Weather/Climate Sensitive Infectious Diseases

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Climate Variability and Change

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

**Temperature**
- Increase in mean and variance
  - More/Fewer cold extremes
  - More hot extremes

**Precipitation**
- Change in skewness
  - More heavy precipitation
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
- Respiratory allergies, poison ivy
- Vector-borne Diseases
- Allergies
- Water-borne Diseases
- Cholera, cryptosporidiosis, campylobacter, leptospirosis
- Environmental Refugees
- Forced migration, civil conflict
- Mental Health
- Environmental Health
- Water and Food Supply
- Severe Weather
- Heat stress, cardiovascular failure
- Main nutrition, diarrhea, harmful algal blooms
- Anxiety, despair, depression, post-traumatic stress

Adapted from J. Paltz

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

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

Human Systems

Disease

Natural Systems

Interdisciplinary Research

Social Science
Epidemiology
Geography
Disease Ecology
Climate Science

Environmental Stimulus
Social Resilience
Infectious Disease Ecology

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

eg, TB, measles

**Anthroponoses**

Direct transmission

- HUMANS → HUMANS

Indirect transmission

- HUMANS → VECTOR/VEHICLE → HUMANS

**Zoonoses**

- ANIMALS → ANIMALS → HUMANS

- ANIMALS → VECTOR/VEHICLE → ANIMALS

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

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**

![Graph showing Influenza Virus Survival](image)

1 Hour Viability
- $p < 0.0001$

Shaman et al. 2010

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

![Graph showing Influenza Virus Transmission](image)

Data
- $p = 0.002$

Shaman et al. 2010

**Tick Survival (%)**

![Bar chart showing Tick Survival](image)

Rogers et al. 2007

Exposure Duration (hours)
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

**a** Projected dengue distribution for 2090

**b** Projected dengue distribution for 2055

Messina et al. 2015

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**

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Temporal Scales:
- Daily
- Weekly
- Monthly
- Annual
- 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

[Graph showing Influenza Activity vs. Specific Humidity (g/kg)]

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

In the environment, Coccidiodes 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 $R^2 = 0.90$

[Graph showing monthly incidence per 100,000 people with observed and predicted values from 1992 to 2005. The graph indicates a strong correlation between climate and incidence.]
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
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
Vectorborne: Mosquitoes, Flies, etc.

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

• 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!