The Use of Biological Indicators for the Evaluation of Multiple Stressors and the Identification of Impairments in Streams

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Data Collected & Analyzed

- Fish Abundance and Species Composition
- Aquatic Macroinvertebrate Communities
- Stream Hydrology
- Water Quality and Nutrients
- Habitat Quality
US Federal Clean Waters Act (CWA)

- "Congressional declaration of goals and policy" to achieve the "Restoration and maintenance of chemical, physical and biological integrity of Nation’s waters..."
The 3 Dimensions of Ecological Integrity (CWA)

- Physical Integrity
- Chemical Integrity
- Biological Integrity

Ecological Integrity
Water Quality Standard

- Consists of three basic elements:
  - **Designated uses** of the water body
    - e.g., recreation, water supply, aquatic life, agriculture
    - “Fishable and Swimable”
  - **Water quality criteria** to protect designated uses
    - numeric pollutant concentrations and narrative requirements
  - **An antidegradation policy** to maintain and protect existing uses
Impaired Waters in the Lower Fox River Basin

Data from: Wisconsin DNR
March 2006
Increased Use of Biological Integrity in establishing Use Classifications and Criteria for meeting Water Quality Standards

- “The Ability of an Aquatic Community to support and maintain a structural and functional performance comparable to the natural habits of a region.”

- As modified from Karr and Dudley (1981)
Cause and Effect: Linking stressors to the resultant biological response

Stressor Agent(s)

- Habitat Structure
- Flow Regime
- Water Quality & Toxicity
- Energy Sources
- Biotic Interactions

Biological Response

Stressors

Stress / Exposure

Response

(Yoder and Rankin, 1998)(Karr and Yoder, 2004)
The Five Major Factors Which Determine the Integrity of Aquatic Resources

<table>
<thead>
<tr>
<th>Chemical Variables</th>
<th>Flow Regime</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solubilities</td>
<td>Land Use</td>
</tr>
<tr>
<td>Adsorption</td>
<td>Ground Water</td>
</tr>
<tr>
<td>Nutrients</td>
<td>Velocity</td>
</tr>
<tr>
<td>Organics</td>
<td>High/Low Extremes</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Biotic Factors</th>
<th>Habitat Structure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parasitism</td>
<td>Width/Depth</td>
</tr>
<tr>
<td>Disease</td>
<td>Bank Stability</td>
</tr>
<tr>
<td>Predation</td>
<td>Channel Morphology</td>
</tr>
<tr>
<td>Feeding</td>
<td>Sinuosity</td>
</tr>
<tr>
<td>Competition</td>
<td>Current Substrate</td>
</tr>
<tr>
<td>Reproduction</td>
<td>Instream Cover</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Energy Source</th>
<th>Energy Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nutrients</td>
<td>Organic Matter Inputs</td>
</tr>
<tr>
<td>Sunlight</td>
<td>1° and 2° Production</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>INTEGRITY OF THE WATER RESOURCE</th>
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<tr>
<td>Principal Goal of the Clean Water Act</td>
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</tbody>
</table>

INTEGRITY OF THE WATER RESOURCE

Principal Goal of the Clean Water Act
Multiple Stressors and Nonlinear Functional Response Relationships

- Reference or maximum vs. Metric vs. Embeddedness
- Metric vs. Metals / Toxins
- Metric vs. Temperature
- Metric vs. Fish Cover / Habitat Quality
Concept of an Index of Biotic Integrity

Some Fishes of the Fox River and It’s Tributaries
Multimetric Components of Biological Integrity

Biological Condition

Stressor Gradient
[Effect of Human Activity]

LOW

HIGH

Native Species

Highly Tolerant Species

Intolerant Species

Deformities and Anomalies

Species with High Tolerance

Species with Low Tolerance
Metrics used for Wisconsin Fish IBI

for Warmwater, Wadeable Streams

Species richness and composition
1. Total number of native species
2. Number of darter species
3. Number of sucker species
4. Number of sunfish species
5. Number of intolerant species
6. Percent (by number of individuals) that are tolerant species

Trophic and reproductive function
1. Percent that are omnivores
2. Percent that are insectivores
3. Percent that are top carnivores
4. Percent that are simple lithophilous spawners

Fish abundance and condition (correction factors)
1. Number of individuals (excluding tolerant species) per 300 m sample
2. Percent with deformities, eroded fins, lesions, or tumors (delt)
### Scoring Criteria for Wisconsin Version of the Fish IBI

<table>
<thead>
<tr>
<th>Metric or correction factor</th>
<th>Scoring Criteria</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>10</td>
</tr>
<tr>
<td>Total number of native* species</td>
<td>&gt;25</td>
</tr>
<tr>
<td>Number of darter species*</td>
<td>&gt;5</td>
</tr>
<tr>
<td>Number of sucker species*</td>
<td>&gt;6.0</td>
</tr>
<tr>
<td>Number of sunfish species*</td>
<td>&gt;4.0</td>
</tr>
<tr>
<td>Number of intolerant species*</td>
<td>&gt;6.5</td>
</tr>
<tr>
<td>Percent (by total individuals) that are tolerant</td>
<td>0-19</td>
</tr>
<tr>
<td>Percent that are omnivores</td>
<td>0-19</td>
</tr>
<tr>
<td>Percent that are insectivores</td>
<td>100-61</td>
</tr>
<tr>
<td>Percent that are top carnivores</td>
<td>100-15</td>
</tr>
<tr>
<td>Percent that are simple lithophilious spawners</td>
<td>100-51</td>
</tr>
<tr>
<td>Number of individuals (excluding tolerant species) per 300 m sampled</td>
<td>If &lt; 50 fish, subtract 10 from overall IBI score</td>
</tr>
<tr>
<td>Percent with deformities, eroded fins, lesions, or tumors (DELT)</td>
<td>If &gt; 4%, subtract 10 from overall IBI score</td>
</tr>
</tbody>
</table>

*values vary by region of state, values in table represent Central/Southern Wisconsin, Source: Lyons, 1992
Contributions to Fish IBI

- Fish abundance
- Simple lithotrophs
- Carnivores
- Insectivore
- Omnivores
- Native species

Very Poor
Poor
Fair

Stream/Year:
- Apple Creek
- Ashwaubenon
- Baird Creek
- Duck Creek
- Spring Brook

Years:
- 2003
- 2004
- 2005
- 2006
Cause and Effect: Linking stressors to the resultant biological response

- Habitat Structure
- Flow Regime
- Water Quality & Toxicity
- Energy Sources
- Biotic Interactions

Stressor Agent(s) → Biological Response

Stressors → Stress / Exposure → Response

(Yoder and Rankin, 1998)(Karr and Yoder, 2004)
Exploring Human-Environmental Impacts using Geo-Spatial Analysis
Impacts of Changing Landscapes:
Baird Creek Satellite Images:

1960

2005
Landscape vs Land Cover
Predictors of IBI

\[ r^2 = 0.84 \]
Potential Stressors Affecting Biological Integrity of Fish and Invertebrates

- Bank Erosion
- Substrate Composition
- Riparian Vegetation
- Canopy Cover
- Depth and Flow
- Water Quality
Impairments Identified from Biological Monitoring

- **Abundance of Fish and Invertebrates**
  - Flow Regime
    - Flashy peak flows
    - Low base flows

- **Species Composition**
  - Habitat
    - Siltation and bank erosion

- **Abundance of Tolerant Species**
  - Dissolved Oxygen
    - Eutrophication and Nutrient loading
We end, I think, at what might be called the standard paradox of the twentieth century: our tools are better than we are, and grow faster than we do. They suffice to crack the atom, to command the tides. But they do not suffice for the oldest task in human history: to live on a piece of land without spoiling it.

Aldo Leopold, 1938
Selway-Bitterroot Wilderness