Tick-Borne Infections Council of North Carolina, Inc.

# NEWSLETTER 2022, Volume 3

**Quote:** "Meanwhile, there is a substantial patient population that perceives their symptoms, suffering, and experiences - Lyme-related or not - are being dismissed, even as researchers rush to tackle "Long COVID," another incompletely understood, post-infectious syndrome that shares many similarities with post-treatment Lyme disease (PTLD)." *Open Forum Infectious Diseases* 2022 © Ross Boyce, doi.org/10.1093/ofid/ofac153

**Special Announcement:** *UNC will be a **core member** of CDC Southeastern Center of Excellence for Vector Borne Diseases (2022 – 2027*), led by the University of Florida. Unlike the initial SECVBD, which was very mosquito (i.e., Zika) focused, this proposal places much greater emphasis on ticks and the emergence of Lyme in western NC and Alpha-gal in central NC. UNC physicians Ross Boyce, MD, MSc, and Scott Commins, MD, PhD, are part of the team. It is headed by:

- Rhoel R Dinglasan PhD MPH, *Professor & Director*
- CDC Southeastern Center of Excellence in Vector-Borne Diseases
- University of Florida Emerging Pathogens Institute, Department of Infectious Diseases & Immunology, College of Veterinary Medicine

## Highlights…

- **Special article on alpha gal from UNC's Dr. Scott Commins**
- **NC study finds that ehrlichiosis probably remains underrecognized**
- **14% of Lyme patients suffer long term effects even with early treatment**
- **Alpha-gal allergy appears related to tick bites, not pathogens**
- **Economic Burden of Reported Lyme Disease in High-Incidence Areas**

- **More than 14% of the world's population may have had Lyme disease**
- **Pathogen prevalence of lone star and blacklegged ticks from central Appalachian, Virginia**
- **Relevance of Spatial and Temporal Trends in Nymphal Tick Density and Infection in NJ Gulf Coast ticks north to New York City in 2021**
- ***Borrelia miyamotoi*, *Borrelia burgdorferi*, and *Babesia microti* Infections in New England Residents**
- **Bourbon virus found in longhorned ticks in Virginia study**
- **Lyme disease bacteria in ticks in the Royal Parks of London, UK**
- **Lyme disease emerging in Canada**
- **In Canadian study, one-fifth of questing ticks (i.e., lone star ticks) infected by the Lyme disease bacteria acquired the infection from birds**

## Special notice:
## COVID-19 vs. Tick-Borne Diseases: How to Tell the Difference

The pandemic has slowed down but is still with us. The link below is to an article from New York but is pertinent to NC. We would add that ticks are active all year in NC, so even in the winter on a warmer day it is possible to contract a tick-borne infection (TBI). Knowledge or evidence of a tick bite is not as easy as this article would imply. Many people who contract a TBI have no knowledge or physical evidence of a tick bite that is noticeable. Also, respiratory symptoms in Covid may not always occur quickly so absence of respiratory symptoms cannot necessarily be used to distinguish TBIs from Covid at the onset of illness. Sometimes, respiratory symptoms with Covid may be minimal. There are cases now reported in the medical literature of late treatment for TBIs due to this confusion. We at TIC-NC are aware of several such cases in our state. (Comments by the newsletter editor M. Herman-Giddens)

There are no state Vector-borne Disease Working Group meeting dates for 2022. Check with us for future dates if they occur.

**Link to Notice to Medical Providers from the State Department of Public Health on Lyme Disease and Rickettsial Diseases: "**Annual Update on Diagnosis and Surveillance for Tickborne Diseases".

The state has started issuing only one letter. Please see the homepage of our website to access. www.tic-nc.org.
To look at the (state) NCDHHS's tick data, go to epi.dph.ncdhhs.gov/cd/diseases/ticks.html.

# From the CDC

## Where To Find CDC Case Definitions and their Statement that the Surveillance Case Definitions Are "not to be used as the sole criteria for establishing critical diagnosis"

### Case Definition and Report Forms:

### The surveillance definition of Lyme disease was revised in January 2022.

See https://www.cste.org/resource/resmgr/ps/ps2021/21-ID-05_Lyme_Disease.pdf for the rationale behind the changes.

- ndc.services.cdc.gov/case-definitions/lyme-disease-2022/
- See: www.cdc.gov/lyme/stats/forms.html for previous case definitions.

### The surveillance definition of Rocky Mountain spotted fever/spotted fever rickettsiosis was revised in 2020.

- ndc.services.cdc.gov/case-definitions/spotted-fever-rickettsiosis-2020/

**Note:** Surveillance case definitions establish uniform criteria for disease reporting and should not be used as the sole criteria for establishing clinical diagnoses, determining the standard of care necessary for a particular patient, setting guidelines for quality assurance, or providing standards for reimbursement.

Accessed and copied 14 September 2019.

**Note**: By the *former* CDC definition, six counties had confirmed cases of Lyme disease in two persons who had not traveled out of the county for 30 days after their tick exposure. **Therefore, these counties were endemic for Lyme disease by the former CDC definition: Wake, Guilford, Haywood, Alleghany, Buncombe, and Wilkes.** Counties with one case of locally acquired Lyme disease were: Cleveland (2008), Wilson (2009), Pitt (2009), Carteret (2009), Gates (2011), Perquimans (2011), Rowan (2013), Union (2013), Caldwell (2013), Franklin (2014), Stanley (2014), Duplin 2014.

## State tick research and/or reports

None. Earlier reports are available online and in our prior newsletters.

## Report from the State or Vectorborne Disease Work Group meeting:

None (no meetings)

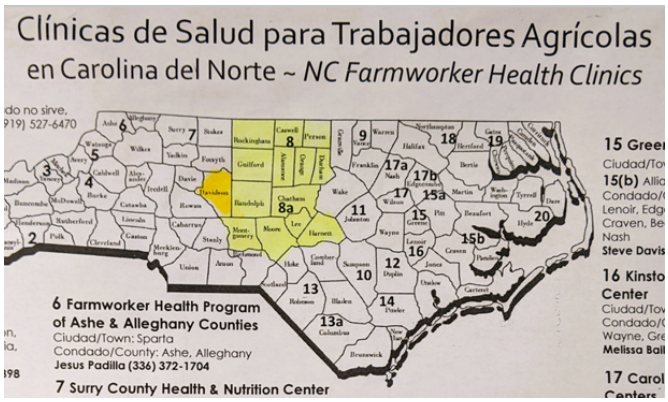
# TIC-NC Activities

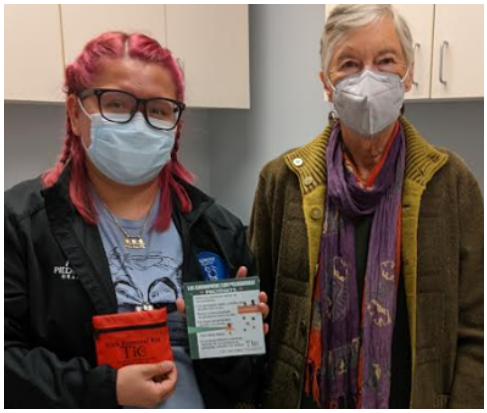
## Our grant: Tick Safety for Outdoor Workers (TSOW)

End of Year Report to the Pesticide Environmental Trust Fund, July 2022
Our year's work was very successful. We:

- Identified organizations that work with migrant workers in local farms.
- Provided teaching to persons aiding the migrant workers about ticks and TBIs, mainly the two Piedmont Health Farmworker Coordinators, Ms. Rodriguez and Ms. Damaso.
- The Coordinators provided 500 tick kits to workers in their district - the yellow counties on the map.
- Provided 500 English/Spanish educational brochures.
- Provided tick repellants.

The Pesticide Environmental Trust Fund Board encouraged us to submit a larger grant in the future.





Top left: Marcia Herman-Giddens with Cecilia Rodriguez
Bottom right: The farmworkers field survey
Bottom left: TIC-NC president Fran McCullough with volunteer Dr. Selvdige

**TIC-NC Talks and Materials Distributed**

**Brochures/booklets:**
Ashe County Public Library
Asheville: news reporters, Trader Joe's, fire station, two doctor's offices

**Interview:**
spectrumlocalnews.com/nc/charlotte/news/2022/06/10/it-s-tick-season-in-north-carolina

**Op-Ed:** Ticks: Deer Play a Deadly Role, News & Observer, July 13, 2022

**Newspaper:** Article mentioning TIC-NC in Chatham News + Record

## The participants in the grant:

- Pesticide Environmental Trust Fund-THANK YOU!
- Our Team
- Chatham County Department of Public Health
- The Farmworker Coordinators Piedmont Health
- Concepcion de Cecilia Gama Rodriguez (Moncure, Chatham County)
- Nereyda Damaso (Prospect Hill, Orange County)

# North Carolina and South

## Pathogen prevalence in *Amblyomma americanum* and *Ixodes scapularis* ticks from central Appalachian Virginia, U.S.A.

Ticks are known vectors of several viral, bacterial, and protozoal pathogens that cause disease in both humans and animals. While pathogen prevalence has been studied extensively in other portions of the United States, pathogen surveillance studies within tick populations in the central Appalachian region of Virginia is almost nonexistent. Two prominent species in this region are *Ixodes scapularis* (the blacklegged tick) and *Amblyomma americanum* (the lone star tick). In this study, we collected ticks biweekly from three habitat types (forest, urban, and pasture) across eight counties in southwest Virginia from June, 2019–November, 2020. *Ixodes scapularis* and *A. americanum* captures were screened for evidence of associated tick-borne pathogens. In this region, *Borrelia burgdorferi* sensu stricto (15.3% in nymphs and 37.6% in adults), *Anaplasma phagocytophilum* (1.9% in nymphs and 12.2% in adults), and *Borrelia miyamotoi* (2.97% in nymphs and 2.33% in adults) were detected in *I. scapularis* ticks. Aside from two previously reported Powassan-positive *I. scapularis* ticks from Floyd County, VA, no additional Powassan-positive ticks are reported here. No evidence of *Ehrlichia chaffeensis*, Heartland virus (HRTV), or Bourbon virus (BRBV) was detected in collected *A. americanum.* Detection and confirmation of multiple emerging tick-borne pathogens in this region raises an increased concern for public health risk, calling for heightened awareness of tick-borne pathogen transmission and increased tick surveillance in understudied areas. Whitlow et al. Journal of Vector Ecology 47(1), 51-60, (24 March 2022). https://doi.org/10.52707/1081-1710-47.1.51.
Eds note: An editorial about this paper is at doi.org/10.1080/23744235.2022.2057584. The editorial is free but the paper itself is behind paywalls.

**Scott Commins MD, Guest Blog – Alpha-gal Syndrome**
Lyme Disease Association, May 6, 2022 | May Awareness LDA Guest Blogger

**Alpha-gal Syndrome: a lens to understand the immune responses to tick bites**
When it comes to ticks and the human immune system, we don't have all the answers and we need to stop pretending as though we do.

Alpha-Gal Syndrome (AGS) is an easy example. At a fundamental level AGS seems straightforward: a tick bite induces an allergy to the alpha-gal sugar found in mammals and, thereafter, one experiences allergic reactions to beef, pork, lamb, venison, etc. However, we know this is an oversimplification. In the dozen years since the initial description of AGS in the U.S. (1), we have learned that these reactions can produce isolated gastrointestinal symptoms (2) and reactions have been reported from heart valves (3), medications (4), even the fumes of cooking meat (5). We have learned that mammal-derived ingredients can be included in numerous products under the label 'natural flavors,' turning safe foods into allergic nightmares. More recently, we have learned that the allergic response to alpha-gal may be linked to cardiovascular disease and atherosclerosis (6,7).

At a fundamental level, Lyme disease also seems straightforward: a tick bite infects a human host with the spirochete *Borrelia burgdorferi*, a bull's eye skin rash called erythema migrans often occurs, and treatment with doxycycline addresses the infection. We equally know this is a gross oversimplification. Many people never recall a tick bite, presence of the rash is variable and infection can be present for days prior to laboratory detection of the spirochete. Patients tell us that Lyme disease can affect neurologic function, cause joint pain and muscle aches, result in profound fatigue, and have devastating effects on the heart.

In both AGS and Lyme disease, there are affected patients whose experience is straightforward. They stop eating red meat and no longer have delayed allergic reactions. Their course of doxycycline treats the infection. In those instances, we appear to have the relevant medical and scientific answers. In the case of AGS, approximately only 20% of patients appear to belong to this category. We are grateful for these more predictable cases when they occur but realize this is a small portion of those overall affected. It is in the struggle to help the remaining patients, however, where I think the real insights will be gained.

But we, as providers, have to listen to our patients. Hearing multiple accounts of red meat cooking fumes causing allergic reactions in patients with AGS has led to inclusion of this in a recent Diagnosis and Management article (5). Recognition of AGS as a cause of isolated gastrointestinal symptoms was due to patients reporting such severe abdominal pain as to seek urgent care in the middle of the night yet have no itching, hives, swelling or other allergic symptoms. Perhaps most important, hearing patients with AGS discuss issues with flushing, cognitive impairment, declining exercise fitness, intolerance of heat/cold, persistent rashes, itching, large skin reaction to bites & stings, heart rate fluctuations, dizziness, fatigue and sleep changes (insomnia, night sweats) led to consideration that their experiences sounded consistent with activation of an innate immune cell, the mast cell.

While serving on the 2nd Tick Borne Disease Working Group, I was struck by the similarity between reports from the public comment volunteers who bravely shared their stories and those we were hearing from patients with AGS seen in the allergy/immunology clinic. Despite being diagnosed with two very different conditions (infection vs allergy), among those patients who develop longer-term, lingering issues, their symptoms seemed to mirror each other. The obvious unifying aspect is that Lyme disease and AGS have tick bites in common. However, current data suggests that the culprit ticks are distinct: bites from the lone star tick (*Amblyomma americanum*) are associated with AGS, while Lyme disease is known to be transmitted principally by the blacklegged deer tick (*Ixodes scapularis*). Although patients may suffer from both diagnoses, the amount of symptom overlap exceeds the co-existence of the two diagnoses in our experience. Rather, I am increasingly convinced that mast cells unite both conditions.

Mast cells are ancient components of inflammation and are thought to be important in host defense. Mast cells are the human body's store of histamine and ordinarily reside near blood vessels or nerves and beneath or in skin, and, within the airways and the gastrointestinal and genitourinary tracts, near or within smooth muscle and mucus-producing glands. Mast cells can remain for long periods of time in the same locations or can both expand locally and migrate into different sites. Unfortunately for study and research, mature mast cells do not circulate in peripheral blood. Instead, their role in host defense occurs at the level of the tissues – and, most critical for tick bite-related conditions – in the skin. Mast cells are known to have a significant role in promoting resistance to certain venoms (e.g., snake, bee, wasp) delivered through the skin and we propose that mast cells can be activated following tick bites.

One thought is that ticks deliver a mast cell-activating signal when attaching to, and feeding through, human skin. This mast cell-activating factor(s) can then lead to the symptoms we associate with a post-tick bite syndrome: flushing, fatigue, sleep disturbance, joint/muscle pain, depression, cognitive impairment (brain fog), neuropathy, headache, heart-related problems, dizziness/syncope, hives/itchiness, numbness/tingling (neuropathy), nausea/vomiting, mood changes, sweats/chills and exercise intolerance. These are exactly the signs and symptoms of patients diagnosed with mast cell activation syndrome.

Mountains of research and study remain to understand the nature of this mast cell activating factor, how to interrupt the causal agent and learn the best ways to treat the resulting symptoms. We have had some success with mast cell stabilizing agents in patients with AGS who report a post-tick bite syndrome and look forward to investigating this approach in a formal study. Interestingly, mast cells are known to be present in atherosclerotic plaques and may act as potential accelerators of heart disease. Thus, the recent association of AGS with atherosclerosis and cardiovascular inflammation raises the possibility that tick bite-induced mast cell activation could play a much larger role in human health and disease (6,7).

Given the overlap of persistent symptoms in some patients with AGS and Lyme disease, we anticipate that research and study results from participants with one condition can inform the other. In both AGS and Lyme disease, we do not have all the answers. I am grateful for organizations, such as LDA, that understand only through working together can we reveal the answers to these large questions.

Lyme disease Awareness Month reminds us to respect what patients are reporting and do the work necessary to fundamentally understand the immune response to tick bites, only then will we have the treatments desperately needed by so many.

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7) Vernon ST, Kott KA, Hansen T, Finemore M, Baumgart KW, Bhindi R, Yang J, Hansen PS, Nicholls SJ, Celermajer DS, Ward MR, van Nunen SA, Grieve SM, Figtree GA. Immunoglobulin E sensitization to mammalian oligosaccharide galactose-α-1,3 (α-gal) is associated with noncalcified plaque, obstructive coronary artery disease, and ST-segment-elevated myocardial infarction. Arterioscler Thromb Vasc Biol. 2022 Mar;42(3):352-361.


## Alpha-gal allergy appears related to tick bites, not pathogens

### Sensitisation and allergic reactions to alpha-1,3-galactose in Podlasie, Poland, an area endemic for tick-borne infections

Ticks transmit several pathogens and seem implicated in the production of specific IgE antibodies to alpha-1,3-galactose (α-gal sIgE). They cause delayed and immediate allergy to mammalian meat and medication including antivenoms, vaccines and monoclonal antibodies.

We assessed the prevalence of α-gal sIgE in forest workers and healthy controls in the Podlasie voivodeship, north-eastern Poland; the relationship between α-gal sIgE and allergy to α-gal-containing products; the correlation between α-gal sIgE and anti-*Borrelia burgdorferi* and anti-tick-borne encephalitis virus (TBEV) antibodies; the relationship between α-gal sIgE and markers of infection with lesser-known pathogens transmitted by ticks such as *Anaplasma phagocytophilum*.

Production of α-gal sIgE was closely related to tick bites. The odds ratio for detectable α-gal sIgE was 9.31 times higher among people with a history of tick bites (OR 9.3; $p < .05$). There was no correlation with the history of TBE, Lyme disease or human granulocytic anaplasmosis. However, serum α-gal sIgE correlated with anti-TBEV IgM antibodies in CSF. There was a strong correlation between α-gal sIgE and total IgE and sIgE to pork and beef.

Our data support the link between I.ricinus ticks and the production of α-gal sIgE and confirm that the pathogens carried by ticks we examined do not seem implicated in this immune response. Rutkowski K, et al. Infectious Diseases, DOI: 10.1080/23744235.2022.2057583.

## NC study finds that ehrlichiosis probably remains underrecognized

**Patterns Testing for Tick-Borne Diseases and Implications for Surveillance in the Southeastern US**

Tick-borne diseases (TBD), including spotted fever group rickettsiosis (SFGR), ehrlichiosis, and, increasingly, Lyme disease, represent a substantial public health concern throughout much of the southeastern United States. Yet, there is uncertainty about the epidemiology of these diseases because of pitfalls in existing diagnostic test methods.

This cross-sectional study included diagnostic test results for TBD at UNC Health, a large academic health care system with inpatient and outpatient facilities, from January 1, 2017, to November 30, 2020. Participants included all individuals seeking routine care at UNC Health facilities who had testing for SFGR, ehrlichiosis, or Lyme disease performed during the study period.

During the 4-year study period, 11 367 individuals (6633 [58.4%] female; 10 793 [95%] non-Hispanic individuals and 8850 [77.9%] White individuals; median [IQR] age, 53 [37-66] years) were tested for TBD. Among the 20 528 diagnostic tests performed, 47 laboratory-confirmed, incident cases of SFGR, 27 cases of ehrlichiosis, and 76 cases of Lyme were confirmed, representing incidence rates of 4.7%, 7.1%, and 0.7%, respectively. However, 3984 of SFGR tests (79.3%) and 3606 of *Ehrlichia* tests (74.3%) lacked a paired convalescent sample. Of 20 528 tests, there were 11 977 tests (58.3%) for Lyme disease from 10 208 individuals, 5448 tests (26.5%) for SFGR from 4520 individuals, and 3103 tests (15.1%) for ehrlichiosis from 2507 individuals. Most striking, testing for ehrlichiosis was performed in only 55% of patients in whom SFGR was ordered, suggesting that ehrlichiosis remains underrecognized. An estimated 187 incident cases of SFGR and 309 of ehrlichiosis were potentially unidentified because of incomplete testing.

In this cross-sectional study, most of the patients suspected of having TBD did not have testing performed in accordance with established guidelines, which substantially limits understanding of TBD epidemiology. Furthermore, the data revealed a large discrepancy between the local burden of disease and the testing performed. These findings underscore the need to pursue more robust, active surveillance strategies to estimate the burden of TBD and distribution of causative pathogens. Marusiak AB, et al. *JAMA Netw Open.* 2022;5(5):e2212334. doi:10.1001/jamanetworkopen.2022.12334.

## Reported County-Level Distribution of Seven Human Pathogens Detected in Host-Seeking *Ixodes scapularis* and *Ixodes pacificus* (Acari: Ixodidae) in the Contiguous United States

Tickborne disease cases account for over 75% of reported vector-borne disease cases in the United States each year. In addition to transmitting the agents of Lyme disease (*Borrelia burgdorferi* sensu strict [Spirochaetales: Spirochaetaceae] and *Borrelia mayonii* [Spirochaetales: Spirochaetaceae]), the blacklegged tick, *Ixodes scapularis*, and the western blacklegged tick, *Ixodes pacificus* collectively transmit five additional human pathogens. By mapping the distributions of tickborne pathogens in host-seeking ticks, we can understand where humans are at risk of contracting tickborne diseases and devise targeted strategies to prevent them.

Using publicly available tickborne pathogen surveillance databases, internal CDC pathogen testing databases, and SCOPUS search records published since 2000, we mapped the county-level distribution of *Borrelia miyamotoi* (Spirochaetales: Spirochaetaceae), *Anaplasma phagocytophilum* (Rickettsiales: Anaplasmataceae), *Ehrlichia muris eauclairensis* (Rickettsiales: Ehrlichiaceae), *Babesia microti* (Piroplasmida: Babesiidae), and Powassan virus (Flaviviridae) reported in host-seeking *I. scapularis* or *I. pacificus* in the contiguous United States. We also updated recently published maps of the distributions of *Borrelia burgdorferi* sensu stricto and *Borrelia mayonii*.

All seven pathogen distributions were more limited than the distributions of vector ticks, with at least one of the seven pathogens detected in 30 states out of 41 total states (73.2% of states) where vector ticks are considered to be established. Prevention and diagnosis of tickborne diseases rely on an accurate understanding by the public and health care providers of where people are at risk for exposure to infected ticks. Our county-level pathogen distribution maps expand on previous efforts showing the distribution of Lyme disease spirochetes and highlight counties where further investigation may be warranted. Fleshman AC, et al. *Journal of Medical Entomology*, 2022; jac049, https://doi.org/10.1093/jme/tjac049.

Ed. note: Article is free. See **maps** in the body of the text: Reported county-level distribution of bacterial pathogens (A) *B. burgdorferi* s.s. and *B. mayonii*, (B) *B. miyamotoi*, and (C) *A. phagocytophilum* (strain not differentiated), in host-seeking *I. scapularis* (eastern United States) or *I. pacificus* (western United States), relative to the previously reported distribution of these vector species.

## It Is Always a Bad Year for Ticks: Update on Ticks and Pathogens

While research indicates that tick-borne diseases are getting worse for people and pets, preventive tools and prevalence mapping can help limit exposure.

February 10, 2022 | Issue: March/April 2022 by M. J. Yabsley

This article is available at the link below. There is no abstract. Using dog data, note the increase of Lyme disease in North Carolina.

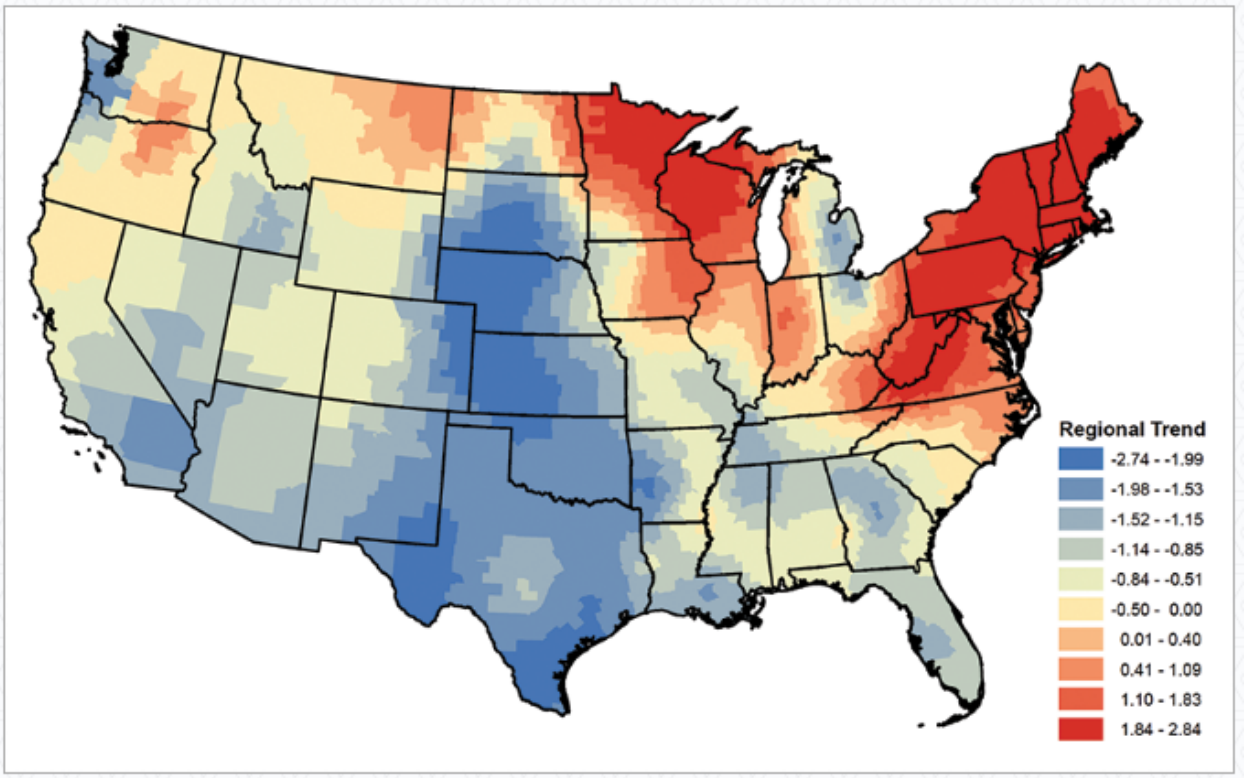



**Figure 4. Regional change in Borrelia burgdorferi seroprevalence in dogs from 2012 to 2018. Regional trends range from decreases or stability of seroprevalence (blue to yellow) to increases (orange to dark red).[11]**

https://todaysveterinarypractice.com/parasitology/update-on-ticks-and-pathogens/.

## Pathogen spillover to an invasive tick species: First detection of Bourbon virus in Haemaphysalis longicornis in the United States

Haemaphysalis longicornis (Neumann, 1901) (Acari: Ixodidae), the Asian longhorned tick, is an invasive tick species present in the USA since at least 2017 and has been detected in one-third of Virginia counties. While this species is associated with the transmission of multiple pathogens in its native geographical range of eastern Asia, little is known about its ability to acquire and transmit pathogens in the USA, specifically those that are transmissible to humans, although from an animal health perspective it has already been shown to vector Theileria orientalis Ikeda strains. Emerging tick-borne viruses such as Bourbon virus (genus: Thogotovirus) are of concern as these newly discovered pathogenic agents have caused fatal clinical cases, and little is known about their distribution or enzootic maintenance.

This study examined H. longicornis collected within Virginia (from ten counties) for Bourbon and Heartland virus using PCR methods. All ticks tested negative for Heartland virus via qRT-PCR (S segment target). Bourbon virus-positive samples were confirmed on two different gene targets, and with Sanger sequencing of the PB2 (segment 1) gene. Bourbon virus RNA was

detected in one nymphal stage H. longicornis from Patrick County, one nymph from Staunton City, one larval pool and one adult female tick from Wythe County, Virginia. An additional 100 Amblyomma americanum (Linnaeus 1758; lone star tick) collected at the same Patrick County site revealed one positive nymphal pool, suggesting that Bourbon virus may have spilled over from the native vector, potentially by co-feeding on a shared Bourbon virus-infected vertebrate host. Blood tested from local harvested deer revealed a 12.0% antibody seroprevalence against Bourbon virus, exposure which further corroborates that this tick-borne virus is circulating in the Southwest Virginia region. Through these results it can be concluded that H. longicornis can carry Bourbon virus and that pathogen spillover may occur from native to invasive tick species. Crumbie A, et al. *Pathogens* **2022**, *11*(4), 454; https://doi.org/10.3390/pathogens11040454.

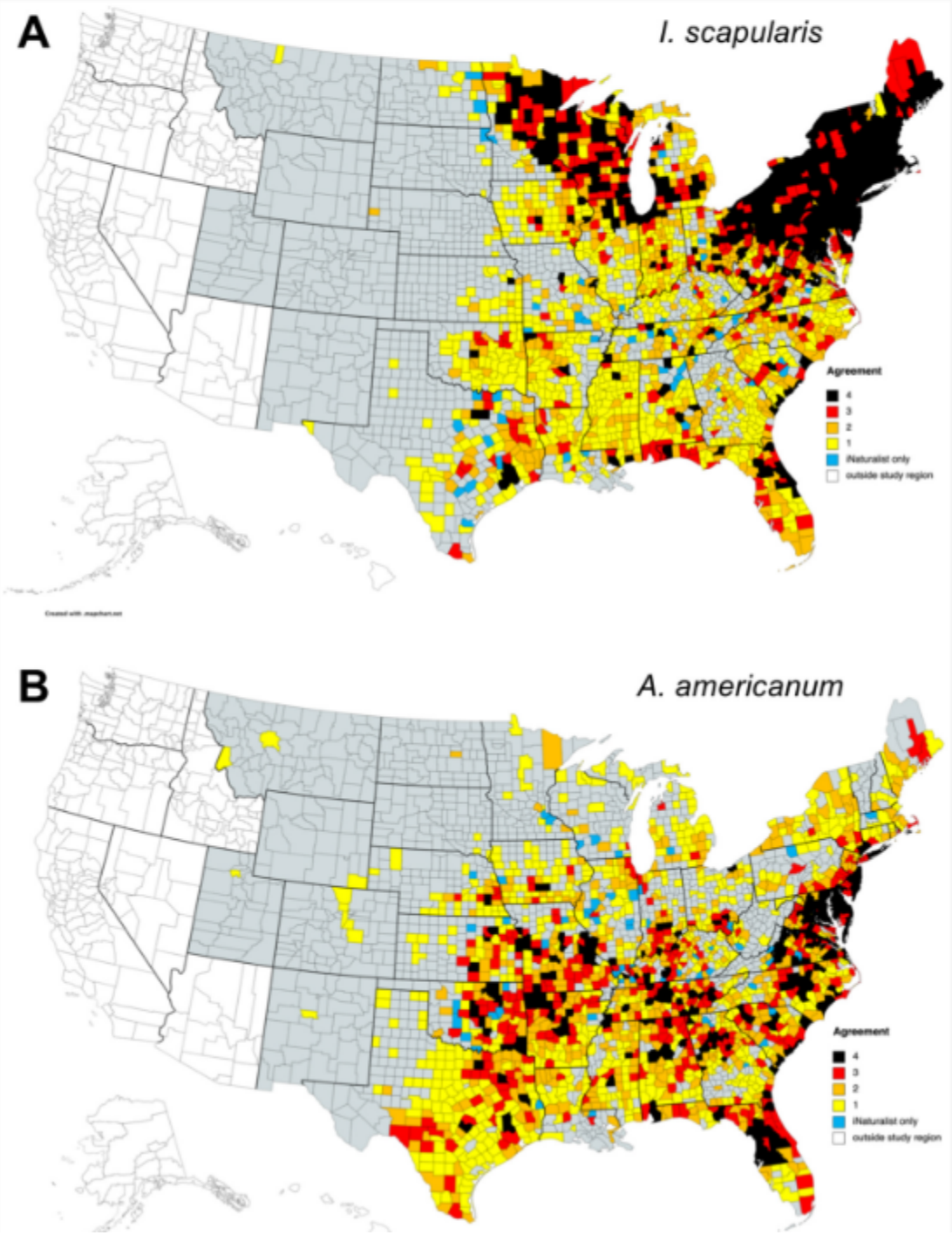
## Study finds the blacklegged tick more widespread across the eastern US than the lone star

### Monitoring Trends in Distribution and Seasonality of Medically Important Ticks in North America Using Online Crowdsourced Records from iNaturalist

Recent increases in the incidence and geographic range of tick-borne diseases in North America are linked to the range expansion of medically important tick species, including *Ixodes scapularis*, *Amblyomma americanum*, and *Amblyomma maculatum.* Passive tick surveillance programs have been highly successful in collecting information on tick distribution, seasonality, host-biting activity, and pathogen infection prevalence. These have demonstrated the power of citizen or community science participation to collect country-wide, epidemiologically relevant data in a resource-efficient manner. This study examined tick observations from the online image-based biological recording platform iNaturalist to evaluate its use as an effective tool for monitoring the distributions of *A. americanum*, *A. maculatum*, *I. scapularis*, and *Dermacentor* in the United States and Canada. The distribution and seasonality of iNaturalist tick observations were found to accurately represent those of the studied species. County-level iNaturalist tick occurrence data showed good agreement with other data sources in documented areas of *I. scapularis* and *A. americanum* establishment, and highlighted numerous previously unreported counties with iNaturalist observations of these species. This study supports the use of iNaturalist data as a highly cost-effective passive tick surveillance method that can complement existing surveillance strategies to update tick distributions and identify new areas of tick establishment. Cull B. *Insects* 2022, *13*(5), 404; https://doi.org/10.3390/insects13050404.

Ed. note: From iNaturalist: “Contribute to Science. Every observation can contribute to biodiversity science, from the rarest butterfly to the most common backyard weed. We share your findings with scientific data repositories like the Global Biodiversity Information Facility to help scientists find and use your data. All you have to do is observe.” https://www.inaturalist.org/ | App: Download from your phone’s App store.

**Figure 4.** Comparison of recorded United States county-level distribution of (**A**) *Ixodes scapularis* and (**B**) *Amblyomma americanum* between iNaturalist data and recent sources of US-wide tick surveillance data Refs. [6,8,31,38,45,72]. The number of surveillance methods reporting tick presence in each county is indicated by the color. [72] includes data from the ArboNET Tick Module. Maps created with mapchart.net. Raw data are available in **Table S3**.



# National Section

## Economic Burden of Reported Lyme Disease in High-Incidence Areas, United States, 2014–2016

Approximately 476,000 cases of Lyme disease are diagnosed in the United States annually, yet comprehensive economic evaluations are lacking. In a prospective study among reported cases in Lyme disease–endemic states, we estimated the total patient cost and total societal cost of the disease. In addition, we evaluated disease and demographic factors associated with total societal cost. Participants had a mean patient cost of ≈$1,200 (median $240) and a mean societal cost of ≈$2,000 (median $700). Patients with confirmed disseminated disease or probable disease had approximately double the societal cost of those with confirmed localized disease.

The annual, aggregate cost of diagnosed Lyme disease could be $345–968 million (2016 US dollars) to US society. Our findings emphasize the importance of effective prevention and early diagnosis to reduce illness and associated costs. These results can be used in cost-effectiveness analyses of current and future prevention methods, such as a vaccine. Hook SA, et al. *Emerging Infectious Diseases*, *28*(6), 1170-1179. https://doi.org/10.3201/eid2806.211335.

## Relevance of Spatial and Temporal Trends in Nymphal Tick Density and Infection Prevalence for Public Health and Surveillance Practice in Long-Term Endemic Areas: A Case Study in Monmouth County, NJ

Tick-borne diseases are a growing public health problem in the United States, and the US northeast has reported consistently high case rates for decades. Monmouth County, New Jersey, was one of the earliest jurisdictions to report Lyme disease cases in 1979 and reports several hundred cases per year nearly 40 yr later.

In the time since, however, tick-borne health risks have expanded far beyond Lyme disease to include a variety of other bacterial pathogens and viruses, and additional vectors, necessitating a continually evolving approach to tick surveillance. In 2017, Monmouth County initiated an active surveillance program targeting sites across three ecological regions for collection of *Ixodes scapularis* Say (Acari: Ixodidae) and *Amblyomma americanum* L. (Acari: Ixodidae) as well as testing via qPCR for associated bacterial pathogens.

During the first five years of this program (2017–2021), we report high levels of spatiotemporal variability in nymphal density and infection prevalence in both species, limiting the granularity with which human risk can be predicted from acarological data. Nonetheless, broader patterns emerged, including an ongoing trend of *A. americanum* dominance, risks posed by *Borrelia miyamotoi*, and the frequency of coinfected ticks.

We present some of the first county-level, systematic surveillance of nymphal *A. americanum* density and infection prevalence in the northeastern US. We also documented a temporary decline in *Borrelia burgdorferi* that could relate to unmeasured trends in reservoir host populations. We discuss the implications of our findings for tick-borne disease ecology, public health communication, and tick surveillance strategies in endemic areas. Jordan RA, et al , *Journal of Medical Entomology*, 2022;, tjac073, https://doi.org/10.1093/jme/tjac073.

## The cotton rat most common bloodmeal host with 59.0% identified for adult Gulf Coast ticks, does not appear to be the primary source of *R. parkeri* infection

**Analyses of Bloodmeal Hosts and Prevalence of *Rickettsia parkeri* in the Gulf Coast Tick *Amblyomma maculatum* (Acari: Ixodidae) From a Reconstructed Piedmont Prairie Ecosystem, North Carolina**

Host feeding patterns and the prevalence of infection with *Rickettsia parkeri* were determined for the primary vector, *Amblyomma maculatum* Koch as well as sympatric tick species *A. americanum* (Linnaeus) and *Dermacentor variabilis* (Say) collected from a reconstructed prairie in the Piedmont region of North Carolina during 2011 and 2012. The occurrence of *R. parkeri* among *A. maculatum* adults and nymphs was 36.9% (45/122) and 33.3% (2/6), respectively.

*Rickettsia parkeri* was detected in a single male *A. americanum* 2.3% (1/43). A PCR-reverse line blot hybridization assay of a 12S rDNA fragment amplified from remnant larval and nymphal bloodmeals of host-seeking ticks was used to identify bloodmeal hosts. Of the tick samples tested, bloodmeal host identification was successful for 29.3% (12/41) of adult *A. americanum* and 39.2% (20/51) of adult *D. variabilis*.

For *A. maculatum*, bloodmeal host identification was successful for 50% (61/122) of adults collected from vegetation and 100% (4/4) of nymphs removed from cotton rats (*Sigmodon hispidus* Say and Ord). The cotton rat was the most common bloodmeal host with 59.0% (36/61) identified for adult *A. maculatum*. No statistically significant association was observed, however, between bloodmeal host and pathogen prevalence for any tick species. While the cotton rat was an important bloodmeal host for *A. maculatum* nymphs, this vertebrate did not appear to be the primary source of *R. parkeri* infection for *A. maculatum*. Johnson et al. *Journal of Medical Entomology*, tjac033, https://doi.org/10.1093/jme/tjac033.

## Two papers on persistent Lyme disease in 10% to 20% even with early treatment

### 1. *Borreliella burgdorferi* Antimicrobial-Tolerant Persistence in Lyme Disease and Posttreatment Lyme Disease Syndromes

The annual incidence of Lyme disease, caused by tick-transmitted *Borreliella burgdorferi*, is estimated to be at least 476,000 cases in the United States and many more worldwide. Ten to 20% of antimicrobial-treated Lyme disease patients display posttreatment Lyme disease syndrome (PTLDS), a clinical complication whose etiology and pathogenesis remain uncertain. Autoimmunity, cross-reactivity, molecular mimicry, coinfections, and borrelial tolerance to antimicrobials/persistence have been hypothesized and studied as potential causes of PTLDS.

Studies of borrelial tolerance/persistence *in vitro* in response to antimicrobials and experimental studies in mice and nonhuman primates, taken together with clinical reports, have revealed that *B. burgdorferi* becomes tolerant to antimicrobials and may sometimes persist in animals and humans after the currently recommended antimicrobial treatment. Moreover, *B. burgdorferi* is pleomorphic and can generate viable-but-nonculturable bacteria, states also involved in antimicrobial tolerance.

The multiple regulatory pathways and structural genes involved in mediating this tolerance to antimicrobials and environmental stressors by persistence might include the stringent (*rel* and *dksA*) and host adaptation (*rpoS*) responses, sugar metabolism (*glpD*), and polypeptide transporters (*opp*).

Application of this recently reported knowledge to clinical studies can be expected to clarify the potential role of bacterial antibacterial tolerance/persistence in Lyme disease and PTLDS. Cabello et al. mBio, Free, full text: https://doi.org/10.1128/mbio.03440-21.

### 2. Risk of post-treatment Lyme disease in patients with ideally-treated early Lyme disease: A prospective cohort study

Post-treatment Lyme disease (PTLD) is characterized by patient-reported symptoms after treatment for *Borrelia burgdorferi* infection. The primary aim of this study was to assess whether participants with a history of Lyme disease (LD) would be more likely to meet criteria for PTLD than those without a history of LD.

We conducted a longitudinal, prospective study among 234 participants with and 49 participants without prior LD. All completed survey metrics for fatigue, pain, sleep, depression, and quality of life. An operationalized PTLD definition was applied to both cohorts, and the distributions of clinical outcomes and symptoms were examined.

In total, 13·7% of participants with a history of prior LD met criteria for PTLD compared with 4·1% of those without a history of prior LD. Participants with prior LD were approximately 5·28 times as likely to meet PTLD criteria compared with those without prior LD ($p = 0·042$) and had

8-15 times as high odds of reporting moderate or severe fatigue and muscle pain ($p = 0{\cdot}002$, $0{\cdot}047$, respectively). Risk of meeting PTLD criteria was also independently increased among females and those with higher exposure to previous traumatic life events.

Participants ideally diagnosed and treated for prior LD reported more symptoms on standardized surveys and were more likely to meet criteria for PTLD than those without prior LD. Aucott JN, et al. International Journal of Infectious Diseases. doi.org/10.1016/j.ijid.2022.01.033.

## Tick control reduced incidence pet TBDs, but not in owners

**Interventions on Tick Abundance, Human Encounters with Ticks, and Incidence of Tickborne Diseases in Residential Neighborhoods, New York, USA**

Tickborne diseases (TBDs) such as Lyme disease result in ≈500,000 diagnoses annually in the United States. Various methods can reduce the abundance of ticks at small spatial scales, but whether these methods lower incidence of TBDs is poorly understood.

We conducted a randomized, replicated, fully crossed, placebo-controlled, masked experiment to test whether 2 environmentally safe interventions, the Tick Control System (TCS) and Met52 fungal spray, used separately or together, affected risk for and incidence of TBDs in humans and pets in 24 residential neighborhoods. All participating properties in a neighborhood received the same treatment. TCS was associated with fewer questing ticks and fewer ticks feeding on rodents.

The interventions did not result in a significant difference in incidence of human TBDs but did significantly reduce incidence in pets. Our study is consistent with previous evidence suggesting that reducing tick abundance in residential areas might not reduce incidence of TBDs in humans. Keesing et al. Emerging Infectious Diseases - www.cdc.gov/eid, doi.org/10.3201/eid2805.211146.

## Gulf Coast ticks north to New York City in 2021, half infected with *Rickettsia parkeri*

**Established Populations of *Rickettsia parkeri*-Infected *Amblyomma maculatum* Ticks in New York City, New York, USA**

We sought to determine the habitat associations and pathogen status of *Amblyomma maculatum* ticks in New York City (NYC), New York, USA, a newly expanded portion of their range.

We collected 88 ticks from two NYC parks on Staten Island, one of the five boroughs of NYC, and compared our findings with similar habitat in Brooklyn, New York during the same time period (April 30–September 1). We tested 76 for pathogens.

We found adult and immature ticks in native and invasive grasses at Freshkills and Brookfield parks on Staten Island. No *A. maculatum* ticks were found in Brooklyn. 52.6% of ticks tested were infected with *Rickettsia parkeri*—the etiological agent of *R. parkeri* rickettsiosis.

This high rate of *R. parkeri* in a dense urban center is of concern to the medical community, who should be aware of this species' presence and the symptoms of *R. parkeri* rickettsiosis. Ramírez-Garofalo JR, et al. Vector-Borne and Zoonotic Diseases, 22:3. doi.org/10.1089/vbz.2021.0085.

## Detection of *Borrelia miyamotoi* and Powassan Virus Lineage II (Deer Tick Virus) from *Odocoileus virginianus* Harvested *Ixodes scapularis* in Oklahoma

*Odocoileus virginianus* (white-tailed deer) is the primary host of adult *Ixodes scapularis* (deer tick). Most of the research into *I. scapularis* has been geographically restricted to the northeastern United States, with limited interest in Oklahoma until recently as the *I. scapularis* populations spread due to climate change. Ticks serve as a vector for pathogenic bacteria, protozoans, and viruses that pose a significant human health risk.

To date, there has been limited research to determine what potential tick-borne pathogens are present in *I. scapularis* in central Oklahoma. Using a one-step multiplex real-time reverse transcription-PCR, *I. scapularis* collected from white-tailed deer was screened for *Anaplasma phagocytophilum*, *Borrelia burgdorferi*, *Borrelia miyamotoi*, *Babesia microti*, and deer tick virus (DTV). Ticks ($n = 394$) were pooled by gender and life stage into 117 samples. Three pooled samples were positive for *B. miyamotoi* and five pooled samples were positive for DTV. This represents a minimum infection rate of 0.8% and 1.2%, respectively. *A. phagocytophilum*, *B. burgdorferi*, and *B. microti* were not detected in any samples. This is the first report of *B. miyamotoi* and DTV detection in Oklahoma *I. scapularis* ticks. This demonstrates that *I. scapularis* pathogens are present in Oklahoma and that further surveillance of *I. scapularis* is warranted. Smalley IV, et al. Vector-Borne and Zoonotic Diseases, doi.org/10.1089/vbz.2021.0057.

## Long-term Data Reveal Differences in Prevalence of Borrelia burgdorferi between Nymph and Adult Blacklegged Ticks (Ixodes scapularis)

Tick-borne diseases pose an immense threat to human health. Lyme disease in particular is increasing in both geographic range and case numbers in recent decades. Surveillance of the prevalence of *Borrelia burgdorferi*, the causative agent of Lyme disease, is essential to understanding the spatial distribution of infection risk. The blacklegged tick (*Ixodes scapularis*) is one of the primary vectors for *B. burgdorferi*.

Using a long-term data set, we compared annual variation in prevalence of *B. burgdorferi* between nymph and adult blacklegged ticks. We also investigated how prevalence varied spatially and related variation in prevalence to weather and land-cover data that were proxies for blacklegged tick hosts. We consistently sampled 105 plots located at 15 different sites

in southeastern Virginia once a year from 2015 – 2019, and an additional 20 plots during some but not all years. We used a PCR-based technique to determine prevalence of *B. burgdorferi* in nymphs and adults separately. The average prevalence of *B. burgdorferi* in nymphs over our five-year study period was 0.10 (credible interval = 0.05 – 0.17) and 0.39 (credible interval = 0.28 – 0.51) for adults. Temporal variation in prevalence was higher in adults than nymphs ranging between 0.13 and 0.60 for adults and 0.05 and 0.25 for nymphs. Our research also suggests a high turnover of *B. burgdorferi* in our study area, with one site never testing positive, and the rest having plots that tested positive a maximum of two out of five years.

Sites that tested positive most frequently were in areas with low-density urban development. We were unable to relate the variation of *B. burgdorferi* prevalence to either land-cover or weather predictor variables. This suggests that long-term studies are needed to elucidate the patterns and factors present in this complex interaction of hosts, ticks, and bacteria. Our research provides important information about *B. burgdorferi* prevalence and Lyme disease risk, which can be used to inform health policies. Adams, Meghan, (2022). *Undergraduate Honors Theses.* William & Mary. Paper 1791. https://scholarworks.wm.edu/honorstheses/1791.

## More than 14% of the world's population may have had Lyme disease

**Global seroprevalence and sociodemographic characteristics of *Borrelia burgdorferi sensu lato* in human populations: a systematic review and meta-analysis**

*Borrelia burgdorferi sensu lato* (*Bb*) infection, the most frequent tick-transmitted disease, is distributed worldwide. This study aimed to describe the global seroprevalence and sociodemographic characteristics of *Bb* in human populations.

Meta-analysis of global *Bb* seroprevalence found the reported pooled seroprevalence was 14.5% (95% CI 12.8% to 16.3%) according to the random effects model (online supplemental appendix 7). Of the 89 studies, 31 lacked WB confirmation of serological testing, and 58 had WB confirmation, with reported pooled *Bb* seropositivity rates of 16.3% (95% CI 13.8% to 18.9%) and 11.6% (95% CI 9.5% to 14.0%), respectively (online supplemental appendix 8).

The reported estimated global *Bb* seropositivity is relatively high, with the top three regions as Central Europe, Western Europe and Eastern Asia. Using the WB to confirm *Bb* serological results could significantly improve the accuracy. More studies are needed to improve the accuracy of global Lyme borreliosis burden estimates. Dong Y, et al. BMJ Global Health, http://dx.doi.org/10.1136/bmjgh-2021-007744. Entire paper free of charge.

## Frequency and Geographic Distribution of *Borrelia miyamotoi*, *Borrelia burgdorferi*, and *Babesia microti* Infections in New England Residents

*Borrelia miyamotoi* is a relapsing fever spirochete that relatively recently has been reported to infect humans. It causes an acute undifferentiated febrile illness that can include

meningoencephalitis and relapsing fever. Like *Borrelia burgdorferi*, it is transmitted by *Ixodes scapularis* ticks in the northeastern United States and by *Ixodes pacificus* ticks in the western United States. Despite reports of clinical cases from North America, Europe, and Asia, the prevalence, geographic range, and pattern of expansion of human *B. miyamotoi* infection are uncertain…

We measured specific antibodies against *B. miyamotoi*, *B. burgdorferi*, and *B. microti* among individuals living in 5 New England states in 2018.

Analysis of 1153 serum samples collected at 11 catchment sites showed that the average seroprevalence for *B. miyamotoi* was 2.8% (range, 0.6%–5.2%), which was less than that of *B. burgdorferi* (11.0%; range, 6.8%–15.6%) and *B. microti* (10.0%; range, 6.5%–13.6%). Antibody screening within county residence in New England showed varying levels of seroprevalence for these pathogens but did not reveal a vectoral geographical pattern of distribution.

Human infections caused by *B. miyamotoi*, *B. burgdorferi*, and *B. microti* are widespread with varying prevalence throughout New England. Johnston D, et al. *Clinical Infectious Diseases*, ciac107, https://doi.org/10.1093/cid/ciac107.

# International & General Section

## Review paper: Personal protection measures to prevent tick bites in the United States: Knowledge gaps, challenges, and opportunities

Personal protection measures to prevent human tick encounters from resulting in bites are widely recommended as the first line of defense against health impacts associated with ticks. This includes using repellents, wearing untreated or permethrin-treated protective clothing, and conducting tick checks after coming inside, aided by removing outdoor clothing articles and running them in a dryer on high heat (to kill undetected ticks) and taking a shower/bath (to aid in detecting ticks on the skin). These measures have the benefit of incurring no or low cost, but they need to be used consistently to be most effective. In this paper, I review the level of use (acceptability combined with behavior) of the above-mentioned personal protection measures and their effectiveness to prevent tick bites and tick-borne disease…

The results are mixed for each personal protection measure, with some studies indicating that regular use of the measure is associated with a reduction in tick-borne disease while other studies found no similar protective effect. One possible interpretation is that these personal protection measures can protect against tick-borne infection but the information gathered to date has not been sufficiently detailed to clarify the circumstances under which protection is achieved, especially with regards to frequency of use, parts of the body being protected, and use of combinations of two or more potentially protective measures. In conclusion, personal protection measures to prevent tick bites are used by the public and merit further study to better understand

how they need to be used to have the greatest public health impact. Eisen L. Ticks and Tick-borne Diseases. https://doi.org/10.1016/j.ttbdis.2022.101944. Entire paper is free.

## In Canadian study, one-fifth of questing ticks infected by the Lyme disease bacteria acquired the infection from birds

**Transmission patterns of tick-borne pathogens among birds and rodents in a forested park in southeastern Canada**

*Ixodes scapularis* ticks are expanding their range in parts of northeastern North America, bringing with them pathogens of public health concern. While rodents like the white-footed mouse, *Peromyscus leucopus*, are considered the primary reservoir of many emerging tick-borne pathogens, the contribution of birds, as alternative hosts and reservoirs, to local transmission cycles has not yet been firmly established.

From 2016 to 2018, we collected host-seeking ticks and examined rodent and bird hosts for ticks at 48 sites in a park where blacklegged ticks are established in Quebec, Canada, in order to characterize the distribution of pathogens in ticks and mammalian and avian hosts. We found nearly one third of captured birds (n = 849) and 70% of small mammals (n = 694) were infested with *I. scapularis*.

Five bird and three mammal species transmitted *Borrelia burgdorferi* to feeding larvae (n larvae tested = 2257) and we estimated that about one fifth of the *B. burgdorferi*-infected questing nymphs in the park acquired their infection from birds, the remaining being attributable to mice. Ground-foraging bird species were more parasitized than other birds, and species that inhabited open habitat were more frequently infested and were more likely to transmit *B. burgdorferi* to larval ticks feeding upon them. Female birds were more likely to transmit infection than males, without age differentiation, whereas in mice, adult males were more likely to transmit infection than juveniles and females.

We also detected *Borrelia miyamotoi* in larvae collected from birds, and *Anaplasma phagocytophilum* from a larva collected from a white-footed mouse. This study highlights the importance of characterizing the reservoir potential of alternative reservoir hosts and to quantify their contribution to transmission dynamics in different species assemblages. This information is key to identifying the most effective host-targeted risk mitigation actions. Dumas A, et al. PLoS ONE 17(4): e0266527. https://doi.org/10.1371/journal.pone.0266527.

**Surveillance for Lyme disease in Canada, 2009–2019**

Lyme disease (LD) is a multisystem infection that can affect the skin, heart, joints and nervous system. In Canada, the incidence of LD cases has increased over the past decade making this a disease of public health concern. The objective of this study is to summarize the epidemiology of LD cases reported in Canada from 2009 through 2019.

Incidence over time, case classification (confirmed and probable), seasonal and geographic distribution, demographic and clinical characteristics of reported LD cases were determined. Logistic regression was used to explore potential demographic risk factors for the occurrence of LD.

During 2009–2019, a total of 10,150 LD cases were reported by the provinces to the Public Health Agency of Canada, of which 7,242 (71.3%) were confirmed and 2,908 (28.7%) were probable cases. The annual count increased from 144 in 2009 to 2,634 in 2019, mainly due to an increase in locally acquired infections, from 65.3% to 93.6%, respectively. The majority of cases (92.1%) were reported from three provinces: Ontario (46.0%); Nova Scotia (28.0%); and Québec (18.1%). Most of the locally acquired cases (74.0%) were reported in the summer months of June (20.0%), July (35.4%) and August (18.6%). The highest incidence rates (cases per 100,000 population) were in children aged 5–9 years (45.0) and in adults aged 65–69 years (74.3), with 57.3% of all reported cases occurring among males. The most common presenting symptoms were single erythema migrans rash (75.1%) and arthritis (34.1%). The frequency of reported clinical manifestations varied among age groups and seasons with erythema migrans and arthritis at presentation reported more frequently in children than older patients.

The results of this report highlight the continued emergence of LD in Canada and the need for further development and implementation of targeted awareness campaigns designed to minimize the burden of LD. Gasmi S et al. *Journal of Public Health Informatics*, *11*(1). doi.org/10.5210/ojphi.v11i1.9892.

## Ecology of Black-Legged Ticks (Ixodes scapularis) at Fort Drum Military Installation: Dissertation

…To study Lyme disease ecology, we used Fort Drum Military Installation in New York as our study area. Fort Drum had 38 cases of Lyme disease from 2004 to 2013, with a 5.7% increase in Lyme disease incidences from 2006 to 2012… Borrelia burgdorferi was identified in 18% of nymph and 48% of adult black-legged ticks on Fort Drum in 2015 and 2016.

…The majority of blacklegged tick bloodmeals came from eastern chipmunks and eastern gray squirrels (26.32 % ± 18.45 36.05 % ± 16.02 ). Based on our results, we recommend focusing on habitat management to reduce tick abundance…

Ed. note. This finding is from a long dissertation. The results are interesting as deer were not found to be a major source of blood meals in this area. For the entire dissertation see: Price, Lucas Eli, "Ecology of Black-Legged Ticks (Ixodes scapularis) at Fort Drum Military Installation, New York" (2022). Graduate Theses, Dissertations, and Problem Reports. 11210. https://researchrepository.wvu.edu/etd/1121.0.

## Ixodes ricinus and Borrelia burgdorferi sensu lato in the Royal Parks of London, UK

Assessing the risk of tick-borne disease in areas with high visitor numbers is important from a public health perspective. Evidence suggests that tick presence, density, infection prevalence and the density of infected ticks can vary between habitats within urban green space, suggesting that the risk of Lyme borreliosis transmission can also vary. This study assessed nymph density, Borrelia prevalence and the density of infected nymphs across a range of habitat types in nine parks in London which receive millions of visitors each year.

Ixodes ricinus were found in only two of the nine locations sampled, and here they were found in all types of habitat surveyed. Established I. ricinus populations were identified in the two largest parks, both of which had resident free-roaming deer populations. Highest densities of nymphs (15.68 per 100 $m^2$) and infected nymphs (1.22 per 100 $m^2$) were associated with woodland and under canopy habitats in Richmond Park, but ticks infected with Borrelia were found across all habitat types surveyed. Nymphs infected with Borrelia (7.9%) were only reported from Richmond Park, where Borrelia burgdorferi sensu stricto and Borrelia afzelii were identified as the dominant genospecies.

Areas with short grass appeared to be less suitable for ticks and maintaining short grass in high footfall areas could be a good strategy for reducing the risk of Lyme borreliosis transmission to humans in such settings. In areas where this would create conflict with existing practices which aim to improve and/or meet historic landscape, biodiversity and public access goals, promoting public health awareness of tick-borne disease risks could also be utilized. Hansford, KM, et al. Exp Appl Acarol (2021). https://doi.org/10.1007/s10493-021-00633-3.

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