Introduction to One-Health and Tick-Borne Diseases
Johnny A. Uelmen, Jr.

Research Interests:
- Climate Change, Arthropod Vectors, Infectious Diseases, One-Health, Zoonosis, GIS & Remote Sensing, Global Health

Academic Background
- B.S. Biology (emphasis in Evolution)
- M.S. Entomology – “Effects of climate on phenology of Forest Tent Caterpillar and natural hosts” & “Supercooling Points of Migrating Insects”
  - Data collected from field research (“prospectively”)
- M.S. Epidemiology – “West Nile Virus in Wisconsin: A One-Health Approach”
  - Data collected from USGS NWHC, DNR, DHS, WVDL (“retrospectively”)
- Ph.D. Environment & Resources – “Effects of a Changing Climate on Emerging and Re-Emerging Zoonotic Diseases”
- Global Health Graduate Certificate
  - Dengue Virus field work in rural Thailand
What is One Health?

- One Health: the collaborative effort of multiple disciplines to attain optimal health for people, animal and the environment.

- Infectious disease “hotspots”
  - Example: *Ribeiroia* infections (on various amphibians) more common along bird flyways.
  - Increases in human populations $\Rightarrow$ expansion into new geographic areas $\Rightarrow$ increased contact with wild and domestic animals (e.g. Rabies & *Salmonella* infection opportunities more likely).
    - World’s total population exceeds 7 billion (and continues to climb).
    - Largely anthropogenic-related forces, like deforestation, consumption of greenhouse gases, etc. lead to changing climate (i.e. warming average annual global temperatures).
    - As environments change, exposures to new viruses, bacteria, and other disease-causing pathogens is expected to increase.
    - Estimated 1000’s, and possibly 1,000,000+ undiscovered viruses alone (many are expected to be harmful) (i.e. Ebola, Marburg, HIV/SIV, Nipah all recent examples).
What is One-Health?

<table>
<thead>
<tr>
<th>Factor (Cause)</th>
<th>Change (Effect)</th>
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<tbody>
<tr>
<td>Human populations are growing and expanding into new geographic areas.</td>
<td>As a result, more people live in close contact with wild and domestic animals. Close contact provides more opportunities for diseases to pass between animals and people.</td>
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<td>The earth has experienced changes in climate and land use, such as deforestation and intensive farming practices.</td>
<td>Disruptions in environmental conditions and habitats provide new opportunities for diseases to pass to animals.</td>
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<td>International travel and trade have increased.</td>
<td>As a result, diseases can spread quickly across the globe.</td>
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https://www.cdc.gov/onehealth/basics/index.html

https://followtheoutbreak.wordpress.com/2013/10/16/opinion-do-we-need-to-induce-stress-in-the-one-health-paradigm/
What is One-Health?

Another Way to Look at the One Health Model:
Why is One-Health an Important Concept?

- The health of people is connected to the health of animals and the environment

- Multidisciplinary collaboration is critical in understanding complete picture of health problems
  - This includes physicians, ecologists, veterinarians, etc.

- Zoonotic diseases (diseases shared between animals and humans) accounts for >60% of all diseases in humans

- Animals share our susceptibility to diseases and are often early warning signs of potential human illness
  - Signs of their diminishing health can be indicators of the overall environmental health
Emerging and Reemerging infections - 70% vector-borne or zoonotic
One-Health in Action

Example: Salmonella

- Non-typhoidal Salmonella causes an estimated 1.2 million infections, 19,000 hospitalizations, and 370 deaths annually in the U.S. (Nakao et al. 2015)

- Most cases are acquired via food-borne route, however, there is a rise in cases stemming from contact with chickens

- Increase in “Backyard” or “Hobby” Farms, specifically aimed at raising chickens

- Many chickens are mail-ordered from hatcheries

- In 2012-2013, there were 8 unrelated outbreaks resulting in 517 illnesses from live poultry
One-Health in Action

Example: Salmonella

- Example from Surveillance & Outbreak Support experience at WI Department of Health Services:
  - Twin toddlers become ill with severe fever & diarrhea
  - Seek medical care and submit stool samples
  - 1 week later, WSLH confirms Salmonella species
  - Investigation into possible origin of Salmonella finds that family mail-ordered chickens from website a few months prior to illness onset, but ended up giving chickens away just prior to onset
  - Children often would walk in chicken coup, “helping” parents clean and feed chickens
  - Parents were very cognizant of hand-washing and risk of disease with chickens, however, children most likely tracked chicken feces on the bottom of their shoes
  - Shoes are brought into house and left in living room area, where children are playing
  - Direct fecal-oral exposure of Salmonella
One-Health in Action

Example: Salmonella

- **Intervention:**
  - Later found that hatchery of mail-order chickens in MI was linked to multiple illnesses in MI, OH, IL, and WI.
  - Owner of hatchery immediately began to make improvements to sanitation, insect, control, and education for employees.
  - Hatchery required to submit monthly samples to MI DHS for monitoring of Salmonella.
  - Previous outbreak (*S. branderup*) in 2012 linked source of Salmonella to unexpected rise in crickets in and around source hatchery, due to unusual summer weather patterns *(Nakao et al. 2015)*.
One-Health in Action

Example: West Nile Virus (WNV)

- WNV is prime example of keystone species as overall indicator of environmental health & disease susceptibility
  - WNV-infected birds cases usually spike in Spring & early Summer → Many humans cases occur 1-2 months later in Mid-late Summer
  - May also serve as an “early warning” system for increased human disease risk
  - Reliable prediction of weather influences (periods of extreme drought and high temperatures) and expected increases in total cases
An evaluation of West Nile virus in Wisconsin
Effects of climate on environmental, wildlife, and human health

Johnny Uelmen
Epidemiology M.S. Student
Entomology M.S.

University of Iowa
West Nile Virus (WNV)

- *Zoonotic **arbovirus from *Flavivirus* genus
- Not a “new” disease
  - First discovered in 1937 from 37 year old woman who fell ill, had fever of 100.6°F near West Nile region of Northern Uganda
- Arrived in the U.S. in 1999 in New York
  - Most likely from Isr98 strain isolated from single goose (Israel 1998)
  - As of 2014: 41,762 cases leading to 1765 deaths
    - 2012: U.S. experienced one of the worst WNV epidemics in which 286 died
    - However, 70-80% infected people asymptomatic
- No vaccine

*Zoonotic disease: disease that can be passed between animals and humans
**Arbovirus: any group of viruses transmitted by mosquitoes, ticks, or other arthropod (Arthropod-borne virus)
West Nile Virus (WNv)

- Preferred host is birds ("amplifying host")
  - Many infected species contain high number of inoculum in blood & tissues - highly infectious
    - Birds that survive infection and have blood "cleared" of infection still able to shed virus particles in tissues/skin for as long as 13 days

- However, has ability to infect multiple hosts
  - 28 mammal, alligator, and amphibian species

Human Symptoms
- Common: headache, high fever, neck stiffness
- Serious: disorientation, coma, tremors, seizures, paralysis

Avian Symptoms
- Initial: Emaciation, drowsiness, pinching off of blood feathers
- Advanced: clumsiness, unawareness of surroundings, head tremors, severe tremors, seizures
Disease Transmission

- Incredibly “successful” disease
  - Ability to infect multiple hosts and vectors is atypical for *Flavivirus* genus
  - Rapid spread across the U.S. (and the world)
- WNv transmittable via common water sources and close proximity to infected animals
  - But by far, greatest means of transmission is attributed to the

**World’s Deadliest Animal**

What is it???
• Kills more humans than all other animals combined\textsuperscript{4}

• Excellent insect vector
  • Capable of living 3-4 months (in lab) and 9 months when inactive

\begin{center}
\begin{tabular}{ll}
\hline
Killer & Number of deaths per year \\
--- & --- \\
10 Shark & 6,000 \\
10 Wolf & 400 \\
100 Lion & 40,000 \\
100 Elephant & 500,000 \\
500 Hippopotamus & 1,000 \\
1,000 Crocodile & 2,000 \\
2,000 Tapeworm & 2,500 \\
2,500 Ascaris roundworm & 10,000 \\
10,000 Freshwater snail (schistosomiasis) & 20,000 \\
10,000 Assassin bug (Chagas disease) & 25,000 \\
10,000 Tsetse fly (sleeping sickness) & 50,000 \\
25,000 Dog (rabies) & 725,000 \\
50,000 Snake & 475,000 Human \\
\hline
\end{tabular}
\end{center}
THE MOSQUITO!

- Kills more humans than all other animals combined\(^4\)
- Excellent insect vector
  - Capable of living 3-4 months (in lab) and 9 months when inactive
- At least 43 mosquito species able to transmit WNV to ~160 bird species capable of amplifying disease in U.S. alone
  - Many of these bird species are migratory
- WNV is the most widespread arbovirus in the world\(^6\)
  - Found on every continent (except Antarctica)
WNV in Wisconsin

- *Culex* spp. primary mosquito vector
  - Capable of feeding on several hosts to satisfy one meal
  - Time between blood meals as early as 4-5 days
- Detected in 70 of 72 counties
- Most common bird hosts:

- 2004 Southeast Wisconsin mammalian surveillance
  - *Flavivirus* antibody prevalence in 70 of 228 medium-sized mammals (31%)
  - 46 of *Flavivirus* antibodies were WNV specific (20%)
Methodology

- Confirmed human and wildlife cases are primary endpoints
- Value in obtaining suspected (not necessarily tested for; based on behavior; etc.) and low “sero-positive” cases for comprehensive surveillance & analyses purposes

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Equine cases in Wisconsin (2003) (ArboNet provided)
Examples of GIS layers
(from project evaluating Malaria in Uganda)
Examples of GIS layers
(from project evaluating Malaria in Uganda)

Hot Spot Analysis - Malaria Cases
Inverse Distance Method

- Cold Spot - 99% Confidence
- Cold Spot - 95% Confidence
- Cold Spot - 90% Confidence
- Not Significant
- Hot Spot - 90% Confidence
- Hot Spot - 95% Confidence
- Hot Spot - 99% Confidence
Examples of GIS layers
(from project evaluating Malaria in Uganda)

• Empirical Bayesian Kriging (EBK)
• Probabilistic Interpolation of Data
  • Quantifies predictors from uncertainty of interpolated values
• EBK is advantageous model for prediction because it creates a spectrum of simulated semivariograms from which the observed process could be generated
  • Differs from classical Kriging models that use only one model
One-Health in Action

Example: Ticks & Disease

• **Tick-borne Diseases (TBD) are on the rise globally** (Torres et al. 2012)

• Lyme Disease is the most prevalent vector-borne disease in the US

• It is a serious disease in human, wildlife, and companion animals

• Like WNV, Lyme is not a “new” disease
  • Wildlife populations are rarely affected by disease, possibly due to the long co-evolution with wildlife hosts (One Health Compendium Case Studies)
  • Domesticated animals and humans suffer, and this disease “re-emerged” in 1970s
Methods of Intervention for Lyme Disease

- To begin to combat Lyme disease, we need to understand the natural history of the disease
  - What is the tick species?
  - What is the tick life cycle?
  - How many blood meals does it require?
  - What are the preferred hosts and equally important, where do the hosts live?
  - What is the infectious disease agent?
  - How does it proliferate through the tick’s advancing life cycle?
  - Where is the “spillover” or cross from animal into humans?
  - What factors are at play for each stage listed above? (i.e. Environmental changes? Changes to flora or fauna? Physical and/or chemical changes? Anthropogenic influences? etc.)
Methods of Intervention for Lyme Disease

- Lyme Disease has likely been spread and contracted for millennia with environmental change (i.e. interglacials) in Europe and North America.
- However, the Lyme epidemic in U.S. likely caused by human-induced land use changes.
- For example, farm land was reverted to woodland (resulting from changing economics and agriculture policy), increasing deer and tick populations.
- Many converted woodlands are parks and protected areas, increasing recreational activity and subsequent exposure risks.
- Infectious agent, *Borrelia burgdorferi*, has evolved for different reservoir hosts that resulted in genetic variants, subsequently causing different manifestation of disease in humans (One Health Compendium of Case Studies).
Methods of Intervention for Lyme Disease

- Key factors related to “success” of Lyme disease proliferation:
  - Changes in biodiversity = environmental health
    - Reservoir hosts (i.e. birds, rodents and other small mammals, deer) abundance is affected by changes in environment
    - Keystone species, like foxes, owls, and hawks, required larger, non-fragmented forests for survival
    - Changes in forest structure can allow mice populations to explode
  - Climate change
    - Warming climates are directly associated with arthropod development
    - Generally, the warmer the temperatures, the faster an arthropod develops = enhance survival through life stages
  - Other anthropogenic factors, including pesticide applications in agriculture
    - Pesticides and other chemical applications are potential harmful to keystone species
    - Inappropriate use of application can lead to excess pesticide in water runoff, exposing a larger area to harmful chemicals
    - May lead to changes in competition and increased abundance of reservoir host
      - Decrease in raptors leads to increase in mouse populations, for example
Simply put, mice are hugely important in the life cycle of Lyme Disease. They can infect up to 95% of ticks that feeds on them are thrive in fragmented forests.
A Changing Climate...

- Earth’s mean temperature has risen ~0.6°F
  - Since record keeping began in 1850s
- Warmest year on record = 2015
- Why & How?
  - Largely Anthropogenic forces
    - Accumulation of greenhouse gases
      - Combustion of fossil fuels and other nonrenewable sources
    - CO₂, CH₄, NO₂ among fastest gases accumulating
    - Deforestation and land clearing (cattle grazing)
      - ~1 billion tons of carbon released per year
Climate Change and Health

• Most notable environmental risk is heat stress
  • 1999-2009 there were 658 deaths/year
  • Vulnerable populations most affected (elderly especially)

• Ironically, industrialized nations emit the most greenhouse gases, yet experience the least burden

CO₂ emissions by country

CO₂ emissions per capita
Climate Change and Health

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CO₂ emissions by country

CO₂ emissions 1850-2011
Climate Change and Health

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CO$_2$ emissions by country

![CO$_2$ emissions by country](image_url)
Wisconsin One-Health Forum

• Monthly discussions for anyone interested (general public, professionals, academia, etc.)
  • Held on Fridays from 4-6pm

• We just had our kick-off meeting this past Friday, but check out the rest of this semester’s schedule:
  • 3/3 – Introduction to One Health and Disease, presented by Dr. Patz (Director, Global Health Institute) & Dr. Sleeman (Director, USGS NWHC)
  • 4/7 – Access to Health & Food Networks in a Changing Climate
  • 5/5 – Tick-Borne Panel

• E-mail list serve to get on list (for information/all postings related to One-Health): join-onehealth@lists.wisc.edu
• Also check us out on Facebook and Twitter (search: Wisconsin One-Health Forum)
Useful Websites

1. CDC’s One Health Page: 
   https://www.cdc.gov/onehealth/index.html

2. Reliable site dedicated to One Health: 
   http://www.onehealthinitiative.com/

3. One of the leading universities on One Health, UC-Davis: 
   https://www.ucdavis.edu/one-health