US-Mexico Border, Climate Change, and Infectious Diseases

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Children and Infectious Disease: Canaries in a Coal Mine

- Diarrhea
- Zoonotic disease
Infectious Disease
Vulnerability of Border Region

• Arid ecosystem
• High biodiversity
• Pacific migratory bird pathway
• High human population mobility (busiest international border in the world)
• Urban development challenges
Urban Development Challenges

- Breeding ground for rodents
- Close exposure of humans and animals
- Contamination of water
Human alteration of the environment ...

- Changes in agriculture *(Salmonella, E. coli)*
- Changing demographics (Nipah virus, Dengue)
- Environment disruption (Lyme disease, SARS)
- Disruption of public health (Rabies)
- Human technology *(Legionella)*
- Climate change
Examples
The Water Cycle

- Precipitation
- Transpiration
- Evaporation
- Run-off
Impact of Altered Precipitation

- Both drought and flooding affect fresh water supplies, increasing transmission of pathogens like Salmonella and Rotovirus.
- Increased rainfall provides more breeding grounds for mosquitoes, promoting transmission of diseases.
- Periodic drought followed by heavy rain often increases rodent populations.
Four Corners Disease (1993)

Drought

Heavy spring rains

Mouse overpopulation

Hantavirus (Sin nombre)

http://www.cdc.gov/ncidod/diseases/hanta/hps/noframes/outbreak.htm
Sources of recent *Salmonella* outbreaks

<table>
<thead>
<tr>
<th>Animal products:</th>
<th>Pets:</th>
<th>Plant products:</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Poultry</td>
<td>• Turtles</td>
<td>• Alfalfa sprouts</td>
</tr>
<tr>
<td>• Beef</td>
<td>• Reptiles</td>
<td>• Bean sprouts</td>
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<tr>
<td>• Pork</td>
<td>• Dogs</td>
<td>• Melons</td>
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<tr>
<td>• Eggs</td>
<td>• Cats</td>
<td>• Marijuana</td>
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<td>• Fish</td>
<td>• Birds</td>
<td>• Lettuce</td>
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<tr>
<td>• Milk</td>
<td>• Pet food</td>
<td>• Onions</td>
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<tr>
<td>• Cheese</td>
<td>• Treats</td>
<td>• Tomatoes</td>
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<td>• Chocolate</td>
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<td>• Peppers</td>
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</tbody>
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*Why has transmission via plants increased recently?*
Growth in plants

Chemotaxis toward photosynthetic cells;

Scanning EM of \emph{Salmonella} on stomata of lettuce leaf (3250x)

GFP labeled \emph{Salmonella} Typhimurium growing inside Arabidopsis tissue

Why?

- Arid farm land / dependent on irrigation
- Highly variable annual rainfall / Frequent droughts
- Mixing of human, animal, and plant pathogens
- Selection for survival of bacteria inside plants
Tijuana River Estuary
Sewage Run-off into Ocean

Increase in human infections on both sides of border
Tijuana River Estuary

Environmental Reservoir of Virulence and Antibiotic Resistance Genes
Many Other Examples

Diseases transmitted by

- ticks (Rickettsia, Mexicali 7/15)
- aerosols (tuberculosis and influenza)
- marine animals (Leptospirosis in Sea Lions, Ensenada, La Paz)
- toxins (red tide/phytoplankton and aflaxotoxin/fungi)
Real-time Impact of Climate Change

- Increased terrestrial temperature
  - Insect vectors: Dengue, Chagas, Reduced biodiversity

- Increased ocean temperature
  - Growth of pathogens: Vibrio parahaemolyticus

- Changes in the water cycle
  - Flooding and drought: Salmonella, EHEC, Rotovirus, etc
  - Rodent vectors: Hanta virus
• Increased average terrestrial and ocean surface temperature
  - Changes in precipitation
  - Storms, floods, drought

• Contamination of water by pathogens
• Increase in number / activity of vectors
• Changes in populations of animal carriers

• Diarrheal diseases
• Diseases transmitted by ticks, mosquitoes, and other insects
• Diseases transmitted from animals
One Health

Salud única

Environmental Reservoir

Human Disease

Pathogen

Animal Disease

Pathogen
Human Health paradigm:

Disease Surveillance → Investigation → Treatment

- Human disease

One Health paradigm:

Environment Surveillance → Prediction → Prevention

- Environment
- Animals
- Human disease

One Health

Environment
Animal Hosts
Human Hosts
Tijuana River Watershed
How does this lead to new disease?

- Reservoirs of potential pathogens in environment
- Disrupt environment
- Natural selection for microbes with new properties
- Exposure of animals to new microbes
- Transmission to Humans
1993 Hanta virus (mice)
1994 Plague (rats)
1995 Ebola (apes)
1996 CJD (“mad cow”)
1997 H5N1 influenza (fowl)
1998 Nipah (bats)
1999 West Nile Virus (birds)
2000 Rift Valley Fever (goats)
2001 [Anthrax]
2002 Norovirus
2003 SARS (bats, game)
2004 Marburg Virus (monkeys)
2005 H5N1 influenza (fowl)
2006 E. coli 0157:H7 (cattle)
2007 Food-borne / MMP
2008 Salmonella (peppers)
2009 H1N1 influenza (pigs)
2010 Salmonella (eggs)
2011 E. coli 0104:H4 (sprouts)
2012 MERS Coronavirus (camels, bats)
2013 Neisseria meningitis
2014 Ebola (bats)
Climate Variation and Infectious Disease

- Wildlife die-offs (threaten biodiversity)
- Sewage runoff (rain / beach closures)
- Zoonotic infectious disease (close contact of humans and animals)
- Vector borne diseases (mosquitos, ticks)
- Emerging infectious disease and antibiotic resistance