Using sequences of assessments to achieve environmental protection

Susan M. Cormier, Ph.D.
Assessment Classifications

• **Based on Intention**
  – *Problem Detection*
    • does not presuppose a problem
  – *Problem Resolution*
    • assumes a problem and seeks a way to reduce risk of deleterious effects to the environment

• **Based on Analysis**
  – *Environmental Epidemiology*
    • determines the probable causes of known effects
  – *Risk Management*
    • determines probable effects from known causes.
Environmental Assessment Framework

Problem Detection

Problem Resolution

Environmental Epidemiology

Risk Management

Condition Assessment

Causal Pathway Assessment

Outcome Assessment

Risk Management Assessment

End
Environmental Assessment Framework

Problem Detection

Condition Assessment

End

Causal Pathway Assessment

Outcome Assessment

Risk Management Assessment

Problem Resolution

Environmental Epidemiology

Risk Management
Environmental Assessment Framework

Problem Detection

Condition Assessment

Causal Assessment

Source Assessment

Risk Assessment

Management Assessment

Problem Resolution

Outcome Assessment

End

Environmental Epidemiology

Risk Management
Environmental Assessment Framework
determine whether an ecosystem or its constituent organisms (including humans) are impaired
Environmental Assessment Framework

- Condition Assessment
- Outcome Assessment
- Causal Pathway Assessment
- Risk Management Assessment
- End
- Causal Assessment
- Source Assessment
- Risk Assessment
- Management Assessment
- Intervention

Problem Resolution
Environmental Assessment Framework

- Stressor Identification Guidance
- CADDIS
- Case Studies

Determine causes of impairments
Environmental Assessment Framework

- Remote sensing of sediment and chlorophyll
- Landscape and Modeling research

Determines sources of the causes of those impairments
estimates the risks associated with alternative management actions
determines the relative desirability of interventions based on risks, benefits and other considerations.
determine the success of intervention after it is selected and implemented
Why Causal Assessment?

• 100% States and Tribes using Biological Condition Assessments in streams and small rivers:
  ▪ Bioassessment identifies impaired waters

• Causal Assessment for TMDL:
  ▪ 2,700 waters listed for biological impairments or as having an unknown cause(s)
  ▪ Thousands more listed waters have some uncertainty about causes
  ▪ Known causes and known sources necessary to allocate loads, implement TMDLs, and restore waters
Stressor Identification Guidance

CADDIS
http://epa.gov/caddis

Case Studies
Characteristics of Causal Relationships

• Co-occurrence
  – An effect occurs where and when its cause occurs and does not occur in the absence of its cause.

• Sufficiency
  – The intensity or frequency of a cause is adequate to produce the observed magnitude of effect.

• Temporality
  – A cause precedes its effects

• Manipulation-sensitive
  – The effect is altered when the cause is altered

• Coherence
  – Internally consistent
  – Consistent with scientific theory
Detect or Suspect Biological Impairment

Stressor Identification

- Define the Case
- List Candidate Causes
- Evaluate Data from the Case
- Evaluate Data from Elsewhere
- Identify Probable Cause

Identify and Apportion Sources

Management Action:
Eliminate or Control Sources, Monitor Results

As Necessary: Acquire Data, and Iterate Process

Decision-maker and Stakeholder Involvement

Biological Condition Restored or Protected
• List of possibilities

• Develop evidence

• Compare strength of evidence among possible choices

• Identify the probable cause
Connecticut

Willimantic River

BAC workshop: May 2000
- Remediated
- Biotic condition improved
- Removed from 303d list

Naugatuck River

- TMDL recently approved
### Strength of Evidence Analysis

<table>
<thead>
<tr>
<th>Types of Evidence that Use Data from the Case</th>
<th>Metals</th>
<th>NH₃</th>
<th>Flow</th>
<th>Silt</th>
<th>Low DO</th>
<th>T</th>
<th>Food</th>
<th>Episodic Mix</th>
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<tr>
<td>Spatial/Temporal Co-Occurrence</td>
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<td>Verified Predictions</td>
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#### Evaluating Multiple Types of Evidence

- **List Candidate Causes**
- **Develop Evidence**

#### Consistency of Evidence
## Spatial.Temporal Co-Occurrence

<table>
<thead>
<tr>
<th>Candidate Cause</th>
<th>Measurement</th>
<th>Upstream reference</th>
<th>Watershed reference</th>
<th>Impaired site</th>
<th>Adverse change compared to references</th>
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<tbody>
<tr>
<td></td>
<td>Total Metals and Ammonia (mg/L)</td>
<td>MR1</td>
<td>RB1</td>
<td>MR3</td>
<td>MR1</td>
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<td>1. Toxics</td>
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<td>0.080</td>
<td>0.037</td>
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<td>NH₃</td>
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<td>+</td>
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| Types of Evidence that Use Data from Elsewhere                     |        |        |      |      |        |   |      |              |
| Stressor-Response from Other Field Studies                         | -      |        | +    | +    | -      |   |      |              |
| Stressor-Response from Laboratory Studies                          | 0      | -------| 0    | +    | +      |   |      |              |
| Consistency of Evidence                                            |        |        |      |      |        |   |      | +            |

**Identify Cause**

**Compare evidence**

Evaluating Multiple Types of Evidence

**Consistency of Evidence**

Identify Cause

Identify Cause

Identify Cause
Mississippi

Methods to speed up assessments—more than 757 court ordered TMDL within 10 yrs.

Stressor Identification for Bogue Homo,
Jones County, Mississippi

December, 2004

Prepared By
MDEQ
Office of Pollution Control
TMDL/WLA Branch

PO Box 10385
Jackson, MS 39289-0385
(601) 961-5171
www.deq.state.ms.us
Maine

Long Creek
- Urbanized system
- Flow alteration & dissolved oxygen are key stressors

Birch Stream, Capisic Brook, Barberry Creek, & Trout Brook
- Urban NPS Assessments

Urban Streams Nonpoint Source Assessments in Maine
Final Report
How much must be removed to restore the resource?
Important: process can be used for any causal agent.
Hypothetical Example:

1. Review current designated uses and criteria for a set of waterbodies

Body of Water

Mid-Atlantic, high gradient, wadeable stream

Designated Use

Aquatic Life
Benthic
Macroinvertebrates
2. Describe SABS effects on the designated uses

- Increased Deposition
  - Increased settled particles
    - % Fines

3. Select specific SABS and response indicators

- Loss of suitable habitat
- Increased temperature, ammonia, and decreased dissolved oxygen
- Smothering
- Increased drift and predation
- Inefficient filter feeding
- Increased physical abrasion

- Decreased survival and growth
- Impaired Invertebrate Assemblage
- EPT Taxa Richness

KEY
- SABS
- Mode of Action
- Biological Response
- Measurement
4. Define potential ranges in value of the SABS and response indicators
### Example: Summary Table of Effects for Different Candidate Criteria

<table>
<thead>
<tr>
<th>Evidence</th>
<th>Method</th>
<th>Effect Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Candidate Criteria for Per Cent Fines</td>
<td></td>
<td>5%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>15%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>20%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>30%</td>
</tr>
</tbody>
</table>

## Thresholds of Biological Effect that are Deemed protective

<table>
<thead>
<tr>
<th>Evidence</th>
<th>Statistical Method</th>
<th>Basis</th>
<th>Threshold</th>
</tr>
</thead>
<tbody>
<tr>
<td>SABS Level for a Proportion of Sites/Resource</td>
<td>Percentile</td>
<td>Precedent (nutrient criteria)</td>
<td>25% all streams, 75% streams ≥ 9 EPT</td>
</tr>
<tr>
<td>Commonly Achieved for a Given SABS Level</td>
<td>Linear Regression</td>
<td>Relative Condition</td>
<td>80%</td>
</tr>
<tr>
<td>Maximum Achievable Given SABS Level</td>
<td>Quantile Regression</td>
<td>Relative Condition</td>
<td>80%</td>
</tr>
<tr>
<td>Conditional Probability of NOT Achieving Use</td>
<td>Change-point Analysis</td>
<td>Detectable Change</td>
<td>Available only after analysis</td>
</tr>
<tr>
<td>Proportion of Species Protected</td>
<td>Species Sensitivity Distribution</td>
<td>Precedent (1985 criteria)</td>
<td>Greater than 95%</td>
</tr>
</tbody>
</table>

5. Identify a response indicator value that protects the designated use
### Summary Table of Effects for Different Candidate Criteria

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<tr>
<td>Candidate Criteria for Per Cent Fines</td>
<td></td>
<td>5% 10% 15% 20% 30%</td>
</tr>
<tr>
<td>Proportion of stream miles</td>
<td>Percentile all miles</td>
<td></td>
</tr>
<tr>
<td>Commonly Achieved</td>
<td>Regression</td>
<td></td>
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<tr>
<td>Maximum Achieved</td>
<td>Quantile Regression</td>
<td></td>
</tr>
<tr>
<td>Probability of NOT Achieving Use</td>
<td>Conditional Probability</td>
<td></td>
</tr>
<tr>
<td>Proportion of Species Protected</td>
<td>SSD</td>
<td></td>
</tr>
</tbody>
</table>

6. Analyze and characterize SABS/response associations
Quantile Regression: Maximum Achieved

Drainage Area
- all
- medium

EPTR Taxa Richness vs. Percent Fines

Key Points:
- 23.6
- 14.3
Species Sensitivity Distribution—Proportion of Species Protected

Proportion of Species Affected
(20% decline in abundance)

Percent Fines

Central Tendency
95% Confidence Interval
### Summary Table of Effects for Different Candidate Criteria

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<td>5%</td>
</tr>
<tr>
<td>Proportion of stream miles</td>
<td>Percentile all miles</td>
<td>11th</td>
</tr>
<tr>
<td></td>
<td>Percentile Miles &gt;9 EPT</td>
<td>23th</td>
</tr>
<tr>
<td>Commonly Achieved</td>
<td>Regression</td>
<td>13.8 taxa (92%)</td>
</tr>
<tr>
<td>Maximum Achieved</td>
<td>Quantile Regression</td>
<td>22 taxa (93%)</td>
</tr>
<tr>
<td>Probability of NOT Achieving Use</td>
<td>Conditional Probability</td>
<td>0.53</td>
</tr>
<tr>
<td>Proportion of Species Protected</td>
<td>SSD</td>
<td>&gt;95%</td>
</tr>
</tbody>
</table>
### Basis for Selecting Candidate Values

<table>
<thead>
<tr>
<th>Precedent</th>
<th>A method used in the past is deemed appropriate for a similar application</th>
</tr>
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<tbody>
<tr>
<td>Weight of Evidence</td>
<td>Criteria are selected that can be defended by several types of scientific evidence that reflects the mechanisms of action and risk.</td>
</tr>
<tr>
<td>Detectable Change</td>
<td>A quantitative change point that is statistically resolved and is ecologically relevant.</td>
</tr>
<tr>
<td>Average of Evidence</td>
<td>An average or a weighted average from all credible methods is used to select the criteria or protective level of the agent.</td>
</tr>
</tbody>
</table>

7. Explain decisions that justify criteria selection
Hypothetical Decision

for high gradient, wadeable streams
three designated uses

- 7% fines  exceptional aquatic life use
- 10% fines  aquatic life use
- 15% fines  limited aquatic life use
Why is everyone excited?

• Uses existing field data sets
• Appropriate for any stressor
• Evidence of cause-effect relationships are useful for other applications

Targets for restoration
Basic Assessment Unit

Initiator

Assessment

Decisions

Actions

Problem

Theses

Analysis

Synthesis

Stop

Next Step

By-Pass

Intervention
Regression - Commonly Achieved

EPT Taxa Richness

Percent Fines

drainage area
- all
- large

13.8
8.1