TICK-BORNE DISEASES: IT'S NOT JUST LYME DISEASE ANYMORE

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NE IPM Advisory Council
Baltimore, MD
October 27, 2016

Few agricultural or health problems confronting human societies have proved as intractable as control of ticks and the many diseases they transmit.

Dan Sonenshine

Biology of Ticks, Vol. 2

Moses Cucura

USDA/Scott Bauer

Kirby Stafford

USDA/Scott Bauer

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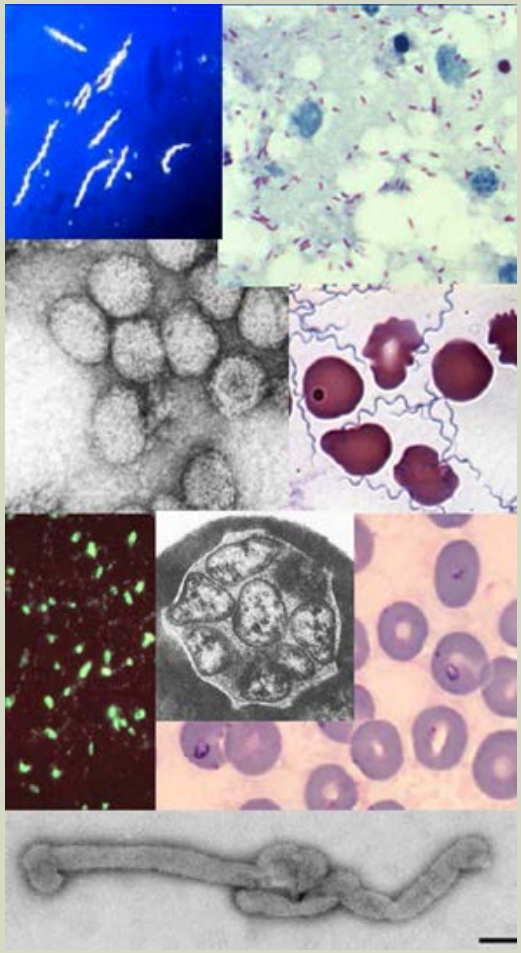
HUMAN TICK-BORNE DISEASES IN THE UNITED STATES

- Lyme disease (*Borrelia burgdorferi*)*
- Anaplasmosis*
- Babesiosis*
- Novel *Borrelia* spp., like new *B. mayonii*
- *Borrelia miyamotoi* infection
- Bourbon virus (Kansas)
- Colorado Tick Fever
- Ehrlichiosis (including *E. muris*-like agent)*
- Heartland virus infection (MO,TN, OK)
- Southern Tick-Associated Rash Illness
- Spotted Fever Group Rickettsia*
- Tick-borne relapsing fever (*B. hermsii*)
- Powassan virus infection*
- Tularemia*
- Tick Paralysis (toxin)
- Red Meal Allergy



*reportable to CDC

Adapted from slide from CDC-Division Vector-Borne Diseases

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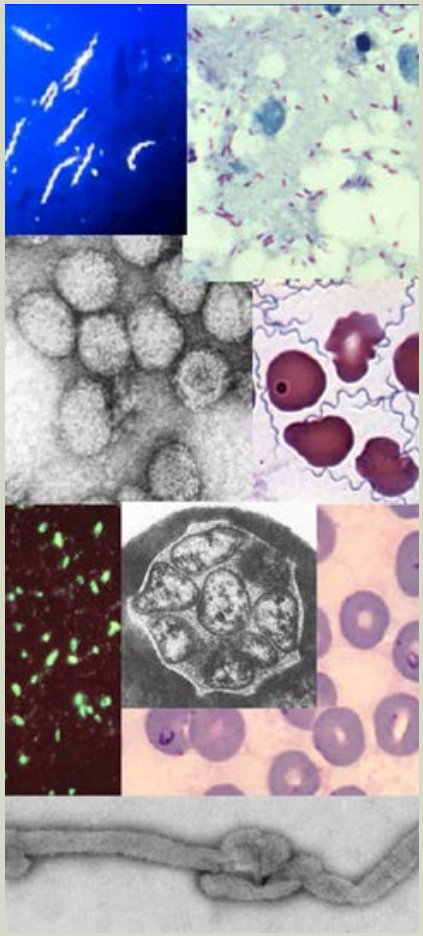
TICK-BORNE DISEASES IN THE U.S., 2014

Disease/agent	Reported cases*
Lyme disease	33,461
Spotted Fever Rickettsiosis	3,647
Anaplasma phagocytophilum	2,800
Babesia	1,759
Ehrlichia chaffeensis	1,475
Anaplasma or Ehrlichia – undetermined/ other	213
Tularemia	180
Powassan virus	8



*total reported cases – confirmed and probable

Adapted from slide from CDC-Division Vector-Borne Diseases

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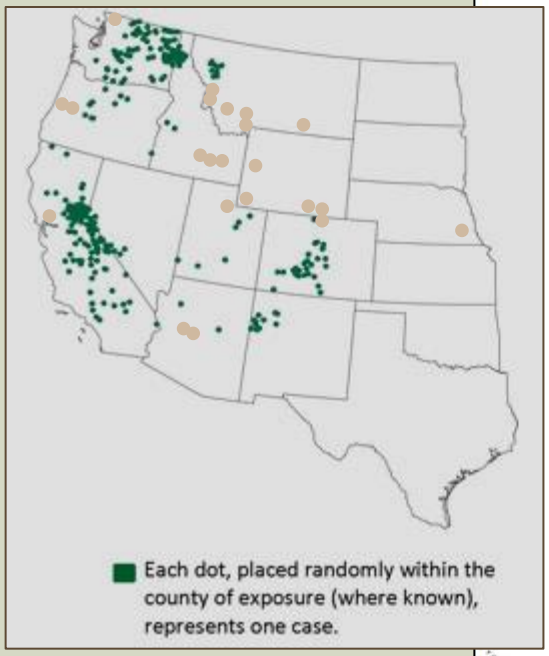
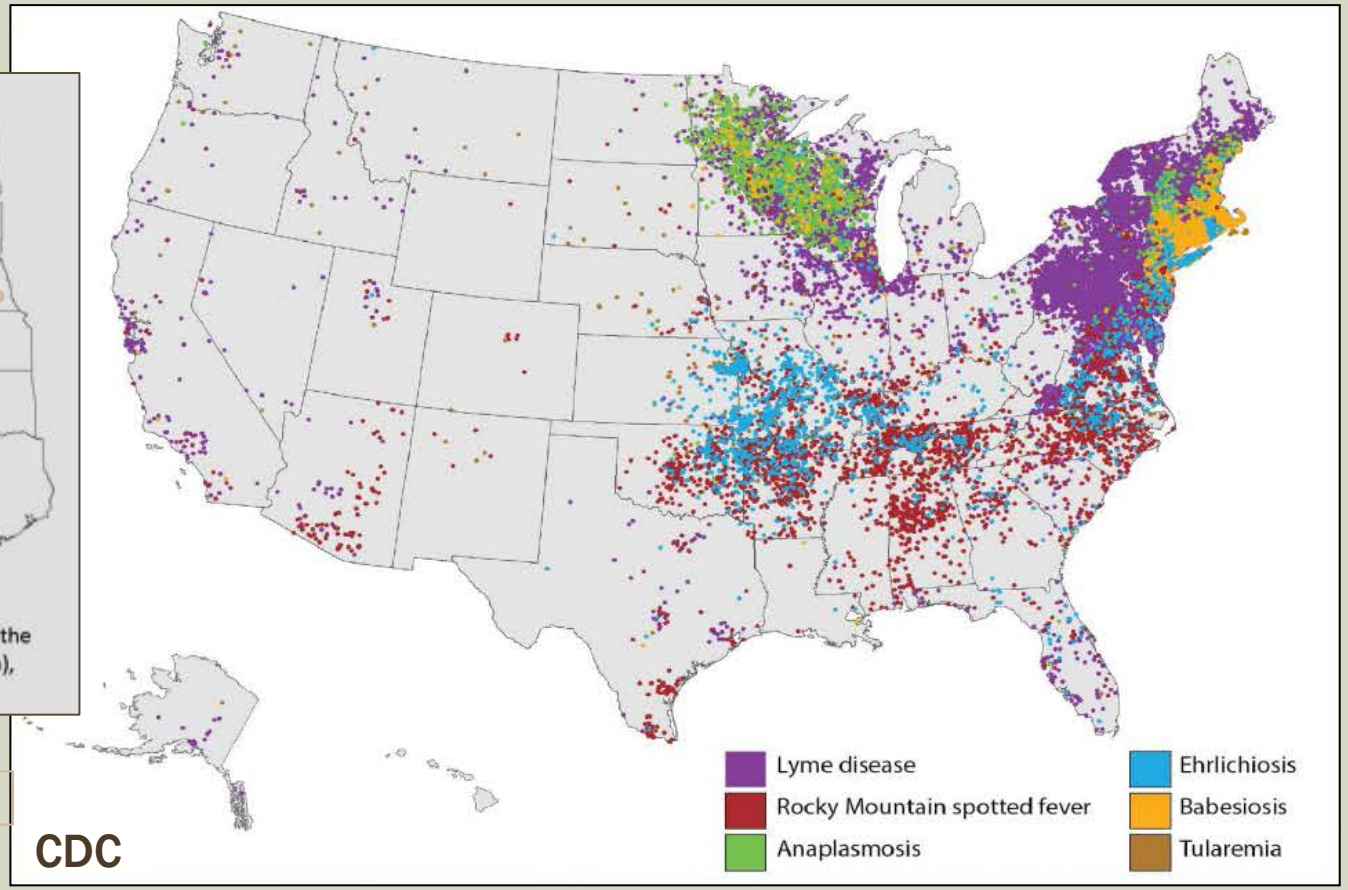
DISTRIBUTION TICK-BORNE DISEASES, 2013



Relapsing Fever, 1990-2011

Colorado Tick Fever, 2002-2012



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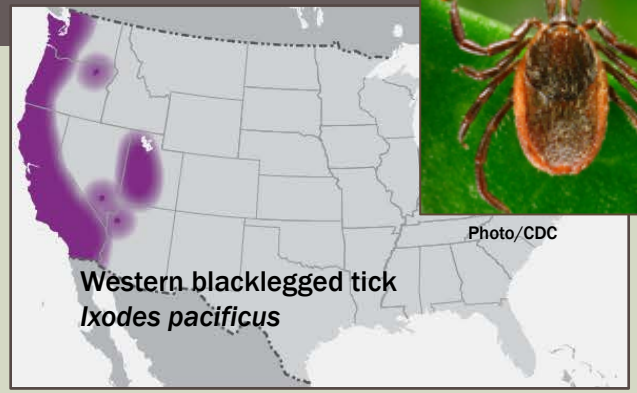
#1

LYME DISEASE – UNITED STATES, 1982-2014
TWO MAJOR TICK VECTORS

Photo/USDA



Photo/CDC

363,000!

33,461

8,102 Probable cases

25,359 confirmed cases

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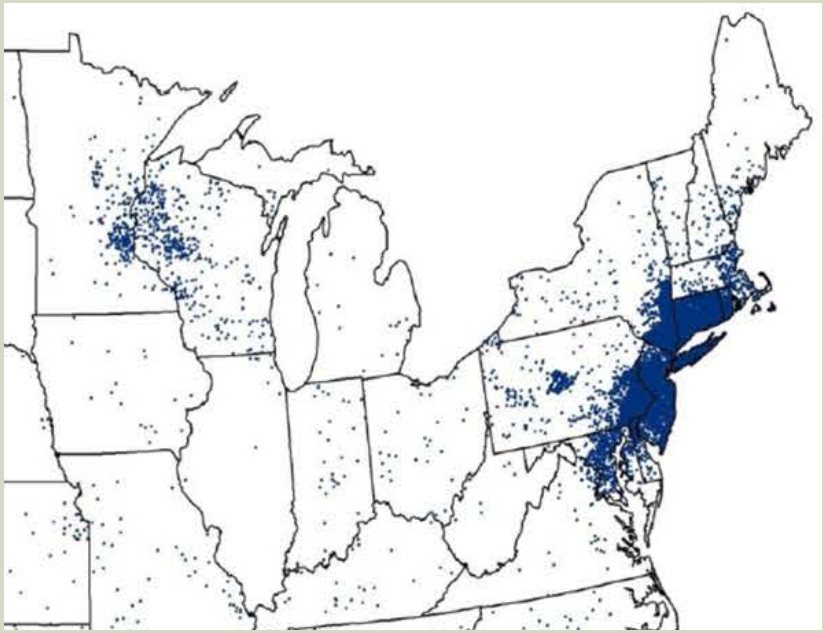
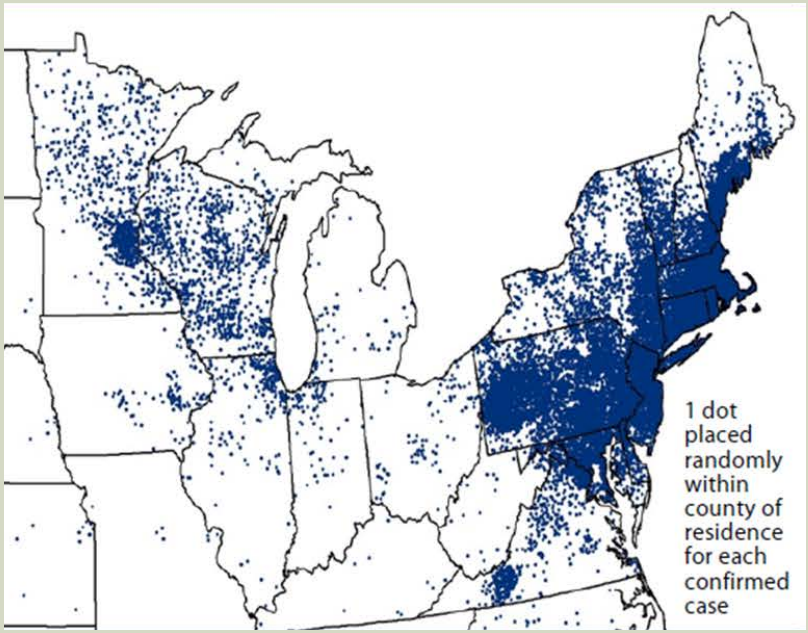
LYME DISEASE CASE DISTRIBUTION – 18 YEAR TREND



1996



2014

300,000 cases of Lyme disease each year!

In 2014, 96% of confirmed Lyme disease cases were reported from 14 states

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

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#2

SPOTTED FEVER RICKETTSIOSIS

CHANGED FROM JUST RMSF IN 2010 (3,797 CASES 2014)

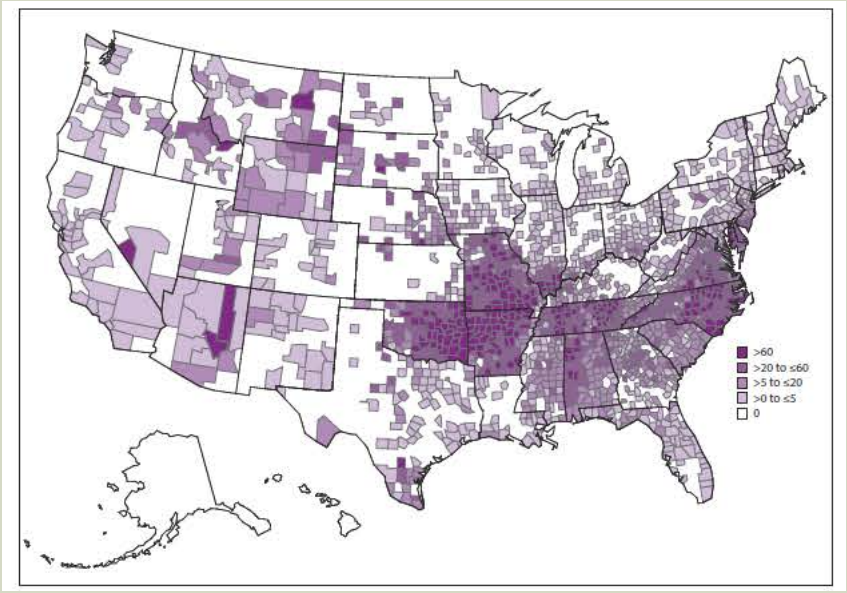
- Rocky Mountain Spotted Fever
  Rickettsia rickettsii
  Vectors: American dog tick, Rocky Mountain wood tick, and Brown dog tick
- *Rickettsia parkeri* rickettsiosis
  Vectors: Gulf Coast Tick, *Amblyomma maculatum* and *Amblyomma triste* (S. Arizona)

Dermacentor variabilis
American dog tick

Dermacentor andersoni
Rocky Mountain wood tick

Rhipicephalus sanguineus
Brown dog tick

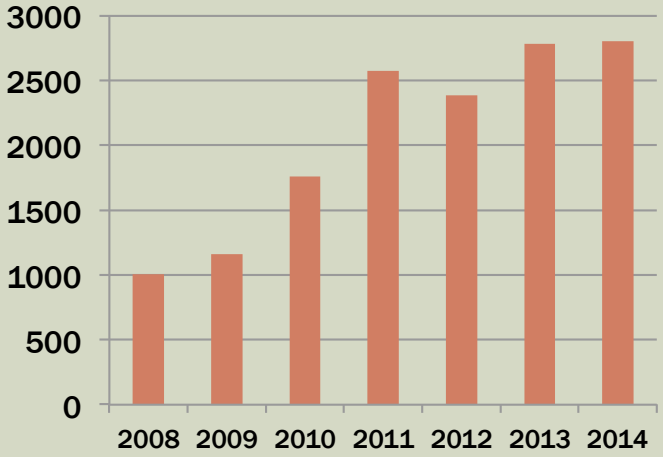
Amblyomma maculatum
Gulf coast tick

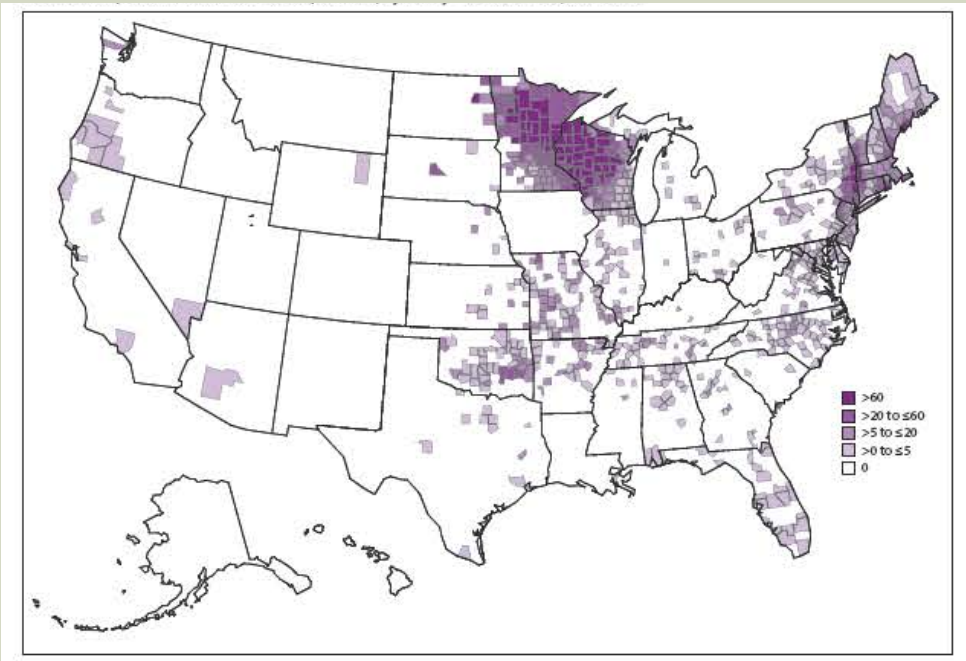


Incidence rate spotted fever rickettsiosis, by county, 2000-2013
Includes RMSF and other spotted fever group rickettsiosis
Biggs et al. MMWR. 65(2): May 13, 2016.

#3

ANAPLASMOSIS REPORTED IN THE U.S.





Reported incidence rate anaplasmosis, by county, 2000-2013 per 1,000,000 persons per year.

Six states (New York, Connecticut, New Jersey, Rhode Island, Minnesota, and Wisconsin) account for 90% of all reported cases of anaplasmosis.

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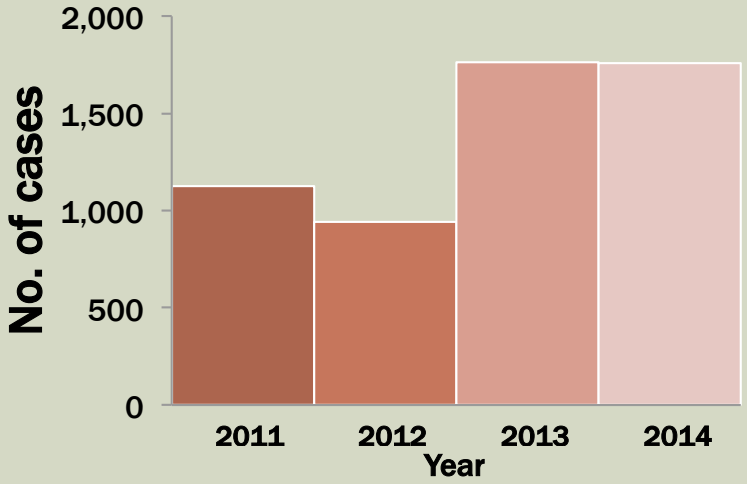
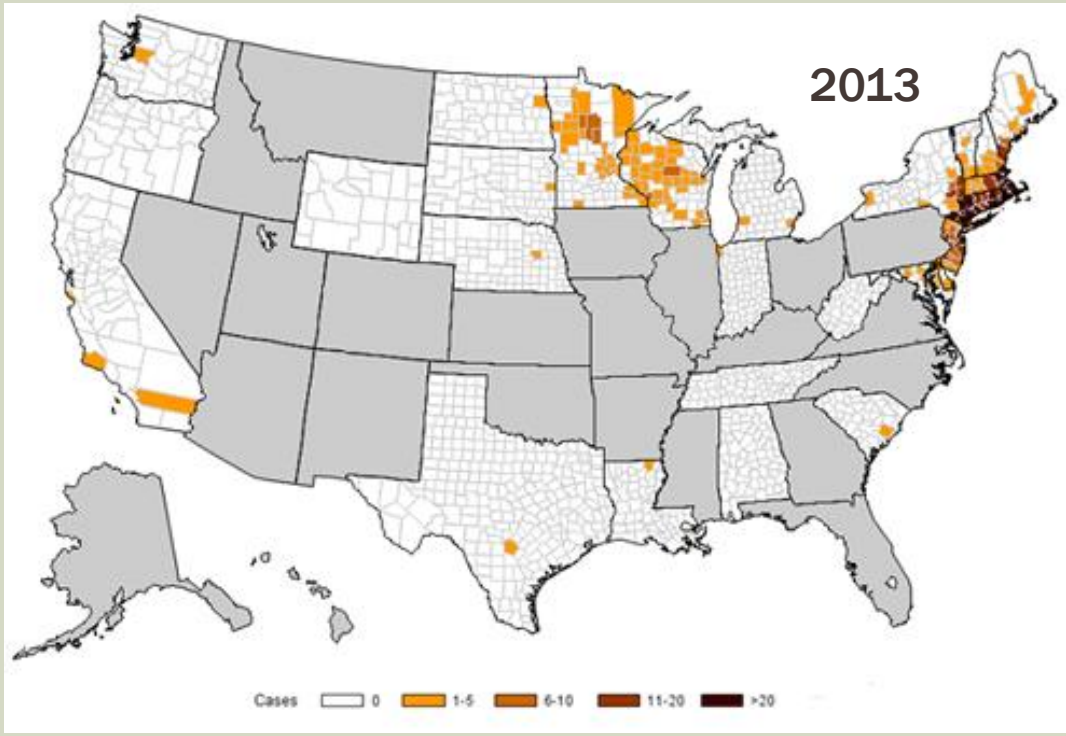
#4

REPORTED CASES HUMAN BABESIOSIS IN THE U.S. 2011-2014





Most (95%) of the cases were reported by 7 states: Connecticut, Massachusetts, Minnesota, New Jersey, New York, Rhode Island, and Wisconsin. Tick-borne transmission of *Babesia* parasites is well established in these states. Nationally reportable in 2011.

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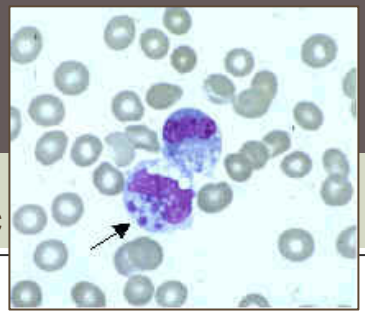
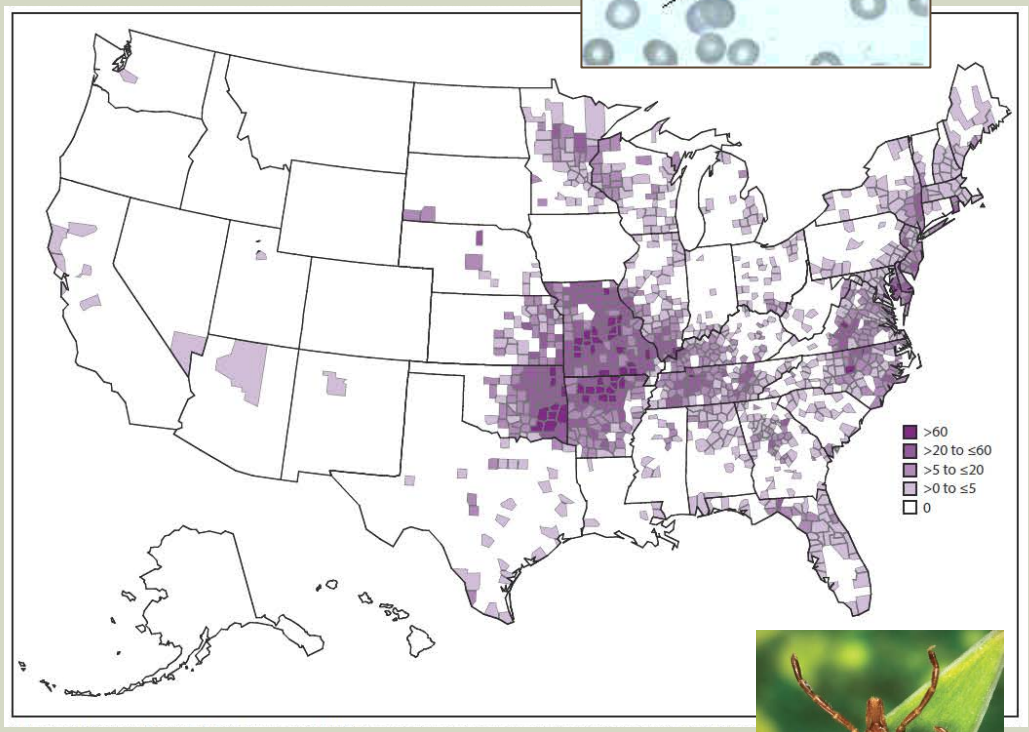
#5

HUMAN EHRLICHIOSIS - 2014

- *Ehrlichia chaffeensis* (1,475 cases) and a few cases of *Ehrlichia ewingii* (17 cases) are transmitted by the lone star tick in the southeastern and southcentral United States
- *Ehrlichia muris*-Like Agent newly described in 2011, transmitted by blacklegged ticks Wisconsin & Minnesota



E. chaffeensis morulae in cytoplasm of monocyte/CDC



Incidence rate ehrlichiosis, by county, 2000-2013
Biggs et al. MMWR. 65(2): May 13, 2016.
Photo/CDC

Photo/CDC

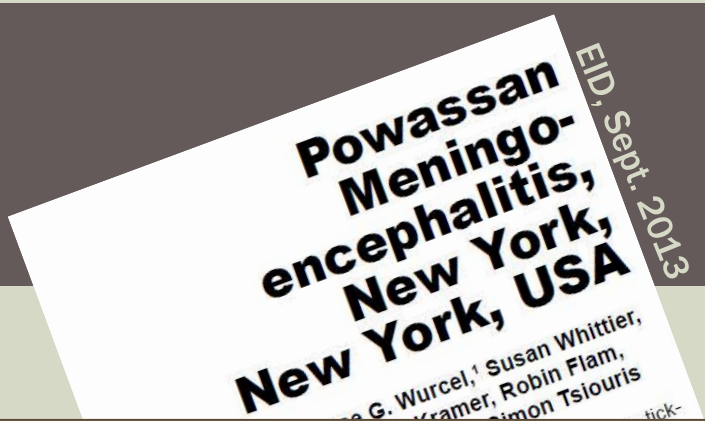
POWASSAN VIRUS

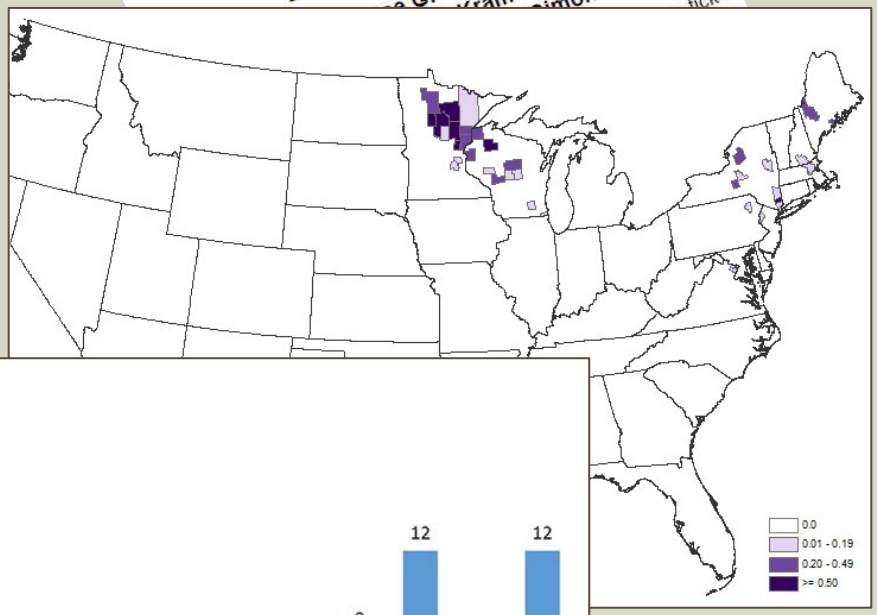
Powassan (POW) Disease

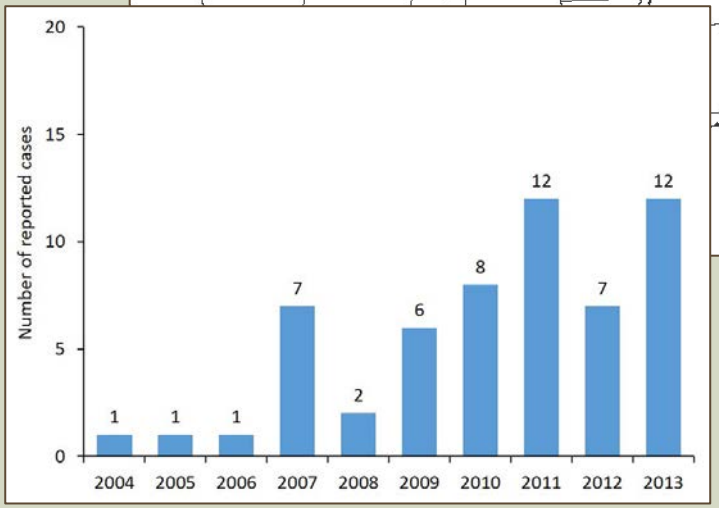
- First described in 1958 in Powassan, Ontario
- Agent: Powassan virus (POWV), flavivirus closely related to West Nile virus (WNV)
  - Lineage II strain ("deer tick virus"), vector: *Ixodes scapularis*
  - Lineage I strain (prototype virus), vector: *Ixodes cookei*

Ixodes scapularis
Blacklegged tick

Ixodes cookei
"Woodchuck" tick







Number of cases reported in US 2004-2013

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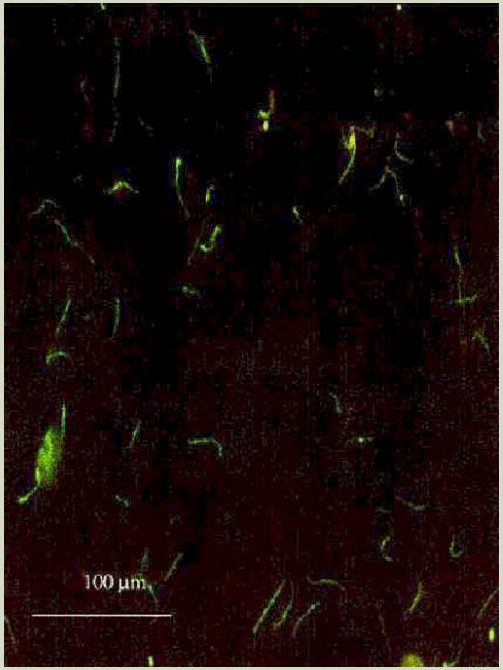
BORRELIA MIYAMOTOI A RELAPSING FEVER *BORRELIA*

- First described from *Ixodes persulcatus* ticks in Japan in 1995.
- Detected in blacklegged ticks in CT in 2001. Transovarially transmitted by female tick. Two percent of nymphal ticks found infected. Unknown if cause disease.
- First human cases of *B. miyamotoi* reported from Russia in 2011 with influenza-like illness; fever, headache, fatigue, myalgia.
- Human cases in United States first described in 2013. Seroprevalence in healthy patients 1%, in patients with viral-like illness at a Lyme clinic 21%.



DFA Staining of spirochetes in *I. scapularis* larvae (Scoles et al. VBZD 2001)

BORRELIA MAYONII N.SP.

Published Online February 5, 2016

Identification of a novel pathogenic *Borrelia* species causing Lyme borreliosis with unusually high spirochaetaemia: a descriptive study

Bobbi S Pritt, Paul S Mead, Diep K Hoang Johnson, David F Neitzel, Laurel B Respicio-Kingry, Jeffrey P Davis, Elizabeth Schiffman, Lynne M Sloan, Martin E Schriefer, Adam J Replogle, Susan M Paskewitz, Julie A Ray, Jenna Bjork, Christopher R Steward, Alecia Deedon, Xia Lee, Luke C Kingry, Tracy K Miller, Michelle A Feist, Elitza S Theel, Robin Patel, Cole L Irish, Jeannine M Petersen

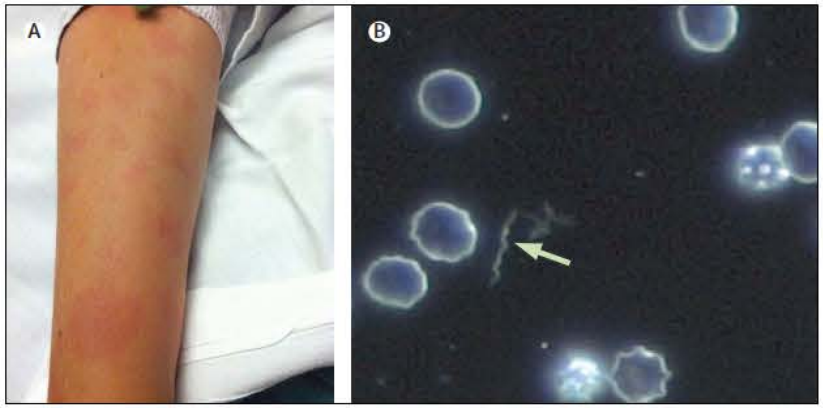


Figure 1: **Diffuse macular rash in patient 1 and dark-field microscopic visualisation of a spirochaete in patient 6.** (A) Diffuse macular rash seen 4 days after onset of symptoms in patient 1. Rash was reported by patient's caregiver to involve the palms and soles, but this was not documented in the medical record. (B) Dark-field microscopic visualisation (400× magnification) of a single spirochaete in diluted blood from patient 6.

- Describes a new pathogenic *Borrelia burgdorferi* sensu lato genospecies (candidatus *Borrelia mayonii*) in the upper midwestern USA, which causes Lyme borreliosis with unusually high spirochaetaemia.
- Distinct clinical features diffuse macular rash (and EM), nausea and vomiting, high fever over 102°F, some neurological symptoms (confused speech, sleepiness, visual problems).
- Prevalence of the novel species in PCR tested *I. scapularis* was 2.9% (19 of 658).

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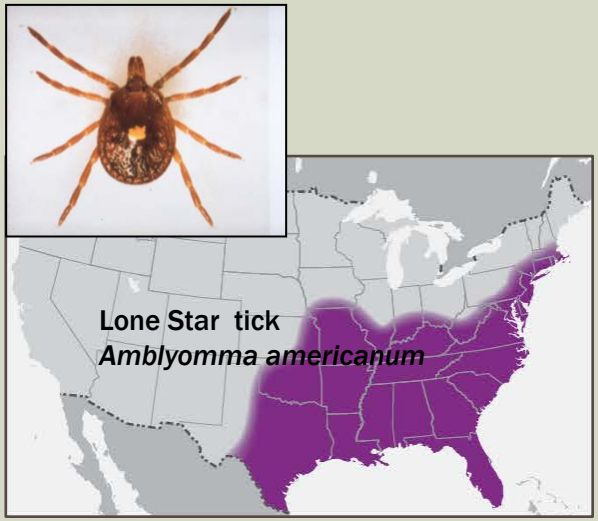
RED MEAT ALLERGY

NBC News
Linda Carroll
Apr 20 2016

- Food allergy triggered by tick bite.
- Delayed anaphylaxis (3-6 hours) to red meat that is related to serum IgE antibodies to the oligosaccharide galactose-a-1,3-galactose (alpha-gal), a sugar carbohydrate found in beef, lamb, pork & venison.
- About 3,500 cases alpha-gal syndrome, distribution cases similar to that lone star tick. Significant correlation between IgE antibodies to alpha-gal and IgE antibodies to proteins derived from *A. americanum*
- Not everyone reacts, unclear how long it lasts. Reaction may decline if no further tick bites, but in others seems to persist.



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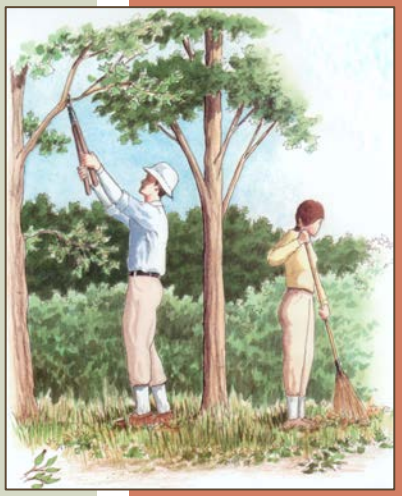
Integrated Tick Management

- Education and behavior change
- Personal protection measures
- Landscape modifications
- Chemical control
  - Synthetic insecticides
  - Botanicals, “natural” compounds
- Biological control
- Host reduction or exclusion
- Host-targeted acaricides
- Host-targeted vaccines

Kirby Stafford



Barnstable Co. Coop. Ext.

Skip Weisenburger

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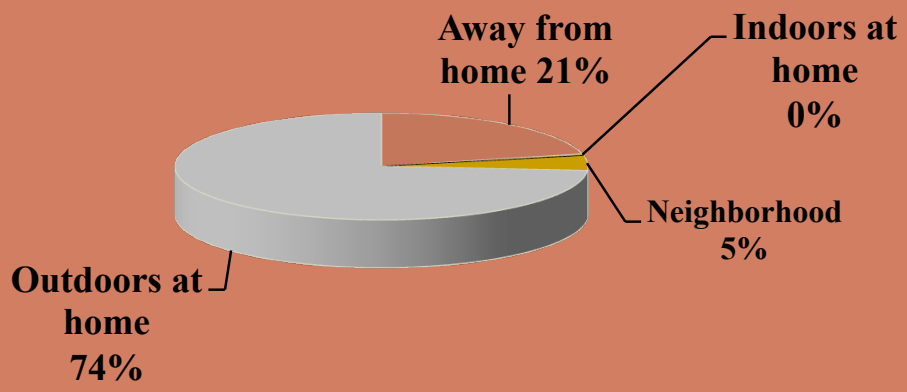
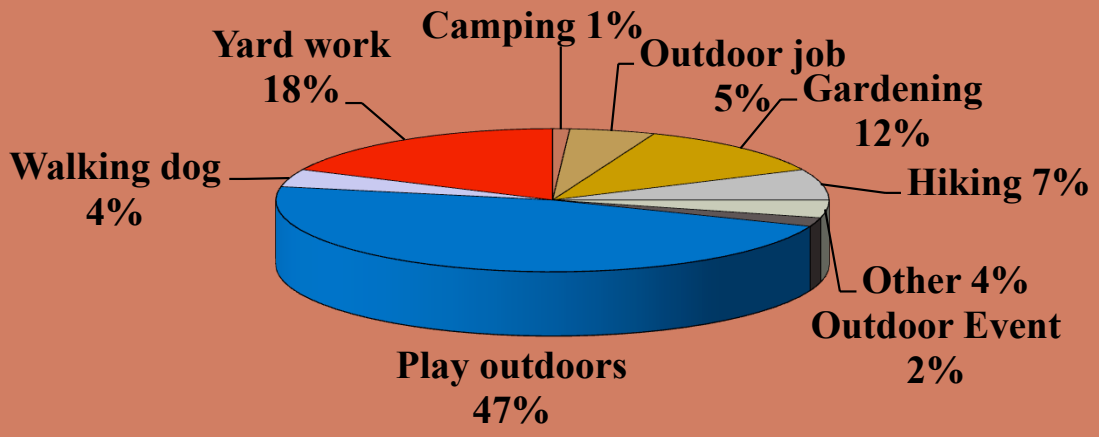
WHAT IS INTEGRATED PEST MANAGEMENT?

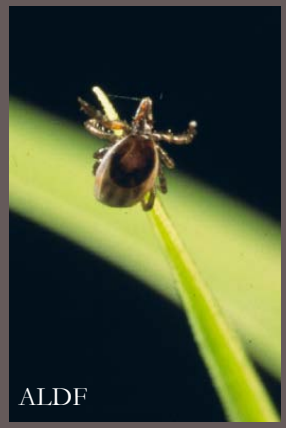
- Classic IPM involves the selection, integration, and implementation of several pest control actions based on predicted ecological, economic, and sociological consequences.
- Difference between control and management, which implies an acceptable level of pest abundance and acceptable level of damage or loss (i.e., for ticks the **risk of disease**).
- Objective of IPM is reduction pest level (or pathogen prevalence) below the economic injury level, the density at which the losses exceed cost of control (cost-benefit analysis).
- Level ticks tolerated likely different for recreational areas and residential areas. Acceptable level risk or cost considerations for some homeowners may be extremely low.
- How much reduction in the risk of transmission or disease incidence is the goal? Can interventions prevent disease?





LYME DISEASE RISK

Data: Stamford Health Department
1989-2000, n = 4551 records and 2001, n = 266 records



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Blacklegged Tick, *Ixodes scapularis*

Western Blacklegged Tick, *Ixodes pacificus*

Lone Star Tick, *Amblyomma americanum*

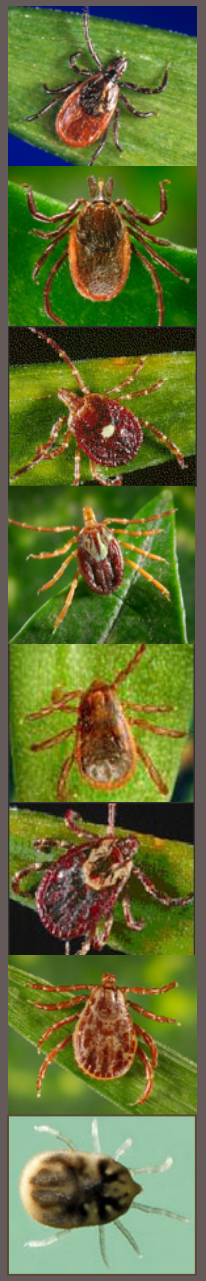
Gulf Coast Tick, *Amblyomma maculatum*

Brown Dog Tick, *Rhipicephalus sanguineus*

American Dog Tick, *Dermacentor variabilis*

Rocky Mountain Wood Tick, *Dermacentor andersoni*

Relapsing Fever Tick, *Ornithordoros hermsi*



The Ticks

There over 1,000 named species of ticks worldwide of which maybe around 100 occur in the United States. Only about 20 or so are of major public health or veterinary importance

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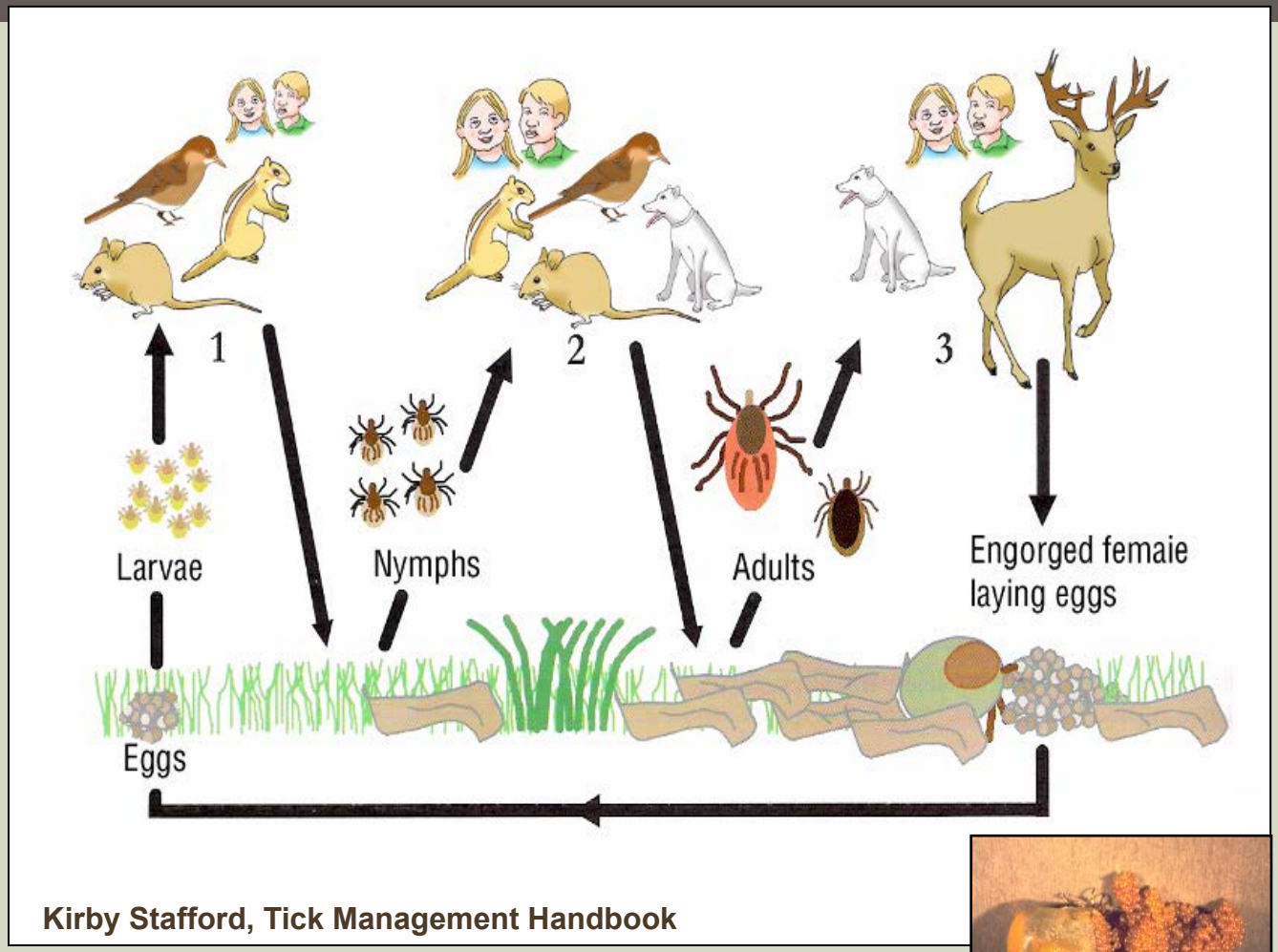
THREE-HOST TICK LIFE-CYCLE



Kirby Stafford, Tick Management Handbook

Drawing of *I. persulcatus* from Pomerantzev, 1959

K. Stafford

J. Occi

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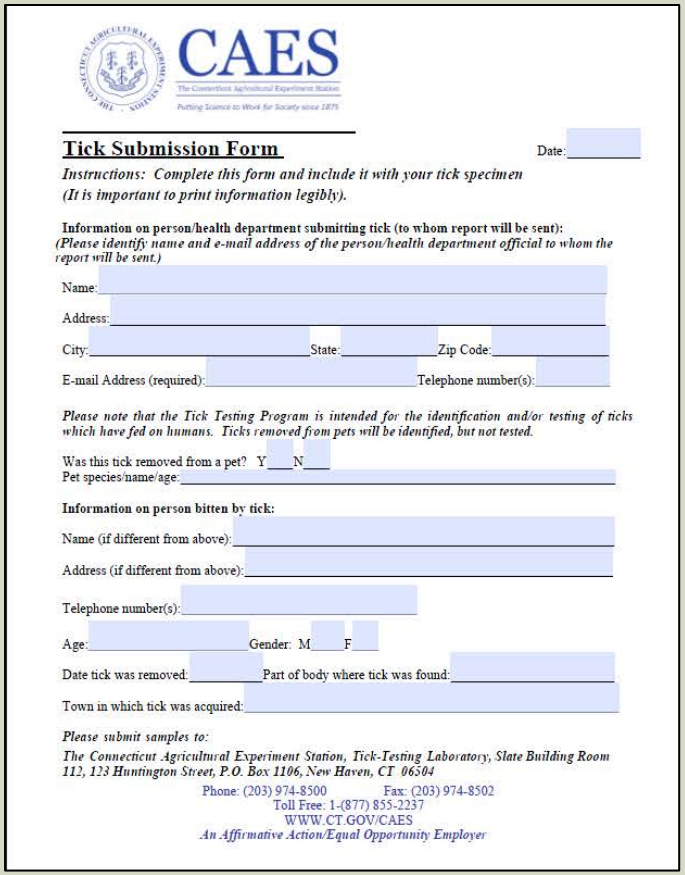
TICK TESTING LABORATORY

CENTER FOR VECTOR BIOLOGY & ZOONOTIC DISEASES

- Testing public established 1990
- Dr. Goudarz Molaei, 2014
- Tested by PCR for the agents of Lyme, babesiosis, anaplasmosis
- Ticks accepted only from CT residents
- CAES "shall not conduct any testing of ticks for Lyme disease except at the request of a state or municipal health official or for scientific purposes."
- Test engorged nymph and female blacklegged and lone star ticks.



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Tick Submission Form Date:_____

Instructions: Complete this form and include it with your tick specimen (It is important to print information legibly).

Information on person/health department submitting tick (to whom report will be sent):
(Please identify name and e-mail address of the person/health department official to whom the report will be sent.)

Name:_____

Address:_____

City:_____State:_____Zip Code:_____

E-mail Address (required):_____Telephone number(s):_____

Please note that the Tick Testing Program is intended for the identification and/or testing of ticks which have fed on humans. Ticks removed from pets will be identified, but not tested.

Was this tick removed from a pet? Y___N___
Pet species/name/age:_____

Information on person bitten by tick:

Name (if different from above):_____

Address (if different from above):_____

Telephone number(s):_____

Age:_____Gender: M____F___

Date tick was removed:_____Part of body where tick was found:_____

Town in which tick was acquired:_____

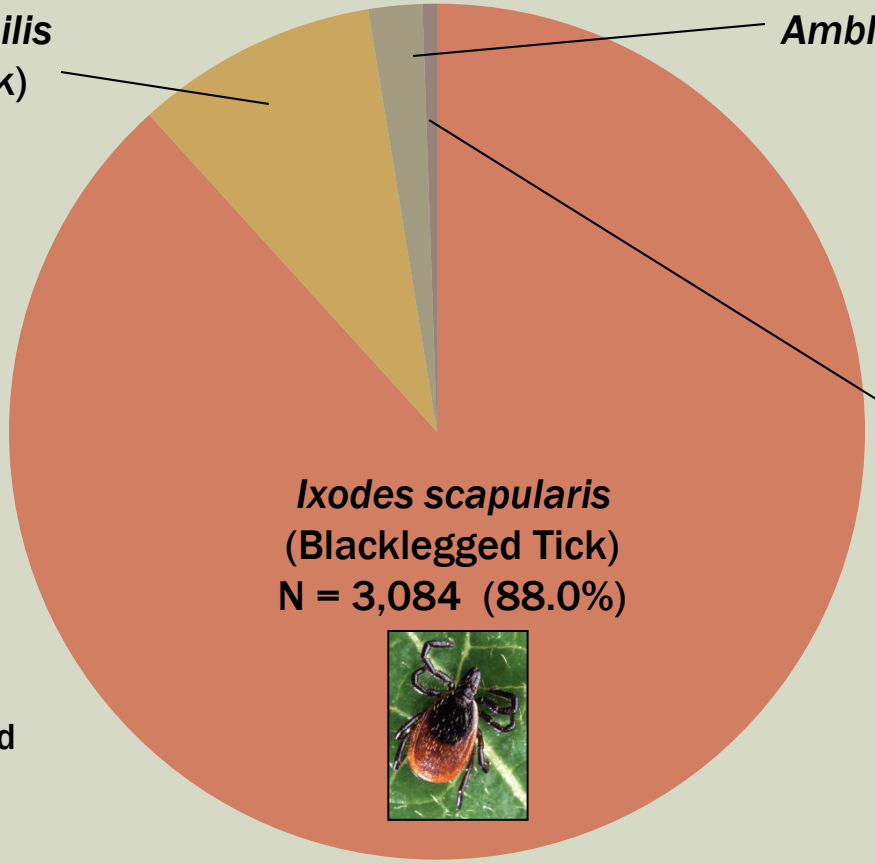
Please submit samples to:

The Connecticut Agricultural Experiment Station, Tick-Testing Laboratory, Slate Building Room 112, 123 Huntington Street, P.O. Box 1106, New Haven, CT 06504

Phone: (203) 974-8500 Fax: (203) 974-8502
Toll Free: 1-(877) 855-2237
WWW.CT.GOV/CAES
An Affirmative Action/Equal Opportunity Employer

SPECIES & NUMBER OF TICKS

RECEIVED FOR TESTING 2015



Dermacentor variabilis
(American Dog Tick)
N = 320 (9.2%)

Amblyomma americanum
(Lone Star Tick)
N = 71 (2.0%)

Other tick species
N = 19 (0.5%)
Incl. 5 *I. cookei*

Ixodes scapularis
(Blacklegged Tick)
N = 3,084 (88.0%)

Total ticks submitted
for identification
N = 3,494

Data courtesy Dr. Goudarz Molaei

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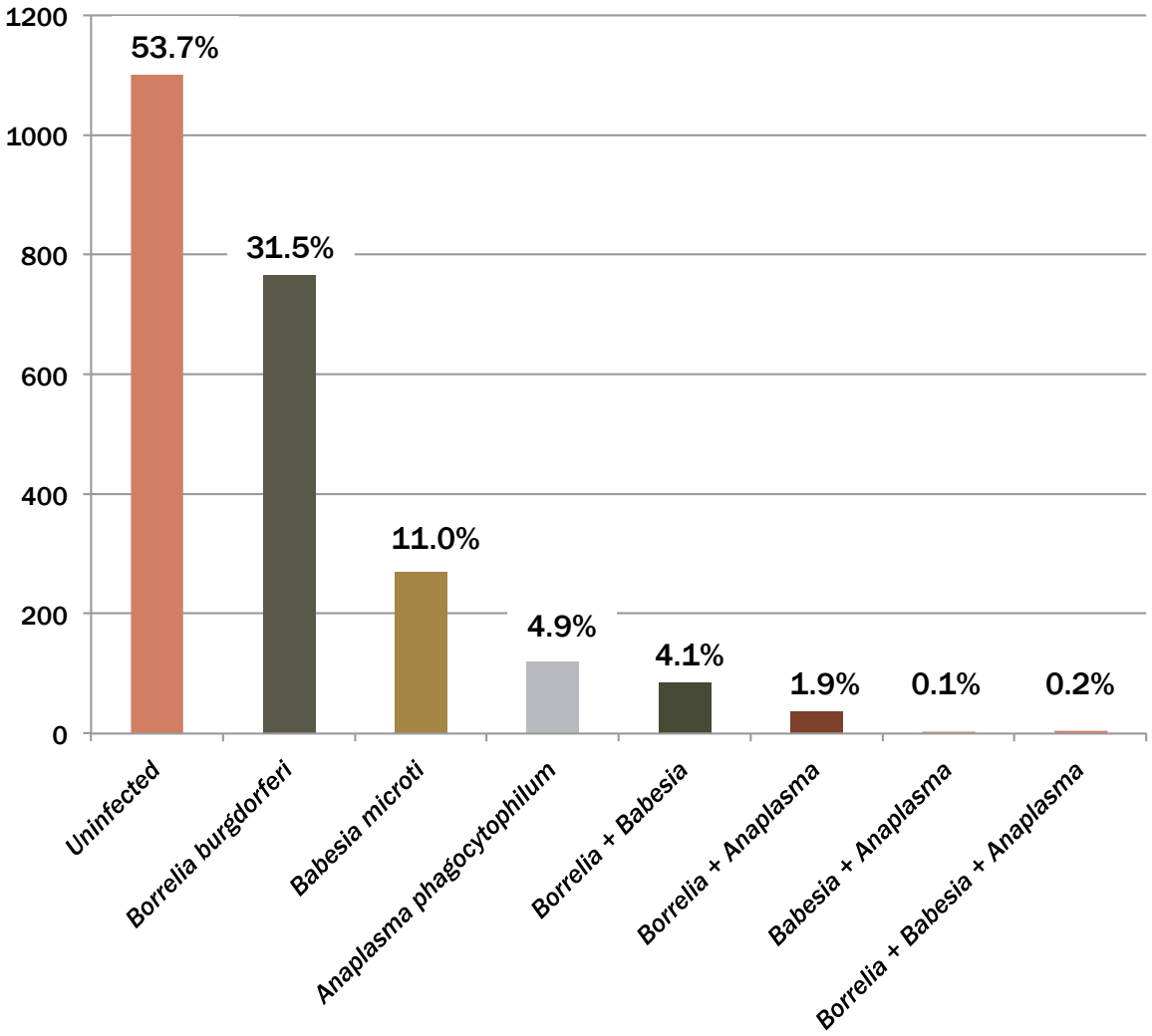
Tick Testing Results, 2015



Data courtesy Dr. Goudarz Molaei, CAES

CAES TICK TESTING LABORATORY

Nymph & Adult

Ixodes scapularis

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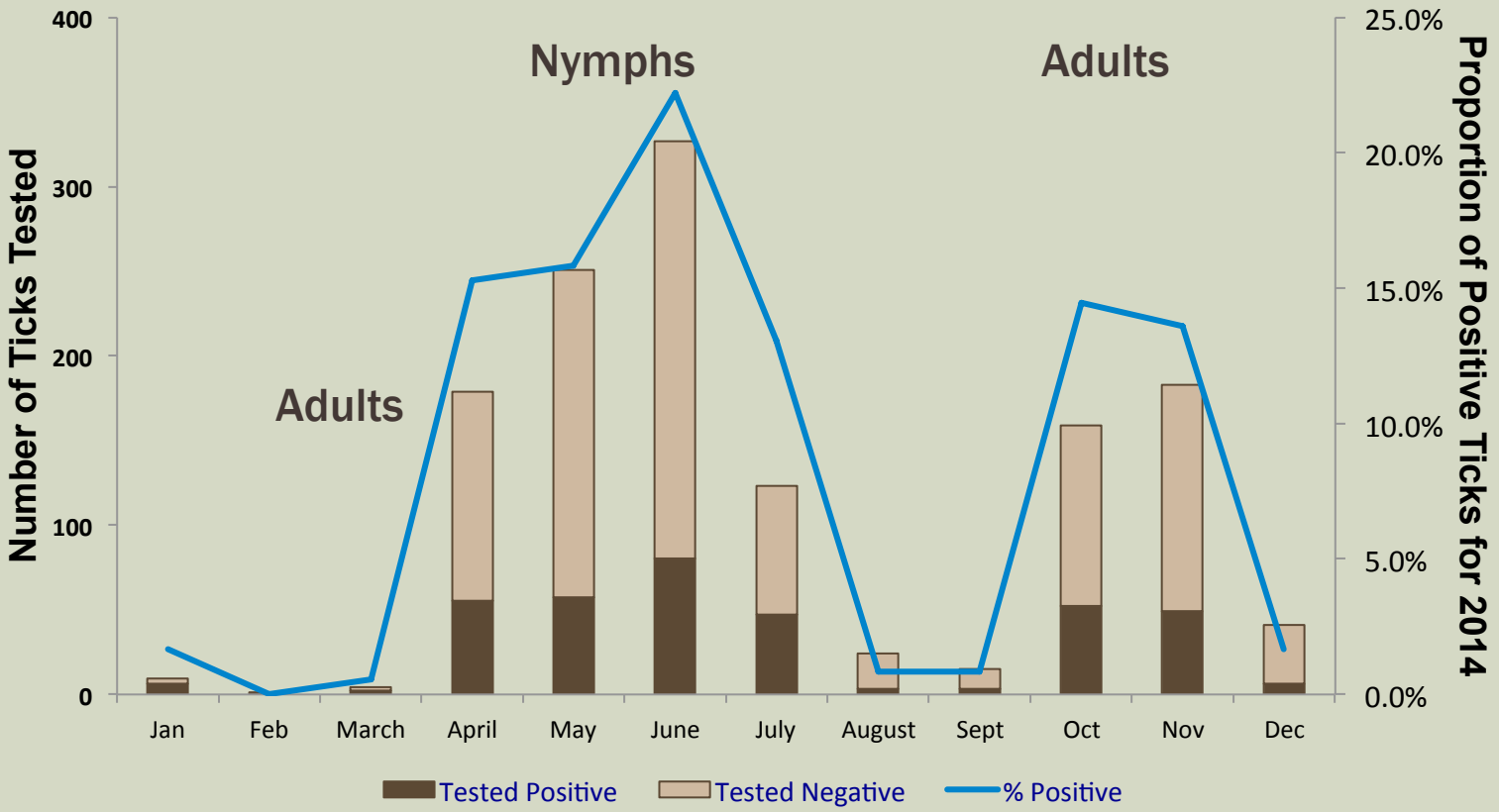
PREVALENCE OF *BORRELIA BURGDORFERI* INFECTION IN TICKS FOUND ON HUMANS, 2014



Center for Vector Biology & Zoonotic Diseases, Tick Testing Lab.

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PERSONAL PROTECTION MEASURES
TICK BITE PREVENTION


Pfizer Central Research


Scott Bauer. ARS

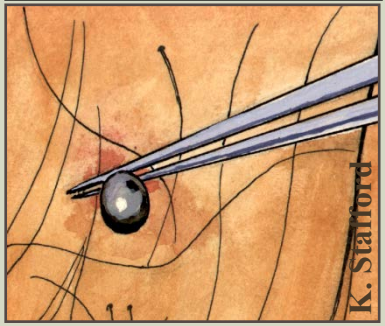
- Clothing – pants tucked in socks
- Skin-based repellents
- Permethrin-based tick repellents
- Permethrin-treated clothing
- Bathing and tick checks
- Flea & tick products for pets

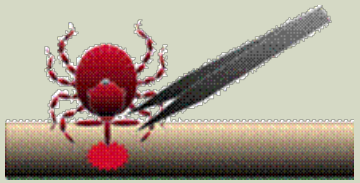

Pfizer Central Research

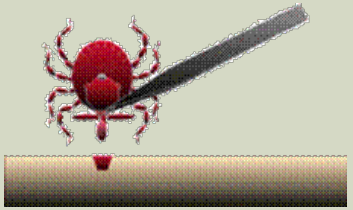

Pfizer Central Research


CDC


Pfizer


K. Stafford





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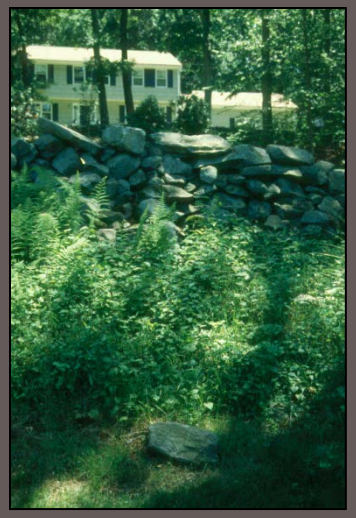

LANDSCAPE OR VEGETATIVE MANAGEMENT

Most ticks require high humidity and cover (canopy)

New England has 240,000 miles of stone walls
Forest land covers nearly 60% (1.9 million acres) of the CT's total land area.

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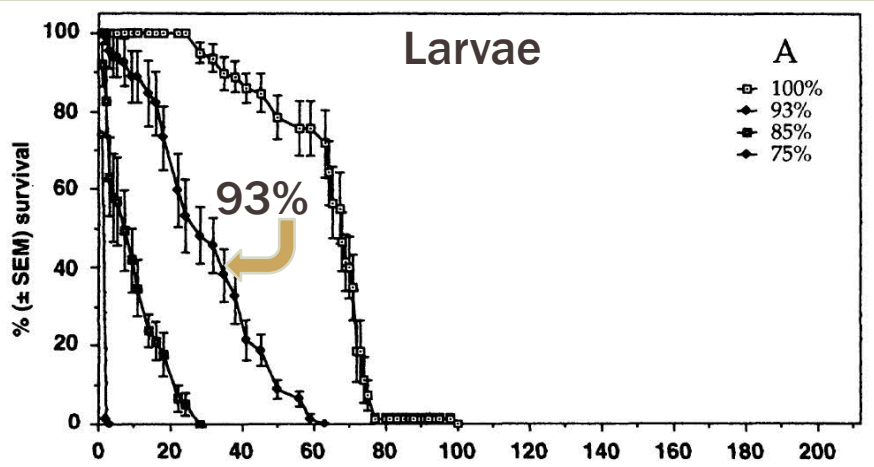
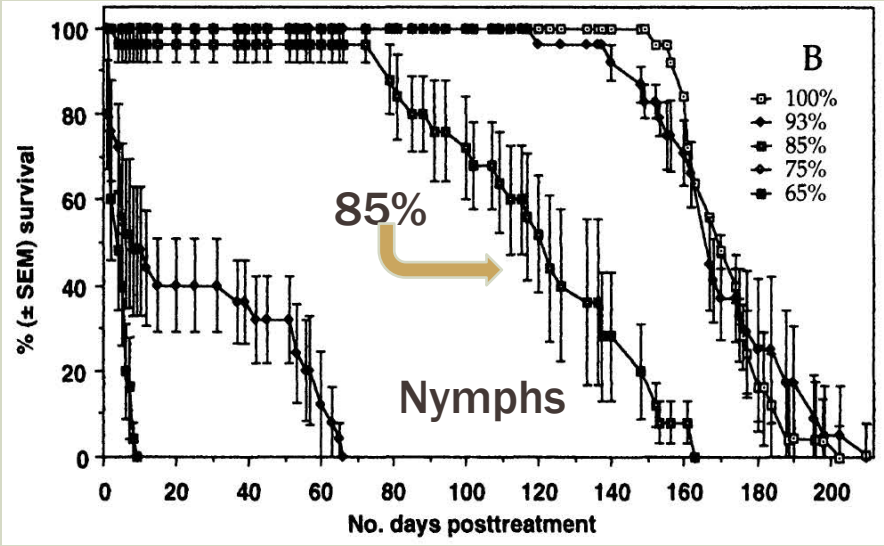
SURVIVAL *IXODES SCAPULARIS* AT DIFFERENT RELALTIVE HUMIDITIES IN THE LABORATORY





Stafford. 1994. J. Med. Entomol. 30:310-314.

Many *Ixodes* ticks require higher humidities for survival than other ticks and quickly die from desiccation when held below their critical equilibrium activity (CEA), the threshold humidity at which ticks are able to maintain their water level by the active uptake of atmospheric water vapor

At room temperature

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HABITAT CHARACTERISTICS & MANAGEMENT

FORUM

What Do We Need to Know About Disease Ecology to Prevent Lyme Disease in the Northeastern United States?

REBECCA J. EISEN,[1,2] JOSEPH PIESMAN,[1] EMILY ZIELINSKI-CUTIERREZ,[1] AND LARS EISEN[3]

J. Med. Entomol. 49(1): 11–22 (2012); DOI: http://dx.doi.org/10.1603/ME11138

- Determining how landscape structure influences the effectiveness of different tick control strategies and identifying "landscape markers" that might suggest improved success of specific interventions.
- Improving the knowledge of how humans use different microhabitats that may pose elevated risk for exposure to infected nymphs, especially in the peridomestic environment.

S. Williams:CAES

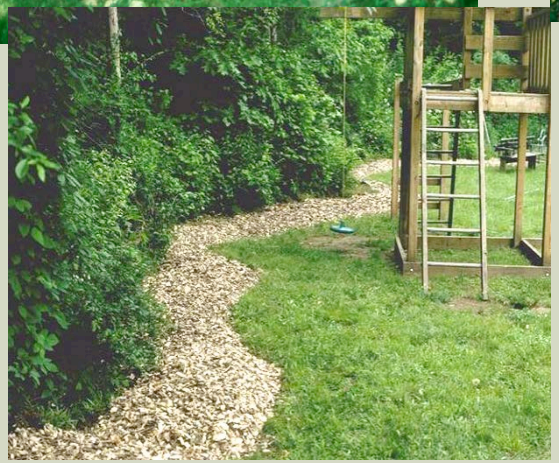
CAES

Invasive Japanese barberry provides suitable habitat for the tick and rodent hosts. When barberry was reduced from 62% of cover to 3% cover by mechanical cutting and burning with propane in controlled areas in 3 sites in CT, it reduced the density of spirochete infected adult ticks to nearly 60% of that of unmanaged infestations.

RESIDENTIAL LANDSCAPE MANAGEMENT

K. Stafford

Leaf Litter Removal
Yard Edge
49-70% reduction



Landscape Barriers
Yard Edge 35-77%
reduction

Clean-up Stone
Walls

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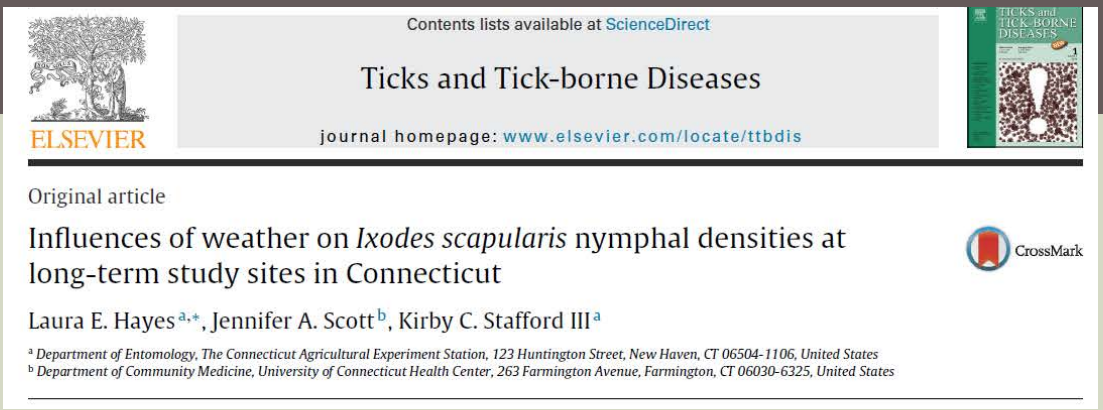
TICK OVERWINTERING & SURVIVAL



Contents lists available at ScienceDirect

Ticks and Tick-borne Diseases

journal homepage: www.elsevier.com/locate/ttbdis

Original article

Influences of weather on *Ixodes scapularis* nymphal densities at long-term study sites in Connecticut

Laura E. Hayes[a,*], Jennifer A. Scott[b], Kirby C. Stafford III[a]

[a] Department of Entomology, The Connecticut Agricultural Experiment Station, 123 Huntington Street, New Haven, CT 06504-1106, United States
[b] Department of Community Medicine, University of Connecticut Health Center, 263 Farmington Avenue, Farmington, CT 06030-6325, United States

- We found an association between greater summer nymphal *I. scapularis* population sizes and higher winter (i.e., January) precipitation (Standardized Precipitation Index).
- Another part of our hypothesis – that greater January snowfall increase tick overwintering survival rates – is supported by previous studies that have found that snow reduces energy loss and keeps soil temperatures much higher than air temperatures in winter.
- Our results support the idea that cold, dry winters may reduce overwintering survival.
- Weather conditions during the coldest months of the year may serve as a bottleneck to tick populations, thereby functioning as an important correlate of not only annual blacklegged tick nymphal densities the following summer, but also entomological risk associated with tick-borne pathogens transmitted by this species.

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TICK OVERWINTERING STUDY CONNECTICUT & MAINE (NE IPM)

Nymphal *Ixodes scapualris* are placed in tubes within the buried tick pots over the winter with Hobo dataloggers in a complete randomized block design with two factors (i.e., combinations of snow removal and leaf litter removal) to examine habitat characteristics on survival and their role in landscape management practices. Adult lone star ticks (*Amblyomma americanum*) will be added for 2016-2017.

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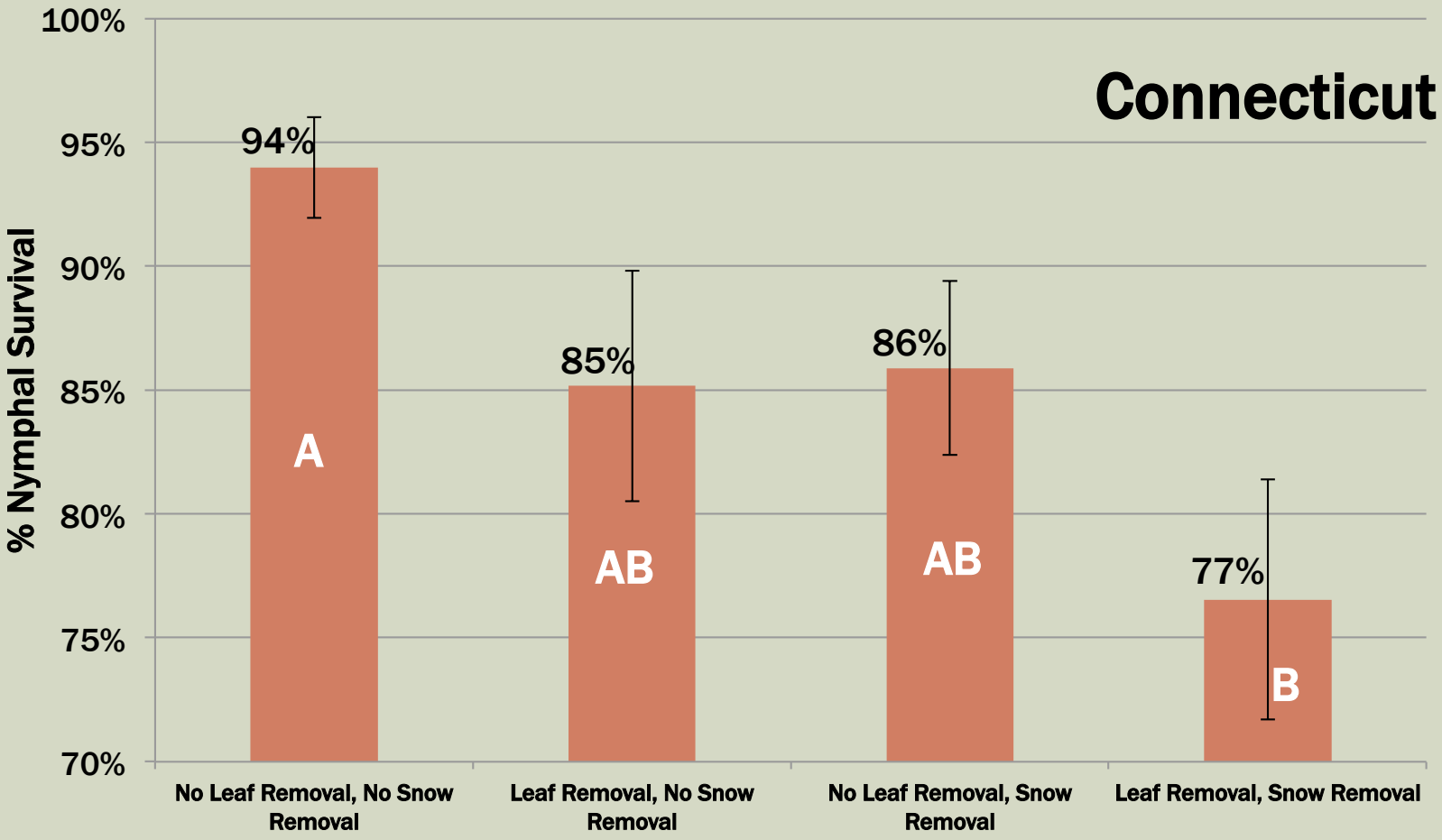
OVERWINTER SURVIVAL IN THE FIELD



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OVERWINTER SURVIVAL IN THE FIELD

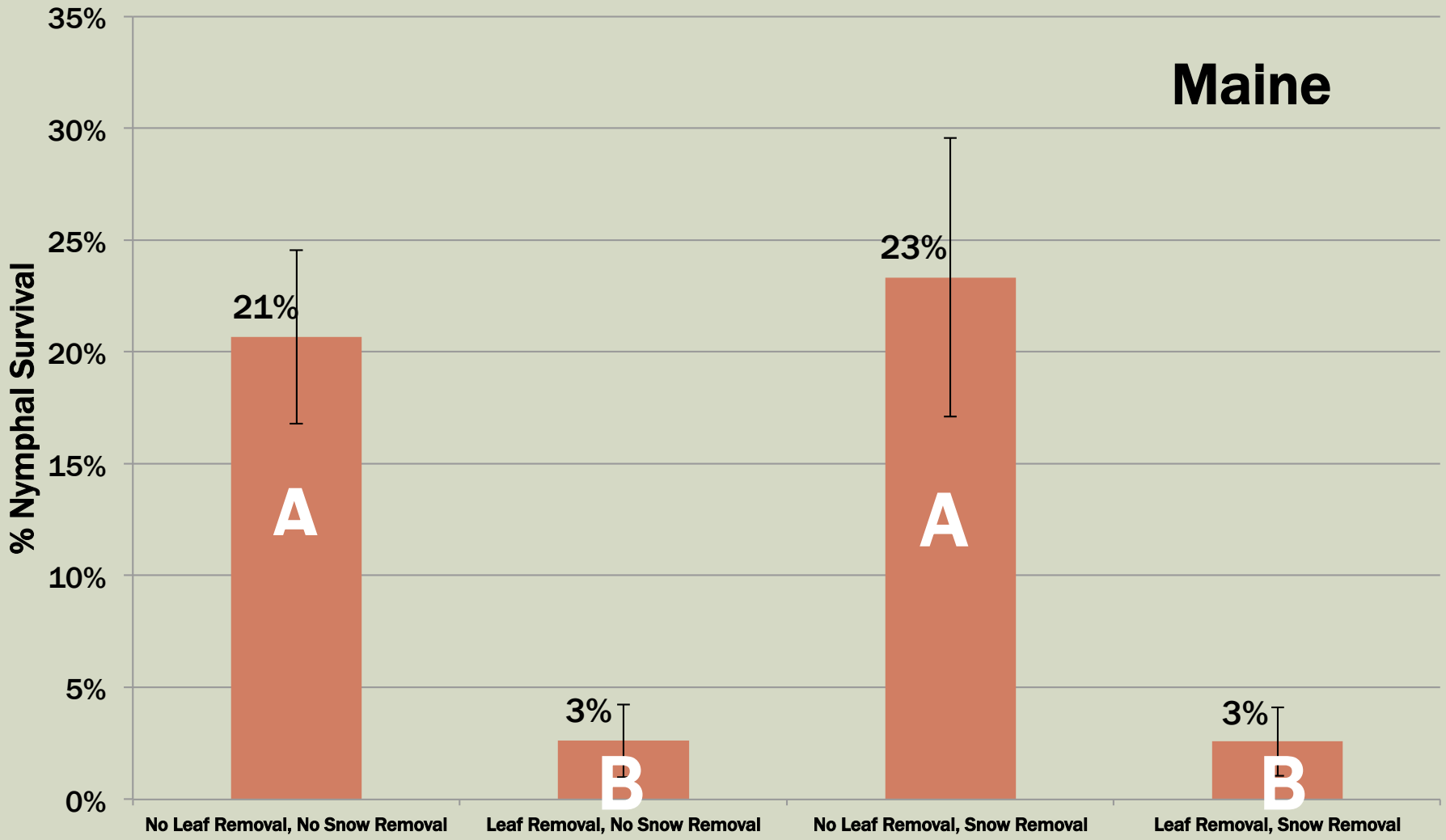

Photo by Skip Weisenburger, The Day

Photo by Kirby Stafford

HOST-TARGETED TICK CONTROL

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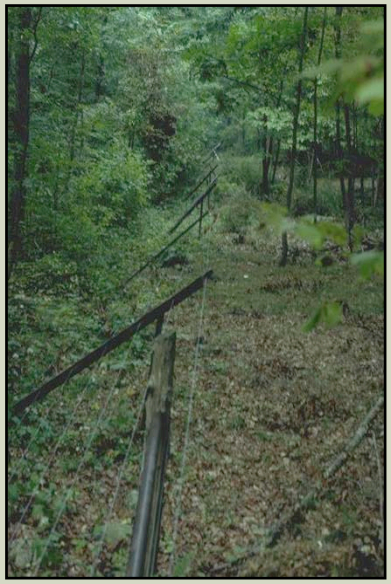
HOST-TARGETED MANAGEMENT

White-tailed Deer

1. Exclusion
2. Reduction
3. Treatment



Rodent Reservoirs

White-footed Mice
Eastern Chipmunk

1. Treatment pesticides
2. Oral Lyme vaccine

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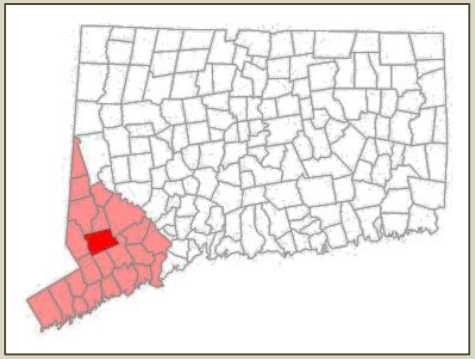
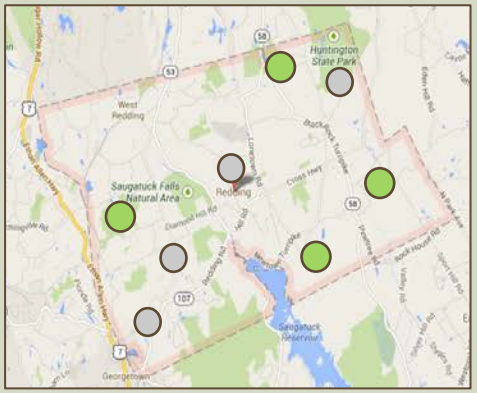
INTEGRATED TICK MANAGEMENT (ITM) CONNECTICUT

CDC COOPERATIVE AGREEMENT AND US BIOLOGIC, INC.

PI'S KIRBY STAFFORD, SCOTT WILLIAMS, GOUDARZ MOLAEI

- (ITM) Project Application Met52 EC Biopesticide Select TCS Rodent Bait Boxes Deer Reduction
- Reservoir-Targeted Vaccine (RTV)(oral rodent Lyme vaccine bait from US Biologic, Inc.)





ITM Treatment Neighborhoods

RTV Treatment Neighborhoods

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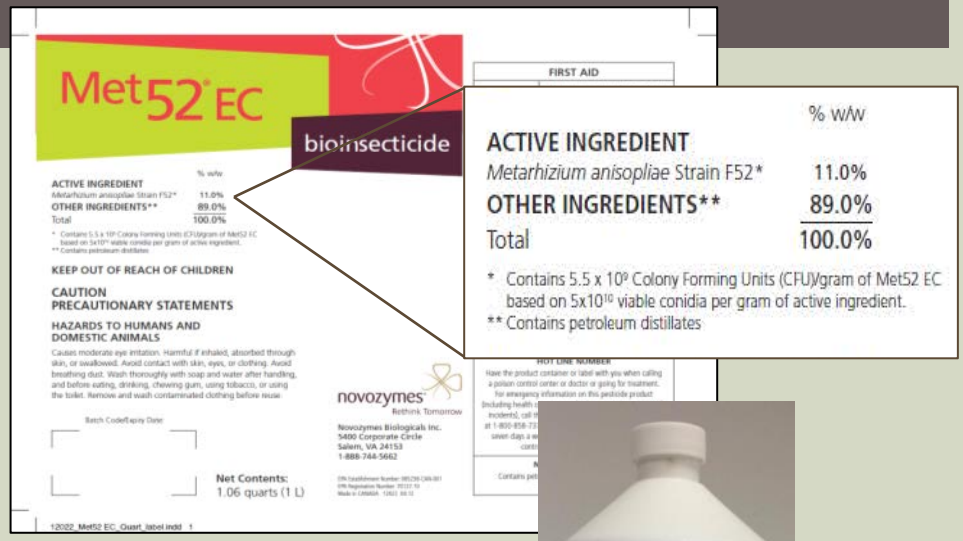
MET52® EC BIOINSECTICIDE

- *Metarhizium anisopliae* Strain52
  Novozymes Biologicals, Inc.
  Monsanto BioAg$_{TM}$ Inc.
- Registered in all states
- Label rate: 2-3 fl. oz. per 1,000 ft^2
  4 gallons water per 1,000 ft^2
- Apply 4-8 week intervals
  Two applications made each summer in this study, except in 2016 when supplies suddenly were tight and less available

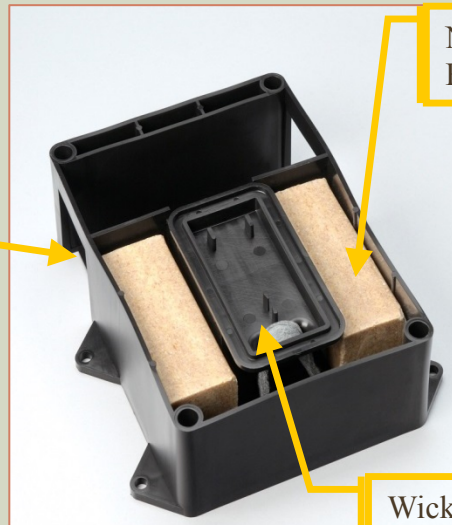


M. anisopliae on female *I. scapularis* *(Photo: Stafford)*

FIPRONIL BAIT BOXES

TICK BOX TECHNOLOGY CORPORATION, NORWALK, CT

Entry Points



A Close-up Look at the System

from Select TCS brochure

Bait boxes installed twice each summer season, May-June and August

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SOME RESULTS ITM PROJECT, REDDING, CT

Host-seeking blacklegged ticks

GLM Results 2013

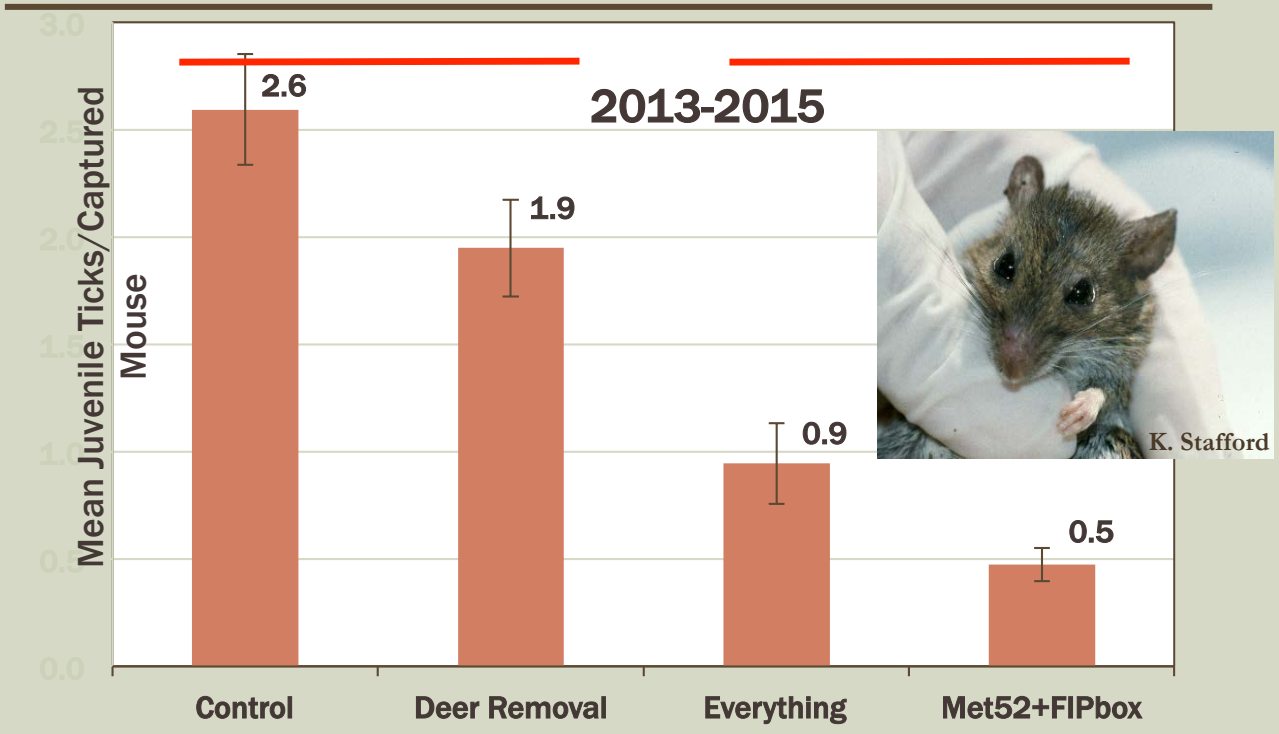
Effect	p-value
Met52 + Box	<0.01
Deer	0.26

GLM Results 2014

Effect	p-value
Met52 + Box	0.02
Deer	0.43

GLM Results 2015

Effect	p-value
Met52 + Box	<0.01
Deer	0.40



Data: Scott Williams, CAES

Met52 + Box = 85.7% control

Met52 + Box = 71.1% control

Met52 + Box = 92.0% control

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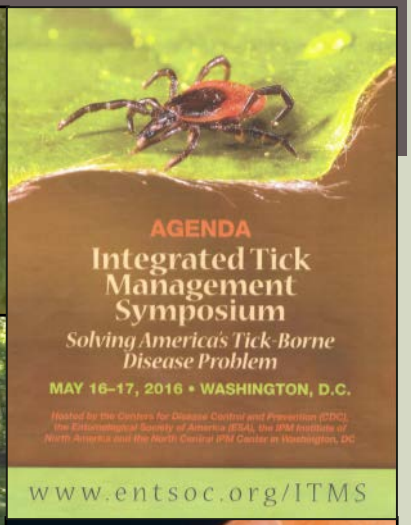
CONCLUSIONS: WHERE DO WE GO FROM HERE?

- While the results for the fourth year (2016) are in progress, three years of data indicate that an integrated control approach to tick management using a spray application and bait boxes can effectively reduce tick abundance and the risk of Lyme disease and other tick-borne diseases
- These studies will add to badly needed information on safe and effective (and affordable) tick prevention tools and ITM methods evaluated across a variety of local settings



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RESERVOIR TARGETED VACCINE (RTV) IN CONNECTICUT

With U.S. Biologic, Inc.

- Inactivated, recombinant OspA vaccine coated on small bait pellets. Used Sidekick bait boxes
- 2014, bait consumption study over summer at 22 residences and bait was amended with the dye Rhodamine-B in late summer
- 91% of mice showed evidence of consuming the Rhodamine-B laced bait either through visual inspection or whisker analysis
- In 2015 & 2016, vaccine coated bait distributed 21-22 residential sites.
- Analysis of tick infection rates and mouse serological responses to the RTV are pending.

Danbury News Times, 4/4/2014

Whisker under fluorescence with RB filter

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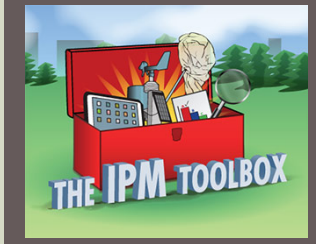

TICK-BORNE DISEASE TOOLBOX

Personal protection measures	Treatment/ vaccination in humans	Landscape/ vegetation management	Killing host-seeking ticks	Rodent - targeted approaches	Deer-targeted approaches
Avoid tick habitat	Antibiotic prophylaxis after tick bite	Xeroscaping/ hardscaping	Synthetic chemical acaricide	Topical acaricide bait box	Topical acaricide feeding station
Protective clothing	Human vaccine	Short grass, remove weeds	Natural product-based acaricide	Oral vaccine	Deer reduction
Tick checks & prompt removal ticks		Remove leaf litter and brush	Fungal acaricide	Oral antibiotic bait	Deer fencing
Synthetic chemical repellent		Remove rodent harborage	Acaricide with semiochemicals	Oral tick growth regulator	Oral tick growth regulator
Natural product-based repellent					Anti-tick vaccine for deer
Permethrin-treated clothing					
Natural product-based soap/lotion					

denotes intervention used in combination with another tick control method

denotes intervention with some supporting data on reduction Lyme disease

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Adapted from slide by Ben Beard, CDC-Division Vector-Borne Diseases

LYME DISEASE & TICK-BORNE DISEASES IN THE U.S.

CURRENT STATE OF AFFAIRS

- Increased distribution of ticks and TBDs; Lyme disease case numbers are higher than ever
- The geographic case distribution is more extensive than ever
- There is significant polarization among stakeholders
- Who is responsible for tick control? Homeowner or the community?
- There is currently no 'magic bullet' that is effective for disease prevention
- In the absence of a human vaccine, the best solutions will probably be Integrated Pest Management methods

Adapted from slide from CDC-Division Vector-Borne Diseases

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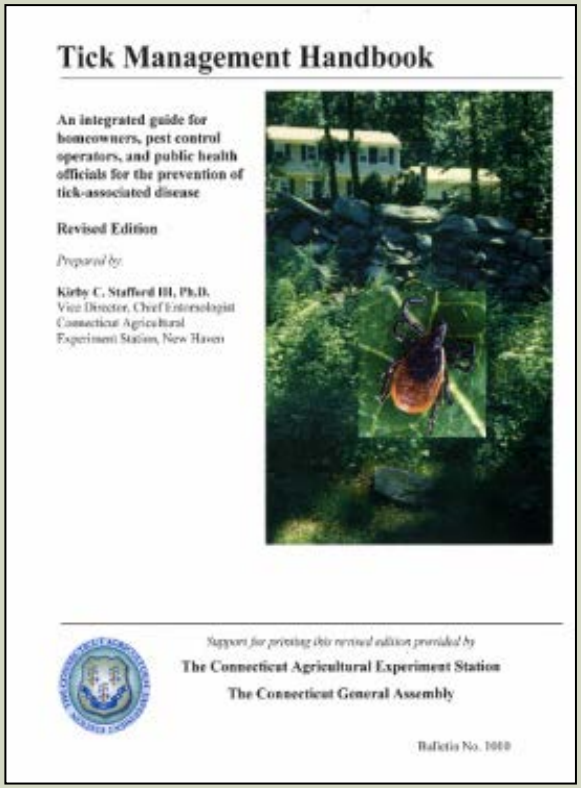
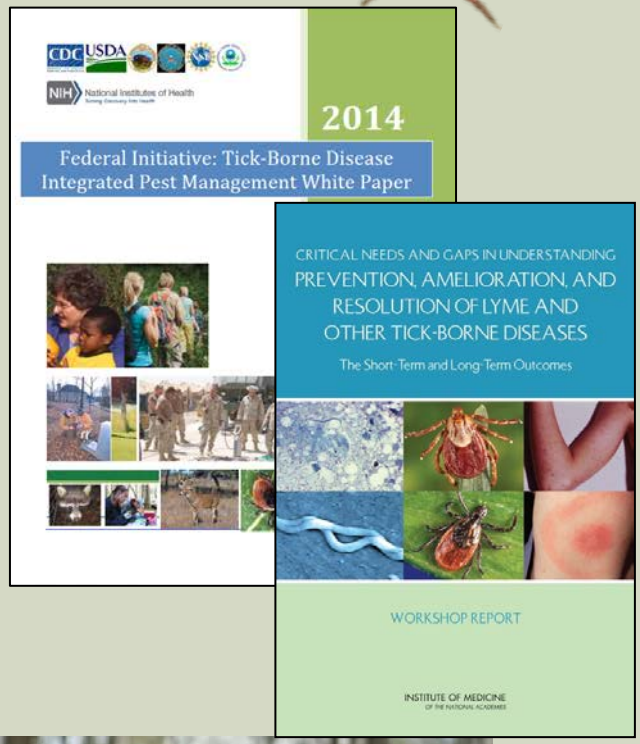
TICKS!





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