Examining the Exposure to Extreme Weather Events and Risk of Campylobacteriosis and Salmonellosis in Maryland, USA

Soneja S., Jiang CJ., Upperman C., Murtugudde R., Sapkota AR., Mitchell C., Sapkota A.

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Background

- Annually across the United States:
  - *Campylobacter* causes ~1 million cases of gastroenteritis
    - Functional gastrointestinal disorders
    - Inflammatory bowel disease
    - Celiac disease
    - Reactive arthritis
    - Guillain-Barre syndrome
  - *Salmonella* causes ~1.2 million cases of acute gastroenteritis, including 23,000 hospitalizations and 450 deaths
    - Enteric fever
    - Food poisoning

- Infection routes via tainted water or food
Relationship to Weather

- Increased risk of campylobacteriosis associated with:
  - Seasonality
  - Daily maximum temperatures
  - Mean weekly temperature
  - Precipitation

- Previous time-series studies have identified associations between average temperature and the number of reported cases of Salmonella infection
The Direction of Extreme Weather Events

Intergovernmental Panel on Climate Change (IPCC) has suggested that the intensity, frequency, and length of extreme weather events will continue to increase as a result of a changing climate (Field et al. 2012)
Our Focus

• Limited data exist on how specific enteric illnesses (e.g., campylobacteriosis and salmonellosis) may be influenced by the frequency of extreme weather events.

• Unclear if risk may disproportionately impact coastal communities already vulnerable due to flooding and sea-level rise.
Study Area: Maryland, USA
Case Data

- Maryland Foodborne Diseases Active Surveillance Network (FoodNet)
  - Jan to Dec from 2002 to 2012
  - Date of confirmed case, species, age, race, and gender

- *Campylobacter* (n=4,804)
- *Salmonella* (n=9,529)

- County level variables (2010 Population and Housing Summary Census)
  - Age
  - Gender
  - Race
  - Socioeconomic data (American Community Survey 2006-2010)
Focusing On The Exposure Metric
Background

• Differing methodologies for defining temperature
  • Linear
  • Non-linear (splines)
  • Threshold
  • Season

• Our exposure metric: **Extreme Heat and Precipitation Events**
  • Built using location and calendar day specific climatology
Defining Extreme Heat and Precipitation Events

- Baseline data from 1960-1989
  - Weather stations from National Climate Data Center
  - Averaged by county and day
  - Baseline values for each day based on 31-day window
Defining Extreme Heat and Precipitation Events

- From baseline data created distribution of maximum daily temperature and precipitation values for each county and day

- Utilizing the distribution of this data, thresholds were identified for each county and calendar day
  - 95th percentile ($ETT_{95}$) = Extreme Heat
  - 90th percentile ($EPT_{90}$) = Extreme Precipitation
Example: Extreme Heat (ETT\textsubscript{95}) values on July 1\textsuperscript{st} (Range: 30-36 °C)
Defining Extreme Heat and Precipitation Events

• Extreme Heat Events: dichotomous variable
  • 1: if Tmax for a given day $> \text{Extreme Heat (ETT}_{95}$
  • 0: Otherwise
  • Same for Extreme Precipitation Events (EPT}_{90}$

• By county and day we can ask ourselves?
  • Is Jan 1 2002 greater or less than Jan 1 threshold?
  • Is Jan 1 2003 greater or less than Jan 1 threshold?
  • Is Jan 1 2004 greater or less than Jan 1 threshold?
  • Etc…
Monthly Average of Extreme Events by County
Statistical Analysis

• Case and extreme weather events aggregated by month and county

• Negative Binomial Generalized Estimating Equations

• Models:
  • Overall - adjusted for age, gender, race, poverty %
  • Stratified models by:
    • Coastal vs. Noncoastal

• Sensitivity analyses
  • Different threshold to define extreme events (90th, 95th, 99th percentiles)
Risk of Campylobacteriosis

The graph illustrates the risk of Campylobacteriosis with 95% CI for coastal and noncoastal areas under different extreme weather types: Heat and Precipitation.
Risk of Salmonellosis
Discussion

• Due to its low-lying flat plain, the Eastern Shore is particularly vulnerable to flooding

• Extreme precipitation events may exacerbate potential water-related transmission pathways
  • Considerable percentage of the coastal population utilizes well water, which may become contaminated
  • Close proximity to water bodies in the coastal areas may mean increased frequency of exposure to contaminated water during recreation
Strengths and Limitations

Strengths

• Relative temperature and precipitation threshold used
  • Reflected the variability in extreme heat/precipitation to each calendar day and county
• Health outcome data encapsulated a lengthy period (2002 to 2012) that encompassed substantial variability for the exposure and health outcome measures

Limitations

• No examination of intensity or duration of extreme weather
• No information on occupational status or specific outbreaks
• Small study area (24 counties in Maryland), with potential for coastal areas to be different than other U.S. coastal regions
  • Presence of concentrated animal feeding operations
  • Substantial portion of the population that uses well water
Conclusion

- Study provides empirical evidence for the association between frequency of extreme **heat** and **precipitation** events and risk of campylobacteriosis/salmonellosis

- Adaptation strategies need to account for the coastal vs. noncoastal differential burden, particularly in light of ever increasing coastal populations

- Future studies with data from multiple states are needed to further evaluate coastal/noncoastal area differences
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Thank you!

Sut Soneja
ssoneja@umd.edu
Demographic Characteristics: *Campylobacter*

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Coastal No. (%)</th>
<th>Noncoastal No. (%)</th>
<th>All No. (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total</strong></td>
<td>2,911 (61%)</td>
<td>1,893 (39%)</td>
<td>4,804 (100%)</td>
</tr>
<tr>
<td><strong>Gender</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>1,555 (53)</td>
<td>1,025 (54)</td>
<td>2,580 (54)</td>
</tr>
<tr>
<td>Female</td>
<td>1,352 (47)</td>
<td>861 (46)</td>
<td>2,213 (46)</td>
</tr>
<tr>
<td>Unknown</td>
<td>4 (0.1)</td>
<td>7 (0.3)</td>
<td>11 (0.2)</td>
</tr>
<tr>
<td><strong>Age (years) [median (interquartile range)]</strong></td>
<td>39 (21-54)</td>
<td>36 (18-53)</td>
<td>38 (20-53)</td>
</tr>
<tr>
<td><strong>Age Group</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;5</td>
<td>308 (11)</td>
<td>205 (11)</td>
<td>513 (11)</td>
</tr>
<tr>
<td>5-17</td>
<td>309 (11)</td>
<td>260 (14)</td>
<td>569 (12)</td>
</tr>
<tr>
<td>18-64</td>
<td>1,953 (67)</td>
<td>1,231 (65)</td>
<td>3,184 (66)</td>
</tr>
<tr>
<td>≥65</td>
<td>334 (12)</td>
<td>188 (10)</td>
<td>522 (11)</td>
</tr>
<tr>
<td>Unknown</td>
<td>7 (0.2)</td>
<td>9 (0.5)</td>
<td>16 (0.3)</td>
</tr>
<tr>
<td><strong>Race/Ethnicity</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-Hispanic White</td>
<td>1,719 (59)</td>
<td>707 (37)</td>
<td>2,426 (51)</td>
</tr>
<tr>
<td>Non-Hispanic Black</td>
<td>371 (13)</td>
<td>36 (2)</td>
<td>407 (9)</td>
</tr>
<tr>
<td>Hispanic</td>
<td>147 (5)</td>
<td>76 (4)</td>
<td>223 (5)</td>
</tr>
<tr>
<td>Other</td>
<td>86 (3)</td>
<td>57 (3)</td>
<td>143 (3)</td>
</tr>
<tr>
<td>Unknown</td>
<td>588 (20)</td>
<td>1017 (54)</td>
<td>1605 (33)</td>
</tr>
<tr>
<td><strong>Season</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Winter</td>
<td>454 (16)</td>
<td>318 (17)</td>
<td>772 (16)</td>
</tr>
<tr>
<td>Spring</td>
<td>569 (20)</td>
<td>382 (20)</td>
<td>951 (20)</td>
</tr>
<tr>
<td>Summer</td>
<td>1,168 (40)</td>
<td>800 (42)</td>
<td>1,968 (41)</td>
</tr>
<tr>
<td>Autumn</td>
<td>720 (25)</td>
<td>393 (21)</td>
<td>1,113 (23)</td>
</tr>
</tbody>
</table>
## Demographic Characteristics: *Salmonella*

### Table 1.
Characteristics of reported Salmonellosis cases: Maryland, 2002 to 2012.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th># Cases</th>
<th>% of Cases</th>
<th>Composition of MD population (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Age</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt; 5</td>
<td>2380</td>
<td>25</td>
<td>6.3</td>
</tr>
<tr>
<td>5 to 17</td>
<td>1661</td>
<td>17.4</td>
<td>17</td>
</tr>
<tr>
<td>18 to 64</td>
<td>4462</td>
<td>46.8</td>
<td>64.3</td>
</tr>
<tr>
<td>65 and over</td>
<td>979</td>
<td>10.3</td>
<td>12.4</td>
</tr>
<tr>
<td>Unreported</td>
<td>47</td>
<td>0.5</td>
<td>NA</td>
</tr>
<tr>
<td><strong>Gender</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>5023</td>
<td>52.7</td>
<td>50.9</td>
</tr>
<tr>
<td>Male</td>
<td>4475</td>
<td>47</td>
<td>49.1</td>
</tr>
<tr>
<td>Unreported</td>
<td>31</td>
<td>0.3</td>
<td>NA</td>
</tr>
<tr>
<td><strong>Race</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-Hispanic White</td>
<td>3755</td>
<td>39.4</td>
<td>54.7</td>
</tr>
<tr>
<td>Non-Hispanic Blacks</td>
<td>2509</td>
<td>26.3</td>
<td>29</td>
</tr>
<tr>
<td>Hispanic</td>
<td>515</td>
<td>5.4</td>
<td>8.2</td>
</tr>
<tr>
<td>Other races</td>
<td>293</td>
<td>3.1</td>
<td>8.2</td>
</tr>
<tr>
<td>Unreported</td>
<td>2457</td>
<td>25.8</td>
<td>NA</td>
</tr>
</tbody>
</table>
Campylobacteriosis Crude Incidence Rate

![Graph showing the crude incidence rate of Campylobacteriosis from 2002 to 2012, comparing noncoastal and coastal regions. The graph indicates a significant increase in incidence rates over the years, particularly for the noncoastal region.]
Results

- We observed that a one day increase in exposure to extreme precipitation event was associated with a 3% increase in the risk of campylobacteriosis in coastal areas of Maryland but such an association was not observed in noncoastal areas.
Results summary salmonella

- We observed a 4.1% increase in salmonellosis risk associated with a 1 unit increase in extreme temperature events (incidence rate ratio (IRR):1.041; 95% confidence interval (CI):1.013–1.069). This increase in risk was more pronounced in coastal versus non-coastal areas (5.1% vs 1.5%). Likewise, we observed a 5.6% increase in salmonellosis risk (IRR:1.056; CI:1.035–1.078) associated with a 1 unit increase in extreme precipitation events, with the impact disproportionately felt in coastal areas (7.1% vs 3.6%).
Risk of campylobacteriosis due to extreme heat/precipitation events
Risk of salmonellosis due to extreme heat/precipitation events