March 2023

Review of environmental management strategies to reduce tick populations

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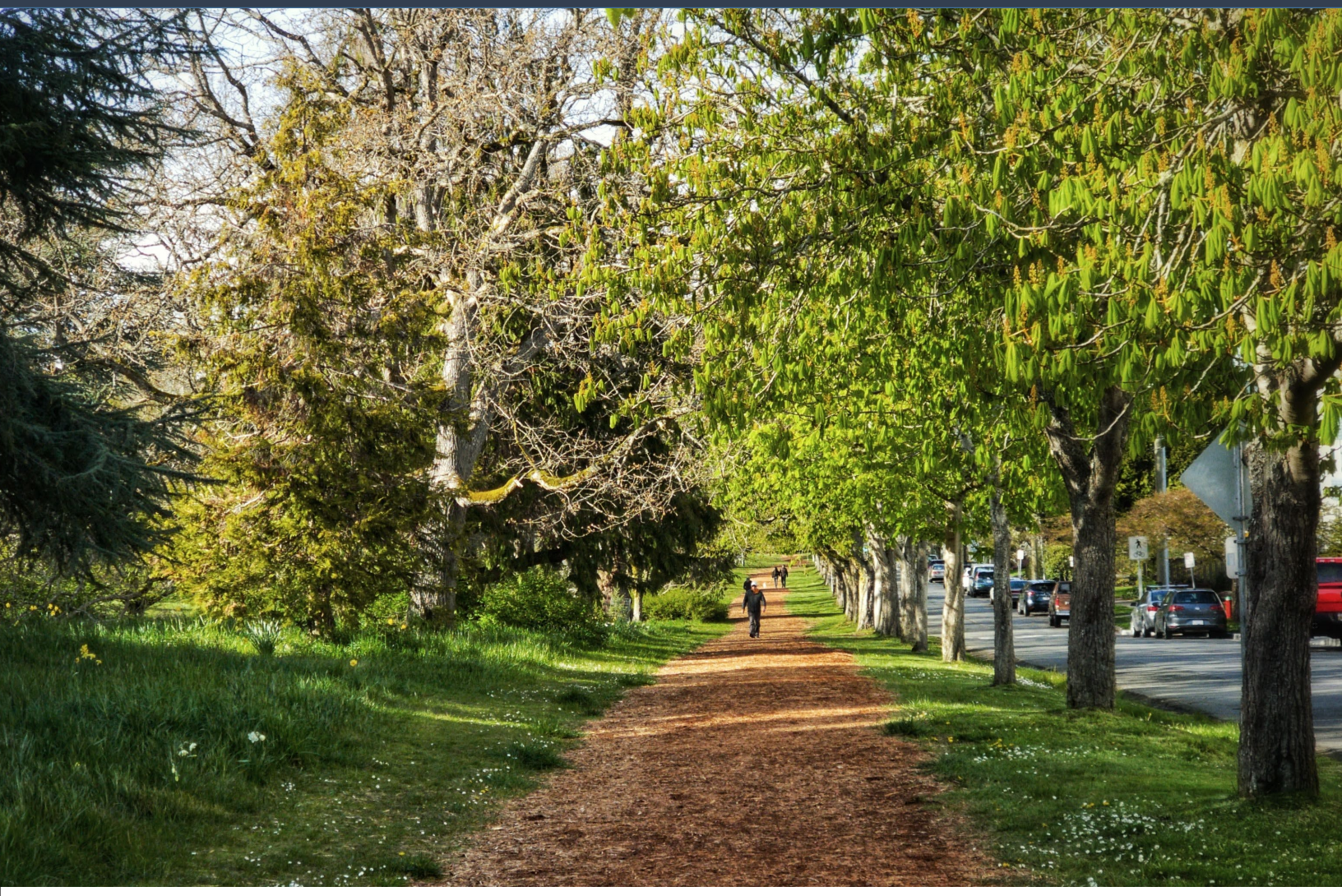

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Key Messages

- Ticks can be found in any outdoor environment. In general, ticks are found in ground cover plants and shrubs, leaf litter, and within 3 metres of the yard perimeter or forest edges.
- Tick species prefer different habitats: *Ixodes* species prefer high moisture environments while *Dermacentor* species prefer drier environments. Additional research on tick biology and habitat preferences by species in Canada is needed.
- Landscape management practices can help reduce ticks by altering the environment to be less welcoming to ticks. Such strategies include: 1) decrease vegetation density to limit tick habitats, 2) increase sunlight and decrease humidity to desiccate ticks, and 3) limit wildlife access and habitats on property through fencing and plant selection.
- Chemical control of ticks with acaricides is effective when applied in late spring/early summer to control nymphal populations. Spraying of high-risk areas only can minimize the negative environmental impacts of acaricides.
- Online citizen science platforms, such as eTick.ca and iNaturalist.ca can help provide real-time information on ticks to park users.
- More research is needed on the effectiveness of park signs to increase awareness and educate park visitors on ticks and tick-borne infections.

Introduction

The range of ticks continues to expand, across North America and within Canada, due to global warming, host-animal migration, and land fragmentation, increasing the potential for exposure to emerging tick-borne pathogens.[1-5] Ticks are known arthropod vectors that can transmit a wide range of bacterial, viral, and protozoan pathogens to humans and other animal species.[6] The aim of this document is to 1) review strategies aimed at reducing tick habitats and tick-borne disease transmission in parks, recreational areas, and residential properties and 2) explore the role of citizen science and risk communication tools in information dissemination and promotion of personal protective behaviours to limit tick encounters. This is the third document in a four-part series focussing on the health risks of tick exposure in Canada. The first review in this series is entitled “A review of ticks in Canada and health risks from exposure” and can be found here. The second review entitled “The impacts of climate and land use change on tick-related risks” can be found here.

Methodology

Scholarly research and grey literature were searched for information on ticks, risk management, land management, landscapes and landscape design, integrated pest management, citizen science, risk communication (through various media), and knowledge, attitudes, and practice. Databases used to identify relevant sources include Web of Science, PubMed, and Google Scholar. Grey literature and reports from academic institutions, federal government, provincial and territorial governments, and public health agencies were also reviewed. Relevant English language results were compiled. Although the search was primarily restricted to sources published after 2000, some earlier pivotal publications were included. Forward and backward chaining of initial results identified additional references.

Articles, reports and websites were selected for review if they pertained to ticks and at least one of the following: management strategies, citizen science, or risk communication. Both the common name and Latin name of pathogens and of known tick vectors were included in the search. The majority of the literature focussed on areas in the United States and parts of Europe where ticks have been endemic for much longer time periods. Where possible literature pertaining to Canada was emphasized. The research was predominantly focussed on Lyme disease and *Ixodes scapularis*; however, similar considerations would apply to other tick-borne pathogens and tick species.

Ultimately, 106 sources were included for review. All literature was analyzed and synthesized by one reviewer and the final report was subject to both internal and external review. A complete list of search terms and the full list of results are available upon request.

Results

Review of environmental management strategies

Ticks can be found across urban, suburban, and recreational areas.[7] Tick encounters are location dependent and can vary greatly even along the same section of a trail, due to a number of interrelated factors that influence tick population survival including tick species, climatic variables, ecology, host population movement patterns, and land use characteristics, as was discussed here.[8]

Tick management is becoming increasingly important in limiting human encounters to both ticks and potential tick-borne infections; however, it is both complex and challenging given the need to consider tick species, animal hosts, environmental habitats, local public health initiatives, and human behaviour.[9,10] While public health and municipalities are responsible for public and recreational lands, to date government-mandated tick initiatives have either been lacking or limited in scope.[9,11-13] Both individual and intersectoral government actions are needed to tackle the steady increase and geographic spread of ticks across North America.[14]

The most effective strategy for managing tick populations in the environment is through an integrated pest management approach using a combination of environmental management strategies to reduce tick habitats and/or limit human contact with tick hotspots.[10,15] Integrated pest management, an ecosystem-based approach, takes into account biological, cultural, physical, and chemical tools to reduce the risk of pests while minimizing the environmental and human impacts.[16] In the context of ticks, integrated pest management refers to strategies that: 1) minimize risk of human tick bites and tick-borne infections; 2) limit tick-related risk to people, animals, and the environment; and 3) minimize the likelihood of chemical insecticide resistance through abatement programs.[16,17] This may involve personal protection measures (previously described here) alongside a combination of strategies at the municipal and residential level, such as landscape management, controlled burns, chemical tick abatement, biological control, and tick prevention in pets.

Landscape management

Ticks are hardy anthropods that can survive extreme weather and environmental conditions. Their survival is correlated with landscape features that foster suitable habitats for ticks and animal hosts. Ticks can be found in any environment, though tick species have habitat preferences.[18] In general, ticks can be found in deciduous woodlands, ground cover with bushy areas, leaf litter, and fallen logs/trunks as well as along the edge of forested areas, also known as the ecotone.[10,12,19-23] *Ixodes* species are often found in moist environments (e.g., leaf litter within forest), while *Dermacentor* species prefer drier habitats and often found in grasses and shrubs.[24] Fewer ticks are generally found in ornamental vegetation (both perennial and annual plants such as lavender, rosemary, chrysanthemum, and iris) bare soil, and short lawns especially in areas with direct sun exposure.[10,12,25-30] Within residential areas, ticks are commonly found within 3 metres of the yard perimeter especially in lots neighbouring wooded areas, stonewalls (freestanding and retaining), or along areas with dense ground cover/ornamental plantings.[10] The goal of tick vector control through landscape management is to modify the vegetation to make the environment less desirable for ticks and animal hosts.[10,12,13] Such modifications can primarily be achieved by:

- Purposeful plant selection to decrease vegetation density to limit tick habitats
- Increased sunlight and decreased humidity to facilitate tick desiccation
- Limited wildlife access and habitats on property through fencing and plant selection.[10]

Box 1 describes several effective landscape management strategies for tick control.

Box 1: Landscape management strategies to limit tick and host animals.[9,10,13,29-31]

Plant selection and design

- Consider using deer-resistant plants to limit deer movement on a property (e.g., lavender, pennyroyal, daffodil, iris, and Russian sage). Purposeful plant selection will limit deer and rodents and may increase insect biodiversity, limiting ticks. The specifics of such plants will vary based on the biogeoclimatic zone. A landscape specialist could be consulted on regional plant selections and their placement.
- Limit dense ground cover and decrease shrub density, especially in frequently travelled areas of property, to limit tick habitats.
- Increase sun exposure to decrease humidity. This decrease in shade can facilitate tick desiccation.

Plant and lawn maintenance (to reduce tick habitats)

- Trim/prune trees, shrubs, and bushes.
- Remove yard waste (leaf litter, brush, weeds, debris)
- Stack wood neatly in dry area away from the house.

Fencing and hardscaping

- Use fencing to limit deer and other host animal movement through property.
- Use hardscaping materials (e.g., concrete, stone, gravel, wood chips) along edges of property (to create tick barrier) and in high-use areas. Such surfaces are difficult for ticks to crawl on.

While many studies focus on tick control in residential properties, such landscape modifications are also effective for recreational areas and parks.[13] For example, an Ottawa-based study found that woodchip borders helped to suppress *Ixodes scapularis* activity along trail margins, thereby decreasing tick encounters and potential tick-borne infections.[32] Of possible wood-product barriers, Alaska yellow-cedar sawdust, provides the greatest protection against nymphal *Ixodes scapularis* ticks due to its naturally occurring repellent qualities (and can be purchased).[33]

Research on tick distribution and management techniques is predominately focussed on *Ixodes scapularis* and in Northeastern United States, where ticks and tick-borne pathogens have been a concern for a

longer time period. Additional research is warranted to identify tick species, their biology, and their distribution across Canada.[34]

Controlled burns

Tick populations can also be reduced through regularly performed controlled forestry burns. Such burns can decrease adult tick populations between 74-97% depending on the severity of the burn site, with the reduction lasting approximately 12 months.[35,36] After this time, there may be an increase in tick populations due to deer movement and availability of food sources for other host animals.[13] This implies that annual burns could help prevent resurgence in tick populations; otherwise, both controlled burn areas and wildfire areas may become tick hot spots – an important consideration for wildfire mitigation strategies and subsequent communication strategies. Controlled burns and rotation of pastures have also been traditionally used by Indigenous populations of North America to control and reduce tick populations.[11]

Chemical tick abatement

Unlike mosquito abatement programs, which have been used in communities for decades, there is no equivalent widespread tick control program.[11] At a smaller scale, acaricides have been shown to be effective against killing *Ixodes* species nymphs and adults in residential settings.[37-39] A list of approved products in Canada can be found here. The Centre for Disease Control and some public health authorities in the United States recommend using acaricides in residential areas for tick control and prevention.[10,31] Acaricide application during the late spring/early summer can reduce 90-100% of nymphs or adult ticks in one season (depending on the timing of the application).[13] Similar recommendations are made in some Canadian municipalities.[40] However, acaricide use in Canada remains limited.[41]

For residential purposes, the application is most successful when applied to shady regions of the yard focussing on tick habitats (leaf litter, shrub vegetation), the perimeter of the property, and along trails and paths.[13,42] While acaricide use is recommended, the effectiveness of widespread application as a public health measure to control *Ixodes scapularis* nymphs is unknown and currently being investigated in the United States.[11] Due to the environmental impacts and health and safety considerations, barrier applications, applied to vegetation near human activity, are preferred as it minimizes negative environmental impacts and limits use.[13]

In some areas in the Northeastern United States, chemical pest control measures that use pyrethroids are becoming more frequent. Pyrethroids are less toxic than traditionally used chemical pesticides but are still effective at controlling tick populations. For example, one application of deltamethrin (a pyrethroid pesticide) applied at the correct time can reduce 95% of *Ixodes scapularis* and 100% of *Amblyomma americanum* nymphs on a residential property plot for approximately 12 weeks.[43-45]

Pyrethroids are registered in Canada, and the environmental and health risks are considered acceptable if used according to the label directions.[46]

Chemicals can also be used to reduce ticks among host animals. This is commonly done through the following: 1) supplying mice with permethrin-treated cotton in cylinders, who then use the cotton for their nests and are thus self-treating; 2) bait boxes for small hosts (e.g., mice and rats); or 3) topical self-grooming application stations for deer.[13] Permethrin-treated nesting materials reduces *Ixodes scapularis* larvae, nymphs and the overall density of host seeking nymphs; however, the effectiveness depends on local ecology and the type of small rodent hosts.[39,47-49] The bait box, developed by the US Centers for Disease Control in collaboration with scientists, is over 85% effective at reducing nymph and larvae on small hosts.[13] Similarly the topical self-grooming application stations (called a 4-poster device) showed over a 90% reduction in *Ameblyomma americanum* and *Ixodes scapularis* adult ticks on deer hosts in treated areas.[11,13,50-53] While such treatments are effective in tested areas, the widespread use in the environment and the feasibility remains uncertain and is species dependent.[9]

Chemical control of tick populations has shown to be effective in experimental settings and may be useful in a location-specific integrated pest management approach. However, overuse and subsequent acaricide resistance are real threats.[54] It must also be noted that while insecticides are effective at reducing tick populations on treated properties or treated hosts, the risk is not reduced to zero and is not equivalent to human protection from tick encounters or tick-borne pathogens.[55] This indicates that human behaviour (e.g., preventative behaviours) plays a role in determining the risk of tick encounters beyond tick abundance and warrants further research.

Biological control

An alternative to chemical control of ticks is through the use of natural predators and pathogens. Predation of ticks by other arthropods, amphibians, reptiles, and birds has been well documented.[54] The effectiveness and success of such predation is dependent on the ecology, microclimate, and niche of a specific location.[54] Policies that promote biodiversity by increasing green space in the built environment and landscape design may be beneficial in naturally reducing tick populations. Further research is needed to evaluate this relationship.[27,56,57]

Planting or encouraging specific flora can also help control certain tick species. For example, entomopathogenic fungi are a group of fungi living in soil that can kill insects. It can be grown on artificial media and products are being examined for their potential to eliminate *Ixodes scapularis*.[9,54,58,59] Recent research also shows that balsam fir (*Abies balsamea)* has a role in reducing overwintering *Ixodes scapularis* nymphal and adult ticks. Specifically, the essential oil from balsam fir needles can kill ticks within days at temperatures of 4 degrees Celsius and below. Whole balsam fir needles are also effective at reducing tick numbers, but it takes longer ($\geq$ 3 weeks) in a laboratory setting and unlikely to occur in

nature. The potential role of biological tick deterrents as well as the role of mitigation strategies aimed at different seasons should be further evaluated.[60]

Other strategies

Deer management and reduction is another tool in managing host animals. Deer management can be achieved through fencing and deer resistant landscaping as previously discussed. In some jurisdictions, deer reduction has been facilitated through regulated hunting.[10] The success of such approaches is mixed.[9]

There is currently one registered human vaccine that protects against tick-borne encephalitis. This vaccine is regularly used in parts of Europe and Asia and for travellers to endemic areas.[61] Several vaccines, targeting Lyme disease, are currently being developed while another vaccine aims to cause an immune response against tick salvia and may offer protection against a range of tick-borne infections.[62] Vaccines exist for canines and cattle, with research examining the potential of vaccinating small host animals such as white-footed mice.[9,10]

Review of the role of citizen science

Citizen science, where the public voluntarily contributes to scientific processes, provides researchers with valuable information and helps to create connection between the public and scientists.[63] The use of citizen science to track ticks has been steadily increasing through community-based, passive surveillance programs and newer technological platforms and may help to increase understanding of recreational tick encounters.[64-68] Research shows that trail reviews mentioning ticks submitted on the AllTrails.com platform could help identify trails (and park regions) where one might be at an increased risk of tick exposure and periods of increased activity.[67] This in turn can facilitate surveillance programs and tailor tick awareness and intervention programs (or protective behaviours).[67] This is a cost-effective way to generate information that can be helpful in understanding tick and pathogen distribution patterns beyond government surveillance and research programs, which often rely on C02-baited tick traps and drag sampling.[69,70] The online reviews also contain information on personal protective behaviours, which could inform public health on risk communication strategies and points of misinformation.[67] One notable limitation of citizen science is that efforts are localized.

While abundant online information exists on how to control ticks and reduce one's risk of tick exposures, there is little information on localized risks for tick encounters and/or how to best manage one's risk in specific environments.[11] Tick information, collected through passive surveillance methods can also be used to generate real-time data for public use. In Canada, the web platform and mobile application eTick allows users to submit tick information via photographs. This information is then evaluated and translated into a real-time risk map shared on their website.[71] In the United States, ticks submitted as

part of New York State's passive surveillance program are used to develop a real-time interactive and visual map called tickMAP. Through this program, individuals can submit collected ticks for identification and pathogen screening.[68] The data are then shared with the individual who submitted the tick and added to the real-time map for New York State.

The online platform iNaturalist.ca also shows the potential for tracking tick species.[72] The crowd-sourced information has been able to identify seasonal patterns and the distributions of tick species.[70] While such community-based initiatives provide important information on where humans and ticks interact, they are limited by data accuracy and individual biases that may be at play. While the maps are detailed, the resolution makes it challenging for an individual to assess actual risk on a specific trail. However, such maps can be helpful for both individuals and clinicians in assessing the overall real-time risk of tick encounters across local geographic areas and can facilitate informed decision making.[11,68]

There is currently no systematic surveillance for recreational areas to understand the actual risk of tick encounters for visitors and park staff, despite increasing use of trail networks across Canadian parks.[69] Additional challenges are: 1) trail users are frequently non-resident visitors who may not be familiar with the local ecosystem or risks, and 2) it is difficult to know the exact location of human-tick encounters.[73-75] As such, data from local areas and citizen science efforts can be instrumental in providing comparable understanding of the risks across regions despite the potential underrepresentation of actual tick distribution.[69] Given the potential usefulness of user-generated information online to public health and increased trail use since the start of the pandemic, there are two calls to action: 1) that trail apps and platforms be encouraged to specifically ask about tick encounters and 2) for public health to consider systematically including citizen science to supplement surveillance data.[67]

Review of risk communication strategies that support tick control efforts

Public health initiatives to reduce tick encounters and tick-borne diseases rely on clear risk communication. Understanding the knowledge, attitudes and practices of target populations is paramount in developing clear public health messages, which can be delivered through various medium including: web sources, visual media, social media, smart phones, public signs and educational initiatives.

Knowledge, attitudes and practices (KAP)

The most effective tick-control measure is to limit activity in high-risk areas during peak activity periods.[11] Most often, individuals are not aware of the risk of tick vectors and can therefore not make informed choices.[11] Knowledge of ticks and tick-borne infections has been shown to increase the likelihood of engaging in protective behaviours.[76] Data shows that personal protective behaviours reduce disease risk,

especially when combined with other control strategies, such as landscape management, to reduce tick exposure.[77-79]

In a 2014 Canadian national campaign to increase awareness and promote protective behaviours to reduce ticks encounters and tick-borne infections, only half of respondents reported adopting a specific protective behaviour: 65% regularly mowed the lawn; 52% reported conducting regular tick checks; 50% wore protective clothing; 41% used a tick repellent; and 41% reported having a shower or bath after visiting a high-risk area.[80] In endemic areas of the United States, 99% of respondents engage in personal protective behaviours against ticks.[81] In Canada, two factors were associated with the adoption of behaviours: 1) discovering a tick on oneself or a family member; and 2) living in the Prairies.[80] This highlights the importance of understanding the local context for effective message development and risk communication.[76,80] Furthermore, traditional communication campaigns need to be revised to increase effectiveness.[82] Innovative approaches from other countries highlight the potential for risk communication through other medium such as smartphone applications and video games which can be readily available online, shared on social media, and viewed repeatedly.[82-86]

Web sources and visual media

The importance of web-based resources remains paramount. Such information should be reliable, written in accessible language, targeted to a specific demographic population, and ideally integrate risk maps into the platform.[11] This information should be targeted to a specific demographic population, ideally with an equity lens, in order to reach those who need the information most and to reduce health disparities.[76,80,87,88] Social media platforms (e.g., Facebook, Twitter, WhatsApp, Instagram, TikTok) should also be considered based on the target population and have the potential to reach a wide audience.[13,89] Timely and targeted communication of risk information will allow individuals to make informed decisions on personal risk exposure to ticks and tick-borne pathogens and give them the tools to mitigate the risk of tick encounters.[11]

The use of engaging and relatable story-based films is an effective tool in communicating health messages.[60,90] In a study comparing a traditional brochure to a five-minute movie, participants who watched the movie demonstrated significantly better knowledge of personal protective behaviours than those who just viewed the online leaflet or received no additional information.[86] Educational videos can also target those at risk, for example children or homeowners.

- "Tick Talk" is an online cartoon aimed at educating 5-10-year-olds on the prevention and seasonality of ticks.[91,92] The curriculum includes a child-friendly brochure, four additional lessons and activities for children to participate in, and resources for summer camps which are held outside.[91] Furthermore, it reflects the cultural makeup of British Columbia.[91,93] Risk communication material aimed at children is advantageous as it can be delivered through organized venues (schools, camps) and the information is shared with parents.[91]

- "Spray Safe, Play Safe" is a story-based film to educate homeowners about residential tick management strategies, including spraying acaricides. After viewing, participants reported greater confidence in how to reduce both personal and residential tick-related risks.[94]

Risk communication through video games can also appeal to younger age groups. In the Netherlands, an online educational video game was created to help users understand risky scenarios while providing information on how to check for ticks. While such games need to balance enjoyment vs. education, and may not be as effective as traditional information sources, they engage youth and are complementary in facilitating conversations with peers, parents, and other community members.[84] Other elementary school programs have used a multi-pronged approach whereby the curriculum teaches students about ticks and how to prevent tick bites.[95] The delivery of the curriculum varies by age (e.g., presentation, video, colouring books, word games, and real life examples), includes catchy slogans, and is followed up with a take-home supplemental information package to be shared with parents.[83]

Smartphone applications

Smartphone applications have recently gained traction for vector-borne diseases and behaviour change.[86,96] The Dutch "Tekenbeet" smartphone application educates users on tick information, how to check for ticks, and how to remove ticks, and is connected to the tick activity in the Netherlands.[86] While knowledge was high among users and non-users of the application, survey results showed that the application does improve preventative behaviour.[86] The Tick App, created in the United States, found that the greatest benefit of the application to users was tick identification through photo submission.[96] One benefit of a phone-based application is the ease with which one can access it.[86] Others are looking at artificial intelligence to allow for real-time tick identification through images submitted via a smartphone application.[97] While there are numerous other smartphone applications for ticks, not all provide reliable information and the sources should always be examined.

Visitor education and public signs

Given that the majority of visitors to national, provincial, and territorial parks are non-resident visitors, education on the risk of ticks and tick-borne infections becomes paramount. In parks, signs and brochures are used to share safety information (including information on ticks).[98] To be effective, the signs must use clear messages and visuals, be non-threatening/alarmist, stand out and be noticed, be near the visitor centre but away from other informational sources, and be positioned to face visitors approaching the park.[98,99] These considerations can minimize the stigmatization of certain parks or regions as "tick hot spots" or give visitors a false sense of security in areas without signs.[100] There is limited research on the effectiveness of park signs in successfully disseminating tick education. Most park visitors do not believe they are at risk for tick encounters.[74,101] In the first known assessment of visitor perceptions of Lyme disease in Canada, it was found that approximately 30% of visitors reported

preparing for tick encounters and using the Ontario parks website, park visitor centre, and trailhead/washroom information boards to learn about ticks in the area.[74] Furthermore, it appeared that the majority of visitors obtained their tick information through their social network, which can often be unreliable and contribute to the spread of misinformation.[74]

Despite the potential challenges of park signs, New York, Wisconsin, and Michigan states have implemented legislation requiring state parks to create tick-related warning signs in parks, campgrounds, and other recreational areas.[102] Given that well-designed signs are effective in creating behaviour change, such signs offer a low-cost public health measure to control against tick-borne infections.[103] Parks Canada shares on their website the names of national parks in areas known to be at risk of Lyme disease.[104] Recognizing the importance of well-developed signs, Parks Canada tests signs for comprehension prior to deployment to ensure effectiveness. A tick-warning sign was retired after testing revealed poor comprehension.[105] The current status of tick-warning signs in Parks Canada is uncertain. Tick-warning signs can also be found in some municipal and provincial parks across Canada, especially in Ontario.[106] Additional research is warranted to understand the effectiveness of such signs on providing tick awareness and education.

Summary

Tick-borne infections continue to be a public health concern in Canada with the expanding range of tick species northwards into and within Canada due to climate warming, migratory animals, and land fragmentation. Tick management is both complex and challenging due to the need to consider tick species, animal hosts, environmental habitats, local public health initiatives, and human behaviour.[9,10]

Given that there is no singular solution on how best to manage tick populations, a systematic approach with intersectoral collaboration between government agencies needs to be utilized to minimize human tick encounters, where all stakeholders engage in strategies to limit ticks in private properties as well as high-use recreational areas.[14]

This review highlights the need for an integrated-pest management approach to reduce tick habitats and/or limit human interaction with tick hot spots. This should utilize a combination of environmental management strategies across private and recreational properties. In residential areas, landowners should decrease vegetation density, increase sunlight, and decrease humidity while limiting wildlife habitats and movement on the property. In recreational areas, trails should be developed using hardscaping material or Alaska yellow-cedar sawdust to minimize tick exposure. Chemical control of ticks in the environment and/or animal hosts and controlled burns are also effective in managing tick populations in the short term. Available research in this area is predominantly focussed on *Ixodes*

scapularis in the Northeastern United states. Additional research on tick biology and habitat preferences by species in Canada is needed.

Citizen science offers unique value that augments passive surveillance efforts. Research shows that trail users have voluntarily been contributing information on tick encounters and personal protective measures on smartphone applications.[67] Online platforms such as etick and iNaturalist can also help public health provide real-time information on tick-related risks. Given the lack of systematic surveillance efforts for recreational areas in Canada and the increased use of Canadian parks by visitors, data obtained through citizen science should be incorporated into public health tick-control strategies. Such efforts can complement existing public health surveillance and are low cost.

Risk communication and education remain paramount to increasing awareness and for encouraging personal protective behaviours. Research highlights the role of using new media such as smartphones, videogames, and films in delivering health information. This review also highlights the research gap around effective and accessible park signage to increase visitor awareness and education on tick-related risks.

Acknowledgements

The author would like to thank NCCEH staff Dr. Leah Rosenkrantz, Dr. Anne-Marie Nicol, Dr. Lydia Ma, and Dr. Sarah Henderson for their guidance in developing this review, and Michele Wiens for literature search support.

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How to cite this document

ISBN: 978-1-988234-54-0

This document can be cited as: Elmieh, N. Review of management strategies to reduce tick-related risks. Vancouver, BC: National Collaborating Centre for Environmental Health. 2023 Mar.

 Production of this document has been made possible through a financial contribution from the Public Health Agency of Canada through the National Collaborating Centre for Environmental Health.

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