Tick Surveillance as a Public Health Tool

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Division of Vector-Borne Diseases

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Outline

- Overview of Trends, New Concerns
- Ticks of Public Health Significance
- National Tick Surveillance Objectives
- Local Tick Surveillance Objectives
- Tick Surveillance Methods to Meet Your Objectives
- ArboNET Tick Module

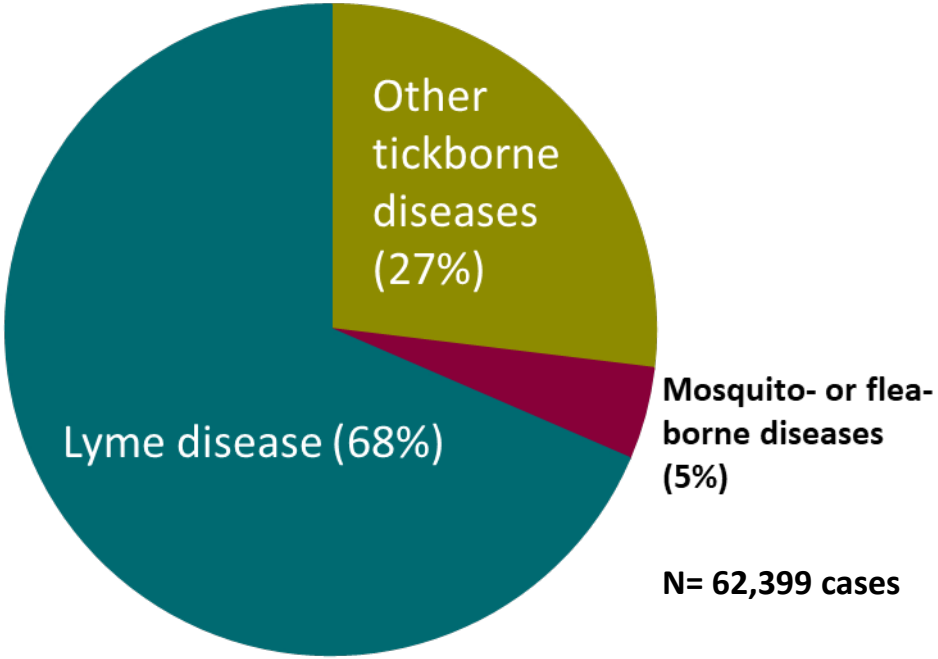
Overview of Trends, New Concerns

Overview of Trends and New Concerns

- Majority of vector-borne diseases in the U.S. are tickborne diseases
- Increasing number of tickborne disease cases over time
- Expanding geographic range of tickborne cases
- Growing number of tickborne agents recognized to cause human disease
- *Introduction of new tick species that may serve as vector of human pathogens*

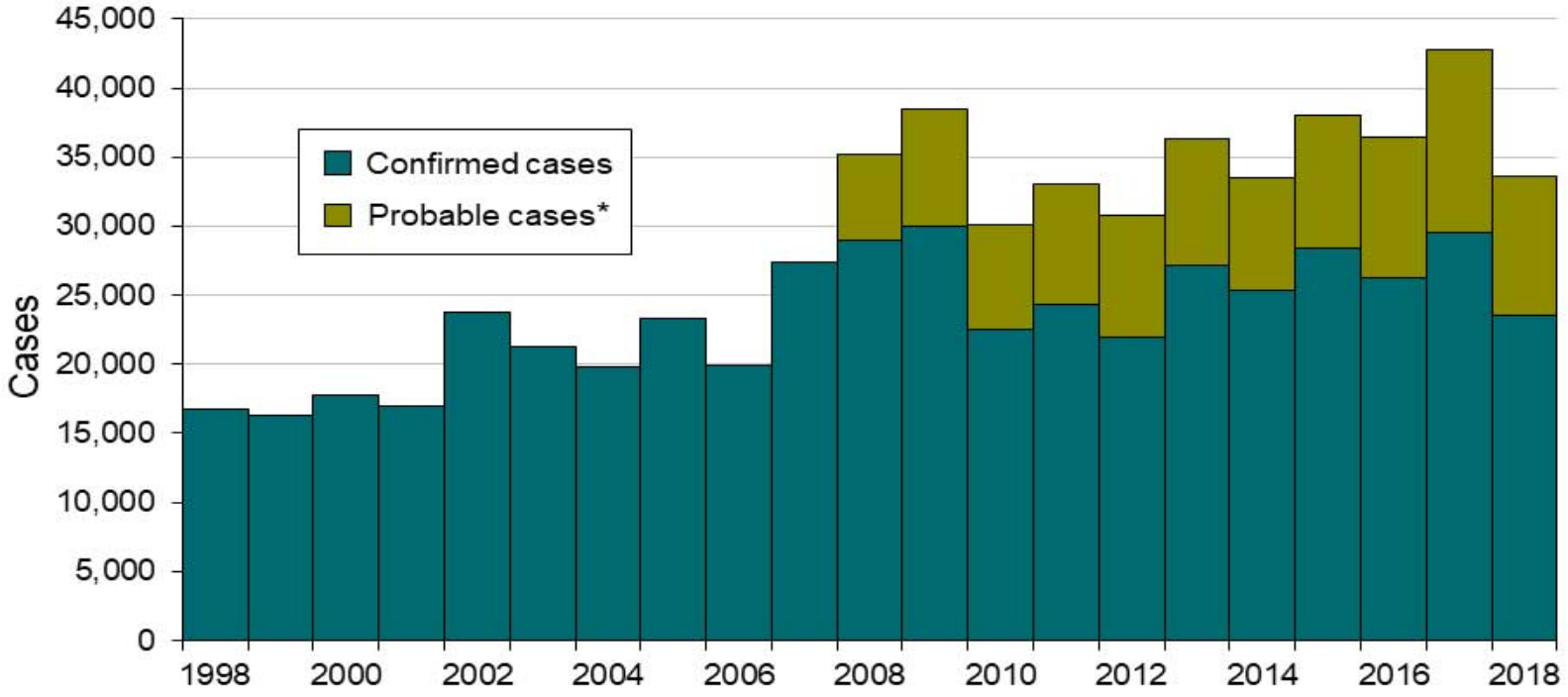
Majority of Reported Vector-Borne Diseases are Spread by Ticks

A majority of vector-borne disease cases in the U.S. are spread by ticks



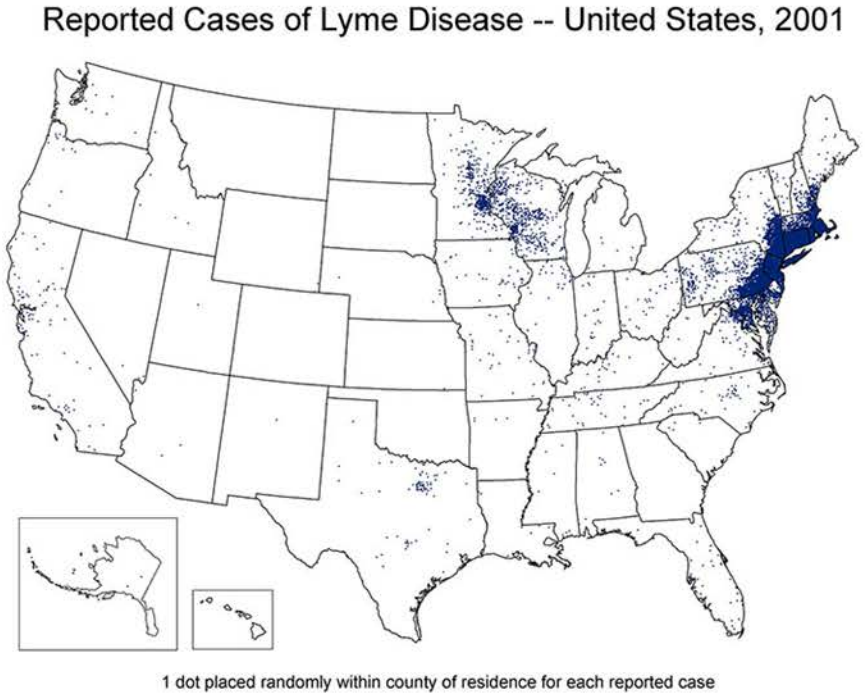
Cases of Nationally Notifiable Vector-borne Diseases Reported in the U.S., 2017

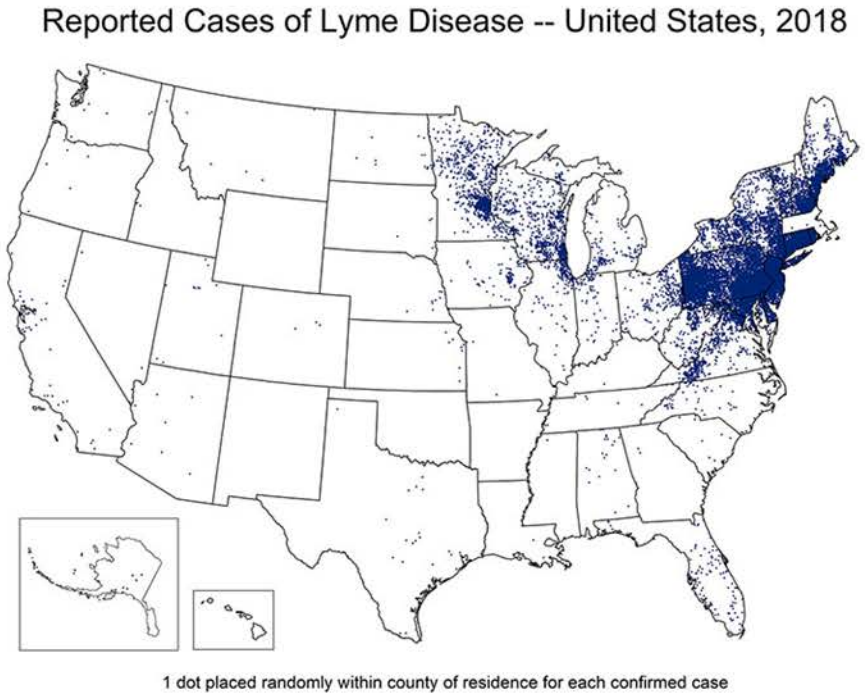
Increasing number of tickborne disease cases



*National Surveillance case definition revised in 2008 to include probable cases;
details at http://www.cdc.gov/ncphi/disss/nndss/casedef/lyme_disease_2008.htm

Expanding Geographic Range of Tickborne Disease Cases



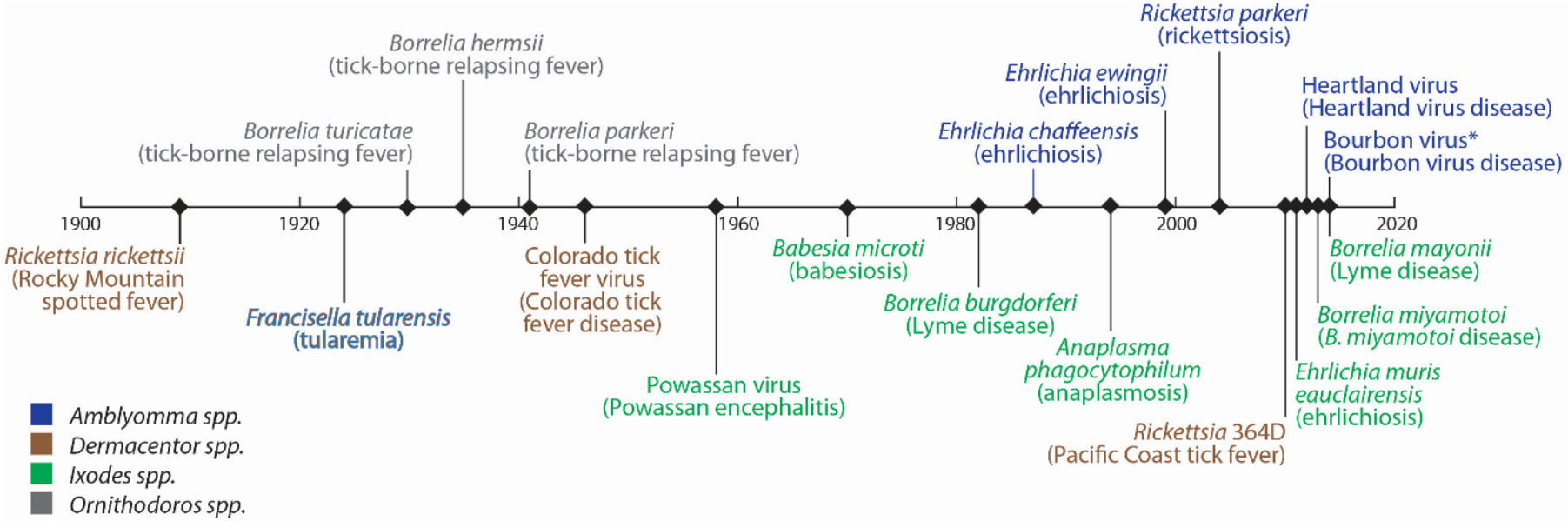


cdc.gov/lyme/stats/index.html

N=17,209

N=33,666

Growing Number of Tickborne Agents Recognized to Cause Human Disease, 1960-2020



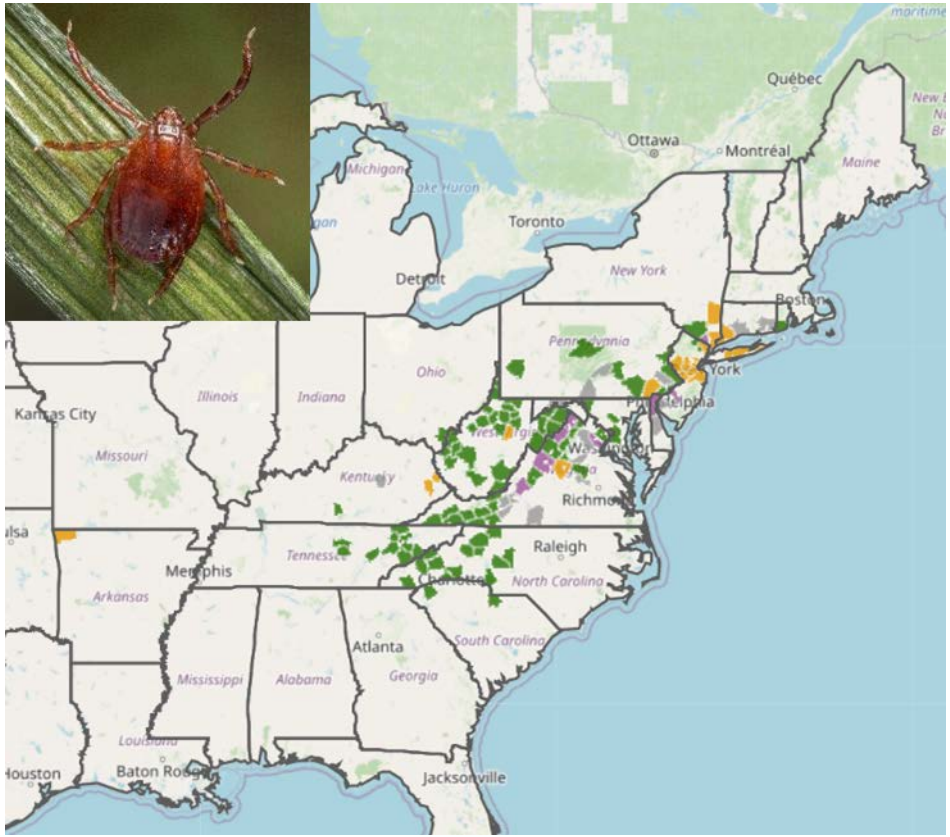
Note: This timeline shows when tickborne pathogens were recognized as causes of human disease. In some cases, organisms were identifed in ticks before they were associated with human disease. In other cases, the disease was recognized before the etiological agent was found to be tickborne.

*Putative vector

https://www.cdc.gov/media/dpk/diseases-and-conditions/lyme-disease/index.html

Asian Longhorned Tick

- Native to Russia, SE Asia, and the Pacific
- First identified in the U.S. on a sheep in NJ in 2017
- Parthenogenetic
- Known biting nuisance/health risk to animals
- Able to transmit several human pathogens
- Current threat level to human health in the U.S. is unknown



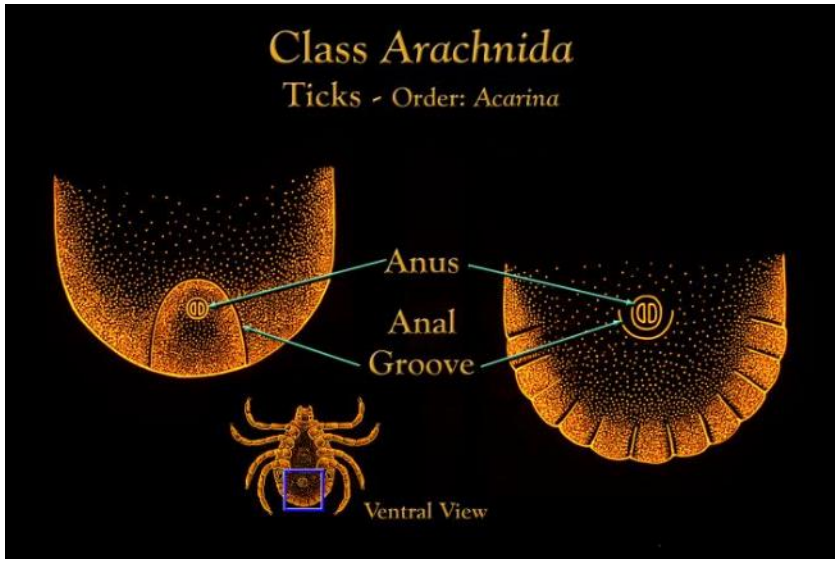
Ticks of Public Health Significance

Ticks of Public Health Significance Are:

- Frequent human biters
- Capable of:
  - acquiring human pathogens during blood feeding on zoonotic hosts
  - maintaining infection between life stages
  - transmitting pathogens during blood feeding
- Of more than 80 species of ticks described in the U.S., roughly a dozen are frequent human biters and proven vectors of human pathogens (bridging vectors)

Prostriate vs. Metastriate

- **Prostriate**: *Ixodes*
  - Describing ticks (of the family Ixodidae) in which the anal groove of the adult is in front of the anus
- **Metastriate***: *Amblyomma*, *Dermacentor*, *Haemaphysalis*, *Rhipicephalus*
  - Describing ticks (of the family Ixodidae) in which the anal groove of the adult is behind the anus.



*United States genera

Taxonomy of ticks

- Ticks are not always familiar to public health workers
- Fortunately, most common adult ticks are fairly easily distinguished
- Adults will be the primary stage collected via drag or flag; immatures of several species will be found via drag or flag
- Immature ticks are more difficult to identify for many workers, even experts
- Engorged ticks may offer a challenge

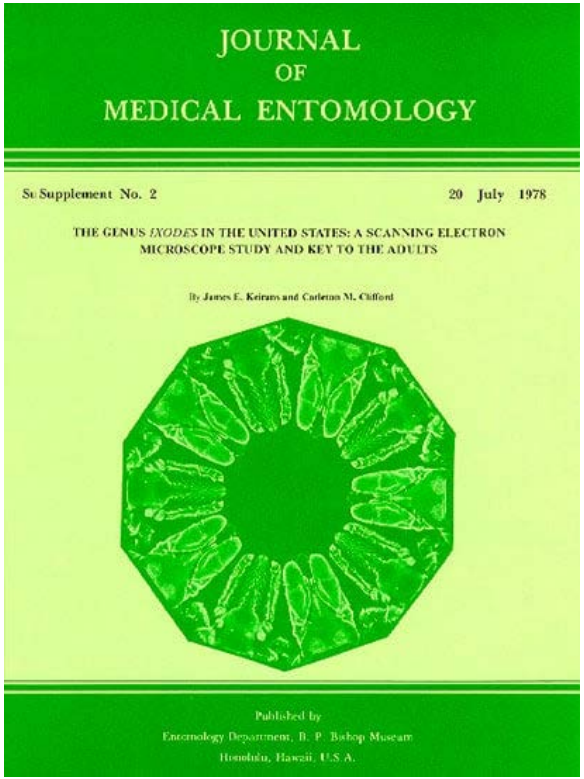
Accurate Identifications

- State-specific and regional keys are not available for all locations
- Older keys may be difficult to locate or obtain
- Reference specimens may not be readily available

- **Identification service**: Difficult ticks could be sent to CDC-RZB for identification and sent back to the state for testing or for use as reference specimens
- **Molecular identification**: Ticks, tick legs, or tick DNA could be provided to CDC-RZB for molecular confirmation of morphotypes.

Proposed Tick Identification Products

- Identification keys (perhaps regional)
- Glossary of tick morphology
- Tick identification workshop (tentative)
- Reference specimens of preserved ticks

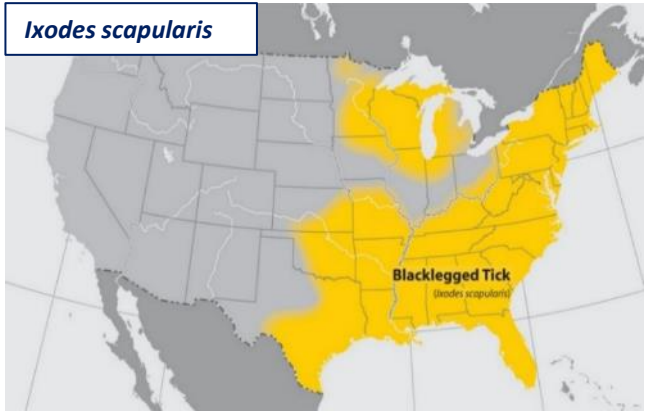


Range Maps of Ticks that Bite Humans in the U.S.

https://www.cdc.gov/ticks/geographic_distribution.html

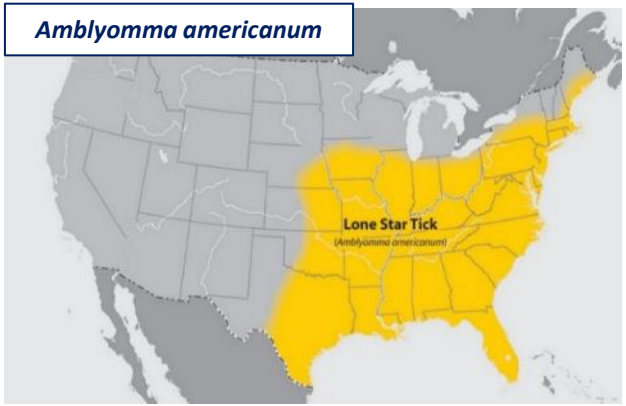
Three Species as Vectors of Majority of Human Diseases

Ixodes scapularis

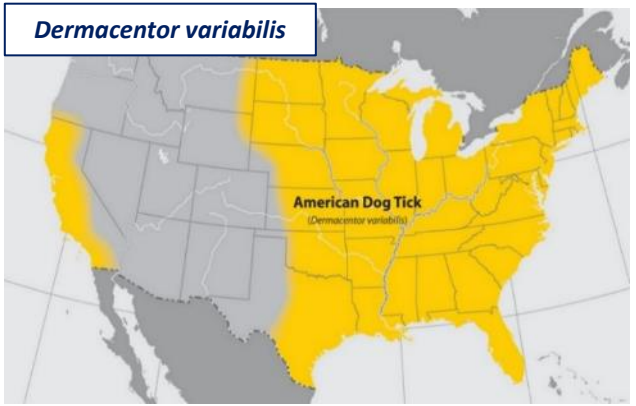


Lyme disease
Anaplasmosis
Babesiosis
***Borrelia miyamotoi* disease**
Powassan disease
Ehrlichiosis (*E. muris eauclairensis*)

Amblyomma americanum



Dermacentor variabilis



Ehrlichiosis; Heartland virus disease; Tularemia; Bourbon virus disease

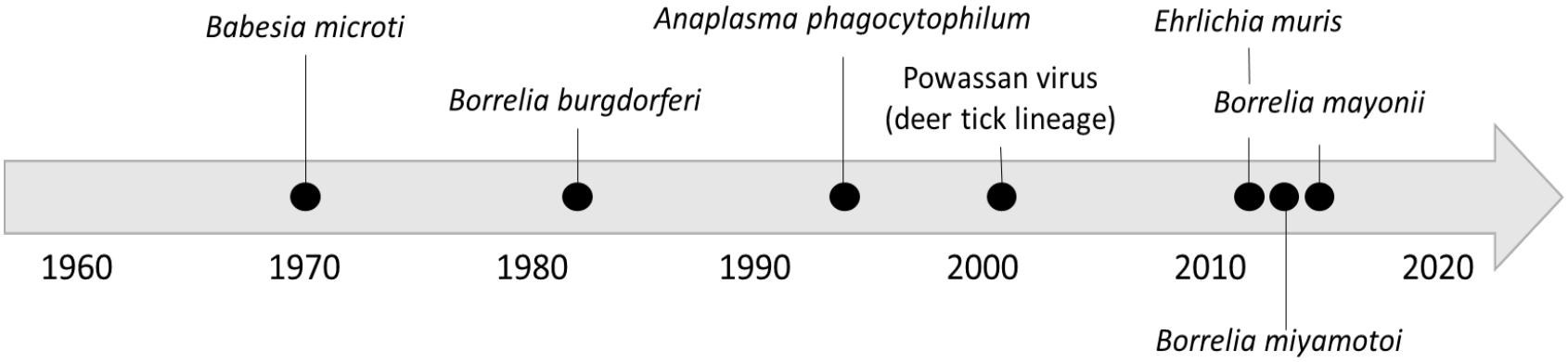
Rocky Mountain spotted fever; Tularemia

Target: *Ixodes scapularis*

- Blacklegged (deer) tick
- Widespread in the eastern U.S.
- Emerging into new areas westward
- Harbors endemic and emerging pathogens
- All life stages can be collected via drag or flag
- Feeds on a wide variety of bird, mammal, and reptile hosts

in.gov/isdh/28005.htm

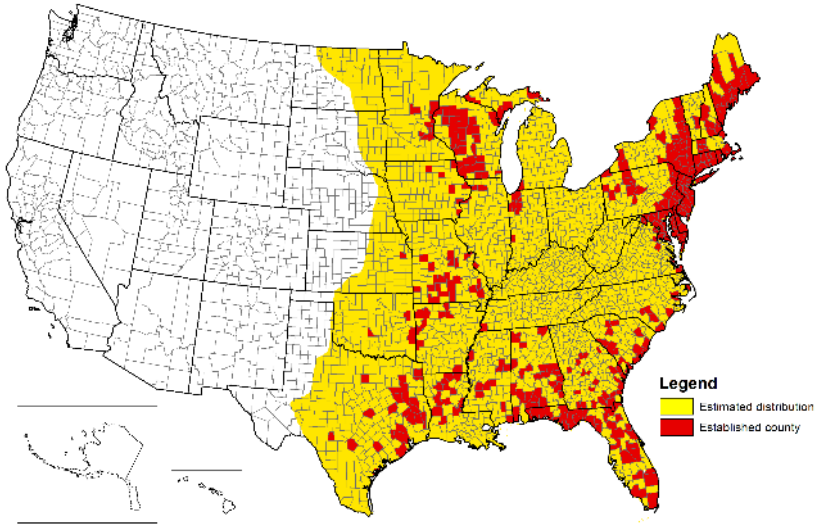
Ixodes scapularis: An Increasing Public Health Concern



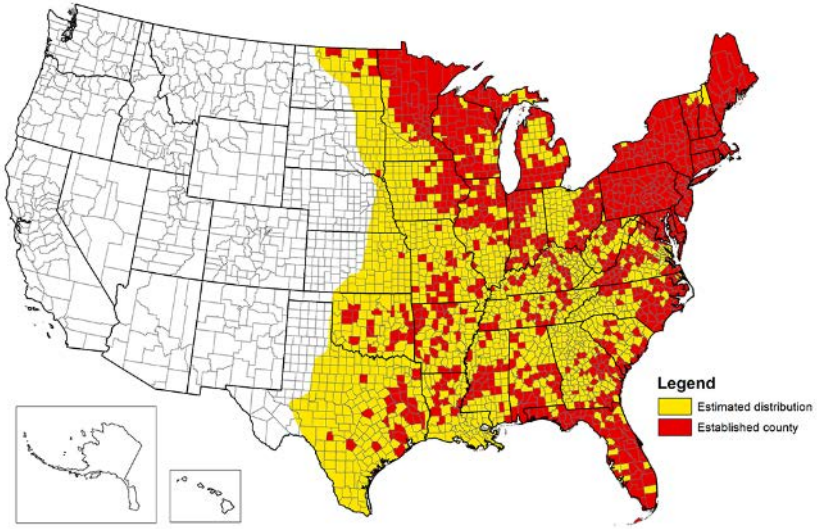
Eisen, RJ and Eisen, L. Trends in Parasitology, 2018. 34:295-309.

Reported Distribution of *Ixodes scapularis* has Expanded

Ixodes scapularis - Estimated and established distribution, 1996



Ixodes scapularis - Estimated and established distribution, 2020



Established: ≥6 or more ticks or >1 life stage recorded in a single year

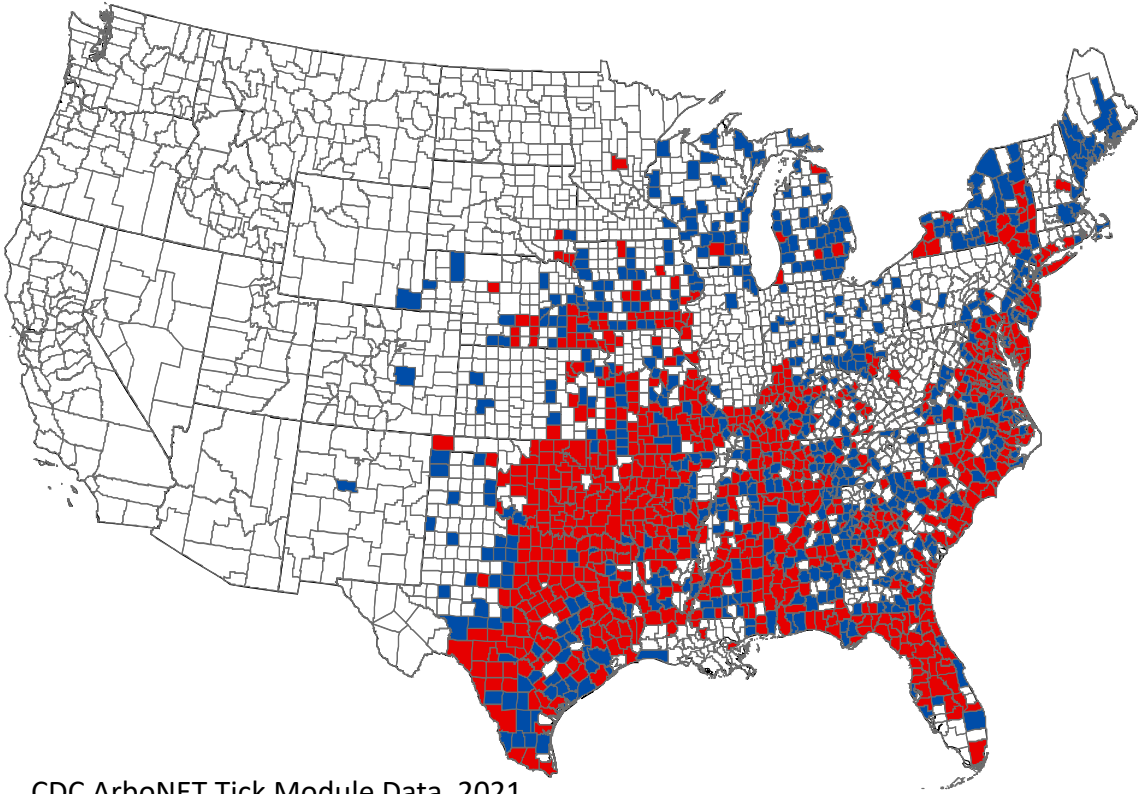
CDCArboNET Tick Module (2021). www.cdc.gov/ticks/surveillance

Target: *Amblyomma americanum*

- Lone star tick
- Very widespread
- Emerging into new areas, northward and westward
- All life stages can be collected via drag or flag
- Harbors endemic and emerging pathogens
- Feeds on a wide variety of avian and mammalian hosts

Image: University of Rhode Island

Reported Distribution of *Amblyomma americanum* is Expanding



The range of the lone star tick has expanded north from its historically identified range

Reported: <6 individuals of a single life stage recorded in a single year

Established: ≥6 or more ticks or >1 life stage recorded in a single year

Reported: 630 counties
Established: 784 counties

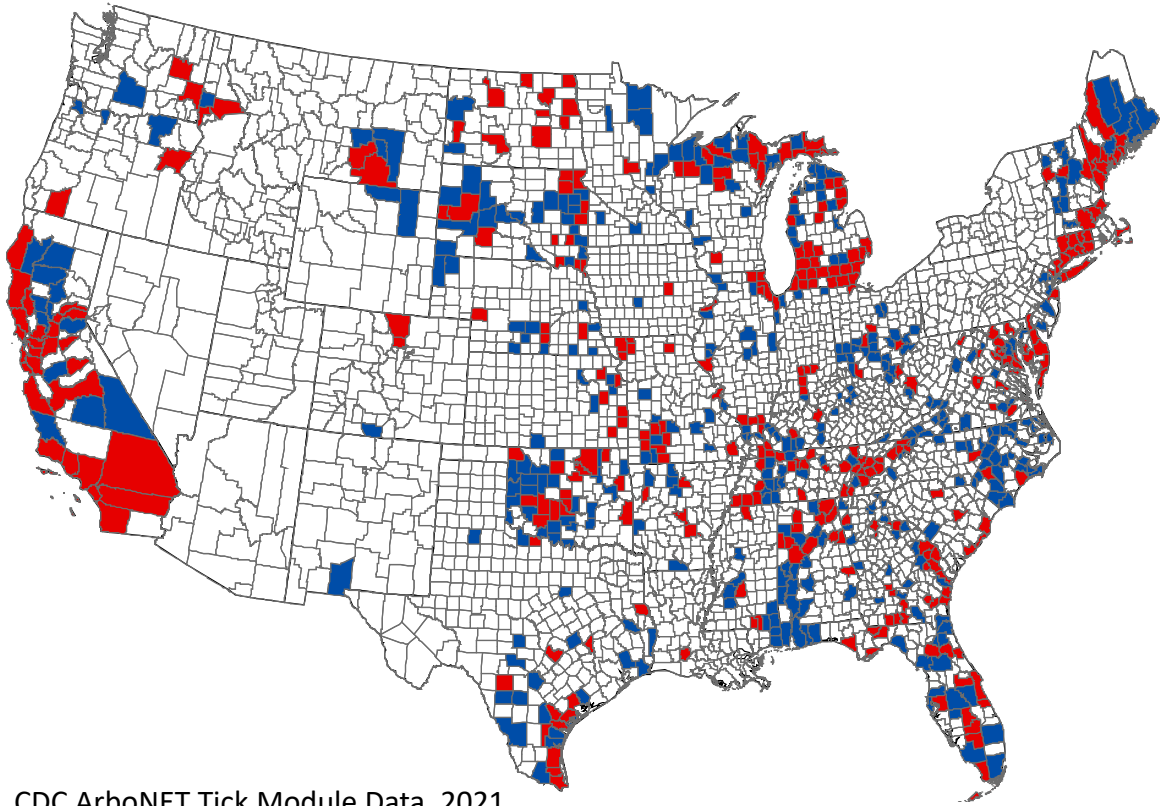
CDC ArboNET Tick Module Data, 2021

Target: *Dermacentor variabilis*

- American dog tick
- Very widespread
- Emerging into new areas westward
- Adult stage collected primarily by drag/flag
- Harbors endemic and emerging pathogens
- Feeds on a wide variety of mammalian hosts

Image: University of Rhode Island

Reported Distribution of *Dermacentor variabilis*



Reported: <6 individuals of a single life stage recorded in a single year

Established: ≥6 or more ticks or >1 life stage recorded in a single year

Reported: 371
Established: 330

CDC ArboNET Tick Module Data, 2021

Target: *Haemaphysalis longicornis*

- Asian longhorned tick
- Recently recognized in U.S.
- Parthenogenetic
- Ongoing surveillance for occurrence in U.S. (USDA)
- Collected off hosts, on drags, and by CO_2 traps with variable efficacy
- Limited pathogen (endemic vs exotic) detection efforts in U.S.

Targets: Other Species of Public Health Interest

- *Amblyomma maculatum*
  - *Rickettsia parkeri*
- *Dermacentor andersoni*
  - *R. rickettsii*
  - CTF virus
- *Dermacentor occidentalis*
  - *R. rickettsii* 364D
- *Rhipicephalus sanguineus*
  - *R. rickettsii*

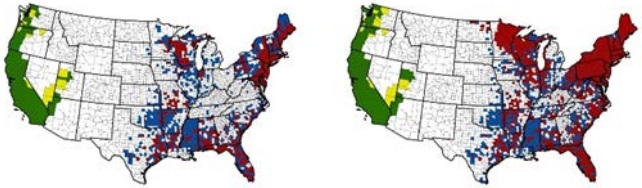
National Tick Surveillance Objectives

Uses of Tick Surveillance Data in Public Health

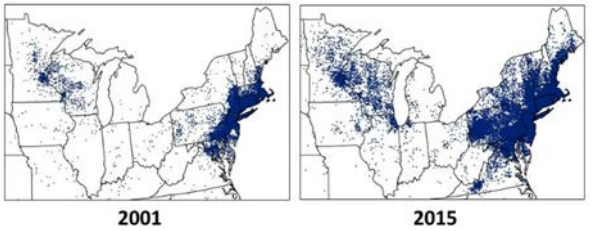
- Provide actionable, evidence-based information to clinicians, the public, and policy-makers on where and when people are at risk for exposure to ticks and tickborne pathogens.
  - Used to target prevention and control strategies
- Explain and predict epidemiological trends
  - Expanding range and incidence of TBD cases
  - Rarity of Lyme disease in the south, despite presence of the vector
  - Risk of exposure to agents of TBDs that are not notifiable
  - Predicting future expansion of ticks and TBD cases
- Maintain a georeferenced collection of nucleic acids from tested ticks to rapidly identify the distribution and prevalence of newly discovered tickborne pathogens

Relationship between Ticks, Pathogens, and Human Illness

Distributions of ticks and tickborne pathogens change over time.



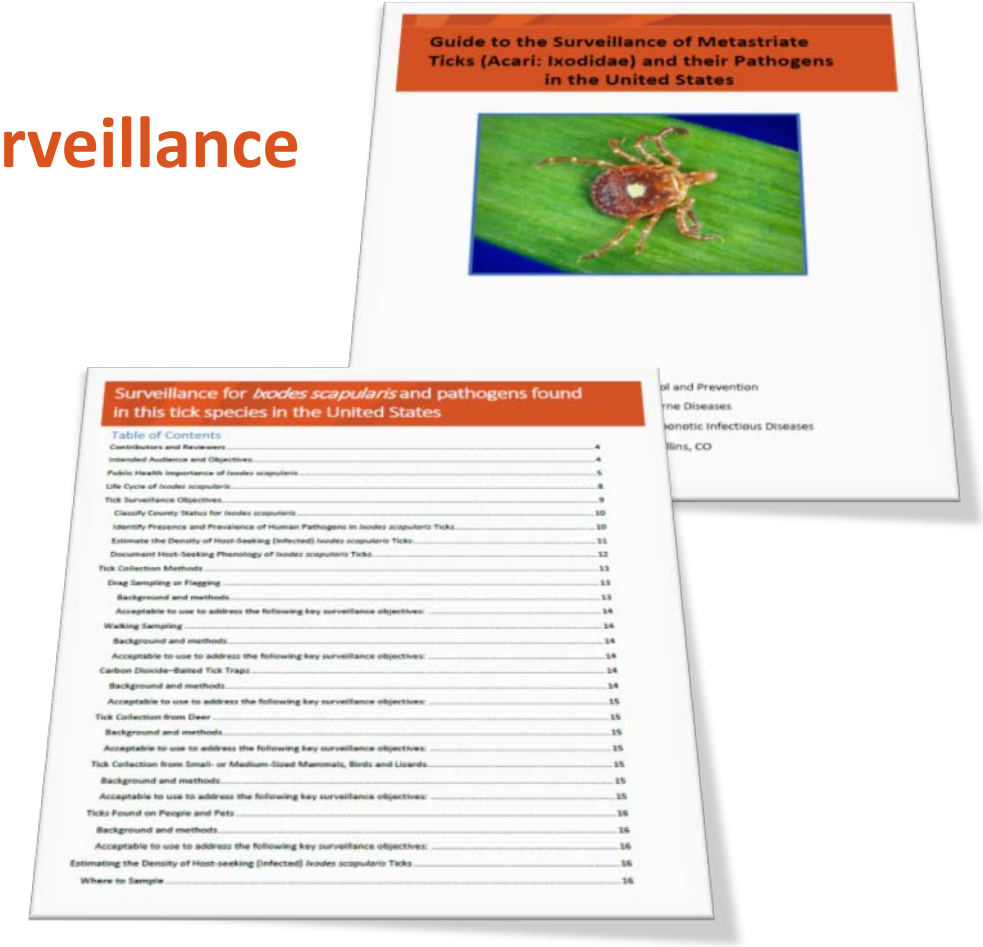
Likelihood of human encounters with ticks and tickborne pathogens change over time and space.



Tick surveillance is intended to monitor trends in presence, abundance, and infection prevalence in medically important ticks to direct public health action.

CDC Objectives for Tick Surveillance

- Classify county status for tick species
- Identify presence and prevalence of human pathogens in ticks
- Estimate the density of host-seeking (infected) ticks
- Document host-seeking phenology of ticks



www.cdc.gov/ticks/surveillance/

Local Tick Surveillance Objectives

Classifying the Geographic Presence/Range of Tick Species Within the County/Community

- Benefits
  - Identifying habitats within the county/community that support tick populations
  - Direct public education for tick-bite prevention
  - Knowledge of areas where tick-control may be necessary
  - Partnerships with other community agencies and organizations
  - Cost-conscious

Identifying the Presence and Prevalence of Human Pathogens in Ticks

- Benefits
  - Direct public education for tick-borne disease prevention
  - Knowledge of diversity of pathogens in an area
  - Knowledge of areas with varying risk for TBD
  - Direct tick-control activities (consider prioritization of high-use vs. isolated areas)

CDC public health image library

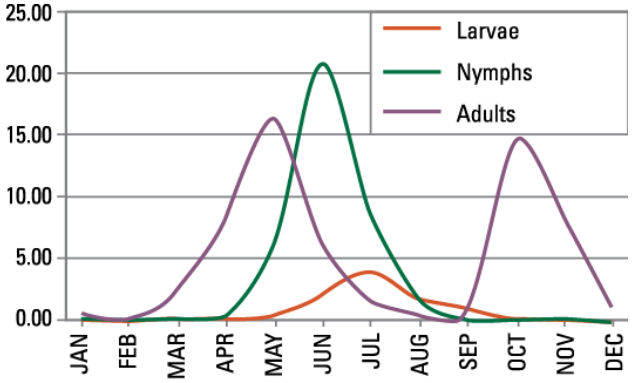
Estimating the Density of Host-Seeking (infected) Ticks: Acaralogic Risk

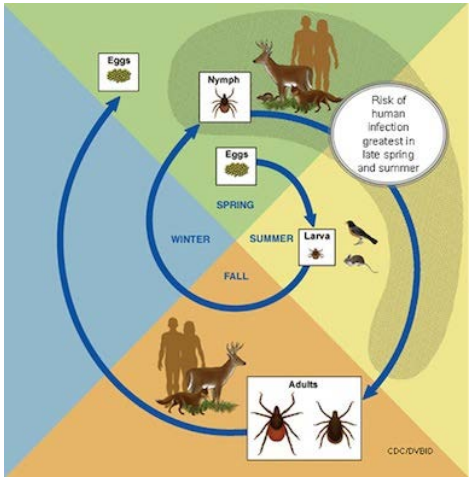
- Benefits of estimating DIN and DIF (#infected ticks/100 or 1000 m^2)
  - Prioritize locations where greater educational outreach is necessary
  - Prioritize locations where tick-control is necessary
  - Allows for metrics to evaluate the impact of tick control efforts
  - Useful even if ticks are not tested for pathogens (historic pathogen prevalence as useful guide)

cdc.gov/ticknet/index.html

Document Local Phenology of Medically Important Tick Species

- Benefit
  - Knowledge of local life cycles can help to identify yearly periods of risk
  - Direct educational campaigns during times of highest risk
  - Direct tick control against appropriate life stages





Tick Surveillance Methods to Meet Your Objectives

Passive Tick Surveillance

Passive surveillance systems accept reports and tick submissions from the public, animal and human healthcare providers.

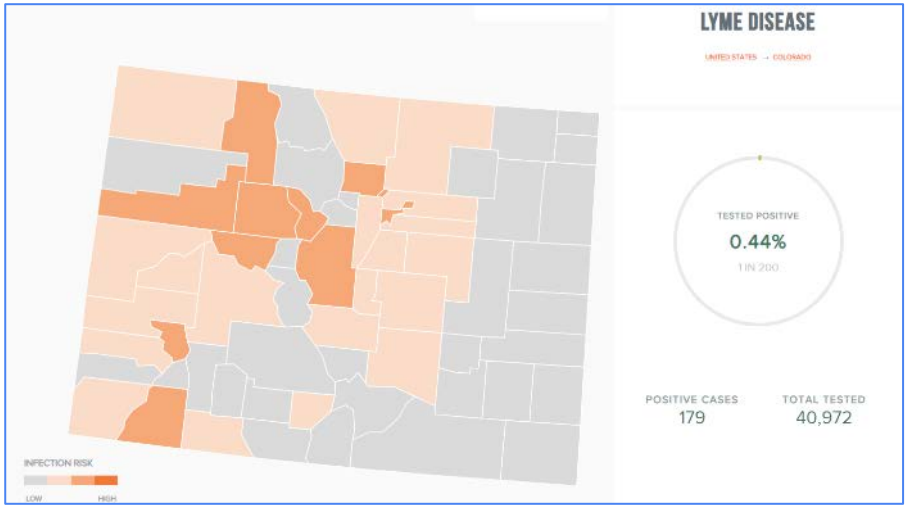
- Ticks found on people, pets, livestock, etc.
- Cost-effective and wide ranging
- Sensitive indicator for emerging species
- Engages the public and partners

prevention.com

michigan.gov/lyme

Passive Tick Surveillance, continued

- Objectives that passive surveillance may help support
  - Presence of a tick species within a county (if travel history is considered)
  - Identifying presence, but not prevalence, of pathogens in ticks (if travel history is considered)



capcvet.org/maps/#/

Improving Passive Tick Surveillance

Because passive tick surveillance may identify ticks encountered during travel away from the area of interest, for all specimens:

- Document the location of exposure if possible
- Ask about travel history of the person or animal
- Determine if the tick was attached

Active Tick Surveillance

Active surveillance is the direct, systematic collection of ticks from the environment or from host animals.

- Drag/flag, walking sampling
- CO_2 baited traps
- Tick collection from deer
- Tick collection from small- or medium-sized mammals, birds & lizards

Active Tick Surveillance: Where to Sample?

- Make sure to obtain permissions and permits (land access, scientific collection permits, etc.)
- Areas chosen based on:
  - Likelihood of human-tick contact
  - Suitable tick habitat such as woodland, forest, or grassy areas
  - Areas where tick species are newly established/emerging
  - Areas where incidence of TBD have changed over time
  - Areas where novel pathogens are suspected to be circulating

Active Tick Surveillance: When to Sample?

- Peak nymphal or adult activity periods
  - Previous phenology studies, passive surveillance, and human case onset are a useful guide
- If estimating tick density, sample each site 3 or more times within peak activity periods
  - More visits = greater precision for density estimates
- Environmental considerations
  - Make sure to check weather for temperature, precipitation, and wind

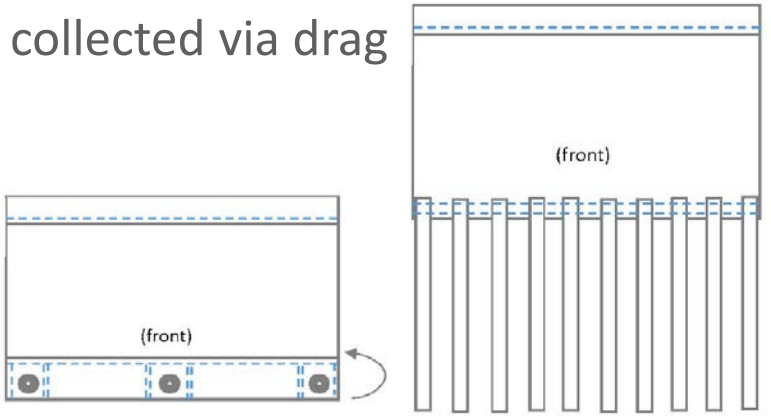
Guidance on Personal Protection

- Use EPA-registered tick repellents
- Treat clothing and gear with permethrin (don't treat drag or flag cloth)
- Long-sleeved shirts tucked into pants & long pants tucked into socks
- Daily tick checks
- Prompt removal of any attached ticks
- Awareness of infected ticks
- Awareness of environmental hazards
- Vertebrate collection and processing safety

Active Tick Surveillance: Tick Dragging & Flagging

Appropriate method for identifying presence & density of ticks, pathogen presence & prevalence, and documenting host-seeking phenology

- Determine tick presence or density by approximating a passing animal
- Typically a 1m^2 cloth, dragged or waved across vegetation or leaf litter
- Some ticks and/or life stages are not readily collected via drag
- Important to check drag/flag cloths often



Active Tick Surveillance: Size of Area to Sample to Estimate the Density of Ticks

- Expansive area
  - At least 750m^2 of linear transects, or 50 transects of 15m^2
  - Fixed sampling grids with flags or stakes
  - Measured rope
  - Measuring the collector's stride length
  - “Smart” technology, GPS units, cell phone mapping, etc.
- Check drag or flag cloth systematically and often
- Include ticks recorded from the collector's body or clothing*

A technician collected 52 Amblyomma americanum females while dragging 750m^2 of transects. 52/750 x 100 = 6.9 ticks/100m^2

Active Tick Surveillance: CO_2 Baited Traps

Appropriate method for identifying presence not density of ticks, pathogen presence & prevalence, and documenting host-seeking phenology

- Ticks are attracted to CO_2 in order to find hosts
- Dry ice is relatively inexpensive and used by many mosquito programs for surveillance
- Sticky tape along platform edges or flannel base
- Different species and stages respond variably to traps
  - *A. americanum* & *H. longicornis*
- Varying levels of wind can disrupt effectiveness

Active Tick Surveillance: Tick Collection From Deer

Appropriate method for identifying presence not density of ticks, and pathogen presence not prevalence

- Important hosts for adult and/or immature stages of *I. scapularis*, *A. americanum*, *A. maculatum*, and *H. longicornis*
- Cost-effective if state or local agencies are already conducting deer check stations or surveys
- Spatially non-specific: however, a good way to direct additional active surveillance methods

Active Tick Surveillance: Tick Collection From Small- or Medium-Sized Mammals & Birds

Appropriate method for identifying presence not density of ticks, pathogen presence not prevalence, and documenting host-seeking phenology

- Sensitive method for determining presence and abundance of immature ticks
- Provides animal-level measures of parasitism
- Costly, labor-intensive
- Collection permits/approved animal protocols
- Safety of staff and animals

Pathogen Detection in Host-Seeking Ticks

Appropriate method for identifying presence & prevalence of pathogens, and to assist calculations of DIN and DIF

- Utilize a detection assay or assays (e.g., real-time PCR or standard PCR) that is specific to the target pathogen.
  - To demonstrate that an assay is pathogen species-specific, it should be tested against a panel comprising genetically-similar species, ideally including any genetically-similar species that might also be found in the same tick species.
  - A published assay that has previously been shown not to detect genetically-similar species meets this requirement.

Estimating Pathogen Prevalence in Host-Seeking Ticks

- Pathogen prevalence and 95% confidence intervals by life stage and site calculated using the Pooled Infection Rate MS Excel Add-In available on the CDC website
- Best practice is to test ≥25 ticks/site
- Greater number of ticks tested = tighter confidence limits

Acaralogic Risk Calculations

To calculate the density of infected nymphs (DIN) or females (DIF):

$$DIN = [\text{ nymphal density }] \text{ x } [\text{ nymphal infection prevalence }]$$

$$DIN = [\frac{n\ nymphs\ collected}{total\ area\ dragged} \text{ x } 100\ ] \text{ x } [\frac{n\ positive\ nymphs}{n\ ticks\ tested}\ ]$$

Guidance on Assay Selection

Metastriate Pathogens

- *Rickettsia rickettsii*
- *Rickettsia parkeri*
- Rickettsia sp. 364D
- *Ehrlichia chaffeensis*
- *Ehrlichia ewingii*
- *Francisella tularensis*
- Colorado tick fever virus
- Heartland virus
- Bourbon virus

Prostriate Pathogens

- *Borrelia burgdorferi* s.s.
- *Borrelia mayonii*
- *Borrelia miyamotoi*
- *Anaplasma phagocytophilum*
- *Babesia microti*
- *Ehrlichia muris eauclairensis*
- *Powassan virus*

Best Practices for Collecting/Storing Ticks

- Data to collect:
  - Site name (simple and consistent), locality. GPS coordinates of site, date, time, environmental conditions, collection method, number & species identification of ticks by life stage, name of collector
- Vials, labeling, storage:
  - Use vials with secure lids, clearly label using solvent-proof marker on paper label inside vial
  - Preserve ticks in 70-95% ethanol, RNALater™ or other RNA stabilization buffer, or frozen at -80°C without preservatives
  - Submit some specimens as vouchers to curated arthropod collections

Guidance on Testing Strategy

- Individual vs. pools (prevalence vs. minimum frequency of infection)
- Site-specific vs. county level
- Broadly-reactive assays vs species-specific
- Human pathogens vs. organisms of unknown or debatable pathogenicity
- Endosymbionts may be highly prevalent
- Surveillance vs. research (pathogen discovery)

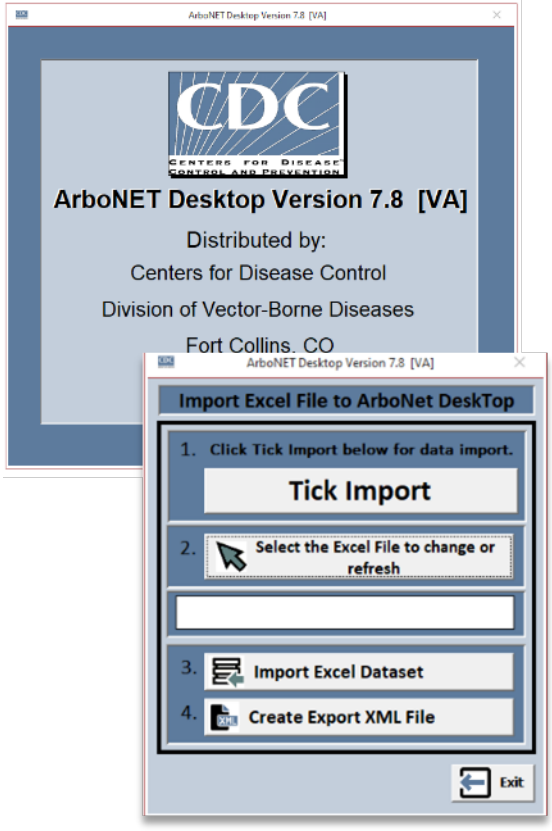
Guidance on Sample Sizes

- Chosen based on expected prevalence of pathogens in questing ticks

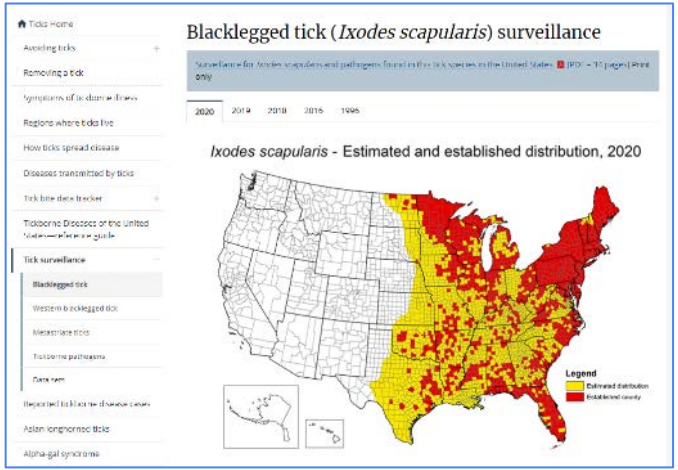
- Prevalence of *Rickettsia rickettsii* is very low (often <0.1%), while *Rickettsia parkeri* can reach 40%
- Prevalence of *Ehrlichia chaffeensis* is about 5%, while *E. ewingii* is variable
- Tick-borne virus prevalences are exceedingly low, requiring large sample sizes for detection; pooling is usually necessary

ArboNET Tick Module

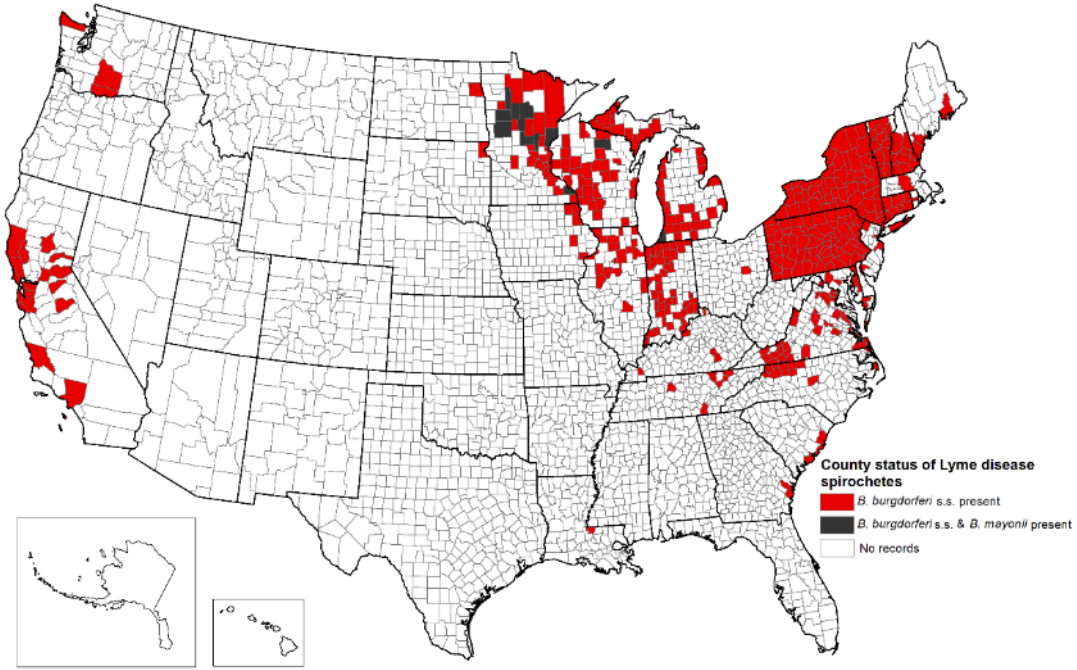
National Tick Surveillance Database: The ArboNET Tick Module



- Microsoft Access-based tool to batch upload and collate tick surveillance and pathogen testing data
- Standardized Microsoft Excel tables for data collection included
- All tick surveillance data are welcome (prostriate and metastriate)
- Maps and datasets published on CDC Tick Surveillance website



Distribution of Lyme disease spirochetes in host-seeking *I. scapularis* and *I. pacificus* ticks, 2020



Reported distribution of counties where Lyme disease spirochetes have been identified. Counties classified as “present” are those where *Borrelia burgdorferi* sensu stricto or *Borrelia mayonii* have been identified in one or more host-seeking *Ixodes scapularis* or *Ixodes pacificus* ticks, using species-specific molecular methods.

Conclusion

I. Tick surveillance is important for local programs:
   I. Provides you with valuable information on TBD risk in your area
   II. Helps to educate the public and human/animal healthcare providers regarding risk of TBD where they live, work, and recreate
   III. Data provided through tick surveillance may help direct tick control activities
   IV. Data provided through tick surveillance allows for the evaluation of tick control measures
II. Depending on your resources, you can start small and grow the program
   I. Consider the data you're collecting now to make sure it's comparable

THANK YOU FOR YOUR PARTICIPATION!