“Coastal Development and Climate Change: A Recipe for Disaster for Coastal Ecosystem and Human Health”

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Collaborators

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- University of South Carolina, Arnold School of Public Health and Baruch Institute

  *Tom Chandler, Dennis Alan, John Ferry, Tim Shaw and Dwayne Porter*

- Centre for Atmospheric Research Experiments, Environment Canada

  *Terry Biddleman*

- NOAA, National Climate Data Center

  *Thomas C. Peterson*
Urbanization in Coastal Ecosystems

- Globally > 55% of the world’s population lives within 50 miles of the coast, 33 of the 50 largest cities in the world are located in coastal areas & more than 80% of world commerce is transported by ships (Dean, 1997)

- Half of the US population (>141 million people) reside within 50 miles of the coast, which occupies less than 11% of the land area of the lower 48 states (NOAA, 1999; 2005)

- U.S. population has increased by 33 million (28%) since 1980 and is expected to increase by another 12 million by 2015 (Crossett et al.; 2004)

- PEW COMMISSION: 25% of all conversion of rural land into suburban/urban land use in the last 300 years for the U.S. has occurred in the 15 year period from 1982-1997 (NRI, 2000)
Consequences of Differences in Economic and Population Growth on the Coastal Zone

• Thus there is **5.19 times more commercial development/land area** in the coastal zone and **5.38 times more people/land area** in the coastal zone.

• Both economic and urban development may result in increased emissions of air and water pollution.

• Thus there will be increased impacts to the environment quality in coastal zone and coastal communities as a result = *May Impact Both Ecosystem and Human Health*
This influx of people, and the associated residential and commercial development of the coastal zone has resulted in significant modification of landscapes such as increased imperviousness.

Major alterations of the hydrological cycle, which change the transport and delivery of water to coastal watersheds.

This in turn results in increased discharges of toxic chemicals (pesticides, trace metals, PAHs, personal care products, and pharmaceuticals), nutrients, and microbes.
Urbanization: Human Activity on Land Ultimately Affects Water Quality & Coastal Ecosystem Health

- Land Use activity may impact water quality
- Altered or Impacted water quality may in turn impact ecosystem health and human health
- Impacts – Increased levels of Harmful Algal Blooms, Human Health Microbes, & Contaminants of Emerging Concern
Reported Major Marine Ecological Disturbances (1970-1996) — Labrador to Venezuela
Urbanization in Coastal Ecosystems

- **COASTAL CONDITION REPORT**: 44% of Estuarine Ecosystems were impaired primarily due to NPS pollution (EPA, 2012)

- **Bricker et al. (1999)** similarly has reported that 67% of our estuaries and bays in the U.S. are moderately or severely impacted by eutrophication

- **In 2005 > 35,000 beach advisories** or closures occurred in the U.S. (EPA, 2005)

- **> 40% of the shellfish beds in the U.S.** had harvest restrictions resulting from urban runoff, discharges from septic tanks, runoff from animal feedlots and wildlife pollution sources (EPA, 2001)
The greatest rate of population change has been in the southeastern US (58% increase) followed by the Pacific (46%) & Gulf of Mexico (45%) coastal regions (Crossett et al., 2004)

Southeastern U.S. includes FL, GA, SC & NC
Urbanization Studies in SE U.S.

- **Land Use in Coastal Ecosystems Study (LUCES)**
  - **Focus:** Compartmental Interfaces in Estuarine Systems Affected by Coastal Urbanization
  - **Location:** SC and GA
  - **Text Book:** Coastal Urbanization.2007 (G. Kleppel et al., Eds.): Van Norstam Press

- **Tidal Creek Project**
  - **Focus:** Tidal Creeks as Sentinel Habitats
  - **Location:** GA, SC & NC
  - **Numerous Reports and Manuscripts** (F. Holland and D. Sanger Lead Authors)

- **Urbanization in Southeast Estuarine Ecosystems (USES)**
  - **Focus:** Comparison of Suburban and Pristine Estuarine Ecosystems (Multi-Disciplinary)
  - **Location:** Murrells Inlet (Suburban) vs. North Inlet (NOAA NERRS Site) in SC
  - **Text Book:** Sustainable Development in the Southeastern Coastal Zone (F.J. Vernberg, W.B. Vernberg and T. Siewicki Eds.); Belle W. Baruch Library in Marine Science Vol. 20; Univ. of South Carolina Press
Population Trends Along the South Carolina Coast

![Population Trends Graph](image-url)
Charleston, SC Urban Growth
Temporal Series Maps

Urban Area
70 Miles$^2$

1973

Urban Area
250 Miles$^2$

1994

Urban Area
868 Miles$^2$

2030

Mapped at 5:1 ratio for year 2015 and 2030

Urban Area
607 Miles$^2$

2015
Effects of Lot Size on Imperviousness

![Bar chart showing the percentage of imperviousness for different lot sizes and land uses.](chart.png)
Effects of Imperviousness on the Water Cycle

NATURAL GROUND COVER = 10% Runoff

10-20% IMPERVIOUS SURFACE = 20% Runoff

35-50% IMPERVIOUS SURFACE = 30% Runoff

75-100% IMPERVIOUS SURFACE = 50% Runoff
Effects of Imperviousness on Water Quality (Schuler et. al. 1992)
## Major Contaminants in Urban NPS Runoff

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Units</th>
<th>Concentration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Suspended Solids</td>
<td>mg/l</td>
<td>54.5</td>
</tr>
<tr>
<td>Total Phosphorus</td>
<td>mg/l</td>
<td>0.26</td>
</tr>
<tr>
<td>Soluble Phosphorus</td>
<td>mg/l</td>
<td>0.10</td>
</tr>
<tr>
<td>Total Nitrogen</td>
<td>mg/l</td>
<td>2.00</td>
</tr>
<tr>
<td>Total Kjeldhal Nitrogen</td>
<td>mg/l</td>
<td>1.47</td>
</tr>
<tr>
<td>Nitrite and Nitrate</td>
<td>mg/l</td>
<td>0.53</td>
</tr>
<tr>
<td>Copper</td>
<td>ug/l</td>
<td>11.1</td>
</tr>
<tr>
<td>Lead</td>
<td>ug/l</td>
<td>50.7</td>
</tr>
<tr>
<td>Zinc</td>
<td>ug/l</td>
<td>129</td>
</tr>
<tr>
<td>BOD</td>
<td>mg/l</td>
<td>11.5</td>
</tr>
<tr>
<td>COD</td>
<td>mg/l</td>
<td>44.7</td>
</tr>
<tr>
<td>Organic Carbon</td>
<td>mg/l</td>
<td>11.9</td>
</tr>
<tr>
<td>PAH</td>
<td>mg/l</td>
<td>3.5*</td>
</tr>
<tr>
<td>Oil and Grease</td>
<td>mg/l</td>
<td>3.0*</td>
</tr>
<tr>
<td>Fecal Coliform</td>
<td>col/100 ml</td>
<td>15,000*</td>
</tr>
<tr>
<td>Fecal Strep</td>
<td>col/100 ml</td>
<td>35,400*</td>
</tr>
<tr>
<td>Chloride (snowmelt)</td>
<td>mg/l</td>
<td>116</td>
</tr>
</tbody>
</table>

* Represents a Mean Value

Source:
1: Pooled NURP/USGS (Smullen and Cave, 1998)
2: Derived from the National Pollutant Removal Removal Database (Winer, 2000)
3: Rabanal and Grizzard 1995
4: Crunkilton et al. (1996)
5: Schueler (1999)
6: Oberts 1994
Summary: Urbanization Effects

**Population Density vs. Impervious Cover**
- NC, SC, GA
- \( P<0.001, R^2=0.81 \)

**Fecal Bacteria vs. Impervious Cover**
- \( r^2 = 0.6342 \)

**Hydrographic Characteristics**
- Urban
- Suburban
- Forested

**Chemical Contamination vs. Impervious Cover**
- High
- Low
- \( r^2 = 0.52 \ p<0.0001 \)
Urbanization Effects on Coastal Ecosystems

Stressor: Coastal Development Activities
- Increased Population Density
- Altered Land Cover
- Increased Impervious Cover

Exposure: Physical-Chemical Changes
- Impaired Water Quality & Hydrography
- Microbial and Pathogen Contamination
- Chemical Contamination

Ecological Response: Living Resources
- Reduced Biological Productivity
- Altered Food Webs
- Impaired Animal Health

Human Response: Health and Welfare
- Beach and Shellfish Bed Closures
- Vulnerability to Flooding
- Quality of Place

Climate Change Interactions with Urbanization??

10-20% Impervious Cover
20-30% Impervious Cover
10-30% Impervious Cover
Urbanization and Climate Change

Urbanization Effects
- Hydrological Cycle
- Nitrogen Cycle
- Phosphorous Cycle

Climate Change
- Carbon Cycle
- How Will Future Climate Change Effects Interact with Current Known Urbanization Effects?

Hypoxia and Eutrophication
CO$_2$ and pH time series in the North Pacific Ocean

- Atmospheric CO$_2$ (ppmv)
- Seawater pCO$_2$ (μatm)
- Seawater pH
 GLOBAL WARMING

- Present level of CO$_2$ – 400 ppm, which has increased by 25% since the start of the industrial revolution & has increased by 12% since 1960.

- This CO$_2$ increase has caused a 1 degree F increase in global temperatures during the 20$^{th}$ century.

- Projections are for CO$_2$ levels to double by 2050 which will increase global temperatures by 1.5 - 4.5 degrees F.
# GLOBAL Climate Change: Green House

<table>
<thead>
<tr>
<th>Gas</th>
<th>Contribution</th>
<th>Atmospheric Concentration (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO₂</td>
<td>55%</td>
<td>400</td>
</tr>
<tr>
<td>CFCs</td>
<td>24%</td>
<td>(12,000X more potent than CO₂ &amp; increasing @ 5%/year)</td>
</tr>
<tr>
<td>CH₄</td>
<td>15%</td>
<td>2ppm (20X more potent than CO₂ &amp; increasing @ 1%/year)</td>
</tr>
<tr>
<td>NO</td>
<td>6%</td>
<td>ppb conc. (&gt;0.25%/yr)</td>
</tr>
</tbody>
</table>
Sources of Information

(Dr. Thomas C. Peterson
NOAA’s National Climatic Data Center)

• Global climate change impacts on the United States
  – June 2009 and 2014 Reports
  – Intense peer-review
  – Intense public-review
  – Available from
    • www.globalchange.gov/usimpacts
A bit about emission scenarios

- Recent carbon dioxide emissions are, in fact, above the highest emissions scenario developed by the IPCC.

- About 1/3 of the CO₂ from fossil fuel burning remains in the atmosphere after 100 years.
- About 1/5 of it remains after 1000 years.
How May Climate Change Affect These Ocean Health Threats?

- Climate may directly affect growth, survival, persistence, distribution, transmission, and virulence of disease-causing organisms and harmful algal blooms and distribution and concentrations of chemical contaminants in coastal and ocean waters.

- Climate may also affect the distribution of disease vectors, including marine organisms.

- Major climate factors are temperature, precipitation (and associated drought, flooding, and runoff), sea level rise, salinity, extreme weather events, and ecological shifts.
# Increased Temperature

<table>
<thead>
<tr>
<th>Global Warming Effects</th>
<th>Ecosystem/Ecological Response</th>
<th>Interactions with Known Coastal Urbanization Effects</th>
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<td>Increased Temperature</td>
<td>Increased melting of polar ice</td>
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<td>Increased thermal stress</td>
<td>Enhanced toxicity of many emerging contaminants of concern (EECs) in combination with elevated temperatures</td>
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<td></td>
<td>Ecological shifts of marine organisms</td>
<td>Increased occurrences of marine animal diseases and human illness/diseases associated with microbes and harmful algal blooms</td>
</tr>
</tbody>
</table>
Global Climate Change: Temperature Effects

- Number of days with temperatures > 100 degrees F
  - Washington, DC – from 1 day/year to 14 days/year
  - Dallas, TX – from 19 days/years to 78 days/year

- Diminishing Crop Production
  - Mid West will have 30-60% less rain, which will reduce crop production
  - Decreasing protein content of P3 plants (soybeans)
  - Weeds (P4 plants) will have higher growth rates in CO2 enriched air = *more herbicide use*
  - Insect pests will consume more P3 plants to meet protein needs = *more insecticide use*
A tendency to have more warming in the middle of continents

Partly due to:
- More drying due to increased evaporation

Projected Temperature Change (°F) from 1961-1979 Baseline

Mid-Century (2041-2059 average)  End of Century (2081-2099 av.)

**Higher Emissions Scenario**

**Lower Emissions Scenario**

Moving states

Even higher emission scenario
IPCC PREDICTED ECOSYSTEM IMPACTS OF GLOBAL CLIMATE CHANGE

<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>Over most land areas, warmer and fewer cold days and nights, warmer and more frequent hot days and nights</td>
<td>Virtually certain</td>
<td>Increased yields in cooler environments; decreased yields in warmer environments; increased insect outbreaks</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Warm spells/heat waves. Frequency increases over most land areas</td>
<td>Very likely</td>
<td>Reduced yields in warmer regions due to heat stress; increased danger of wildfires</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heavy precipitation events. Frequency increases over most areas</td>
<td>Very likely</td>
<td>Damage to crops; soil erosion, inability to cultivate land due to waterlogging of soils</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Area affected by drought increases</td>
<td>Likely</td>
<td>Lor damage and failure; increased livestock deaths; increased risk of wildfire</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intense tropical cyclone activity increases</td>
<td>Likely</td>
<td>Damage to crops; windthrow (uprooting) of trees; damage to coral reefs</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increased incidence of extreme high sea level [exclude tsunamis]</td>
<td>Likely¹</td>
<td>Salinisation of irrigation water, estuaries and freshwater systems</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
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<td></td>
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</tr>
</tbody>
</table>

- Increased temperatures (warmer nights and fewer colder days)
- Increased heat waves
- Increased Heavy Precipitation Events
- Increased Periods of Drought
- Increased Tropical Cyclone Activity
- Increased Sea Level Rise
- **Overall increased extreme weather**

¹ See Working Group I Fourth Assessment Table 3.7 for further details regarding definitions.

² Define high sea level depends on average sea level and on regional weather systems. It is defined as the highest 1% of hourly values of observed sea level at a station.

³ In all scenarios, the projected global average sea level at 2100 is higher than in the reference period [Working Group I Fourth Assessment 10.6]. The effect of changes in regional weather systems on sea level extremes has not been assessed.
Global Warming: Melting of Polar Ice

- Temperatures in the Arctic are rising at almost twice the rate of that of the rest of the world.

- According to the multinational Arctic Climate Impact Assessment, at least half of the Arctic's summer sea ice will melt by the century's end. The Arctic region is likely to warm 7 to 13 degrees Fahrenheit (4 to 7 degrees Celsius) during the same time.

- By all accounts, the glaciers of Greenland are melting twice as fast as they were five years ago. Recorded spring temperatures on the ice cap have reached almost 20 degrees above normal, hovering just below freezing.

- Glaciers in British Columbia have shrunk by 16 percent in total area between 1985 and 2000.

- Average temperatures worldwide have increased by 0.6 degrees Celsius, which is enough to raise sea levels and change rainfall patterns.

- Average temperature in Antarctica has increased $60^\circ$C over the past 30 years.
Global Temperature Increases

- Polar Ice Melting
  - ~279 species of plants and animals are already responding to climate change by moving closer to the poles

Above from left to right: Polar Bear cubs (*Ursus maritimus*), Adelie penguins (*Pygoscelis adeliae*), and a Pacific Walrus (*Odobenus rosmarus divergens*) with a calf

All three animals are threatened by habitat loss from climate change as well as direct heat stress from increased temperature

Images: (Scientific American, 2009, FLICKR; Montaigne, F. 2010, Scientific American; USGS, 2012)
## Trace Metal Levels in Polar Ice

<table>
<thead>
<tr>
<th>Contaminant</th>
<th>Conc. In Polar Ice (ppt)</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pb</td>
<td>Arctic Snow/Ice 105 - 205</td>
<td>Cheam et al. 1998</td>
</tr>
<tr>
<td></td>
<td>Arctic Snow/Ice 185 - 214</td>
<td>Garbarino et al. 2002</td>
</tr>
<tr>
<td>Hg</td>
<td>Arctic Snow/Ice: 1.3 - 8.1</td>
<td>Aspmoetal et al. 2006</td>
</tr>
<tr>
<td>Cd</td>
<td>Arctic Snow/Ice: 3.4 - 7.4</td>
<td>Cheam et al. 1998</td>
</tr>
<tr>
<td></td>
<td>Arctic Snow/Ice: 13 - 36</td>
<td>Barbarino et al. 2002</td>
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ppt = parts per trillion
### Persistent Organic Pollutants (POPs) Levels in Polar Ice

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<th>Reference</th>
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<tbody>
<tr>
<td>Endosulfan</td>
<td>Arctic Snow/Ice: 30.4 – 360</td>
<td>Hermanson et al., 2005</td>
</tr>
<tr>
<td>Chlorpyrifos</td>
<td>Arctic Snow/Ice: 16.2</td>
<td>Hermanson et al., 2005</td>
</tr>
<tr>
<td>Atrazine</td>
<td>Arctic Snow/Ice: 2.1</td>
<td>Hermanson et al., 2005</td>
</tr>
<tr>
<td>DDT</td>
<td>Antarctica Snow/Ice: 813 ng/m2, Antarctica Melt Water: 18.7</td>
<td>Geisz et al., 2008</td>
</tr>
</tbody>
</table>

(Note there is 3.6 tons of DDT estimated to be in Antarctica Peninsula Ice Sheet; West Antarctica Ice Sheet is losing ice at rate of 210 Gtons/yr = resulting in 1-4 Kg of DDT/Yr being released into the Antarctic Environment each year)
### Increased Temperature

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Sublethal Pesticide Exposure Effects on Thermal Tolerances of Fish

- Sublethal (e.g. LC$_{25}$) effects of 4 pesticides on thermal tolerances of 4 species of FW fish – Eastern Rainbow, Western Carp, Silver Perch & Rainbow Trout (Patra et al. 2007. ETC 26: 1454-59)

- Results:

<table>
<thead>
<tr>
<th>Species</th>
<th>Endosulfan</th>
<th>Chlorpyrifos</th>
<th>Thermal Max W/O</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silver Perch</td>
<td>-3.8</td>
<td>-3.8</td>
<td>32.2-34.7</td>
</tr>
<tr>
<td>Eastern Rainbow</td>
<td>-4.1</td>
<td>-2.5</td>
<td>33.9 – 38.0</td>
</tr>
<tr>
<td>Western Carp</td>
<td>-3.1</td>
<td>-4.3</td>
<td>31.8 – 36.1</td>
</tr>
<tr>
<td>Rainbow Trout</td>
<td>-4.8</td>
<td>-5.9</td>
<td>24.8 – 30.0</td>
</tr>
</tbody>
</table>

- Rainbow Trout the most coldwater species was affected the most and may not survive temperatures below 20°C
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</tbody>
</table>
Climate change is already impacting plant hardiness zones

Observed and Projected Changes in Plant Hardiness Zones

Source: USDA

Source: National Arbor Day Foundation

Lower Emissions Scenario by 2090

Higher Emissions Scenario by 2090
Vibrios: Naturally Occurring Harmful Bacteria

- **V. cholerae** occurs in US waters too!
- Vp and Vv most common cause of seafood poisonings - underreported, misdiagnosed and increasing
- **Vv can result in death** ~ 200 ‘89 - ‘04 & 5 confirmed deaths related to Katrina; associated with 95% of fatalities associated with seafood consumption. 50-60% fatality rate for susceptible individuals; wound infections kill 20-30% of healthy individuals affected.
- **Vp estimated at 8,000 cases per year**, but this is thought to be very low due to under reporting; Not Officially Reported to CDC until 2007; Outbreaks all over the US including 1st time in Alaska in 2004.
- **Vibrio** infection rates have increased 41% over the last decade.
- Rate of Antibiotic Resistance in Vibrios has increased 31% over the past decade (Colwell et al, 2009)
Between 1996 and 2001, the incidence of *Vibrio* infections increased by more than 80%.

More importantly, despite a significant decline (30-45%) in the incidence of most bacterial foodborne infections in the United States in 2004, the incidence of *Vibrio* infections increased by 47% over the baseline period of 2001-2002.

The CDC estimates that 8000 *Vibrio* infections and approximately 60 deaths related to *Vibrio* infections may occur annually in the United States.

*Vibrio* infections are acquired through consumption of contaminated raw or undercooked shellfish such as oysters, clams, mussels, or crabs.

Exposure of wounds to contaminated sea water, injury caused by contaminated seashells, and shark and alligator bites are potential alternative sources of infection.
Current published literature has already established the US northern geographic range extension of Vibrios into southern coast of Alaska from Vancouver, British Columbia, which is approximately 1000 km further north than previously documented (McLaughlin et al, 2005).

McLaughlin et al. (2005) identified the source of a *Vibrio parahaemolyticus* outbreak on a cruise ship as consumption of oysters produced on a farm in Alaska where this bacteria had not been observed previously detected.

Between 1997 and 2004, temperatures at the Alaskan oyster farm increased 0.21°C each year during July and August, and all the infected oysters were harvested when the average daily temperature was above 15°C. **Interestingly, the average daily temperature was 15°C or greater during July and August of 2004 in Alaska for the first time recorded** (McLaughlin et al., 2005).

# Vibrio Infections and Morbidity

<table>
<thead>
<tr>
<th>Vibrio Species</th>
<th>Gastroenteritis (%)</th>
<th>Wound Infection (%)</th>
<th>Septicemia (%)</th>
<th>Miscellaneous (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>V parahaemolyticus</td>
<td>59</td>
<td>34</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>V vulnificus</td>
<td>5</td>
<td>45</td>
<td>43</td>
<td>7</td>
</tr>
<tr>
<td>Non-01 V cholerae</td>
<td>67</td>
<td>9</td>
<td>15</td>
<td>...</td>
</tr>
<tr>
<td>V alginolyticus</td>
<td>5-12</td>
<td>71</td>
<td>1</td>
<td>10-15</td>
</tr>
<tr>
<td>V mimicus</td>
<td>85</td>
<td>3</td>
<td>3</td>
<td>...</td>
</tr>
<tr>
<td>V fluvialis</td>
<td>73</td>
<td>10</td>
<td>6</td>
<td>...</td>
</tr>
<tr>
<td>V damsela</td>
<td>Rare</td>
<td>&gt;95</td>
<td>Rare</td>
<td>...</td>
</tr>
<tr>
<td>V furnissii</td>
<td>&gt;90</td>
<td>Rare</td>
<td>Rare</td>
<td>...</td>
</tr>
<tr>
<td>Vibrio metschnikovii</td>
<td>Common</td>
<td>Rare</td>
<td>Rare</td>
<td>...</td>
</tr>
<tr>
<td>V hollisae</td>
<td>85</td>
<td>7</td>
<td>5</td>
<td>...</td>
</tr>
<tr>
<td>V cincinnatiensis</td>
<td>Rare</td>
<td>Rare</td>
<td>Rare</td>
<td>Meningitis</td>
</tr>
</tbody>
</table>

Ho et al., 2004. CDC
Seasonality of Vibrio Infections in the US

Month

Gastroenteritis  Sepsis  Wound

Jan  Feb  Mar  Apr  May  Jun  Jul  Aug  Sep  Oct  Nov  Dec
**V. vulnificus Cases and Effects of Temperatures > 20°C**

Anselin Local Moran's I for Total Vibrio vulnificus Cases between 2000-2005 in N.C. Counties

Legend
co37_d00_ClustersOutliers1
LMiZScore

< -2.58 Std. Dev.
-2.58 - -1.96 Std. Dev.
-1.96 - -1.65 Std. Dev.
-1.65 - 1.65 Std. Dev.
1.65 - 1.96 Std. Dev.
1.96 - 2.58 Std. Dev.
> 2.58 Std. Dev.

Hot Spot Analysis for Total Vibrio vulnificus Cases between 2000-2005 in N.C. Counties

Legend
co37_d00_HotSpots1
GiZScore

< -2.58 Std. Dev.
-2.58 - -1.96 Std. Dev.
-1.96 - -1.65 Std. Dev.
-1.65 - 1.65 Std. Dev.
1.65 - 1.96 Std. Dev.
1.96 - 2.58 Std. Dev.
> 2.58 Std. Dev.
Harmful Algal Blooms (HABs)
Evidence for accelerated growth when water temperatures >13°C

Nishitani and Chew (1984): Aquaculture

Moore et al. (in review): Environmental Health
Comparison of Leading Causes of Illness

**Drinking Water**
- **Total Cases US 1920-2002** – 10,646 cases/year
- **Etiology of Disease Outbreaks, 1991-2001 in Drinking Water**
  - Acute Gastroenteritis Infection (AGI) Unknown Origin 38%
  - **Chemical Poisonings 16%**
    - Giardiasis 12%
    - Cryptosporidiosis 7%
    - Norovirus 6%
    - E. coli 0157:H7 5%
    - Shigellosis 4%
    - Legionella 3%
    - Campylobacteriosis 3%

**Surface Water**
- **Total Cases US in 2004** – 2,968 cases
- **Etiology of Disease Outbreaks in Surface Water**
  - *Bacteria* (21% of all cases)- Pseudomonas sp.; Legionella; Shigella; *E. coli* & MRSA
  - *Parasites* (53%)
    - Cryptosporidium and Giardia
  - *Viruses* (13%)
    - Norovirus
  - *Chemical Toxins* (1%)
    - Mycrosytin (toxin from blue-green algae)
Potentially toxic cyanobacteria (max. abundance)

- **Microcystis aeruginosa**
  - 41,000 cells / mL

- **Anabaena spp.**
  - 87,000 cells / mL

- **Anabaena circinalis**

- **Cylindrospermopsis raciborskii**
  - 270,000 cells / mL

- **Raphidiopsis curvata**
  - 1,000 cells / mL

- **Cylindrospermopsis philippinensis**
  - 23,000 cells / mL

Falls Lake

Drinking water for 0.5 million people

LMs: E. Allen
Extent and Magnitude of the Problem in the US

- **EPA found there are > 123,000 lakes > 10 acres in size in the US and 33% have CHAB blooms in them.**
- U.S. EPA testing in 2007 found detectable levels of microcystin in 7 of 19 Ohio lakes tested (37%).
- The water supply in Toledo, Ohio, was closed for drinking by residents in August, 2014. **> 500,000 people were affected by this closure.**
- **EPA Guidelines** - 0.3 micrograms per liter (ug/L) for microcystin and 0.7 ug/L for cylindrospermopsin as the level not to be exceeded in drinking water for children younger than “school age. Levels of 1.6 ug/L for microcystin and 3.0 ug/L for cylindrospermopsin for all other age groups.
- Causes of these CHAB blooms include dams, climate change, and increased runoff of nutrients from urbanization and agriculture.
- Preventing of Climate Change and Eutrophication are paramount in controlling this problem with CHABs.
Cyanobacteria abundance (phycocyanin RF)

**Upstream from potable water treatment plant**

August 19, 2008

**Water treatment plant intake**

**Vertical profiles**
Severity of This Eutrophication/HAB Problem in NC

- Estimated Restoration Costs
  Falls Lake Reservoir - >$200M
- Similar Problems - Neuse, Yadkins & Other NC Watersheds
- Restoration Cost Chesapeake Bay - > $1-3 Billion

Albemarle-Pamlico Estuarine System - 2nd largest estuary on U.S. mainland
A harmful algal bloom has been identified in patches from southern Lee to central Collier County. Patchy very low impacts are possible from southern Lee County to central Collier County today through Thursday. No other impacts are expected.

**Conditions Report (public)**

**HAB Bulletin (managers)**

http://www.csc.noaa.gov/crs/habf
Current Experimental Vibrio Forecast Products

- Nowcasts and 3 day forecast – UMCES and NOAA
- 14 and monthly forecasts - UMD ESSIC
## Increased Sea Level Rise

<table>
<thead>
<tr>
<th>Global Warming Effects</th>
<th>Ecosystem/Ecologic al Response</th>
<th>Interactions with Known Coastal Urbanization Effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sea Level Rise</td>
<td>Increased coastal flooding and subsidence</td>
<td>Destruction of coastal property/commerce, including infrastructure such as drinking water supplies and waste water treatment facilities &amp; altered pathogen distributions</td>
</tr>
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<td>Extreme Weather</td>
<td>Increased runoff and drought</td>
<td>Enhanced exposure of marine organisms and humans to chemical contaminants, microbes and nutrients</td>
</tr>
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<td>Altered Salinity Regimens</td>
<td>Increased osmoregulation stress</td>
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</tr>
<tr>
<td></td>
<td></td>
<td>Enhanced toxicity of many EECs</td>
</tr>
</tbody>
</table>
Climate Change Sea Level Rise

The diagram illustrates the estimated sea level rise over time, divided into three periods:

1. Estimates of the past
2. Instrumental record
3. Projections of the future

The x-axis represents the years from 1800 to 2100, and the y-axis represents sea level relative to the 1980-1999 period in millimeters (mm). The graph shows a steady increase in sea level rise, with projections indicating an accelerated trend in the future.
Global Climate Change: Sea Level Rise Effects

- **Sea Level Rise**
  - Normal Eustatic Sea Level Rise – 10-20 cm/100 years (4-8 inches)
  - With 1.5-4.5 Degree F Increase – 70-100 cm/100 year rise (28-40 inches)

- **Coastal Land Use Vulnerable to Flooding**

  - [Commercial Land Use](#)
  - [Urban/Industrial Land Use](#)
  - [Suburban Land Use](#)
Total Vv/Vp densities in surface water measured monthly from April-October 2012
V. *vulnificus* densities were correlated against water quality variables.

The multi-linear regression model values for the environmental variables in relation to *Vibrio vulnificus* densities were as follows:

- Conductivity (P< 0.0001)
- Turbidity (P< 0.0001)
- Temperature (P=0.0654)

The multiple linear model using these water quality variables explained 62% of *Vibrio vulnificus* distributions.

• We used five different GCMs – spanning a range of predictions
• Two simulation periods
  • Historic  1981 – 2010
  • Future    2041 – 2070
Predicted Increase in Specific Conductance in Winyah Bay with Sea Level Rise
Winyah Bay Station WR 4: Future Vibrio vulnificus Abundances with different Sea Level Rise Predictions
# Increased Runoff and Drought

<table>
<thead>
<tr>
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</tr>
<tr>
<td></td>
<td></td>
<td>Enhanced toxicity of many EECs</td>
</tr>
</tbody>
</table>
Heavy precipitation events have been increasing and are projected to continue to increase.
Projected decrease in precipitation in the south, increases in the north

- These are projections for the end of the century
- Uncertainty – disagreement between models is large
- Hashing is where agreement between models is greater
- Uncertainty over the next few decades is large
Developed Watershed

- Rainfall
- Evapotranspiration (PET)
- Stormwater Runoff
- Subsurface flow
- Groundwater recharge
National Academy of Sciences (NRC, 2002) reported that polycyclic aromatic hydrocarbon (PAHs) and other petroleum products running off of roadways, parking lots and driveways in the U.S. cumulatively account for more than **10.9 million gallons of petroleum pollution in an 8 month period**, which is the equivalent to the volume of oil spilled in the EXXON VALDEZ Oil Spill.
Contaminants of Emerging Concern (CECs)
Pharmaceuticals in the Environment

Patient use is the primary pathway human pharmaceuticals enter the environment.
“Monitoring Strategies for Chemicals of Emerging Concern (CECs) in California’s Aquatic Ecosystems”

Recommendations of a Science Advisory Panel

Paul Anderson, Nancy Denslow, Jörg E. Drewes, Adam Olivieri, Daniel Schlenk (Chair), Geoffrey I. Scott, and Shane Snyder

California Water Resources Control Board
Southern California Coastal Water Research Project,
Costa Mesa, CA
Technical Report 692
May 2012
Toxicity curve shift to left at higher temperature indicates greater toxicity.

Toxicity curve shift to right at higher salinity indicates less toxicity.
# Pharmaceuticals in US Surface Waters: Frequency of Detection

<table>
<thead>
<tr>
<th>Drug</th>
<th>% Frequency of Detection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steroids</td>
<td>89</td>
</tr>
<tr>
<td>Nonprescription Drugs</td>
<td>81</td>
</tr>
<tr>
<td>Insect Repellent</td>
<td>74</td>
</tr>
<tr>
<td>Detergents</td>
<td>69</td>
</tr>
<tr>
<td>Disinfectants</td>
<td>66</td>
</tr>
<tr>
<td>Plasticizers</td>
<td>64</td>
</tr>
<tr>
<td><strong>Fire Retardants</strong></td>
<td><strong>60</strong></td>
</tr>
<tr>
<td><strong>Antibiotics</strong></td>
<td><strong>48</strong></td>
</tr>
<tr>
<td>Insecticides</td>
<td>45</td>
</tr>
<tr>
<td>PAHs</td>
<td>44</td>
</tr>
<tr>
<td>Hormones</td>
<td>37</td>
</tr>
<tr>
<td>Other Prescription Drugs</td>
<td>32</td>
</tr>
<tr>
<td>Antioxidants</td>
<td>29</td>
</tr>
<tr>
<td>Fragrances</td>
<td>27</td>
</tr>
<tr>
<td>Solvents</td>
<td>24</td>
</tr>
</tbody>
</table>

*USGS: 1999-2000 Survey of 139 US Waterways*
Concentrations of Perfluorinated Chemicals in Wildlife & Humans

PFOS (ng/mL=ppb)

- Baltic Sea Ringed seal
- Beaufort Sea Polar bear
- CHS SC
- IRL FL
- Riccione, Italy captive
- Midwest USA Bald eagle
- USA Human
- Canada Human
- Production Plant Workers, USA Human

Mean = 1316
Mean = 1320
10,600

bottlenose dolphin
Oxytetracycline Findings

Sample sites: from treatment plant to estuary
Induction of *E. coli* Antibiotic Resistance

- **Tidal Cycles**
  - 1 Cycle
  - 2 Cycles

- **Time to Development of Resistance (hrs)**: 0, 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24

- **Tetracycline Concentration (µg/L)**: 0.1, 1, 10, 100, 1,000, 10,000, 100,000

- **Environmentally Relevant Surface Water Concentrations**
- **Effluent Concentrations**
- **MIC**
## Summary of Antibiotic Resistance Issues in the US

### Rates of Microbial Antibiotic Resistance

<table>
<thead>
<tr>
<th>Watershed</th>
<th>Effects Measured</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>MD (Ches. Bay)</td>
<td>MAR ( E. coli ) = 2.8 - 9% in marine waters</td>
<td>Kaspar et al. 1990</td>
</tr>
<tr>
<td>FL</td>
<td>MAR ( E. coli ) = 13 - 25% in marine waters</td>
<td>Parveen et al. 1997</td>
</tr>
<tr>
<td>SC(^3)</td>
<td>MAR ( E. coli ) = 0.9-3.9% in FW &amp; MW</td>
<td>NOAA. 2011</td>
</tr>
<tr>
<td>SC(^4)</td>
<td>MAR ( E. coli ) = 1-3% in coastal waters</td>
<td>Van Dolah et al.</td>
</tr>
<tr>
<td>SC STPs</td>
<td>MAR ( E. coli ) = 5-22% in effluent</td>
<td>Webster et al. 2004</td>
</tr>
<tr>
<td>SC CAFOs</td>
<td>MAR ( E. coli ) = 12-16% in effluent</td>
<td>NOAA, 2011</td>
</tr>
<tr>
<td>SC Dolphins</td>
<td>MAR ( E. coli ) measured in 39% of dolphins</td>
<td>NOAA, 2011</td>
</tr>
<tr>
<td>FL Dolphins</td>
<td>MAR ( E. coli ) measured in 8% of dolphins</td>
<td>NOAA, 2011</td>
</tr>
</tbody>
</table>

### Detectable Levels of Antibiotics in Surface Waters or Pollution Sources

- US Watersheds: 48% of the sites had detectable levels of antibiotics | USGS, 2002
- SC Golf Course 1: 61 ng/L Tetracycline in effluent | NOAA, 2011  
  effluent used for golf course irrigation
61% of sick and stranded marine wildlife sampled exhibited resistance to one to as many as ten common antibiotics.

Bacteria isolated from 39% of wild-caught dolphins in the Charleston, SC area were resistant to $\geq 3$ common antibiotics (Amp-Amx-Cf-P).
Antibiotics of Concern: Compounds in the Environment

- **SC Effluent**—Triclosan, Tetracyclines (COT), Ampicillin, Penicillin,
- **Ches. Bay Effluent**—Erythromycin, Sulfamethoxazole & Trimethoprim
- **Southern CA Water**—Sulfamethoxazole, Calrithramycin, Sulfamethizole, Trimethoprim
- **Southern CA Sediments**—Ciproflaxin, Erythromycin, Tricarbam, Sulfamethoxazole, Trimethoprim
- **Southern CA Mussels**—Sulfamethizole, Erythromycin, Triclocarban
Antibiotic Resistance

• How bacteria develop resistance:
  • **Mutations** - Mutations are relatively rare, occurring in only 1 event per $10^7–10^{10}$ bacteria
  • **Plasmids** – packets of DNA that exist outside of the microbe that contain the genetic code for developing resistance. Plasmids may be exchanged between different microbes
  • WWTP treatment may select for more resistance and enhances plasmid production as a result (Uyaguari et al, 2011)
FIG. 1. Sampling site locations: A) WWTP and Charleston Harbor sites. The WWTP, site 1 (principal effluent) is located in Charleston, SC. Environmental collection sites were labeled as follows: site 2 (outfall/discharge site), Site 3 (Ashley River); site 4 (Ashley and Cooper River mixing zone); site 5 (Cooper River); site 6 (Charleston Harbor mouth). B) Site 7 (North Inlet control site). Dark gray shaded zones represent areas of urban land cover.

Final Effluent Has Highest Levels of Resistance

FIG. 3. Copy number of the \( \text{bla}_{M-1} \) gene \( \text{ml}^{-1} \) of sample (A), and ng \( \text{ml}^{-1} \) of DNA (B). Copy numbers were quantified by qPCR using metagenomic DNA extracted from 3 stages in the WWTP: Raw sewage (RS), Activated sludge (AS), and Principal effluent (PE). Black/gray bars represent GCN means for each treatment (n=3) during years 2007 and 2009 respectively. Error bars indicate standard deviations. Means with different upper and lower case letters indicate significant differences across treatment for years 2007 and 2009, respectively.

Levels of Resistance Genes >1,000X Higher In Sediment Than Effluent

FIG. 4. Copy number of the bla\textsubscript{M-1} gene in sediments g\textsuperscript{-1} of sample (A), and ng\textsuperscript{-1} of DNA (B). Copy numbers were quantified by qPCR using metagenomic DNA extracted from 5 different sites in the Charleston Harbor area: Site 2 (WWTP outfall), Site 3 (Ashley River), Site 4 (Ashley and Cooper River mixing zone), Site 5 (Cooper River), Site 6 (Charleston Harbor mouth), and Site 7 (NI control site). Bars represent the mean for each treatment (n=3). Error bars indicate standard deviations. Means with different letters indicate statistical significance at the 0.05 level.

Antibiotic Resistance in *Vibrio parahaemolyticus* (Baker–Austin et al., 2008. Journal of Food Protection 71:2552)
The frequency of multiple resistances to antibiotics from all sources was unexpectedly high, particularly during summer months, and a substantial proportion of isolates (17.3%) were resistant to eight or more antimicrobial agents.

Numerous isolates demonstrated resistance to antibiotics routinely prescribed for *V. vulnificus* infections, such as doxycycline, tetracycline, aminoglycosides and cephalosporins.

This report is the first to demonstrate prevalent antibiotic resistance in a human pathogen with no clinical reservoirs (importance of Env. Factors such as climate).

(Baker Austin et al. 2009 Microb. Ecol. 57:151–159)
Impacts of Pathogens

- Pathogens may cause disease in humans from consumption of food, drinking water and contact recreation, such as swimming. Effects may include gastrointestinal effects, upper respiratory illness and wound infections.

- The health consequences due to marine-borne pathogens in the USA have annual costs on the order of $900 million (Ralston et al., 2011).

- This includes:
  - $350 million due to pathogens and marine toxins specifically identified as causing food-borne disease,
  - $300 million due to seafood-borne disease with unknown etiology,
  - $300 million due to gastrointestinal illness from beach recreation and
  - $30 million from direct exposure to the Vibrio species (Ralston et al., 2011).
Deaths attributable to AMR every year compared to other major causes of death

- AMR now 700,000 (low estimate)
- AMR in 2050 10 million
- Cancer 8.2 million
- Cholera 100,000 – 120,000
- Diabetes 1.5 million
- Diarrhoeal disease 1.4 million
- Measles 130,000
- Road traffic accidents 1.2 million
- Tetanus 60,000

Sources:
- Diabetes www.who.int/mediacentre/factsheets/fs312/en/
- Cancer www.who.int/mediacentre/factsheets/fs310/en/
- Cholera www.who.int/mediacentre/factsheets/fs314/en/
- Diarrhoeal disease www.sciencedirect.com/science/article/pii/S0140673612617380
- Road traffic accidents www.who.int/mediacentre/factsheets/fs315/en/

(Reference: O’neill, J. 2014. The Review of Antimicrobial Resistance. Study directed by UK Prime Minister)
Global Climate Change and Health

Present
- Undernutrition
- Heat
- Food and water-borne infections
- Vector-borne diseases
- Occupational health
- Air quality
- Mental health and violence
- Extreme weather events

2030-2040
"Era of Committed Climate Change"
+ 1.5°C
- Undernutrition
- Heat
- Food and water-borne infections
- Vector-borne diseases
- Occupational health
- Air quality
- Mental health and violence
- Extreme weather events

2080-2100
"Era of Climate Options"
+ 4°C
- Undernutrition
- Heat
- Food and water-borne infections
- Vector-borne diseases
- Occupational health
- Air quality
- Mental health and violence
- Extreme weather events

Risk and potential for adaptation
- Risk level with current adaptation
- Potential for adaptation to reduce risk
- Risk level with high adaptation
Global Climate Change: Energy Policy Options

- Improved Energy Efficiencies in cars and other facets of energy production (i.e. car mileage of 45 mpg = reduce CO₂ levels by 40%)

- Replace fossil fuels with “Soft Path (renewable) Technologies” such as solar, wind power & biofuels

- Replace all coal fired power plants – 14 % reduction in CO₂ but will cost $144B/year & would require building a new plant every 2.5 days until 2025

- Reverse Forest Loss (absorbs CO₂)

- Reduce CFC Emissions

- Tax Fossil Fuels (Coal> Oil > Natural Gas)

- Diversification of Energy Production including Nuclear Options
Which Energy Source Has the Smallest CO₂ Footprint?

- The Swedish utility Vattenfall did a study of full life cycle emissions of Nuclear, Hydro, Coal, Gas, Solar Cell, Peat and Wind which the utility uses to produce electricity.
- The net result of the study was that nuclear power produced 3.3 grams of carbon dioxide per KW-Hr of produced power vs. 400 for natural gas and 700 for coal. The study concluded that nuclear power produced the smallest amount of CO₂ of any of their conventional electricity sources.
Impacts of Energy Production on Health

• Claims exist that the problems of nuclear waste do not come anywhere close to approaching the problems of fossil fuel waste in terms of volumes and the ability to safely manage waste, particularly air emissions.

• A 2004 article from the BBC states: "The World Health Organization (WHO) says 3 million people are killed worldwide by outdoor air pollution annually from vehicles and industrial emissions, and 1.6 million indoors through using solid fuel."

• In the U.S. alone, fossil fuels waste kills 20,000 people each year due to complications with respiratory and heart disease.
Effect of Climate Change on Human Health

- The Global Humanitarian Forum (GHF) published a report estimating that 315,000 people die due to climate change every year, and they predict this will rise to half a million by the year 2030.

- While such estimates of direct deaths remain low relative to the size of the global population, about 310 million people are expected to have suffered ill health because of climate change by 2030.

- Nine out of ten of these climate affected people will be in developing countries and the number of healthy years of life lost to environmental change, including climate change, is set to be 500 times higher in Africa than Europe.

DALYs = Disability Adjusted Lost Years
Possible Effects of Global Warming on Known Urbanization Effects on Coastal Ecosystems

Possible Effects of Global Warming on Known Urbanization Effects on Coastal Ecosystems

Global Warming may greatly impact Coastal Ecosystem Sustainability
Author of 51 Books - Documents evidence of our transition from fossil fuels to renewable energy sources

Evidence of the transition:

- Nations are increasing renewable energy – Denmark (34%), Spain and Portugal (20%)
- US States are increasing renewable energy – Iowa and South Dakota (26%) and Texas (10%)
- From 2010-2014, the number of coal plants in the US generating energy was reduced from 500 to 343 (>25% reduction)
- 2007-2013 China Coal use declined 18%
- 1994-2013, the number of gas stations in the US decreased from 203,000 to 153,000 (>25% reduction)
Brown Shrimp in North Inlet: Earlier Arrival

Dr. Dennis Alan reports earlier arrival dates
For brown shrimp at North Inlet: 1980-2008

Arrival dates of brown shrimp postlarvae in the estuary

first occurrence: positive correlation with water temperature:  $r = 0.37$  $p < 0.001$

Long-term trend  $r^2 = 0.35$  $p = 0.001$

*Missing data
Temperature Change in North Inlet

Dr. Dennis Alan reports increased water temperatures at North Inlet: 1980-2008

**Winter water temperature at North Inlet estuary, SC 1980 – 2010**

Long-term increase: $r = 0.36$, $p = 0.05$

Estimated change: $+1.7^\circ C$

Winter Surface Water Temperature Residuals (1980-2010)
(Based on biweekly samples in Town Creek, station BB; n=6 or 7)

Winter water temperature correlated with winter NAO index, $r = 0.60$, $p = 0.002$
CONCLUSION: Climate Change

CLIMATE SUMMIT

WHAT IF IT'S A BIG HOAX AND WE CREATE A BETTER WORLD FOR NOTHING?

- ENERGY INDEPENDENCE
- PRESERVE RAINFORESTS
- SUSTAINABILITY
- GREEN JOBS
- LIVABLE CITIES
- RENEWABLES
- CLEAN WATER, AIR
- HEALTHY CHILDREN
- ETC. ETC.
CONCLUSIONS: Climate Change

The full report is available from www.globalchange.gov/usimpacts
CONTACT INFORMATION

Dr. Geoffrey I. Scott

Chair, Dept. of Env. Health Sciences
Arnold School of Public Health
University of South Carolina
PHRC 401E, 921 Assembly Street
Columbia, SC 29208

Email: geoff.scott@sc.edu; Phone: 803/777-8964
### Climate Change and Health

#### Disease Categories

<table>
<thead>
<tr>
<th>Disease</th>
<th>Area</th>
<th>Cases-yr</th>
<th>Climate Sensitivity and Confidence in Climate Effect</th>
<th>Key references</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mosquito-borne diseases</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Tick-borne diseases</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Other vector-borne diseases</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hemorrhagic fever with renal syndrome (HFRS)</td>
<td>Global</td>
<td>0.15 – 0.2 million</td>
<td>![Temperature icon] ![Temperature icon] ![Temperature icon] ![Clouds icon] ![Clouds icon] ![Percentage icon]</td>
<td>Fang et al 2010</td>
</tr>
<tr>
<td>Plague</td>
<td>Endemic in many locations worldwide</td>
<td>about 40,000</td>
<td></td>
<td>Stenseth et al 2006, Xu et al 2011, Ari et al 2010</td>
</tr>
</tbody>
</table>

#### Climate drivers

- Temperature
- Precipitation
- Humidity

#### Climate driver variables

- Increase or decrease
- Increased
- Decreased
- More
- Fewer

#### Confidence levels

- High confidence in global effect
- High confidence in local effect
- Low confidence in effect

1. Effects are specific to Anopheles spp