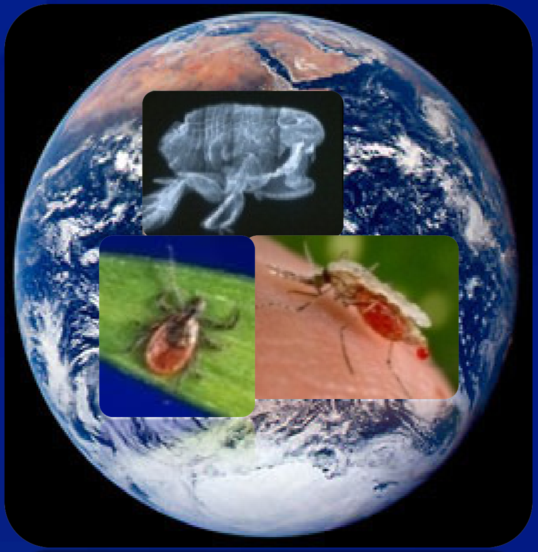
Climate Change as a Driver for Vector-Borne Disease Emergence

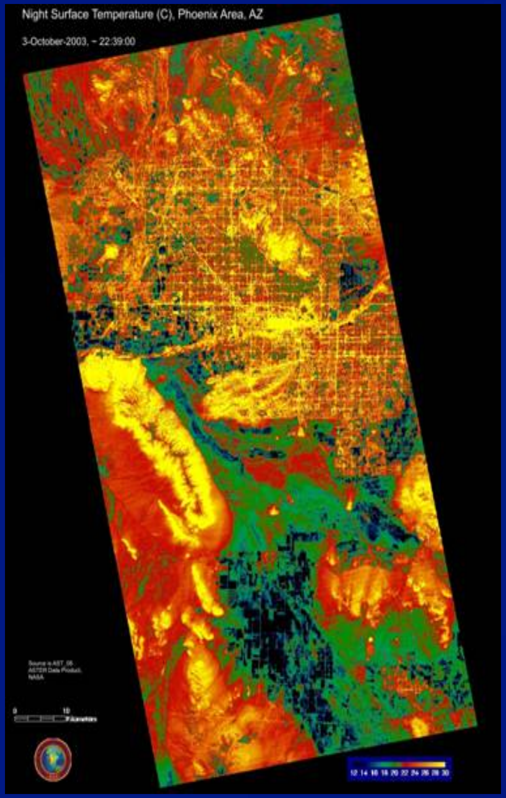


C. Ben Beard, Ph.D.
Associate Director for Climate Change
CDC- National Center for Emerging and Zoonotic Infectious Diseases
Chief, Bacterial Diseases Branch, CDC\DVBD, Fort Collins, CO

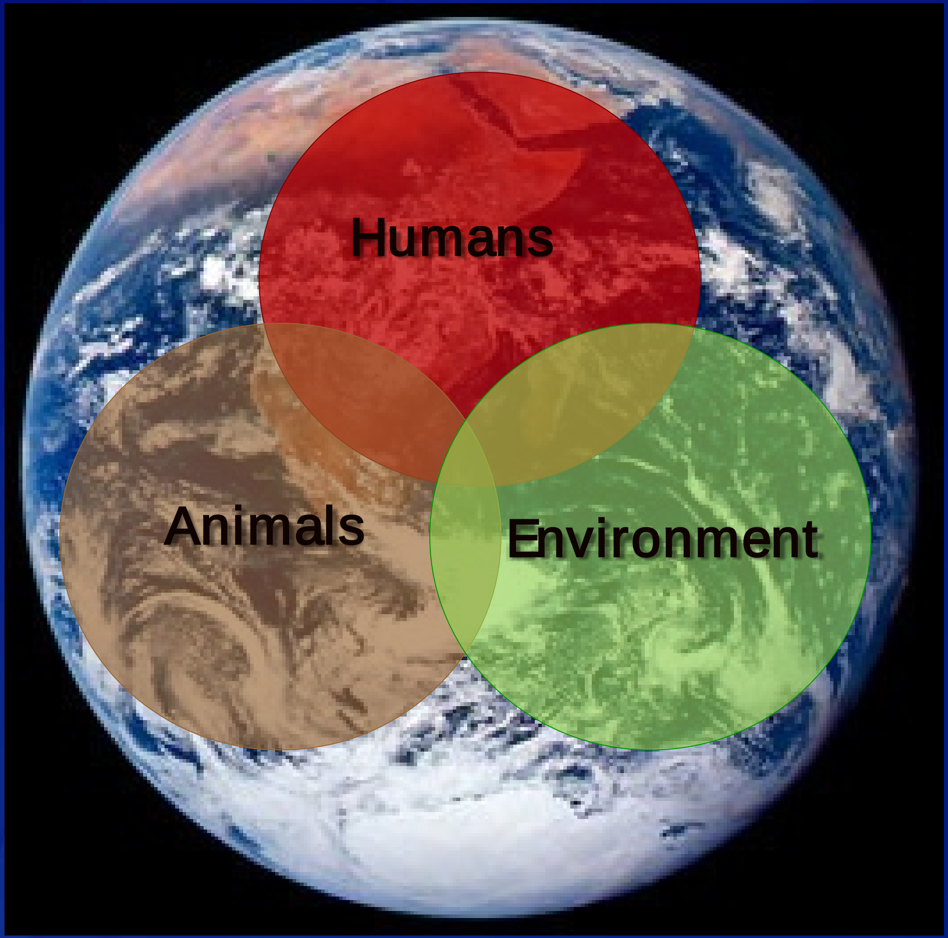
Climate Change = Climate Variability and Disruption

Increasing temperatures…

- Longer and warmer summers
- Shorter and milder winters
- Increased frequency of severe and unpredictable weather events (e.g. storms, heat waves, draughts)
- Regional variations



One World – One Health



Changes in climate lead to changes in the environment, which lead to changes in ecology, which result in changes in the incidence and distribution of diseases

Climate Change and Infectious Diseases

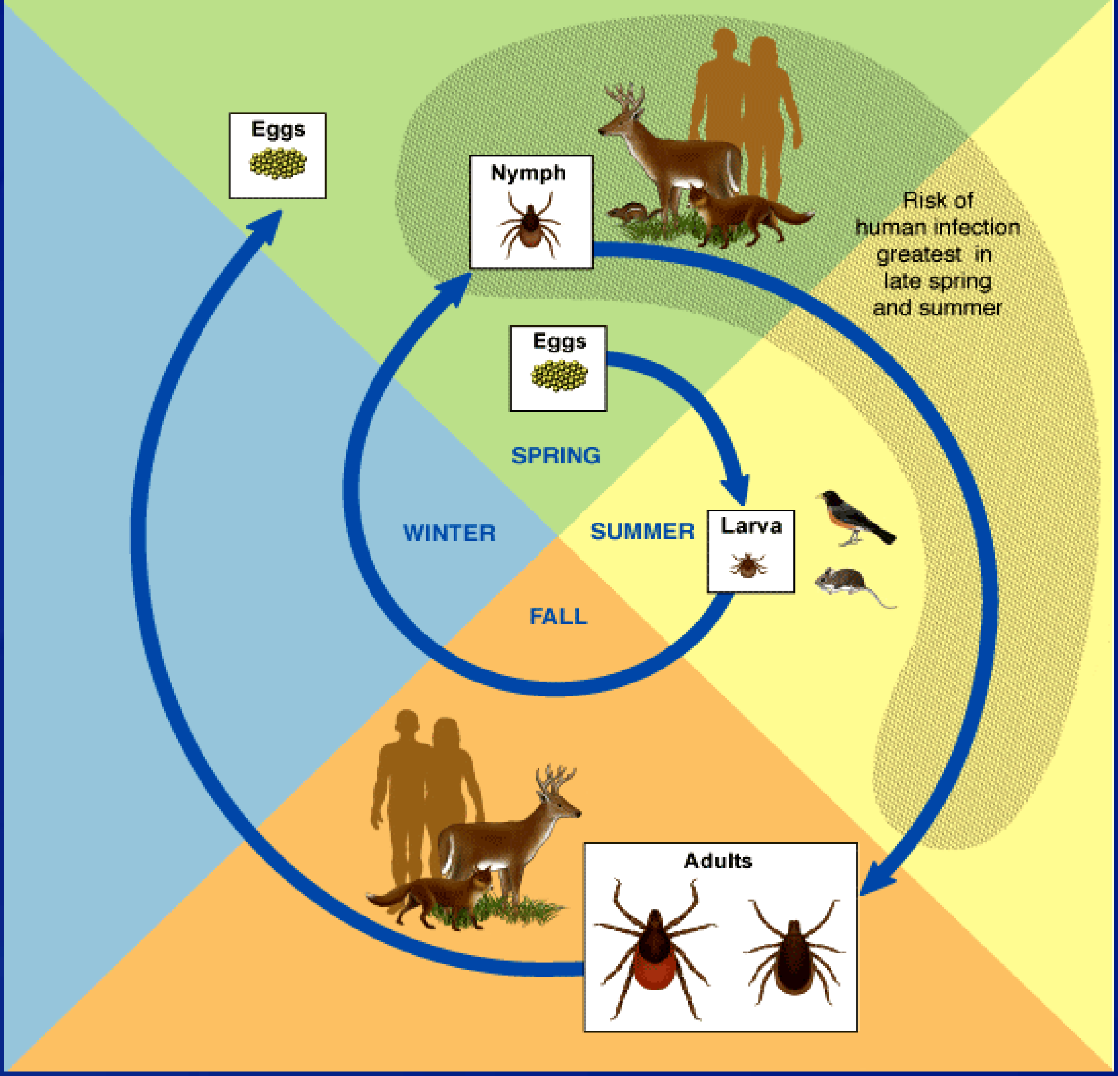
- Climate affects the distribution and abundance of vectors, hosts, and pathogens
- Climatic variables (temperature and rainfall) affect disease transmission efficiency by impacting vector-pathogen physiology, interaction, and survival
- Climatic perturbations (ex. severe storms, draughts, weather patterns, ENSO, etc.) affect disease occurrence patterns and drive disease outbreaks
- Changes in climate will result in changes in incidence and distribution of environmentally-associated diseases

Case Study – Lyme Disease in the U.S.

Lyme Disease

- Caused by the spirochetal bacterium *Borrelia burgdorferi*
- Transmitted by *Ixodes* spp. ticks
- Reservoirs for the spirochete include
  - Small mammals (field mice, squirrels, chipmunks, etc.)
  - Birds
- Hosts for the tick include
  - Small mammals (larvae & nymphs)
  - Deer and other large mammals (adults)
- Deer required for tick population maintenance

Lyme Disease Transmission Cycle

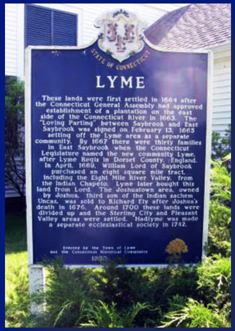


First Known Case of Lyme Disease – Oetzi, the 5,000 year old Tyrolean iceman

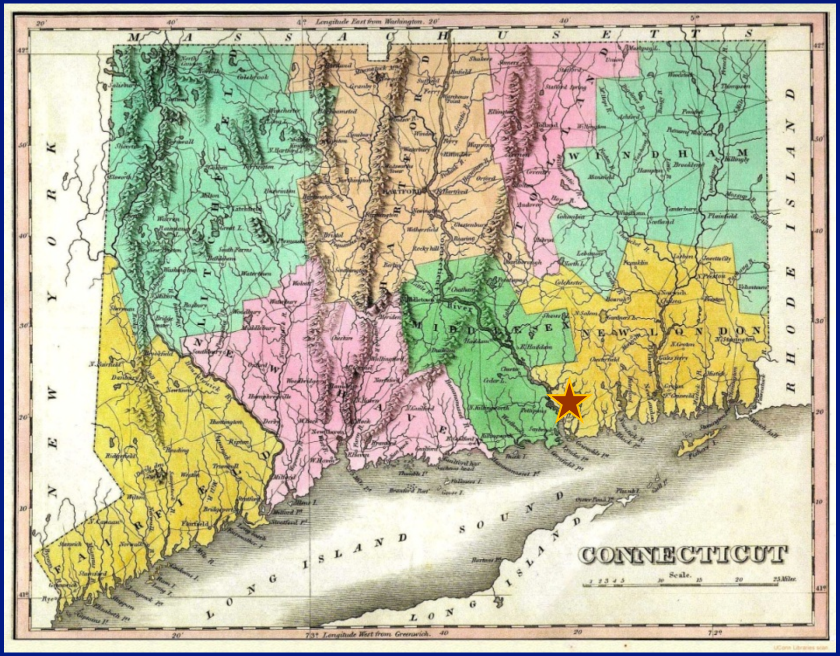
Perhaps most surprising, researchers found the genetic footprint of bacteria known as Borrelia burgdorferi in his DNA—making the Iceman the earliest known human infected by the bug that causes Lyme disease.

Stephen Hall, National Geographic

Lyme Disease – History and Emergence



- 1st cases of juvenile rheumatoid arthritis in late 1970's – Lyme, CT
- The agent *Borrelia burgdorferi* was discovered and described in early 1980's
- Earlier reports, 1940's …Montauk Point, Long Island, NY



Source: The *Connecticut Digital Map Library*
http://www.rootsweb.com/~usgenweb/maps/connecticut/

Young & Delleker sc. -- Philadelphia : *Anthony Finley*.
Scan courtesy of University of Connecticut, UConn Libraries

Lyme in the Upper Midwest

Erythema Chronicum Migrans

Rudolph J. Scrimenti, MD, Milwaukee

To my knowledge, this is the first case of erythema chronicum migrans in the United States. Eruption and radicular pain followed a wood tick bite. Treatment with benzathine penicillin G (Bicillin) was curative.

A MIGRATING erythema with systemic symptoms resulting from a tick bite is unusual in the United States. Our knowledge of this curious condition comes from European reports. This toxic, circinate skin eruption advances peripherally and is occasionally associated with neurological symptoms. The cause is uncertain. However, some believe it to be an infectious agent, perhaps a spiro-

Accepted for publication March 15, 1970.
From the Department of Dermatology, Marquette School of Medicine, Milwaukee.
Reprint requests to 5255 N Hollywood Ave, Milwaukee 53217 (Dr. Scrimenti).

Report of a Case

In January 1969 a 57-year-old physician had chronic erythema of the right side of the torso which was unresponsive to flurandrenolide (Cordran). A recent hospitalization failed to reveal any cause for his complaints of headache, malaise, and dull pain radiating over the right hip. Periodic, low-grade fever accompanied the progression of the skin eruption.

An annular area of edema and erythema was present, extending from the mid-chest to mid-back and encircling the right axilla and iliac crest. The dermatomes innervated by T-12 and L-1 were hyperesthetic. Above the iliac crest there was a tender, punctate area of redness and induration. The patient stated this was the site of a wood tick bite sustained three months previously while grouse hunting in north central Wisconsin (Medford). He recalled that after removing the tick from the skin, a nickel-sized welt appeared at the bite site. It slowly spread peripherally, cleared centrally, and culminated in the large circular area now present. A morbilliform eruption of the upper part of the torso appeared shortly after the bite, but vanished within one week while the patient took a combination antihistamine decongestant (chlorpheniramine maleate, phenylpropanolamine hydrochloride, and isopropamide iodide [Ornade]). It has not recurred.

THE YALE JOURNAL OF BIOLOGY AND MEDICINE **57** (1984), 685–696

Lyme Disease in Wisconsin: Epidemiologic, Clinical, Serologic, and Entomologic Findings

JEFFREY P. DAVIS, M.D., WENDY L. SCHELL, M.S., TERRY E. AMUNDSON, Ph.D., MARVIN S. GODSEY, Jr., B.S., ANDREW SPIELMAN, Ph.D., WILLY BURGDORFER, Ph.D., ALAN G. BARBOUR, M.D., MARTIN LaVENTURE, M.P.H., AND RICHARD A. KASLOW, M.D.

- 1st published report of EM involved a patient in Taylor, WI in 1969
- 1980 – 1982, 80 confirmed Lyme disease cases reported in WI
- *"Lyme disease is widespread in Wisconsin, with ecological and clinical features similar to those occurring along the eastern seaboard."*

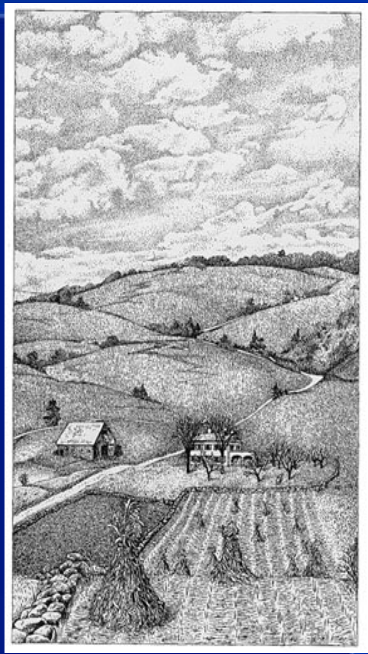
Lyme Disease Emergence and Changing Land Use Patterns (1860s – 1980s)

Source:

Bald hills: New England before the trees returned. From *Thoreau's Country.*

American Scientist Online

Http://www.amercanscientist.org



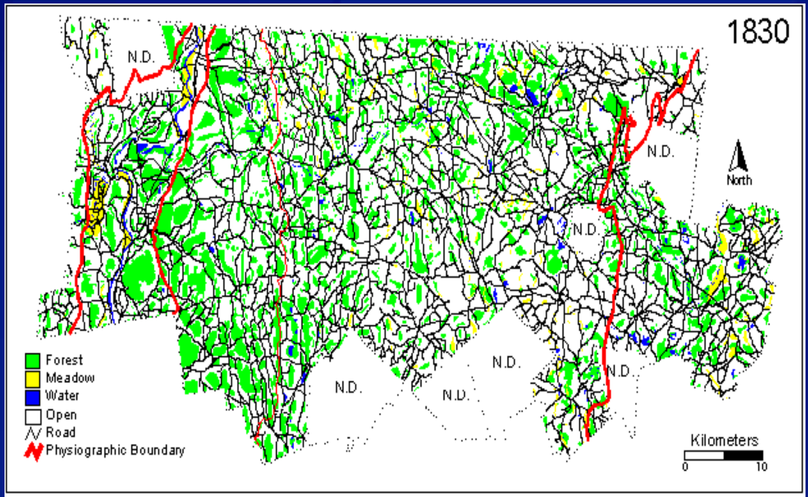
Chipman Hill, Middlebury, Vt., 1860s

Chipman Hill, 1900s

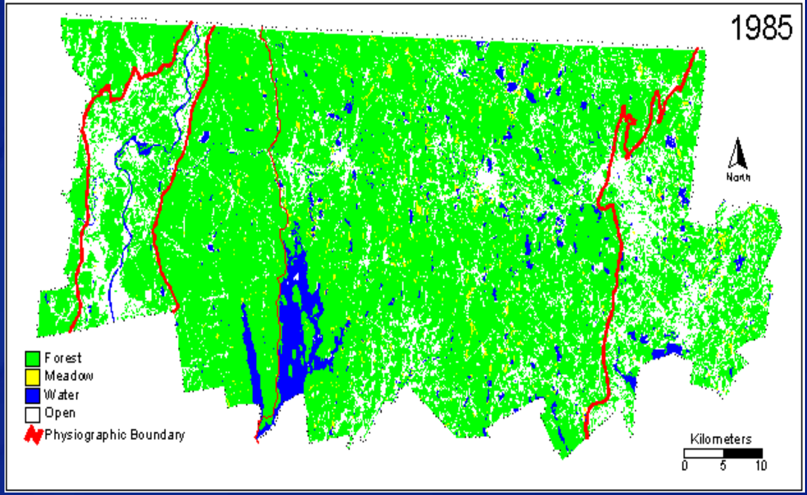
Chipman Hill, 1980s

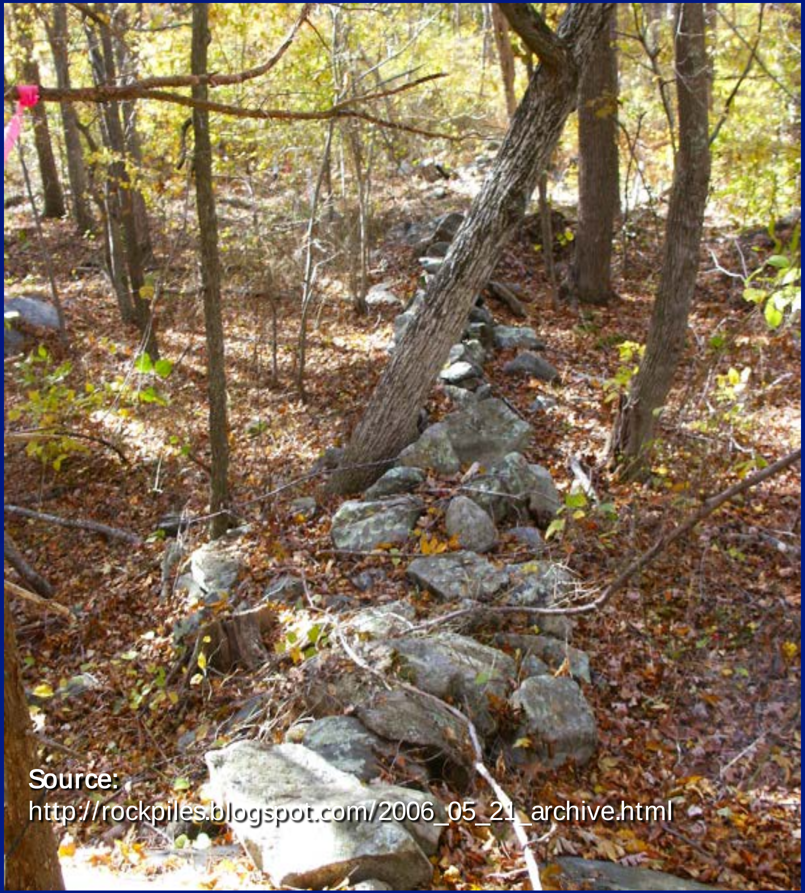
Source: Henry Sheldon Museum - http://henrysheldonmuseum.org

Lyme Disease – Emergence



Source:
http://biology.usgs.gov/luhna/harvardforest.html

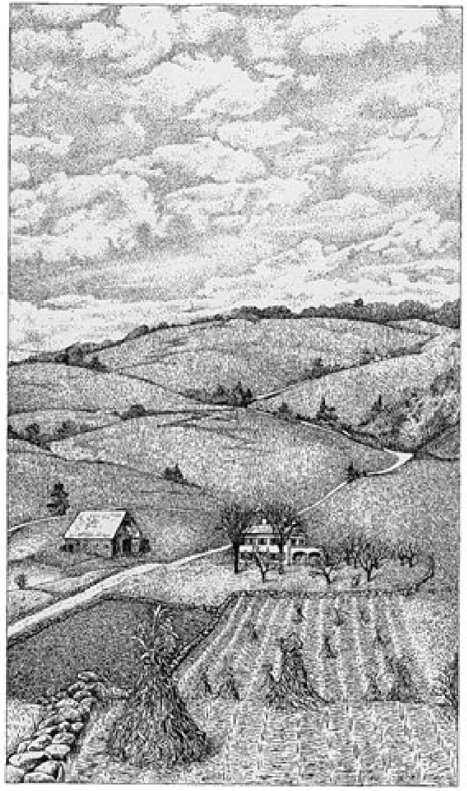




Source:
http://rockpiles.blogspot.com/2006_05_21_archive.html

"In Connecticut, the number of deer has increased from about 12 in 1896 to 76,000 today." [Kirby Stafford Connecticut Agriculture Experiment Station]

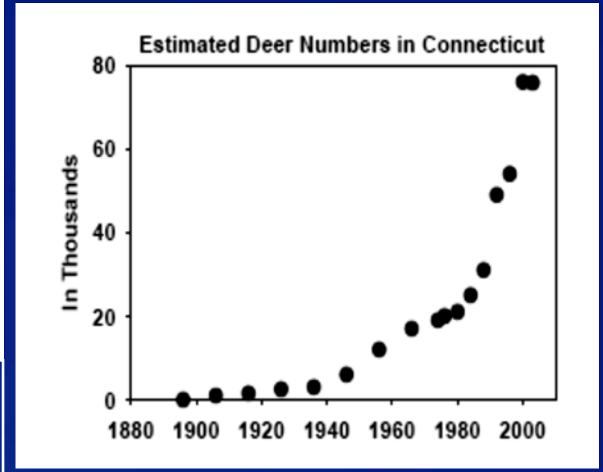
Tick-borne Disease Emergence – Re-emergence in the U.S.



Source:

Bald hills: New England before the trees returned. From *Thoreau's Country.*

American Scientist Online
Http://www.amercanscientist.org



Source: K. Stafford, CT Agricultural Experiment Station

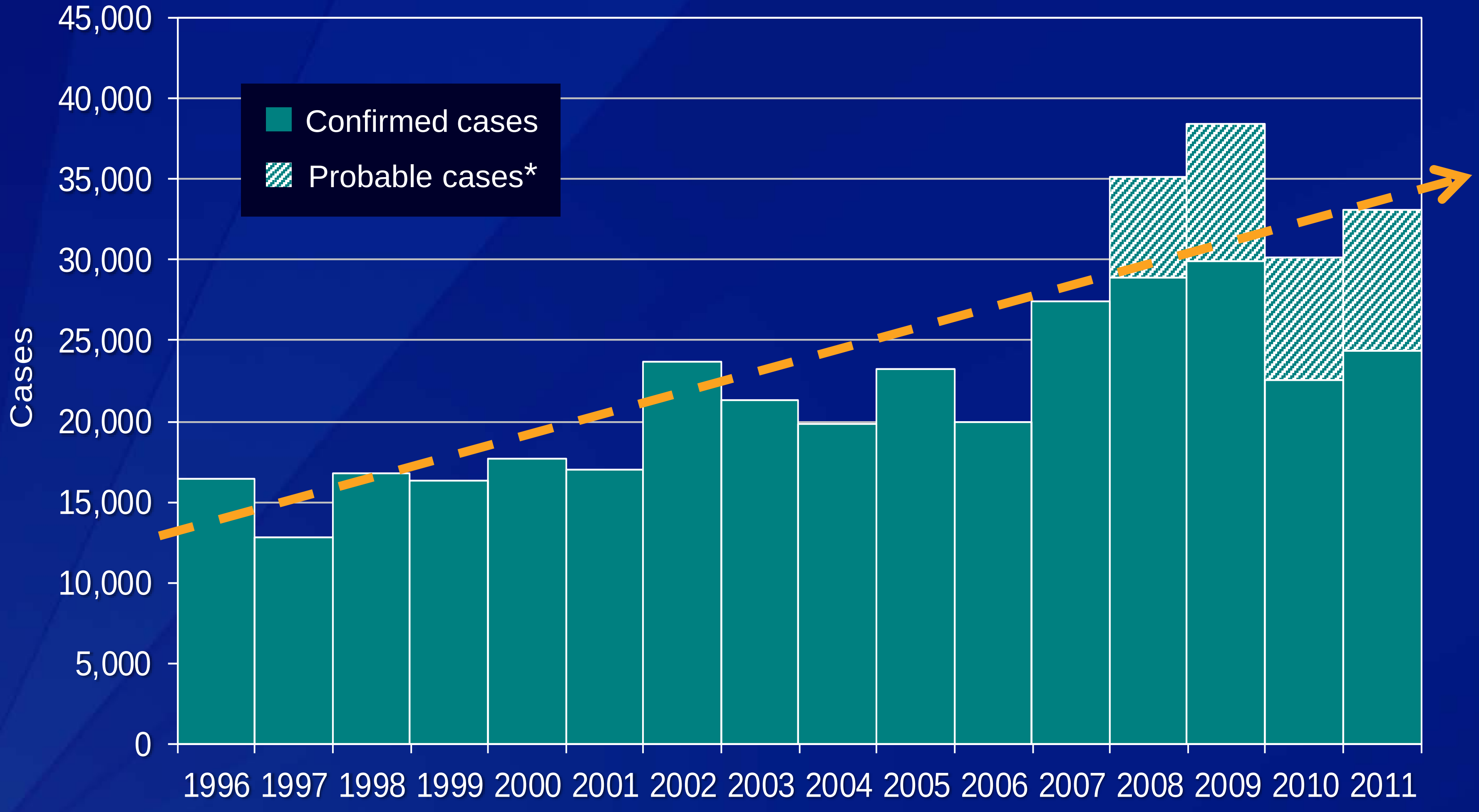
- Reforestation
- Overabundant deer
- Increased numbers of ticks
- Expansion of suburbia into wooded areas
- Increased exposure opportunities
- Changes in diagnostic, surveillance, and reporting practices

Top 10 Notifiable Diseases in the United States, 2011

Disease	Case numbers
1. Chlamydia	1,412,791
2. Gonorrhea	321,849
3. Salmonellosis	51,887
4. Syphilis	46,042
5. HIV/AIDS (new cases)	35,266
6. Lyme disease	33,097
7. Coccidioidomycosis	22,634
8. Pertussis	18,719
9. Streptococcus pneumoniae	17,138
10. Giardiasis	16,747

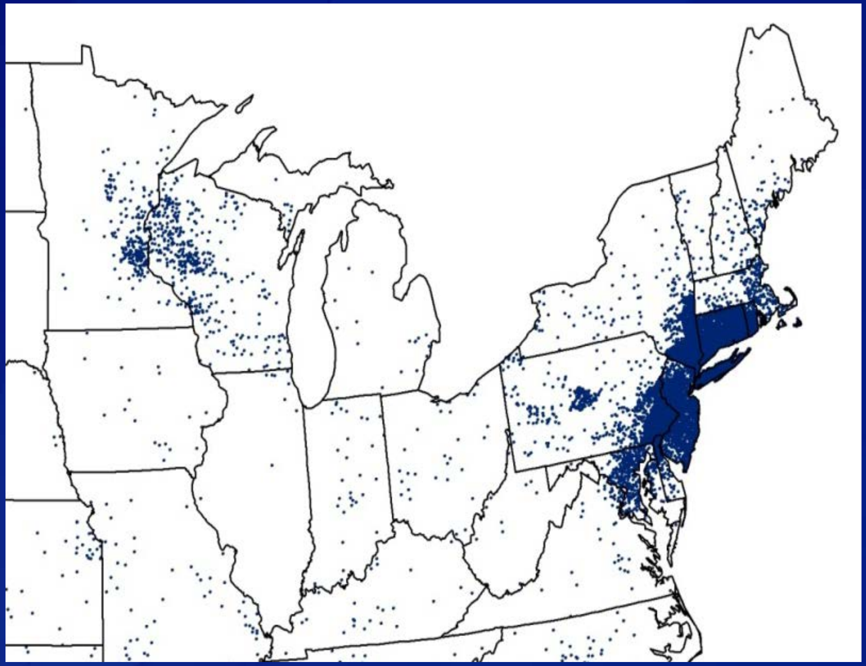
Ranked 3rd highest incidence notifiable disease in Mid-Atlantic states and 2nd in New England states

Reported Cases of Lyme Disease by Year, United States, 1996-2011

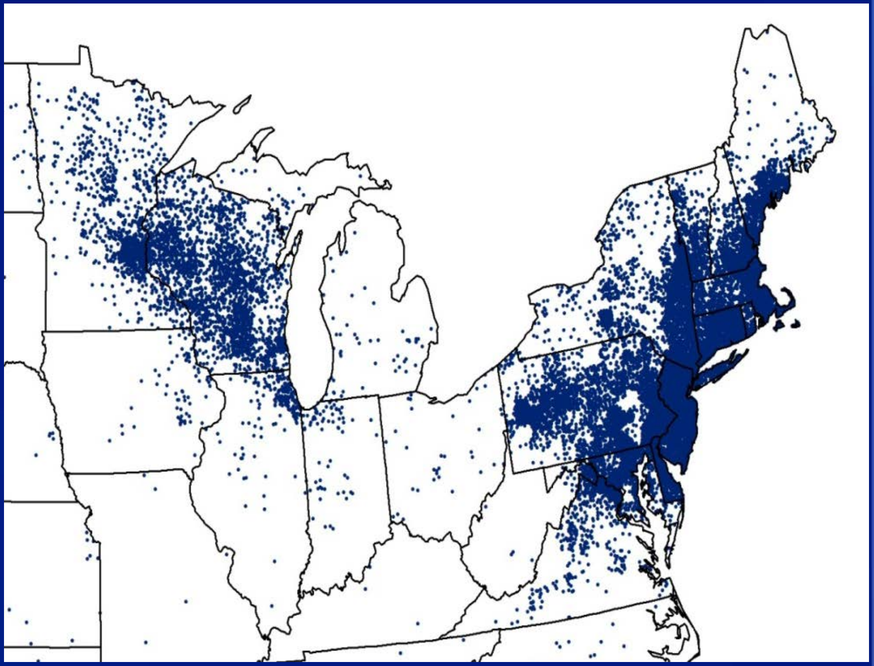


*National Surveillance case definition revised in 2008: http://www.cdc.gov/ncphi/disss/nndss/casedef/lyme_disease_2008.htm

Lyme Disease U.S. Case Distribution – 16 year Trend



1996



2011

http://www.cdc.gov/lyme/stats/maps/interactiveMaps.html

Tick-borne Diseases in the United States, 2002-2011

Disease	Year									
	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Lyme	23,763	21,273	19,859	21,304	19,931	27,444	35,198	38,468	30,158	33,097
RMSF	1,104	1,091	1,738	2,029	2,288	2,221	2,563	1,815	1,985	2,802
Eh/An (total)*	750	727	934	1,404	1,455	1,999	2,107	2,267	2,615	3,586
Babesia‡										1,128

*Includes HGA, HME, and other or unspecified ehrlichiosis
‡Babesiosis became nationally notifiable in 2010

Models for Lyme Disease Emergence

Reemergence from Isolated Refugia:

- Changing land use patterns
  - Agriculture to Industry
  - Reforestation
  - Growth of suburbia
- Increased biodiversity associated with resurging populations of zoonotic hosts (deer, rodents, etc.)
- Increased tick abundance
- Increased exposure opportunities
- Disease "re-emergence" both in case numbers and distribution, from local refugia

Reemergence through Decreasing Biodiversity:

- High biodiversity is protective (dilution effect) and lower biodiversity increases risk
  - Hosts differ in ability to harbor pathogens and infect vectors
  - Lower quality hosts decrease the rate of successful host/pathogen/vector encounters
  - Better quality hosts have thrived under the selective pressures of suburban growth and habitat fragmentation
- Suburban expansion and landscape fragmentation have resulted in increased white-footed mouse populations, increased tick abundance, and increased Lyme disease risk in humans

An Issue of Scale…

TREE-1628; No. of Pages 9 ARTICLE IN PRESS

Review

Cell PRESS

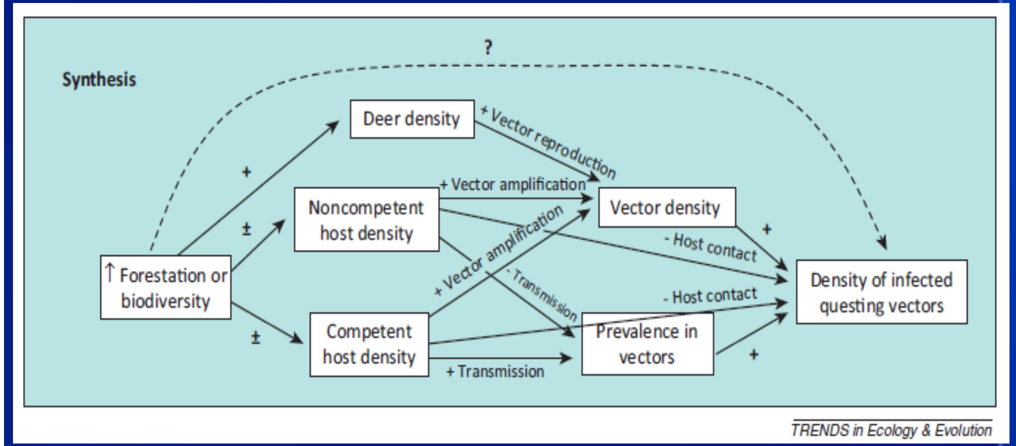
Biodiversity and disease: a synthesis of ecological perspectives on Lyme disease transmission

Chelsea L. Wood[1] and Kevin D. Lafferty[2]

[1] Department of Biology, Stanford University, Stanford, CA 94305, USA
[2] US Geological Survey, Western Ecological Research Center, c/o Marine Science Institute, University of California, Santa Barbara, CA 93106, USA

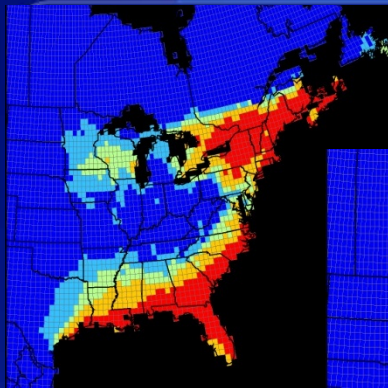
Recent reviews have argued that disease control is among the ecosystem services yielded by biodiversity. Lyme disease (LD) is commonly cited as the best example of the 'diluting' effect of biodiversity on disease transmission, but many studies document the opposite relationship, showing that human LD risk can increase with forestation. Here, we unify these divergent perspectives and find strong evidence for a positive link between biodiversity and LD at broad spatial scales (urban to suburban to rural) and equivocal evidence for a negative link between biodiversity and LD at varying levels of biodiversity within forests. This finding suggests that, across zoonotic disease agents, the biodiversity–disease relationship is scale dependent and complex.

…and the specific question being asked… The drivers of disease emergence? Seasonal risk? Or the most effective approaches for prevention and control in different locations? All rely on an understanding of the ecology.



Trends in Ecology & Evolution
http://dx.doi.org/10.1016/j.tree.2012.10.001

Projected Distribution of *Ixodes scapularis*



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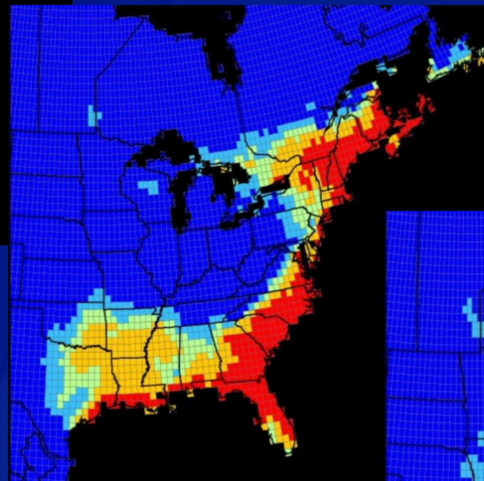
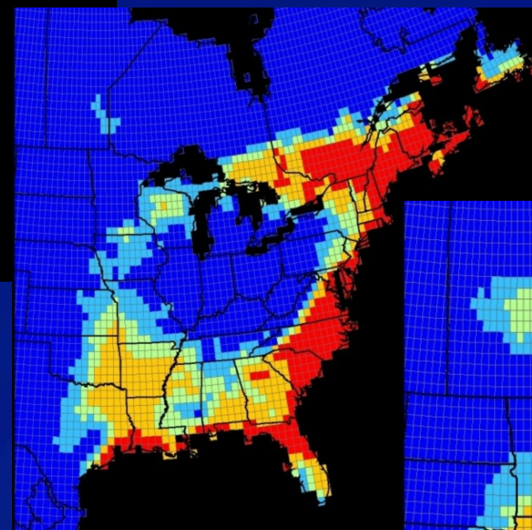
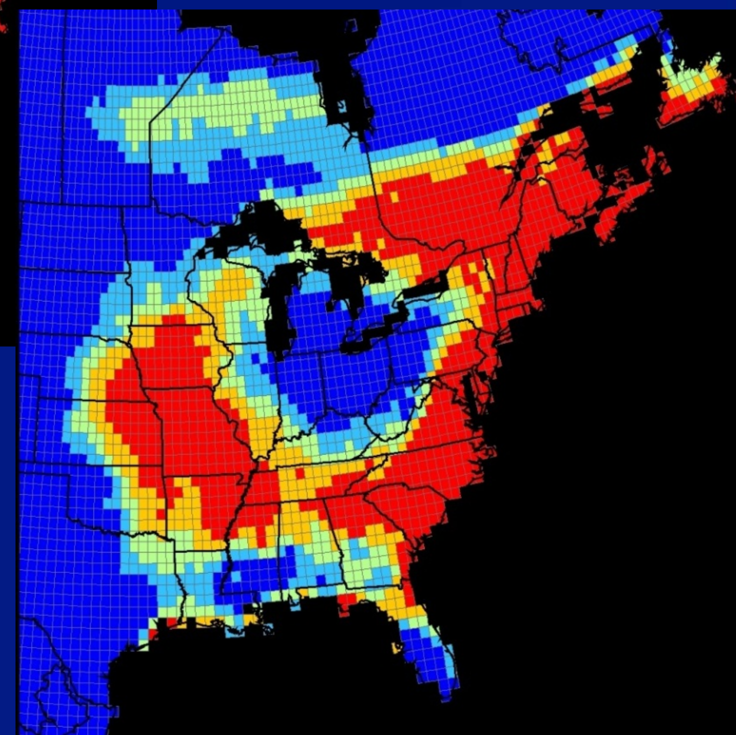


2020



2050

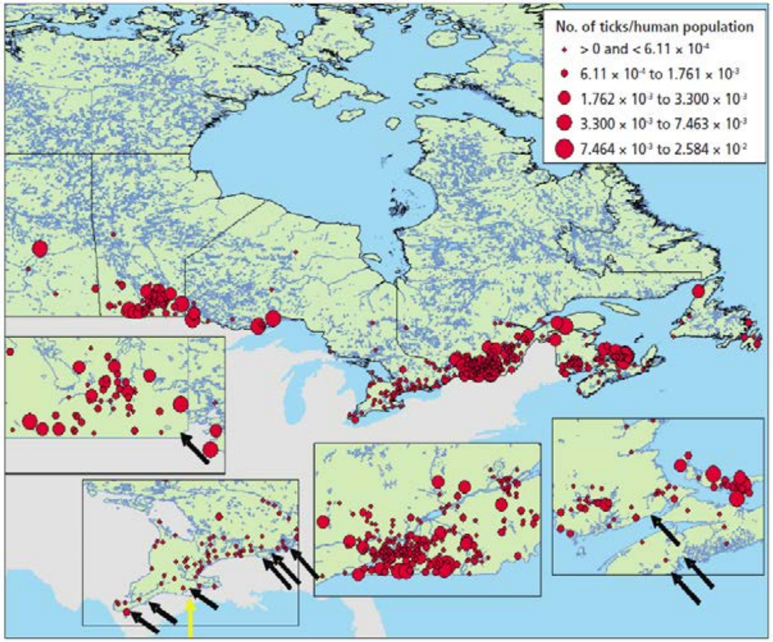


2080

Based upon CGCM1 Climate Change Model

Brownstein et al. 2005 EcoHealth 2: 38-45

Lyme Disease Northward Expansion into Canada



CMAJ REVIEW

The emergence of Lyme disease in Canada

Nicholas H. Ogden DPhil, L. Robbin Lindsay PhD, Muhammad Morshed PhD, Paul N. Sockett PhD, Harvey Artsob PhD

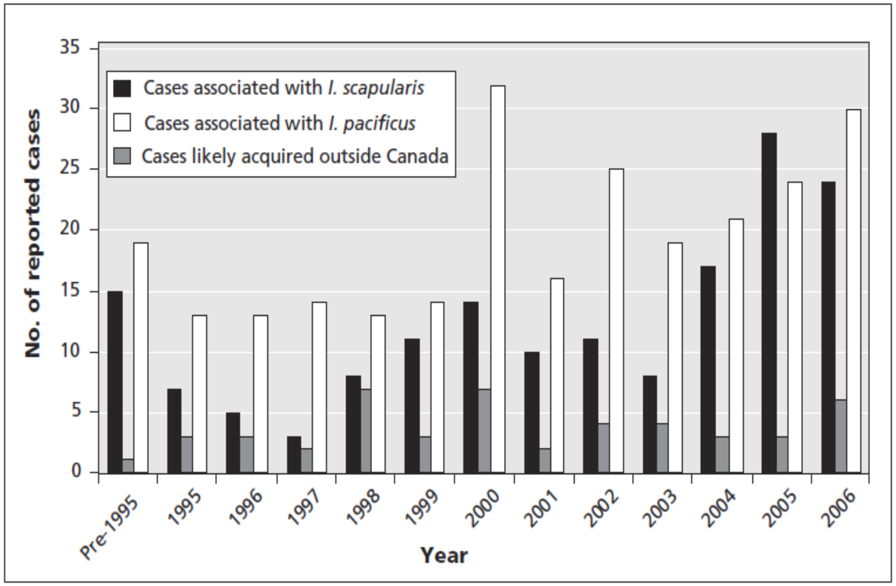
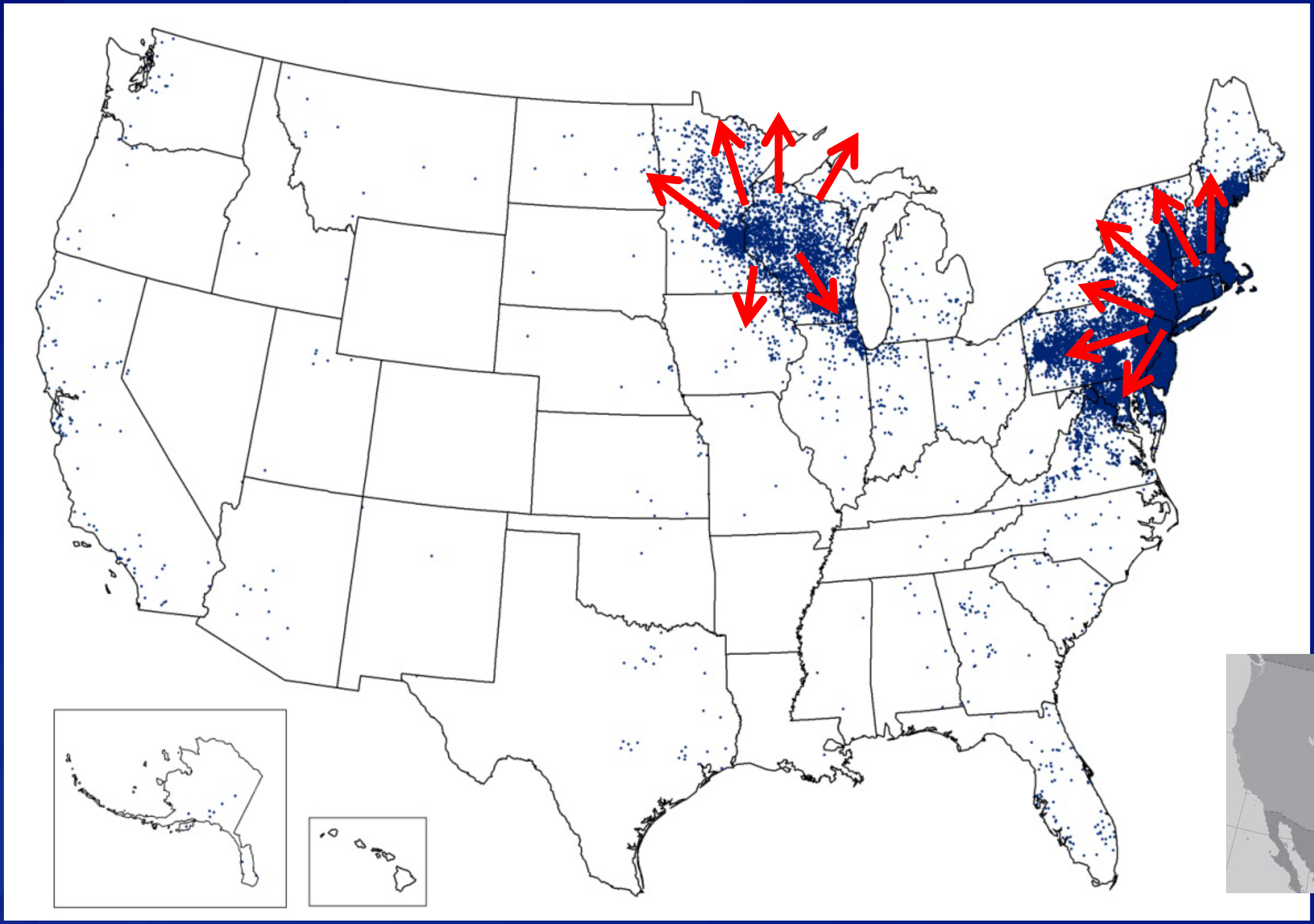
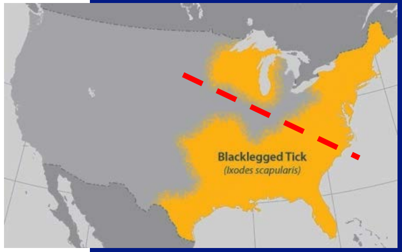


Figure 3: Annual number of cases of Lyme disease reported voluntarily by the provinces and territories since the late 1980s. Cases of Lyme disease in British Columbia were probably transmitted by *Ixodes pacificus*, whereas cases from all other provinces with cases that were potentially locally acquired (i.e., Manitoba, Ontario, Quebec, New Brunswick, Nova Scotia and Newfoundland and Labrador) were probably associated with *Ixodes scapularis*. Cases affecting patients with a history of travel to an endemic area outside Canada during the period when they likely acquired the infection are considered travel-related or nonendemic. Reproduced with permission from the Minister of Public Works and Government Services Canada, 2008.[15]

Reported Cases of Lyme Disease in the United States – 2011



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



Lyme Disease Expansion – Southward

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Delaware	77	167	167	152	194	212	339	646	482	715	772
Maryland	659	899	688	608	738	691	891	1235	1248	2576	2218
Virginia	73	122	149	156	259	195	216	274	957	959	933

New evidence leads officials to affirm Lyme risk in N.C.

Warning about tick-borne disease

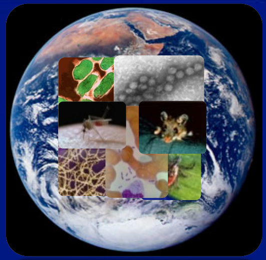
By Sarah Avery
savery@newsobserver.com

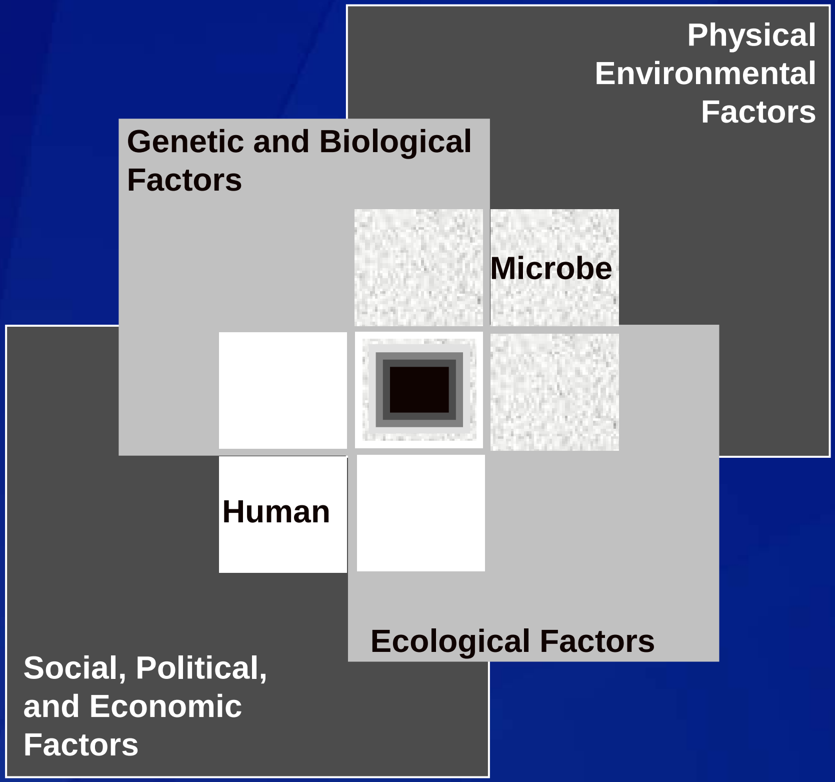
Posted: Friday, Oct. 02, 2009

After years of cautioning that people were unlikely to get Lyme disease in North Carolina, state health leaders are now advising that the tick-borne illness can, in fact, be acquired here.

Based on the new evidence, Dr. Megan Davies, state epidemiologist, said the state is now working to get the word to doctors, who for years were reluctant to even test patients for Lyme because it wasn't considered much of a possibility.

Factors Influencing Disease Emergence (Institute of Medicine 2003 report – *Microbial Threats to Health*)





Convergence Model for Emerging Diseases

- Microbial adaptation and change
- Human susceptibility to infection
- Climate and weather
- Changing ecosystems
- Economic development and land use
- Human demographics and behavior
- Technology and industry
- International travel and commerce
- Breakdown of public health measures
- Poverty and social inequality
- War and famine
- Lack of political will
- Intent to harm

Climate Change and Public Health

Specific Research Needs…

- Long-term surveillance on climate change and the impact on disease ecology and epidemiology
- Integrated data systems with comparable scales
- Models that predict the potential impact of long term climate change and short term climate disruption
- Knowledge of what adaptation and mitigation strategies have the greatest potential for success
- Better understanding of potential future challenges
  - Increase in vector populations and distributions
  - Increase in duration of transmission season
  - Exotic introductions
  - More rapid environmental degradation of pesticides
- Resistance management strategies and options, including a greater reliance on validated IPM approaches

Conclusion

- Vector-borne, zoonotic, and environmentally-associated diseases are significantly affected by climate and are at the forefront of concern over global emerging diseases
- A *One Health* paradigm emphasizes the critical relationship between human health, animal health, and the environment in understanding the drivers of disease emergence
- Complex weather patterns and global climate change directly impact the ecology of vector-borne and zoonotic diseases
- A integrated understanding of climate, ecology, and epidemiology is critical for predicting and averting future epidemics of vector-borne and zoonotic diseases
- The best preparation to prevent, mitigate, and adapt to emerging infectious disease threats related to climate change is to continue our investment in disease surveillance and maintain a strong national public health system so that when diseases occur in new areas, they will be quickly detected and reported, allowing prevention and control activities to be rapidly and effectively mobilized.

Thank you for your attention!

Questions?

The findings and conclusions in this report have not been formally disseminated by the Centers for Disease Control and Prevention and should not be construed to represent any agency determination or policy