Lyme disease: ecology and emergence

Context

- 1975: a resident of Old Lyme, CT reported to the State Health Dept that there were 12 children in the town with Juvenile Rheumatoid Arthritis
- Rheumatology Clinic@ Yale is notified of an "epidemic" of JRA in family, community
- Surveillance system set up-
  - 39 children, 12 adults identified with a "rash" of sxs
  - 17/39 children lived on one road
  - 10% of the children in a slightly wider area had symptoms

Symptoms

- Swelling in knee or other ***large*** joint x 1 wk
- Recurrence frequent
- 50%: reported nonspecific syndrome
  – Fever
  – Muscle aches (myalgias)
  – Joint pain generally (arthralgias)
  – Headache, chills, malaise
- Many noted a “circular” rash about 1 month before the symptoms

Context

- Similar syndrome known to be in Europe—
  - Erythema migrans (“moving redness”)
- Caused by bite from a tick
  - Ixodes ricinus—”sheep tick”
- Not associated with arthritis

Controversy of “chronic Lyme”

Boston
East Breakwater Ba
Providence
Hartford
Connecticut
Rhode Island
Old Lyme, CT
Fishers Island
Block Island
Fishers Island Ridge
Nantucket Sh
Long Island Sound
Gardiners Island
Block Island Ridge
New York
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Image Landsat
Data SIO, NOAA, U.S. Navy, NGA, GEBCO


Connecticut
Rhode Island
New Bedford
New Haven
Old Lyme, CT
Fishers Island
Fishers Island Ridge
Block Island
Fishers Island Furrow
Rhode Island Shelf Valley
Stamford
Long Island Sound
Gardiners Island
Block Island Ridge


Goose Island
Calves Island Bar
Calves Island
Old Lyme, CT
Old Lyme
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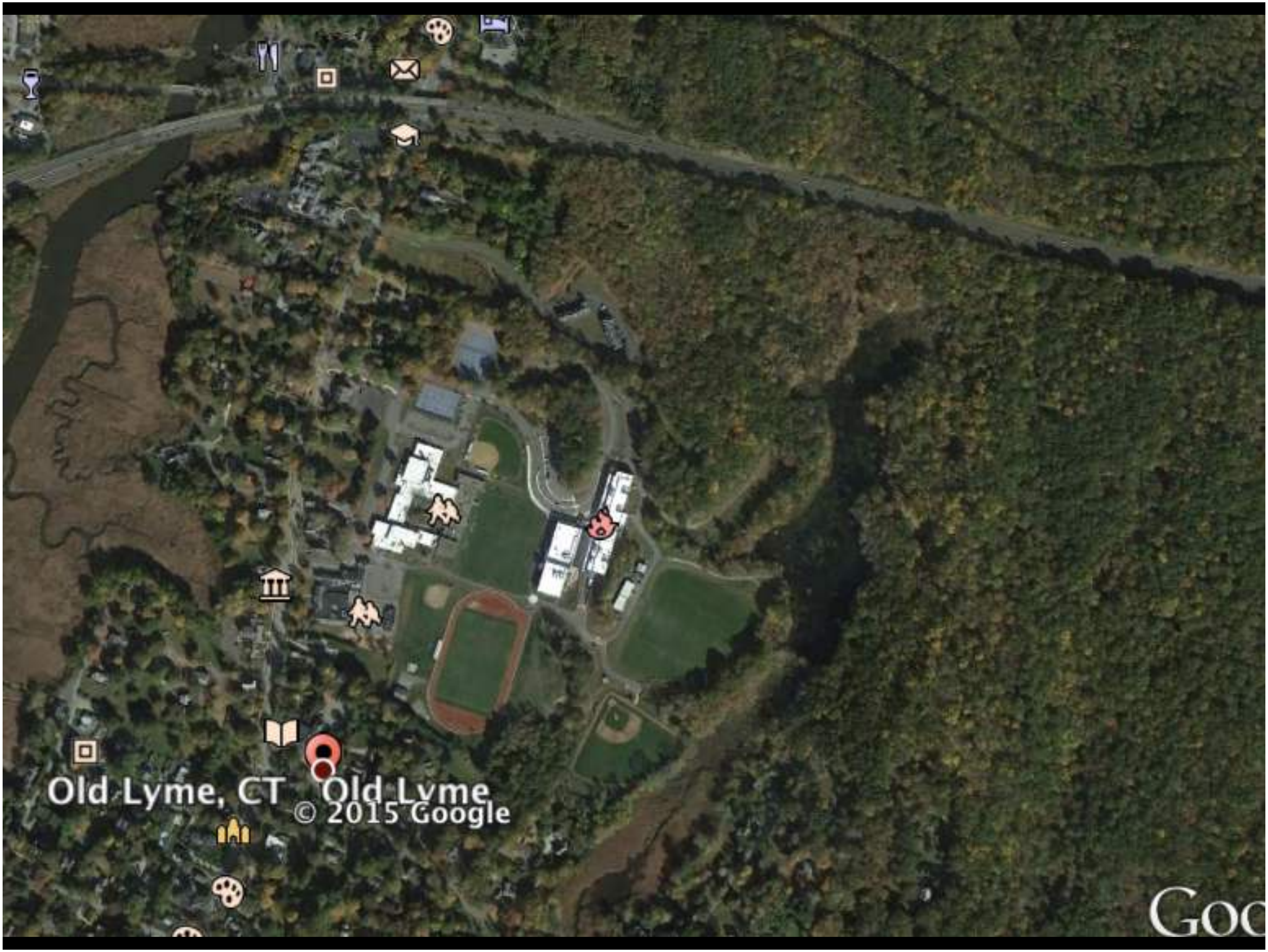
Old Lyme, CT
Old Lyme
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Back to the US

- Surveillance around Lyme CT
- Introductory lectures to population, providers
- People then went to clinics, providers
  - "passive surveillance" vs. "active surveillance"
- Incidence on one side of river: 2.8/1000
- Incidence on other: 0.1/1000
- Some remembered tick bite

(cont)

- Tick-the “deer tick” or Ixodes scapularis (conflict about whether it was called I. dammini)
- Many ticks on high prevalence side of river
- Few ticks on low prevalence side
- Entomologic survey:
  - Many ticks on Peromyscus leucopis (white footed mouse)
  - Many mature ticks on white tailed deer

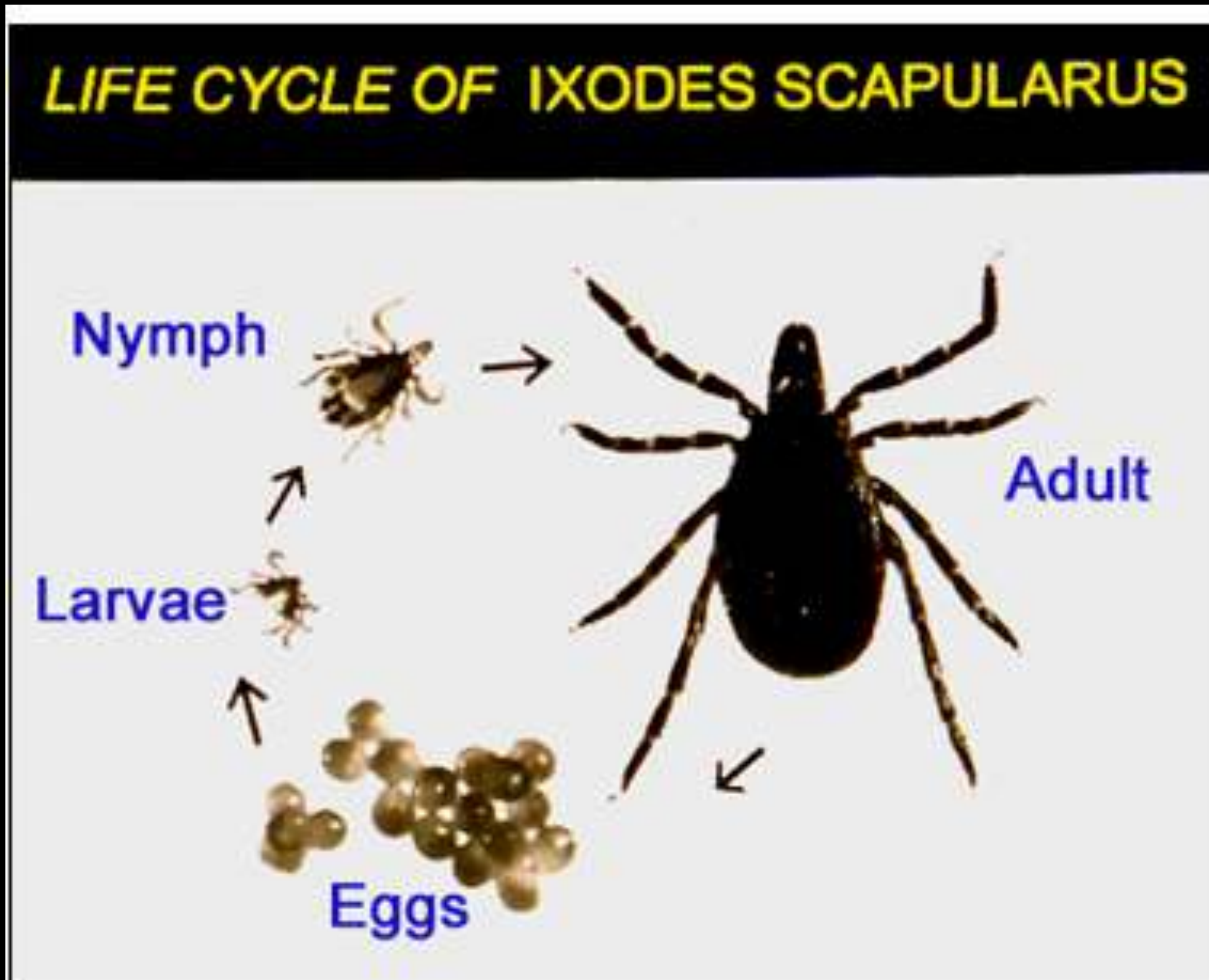
Long search for pathogen

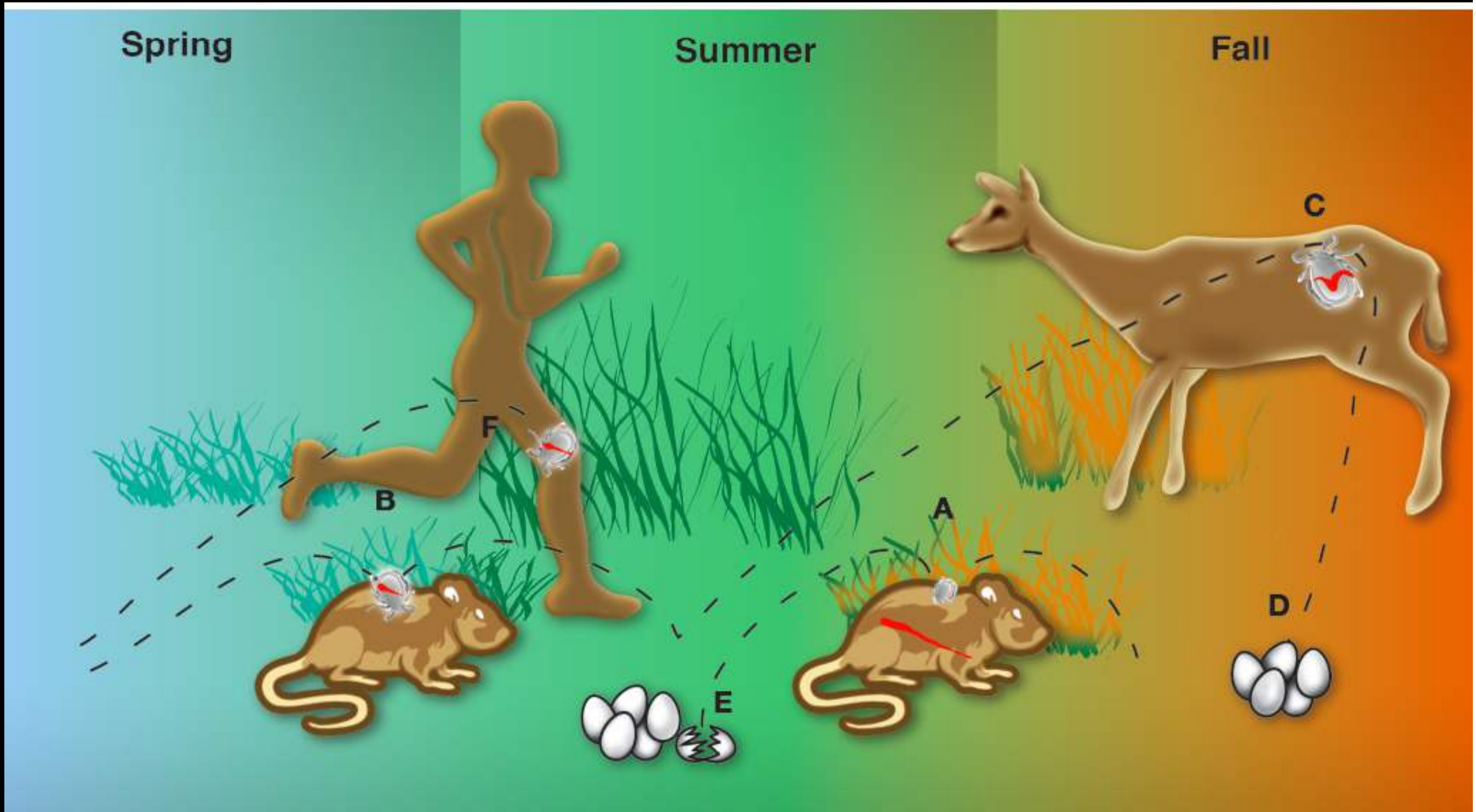
- Many techniques used w/o results
- Willy Burgdorfer, Yale—medical entomologist
  - Specialty: ticks
  - Noted bacteria in ticks
  - Assoc. with immune response in those with Lyme Disease
  - Similar to samples from Europe, late 1940s
  - Same bacterium found in patients: Borrelia burgdorferi—gram negative spirochetes

America, or was it there for thousands of years?

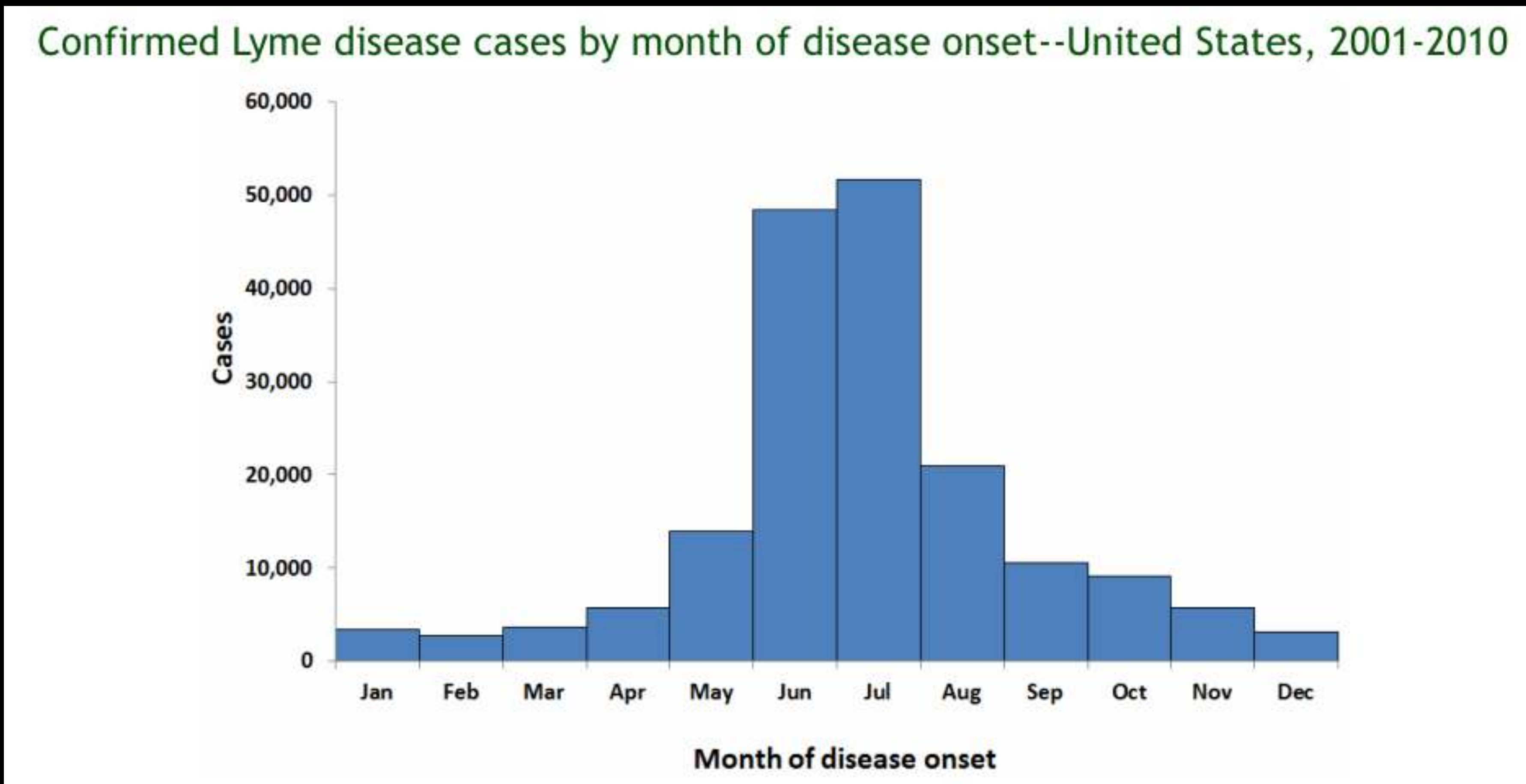
How was it imported?

ASTMH/Zaiman
"A Pictorial Presentation of Parasites"


LIFE CYCLE OF IXODES SCAPULARUS
Nymph
Adult
Larvae
Eggs

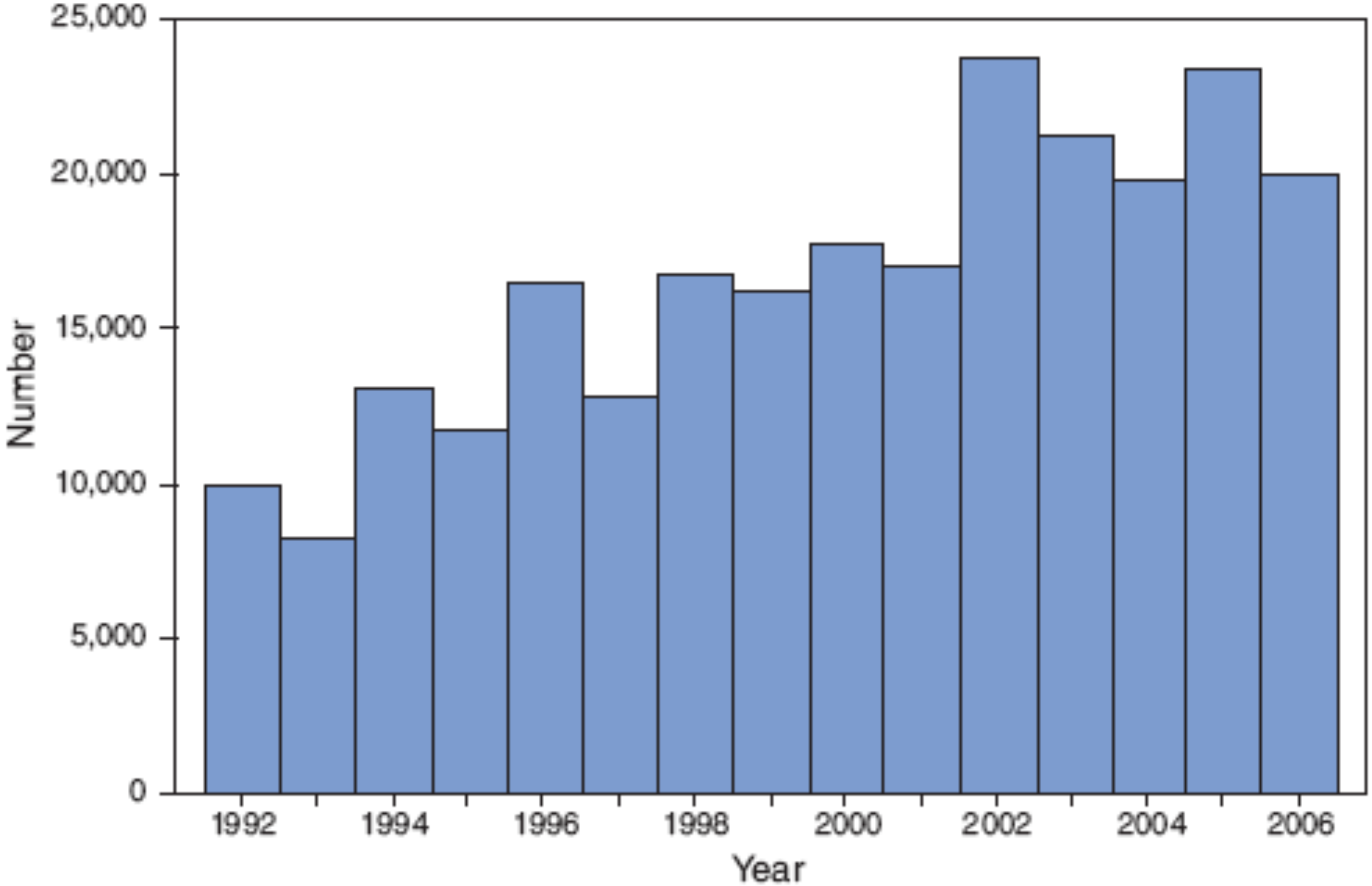


Source: Steere et al, The emergence of Lyme Disease, Journal of Clinical Investigation 2004; 113:1093-1101


Confirmed Lyme disease cases by month of disease onset--United States, 2001-2010
60,000
50,000
40,000
30,000
20,000
10,000
0
Cases
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month of disease onset

Source: CDC

FIGURE 1. Number* of reported Lyme disease cases, by year — United States, 1992–2006



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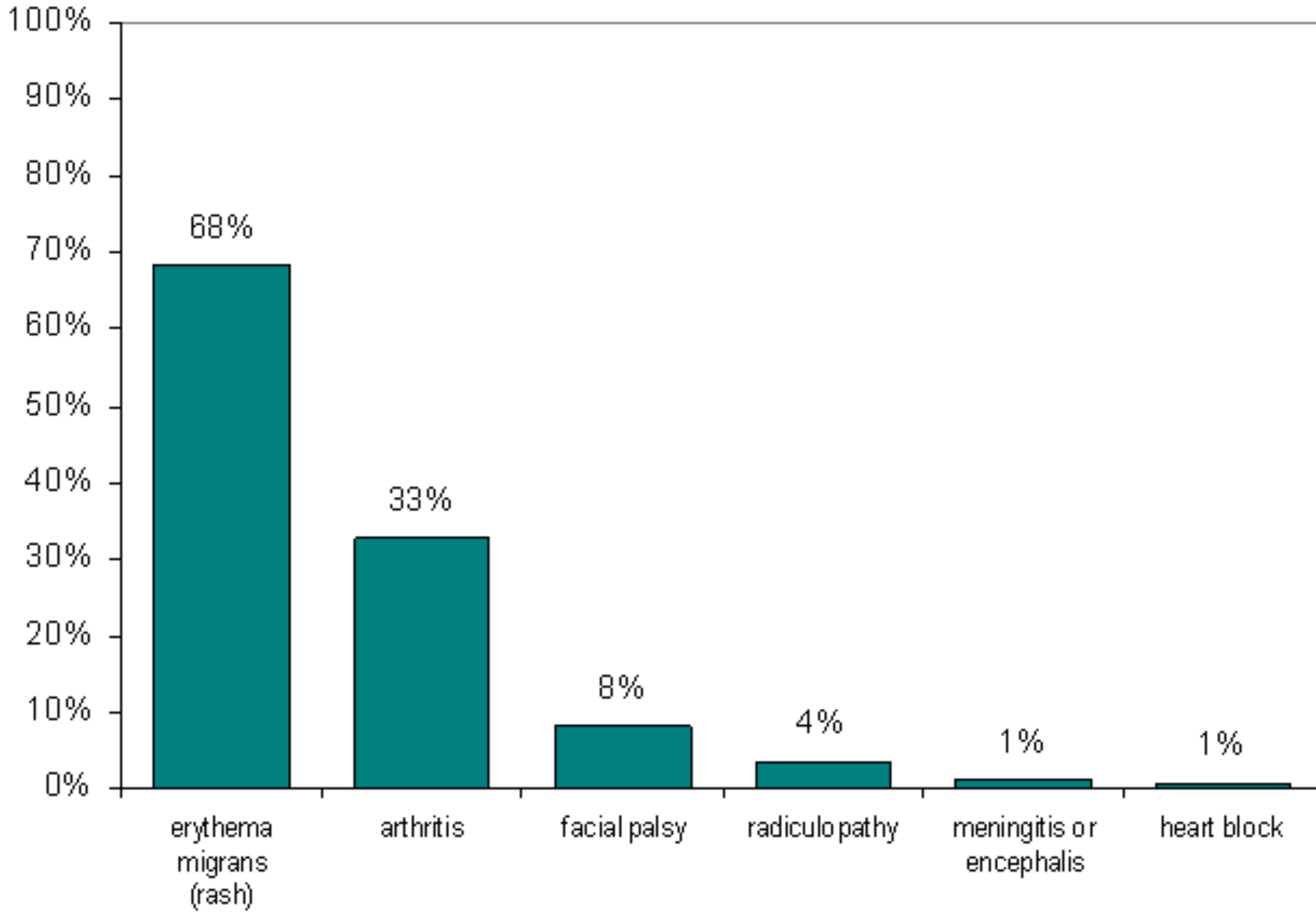
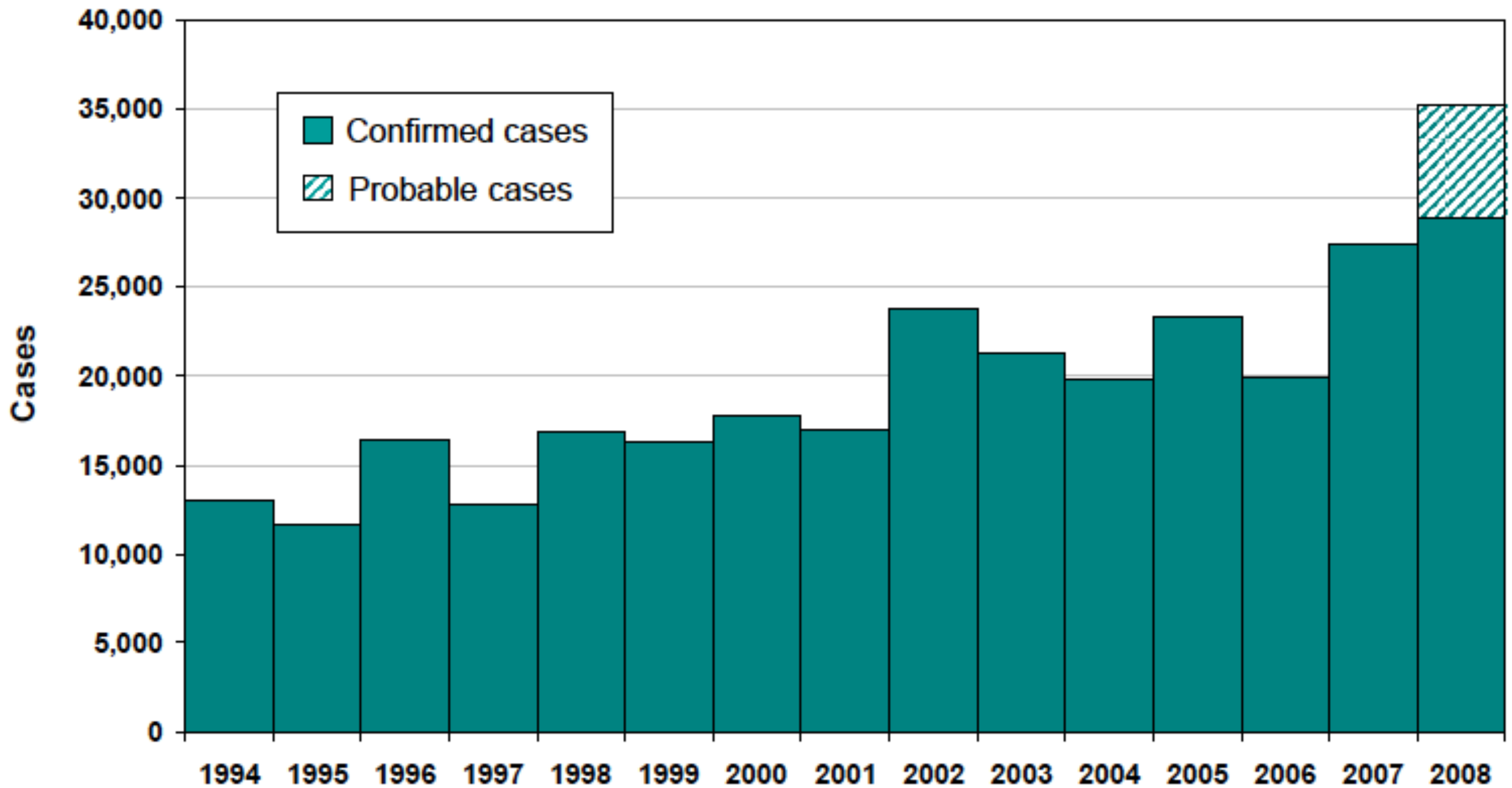
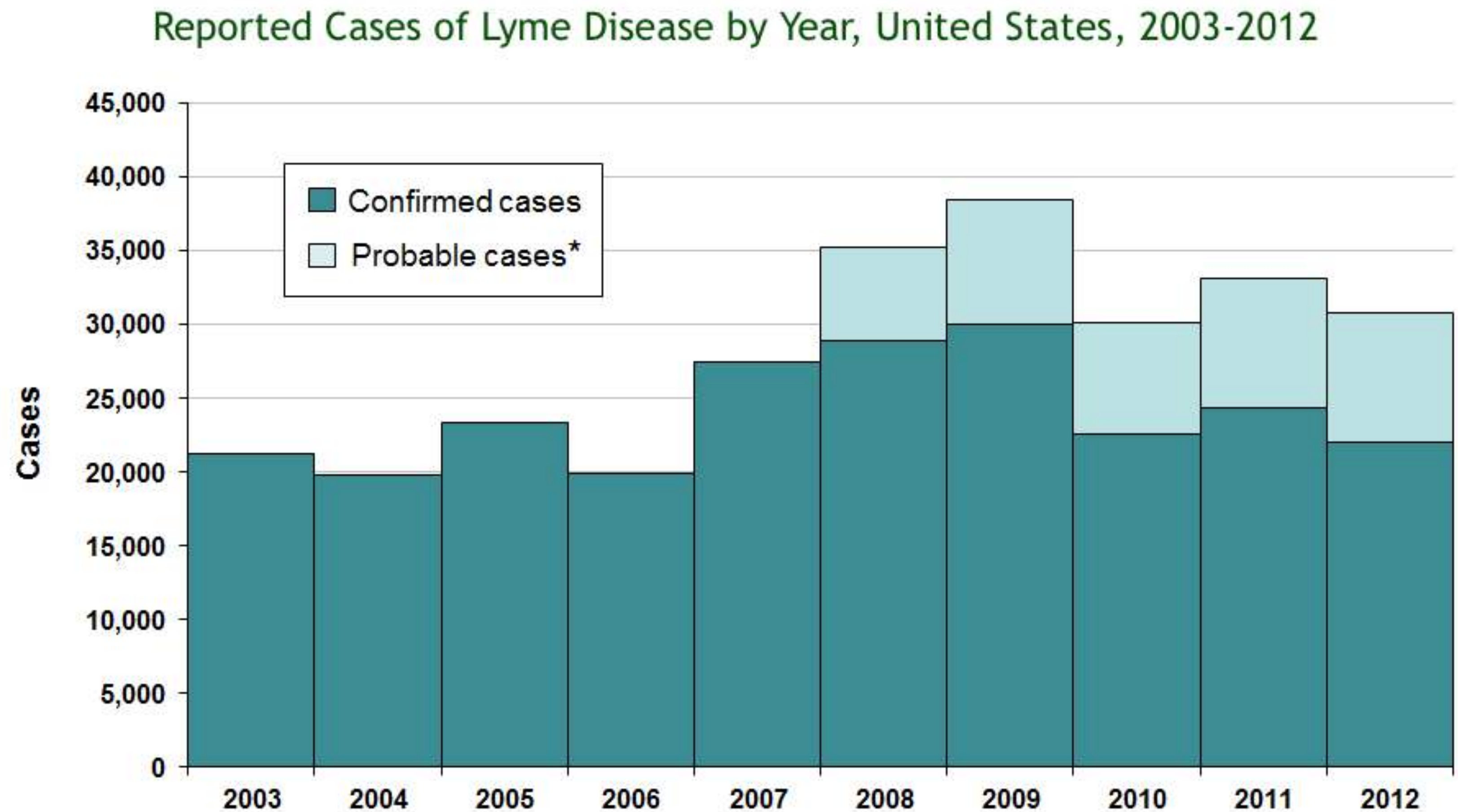
Reported Clinical Findings Among Lyme Disease Patients, 1992-2004



Reported Cases of Lyme Disease by Year, United States, 1994-2008



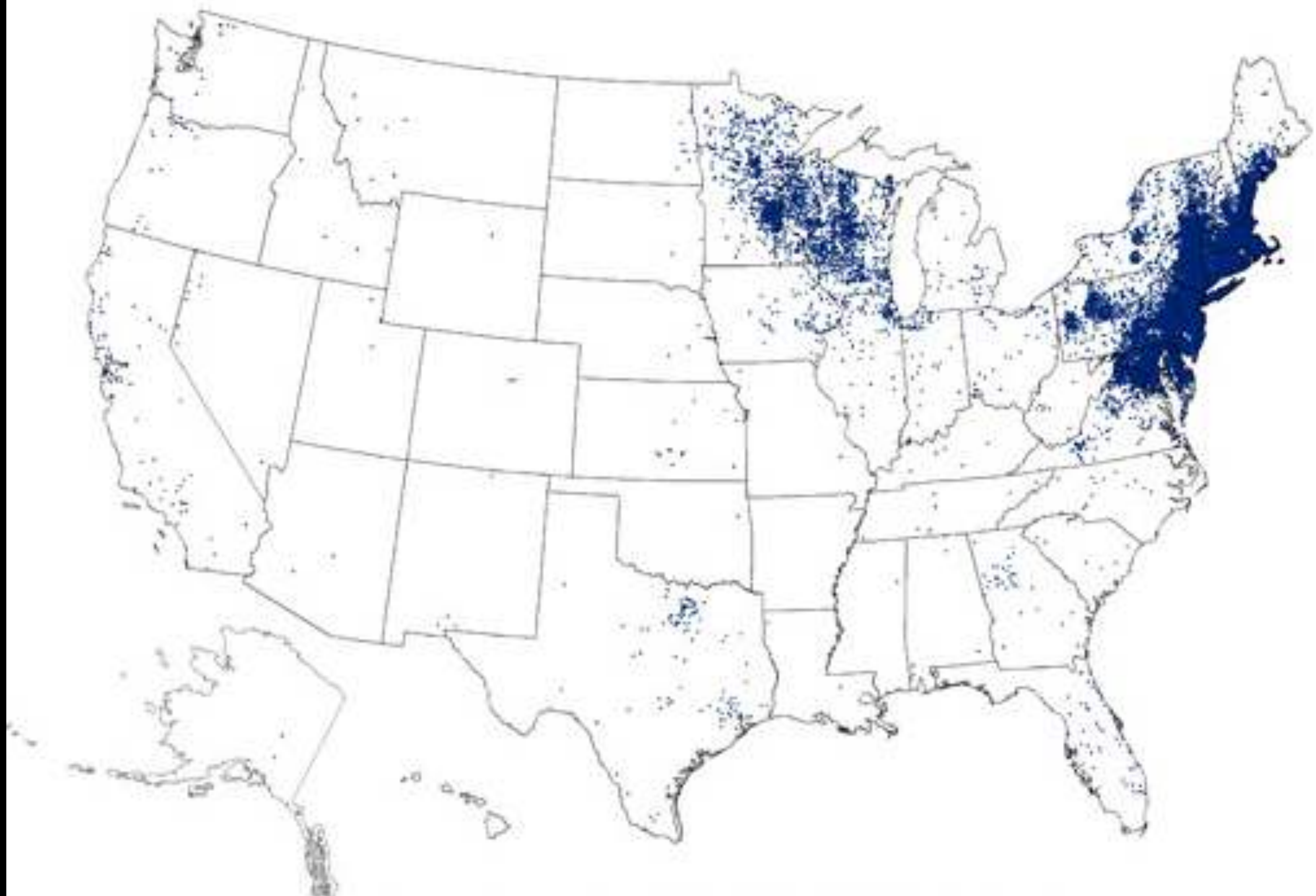
State health departments reported 28,921 confirmed cases and 6,277 probable cases of Lyme disease to CDC in 2008. This represents a 5% increase in confirmed cases compared to 2007. The definition and reporting of probable cases was initiated in 2008 based on revisions to the national surveillance case definition.



The graph displays the number of reported cases of Lyme disease from 2003 through 2012. The number of confirmed cases ranged from a low of 19,804 in 2004 to high of 29,959 in 2009.

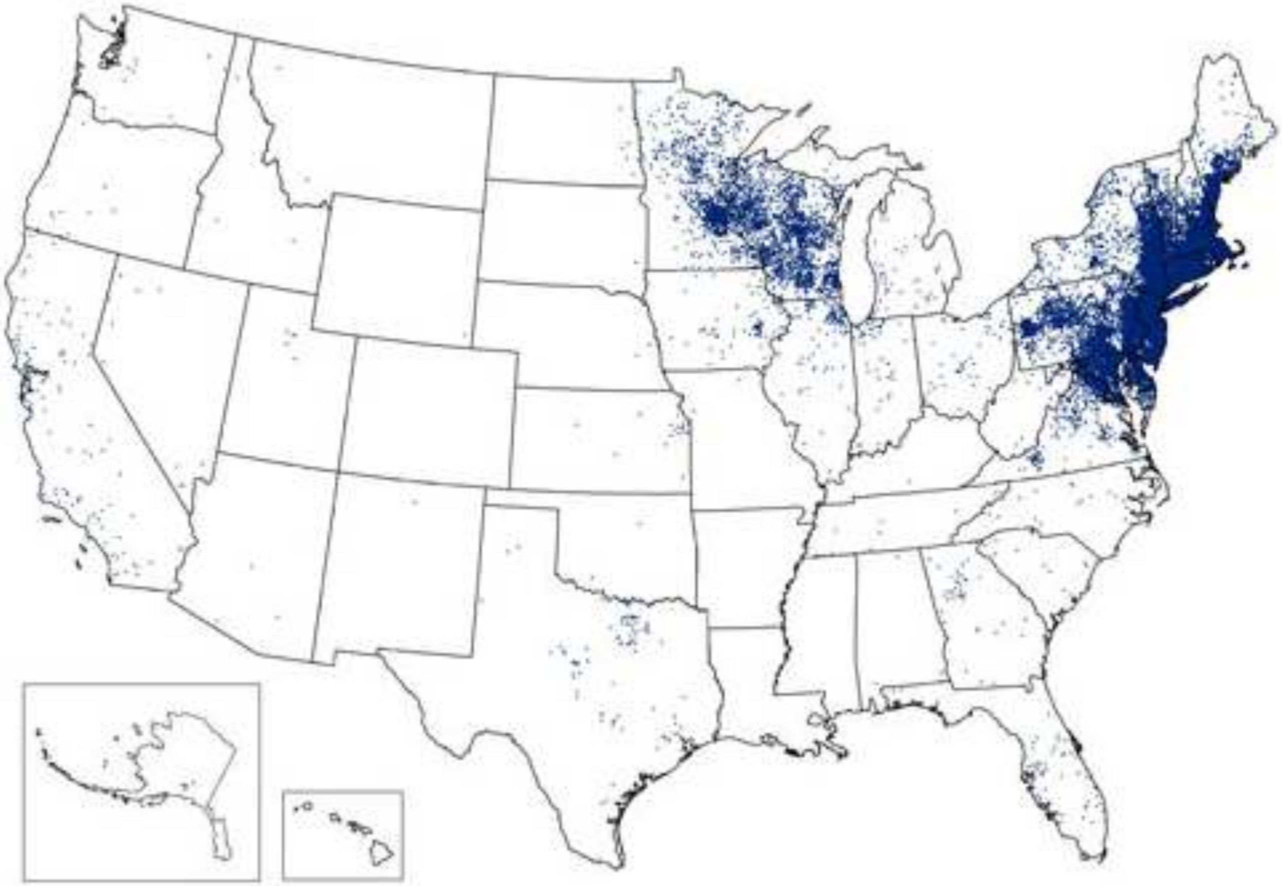
Source: CDC

Reported Cases of Lyme Disease -- United States, 2008



1 dot placed randomly within county of residence for each confirmed case

Reported Cases of Lyme Disease -- United States, 2009

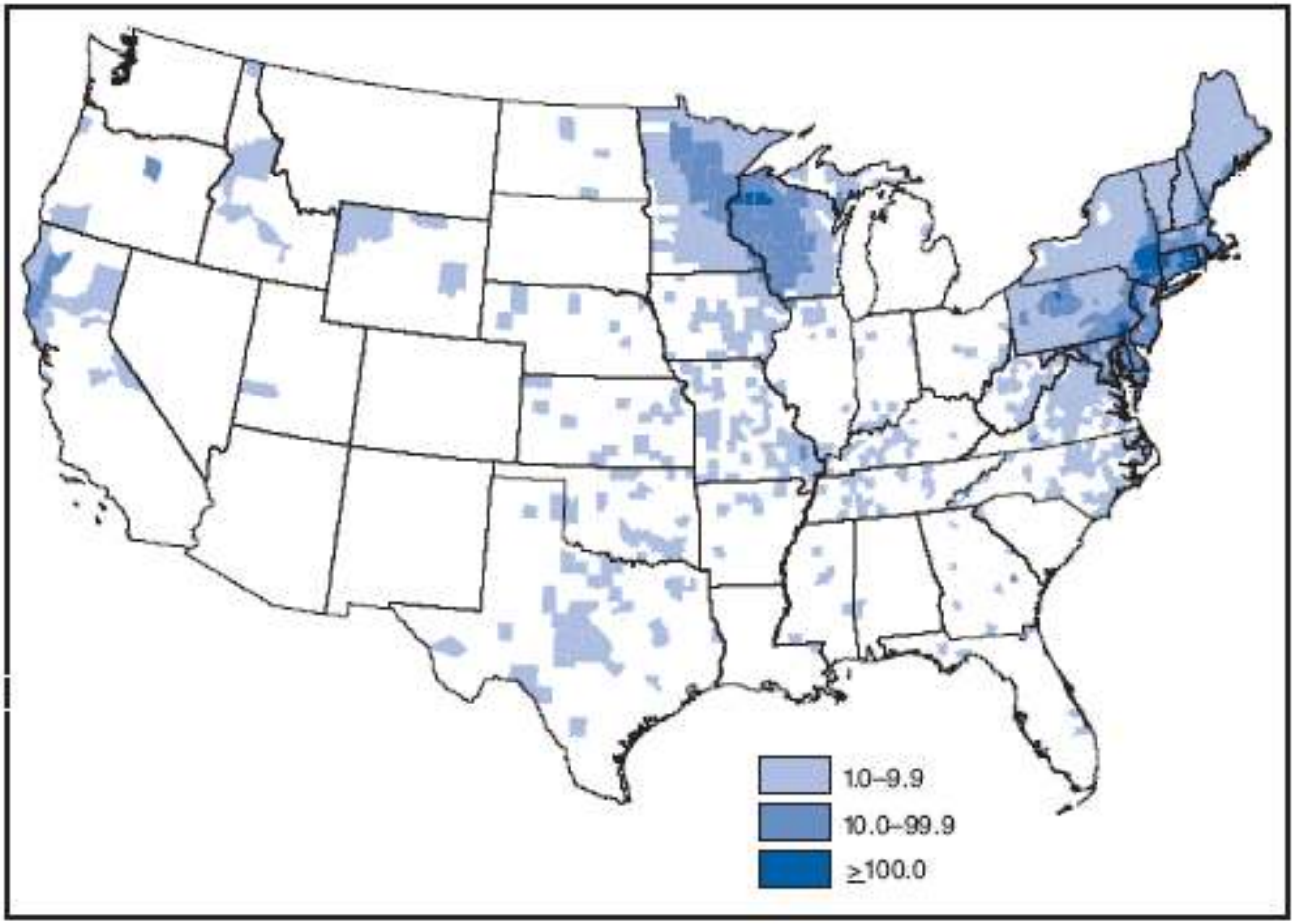


1 dot placed randomly within county of residence for each confirmed case

Reported Cases of Lyme Disease -- United States, 2011

1 dot placed randomly within county of residence for each confirmed case

FIGURE 2. Average rate* of Lyme disease, by county of residence† — United States, 1992–2006§



* Per 100,000 population.

† County of residence was available for 98.1% of cases reported during 1992–2006.

§ During 2003, Pennsylvania reported 4,722 confirmed cases and 1,008 suspected cases.

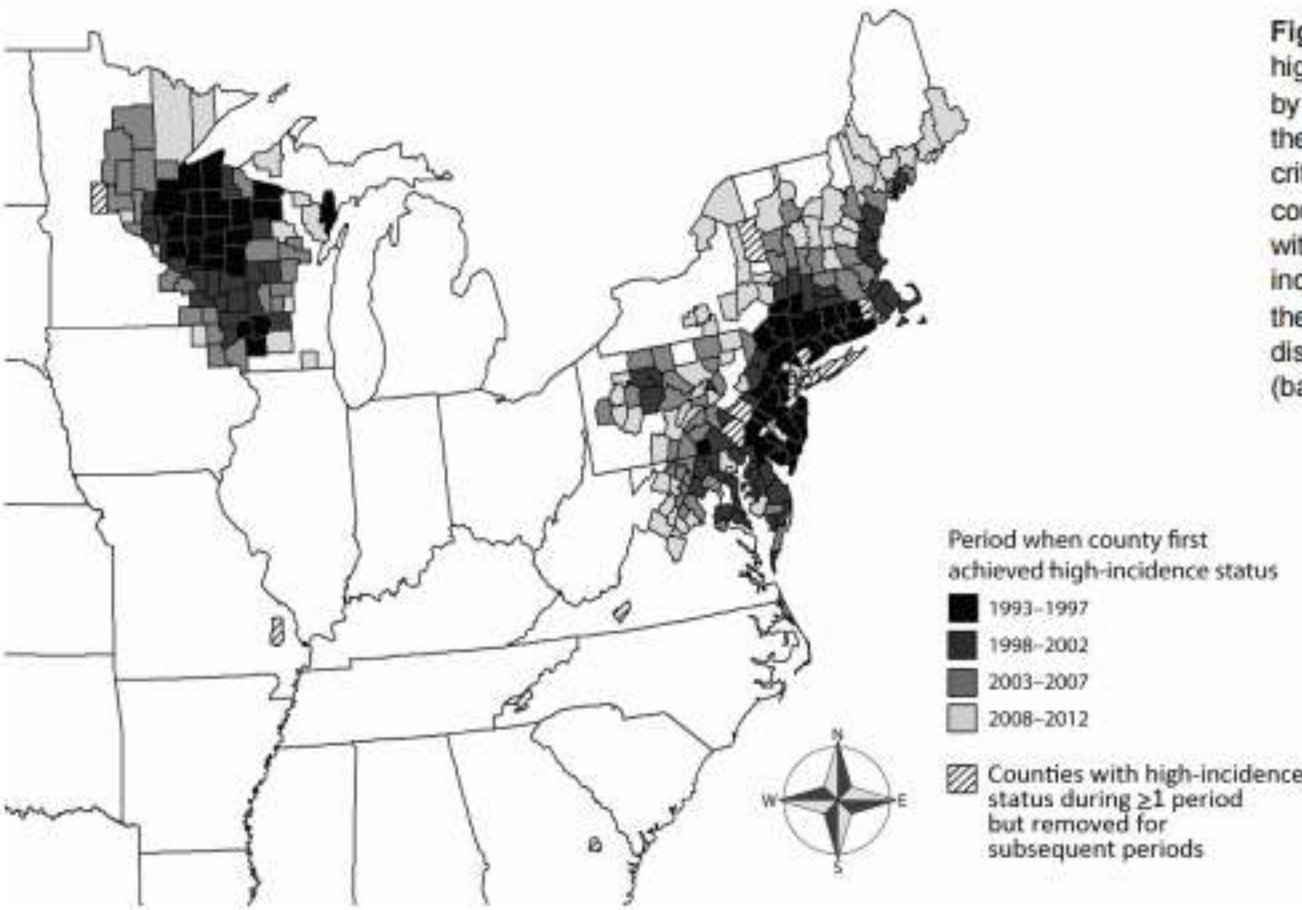


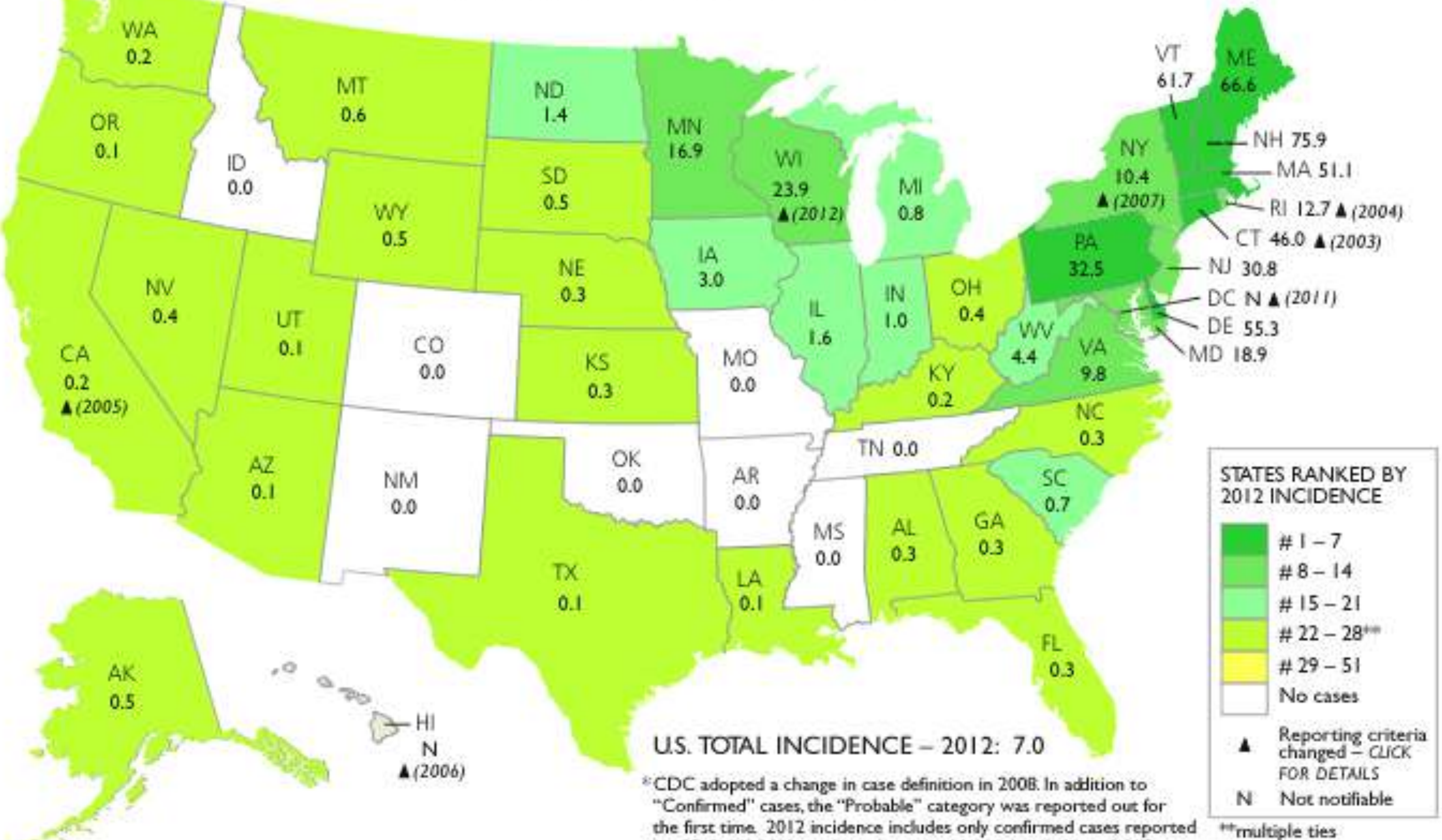
Figure. United States counties with high incidence of Lyme disease by the period when they first met the designated high-incidence criteria, 1993–2012. High-incidence counties were defined as those within a spatial cluster of elevated incidence and those with ≥2 times the number of reported Lyme disease cases as were expected (based on the population at risk).

In the north-central high-incidence focus, the geographic center remained relatively stable in northwestern Wiscon- incidence, the limited movement of the geographic centers suggests relatively constant rates of geographic expansion

SOURCE: Kugster et al, Emerg Inf Dis, 2015

LYME DISEASE INCIDENCE REPORTED BY CDC – 2012*

(cases per 100,000 population)

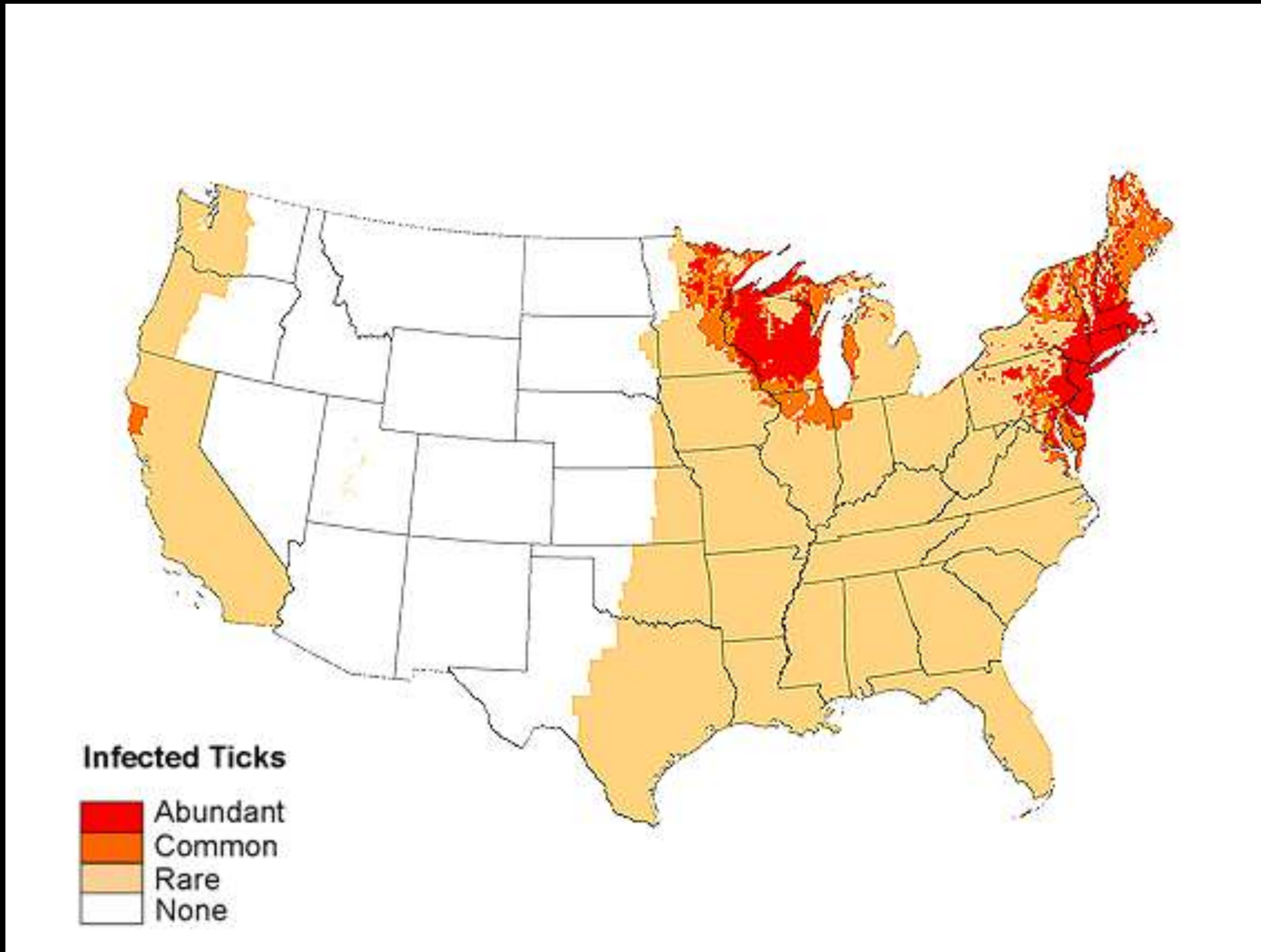


U.S. TOTAL INCIDENCE – 2012: 7.0

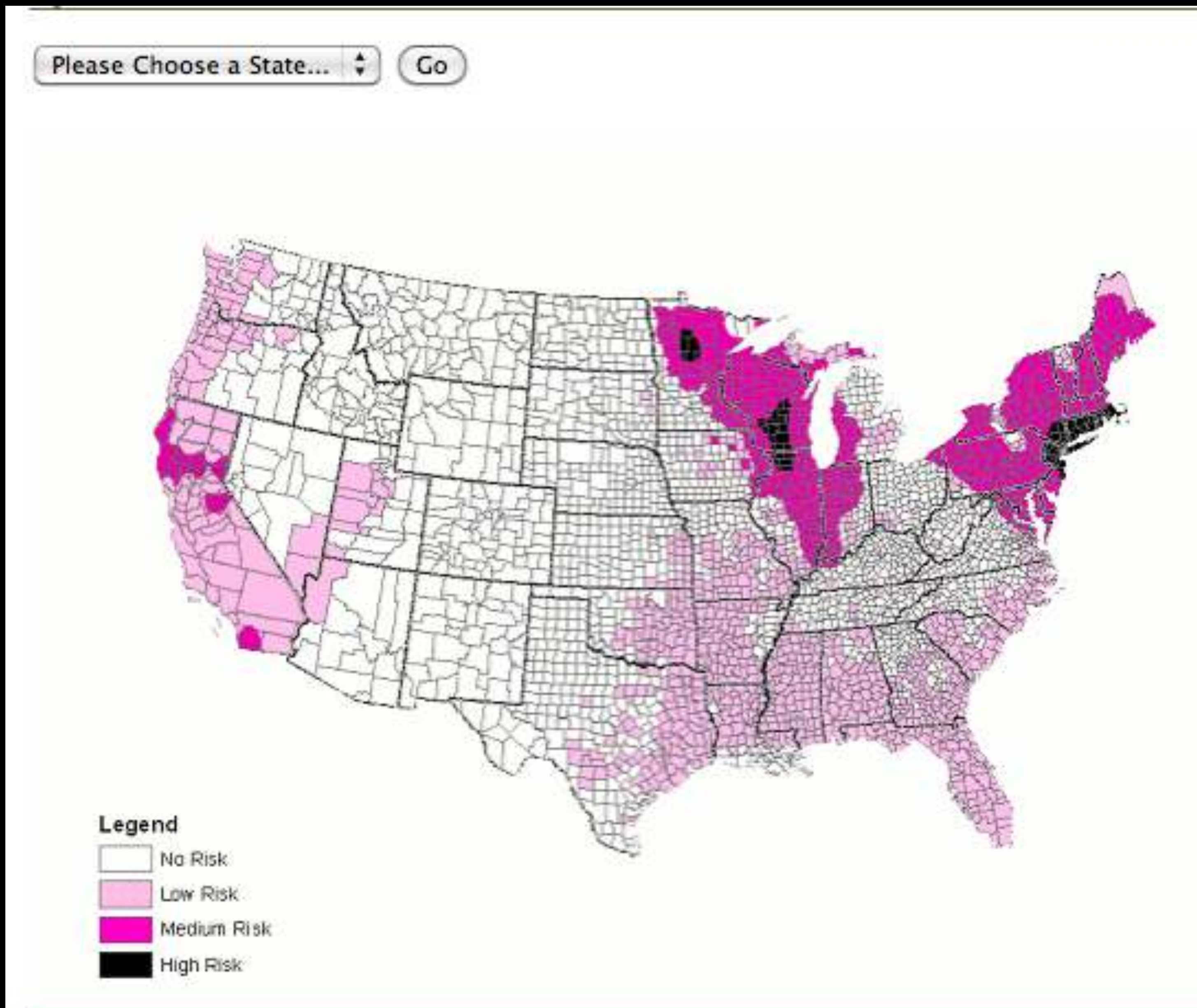
*CDC adopted a change in case definition in 2008. In addition to "Confirmed" cases, the "Probable" category was reported out for the first time. 2012 incidence includes only confirmed cases reported by CDC. US 2012 confirmed cases = 22,014 / probable = 8,817.

Source: Data compiled from CDC pub. data (DVBID)

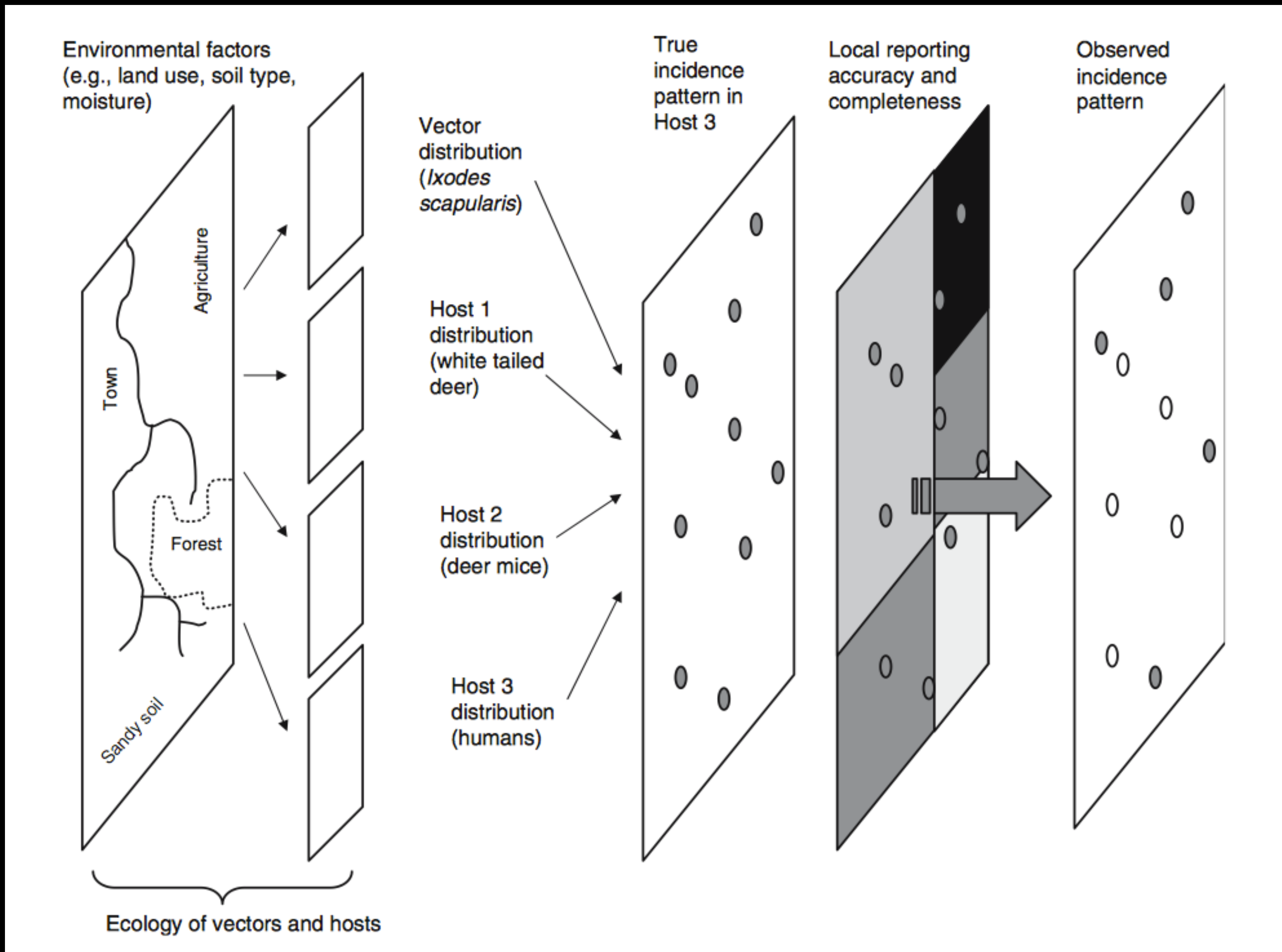
Note: According to CDC only 10% of Lyme disease cases that meet the case definition are reported, meaning incidence of 10 = likely 100 cases/100,000 meeting CDC criteria. This data does not include all the cases that fall outside the stringent surveillance case definition.



http://www.aldf.com/usmap.shtml


Please Choose a State...
Go
Legend
No Risk
Low Risk
Medium Risk
High Risk

CONCEPTS, LYME DISEASE RISK MAP



Source: WALLER, L.

[redacted]

A Climate-Based Model Predicts the Spatial Distribution of the Lyme Disease Vector *Ixodes scapularis* in the United States

John S. Brownstein, Theodore R. Holford, and Durland Fish

Department of Epidemiology and Public Health, Yale School of Medicine, New Haven, Connecticut, USA

An understanding of the spatial distribution of the black-legged tick, *Ixodes scapularis*, is a fundamental component in assessing human risk for Lyme disease in much of the United States. Although a county-level vector distribution map exists for the United States, its accuracy is limited by arbitrary categories of its reported presence. It is unknown whether reported positive areas can support established populations and whether negative areas are suitable for established populations. The steadily increasing range of *I. scapularis* in the United States suggests that all suitable habitats are not currently occupied. Therefore, we developed a spatially predictive logistic model for *I. scapularis* in the 48 conterminous states to improve the previous vector distribution map. We used ground-observed environmental data to predict the probability of established *I. scapularis* populations. The autologistic analysis showed that maximum, minimum, and mean temperatures as well as vapor pressure significantly contribute to population maintenance with an accuracy of 95% ($p < 0.0001$). A cutoff probability for habitat suitability was assessed by sensitivity analysis and was used to reclassify the previous distribution map. The spatially modeled relationship between *I. scapularis* presence and large-scale environmental data provides a robust suitability model that reveals essential environmental determinants of habitat suitability, predicts emerging areas of Lyme disease risk, and generates the future pattern of *I. scapularis* across the United States. *Key words:* autologistic model, climate matching, GIS, habitat suitability, *Ixodes scapularis*, landscape epidemiology, Lyme disease, risk maps, spatial analysis, vector-borne disease. *Environ Health Perspect* 111:1152–1157 (2003). doi:10.1289/ehp.6052 available via *http://dx.doi.org/* [Online 12 February 2003]

temperature are major causes of mortality in nonfeeding ticks because the seasonal patterns of these variables control both developmental success and rates for all stages (Needham and Teel 1991). Because 98% of the *I. scapularis* life cycle occurs off of the host, climate should play a major role in the distribution of tick populations across the United States (Fish 1993). However, the complex relationship between the tick vector and the environment hinders a detailed understanding of the ecologic constraints on the distribution of *I. scapularis*.

Moreover, there is still no consensus on the precise geographic distribution of Lyme disease in the United States because of increased human case surveillance, overdiagnosis, underreporting, and human travel. In addition, the underlying ecologic data supporting vector distribution are limited and incomplete because of uneven sampling and a lack of standardized field techniques (Dennis et al. 1998; Fish and

[redacted]

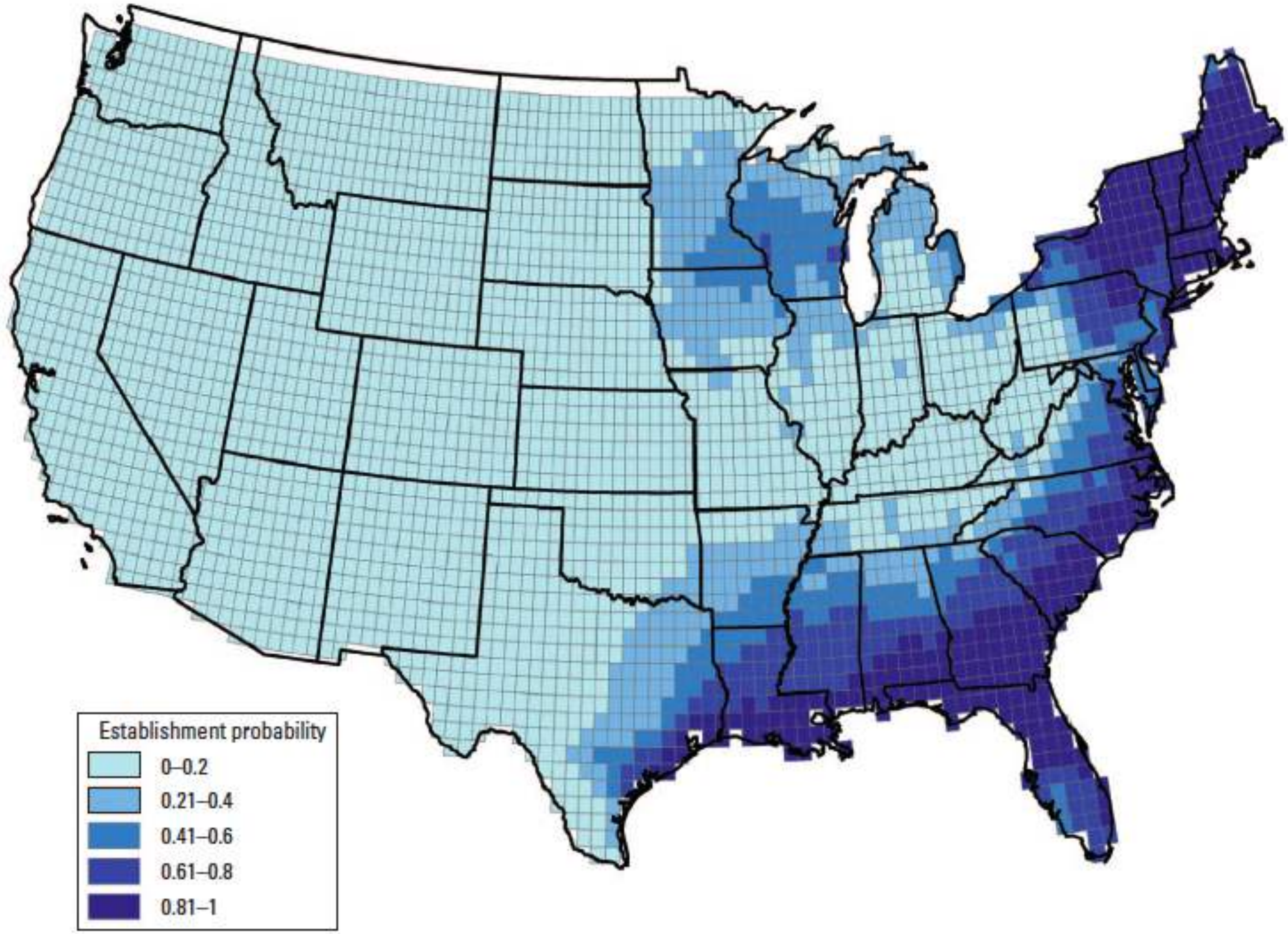


Figure 2. Probability surface for *I. scapularis* population maintenance derived from the autologistic model

LYME HABITAT SUITABILITY--

Environ Health Perspect
111:1152–1157 (2003).

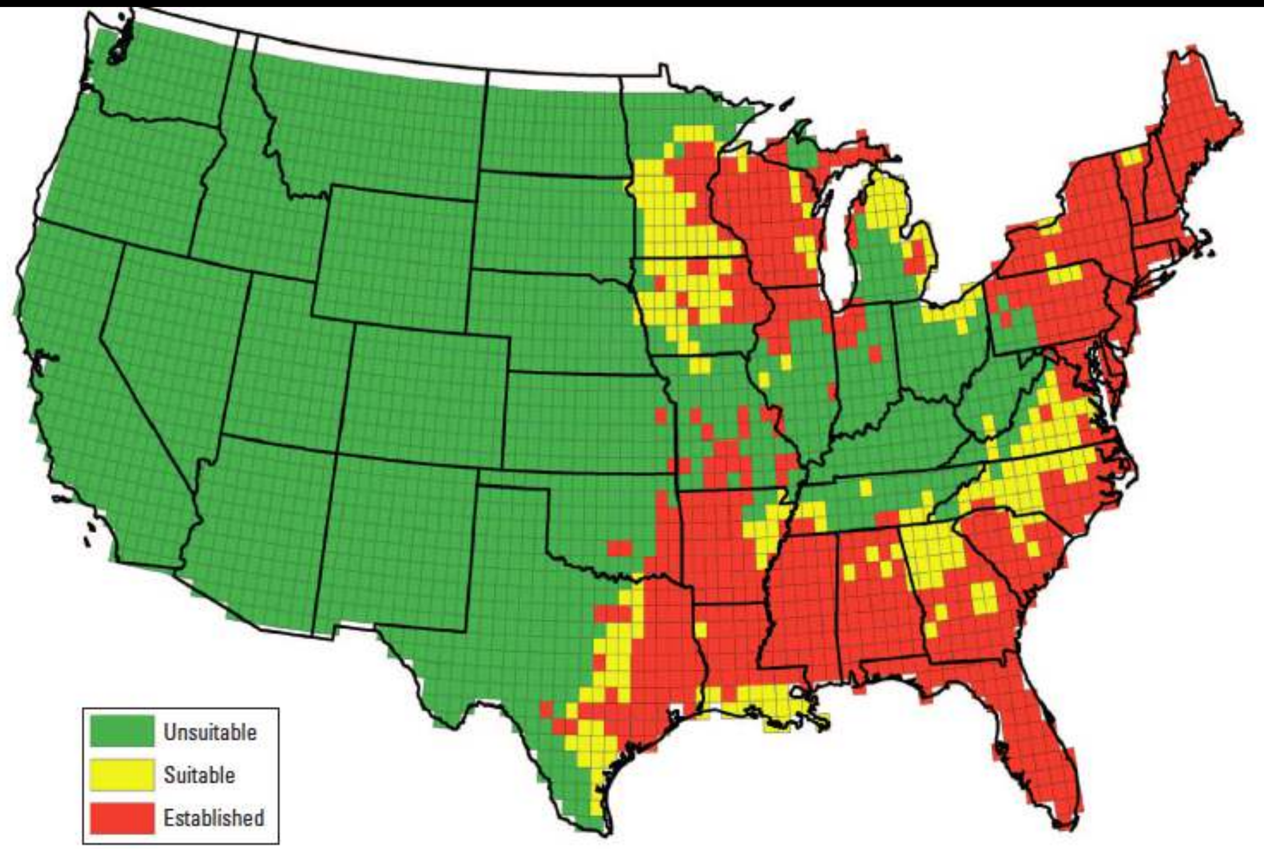


Figure 5. New distribution map for *I. scapularis* in the United States. To determine whether a given cell can support *I. scapularis* populations, a probability cutoff point for habitat suitability from the autologistic model was assessed by sensitivity analysis. A threshold of 21% probability of establishment was selected, giving a sensitivity of 97% and a specificity of 86%. This cutoff was used to reclassify the reported distribution map (Dennis et al. 1998). The autologistic model defined 81% of the reported locations (n = 427) as established and 14% of the absent areas (n = 2,327) as suitable. All other reported and absent areas were considered unsuitable. All areas previously defined as established maintained the same classification.

Fragmentation of land

- Several studies confirm
- Land fragmentation conducive to Lyme disease existence
- More fragmentation—more Lyme

What might have happened to explain Lyme?

Components in understanding

- Land
- Population
- Agriculture
- Economy
- Zoogeography
- Entomology
- And lots of other things

Emergence: IOM-1

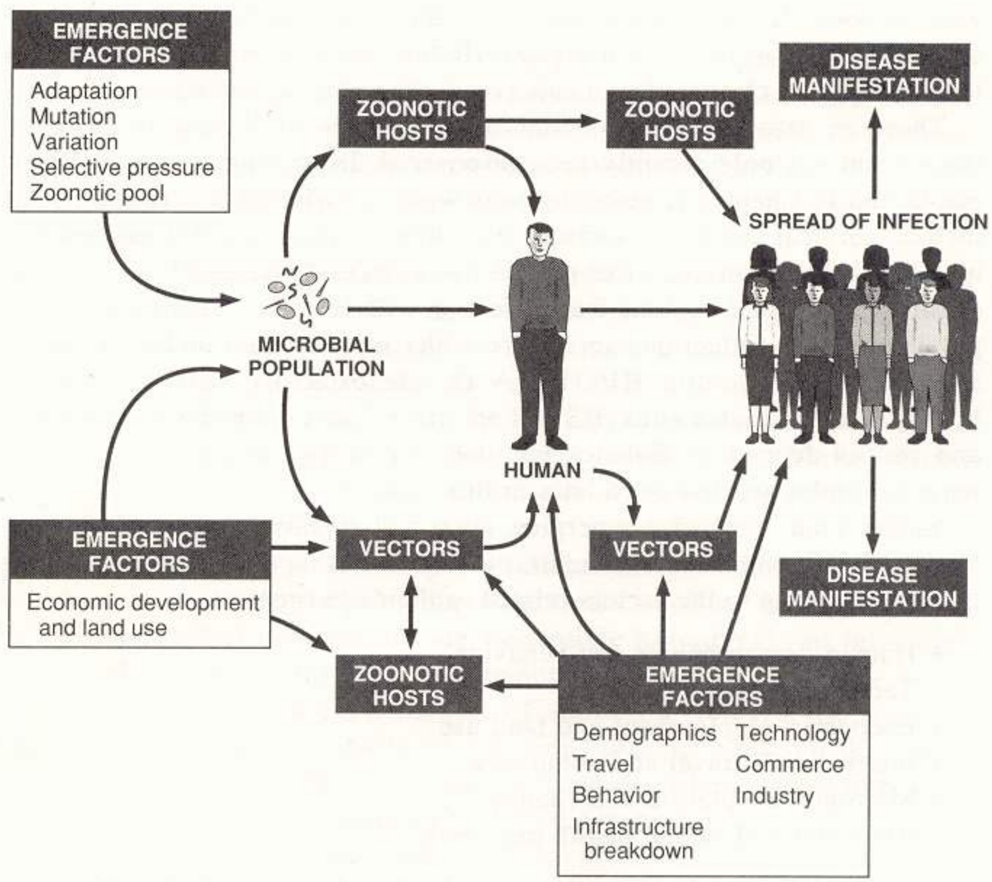
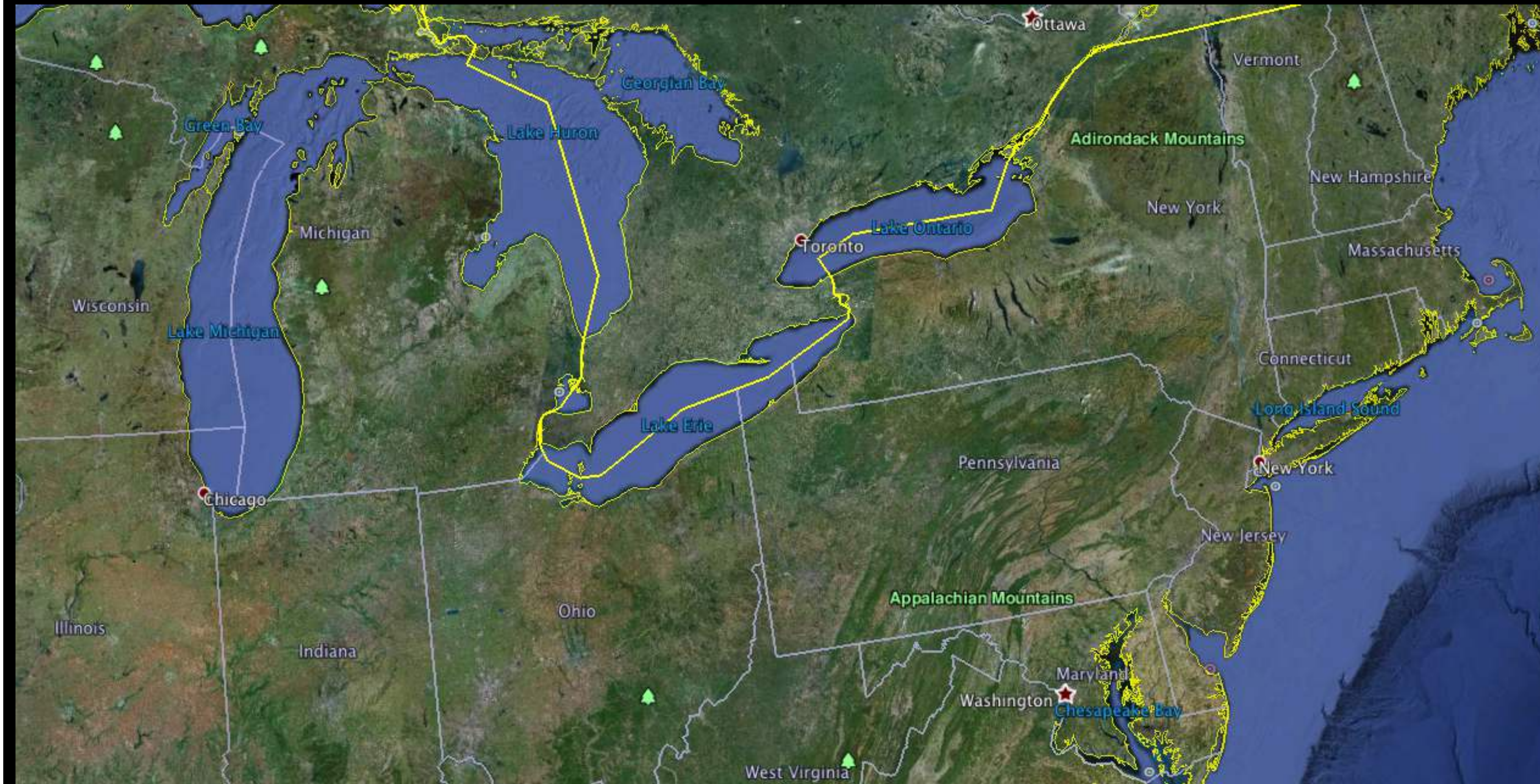


FIGURE 2-1 Schematic of infectious disease emergence.


Ottawa
Vermont
Georgian Bay
Green Bay
Lake Huron
Adirondack Mountains
New Hampshire
New York
Michigan
Lake Ontario
Toronto
Massachusetts
Wisconsin
Lake Michigan
Connecticut
Lake Erie
Long Island Sound
Pennsylvania
New York
Chicago
New Jersey
Appalachian Mountains
Ohio
Illinois
Indiana
Maryland
Washington
Chesapeake Bay
West Virginia

Steps in Distribution of Lyme disease

- Need to understand historical geography of US and Canada

European arrival

- Amerindians and Europeans both cleared land
- Agriculture and settlement

Industrialization and urbanization

- Concentration of more population in urban areas, E. seaboard
- Required agriculture from periphery
- Land clearance
- Forced deer north, and into more rural areas

- DEER ARE “EDGE DWELLERS”-interface of forest, non-forest

Next

- Increases in population
- More urbanization
- Commercial agriculture
- Agriculture moved to the north and west
- Pushed deer further north

Then.....

- Construction of railroads
- Allows suburbanization
- Land value high in center-supply and demand
- Social values: people crave larger and larger homes

Suburbs in proximity to

- Second growth forest
- Deer move to south to major population centers, forests

- People live very very close to deer-same land

CREATES CONDITIONS FOR LYME

INTERSTATE HIGHWAY SYSTEM

- Begun mid 50’s
- More or less complete by 1970