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Canada

Environmental risk from Lyme disease in central and eastern Canada: a summary of recent surveillance information

Ogden NH[1*], Koffi JK[1], Pelcat Y[2], Lindsay LR[2]

[1] Centre for Food-borne, Environmental and Zoonotic Infectious Diseases, Public Health Agency of Canada, Saint-Hyacinthe, Quebec
[2] National Microbiology Laboratory, Public Health Agency of Canada, Winnipeg, Manitoba
* Corresponding author: nicholas.ogden@phac-aspc.gc.ca

Abstract

Background: Lyme disease is the most commonly reported vector-borne disease in the temperate world. It is emerging in central and eastern Canada due to spread of the tick vector *Ixodes scapularis* into and within Canada to form new areas of environmental risk known as Lyme disease-endemic areas. Identifying the geographic location of Lyme disease-endemic areas is important to identify the population at risk, target interventions, and inform the clinical diagnosis of Lyme disease patients.

Objective: To provide an up-to-date picture of current and emerging areas of Lyme disease risk in eastern and central Canada by summarizing recent information on Lyme disease-endemic areas, and surveillance for *I. scapularis* ticks.

Methods: Data on locations where *I. scapularis* have been found in field surveillance studies by a range of federal and provincial organizations were collated and mapped to obtain a fuller picture of the occurrence of *I. scapularis* in Canada. The geographic locations of ticks submitted in passive tick surveillance were mapped for comparison.

Results: The number of confirmed Lyme disease-endemic areas in southern Manitoba, southern and eastern Ontario, southern Quebec, southern New Brunswick and in some locations in Nova Scotia increased from 10 in 2009 to 22 confirmed endemic areas in 2012. The collated field surveillance data indicated that *I. scapularis* tick populations and Lyme disease risk are more geographically widespread than known Lyme disease-endemic areas and that the pattern of emergence of tick populations varies among provinces. There was a tenfold increase in the numbers of *I. scapularis* reported for passive surveillance from 2 059 submissions from 1990 to 2003 to 25 738 submissions from 2004 to 2012.

Conclusions: The increasing numbers of Lyme disease-endemic areas, the much wider distribution of tick populations identified by field surveillance, as well as the marked increase in numbers of ticks identified through passive surveillance suggest that the geographic scope of environmental risk of acquiring Lyme disease is expanding in central and eastern Canada, although here it still remains mostly limited to the southern parts of five provinces.

Introduction

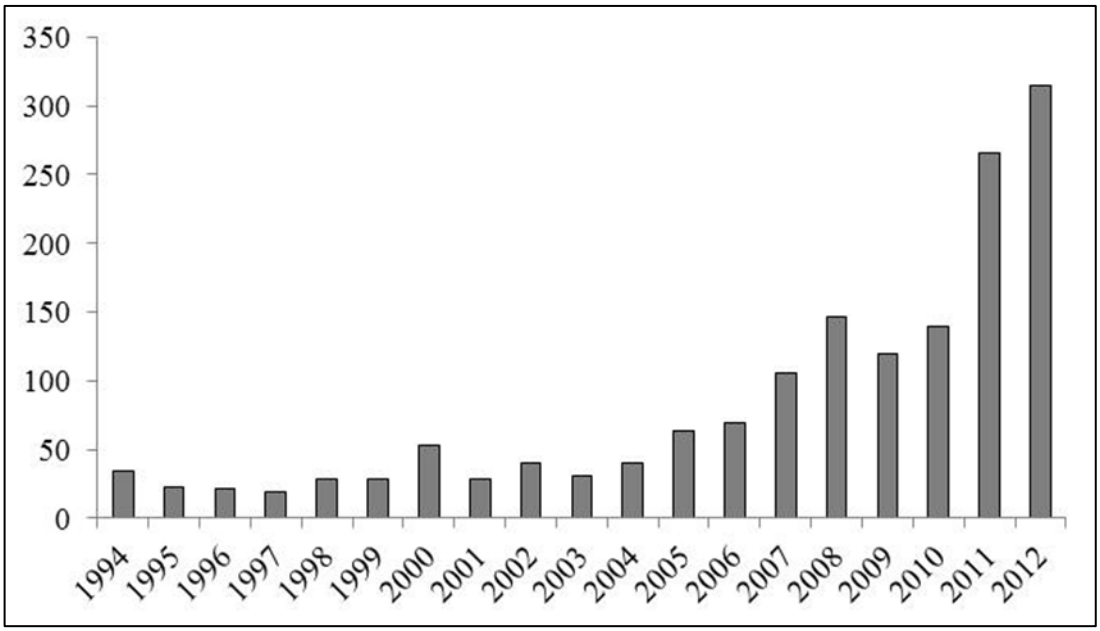
Lyme disease, caused by the bacterium *Borrelia burgdorferi,* is the most commonly reported vector-borne disease in the temperate zone, particularly affecting North America (1, 2). *B. burgdorferi* is transmitted by ticks, which feed on wildlife reservoir hosts of *B. burgdorferi*, particularly rodents and birds. *Ixodes scapularis*, the blacklegged tick, is the main vector in eastern and central North America. *Ixodes pacificus*, the western blacklegged tick, is the main vector west of the Rocky Mountains. Both tick species are indiscriminate in their choice of host and will feed on humans, and in doing so, may transmit pathogens from wildlife to humans. This study focuses on surveillance data for *I. scapularis* ticks from central and eastern Canada. Studies to obtain data on *I. pacificus* occurrence in western Canada are underway and will be presented in future articles.

Risk of infection from *B. burgdorferi* and other *I. scapularis*-borne pathogens (*Anaplasma phagocytophilum*, *Babesia microti*, *Borrelia miyamotoi*, a novel *Ehrlichia muris*-like bacterium, and Powassan virus (3-5) is increasing in eastern and central Canada as populations of *I. scapularis* are spreading north at an estimated rate of 33-55 km per year (6).

It is important to identify where populations of the tick are becoming established in Canada, because the geographic occurrence of these ticks defines where people can acquire Lyme disease now or in the near future (7). The annual incidence of reported human Lyme disease cases has increased markedly in Canada over the last few years (**Figure 1**). In 2004 there were 40 reported cases of Lyme disease in Canada; in 2012 there were 315 reported cases. This may reflect an increase in the reporting of cases, but under-reporting might also be occurring (8).

In this paper, we describe where environmental risk of Lyme disease is currently thought to occur based on data of confirmed and suspect Lyme disease-endemic areas, results of a simplified field surveillance method to detect emerging Lyme disease risk areas, and passive tick surveillance, which involves the submission of ticks found attached to patients of participating veterinary and medical clinics. Detection of Lyme disease-endemic areas is the gold standard method of surveillance for Lyme disease risk in the environment, but because it requires multiple site visits over two years it is not very timely or practical. Drag sampling alone is more practical and timely but is less sensitive and specific (9). Passive tick surveillance is a sensitive method of detecting *I. scapularis* ticks, but is relatively unspecific in terms of the geographic location of tick populations, because small numbers of ticks are dispersed long distances from tick populations by migratory birds. These dispersed ticks are known as adventitious ticks (10).

Figure 1: The number of cases of Lyme disease reported in Canada from 1994 to 2012*



*Numbers of cases before 2009, when Lyme disease became nationally notifiable in Canada, are estimates based on information from provincial public health organizations (10).

Information on where risk is occurring is useful for public health practitioners to identify where to focus prevention and control activities, for health care professionals to assist in diagnosis of Lyme disease, and to assist the public in making informed choices on prevention and control. Information on western Canada is currently pending the results of ongoing field studies.

The objective of this study was to map out our current knowledge of where the risk of Lyme disease is occurring in central and eastern Canada by:

- Collating knowledge of known Lyme disease-endemic areas;
- Identifying likely emerging Lyme disease-endemic areas detected in field surveillance for ticks;
- Identifying risk posed by adventitious ticks by analysis of passive tick surveillance data.

Methods

Three types of surveillance data were collated: data on Lyme disease-endemic areas that involved extensive testing, data on field surveillance conducted between 2008 and 2013, and passive tick surveillance collected between 2004 and 2012.

Lyme disease-endemic areas

Lyme disease-endemic areas are localities where transmission of *B. burgdorferi* by resident populations of vector ticks has been confirmed (11). Confirmation involves drag sampling (trailing a 1-m^2 square of flannel across the woodland floor for at least three person-hours per site) to collect ticks from the environment that are looking for a blood meal, and the capture of the wild rodents that are important reservoir hosts for *B. burgdorferi*. Detection of all three developmental stages of the tick (larva, nymph, and adult) and *B. burgdorferi* for more than one year is needed to confirm a location as a Lyme disease-endemic area. Suspect Lyme disease-endemic areas are locations where ticks of more than one developmental stage have been found, where *B. burgdorferi* has been detected in ticks or rodent samples, but where a second year of field sampling has not yet taken place. These known or suspect Lyme disease-endemic areas are based on data provided by provincial public health organizations, and were mapped using ArcGIS Version 10.2 (ESRI).

Field surveillance

Data were collated on occurrence of *I. scapularis* in field studies conducted by experienced field personnel in collaborations of the Public Health Agency of Canada with provincial government organizations in New Brunswick (2008), Quebec (2010-2012), Manitoba (2010-2012), Nova Scotia (2012), and Ontario (2012-2013). In addition, data from surveillance conducted from 2010 to 2012, and using drag sampling only, were provided by several local public health units in Ontario. In New Brunswick, northwestern Ontario and some sites in Manitoba, both drag sampling (for at least three person-hours per site) and capture of wild rodents (with appropriate ethical approval) were used (12). In all other studies only drag sampling was used.

The species of all ticks in all studies were identified at the Public Health Agency of Canada's National Microbiology Laboratory using standard identification keys. The locations of sampling sites were mapped using ArcGIS Version 10.2 (ESRI). The proportion and exact binomial 95% confidence intervals of sites on which *I. scapularis* were found in different locations were calculated. As these data were not all gathered contemporaneously or by a standardized technique in terms of season and drag-sampling effort, more detailed statistical analysis was not attempted.

Passive tick surveillance

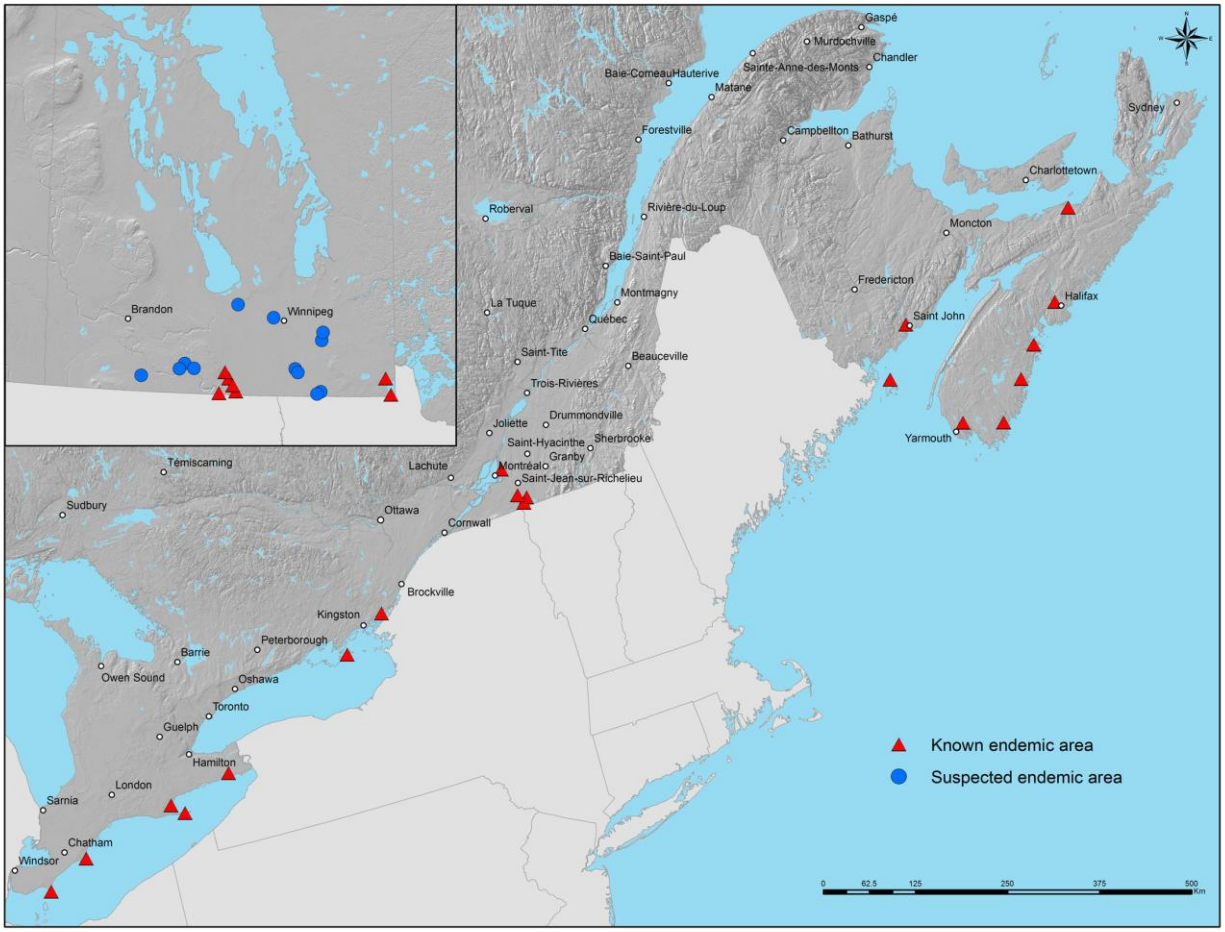
The locations of attachment of ticks submitted via provincial public health partners from participating medical and veterinary clinics, and by the general public from 2004 to 2012 were geocoded and mapped in ArcGIS Version 10.2 (ESRI). Only ticks submitted from people or domestic animals that had no history of recent travel were included in the analysis.

Results

Lyme disease-endemic areas

There are currently 18 confirmed and four suspect Lyme disease-endemic areas where *I. scapularis* has been established; these occur in southern Manitoba, southern and eastern Ontario, southern Quebec, southern New Brunswick and in some locations in Nova Scotia (**Figure 2**). Some of the Lyme disease-endemic areas in southern Manitoba, southeastern Ontario, and southern Quebec comprise multiple individual locations (15).

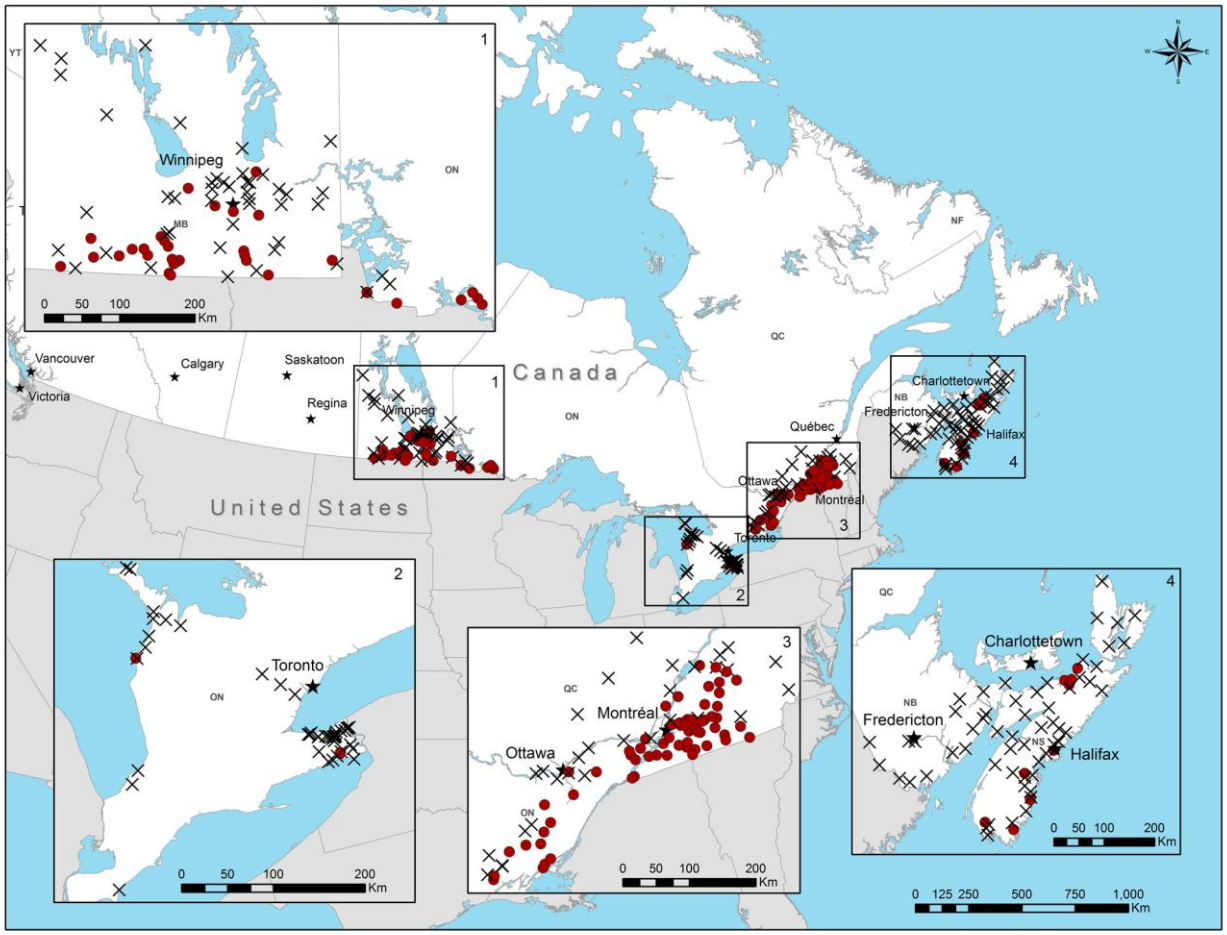
Figure 2: The distribution of known (red triangles) and suspect (blue circles) Lyme disease-endemic areas in Canada



Field surveillance

Field surveillance data from 296 sites were collated (70 in Manitoba, 87 in Ontario, 73 in Quebec, 16 in New Brunswick, and 50 in Nova Scotia) to identify potentially emerging *I. scapularis* populations and possible Lyme disease risk (**Figure 3**).

Figure 3: Results of field surveillance activities for blacklegged ticks in Canada from 2008 to 2012*

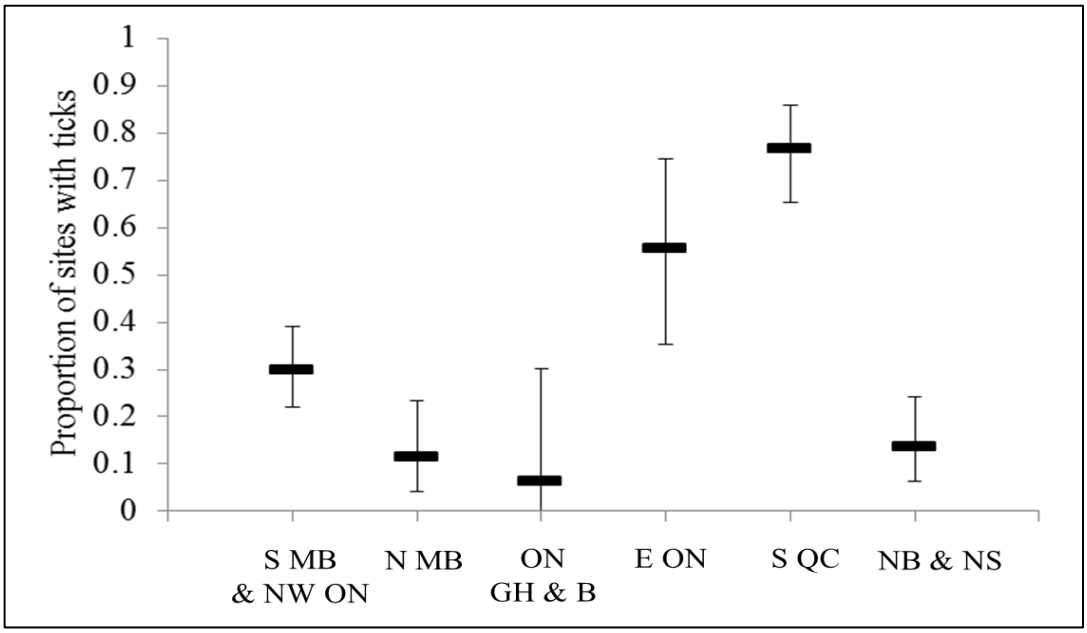


*Sites where at least one *I. scapularis* tick was found are indicated by filled circles. Sites where *I. scapularis* were not found are indicated by crosses.

The extent of locations where *I. scapularis* were found varied from province to province (**Figure 3**). *I. scapularis* were found in many woodland sites across southern Quebec and eastern Ontario (effectively comprising a contiguous zone of *I. scapularis* range expansion), and in a region extending across Manitoba south of Winnipeg into northwestern Ontario. Populations of *I. scapularis* are not known to occur at present in Alberta and Saskatchewan.

We assessed the proportion of sites in a region where *I. scapularis* ticks were found. In southern Quebec and eastern Ontario, the proportion of *I. scapularis*-positive sites was considerably greater than in the sites in Manitoba north of Winnipeg, in the Golden Horseshoe and Bruce Peninsula regions of Ontario, and in New Brunswick and Nova Scotia (**Figure 4**).

Figure 4: The proportion of sites visited in field surveillance, in different regions of Canada, at which *I. scapularis* ticks were found*



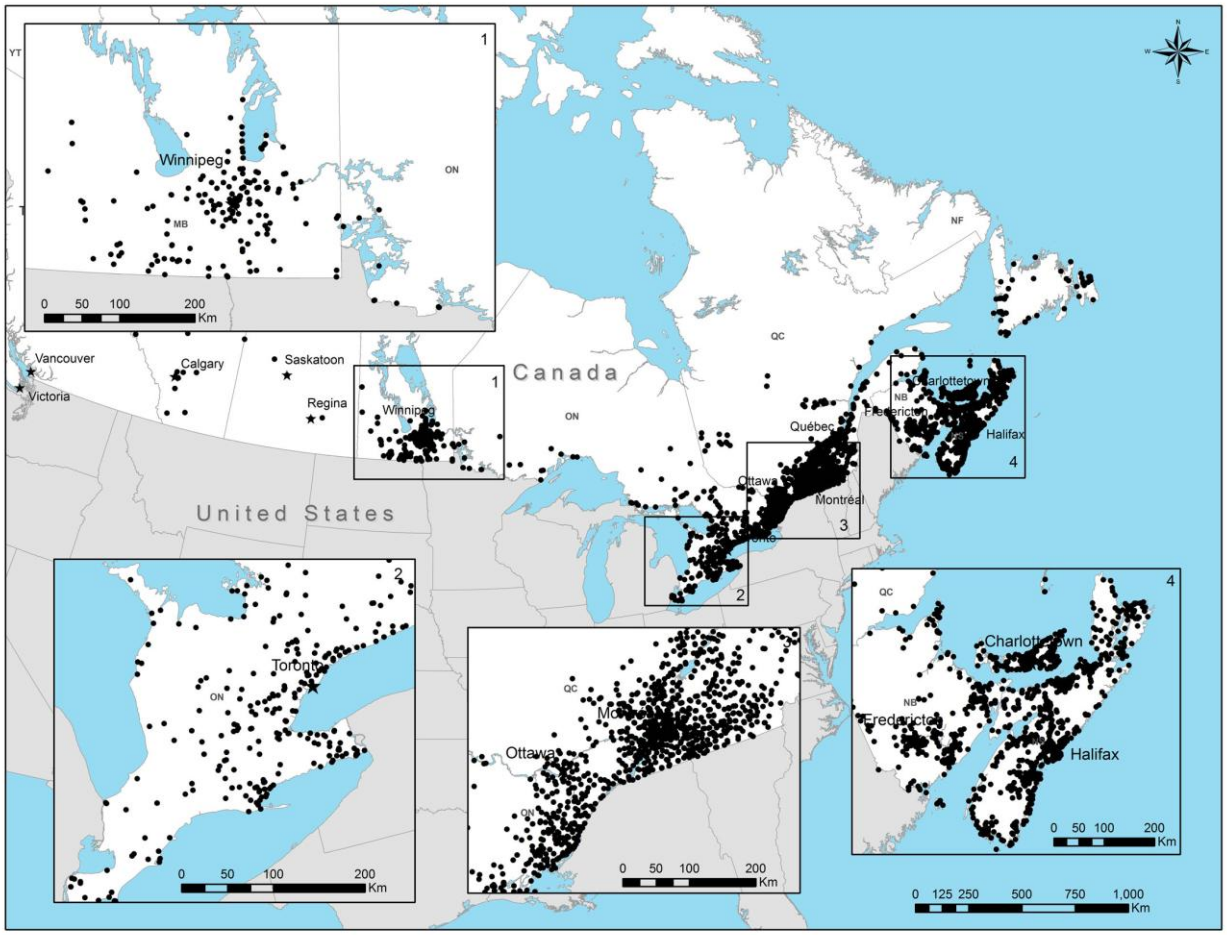
*The regions were Manitoba south of Winnipeg and northwestern Ontario (S MB & NW ON), Manitoba north of Winnipeg (N MB), Golden Horseshoe and Bruce Peninsula regions of Ontario (ON GH & B), eastern Ontario (E ON), southern Quebec (S QC), and New Brunswick and Nova Scotia (NB & NS). The error bars show exact binomial 95% confidence intervals for the proportion.

Passive tick surveillance

From 2004 to 2012 there were 25 738 individual submissions, comprising 28 388 individual ticks, from medical and veterinary clinics in nine Provinces (221 from Alberta, 10 from Saskatchewan, 1 063 from Manitoba, 9 905 from Ontario, 9 371 from Quebec, 1 631 from New Brunswick, 829 from Prince Edward Island, 2 553 from Nova Scotia, and 155 from Newfoundland). This represents over a tenfold increase compared with the 2 059 *I. scapularis* submissions from 1990 to 2003 (10).

The 2004 to 2012 submissions included 569 that comprised comprising nymphs only, 14 that comprised larvae only, 24 925 that comprised adult ticks only, and 230 submissions comprising multiple ticks of more than one tick stage. Interprovincial comparisons of numbers of submitted ticks are not possible due to variations in effort amongst and within provinces, and changes in effort from year to year. The likely locations where ticks were acquired by domestic animals or humans from which they were collected are shown in **Figure 5**.

Figure 5: The probable locations where *I. scapularis* ticks submitted from 2004 to 2012 in passive surveillance (acquired via domestic animal and human patients of participating veterinary and medical clinics)



Discussion

In this study we have presented data on surveillance for the tick vector *I. scapularis* and for Lyme disease-endemic areas where the presence of the *B. burgdorferi* has been confirmed. These surveillance data indicate that *I. scapularis* continues to expand its range into southern parts of central and eastern Canada.

Lyme disease-endemic areas are emerging in eastern and central Canada. In 2009 only 10 areas were confirmed in central and eastern Canada (indicated by arrows in Fig 2) (13), whereas now there are now 22 known or suspect Lyme disease-endemic areas in south central and southeastern Canada.

The field surveillance data collated from a number of sources showed that the geographic scope of *I. scapularis* invasion is much greater than that of Lyme disease-endemic areas. The patterns of *I. scapularis* invasion appear to vary from place to place. As expected, invasion is most likely in southern regions of Canada that are closer to

the United States border, as demonstrated by surveillance in Manitoba. Broad regions of *I. scapularis* invasion are occurring in a contiguous region of southern Manitoba and northwestern Ontario, and in a contiguous region of eastern Ontario and southern Quebec. In southern Ontario west of Toronto, southern New Brunswick, and in Nova Scotia, there was little evidence of Lyme disease risk in the sites visited outside of known Lyme disease-endemic areas.

Geographic differences in *I. scapularis* are likely due to differences in rates with which ticks are being carried in from source tick populations, and the factors that determine the suitability of any one location for tick populations to become established (i.e. climate, habitat, and the abundance of suitable wild animal hosts) (14-15). However, in general the field surveillance supports the accuracy of risk maps that have been developed for current and future (with climate change) invasion of *I. scapularis* (14).

There are a number of limitations to this surveillance study. First, there are no data available from western Canada. We know Lyme disease-endemic areas occur in British Columbia, but Lyme disease risk may be relatively low because *I. pacificus* is a less efficient vector than *I. scapularis* (13). There are limitations to the field surveillance data. It is possible that ticks at low densities could have been present on some sites where *I. scapularis* were not found. Results may have also varied due to variations in operator experience, effort per site, and year and month of surveillance. Finally, some of these data date back to 2008 and may no longer reflect the current situation.

The distribution of ticks submitted in passive surveillance was similar to that of tick populations identified in field surveillance. However, this also suggests a low-level risk of exposure of Canadians to Lyme disease in the more northern regions of Manitoba, Ontario, and Quebec, as well as in Newfoundland and Prince Edward Island. This is likely due to ticks being dispersed from established Lyme disease-endemic areas in Canada and the United States by migratory birds and other hosts (10, 16). The increasing numbers of Lyme disease-endemic areas, the much wider distribution of tick populations identified by field surveillance, as well as a tenfold increase in the numbers of *I. scapularis* submitted in passive surveillance illustrate the changing landscape of Lyme disease risk in Canada. This is consistent with the increase in reported cases of human Lyme disease.

Future research efforts should be targeted towards integrated surveillance for human cases and *I. scapularis* ticks to identify Lyme disease risk areas and guide the targeting of public health responses. The quantification of the relationship between environmental risk and human case occurrence and incidence is currently under development as part of the national Lyme disease surveillance program. However, expanding surveillance for environmental risk would constitute good public health practice by identifying emerging Lyme disease risk (as well as risk from other *I. scapularis*-borne diseases), and allowing implementation of prevention efforts prior to the occurrence of high numbers of human cases.

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Conflict of interest

There are no conflicts of interest to declare.

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Assessment of a screening test to identify Lyme disease risk

Ogden NH[1*], Koffi JK[1], Lindsay LR[2]

[1] Centre for Food-borne, Environmental and Zoonotic Infectious Diseases, Public Health Agency of Canada, Saint-Hyacinthe, Quebec
[2] National Microbiology Laboratory, Public Health Agency of Canada, Winnipeg, Manitoba
* Corresponding author: nicholas.ogden@phac-aspc.gc.ca

Abstract

Background: Lyme disease is emerging in eastern and central Canada due to the spread of the tick vector *Ixodes scapularis*. Currently, the test to establish Lyme disease-endemic areas requires multiple site visits and multiple sampling methods, and is consequently complex, time-consuming, and resource-expensive.

Objective: To assess the capacity of drag sampling alone as a screening technique to identify areas of Lyme disease risk.

Method: We conducted a retrospective analysis of field surveillance data obtained at 100 site visits in 2007 and 2008 in southern Quebec.

Outcome: Drag sampling used alone had 50% sensitivity but 86% specificity to identify early-established *I. scapularis* populations. Ticks were found throughout the period May to October.

Conclusion: One site visit of drag sampling of three person-hours between May and October may be sufficient to identify a Lyme disease risk location. This information can be used by public health professionals to develop public health responses and by medical practitioners to assist in the clinical diagnosis of Lyme disease.

Introduction

Lyme disease in North America is caused by the spirochete *Borrelia burgdorferi* sensu stricto (henceforth referred to as *Borrelia burgdorferi*), which is transmitted by the tick vector *Ixodes scapularis* in eastern and central North America (1). The geographic range of *I. scapularis* is spreading from the United States into eastern and central Canadian provinces (2), due to dispersal of ticks by songbirds during spring migration, and enhanced environmental suitability for the tick with a changing climate (3). Generally, where the ticks have become established, Lyme disease risk follows (4).

Critical to the management of the expanding risk of Lyme disease in Canada is identifying where the ticks have become established and are transmitting *B. burgdorferi* among their wildlife hosts (5). This is important both to inform public health activities by identifying the population at risk, and to aid in the clinical diagnosis of Lyme disease and the interpretation of laboratory tests (5-6).

The occurrence of possible new locations of Lyme disease risk can be signaled by the occurrence of Lyme disease cases in these locations, or by information from passive tick surveillance (7, 3). The current gold standard to confirm the presence of Lyme disease risk (i.e. to identify a Lyme disease-endemic area) in these areas, or in prospective studies, requires considerable human and financial resources over a two-year period. Endemic areas for the tick vectors are defined as a contiguous sampling area where “all three stages larva, nymph and adult are present …. on resident animals or in the environment for at least 2 consecutive years” (7), Lyme disease-endemic areas are those where the tick vectors are endemic and where there is evidence the ticks are transmitting *B. burgdorferi* among reservoir hosts (7). Identification of these areas requires drag sampling and the capture and testing of a minimum of 30 wild rodents.

Drag sampling involves trailing a 1-m^2 flannel through the habitat to collect unfed ticks that are host-seeking on the woodland floor. Rodents are captured in live traps and examined for ticks. Wild rodents are natural hosts of larval and nymphal ticks as well as being reservoir hosts for *B. burgdorferi*. Ticks and blood and tissue samples from captured rodents are tested for evidence of *B. burgdorferi* infection by polymerase chain reaction (PCR), serology, and/or culture. Although this method has a high specificity and sensitivity to detect infected ticks and *B. burgdorferi*, it is time consuming. It requires multiple site visits to place traps and then open them to sample rodents the following day. This process is usually repeated three times a year for two years. This is challenging both logistically and in terms of human and financial resource needs, is limited by the availability of trained field operatives and may limit the amount of field surveillance that can be conducted by provincial and municipal public health organizations.

In the United States, the mainstay of field surveillance is drag sampling alone, based on the observation that the numbers of infected ticks collected by drag sampling correlates with risk to humans (8). It is also known that different tick stages are active at different times of the year, and tick abundance overall can vary from one year to the next, particularly in emerging risk areas (10).

The objective of this study was to assess whether drag sampling alone may be sufficient as a screening technique to identify *I. scapularis* populations and Lyme disease risk in Canada and whether this may be affected by the time of year sampling occurs.

Methods

To assess drag sampling alone as a screening technique to identify Lyme disease risk, we retrospectively analyzed data from previous field studies carried out at 71 individual sites in southern Quebec in 2007 and 2008. (3, 9). Sites were selected to ensure the habitat was suitable for *I. scapularis* and to minimize intersite variations in habitat. Variations in presence and numbers of *I. scapularis* ticks was mostly determined by temperature conditions at the sites (3). Some of the 71 sites were visited up to four times over the period from 2007 to 2008, so there were data from 100 site visits. At each site visit, the presence of *I. scapularis* was determined by drag sampling the environment (with an effort of three person-hours per site visit), and by examination of captured rodents for feeding ticks. At each site visit, 15 mice were captured, giving 95% probability of detecting a tick-infested rodent if the true prevalence is 20%. This was lower than the 30 mice recommended by guidelines developed by Health Canada in 1991 (to give 95% probability of detecting an infested mouse if the true prevalence was 10%), as the objective in the 1991 guidelines was to confirm the absence of ticks (7). The species of all collected ticks was determined using standard tick identification keys (3). All identification of ticks and laboratory analyses for *B. burgdorferi* infection in samples collected from these sites were conducted at the Public Health Agency of Canada's National Microbiology Laboratory.

For each site visit, the identification of *I. scapularis* on rodents and by drag sampling were considered as binary data (i.e. either present or absent). To assess the sensitivity and specificity of drag sampling, the presence or absence of ticks by drag sampling was compared with the presence or absence of ticks in the captured rodents. Sensitivity of drag sampling was calculated as the proportion of site visits where ticks were found by drag sampling and there were also *I. scapularis*-infested rodents. Specificity was the proportion of the site visits where ticks were absent by drag sampling and there were no *I. scapularis*-infested rodents. Ticks collected by drag sampling during site visits where there were no *I. scapularis*-infested rodents could be considered to be adventitious ticks, i.e. ticks carried into the site by animal or bird hosts that acquired the ticks in other locations.

To explore whether the season or year of site visits had an impact on the ability of drag sampling to detect ticks, two logistic regression models were created in which site identification number was a random effect (as some sites were visited multiple times). In the first model, we explored whether there were seasonal variations in the capacity of examination of captured rodents to detect *I. scapularis* on a site. In this model, the outcome variable was presence of *I. scapularis* as determined by examination of captured rodents, and the explanatory variables were year of sampling and season of sampling (season 1 being May to June, season 2 being July to August, and season 3 being September to October). In the second model, we explored whether the season and year of sampling were associated with variations in the capacity of drag sampling to predict the presence of *I. scapularis*

on rodents. Interactions amongst drag-sampling results and season were also explored. All analyses were conducted in Stata SE 11.0 (StataCorp, College Station, Tx) and the threshold for significance was P <0.05.

Results

A total of one hundred site visits were conducted at 71 sites over a two-year period. At all the sites visited, the density of ticks and *B. burgdorferi* infection prevalence were low (3), which was consistent with early stage of establishment of the tick and *B. burgdorferi* transmission cycles (10, 11). Eleven of the sites at which *I. scapularis* were identified at visits in 2007 were revisited in 2008 at least once. At the 2008 site visits, two or more stages of *I. scapularis* were detected at all of the sites, supporting the idea that these sites did not just have adventitious ticks as they contained reproducing populations of *I. scapularis* (3).

Of the 58 site visits at which *I. scapularis* were collected from captured rodents, 29 also yielded *I. scapularis* by drag sampling, so the sensitivity of drag sampling was 50% (**Table 1**). Of the 42 site visits at which no *I. scapularis* were found on rodents, 36 yielded no *I. scapularis* by drag sampling, so the specificity of drag sampling was 86% (36/42). However, on two of the sites on which drags were positive, rodent testing was negative, but ticks were found on rodents at previous or subsequent visits, suggesting that in these two instances, ticks collected by drag sampling were not adventitious ticks.

Table 1: Sensitivity and specificity of drag sampling alone to detect *I. scapularis* feeding on captured rodents (n=100 site visits)

	***I. scapularis* ticks detected on rodents n=58**	***I. scapularis* ticks not detected on rodents n=42**
Drag sampling was POSITIVE	29/58 = 50% sensitivity	6/42
Drag sampling was NEGATIVE	29/58	36/42 = 86% specificity

The proportion of site visits at which *I. scapularis* were collected from captured rodents was significantly greater in 2008 than 2007 (odds ratio [OR] = 10.7, 95% CI 1.01 – 105.6, P <0.05), but there was no significant variation amongst seasons (x^2 = 2.4, df = 2, P> 0.1). Similarly, the proportion of site visits at which *I. scapularis* were collected by drag sampling was significantly greater in 2008 than 2007 (OR = 6.4, 95% CI 2.23 – 18.36, P <0.05), but there was no significant variation among seasons (x^2 = 2.6, df = 2, P> 0.1). The seasonal activity of the different stages of *I. scapularis* on rodents and drags was also consistent with that expected of northeastern North America (i.e. adults active in spring and autumn, nymphs active in spring and early summer, and larvae active in late summer and early autumn) (3). When the detection of *I. scapularis* on drag sampling was included as an explanatory variable, it was significantly associated with the detection of *I. scapularis* on captured rodents (OR = 9.48, 95% CI = 1.46 – 60.94) but there were no significant interactions with the season or year.

Discussion

This analysis suggests that drag sampling has good specificity, but less sensitivity than examination of captured rodents to identify where Lyme disease may be acquired now or in the near future. A specificity of almost 90% suggests that if *I. scapularis* ticks are found by drag sampling, it is likely a risk area for Lyme disease. A sensitivity of 50% suggests that some sites with low densities of ticks will be missed by drag sampling alone. However, sites where ticks are present in rodents but undetected by drag sampling are most likely sites where tick populations and *B. burgdorferi* transmission cycles are at a very early stage of establishment, and pose a low level of Lyme disease risk to the public (10). When ticks were found by drag sampling and on rodents, ticks were also found at that site in the following year. Together, this means there is relatively high confidence that if an *I. scapularis* tick is found by drag sampling, then an emerging, self-sustaining, reproducing population of *I. scapularis* ticks likely is present at that location.

The strength of this study is that our preliminary evidence suggests this simple field technique can offer a good indication of Lyme disease risk. This is consistent with American studies linking drag sampling results to human disease incidence (8). This is also consistent with what has occurred in Ontario and Quebec: as tick populations become more firmly established, tick density and tick infection prevalence will rise (4). Screening for Lyme disease risk by drag sampling alone is also relatively easy and cheap to operationalize and did not seem to be affected by seasonal variation.

A limitation of this study was using the positive rodent test as the comparator, versus the more comprehensive 1991 guidelines test for establishing a Lyme disease-endemic area. The rodent test was a good proxy but was not ideal, as evidenced by the two instances where drag sampling was positive but rodent test was negative. The assumption that these were adventitious ticks was not substantiated as ticks were found in rodents at those sites in subsequent years. Drag sampling also detects adult ticks active in spring and autumn, and these do not feed on rodents so would not be detected by rodent capture alone (10).

Another potential limitation of the study is that it did not assess the effectiveness of field training. Not all ticks, for example, are easily identifiable. Larvae active in late summer are smaller than spring-active nymphs and individually less likely to be found (10). Training of field staff to identify the very small immature ticks would be needed, but this training would be much easier to implement than training for capture, handling and/or anesthesia and examination of rodents.

Further study is warranted to explore the relationships between tick abundance and infection prevalence and incidence of human cases to more clearly be able to quantify the relationship between environmental measures of risk and disease risk. Also, replication of the study in different habitats and geographic locations (e.g. woodlands of British Columbia, Manitoba, and the Maritimes) would be prudent to explore and ensure the generalizability of the findings.

Drag sampling may be most useful in identifying the progression of areas at risk in provinces where Lyme disease risk has already been established. Once a Lyme disease-endemic area is confirmed, then the one-visit drag-sampling method could be employed to identify areas of risk over a wider geographic area. However, it may be prudent for public health practitioners in provinces (such as Alberta, Saskatchewan, and Prince Edward Island) and the territories where *I. scapularis* or *I. pacificus* do not presently occur, to use the 1991 guidelines methodology recommended to detect Lyme disease-endemic areas (7) before using this screening test to assess emerging tick populations.

Our study suggests that a single drag-sampling visit may be a good screening test to detect Lyme disease risk locations to complement the 1991 guidelines approach to confirming a Lyme disease-endemic area. Studies assessing the effectiveness of teaching drag-sampling are indicated, as this would be a simple cost-effective way for local or regional public health to determine Lyme disease risk in their jurisdiction. This could then be used to alert public health and medical practitioners, and the public of a Lyme disease risk and enable a timelier implementation of public health interventions.

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Conflict of interest

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Summary of the Public Health Agency of Canada's *Action Plan on Lyme Disease*

Harymann M[1]*, Ogden N[1], Lindsay R[1], Lawless V[1], Deilgat M[1] and Sternthal S[1]

[1] Public Health Agency of Canada, Centre for Food-borne, Environmental and Zoonotic Infectious Diseases
* Corresponding author: marian.harymann@phac-aspc.gc.ca

Abstract

Background: Lyme disease is an emerging infectious disease in Canada that requires a comprehensive approach to prevention and control. It is a serious illness caused by a bacterium transmitted by certain types of ticks. The risk of Lyme disease currently exists in southern parts of British Columbia and Manitoba, southern and eastern Ontario, southern Quebec and New Brunswick, and in some locations in Nova Scotia.

Objective: To highlight the Public Health Agency of Canada's *Action Plan on Lyme Disease,* which aims to mitigate the risks to Canadians posed by Lyme disease through concrete activities being undertaken jointly with the provinces, territories, and various stakeholders.

Approach: A multidisciplinary approach was used to assess the evidence on Lyme disease in Canada, analyze stakeholder concerns and evaluate what was currently available to inform public health professionals and the public. This assessment informed the development of an action plan intended to address the prevention, diagnosis and treatment of Lyme disease.

Results: The *Action Plan on Lyme Disease* sets out concrete action to be undertaken over three years, beginning in March 2014. It is built upon three pillars: 1.) Engagement, education and awareness, 2.) Surveillance, prevention and control, and 3.) Research and diagnosis.

Conclusion: Effective prevention and control of Lyme disease in Canada requires a coordinated multi-partner and stakeholder engagement approach.

Introduction

Lyme disease is an emerging infectious disease in Canada that requires a comprehensive approach to prevention and control. It is a serious illness caused by a bacterium transmitted by certain types of ticks. The risk of Lyme disease currently exists in southern parts of British Columbia and Manitoba, southern and eastern Ontario, southern Quebec and New Brunswick, and in some locations in Nova Scotia. As migratory birds and other animal hosts carry ticks to new areas, the risk of Lyme disease is spreading. To promote prevention, early diagnosis, and treatment, greater public awareness of the disease is needed along with collaborative engagement of public health and health care professionals, academics, scientists, and patient advocacy groups.

The objective of this *Action Plan* is to mitigate the risks to Canadians posed by Lyme disease through concrete activities being undertaken jointly with the provinces, territories, and various stakeholders.

Approach

A multidisciplinary approach was used to assess the surveillance, risk assessment, and research evidence on Lyme disease in Canada and internationally; to analyze diverse stakeholder concerns regarding prevention, diagnosis and treatment of the disease; and to evaluate the usefulness of information available to public health professionals and the public. This information was then used to inform the development of an action plan intended to address the prevention of Lyme disease, so that any Lyme disease cases that do occur can be diagnosed and

treated early in the course of disease. The plan was also aligned with priority areas of the Public Health Agency of Canada and key federal objectives (**Figure 1**).

The Action Plan

The *Action Plan* is built upon three pillars: 1.) Engagement, education and awareness, 2.) Surveillance, prevention and control, and 3.) Research and diagnosis.

Engagement, education and awareness

A key element in preventing Lyme disease and promoting early diagnosis and treatment is raising public awareness and healthcare provider knowledge. To achieve this goal, activities will focus on:

- An advertising campaign targeting health care professionals, as well as Canadians practising outdoor activities;
- Stakeholder outreach, e.g. the dissemination of a comprehensive toolkit of educational materials for a range of end users, including public health professionals;
- Media engagement, including proactive interviews with experts and a partnership with News Canada;
- Social media activities, including Facebook, Twitter, and blogs.

The Public Health Agency of Canada (the Agency) is actively engaging provincial and territorial health authorities and other stakeholders to coordinate a national communications response to Lyme disease to better protect Canadians.

Surveillance, prevention and control

The collection, analysis, and interpretation of epidemiological data are essential features of public health practice. The Agency has developed an approach to national surveillance for both ticks and human cases of Lyme disease. The surveillance aims to measure national and regional changes in incidence and to identify populations at risk. To address the need for continued and enhanced surveillance, prevention, and control for Lyme disease, the Agency is:

- Working with partners to explore innovative ways to conduct surveillance;
- Developing strategies to encourage preventive behaviour;
- Conducting systematic reviews and other research on the epidemiology, prevention, and control of Lyme disease in Canada to inform the development of public health guidelines;
- Undertaking field studies to inform risk models that identify emerging risk areas.

The Agency also plans to consult with stakeholders to help improve prevention efforts, and public health guidelines on Lyme disease to reflect the latest scientific evidence and best practices.

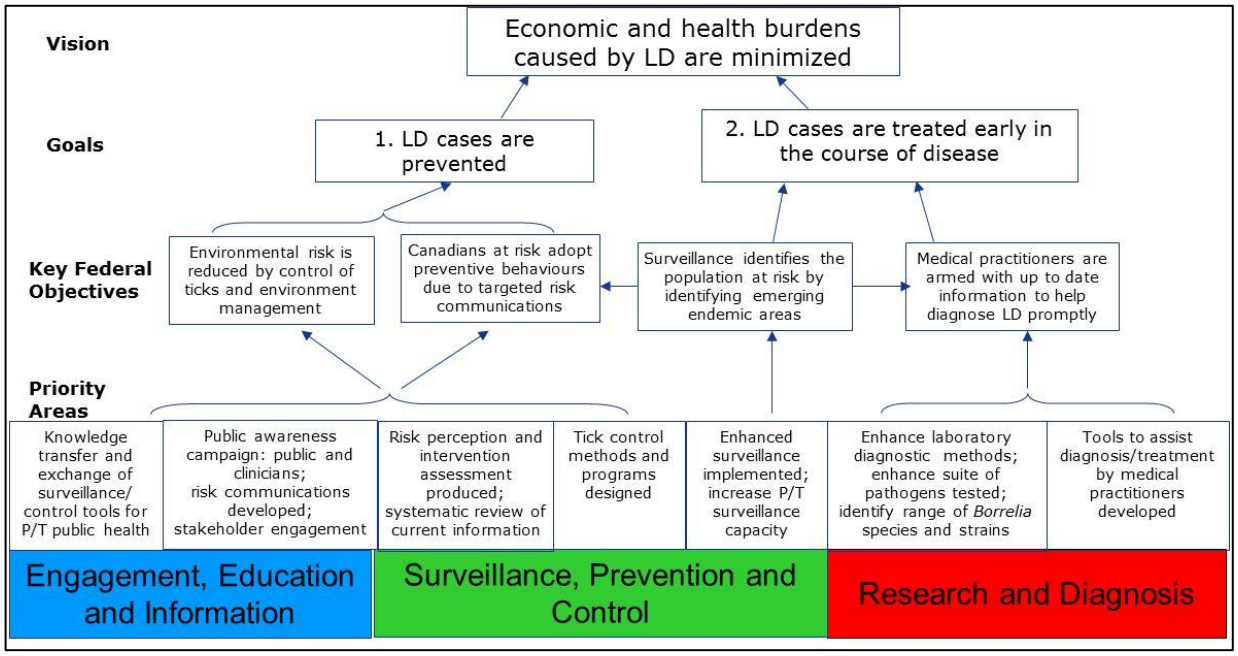
Research and diagnosis

There is a need for continued research on Lyme disease and other emerging tick-borne diseases to better understand the causes and complications of the disease, and how to effectively diagnose and treat it. Through examination of evidence-based research, the Agency will explore:

- New methods of controlling the ticks that carry and spread Lyme disease;
- Improved diagnostic methods as they become available;
- The strains and species of tick-borne pathogens, their geographic locations, and their possible implications for diagnosis and disease severity.

Clinical practice and laboratory guidelines will be reviewed and updated.

Figure 1: The three pillars of the *Action Plan on Lyme Disease* and their alignment with priority areas, key federal objectives, goals, and vision



Conclusion

Effective prevention and control of Lyme disease in Canada requires a coordinated multi-partner and stakeholder engagement approach. This will contribute to minimizing the impact of Lyme disease through:

- Improved understanding and awareness of Lyme disease by the public, health care providers, and other stakeholders;
- Enhanced national surveillance to pinpoint where the disease is emerging and which populations are at risk;
- Research to generate new insights into effective diagnosis and treatment;
- Promotion of early diagnosis and treatment of Lyme disease.

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Conflict of interest statement

There are no conflicts of interest to declare.

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Lyme disease prevention and control – the way forward

Beard CB[1]*

[1] Division of Vector-Borne Diseases, U.S. Centers for Disease Control and Prevention (CDC), Fort Collins, CO

* Corresponding author: cbeard@cdc.gov

Introduction

Lyme borreliosis is a tick-borne illness caused by the spirochete *Borrelia burgdorferi*, harbored primarily by small rodents, and transmitted by ticks in the genus *Ixodes*. It was first recognized clinically in the 1970s, in a cluster of juvenile arthritis cases in Connecticut (1). Over the last twenty five years, Lyme disease has been increasing steadily in the United States, both in case numbers and in geographic distribution. As noted in the other articles in this issue, Lyme disease has started to show a similar pattern in Canada. In the United States, there were over 30,000 cases reported to the Centers for Disease Control and Prevention (CDC) in 2012, making it the 7th most common reportable condition. The increasing numbers of cases is thought to have resulted from expanding deer populations and suburban growth that have led to abundant reservoir hosts, more ticks, and greater opportunities for exposure in humans (2). It is important to note that the observed trends for Lyme disease emergence are similar for several other tick-borne diseases that share similar ecologies, including anaplasmosis, babesiosis, ehrlichiciosis, and Powassan disease.

Symptoms of Lyme disease range from an erythema migrans rash, early in the course of infection, to neuritis (e.g., facial palsy), carditis, and arthritis in later, disseminated stages of illness. Prompt treatment with 2-4 weeks of oral doxycycline results in symptomatic cure of the great majority of patients. Nevertheless, a subset of patients, especially those diagnosed and treated in later stages of illness, may have persistent fatigue, muscle aches, short-term memory problems, and other nonspecific symptoms. Consequently, one of the highest priority research needs in the field of Lyme disease is to elucidate the specific cause or causes of symptoms in these patients and to determine the safest and most effective treatment options. This question is the focus of several current or recently published research studies in humans and non-human primates that are evaluating treatment response, clinical outcome, and the possibility of spirochete persistence following treatment (3-5).

Another very high priority research need is for improved diagnostics. The currently validated diagnostic tests in common use for Lyme disease are all serologic tests that rely on a detectable antibody response. Consequently, these tests have limited value early in infection or in patients who have had prior infection, depending on how long ago the infection occurred. Some of the more promising research that is ongoing in this area focuses on the identification of direct diagnostic targets. These may either be nucleic acids or low molecular weight cellular metabolites that are indicators of active infection or a specific host-mediated response to infection.

One last highly critical research need worth noting is for the development and evaluation of safe and effective prevention and control tools and methods. This topic will be discussed further below.

In addition to these research needs, other critical needs must be addressed in order to establish and maintain an effective public health response. These include 1.) an accurate understanding of disease distribution and risk; 2.) an awareness of the disease among the public at risk and knowledge about how to protect themselves; 3.) informed healthcare providers who can recognize the disease and provide early and accurate diagnosis and treatment; 4.) validated prevention and control practices; and 5.) effective multi-level collaboration toward the goal of prevention. The remaining sections of this paper briefly discuss each of these topics.

Future Efforts

Disease distribution and risk

The starting point for an effective public health response to Lyme disease is to maintain accurate information on disease distribution and the specific locations and areas of risk. This is required to track disease trends and project future emergence, and is critical for targeting prevention education and resources for control. This is particularly true for emerging diseases like Lyme disease where the disease is expanding into areas where it did not previously exist and may not be recognized. It is also important to understand local disease ecology and epidemiology so that interventions can be targeted effectively to particular locations where infection risk is greatest.

Public awareness

Once the specific region or regions of enzootic activity and the specific epidemiologic risks have been identified, there is a need to raise awareness in these at-risk communities. Some of the methods available include the use of trail signs, public service announcements, and prevention information targeted to specific high-risk groups. Resources are increasingly available, both in Canada (6) and in the United States (7). Targeting prevention messages to areas where the disease is newly emerging will make newly at risk populations more aware of the problem and of what can be done about it. These groups may also be more eager to engage.

Healthcare provider education

Healthcare provider education is highly important in these areas of emerging risk. Despite the controversy that surrounds treatment of patients with persistent symptoms associated with Lyme disease, a common point of agreement is that early and accurate diagnosis and treatment (also referred to as secondary prevention) is the most effective way to reduce serious clinical outcomes. A recent report of Lyme carditis and sudden cardiac death emphasizes the need for vigilance in Lyme endemic areas to ensure prompt recognition and early, appropriate therapy (8). Healthcare providers also play an important role in prevention education by informing their patients about the ways to reduce their exposure to vector ticks. Several courses are now available for continuing medical education credit as well as other useful information (9-10).

Prevention and control practices

The most useful prevention tool for Lyme borreliosis would be a safe and effective human vaccine that has been adequately evaluated in both children and adults. No such vaccine is available at this time. Consequently, Lyme disease prevention recommendations currently include activities aimed at reducing exposure to infected ticks. These methods include such practices as area pesticide applications, landscape management, deer management, applying repellants or toxicants to skin or clothing, tick checks, showering after being in tick habitat, and host-targeted interventions (11). Some examples of the latter include reservoir-targeted vaccines, 4-poster deer devices, and bait boxes that contain acaricides that kill ticks on rodent hosts. In general, while these methods can reduce the numbers of ticks, scant evidence exists that their use actually reduces human illness. The human Lyme disease vaccine LYMErix™ was the only intervention that was ever demonstrated in large community trials to reduce human illness (12). In the absence of a human vaccine, the most effective efforts to reduce exposure to infected ticks will probably require a combination of personal protective measures and coordinated local activities aimed at reducing tick densities in places where people are most likely exposed. In evaluating these measures, however, true prevention outcomes should be assessed. Many studies have looked at the reduction in entomological risk (i.e. the reduction in abundance of infected nymphal ticks), but few measure the actual reduction in physician-diagnosed disease or a suitable proxy such as the numbers of ticks found on people in treated versus untreated groups (13).

Multi-level collaboration

The fifth and final critical need is for multi-level collaboration in the development and implementation of disease prevention efforts. Effective control begins at the local level, in the backyards, neighborhoods, parks, and green spaces where infected ticks are encountered. The best solutions for prevention are likely local solutions that account for variation in local disease ecology, the corresponding unique patterns of risk, and population preferences. Public health agencies at federal, state, and provincial levels, however, can more easily conduct or fund evaluation studies and can also draw from the experience of multiple communities across broad geographic areas. Having identified and validated the best prevention practices, they can then make this information available in the form of evidence-based guidelines and recommendations. Through their influence, they can stimulate communication and collaboration among the key public health partners, such as local health departments and community groups, including patient advocacy groups. People are likely to encounter infected ticks in multiple locations, including their own yards, their neighbor's yard, and public areas. For this reason, effective collaboration and coordination among key prevention partners at multiple levels will be essential in achieving lasting control. The Public Health Agency of Canada has recently launched a national *Action Plan on Lyme Disease* that will inform these efforts (14).

Conclusion

Lyme and other tick-borne diseases are on the increase in Canada and the U.S. There are a number of very important needs that are being addressed through current research, including improved diagnostic tests, an understanding of the cause of persistent symptoms and the corresponding best treatment options, and a safe and effective vaccine. An effective public health response depends upon an accurate understanding of the problem, knowledge and awareness among both healthcare providers and the population at risk, the availability of effective prevention and control methods that can reduce human illness, and the development and coordination of a national action plan that is applied locally, according to unique epidemiologic and ecological features of disease risk.

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