Weather/Climate Sensitive Infectious Diseases

Cory Morin
NASA Postdoctoral Program Fellow
cory.morin@nasa.gov

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Climate Variability and Change

- Shift in mean and variance
- Increase in frequency of extreme conditions
Climate Effects on Human Health

Pathogens
- Vector-borne
- Rodent-borne
- Water/food-borne
- Soil-borne
- Air-borne

Extreme Temperatures

Extreme Weather
- Flooding
- Hurricanes
- Tornadoes

Air Quality
- Pollen
- Ozone
- Particulate Matter
Pathways from Climate Change to Health Outcomes

Impact of Climate Change on Human Health

- Injuries, fatalities
- Asthma, cardiovascular disease
- Malaria, dengue, encephalitis, hantavirus, Rift Valley fever
- Heat stress, cardiovascular failure
- Severe Weather
- Air Pollution
- Vector-borne Diseases
- Water-borne Diseases
- Respiratory allergies, poison ivy
- Malnutrition, diarrhea, harmful algal blooms
- Water and Food Supply
- Mental Health
- Environmental Refugees
- Cholera, cryptosporidiosis, campylobacter, leptospirosis
- Anxiety, despair, depression, post-traumatic stress
- Forced migration, civil conflict

Adapted from J. Paltz

https://toolkit.climate.gov/image/505
Interdisciplinary Research

Risk

- Vulnerability

\[ V = f(E, S, A) \]

- Exposure
- Sensitivity
- Adaptive Capacity

\( \{ \text{Environmental Stimulus} \} \)
\( \{ \text{Social Resilience} \} \)
Infectious Disease Ecology

A *multi-factorial* relationship between hosts, agents, environment, and possibly a vector or reservoir.
Infectious Disease Transmission Cycles

**Anthroponoses**
- Direct transmission
- HUMANS → HUMANS

**Zoonoses**
- ANIMALS → ANIMALS → HUMANS

**Indirect transmission**
- HUMANS → VECTOR/VEHICLE → HUMANS

- ANIMALS → VECTOR/VEHICLE → ANIMALS

**Examples**
- eg, TB, measles
- eg, malaria, dengue
- eg, rabies
- eg, bubonic plague, Lyme

National Research Council, 2001
How Does Climate Affect Pathogen Ecology?

• Variables
  • Temperature: minimum, maximum, range
  • Precipitation: total, days with or without
  • Humidity: specific, relative
  • Wind: speed, direction
  • Other variables: surface pressure, ENSO
  • Climate Change

• Scale of Response
  • Temporal scale: daily, monthly, annual
    • Lags: delayed responses to weather/climate conditions
  • Spatial scale: point, local, regional
Temperature Effects on Pathogen Ecology

- Pathogen growth, survival, and incubation periods
- Vector/reservoir dynamics
- Human responses

![Graph showing growth rate vs. temperature for psychrophiles and mesophiles.]

![Diagram illustrating the 2-year life cycle of the deer tick.]

http://50.6.156.112/deerTickEcology.shtml
Precipitation Effects on Pathogen Ecology

- Flooding causing contamination of drinking water
- Increasing in habitat for vectors such as mosquitoes


http://www.sgvmosquito.org/services_mosquitos.php
Humidity Effects on Pathogen Ecology

- Pathogen Survival
- Pathogen Transmission
- Vector Survival

**Pathogen Survival**

- Rogers et al. 2007

**Pathogen Transmission**

- Shaman et al. 2010

**Vector Survival**

- Shaman et al. 2010
Wind Effects on Pathogen Ecology

- Pathogen Dispersal
- Vector Dispersal


https://en.wikipedia.org/wiki/Bluetongue_disease
• The El Nino Southern Oscillation (ENSO) effects the previously discussed atmospheric variables
• Caution, effects are NOT always consistent
Climate Change Effects on Pathogen Ecology

- Increase in pathogen/vector range, seasonality, and magnitude

Messina et al. 2015

Nature Reviews | Microbiology

Morin et al. 2013
Temporal Scale and Pathogen Ecology

**Daily**
- Weather events
  - Storm
  - Frost
- Role
  - Habitat destruction or creation
  - Die offs

**Weekly**
- Weather systems
  - Frontal system
  - Heatwave
- Role
  - Water contamination
  - Life cycle acceleration
  - Vulnerability

**Monthly**
- Seasonal cycles
  - Precipitation patterns
- Role
  - Cycles of transmission
  - Potential introductions

**Annual**
- Climate regimes
  - Climate change
  - Ecological shifts
- Role
  - Species range expansion
  - Novel ecologies

**Decadal**
- Climate regimes
  - Climate change
  - Ecological shifts
- Role
  - Species range expansion
  - Novel ecologies
Time Lags in Pathogen Ecology

- **Daily**
  - Noise

- **Weekly**
  - Pathogen development
  - Vector proliferation
  - Incubation periods

- **Monthly**
  - Host/reservoir behavior
  - Other biotic responses

- **Annual**
  - Pathogen / reservoir / host colonization
  - Adaption / evolution

- **Decadal**
Spatial Scale and Pathogen Ecology

Site/Point
- Microclimate
  - Pool of standing water
  - Protected area like sewer
- Role
  - Vector/pathogen growth
  - Transmission source

Local
- Ecosystem
  - Wetlands area
  - Forrest
- Role
  - Host, pathogen, vector, habitat
  - Facilitation of pathogen transmission cycle

Regional
- Climate zone
  - Tropical, Arid, temperate
- Role
  - Creation of meta-populations
  - Pathogen range expansion

Continental

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Continental
Survey of Some Important Climate Regulated Infectious Diseases

- Airborne: Influenza
- Soil-borne: Valley fever
- Food-borne: Salmonella, E. coli
- Water-borne: Cholera
- Rodent-borne: Hanta vius pulmonary syndrome, plague
- Vector-borne: Dengue fever, Lyme disease
Airborne: Influenza

- Viral infection transmitted via airborne and contact routes
  - Associated with ~250,000 - 5000,000 deaths annually
- Specific humidity is the best predictor of transmission

[Link to Influenza Prevention Wikipedia article]
Airborne: Influenza

- Epidemics occur at low and high levels of specific humidity
Soil-borne: Valley Fever

• Valley fever is caused by the soil fungus Coccidiodes
• Symptoms: fatigue, cough, fever, shortness of breath, headache, night sweats, muscle/joint pain, rash
  • Most people do not show symptoms
  • Severe symptoms are rare
• Infection occurs by breathing in the spores

In the environment, Coccidioides spp. exists as a mold (1) with septate hyphae. The hyphae fragment into arthroconidia (2), which measure only 2-4 μm in diameter and are easily aerosolized when disturbed (3). Arthroconidia are inhaled by a susceptible host (4) and settle into the lungs. The new environment signals a morphologic change, and the arthroconidia become spherules (5). Spherules divide internally until they are filled with endospores (6). When a spherule ruptures (7) the endospores are released and disseminate within surrounding tissue. Endospores are then able to develop into new spherules (6) and repeat the cycle.
Soil-borne: Valley Fever

- Grow and blow hypothesis: moist conditions to grow, dry conditions to blow

Reconstructed $R^2 = 0.90$
Waterborne/Foodborne: E. coli, Salmonella

- Escherichia coli and Salmonella are intestinal bacteria found in humans and animals.
- Symptoms: Diarrhea, stomach cramps, fever.

Temperature Relationship

Precipitation Relationship

Figure 4.2 Relationship between mean temperature and monthly reports of Salmonella cases in New Zealand 1965 - 2000
Waterborne/Foodborne: Cholera

- Caused by bacteria *Vibrio cholerae*
- Symptoms: Diarrhea, vomiting, cramps
  - Severe symptoms are rare
- Cause by water or food contamination
- Climate relationship: ocean temps, pH, and salinity affect zooplankton blooms

http://www.cdc.gov/cholera/general/
http://healthline.com
Waterborne: Schistosomiasis

• Caused by *Schistosoma* nematodes
• Symptoms: rash (initial), fever couch, much ache (later), abdominal pains, enlarged liver, blood in stool and urine (chronic)
• Snail is vector for nematode and are sensitive to water temperature

https://en.wikipedia.org/wiki/Schistosoma
Rodentborne: Hantavirus, Plague

- **Hantavirus pulmonary syndrome (HPS)**
  - Virus transmitted through mouse urine, feces, and saliva
  - Early stage symptoms: fatigue, fever, and muscle aches
  - Late stage symptoms: coughing, shortness of breath, chest tightness

- **Plague**
  - Caused by bacteria *Yersinia pestis* carried by fleas on rodents
  - Symptoms: sudden onset of fever, headache, chills, and weakness
Rodentborne: Hantavirus, Plague

- **Climate relationship**
  - Warm wet springs increase vegetation availability
  - Rodent population explodes increasing rodent-human contact
  - In the case of HPS, dry summer increases aerosolization of virus

- **Relationship not as strong as with many other diseases**

http://www.infectionlandscapes.org/2012/09/hantaviruses.html
Vectorborne: Tick

- Ticks spread pathogens through blood meals
  - Life cycle tied to seasonal temperatures
  - Examples: Lyme diseases, Rocky Mountain spotted fever, Babesiosis, Powassan disease

R_0 for Lyme disease under various climate change scenarios (Ogden et al. 2014)
Vectorborne: Mosquitoes, Flies, ect.

- Many insect species transmit pathogens
  - Mosquitoes: malaria (anopheles), dengue fever (aedes), West Nile virus (Culex), ect.
  - Flies: onchocerciasis (blackfly), trypanosomiasis (tsetse fly), leishmaniasis (sandfly), ect.

- Unique ecologies but usually influenced by climate
Vectorborne: Mosquitoes, Flies, etc.

- Weather/climate can influence pathogen ecology through multiple routes
Overall Conclusions

• Understanding climate and environmental effects on infectious disease ecology provides opportunities to simulate, investigate, and predict transmission dynamics

• However, natural and human systems are complex and coupled requiring interdisciplinary efforts to truly understand

• Future research must identify methods to transition research to better public health practice
  • Incorporate socio-economic and demographic variables into models
  • Creation of seasonal forecasts to help preparedness

• Without surveillance, treatment, and assessment of intervention strategies models will not be effective in reducing the burden of diseases!