Calculating and Mapping Stream Biological Health

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Ideal Scenario

• One sampling design across all jurisdictions
  • Samples collected using the same protocol
  • Samples randomly distributed across the basin
  • Clearly defined sampling periods for trend analysis
National River and Stream Assessment (NRSA)

NRSA vs. Chessie BIBI

n = 108

n = 2809
Ideal Scenario

- One sampling design across all jurisdictions
  - Samples collected using the same protocol
  - Samples randomly distributed across the basin
  - Clearly defined sampling periods for trend analysis

Can we work backwards?
Issues to Keep in Mind

• How to equate a Chessie BIBI rating to stream miles
  • One sampling event equals X amount of miles?
  • Aggregate by a spatial unit (e.g., HUC 12) and use sampling events within a spatial unit cell to represent all stream miles within that spatial unit cell?

• Spatial and Temporal Influence
  • Sampling density and frequency (Sampling Rounds)
  • The amalgamation of two or more random sampling designs does NOT equate to a single random sampling design
  • Stream access, generally, leads to a larger proportion of streams sampled in urban areas
    • 2000-2008 vs. 2004-2008 baseline periods (Other Suggestions?)

• Index Resolution
  • Region indices vs. Bioregion indices
Six Methods

1. No Spatial Aggregation
2. Watershed Mean Score
3. Ratings Weighted by Stream Mile
4. Random Sample
5. Bootstrap
6. Random Forest
1) No Spatial Aggregation

Process

1. The proportion of Acceptable, Fair, and Degraded sampling events found in the basin
1) No Spatial Aggregation
1) No Spatial Aggregation

![Graph showing individual sample ratings for different regions and bioregions from 2000 to 2008. The graph indicates percentages for each category: Acceptable, Fair, Degraded, and Insufficient. The percentages are as follows:

- Region_2004_2008: 29% Acceptable, 14% Fair, 56% Degraded
- Region_2000_2008: 29% Acceptable, 15% Fair, 56% Degraded
- Bioregion_2004_2008: 29% Acceptable, 15% Fair, 55% Degraded
- Bioregion_2000_2008: 29% Acceptable, 16% Fair, 55% Degraded]
1) No Spatial Aggregation

**Pros**
- Simplest approach ([CBP Method](#))

**Cons**
- Spatial bias
  - Frequency and density of samples
- How to convert to stream mile units?
  - Should each point represent one stream mile?
  - Should stream order influence the number of stream miles represented by a point?
  - If the data is mapped, should the representative stream miles be drawn above the sampling point or be split by the sampling point?
1) No Spatial Aggregation
1) No Spatial Aggregation
Stream Segments
2) Watershed Mean Score

**Process**

1) Chessie BIBI results are aggregated by a spatial unit (HUC8, HUC10, HUC12, or Catchment)
   - Any spatial unit cells without the appropriate number samples are classified as "Insufficient"
2) The number of stream miles is found for each spatial unit cell
3) The number of stream miles in a spatial unit cell is divided by the number of Chessie BIBI samples reported in the cell
4) Chessie BIBI ratings are weighted by the divided number of stream miles in a spatial unit cell
5) Stream miles are summed by Acceptable, Fair, Degraded, and Insufficient at the Chesapeake Bay basin level
2) Watershed Mean Score

Stream Miles: 100

\[
30 = \frac{80 + 30 + 5 + 5}{4}
\]

100 Degraded Stream Miles
2) Watershed Mean Score

**Pros**
- Simple calculation
- Can be mapped

**Cons**
- Differing sample weights
- Altered ratings
  - Large spatial units tend to be classified as "Fair"
2) Watershed Mean Score

Stream Miles: 100

\[ 50 = \frac{100 + 100 + 0 + 0}{4} \]

100 Fair Stream Miles
2) Watershed Mean Score
2) Watershed Mean Score
3) Proportional Watershed Rating

Process

1) Chessie BIBI results are aggregated by a spatial unit (HUC8, HUC10, HUC12, or catchment)
   - Any spatial unit cells without the appropriate number samples are classified as "Insufficient"

2) Find the number of stream miles represented in each spatial unit cell

3) Divide the number of stream miles in a spatial unit cell by the number of Chessie BIBI samples reported in the cell

4) Use the divided stream miles as a weighting factor for each Chessie BIBI sample rating

5) Summarize the proportion of stream miles representing Acceptable, Fair, Degraded, and Insufficient at the Chesapeake Bay basin level
3) Proportional Watershed Rating

Stream Miles: 100

- 25 Acceptable Stream Miles
- 25 Degraded Stream Miles
- 25 Degraded Stream Miles
- 25 Degraded Stream Miles
3) Proportional Watershed Rating

**Pros**
- Reduces spatial bias
- Representative of original rating

**Cons**
- Differing sample weights
  - Reduces the weight of samples in densely sampled areas
  - Increases the weight of samples in sparsely sampled areas
- Cannot be mapped (assigned weights are arbitrary spatial units)
3) Proportional Watershed Rating

Stream Miles: 100

- 25 Acceptable Stream Miles
- 25 Degraded Stream Miles
- 25 Degraded Stream Miles
- 25 Degraded Stream Miles

100 Acceptable Stream Miles
3) Proportional Watershed Rating

![Proportional Watershed Rating chart]

- **HUC8**
  - Region_2004_2008: 37% Acceptable, 17% Fair, 44% Degraded, 46% Insufficient
  - Region_2000_2008: 36% Acceptable, 17% Fair, 46% Degraded, 41% Insufficient
  - Bioregion_2004_2008: 40% Acceptable, 17% Fair, 41% Degraded, 45% Insufficient
  - Bioregion_2000_2008: 38% Acceptable, 16% Fair, 45% Degraded, 41% Insufficient

- **HUC10**
  - Region_2004_2008: 31% Acceptable, 16% Fair, 40% Degraded, 13% Insufficient
  - Region_2000_2008: 34% Acceptable, 17% Fair, 44% Degraded, 13% Insufficient
  - Bioregion_2004_2008: 34% Acceptable, 17% Fair, 36% Degraded, 13% Insufficient
  - Bioregion_2000_2008: 35% Acceptable, 17% Fair, 43% Degraded, 5% Insufficient

- **HUC12**
  - Region_2004_2008: 19% Acceptable, 10% Fair, 27% Degraded, 43% Insufficient
  - Region_2000_2008: 25% Acceptable, 13% Fair, 33% Degraded, 29% Insufficient
  - Bioregion_2004_2008: 21% Acceptable, 10% Fair, 25% Degraded, 44% Insufficient
  - Bioregion_2000_2008: 26% Acceptable, 13% Fair, 32% Degraded, 30% Insufficient

- **Catchment**
  - Region_2004_2008: 91% Acceptable, 0% Fair, 0% Degraded, 0% Insufficient
  - Region_2000_2008: 87% Acceptable, 0% Fair, 0% Degraded, 0% Insufficient
  - Bioregion_2004_2008: 91% Acceptable, 0% Fair, 0% Degraded, 0% Insufficient
  - Bioregion_2000_2008: 87% Acceptable, 0% Fair, 0% Degraded, 0% Insufficient
3) Proportional Watershed Rating

Proportional Watershed Rating (Insufficient Excluded)

<table>
<thead>
<tr>
<th>Index Type and Period</th>
<th>HUC8</th>
<th>HUC10</th>
<th>HUC12</th>
<th>Catchment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Region_2004_2008</td>
<td>37%</td>
<td>35%</td>
<td>34%</td>
<td>31%</td>
</tr>
<tr>
<td>Region_2000_2008</td>
<td>37%</td>
<td>35%</td>
<td>35%</td>
<td>31%</td>
</tr>
<tr>
<td>Bioregion_2004_2008</td>
<td>41%</td>
<td>39%</td>
<td>37%</td>
<td>32%</td>
</tr>
<tr>
<td>Bioregion_2000_2008</td>
<td>38%</td>
<td>37%</td>
<td>37%</td>
<td>32%</td>
</tr>
</tbody>
</table>

Rating: 
- Acceptable
- Fair
- Degraded
4) Random Sample

Process

1) Chessie BIBI results are aggregated by a spatial unit (HUC8, HUC10, HUC12, or catchment)
   - Any spatial unit cells without the appropriate number samples are classified as "Insufficient"

2) A random sample with replacement of spatial units

3) Find the number of stream miles represented in each spatial unit cell

4) The spatial unit cell rating is weighted by the number of stream miles

5) Summarize the proportion of stream miles representing Acceptable, Fair, Degraded, and Insufficient at the Chesapeake Bay basin level
4) Random Sample

Stream Miles: 100

\[
\frac{3}{4} \text{ probability that Degraded selected}
\]

100 Degraded Stream Miles
4) Random Sample

**Pros**
- Each spatial unit has an equal probability of being selected
- Can be mapped

**Cons**
- Differing sample weights
  - Reduces the weight of samples in densely sampled areas
  - Increases the weight of samples in sparsely sampled areas
- Represented samples (Non-Insufficient)
4) Random Sample

Stream Miles: 100

$\frac{1}{4}$ probability that Degraded selected

100 Degraded Stream Miles
4) Random Sample

![Random Sample Graph](image_url)
4) Random Sample
5) Bootstrap

**Process**

1) Chessie BIBI results are aggregated by a spatial unit (HUC8, HUC10, HUC12, or catchment)
   - Any spatial unit cells without the appropriate number samples are classified as "Insufficient"
2) Iteratively perform a random sample with replacement of spatial units
3) Find the number of stream miles represented in each spatial unit cell
4) For each iteration, spatial unit cell rating is weighted by the number of stream miles
5) For each iteration, summarize the proportion of stream miles representing Acceptable, Fair, Degraded, and Insufficient at the Chesapeake Bay basin level
6) Find the mean and standard deviation of the proportion of stream miles representing Acceptable, Fair, Degraded, and Insufficient at the Chesapeake Bay basin level for all iterations
5) Bootstrap

Acceptable Stream Miles ± SD

Degraded Stream Miles ± SD

x100,000
5) Bootstrap

Pros

• Each spatial unit has an equal probability of being selected
• Measure of variation around stream condition

Cons

• Differing sample weights
  • Reduces the weight of samples in densely sampled areas
  • Increases the weight of samples in sparsely sampled areas
5) Bootstrap

Reality

<table>
<thead>
<tr>
<th></th>
<th>Acceptable</th>
<th>Fair</th>
<th>Degraded</th>
</tr>
</thead>
<tbody>
<tr>
<td>40%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>40%</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Time Period 1

<table>
<thead>
<tr>
<th></th>
<th>Acceptable</th>
<th>Fair</th>
<th>Degraded</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>33.3%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>66.7%</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Time Period 2

<table>
<thead>
<tr>
<th></th>
<th>Acceptable</th>
<th>Fair</th>
<th>Degraded</th>
</tr>
</thead>
<tbody>
<tr>
<td>66.7%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>33.3%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.0%</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
5) Bootstrap
5) Bootstrap
5) Bootstrap
5) Bootstrap
6) Random Forest
Trend Analysis
Trend Analysis

• None of the proposed methods completely eliminate spatial bias

• Spatial bias is not constant across time periods
Trend Analysis: Methods 1-5

Individual Sample Ratings

<table>
<thead>
<tr>
<th>Bioregion Type and Period</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bioregion_1994_1998</td>
<td>Acceptable 29%</td>
</tr>
<tr>
<td>Bioregion_1999_2003</td>
<td>Acceptable 29%</td>
</tr>
<tr>
<td>Bioregion_2004_2008</td>
<td>Acceptable 29%</td>
</tr>
<tr>
<td>Bioregion_2009_2013</td>
<td>Acceptable 44%</td>
</tr>
</tbody>
</table>

Mean Rating (Insufficient Excluded)

<table>
<thead>
<tr>
<th>Bioregion Type and Period</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bioregion_1994_1998</td>
<td>Acceptable 28%</td>
</tr>
<tr>
<td>Bioregion_1999_2003</td>
<td>Acceptable 27%</td>
</tr>
<tr>
<td>Bioregion_2004_2008</td>
<td>Acceptable 32%</td>
</tr>
<tr>
<td>Bioregion_2009_2013</td>
<td>Acceptable 49%</td>
</tr>
</tbody>
</table>

Weighted by Stream Mile (Insufficient Excluded)

<table>
<thead>
<tr>
<th>Bioregion Type and Period</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bioregion_1994_1998</td>
<td>Acceptable 30%</td>
</tr>
<tr>
<td>Bioregion_1999_2003</td>
<td>Acceptable 34%</td>
</tr>
<tr>
<td>Bioregion_2004_2008</td>
<td>Acceptable 37%</td>
</tr>
<tr>
<td>Bioregion_2009_2013</td>
<td>Acceptable 48%</td>
</tr>
</tbody>
</table>

Random Sample (Insufficient Excluded)

<table>
<thead>
<tr>
<th>Bioregion Type and Period</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bioregion_1994_1998</td>
<td>Acceptable 36%</td>
</tr>
<tr>
<td>Bioregion_1999_2003</td>
<td>Acceptable 31%</td>
</tr>
<tr>
<td>Bioregion_2004_2008</td>
<td>Acceptable 45%</td>
</tr>
<tr>
<td>Bioregion_2009_2013</td>
<td>Acceptable 25%</td>
</tr>
</tbody>
</table>

Bootstrap (Insufficient Excluded)

<table>
<thead>
<tr>
<th>Bioregion Type and Period</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bioregion_1994_1998</td>
<td>Acceptable 31%</td>
</tr>
<tr>
<td>Bioregion_1999_2003</td>
<td>Acceptable 34%</td>
</tr>
<tr>
<td>Bioregion_2004_2008</td>
<td>Acceptable 37%</td>
</tr>
<tr>
<td>Bioregion_2009_2013</td>
<td>Acceptable 47%</td>
</tr>
</tbody>
</table>
Trend Analysis: Methods 1-5

**Individual Sample Ratings**
- Percentage of Streams (%)
- Rating: Acceptable, Fair, Degraded

**Mean Rating (Insufficient Excluded)**
- Percentage of Streams (%)
- Rating: Acceptable, Fair, Degraded

**Proportional Watershed Rating (Insufficient Excluded)**
- Percentage of Streams (%)
- Rating: Acceptable, Fair, Degraded

**Random Sample (Insufficient Excluded)**
- Percentage of Streams (%)
- Rating: Acceptable, Fair, Degraded

**Bootstrap (Insufficient Excluded)**
- Percentage of Streams (%)
- Rating: Acceptable, Fair, Degraded
Looks good, right?
Wrong

(Maybe)
Spatial and Temporal Bias
Spatial and Temporal Bias

![Bar Charts for BLUE, CA, LNP, MAC, NAPU, NCA, NRV, PIED, SEP, SGV, SRV, UNP]
Spatial and Temporal Bias

![Spatial and Temporal Bias Graph](image-url)
Spatial and Temporal Bias
Spatial and Temporal Bias
Spatial and Temporal Bias
Trend Analysis

Reality

- 40% Acceptable
- 20% Fair
- 40% Degraded

Random Sample

- 43% Acceptable
- 14% Fair
- 43% Degraded
Trend Analysis

Reality

40% Acceptable
20% Fair
40% Degraded

Bootstrap Sample

42.9% ± 3.5% Acceptable
16.2% ± 2.2% Fair
42.9% ± 3.5% Degraded
Trend Analysis

Time Period 1

- 66.7% Degraded
- 33.3% Fair
- 0.0% Acceptable

Time Period 2

- 66.7% Acceptable
- 33.3% Fair
- 0.0% Degraded
Trend Analysis

Time Period 1

- 0.0% Acceptable
- 33.3% Fair
- 66.7% Degraded

Time Period 2

- 66.7% Acceptable
- 33.3% Fair
- 0.0% Degraded
Trend Analysis

Time Period 1

- 0.0% Acceptable
- 20% Fair
- 40% Degraded
- 40% Insufficient

Time Period 2

- 40% Acceptable
- 20% Fair
- 0% Degraded
- 40% Insufficient
Conclusions and Recommendations

• Spatial and temporal discrepancies make it difficult to evaluate trends
• None of the proposed methods
• Recommended next steps:
  1. Blocking design
  2. Spatial autocorrelation reduction
  3. Modeling
    ▪ Random Forest Model
    ▪ Spatial Stream Network (SSN) Model
Questions or Comment?