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Research article

Sampling, Distribution, Dispersal

County-Scale Distribution of *Ixodes scapularis* and *Ixodes pacificus* (Acari: Ixodidae) in the Continental United States

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Abstract

The blacklegged tick, *Ixodes scapularis* Say, is the primary vector to humans in the eastern United States of the Lyme disease spirochete *Borrelia burgdorferi*, as well as causative agents of anaplasmosis and babesiosis. Its close relative in the far western United States, the western blacklegged tick *Ixodes pacificus* Cooley and Kohls, is the primary vector to humans in that region of the Lyme disease and anaplasmosis agents. Since 1991, when standardized surveillance and reporting began, Lyme disease case counts have increased steadily in number and in geographical distribution in the eastern United States. Similar trends have been observed for anaplasmosis and babesiosis. To better understand the changing landscape of risk of human exposure to disease agents transmitted by *I. scapularis* and *I. pacificus*, and to document changes in their recorded distribution over the past two decades, we updated the distribution of these species from a map published in 1998. The presence of *I. scapularis* has now been documented from 1,420 (45.7%) of the 3,110 continental United States counties, as compared with 111 (3.6%) counties for *I. pacificus*. Combined, these vectors of *B. burgdorferi* and other disease agents now have been identified in a total of 1,531 (49.2%) counties spread across 43 states. This marks a 44.7% increase in the number of counties that have recorded the presence of these ticks since the previous map was presented in 1998, when 1,058 counties in 41 states reported the ticks to be present. Notably, the number of counties in which *I. scapularis* is considered established (six or more individuals or one or more life stages identified in a single year) has more than doubled since the previous national distribution map was published nearly two decades ago. The majority of county status changes occurred in the North-Central and Northeastern states, whereas the distribution in the South remained fairly stable. Two previously distinct foci for *I. scapularis* in the Northeast and North-Central states appear to be merging in the Ohio River Valley to form a single contiguous focus. Here we document a shifting landscape of risk for human exposure to medically important ticks and point to areas of re-emergence where enhanced vector surveillance and control may be warranted.

Key words: *Ixodes scapularis, Ixodes pacificus*, distribution, Lyme disease

The blacklegged tick, *Ixodes scapularis* Say, is the primary vector to humans in the eastern United States of the Lyme disease spirochete *Borrelia burgdorferi*, as well as the relapsing fever spirochete, *Borrelia miyamotoi*; causative agents of anaplasmosis (*Anaplasma phagocytophilum*) and babesiosis (*Babesia microti*); and Powassan encephalitis virus (Piesman and Eisen 2008, Ebel 2010, Krause et al. 2015). Its close relative in the far western United States, the western blacklegged tick *Ixodes pacificus* Cooley and Kohls, is the primary vector to humans in that region of Lyme disease and anaplasmosis agents, as well as relapsing fever spirochetes (*B. miyamotoi*; Lane et al. 1994, Teglas and Foley 2006, Krause et al. 2015). Lyme disease is the most commonly reported vector-borne disease in the United States. It is a geographically focal illness, with the majority of cases reported from the Northeastern and North-Central states and discrete areas of risk in the Pacific Coast states (Mead 2015). Since 1991, when standardized surveillance and reporting began, Lyme disease case counts have increased steadily from roughly 10,000 cases in 1991 to more than 30,000 cases in 2008 and subsequent years (Bacon et al. 2008, Mead 2015); the true burden of disease is estimated to be roughly 10-fold greater (Hinckley et al. 2014, Nelson et al. 2015). In addition to the increase in case counts over time, the geographical foci of high-incidence counties have expanded both in the North-Central and in the Northeastern United States (Kugeler et al. 2015).

Rising case counts and geographical expansion of Lyme disease endemic areas have been attributed to range expansion of *I. scapularis* in the eastern United States (Bacon et al. 2008, Rydzewski et al. 2012, Lee et al. 2013, Brinkerhoff et al. 2014, Robinson et al. 2014,

Wang et al. 2014, Khatchikian et al. 2015, Kugeler et al. 2015, Stone et al. 2015). However, because of a lack of systematic surveillance of *I. scapularis* and *I. pacificus*, national trends in the geographic distribution of these medically important ticks are difficult to document. To better understand the changing landscape of risk of human exposure to *I. scapularis* and *I. pacificus* in the United States, and to document changes in their distribution over the past two decades, we updated the reported distribution of these species from the map previously published by Dennis et al. (1998).

Materials and Methods

County Status Definitions

The definitions used to classify *I. scapularis* or *I. pacificus* as "established" or "reported" in a county follow Dennis et al. (1998). Counties were classified as established if at least six individual ticks or at least two of the three host-seeking life stages had been identified in a single collection period. Here, a single collection period is defined as a single year. Counties were classified as reported if they failed to meet the criteria for established but if at least one tick of any life stage had been identified at any time in that county, or if county records did not specify the number of ticks or life stages collected. Lack of tick records from a county—"no records"—does not imply that ticks are absent from that county, only that records of ticks having been collected in the county are lacking.

The county status (i.e., established, reported, or no records) given by Dennis et al. (1998) was used as the basis for our updated county status. If a county was classified as established by Dennis et al. (1998), it remained established in the updated classification regardless of whether more recent tick records were available. A county classified as reported by Dennis et al. (1998) retained this status in the updated classification, unless more recent collection records changed the county's classification from reported to established. Herein, the term county refers to counties and county equivalents corresponding with five-digit Federal Information Processing Standard (FIPS) coding.

Data Sources

Six independent literature searches were conducted using Scopus and PubMed databases with the following key words "*Ixodes scapularis*," "*Ixodes pacificus*," and "tick" to identify relevant articles and abstracts published from 1996 through 25 August 2015. We also conducted a search to ensure that papers using the junior synonym "*Ixodes dammini*" rather than *Ixodes scapularis* were included. All reports that explicitly presented county-specific tick data were included in our database. In addition, we visited individual state health department Web sites to identify county-level tick surveillance data, and contacted public health officials, acarologists, and Lyme disease investigators throughout the United States to assess county-level tick collection data.

GIS Mapping

Our final database containing state, county, county FIPS code, county status as per Dennis et al. (1998), and the updated county status was joined based on FIPS codes to a continental United States county map using ArcMap 10.3 (ESRI, Redlands, CA).

Results

Counties With Recorded Presence of *I. scapularis* or *I. pacificus*

Our updated county status records show that *I. scapularis* now has been collected from 37 states, from the eastern seaboard to the eastern edge of the Great Plains, and *I. pacificus* from six western states (Tables 1–3; Fig. 1). No single state has records of both tick species, and five states in the Rocky Mountain region lack records for either *I. scapularis* or *I. pacificus*: Colorado, Idaho, Montana, New Mexico, and Wyoming. The presence of *I. scapularis* has now been documented from 1,420 (45.7%) of the 3,110 continental United States counties, as compared with 111 (3.6%) counties for *I. pacificus*. Combined, these primary vectors of *B. burgdorferi* and other tick-borne disease agents now have been identified in a total of 1,531 (49.2%) counties spread across 43 states. This marks a 44.7% increase in the number of counties that have recorded the presence of these ticks since the survey conducted by Dennis et al. (1998), when 1,058 counties in 41 states reported the ticks to be present. Nebraska and North Dakota are the two states where *I. scapularis* was recorded only after the Dennis et al. (1998) survey.

Counties Where *I. scapularis* Is Classified as Established or Reported

Ixodes scapularis now is classified as established in 842 counties (27.1% of counties in the continental United States) distributed across 35 states (Tables 1–3; Fig. 1). This more than doubles the number of counties in which the tick is classified as established since the previous survey by Dennis et al. (1998), when it was considered established in 396 counties (12.7% of counties in the continental United States) spanning 32 states (Tables 1–2; Fig. 1–2). In total, 446 counties were updated from either no records ($n = 262$) or reported ($n = 184$) to established, and 208 counties were updated from no records to reported (Table 2; Fig. 2). Counties with *I. scapularis* classified as established were added for three states: Kentucky, North Dakota, and Ohio.

The data presented here suggest that *I. scapularis* over the past two decades has expanded from its northeastern focus northward into upstate New York, Vermont, New Hampshire, and northern Maine; westward across Pennsylvania, eastern Ohio, and New York; and south- and southwestward into West Virginia, Virginia, and North Carolina (Fig. 2). A similar geographic expansion for *I. scapularis* appears to have occurred from the long-established focus in the North-Central states, with notable spread of counties where the tick is now classified as established in all four cardinal directions (Fig. 2). The two previously distinct foci in the Northeast and North-Central states appear to be merging in the Ohio River Valley to form a single contiguous focus. In striking contrast to the Northeast and North-Central states, in the far South and South-Central states, counties where *I. scapularis* is classified as established have remained relatively stable since the survey by Dennis et al. (1998) (Figs. 1–2).

Ixodes scapularis is now classified as reported in 578 counties (18.6% of counties in the continental United States) distributed across 30 states (Table 1; Fig. 1). Counties classified as reported for *I. scapularis* generally clustered around counties classified as established for this tick. The overall ratio of counties in which *I. scapularis* is classified as established versus reported (established:reported) was 1.41:1 in this study, as compared with 0.71:1 in the previous Dennis et al. (1998) survey.

Table 1. Number (%) of continental United States counties in which *I. scapularis* or *I. pacificus* were classified as reported or established, by December 1996 (from Dennis et al. 1998) and August 2015

Species/State	No. (%) counties with reported status		No. (%) counties with established status	
	By 1996	By 2015	By 1996	By 2015
I. scapularis	556 (17.8)	578 (18.6)	396 (12.7)	842 (27.1)
Alabama	20 (29.9)	21 (31.3)	25 (37.3)	25 (37.3)
Arkansas	37 (49.3)	25 (33.3)	9 (12.0)	27 (36.0)
Connecticut	0 (0)	0 (0)	8 (100)	8 (100)
Delaware	0 (0)	0 (0)	3 (100)	3 (100)
Florida	22 (32.8)	15 (22.4)	35 (52.2)	52 (77.6)
Georgia	31 (19.5)	35 (22.0)	23 (14.5)	35 (22.0)
Illinois	47 (46.1)	29 (28.4)	4 (3.9)	35 (34.3)
Indiana	25 (27.2)	37 (40.2)	8 (8.7)	29 (31.5)
Iowa	17 (17.2)	25 (25.3)	7 (7.1)	14 (14.1)
Kansas	14 (13.3)	14 (13.3)	1 (1.0)	1 (1.0)
Kentucky	2 (1.7)	4 (3.3)	0 (0)	14 (11.7)
Louisiana	12 (18.8)	23 (36.0)	12 (18.8)	12 (18.8)
Maine	3 (18.8)	0 (0)	13 (81.3)	16 (100)
Maryland	2 (8.3)	2 (8.7)	21 (87.5)	21 (91.3)
Massachusetts	3 (21.4)	0 (0)	9 (64.3)	14 (100)
Michigan	22 (26.5)	16 (19.3)	5 (6.0)	24 (28.9)
Minnesota	12 (13.8)	3 (3.5)	9 (10.3)	45 (51.7)
Mississippi	72 (87.8)	71 (86.6)	10 (12.2)	11 (13.4)
Missouri	8 (7.0)	8 (7.0)	21 (18.3)	23 (20.0)
Nebraska	0 (0)	3 (3.2)	0 (0)	0 (0)
New Hampshire	5 (50.0)	1 (10.0)	5 (50.0)	9 (90.0)
New Jersey	0 (0)	0 (0)	21 (100)	21 (100)
New York	20 (32.3)	1 (1.6)	31 (50.0)	61 (98.4)
North Carolina	23 (23.0)	16 (16.0)	7 (7)	43 (43.0)
North Dakota	0 (0)	3 (5.7)	0 (0)	5 (9.4)
Ohio	5 (5.7)	31 (35.6)	0 (0)	33 (37.5)
Oklahoma	36 (46.8)	36 (46.8)	3 (4.0)	3 (4.0)
Pennsylvania	26 (38.8)	0 (0)	23 (34.3)	67 (100)
Rhode Island	0 (0)	0 (0)	5 (100)	5 (100)
South Carolina	14 (30.4)	19 (41.3)	13 (28.3)	14 (30.4)
South Dakota	2 (3.0)	2 (3.0)	2 (3.0)	0 (0)
Tennessee	6 (6.3)	27 (28.4)	1 (1.1)	16 (16.8)
Texas	39 (15.4)	45 (17.7)	24 (9.5)	26 (10.2)
Vermont	6 (43.0)	2 (14.3)	1 (7.1)	11 (78.6)
Virginia	4 (3.0)	29 (21.6)	8 (6.0)	43 (32.1)
West Virginia	2 (3.6)	20 (36.4)	2 (3.6)	23 (41.8)
Wisconsin	16 (22.2)	15 (20.8)	29 (40.3)	51 (70.8)
I. pacificus	16 (0.5)	16 (0.5)	90 (2.9)	95 (3.1)
Arizona	1 (6.7)	1 (6.7)	0 (0)	0 (0)
California	1 (1.72)	1 (1.72)	55 (94.8)	55 (94.8)
Nevada	2 (11.8)	2 (11.8)	0 (0)	0 (0)
Oregon	4 (11.1)	4 (11.1)	18 (50.0)	18 (50.0)
Utah	4 (13.8)	3 (10.3)	4 (13.8)	4 (13.8)
Washington	5 (12.8)	6 (15.3)	12 (30.8)	16 (41.3)

Counties Where *I. pacificus* Is Classified as Established or Reported

Ixodes pacificus is now classified as established in 95 counties, and as reported in 16 additional counties, spanning 6 states (Tables 1, 3; Fig. 1). The majority of these counties are in the Pacific Coast states of California, Oregon, and Washington. Our new data mark a very modest increase in the number of western counties in which *I. pacificus* is classified as established since the survey by Dennis et al. (1998), when the tick was listed as established in 90 counties; the number of counties with reported status remained stable. In total, five counties were updated from either no records ($n = 1$) or reported ($n = 4$) to established and four counties were updated from no records to reported (Table 3; Fig. 2). All county status changes occurred in Washington, Oregon, or Utah (Tables 1, 3; Figs. 1–2). The overall ratio of counties in which *I. pacificus* is classified as established versus reported was 5.94:1 in this study, compared with 5.6:1 (Dennis et al. 1998).

Discussion

Data on the current geographic distributions of medically important tick vectors, such as *I. scapularis* and *I. pacificus*, provide information complementary to epidemiological data on geographic disease case occurrence to inform the medical community and the public of where risk for exposure to tick-borne disease agents may occur. The lack of routine systematic surveillance across the continental United States of ticks of public health importance hampers our ability to define their current geographic distributions and to monitor changes in their ranges and densities over time. Although we are able to report in this paper where *I. scapularis* and *I. pacificus* are now known to be present at the county level, our certainty in where the tick is absent is low, especially at the edges of their ranges and in regions where they can be assumed to occur only at low densities. Range contractions, if they occurred, were not quantified in this study because counties that were previously considered established maintained that status here. Nonetheless, using survey methods similar to those of Dennis et al. (1998), specifically, literature review and inclusion of unpublished data from individual researchers and state public health departments, we showed a substantial increase over the past nearly two decades in counties classified as having *I. scapularis* present. Moreover, the number of counties in which *I. scapularis* is considered established has more than doubled since the previous national distribution map was published (Dennis et al. 1998). The majority of county status changes occurred in the North, while the distribution in the South remained fairly stable. The North-Central focus for *I. scapularis* in Minnesota and Wisconsin appears to have expanded in all cardinal directions, and the Northeastern focus has spread inland from the Atlantic seaboard and expanded in both northerly and southerly directions. As a result, the two previously distinct foci in the North-Central and Northeastern United States have now converged in the Ohio River Valley to form a single larger focus. In striking contrast to *I. scapularis*, increases in counties reporting the presence of *I. pacificus* in the Far West were very modest.

Population genetic analyses provide support for the theory that *I. scapularis* was once established across the Northeastern and North-Central United States for thousands of years and likely colonized the region following the recession of the Pleistocene ice sheet (Humphrey et al. 2010). Thus, current trends may represent recolonization of the tick's historical range. Rapid deforestation and suppression of white-tailed deer during the late 1800s and early 1990s may have restricted *I. scapularis* to focal refugia (Spielman et al. 1985, Lee et al. 2013). Reforestation and increasing abundance of white-tailed deer, the primary hosts of adult *I. scapularis* (Spielman et al. 1985), are considered to have contributed to the dramatic expansion of the tick's range over the past half century (Spielman 1994).

Our updated species distribution map shows a continued range expansion for *I. scapularis*, particularly in northern states. Given the lack of systematic surveillance for *I. scapularis*, one might ask if the range expansion suggested by our data is real or merely an artifact

Table 2. Status for *I. scapularis* by continental United States county. Fields left blank indicate that status was inherited from Dennis et al. (1998)

State and county	Status by August 2015[a]	Status change from Dennis et al. (1998)[b]	Source for change of status from Dennis et al. (1998) survey
Alabama			
Autauga	Established		
Baldwin	Reported		
Barbour	Established		
Bibb	Established		
Bullock	Established		
Butler	Established		
Chambers	Established		
Chilton	Reported		
Choctaw	Established		
Clarke	Established		
Clay	Reported		
Cleburne	Reported		
Coffee	Reported	N-R	http://vectormap.nhm.ku.edu/vectormap/
Colbert	Established		
Conecuh	Established		
Coosa	Established		
Covington	Established		
Crenshaw	Reported		
Dale	Reported		
Elmore	Established		
Escambia	Established		
Franklin	Established		
Geneva	Reported		
Hale	Established		
Henry	Established		
Houston	Reported		
Jackson	Established		
Jefferson	Reported		
Lawrence	Reported		
Lee	Established		
Lowndes	Reported		
Madison	Reported		
Marengo	Reported		
Mobile	Established		
Monroe	Established		
Montgomery	Reported		
Pickens	Established		
Randolph	Reported		
Russell	Established		
Sumter	Reported		
Talladega	Reported		
Tallapoosa	Established		
Tuscaloosa	Reported		
Washington	Reported		
Wilcox	Reported		
Winston	Established		
Arkansas			
Ashley	Established		
Baxter	Established		
Benton	Established	R-E	(Trout and Steelman 2010)
Boone	Established	R-E	(Trout and Steelman 2010)
Calhoun	Reported		
Carroll	Reported		
Clark	Established	N-E	(Trout and Steelman 2010)
Cleburne	Established	N-E	(Trout and Steelman 2010)
Columbia	Reported		
Conway	Reported		
Crawford	Established	R-E	(Trout and Steelman 2010)
Dallas	Reported		
Drew	Reported		
Faulkner	Established	N-E	(Trout and Steelman 2010)

(continued)

Table 2. Continued

State and county	Status by August 2015[a]	Status change from Dennis et al. (1998)[b]	Source for change of status from Dennis et al. (1998) survey
Franklin	Established		
Fulton	Established	R-E	(Trout and Steelman 2010)
Garland	Established	R-E	(Trout and Steelman 2010)
Grant	Established	R-E	(Trout and Steelman 2010)
Hempstead	Established	N-E	(Trout and Steelman 2010)
Howard	Reported		
Izard	Reported		
Jefferson	Reported		
Johnson	Reported		
Lafayette	Reported		
Lawrence	Established	R-E	(Trout and Steelman 2010)
Lincoln	Reported		
Logan	Reported		
Madison	Established		
Marion	Established	R-E	(McAllister et al. 2013)
Montgomery	Reported		
Nevada	Reported		
Newton	Reported		
Ouachita	Reported		
Perry	Reported		
Pike	Reported		
Poinsett	Established	N-E	(Trout and Steelman 2010)
Polk	Established		
Pope	Established	R-E	(Trout and Steelman 2010)
Prairie	Established	R-E	(Trout and Steelman 2010)
Pulaski	Reported		
Randolph	Reported		
Saline	Established	N-E	(Trout and Steelman 2010)
Scott	Reported		
Searcy	Established		
Sebastian	Established		
Sevier	Established	R-E	(Trout and Steelman 2010)
Sharp	Reported		
Stone	Established		
Union	Established	R-E	(Trout and Steelman 2010, McAllister et al. 2013)
Van Buren	Reported		
Washington	Established		
Yell	Reported		
Connecticut			
Fairfield	Established		
Hartford	Established		
Litchfield	Established		
Middlesex	Established		
New Haven	Established		
New London	Established		
Tolland	Established		
Windham	Established		
Delaware			
Kent	Established		
New Castle	Established		
Sussex	Established		
District of Columbia	Established	N-E	T. L. Johnson, unpublished
Florida			
Alachua	Established		
Baker	Established		
Bay	Established		
Bradford	Reported		
Brevard	Established	N-E	J. Corn/SCWDS, unpublished; J. Mertins/NVSL, unpublished
Brevard	Reported		
Broward	Reported		
Calhoun	Established		
Charlotte	Reported		
Citrus	Reported		

(continued)

Table 2. Continued

State and county	Status by August 2015[a]	Status change from Dennis et al. (1998)[b]	Source for change of status from Dennis et al. (1998) survey
Clay	Established		
Collier	Established		
Columbia	Established		
DeSoto	Established	N-E	J. Corn/SCWDS, unpublished; J. Mertins/NVSL, unpublished
Dixie	Established		
Duval	Reported		
Escambia	Established		
Flagler	Established		
Franklin	Established		
Gadsden	Established		
Gilchrist	Reported	N-R	K. Sayler, unpublished
Glades	Established		
Gulf	Established		
Hamilton	Established	R-E	J. Corn/SCWDS, unpublished; J. Mertins/NVSL, unpublished
Hardee	Reported		
Hendry	Established	R-E	J. Corn/SCWDS, unpublished; J. Mertins/NVSL, unpublished
Hernando	Established		
Highlands	Established	R-E	J. Corn/SCWDS, unpublished; J. Mertins/NVSL, unpublished
Hillsborough	Established	R-E	J. Corn/SCWDS, unpublished; J. Mertins/NVSL, unpublished
Holmes	Reported	N-R	J. Corn/SCWDS, unpublished; J. Mertins/NVSL, unpublished
Indian River	Established	N-E	C. Lord, unpublished
Jackson	Established		
Jefferson	Established		
Lafayette	Established		
Lake	Established	R-E	J. Corn/SCWDS, unpublished; J. Mertins/NVSL, unpublished
Lee	Established	R-E	J. Corn/SCWDS, unpublished; J. Mertins/NVSL, unpublished
Leon	Established		
Levy	Established	R-E	K. Sayler, unpublished
Liberty	Established		
Madison	Established	N-E	K. Sayler, unpublished
Manatee	Reported		
Marion	Established		
Martin	Established		
Miami-Dade	Established		
Monroe	Established	R-E	J. Corn/SCWDS, unpublished; J. Mertins/NVSL, unpublished
Nassau	Established		
Okaloosa	Established		
Okeechobee	Established	N-E	Wisely, Cleveland, Satterlee, and Lord, unpublished
Orange	Established		
Osceola	Established		
Palm Beach	Established		
Pasco	Reported		
Pinellas	Established	N-E	J. Corn/SCWDS, unpublished; J. Mertins/NVSL, unpublished
Polk	Established		
Putnam	Established	R-E	J. Corn/SCWDS, unpublished; J. Mertins/NVSL, unpublished
Santa Rosa	Established		
Sarasota	Established	R-E	J. Corn/SCWDS, unpublished; J. Mertins/NVSL, unpublished
Seminole	Established	R-E	J. Corn/SCWDS, unpublished; J. Mertins/NVSL, unpublished
St. Johns	Reported		
St. Lucie	Reported	N-R	L. Durden, unpublished

(continued)

Table 2. Continued

State and county	Status by August 2015[a]	Status change from Dennis et al. (1998)[b]	Source for change of status from Dennis et al. (1998) survey
Sumter	Established		
Suwannee	Reported	N-R	L. Durden, unpublished
Taylor	Established		
Union	Reported		
Volusia	Established		
Wakulla	Established		
Walton	Established		
Washington	Reported	N-R	J. Corn/SCWDS, unpublished; J. Mertins/NVSL, unpublished
Georgia			
Appling	Reported	N-R	L. Durden, unpublished
Atkinson	Reported		
Bacon	Reported	N-R	L. Durden, unpublished
Baker	Reported		
Baldwin	Reported		
Bibb	Reported		
Bleckley	Established		
Brantley	Established		
Brooks	Reported		
Bryan	Reported		
Bulloch	Established		
Burke	Established	R-E	L. Durden, unpublished
Calhoun	Reported		
Camden	Reported		
Candler	Established	N-E	L. Durden, unpublished
Charlton	Established		
Chatham	Established		
Chattahoochee	Reported		
Clarke	Reported	N-R	L. Durden, unpublished
Clinch	Established		
Coffee	Reported		
Columbia	Reported		
Cook	Reported		
Crisp	Reported		
Decatur	Reported		
Dougherty	Established		
Echols	Reported		
Effingham	Established		
Emanuel	Established	N-E	L. Durden, unpublished
Evans	Established	R-E	L. Durden, unpublished
Forsyth	Reported	N-R	L. Durden, unpublished
Glynn	Established		
Grady	Established		
Hancock	Reported		
Houston	Established		
Irwin	Established		
Jasper	Established		
Jeff Davis	Reported		
Jefferson	Established	N-E	L. Durden, unpublished
Jenkins	Established	N-E	L. Durden, unpublished
Johnson	Established	N-E	L. Durden, unpublished
Jones	Reported		
Laurens	Established	N-E	L. Durden, unpublished
Liberty	Established		
Long	Reported		
Lowndes	Established		
McDuffie	Established		
McIntosh	Established		
Monroe	Established		
Montgomery	Established	N-E	L. Durden, unpublished
Morgan	Reported		
Muscogee	Reported		

(continued)

Table 2. Continued

State and county	Status by August 2015[a]	Status change from Dennis et al. (1998)[b]	Source for change of status from Dennis et al. (1998) survey
Pierce	Reported		
Pulaski	Reported		
Putnam	Established		
Talbot	Established		
Taliaferro	Reported		
Tattnall	Reported	N-R	L. Durden, unpublished
Telfair	Established		
Terrell	Reported		
Thomas	Established		
Tift	Reported	N-R	L. Durden, unpublished
Toombs	Established	N-E	L. Durden, unpublished
Treutlen	Established	N-E	L. Durden, unpublished
Twiggs	Reported		
Ware	Established		
Washington	Established	N-E	L. Durden, unpublished
Wayne	Reported		
Wilkes	Reported		
Wilkinson	Reported		
Illinois			
Boone	Reported		
Brown	Reported		
Bureau	Established	R-E	(Cortinas and Kitron 2006)
Carroll	Established		
Cass	Reported	N-R	(Cortinas and Kitron 2006)
Champaign	Established	R-E	http://www.idph.state.il.us/envhealth/pdf/Deer_Tick_Range.pdf
Clark	Established	R-E	http://www.idph.state.il.us/envhealth/pdf/Deer_Tick_Range.pdf
Coles	Established	R-E	http://www.idph.state.il.us/envhealth/pdf/Deer_Tick_Range.pdf
Cook	Established	R-E	(Rydzewski et al. 2012); http://www.idph.state.il.us/envhealth/pdf/Deer_Tick_Range.pdf
Crawford	Reported		
Cumberland	Reported		
De Witt	Established	N-E	http://www.idph.state.il.us/envhealth/pdf/Deer_Tick_Range.pdf
DuPage	Established	R-E	(Rydzewski et al. 2012); http://www.idph.state.il.us/envhealth/pdf/Deer_Tick_Range.pdf
Edgar	Reported		
Fayette	Reported		
Franklin	Reported		
Fulton	Established	N-E	(Cortinas et al. 2002)); (Cortinas and Kitron 2006); http://www.idph.state.il.us/envhealth/pdf/Deer_Tick_Range.pdf
Gallatin	Reported		
Grundy	Established	R-E	(Cortinas and Kitron 2006); http://www.idph.state.il.us/envhealth/pdf/Deer_Tick_Range.pdf
Henry	Established	R-E	http://www.idph.state.il.us/envhealth/pdf/Deer_Tick_Range.pdf
Iroquois	Reported		
Jackson	Reported		
Jo Daviess	Established	R-E	http://www.idph.state.il.us/envhealth/pdf/Deer_Tick_Range.pdf
Kankakee	Established	R-E	(Cortinas and Kitron 2006); http://www.idph.state.il.us/envhealth/pdf/Deer_Tick_Range.pdf
Knox	Reported		
Lake	Established	N-E	(Rydzewski et al. 2012); http://www.idph.state.il.us/envhealth/pdf/Deer_Tick_Range.pdf
LaSalle	Established	R-E	(Cortinas and Kitron 2006); http://www.idph.state.il.us/envhealth/pdf/Deer_Tick_Range.pdf
Lawrence	Reported		
Lee	Established	R-E	http://www.idph.state.il.us/envhealth/pdf/Deer_Tick_Range.pdf

(continued)

Table 2. Continued

State and county	Status by August 2015[a]	Status change from Dennis et al. (1998)[b]	Source for change of status from Dennis et al. (1998) survey
Macoupin	Established	N-E	http://www.idph.state.il.us/envhealth/pdf/Deer_Tick_Range.pdf
Madison	Reported		
Marshall	Established	R-E	(Cortinas and Kitron 2006); http://www.idph.state.il.us/envhealth/pdf/Deer_Tick_Range.pdf
Mason	Established	N-E	http://www.idph.state.il.us/envhealth/pdf/Deer_Tick_Range.pdf
McDonough	Established	N-E	http://www.idph.state.il.us/envhealth/pdf/Deer_Tick_Range.pdf
McHenry	Reported		
McLean	Established	R-E	http://www.idph.state.il.us/envhealth/pdf/Deer_Tick_Range.pdf
Menard	Reported		
Mercer	Reported		
Monroe	Established		
Montgomery	Reported	N-R	http://www.idph.state.il.us/envhealth/pdf/Deer_Tick_Range.pdf
Morgan	Reported	N-R	(Cortinas and Kitron 2006)
Ogle	Established		
Peoria	Established	R-E	(Cortinas and Kitron 2006); http://www.idph.state.il.us/envhealth/pdf/Deer_Tick_Range.pdf
Perry	Reported		
Piatt	Established	R-E	(Rydzewski et al. 2011); http://www.idph.state.il.us/envhealth/pdf/Deer_Tick_Range.pdf
Pope	Reported		
Putnam	Established	R-E	(Cortinas and Kitron 2006); http://www.idph.state.il.us/envhealth/pdf/Deer_Tick_Range.pdf
Randolph	Reported		
Rock Island	Established		
Saline	Reported		
Sangamon	Reported		
Schuyler	Established	R-E	(Cortinas and Kitron 2006)
Scott	Reported		
Shelby	Established	N-E	http://www.idph.state.il.us/envhealth/pdf/Deer_Tick_Range.pdf
St. Clair	Reported		
Stephenson	Reported		
Tazewell	Established	R-E	(Cortinas et al. 2002, Cortinas and Kitron 2006); http://www.idph.state.il.us/envhealth/pdf/Deer_Tick_Range.pdf
Union	Reported		
Vermilion	Established	N-E	http://www.idph.state.il.us/envhealth/pdf/Deer_Tick_Range.pdf
Wabash	Established	N-E	http://www.idph.state.il.us/envhealth/pdf/Deer_Tick_Range.pdf
Will	Established	R-E	(Cortinas and Kitron 2006); http://www.idph.state.il.us/envhealth/pdf/Deer_Tick_Range.pdf
Williamson	Reported		
Winnebago	Established	R-E	http://www.idph.state.il.us/envhealth/pdf/Deer_Tick_Range.pdf
Woodford	Established	N-E	(Cortinas and Kitron 2006); http://www.idph.state.il.us/envhealth/pdf/Deer_Tick_Range.pdf
Indiana			
Adams	Reported	N-R	R. Pinger, unpublished
Bartholomew	Established	R-E	R. Pinger, unpublished
Benton	Reported	N-R	R. Pinger, unpublished
Boone	Reported	N-R	R. Pinger, unpublished
Brown	Reported		
Carroll	Reported	N-R	R. Pinger, unpublished
Cass	Established	R-E	(Raizman et al. 2012); E. Raizman, unpublished
Clark	Reported	N-R	R. Pinger, unpublished
Clay	Established	R-E	(Raizman et al. 2012); E. Raizman, unpublished
Daviess	Reported	N-R	R. Pinger, unpublished

(continued)

Table 2. Continued

State and county	Status by August 2015[a]	Status change from Dennis et al. (1998)[b]	Source for change of status from Dennis et al. (1998) survey
Dearborn	Reported	N-R	R. Pinger, unpublished
Dubois	Established	R-E	(Raizman et al. 2012); E. Raizman, unpublished
Elkhart	Reported	N-R	R. Pinger, unpublished
Fountain	Reported		
Franklin	Established	R-E	(Raizman et al. 2012); E. Raizman, unpublished
Fulton	Established	R-E	(Raizman et al. 2012); E. Raizman, unpublished
Grant	Reported		
Greene	Reported	N-R	R. Pinger, unpublished
Hamilton	Reported	N-R	(Raizman et al. 2012); E. Raizman, unpublished
Hendricks	Reported	N-R	R. Pinger, unpublished
Howard	Reported	N-R	R. Pinger, unpublished
Huntington	Reported		
Jasper	Established		
Jefferson	Established	N-E	(Raizman et al. 2012); E. Raizman, unpublished
Jennings	Established	N-E	(Raizman et al. 2012); E. Raizman, unpublished
Johnson	Reported	N-R	R. Pinger, unpublished
Knox	Reported	N-R	R. Pinger, unpublished
Kosciusko	Established	N-E	(Raizman et al. 2012); E. Raizman, unpublished
LaGrange	Reported		
Lake	Established	R-E	(Raizman et al. 2012); E. Raizman, unpublished
LaPorte	Established		
Lawrence	Reported	N-R	
Madison	Reported		
Marshall	Reported		
Martin	Established	N-E	(Raizman et al. 2012); E. Raizman, unpublished
Monroe	Established	N-E	(Raizman et al. 2012); E. Raizman, unpublished
Montgomery	Established	N-E	(Raizman et al. 2012); E. Raizman, unpublished d
Morgan	Established	R-E	(Raizman et al. 2012); E. Raizman, unpublished
Newton	Established		
Orange	Reported		
Owen	Established	N-E	(Raizman et al. 2012); E. Raizman, unpublished
Parke	Established	R-E	(Raizman et al. 2012); E. Raizman, unpublished
Pike	Reported		
Porter	Established		
Posey	Reported		
Pulaski	Established		
Putnam	Established	N-E	(Raizman et al. 2012); E. Raizman, unpublished
Randolph	Reported	N-R	R. Pinger, unpublished
Ripley	Reported	N-R	R. Pinger, unpublished
Shelby	Reported	N-R	(Raizman et al. 2012); E. Raizman, unpublished
St. Joseph	Established	R-E	(Raizman et al. 2012); E. Raizman, unpublished
Starke	Established		
Steuben	Reported	N-R	R. Pinger, unpublished
Sullivan	Established	N-E	(Raizman et al. 2012); E. Raizman, unpublished
Switzerland	Reported	N-R	R. Pinger, unpublished
Tippecanoe	Established	R-E	(Raizman et al. 2012); E. Raizman, unpublished
Union	Reported	N-R	(Raizman et al. 2012); E. Raizman, unpublished
Vanderburgh	Reported	N-R	R. Pinger, unpublished
Vermillion	Reported		
Vigo	Established		
Wabash	Reported		
Warren	Established	N-E	(Raizman et al. 2012); E. Raizman, unpublished
Warrick	Reported		
Washington	Reported		
White	Established		
Whitley	Reported	N-R	(Raizman et al. 2012); E. Raizman, unpublished
Iowa			
Benton	Reported	N-R	(Lingren et al. 2005)
Bremer	Established		
Buena Vista	Reported		
Calhoun	Reported	N-R	(Lingren et al. 2005)
Cedar	Reported	N-R	(Lingren et al. 2005)
Cerro Gordo	Established		

(continued)

Table 2. Continued

State and county	Status by August 2015[a]	Status change from Dennis et al. (1998)[b]	Source for change of status from Dennis et al. (1998) survey
Clayton	Reported		
Clinton	Reported	N-R	(Lingren et al. 2005)
Crawford	Reported	N-R	(Lingren et al. 2005)
Dallas	Reported		
Delaware	Reported		
Des Moines	Established		
Dubuque	Reported		
Fayette	Reported		
Floyd	Reported		
Greene	Reported	N-R	(Lingren et al. 2005)
Guthrie	Reported	N-R	(Lingren et al. 2005)
Hancock	Reported	N-R	(Lingren et al. 2005)
Iowa	Reported		
Jackson	Established		
Jasper	Reported	N-R	(Lingren et al. 2005)
Johnson	Established	R-E	(Lingren et al. 2005)
Keokuk	Established	N-E	(Lingren et al. 2005)
Kossuth	Reported	N-R	(Lingren et al. 2005)
Linn	Established		
Louisa	Reported		
Marshall	Reported		
Muscatine	Established		
Palo Alto	Reported	N-R	(Lingren et al. 2005)
Polk	Established	R-E	(Lingren et al. 2005)
Scott	Established	R-E	(Lingren et al. 2005)
Story	Established	R-E	(Lingren et al. 2005)
Tama	Reported	N-R	(Lingren et al. 2005)
Washington	Reported	N-R	(Lingren et al. 2005)
Webster	Established	R-E	(Lingren et al. 2005)
Winnebago	Reported		
Winneshiek	Established	R-E	(Lingren et al. 2005)
Woodbury	Reported	N-R	(Lingren et al. 2005)
Kansas			
Bourbon	Reported		
Chautauqua	Reported		
Cherokee	Reported		
Coffey	Reported		
Cowley	Reported		
Crawford	Reported		
Douglas	Established		
Jefferson	Reported		
Johnson	Reported		
Labette	Reported		
Linn	Reported		
Miami	Reported		
Montgomery	Reported		
Riley	Reported		
Shawnee	Reported		
Kentucky			
Ballard	Reported		
Boone	Established	N-E	L. Townsend, unpublished
Carroll	Established	N-E	L. Townsend, unpublished
Christian	Reported		
Clay	Established	N-E	L. Townsend, unpublished
Estill	Established	N-E	L. Townsend, unpublished
Fayette	Established	N-E	L. Townsend, unpublished
Hancock	Reported	N-R	L. Townsend, unpublished
Hardin	Established	N-E	L. Townsend, unpublished
Jackson	Established	N-E	L. Townsend, unpublished
Knox	Established	N-E	L. Townsend, unpublished
Lee	Established	N-E	L. Townsend, unpublished
McCreary	Established	N-E	L. Townsend, unpublished

(continued)

Table 2. Continued

State and county	Status by August 2015[a]	Status change from Dennis et al. (1998)[b]	Source for change of status from Dennis et al. (1998) survey
Meade	Established	N-E	B. Pagac and M. Miller, unpublished
Owsley	Established	N-E	L. Townsend, unpublished
Pulaski	Established	N-E	L. Townsend, unpublished
Trimble	Established	N-E	L. Townsend, unpublished
Warren	Reported	N-R	(Onwu 2012)
Louisiana			
Allen	Established		
Avoyelles	Established		
Bienville	Established		
Bossier	Reported		
Caldwell	Established		
Catahoula	Reported	N-R	(Mackay and Foil 2005)
Claiborne	Reported		
Concordia	Established		
De Soto	Reported	N-R	(Mackay and Foil 2005)
East Baton Rouge	Reported		
East Carroll	Reported	N-R	(Mackay and Foil 2005)
Grant	Established		
Jackson	Established		
Jefferson Davis	Reported	N-R	(Mackay and Foil 2005)
Lafayette	Reported	N-R	(Mackay and Foil 2005)
Lincoln	Established		
Madison	Reported		
Morehouse	Established		
Natchitoches	Established		
Ouachita	Reported		
Pointe Coupee	Reported	N-R	(Mackay and Foil 2005)
Rapides	Reported		
Sabine	Reported		
St. John the Baptist	Reported	N-R	(Mackay and Foil 2005)
St. Landry	Reported		
St. Martin	Reported	N-R	(Mackay and Foil 2005)
St. Mary	Reported	N-R	(Mackay and Foil 2005)
St. Tammany	Reported		
Tangipahoa	Reported		
Tensas	Reported		
Union	Established		
Vermilion	Reported	N-R	(Mackay and Foil 2005)
Vernon	Established		
Washington	Reported	N-R	(Mackay and Foil 2005)
Winn	Reported		
Maine			
Androscoggin	Established		
Aroostook	Established	R-E	http://www.maine.gov/dhhs/mecdc/infectious-disease/epi/vector-borne/lyme/documents/2014-lyme-legislature.pdf
Cumberland	Established		
Franklin	Established	R-E	http://www.maine.gov/dhhs/mecdc/infectious-disease/epi/vector-borne/lyme/documents/2014-lyme-legislature.pdf
Hancock	Established		
Kennebec	Established		
Knox	Established		
Lincoln	Established		
Oxford	Established		
Penobscot	Established		
Piscataquis	Established	R-E	http://www.maine.gov/dhhs/mecdc/infectious-disease/epi/vector-borne/lyme/documents/2014-lyme-legislature.pdf
Sagadahoc	Established		
Somerset	Established		
Waldo	Established		

(continued)

Table 2. Continued

State and county	Status by August 2015[a]	Status change from Dennis et al. (1998)[b]	Source for change of status from Dennis et al. (1998) survey
Washington	Established		
York	Established		
Maryland			
Allegany	Reported		
Anne Arundel	Established		
Baltimore City			
Baltimore	Established		
Calvert	Established		
Caroline	Established		
Carroll	Established		
Cecil	Established		
Charles	Established		
Dorchester	Established		
Frederick	Established		
Garrett	Reported		
Harford	Established		
Howard	Established		
Kent	Established		
Montgomery	Established		
Prince George's	Established		
Queen Anne's	Established		
Somerset	Established		
St. Mary's	Established		
Talbot	Established		
Washington	Established		
Wicomico	Established		
Worcester	Established		
Massachusetts			
Barnstable	Established		
Berkshire	Established	R-E	http://stats.tickdiseases.org/
Bristol	Established		
Dukes	Established		
Essex	Established		
Franklin	Established		
Hampden	Established		
Hampshire	Established		
Middlesex	Established	R-E	http://stats.tickdiseases.org/
Nantucket	Established		
Norfolk	Established	N-E	http://stats.tickdiseases.org/
Plymouth	Established		
Suffolk	Established	N-E	http://stats.tickdiseases.org/
Worcester	Established	R-E	http://stats.tickdiseases.org/
Michigan			
Alger	Reported	N-R	(Schaar 2012)
Allegan	Established	R-E	(Foster 2004, Hamer et al. 2010)
Baraga	Reported		
Barry	Established	N-E	J. Tsao, S. Hamer, I. Arsnoe, and G. Hickling, unpublished
Benzie	Established	N-E	(Hamer et al. 2010); J. Sidge unpublished
Berrien	Established		
Cass	Established	N-E	(Hamer et al. 2009); E. Foster, unpublished
Charlevoix	Established	N-E	E. Foster and J. Sidge, unpublished
Chippewa	Established		
Clinton	Reported		
Delta	Established		
Dickinson	Established	R-E	I. Arsnoe, unpublished
Emmet	Reported	N-R	J. Sidge, unpublished
Genesee	Reported		
Gogebic	Established		
Hillsdale	Reported	N-R	E. Foster, and J. Tsao, unpublished
Houghton	Reported		
Ingham	Established	R-E	E. Foster, and J. Tsao, unpublished

(continued)

Table 2. Continued

State and county	Status by August 2015[a]	Status change from Dennis et al. (1998)[b]	Source for change of status from Dennis et al. (1998) survey
Ionia	Established	N-E	(Hamer et al. 2010)
Iron	Reported	N-R	(Walker et al. 1998)
Jackson	Reported		
Kalamazoo	Established	N-E	J. Tsao and G. Hickling, unpublished
Kent	Reported		
Lapeer	Reported		
Leelanau	Established	R-E	E. Foster, J. Tsao and J. Sidge, unpublished
Livingston	Reported		
Mackinac	Reported		
Manistee	Established	R-E	(Hamer et al. 2010)
Marquette	Reported		
Mason	Established	N-E	J. Tsao and J. Sidge, unpublished
Menominee	Established		
Midland	Reported		
Muskegon	Established	R-E	(Hamer et al. 2009, Hamer et al. 2010)
Oakland	Reported		
Oceana	Established	R-E	J. Tsao, and J. Sidge, unpublished
Ontonagon	Established	R-E	E. Foster, unpublished
Ottawa	Established	R-E	(Hamer et al. 2009); E. Foster, unpublished
Schoolcraft	Established	R-E	I. Arsnoe, unpublished
St. Joseph	Established	N-E	J. Tsao and E. Foster, unpublished
Van Buren	Established	N-E	(Foster 2004, Hamer et al. 2009, Hamer et al. 2014)
Minnesota			
Aitkin	Established	R-E	D. Neitzel, unpublished
Anoka	Established		
Becker	Established	N-E	(Sanders and Guilfoile 2000), D. Neitzel, unpublished
Beltrami	Established	R-E	(Sanders and Guilfoile 2000), D. Neitzel, unpublished
Benton	Established	N-E	T. Johnson and D. Neitzel, unpublished
Brown	Reported	N-R	D. Neitzel, unpublished
Carlton	Established	R-E	(Sanders and Guilfoile 2000), D. Neitzel, unpublished
Carver	Established		
Cass	Established	N-E	(Sanders and Guilfoile 2000)
Chisago	Established		
Clearwater	Established	N-E	(Sanders and Guilfoile 2000), D. Neitzel, unpublished
Cook	Established	N-E	D. Neitzel, unpublished
Crow Wing	Established	R-E	
Dakota	Established		
Douglas	Established	R-E	D. Neitzel, unpublished
Fillmore	Established	N-E	D. Neitzel, unpublished
Goodhue	Established	N-E	D. Neitzel, unpublished
Hennepin	Established	N-E	D. Neitzel, unpublished
Houston	Established	R-E	D. Neitzel, unpublished
Hubbard	Established	N-E	(Sanders and Guilfoile 2000), D. Neitzel, unpublished
Isanti	Established	R-E	D. Neitzel, unpublished
Itasca	Established	N-E	(Sanders and Guilfoile 2000)
Kanabec	Established	R-E	D. Neitzel, unpublished
Kandiyohi	Established	N-E	(Diuk-Wasser et al. 2006); D. Neitzel, unpublished
Koochiching	Established	N-E	(Sanders and Guilfoile 2000)
Lake	Established	N-E	D. Neitzel, unpublished
Lake of the Woods	Established	N-E	(Sanders and Guilfoile 2000), D. Neitzel, unpublished
Mahnomen	Established	N-E	D. Neitzel, unpublished
Mille Lacs	Established	R-E	(Sanders and Guilfoile 2000)
Morrison	Established		
Nicollet	Reported	N-R	T. Johnson and D. Neitzel, unpublished
Olmsted	Established	R-E	D. Neitzel, unpublished

(continued)

Table 2. Continued

State and county	Status by August 2015[a]	Status change from Dennis et al. (1998)[b]	Source for change of status from Dennis et al. (1998) survey
Otter Tail	Established	N-E	D. Neitzel, unpublished
Pine	Established		
Pope	Established	N-E	D. Neitzel, unpublished
Ramsey	Established		
Rice	Reported	N-R	T. Johnson and D. Neitzel, unpublished
Scott	Established		
Sherburne	Established	N-E	(Diuk-Wasser et al. 2006), D. Neitzel, unpublished
Sibley	Established	N-E	T. Johnson and D. Neitzel, unpublished
St. Louis	Established	N-E	(Sanders and Guilfoile 2000), D. Neitzel, unpublished
Stearns	Established	N-E	D. Neitzel, unpublished
Todd	Established	R-E	D. Neitzel, unpublished
Wabasha	Established	N-E	D. Neitzel, unpublished
Wadena	Established	N-E	(Sanders and Guilfoile 2000), D. Neitzel, unpublished
Washington	Established		
Winona	Established	R-E	D. Neitzel, unpublished
Wright	Established	N-E	D. Neitzel, unpublished
Mississippi			
Adams	Reported		
Alcorn	Reported		
Amite	Reported		
Attala	Reported		
Benton	Reported		
Bolivar	Established		
Calhoun	Reported		
Carroll	Reported		
Chickasaw	Reported		
Choctaw	Reported		
Claiborne	Reported		
Clarke	Reported		
Clay	Reported		
Coahoma	Reported		
Copiah	Established		
Covington	Reported		
DeSoto	Reported		
Forrest	Reported		
Franklin	Reported		
George	Reported		
Greene	Reported		
Grenada	Reported		
Hancock	Reported		
Harrison	Reported		
Hinds	Established		
Holmes	Reported		
Humphreys	Reported		
Issaquena	Reported		
Itawamba	Reported		
Jackson	Established		
Jasper	Reported		
Jefferson	Reported		
Jefferson Davis	Reported		
Jones	Reported		
Kemper	Reported		
Lafayette	Reported		
Lamar	Reported		
Lauderdale	Reported		
Lawrence	Reported		
Leake	Reported		
Lee	Reported		
Leflore	Reported		
Lincoln	Reported		

(continued)

Table 2. Continued

State and county	Status by August 2015[a]	Status change from Dennis et al. (1998)[b]	Source for change of status from Dennis et al. (1998) survey
Lowndes	Reported		
Madison	Reported		
Marion	Reported		
Marshall	Established	R-E	(Goltz and Goddard 2013, Goltz et al. 2013)
Monroe	Reported		
Montgomery	Reported		
Neshoba	Reported		
Newton	Reported		
Noxubee	Established		
Oktibbeha	Established		
Panola	Reported		
Pearl River	Reported		
Perry	Established		
Pike	Reported		
Pontotoc	Reported		
Prentiss	Reported		
Quitman	Reported		
Rankin	Established		
Scott	Established		
Sharkey	Reported		
Simpson	Reported		
Smith	Reported		
Stone	Reported		
Sunflower	Reported		
Tallahatchie	Reported		
Tate	Reported		
Tippah	Reported		
Tishomingo	Reported		
Tunica	Reported		
Union	Reported		
Walthall	Reported		
Warren	Reported		
Washington	Reported		
Wayne	Reported		
Webster	Reported		
Wilkinson	Reported		
Winston	Established		
Yalobusha	Reported		
Yazoo	Reported		
Missouri			
Adair	Established	N-E	S. Fore and H.-J. Kim, unpublished
Benton	Established		
Bollinger	Established		
Boone	Reported		
Callaway	Established		
Cape Girardeau	Established	R-E	(Kollars et al. 1997, Kollars et al. 1999)
Clark	Reported		
Dallas	Established		
Dent	Established		
Douglas	Established		
Gasconade	Established		
Greene	Established		
Howell	Established		
Jasper	Established		
Johnson	Established		
Laclede	Established		
Montgomery	Reported		
New Madrid	Reported		
Newton	Reported	N-R	http://vectormap.nhm.ku.edu/vectormap/
Osage	Established		
Pulaski	Established		
Scott	Reported		

(continued)

Table 2. Continued

State and county	Status by August 2015[a]	Status change from Dennis et al. (1998)[b]	Source for change of status from Dennis et al. (1998) survey
St. Charles	Established		
St. Clair	Reported		
St. Louis	Reported		
Stoddard	Established		
Stone	Established		
Taney	Established		
Texas	Established		
Wayne	Established		
Webster	Established		
Nebraska			
Cass	Reported	N-R	(Cortinas and Spomer 2014)
Lancaster	Reported	N-R	(Cortinas and Spomer 2014)
Pawnee	Reported	N-R	(Cortinas and Spomer 2014)
New Hampshire			
Belknap	Established	R-E	http://www.dhhs.nh.gov/dphs/cdcs/lyme/documents/tick-borne-bulletin-2014.pdf
Carroll	Established	R-E	http://www.dhhs.nh.gov/dphs/cdcs/lyme/documents/tick-borne-bulletin-2014.pdf
Cheshire	Established	R-E	http://www.dhhs.nh.gov/dphs/cdcs/lyme/documents/tick-borne-bulletin-2014.pdf
Coos	Reported		
Grafton	Established		
Hillsborough	Established		
Merrimack	Established		
Rockingham	Established		
Strafford	Established		
Sullivan	Established	R-E	http://www.dhhs.nh.gov/dphs/cdcs/lyme/documents/tick-borne-bulletin-2014.pdf
New Jersey			
Atlantic	Established		
Bergen	Established		
Burlington	Established		
Camden	Established		
Cape May	Established		
Cumberland	Established		
Essex	Established		
Gloucester	Established		
Hudson	Established		
Hunterdon	Established		
Mercer	Established		
Middlesex	Established		
Monmouth	Established		
Morris	Established		
Ocean	Established		
Passaic	Established		
Salem	Established		
Somerset	Established		
Sussex	Established		
Union	Established		
Warren	Established		
New York			
Albany	Established		
Allegany	Established	R-E	M. Prusinski/New York Department of Health, unpublished
Bronx	Established		
Broome	Established		
Cattaraugus	Established		
Cayuga	Established	N-E	M. Prusinski/New York Department of Health, unpublished
Chautauqua	Established	R-E	M. Prusinski/New York Department of Health, unpublished
Chemung	Established	N-E	

(continued)

Table 2. Continued

State and county	Status by August 2015[a]	Status change from Dennis et al. (1998)[b]	Source for change of status from Dennis et al. (1998) survey
			M. Prusinski/New York Department of Health, unpublished
Chenango	Established	R-E	M. Prusinski/New York Department of Health, unpublished
Clinton	Established		
Columbia	Established		
Cortland	Established	N-E	M. Prusinski/New York Department of Health, unpublished
Delaware	Established		
Dutchess	Established		
Erie	Established		
Essex	Established		
Franklin	Established	R-E	M. Prusinski/New York Department of Health, unpublished
Fulton	Established		
Genesee	Established	R-E	M. Prusinski/New York Department of Health, unpublished
Greene	Established		
Hamilton	Established	N-E	M. Prusinski/New York Department of Health, unpublished
Herkimer	Established	R-E	M. Prusinski/New York Department of Health, unpublished
Jefferson	Established		
Kings	Established		
Lewis	Established	R-E	M. Prusinski/New York Department of Health, unpublished
Livingston	Established	R-E	M. Prusinski/New York Department of Health, unpublished
Madison	Established	R-E	M. Prusinski/New York Department of Health, unpublished
Monroe	Established	R-E	M. Prusinski/New York Department of Health, unpublished
Montgomery	Established		
Nassau	Established		
New York	Established	N-E	M. Prusinski/New York Department of Health, unpublished
Niagara	Established	N-E	M. Prusinski/New York Department of Health, unpublished
Oneida	Established		
Onondaga	Established	R-E	M. Prusinski/New York Department of Health, unpublished
Ontario	Established	R-E	M. Prusinski/New York Department of Health, unpublished
Orange	Established		
Orleans	Reported	N-R	M. Prusinski/New York Department of Health, unpublished
Oswego	Established	R-E	M. Prusinski/New York Department of Health, unpublished
Otsego	Established		
Putnam	Established		
Queens	Established	R-E	M. Prusinski/New York Department of Health, unpublished
Rensselaer	Established		
Richmond	Established	R-E	M. Prusinski/New York Department of Health, unpublished
Rockland	Established		
Saratoga	Established		
Schenectady	Established		
Schoharie	Established		
Schuyler	Established	N-E	M. Prusinski/New York Department of Health, unpublished
Seneca	Established	N-E	

(continued)

Table 2. Continued

State and county	Status by August 2015[a]	Status change from Dennis et al. (1998)[b]	Source for change of status from Dennis et al. (1998) survey
			M. Prusinski/New York Department of Health, unpublished
St. Lawrence	Established	R-E	M. Prusinski/New York Department of Health, unpublished
Steuben	Established	N-E	M. Prusinski/New York Department of Health, unpublished
Suffolk	Established		
Sullivan	Established		
Tioga	Established	R-E	M. Prusinski/New York Department of Health, unpublished
Tompkins	Established	R-E	M. Prusinski/New York Department of Health, unpublished
Ulster	Established		
Warren	Established		
Washington	Established		
Wayne	Established	N-E	M. Prusinski/New York Department of Health, unpublished
Westchester	Established		
Wyoming	Established	R-E	M. Prusinski/New York Department of Health, unpublished
Yates	Established	R-E	M. Prusinski/New York Department of Health, unpublished
North Carolina			
Alamance	Established	N-E	B. Harrison/NCPHPM[c], unpublished
Anson	Reported		
Beaufort	Established		
Bertie	Established	N-E	B. Harrison/NCPHPM[c], unpublished
Bladen	Established		
Brunswick	Established		
Camden	Established	R-E	B. Harrison/NCPHPM[c], unpublished
Carteret	Established	R-E	B. Harrison/NCPHPM[c], unpublished
Catawba	Reported		
Chatham	Established	R-E	(Smith et al. 2010)
Chowan	Established	R-E	B. Harrison/NCPHPM[c], unpublished
Columbus	Established	R-E	B. Harrison/NCPHPM[c], unpublished
Craven	Established	R-E	B. Harrison/NCPHPM[c], unpublished
Cumberland	Established		
Currituck	Reported		
Dare	Established		
Duplin	Established	N-E	B. Harrison/NCPHPM[c], unpublished
Durham	Established	N-E	B. Harrison/NCPHPM[c], unpublished
Edgecombe	Established	N-E	B. Harrison/NCPHPM[c], unpublished
Forsyth	Reported	N-R	B. Harrison/NCPHPM[c], unpublished
Gates	Established	R-E	B. Harrison/NCPHPM[c], unpublished
Granville	Reported	N-R	B. Harrison/NCPHPM[c], unpublished; http://vectormap.nhm.ku.edu/vectormap/
Greene	Established	N-E	B. Harrison/NCPHPM[c], unpublished
Guilford	Reported	N-R	B. Harrison/NCPHPM[c], unpublished
Halifax	Established	N-E	B. Harrison/NCPHPM[c], unpublished
Harnett	Established	N-E	B. Harrison/NCPHPM[c], unpublished
Haywood	Reported	N-R	B. Harrison/NCPHPM[c], unpublished
Hertford	Established	R-E	B. Harrison/NCPHPM[c], unpublished
Hoke	Established		
Hyde	Established	R-E	B. Harrison/NCPHPM[c], unpublished
Johnston	Established	N-E	B. Harrison/NCPHPM[c], unpublished
Jones	Established	R-E	B. Harrison/NCPHPM[c], unpublished
Lenoir	Reported		
Martin	Established	R-E	B. Harrison/NCPHPM[c], unpublished
Mecklenburg	Reported	N-R	B. Harrison/NCPHPM[c], unpublished
Moore	Reported		
Nash	Established	N-E	B. Harrison/NCPHPM[c], unpublished
New Hanover	Established	R-E	B. Harrison/NCPHPM[c], unpublished

(continued)

Table 2. Continued

State and county	Status by August 2015[a]	Status change from Dennis et al. (1998)[b]	Source for change of status from Dennis et al. (1998) survey
Onslow	Established		
Orange	Established	N-E	B. Harrison/NCPHPM[c], unpublished
Pamlico	Established	R-E	B. Harrison/NCPHPM[c], unpublished
Pasquotank	Reported	N-R	B. Harrison/NCPHPM[c], unpublished
Pender	Established	R-E	B. Harrison/NCPHPM[c], unpublished
Perquimans	Established	N-E	B. Harrison/NCPHPM[c], unpublished
Pitt	Reported	N-R	B. Harrison/NCPHPM[c], unpublished
Randolph	Reported	N-R	http://vectormap.nhm.ku.edu/vectormap/
Robeson	Established	N-E	B. Harrison/NCPHPM[c], unpublished
Rowan	Established	N-E	B. Harrison/NCPHPM[c], unpublished
Rutherford	Reported		
Sampson	Established	R-E	B. Harrison/NCPHPM[c], unpublished
Scotland	Established	N-E	B. Harrison/NCPHPM[c], unpublished
Stokes	Established	N-E	(Sakamoto et al. 2014); B. Harrison/NCPHPM[c], unpublished
Surry	Reported	N-R	B. Harrison/NCPHPM[c], unpublished
Tyrrell	Established	N-E	B. Harrison/NCPHPM[c], unpublished
Vance	Reported	N-R	B. Harrison/NCPHPM[c], unpublished
Wake	Established	R-E	B. Harrison/NCPHPM[c], unpublished
Warren	Established	N-E	B. Harrison/NCPHPM[c], unpublished
Washington	Established	R-E	B. Harrison/NCPHPM[c], unpublished
Wayne	Established	N-E	H. Gaff, unpublished; B. Harrison/NCPHPM[c], unpublished
North Dakota			
Bottineau	Established	N-E	M. Feist and J. Vaughan, unpublished
Eddy	Established	N-E	(Russart et al. 2014)
Grand Forks	Established	N-E	(Russart et al. 2014, Stone et al. 2015)
Pembina	Established	N-E	(Russart et al. 2014)
Ramsey	Established	N-E	(Russart et al. 2014)
Ransom	Reported	N-R	M. Feist and J. Vaughan, unpublished
Rolette	Reported	N-R	(Russart et al. 2014)
Steele	Reported	N-R	(Russart et al. 2014)
Ohio			
Adams	Established	N-E	R. Gary/Ohio Department of Health, unpublished
Ashland	Reported	N-R	http://www.odh.ohio.gov/lyme
Ashtabula	Established	N-E	(Wang et al. 2014), R. Gary/Ohio Department of Health, unpublished
Athens	Reported	N-R	(Wang et al. 2014), http://www.odh.ohio.gov/lyme
Auglaize	Reported	N-R	http://www.odh.ohio.gov/lyme
Belmont	Established	N-E	R. Gary/Ohio Department of Health, unpublished
Brown	Reported	N-R	http://www.odh.ohio.gov/lyme
Butler	Reported		
Carroll	Established	N-E	(Wang et al. 2014), R. Gary/Ohio Department of Health, unpublished
Clermont	Reported		
Columbiana	Established	N-E	(Wang et al. 2014), R. Gary/Ohio Department of Health, unpublished
Coshocton	Established	N-E	(Wang et al. 2014), R. Gary/Ohio Department of Health, unpublished
Cuyahoga	Established	N-E	R. Gary/Ohio Department of Health, unpublished
Delaware	Reported	N-R	http://www.odh.ohio.gov/lyme
Erie	Reported	N-R	http://www.odh.ohio.gov/lyme
Fairfield	Reported	N-R	http://www.odh.ohio.gov/lyme
Fayette	Reported	N-R	http://www.odh.ohio.gov/lyme
Franklin	Reported	N-R	R. Gary, unpublished; http://vectormap.nhm.ku.edu/vectormap/
Gallia	Established	N-E	(Wang et al. 2014), R. Gary/Ohio Department of Health, unpublished
Geauga	Reported	N-R	http://www.odh.ohio.gov/lyme
Greene	Reported	N-R	http://www.odh.ohio.gov/lyme
Guernsey	Established	N-E	(Wang et al. 2014), R. Gary/Ohio Department of Health, unpublished

(continued)

Table 2. Continued

State and county	Status by August 2015[a]	Status change from Dennis et al. (1998)[b]	Source for change of status from Dennis et al. (1998) survey
Hamilton	Established	R-E	R. Gary/Ohio Department of Health, unpublished
Harrison	Established	N-E	(Wang et al. 2014), R. Gary/Ohio Department of Health, unpublished
Highland	Reported	N-R	(Wang et al. 2014), http://www.odh.ohio.gov/lyme
Hocking	Established	N-E	(Wang et al. 2014), R. Gary/Ohio Department of Health, unpublished
Holmes	Established	N-E	(Wang et al. 2014), R. Gary/Ohio Department of Health, unpublished
Jackson	Established	N-E	(Wang et al. 2014), R. Gary/Ohio Department of Health, unpublished
Jefferson	Established	N-E	(Wang et al. 2014), R. Gary/Ohio Department of Health, unpublished
Knox	Established	N-E	(Wang et al. 2014), R. Gary/Ohio Department of Health, unpublished
Lake	Established	N-E	R. Gary/Ohio Department of Health, unpublished
Lawrence	Established	N-E	(Wang et al. 2014), R. Gary/Ohio Department of Health, unpublished
Licking	Established	N-E	(Wang et al. 2014), R. Gary/Ohio Department of Health, unpublished
Lucas	Reported	N-R	http://www.odh.ohio.gov/lyme
Madison	Reported	N-R	http://www.odh.ohio.gov/lyme
Mahoning	Reported	N-R	http://www.odh.ohio.gov/lyme
Medina	Established	N-E	R. Gary/Ohio Department of Health, unpublished
Meigs	Reported	N-R	http://www.odh.ohio.gov/lyme
Monroe	Established	N-E	(Wang et al. 2014), R. Gary/Ohio Department of Health, unpublished
Montgomery	Reported	N-R	http://www.odh.ohio.gov/lyme
Morgan	Established	N-E	(Wang et al. 2014), R. Gary/Ohio Department of Health, unpublished
Morrow	Reported	N-R	http://www.odh.ohio.gov/lyme
Muskingum	Established	N-E	(Wang et al. 2014), R. Gary/Ohio Department of Health, unpublished
Noble	Established	N-E	(Wang et al. 2014), R. Gary/Ohio Department of Health, unpublished
Ottawa	Reported	N-R	http://www.odh.ohio.gov/lyme
Paulding	Reported	N-R	
Perry	Established	N-E	R. Gary/Ohio Department of Health, unpublished
Pickaway	Reported	N-R	http://www.odh.ohio.gov/lyme
Pike	Established	N-E	(Wang et al. 2014), R. Gary/Ohio Department of Health, unpublished
Portage	Established	N-E	R. Gary/Ohio Department of Health, unpublished
Richland	Established	N-E	(Wang et al. 2014), R. Gary/Ohio Department of Health, unpublished
Ross	Established	N-E	(Wang et al. 2014), R. Gary/Ohio Department of Health, unpublished
Scioto	Reported	N-R	http://www.odh.ohio.gov/lyme
Stark	Established	N-E	R. Gary/Ohio Department of Health, unpublished
Summit	Established	N-E	R. Gary/Ohio Department of Health, unpublished
Trumbull	Established	N-E	R. Gary/Ohio Department of Health, unpublished
Tuscarawas	Reported	N-R	(Wang et al. 2014), http://www.odh.ohio.gov/lyme
Union	Reported	N-R	http://www.odh.ohio.gov/lyme
Vinton	Reported	N-R	(Wang et al. 2014), http://www.odh.ohio.gov/lyme
Warren	Reported	N-R	http://www.odh.ohio.gov/lyme
Washington	Reported	N-R	http://www.odh.ohio.gov/lyme
Wayne	Established	R-E	R. Gary/Ohio Department of Health, unpublished
Williams	Reported		
Wood	Reported	N-R	http://www.odh.ohio.gov/lyme
Oklahoma			
Adair	Reported		
Atoka	Reported		
Caddo	Reported		
Carter	Reported		

(continued)

Table 2. Continued

State and county	Status by August 2015[a]	Status change from Dennis et al. (1998)[b]	Source for change of status from Dennis et al. (1998) survey
Cherokee	Established		
Coal	Reported		
Comanche	Reported		
Creek	Reported		
Delaware	Reported		
Garfield	Reported		
Garvin	Reported		
Haskell	Reported		
Hughes	Reported		
Johnston	Reported		
Latimer	Reported		
Le Flore	Established		
Lincoln	Reported		
Love	Reported		
Mayes	Reported		
McClain	Established		
McCurtain	Reported		
McIntosh	Reported		
Murray	Reported		
Muskogee	Reported		
Oklahoma	Reported		
Okmulgee	Reported		
Ottawa	Reported		
Pawnee	Reported		
Payne	Reported		
Pittsburg	Reported		
Pontotoc	Reported		
Pottawatomie	Reported		
Pushmataha	Reported		
Rogers	Reported		
Seminole	Reported		
Sequoyah	Reported		
Tulsa	Reported		
Wagoner	Reported		
Washington	Reported		
Pennsylvania			
Adams	Established	R-E	(Han et al. 2014, Hutchinson et al. 2015)
Allegheny	Established	R-E	(Hutchinson et al. 2015)
Armstrong	Established	R-E	(Hutchinson et al. 2015)
Beaver	Established	N-E	(Hutchinson et al. 2015)
Bedford	Established	N-E	(Hutchinson et al. 2015)
Berks	Established		
Blair	Established		
Bradford	Established	N-E	(Hutchinson et al. 2015)
Bucks	Established		
Butler	Established		
Cambria	Established	R-E	(Hutchinson et al. 2015)
Cameron	Established		
Carbon	Established	N-E	(Hutchinson et al. 2015)
Centre	Established		
Chester	Established		
Clarion	Established		
Clearfield	Established		
Clinton	Established	R-E	(Hutchinson et al. 2015)
Columbia	Established	R-E	(Hutchinson et al. 2015)
Crawford	Established	R-E	(Hutchinson et al. 2015)
Cumberland	Established	R-E	(Hutchinson et al. 2015)
Dauphin	Established	R-E	(Hutchinson et al. 2015)
Delaware	Established		
Elk	Established		
Erie	Established		
Fayette	Established	N-E	(Hutchinson et al. 2015)

(continued)

Table 2. Continued

State and county	Status by August 2015[a]	Status change from Dennis et al. (1998)[b]	Source for change of status from Dennis et al. (1998) survey
Forest	Established	N-E	(Hutchinson et al. 2015)
Franklin	Established	N-E	(Hutchinson et al. 2015)
Fulton	Established	R-E	(Hutchinson et al. 2015)
Greene	Established	N-E	(Hutchinson et al. 2015)
Huntingdon	Established	R-E	(Hutchinson et al. 2015)
Indiana	Established	N-E	(Hutchinson et al. 2015)
Jefferson	Established	R-E	(Hutchinson et al. 2015)
Juniata	Established	N-E	(Hutchinson et al. 2015)
Lackawanna	Established	R-E	(Hutchinson et al. 2015)
Lancaster	Established		
Lawrence	Established	R-E	(Hutchinson et al. 2015)
Lebanon	Established	R-E	(Hutchinson et al. 2015)
Lehigh	Established		
Luzerne	Established	R-E	(Hutchinson et al. 2015)
Lycoming	Established	R-E	(Hutchinson et al. 2015)
McKean	Established		
Mercer	Established		
Mifflin	Established	R-E	(Hutchinson et al. 2015)
Monroe	Established		
Montgomery	Established		
Montour	Established	N-E	(Hutchinson et al. 2015)
Northampton	Established		
Northumberland	Established	R-E	(Hutchinson et al. 2015)
Perry	Established	R-E	(Hutchinson et al. 2015)
Philadelphia	Established		
Pike	Established		
Potter	Established	R-E	(Hutchinson et al. 2015)
Schuylkill	Established	R-E	(Hutchinson et al. 2015)
Snyder	Established	N-E	(Hutchinson et al. 2015)
Somerset	Established	N-E	(Hutchinson et al. 2015)
Sullivan	Established	N-E	(Hutchinson et al. 2015)
Susquehanna	Established	N-E	(Hutchinson et al. 2015)
Tioga	Established	N-E	(Hutchinson et al. 2015)
Union	Established	R-E	(Hutchinson et al. 2015)
Venango	Established	N-E	(Hutchinson et al. 2015)
Warren	Established	R-E	(Hutchinson et al. 2015)
Washington	Established	R-E	(Hutchinson et al. 2015)
Wayne	Established		
Westmoreland	Established	R-E	(Hutchinson et al. 2015)
Wyoming	Established	N-E	(Hutchinson et al. 2015)
York	Established		
Rhode Island			
Bristol	Established		
Kent	Established		
Newport	Established		
Providence	Established		
Washington	Established		
South Carolina			
Abbeville	Reported		
Aiken	Established		
Allendale	Reported		
Anderson	Reported		
Barnwell	Established		
Beaufort	Established		
Berkeley	Established		
Calhoun	Reported	N-R	(Williams et al. 1999)
Charleston	Established		
Chester	Established		
Chesterfield	Reported	N-R	(Williams et al. 1999)
Colleton	Reported		
Darlington	Reported		
Dorchester	Reported		

(continued)

Table 2. Continued

State and county	Status by August 2015[a]	Status change from Dennis et al. (1998)[b]	Source for change of status from Dennis et al. (1998) survey
Edgefield	Established		
Fairfield	Reported		
Florence	Established		
Georgetown	Established		
Greenville	Reported	N-R	(Williams et al. 1999)
Greenwood	Reported		
Hampton	Established		
Horry	Reported		
Jasper	Established	R-E	L. Durden, unpublished
Laurens	Reported		
McCormick	Established		
Newberry	Established		
Orangeburg	Reported		
Pickens	Reported		
Richland	Reported	N-R	(Williams et al. 1999)
Saluda	Reported	N-R	(Williams et al. 1999)
Spartanburg	Reported		
Sumter	Reported	N-R	http://vectormap.nhm.ku.edu/vectormap/
Union	Established		
South Dakota			
Brookings	Reported		
Codington	Reported		
Tennessee			
Anderson	Established	N-E	(Rosen et al. 2012)
Bedford	Established	R-E	(Rosen et al. 2012)
Bledsoe	Reported	N-R	(Rosen et al. 2012)
Campbell	Established	N-E	(Rosen et al. 2012)
Claiborne	Reported	N-R	(Rosen et al. 2012)
Clay	Reported	N-R	(Rosen et al. 2012)
Coffee	Established	N-E	G. Hickling, unpublished
Cumberland	Reported	N-R	(Harmon et al. 2011, Rosen et al. 2012)
Davidson	Reported	N-R	(Rosen et al. 2012)
DeKalb	Established	N-E	(Rosen et al. 2012)
Fayette	Established	N-E	(Rosen et al. 2012, Mays et al. 2014)
Fentress	Reported		
Franklin	Established	N-E	G. Hickling, unpublished
Giles	Reported	N-R	(Rosen et al. 2012)
Grainger	Reported	N-R	(Rosen et al. 2012)
Hamilton	Established	N-E	(Rosen et al. 2012)
Henry	Reported	N-R	(Rosen et al. 2012)
Humphreys	Reported	N-R	(Rosen et al. 2012)
Jackson	Established	N-E	(Rosen et al. 2012)
Knox	Established	N-E	G. Hickling, unpublished
Lake	Reported		
Lauderdale	Reported	N-R	(Rosen et al. 2012)
Lawrence	Established	N-E	(Rosen et al. 2012)
Loudon	Established	N-E	(Rosen et al. 2012)
Marion	Established	R-E	(Rosen et al. 2012)
Marshall	Established	N-E	(Rosen et al. 2012)
Maury	Reported	N-R	(Rosen et al. 2012)
Montgomery	Reported	N-R	http://vectormap.nhm.ku.edu/vectormap/
Obion	Reported	N-R	(Rosen et al. 2012)
Pickett	Reported	N-R	(Rosen et al. 2012)
Rhea	Established	N-E	(Rosen et al. 2012)
Roane	Reported	N-R	(Rosen et al. 2012)
Rutherford	Reported		
Scott	Reported		
Sequatchie	Reported	N-R	(Rosen et al. 2012)
Shelby	Established		
Stewart	Reported	N-R	(Rosen et al. 2012)
Sumner	Reported	N-R	(Rosen et al. 2012)
Tipton	Reported	N-R	(Rosen et al. 2012)

(continued)

Table 2. Continued

State and county	Status by August 2015[a]	Status change from Dennis et al. (1998)[b]	Source for change of status from Dennis et al. (1998) survey
Warren	Reported	N-R	(Rosen et al. 2012)
Wayne	Reported	N-R	(Rosen et al. 2012)
White	Reported	N-R	(Rosen et al. 2012)
Williamson	Reported	N-R	(Rosen et al. 2012)
Texas			
Anderson	Established		
Angelina	Established		
Aransas	Established		
Austin	Reported		
Bandera	Reported		
Bastrop	Reported		
Bell	Established		
Bexar	Established		
Blanco	Reported	N-R	S. Hamer, unpublished
Bowie	Reported		
Brazoria	Established		
Brazos	Established	R-E	(Sanders et al. 2013, Rodriguez et al. 2015)
Cameron	Reported	N-R	(Feria-Arroyo et al. 2014)
Cass	Established		
Cherokee	Established		
Colorado	Reported		
Coryell	Reported	N-R	(Sanders et al. 2013)
Dallas	Reported		
Edwards	Reported		
Fort Bend	Reported		
Franklin	Reported		
Freestone	Established	N-E	S. Hamer, unpublished
Grayson	Reported		
Gregg	Reported		
Hamilton	Reported		
Harris	Established		
Harrison	Reported		
Hays	Reported		
Henderson	Established		
Hidalgo	Reported	N-R	(Feria-Arroyo et al. 2014)
Houston	Reported		
Hunt	Reported		
Jasper	Established		
Jefferson	Reported		
Kerr	Reported		
Kleberg	Reported		
Lamar	Reported		
Lampasas	Reported		
Lavaca	Established		
Leon	Established		
Liberty	Reported		
Llano	Reported		
Marion	Established		
Mason	Reported	N-R	(Feria-Arroyo et al. 2014)
Matagorda	Reported		
Montgomery	Established		
Nacogdoches	Established		
Newton	Reported		
Palo Pinto	Reported		
Parker	Established		
Polk	Established		
Real	Established		
Robertson	Reported		
Rusk	Reported		
Sabine	Reported		
San Augustine	Reported		
Shelby	Reported		

(continued)

Table 2. Continued

State and county	Status by August 2015[a]	Status change from Dennis et al. (1998)[b]	Source for change of status from Dennis et al. (1998) survey
Smith	Established		
Sutton	Reported		
Tarrant	Reported	N-R	(Feria-Arroyo et al. 2014)
Taylor	Reported		
Trinity	Established		
Tyler	Established		
Upshur	Reported		
Uvalde	Reported		
Victoria	Reported		
Walker	Reported		
Waller	Established		
Washington	Reported	N-R	S. Hamer, unpublished
Wood	Established		
Zavala	Reported		
Vermont			
Addison	Established	N-E	https://apps.health.vermont.gov/gis/vttracking/tick tracker/2014Summary/
Bennington	Established	R-E	https://apps.health.vermont.gov/gis/vttracking/tick tracker/2014Summary/
Caledonia	Established	R-E	https://apps.health.vermont.gov/gis/vttracking/tick tracker/2014Summary/
Chittenden	Established	R-E	https://apps.health.vermont.gov/gis/vttracking/tick tracker/2014Summary/
Franklin	Established	N-E	https://apps.health.vermont.gov/gis/vttracking/tick tracker/2014Summary/
Grand Isle	Established	N-E	https://apps.health.vermont.gov/gis/vttracking/tick tracker/2014Summary/
Lamoille	Reported		
Orange	Established	N-E	(Serra et al. 2013)
Orleans	Reported	N-R	https://apps.health.vermont.gov/gis/vttracking/tick tracker/2014Summary/
Rutland	Established	R-E	https://apps.health.vermont.gov/gis/vttracking/tick tracker/2014Summary/
Washington	Established	N-E	https://apps.health.vermont.gov/gis/vttracking/tick tracker/2014Summary/
Windham	Established	R-E	https://apps.health.vermont.gov/gis/vttracking/tick tracker/2014Summary/
Windsor	Established		
Virginia			
Accomack	Established		
Albemarle	Established	N-E	D. Gaines, unpublished
Alleghany	Reported	N-R	D. Gaines, unpublished
Appomattox	Established	N-E	R.J. Brinkerhoff, unpublished
Arlington	Reported	N-R	http://vectormap.nhm.ku.edu/vectormap/
Augusta	Established	N-E	D. Gaines, unpublished
Bath	Reported	N-R	D. Gaines, unpublished
Bedford City	Reported	N-R	http://vectormap.nhm.ku.edu/vectormap/
Bedford	Established	N-E	M. Shanks, D. Gaines, unpublished
Bland	Established	N-E	M. Shanks, D. Gaines, unpublished
Brunswick	Reported	N-R	D. Gaines, unpublished
Buckingham	Established	N-E	D. Gaines, unpublished; R.J. Brinkerhoff, unpublished
Caroline	Established		
Charles City	Reported	N-R	D. Gaines, unpublished; R.J. Brinkerhoff, unpublished
Chesapeake	Established		
Chesterfield	Established	N-E	(Kelly et al. 2014)
Craig	Established	N-E	M. Shanks, D. Gaines, unpublished
Culpeper	Reported	N-R	H. Gaff, unpublished; http://vectormap.nhm.ku.edu/ vectormap/
Cumberland	Reported	N-R	R.J. Brinkerhoff, unpublished

(continued)

Table 2. Continued

State and county	Status by August 2015[a]	Status change from Dennis et al. (1998)[b]	Source for change of status from Dennis et al. (1998) survey
Dinwiddie	Reported	N-R	http://vectormap.nhm.ku.edu/vectormap/
Essex	Reported	N-R	H. Gaff, unpublished
Fairfax	Established		
Fauquier	Established	R-E	R.J. Brinkerhoff, unpublished
Floyd	Established	N-E	D. Gaines, unpublished
Fluvanna	Established	N-E	R.J. Brinkerhoff, unpublished
Franklin	Established	N-E	M. Shanks, D. Gaines, unpublished
Frederick	Established	N-E	D. Gaines, unpublished
Giles	Established	N-E	(Herrin et al. 2014)
Gloucester	Reported	N-R	H. Gaff, unpublished; http://vectormap.nhm.ku.edu/vectormap/
Goochland	Established	N-E	(Kelly et al. 2014)
Greensville	Reported	N-R	H. Gaff, unpublished
Hampton	Established	N-E	H. Gaff, unpublished
Hanover	Reported	N-R	R.J. Brinkerhoff, unpublished
Henrico	Reported	N-R	D. Gaines, unpublished
Isle of Wight	Established	N-E	H. Gaff, unpublished
James City	Established	N-E	(Kelly et al. 2014); H. Gaff, unpublished
King and Queen	Reported	N-R	H. Gaff, unpublished
King George	Established	N-E	D. Gaines, unpublished; H. Gaff, unpublished
Lancaster	Reported	N-R	H. Gaff, unpublished
Loudoun	Established	N-E	H. Gaff, unpublished
Lynchburg	Established	N-E	D. Gaines, unpublished
Mecklenburg	Reported	N-R	D. Gaines, unpublished
Middlesex	Established	N-E	H. Gaff, unpublished
Montgomery	Established	N-E	D. Gaines, unpublished
Nelson	Established	N-E	Kelly et al. 2014
New Kent	Established	N-E	R.J. Brinkerhoff, unpublished
Newport News	Established		
Norfolk	Reported	N-R	H. Gaff, unpublished
Northampton	Established	N-E	(Kelly et al. 2014); H. Gaff, unpublished
Northumberland	Reported	N-R	H. Gaff, unpublished; http://vectormap.nhm.ku.edu/vectormap/
Portsmouth	Established	N-E	H. Gaff, unpublished
Powhatan	Established	N-E	R.J. Brinkerhoff, unpublished
Prince Edward	Reported	N-R	R.J. Brinkerhoff, unpublished
Prince George	Reported		
Prince William	Established	N-E	H. Gaff, unpublished; http://vectormap.nhm.ku.edu/vectormap/
Pulaski	Established	N-E	(Herrin et al. 2014)
Rappahannock	Reported	N-R	http://vectormap.nhm.ku.edu/vectormap/
Richmond	Reported	N-R	D. Gaines, unpublished; H. Gaff, unpublished
Roanoke	Established	N-E	D. Gaines, unpublished
Rockbridge	Established	N-E	D. Gaines, unpublished
Rockingham	Reported	N-R	D. Gaines, unpublished
Shenandoah	Reported	N-R	D. Gaines, unpublished
Southampton	Established	R-E	H. Gaff, unpublished
Spotsylvania	Reported	N-R	http://vectormap.nhm.ku.edu/vectormap/
Stafford	Established		
Suffolk	Established	N-E	D. Gaines, unpublished; H. Gaff, unpublished
Sussex	Reported	N-R	H. Gaff, unpublished
Virginia Beach	Established		
Warren	Established	N-E	D. Gaines, unpublished
Washington	Reported	N-R	http://vectormap.nhm.ku.edu/vectormap/
Westmoreland	Established	N-E	H. Gaff, unpublished
York	Established		
West Virginia			
Barbour	Established	N-E	http://www.dhhr.wv.gov/oeps/disease/Zoonosis/Mosquito/Documents/arbovirus/vectorborne-disease-report.pdf#page=3; E. Dotseth, unpublished
Berkeley	Established		
Boone	Reported		

(continued)

Table 2. Continued

State and county	Status by August 2015[a]	Status change from Dennis et al. (1998)[b]	Source for change of status from Dennis et al. (1998) survey
Braxton	Established	N-E	E. Dotseth, unpublished
Brooke	Established	N-E	http://www.mamca.org/2014Meeting/0306_0840_SR_WV.pdf; E. Dotseth, unpublished
Cabell	Reported	N-R	http://www.dhhr.wv.gov/oeps/disease/zoonosis/documents/wv-zd-summary-2014.pdf
Doddridge	Reported	N-R	http://www.dhhr.wv.gov/oeps/disease/Zoonosis/Mosquito/Documents/arbovirus/vectorborne-disease-report.pdf#page=3
Fayette	Reported	N-R	E. Dotseth, unpublished
Gilmer	Established	N-E	E. Dotseth, unpublished
Grant	Reported	N-R	http://www.dhhr.wv.gov/oeps/disease/Zoonosis/Mosquito/Documents/arbovirus/vectorborne-disease-report.pdf#page=3
Greenbrier	Established	N-E	http://www.mamca.org/2014Meeting/0306_0840_SR_WV.pdf; E. Dotseth, unpublished
Hampshire	Reported	N-R	http://www.mamca.org/2014Meeting/0306_0840_SR_WV.pdf
Hancock	Established	N-E	http://www.dhhr.wv.gov/oeps/disease/Zoonosis/Tick/documents/tickborne-disease-summary-2013.pdf
Hardy	Established	N-E	http://www.dhhr.wv.gov/oeps/disease/zoonosis/tick/documents/tickborne-disease-summary-2013.pdf; E. Dotseth, unpublished
Harrison	Established	N-E	http://www.dhhr.wv.gov/oeps/disease/zoonosis/tick/documents/tickborne-disease-summary-2013.pdf; E. Dotseth, unpublished
Jackson	Reported	N-R	http://www.dhhr.wv.gov/oeps/disease/Zoonosis/Mosquito/Documents/arbovirus/vectorborne-disease-report.pdf#page=3
Jefferson	Established		
Kanawha	Established	N-E	http://www.dhhr.wv.gov/oeps/disease/Zoonosis/Tick/documents/tickborne-summary-2012.pdf
Lewis	Established	N-E	E. Dotseth & M. Mark-Carew, unpublished
Lincoln	Reported	N-R	http://www.dhhr.wv.gov/oeps/disease/Zoonosis/Mosquito/Documents/arbovirus/vectorborne-disease-report.pdf#page=3
Logan	Reported	N-R	http://www.dhhr.wv.gov/oeps/disease/Zoonosis/Mosquito/Documents/arbovirus/vectorborne-disease-report.pdf#page=3
Marion	Established	N-E	http://www.dhhr.wv.gov/oeps/disease/zoonosis/tick/documents/tickborne-disease-summary-2013.pdf; E. Dotseth, unpublished
Marshall	Reported	N-R	http://www.dhhr.wv.gov/oeps/disease/zoonosis/tick/documents/tickborne-disease-summary-2013.pdf
Mercer	Established	N-E	http://www.dhhr.wv.gov/oeps/disease/Zoonosis/Mosquito/Documents/arbovirus/vectorborne-disease-report.pdf#page=3; E. Dotseth, unpublished
Mineral	Reported	N-R	http://www.dhhr.wv.gov/oeps/disease/Zoonosis/Mosquito/Documents/arbovirus/vectorborne-disease-report.pdf#page=3
Monongalia	Established	N-E	http://www.dhhr.wv.gov/oeps/disease/zoonosis/tick/documents/tickborne-disease-summary-2013.pdf; E. Dotseth, unpublished
Monroe	Established	N-E	E. Dotseth, unpublished
Morgan	Reported		
Ohio	Reported	N-R	E. Dotseth, unpublished
Pocahontas	Reported	N-R	E. Dotseth, unpublished
Preston	Established	N-E	http://www.mamca.org/2014Meeting/0306_0840_SR_WV.pdf; E. Dotseth, unpublished

(continued)

Table 2. Continued

State and county	Status by August 2015[a]	Status change from Dennis et al. (1998)[b]	Source for change of status from Dennis et al. (1998) survey
Putnam	Reported	N-R	http://www.dhhr.wv.gov/oeps/disease/zoonosis/documents/wv-zd-summary-2014.pdf
Raleigh	Established	N-E	E. Dotseth, unpublished
Randolph	Reported	N-R	http://www.mamca.org/2014Meeting/0306_0840_SR_WV.pdf
Ritchie	Reported	N-R	E. Dotseth, unpublished
Summers	Established	N-E	http://www.dhhr.wv.gov/oeps/disease/zoonosis/tick/documents/tickborne-disease-summary-2013.pdf; E. Dotseth, unpublished
Taylor	Established	N-E	http://www.dhhr.wv.gov/oeps/disease/zoonosis/tick/documents/tickborne-disease-summary-2013.pdf; E. Dotseth, unpublished
Tucker	Reported	N-R	http://www.dhhr.wv.gov/oeps/disease/Zoonosis/Tick/documents/tickborne-disease-summary-2013.pdf
Tyler	Reported	N-R	http://www.dhhr.wv.gov/oeps/disease/zoonosis/documents/wv-zd-summary-2014.pdf
Upshur	Established	N-E	E. Dotseth, unpublished
Wetzel	Established	N-E	E. Dotseth, unpublished
Wirt	Established	N-E	E. Dotseth, unpublished
Wood	Reported	N-R	E. Dotseth, unpublished
Wisconsin			
Adams	Established		
Ashland	Established	R-E	S. Paskewitz, unpublished
Barron	Established		
Bayfield	Established	N-E	S. Paskewitz, unpublished
Brown	Established	N-E	S. Paskewitz, unpublished
Buffalo	Established	R-E	(Michalski et al. 2006)
Burnett	Established		
Chippewa	Established		
Clark	Established		
Columbia	Established		
Crawford	Established		
Dane	Established		
Dodge	Reported	N-R	(Lee et al. 2013)
Door	Established	R-E	S. Paskewitz, unpublished
Douglas	Established	N-E	S. Paskewitz, unpublished.
Dunn	Established	N-E	S. Paskewitz, unpublished
Eau Claire	Established		
Florence	Reported	N-R	http://labs.russell.wisc.edu/wisconsin-ticks/presence-of-ixodes-scapularis-on-hunter-killed-deer-in-wisconsin-2008-09/
Fond du Lac	Reported	N-R	Lee et al. 2013; http://labs.russell.wisc.edu/wisconsin-ticks/presence-of-ixodes-scapularis-on-hunter-killed-deer-in-wisconsin-2008-09/
Forest	Established	N-E	S. Paskewitz, unpublished
Grant	Established		
Green	Established		
Green Lake	Established	N-E	(Michalski et al. 2006)
Iowa	Established		
Jackson	Established		
Jefferson	Established	R-E	S. Paskewitz, unpublished
Juneau	Established	N-E	S. Paskewitz, unpublished
Kenosha	Reported	N-R	(Lee et al. 2013)
La Crosse	Established		
Lafayette	Reported		
Langlade	Established	N-E	S. Paskewitz, unpublished
Lincoln	Established		
Manitowoc	Reported		
Marathon	Established		
Marinette	Established		
Menominee	Established	N-E	S. Paskewitz, unpublished

(continued)

Table 2. Continued

State and county	Status by August 2015[a]	Status change from Dennis et al. (1998)[b]	Source for change of status from Dennis et al. (1998) survey
Milwaukee	Established	N-E	S. Paskewitz, unpublished
Monroe	Established		
Oconto	Established	N-E	S. Paskewitz, unpublished
Oneida	Established	R-E	S. Paskewitz, unpublished
Outagamie	Reported		
Ozaukee	Reported	N-R	http://labs.russell.wisc.edu/wisconsin-ticks/presence-of-ixodes-scapularis-on-hunter-killed-deer-in-wisconsin-2008-09/
Pierce	Reported	N-R	S. Paskewitz, unpublished
Polk	Reported		
Portage	Established		
Price	Established		
Racine	Established		
Richland	Established		
Rock	Established		
Rusk	Established		
Sauk	Established		
Sawyer	Established		
Shawano	Reported	N-R	(Lee et al. 2013)
Sheboygan	Established	R-E	S. Paskewitz, unpublished
St. Croix	Established	R-E	S. Paskewitz, unpublished
Taylor	Established		
Trempealeau	Established		
Vernon	Reported		
Vilas	Established	N-E	S. Paskewitz, unpublished
Walworth	Established	R-E	(Caporale et al. 2005, Lee et al. 2013)
Washburn	Established		
Waukesha	Established	R-E	S. Paskewitz, unpublished
Waupaca	Established	N-E	S. Paskewitz, unpublished
Waushara	Reported		
Winnebago	Reported		
Wood	Reported	N-R	S. Paskewitz, unpublished

[a]Established: Six or more ticks or two or more tick life stages; Reported: Fewer than six ticks and one tick life stage only.
[b]N-R, change from No Records to Reported; N-E, change from No Records to Established; R-E, change from Reported to Established.
[c]NCPHPM: North Carolina Public Health Pest Management, terminated in 2011.
[d]SCWDS: Southeastern Cooperative Wildlife Disease Study.
[e]National Veterinary Services Laboratories.

of enhanced tick surveillance and research activities in some areas. A true range expansion of *I. scapularis* in northern states, as described in this report, is supported by the largely concordant changes in the distribution of human Lyme disease cases captured through mandatory reporting of the disease since 1991 (Rand et al. 2007, Raizman et al. 2012, Lee et al. 2013, Serra et al. 2013, Brinkerhoff et al. 2014, Robinson et al. 2014, Wang et al. 2014, Kugeler et al. 2015, Mead 2015). Moreover, as detailed later in the text, true range expansions of *I. scapularis* have been documented in some areas where tick surveillance was conducted routinely during the period of emergence, or where extensive surveys were conducted at discrete time-points spanning periods from when the tick was absent through invasion and establishment.

The North-Central States

Within the North-Central United States, *I. scapularis* was first described in a focal area of northwestern Wisconsin in the late 1960s (Jackson and DeFoliart 1970). State-wide surveys of adult *I. scapularis* collected from hunter-killed deer in Wisconsin from 1981–1989 (French et al. 1992) revealed that the tick had become established in western, southern, and focal parts of the north, but no evidence of the tick was found in other areas in the north or southeastern reaches of Wisconsin. Subsequent surveys of hunter-killed deer documented continued expansion into the north during the early 1990s (Riehle and Paskewitz 1996) and eventual invasion of eastern Wisconsin by 2008–2009 (Lee et al. 2013). *Ixodes scapularis* now appears to be present throughout most of the habitat that is predicted to be suitable for the tick in the state of Wisconsin (Guerra et al. 2002, Diuk-Wasser et al. 2010).

In neighboring Minnesota to the west, *I. scapularis* was classified as reported or established primarily in counties bordering Wisconsin in the east-central portion of Minnesota in the mid-1990s (Dennis et al. 1998). Opportunistic sampling during 1998–1999 revealed the presence of *I. scapularis* in additional northern and central Minnesota counties (Sanders and Guilfoile 2000), and new county records from the south-central portion of the state are presented in this report. Paralleling this expansion of the tick's known range in Minnesota, Robinson et al. (2014) noted increases in both the numbers and geographical distributions of *I. scapularis*-borne diseases in Minnesota from 1996 through 2011. The north-westerly expansion appears to have continued into eastern North Dakota (Russart et al. 2014, Stone et al. 2015), beyond or near the limit of habitat

previously predicted to be suitable for *I. scapularis* (Estrada-Pena 2002, Brownstein et al. 2003, Diuk-Wasser et al. 2010).

Wisconsin likely served as a primary source for a southerly invasion of *I. scapularis* into Illinois, specifically along the Rock River corridor (Cortinas and Kitron 2006). Surveys of hunter-killed deer from Illinois conducted from 1988–1996 showed that infested deer were restricted largely to northern counties (Cortinas et al. 2002). However, similar surveys conducted from 1998 to 2003 showed expansion of the tick's range to more southern counties and noted that *I. scapularis* densities decreased along a northern to southern gradient, suggesting that Illinois was first colonized in the northwestern and north-central counties, where *I. scapularis* indeed was first discovered in the state in the late 1980s (Bouseman et al. 1990, Cortinas and Kitron 2006). Populations of *I. scapularis* in the extreme northeast along the Illinois River speculatively may have originated from established populations in northwestern Indiana (Cortinas and Kitron 2006). In Indiana, where *I. scapularis* was first collected from deer in northwestern counties in 1987 (Pinger and Glancy 1989), densities of *I. scapularis* are greatest along the western border and decrease eastward; expansion to eastern counties was observed between 2005 and 2007 (Pinger et al. 1996, Keefe 2008, Raizman et al. 2012).

Hamer et al. (2010) proposed that established *I. scapularis* populations in Indiana seeded colonization of lower Michigan, where the tick was first discovered in southwestern lower Michigan in 2002 (Foster 2004). Invasion of *I. scapularis* northward along the coast of Lake Michigan was documented from 2004–2008; in 2004, ticks were collected only from the southernmost of the sampled sites, whereas they were found in all sites by 2008. Tick densities decreased from south to north, supporting a view that densities would be higher in areas where the tick has been longer established. Notably, although inland transects were also surveyed, no evidence of *I. scapularis* invasion was observed in these transects (Hamer et al. 2010). Subsequently, *I. scapularis* has been reported also from inland counties in southern Michigan (Table 2). Colonization of the Upper Peninsula of Michigan most likely occurred via northern Wisconsin and preceded colonization of the Lower Peninsula by more than a decade, as *I. scapularis* was discovered already in the 1980s in Menominee County in the Upper Peninsula of Michigan (Strand et al. 1992, Walker et al. 1994).

The Northeast

Similar to *I. scapularis* expansion in the North-Central focus, the tick's range in the northeastern focus appears to have expanded in all directions, except for eastward, where the Atlantic Ocean prevents further spread. Since the survey by Dennis et al. (1998), *I. scapularis* appears to have expanded northward in Maine, New Hampshire, and Vermont. In Maine, analysis of public submission of ticks from 1989 to 2006 showed a northerly expansion along the Atlantic coastline, followed by invasion inland along river corridors (Rand et al. 2007). *Ixodes scapularis* is now considered established in all Maine counties. In Vermont, drag sampling was conducted from June 2011 to June 2012 along a north-south transect following the Connecticut River: densities of *I. scapularis* generally decreased from south to north, with no ticks collected from the northernmost sites (Serra et al. 2013). Expansion of the tick's range in these New England states likely contributed, together with increasing tick densities in already established areas, to a 5–10-fold increase in incidence of reported Lyme disease cases in those states during the past decade (Mead 2015).

Since the survey by Dennis et al. (1998), the number of New York counties where *I. scapularis* is considered established has nearly doubled from 50.0 to 98.4%. At the time of the previous report, the tick was established primarily in the southeastern and eastern portions of the state and appears to have expanded in northerly and westerly directions. In parallel with this observation, from 1990 to 2000, Lyme disease surveillance data revealed a northward and westward expansion in the disease focus from a central cluster in the southeastern portion of the state (i.e., Westchester County). Moreover, during the same timeframe, the primary epidemiological focus shifted northward along the Hudson River (Chen et al. 2005). Population genetic analysis of *I. scapularis* collected from a transect along the Hudson River from 2004 to 2009 indicated recent rapid expansion of the tick's range, primarily in a northerly direction along the Hudson River (Khatchikian et al. 2015); expansion appears to be the result of local migration of the ticks, via movements of mammal hosts, but some long-distance migration, perhaps via infestation of birds, was detected. Importantly, the DNA sequence analyses provide evidence for recent range expansion, as opposed to recent detection of in situ populations.

Neighboring New York to the south, Pennsylvania also experienced a recent westward expansion of *I. scapularis*. In 2003, Lyme disease cases were reported primarily from eastern counties in Pennsylvania. By 2013, human Lyme disease case counts increased markedly in western counties, with cases reported throughout the state (Mead 2015). This mirrors data for range expansion of *I. scapularis* in Pennsylvania. No *I. scapularis* were collected during a statewide survey from 1963 to 1967 (Snetsinger 1968), whereas the tick was recorded from 49 of 67 counties by the late 1990s (Dennis et al. 1998). A statewide survey conducted during 2012–2014 (Hutchinson et al. 2015) revealed that the tick now is established in all 67 counties. It is likely that the east-to-west tick expansion across Pennsylvania continued into neighboring Ohio to the west, where active tick surveillance was conducted from 1983 to 2012. Surveillance data showed a dramatic increase in *I. scapularis* abundance beginning in 2009. Arguing against increasing tick surveillance as a primary source for the observed range expansion in Ohio, the spread of the tick was observed when Ohio's tick surveillance programs were being considered for termination and their budgets were dwindling (Wang et al. 2014). Currently, the *I. scapularis* range in Ohio is largely consistent with the range of deciduous forest in the state. As a result of the westward expansion of the previous northeastern focus and the eastward expansion of the previous North-Central focus, the distribution of *I. scapularis* now appears to be continuous across northern states with convergence of the two previously distinct foci in the Ohio River Valley.

The West Virginia, Virginia, and North Carolina Area

Ixodes scapularis has also expanded its range in West Virginia, where only 4 counties reported the tick previously (Dennis et al. 1998) and now 43 counties are classified as either reported ($n = 20$) or established ($n = 23$). Review of Lyme disease and *I. scapularis* surveillance reports (see references in Table 2) suggests that the tick is expanding westward across the state, with highly Lyme disease endemic counties still focused in the eastern panhandle. Similarly, in Virginia, *I. scapularis* was considered established primarily in eastern coastal counties previously (Dennis et al. 1998), but the current survey shows the tick to now be established throughout most of Virginia, with the highest densities of openly host-seeking ticks occurring in higher elevation sites (Brinkerhoff et al. 2014, Kelly et al. 2014). The spread of openly host-seeking *I. scapularis* appears to

Table 3. Records of *I. pacificus* by state and county. Fields left blank indicate status was inherited from Dennis et al. (1998)

State and county	Status by Aug. 2015[a]	Status change from Dennis et al. (1998)[b]	Source for change of status from Dennis et al. (1998) survey
Arizona			
Mohave	Established		
California			
Alameda	Established		
Amador	Established		
Butte	Established		
Calaveras	Established		
Colusa	Established		
Contra Costa	Established		
Del Norte	Established		
El Dorado	Established		
Fresno	Established		
Glenn	Established		
Humboldt	Established		
Imperial	Established		
Inyo	Established		
Kern	Established		
Kings	Established		
Lake	Established		
Lassen	Established		
Los Angeles	Established		
Madera	Established		
Marin	Established		
Mariposa	Established		
Mendocino	Established		
Merced	Established		
Mono	Reported		
Monterey	Established		
Napa	Established		
Nevada	Established		
Orange	Established		
Placer	Established		
Plumas	Established		
Riverside	Established		
Sacramento	Established		
San Benito	Established		
San Bernardino	Established		
San Diego	Established		
San Francisco	Established		
San Joaquin	Established		
San Luis Obispo	Established		
San Mateo	Established		
Santa Barbara	Established		
Santa Clara	Established		
Santa Cruz	Established		
Shasta	Established		
Sierra	Established		
Siskiyou	Established		
Solano	Established		
Sonoma	Established		
Stanislaus	Established		
Sutter	Established		
Tehama	Established		
Trinity	Established		
Tulare	Established		
Tuolumne	Established		
Ventura	Established		
Yolo	Established		
Yuba	Established		
Nevada			
Clark	Reported		
Lincoln	Reported		

(continued)

Table 3. Continued

State and county	Status by Aug. 2015[a]	Status change from Dennis et al. (1998)[b]	Source for change of status from Dennis et al. (1998) survey
Oregon			
Benton	Established		
Clackamas	Established		
Clatsop	Established		
Columbia	Reported		
Coos	Established		
Curry	Established		
Douglas	Established		
Hood River	Established		
Jackson	Established		
Jefferson	Reported		
Josephine	Established		
Lane	Established		
Lincoln	Established		
Linn	Established		
Marion	Established		
Multnomah	Established		
Polk	Reported		
Sherman	Established		
Tillamook	Established		
Umatilla	Reported		
Wasco	Established		
Washington	Established		
Utah			
Beaver	Reported		
Juab	Established		
Millard	Reported		
Piute	Reported		
Salt Lake	Established		
Tooele	Established	R-E	(Davis et al. 2015)
Utah	Established		
Washington	Established		
Washington			
Chelan	Established		
Clallam	Established	N-E	E. Dykstra, unpublished
Clark	Established		
Cowlitz	Established	R-E	E. Dykstra, unpublished
Island	Reported		
Jefferson	Established		
King	Established	R-E	E. Dykstra, unpublished
Kitsap	Established	R-E	E. Dykstra, unpublished
Kittitas	Reported	N-R	E. Dykstra, unpublished
Klickitat	Established		
Lewis	Established		
Mason	Established		
Okanogan	Reported	N-R	E. Dykstra, unpublished
Pacific	Reported	N-R	E. Dykstra, unpublished
Pierce	Established		
San Juan	Established		
Skagit	Established		
Skamania	Established		
Snohomish	Reported		
Thurston	Established		
Whatcom	Established		
Yakima	Reported	N-R	E. Dykstra, unpublished

Fields left blank indicate status was inherited from Dennis et al. (1998)

[a]Established: Six or more ticks or two or more tick life stages; Reported: Fewer than six ticks and one tick life stage only.

[b]N-R, change from No Records to Reported; N-E, change from No Records to Established; R-E, change from Reported to Established.

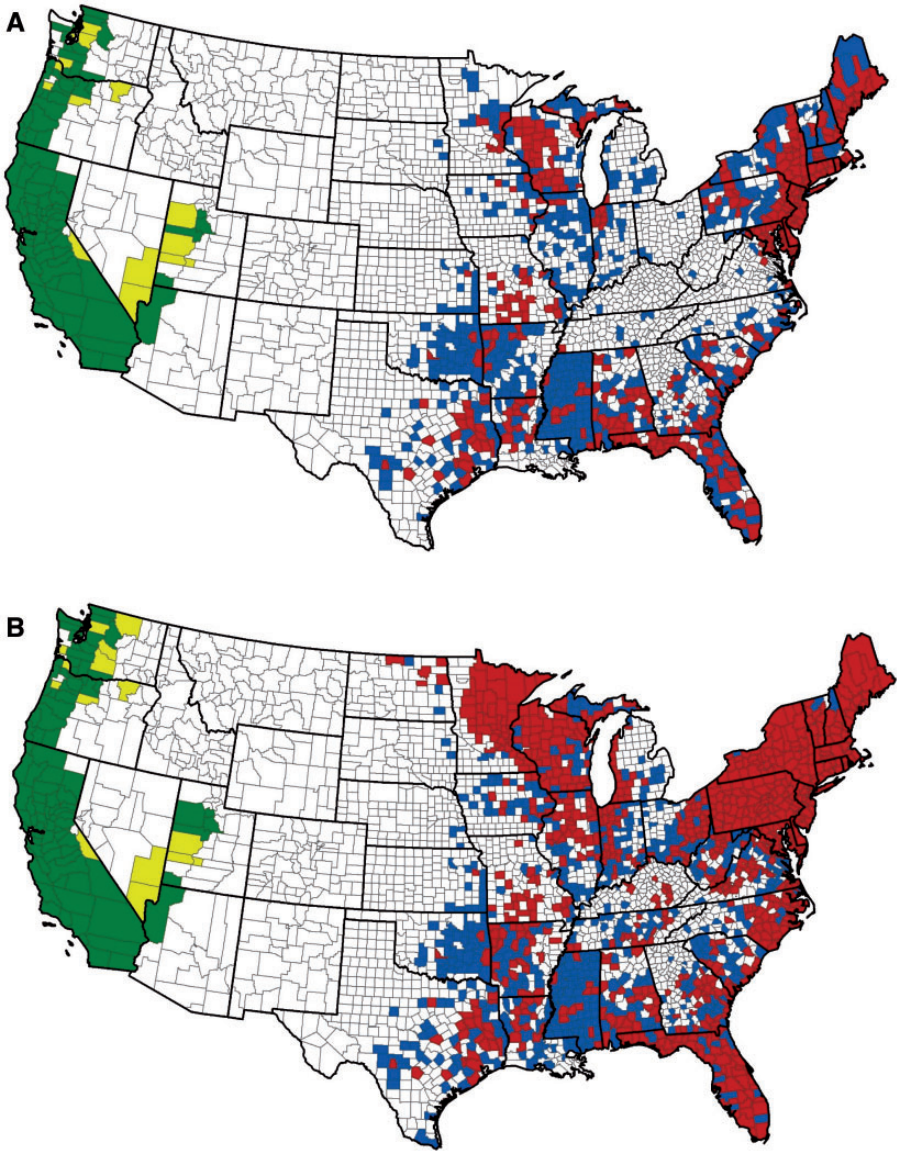

Fig. 1. Distribution by county of recorded presence of *I. scapularis* and *I. pacificus* in the continental United States (a) 1907–1996 (from Dennis et al. 1998), (b) 1907–2015. Counties classified as established (red or green) for a given tick species had at least six ticks or two life stages recorded within a single calendar year. Counties with fewer ticks of a single life stage were classified as reported (blue or yellow) for the tick species. Counties shown in white indicate "no records."

have proceeded in a southwesterly direction in Virginia, concordant with the expanding geographic distribution of Lyme disease cases and increasing incidence in Virginia (Brinkerhoff et al. 2014, Lantos et al. 2015). Comparison of the previous and current distributions of *I. scapularis* in North Carolina also suggests an inland incursion of the tick (Fig. 1). One important caveat to these findings for West Virginia, Virginia, and North Carolina is that the observed spread of *I. scapularis* may have resulted from southerly spread of *I. scapularis* from states to the north where this tick is more prone, as compared with southern populations, to seek hosts openly from vegetation (Arsnoe et al. 2015) and therefore is more readily contacted by tick dragging or flagging (Diuk-Wasser et al. 2006), or by humans and their pets (Stromdahl and Hickling 2012). Stated differently, this may be an invasion of more easily surveyed northern populations of *I. scapularis* rather than invasion at the species level in areas where more cryptic southern populations already may have been present but had not been recognized. Regardless, the end result is range expansion of *I. scapularis* populations that commonly contact and bite humans in West Virginia, Virginia, and North Carolina.

The Allegheny Mountains to Mississippi Valley Area

The authors (Dennis et al. 1998) of the previous survey were intrigued with the lack of *I. scapularis* records, despite collection efforts, from the Allegheny Mountains to the Mississippi Valley (an area spanning western Pennsylvania southeastward across Kentucky and Tennessee), because of the tick's large geographical coverage in the eastern United States spanning variable climates and forested habitat types. Habitat suitability modeling suggested that the area ranged from low (Brownstein et al. 2003, Diuk-Wasser et al. 2010) to moderately suitable (Estrada-Pena 2002). Our revised distribution map shows the tick to now be established in this region, attesting to its climate and habitat suitability for *I. scapularis*. Several

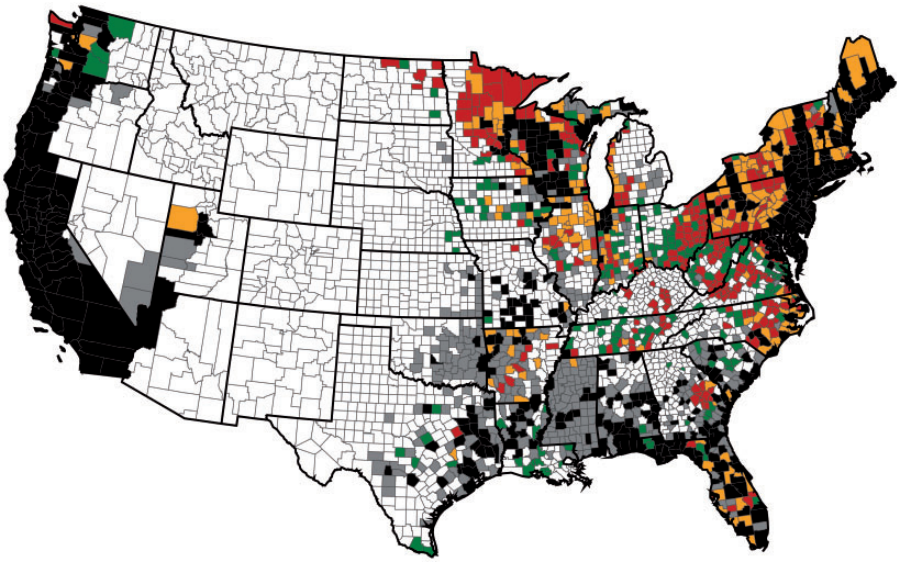

Fig. 2. Changes in county status for *I. scapularis* and *I. pacificus* from December 1996 (Dennis et al. 1998) to August 2015 (our data). Black or gray color indicates that county status already was established (black) or reported (gray) for *I. scapularis* or *I. pacificus* by Dennis et al. (1998) and considered to be the same in this study. Red or orange color indicates that the status of a county changed from no records to established (red) or from reported to established (orange). Green color indicates that the status of a county changed from no records to reported.

studies have documented a trend in which the tick expands along riparian corridors (Cortinas et al. 2002, Cortinas and Kitron 2006, Rand et al. 2007, Hamer et al. 2010, Serra et al. 2013, Kelly et al. 2014, Khatchikian et al. 2015). This provides a hypothesis for how the area from the Allegheny Mountains to the Mississippi Valley could have been or is currently being invaded from areas to the north and east with already established tick populations, first along distinct dispersal corridors followed by more diffuse short-range tick dispersal to suitable habitats across the landscape.

The Southeast

In contrast to the observed concordance between the reported distributions of *I. scapularis* and human Lyme disease in the North-Central, Northeastern, and Mid-Atlantic States, a wide distribution of this tick vector in the Southeast is not similarly associated with widespread Lyme disease case occurrence (Mead 2015). Lack of concordance in the Southeast could arise for several reasons. First, our map displays a coarse, county-scale representation of where the tick is classified as reported or established. The advantage of the county-scale representation is that it matches the spatial scale at which epidemiological surveillance data are presented. However, in some instances, the vector tick may be established only in limited areas of a particular county, putting very few humans at risk for exposure to tick bites (Eisen and Eisen 2007, Eisen and Eisen 2008). Second, while the presence of at least one tick vector species is a prerequisite for sustaining enzootic transmission of *B. burgdorferi*, density of *B. burgdorferi*-infected host-seeking nymphs of a species that commonly bite humans is a better surrogate for human risk of exposure to Lyme disease spirochetes compared with tick presence data alone. At coarse spatial scales such as states or regions of the United States, density of infected *I. scapularis* nymphs is significantly and positively associated with Lyme disease incidence (Mather et al. 1996, Stafford et al. 1998, Pepin et al. 2012).

A recent systematic field survey of *I. scapularis* revealed that both the density of host-seeking *I. scapularis* nymphs and their rate of infection with *B. burgdorferi* generally were greater in the northern compared with southern states (Diuk-Wasser et al. 2012). This is in agreement with field studies indicating that *I. scapularis* larvae feed primarily on white-footed mice, *Peromyscus leucopus* Rafinesque, and other small, highly reservoir-competent mammals in the northeast (Spielman et al. 1985, Giardina et al. 2000), whereas they feed frequently on lizards of, at best, low reservoir-competence for *B. burgdorferi* in the southeast (Apperson et al. 1993). Moreover, the tick's host-seeking behavior differs between northern and southern states, such that collection of *I. scapularis* nymphs by drag sampling (Diuk-Wasser et al. 2006) or from humans (Stromdahl and Hickling 2012) is rare in the south but commonplace in the north. Variable contact rates between humans and nymphal ticks resulting from regional differences in host-seeking behavior could, in large part, explain regional differences in Lyme disease incidence between the northern and southern parts of the eastern United States (Diuk-Wasser et al. 2012, Stromdahl and Hickling 2012, Kelly et al. 2014, Arsnoe et al. 2015). A recent experimental field study showed differences in host-seeking behavior between *I. scapularis* of northern versus southern origin, such that ticks of northern origin were more likely to ascend vegetation while questing for a host, regardless of whether field release arenas were located in the north or south, suggesting that host-seeking behavior is strongly determined by genetics and to a lesser extent by environmental conditions (Arsnoe et al. 2015). Indeed, population genetic studies show two distinct clades, with the southern clade restricted to the south and the so-called American clade predominant in the north (Norris et al. 1996, Qiu et al. 2002, Humphrey et al. 2010, Van Zee et al. 2013, Sakamoto et al. 2014).

The Far-Western States

The recorded county-level distribution of *I. pacificus* has changed very little since the previous survey (Dennis et al. 1998). The tick is established primarily in coastal states along the Pacific Ocean (Washington, Oregon, and California), but also can occur locally in especially cool or moist settings in more arid inland states (Arizona, Nevada, and Utah). In contrast to *I. scapularis*, few studies have

sought to define the environmental variables that define the distribution of *I. pacificus* (Eisen et al. 2006b). Owing in part to sizeable western counties commonly encompassing vast ecological diversity, often with only a portion of a given county presenting risk for human exposure to *I. pacificus*, there is a lack of concordance between the vector's range as defined at the county level and the incidence of Lyme disease. For example, in California, although the tick is established in all but three counties, Lyme disease incidence is highest in north-coastal counties (Eisen et al. 2006b). Although *B. burgdorferi*-infected host-seeking nymphs may be established in limited regions of counties, few humans may be exposed (Eisen et al. 2006b). In addition, densities of host-seeking *I. pacificus* appear to be much lower in southern (Lane et al. 2013) compared with northern California (Eisen et al. 2006a). Likewise, infection rates with *B. burgdorferi* also appear to be lower in host-seeking nymphs from southern compared with northern California (Eisen et al. 2010, Lane et al. 2013).

Future Research Needs

The data presented and discussed here provide strong support for systematic sampling to assess the density of host-seeking *I. scapularis*, and the density of nymphs infected with *B. burgdorferi* and other *I. scapularis*-borne human pathogens, in strategic areas where the tick can be expected to invade or increase dramatically in numbers in the near future. We also recognize needs for: 1) improved regional habitat suitability models to better define the likely extent for continued expansion of *I. scapularis*; 2) population genetic studies aimed at identifying changes in the geographic range of the American clade of *I. scapularis*, especially in areas previously dominated by the southern clade such as Virginia, and North Carolina where American clade invasion likely results in increased human tick bites; and 3) longitudinal studies aimed at identifying how the convergence of the North-Central and Northeastern tick foci may result in changes in *B. burgdorferi* genotypes (Pepin et al. 2012), particularly those most likely to cause disease in humans, in the convergence area itself as well as across the North-Central and Northeast states.

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