservation of Data: The data collected during this interview including audio files and transcripts will be kept in a secure manner for the duration of the study. Any video generated by the recording feature on platforms such as teams or zoom will be permanently deleted from the researcher's computer immediately after completion of the interview by deleting the video file from files on the computer as well as computer recycle bins. Only study team members will have access to these data. Exported data files will be password-protected and only be accessible by the research team members. All data will be retained for a period of 5 years from the point of publication of results.

Compensation: As a thank you for my participation I will receive a $15CAD gift card to Tango, a company that allows me to choose my gift card from a catalogue of options. I will receive a gift card as a thank you for my time even if I chose to withdraw from the study later on.

Voluntary Participation: I am under no obligation to participate and if I choose to participate, I can withdraw from the study at any time and/or refuse to answer any questions, without suffering any negative consequences. If I choose to withdraw, all data gathered until the time of withdrawal will be removed from the dataset and not used in this study if that is my wish.

If I have any questions about the study, I may contact the researcher or their supervisor. If I have any questions regarding the ethical conduct of this study, I may contact the Office of Research Ethics and Integrity via email (ethics@uottawa.ca) or telephone (613-562-5387).

It is recommended that I (keep/print/save) a copy of this consent form for my records.

Acceptance: By verbally agreeing, I agree to participate in this research study. The recording of my verbal agreement will serve as proof of consent to participate in this research study.

8.3.5 Key informant interview guide

Semi-structured key informant interview guide

Introduction:

Hello, I am (interviewer name). I am a student researcher with the University of Ottawa School of Epidemiology and Public Health. Thank you for agreeing to speak with us today.

For the purposes of this research, we will be recording this session. This recording will be used so that we can listen to, and transcribe our discussion to ensure that all the information we document is accurate. This recording will not be made available outside of the research team involved in the project. Results from the interviews will not specifically identify individuals interviewed or their organizations. We will report results in an aggregate form and by the types of stakeholders we have interviewed. Do you have any questions? May I start the recording now?

Overview of the Project:

As I mentioned in our initial communication and consent process our goal to understand the most feasible and acceptable tick control interventions in a context that is specific to Ottawa. This is an important step to reducing the number of cases of Lyme disease in the area. We would like to do this in order to make future recommendations on possible interventions that could be used at a larger scale.

To achieve this goal, we are going to start with these key informant interviews like this one to understand your, and your organizations', perspective on the issue. We will then use that information to create a survey which will measure how acceptable the community finds the most feasible options we discuss during these interviews. We are particularly interested in hearing about your opinion through your work with (organization name).

Introductory questions:

1. Can you tell me a bit about who you are, who you work for, and what you do for your organization?
    a. Who are your "clientele or your service users"? What activities do they engage in?
2. How is your organization affected by ticks in anyway? For example, are your "clients/ service users" at risk of getting bitten by ticks?
    a. How important would you say this issue is to you?
    b. How important would you say this issue is to your organization?
    c. Do you feel that you have an obligation or a role in the control of ticks? [and why?]
    d. Does your organization feel that you have an obligation or a role in the control of ticks? [and why?]
    e. Is there anything else you want to add?
3. How is your organization affected by Lyme disease in anyway? For example, are your "clients/ service users" at risk of contracting Lyme disease?
    a. How important would you say this issue is to you?
    b. How important would you say this issue is to your organization?
    c. Do you feel that you have an obligation or a role in the control of Lyme Disease? [and why?]
    d. Does your organization feel that you have an obligation or a role in the control of Lyme Disease? [and why?]
    e. Is there anything else you want to add?

4. How are you or your organization currently involved in any efforts to control ticks?
    a. What steps are you taking?
    b. What steps is your organization taking?
    c. Do you think these control activities have been successful?
        i. Why or why not? Technical guidance, budget, availability of resources, leadership, buy-in
    d. What do you think could be improved to make these activities more successful or sustainable?
5. How are you or your organization currently involved in any efforts to control Lyme Disease?
    a. What steps are you taking?
    b. What steps is your organization taking?
    c. Do you think these control activities have been successful?
        i. Why or why not? Technical guidance, budget, availability of resources, leadership, buy-in
    d. What do you think could be improved to make these activities more successful or sustainable?

    e. *Have you seen any changes during your time with your organization?*
    f. *What led to these changes?*

Break: present control options with list for key informant to review

Landscape management	**Management of wildlife host parasitism, movement, and density**	**Chemical insecticides, biological control agents, natural tick control products**	**Personal protection**
Vegetation clearing Vegetation burning Barrier approaches (e.g. Japanese barberry)	Deer Management • Deer exclusion • Deer reduction Deer parasitism suppression • 4 poster [topical treatment], • Vaccine Small mammal management ○ Rodent parasitism and pathogen infection suppression ▪ Acaracide-treated nesting material ▪ Bait Boxes ▪ Rodent reduction ▪ Oral vaccine bait ▪ Animal host vaccines	Chemical control • Organophosphates • Carbamates • Pyrethroids Natural products/ Biocontrol • Natural enemies • Wolf Spiders • Biological agents • Entomopathogenic bacteria • Entomopathogenic fungi • Nematodes	Permethrin treated clothing/uniforms Application of spray repellents to skin or clothing Exposure and preventive behaviors or individual behavior changes • Habitat avoidance • Checking • Showering/ Bathing

1. Do you have questions on any of these control methods before we discuss them?

Questions on Intervention Categories:

Repeat these for each category type (n=4):
Order statement w/in categories, then probe for "why's"

1. What types of interventions (Table 2) would your organization be most inclined to participate in, which overall category do you think your organization would be most interested in being applied or applying themselves? [and why?]
    a. Within this [x] category which specific intervention type(s) do you think would be the most highly feasible (readily implemented)? [and why?]
    b. Within this category which specific intervention types do you think would be the least feasible (not readily implemented)? [and why?]
2. Do you think that this intervention type would be highly acceptable to you, your organization, and the larger community? [and why?]
3. Do you think the feasibility and acceptability line up well to make this a successful (or potentially successful) intervention?

--*After completing w/in category ranking*--

4. Of all the interventions in these four categories which one do you think would be the most successful and feasible to you and your organization?

Questions on community (select the most highly ranked intervention from the last section):

1. What do you think about your community's trust in this intervention?
    a. How do you think we can reach the most high-risk communities with this intervention?
    b. Do you think that there will be differences in trust across high and low risk communities?
    c. What advice do you have for the roll out of this intervention and increasing community trust?
2. What suggestions do you have for the messages we might use to promote the acceptability of this intervention in the future?
    a. What is the most important thing to communicate about this intervention?
    b. What do you think would encourage people to trust or even use this intervention?
    c. Who do you think should deliver messaging and communication (and how)?

Conclusion:

Thank you for your time and sharing your experience with us. Before we close the interview do you have any other comments on your experience with Lyme disease control programs you would like to discuss? Do you have any questions we can answer?
Thank you again and have a nice day.

8.3.6 Survey consent forms

Consent Form (EN)

Investigating the Feasibility and Acceptability of Lyme Disease Interventions in Ottawa

Katarina Ost; MPH

PhD Candidate; Faculty of Medicine, School of Epidemiology and Public Health

Doctoral Thesis under the supervision of Dr. Manisha Kulkarni

Manisha Kulkarni; PhD BSc

Professor; Faculty of Medicine, School of Epidemiology and Public Health

Funding: CIHR-CGS [476872]

Invitation to Participate: I am invited to participate in the abovementioned research study conducted by Katarina Ost and Manisha Kulkarni, as a part of Ms. Ost's PhD thesis.

Purpose of the Study: The purpose of this study is to learn more about certain preventive activities that reduce tick bites and Lyme disease and how acceptable and feasible (doable) these activities are to people living in Ottawa. This study is titled "Assessing the feasibility and acceptability of Lyme disease prevention activities in Ottawa"

Participation: My participation will consist of completing a short questionnaire which should take around 20-25 minutes. I will be asked a few questions about myself, my Lyme disease exposure and risk, and any preventive behaviours I may exercise to avoid a tick bite, as well as how acceptable I find certain prevention and control activities. For this process I will be identified by a study code, not by my name, so that the views I express and answers I provide will remain completely anonymous. Likewise, geographic information I provide will be aggregated to the neighbourhood level, so I will not be identifiable by my location.

Risks: My participation in this study will entail that I may disclose information on my personal experiences and this may cause me to feel uncomfortable. I am not required to answer any questions that I am not comfortable answering and may withdraw at any time without penalty. I have received assurance from the researchers that every effort will be made to minimize these risks by protecting my personal identifiable information.

Benefits: My participation in this study will not have any direct personal benefits, but will contribute to our knowledge of Lyme disease interventions to inform prevention activities in the future.

Confidentiality and Privacy I have received assurance from the researchers that the information I will share will remain strictly confidential. I understand that the contents will be used only for *the purposes of* *this study* and that my identity will be protected by using a user ID rather than my personal information. In order to minimize the risk of security breaches and to help ensure my confidentiality, it is recommended that I use standard safety measures, such as signing out of my account, closing my browser, and locking my device when I am no longer using it/when I have completed the study.

Conservation of Data: The data and electronic copies of responses will be encrypted and stored on the secure data servers of Leger360 and University of Ottawa (Canada). Exported data files will be password-protected and only be accessible by the research team members. All data will be retained for a period of 5 years from the point of publication of results.

Compensation: I understand that I will not be compensated by the study team for participating in this study. However, I may receive compensation through the Leger 360 membership program in the form of rewards points according to Leger 360's policy.

Voluntary Participation: I am under no obligation to participate and if I choose to participate, I can withdraw from the study at any time and/or refuse to answer any questions I do not wish to, without suffering any negative consequences. If I choose to withdraw during the survey the partial or fully collected data collected up to that point will not be used if that is my wish.

If I have any questions about the study, I may contact the researcher or their supervisor. If I have any questions regarding the ethical conduct of this study, I may contact the Office of Research Ethics and Integrity via email (ethics@uottawa.ca) or telephone (613-562-5387).

It is recommended that I *(keep/print/save)* a copy of this consent form for my records.

Consent section

- The study has been explained to me, I have been given the opportunity to ask questions concerning this study. Any such questions have been answered to my full satisfaction. I understand participation is voluntary and I may revoke this consent at any time without penalty or loss of benefits, if any.
- I agree to take part to the survey
- I also agree that the data generated from this study can be used in the future for other related research.

Acceptance: By selecting the consent statement below, I agree to participate in this research study.

- ☐ Yes, I want to participate.
  (Name/Code): ____________________
- ☐ No, I do not want to participate.

8.3.7 Survey instrument

Project Title: Investigating the Feasibility and Acceptability of Lyme Disease Interventions in Ottawa

Katarina Ost; MPH

PhD Candidate; Faculty of Medicine, School of Epidemiology and Public Health

Doctoral Thesis under the supervision of Dr. Manisha Kulkarni

Manisha Kulkarni; PhD BSc

Professor; Faculty of Medicine, School of Epidemiology and Public Health

Funding: CIHR-CGS [476872]

1. Please indicate the level of your agreement/ disagreement with the following statements regarding Landscape management strategies to try to control ticks and reduce Lyme disease.

Landscape management strategies in this category include actions such as mowing long grasses, removing fallen leaves, clearing vegetation or shrubs, or using barrier approaches (such as putting down gravel or woodchips between tick habitat and the areas where humans are living, working, or playing).

	I disagree a lot	I disagree	I agree	I agree a lot
Landscape management strategies in this category work against ticks				
Landscape management strategies in this category work against Lyme disease				

I would use these landscape management strategies in this category on my own property (or if I had a property)				
I would like these landscape management strategies in this category to be used in public spaces				
I would recommend these landscape management strategies in this category to friends or family				
I would be willing to change the way I take care of my property (or if I had a property) to incorporate landscape management strategies in this category				
I like landscape management strategies in this category				
Landscape management strategies in this category are a good way to improve health and prevent illness caused by ticks				

and tick-borne diseases				
Overall, these landscape management strategies will help my community				

2. Do you have any concerns or comments you would like to add about any of these strategies? [350 character count limit] [optional response]

3. Please indicate the level of your agreement/ disagreement with the following statements regarding Landscape management strategies to try to control ticks and reduce Lyme disease.

Landscape management strategies in this category include actions such as controlled fires or chemical burns to clear vegetation that supports tick populations.

	I disagree a lot	I disagree	I agree	I agree a lot
I would support the use of landscape strategies like controlled fires if they				

were used by a governmental agency or other organization in public spaces.				
I would support the use of landscape strategies like chemical burns if they were used by a governmental agency or other organization in public spaces.				

4. Do you have any concerns or comments you would like to add about any of these strategies? [350 character count limit] [optional response]

5. Please indicate the level of your agreement/ disagreement with the following statements regarding wildlife management strategies to control ticks and reduce Lyme disease. These strategies try to keep deer out of human activity areas like parks or gardens (deer are wildlife animals important to sustaining tick populations in nature).

Wildlife management strategies in this section include actions such as deer fencing to keep deer out of human activity areas like parks or gardens.

	I disagree a lot	I disagree	I agree	I agree a lot
These deer management strategies work against ticks				

These deer management strategies work against Lyme disease				
I would use these deer management strategies on my own property (or if I had a property)				
I would like these deer management strategies to be used in public spaces				
I would recommend these deer management strategies to friends or family				
I would be willing to change the way I take care of my property (or if I had a property) to incorporate these deer management strategies				
I like these deer management strategies				
These deer management strategies are a good way to improve health and prevent illness caused by ticks and tick-borne diseases				
Overall, these deer management strategies will				

help my community				

6. Do you have any concerns or comments you would like to add about any of these strategies? [350 character count limit] [optional response]

---

7. Please indicate the level of your agreement/ disagreement with the following statements regarding wildlife management strategies to control ticks and reduce Lyme disease. These strategies try to reduce ticks on white tailed deer (which are wildlife animals important to sustaining tick populations in nature).

Wildlife management strategies in this section include actions such as: Deer topical treatment (treating their fur), oral treatments to reduce ticks on deer, or hunting to reduce deer populations.

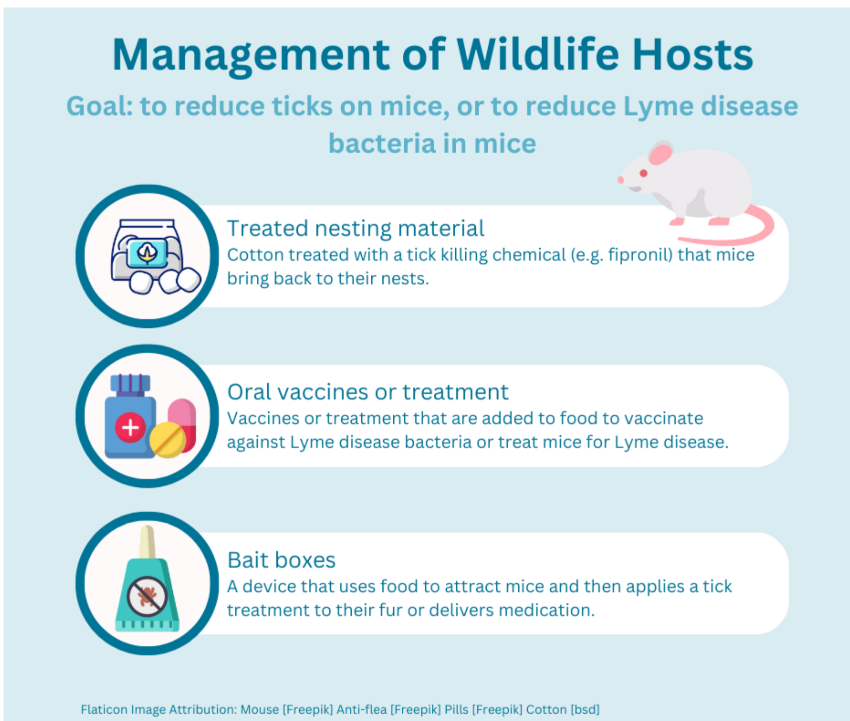
	I disagree a lot	I disagree	I agree	I agree a lot
I would support the use of controlled hunts for deer if they were used by a governmental agency or other organization in public spaces.				
I would support the use of topical treatments or oral treatments for deer if they were used by a governmental				

agency or other organization in public spaces.				

8. Do you have any concerns or comments you would like to add about wildlife management strategies in this category? [350 character count limit] [optional response]

---

9. Please indicate the level of your agreement/ disagreement with the following statements regarding <u>wildlife management strategies</u> to control ticks and reduce Lyme disease. These strategies try to reduce ticks or bacteria in mice (which are wildlife animals important to sustaining tick populations in nature).



Wildlife management strategies in this section include actions such as: Rodent topical treatment (treating their fur), oral vaccine or medication to try to reduce ticks or Lyme disease bacteria in mice.

	I disagree a lot	I disagree	I agree	I agree a lot
Rodent targeted management strategies work against ticks				
Rodent targeted management strategies work				

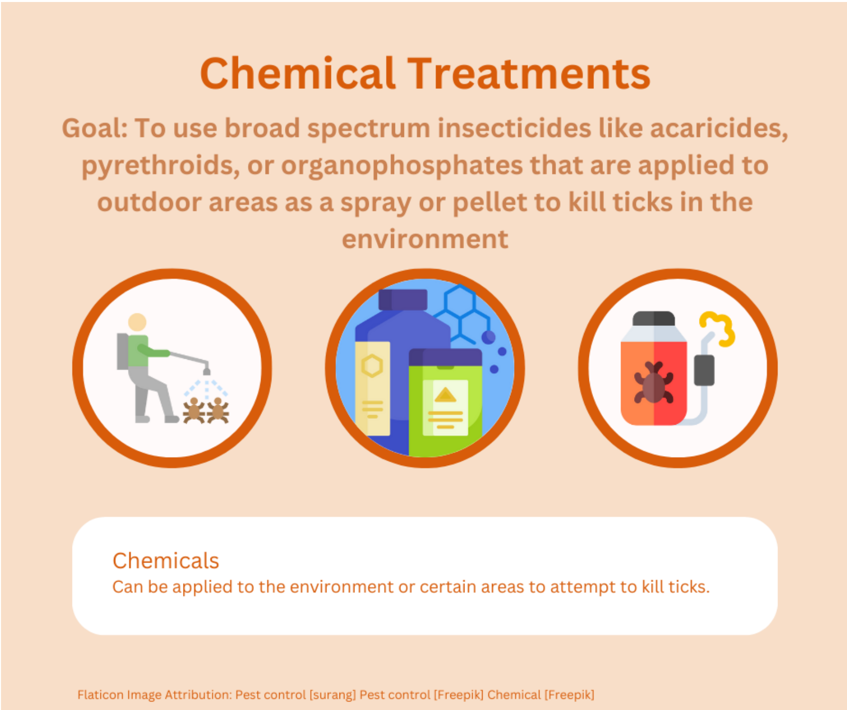
against Lyme disease				
I would use these Rodent targeted management strategies on my own property (or if I had a property)				
I would like this rodent targeted management strategies to be used in public spaces				
I would recommend these rodent targeted management strategies to friends or family				
I would be willing to change the way I take care of my property (or if I had a property) to incorporate rodent targeted management strategies				
I like rodent targeted management strategies				
Rodent targeted strategies are a good way to improve health and prevent illness caused by ticks and tick-borne diseases				

Overall, rodent targeted management strategies will help my community				

10. Do you have any concerns or comments you would like to add about any of these strategies? [350 character count limit] [optional response]

---

11. Please indicate the level of your agreement/ disagreement with the following statements regarding chemical strategies (applied to the environment) to try to control ticks and reduce Lyme disease.



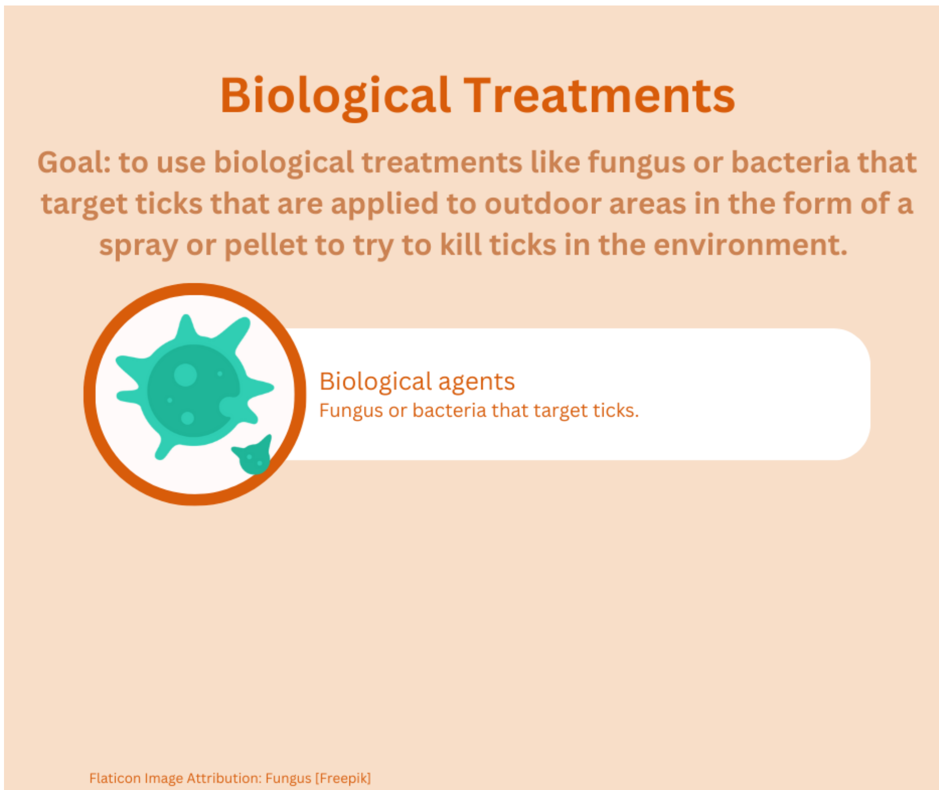
These strategies include Chemical control through insecticides (e.g. Organophosphates, Carbamates, Pyrethroids). These chemical products can be applied to the environment in the form of sprays or pellets.

	I disagree a lot	I disagree	I agree	I agree a lot
Chemical control strategies work against ticks				
Chemical control strategies work				

against Lyme disease				
I would use these chemical control strategies on my own property (or if I had a property)				
I would like these chemical control strategies to be used in public spaces				
I would recommend these chemical control strategies to friends or family				
I would be willing to change the way I take care of my property (or if I had a property) to incorporate chemical control strategies				
I like chemical control strategies				
Chemical, control strategies are a good way to improve health and prevent illness caused by ticks and tick-borne diseases				
Overall, chemical control strategies will help my community				

12. Do you have any concerns or comments you would like to add about any of these strategies? [350 character count limit] [optional response]

13. Please indicate the level of your agreement/ disagreement with the following statements regarding biological strategies to try to control ticks and reduce Lyme disease.



These products are often bacteria, or fungi that attack ticks and can be products applied to outdoor areas as sprays or pellets. These strategies include biocontrol, biological agents, entomopathogenic bacteria, entomopathogenic fungi that try to kill ticks in the environment.

	I disagree a lot	I disagree	I agree	I agree a lot
Biological control strategies work against ticks				
Biological control strategies work against Lyme disease				
I would use these biological control				

strategies on my own property (or if I had a property)				
I would like these biological control strategies to be used in public spaces				
I would recommend these biological control strategies to friends or family				
I would be willing to change the way I take care of my property (or if I had a property) to incorporate biological control strategies				
I like biological control strategies				
Biological control strategies are a good way to improve health and prevent illness caused by ticks and tick-borne diseases				
Overall, biological control strategies will help my community				

14. Do you have any concerns or comments you would like to add about any of these strategies? [350 character count limit] [optional response]

---

15. Please indicate the level of your agreement/ disagreement with the following statements regarding natural products to control ticks and reduce Lyme disease.

These strategies include natural products which are often plant based (e.g. garlic, cedar and other plant compounds) and can be applied to the environment as a pellet or spray to try to kill ticks.

	I disagree a lot	I disagree	I agree	I agree a lot
Natural control strategies work against ticks				
Natural control strategies work against Lyme disease				
I would use these natural control strategies on my own property (or if I had a property)				
I would like these natural control strategies to be				

used in public spaces				
I would recommend these natural control strategies to friends or family				
I would be willing to change the way I take care of my property (or if I had a property) to incorporate natural control strategies				
I like natural control strategies				
Natural control strategies are a good way to improve health and prevent illness caused by ticks and tick-borne diseases				
Overall, natural control strategies will help my community				

16. Do you have any concerns or comments you would like to add about any of these strategies? [350 character count limit] [optional response]

---

17. Please indicate the level of your agreement/ disagreement with the following statements regarding <u>personal protection strategies</u> in this category to try to control ticks and reduce Lyme disease.

These strategies may include things like Permethrin treated clothing/uniforms, or application of spray repellents to skin or clothing to try to repel ticks when people are outdoors.

	I disagree a lot	I disagree	I agree	I agree a lot
Personal protection strategies in this category work against ticks				
Personal protection strategies in this category work against Lyme disease				
I would use these personal protection strategies in this category				

I would like the personal protection strategies in this category to be promoted in public spaces				
I would recommend personal protection strategies in this category to friends or family				
I would be willing to change my family's routine to incorporate these personal protection strategies				
I like personal protection strategies in this category				
Personal protection strategies in this category are a good way to improve health and prevent illness caused by ticks and tick-borne diseases				
Overall, people using personal protection strategies in this category will help my community				

18. Do you have any concerns or comments you would like to add about any of these strategies? [350 character count limit] [optional response]

19. Please indicate the level of your agreement/ disagreement with the following statements regarding personal protection strategies in this category to control ticks and reduce Lyme disease.

These strategies may include things individual behaviour changes to try to avoid tick bites or Lyme disease (avoiding tick habitat, checking your skin for ticks after being outside, or showering/bathing to remove ticks that haven't bitten you yet).

	I disagree a lot	I disagree	I agree	I agree a lot
Personal protection strategies in this category work against ticks				
Personal protection strategies in this category work against Lyme disease				
I would use these personal protection				

strategies in this category				
I would like the personal protection strategies in this category to be promoted in public spaces				
I would recommend personal protection strategies in this category to friends or family				
I would be willing to change my family's routine to incorporate these personal protection strategies				
I like personal protection strategies in this category				
Personal protection strategies in this category are a good way to improve health and prevent illness caused by ticks and tick-borne diseases				
Overall, personal protection strategies in this category will help my community				

20. Do you have any concerns or comments you would like to add about any of these strategies? [350 character count limit] [optional response]

Residential/ Recreational Practices and Feasibility:

1. Regarding the outside environment of your primary residence (the place where you slept the last week), what is the statement that best applies to your situation:
    a. I do not have access to an outdoor yard
    b. I have access to an outdoor yard, but I do not have the responsibility for its maintenance
    c. I have access to an outdoor yard, and I have the responsibility for its maintenance

2. How often do you visit forested parks or trails between May and October within the last year within Ottawa, including the Greenbelt
    a. Frequently: more than 25 times a year
    b. Often: from 11 to 25 times a year
    c. Sometimes: from 2 to 10 times a year
    d. Rarely: less than 2 times a year
    e. Never

3. Within the last year have you had a dog or outdoor cat living in your primary residence with you?
    a. Yes
    b. No

4. Within the last year which of the following measures have you taken to protect your dog or cat? **[check all that apply]**
    a. Vaccination
    b. Topical preventive treatment
    c. Oral preventive treatment (chewable tablets)
    d. Medicated collars
    e. Other
    f. I don't use any of these products
    g. I don't have a dog or cat

5. How often do you protect your dog or outdoor cat against ticks using vaccination, topical treatment, oral treatment, or medicated collars?
    a. Never
    b. Sometimes
    c. Often
    d. Always
    e. I don't know
    f. I don't have a dog or cat

6. How many times have you been bitten by a tick in the last year?
    a. Never
    b. 1-2 times
    c. 3 or more times

7. How many times in the last year have you found a tick crawling on your skin or clothing?
    a. Never
    b. 1-2 times
    c. 3 or more times

8. How often do you personally use protection against ticks when you go outside?
    a. Never
    b. Sometimes
    c. Often
    d. Always
    e. I don't know

9. When you use personal protection against ticks, what do you use? **[check all that apply]**
    a. Bug spray
    b. Clothing protection (long pants, long sleeves, tucking your pants into your socks)
    c. Regular tick checks after spending time outside
    d. Showering immediately after time outside
    e. I do not, or would not use any of these tick prevention methods

10. What is your preferred method of protection against ticks?
    a. Bug spray
    b. Clothing protection (long pants, long sleeves, tucking your pants into your socks)
    c. Regular tick checks after spending time outside
    d. Showering immediately after time outside
    e. I do not, or would not use any of these tick prevention methods

The next FOUR questions relate to your choice of preferred personal protection method (in Question 10).

11. How easy would your preferred personal protection method from *Question 10* be for you to implement?
    a. Very difficult
    b. Somewhat difficult
    c. Somewhat easy
    d. Very easy
    e. I don't know

12. How affordable is your preferred personal protection method from *Question 10*?
    a. Very costly
    b. Somewhat costly
    c. Somewhat affordable
    d. Very affordable
    e. I don't know

13. How available is your preferred personal protection method from *Question 10*?

a. Not available at all
b. Available, but difficult to find
c. Available, and easy to find
d. I don't know

14. What do you need to make your preferred personal protection method from *Question 10* easier to use?
    a. More time
    b. More affordable
    c. More availability
    d. More information on how this method works
    e. I don't know

15. Do you use any tick prevention around your house? (such as a spray, fencing to keep out deer, tick prevention for wildlife, or landscaping techniques)
    a. Yes
    b. No
    c. I don't know
    d. I don't own or live in a house with a yard

16. If you use some sort of tick prevention around your house, what do you use? **[check all that apply]**
    a. A spray applied to my yard
    b. Fencing to keep out deer
    c. Tick prevention for wildlife (like tick tubes for mice)
    d. Landscaping techniques
    e. Other (specify): __________
    f. I don't know
    g. I don't own or live in a house with a yard

Prevention Responsibility:

Now we would like to understand your preferences for the management of ticks and Lyme Disease in Ottawa.

17. Please order in order of importance (1 being the most important and 4 being the least important) who should be the most responsible for tick or Lyme disease prevention measures in the following settings?

	The individual	A community organization	The local government	The provincial government
In a residential setting (near your home or neighborhood)				

In a recreational setting (trails, parks, camping grounds)				

Social Norms:

1. How common do you think Lyme disease is in your community?
    a. Very common
    b. Somewhat common
    c. Somewhat uncommon
    d. Very uncommon

2. Do you personally know anyone (such as a family member, friend or neighbor) who has ever had Lyme disease?
    a. Yes
    b. No
    c. I don't know

3. Do you think you have ever had Lyme disease?
    a. Yes
    b. No

4. Have you ever been diagnosed with Lyme disease?
    a. Yes
    b. No
    c. I don't know

5. Do you know anyone who uses some sort of tick prevention on members of their family? (such as clothing protection, bug spray, doing regular tick checks, showering or bathing after spending time outdoors)
    a. Yes
    b. No
    c. I don't know

6. Do you know anyone who uses some sort of tick prevention around their house? (such as a spray, fencing to keep out deer, tick prevention for wildlife, or landscaping techniques)
    a. Yes
    b. No
    c. I don't know

Demographics:

1. What is your gender:

a. Woman
b. Man
c. Non-binary/ third gender
d. Prefer to self-describe ________________
e. I prefer not to answer

2. What is your sex:
   a. Female
   b. Male
   c. Prefer not to answer

3. What age group do you belong to?
   a. 18-24 years old
   b. 25-34 years
   c. 35-44 years
   d. 45-54 years
   e. 55-64 years
   f. 65-74 years
   g. 75 years or older
   h. I prefer not to answer

4. Do you identify as an Indigenous person, that is, First Nations, Métis or Inuk (Inuit)?
   a. Yes
   b. No
   c. Prefer not to answer

5. Which population group do you belong to? (check all that apply):
   a. White
   b. South Asian (e.g., East Indian, Pakistani, Sri Lankan, etc.)
   c. Chinese
   d. Black
   e. Filipino
   f. Latin American
   g. Arab
   h. Southeast Asian (e.g., Vietnamese, Cambodian, Laotian, Thai, etc.)
   i. West Asian (e.g., Iranian, Afghan, etc.)
   j. Korean
   k. Japanese
   l. Other (specify):____________

6. How long have you lived in Canada?
   a. Less than 1 year
   b. 1 to 5 years
   c. 6 to 10 years
   d. 10+ years

7. How long have you lived in Ontario?

a. Less than 1 year
b. 1 to 5 years
c. 6 to 10 years
d. 10+ years

8. What language do you speak most often at home?
    a. English
    b. French
    c. Other (specify):__________

9. What is the total before-tax income of all household members for 2023?
    a. $ 19,999 or less
    b. Between $ 20,000 and $ 39,999
    c. Between $ 40,000 and $ 59,999
    d. Between $ 60,000 and $ 79,999
    e. Between $80,000 and $99,999
    f. Between $ 100,000 and $ 119,999
    g. $ 120,000 or more
    h. I prefer not to answer

10. What is the highest level of education you have completed?
    a. Primary (elementary school)
    b. Secondary (high school)
    c. College (technical training and/or certificate)
    d. University: graduate certificate and/or diploma
    e. University: undergraduate degree (Bachelor's)
    f. University: graduate degree (Master's)
    g. University: graduate degree (Doctorate)
    h. Other (specify): ______________________________________

11. Select the description that most closely describes your job or occupation:
    a. I work inside or at a desk most days or everyday
    b. My work involves a mix of indoor and outdoor activities consistently
    c. My work is outdoors most days or everyday
    d. Retired
    e. Other (specify): ________________________

12. Please enter the first 3 letters of your postal code, you may add the full 6 digit postal code if you are comfortable **Note that depending on one's location, some postal codes are specific to less than a handful of households.*

__ __ __ mandatory (__ __ __) optional
Thank you

8.3.8 Forward Sortation Area (FSA) classification

Stratum	FSA
Urban	K1H
	K1L
	K1M
	K1N
	K1P
	K1R
	K1S
	K1Y
	K1Z
	K2A
	K2B
	K2C
	K2P
Suburban East	K1B
	K1C
	K1E
	K1J
	K1K
	K1W
	K4A
Suburban South	K1T
	K1V
	K2E
	K2G
	K2J
Suburban West	K2H
	K2K
	K2L
	K2M
	K2R
	K2S
	K2T
	K2V
Rural	K0A
	K1G
	K1X
	K2W
	K4B
	K4C

	K4M
	K4P