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Application of the Probability-based Maryland Biological Stream Survey to the State’s Water Quality Standards Program

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Outline

- Needs of WQS program
- Need to assess all streams
- Need for detailed information
- DNR and MDE partnership
- Evolving MBSS design
Needs of WQS Program

• Clean Water Act presents a daunting task for states
  – CWA 305b requires comprehensive inventory
  – CWA 303d requires listing of all impaired waters
  – TMDLs require identification of stressors for all impaired waters
  ➢ All streams must be assessed
  ➢ Assessment must fit the scale of restoration
Traditional Biomonitoring Programs

- Historically states have monitored stream sites that are selected on an “ad hoc” basis, i.e., where
  - Problems are expected
  - Ease of access
    - Belief that sampling more sites will meet CWA
- Intensive sampling effort is focused at the site level
  - To insure all taxa are captured
  - To increase precision
    - Belief that more sampling effort at site will meet CWA
Ad Hoc Sampling

• Long history of ad hoc sampling perpetuates the belief that the condition of streams in an area (e.g., watershed or state) can be assessed if enough sites are sampled

• How much stream length can really be assessed directly?

• Example: How much of Maryland can be assessed directly?
Ad Hoc Sampling

• Over five years, MBSS can directly sample 1,500 75-m sites or 112 km (70 miles) of streams statewide.

• If sampled ad hoc, only 0.76 % of Maryland’s 14,811 stream km (9,203 stream miles) would be assessed.
Ad Hoc Sampling

• Can we say anything about the other 99% of streams?

• Can we assume that sampling a 75-m segment is representative of a longer length of stream or even an entire watershed?

• *To answer:* How variable are IBI scores with scale?
Scale Variability

- Evaluated variability of MBSS IBIs at scales ranging from
  - same site on same day
  - within 0.5 km within same index period
  - within 1.0 km
  - within same reach (average of 2.2 km)
  - same 12-digit watershed (average of 14 km)
  - same 8-digit watershed (average of 111 km)
Benthic IBI Variability with Scale

Scale Variability
Fish IBI Variability with Scale

Scale Variability
# IBI Variability with Scale

## B-IBI

<table>
<thead>
<tr>
<th></th>
<th>Mean CV</th>
<th>N</th>
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<tbody>
<tr>
<td>Site</td>
<td>0.039</td>
<td>66</td>
</tr>
<tr>
<td>0.5 km</td>
<td>0.115</td>
<td>51</td>
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<tr>
<td>1.0 km</td>
<td>0.094</td>
<td>80</td>
</tr>
<tr>
<td>Reach</td>
<td>0.110</td>
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<td>12-digit</td>
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<td>526</td>
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<tr>
<td>8-digit</td>
<td>0.282</td>
<td>133</td>
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## F-IBI

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<tbody>
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<tr>
<td>0.5 km</td>
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<td>45</td>
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<tr>
<td>1.0 km</td>
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<tr>
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<tr>
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<td>486</td>
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<tr>
<td>8-digit</td>
<td>0.417</td>
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</table>
Ad Hoc Sampling

• Assume that 75-m sites are representative of 2.2 km reaches (based on CV =10%)

• 1,500 MBSS sites can assess 3,300 km (2,050 miles) of streams statewide
  – i.e., 22% of Maryland’s 14,811 stream km (9,203 stream miles)
  ➢ Ad hoc sampling will still leave 78% of stream km unassessed
Ad Hoc Sampling

- Maryland is a small state with a robust program, but using ad hoc sampling
  - Only 1 to 22% of a state’s stream lengths can be assessed
- Condition of all streams in an area (e.g., watershed or state) cannot be assessed simply by sampling more ad hoc sites
  - This is Lesson #1
  - Need to implement a probability-based survey for to infer condition (e.g., means and confidence intervals) at “reaches” not sampled
Intensive Site Sampling

• Recent research has focused on improving assessment of streams at the site level
  – Replicate samples at each site
  – Fixed-count sampling, minimum subsample sizes, and levels of taxonomic identification

• Will increased effort at individual sites provide better assessments of all streams?
Sampling Effort

• We evaluated 73 MBSS sites where two benthic samples of 100 organisms were collected as replicates to provide a surrogate 200-organism subsample
  – How many additional taxa were collected in the second sample?
  – What increase in precision of IBI was obtained with a replicate sample?
Overlap of Taxa By Replicate

Proportion of Total Organisms Observed

Frequency

0.4 0.5 0.6 0.7 0.8 0.9

0 5 10 15

Overlaying Bar Chart and Circles

Intensive Site Sampling
Subsample Effort

• What are the gains from 200-organism subsample at all sites
  – in IBI precision
  – proportion of taxa captured?

• Assuming 25% greater laboratory effort for 200- vs. 100-organism subsample, what is the cost benefit?
Subsample Effort for Fixed Number of Sites (73)

IBI

Number of Organisms Sorted

Number of Taxa

Field and Lab Cost

RSE (%)

Subsample Size

Number of Organisms

Number of Taxa

Cost (dollars)

Subsample Size

Subsample Size

Subsample Size

Subsample Size
Subsample Effort at Fixed Cost

IBI

Number of Organisms Sorted

RSE (%)

Number of Taxa

Field and Lab Cost

Subsample Size

Number of Organisms

Subsample Size

Cost (dollars)

Subsample Size

Intensive Site Sampling
Subsample Effort

• For fixed number of sites, using 200 organisms rather than 100 results in
  – 3% increase in IBI precision
  – 16% more taxa

• For fixed field and lab cost, using 200 organisms requires that 15% fewer sites be sampled, resulting in
  – 3% decrease in IBI precision
  – 1% more taxa

Intensive Site Sampling
Subsample Effort

- Additional sampling effort at individual sites provides
  - No improvement in IBI precision
  - Some more taxa (but not per cost)

- Increased effort at individual sites does **not** provide better assessments of all streams
  - This is Lesson #2
  - Sampling effort should be allocated to meet assessment objectives at desired scale
Lessons

• Ad hoc sampling cannot assess all streams
  • “The Elephant in the Room”
    ➢ Probability-based sampling is needed to infer condition

• Intensive site sampling does not increase the assessment of all streams
  • “Gilding the Lilly”
    ➢ Sampling effort should be allocated according to desired scale
DNR and MDE Partnership

- Used MBSS data to develop biocriteria to support WQS
- Applied the lessons of probability-based sampling to assess all waters for 305b and 303d
- Used MBSS data to develop a method for identifying watersheds impaired by
  - Flow or sediment
  - Energy sources
  - Inorganic pollutants
- Augmenting core MBSS with sampling to get more detail for TALUs and TMDLs
MBSS Design

- Maryland can sample about 200 core monitoring sites per year
- Random sampling can give robust estimate with 10 sites in a watershed
- MD 8-digit watersheds (with smaller watersheds combined) equals 84 PSUs
- 84 PSUs x 10+ sites = about 1,000 sites
- Maryland can sample statewide at 8-digit scale (average of 111 km) every 5 years
Biocriteria Status by Watershed

- Pass
- Inconclusive
- Fail

DNR and MDE
Likely Stressors in Failing Watersheds

- Watersheds with failing biocriteria score
- High inorganic pollutants
- High energy source
- High flow or sediment
- Watersheds with passing or inconclusive scores
MBSS Design

- MBSS will conduct “biocriteria” round every 10 years, i.e., 2000-2004 and then 2010-2014
- All streams will be included in probability design with some partial replacement to improve trends detection
- Intervening MBSS rounds will address WQS needs for
  - 303d listings on finer scale
  - TALU designations for high-quality waters (Tier II)
  - Additional identification of stressors
MBSS Design

• In 2007, MBSS is sampling
  – Additional random sites in watersheds with less than 10 sites or indeterminate condition
  – Sites in adjacent reaches to known high-quality waters using adaptive approach

• As needed, MDE will sample watersheds to identify stressors not found with method employing MBSS data
Conclusion

• DNR and MDE partnership is using probability-based MBSS as an effective tool to meet the needs of Maryland water quality standards program