Geographic risk for transmission of Lyme disease spirochetes
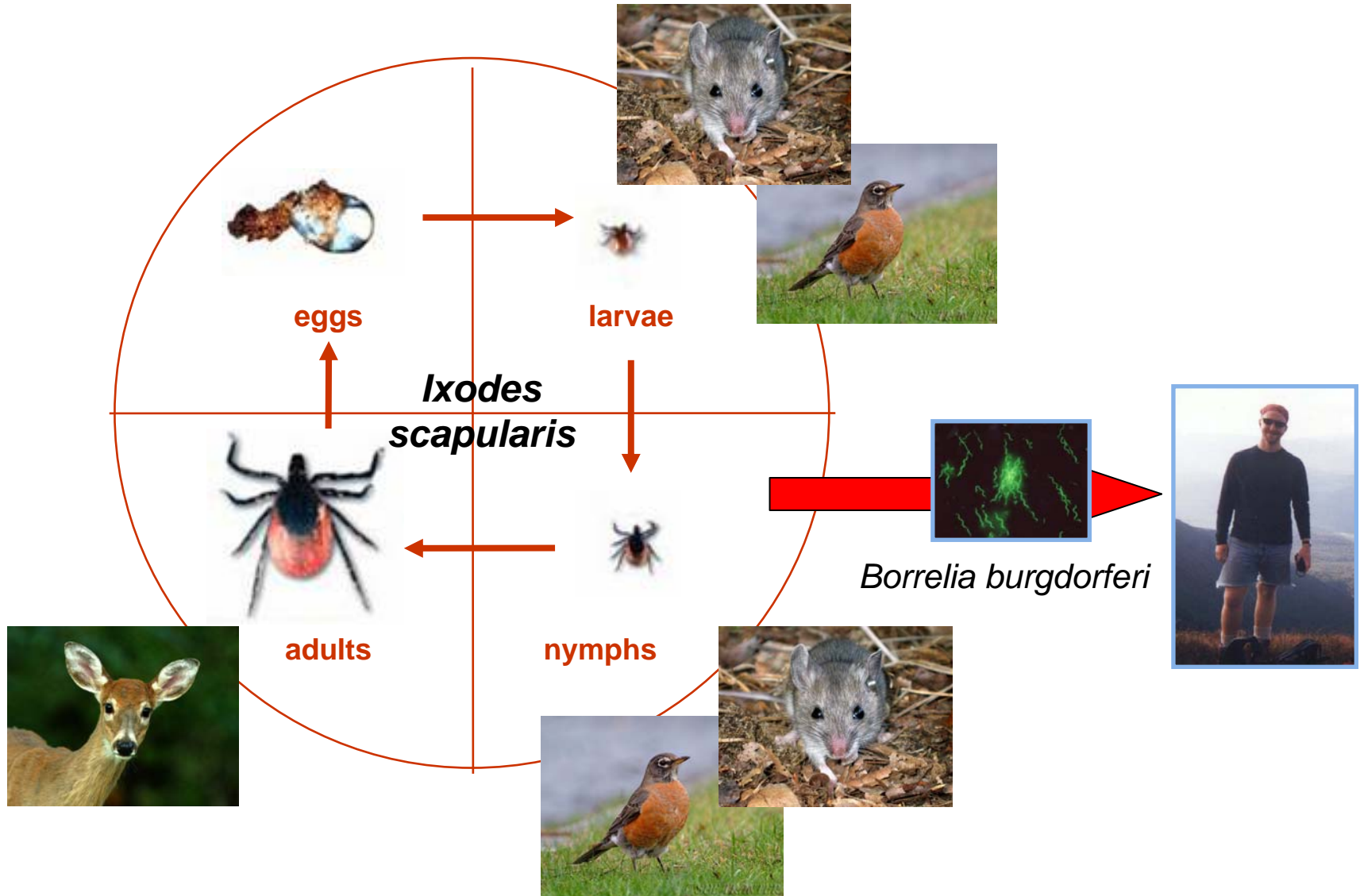
How best to monitor: Human and/or tick surveillance

Tick-Borne Diseases & Epi Activity

Ixodes scapularis life cycle

eggs

larvae

Ixodes scapularis

adults

nymphs

Borrelia burgdorferi

Ixodes scapularis: Larva, Nymph, Adult
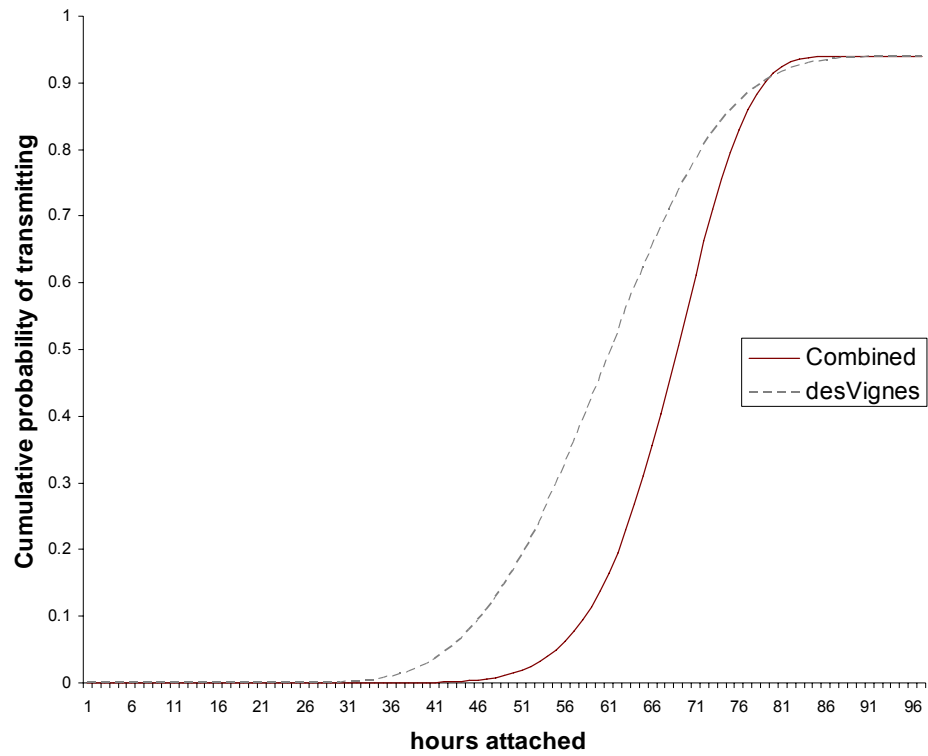

Photo by R Johnson

Fig 1. Probability of infected *Ixodes scapularis* nymphs transmitting *Borrelia burgdorferi*

Evidence that nymphal *Ixodes scapularis* are the key vector stage

- Nymphs quest from May-July when vast majority of human cases of Lyme disease are acquired
- Nymphs small enough to escape detection and feed for >48 hrs needed to transmit
- Patient studies on prophylaxis of tick-bite implicate nymphs (Nadelman et al. 2001; Sood et al. 1997)
- Geographic distribution of spirochete infected nymphal *I. scapularis* questing & biting people tied to areas with high Lyme disease human risk*
- *Data collected in sporadic fashion, not systematic

CDC

Reported Lyme disease cases by month of illness onset - United States, 2003-2005
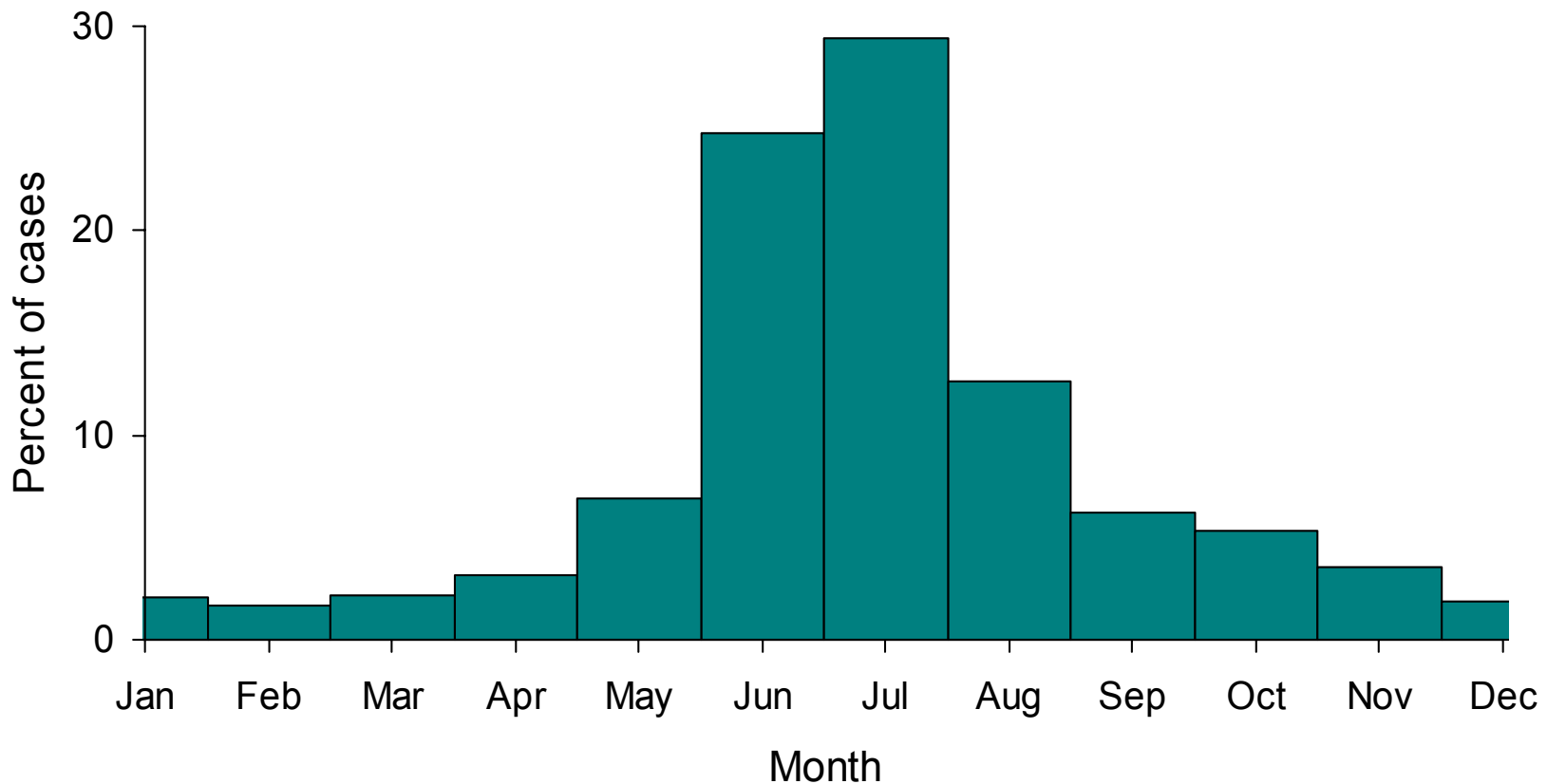
Reported by-county distribution of the Lyme disease vectors Ixodes scapularis and Ixodes pacificus, United States 1907-1996

Vector presence
Established* Ixodes scapularis
Reported Ixodes scapularis
Established* Ixodes pacificus
Reported Ixodes pacificus

CDC
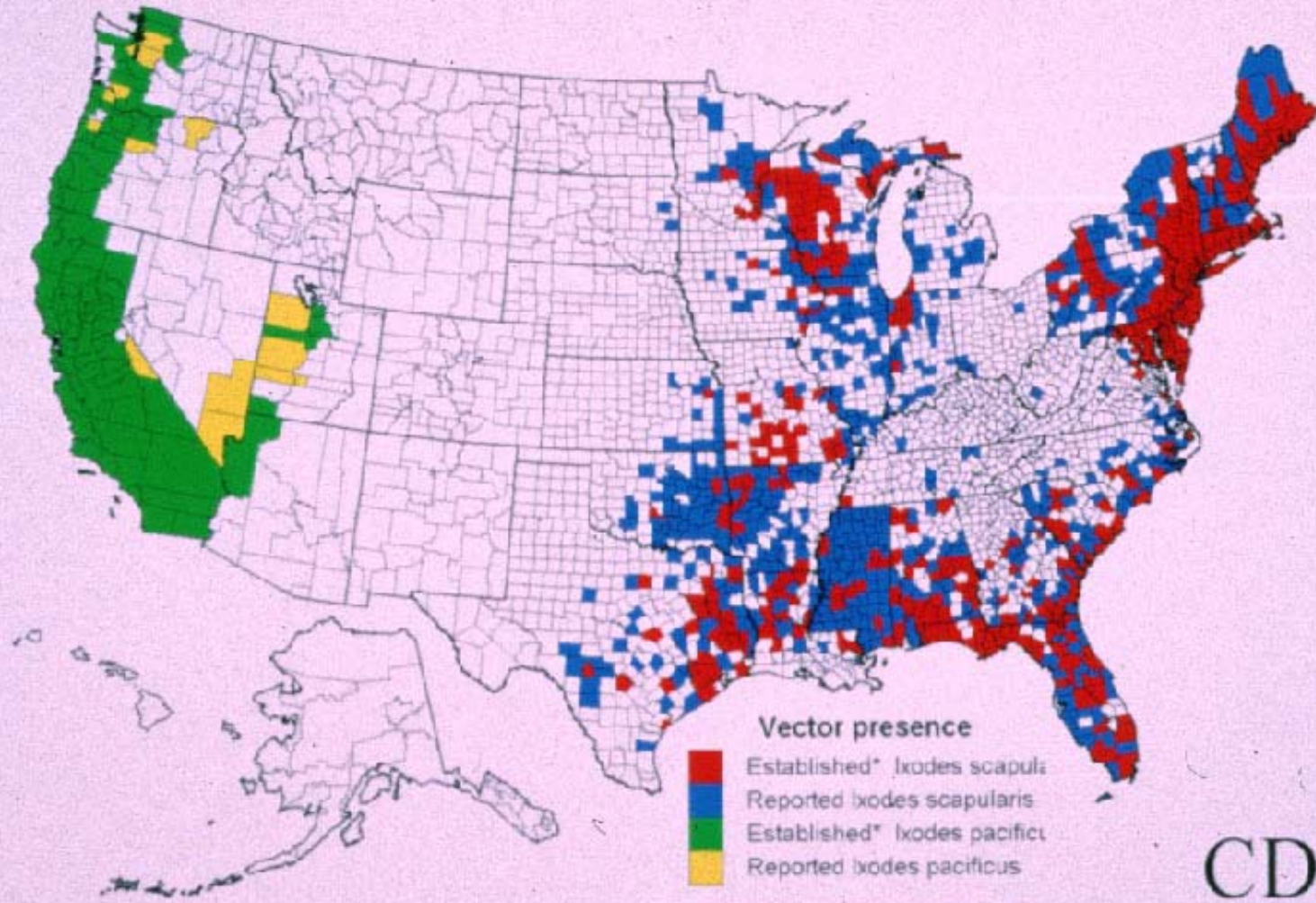
Spatial model of human risk for infection with *I. scapularis*-borne *Borrelia* in the US

Yale Vector Ecology Lab
Durland Fish
Anne Gatewood
Gwenael Vourc'h
Liza Lutzker
Kelly Liebman

David Boozer
Elizabeth Racz
Jessica Payne
Laura Krueger
Kate Hansen
Brady Heward
Kyle Pias

73 field collectors!

Funding
Centers for Disease Control and Prevention

Collaborating institutions
Michigan State University
University of Illinois
University of CA, Irvine
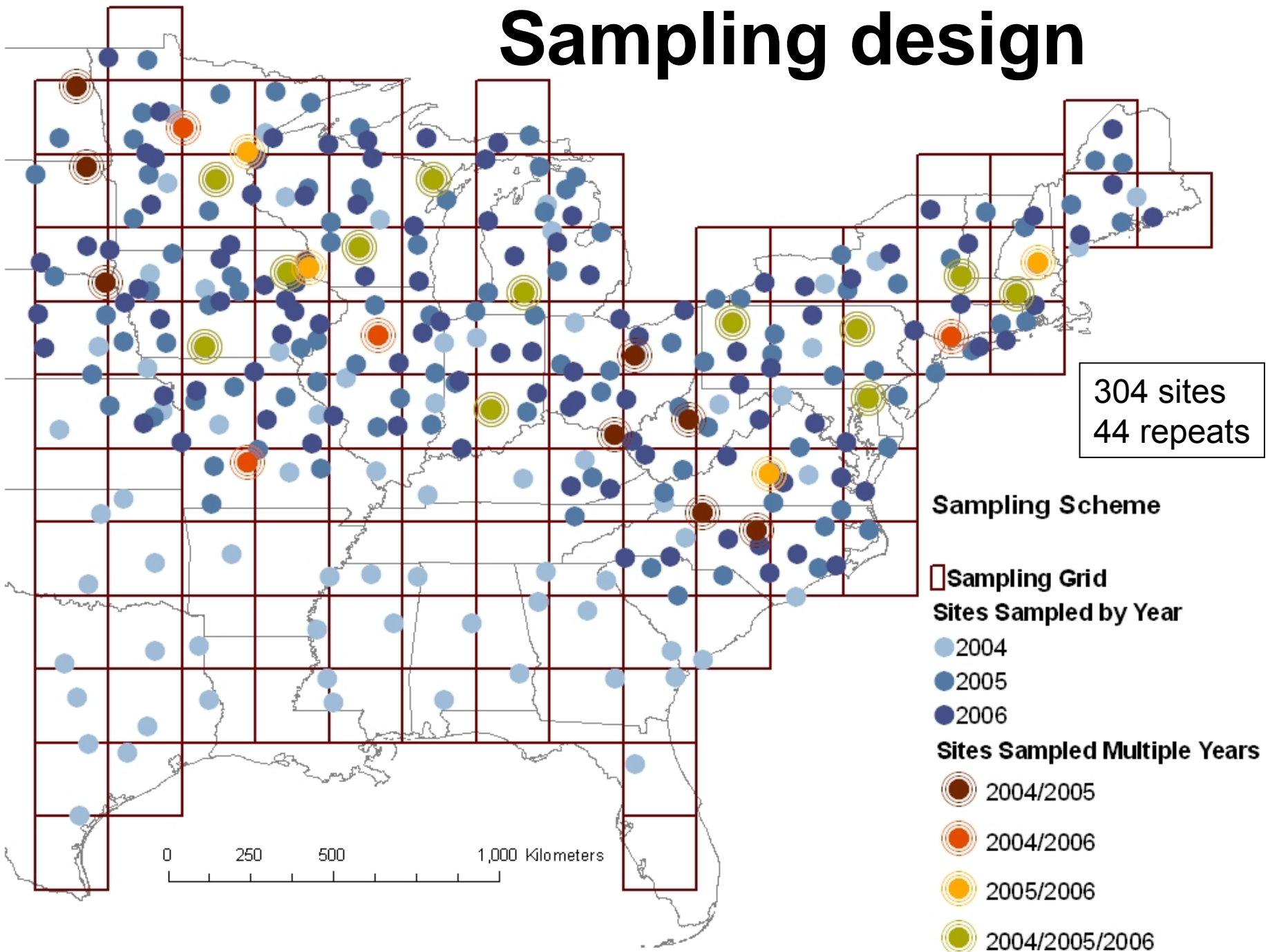University of Bath, UK: K. Kurtenbach

Yale Center for Earth Observation
Roland Geerken
Larry Bonneau
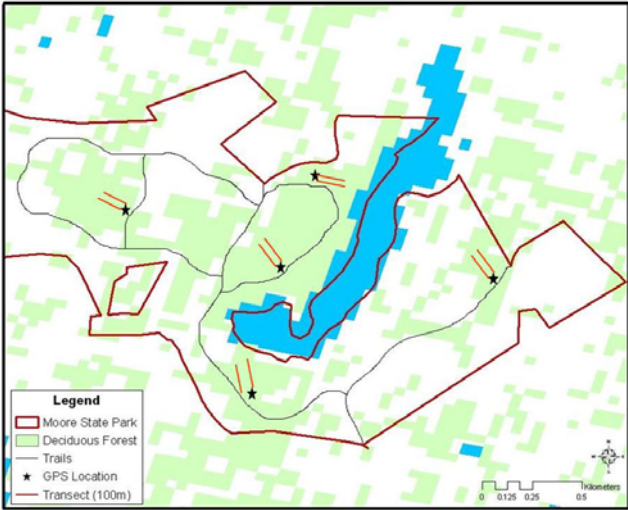Ronald Smith

Yale EPH Biostatistics Division
Paul Cislo
Theodore Holford
Yongtao Guan

NASA Ames - Forrest Melton

Sampling design

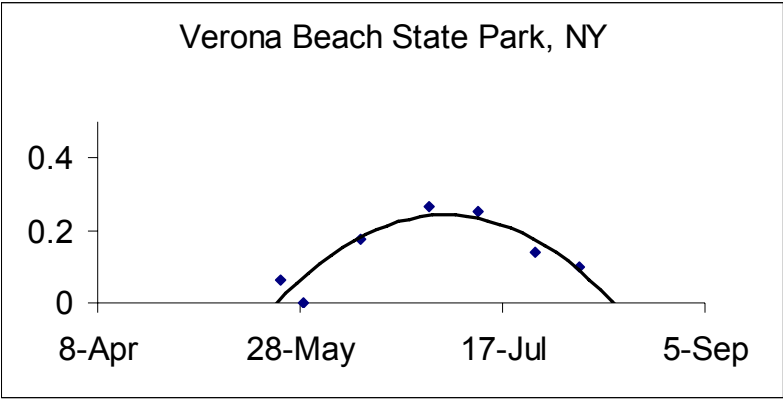304 sites
44 repeats

Sampling Scheme

☐ **Sampling Grid**

Sites Sampled by Year
- ● 2004
- ● 2005
- ● 2006

Sites Sampled Multiple Years
- ◉ 2004/2005
- ◉ 2004/2006
- ◉ 2005/2006
- ◉ 2004/2005/2006

0   250   500   1,000 Kilometers

Field data

5 transects per site
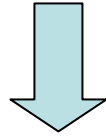

Verona Beach State Park, NY

4-6 visits/site during nymphal host-seeking
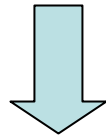
Objectives

1. Density of host-seeking nymphs

2. Nymphal infection prevalence

3. *B. burgdorferi* population genetic structure
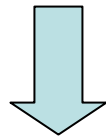
Landscape predictors of infection

↑ Fragmentation

⬇

↑ Reservoir-Competent Hosts

⬇

↑ Circulating *B. burgdorferi*

⬇

↑ Nymphal infection prevalence

Efforts to flag nymphal *I. scapularis* in the southern US

- J Piesman (AL, GA, MS)
- Goddard & Piesman 2006 J Vector Ecology 31: 421-422.
- Sampled in Copiah Co., MS – best area to collect adult *I. scapularis* in MS
- 29 hours of flagging; 894 immature ticks collected; 3 nymphal *I. scapularis*
- If comparable effort in northeast US my estimate of # nymphs collected = ca. 1,500

Lyme disease cases reported to CDC, United States, 1991-2006
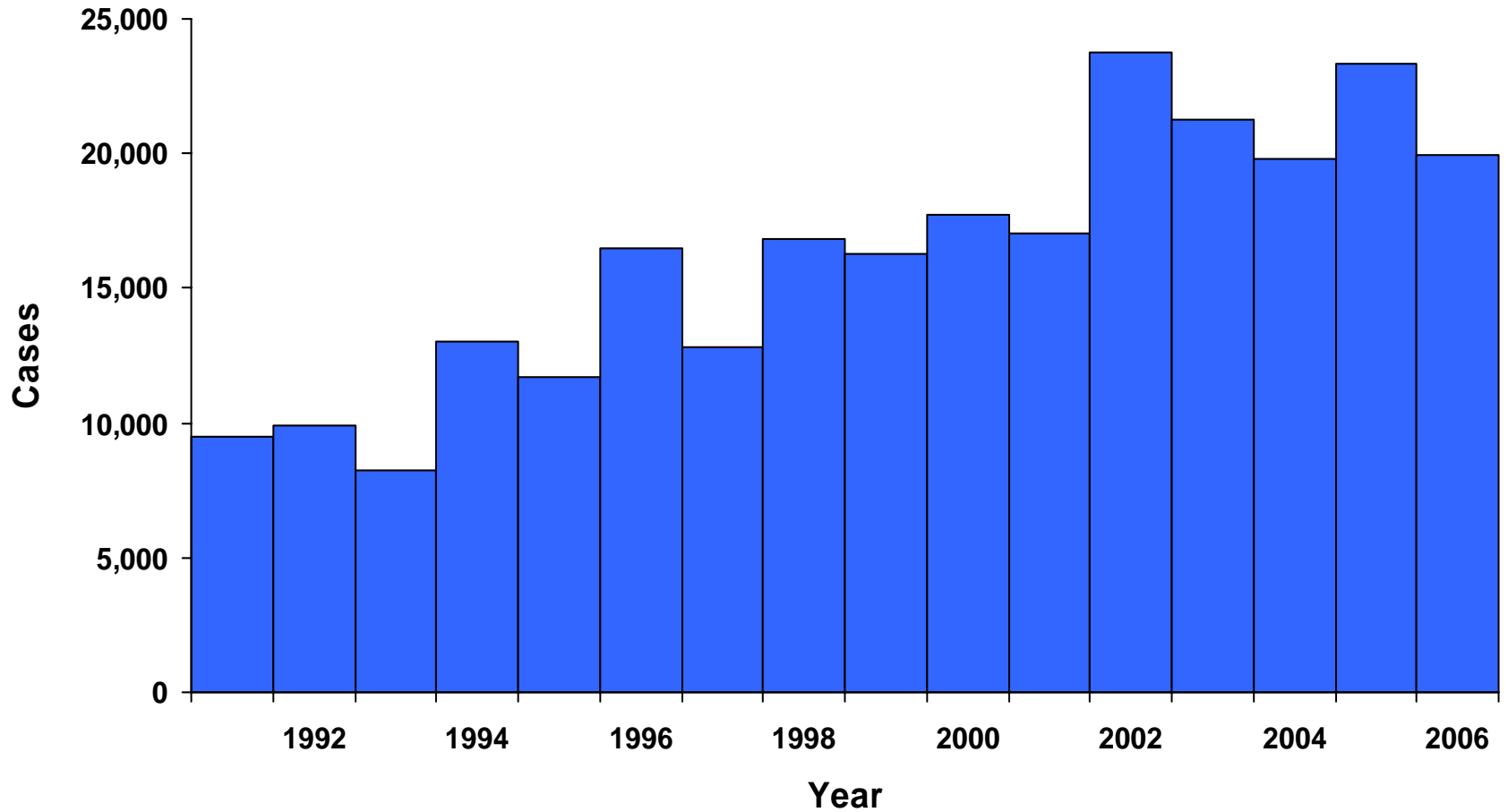
LYME DISEASE. Number of reported cases, by county — United States, 2006
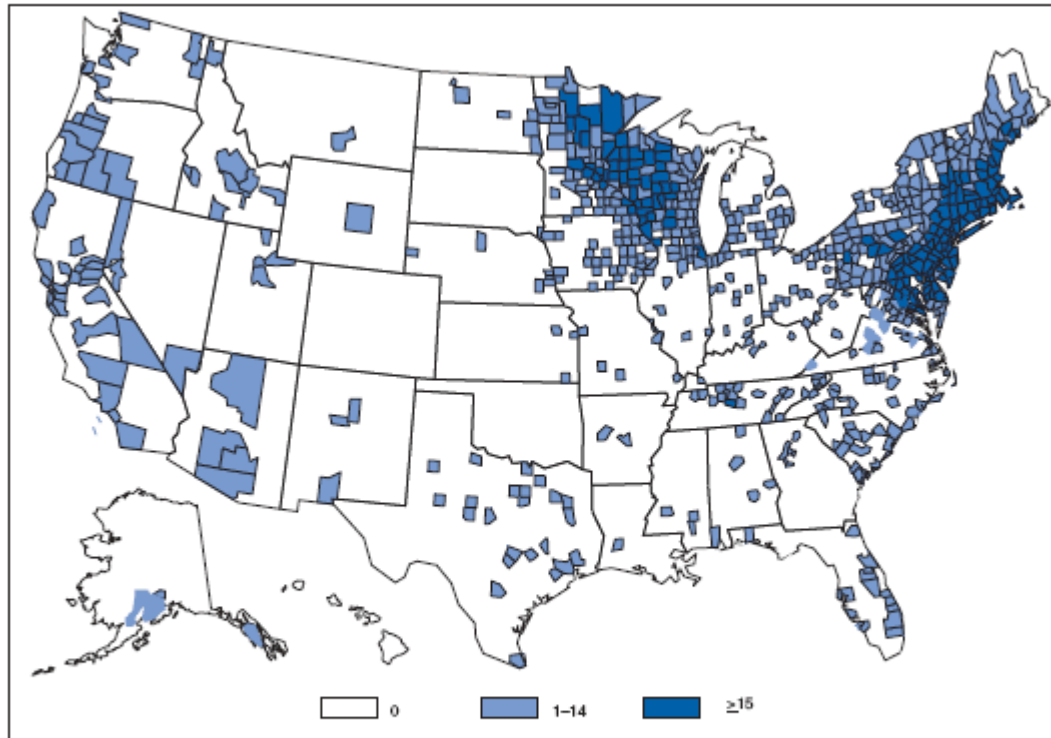
Cases are reported by state of residence rather than state of exposure. A rash that can be confused with the erythema migrans of early Lyme disease sometimes occurs following bites of the lone star tick (*Amblyomma americanum*). These ticks, which do not transmit the Lyme disease bacterium, are common human-biting ticks in the southern and southeastern United States.

19,931 cases in 2006

Reported cases of Lyme disease, United States, 2006
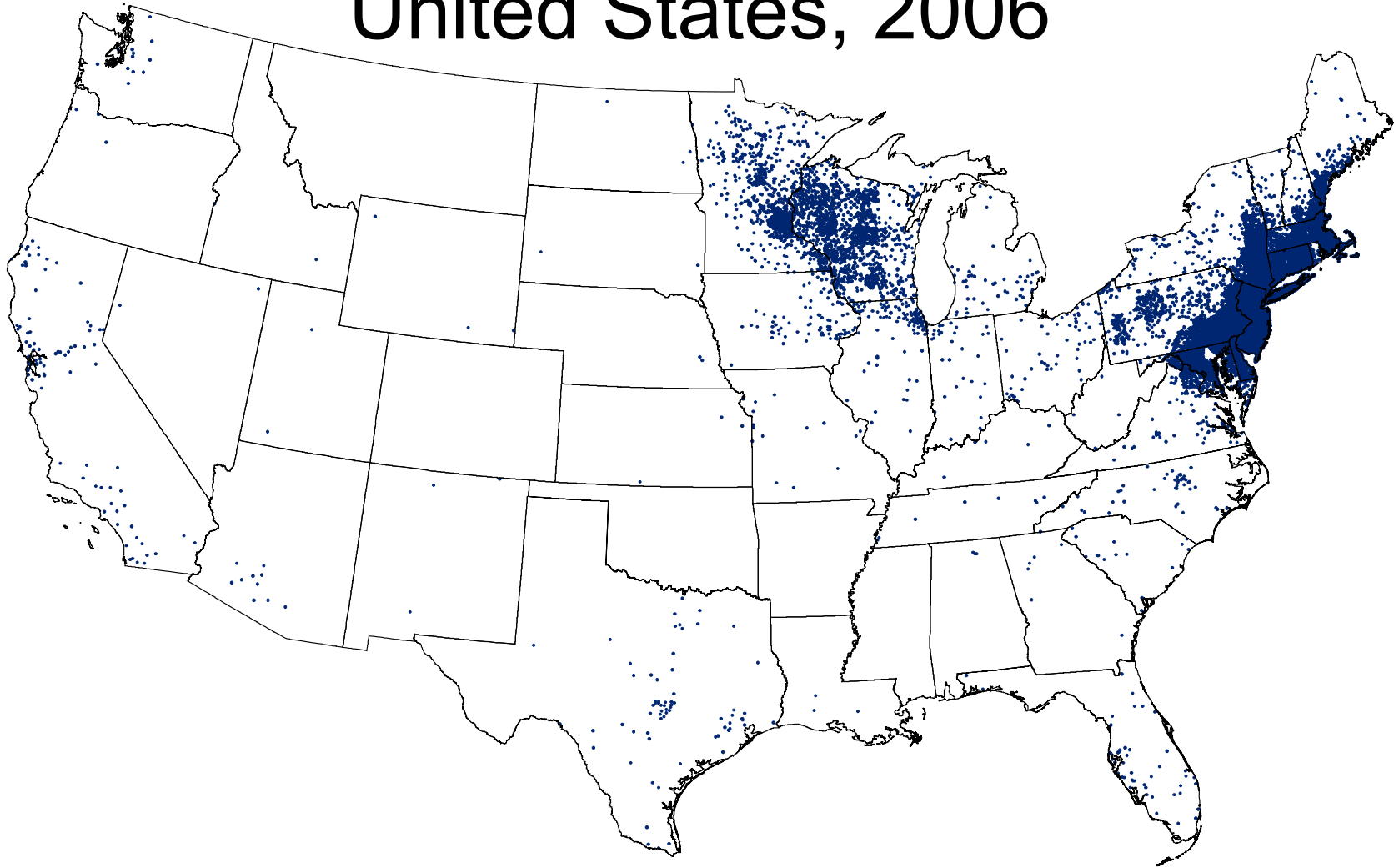
1 dot placed randomly within county of residence for each reported case

Lyme disease high incidence counties, Northeastern United States

1997

2005

Incidence per
100,000 persons

10-49

50-99

100-199

200-499

500+
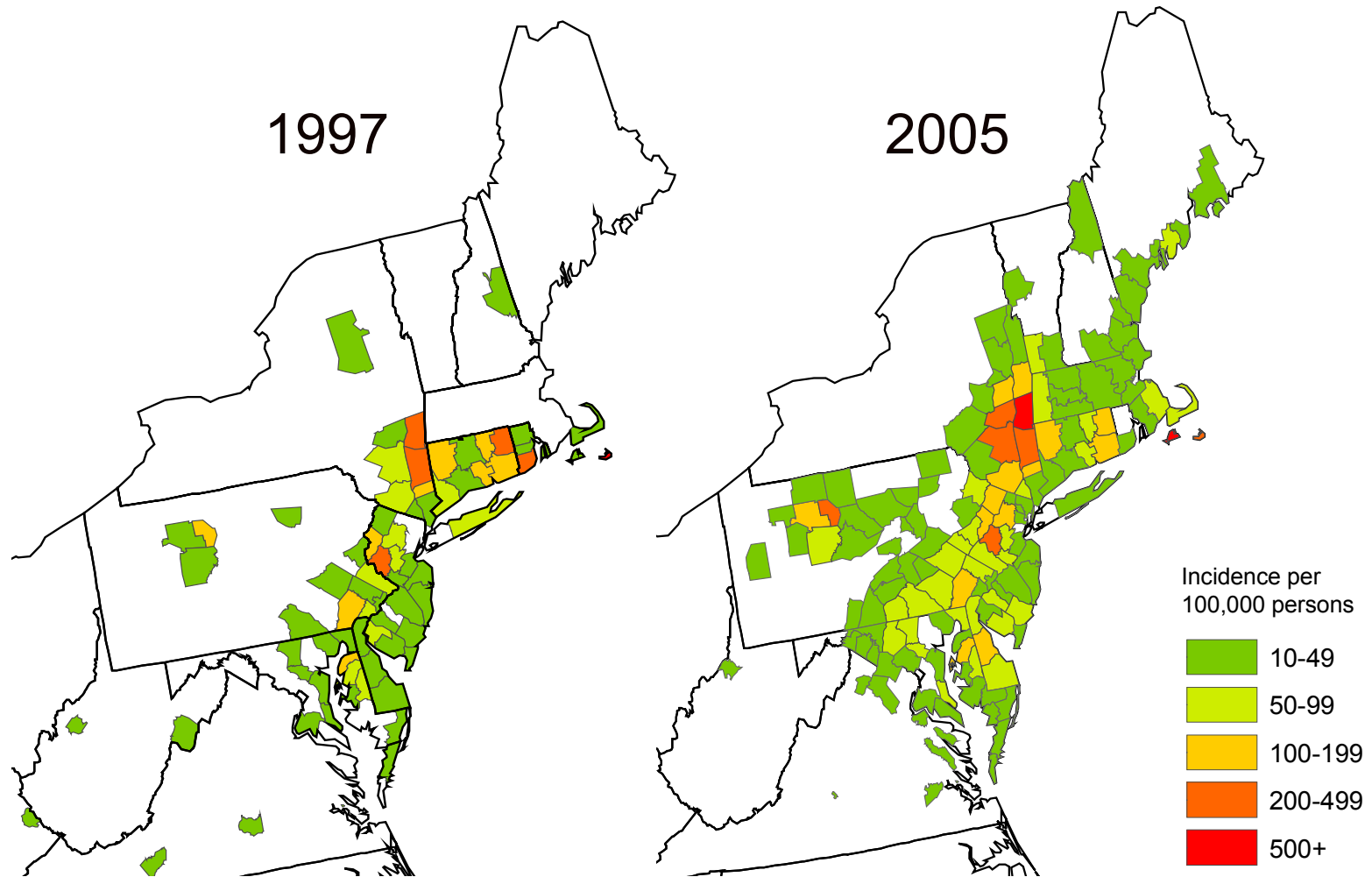
Goals of Lyme disease Surveillance

• Define the demographic, geographic, and seasonal distribution

• Consistently monitor disease trends

• Identify risk factors for transmission in areas where Lyme disease in newly emerging

• Evaluate the impact of prevention and control measures

Former Lyme disease Surveillance Case Definition (1996)

- Exposure
    - wooded, brushy, or grassy areas in a Lyme disease endemic county

- Endemic county
    1) at least two confirmed cases have been previously acquired or
    2) established populations of a known tick vector are infected with *B. burgdorferi*

- Laboratory evidence of infection:
    1) positive culture for *B. burgdorferi*
    2) diagnostic IgM or IgG in serum or CSF

- Case classification
    1) Confirmed
        a) erythema migrans (EM) or
        b) at least one late manifestation (i.e. specific musculoskeletal, neurologic, or cardiac manifestation) that has laboratory evidence of infection

New Lyme disease Surveillance Case Definition (2008)

- Exposure and endemic county remain the same

- **Make laboratory evidence more specific**
    1) positive culture for *B. burgdorferi*
    2) two-tier testing using established criteria
    3) single-tier IgG immunoblot seropositivity using established

- **Additional levels of case classification**
    1) Confirmed Case
        a) EM with a known exposure
        b) EM without a known exposure but with lab evidence
        c) at least one late manifestation with lab evidence of infection

    2) Probable
        a) Any other case of physician-diagnosed Lyme disease with lab evidence of infection

    3) Suspected
        a) EM without exposure and without lab evidence of infection
        b) No clinical information with lab evidence of infection

Lyme disease Surveillance Case Definition (1996)

Late manifestations (when alternate explanation not found):

- *Musculoskeletal system.* Recurrent, brief attacks (weeks or months) of objective joint swelling in one or a few joints, sometimes followed by chronic arthritis in one or a few joints. Manifestations not considered as criteria for diagnosis include chronic progressive arthritis not preceded by brief attacks and chronic symmetrical polyarthritis. Additionally, arthralgia, myalgia, or fibromyalgia syndromes alone are not criteria for musculoskeletal involvement.

Lyme disease Surveillance Case Definition (1996)

Late manifestations (cont'):

- *Nervous system*. Any of the following, alone or in combination: lymphocytic meningitis; cranial neuritis, particularly facial palsy (may be bilateral); radiculoneuropathy; or, rarely, encephalomyelitis. Encephalomyelitis must be confirmed by demonstration of antibody production against *B. burgdorferi* in the CSF, evidenced by a higher titer of antibody in CSF than in serum. Headache, fatigue, paresthesia, or mildly stiff neck alone are not criteria for neurologic involvement.

Lyme disease Surveillance Case Definition (1996)

Late manifestations (cont'):

- *Cardiovascular system*. Acute onset of high-grade (2nd-degree or 3rd-degree) atrioventricular conduction defects that resolve in days to weeks and are sometimes associated with myocarditis. Palpitations, bradycardia, bundle branch block, or myocarditis alone are not criteria for cardiovascular involvement.

Lyme disease Surveillance Case Definition (1996)

Erythema migrans (EM):

Skin lesion that typically begins as red macule or papule and expands over days to weeks…often with partial central clearing. A single primary lesion must reach $\geq$ 5 cm in size. Secondary lesions may occur. Annular erythematous lesions occurring within several hours of a tick bite…do not qualify as EM. For most patients, EM lesion is accompanied by other acute symptoms, particularly fatigue, fever, headache, mildly stiff neck, arthralgia, or myalgia…. The diagnosis of EM must be made by a physician. <u>Laboratory confirmation is recommended for persons with no known exposure.</u>

Lyme disease Surveillance Case Definition (1996)

- *Exposure:* having been (less than or equal to 30 days before onset of EM) in wooded, brushy, or grassy areas (i.e., potential tick habitats) in a county in which Lyme disease is **endemic**. A history of tick bite is not required.

- *Endemic county:* a county in which at least two confirmed cases have been previously acquired or in which established populations of a known tick vector are infected with *B. burgdorferi*.