Weather/Climate Sensitive Infectious Diseases

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Climate Variability and Change

- Shift in mean and variance
- Increase in frequency of extreme conditions

Source: IPCC 2013
Climate Effects on Human Health

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

**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
- Vector-borne Diseases
- Respiratory allergies, poison ivy
- Water-borne Diseases
- Cholera, cryptosporidiosis, campylobacter, leptospirosis
- Environmental Refugees
- Forced migration, civil conflict
- Mental Health
- Anxiety, despair, depression, post-traumatic stress
- Heat
- Severe Weather
- Heat stress, cardiovascular failure
- Water and Food Supply

Adapted from J. Fultz

https://toolkit.climate.gov/image/SOS
Risk
- Vulnerability
  \[ V = f (E, S, A) \]

Environmental Stimulus
- Exposure
- Sensitivity
- Adaptive Capacity

Social Resilience

Interdisciplinary Research
- Social Science
  - Epidemiology
  - Geography
- Disease Ecology
- Climate Science
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**
- Direct transmission
  - ANIMALS
  - ANIMALS
  - HUMANS

- Indirect transmission
  - HUMANS
  - ANIMALS
  - ANIMALS
  - VECTOR/VEHICLE

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 rates of Psychrophiles and Mesophiles over temperature (°C)]

![Diagram depicting the 2-Year Life Cycle of the Deer Tick: Spring, Summer, Winter, Fall]

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

**b) Influenza Virus Survival Regression on Specific Humidity**

Shaman et al. 2010

1 Hour Viability

- + 1 Hour Viability
- - p<0.0001

**a) Influenza Virus Transmission Regression on Specific Humidity**

Shaman et al. 2010

Data

- + Data
- - p=0.002

**b) Tick Survival (%)**

Rogers et al. 2007

- 62% Humidity
- 75% Humidity
- 60% Humidity
- 40% Humidity

Exposure Duration (hours)

4 8 12 16 20 24
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.

High Resolution Images can be found at:
http://www.cpc.ncep.noaa.gov/products/precip/CWlink/ENSO/ENSO-Global-impacts/
Climate Change Effects on Pathogen Ecology

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

[Graphs and maps showing changes in pathogen distribution and mosquito population over time, with references to Messina et al. 2015 and 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**
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
    - Forest
  - 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


Tamerius et al. 2013
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 cough, 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

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

R₀ 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), trypansomiasis (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!