Preparing in Canada for the Asian longhorned tick

September 1, 2022

This work is an initiative of the Canadian Animal Health Surveillance System (CAHSS) Vector and Vector Borne Disease Network (www.cahss.ca). CAHSS is a division of Animal Health Canada. CAHSS is a member-driven network of networks with broad based support from animal sectors and federal-provincial-territorial governments that works together for effective, responsive, and integrated animal health surveillance in Canada.

Key authors: Elton Ko[1], Doris Leung[1], Stefan Iwasawa[2], Theresa Burns[1]

Key reviewers: Dr. Susan Cork[3], Dr. Shaun Dergousoff[4], Dr Andrea Osborn[5], Talia Strang[1]

1. Canadian Animal Health Surveillance System (www.cahss.ca)
2. Centre for Coastal Health (centreforcoastalhealth.ca)
3. Faculty of Veterinary Medicine, University of Calgary
4. Agriculture and Agri-Food Canada
5. Canadian Food Inspection Agency and Community for Emerging and Zoonotic Diseases (www.cezd.ca)

Funding for this work has been provided through the AgriAssurance Program under the Canadian Agricultural Partnership, a federal-provincial-territorial initiative.

We thank Dr. Denise Bonilla (United States Department of Agriculture), Dr. Andrea Egizi (Rutgers School of Environmental and Biological Sciences) and Dr. Alan Heath (Hopkirk Research Institute, Massey University) for participating in expert interviews.

Table of Contents

Executive Summary....................4

Preparedness....................5

Information sharing and communications....................5

Introduction....................6

Methods....................8

Results- Literature Review and Expert Opinions....................10

Potential Public Health Impacts of ALHT....................10

Potential Impacts of ALHT in Livestock....................10

Invasion Pathways, early detection and risk mitigation for ALHT....................11

Key findings on ALHT government and agency policies in Canada and the United States....................15

Information and communications products for ALHT....................18

Summary, Recommendations and Conclusions....................20

Key Themes from ALHT Expert Interviews – May 2022....................20

Summary of ALHT Invasion Pathways....................20

Summary of ALHT Policy....................20

Summary of ALHT Information Products....................20

Recommendations....................21

Preparedness....................21

Information sharing and communications....................22

Conclusion....................23

References....................24

Appendix 1: Questions for ALHT experts....................30

EXECUTIVE SUMMARY

The Asian Longhorned tick (ALHT) is an emerging pest of livestock, companion animals, wildlife, and humans in the United States (US). Globally, ALHT is vector of livestock pathogens, such as *Theileria orientalis* Ikeda, and human pathogens, such as severe fever with thrombocytopenia virus.

Given the US incursion and range expansion of ALHT, as well as the various models that have predicted ALHT habitat suitability in southern coastal areas of Canada, it is important to assess the probability and impact of ALHT introduction into Canada, and to develop plans and implement priority actions to educate stakeholders and mitigate risk.

As an early step in addressing this emerging risk, the Canadian Animal Health Surveillance System (CAHSS) vector borne disease network engaged in a process to review publicly available information that could inform planning, and to use this information to develop a list of recommendations. This work is synthesized in this report, titled 'Preparing in Canada for the Asian longhorned tick'.

To develop the report, the following workflow was established:

1) Generate an inventory and summary descriptions of key documents, including
    a. National (Canada and US), US state and provincial plans and strategies for ALHT
    b. Communications documents for human health care providers, veterinarians, animal owners, and the general public (US and Canada)
    c. Peer-reviewed and grey literature evaluations of introduction pathways for ALHT via human and animal movements, including wild birds, wild terrestrial animals, companion animals, and livestock species, including horses
2) Conduct strategic interviews with public and veterinary stakeholders to confirm literature review results and fill knowledge gaps
3) Create preliminary recommendations for next steps for ALHT preparedness planning for western Canadian provinces

Key findings included:

- Possible invasion pathways of ALHT into suitable areas of Canada include transport on companion animals, livestock, migratory birds, wildlife, and people.
- A case study series from the US (2) underscores the need for supporting robust active and passive tick surveillance programs, and the expansion of these programs to account for ALHT.
- Stakeholders such as veterinarians, and livestock and pet owners, should continue to be made aware of tick identification programs such as eTick, as well as the value of risk reduction measures for animals moving from ALHT endemic areas.
- Raising awareness and supporting preparation among livestock industry stakeholders is important, as ALHT can create high negative livestock health and welfare impacts.

The process generated eight preparedness recommendations, and an additional five recommendations focused on communication and information sharing.

PREPAREDNESS

1. Ensure passive surveillance systems have the capacity to pair molecular taxonomy with morphological taxonomy to reduce misidentification risk.
2. Review the state of regulatory authority with regards to ALHT and associated pathogens and consider options to enhance regulatory authority where gaps are documented.
3. Document animal movement patterns from US infested areas to Canada in order to target highest risk movement patterns for stakeholder education and surveillance.
4. Examine companion animal import requirements from countries such as New Zealand and Australia and consider feasibility of implementing relevant import requirements for movement of companion animals into Canada from infested locations.
5. Review and publish a summary of licenced acaracides in Canada that are effective for ALHT in livestock and confirm the process for emergency drug release (EDR) for usage on ALHT if necessary.
6. Examine the feasibility of tick collection and submission from migratory wild birds, caught as part of banding programs.
7. Continue to prioritize linkages between the National Microbiology Laboratory and healthcare providers to monitor for the potential presence of new tick-borne diseases, such as SFTSV.
8. Consider implementing a stakeholder tabletop exercises at the national level.

INFORMATION SHARING AND COMMUNICATIONS

9. Promote existing passive surveillance systems for tick identification in Canada in regions of Canada that show habitats suitable for ALHT with key groups such as veterinarians, farmers, outdoor enthusiasts, and hunters.
10. Develop summary information about ALHT for policymakers and livestock, equine, and veterinary associations.
11. Develop one-page overviews and accompanying social media and other communications materials for owners and veterinarians for animal that travel between US infested areas and Canada, including cattle, horses, and companion animals.
12. Develop stakeholder-specific best practices documents for importing each domestic animal class from endemic regions.
13. Develop draft communications documents and plans to use in the event of ALHT incursion into Canada, so that regular updates on the status of invasive populations can be given by the relevant government agencies/research institutions.

INTRODUCTION

The Asian Longhorned tick (ALHT), *Haemaphysalis longicornis*, is a tick species that has been introduced recently to the United States (US), and has become an invasive pest in several states across the US. Native to East Asia, it was first detected on a sheep in New Jersey, US in 2017 (14). However, previously collected tick specimens were retroactively identified as ALHT, showing that the tick has been in the US since at least 2010 (4).

The following life cycle of ALHT has been adapted from Fonseca et al. (15). ALHT larvae hatch from eggs laid in the soil. ALHT individuals go through four-life stages: eggs, 6-legged larvae, 8-legged nymphs, and 8-legged adults (Figure 1), the latter three of which feed on blood exclusively. Bloodmeals are necessary for molting between life stages and are also necessary for egg development in female ticks. Thus, ALHT moves on and off hosts three times.

Invasive populations of ALHT found in the US are parthenogenetic (42), meaning that females can reproduce without mating. Parthenogenetic populations of ALHT are distributed in Australia and New Zealand as well (20).

Adult females can lay up to approximately 2500 eggs, which hatch in the late summer to early fall. After hatching, the larvae begin questing on grass. Upon successfully attaching to a host, the larvae will blood feed for 3 to 5 days, then drop onto the ground and begin molting into a nymph. The nymph then overwinters. During spring, the nymphs exit diapause, look for a new host, and blood feed for 5 to 7 days. Afterwards, they drop off and molt into adults. The adults then look for another host, feed for 7 to 14 days, then drop off to digest the bloodmeal, simultaneously developing their eggs. Afterwards, the females lay their eggs and die.

As of April 2022, ALHT has not yet been detected in Canada. However, habitat modelling studies indicate that there is suitable habitat in the Eastern provinces (South Quebec-Nova Scotia) and the West Coast of British Columbia (28, 44). It is important to note that ALHT can overwinter at several stages (Figure 1) – this could be relevant to Canada as it could help continue northward range expansion and establishment.

ALHT has the potential to become a major pest of livestock, such as cattle (20). Understanding the biology and ecology of ALHT will be important to predict potential effects if it were introduced into Canada. Additionally, cataloging currently available resources on ALHT in invaded areas, including both policy and communications documents, will assist in the generation of similar materials from a Canadian perspective in the future. Examining plausible introduction pathways of ALHT into Canada can also inform policy on preventing ALHT incursion into Canada.

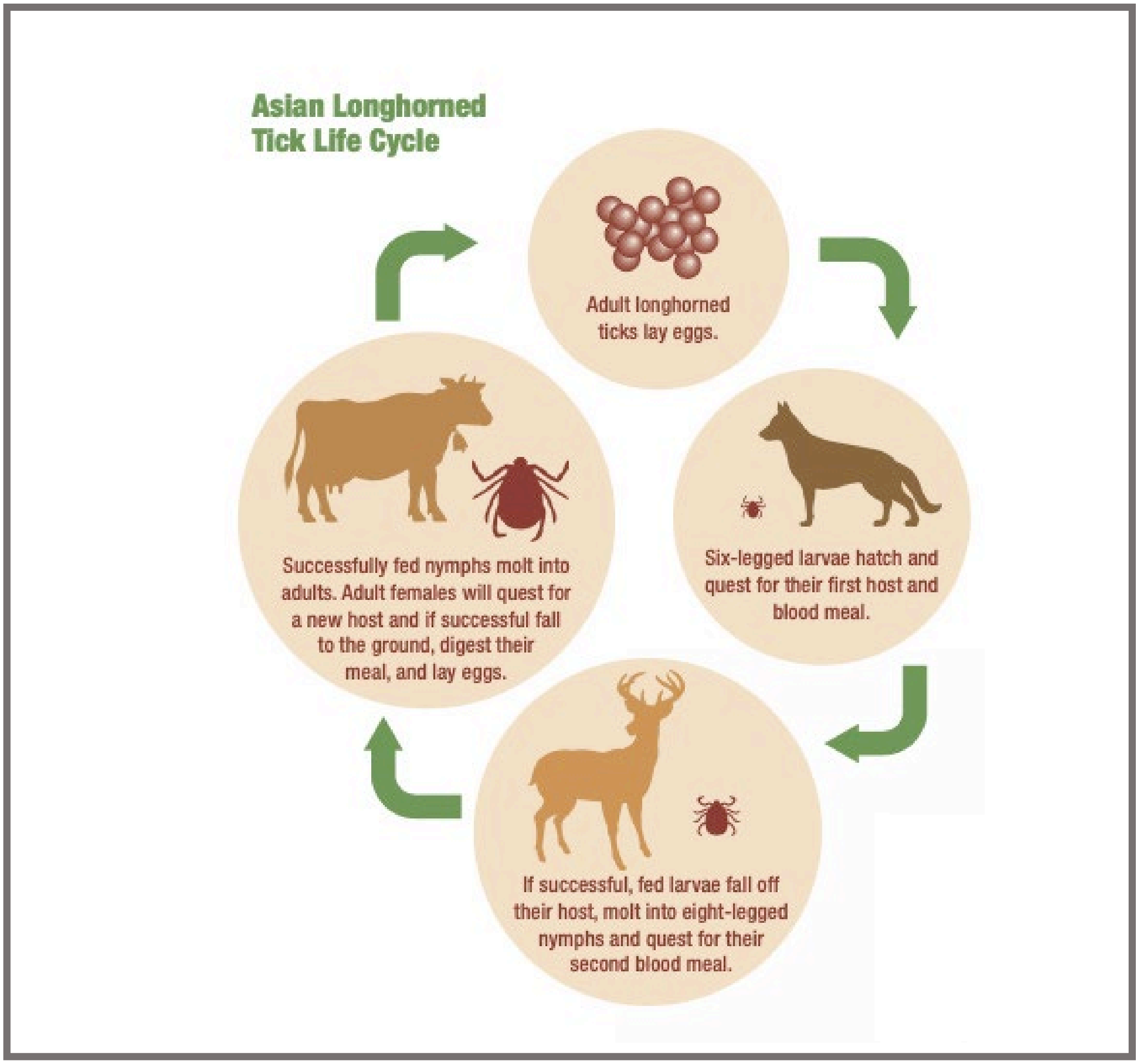

Figure 1. The life cycle of the Asian longhorned tick. Adapted from the North Central IPM Center.

METHODS

A scoping literature review was performed to gather and synthesize literature related to the following themes:

- Potential public health impacts of ALHT
- Potential impacts of ALHT in livestock
- Invasion pathways, early detection, and risk mitigation for ALHT
- ALHT government and agency policies in Canada and the United States
- Information and communications products for ALHT

Grey literature pertaining to ALHT policy and communications documents, and peer-reviewed literature regarding introduction pathways were searched using terms that included "*Haemaphysalis longicornis*", "*H. longicornis*", "Asian Longhorned Tick", "*Haemaphysalis longicornis* response plan", "federal *Haemaphysalis longicornis* response", and "*Haemaphysalis longicornis* introduction pathways". The search targeted North American literature and most information was from 2017-2022 because ALHT was detected in the US in 2017.

Grey literature was located using general purpose search engines, specifically Google and Bing. Peer-reviewed literature was searched for on Google Scholar, PubMed and Sci-Hub. After finding relevant literature, a copy of the document was saved and later shared with the project steering committee. The title of each document was recorded on an Excel spreadsheet, summarized, and ranked out of 4-stars for its relevance.

Grey literature received two separate 4-star ratings: one rating for relevance to ALHT policy (available on request) and another for its value as a communications document. Peer-reviewed literature was recorded on a separate spreadsheet with the same format (available on request). However, peer-reviewed literature only received one 4-star rating regarding its relevance to ALHT introduction pathways.

During the literature search, items relevant to other species of ticks, but not specifically ALHT, were also included. For example, information about the cattle fever tick (CFT) eradication program was also included as part of the literature review process. Although CFT is a one-host tick, these materials were deemed to be likely relevant to future eradication/control efforts in Canada, and lessons can be learned when designing similar control/eradication programs for other cattle pests such as ALHT.

Moreover, other documents, such as municipal plans for control of other vector species (e.g., mosquitoes) were also included. These documents may provide insight relevant to designing vector control for other pests, such as ALHT.

Materials relevant to stakeholders, such as fact sheets or best practices for ALHT control in cattle farms, were searched for. American materials were actively searched out from the literature review. Similar materials from other nations were excluded. After collecting 59 fact sheets in which information became repetitive, further fact sheets were excluded unless they contained new information on ALHT. The majority of fact sheets contained general information about ALHT and general protective measures.

During the literature review process, authors of highly relevant publications were identified as potential interviewees. The potential interviewees were contacted via email, and if agreed upon, a brief, 15-to-30-minute interview was scheduled. Three interviews were completed: Dr. Denise Bonilla (United States Department of Agriculture), Dr. Andrea Egizi (Rutgers School of Environmental and Biological Sciences) and Dr. Alan Heath (Hopkirk Research Institute, Massey University). Interviews were conducted virtually over the Zoom meeting platform. During the interview, a series questions regarding policy, control methods and introduction pathways was asked (Appendix 1). Each interview was recorded, transcribed, and incorporated into the final report.

RESULTS- LITERATURE REVIEW AND EXPERT OPINIONS

POTENTIAL PUBLIC HEALTH IMPACTS OF ALHT

The role of ALHT as a vector for human tick-borne pathogens of concern in North America is an active area of research, with new information emerging frequently. To date, there have not been detections of pathogens that could cause negative effects on human health in ALHT specimens found in North America. However, laboratory studies have shown that ALHT is a competent vector for *Rickettsia rickettsii*, the causative agent of Rocky Mountain spotted fever, Powassan virus, and Heartland virus (40, 48) Additionally, ALHT is a competent vector for Severe Fever with Thrombocytopenia Syndrome virus (SFTSV) in East Asia. SFTSV is an emerging tick-borne disease that can infect humans and other mammals (62). It can lead to high mortality (6-30%) rates in humans (61). This virus has not been reported in North America; however, the related Heartland virus is present in the US (4). This has raised concerns that ALHT could act as a vector for Heartland virus (4), or individuals infected with SFTSV could be introduced into the US (60). Currently, Canada has capacity to look for rare and emerging viral infections in people, since physicians and laboratories can submit samples from patients with undiagnosed and unusual illnesses to Canada's National Microbiology Laboratory for screening.

ALHT is not a competent vector for certain other tick-borne diseases. For example, the geographical overlap between human granulocytic anaplasmosis (HGA) caused by *Anaplasma phagocytophilum,* and ALHT range in the US was significant, initially raising concerns for its vector competence (26). However, laboratory studies revealed that it was not a competent vector. Additionally, ALHT failed to serve as a vector of the causative agent of Lyme disease, *Borrelia burgdorferi,* in laboratory studies (5) and shows an aversion to the white-footed mouse, the primary reservoir of *B. burgdorferi* in the USA (45).

In the US and Canada, established tick species of public health interest, specifically *Ixodes scapularis*, mostly utilize wooded areas as habitat (58). However, ALHT is commonly found in areas with short grass and well-managed lawns (58).

In Canada, common tick avoidance guidance includes walking on cleared pathways (Public Health Agency of Canada 2022) and a reminder that ticks are mostly found in wooded areas or within tall grass (37). Information and advice from the Public Health Agency of Canada (PHAC) is focused on Lyme disease and Ixodes scapularis, and not other tick species. Veterinary and public health websites should therefore expand to include other recommendations and information on other species of ticks aside from *Ixodes* species

POTENTIAL IMPACTS OF ALHT IN LIVESTOCK

The role of ALHT as a vector for domestic animal tick-borne pathogens of concern in North America is an active area of research, with new information emerging frequently. To date, the most significant health and economic impact is due to infection of cattle with the Ikeda strain of *Theileria orientalis,* a causative agent of bovine theileriosis. Ticks collected in the US are competent vectors (12), and the pathogen has been detected in cattle herds and ALHT in the US (31, 51). *T. orientalis* was first identified in Australia in the early 1900s (21). Now, a large proportion of cattle have been affected by this parasite, as approximately 71% (213/301) of cattle in the state of Victoria between 2010 and 2012 were PCR-positive for *Theileria orientalis*. (35). Consequently, the financial impact of *T. orientalis* Ikeda to the Australian cattle industry has been estimated at $19.6 million AUD annually (24). *T. orientalis* Ikeda can cause mortality of >5% in certain herds (57) and has been associated with mortality in the US (32).

In addition to *T. orientalis,* in laboratory studies, ALHT has been infected with pathogens that can cause disease in livestock, such as anaplasmosis (49) and babesiosis (18).

INVASION PATHWAYS, EARLY DETECTION AND RISK MITIGATION FOR ALHT

Invasion pathways are the routes in which ALHT can enter new areas from already infested areas. The literature indicates that the four most probable invasion pathways for ALHT are from infested livestock, migratory birds, companion animals, and wild cervids. The literature describing each of these is reviewed in detail below. Other invasion pathways considered less probable include attachment to humans or vehicles.

LIVESTOCK

One potential invasion pathway of ALHT is the importation of livestock animals from infested regions. Horses (Beard et al. 2018), chickens (14), sheep (3, 14) and cattle (3, 18, 30) are hosts of ALHT. Cattle are the most common livestock hosts of ALHT in the US (56). Heavy infestations of ALHT have been implicated in high mortality rates of cattle in the US (30), primarily caused by blood loss (58). The first confirmed case of ALHT in the US was reported on a sheep in New Jersey in 2017, and they can have large number of ticks on them (42). Horses (6) have been found to be infested during importation at entry points into the US recently (14). In 1969, an ALHT infested horse was also intercepted in New Jersey quarantine (6). Current import requirements for livestock and poultry into Canada do not require veterinary examination for ectoparasites or ectoparasite treatment.

COMPANION ANIMALS

The importance of companion animals as potential introduction pathways of ALHT has been noted in previous publications (e.g 13, 36). The movement of a farm worker with his infested dog into Western Australia was implicated in spreading ALHT into that region (41).

An infested dog was first discovered in quarantine in Hawaii in 1967 (20). Currently, dogs are the second most commonly reported infested animal in the US (56) and in Japan (47). There are currently no ectoparasite treatment requirements for companion animals, such as dogs and cats, for entry into the US (14) or Canada. In addition, we did not find any guidelines or best practices documents focused on reducing risk of long-distance tick movements on companion animals. However, there are publications showing that commercially available ectoparasite treatments for companion animals show adequate efficacy against ALHT (e.g. 24, 27, 52). Voluntary ectoparasite treatment is not routine for dogs moving from endemic to non-endemic areas. Egizi et al. reported that dogs rescued from Korea and imported into the US were not treated upon export from Korea, or initial entry into the US (14).

WILD CERVIDS

White-tailed deer are the most commonly reported ALHT infested wildlife in the US (13, 56). Tick infestations on individual white-tailed deer can reach very high numbers. For example, White et al. reported over 1000 ticks on a single deceased deer (58). This suggests that deer and other wildlife may be important to maintaining ALHT populations (58). Movement of deer has been suggested as a potential introduction pathway of ALHT to new areas in the US. Mark-recapture studies indicate some deer can possess home ranges up to 48 km (31), suggesting they can transport ALHT across state or county lines (14).

White-tailed deer populations are positively correlated with populations of other tick species of medical and veterinary importance, such as *Ixodes scapularis* and *Amblyomma americanum* (53). Removing or reducing deer populations is a method of tick control that can significantly reduce tick populations in an area; however, these reductions need to be maintained indefinitely to reduce the public exposure to ticks (43).

MIGRATORY BIRDS

Migratory birds have been proposed as a potential ALHT introduction pathway. In China, local outbreaks of severe fever with thrombocytopenia syndrome virus (SFTSV) are strongly correlated with the migratory paths of birds (63), suggesting long-range transportation of ALHT.

However, very few birds have been found to be ALHT positive in the US to date. As of December 2021, only 11 birds have been positive for ALHT in the US (56). Other American surveys have reported no ALHT on birds (52 (0 out of 39 birds), 56 (0 out of 32 birds)). However, in other tick species, even low levels of tick infestations on migratory birds can lead to the transport of millions of ticks in a single migration season (33). Thus, performing tick surveys on numerous migratory birds, performed alongside pre-existing banding programs, could be potentially an important tool to detect ALHT introductions in the future. As ticks rapidly leave dead carcasses, dead bird surveillance for ALHT may not be highly effective.

ACARACIDE TREATMENT OF ANIMALS FOR ALHT

As of 2020, there were no acaricides registered for on-label usage for ALHT in the US (Duncan et al. 2020). However, common commercial acaricides, such as permethrin and lambda-cyhalothrin based products, remain effective for ALHT control (7, 24, 27, 52). In previous studies, each tested acaricide killed off all exposed ALHT individuals within 24 hours (8). These products can be applied as spray and pour-on treatments on cattle. Additionally, certain products such as carbamates and pyrethroids can be applied to the environment where ALHT may be found and has been effective in previous studies (34). Field treatments may be of particular importance; ALHT spends more time in the environment than on hosts (55). Newer application methods, such as the 4-poster system (Figure 2), have been deployed in the field to assist in the dissemination of acaricides for treatment of deer (46). The 4-poster system consists of a baited system with four applicators containing acaricide (59). When the deer goes for the bait in the feeding station, it will contact the applicators and be treated with acaricide. Previous studies have demonstrated its efficacy for tick species such as *I. scapularis* (59). As commonly used acaricides are also effective on ALHT (34), it is likely this system could assist in future ALHT control. However, further research into its efficacy for ALHT control or for acaracide resistance in different geographic regions is recommended. Additionally, unintended consequences, such as potential impact on Chronic Wasting disease transmission would need to be evaluated.

Expert opinion: Invasion pathways and establishment

Invasion Pathways

'Prior to the introduction of ALHT within a new country, such as Canada, a study of the most likely introduction pathways should be undertaken, areas suitable for introduction should be identified, and surveillance systems should be implemented in areas where introduction is most likely' (A. Heath, personal communication).

'As there are no ectoparasite treatment requirements for dogs entering the US, dogs could potentially be an introduction pathway of ALHT into Canada as well. The creation of ectoparasite treatment requirements for companion animals crossing into Canada is a beneficial idea. However, the feasibility of implementing such requirements remains uncertain. More restrictive requirements, such as quarantining companion animals prior to entry, are unlikely to be feasible' (A. Egizi, personal communication).

'Companion animals transported between Australia and New Zealand are examined by veterinarians no more than three days prior to departure from Australia and are treated with acaricide. Upon arrival in New Zealand, they are examined once again and usually put in a period of quarantine. However, depending on the examining veterinarian, examinations can sometimes be performed relatively superficially, and ticks could be missed. Implementation of a similar system for companion animals transiting between Canada and the US may be feasible' (A. Heath, personal communication).

'If borders could have animal health technicians or veterinarians that could screen pets in cars, I think this would be a useful way to slow tick movement across borders. Even better would be staff that could treat the animal upon noticing an infestation' (D. Bonilla, personal communication).

'In New Zealand, ALHT was possibly introduced on cattle imported from Australia in the 19th century. The movement of cattle between the US and Canada could thus potentially introduce ALHT individuals across borders' (A. Heath, personal communication).

ALHT establishment

'A single individual could theoretically start a population in Canada (Andrea Egizi, personal communication). However, low temperatures may be a limiting factor for ALHT spread within Canada; temperatures below 12^{o}C for long periods of time are sufficient to prevent egg hatching' (A. Heath, personal communication).

'As ALHT is a generalist, capable of utilizing many hosts, it is very easy for them to establish a foothold in new areas. Additionally, infested wildlife can continually re-introduce ALHT into areas they have been previously eradicated from. Current control and surveillance methods in the US may delay the inevitable spread of ALHT to new areas within the US' (A. Egizi, personal communication).

KEY FINDINGS ON ALHT GOVERNMENT AND AGENCY POLICIES IN CANADA AND THE UNITED STATES

Out of 191 grey literature documents collected, two Canadian documents focused on ALHT were found. The first was authored by the Government of Ontario (40). The primary goal of the report was to raise awareness of ALHT and assess public health implications of ALHT if it were introduced to Ontario. The second was a Community for Emerging and Zoonotic Diseases (CEZD) report to assess the readiness of Alberta and Ontario for ALHT incursion (9). The report was prepared as the first phase of a domestic Canadian effort to identify and communicate disease risks, and to enable rapid communication and information sharing during emerging disease situations prior to the situations becoming public knowledge. The report states that both the domestic Alberta and Ontario networks are strong, but also identified some gaps in expertise amongst hunters, ecological experts, and pest control experts. The report also provides a flow chart of communications linkages between different groups, including government, veterinary, and research institutions. Amendments to certain legislation, such as the Alberta Pest and Nuisance regulations, were recommended. Knowledge gaps identified included performing risk assessments to guide decision-making by authorities, the validation of tick pathogen testing methods and the employment of additional expertise in the event of ALHT incursions in Canada.

An additional five documents focused on US federal or state policy around ALHT were found. Some federal US agencies, such as the United States Department of Agriculture (55) and United States Armed Forces (1), have created specific response plans for ALHT.

The USDA's ALHT plan had a stated purpose of guiding ALHT identification activities of the USDA veterinary service (VS), along with State and local partners (55). The plan gives background information on ALHT's biology and ecology, and states that the USDA VS Emerging Animal Disease Preparedness and Response plan will be executed in the event of emergence of ALHT-associated tick-borne pathogens. The plan also defines passive and active surveillance and gives examples for both program types. Methods of managing and standardizing collected data are discussed, along with procedures for investigating new detections of ALHT. Finally, the plan stresses the importance of public outreach in the surveillance methods for ALHT, and links to documents available on the USDA website.

At the US state level, New York appears to be one of the most well-prepared states for ALHT. The New York State Department of Health (NYSDOH) maintains an active tick surveillance program comprising 100 to 150 sites spread over all counties (2). Twenty-five new sites were added after the emergence of ALHT (2). The New York State Integrated Pest Management program (NYS IPM) regularly performs public outreach as well (23). In 2019, NYS IPM began including ALHT specimens with their outreach materials to educate the public (23). New York State is one of the only states in the US that conducts active tick surveillance, which can provide important information such as ALHT's distribution and population in each area (2). The surveillance program is designed to provide information on the risk levels posed by the tick to a given population (2). Finally, the New York state government signed ALHT legislation into law in 2020. The law placed ALHT on the invasive species list and directed the Commissioner of Agriculture and Markets to create and distribute an ALHT informational pamphlet to farmers (27).

Figure 2. Photograph of a 4-poster self-treatment bait station, with auto-dissemination of acaricide to deer as it feeds. Adapted from Kilburn, 2018 (22).

Expert opinion: Surveillance for ALHT

'Tick surveillance programs that employ both active and passive tick surveillance are terrific ways to monitor for introductions of exotic ticks' (D. Bonilla, personal communication).

'With the use of the molecular taxonomy paired with morphological taxonomy that fewer misidentifications will happen, and eradication efforts can happen earlier' (D. Bonilla, personal communication).

'Current tick surveillance programs that focus mainly on I. scapularis are likely to miss ALHT, as their primary habitats differ I. scapularis exists primarily in forest habitats and in areas with leaf litter. However, ALHT is found in areas of ecotone (i.e., transitional areas between habitats) and tall grasses on the edge of forests. Therefore, surveillance programs targeting native ticks such as I. scapularis should be modified accordingly to capture ALHT individuals. For example, tick dragging should be performed both within forests, and in ecotone areas to sample for potential ALHT populations' (A. Egizi, personal communication).

'Passive ALHT surveillance programs should target companion animals such as dogs. Humans are not a preferred host of ALHT, and thus early detection is unlikely to occur through passive surveillance methods targeting humans. However, passive surveillance programs in the US have detected ALHT on humans, but these detections occurred in areas where large infestations were already present' (A. Egizi personal communication).

'The best recommendation to livestock producers right now is to keep an eye on their animals at least weekly to check for tick infestations. Because ALT are somewhat new to North America, our pesticides don't include them on the label yet. However, any pesticide labels for ticks should work against ALT. Producers should treat at label rates and recommendations' (A. Bonilla, personal communication).

'In New Zealand, cattle monitoring programs examine cattle on the west coast for Culicoides spp. biting midges, which are the vector of Bluetongue virus. Culicoides spp. are most likely to enter the country from Australia, and thus monitoring focuses only on the west coast of New Zealand (A. Heath, personal communication). Taking inspiration from this, a similar program monitoring livestock in the areas of Canada at highest risk of introduction (e.g., southern Ontario) could assist in early detection. This monitoring could also be combined with other methods, such as CO_2 *trapping and tick dragging' (A. Heath, personal communication).*

INFORMATION AND COMMUNICATIONS PRODUCTS FOR ALHT

Forty-five percent (86/191) of the documents returned by the grey literature search consisted of factsheets containing general tick-preventative and treatment advice or press releases reporting on updates on ALHT populations within the US. Most of the factsheets provided general background information about ALHT, including its potential impacts. The general tick prevention advice given included wearing long sleeves, using repellents such as DEET, or avoiding areas of branch or long grass, and using permethrin-treated clothing. Regularly examining yourself for ticks is also recommended, as is pasture management (i.e., keeping grass and brush trimmed) (17).

Many US states issued press releases about the initial detections of ALHT within those states, or in neighboring states. These press releases usually included generalized information about ALHT, and methods for the public to protect themselves and their animals. The press releases often encouraged members of the public to collect ticks, and to submit these ticks to appropriate health authorities for identification (i.e., 15, 50).

A smaller amount (14%; 26/191) of more targeted factsheets and guidelines were also discovered during the literature review. For example, Dellinger & Day wrote a factsheet aimed at horse owners (11). Preventative advice included pasture controls, keeping horses out of wooded areas, and quarantining and inspecting new horses prior to introduction to the herd.

Other factsheets also discussed ALHT's ability to feed on wildlife hosts with large home ranges, and its potential for expansion of geographic range given its tolerance to cold climates (7). Documents oriented towards livestock owners with specific instructions, including registered pesticides and application methods, have been produced by organizations such as Virginia Tech University (i.e., 10), which listed best practices for inspecting cattle for ALHT, and chemical control methods. Additional information included herd management techniques, including pasture management, and inspecting new cattle for ticks prior to introduction with the herd.

Expert opinion: Engagement about ALHT

'We've had different types of outreach here in the United States varying from the county to the city to the state level and concerning residents, producers, pet owners, wildlife, park goers, and many other groups. The were done after the fact. Canada can be proactive. Putting outreach out to large and small animal veterinarians as a good starting point' (D. Bonilla, personal communication).

ENGAGEMENT WITH VETERINARIANS

'Building relationships with veterinarians is also important. After establishing in an area, ALHT can infest dogs in high numbers, therefore educating veterinarians on ALHT and building relationships with them can assist in ALHT detection efforts' (A. Egizi, personal communication).

'Organizing a symposium or other forum with ALHT experts and relevant stakeholders would be beneficial to increase preparedness and coordination' (A. Heath, personal communication).

'Concerns about ALHT, and the surveillance methods being utilized, should be disseminated widely to stakeholders such as livestock owners or veterinarians. For example, in New Zealand the brown dog tick, Rhipicephalus sanguineus, is often introduced in large numbers on dogs entering the country, however, they have not yet established in the country. Information about the brown dog tick was disseminated to relevant agencies, veterinary services and published in veterinary journals. A similar program to increase awareness of ALHT in Canada could result in more vigilant observers in areas most at risk of ALHT introduction, and thus assist in the setup of a surveillance system for ALHT' (A. Heath, personal communication).

ENGAGEMENT WITH LIVESTOCK OWNERS

'Educating livestock owners about ALHT, advising them to submit ticks for identification, and encouraging them to apply preventative measures to their animals are important steps that should be taken. As ALHT is mainly a concern for livestock due to its ability to transmit Theileria orientalis Ikeda, building relationships with livestock owners and raising awareness of ALHT with them should be a priority Educating livestock owners about ALHT, advising them to submit ticks for identification, and encouraging them to apply preventative measures to their animals are important steps that should be taken' (A. Egizi, personal communication).

SUMMARY, RECOMMENDATIONS AND CONCLUSIONS

KEY THEMES FROM ALHT EXPERT INTERVIEWS – MAY 2022

- ALHT can be introduced to Canada from domestic animals (e.g., dogs) or livestock (e.g., cattle, sheep) that travel from infested areas.
- Once introduced, ALHT can establish quicky, is extremely difficult to control or eradicate given its multi-host lifecycle and parthenogenetic reproductive potential.
- Raising awareness and educating Canadian livestock owners and veterinarians is critically important for early detection of ALHT and prevention of spread and establishment in Canada.
- Passive surveillance programs should be supported and promoted and should have capacity to pair molecular taxonomy with morphological taxonomy.

SUMMARY OF ALHT INVASION PATHWAYS

Based on the available evidence (65 peer-reviewed papers reviewed), movement of companion animals and livestock from endemic areas is a pathway for ALHT introduction into Canada.

As ALHT has a wide host range, is often found on wildlife such as white-tailed deer, and the geographic range is expanding northward. Although North American migratory birds are considered a lower risk as introduction hosts, it should be noted that even a low level of ALHT infestation could lead to significant numbers of individuals being introduced.

SUMMARY OF ALHT POLICY

Collaborative Canadian and regional planning for ALHT could reduce probability of establishment of ALHT, assist in early detection, and guide the response. A review of current regulatory authority with regards to ALHT and associated pathogens, and options to increase authority where needed, should be considered.

Policy for cattle, horse, and companion animal movement requirements could be targets for review through an ALHT incursion-risk lens. Pre-entry external parasite control requirements, such as are in place in Australia and New Zealand, could be considered, (3) but may require amendment to federal regulations. There may be a need for amendments based on a risk assessment and proof of absence of ALHT in Canada.

The logistic feasibility of adding tick examination to existing hands-on migratory bird monitoring programs should be considered (i.e., alongside banding programs), especially for bird species that move between US endemic areas and parts of Canada with suitable habitat.

SUMMARY OF ALHT INFORMATION PRODUCTS

The majority of currently available ALHT information products are written for a general audience and are not specific to Canada. A smaller number of targeted documents, such as best management practices for livestock owners, have been created. These documents are useful, as they summarize currently available treatment options and preventative measures that can be taken, however they are not specific to Canada. Finally, many institutions, such as municipal and state governments, issue press releases when ALHT is found in new areas, and this can assist in increasing public awareness of ALHT and increasing vigilance.

RECOMMENDATIONS

General recommendations include engaging in an information sharing campaign to raise awareness about ALHT and promote Canada's passive surveillance system for ticks with key stakeholder groups including

- Federal and provincial government policy and programs staff, including in agriculture and public health
- Owners and veterinarians for animal that travel between US infested areas and Canada, including cattle, horses, and companion animals
- Individuals that interact with migratory wildlife and wildlife in habitat suitable for ALHT establishment such as hunters, conservation staff and veterinary pathologists

PREPAREDNESS

1. Ensure passive surveillance systems have capacity to pair molecular taxonomy with morphological taxonomy to reduce misidentification risk.
2. Review state of regulatory authority with regards to ALHT and associated pathogens and consider options to enhance regulatory authority where gaps are documented.
3. Document animal movement patterns from US infested areas to Canada in order to target highest risk movement patterns for stakeholder education and surveillance.
4. Examine companion animal import requirements from countries such as New Zealand and Australia and consider feasibility of implementing relevant import requirements for movement of companion animals into Canada from infested locations.
5. Review and publish a summary of licenced acaracides in Canada that are effective for ALHT in livestock and confirm the process for emergency drug release (EDR) for usage on ALHT if necessary.
6. Examine feasibility of tick collection and submission from migratory wild birds, caught as part of banding programs.
7. Continue to prioritize linkages between the National Microbiology Laboratory and healthcare providers to monitor for the potential presence of new tick-borne diseases, such as SFTSV.
8. Consider implementing a stakeholder table-top exercises at the national level.

INFORMATION SHARING AND COMMUNICATIONS

9. Promote existing passive surveillance systems for tick identification in Canada in regions of Canada that show habitats suitable for ALHT with key groups such as veterinarians, farmers, outdoor enthusiasts, and hunters.
10. Develop summary information about ALHT for policymakers and livestock, equine and veterinary associations.
11. Develop one-page overviews and accompanying social media and other communications materials for owners and veterinarians for animal that travel between US infested areas and Canada, including cattle, horses, and companion animals.
12. Develop stakeholder-specific best practices documents for importing each domestic animal class from endemic regions.
13. Develop draft communications documents and plans to use in the event of ALHT incursion into Canada, so that regular updates on the status of invasive populations can be given by the relevant government agencies/research institutions.

CONCLUSION

Our report shows that ALHT is an emerging threat to animal and human health in the US. It is a parthenogenetic pest with a wide host range. Although ALHT is not present in Canada, there are areas of suitable habitat, which are predicted to expand with climate change, and multiple potential invasion pathways. Thus, it is prudent to develop and implement recommendations to minimize and mitigate risk and increase the probability of early detection. Based on this work, eight preparedness and five communications recommendations have been developed. Continuing to foster engagement and information sharing about ALHT between stakeholders is critical to increase the probability of early detection should ALHT arrive in Canada.

REFERENCES

1. Armed Forces Pest Management Board (2020). Surveillance Guide & Response Plan for the Asian Longhorned Tick, *Haemaphysalis longicornis.* Retrieved from https://www.acq.osd.mil/eie/afpmb/docs/techguides/tg8.pdf.
2. ASTHO (2020). Case Studies in Tick Surveillance and Tick-borne Disease Prevention. Retrieved from https://www.astho.org/globalassets/report/case-studies-in-tick-surveillance-and-tick-borne-disease-prevention.pdf.
3. Australian Government Department of Agriculture, Fisheries and Forestry (2022). External and internal parasite treatment (dogs and cats). Retrieved from https://www.agriculture.gov.au/biosecurity-trade/cats-dogs/step-by-step-guides/parasite-treatment.
4. Beard, C. B., Occi, J., Bonilla, D. L., Egizi, A. M., Fonseca, D. M., Mertins, J. W., Backenson, B. P., Bajwa, W. I., Barbarin, A. M., Bertone, M. A., Brown, J., Connally, N. P., Connell, N. D., Eisen, R. J., Falco, R. C., James, A. M., Krell, R. K., Lahmers, K., Lewis, N., Little, S. E., Neault, M., Pérez de León, A. A., Randall, A. R., Ruder, M. G., Saleh, M. N., Schappach, B. L., Schroeder, B. A., Seraphin, L. L., Wehtje, M., Wormser, G. P., Yabsley, M. J., & Halperin, W. (2018). Multistate infestation with the exotic disease–vector tick *Haemaphysalis longicornis*—United States, August 2017–September 2018. *Morbidity and mortality weekly report*, *67*(47), 1310.
5. Breuner, N. E., Ford, S. L., Hojgaard, A., Osikowicz, L. M., Parise, C. M., Rizzo, M. F. R., Bai, Y., Levin, M. L., Eisen R. J., & Eisen, L. (2020). Failure of the Asian longhorned tick, Haemaphysalis longicornis, to serve as an experimental vector of the Lyme disease spirochete, *Borrelia burgdorferi* sensu stricto. *Ticks and tick-borne diseases*, *11*(1), 101311.
6. Burridge, M. J. (2011). *Non-native and invasive ticks*. University Press of Florida.
7. Burtis, J., Egizi, A., Occi, J., Mader, E., Lejeune, M., Stafford, K., & Harrington, L. (2018). Intruder Alert: Asian Longhorned Tick-What You Need to Know about the Invasive Tick *Haemaphysalis longicornis*
8. Butler, R. A., Chandler, J. G., Vail, K. M., Holderman, C. J., & Trout Fryxell, R. T. (2021). Spray and pour-on acaricides killed Tennessee (United States) field-collected *Haemaphysalis longicornis* nymphs (Acari: Ixodidae) in laboratory bioassays. *Journal of Medical Entomology*, *58*(6), 2514-2518.
9. CEZD (2020). Domestic Pilot Project to Assess Readiness for Asian Longhorned Tick Incursion into Alberta and Ontario. Retrieved from https://cezd.ca/CAHSS/Assets/Documents/CEZD%20Pilot%20Summary%20Report_ALHT_2020.pdf.
10. Day, E. R. (2021). Livestock Area Fly Control. Retrieved from https://vtechworks.lib.vt.edu/bitstream/handle/10919/105522/456-016_ENTO-398B_.pdf?sequence=1.

11. Dellinger, T. A., & Day, E. (2020). Managing the Asian Longhorned Tick: Checklist for Best Management Practices for Cattle Producers. Retrieved from https://www.pubs.ext.vt.edu/content/dam/pubs_ext_vt_edu/ENTO/ento-382/ENTO-382.pdf.
12. Dinkel, K. D., Herndon, D. R., Noh, S. M., Lahmers, K. K., Todd, S. M., Ueti, M. W., Scoles, G. A., Mason, K. L., & Fry, L. M. (2021). A US isolate of *Theileria orientalis*, Ikeda genotype, is transmitted to cattle by the invasive Asian longhorned tick, *Haemaphysalis longicornis*. *Parasites & Vectors*, *14*(1), 1-11.
13. Duncan, K. T., Sundstrom, K. D., Saleh, M. N., & Little, S. E. (2020). *Haemaphysalis longicornis*, the Asian longhorned tick, from a dog in Virginia, USA. *Veterinary Parasitology: Regional Studies and Reports*, *20*, 100395.
14. Egizi, A., Bulaga-Seraphin, L., ALHT, E., Bajwa, W. I., Bernick, J., Bickerton, M., Campbell, S. R., Connally, N., Doi, K., Falco, R. C., Gaines, D. N., Greay, T. L., Harper, V. L., Heath, A. C. G., Jiang, J., Klein, T. A., Maestas, L., Mather, T. N., Occi, J. L., Oskam, C. L., Pendleton, J., Teator, M., Thompson, A. T., Tufts, D. M., Umemiya-Shirafuji, R., VanAcker, M. C., Yabsley, M. J., & Fonseca, D. M. (2020). First glimpse into the origin and spread of the Asian longhorned tick, *Haemaphysalis longicornis*, in the United States. *Zoonoses and public heALHTh*, *67*(6), 637-650.
15. Fonseca, D. M., Egizi, A., & Occi, J. (2017). Global Health: the tick that binds us all. Review of the biology and ecology of *Haemaphysalis longicornis* Neumann, 1901. Retrieved from https://fonseca-lab.com/research/global-health-the-tick-that-binds-us-all/.
16. Government of Rhode Island (2018). Non-Native, Exotic Tick Found in New England For First Time. Retrieved from https://www.ri.gov/press/view/34770.
17. Grove, D., Fryxell, R. T., Hickling, G., Vail, K., & Ivey, J. (2019). Asian Longhorned Tick. Retrieved from https://trace.tennessee.edu/cgi/viewcontent.cgi?article=1017&context=utk_agexfish.
18. Guan, G., Moreau, E., Liu, J., Hao, X., Ma, M., Luo, J., Chauvin, A., & Yin, H. (2010). Babesia sp. BQ1 (Lintan): molecular evidence of experimental transmission to sheep by *Haemaphysalis qinghaiensis* and *Haemaphysalis longicornis*. *Parasitology International*, *59*(2), 265-267.
19. Heath, A. C. G. (2016). Biology, ecology and distribution of the tick, *Haemaphysalis longicornis* Neumann (Acari: Ixodidae) in New Zealand. *New Zealand veterinary journal*, *64*(1), 10-20.
20. Hoogstraal, H., Roberts, F. H., Kohls, G. M., & Tipton, V. J. (1968). Review of *Haemaphysalis* (*kaiseriana*) *longicornis* neumann (resurrected) of Australia, New Zealand, New Caledonia, Fiji, Japan, Korea, and Northeastern China and USSR, and its parthenogenetic and bisexual populations (Ixodoidea, Ixodidae). *The Journal of parasitology*, 1197-1213.
21. Islam, M. K., Jabbar, A., Campbell, B. E., Cantacessi, C., & Gasser, R. B. (2011). Bovine theileriosis–an emerging problem in south-eastern Australia? *Infection, Genetics and Evolution*, *11*(8), 2095-2097.
22. Kilburn, J. (2018). Ticks, Deer, and Diseases: *New Concerns and Research*. *Connecticut Wildlife*, *38*(6), 20-21
23. Lampman, J., Gangloff-Kaufmann, J., Frye, M., Dunn, A., Marvin, D., Braband, L. (2019). Tick IPM Outreach and Research Activities, NYS IPM Program, 2019. Retrieved from

https://ecommons.cornell.edu/bitstream/handle/1813/69812/2019lampman-NYSIPM.pdf?sequence=1.

24. Lane, J., Jubb, T., Shephard, R., Webb-Ware, J., & Fordyce, G. (2015). Priority list of endemic diseases for the red meat industries.
25. Lebon, W., J. Liebenberg, N. Perier, D. Carithers, and F. Beugnet. (2019). Efficacy of a Single Spot-on Administration of Fipronil and Permethrin (Frontline Tri-act®) Against Haemaphysalis longicornis Tick Infestation in Dogs. Intern J Appl Res Vet Med. 17: 93–99.
26. Levin, M. L., Stanley, H. M., Hartzer, K., & Snellgrove, A. N. (2021). Incompetence of the Asian longhorned tick (Acari: Ixodidae) in transmitting the agent of Human Granulocytic Anaplasmosis in the United States. *Journal of medical entomology*, *58*(3), 1419-1423.
27. Metzger, J. (2020). Hudson Valley Legislators' Bill to Address New Tick Threat Signed into Law. Retrieved from https://www.nysenate.gov/newsroom/press-releases/jen-metzger/hudson-valley-legislators-bill-address-new-tick-threat-signed.
28. Meyer, L., N. Lekouch, G. Altreuther, B. Schunack, and Pollmeier M. (2022). Sustained efficacy of collars containing 10% w/w imidacloprid and 4.5% w/w flumethrin (Seresto®) in dogs against laboratory challenge with Haemaphysalis longicornis (Neumann, 1901) ticks. Parasites & Vectors. 15: 77.
29. Namgyal, J., Couloigner, I., Lysyk, T. J., Dergousoff, S. J., & Cork, S. C. (2020). Comparison of habitat suitability models for *Haemaphysalis longicornis* Neumann in North America to determine its potential geographic range. *International journal of environmental research and public heALHTh*, *17*(21), 8285.
30. Neault, M. (2019). State Veterinarian reminds livestock and pet owners to watch out for ticks. Retrieved from https://www.ncagr.gov/paffairs/release/2019/StateVeterinarianremindslivestockandpetownerstowatchoutforticks.htm.
31. New Jersey Division of Fish & Wildlife (2004). Biology of the White-Tailed Deer *Odocoileus virginianus*. Retrieved from https://nj.gov/dep/fgw/deerbiol.htm.
32. Oakes, V. J., Yabsley, M. J., Schwartz, D., LeRoith, T., Bissett, C., Broaddus, C., Schlater, J. L., Todd S. M., Boes, K. M., Brookhart, M., & Lahmers, K. K. (2019). *Theileria orientalis* Ikeda genotype in cattle, Virginia, USA. *Emerging Infectious Diseases*, *25*(9), 1653.
33. Ogden, N. H., Lindsay, L. R., Hanincová, K., Barker, I. K., Bigras-Poulin, M., Charron, D. F., Heagy, A., Francis, C. M., O'Callaghan, C. J., Schwartz, I., & Thompson, R. A. (2008). Role of migratory birds in introduction and range expansion of *Ixodes scapularis* ticks and of *Borrelia burgdorferi* and *Anaplasma phagocytophilum* in Canada. *Applied and environmental microbiology*, *74*(6), 1780-1790.
34. Park, G. H., Kim, H. K., Lee, W. G., Cho, S. H., & Kim, G. H. (2019). Evaluation of the acaricidal activity of 63 commercialized pesticides against *Haemaphysalis longicornis* (Acari: Ixodidae). *Entomological Research*, *49*(7), 330-336.

35. Perera, P. K., Gasser, R. B., Anderson, G. A., Jeffers, M., Bell, C. M., & Jabbar, A. (2013). Epidemiological survey following oriental theileriosis outbreaks in Victoria, Australia, on selected cattle farms. *Veterinary Parasitology*, *197*(3-4), 509-521.
36. Pritt, B. S. (2020). *Haemaphysalis longicornis* is in the United States and biting humans: Where do we go from here? *Clinical Infectious Diseases*, *70*(2), 317-318.
37. Public Health Agency of Canada (2018). Lyme disease prevention toolkit. Retrieved from https://www.canada.ca/en/public-health/services/publications/diseases-conditions/lyme-disease-prevention-toolkit.html#a3.
38. Public Health Agency of Canada (2020). Lyme disease: Prevention and risks. Retrieved from https://www.canada.ca/en/public-health/services/diseases/lyme-disease/prevention-lyme-disease.html.
39. Public Health Agency of Canada (2022). Pamphlet: Enjoy the outdoors, without a tick. Retrieved from https://www.canada.ca/en/public-health/services/diseases/lyme-disease/prevention-lyme-disease.html.
40. Public Health Ontario (2019). The Asian Longhorned Tick: Assessing Public Health Implications for Ontario. Retrieved from https://www.publichealthontario.ca/-/media/documents/F/2019/focus-on-asian-longhorned-tick.pdf?la=en
41. Raghavan, R. K., Barker, S. C., Cobos, M. E., Barker, D., Teo, E. J. M., Foley, D. H., Nakao, R., Lawrence, K., Heath A. C. G., & Peterson, A. T. (2019). Potential Spatial Distribution of the Newly Introduced Long-horned Tick, *Haemaphysalis longicornis* in North America. *Nature Scientific Reports, 9,* 498.
42. Rainey, T., Occi, J. L., Robbins, R. G., & Egizi, A. (2018). Discovery of *Haemaphysalis longicornis* (Ixodida: Ixodidae) parasitizing a sheep in New Jersey, United States. *Journal of Medical Entomology*, *55*(3), 757-759.
43. Rand, P. W., Lubelczyk, C., Holman, M. S., Lacombe, E. H., & Smith, R. P. (2004). Abundance of *Ixodes scapularis* (Acari: Ixodidae) after the complete removal of deer from an isolated offshore island, endemic for Lyme disease. *Journal of medical entomology*, *41*(4), 779-784.
44. Rochlin, I. (2019). Modeling the Asian longhorned tick (Acari: Ixodidae) suitable habitat in North America. *Journal of medical entomology*, *56*(2), 384-391.
45. Ronai, I., Tufts, D. M., & Diuk-Wasser, M. A. (2020). Aversion of the invasive Asian longhorned tick to the white-footed mouse, the dominant reservoir of tick-borne pathogens in the USA. *Medical and Veterinary Entomology*, *34*(3), 369-373.
46. Schulze, T. L., Jordan, R. A., Hung, R. W., & Schulze, C. J. (2009). Effectiveness of the 4-Poster passive topical treatment device in the control of *Ixodes scapularis* and *Amblyomma americanum* (Acari: Ixodidae) in New Jersey. *Vector-Borne and Zoonotic Diseases*, *9*(4), 389-400.
47. Shimada, Y., Beppu, T., Inokuma, H., Okuda, M., & Onishi, T. (2003). Ixodid tick species recovered from domestic dogs in Japan. *Medical and Veterinary Entomology*, *17*(1), 38-45.
48. Stanley, H. M., Ford, S. L., Snellgrove, A. N., Hartzer, K., Smith, E. B., Krapiunaya, I., & Levin, M. L. (2020). The ability of the invasive Asian longhorned tick *Haemaphysalis longicornis* (Acari: Ixodidae) to acquire and transmit *Rickettsia rickettsii* (Rickettsiales: Rickettsiaceae), the agent of

Rocky Mountain spotted fever, under laboratory conditions. *Journal of Medical Entomology*, *57*(5), 1635-1639.

49. Sun, J., Liu, Q., Lu, L., Ding, G., Guo, J., Fu, G., Zhang, J., Meng, F., Wu, H., Song, X., Ren, D., Li, D., Guo, Y., Wang, J., Li, G., Liu, J., & Lin, H. (2008). Coinfection with four genera of bacteria (*Borrelia*, *Bartonella*, *Anaplasma*, and *Ehrlichia*) in *Haemaphysalis longicornis* and *Ixodes sinensis* ticks from China. *Vector-Borne and Zoonotic Diseases*, *8*(6), 791-796.
50. Tennessee Department of Agriculture (2019). Invasive Tick Detected in Six Additional Tennessee Counties. Retrieved from https://www.tn.gov/agriculture/news/2019/10/17/invasive-tick-detected-in-six-additional-tennessee-counties.html#:~:text=NASHVILLE%20%E2%80%93%20The%20Tennessee%20Department%20of,tick%20in%20an%20additional%20six.
51. Thompson, A. T., White, S., Shaw, D., Egizi, A., Lahmers, K., Ruder, M. G., & Yabsley, M. J. (2020). Theileria orientalis Ikeda in host-seeking *Haemaphysalis longicornis* in Virginia, USA. *Ticks and Tick-borne Diseases*, *11*(5), 101450.
52. Toyota, M., K. Hirama, T. Suzuki, R. Armstrong, and T. Okinaga. 2019. Efficacy of orally administered fluralaner in dogs against laboratory challenge with Haemaphysalis longicornis ticks. Parasites & Vectors. 12: 43.
53. Tsao, J. I., Hamer, S. A., Han, S., Sidge, J. L., & Hickling, G. J. (2021). The contribution of wildlife hosts to the rise of ticks and tick-borne diseases in North America. *Journal of medical entomology*, *58*(4), 1565-1587.
54. Tufts, D. M., VanAcker, M. C., Fernandez, M. P., DeNicola, A., Egizi, A., & Diuk-Wasser, M. A. (2019). Distribution, host-seeking phenology, and host and habitat associations of *Haemaphysalis longicornis* ticks, Staten Island, New York, USA. *Emerging infectious diseases*, *25*(4), 792.
55. USDA (2019). Monitoring *Haemaphysalis longicornis*, the Asian longhorned tick, populations in the United States. Retrieved from https://www.aphis.usda.gov/animal_health/animal_diseases/tick/downloads/h-longicornis-response-plan_usda.pdf.
56. USDA (2021). National *Haemaphysalis* longicornis (Asian longhorn tick) Situation Report. Retrieved from https://www.aphis.usda.gov/animal_health/animal_diseases/tick/downloads/longhorned-tick-sitrep.pdf.
57. Vink, W. D., Lawrence, K., McFadden, A. M. J., & Bingham, P. (2016). An assessment of the herd-level impact of the *Theileria orientalis* (Ikeda) epidemic of cattle in New Zealand, 2012–2013: a mixed methods approach. *New Zealand veterinary journal*, *64*(1), 48-54.
58. White, S. A., Bevins, S. N., Ruder, M. G., Shaw, D., Vigil, S. L., Randall, A., Deliberto, T. J., Dominguez, K., Thompson, A. T., Mertins, J. W., Alfred, J. T., & Yabsley, M. J. (2020). Surveys for ticks on wildlife hosts and in the environment at Asian longhorned tick (*Haemaphysalis longicornis*)-positive sites in Virginia and New Jersey, 2018. *Transboundary and Emerging Diseases*, *68*(2), 605-614.

59. Wong, T. J., Schramm, P. J., Foster, E., Hahn, M. B., Schafrick, N. H., Conlon, K. C., & Cameron, L. (2017). The Effectiveness and Implementation of 4-Poster Deer Self-Treatment Devices for Tick-borne Disease Prevention: A Potential Component of an Integrated Tick Management Program. Climate and Health Technical Report Series–Climate and Health Program. *Climate and HeALHTh Technical Report Series–Climate and Health Program*.
60. Wormser, G. P., McKenna, D., Piedmonte, N., Vinci, V., Egizi, A. M., Backenson, B., & Falco, R. C. (2020). First recognized human bite in the United States by the Asian longhorned tick, *Haemaphysalis longicornis*. *Clinical Infectious Diseases*, *70*(2), 314-316.
61. Zhan, J., Wang, Q., Cheng, J., Hu, B., Li, J., Zhan, F., Song, Y., & Guo, D. (2017). Current status of severe fever with thrombocytopenia syndrome in China. *Virologica Sinica*, *32*(1), 51-62.
62. Zhang, X., Liu, Y., Zhao, L., Li, B., Yu, H., Wen, H., & Yu, X. J. (2013). An emerging hemorrhagic fever in China caused by a novel bunyavirus SFTSV. *Science China Life sciences*, *56*(8), 697-700.
63. Zhang, X., Zhao, C., Cheng, C., Zhang, G., Yu, T., Lawrence, K., Li, H., Sun, J., Yang, Z., Ye, L., Chu, H., Wang, Y., Han, X., Jia, Y., Fan, S., Kanuka, H., Tanaka, T., Jenkins, C., Gedye, K., Chandra, S., Price, D. C., Liu, Q., Ki Choi, Y., Zhan, X., Zhang, Z., & Zheng, A. (2022). Rapid Spread of Severe Fever with Thrombocytopenia Syndrome Virus by Parthenogenetic Asian Longhorned Ticks. *Emerging infectious diseases*, *28*(2), 363.

APPENDIX 1: QUESTIONS FOR ALHT EXPERTS

1. Most ALHT control methods on livestock animals appear to use generalized methods, such as the application of acaricides. In your experience, are there any more specific methods that target ALHT that should be recommended to livestock producers?
2. In your opinion, what is the most likely carrier and pattern for entry of ALHT into new regions of North America, in particular Canada?
3. In previous papers, it has been stated that companion animals are a potential source of ALHT introduction to new areas. In your opinion, would it be of value to introduce requirements or recommended practices for companion animals crossing borders? How feasible do you think it would be?
4. In New York, tick surveillance programs were already well established prior to the introduction of ALHT. Do you think surveillance programs monitoring for other ticks are well-equipped to detect new introductions of ALHT? If not, how do you think they could be modified to account for potential introductions of ALHT?
5. Do you think it is possible to keep areas free of ALHT, or are all the current control and surveillance methods more about delaying the inevitable, and keeping introductions to management levels?
6. How feasible is it to keep new areas free of ALHT?
7. Do you think the current control and surveillance methods are about delaying the inevitable?
8. Knowing what you know now, if you could go back in time before the introduction of ALHT in the US, how would you change how things were handled?
9. If you could give Canadian stakeholders advice on ALHT, what would it be?
10. What type of engagement should be used to increase ALHT awareness in Canada? Who should be engaged?
11. Do you have any additional comments or feedback?