Fecal Indicator Bacteria Dynamics in Bogue Sound, NC

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Fecal Indicator Bacteria

- Bacteria used to monitor recreational waters for fecal contamination
  - Non-pathogenic
  - Serve as proxies for the presence of pathogens
- High concentrations associated with GI illness and risk
- WHO and USEPA approved indicators for aquatic environments
- If above set standards, public notified
Fecal Indicator Bacteria

**Escherichia coli (EC)**
- Salt sensitive
- 320 MPN/100mL marine water

**Enterococci (ENT)**
- Not salt sensitive
- Preferred indicator for marine systems
- 104 MPN/100mL marine water
Bogue Banks, NC

Carteret County, NC population

- + 95% from 1970 to 2003
- + 13% since 1990
- Atlantic Beach +89.3% from 1980 to 2000
- Pine Knoll Shores +135.9% from 1980 to 2000
- Indian Beach +75.9% from 1980 to 2000
Contributing Factors to Adverse Water Quality

* Impervious Surface Coverage
* FIB linked to increased population and urban land use (Mallin et al., 2000)
* High number of septic systems
* Shallow groundwater table
* Prone to extreme storm events

1958 photograph courtesy of Tony Rodriguez, PhD
Changing Climate

- Longer duration of non-precipitation events
- More frequent, high intensity precipitation events
- Increased flooding from large storms

U.S. Drought Monitor
Southeast

http://droughtmonitor.unl.edu
Objectives

1. Quantify fecal indicator bacteria concentrations in waters of Atlantic Beach, NC

2. Determine precipitation impacts on fecal indicator bacteria concentrations
Sample Site Locations
## Sample Site Locations

<table>
<thead>
<tr>
<th>Site</th>
<th>Site ID</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pine Knoll Shores marina</td>
<td>1</td>
</tr>
<tr>
<td>Mimosa Bridge, Pine Knoll Shores</td>
<td>2</td>
</tr>
<tr>
<td>Pine Knoll Shores Park Access</td>
<td>3</td>
</tr>
<tr>
<td>Head of Hoop Hole Creek /Lee Road</td>
<td>4</td>
</tr>
<tr>
<td>Croatan Mobile Homes</td>
<td>5</td>
</tr>
<tr>
<td>Bogue Shores Motel</td>
<td>6</td>
</tr>
<tr>
<td>Atlantic Station Shopping Center stormwater basin</td>
<td>7</td>
</tr>
</tbody>
</table>
Field Sampling

- 13 sample dates (n=86)
- 10 Dry dates
- 3 Wet dates (>6mm)

- Environmental parameters
  - Temperature (°C)
  - Turbidity (NTU)
  - Salinity (ppt)
Fecal Indicator Bacterial Enumeration

- IDEXX – defined substrate technology
- Colielt-18 (EC) and Enterolert (ENT)
- Color change = growth of target bacteria on specific substrate
Statistical Analysis

- SPSS version 20.0 statistical analysis software (Chicago, IL)
- One-way ANOVA
  - Bonferroni Post Hoc
- Independent t-test
- Spearman Rank Correlation
- FIB MPN values log transformed
  - Reduced skewness
Results

Site ID
1 2 3 4 5 6 7

E. coli concentration (Log MPN/100 ml)

E. coli

Site ID
1 2 3 4 5 6 7
Results

[Graph showing the Enterococci concentration (Log MPN/100 ml) across different site IDs (1 to 7). The x-axis represents Site ID, and the y-axis represents Enterococci concentration (Log MPN/100 ml). The graph includes a red horizontal line indicating a threshold.]
Freshwater Sites

Site 4: Headstream to Hoop Hole creek

Site 7: Stormwater basin, Atlantic Station Shopping Center
Wet and Dry not significantly different for both EC ($p=0.565$) and ENT ($p=0.103$)

- Shallow and secluded from high winds
- Freshwater inputs are a single factor
Salt Water Sites

Site 1: PKS Marina
Site 2: Mimosa Bridge
Site 3: PKS park
Site 5: Croatan Mobile Homes
Site 6: Bogue Shores Motel
Wet and Dry significantly different for both EC ($p=0.032$) and ENT ($p=0.008$)

* Wet events significantly stronger winds

* Wind speed positively correlated to EC and ENT
Sampling dates

Concentration (Log MPN/100 ml)
0 1 2 3 4 5

Precipitation (mm)
0 10 20 30 40

E. coli
Enterococci
Precipitation (24 hour)
Enterococci (Log$_{10}$ MPN 100 ml$^{-1}$)

$E. coli$ (Log$_{10}$ MPN 100 ml$^{-1}$)

Dry Regression

Wet Regression

$r^2 = 0.065$

$r^2 = 0.040$
Conclusions

* Objective 1: Determine FIB concentrations in Atlantic Beach, NC

  * EC geometric mean of 2.01 Log MPN/100mL across all dates and sites
  * ENT geometric mean of 1.56 Log MPN/100mL across all dates and sites
  * Total number of excedances equaled 31 for EC; 20 for ENT
    * Sites 3 and 5 had most EC excedances
    * Site 4 had the most ENT excedances followed by site 5
Objective 2: Determine precipitation’s affect on FIB community

- Precipitation has minimal impact on EC concentrations
- Potential inputs from septic systems, sediment, and waterfowl
- Reservoir population of EC

- ENT levels significantly higher following Hurricane Sandy
- Correlation between ENT and wind speed (resuspension)
- 6mm rainfall threshold not enough to impact ENT and EC concentrations
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