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The Need for a National Strategy to Address Vector-Borne Disease Threats in the United States

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Abstract

Vector-borne diseases (VBDs) cause significant morbidity and mortality each year in the United States. Over the last 14 yr, over 700,000 cases of diseases carried by ticks, mosquitoes, and fleas have been reported from U.S. states and territories to the Centers for Disease Control and Prevention. The number of reported cases has been increasing annually with two major trends: a steady increase in tick-borne diseases and increasing intermittent outbreaks of mosquito-borne arboviruses. The factors that are driving VBD introduction and emergence vary among diseases but are not likely to disappear, indicating that current trends will continue and probably worsen in the absence of effective prevention and control tools and implementation capacity. There are a number of challenges to preventing VBDs, including the lack of vaccines and effective vector control tools, insecticide resistance, and eroding technical capacities in public health entomology at federal, state, and local levels. For these reasons, a national strategy is needed to address VBD threats and to reverse the alarming trend in morbidity and mortality associated with these diseases.

Keywords

vector; tick; mosquito; prevention; national strategy

Vector-borne diseases (VBDs) are of great importance in the United States, resulting in significant morbidity and mortality each year. From 2004 to 2017, over 700,000 cases of 16 diseases caused by viral, bacterial, or parasitic agents were reported to the Centers for Disease Control and Prevention (CDC) (Centers for Disease Control and Prevention 2018, Curren et al. 2018, Rosenberg et al. 2018). In 2017, the top five reported VBDs were Lyme disease (42,743 cases), anaplasmosis/ehrlichiosis (7,718 cases), spotted fever rickettsiosis (7,718 cases), babesiosis (2,368 cases), and West Nile virus (WNV) disease (2,097 cases). Among the reported WNV disease cases, there were 146 deaths.

In terms of the total burden of illness associated with VBDs each year, it is important to note that reported cases represent only a small fraction of those sickened by these infections. The reasons for under-reporting vary by disease. For WNV infection, most reported cases have neuroinvasive disease (meningitis, encephalitis, and acute flaccid paralysis) as these patients are often hospitalized and tested. However, for every one case of WNV neuroinvasive

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disease, 30–70 WNV non-neuroinvasive cases occur (Burakoff et al. 2018). Yet only a tiny fraction of those are reported, in large part due to under-diagnosis. Many patients do not seek medical care, physicians may not consider WNV as a possible diagnosis, and diagnostic tests may not be ordered. For Lyme disease, under-reporting is not influenced so much by under-diagnosis as by the burden associated with the reporting process itself, which can require both laboratory and supportive clinical data for case classification. Recent studies indicate that the total number of annual cases likely exceeds 300,000 (Hinckley et al. 2014, Nelson et al. 2015), suggesting that national under-reporting for Lyme disease occurs by a factor of around 8- and 12-fold.

VBD Trends

VBD cases in the United States have steadily increased over the last two decades. From 2004 to 2016, the number of reported VBD cases tripled (Rosenberg et al. 2018). Two primary trends characterize the observed increase in reported cases. The first is a steady increase in tick-borne disease incidence over a broadening geographic distribution (Figs. 1 and 2). For Lyme disease, from 1993 to 2012, the number of high-incidence counties more than tripled in the northeastern United States and more than doubled in the north-central United States (Kugeler et al. 2015). Nearly all other tick-borne disease cases have also increased as well, as evidenced by record numbers of cases for all reportable tick-borne diseases in 2017 (Centers for Disease Control and Prevention 2018). *Ixodes scapularis* Say (Acari: Ixodidae), the most important tick vector in the United States, can transmit the pathogens that cause borreliosis, anaplasmosis, babesiosis, and Powassan virus disease. The number of counties where *I. scapularis* is established has more than doubled in the last 20 yr (Eisen et al. 2016).

A second observed trend accounting for the increase in VBDs in the United States over the last two decades is increasing intermittent outbreaks of mosquito-borne arboviruses. These include WNV, which has become endemic throughout the contiguous United States during this time, as well as exotic diseases like chikungunya and Zika, which have been more recently introduced to the western hemisphere. In the U.S. territories, dengue is a constant threat, resulting in widespread periodic outbreaks. Large outbreaks of dengue, chikungunya, and Zika in the Caribbean region have led to introductions into the continental United States with subsequent local mosquito-borne transmission (Brathwaite Dick et al. 2012, Kendrick et al. 2014, Likos et al. 2016). Most recently, during 2016 and 2017, there were 42,798 symptomatic cases of Zika reported in U.S. states and territories, including 37,032 locally acquired cases in Puerto Rico and 5,334 travel-related and 231 locally acquired cases, presumably mosquito-transmitted cases, in the continental United States (Centers for Disease Control and Prevention 2019a).

Drivers for VBD Emergence

The factors contributing to VBD introduction and emergence in the United States are complex and vary among diseases. Global travel and trade have been responsible for introduction of exotic arboviruses going all the way back to the slave trade in the 1600s when both yellow fever virus and its mosquito vector *Aedes aegypti* (L.) (Diptera:

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Culicidae) were presumably introduced from Africa (Barrett and Monath 2003). Shipments of used tires and lucky bamboo have transported *Aedes albopictus* (Skuse) (Diptera: Culicidae) throughout the Americas (Madon et al. 2002). Both Zika and chikungunya were introduced into the United States via infected travelers (Kendrick et al. 2014, Likos et al. 2016). Most recently, the Asian Longhorned tick *Haemaphysalis longicornis* Neumann (Acari: Ixodidae) has been documented as an invasive species now reported from nine states and detected biting a range of animals, including livestock, wildlife, pets, and humans (Beard et al. 2018). This tick is an important disease vector in other parts of the world and was presumably introduced into the United States through movement of pets or livestock.

Quite different factors have likely contributed to the emergence of arboviral and ‘arbobacterial’ diseases associated with *I. scapularis* and some of the other native tick species in the United States. The geographic expansion of Lyme disease and accompanying increase in human infection has been associated with changing land use patterns, chiefly with reforestation, expanding deer populations, changes in biodiversity, and growth of suburbia (Wood and Lafferty 2013). This combination of factors has placed an ever-increasing human population at greater risk for exposure to the bites of infected ticks. Climate change has no doubt influenced both the geographic distribution and seasonality of tick-borne diseases (Beard 2016). Temperature minimums define the northern distribution of arthropod vectors and influence their basic reproductive rate and subsequent population size (Ogden et al. 2006, Ogden et al. 2014). Milder winters, earlier springs, warmer summers, and longer growing seasons have been linked to changes in disease seasonality with Lyme disease (Moore et al. 2014, Monaghan et al. 2015, Beard et al. 2016).

Travel, trade, changing land-use patterns, growth of suburbia, and climate change are factors that are increasing at accelerating rates. Consequently, the effect of these factors as drivers for VBD emergence are likely to increase, strongly suggesting that in the absence of effective prevention and control tools and the capacity to implement them in a timely manner, the trends and patterns observed over the last two decades will continue and likely worsen.

Challenges to Preventing and Controlling VBDs

Several factors hinder prevention and control of VBDs. Currently, no licensed vaccines exist for any endemic human VBD in the United States. As a result, VBD prevention relies on vector control efforts and personal protection. Yet there is a dearth of high-quality data demonstrating the efficacy of vector control on reducing disease occurrence during seasonal exposure or outbreaks. For example, a randomized control trial involving over 2,700 homes, looking at a single springtime barrier acaricide application achieved 63% reduction in ticks between treated and untreated properties. There was no reduction, however, in the number of human tick encounters or physician-diagnosed Lyme disease cases (Hinckley et al. 2016). There is a similar lack of robust data from randomized control trials that demonstrate the efficacy of available interventions for control of mosquito-borne diseases (Wilson et al. 2015). High-quality data from rigorously designed studies that capture both entomologic and epidemiologic outcomes are badly needed for making sound, evidence-based public health recommendations. Large prospective community trials that are adequately powered to

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measure a reduction in disease incidence are very expensive, which is the reason why most data on the efficacy of vector control for prevention of VBDs come from observational studies.

Another hindrance to effective vector control is insecticide resistance. This was particularly important in Puerto Rico during the Zika outbreak where populations of *Ae. aegypti* from San Juan were resistant to multiple insecticides, including both Type I and Type II pyrethroids (Estep et al. 2017). Insecticide resistance varies by target species and can be highly localized. However, relatively little systematically collected information is available to guide effective vector control in the United States. A recent survey that evaluated 1,083 vector control organizations found that 84% failed to maintain at least one of the five core competencies for effective vector control (National Association of County and City Health Officials 2017). These competencies included such things as conducting routine mosquito surveillance and pesticide resistance monitoring and then using the resulting data to guide operational decisions. Maintaining high-quality information on vector population density and susceptibility to available pesticides is critical for effective vector control.

Still other challenges exist to VBD prevention and control activities such as public opposition to the use of synthetic pesticides. In Miami, Florida, there was significant public protest to aerial spraying of the insecticide Naled during the Zika virus outbreak in 2016, despite the occurrence of active local virus transmission (Karimi and Visser 2016). In Puerto Rico, during the same outbreak, public outcry resulted in a decision not to allow aerial spraying at all despite over 35,000 locally acquired Zika cases. The lack of a timely response can also compromise the effectiveness of vector control interventions. During the 2012 WNV outbreak in Texas, there were 1,868 reported cases including 844 cases of WNV neuroinvasive disease and 89 deaths (Centers for Disease Control and Prevention 2019b). Following a mild winter and early spring, the first positive mosquito pool was detected in the Dallas-Fort Worth area in late May close to when the first human case was reported (Chung et al. 2013). The number of cases rose precipitously from mid-June through early August. Aerial spraying was not implemented, however, until mid-August, after human case numbers were already declining. These data suggest that early vector-control interventions based on vector surveillance data are not always implemented effectively.

For tick control, the challenges are quite different. Interventions are seldom carried out by municipal governments or vector control districts but more frequently implemented by private property owners, chiefly homeowners. The deer that host adult *I. scapularis* and the rodents that harbor the various pathogens transmitted by this tick range freely between homeowner properties and adjacent green spaces, depositing ticks that can infect residents. Identifying interventions that are effective and affordable for homeowners has been a significant challenge for tick-borne disease prevention and control (Eisen and Eisen 2018). In the absence of a vaccine for any of these pathogens, safe and effective tick control methods must be developed and validated for use in local communities in order to reverse the upward trends in tick-borne disease incidence.

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The Need for a National Strategy

The increasing disease incidence and other challenges noted above, together with eroding technical capacities in public health entomology at federal, state, and local levels (Hadler et al. 2014), leave the nation largely unprepared to respond to VBD threats. A recent call to action was issued to create a national strategy for addressing this need (Petersen et al. 2019). Both development and implementation of such a strategy will require collaboration between stakeholders at multiple governmental levels, together with partners from academics, industry, patient organizations, and communities. An effective national strategy should 1) develop a vision, mission, goals, and substrategies within the goals, and 2) describe accountability among the federal agencies and institutes. Once a national strategy has been created, detailed action plans can be developed and prioritized, which can be used to define key activities and specify success measures and timelines. Some of the specific needs that should be addressed and sustained in a national strategy to respond to VBD emerging threats include 1) basic understanding of VBD biology, ecology, and exposure risk, 2) vector and pathogen detection and diagnosis, 3) disease prevention and control tools and methods, 4) facilitated process to bring new vector control products to market and deploy them when needed, and 5) adequate workforce and resource capacity.

The complex nature of VBD transmission cycles, typically involving zoonotic reservoirs and vector populations, both of which are broadly dispersed in the environment, pose unique technological challenges for effective control. Consequently, successful efforts to establish and maintain an effective national system to detect and respond to emerging VBD threats will require a high level of coordination, cooperation, and perseverance involving all of the key stakeholders.

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References Cited

Barrett AD, and Monath TP. 2003 Epidemiology and ecology of yellow fever virus. Adv. Virus Res 61: 291–315. [PubMed: 14714435]

Beard CB, Eisen RJ, Barker CM, Garofalo JF, Hahn M, Hayden M, Monaghan AJ, Ogden NH, and Schramm PJ. 2016 Vector-borne diseases, pp. 129–156. In Crimmins A, Balbus J, Gamble JL, Beard CB, Bell JE, Dodgen D, Eisen RJ, Fann N, Hawkins MD, Herring SC, et al. (eds.), The impacts of climate change on human health in the United States: a scientific assessment. U.S. Global Change Research Program, Washington, D.C.

Beard CB, Occi J, Bonilla DL, Egizi AM, Fonseca DM, Mertins JW, Backenson BP, Bajwa WI, Barbarin AM, Bertone MA, et al. 2018 Multistate infestation with the exotic disease-vector tick Haemaphysalis longicornis – United States, August 2017–September 2018. MMWR. Morb. Mortal. Wkly. Rep 67: 1310–1313. [PubMed: 30496158]

Brathwaite Dick O, San Martín JL, Montoya RH, del Diego J, Zambrano B, and Dayan GH. 2012 The history of dengue outbreaks in the Americas. Am. J. Trop. Med. Hyg 87: 584–593. [PubMed: 23042846]

Burakoff A, Lehman J, Fischer M, Staples JE, and Lindsey NP. 2018 West Nile virus and other nationally notifiable arboviral diseases – United States, 2016. MMWR. Morb. Mortal. Wkly. Rep 67: 13–17. [PubMed: 29324725]

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Centers for Disease Control and Prevention. 2018 National notifiable diseases surveillance system, 2017 annual tables of infectious disease data. Centers for Disease Control and Prevention. https://www.cdc.gov/nndss/infectious-tables.html

Centers for Disease Control and Prevention. 2019a Zika virus: statistics and maps yearly case counts for US states and territories. Centers for Disease Control and Prevention https://www.cdc.gov/zika/reporting/index.html?CDC_AA_refVal=https%3A%2F%2Fwww.cdc.gov%2Fzika%2Freporting%2Fcase-counts.html

Centers for Disease Control and Prevention. 2019b Final annual maps and data for 1999–2017. Centers for Disease Control and Prevention https://www.cdc.gov/westnile/statsmaps/finalmapsdata/index.html

Chung WM, Buseman CM, Joyner SN, Hughes SM, Fomby TB, Luby JP, and Haley RW. 2013 The 2012 West Nile encephalitis epidemic in Dallas, Texas. JAMA. 310: 297–307. [PubMed: 23860988]

Curren EJ, Lehman J, Kolsin J, Walker WL, Martin SW, Staples JE, Hills SL, Gould CV, Rabe IB, Fischer M, et al. 2018 West Nile virus and other nationally notifiable arboviral diseases – United States, 2017. MMWR. Morb. Mortal. Wkly. Rep 67: 1137–1142. [PubMed: 30335737]

Eisen RJ, and Eisen L. 2018 The blacklegged tick, Ixodes scapularis: an increasing public health concern. Trends Parasitol. 34: 295–309. [PubMed: 29336985]

Eisen RJ, Eisen L, and Beard CB. 2016 County-scale distribution of Ixodes scapularis and Ixodes pacificus (Acari: Ixodidae) in the Continental United States. J. Med. Entomol 53: 349–386. [PubMed: 26783367]

Estep AS, Sanscrainte ND, Waits CM, Louton JE, and Becnel JJ. 2017 Resistance status and resistance mechanisms in a strain of Aedes aegypti (Diptera: Culicidae) from Puerto Rico. J. Med. Entomol 54: 1643–1648. [PubMed: 28981681]

Hadler JL, Patel D, Bradley K, Hughes JM, Blackmore C, Etkind P, Kan L, Getchell J, Blumenstock J, and Engel J; Centers for Disease Control and Prevention (CDC). 2014 National capacity for surveillance, prevention, and control of West Nile virus and other arbovirus infections – United States, 2004 and 2012. MMWR. Morb. Mortal. Wkly. Rep 63: 281–284. [PubMed: 24699764]

Hinckley AF, Connally NP, Meek JI, Johnson BJ, Kemperman MM, Feldman KA, White JL, and Mead PS. 2014 Lyme disease testing by large commercial laboratories in the United States. Clin. Infect. Dis 59: 676–681. [PubMed: 24879782]

Hinckley AF, Meek JI, Ray JA, Niesobecki SA, Connally NP, Feldman KA, Jones EH, Backenson PB, White JL, Lukacik G, et al. 2016 Effectiveness of residential acaricides to prevent lyme and other tick-borne diseases in humans. J. Infect. Dis 214: 182–188. [PubMed: 26740276]

Karimi F, and Visser S. 2016 Zika aerial spraying in Miami completed despite health concerns. CNN https://www.cnn.com/2016/09/09/health/florida-zika-spraying-starts/index.html

Kendrick K, Stanek D, and Blackmore C; Centers for Disease Control and Prevention (CDC). 2014 Notes from the field: transmission of chikungunya virus in the continental United States – Florida, 2014. MMWR. Morb. Mortal. Wkly. Rep 63: 1137. [PubMed: 25474035]

Kugeler KJ, Farley GM, Forrester JD, and Mead PS. 2015 Geographic distribution and expansion of human lyme disease, United States. Emerg. Infect. Dis 21: 1455–1457. [PubMed: 26196670]

Likos A, Griffin I, Bingham AM, Stanek D, Fischer M, White S, Hamilton J, Eisenstein L, Atrubin D, Mulay P, et al. 2016 Local mosquito-borne transmission of Zika virus – Miami-Dade and Broward Counties, Florida, June–August 2016. MMWR. Morb. Mortal. Wkly. Rep 65: 1032–1038. [PubMed: 27684886]

Madon MB, Mulla MS, Shaw MW, Kluh S, and Hazelrigg JE. 2002 Introduction of Aedes albopictus (Skuse) in southern California and potential for its establishment. J. Vector Ecol 27: 149–154. [PubMed: 12125866]

Monaghan AJ, Moore SM, Sampson KM, Beard CB, and Eisen RJ. 2015 Climate change influences on the annual onset of Lyme disease in the United States. Ticks Tick. Borne. Dis 6: 615–622. [PubMed: 26025268]

Moore SM, Eisen RJ, Monaghan A, and Mead P. 2014 Meteorological influences on the seasonality of Lyme disease in the United States. Am. J. Trop. Med. Hyg 90: 486–496. [PubMed: 24470565]

National Association of County and City Health Officials. 2017 Mosquito control capabilities in the U.S, pp. 25 National Association of County and City Health Officials, Washington D.C.

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Nelson CA, Saha S, Kugeler KJ, Delorey MJ, Shankar MB, Hinckley AF, and Mead PS. 2015 Incidence of clinician-diagnosed lyme disease, United States, 2005–2010. Emerg. Infect. Dis 21: 1625–1631. [PubMed: 26291194]

Ogden NH, Maarouf A, Barker IK, Bigras-Poulin M, Lindsay LR, Morshed MG, O'callaghan CJ, Ramay F, Waltner-Toews D, and Charron DF. 2006 Climate change and the potential for range expansion of the Lyme disease vector Ixodes scapularis in Canada. Int. J. Parasitol 36: 63–70. [PubMed: 16229849]

Ogden NH, Radojevic M, Wu X, Duvvuri VR, Leighton PA, and Wu J. 2014 Estimated effects of projected climate change on the basic reproductive number of the Lyme disease vector Ixodes scapularis. Environ. Health Perspect 122: 631–638. [PubMed: 24627295]

Petersen LR, Beard CB, and Visser SN. 2019 Combatting the increasing threat of vector-borne disease in the United States with a national vector-borne disease prevention and control system. Am. J. Trop. Med. Hyg 100: 242–245. [PubMed: 30499427]

Rosenberg R, Lindsey NP, Fischer M, Gregory CJ, Hinckley AF, Mead PS, Paz-Bailey G, Waterman SH, Drexler NA, Kersh GJ, et al. 2018 Vital signs: trends in reported vectorborne disease cases – United States and territories, 2004–2016. MMWR. Morb. Mortal. Wkly. Rep 67: 496–501. [PubMed: 29723166]

Wilson AL, Boelaert M, Kleinschmidt I, Pinder M, Scott TW, Tusting LS, and Lindsay SW. 2015 Evidence-based vector control? Improving the quality of vector control trials. Trends Parasitol. 31: 380–390. [PubMed: 25999026]

Wood CL, and Lafferty KD. 2013 Biodiversity and disease: a synthesis of ecological perspectives on Lyme disease transmission. Trends Ecol. Evol 28: 239–247. [PubMed: 23182683]

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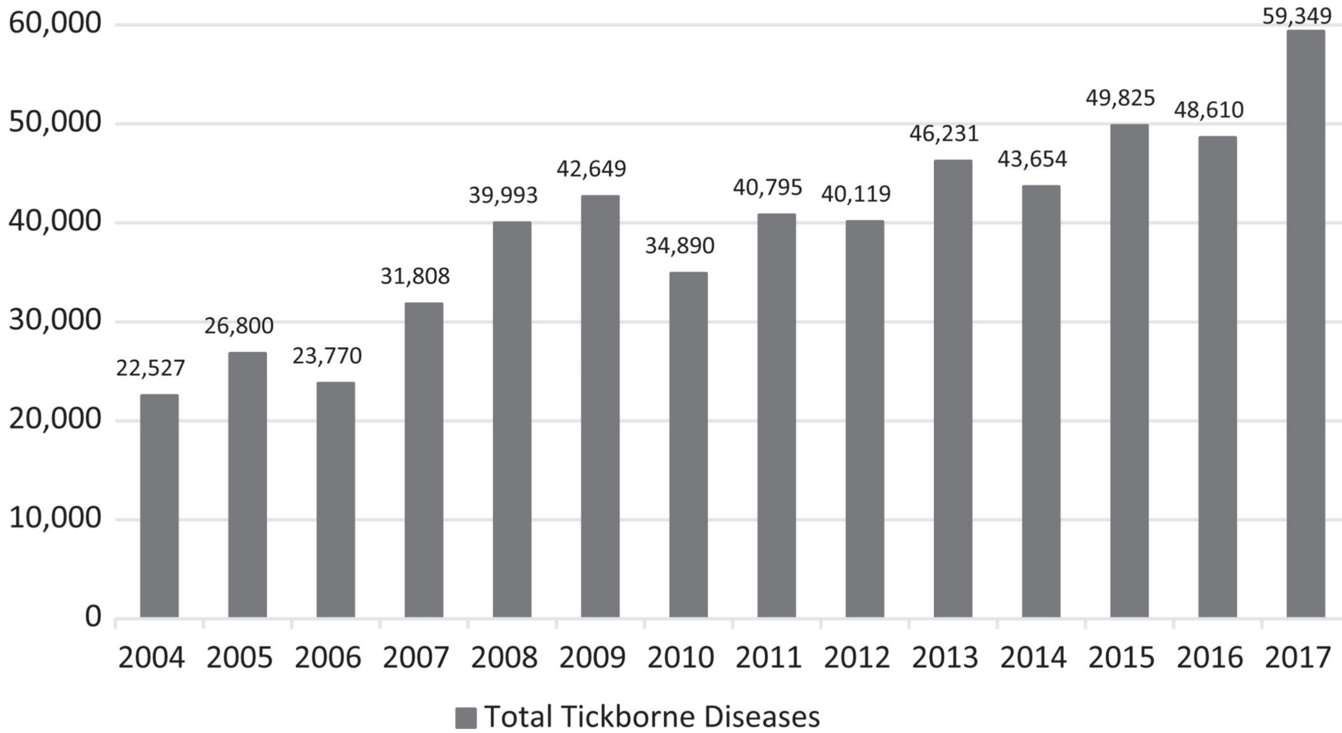

Figure 1.

Total Tick-Borne Disease Cases, United States, 2004–2017. Total number of reported cases of tick-borne diseases each year from 2004 through 2017.

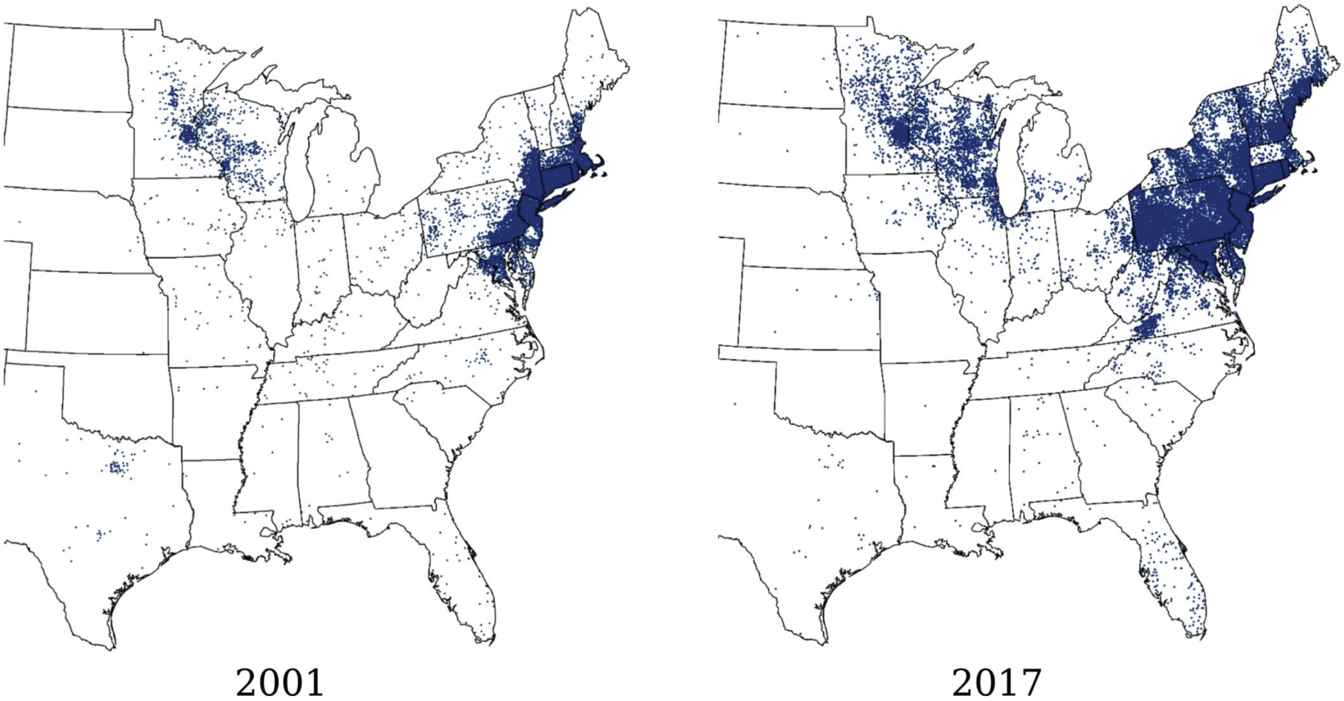

Figure 2.

Reported cases of Lyme disease in the United States. One dot placed randomly within county of residence for each confirmed case. Note: In 2016, Massachusetts transitioned to a surveillance method that relies primarily on laboratory reports. This method does not currently align with the national surveillance case definition as set by the Council of State and Territorial Epidemiologists. Therefore, information on most Lyme disease cases occurring in Massachusetts is not sent to CDC. Contact the MA Department of Public Health for case numbers. While Lyme disease cases are reported in the western United States, they are not shown on this map because there was not significant change to note over the time period shown.

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