Climate Change and Health in Baltimore City

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PRECEPTORS:

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Project Introduction and Overview

Setting
◦ Baltimore City Health Department

Objective & aims
◦ Identify climate-related vulnerabilities relevant to public health in Baltimore City at the local scale
◦ Carry out the first two steps of CDC’s Building Resistance Against Climate Effects (BRACE) framework
Climate Change and Human Health

Direct impacts\textsuperscript{1, 2}
\begin{itemize}
\item More extreme weather events
  \begin{itemize}
  \item Morbidity and mortality from trauma
  \item Mental health impacts on survivors
  \end{itemize}
\end{itemize}

Indirect impacts\textsuperscript{1, 2}
\begin{itemize}
\item Infectious disease
  \begin{itemize}
  \item Favorable conditions for vectors and bacteria
  \end{itemize}
\item Food sustainability
\item Chronic disease exacerbations
\end{itemize}
Climate Change and Human Health

150,000 deaths worldwide attributed to climate-related causes from temperature, diarrhea, malnutrition, flood, and malaria in 2000[^3]

70% increase in risk of mortality during 2003 European heat wave resulting in 70,000 deaths[^4]

Recent disasters
- Hurricane Harvey
- Hurricane Maria
- Wildfires in California
Building Resilience Against Climate Effects (BRACE)

Five step process for guiding local health departments in assessing vulnerabilities and planning adaptations to climate change

1. Anticipate climate impacts and assess vulnerabilities
2. Project the disease burden
3. Assess public health interventions
4. Develop and implement a climate and health adaptation plan
5. Evaluate impact and improve quality of activities
BRACE

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BRACE

Five step process for guiding local health departments in assessing vulnerabilities and planning adaptations to climate change

1. Anticipate climate impacts and assess vulnerabilities
   ◦ Select conditions of interest
BRACE

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1. Anticipate climate impacts and assess vulnerabilities
   ◦ Select conditions of interest
   ◦ Review literature for risk factors
BRACE

Five step process for guiding local health departments in assessing vulnerabilities and planning adaptations to climate change

1. Anticipate climate impacts and assess vulnerabilities
   ◦ Select conditions of interest
   ◦ Review literature for risk factors
   ◦ Map risk factors to reveal vulnerable communities
BRACE

Five step process for guiding local health departments in assessing vulnerabilities and planning adaptations to climate change

1. Anticipate climate impacts and assess vulnerabilities
2. Project the disease burden
   ◦ Determine historical relationship between meteorological factors and disease burden
BRACE

Five step process for guiding local health departments in assessing vulnerabilities and planning adaptations to climate change

1. Anticipate climate impacts and assess vulnerabilities
2. Project the disease burden
   ◦ Determine historical relationship between meteorological factors and disease burden
   ◦ Collect climate projections for the future
BRACE

Five step process for guiding local health departments in assessing vulnerabilities and planning adaptations to climate change

1. Anticipate climate impacts and assess vulnerabilities
2. Project the disease burden
   ◦ Determine historical relationship between meteorological factors and disease burden
   ◦ Collect climate projections for the future (exposure)
   ◦ Apply historical relationship to project future disease burden (outcome)
Conditions of interest

Morbidity and mortality from temperature extremes
  ◦ Heat and cold

Infectious disease
  ◦ Vector borne & foodborne
    ◦ Lyme disease, salmonellosis, campylobacteriosis, vibriosis
  ◦ Legionellosis
Methods

Data sources

◦ Historical meteorological data
  ◦ National Oceanic and Atmospheric Administration (NOAA)
  ◦ Daily temperature and precipitation recorded at Maryland Science Center in downtown Baltimore (Jan. 2000-Feb. 2019)

◦ Heat and cold morbidity and mortality
  ◦ Maryland Health Services Cost Review Commission
    ◦ ED visits, hospitalizations
    ◦ Vital statistics for Baltimore City

◦ Infectious disease cases
Methods

Data sources
- Climate model projections (exposure)
  - 2020-2099
  - Northwest Knowledge Network
    - 4km and 6km spatial resolution
  - USGS Geo Data Portal
    - 1/16th degree spatial resolution

Vulnerability assessment
- Literature review for sociodemographic and environmental risk factors associated with each condition
- Mapped each risk factor by Community Statistical Area (CSA)
- Overlay maps to reveal cumulative risk
Methods

Analysis of relationship between meteorological factors and disease burden

- Construct GLM (Poisson or negative binomial)
  - Exposure: average number of days above 95°F in previous days or weeks
  - Exposure: average number of days of extreme precipitation in previous days or weeks
    - 95th or 99th percentile of daily precipitation
  - Outcome: number of cases/deaths
  - Other variables: race, sex, age

- Lagged variables
  - Previous days or weeks have health impacts today

- Fourier harmonic terms
  - Sine and cosine functions of time that control for seasonality
Findings – Vulnerable Communities in Baltimore City

Incorporates percent of population that is aged 65+ years, African American race, living in poverty; and percent of land covered by vegetation and parks.

Data source: Baltimore Neighborhood Indicators Alliance (2015); 2017 Baltimore Neighborhood Health Profiles

Incorporates percent of population that is aged 65+ years, African American race; and median household income.

Data source: Baltimore Neighborhood Indicators Alliance (2015); 2017 Baltimore Neighborhood Health Profiles
Findings – Vulnerable Communities in Baltimore City

Incorporates percent of population that is male, aged 65+ years, living in poverty.

Incorporates land use (area covered by forests, urban parks and open space, cemeteries), percent of population that is aged 5-18 years; and median household income.

Data source: Baltimore Neighborhood Indicators Alliance (2015); 2017 Baltimore Neighborhood Health Profiles

Data source: Baltimore Neighborhood Indicators Alliance; 2017 Baltimore Neighborhood Health Profiles; Maryland Department of Planning Open GIS: Land Use Land Cover (2010)
Findings – Baltimore’s Projected Climate

Warmer with different precipitation patterns

◦ Fewer spikes in precipitation
◦ Steadier ongoing precipitation
  ◦ Greater overall volumes
## Findings – Salmonellosis in Baltimore City

<table>
<thead>
<tr>
<th>Parameter</th>
<th>IRR (95% CI)</th>
<th>P-value</th>
<th>Number of cases (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Precipitation (95th percentile)</td>
<td>1.10 (1.01-1.20)</td>
<td>0.021</td>
<td>-</td>
</tr>
<tr>
<td>Maximum Temperature &gt;= 95°F</td>
<td>1.04 (1.01-1.07)</td>
<td>0.008</td>
<td>-</td>
</tr>
<tr>
<td>Race</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>White (reference)</td>
<td>1.00</td>
<td></td>
<td>326 (19.1%)</td>
</tr>
<tr>
<td>Black or African American</td>
<td>4.06 (3.58-4.60)</td>
<td>&lt;0.000</td>
<td>1290 (75.5%)</td>
</tr>
<tr>
<td>Other</td>
<td>0.29 (0.23-0.36)</td>
<td>&lt;0.000</td>
<td>93 (5.4%)</td>
</tr>
<tr>
<td>Age</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt; 5 years (reference)</td>
<td>1.00</td>
<td></td>
<td>558 (32.7%)</td>
</tr>
<tr>
<td>5-&lt;18 years</td>
<td>0.45 (0.39-0.52)</td>
<td>&lt;0.000</td>
<td>250 (14.6%)</td>
</tr>
<tr>
<td>18-&lt;65 years</td>
<td>1.43 (1.27-1.61)</td>
<td>&lt;0.000</td>
<td>770 (45.1%)</td>
</tr>
<tr>
<td>65 years +</td>
<td>0.24 (0.20-0.29)</td>
<td>&lt;0.000</td>
<td></td>
</tr>
<tr>
<td>Sex</td>
<td>1.08 (0.98-1.20)</td>
<td>0.130</td>
<td>823 male (48.2%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>886 female (51.8%)</td>
</tr>
</tbody>
</table>

Parameters estimated by Fourier harmonic-adjusted negative binomial regression for salmonellosis cases

- 10% increase in cases associated with extreme precipitation (95th percentile or beyond)
- 4% increase in cases associated with temperatures above 95°F
- Demographic groups at risk
  - African American race
  - Children < 5 years
  - Adults 18 to 65 years
Findings – Campylobacteriosis in Baltimore City

- No significant association found between campylobacteriosis and precipitation
- 3% decrease in cases associated with temperatures above 95°F
- Demographic groups at risk
  - White race
  - Children < 5 years
  - Adults 18 to 65 years
  - Adults 65+

<table>
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<th>IRR (95% CI)</th>
<th>P-value</th>
<th>Number of cases (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Precipitation (99th percentile)</td>
<td>0.87 (0.62-1.22)</td>
<td>0.427</td>
<td>-</td>
</tr>
<tr>
<td>Maximum Temperature &gt;= 95°F Race</td>
<td>0.97 (0.95-0.99)</td>
<td>0.041</td>
<td>-</td>
</tr>
<tr>
<td>White (reference)</td>
<td>1.00</td>
<td></td>
<td>373 (58.5%)</td>
</tr>
<tr>
<td>Black or African American</td>
<td>0.56 (0.47-0.67)</td>
<td>&lt;0.000</td>
<td>207 (32.5%)</td>
</tr>
<tr>
<td>Other</td>
<td>0.16 (0.12-0.21)</td>
<td>&lt;0.000</td>
<td>58 (9.1%)</td>
</tr>
<tr>
<td>Age</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt; 5 years (reference)</td>
<td>1.00</td>
<td></td>
<td>52 (8.2%)</td>
</tr>
<tr>
<td>5-18 years</td>
<td>0.87 (0.57-1.32)</td>
<td>0.501</td>
<td>45 (7.1%)</td>
</tr>
<tr>
<td>18-65 years</td>
<td>8.94 (6.62-12.08)</td>
<td>&lt;0.000</td>
<td>465 (72.9%)</td>
</tr>
<tr>
<td>65 years +</td>
<td>1.44 (0.99-2.09)</td>
<td>0.053</td>
<td>76 (11.9%)</td>
</tr>
<tr>
<td>Sex</td>
<td>0.99 (0.84-1.17)</td>
<td>0.909</td>
<td>320 male (50.2%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>318 female (49.8%)</td>
</tr>
</tbody>
</table>

Parameters estimated by Fourier harmonic-adjusted Poisson regression for campylobacteriosis cases
Findings – Vibriosis in Baltimore City

- 9% increase in cases associated with extreme precipitation (99\textsuperscript{th} percentile or beyond)
- No significant relationship between temperature and vibriosis
- Demographic groups were not included due to very small numbers

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<tr>
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<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Precipitation (99\textsuperscript{th} percentile)</td>
<td>1.09 (1.02-1.16)</td>
<td>0.011</td>
</tr>
<tr>
<td>Maximum Temperature $\geq 95^\circ F$</td>
<td>1.18 (0.64-2.16)</td>
<td>0.582</td>
</tr>
</tbody>
</table>

\textbf{Table 3} Parameters estimated by Fourier harmonic-adjusted negative binomial regression for salmonellosis cases
Findings – Future Disease Burden of Foodborne Illness

Cases per year in the decade 2090-2099

- Low end of 95% confidence interval for less extreme climate scenario to high end of 95% CI for more extreme climate scenario
- Salmonellosis
  - 90.2-218.5 cases
  - 136.1 cases per year under historical conditions
- Campylobacteriosis
  - 26.3-118.5 cases
  - 51.5 cases per year under historical conditions
Findings – Future Disease Burden of Foodborne Illness

Cases per year in the decade 2090-2099

- Low end of 95% confidence interval for less extreme climate scenario to high end of 95% CI for more extreme climate scenario

- Vibriosis
  - 1.8-7.3 cases
  - 2.3 cases per year under historical conditions
Findings – Work in Progress

Analyzing relationship between meteorological factors and remaining conditions of interest
  ◦ Heat and cold morbidity and mortality; legionellosis; Lyme Disease

Projecting burden of disease under projected climate futures
Limitations and Challenges

Vulnerability factors
- Little data availability for some risk factors
- Not applicable for foodborne illnesses

Climate projection
- Incorporation of uncertainty
- 5 climate models for temperature, 3 for precipitation

Use of only temperature and precipitation

Infectious disease
- High degree of missingness for date of onset
  - Supplemented with other estimates of date
Lessons Learned

Climate modeling is a complex discipline

Categorization of climatic exposures must be done with care

Building redundancies into the plan is essential

- Availability and suitability of data may not match the theoretical ideal
Policy and Practice Implications

BRACE framework can be implemented in the context of Baltimore City
Climatic factors have relationship to human health outcomes
Vulnerability maps can be used in distributing resources and programs
Local-level estimates can be used to advocate for programs
  ◦ Code Red and Code Blue
Identifying, implementing, and assessing the impact of interventions
Acknowledgments

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References


Thank you!
Questions or comments?

Contact: Bailey Evenson, bevenso1@jhu.edu
Findings – Baltimore’s Projected Climate

Trends in Maximum Daily Temperature, 2020-2099

Maximum Daily Temperature (F)

Year

January February March April May June

July August September October November December

RCP 4.5
RCP 8.5
Historical Average
Findings – Baltimore’s Projected Climate
Climate Change Projections

“Mathematic models for quantitatively describing, simulating, and analyzing interactions between the atmosphere and ocean, land, and ice”

Representative Concentration Pathways (RCP)
- Standardized scenarios used in climate modeling
- Defined inputs, varying in severity

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Mean Temperature Increase (°C)</th>
<th>Mean Sea Level Rise (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>RCP 2.6</td>
<td>1.0</td>
<td>0.4</td>
</tr>
<tr>
<td>RCP 4.5</td>
<td>1.8</td>
<td>0.47</td>
</tr>
<tr>
<td>RCP 6.0</td>
<td>2.2</td>
<td>0.48</td>
</tr>
<tr>
<td>RCP 8.5</td>
<td>3.7</td>
<td>0.63</td>
</tr>
</tbody>
</table>