Weather/Climate Sensitive Infectious Diseases

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Climate Variability and Change

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

**Extreme Temperatures**
- Vector-borne
- Rodent-borne
- Water/food-borne
- Soil-borne
- Air-borne

**Extreme Weather**
- Flooding
- Hurricanes
- Tornadoes

**Air Quality**
- Pollen
- Ozone
- Particulate Matter

**Pathogens**
Pathways from Climate Change to Health Outcomes

Impact of Climate Change on Human Health

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

Adapted from J. Paltz

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

- Risk
  - Vulnerability
  - \( V = f(E, S, A) \)
  - Exposure
  - Sensitivity
  - Adaptive Capacity

Environmental Stimulus

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

- Anthroponoses
  - Direct transmission
  - Indirect transmission

- Zoonoses
  - Direct transmission
  - Indirect transmission

**Examples:**
- Anthroponoses: eg, TB, measles
- Zoonoses: eg, rabies
- Indirect transmission: eg, malaria, dengue
- Direct transmission: 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 of 2-Year Life Cycle of the Deer Tick]

[Image of a person hiking]

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
Wind Effects on Pathogen Ecology

- Pathogen Dispersal
- Vector Dispersal


https://en.wikipedia.org/wiki/Bluetongue_disease
ENSO Effects on Pathogen Ecology

- 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
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**
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
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
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
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
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

R₀ for Lyme disease under various climate change scenarios (Ogden et al. 2014)

http://www.cbc.ca/gfx/pix/lyme-tick-lores.jpg

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!