Vectorborne Infections and IPM on a Shrinking Planet

Laura C. Harrington, Department of Entomology, Cornell University

CDC REPORT MAY 2018


- Tick borne disease more than doubled from 2004-2016 in the USA
- Lyme disease is the number one US infection and continues to increase
- Other TB pathogens are on the rise
- 9 new vector borne diseases were reported in the US and territories

Why are these vectors and diseases so hard to control?

- No available vaccines
- No treatment for viral infections
- Many infections have animal reservoirs making monitoring and control even more difficult
- Some infections have a large proportion of asymptomatic people, making monitoring difficult
- Insecticide resistance is thought to be common and increasing
- Low emphasis and resources for testing IPM strategies
- Limited expertise and limited local funding/resources for control

The vector situation in New York state

- Range expansion of the blacklegged tick
- Introduction of the lonestar tick
- Introduction of the longhorned tick
- Introduction and range expansion of the Asian tiger mosquito

The pathogen/parasite situation in New York state

- Increased incidence of Lyme disease, babesiosis, anaplasmosis and ehrlichiosis
- Increases of rare TB viral infection in people (POW)
- Emergence of newly recognized bacteria, such as B. miyamotoi
New York Vectors

Rocky Mountain Spotted Fever (RMSF)
Ehrlichiosis
Tularemia
Southern Tick-Associated Rash Illness (STARI)
Heartland Virus
Alpha-Gal Allergy

Longhorned Tick

Native to eastern Asia and invasive in Australia and New Zealand.
Identified by researchers in New Jersey in 2017.
Likely been present in United States for many years before detection.
Now found in several northeastern states including New York.

Asian Tiger Mosquito

- Eggs can remain dry and dormant for months
- Aedes larvae hatch upon stimulation (flooding, reduced O₂)

Mosquito larvae: respiration and feeding

- Short breathing siphon
- Trachea enter the siphon and breathing occurs through spiracles
- Larvae hangs at angle to respire and feed just below the water column

- Pupal stage non-feeding
- Respiration through trumpets
- Able to move to evade predation
Predators
- Insects (dragonfly larvae and other aquatic insect predators)
- Toxorhynchites mosquito larvae
- Copepods
- Fish

Host seeking
- several stages activation (low or high light intensity)
- orientation (visual and chemical, heat (<20 m))
- landing
- probing

The Asian tiger mosquito is a day active mosquito, although it can be captured in traps at night, suggesting it may also feed on people at night.

BLOOD IS ESSENTIAL FOR EGG PRODUCTION

Pathogens are ingested by the mosquito, after incubation period, and can be injected into a new host.

Blood fed females rest in sheltered places while they digest their meal and eggs develop

Plant sugar feeding can be common and improves survival and fitness
Females lay their eggs singly, just above the water line in natural and human made containers.

Asian tiger mosquitoes are competent to transmit at least 22 different pathogens impacting human and animal health.

<table>
<thead>
<tr>
<th>Pathogen</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chikungunya</td>
<td></td>
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<tr>
<td>Dengue</td>
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<tr>
<td>Eastern Equine Encephalitis</td>
<td>Jamestown Canyon virus</td>
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<tr>
<td>Keystone virus</td>
<td>La Crosse virus</td>
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<tr>
<td>Mayaro virus</td>
<td>Oropouch virus</td>
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<tr>
<td>Zika virus</td>
<td>Potosi</td>
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<tr>
<td>Rift Valley fever</td>
<td>Cache Valley</td>
</tr>
<tr>
<td>Sindbis</td>
<td>Trinitatus</td>
</tr>
<tr>
<td>West Nile virus</td>
<td>Venezuelan encephalitis</td>
</tr>
<tr>
<td>Yellow fever virus</td>
<td>Dog heartworm</td>
</tr>
</tbody>
</table>

Other serious potential introductions in USA

Japanese Encephalitis (30% mortality)
Venezuelan Encephalitis (25% mortality)
Rift Valley Fever (up to 50% mortality)

CHIKUNGUNYA

from the Makonde language “that which bends up”

Surprising recent geographic expansion concurrent with Asian Tiger mosquito (A226V mutation Alanine to Valine residue at position 226 in E1 gene)

Zika

- Symptoms are similar to that of dengue or chikungunya
- Conjunctivitis
- Guillan-Barre
- Microcephaly (infants exposed in utero)
- 80% are asymptomatic
- Symptoms are similar to that of dengue or chikungunya

Also transmitted by Aedes spp.

Adult Identification- Asian tiger

Source: http://fmel.ifas.ufl.edu/key/
Why is the Asian tiger mosquito such an invader?
- Dormant egg stage and container-aided dispersal
- Ability to overwinter
- Superior larval competitor

Common larval habitats in New York State
- Tree holes
- Lucky bamboo
- Plant Nurseries
- Catch basins / construction material
- Cemetary vases
- Junkyards

Asian tiger mosquito ecology and egg laying habits make it extremely difficult to control
Wolbachia and Genetic Modification?

- Population replacement with Wolbachia
- Population reduction with Wolbachia and GMM

NEVBD GOALS

1. Train a cadre of public health entomologists with the knowledge and skills required to rapidly detect, prevent and respond to vector-borne disease threats in the US

NEVBD GOALS

2. Build effective communities of practice via collaborations between academic communities and public health organizations at federal, state, and local levels for vector-borne disease surveillance, response and prevention
NEVBD GOALS

3. To conduct applied research to develop and validate effective vector-borne disease prevention and control tools and methods necessary to anticipate and respond to disease outbreaks

MS PROGRAM IN VECTOR BORNE DISEASE BIOLOGY/ENTOMOLOGY

- Goal: provide foundation from which graduates can immediately enter the workforce
  - Vector-borne disease surveillance
  - Vector surveillance and control

- First cohort selected, matriculating August 2018
  - 3 students
  - Backgrounds in mosquito surveillance & control, public health, and microbiology

PARTNERSHIP - MPH PRACTICUM PROJECTS

- Tick-borne disease physician education project
  - Partnership with NEVBD, Tompkins County Health Department, local infectious disease physicians
  - Provide in-clinic seminars on tick-borne disease diagnosis, treatment, and prevention
  - Awarded grant from Engaged Cornell to support implementation

- Veterinary tick-borne disease surveillance
  - Partnership with NEVBD, Cornell Animal Health Diagnostic Center
  - Analysis of passive tick surveillance data
  - Recommendations on integration of veterinary data into wider field of vector-borne disease surveillance

STUDENT INTERNSHIPS

- Summer 2018: CCE Summer Internship Program
  - Management of Ticks in the Northeast, Bailey Willett
  - CCE Suffolk County, Suffolk County Department of Public Works – Vector Control

- Summer 2019: MS VBD Internship Program
  - Fully funded placement with colleagues in CCE Health departments/vector control units

VECTOR BIOLOGY BOOT CAMP

- Next offering in May 2019

  LEARNING MODULES
  - Arthropod Surveillance
  - Arthropod Collection & Testing
  - Taxonomy & Identification
  - Vector Control
  - Data Interpretation & Management

WEBINAR SERIES

Webinar on Tick management!
August 30, 2018
9:30 am - 11:00 am, EST
Drs. Kirby Stafford and Scott Williams
Register at http://neregionalvectorcenter.com

- One to two-hour webcasts
  - In-depth seminars on targeted topics
  - Topics identified through NEVBD stakeholder feedback

- Targets for 2018 webinar development
  - Lessons from longhorned tick control in New Zealand
  - Communicating with the media and the public
  - Insecticide resistance monitoring
ONGOING CORNELL PARTNERSHIPS
- New York State Integrated Pest Management
  - "Don’t Get Ticked, NY" Campaign
  - Tick Surveillance – Citizen Science
- Cornell Animal Health Diagnostic Center
  - Expand surveillance for ticks & tick-borne disease
  - Support training opportunities with Cornell students
  - Expert guidance to regional partners & the public

THE NEVBD HAS 6 RESEARCH CLUSTERS:
- Predicting current and future infection risks in the Northeast region

THE NEVBD HAS 6 RESEARCH CLUSTERS:
- Investigating mosquito trapping methods

THE NEVBD HAS 6 RESEARCH CLUSTERS:
- Novel vector-pathogen interactions

THE NEVBD HAS 6 RESEARCH CLUSTERS:
- Overwintering biology of vectors, including climate change-induced effects

THE NEVBD HAS 6 RESEARCH CLUSTERS:
- Controlling and managing vectors
THE NEVBD HAS 6 RESEARCH CLUSTERS:

- Basic field biology of mosquito vectors

Biology of winter diapause in *Ae. albopictus*

**Project goal:**
- No prior field-based studies of *Ae. albopictus* diapause, despite its importance as a susceptible life stage for understanding control and potential to invade
- Understand the timing, drivers and variation of diapause induction in the field
- Understand the role of urbanization on these drivers

**Results:**
- Diapause appears to be induced by a combination of temperature and photoperiod
- Eggs can quickly exit diapause when stimulated by higher temperature
- Differences occur between populations, even within New York State
- Study will be replicated this year

Drones and neural networks for better larval surveillance

**Project background:**
- Larval surveys are very time and labor intensive
- Drones can capture high resolution imagery
- Neural networks can be used for image recognition

**Project goals:**
- Flying drones flown over suburban neighborhoods to collect images of habitat
- Simultaneous on the ground entomological surveys
- Training a neural network to find containers most likely to be mosquito positive

**Results:**
- Significantly faster surveillance with drones than on the ground
- 64% of containers identified could be seen from the UAV, with almost 2,000 additional potential habitats identified from the aerial images
- Can’t identify obstructed views (porches, awnings and trees)

MOSQUITO IDENTIFICATION BY CHORION SCULPTURE

**Project background:**
- Current identification techniques are cumbersome, depend on hatching viable eggs, growing larvae to ID

**Project goals:**
- Characterize differences in chorion sculpture between container-breeding species
- Test the speed and practicality of this technique on field collected samples
- Write a user-friendly guide
CONTAINER SPECIES THAT LAY ABOVE THE WATER-LINE IN THE NORTHEAST

- We have three Aedes species that we regularly collect in ovitraps:
  - *Aedes albopictus* (Asian tiger mosquito)
  - *Aedes japonicus* (Asian bush mosquito)
  - *Aedes triseriatus* (eastern tree hole mosquito)

Aedes albopictus Aedes japonicus

Aedes triseriatus

Talya Shragai

**Feeding Ecology of Ae. albopictus**

- Blood feeding frequency and forage ratios across an urban gradient to understand human risk and zoonotic risk

- Sugar feeding frequency and sugar source forage ratios to understand utility of toxic sugar baits

Kara Fikrig
A region-wide insecticide resistance map for the Northeast

- Region-wide comprehensive measures of IR have not been conducted
- Very little data for tick vectors
- Data on baseline susceptibility and how it might vary regionally is important
- Limited training in this area

James Burtis, Cornell Postdoctoral researcher

NEVBD’s Integrated Tick Management Projects

Slides Courtesy of Dr. Kirby Stafford III, Connecticut Agricultural Experiment Station

INTEGRATED TICK MANAGEMENT

<table>
<thead>
<tr>
<th>Purpose of management</th>
<th>Example</th>
<th>Type analysis</th>
<th>Decision making</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protect commodity (traditional ag IPM)</td>
<td>Ticks on cattle, nuisance ticks in tourist area</td>
<td>Cost/benefit</td>
<td>Lower tick numbers in effective, cost-efficient manner</td>
</tr>
<tr>
<td>Manage tick-borne disease of humans</td>
<td>Ticks carrying human pathogens</td>
<td>Cost/efficiency</td>
<td>Allocate available resources to maximally lower the number of human cases of disease</td>
</tr>
</tbody>
</table>

Tick control or management may have several different objectives: 1) lower direct damage to animals; 2) prevent transmission TBD to animals; 3) lower nuisance to humans from ticks, and 4) prevent TBD of humans.

THEORY TICK MANAGEMENT

- Commodity Protection (e.g., livestock)
- Manage Human Tick Bites and Disease Risk
  - Target Vector, Host, and/or Pathogen
  - Change Human Host Behavior or Exposure
  - Control Tick
  - Control Tick Reproductive Host
  - Control Tick-Pathogen Reservoir Host
  - Reduce Pathogen Prevalence
  - Reduce Pathogen Transmission
  - Alter Environment Host
  - Alter Environment Vector

CHALLENGES TO EFFECTIVE PUBLIC TICK CONTROL

1. Where ticks are located (much northeast forested with likely tick habitat)
2. Institutional and social restraints vs. benefit to public health
   - High cost implementation and monitoring
   - Variable public acceptance and consensus
   - Complexity implementation and variable, uncertain efficacy
3. Information gaps
   - Cost benefit analysis control measures
   - Tick density and pathogen prevalence data – set action thresholds and degree of suppression (IPM Model)

(Slide based on talk by Robert Jordan)
CLASSIC IPM TACTICS PYRAMID AND THOSE SPECIFIC TO TICKS

Conventional pesticides
Pyrethroids, carbamates, fipronil neonicotinoids, formamidines, isoxazolines

Chemical (bialorational)
Repellents, botanicals, microbials (biopesticides)
Insecticidal soap, semiochemicals

Biological
Pathogens, parasites, predators, vaccines (?)

Physical-Mechanical
Habitat modification resistant livestock

Cultural
Host management, fencing

Prevention

Intervention

% REDUCTION IXODES SCAPULARIS NYMPHS APPLICATION ACARICIDES TO THE ENVIRONMENT

<table>
<thead>
<tr>
<th>Acaricide</th>
<th>Application</th>
<th>reduction nymphs*</th>
<th>Time evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pyrethroids</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bifenthrin</td>
<td>Spray</td>
<td>45-100%</td>
<td>1-4 wks</td>
</tr>
<tr>
<td>Cyfluthrin</td>
<td>Spray</td>
<td>88-100%</td>
<td>2-8 wks</td>
</tr>
<tr>
<td>Cyfluthrin</td>
<td>Granules</td>
<td>87-97%</td>
<td>1-8 wks</td>
</tr>
<tr>
<td>Deltamethrin</td>
<td>Granules</td>
<td>87-100%</td>
<td>1-5 wks</td>
</tr>
<tr>
<td>Carbamate</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carbaryl</td>
<td>Spray</td>
<td>43-93%</td>
<td>2-13 wks</td>
</tr>
<tr>
<td>Carbaryl</td>
<td>Granules</td>
<td>46-96%</td>
<td>1 wk-3 mo</td>
</tr>
<tr>
<td>Natural</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rosemary, etc.*</td>
<td>Spray (low, 2x)</td>
<td>73-95%</td>
<td>1-5 wks</td>
</tr>
<tr>
<td>Rosemary, etc.*</td>
<td>Spray (high)</td>
<td>100%</td>
<td>1-2 wks</td>
</tr>
</tbody>
</table>

*Rosemary, peppermint, wintergreen


TOWARDS IPM AND BREAKING THE CYCLE: TICK RESEARCH EFFORTS BY NEVBD

- Expansion of surveillance activities by NYS DOH (Backenson)
- Lone star tick infestation monitoring and 4-poster study on Manresa Island CT (Stafford)
- Testing oral vaccine for mice (CAES)
- Investigation of longhorned tick populations in NY and NJ (Fonseca and Backenson)
- Development of factsheets and information for longhorned tick (NEVBD team)
- Enhanced POWV surveillance (Backenson)

Landscape-based models for blacklegged tick
Intensive work on transmission driving factors for Lyme disease on Staten island (over 400 household surveys and sampling; Diuk-Wasser)
Arena testing of Essentria, Cedar, Mavrik and Talstar granular on lonestar and blacklegged ticks (Cucera, Suffolk Co)
Testing sprays of Demand CD and Archer Insect Growth Regulator for blacklegged tick control (Stafford)
Fire Island tick management efficacy testing (Burtis/Harrington, Suffolk Co)
WHAT WE DON’T KNOW ABOUT THE LONGHORNED TICK

- Phenology/seasonality
- Habitat preferences
- Importance as a vector, especially for local tick borne pathogens
- Impact on livestock
- Best control practices
- How it is moved to new areas and how to prevent movement
- How long it has been in the US

http://neregionalvectorcenter.com/longhorned-tick

CONNECT WITH NEVBD

- January 2019 – Annual Meeting
  - New Haven, Connecticut
- NEVBD Quarterly Digest Newsletter
- NEVBD Social Media

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