Tick Surveillance

2017 Summary

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Summary

Tick surveillance can be passive (examining ticks that are voluntarily submitted by the public) or active (targeted collection of ticks in their natural habitat). Both methods are useful for monitoring changes to the risk from Lyme disease and other tick-borne diseases.

Both active and passive tick surveillance are carried out in Saskatchewan and provide useful information on tick activity in the province. Surveillance began in 1995 and active surveillance for *Ixodes scapularis* (the black-legged tick) has been ongoing in Saskatchewan since 2009. The black-legged tick is the primary carrier for the agents that cause Lyme disease and a number of other tick-borne diseases in Canada and the U.S. The active surveillance program has the objectives of assessing the risk of Lyme disease in the province by checking for black-legged ticks and determining if they have become established in any areas of the province, and determining what fraction of them carry the bacteria responsible for Lyme disease or other tick-borne diseases such as anaplasmosis and babesiosis. Confirmed human cases of Lyme disease or other tick-borne diseases are also recorded. The risks of acquiring Lyme disease from infected ticks increases substantially in areas where the black-legged tick has become established.

Black-legged ticks submitted or collected through the surveillance program are tested for *Borrelia burgdorferi* (the agent that causes Lyme disease), *Anaplasma phagocytophilum* (the agent that causes anaplasmosis) and as of 2013, *Babesia microti* (the agent that causes babesiosis), *Borrelia miyamotoi* (the agent that causes relapsing fever) and *Borrelia mayonii*, a newly described organism that can cause Lyme disease.

The sampling locations for active tick surveillance are determined by a numbers of factors including: computer modelling to map habitats likely to sustain tick populations, information from the passive sampling program (such as where black-legged ticks have been collected), and any known human or animal Lyme disease cases that can be tracked to a definitive location. Other factors that are considered in sample site selection include sampling in suitable habitat areas such as parks and recreational areas where there is a high interaction between people, pets, wildlife, and proximity to known risk areas in neighbouring jurisdictions.

A small number of black-legged ticks have been found over past years of passive sampling, but no reproducing populations of ticks have been detected in any areas of the province despite several years of active sampling. This means that, at present, there are no known Lyme disease risk areas in the province. However, the possibility of black-legged ticks being dropped by migrating birds exists across the province, and approximately 12 percent of these ticks are infected with the bacteria that causes Lyme disease. Thus, there is still a risk to humans of contracting Lyme disease from an infected tick in Saskatchewan; even in the absence of known risk areas. Furthermore, since adult black-legged ticks are active in the spring and fall months, and nymphs are found in the late spring and summer, the risk of being bitten by an infected tick can exist for the entire spring, summer, and fall period.

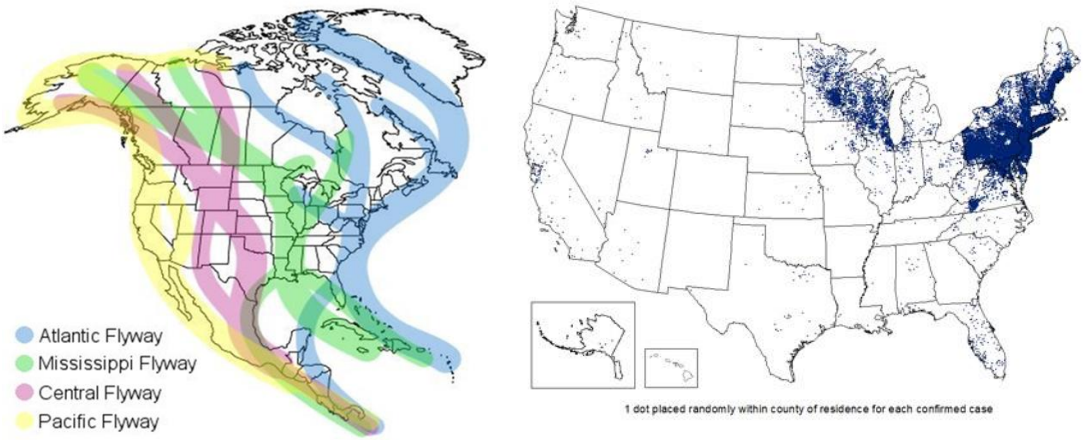
2017 Tick Surveillance Summary

- The majority of ticks (>96%) obtained through the surveillance program were the American dog tick (*Dermacentor variabilis*). This species is not a competent vector of Lyme disease.
- In 2017, 5,112 ticks were collected through voluntary submissions. 15 black-legged ticks were identified; four (27 %) tested positive for the bacteria that causes Lyme disease.
- Of the 26,666 ticks collected through voluntary submissions since 2008, eight of 65 black-legged ticks (12%) have tested positive for the bacteria that causes Lyme disease. Five ticks (8 %) have tested positive for the bacteria that causes anaplasmosis. Three ticks were co-infected with both agents.
- Active tick surveys have increased in recent years. 151 active surveys have been completed in the province since 2014; 20 surveys at 16 sites were completed in 2017.
- 549 ticks were collected through active surveys in 2017 - all identified as American dog ticks.

Introduction

Lyme disease is caused by a bacterial infection transmitted to humans through the bite of certain types of ticks, most notably some species within the genus *Ixodes*. The range of the primary vector of Lyme disease in Canada, *Ixodes scapularis,* the black-legged tick, has been rapidly expanding in Canada in recent years. Localized areas in southern Ontario, Quebec, New Brunswick, Nova Scotia, and Manitoba are now considered endemic for this tick. The risk of acquiring Lyme disease increases in areas where populations of infected black-legged ticks are established. Another vector of Lyme disease, *Ixodes pacificus* or Western black-legged tick, is established in areas of southern British Columbia. Populations of black-legged ticks are not known to be established in Saskatchewan at this time however, small numbers of infected black-legged ticks are transported into the province by birds migrating north. Several major flyways converge over Saskatchewan and can have birds that have picked up infected ticks in the Midwestern and central states in the U.S. (Figure 1).

Figure 1: North American Bird Flyways and Reported Cases of Lyme Disease – United States, 2016



(source: http://birding.about.com/od/birdingbasics/ss/North-America-Migration-Flyways.htm and https://www.cdc.gov/lyme/stats/maps.html)

The majority of ticks found in Saskatchewan are the American dog tick *(Dermacentor variabilis*). Other common species include the Rocky Mountain wood tick (*Dermacentor andersoni*) and the winter tick (*Dermacentor albipictus*). These species are not competent vectors of Lyme disease. A few ticks (0.2 %) are the black-legged tick, occasionally found in the southern and central part of the province. Eight of 65 (12 %) black-legged ticks submitted for testing since 2008 have tested positive for *Borrelia burgdorferi,* the bacteria that causes Lyme disease (Table 1). Black-legged ticks may carry other organisms that cause human disease, including anaplasmosis and babesiosis. These diseases have not been documented in humans in Saskatchewan although, five black-legged ticks have tested positive for the bacteria that causes anaplasmosis.

Determining Lyme Disease Risk

Monitoring for black-legged ticks and the prevalence of infection with *Borrelia* or other bacteria allows public health officials to assess the risk of human exposure to infected ticks in a given area. A Lyme disease risk area is defined as a location in which there is:

- evidence of established (reproducing) populations of black-legged ticks. This is indicated by the presence of all three life-cycle stages (larva, nymph, adult) in an area, found over more than one year; and,
- likely transmission of *B. burgdorferi.* This is demonstrated by laboratory testing (molecular detection or culture) of *B. burgdorferi* in ticks and/or rodent samples.

The following methods are used to determine risk areas in Saskatchewan:

1) drag sampling for ticks [1];
2) field-validated signals from passive tick surveillance [2].

The risk can increase substantially in areas where infected tick populations become established. Tick abundance and infection rates for the bacteria that cause Lyme disease can be much higher and more localized in established areas than in non-established areas[3].

Lyme disease risk areas identified in Canada are summarized at: http://www.healthycanadians.gc.ca/diseases-conditions-maladies-affections/disease-maladie/lyme/risks-risques-eng.php#a3. The relevant provincial and territorial websites can be found at this same link.

In order to maximize the probability of finding any risk areas (i.e. sites with established black-legged tick populations) in Saskatchewan, the active surveillance program prioritizes the locations with the highest likelihood (risk) of supporting an established tick population. If such populations were found, this would be the first Lyme disease risk area known in Saskatchewan.

Several sources of information are used in determining these priority locations for active tick surveillance. These information sources include computer models, information from the passive surveillance program, any known human or animal cases of Lyme disease, and information from other nearby jurisdictions with known populations.

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[1] Ogden NH, Koffi JK, Pelcat Y, Lindsay LR. Environmental risk from Lyme disease in central and eastern Canada: a summary of recent surveillance information. Can Comm Dis Rep 2014; 40: 74-82

[2] Koffi JK, Leighton PA, Pelcat Y et al. Passive surveillance for *Ixodes scapularis* ticks: enhanced analysis for early detection of emerging Lyme disease risk. J Med Entomol 2012; 49: 400-409

[3] Lindsay LR (National Microbiology Laboratory)(Personal communication)

Tick Surveillance in Saskatchewan

The Ministry of Health (Population Health Branch) has collaborated since 1995 with the Roy Romanow Provincial Laboratory (RRPL) (formerly the Saskatchewan Disease Control Laboratory), the Public Health Agency of Canada - National Microbiology Laboratory (NML), and, since 2009, the University of Saskatchewan (U. of S.) to monitor ticks in the province. In 2016 and 2017, the former Regina Qu'Appelle Health Region assisted with the spring and fall surveys of ticks in southeastern Saskatchewan.

The goal of the Tick Surveillance Program is to assess the risk of acquiring Lyme disease and other tick-borne disease by determining whether the vector is present and/or established in Saskatchewan. Tick surveillance can determine the distribution and level of establishment of tick populations, specifically black-legged tick populations, within an area; monitor the infection prevalence; and, assess the possible risk of infection to humans. The status of black-legged tick populations in an area are classified as one of:

- Established – field surveillance suggests that reproducing populations occur;
- Adventitious – ticks are found only sporadically, both in time and space, and usually only a single stage of tick (i.e. adult females) is present; or,
- Not Present – ticks have not been found in an area after studies have been conducted to assess the level of establishment.

Tick surveillance can be passive (examining ticks voluntarily submitted by the public) or active (targeted collection of ticks in their natural habitat). Both methods are useful for monitoring changes to the risk from Lyme disease or other tick-borne diseases.

Passive Surveillance

The objectives of passive tick surveillance is to assess potential risk of Lyme disease across the province and to provide input to the active program regarding when and where to sample for ticks.

Methods

Ticks voluntarily submitted by veterinarians, health care workers, general public, and other interested parties are sorted and identified at the RRPL and the U of S. All black-legged ticks are submitted to the NML for identification and testing for *Borrelia burgdorferi* (the agent that causes Lyme disease), *Anaplasma phagocytophilum* (the agent that causes anaplasmosis), *Babesia microti* (the agent that causes babesiosis), *Borrelia miyamotoi (*the agent that causes relapsing fever), and *Borrelia mayonii*, a newly described organism that can cause Lyme disease.

More information about how to submit ticks under the program can be found at: https://www.saskatchewan.ca/residents/health/diseases-and-conditions/lyme-disease#submitting-ticks-for-testing

Passive surveillance is recommended for jurisdictions, such as Saskatchewan, where established populations do not exist. It is found to be less useful in areas where there are known established tick populations[4].

[4] Koffi JK, Leighton PA, Pelcat Y et al. Passive surveillance for *Ixodes scapularis* ticks: enhanced analysis for early detection of emerging Lyme disease risk. J Med Entomol 2012; 49: 400-409

Active Surveillance

The objective of active surveillance is to detect the location of any established black-legged tick populations and to identify Lyme disease risk areas (if any) in the province. Active surveillance uses targeted surveys to look for black-legged ticks in locations where other information (passive surveillance, human cases, and suitable habitat) suggest the possibility of tick populations occurring. In order to establish baseline information on tick populations, an important goal of active surveillance is to do repeated sampling at many of the same sites every year and seasonal sampling (i.e. spring or fall) at other sites.

Methods

Figure 2: Tick Surveillance Using a Drag

Active surveillance in Saskatchewan is primarily done by tick dragging. This consists of dragging a white flannel cloth over and around vegetation where ticks may be present, as shown in Figure 2. The cloth is 1m² and is attached to a 1.2m wooden dowel or plastic piping, with a cord or rope used to pull the drag cloth (Figure 2). To be consistent with sampling methods in other provinces, a standard 2 km survey per site has been adopted in Saskatchewan. Each survey consists of collecting and recording ticks every 10m; a total of 200 times. After each 10m drag, ticks are removed from the drag cloth, and from the clothing of the sampler, using fine forceps or a fine paint brush. Numbers and species found are recorded for each 10m. The total distance of each survey is 2000m or 2 km. Because the drag cloth is 1m², the total area sampled per site is 2000m² or 0.2 hectare. Any adult black-legged ticks and nymphs found are placed into collection vials and sent to the NML for identification and testing.

Occasionally tick flagging may be used instead of dragging, which involves moving the cloth in a waving motion over and through vegetation. With flagging, the end of the drag cloth can be gripped at one end so that the cloth hangs vertically downwards, and swept over the vegetation. Ticks that are questing for passing hosts cling to the cloth and can be removed for identification and counting. The dragging technique is used over relatively open ground, whereas flagging is usually done in densely brushy ground.

Active tick surveillance by drag or flag sampling is done by staff from the Ministry of Health, the former Regina Qu'Appelle Health Region, or the U of S, and occurs throughout the tick season from April to November. Drag/flag sampling is usually done in the late morning or early afternoon. Sampling is not done when it is raining, when the vegetation is wet (from rain or dew), or when temperatures are below 4°C. Adult black-legged ticks are mostly active in the spring and fall months, while nymphs are found in the spring and summer months. Sampling schedules are created with this timing in mind.

Site Determination

Sites for active sampling include provincial parks, provincial recreation/historic sites and ecological reserves, national historic sites, regional parks, urban parkways, sites where black-legged ticks have been collected by passive surveillance, as well as sites of most likely exposure for human or domestic animal Lyme disease cases. Sites also include those tested annually or several times per year as "sentinel" sites along the Upper Assiniboine, Qu'Appelle and Souris River watersheds, which are tributaries to the larger Assiniboine River watershed in southern Manitoba where established populations of black-legged ticks have been found. A more detailed summary of the site selection criteria is included in Appendix A.

The potential habitat sites have been identified through a climate and habitat suitability mapping project for the black-legged tick in the province (Appendix A). This is a joint project between the Ministry of Health and PHAC and integrates various layers of data such as temperature, relative humidity, woodland habitat, and other factors such as deer density. This project has identified areas of low to high potential (risk index 0-5) for establishment of black-legged ticks and this has helped to further guide tick surveillance efforts. Of the 64.6 million hectares of habitat classified, 106,049 ha have been classified as having a high risk potential for establishment of the black-legged tick. Most active tick surveys are conducted in high risk areas.

Surveillance Results

Passive Surveillance

In 2017, 5,112 ticks were submitted by passive surveillance and 15 (0.3%) were adult black-legged ticks (Table 1). Four ticks (4) were positive for the Lyme disease agent, *B. burgdorferi*. Most black-legged ticks were collected from dogs (8/15), but six were from other hosts (human – 3, cat – 2, horse – 1).

There was no significant change in black-legged ticks collected or positive test results from 2008-2016 (Av. 1 positive tick/yr.; range 0-2). However, the numbers collected and numbers that tested positive did rise in 2017 (4/15= 27 %) (Table 1). It is unclear whether this represents an actual increase in tick numbers and infected ticks or is a result of increased awareness by the public to submit black-legged ticks.

Over the last ten years (2008-2017), 26,666 ticks were collected and of these 65 (0.2%) were black-legged ticks. Eight (12%) of these were infected with *B. burgdorferi* and five (8%) were infected with *A. phagocytophilum.* Three ticks were co-infected with both agents (Table 1).

Table 1: Number of Ticks collected, Black-legged Ticks and Ticks Positive for *Borrelia burgdorferi* and *Anaplasma phagocytophilum* (2008-2017)

Year	Ticks					
	Ticks (all species)	Black-legged ticks	Black-legged ticks positive for *Borrelia burgdorferi* [1]	Black-legged ticks positive for *Anaplasma phagocytophilum* [2]	Black-legged ticks co-infected with both *Borrelia* and *Anaplasma*	Total Black-legged ticks positive
2008	N/A	5	0	1	0	1
2009	1,478	5	1	1	1	1
2010	1,139	3	0	0	0	0
2011	736	3	1	0	0	1
2012	2,896	1	0	0	0	0
2013	1,726	10	1	2	1	2
2014	3,176	5	0	0	0	0
2015	5,103	9	1	1	1	1
2016	5,300	9	0	0	0	0
2017	5,112	15	4	0	0	4
Total	**26,666**	**65**	**8**	**5**	**3**	**10**

Notes:
[1] *Borrelia burgdorferi* is the bacteria that causes Lyme disease.
[2] *Anaplasma phagocytophilum* is the bacteria that causes anaplasmosis, an illness with symptoms that can range from fever, muscle pain, head ache to severe symptoms such as difficulty breathing, hemorrhage, renal failure or neurological problems that can be fatal.

Black-legged ticks have been collected throughout the province but predominantly in the moister and more wooded moist mixed-grass prairie, aspen parkland and boreal transition areas (Figure 4). Only two percent have been found in the drier and less wooded, mixed-grass prairie ecoregion (Figure 3).

Figure 3: Percent Black-legged Ticks by Ecoregion

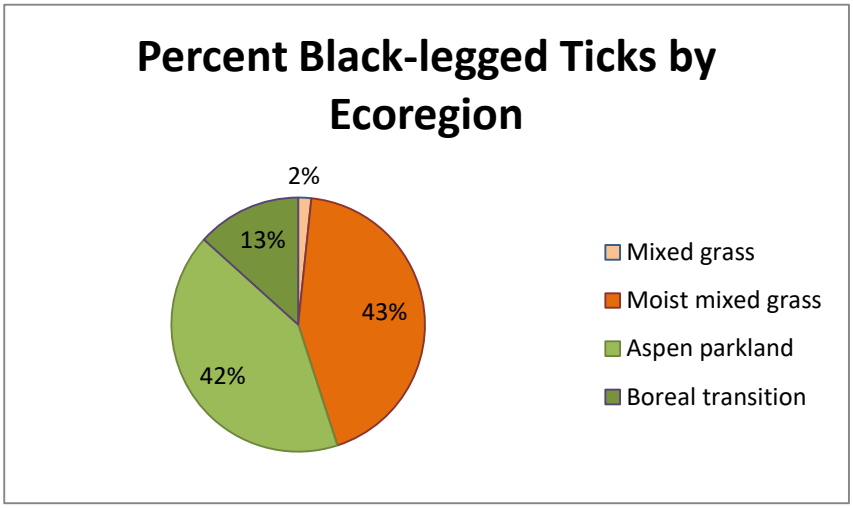
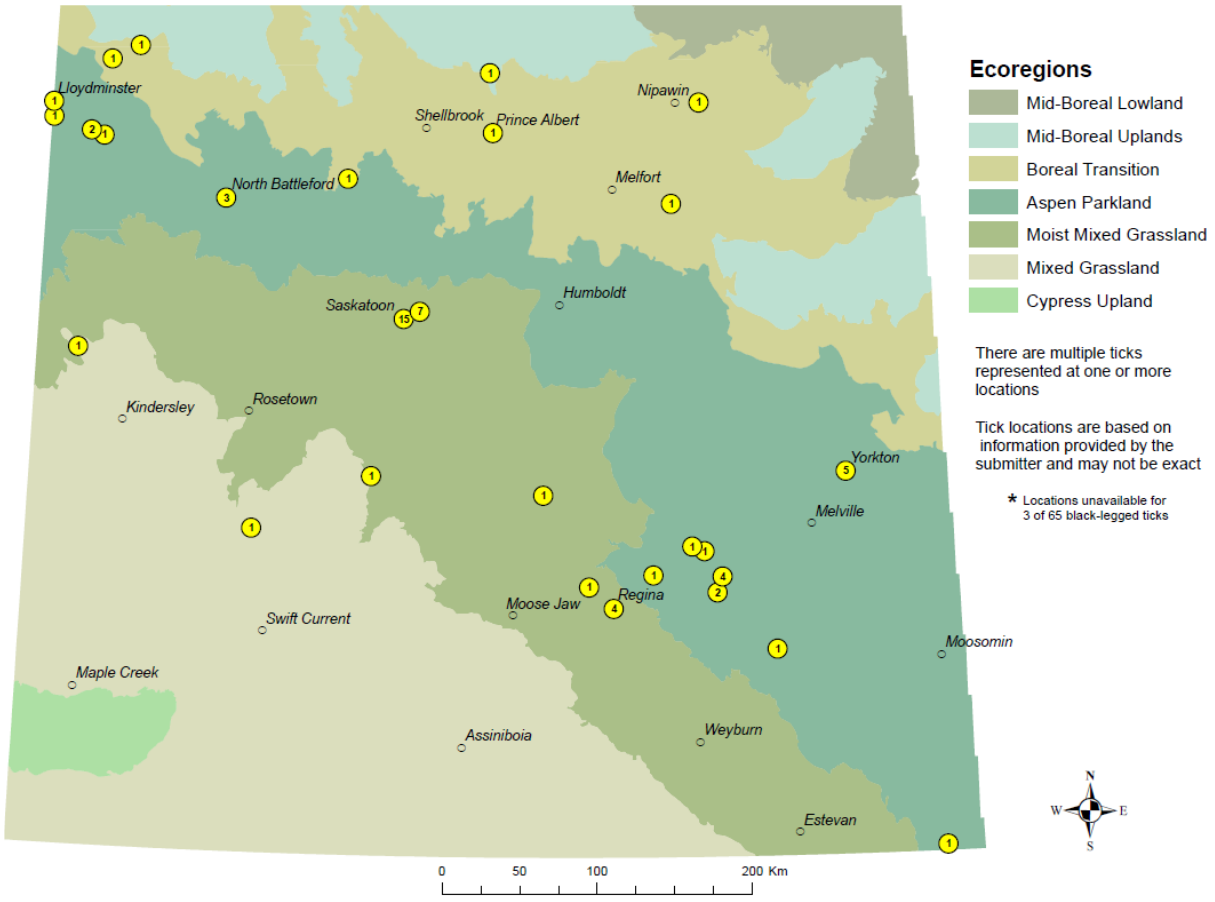


Figure 4: Black-legged Tick Locations in Saskatchewan 2008-2017 (N=62)*



Active Surveillance

Results

Spring surveys – Ten surveys were conducted in the spring of 2017 in southeastern Saskatchewan (Table 2). These included six provincial parks, three recreation and historic sites, and one regional park. The surveys were done between May 24 and June 26, 2017.

Dragging was done during the late morning-early afternoon period when conditions were generally favourable for tick activity (i.e. sunny or partly overcast, low winds). Temperatures during the spring sampling period were generally warm and ranged from 14 – 21°C (mean 18.1°C).

511 ticks were collected in the spring surveys (255 females, 255 males, 1 nymph) and all were the American dog tick (*Dermacentor variabilis*). There were no black-legged ticks collected in any of the spring surveys.

Fall surveys – Ten surveys were completed in the fall of 2017 in southeastern Saskatchewan (Table 3). These included two provincial parks, three provincial ecological reserves and historic sites, one national historic site, one small community on the Qu'Appelle River (Tantallon), one community (Earl Grey) and, one farmstead (Carievale) where black-legged ticks have been detected through passive surveillance.

The fall survey program began on September 21 and the last survey was completed on October 28, 2017.

Sampling was done during the early afternoon period when temperatures warmed up enough to stimulate tick activity. Temperatures at the beginning of the fall sampling period (September, October) were relatively warm and ranged from 11 – 21°C (mean 16.1°C). However, fall sampling was halted due to an abrupt change to winter conditions, including snow and freezing temperatures. No surveys were completed in November, the first two weeks of which are usually warm enough for black-legged ticks to remain active.

Weather during the spring and fall sampling period – Temperatures were above normal throughout the spring and fall sampling period (May to October) (Table 2). Precipitation was well below normal throughout southern Saskatchewan (range 40 – 79 percent below normal), with some locations recording their driest year on record with only 40 percent of normal precipitation. It will be interesting to see what effects the abnormally dry conditions will have on the establishment and maintenance of tick species that require relatively moist and humid conditions, species such as the black-legged tick (*Ixodes scapularis*) and the American dog tick (*Dermacentor variabilis*).

Table 2: Mean Monthly Temperatures Difference from Normal – Southern Saskatchewan 2017

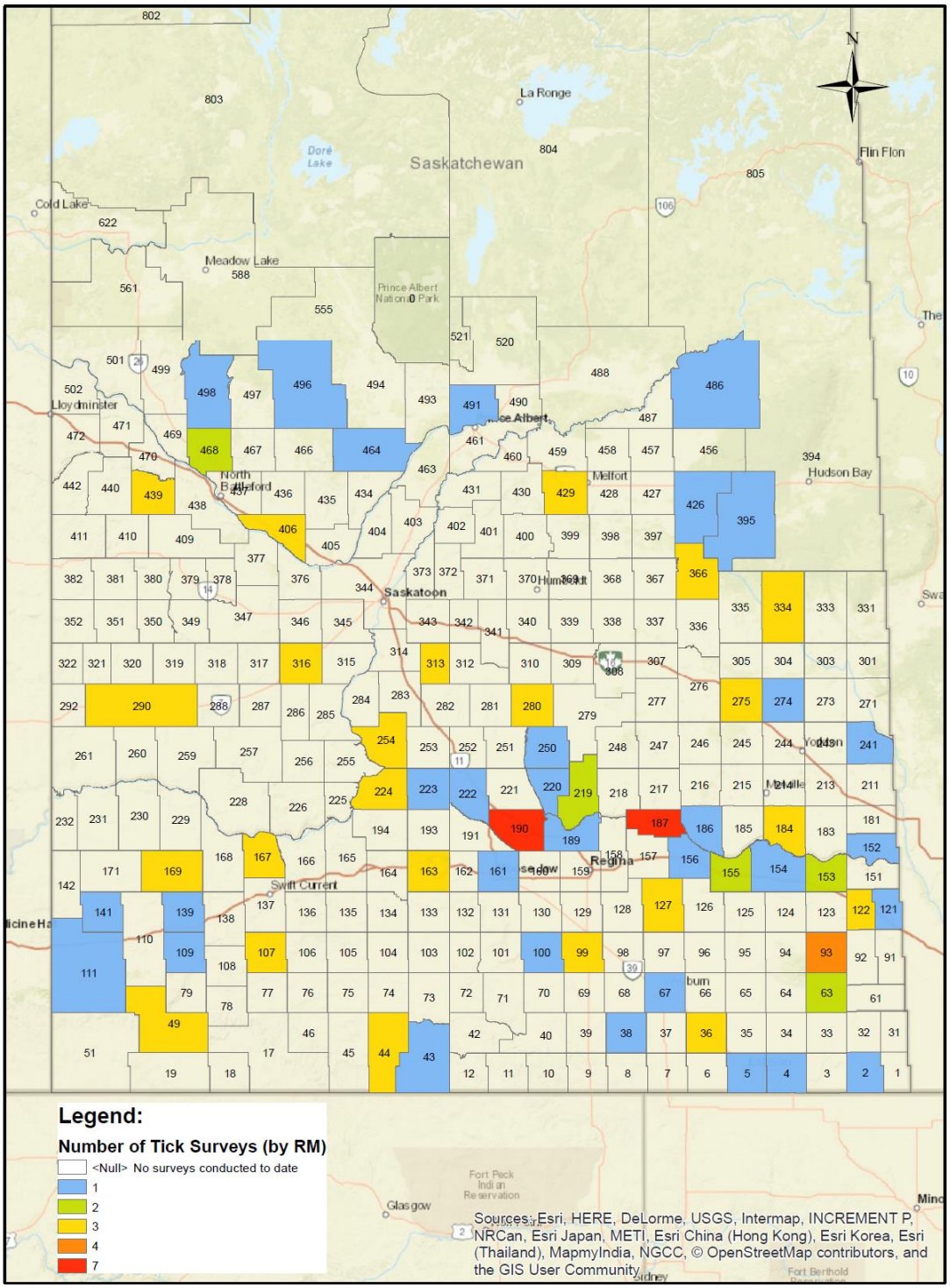
Month	Difference from normal
May	+ 1.5
June	+ 0.3
July	+ 1.7
Aug	+ 0.2
September	+ 1.2
October	+ 0.6

Table 3: Active Tick Surveillance Sites in Saskatchewan (2017)

Location	Latitude	Longitude	Date	Ix. scapularis	D. variabilis
Buffalo Pound	50.583300	-105.415800	May 30 2017	0	57
Crooked Lake	50.596030	-102.658183	May 31 2017	0	60
Danielson	51.257560	-106.815010	June 6 2017	0	44
Douglas	51.037262	-106.484438	June 6 2017	0	49
Echo Valley	50.793290	-103.894600	Sept 27 2017	0	0
Echo Valley	50.793290	-103.894600	June 7 2017	0	42
Moose Mountain	49.824480	-102.345650	Sept 26 2017	0	0
Moose Mountain	49.824480	-102.345650	May 24 2017	0	38
Bird's Point (Round Lake)	50.536900	-102.334999	June 15 2017	0	41
Cannington Manor	49.733299	-102.016701	Oct 12 2017	0	0
Cannington Manor	49.733299	-102.016701	June 21 2017	0	43
Qu'Appelle Coulee	50.528610	-103.287100	Oct 5 2017	0	0
Woodlawn (Estevan)	49.114750	-102.985560	June 20 2017	0	106
Fort Esperance (Welby)	50.492222	-101.577500	Sept 25 2017	0	0
Fort Esperance (Welby)	50.492222	-101.577500	June 26 2017	0	31
Tantallon	50.533589	-101.842452	Sept 26 2017	0	0
Earl Grey	50.932613	-104.713629	Sept 21 2017	0	0
Earl Grey	50.932613	-104.713629	Oct 17 2017	0	0
Carievale	49.033871	-101.677315	Oct 12 2017	0	0
Qu'Appelle River east of Buffalo Pound	50.578496	-105.267627	Oct 28 2017	0	0

Active tick surveys have increased in recent years. One hundred and fifty-one (151) active surveys have been completed in the province since 2014 (Figure 5).

Figure 5: Number of Active Tick Surveys by Rural Municipality, 2014-2017



Habitat quality **–** All sites were located in areas with high potential risk for black-legged tick establishment (Appendix A). Habitat quality was rated as excellent at most sites and ranged from brushy sites with high grass along walking or game trails, campsites in wooded areas to wooded

understory vegetation in undisturbed aspen poplar bluffs. Special attention for sampling was focused along hiking and game trails, deer bedding areas, and woodpiles in campsites (Appendix B).

Habitat quality and suitability also varied depending on geographic location in the watershed. For example, sites were warmer on the south-facing slopes of the Qu'Appelle River valley than on the north facing slopes. Sites further west along the upper Qu'Appelle River valley were more arid and dominated by native mixed grass vegetation. Shrubby and treed areas were characteristically shorter, patchy and confined to smaller ravine and hillside areas. However, more suitable habitat exists throughout the entire Qu'Appelle River valley in the riparian areas nearest the river. Conversely, sites along the eastern Qu'Appelle River valley closer to Manitoba were moister with larger tracts of aspen, ash, oak and other treed vegetation predominating (Appendix B).

Next Steps

Active surveillance for black-legged ticks will continue at 28 high risk potential sites in the Upper Assiniboine River watershed near Yorkton and the Souris River watershed north and east of Estevan. Approximately 30 high risk potential sites will be surveyed in aspen parkland habitat in east central and central Saskatchewan between Yorkton and Saskatoon, with particular emphasis in the aspen parkland and boreal transition areas near Greenwater Provincial Park and along the South Saskatchewan River between Outlook and Saskatoon.

Several "sentinel" sites along the Qu'Appelle River that were sampled in 2016 and 2017 will be re-sampled in the spring, summer and fall of 2018. These sites include: Buffalo Pound, Echo Valley and Crooked Lake Provincial Parks, Bird's Point Provincial Recreation Site, and Fort Esperance and Fort Livingstone National Historic Sites.

Passive surveillance will continue with increased emphasis placed on submissions from veterinary clinics and provincial park staff in southeastern and east central Saskatchewan. An information package on tick identification, with shipping and handling instructions, will be sent to all veterinary clinics in southeastern and east central Saskatchewan. In addition, communication materials including signage, disease risk, and information of prevention of tick bites will be prepared and sent to all provincial parks and historic sites in southeastern Saskatchewan.

Acknowledgements

We would like to thank the staff from the Roy Romanow Provincial Lab (formerly Saskatchewan Disease Control Laboratory), staff from the Saskatchewan Health Authority (SHA - formerly Regina Qu'Appelle Health Region), and the U. of S. for their hard work during the spring and fall surveys. We would also like to thank Neil Chilton, U. of S., Rob Schuba, SHA, Jules Koffi and Nick Ogden, PHAC, for their assistance with the Saskatchewan Tick Surveillance Program. Lastly, we would like to thank PHAC for their support and funding of the 2016 and 2017 surveys.

Appendix A: Site Selection for Active Surveillance

In Saskatchewan, active tick surveillance efforts are prioritized based on a number of criteria including:

- sites where black-legged ticks have been detected through the passive surveillance program;
- sites of most likely exposure for human or domestic animal cases;
- sites in suitable habitat areas where climate models have predicted the establishment of the black-legged ticks [5] [6] [7] (Figure 6). These models suggest that areas in southern Saskatchewan, and in particular southeastern Saskatchewan, are suitable for the potential establishment of this tick. Areas include wooded riparian and lake edges in river valleys, aspen poplar bluffs, and fragmented forested uplands (e.g. Moose Mountain Provincial Park, Duck Mountain Provincial Park) because of their potentially more hospitable habitat and abundance of host species (i.e. small rodents, rabbits, birds, deer). In addition, this region of the province is in close proximity to areas of southern Manitoba where established populations of the black-legged tick have been detected[8]; and,
- sites with suitable habitat where there is a high degree of interaction among people, domestic animals, and wildlife (i.e. provincial parks, provincial ecological reserves, recreation and historic sites, national historic sites, urban parkways, and regional parks).

Active surveillance for the black-legged tick has been conducted in the province since 2008 and the number of surveys was increased in 2014. Surveillance included surveys throughout southern Saskatchewan in 2014 and 2015, and at additional sites identified through a pilot project for surveys in the southeast region in 2016 and 2017. Funding for the surveys in the last two years has been provided through the PHAC.

It is important to note that reproducing or established black-legged tick populations have not been detected in Saskatchewan. In order to establish baseline information on tick populations, an important goal of active surveillance is to do repeated sampling at many of the same sites every year, and seasonal sampling (i.e. spring or fall) at other sites.

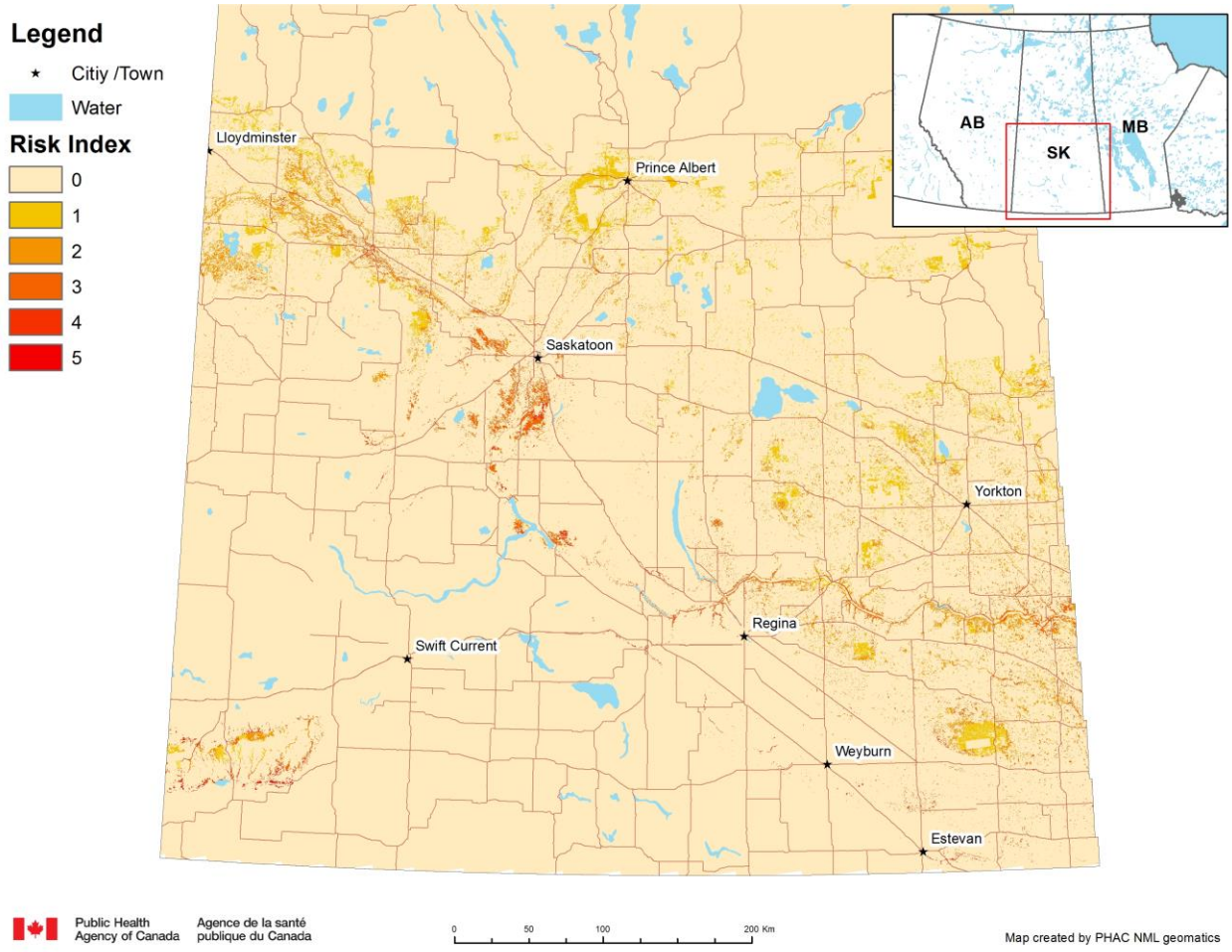
[5] Ogden NH, Maarouf A, Barker IK et al. Projections for range expansion of the Lyme disease vector *Ixodes scapularis*, in response to climate change. Int J Parasitol. 2006. 36: 63-70

[6] Gabriele-Rivet V, Koffi J, Pelcat Y et al. A risk model for the Lyme disease vector *Ixodes scapularis* (Acari: Ixodidae) in the Prairie provinces of Canada. 2017. J. of Med. Ent. (in press)

[7] Wittrock V and Wheaton E. Climate connections with vector-borne diseases: a case study of the Ixodes scapularis tick and Lyme disease in the Canadian prairies. 2010. SRC Publication No. 12829-15E10

[8] Graham-Derham S (Manitoba Health, Seniors and Active Living)(personal communication)

Figure 6: Potential Risk Areas for Black-legged Tick Establishment in Saskatchewan – Low to High Potential Risk (Risk Index 0 – 5)



Appendix B – Habitat Quality

Examples of the habitat quality are shown below. They included brushy sites with high grass along walking or game trails, campsites in wooded areas, to wooded understory vegetation in undisturbed aspen poplar bluffs. Special attention for sampling was focused along hiking and game trails, deer bedding areas, and woodpiles in campsites (Figure 7).

Habitat quality and suitability also varied depending on geographic location in the watershed. For example, sites were warmer on the south-facing slopes of the Qu'Appelle River valley than on the north facing slopes. Sites further west along the upper Qu'Appelle River valley were more arid and dominated by native mixed grass vegetation (Figure 2). Shrubby and treed areas were characteristically shorter, patchy and confined to smaller ravine and hillside areas. However, more suitable habitat exists throughout the entire Qu'Appelle River valley in the riparian areas nearest the river (Figure 8).

Figure 7: Hiking trail in Good Spirit Provincial Park

Figure 8: Riparian habitat near Qu'Appelle River

Conversely, sites along the eastern, lower Qu'Appelle River valley were moister with larger tracts of aspen, ash, oak, and other treed vegetation predominating (Figure 9).

Figure 9: Bird's Point – Moister, more heavily treed portion of the lower Qu'Appelle River Valley