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Ecological Principles of Disease Systems: Population Interactions and Dynamics

Gregory E. Glass, PhD
Johns Hopkins University

Module 1 Introduction, by Dr. Vern Carruthers, PhD

- Module 1: disease ecology
  - Disease ecology principles
  - Infectious diseases
  - Dr. Greg Glass, professor of molecular microbiology and immunology

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Section A

Disease Ecology, Epidemiology, and Niche

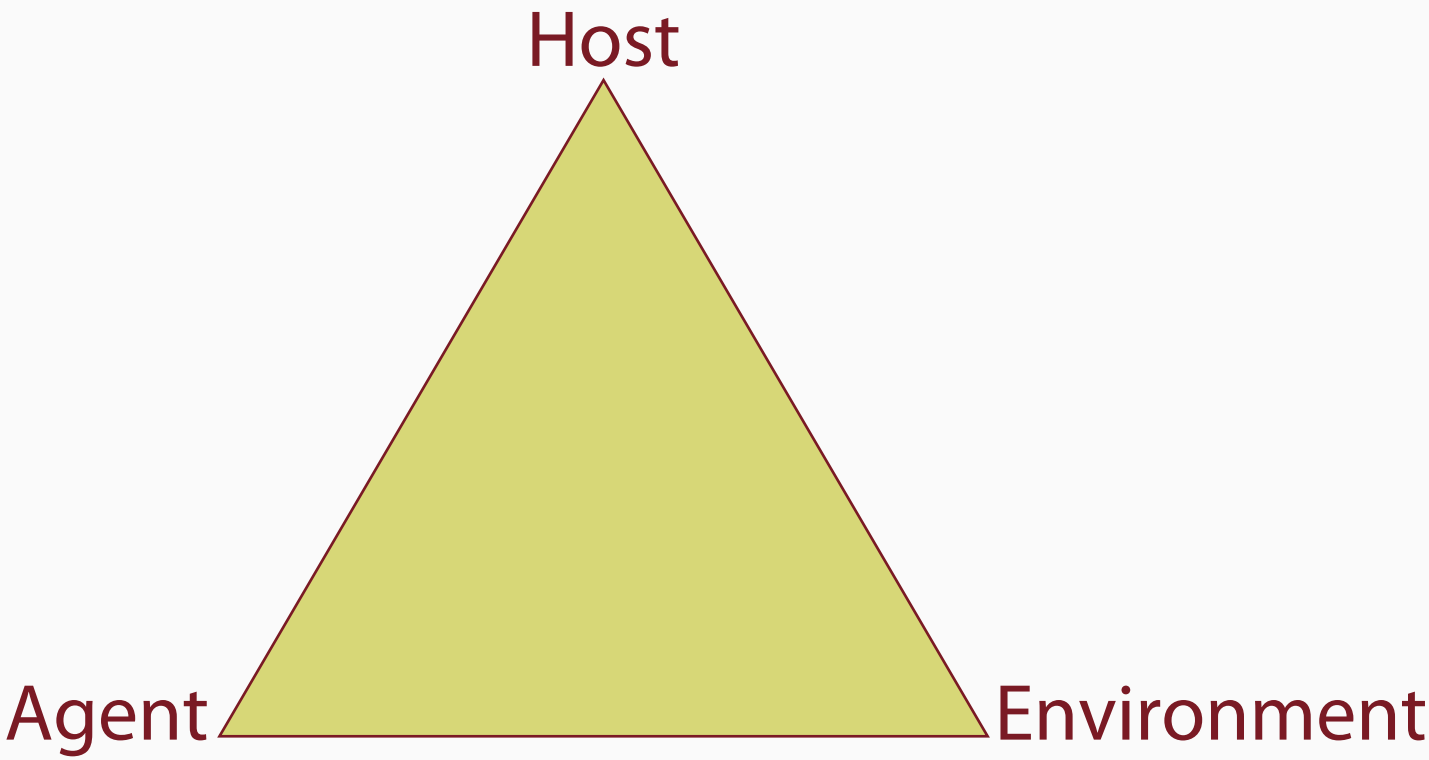
- In this lecture, we will:
  - Characterize the biological level of organization that disease ecology represents
  - Differentiate disease ecology from observational epidemiology
  - Introduce the key concept of niche
  - Demonstrate how niche overlap is related to risk of disease

- Differs from a traditional medical approach in that it's **not** concerned with describing the pathology of individuals
- Differs from epidemiology in that the emphasis is on general processes of population interactions rather than characterization of specific diseases

Differences with Epidemiology

- Epidemiology: the study of the determinants of diseases and injuries (in human populations)
  - What causes disease?
  - How do you identify the causes?
  - Mechanistic
- Disease ecology: the study of the underlying principles that influence the spatio-temporal patterns of diseases
  - Why do the patterns of disease occur as they do?
  - Conceptual: what variables are important?

Epidemiologic Disease Model



Disease Ecology Paradigm

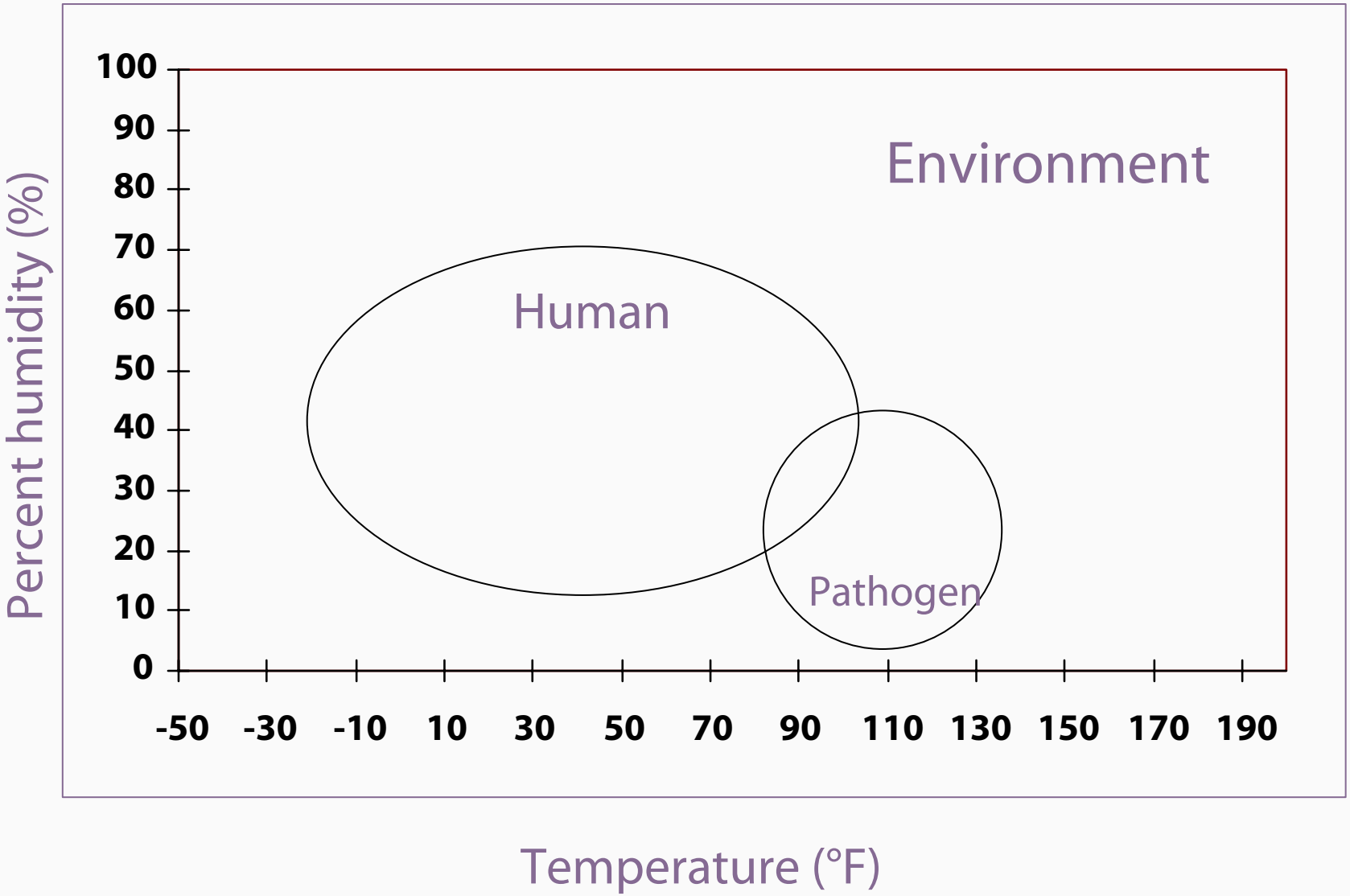
- Incidence, spatial distribution, and timing of diseases reflect the interactions of populations with each other, in the environment

- Populations are systems of organisms interacting with and in the environment, and these interactions result in emergent properties

- Emergent properties: outcomes of higher-order interactions among components of a system that can't be anticipated by studying the components in isolation
  - Example: can the introduction of an efficacious vaccine actually make a disease situation worse?

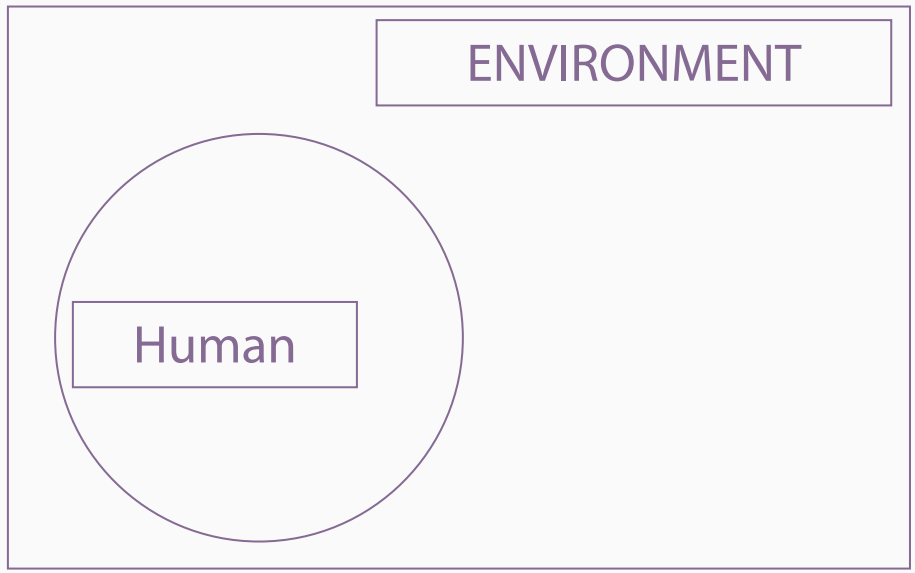
Ecology of Infectious Diseases

- Basic concept of ecology is related to the niche
- Niche: those sets of biotic and abiotic conditions in the environment that define the limit of a species' ability to survive
- In disease ecology, the dynamics of infectious disease are viewed as the overlap in time-space of niches of the component populations

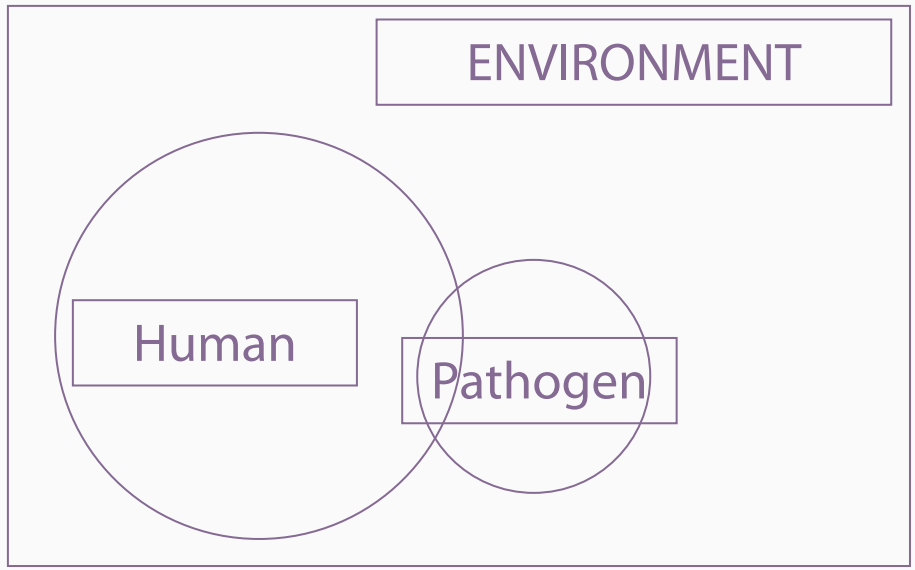

Percent humidity (%)
100
90
80
70
60
50
40
30
20
10
0
Environment
Human
Pathogen
-50
-30
-10
10
30
50
70
90
110
130
150
170
190
Temperature (°F)

Examples of Population Interactions

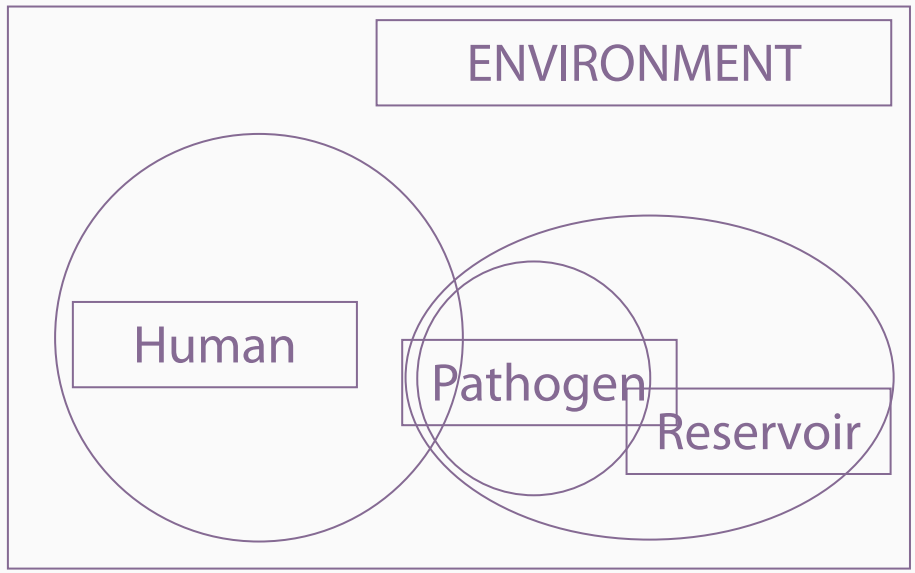
- Environmental diseases
  - For example, toxins (lead poisoning), cancers, environmental shortages, (famine)



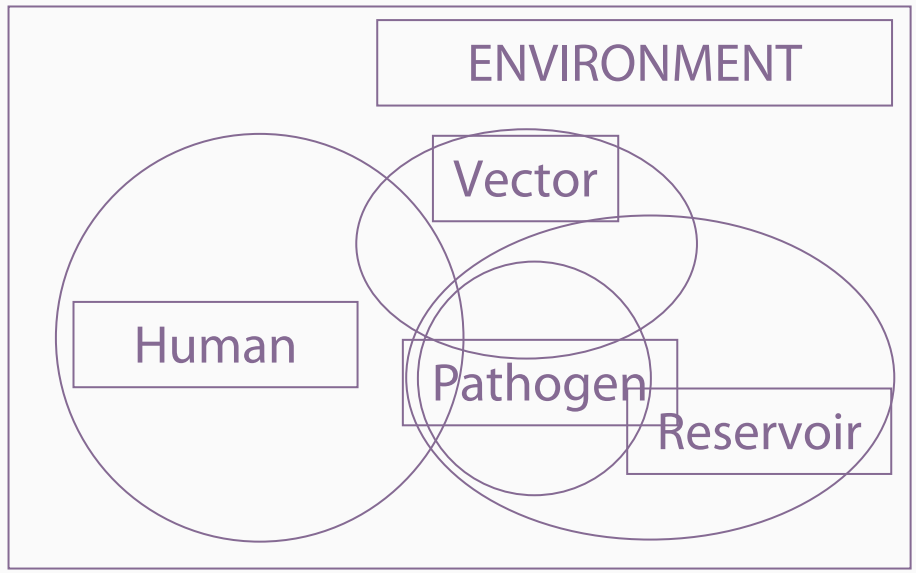
- Directly transmissible infectious disease
- Two-population system
  - For example, many viral (influenza, measles), bacterial (tetanus), fungal (aspergillus) infections



- Zoonotic diseases
  - Pathogen primarily resides in a second species and is transmitted to humans without an intermediary species
    - For example, rabies, schistosomiasis



- Vector-borne diseases
  - Infectious agents transmitted to humans through action of another species
- Many vector-borne diseases are transmitted by arthropods
  - For example, Lyme disease, bubonic plague, Bartonelloses, WNV



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Section B

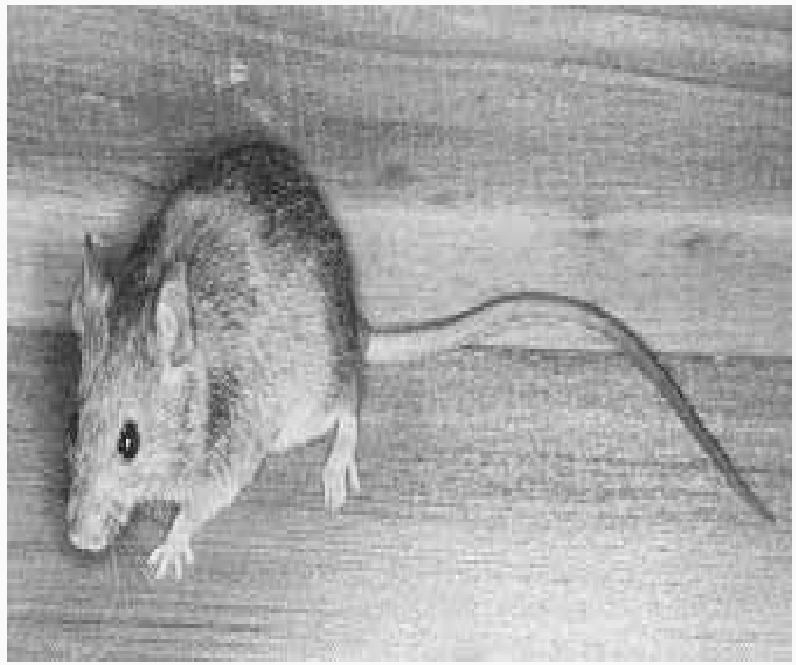
Real-Life Examples

Examples of Rodent-Borne Pathogens

Organism	Host	Transmission
Capillaria hepatica	R. norvegicus and other rodents	Oral
Trichinella spiralis	R. norvegicus and other mammals	Oral
Yersinia pestis	R. norvegicus and other rodents	Vector
Leptospira	R. norvegicus and other mammals	Contact
LCMV	*M. musculus*	Aerosol
Hantaviruses	*A. agrarius, R. norvegicus, C. glareolus*	Aerosol

Niche Differences—Example: LCMV

- Family: Arenaviruses
- Host: *Mus musculus* (house mouse)
- Transmission: air-borne from feces, urine, saliva
- Disease: aseptic meningitis
- Epidemiology: one of the main causes of aseptic meningitis in urban areas



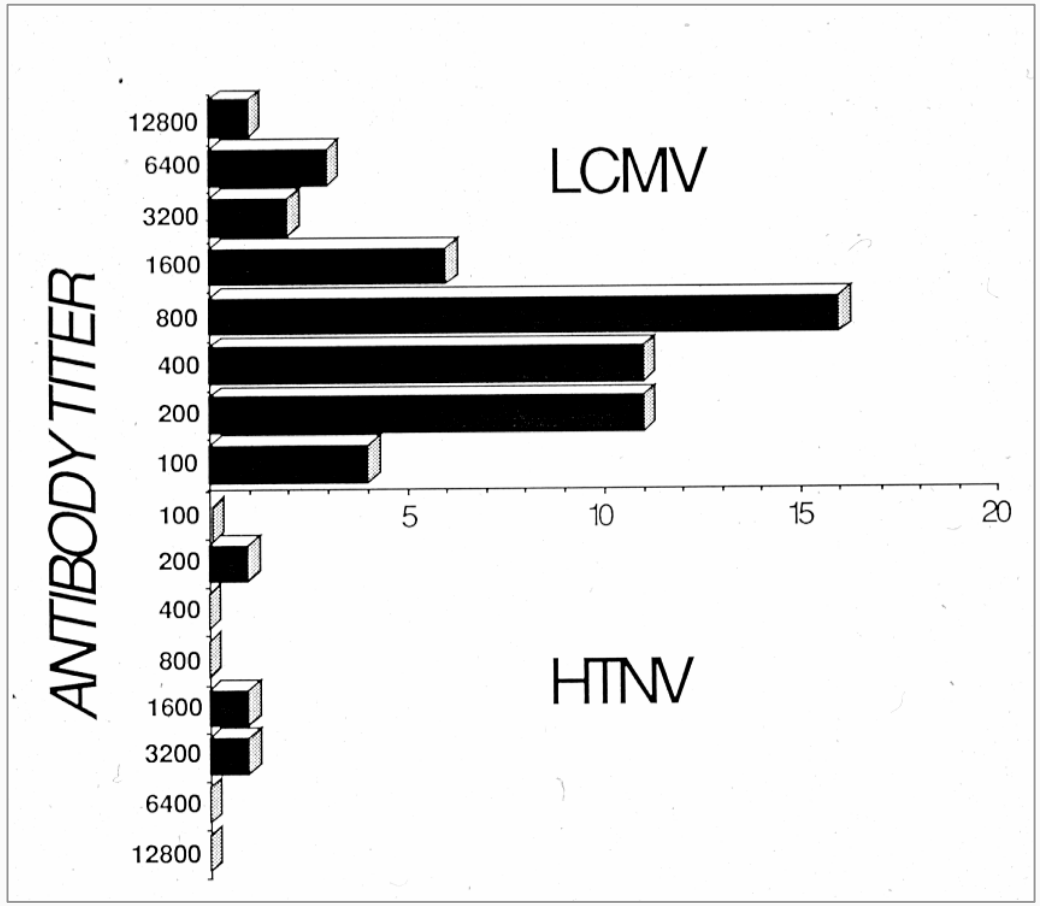
Niche Differences—Example: Hantavirus

- Family: Bunyaviruses
- Host: *P. maniculatus, R. norvegicus, C. glareolus*
- Transmission: airborne from feces, urine
- Disease: hantaviral pulmonary syndrome, acute kidney failure

Photo: Greg Glass

Different Niches Affect Prevalence in Humans

- Note: strikingly different prevalences for LCMV and HTNV
- The number of people in sample infected with hantaviruses is very small
- A large fraction had been infected with LCMV



Graph used with permission of James E. Childs.

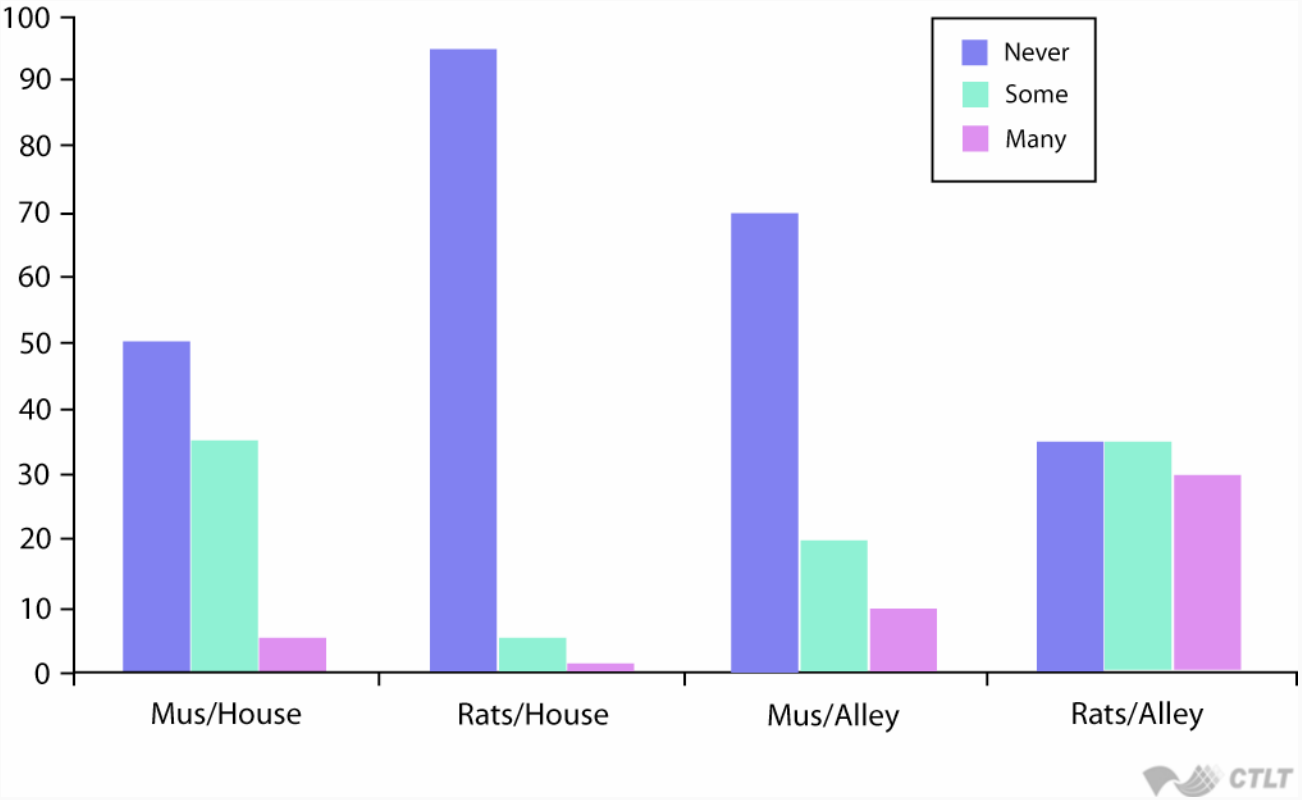
Source: Childs JE, Glass GE, Korch GW, Ksiazek TG, Leduc JW. Lymphocytic choriomeningitis virus infection and house mouse (*Mus musculus*) distribution in urban Baltimore. *Am J Trop Med Hyg* 1992 Jul;47(1):27–34.

Contacts Between Rats/Mice and Humans Differ

Baltimore, Maryland

Photo courtesy of James E. Childs.

Rodent Exposure in Baltimore



Source: Adapted by CTLT from Childs JE, Glass GE, Korch GW, Ksiazek TG, Leduc JW. Lymphocytic choriomeningitis virus infection and house mouse (*Mus musculus*) distribution in urban Baltimore. *Am J Trop Med Hyg* 1992 Jul;47(1):27–34.

Niches and Consequences for Control

- Example: Schistosomiasis
  - Infection with *Schistosoma* spp.
  - Eggs shed in feces or urine of infected individual
  - Infect selected species of snails
  - Eggs hatch into infective forms (cercariae) in water
  - Prevalence in some villages → 80%

Schistosomiasis and Large-Scale Agro-Ecosystems

- Schistosomiasis is associated with large-scale agro-ecosystems needing water

Agricultural field in Egypt affected by building of Aswan Dam

Photo: Courtesy of Clive Shiff

Is Schistosomiasis an Occupational Disease?

- Increased conditions are suitable for snails
- Concurrent increase in human activity that contacts with snails

Photo: Courtesy of Clive Shiff

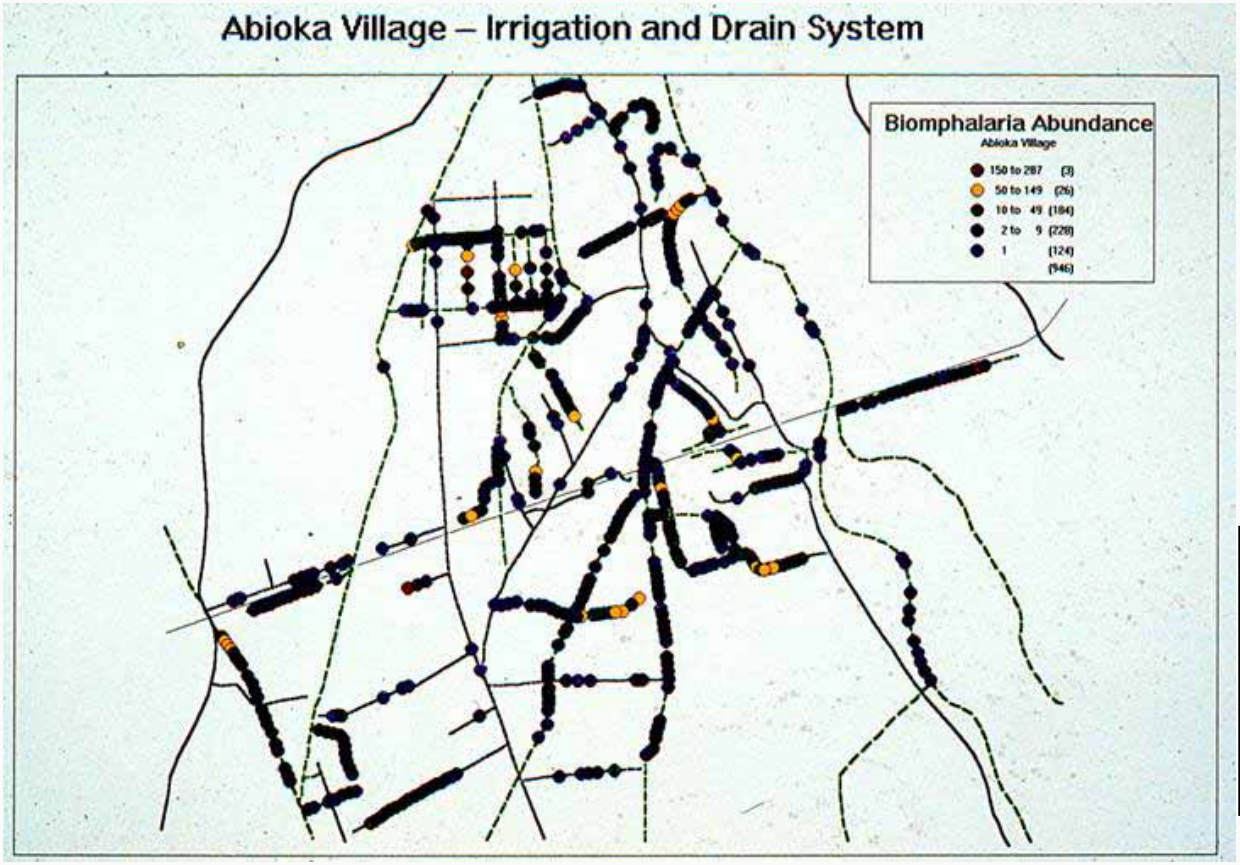
Is Schistosomiasis Associated With ADL?

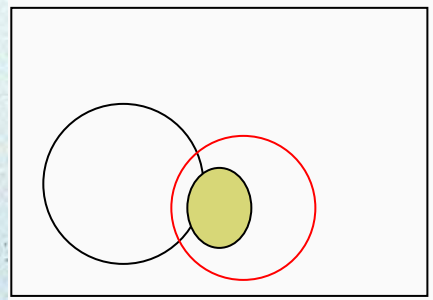
- Water canal in Abioka village, Egypt
- Study site for schistosomiasis and snail contact

Photo: Courtesy of Clive Shiff

Abioka Village

- Over 900 out of 1500 sampling site had no snails
- The majority of the canals at this site are unsuitable environments for snail host





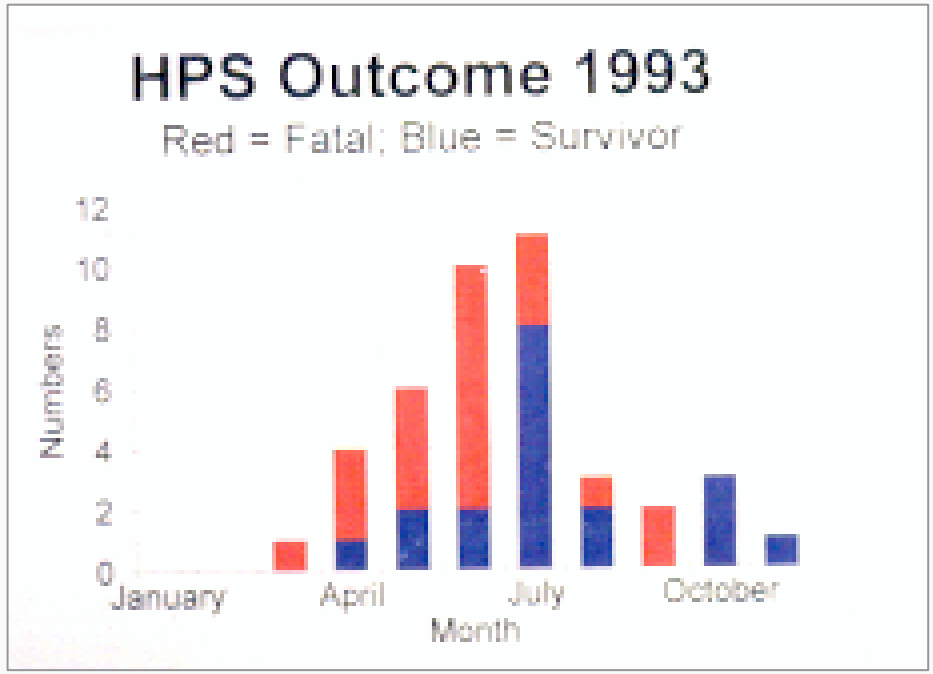
Hantaviral Pulmonary Syndrome (HPS)

- Spatio-temporal fluctuations in niche overlap affects disease rates
- HPS is associated with hantaviruses from sigmodontine rodents
- Associated with capillary leak syndrome, noncardiogenic shock, interstitial pulmonary edema, respiratory failure
- First recognized in spring, 1993

Courtesy of Jonathan Samet

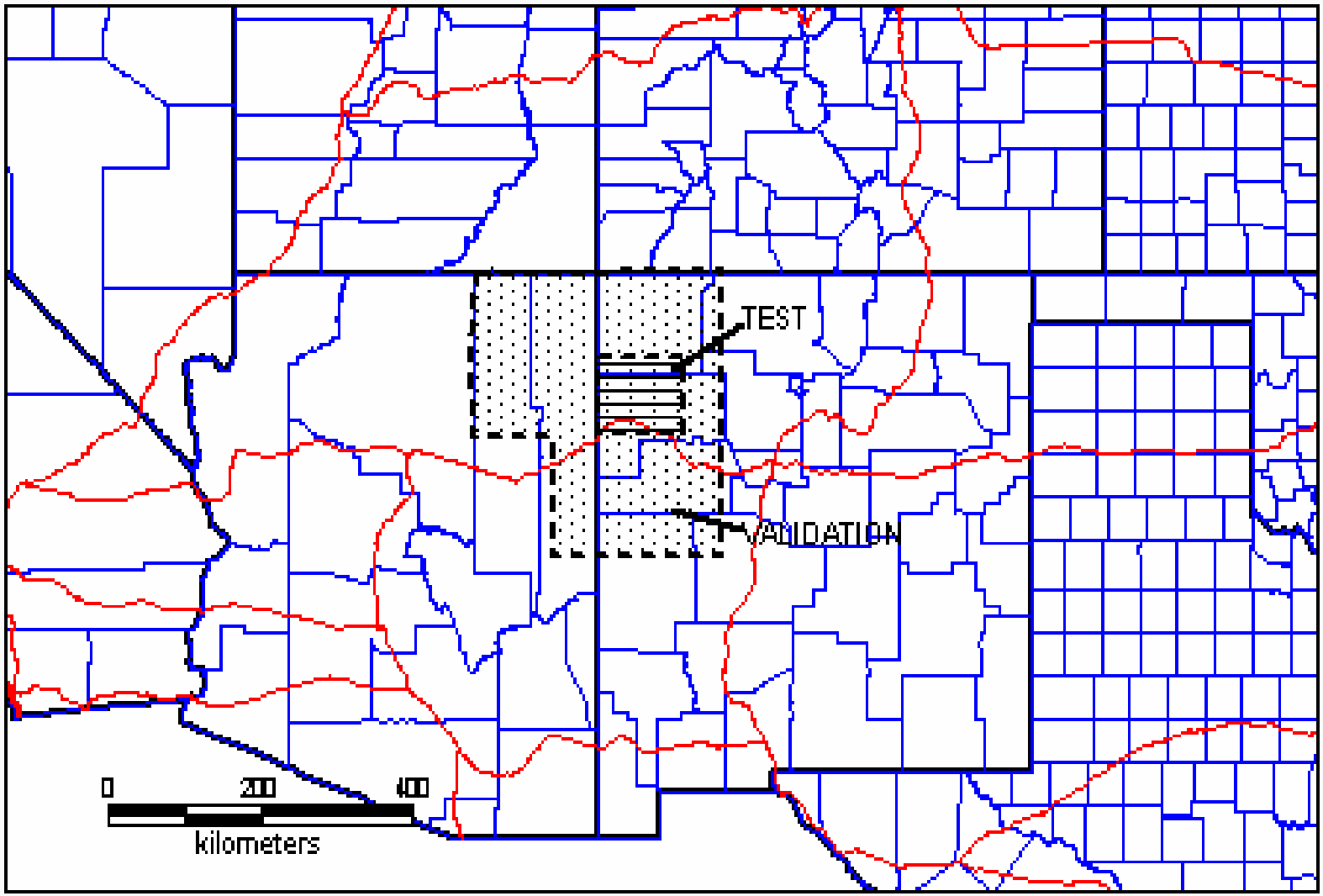
Epidemic Curve

- Mortality is extreme
- Number of human cases relatively low
  - 327 cases as of August, 2002
- Number of cases vary among years



Courtesy of Jonathan Samet

Hyper-Endemic Area for HPS in North America



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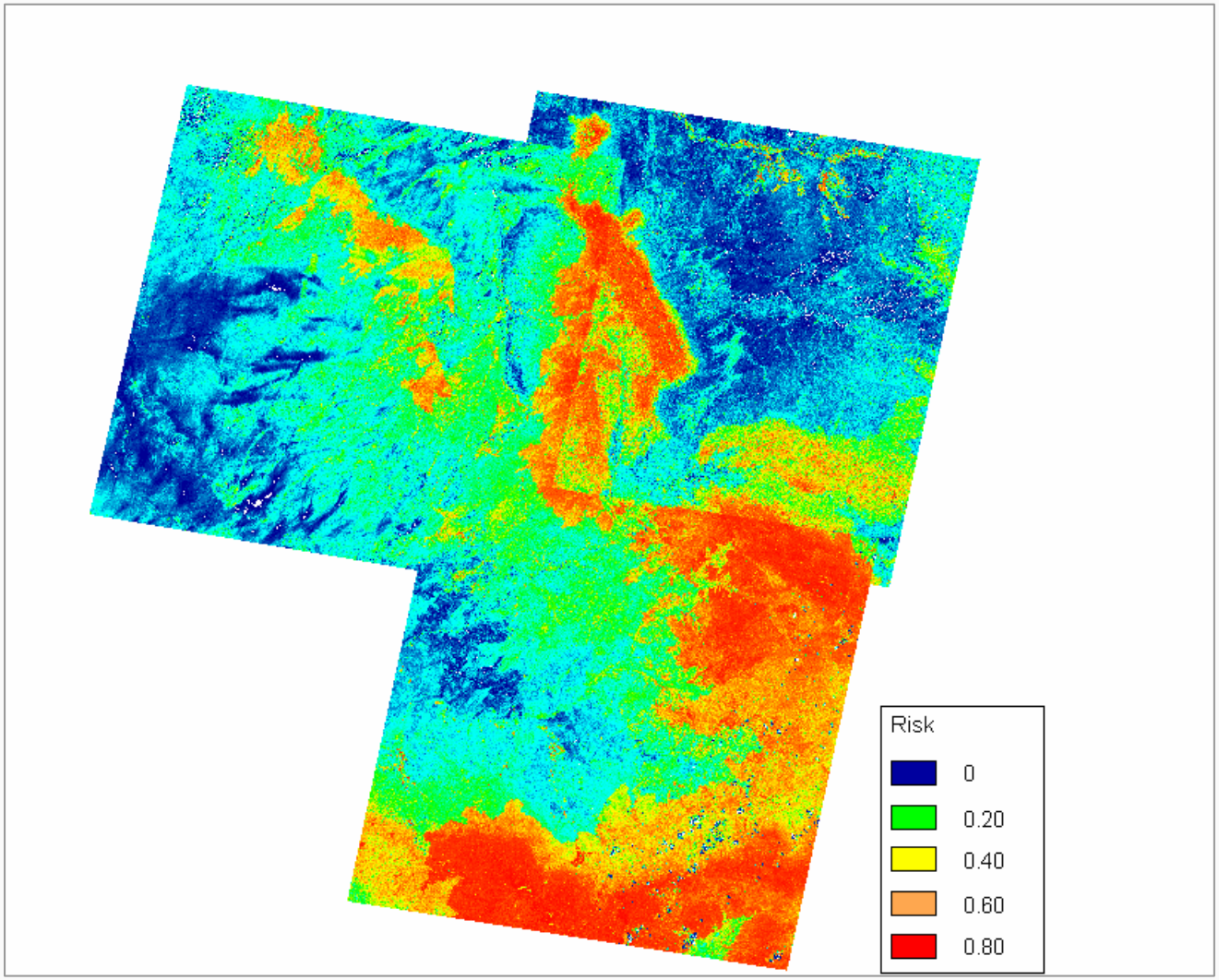
HPS: Southwestern, USA: 1992



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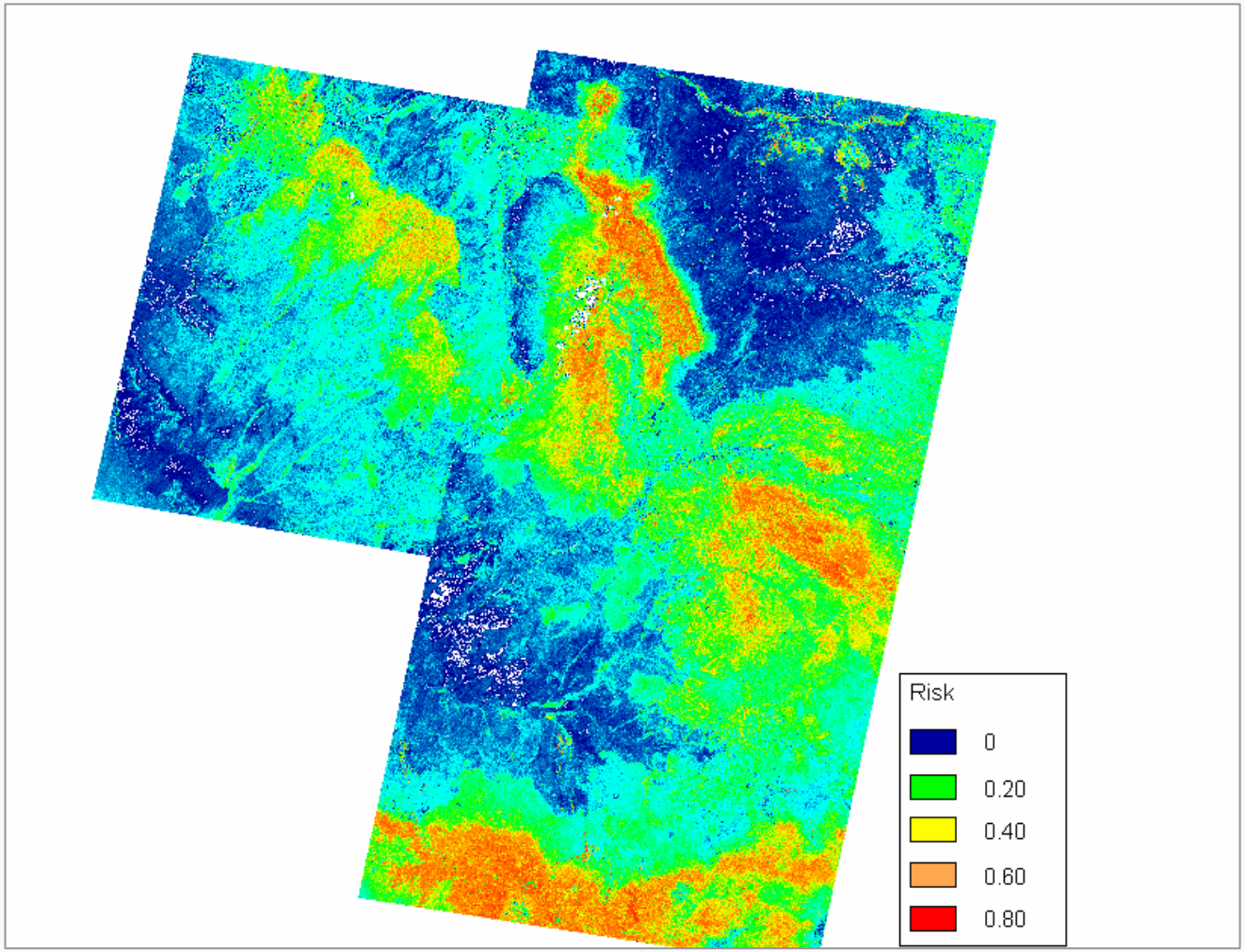
HPS: Southwestern, USA: 1993



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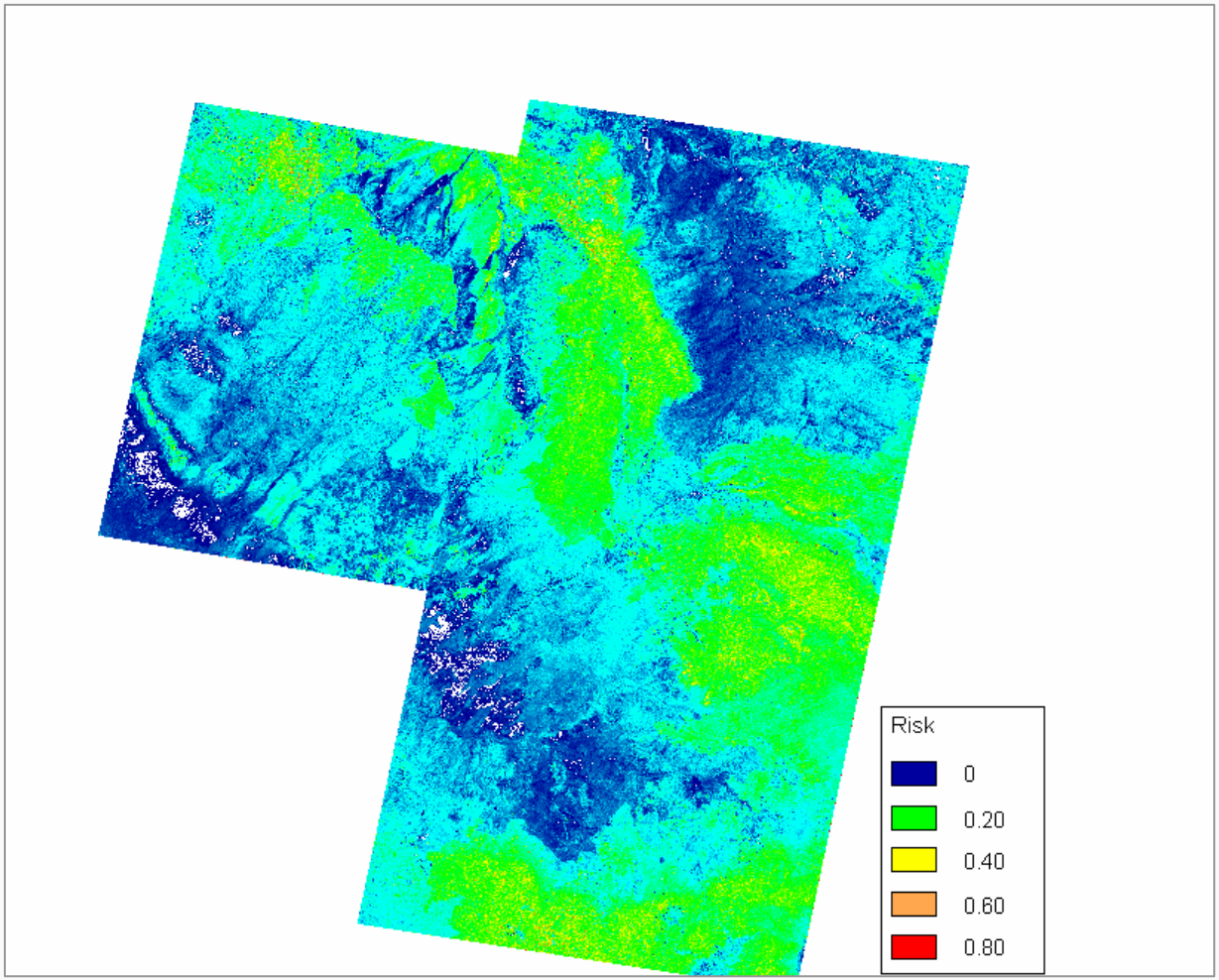
HPS: Southwestern, USA: 1995



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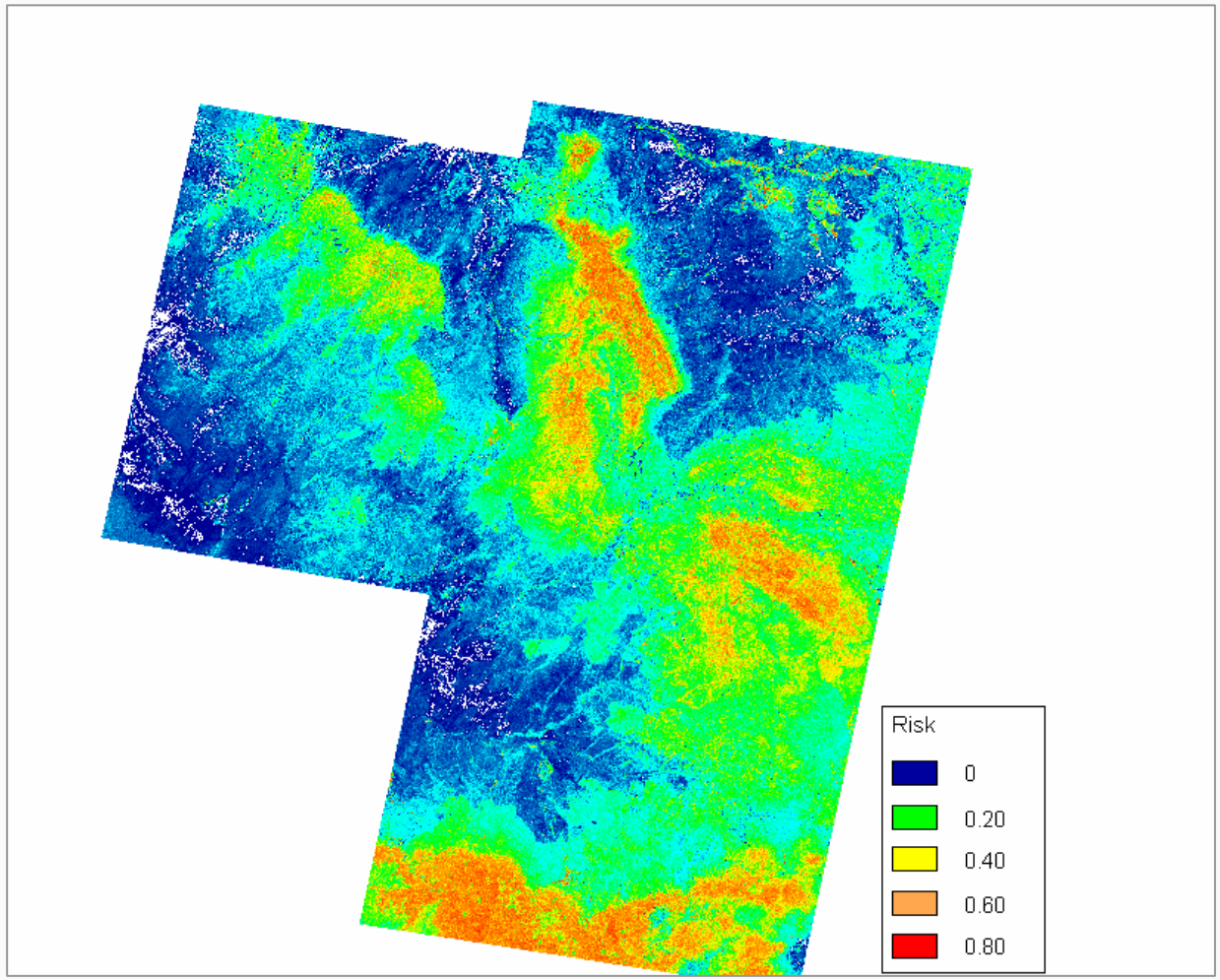
HPS: Southwestern, USA: 1998



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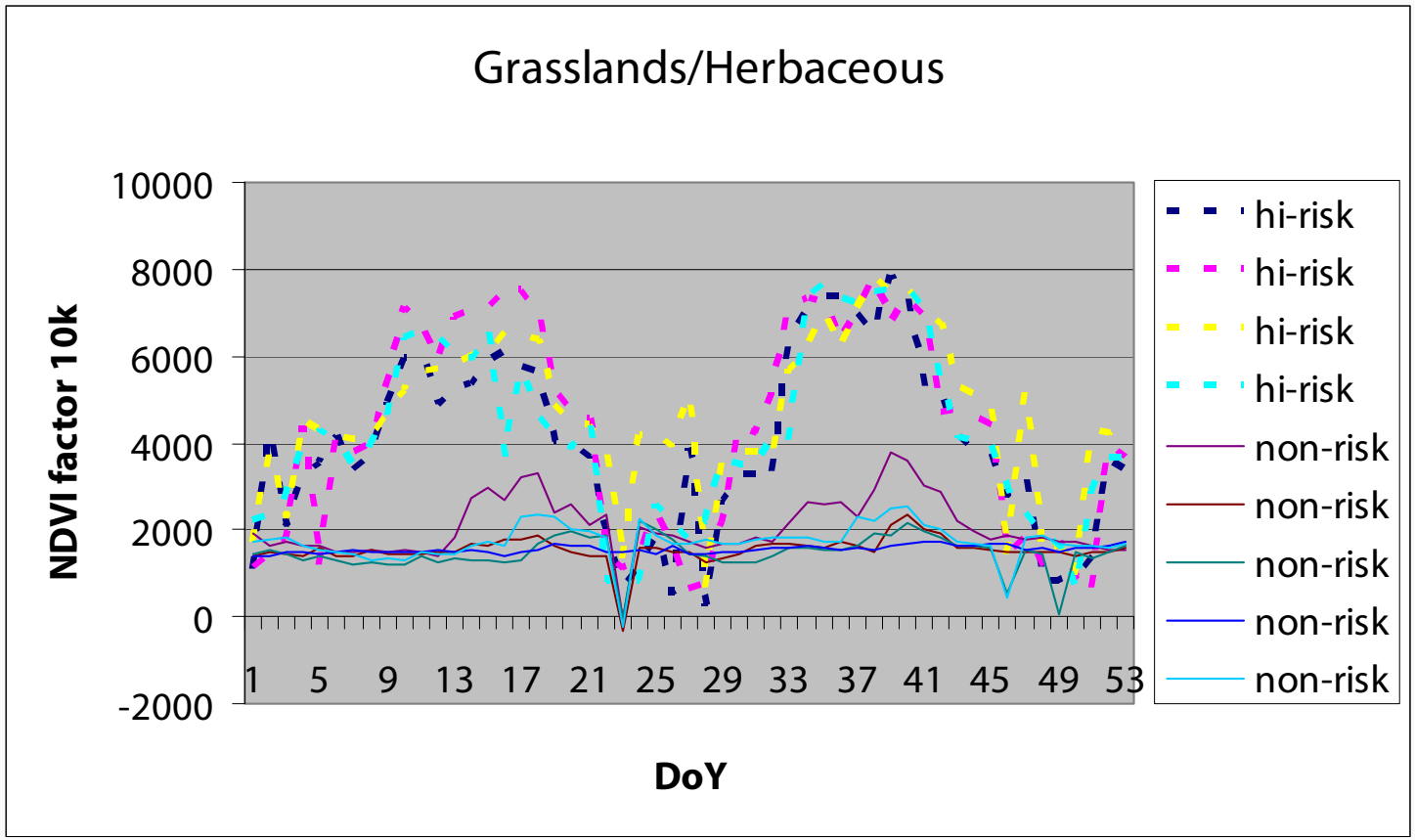
- Vegetation grows more rapidly, more lushly, longer during season where risk is high



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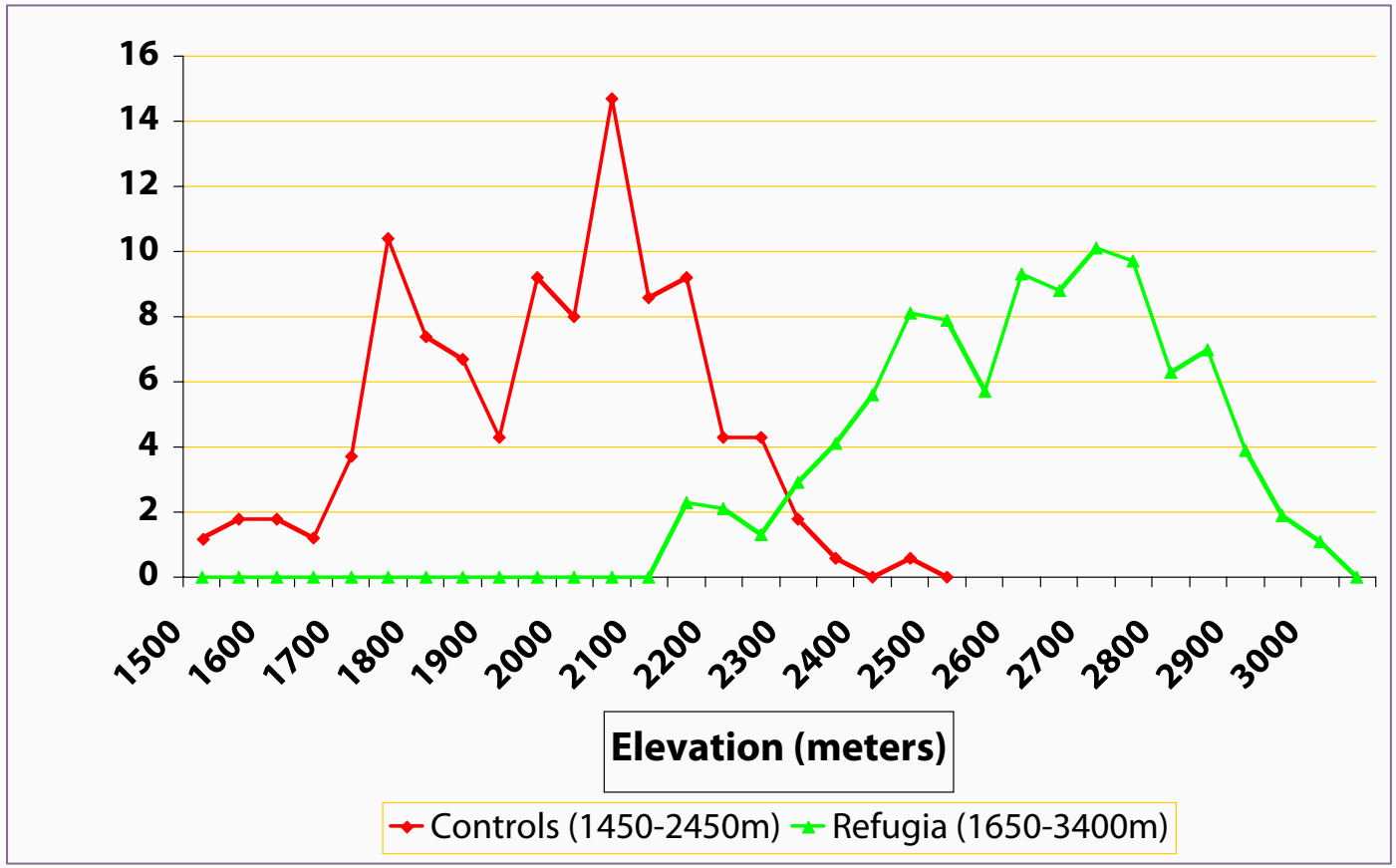
HPS and Elevation

- HPS cases may be rare because people do not live at elevations where persistent high-risk conditions are common



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Summary

- Populations: systems of organisms interacting with and in the environment
- Niches: sets of biotic and abiotic conditions in the environment that define the limit of a species' ability to survive
- Dynamics of infectious diseases: represent the overlap in time-space of niches of the component populations
  - The extent of overlap can vary with time and space