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

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Background

Lyme Disease (LD) is caused by the spirochete bacterium *Borrelia burgdorferi*, which is maintained in nature in a transmission cycle between *Ixodes* ticks (e.g. blacklegged ticks, *I. scapularis*, in eastern North America) and small mammals (e.g. white-footed mice, *Peromyscus leucopus*) (1). This tick species is spreading northward in eastern Canada due to climate and environmental changes, posing an increasing risk to public health (1). Eastern Ontario is considered a hotspot of LD emergence with some of the highest rates of LD incidence in the country (2). The expansion of blacklegged tick populations in the Ottawa region also presents additional emerging tick-borne disease threats. The city of Ottawa was declared an at-risk area for LD for the first time in 2017 (3).

Recent tick surveillance conducted by our team in 2017-2018 identified that the Ottawa region is broadly environmentally suitable for *I. scapularis* tick establishment, with evidence of *B. burgdorferi* infection in ticks from multiple sites (4). We identified hotspots for environmental risk of Lyme disease in close proximity to densely populated suburban neighbourhoods, particularly those bordering greenspace (5, 6).

Ottawa is experiencing rapid growth and expansion, surpassing a population size of 1 million in June 2019. Population growth and land use change are occurring at an accelerated rate alongside warming temperatures due to climate change (7). Urban expansion, which is often characterized by the encroachment of new subdivisions into zones with enzootic transmission of tick-borne pathogens, is placing more and more people at risk of infection with Lyme disease and other tick-borne infections (8). In conjunction with new urban developments, adaptation strategies to respond to the heat effects of climate change in Ottawa involve urban greening initiatives which may have unintended consequences on tick-borne diseases by increasing tick habitat and changing host ecology (9, 10).

Project purpose:

This project will conduct monitoring and surveillance of ticks and tick-borne pathogens in areas along a gradient of urban development to better respond to climate driven emergence of infectious diseases in at-risk populations.

Study location:

The project will be carried out in the city of Ottawa, given recent increases in Lyme disease incidence in this region and our previous research that has characterized environmental risk. Activities will be conducted over three years with surveillance activities throughout the spring-to-fall transmission seasons of 2020 and 2021.

Project objectives:

This project will aim to address knowledge gaps regarding the impacts of urban development on ticks and tick-borne disease transmission. To do so, we will simultaneously monitor environmental changes in selected sites alongside changes in tick populations, wildlife reservoir host populations, and pathogen infection rates, and develop risk models to predict the future impacts of urban development. We will compare risk in residential and endemic settings by assessing environmental risk indices (e.g. density of infected nymphs) around neighborhoods where forest fragmentation is recent and/or ongoing.

This will be accomplished through four specific objectives:

1. Site selection: To identify priority tick-borne disease surveillance sites, comprised of locations undergoing urban development or urban greening.
2. One Health surveillance: To monitor ticks, wildlife hosts, pathogen infection rates and environmental changes in the selected sites.
3. Risk analysis: To assess changes in tick-borne disease transmission associated with urban development and/or greening, and develop predictive models of the impacts of projected land-use changes on tick-borne diseases.
4. Best practices report: To develop a set of best practices to inform healthy urban planning and public health mitigation strategies in the context of climate change adaptation, urban development and tick-borne diseases.

Objective 1.0: Site selection:

Following consultations with Ottawa Public Health, the National Capital Commission and the City of Ottawa, we identified 4 potential neighbourhoods that would be suitable for project activities: (1) Shirley Bay - Kanata Lakes area; (2) Stoney Swamp - Stonehaven expansion; (3) Stittsville neighborhood – Upper Poole Creek corridor; and (4) Carp Hill Wetland Complex.

Objective 2.0: One Health Surveillance:

Ticks will be collected by drag sampling according to standard protocols every 4 weeks in each site between May and October in 2020 and 2021. Sampling will be conducted by trained fieldworkers over an area of 200m^2 per site. This will allow us to develop comparable estimates of tick density across sites. We will conduct small mammal sampling for two sessions of two consecutive days per site in the peak period of mouse activity near the end of July using a sampling grid with 150 Sherman live traps in each site (i.e. 600 trap-days per site). We will follow approved animal care protocols to collect ear punch tissue biopsies from small mammals for subsequent pathogen testing. We will install 2 trail cameras in each site to collect information on the presence and abundance of deer populations. All data points will be georeferenced.

Collected ticks and tissue biopsies from small mammals will be transported to the University of Ottawa for tick species identification, nucleic acid extraction and detection of *Borrelia burgdorferi, Borrelia miyamotoi, Anaplasma plagocytophilum*, and *Babesia microti* using validated quantitative polymerase chain reaction (qPCR) protocols previously established in our lab.

A sampling frame for monitoring of ticks and small mammals, and to estimate presence and density of deer populations, was developed based on sample size calculations and logistical considerations.

Sampling sites will be situated along a gradient of urban development, including the following three "groups": (1) natural wooded zones (e.g. Greenbelt), (2) established residential/woodland interface, (3) within-neighbourhood residential yards and trails including, where applicable, zones of active urban development (leading edge). In practice, each "group" may encompass a range of woodland/residential environments, so these categories are only meant to ensure even sampling across the gradient. Continuous measures of urban development will be used in lieu of categorical groupings in the analyses.

Monitoring activities will be conducted in each site between May and October each year. This will include monthly drag sampling for ticks at multiple 200 m^2 sites, 600 trap-nights of small mammal trapping for mice and other potential reservoir hosts, and installation of trail cameras for detection of deer.

<u>Sample size:</u>
Sample size was calculated using GLIMMPSE v.2.1.0. for general linear mixed models (Coker-Dukowitz et al., 2014). To simplify calculations and provide conservative estimates of effect size, comparisons were made based on categorical groups (as described above).

Assuming a mean density of 2 ticks per 200 m^2 in woodland sites (based on previous drag sampling data), with 12 sites per group and 6 repeated measures per site per year we would be able to detect a 25% difference in tick density between groups, with 80% power, 5% level of significance and a within-site correlation of 0.5 to account for repeated measures. Given that the four neighbourhoods are comparable with respect to ecological factors related to tick habitat (Talbot et al., 2020), neighbourhood-level clustering was not accounted for in the calculations.

Sampling frame:

We will aim to divide the 12 sites per group (total 36 sites) equally among neighbourhoods. Each of the four neighbourhoods will therefore contain:

- 3 groups (woodland, interface, and residential)
    - 3 tick monitoring sites per group, each site with 200 m^2 total area
    - 1 small mammal sampling grid per group, each with 1500 m^2 total area (150 traps with 10 m trap spacing)
    - 1 trail camera per group

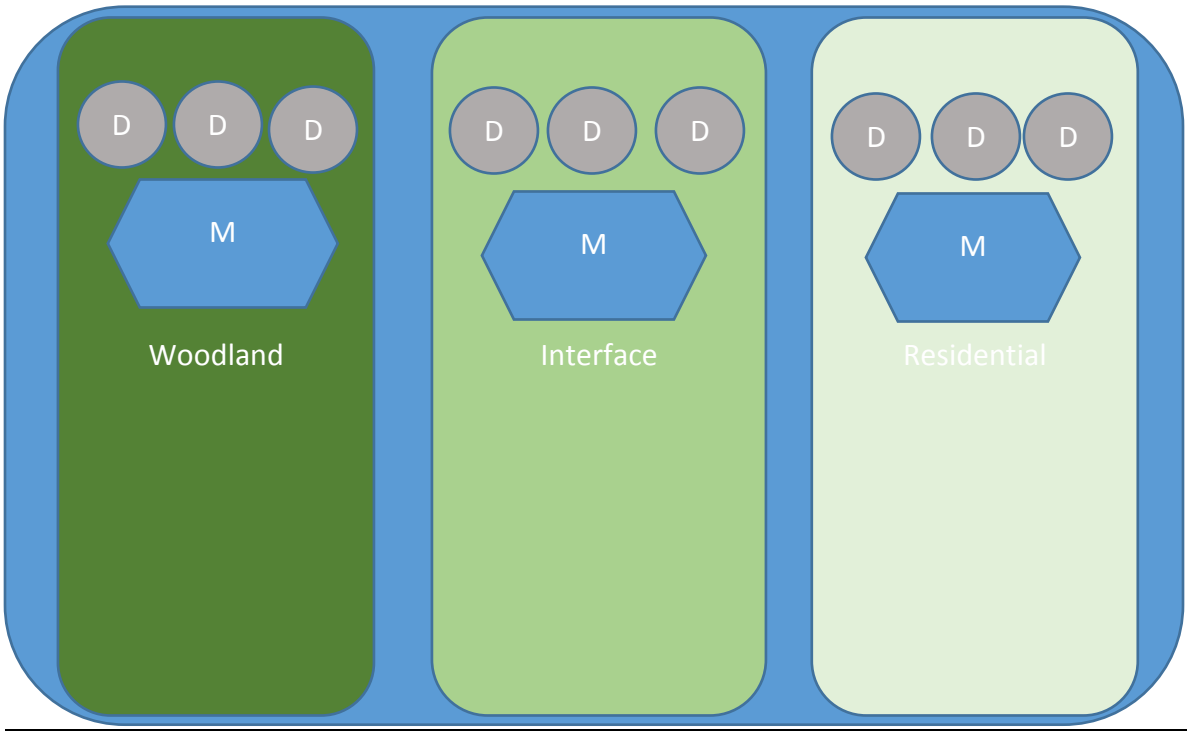

Figure 1. Diagram of sampling frame within one neighbourhood (of total four neighbourhoods). D=drag sample site; M=mouse trapping grid.

Analysis plan:

Generalized linear mixed models will be used to assess the impact of urban development on Lyme disease environmental risk accounting for repeated measures. Urban development will be measured using different indices (e.g. proportion of forest cover, forest fragmentation index, patch size and patch connectivity). Main outcome measures include: (1) density of *I. scapularis* ticks (all stages), (2) density of *B. burgdorferi*-infected *I. scapularis* (adult and nymph), (3) density of *B. burgdorferi*-infected *I. scapularis* nymphs. Models will adjust for potential confounders and interactions. Separate analysis will be conducted for outcomes related to small mammals (e.g. host species composition and density, prevalence of infection) and white-tailed deer (e.g. density).

Expected Results

By conducting surveillance and monitoring activities for infectious disease agents in ticks and small mammal reservoir hosts, we will enhance our understanding of the drivers of human risk for tick-borne diseases in relation to urban planning. In turn, this will enhance capacity and tools to detect and respond to disease threats, by (a) identifying at-risk locations and populations for better targeting of interventions, (b) developing a set of best practices for healthy urban planning in order to mitigate the emergence of tick-borne diseases in Canadian cities in the context of climate change, and (c) strengthening tick and tick-borne disease surveillance efforts in residential zones to inform immediate public health action and prevent human disease.

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