

# Potential Effects of Climate Change on Tick-borne Diseases in Rhode Island

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## ABSTRACT

Human cases of tick-borne diseases have been increasing in the United States. In particular, the incidence of Lyme disease, the major vector-borne disease in Rhode Island, has risen, along with cases of babesiosis and anaplasmosis, all vectored by the blacklegged tick. These increases might relate, in part, to climate change, although other environmental changes in the northeastern U.S. (land use as it relates to habitat; vertebrate host populations for tick reproduction and enzootic cycling) also contribute. Lone star ticks, formerly southern in distribution, have been spreading northward, including expanded distributions in Rhode Island. Illnesses associated with this species include ehrlichiosis and alpha-gal syndrome, which are expected to increase. Ranges of other tick species have also been expanding in southern New England, including the Gulf Coast tick and the introduced Asian longhorned tick. These ticks can carry human pathogens, but the implications for human disease in Rhode Island are unclear.

**KEYWORDS:** ticks, climate change, Lyme disease, Babesiosis, Ehrlichiosis

## INTRODUCTION

Ticks are major disease vectors in north temperate regions worldwide, transmitting a wide variety of pathogen types. Although mosquitoes are recognized as vectors of widespread tropical diseases such as malaria and dengue, they are responsible for far fewer cases of disease than ticks in North America. In Rhode Island, mosquitoes are responsible for an average of only about one human case of arboviral disease per year.<sup>1</sup> In contrast, annual cases of tickborne ailments in Rhode Island run into the thousands (<https://health.ri.gov/data/diseases/>). Climate change would be expected to result, overall, in a poleward shift in the distributions of tick-borne diseases.<sup>2</sup> However, numerous other environmental and socioeconomic factors that affect vector-borne disease transmission are also changing. This complicates direct predictions of climate change effects on future disease distribution patterns, and only a few examples have been demonstrated convincingly for tick-borne pathogens.<sup>2</sup> In this brief review

we identify the major tick-borne diseases that currently occur in Rhode Island, describe the underlying transmission dynamics, and consider the likely effects of climate change. We also discuss tick species that have recently spread into the region and the pathogens they might bring with them.

## MAJOR TICK-BORNE DISEASES IN RHODE ISLAND

The major tick disease vector in Rhode Island is the blacklegged tick (sometimes called the deer tick), *Ixodes scapularis*, which transmits the spirochete that causes Lyme disease. Several tick-borne pathogens cause human disease in Rhode Island, with Lyme disease being far the most common (Table 1). Reported cases of Lyme disease in the state are in the vicinity of 1,000 per year, but this is undoubtedly a substantial underestimate. A recent CDC estimate using insurance claims data indicates that the annual number of cases diagnosed in the US from 2010–2018 averaged about 476,000, compared to the average of only about 35,000 cases per year reported to the agency.<sup>3</sup>

The blacklegged tick is concentrated in woodlands with leaf litter and is most abundant in the southern portion of Rhode Island, but numbers fluctuate substantially from year

**Table 1.** Major tick-borne diseases in Rhode Island

Tick vector	Disease	Pathogen	Mean # cases per yr. (2015–2019)*
Blacklegged tick, deer tick ( <i>Ixodes scapularis</i> )	Lyme disease	<i>Borrelia burgdorferi</i>	1,004.2
	Anaplasmosis	<i>Anaplasma phagocytophilum</i>	141.4
	Babesiosis	<i>Babesia microti</i>	165.8
	Powassan Encephalitis	Powassan virus, Deer tick virus	0.8
Lone star tick ( <i>Amblyomma americanum</i> )	Ehrlichiosis	<i>Ehrlichia chaffeensis</i> , <i>E. ewingi</i>	57.0
American dog tick ( <i>Dermacentor variabilis</i> )	Spotted Fever Group Rickettsiosis	<i>Rickettsia rickettsii</i> , <i>R. spp.</i>	6.0

\* Data in Table 1 and Figure 1 from CDC (<https://www.cdc.gov/nndss/data-statistics/infectious-tables/index.html>)

to year such that dense populations extend throughout the state in some years.<sup>4</sup> In addition to Lyme disease, which is caused by a spirochete, the blacklegged tick is also the primary vector of the two other major tick-borne pathogens in Rhode Island, the rickettsia that causes anaplasmosis and the protozoan that causes babesiosis (Table 1). This tick can also transmit pathogens less commonly reported in Rhode Island, including Powassan encephalitis virus, and the relapsing fever spirochete *Borrelia miyamotoi*.<sup>5</sup>

Two other tick species are important vectors of human pathogens in Rhode Island, the lone star tick, *Amblyomma americanum*, which transmits the rickettsiae that cause ehrlichiosis and possibly those that cause Rocky Mountain Spotted Fever, and the American dog tick, *Dermacentor variabilis*, the primary vector of Rocky Mountain Spotted Fever (Table 1). These two tick species can also transmit the bacterium *Francisella tularensis*, which causes tularemia, but this pathogen is often transmitted via infectious fluids through handling or even breathing aerosols from infected animals rather than from tick bite. These diseases are far less common than some of those vectored by *I. scapularis*, but the distributions of these tick species are changing,<sup>6</sup> and effects of climate change are potentially important. Resources for identification of tick species, and information sources relevant to disease transmission and status in Rhode Island are readily available online (<https://web.uri.edu/tickencounter/>).

## CLIMATE CHANGE AND TRANSMISSION PATTERNS OF TICK-BORNE PATHOGENS

### Lyme disease, Anaplasmosis, Babesiosis

Rhode Island is near the center of the current geographic distribution of Lyme disease, and is likely to remain an epicenter of Lyme and other major tick-borne diseases in the foreseeable future. In the eastern and central U.S., Lyme disease is most common in the northern states, and relatively uncommon in the south (<https://www.cdc.gov/lyme/data-surveillance/maps-recent.html>). This pattern results primarily from latitudinal trends in host-seeking behavior and host associations of larval and nymphal ticks. Northern *I. scapularis* wait on leaves and twigs at the leaf litter surface and attach to passing hosts, while southern ticks remain below the litter surface when host-seeking.<sup>7</sup> Therefore, people frequently encounter northern ticks in their woodland habitats, but there is relatively little human exposure in the south.<sup>8</sup> Furthermore, northern larval and nymphal ticks feed primarily on small mammals such as rodents and shrews, which are excellent reservoirs for the Lyme spirochete, while southern ticks feed mostly on lizards, which are relatively poor reservoirs, so prevalence of spirochetal infection is much lower in southern than in northern ticks.<sup>9</sup> Some of these latitudinal differences might well be related to north-south climatic differences,<sup>10</sup> and so might be affected by climate change. Some modeling studies predict that climate

change-related effects on factors such as tick development and phenology are likely to result in increases in Lyme disease incidence in the northeast,<sup>11,12</sup> as well as increased spread northward into Canada. Indeed, cases of Lyme disease have been increasing in the U.S., and northward spread into Canada has been documented.<sup>13</sup> However, predictions for changes in current endemic areas vary with model assumptions and local complexities,<sup>14</sup> so these effects remain uncertain for Rhode Island. Human cases of Lyme disease reported to the CDC have been increasing in Rhode Island (Figure 1A). Furthermore, evidence from various sources suggest that populations of *I. scapularis*, and human cases of associated diseases, have been increasing in the northeast,<sup>6,15</sup> and that these changes result, at least in part, from the effects of climate change.<sup>2</sup>

Epidemiological trends in cases of anaplasmosis and babesiosis are expected to be similar to those for Lyme disease, because they have the same tick vector species, *I. scapularis*, and the same primary reservoir species, the white-footed mouse (*Peromyscus leucopus*). As such, patterns of epizootiology are similar for these pathogens, except that transmission efficiency is apparently greater for *Borrelia burgdorferi* than for *Anaplasma phagocytophila*<sup>16</sup> or *Babesia microti*,<sup>17</sup> so infection prevalence of these pathogens in ticks is lower than that of Lyme spirochetes, and there are fewer human cases (Figure 1B). Thus, anaplasmosis and babesiosis are likely to remain important in Rhode Island,

Figure 1A.

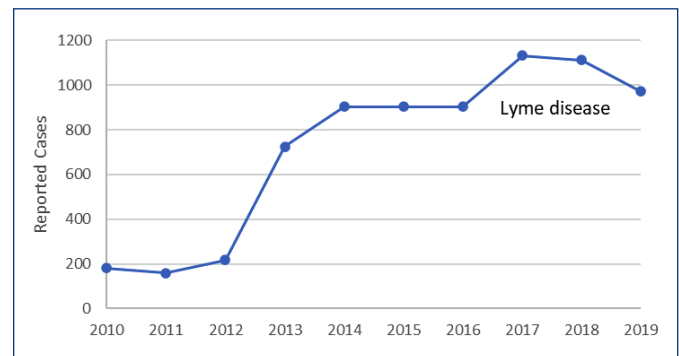
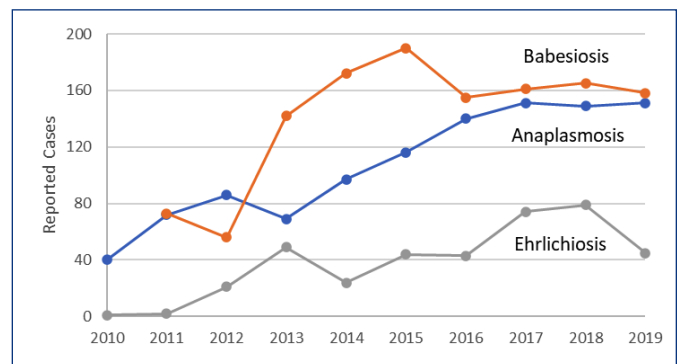


Figure 1B.



and though cases are expected to increase, they will likely remain less prevalent than Lyme disease.

### Ehrlichiosis, alpha-gal syndrome

The lone star tick, *A. americanum*, is the vector of the rickettsiae that cause ehrlichiosis.<sup>18</sup> Growing evidence indicates that lone star tick bites are also responsible for alpha-gal syndrome (also called red meat allergy or tick bite meat allergy), an allergic response to the carbohydrate galactose-alpha-1,3-galactose, which is found in mammalian meat.<sup>19</sup> Populations of this tick species are spreading northward<sup>20</sup> and ehrlichiosis cases have been increasing in Rhode Island (<https://health.ri.gov/data/diseases/Ehrlichiosis.pdf>). Lone star ticks were formerly southern in distribution, with dense populations from central New Jersey and southward, but populations increased substantially on Long Island, NY, in the late 1980s and 1990s, and they are now established in Connecticut.<sup>21</sup> Climate change might contribute to the northward spread of this species, but increasing populations of its primary hosts, including white-tailed deer, coyotes, and wild turkeys, are also important.<sup>20</sup> This tick has previously been rare on the mainland of Rhode Island, although a dense population has existed on Prudence Island in Narragansett Bay, at least since 1990.<sup>22</sup> Populations have increased substantially since 2016 on Conanicut Island, and established populations (all three life stages) are now being detected at mainland sites, especially in coastal communities on both sides of Narragansett Bay and the south coast (TNM, personal observation). Thus, lone star ticks are spreading northward, likely related to changes in climate and in host distributions. Rhode Island is within the potential range of this species predicted by some models, but not others.<sup>23</sup> Given the recent local increases in *A. americanum* populations and the persistent population on Prudence Island, it is reasonable to expect increases in Rhode Island cases of ehrlichiosis and alpha-gal syndrome in the future.

### Spotted fever group rickettsioses

The primary vector of *Rickettsia rickettsii*, etiologic agent of Rocky Mountain Spotted Fever (RMSF) in North America, is the American dog tick, *D. variabilis*, which is responsible for modest numbers of human cases in Rhode Island (Table 1). This species is distributed widely in the eastern U.S., and climate change might well result in larger populations in the northern U.S. and Canada.<sup>6</sup> Most RMSF cases currently occur in a band from the Carolinas to Oklahoma,<sup>24</sup> so climate change could result in greater numbers of cases in our area. This pathogen is maintained vertically in *D. variabilis* (passed from mother to offspring), and outbreaks tend to be focal, with local amplification presumably resulting from horizontal transmission by ticks among mammal hosts.<sup>25</sup> However, these dynamics are poorly understood, so it is difficult to predict the likely effects of a changing climate on the epidemiology of RMSF.

Another spotted fever group rickettsia, *R. parkeri*, is transmitted by the Gulf Coast tick, *Amblyomma maculatum*. This tick was formerly found only in the southern states, but it has recently expanded its range into the mid-Atlantic region,<sup>26</sup> and an established population has recently been reported in Connecticut.<sup>27</sup> Human infection with *R. parkeri* has not yet been detected in Rhode Island, but given the northward range expansion of the vector, this possibility is worthy of attention in the future.

### TICK SPECIES LIKELY TO SPREAD INTO RHODE ISLAND

Northward spread of two tick species has already been discussed: *A. americanum*, which is already present in Rhode Island and is likely to increase in the future, and *A. maculatum*, which has not yet been detected in the state, but which is spreading into the region. Both species present potential implications for human health, and their range expansion might be related, at least in part, to climate change.

A third tick species that was introduced into the United States, presumably from its native range in Asia, has recently appeared in the region, and the implications for human health are currently unclear. The Asian longhorned tick, *Haemaphysalis longicornis*, was first detected in North America in 2017. Examinations of earlier collections indicate that this species was present in the United States several years before that detection. It has now been detected in 16 states, and on dozens of animal species ([https://www.aphis.usda.gov/animal\\_health/animal\\_diseases/tick/downloads/longhorned-tick-sitrep.pdf](https://www.aphis.usda.gov/animal_health/animal_diseases/tick/downloads/longhorned-tick-sitrep.pdf)). Populations are known to exist on Block Island, and *H. longicornis* has recently been collected on the Rhode Island mainland (TNM, personal observation). The North American populations are parthenogenetic and can rapidly increase to high densities. This tick is known to vector numerous pathogens in Asia, including Severe Fever with Thrombocytopenia Syndrome (SFTS) virus,<sup>28</sup> and has become an introduced pest of cattle in Australia. It serves as a vector of the cattle pathogen *Theileria orientalis* Ikeda in Virginia.<sup>29</sup> To date, no human pathogens have been isolated from *H. longicornis* in the United States, except for one *B. burgdorferi* isolate from Pennsylvania.<sup>30</sup> Lab studies suggest that *H. longicornis* is not a competent vector of *B. burgdorferi*<sup>31</sup> or of *A. phagocytophilum*,<sup>32</sup> but that this tick species can acquire and transmit the RMSF pathogen *R. rickettsii*.<sup>33</sup> The potential role of this species as a vector of human pathogens in the U.S. remains unclear. Fortunately, this species does not readily bite humans, although cases of attachment to humans have been reported in the United States.<sup>34</sup> Rhode Island is within the predicted distribution of this species,<sup>35</sup> and populations are likely to increase in the future.

## CONCLUSIONS

Incidence levels of tick-borne diseases generally respond to changes in environmental conditions such as habitat, vertebrate host populations, and climate, as well as to factors that influence tick encounter by people. Human cases of several tick-associated diseases in Rhode Island, Lyme disease chief among them, but also anaplasmosis, babesiosis, ehrlichiosis, and alpha-gal syndrome, are likely to increase in the future. Northward range expansions of some tick species into Rhode Island are likely, but the implications for human health are unclear.

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