Integrating Indicators of Ecological Condition and Services into a Policy Framework (ConServ, an EPA Co-Op)

- Jan Stevenson – Michigan State University
  - ecology and assessment of algae, streams, lakes, and wetlands
- Siobhan Fennessey – Kenyon College
  - ecology and assessment of plants and wetlands
- Chuck Hawkins – Utah State
  - ecology and assessment of invertebrates and streams
  - modeling reference condition
- Frank Lupi – Michigan State University
  - valuation of ecosystem services
Ecological Assessment & Management: Grand Challenges

• Assessing Ecological Condition (Assessment)
  – Relating reference condition among ecoregions & habitat type
  – Characterizing reference condition in wetlands

• Assessing Ecosystem Services (Assessment)
  – Assessing ecosystem services
  – Defining expected condition for ecosystem services

• Valuing Ecosystem Services (Assessment)
  – Scaling to national level
  – Valuing “ecological condition and integrity”
    • as related to “physical, chemical and biological integrity”

• Managing Aquatic Resources (Policy)
  – Tradeoffs among “uses”
  – Water quality criteria development
Existing Solutions

1. Conceptual Models (Assessment)
2. Existing Data (Assessment)
3. Expected Condition (Assessment)
   - aka Reference Condition
4. Tiered Aquatic Life Uses (Policy)
5. Thresholds (Assessment)
6. Water Quality Standards (Policy)
   - Use Designations, Criteria to Protect Uses, Antidegradation Policy
7. Site Listings and TMDLs (Policy)
Managing Aquatic Ecosystems (A Conceptual Model)

Simplification of Figure 4.2 in Stevenson et al. (2004), chapter in Barbour et al. in: Ecological Assessment of Aquatic Resources: Linking Science to Decision-Making.
Coupled Human & Natural Systems (CHANS)

Millennium Ecosystem Assessment Model
Another Conceptual Model
(Stevenson, 2010)

**Human Well Being**
- Health
- Security
- Materials for Life
- Good Social Relations
- Freedom of Choice

**Environmental Policy**
- Government Decisions
- Individual Decisions
- Agencies & Institutions
- Laws, Regulations, Rules
- Enforcement

**Ecosystem Services**
- Cultural and Aesthetic
- Provisioning
- Regulatory
- Supporting

**Human Activities**
- Demographics
- Industry and Agriculture
- Urban Development
- Science & Technology
- Pollution Prevention
- Pollution Treatment/Storage

**Stressors**
- Contaminants (Pollutants)
- Habitat Alterations
- Invasive Species
- Climate Change
- Microbial Pathogens
Ecosystem Services
(Millennium Ecosystem Assessment)
Refining Conceptualization and Definition of Ecosystem Services

Human Activities

Contaminants & Habitat Alterations

Ecosystem Goods & Services

Ecological Condition

Regulating Services

Supporting Services

Human Well Being

- Security
- Materials for life
- Health
- Social Relations
- Freedom

Ecosystem Valuation

Provisioning & Cultural Services

“Final Services”

“Intermediate Services”
Linkages (Couplings) in Models are Hypotheses or Known Relationships

**Human Activities**

**Contaminants & Habitat Alterations**

**Ecological Condition**

CHANS - Coupled Human and Natural Systems
Michigan – Land of Water Studies

- Sampled hundreds of streams, lakes, and wetlands
- Measure
  - Natural features
  - Nutrient Concentrations
  - Fish Biomass
  - Fish Biodiversity
  - Invertebrate Biodiversity
  - Plant Biodiversity
  - Algal Biodiversity
- Developed Stressor-Response Relationships
Muskegon Watershed Research Partnership
Large Quantity of Existing Data
(Data from Multiple Large-Scale Survey Projects,
Acknowledge Mike Wiley (U. Mich), Paul Seelbach (MDNRE))

- **MDEQ**: STORET nutrient and habitat data linked to NHD-LULC data
- **MRI**: Michigan Rivers Inventory of fish and invertebrates relates fish biomass and species composition to many factors, including nutrients (MDNRE)
- **MRW**: Muskegon River Watershed project relates fish, inverts, algae to nutrients and land use (GLFT) in streams, lakes, and wetlands
- **ILWIMI**: EPA-STAR project relating land use, land cover, and landscape attributes to fish, inverts, and algae in streams (w/ DO)
- **STAR-DO**: EPA-STAR project relating LULC, nutrients, hydrology, DO, and stream biota using surveys and watershed modeling
- **SAIN**: EPA-STAR project relating nutrients, algae, and inverts in 2 disturbance regimes
- **EPA Wetlands**: EPA funded project of wetlands in MI and KY
- **Great Lakes Restoration Initiative**
Tradeoffs Emerge from Stream Responses to Human Disturbance in Michigan

Valued Ecological Attributes
(Aquatic Biodiversity, Fisheries Production)

Nutrient Condition (TP μg/L)

- Algal Blooms
- Anoxia
- Fish
- Algae & Inverts
Assessing Condition & Services

( Anticipated in SETAC Pellston Conference Consensus )

• Assessed Condition
  = Deviation in Observed from Expected Condition

• Expected Condition
  – Legislated or regulated condition (e.g. pH<9)
  – Services = Desired (e.g. lots of big fish)
  – Close to Natural (i.e. reference condition)
    • Minimally disturbed/best available
    • Best attainable
    • Refined regionally or by site for natural potential

Assessment: Deviation from Expected Biological Condition

Valued Ecological Attributes
(Aquatic Biodiversity, Fisheries Production)

Nutrient Condition
(TP μg/L)

Anoxia
Algal Blooms
Assessment: Deviation from Expected Condition & Services

Valued Ecological Attributes

(Aquatic Biodiversity
Fisheries Production

Nutrient Condition (TP μg/L)

Algal Blooms
Anoxia

EC

Fish

Algae & Inverts

Valued Ecological Attributes

Nutrient Condition (TP μg/L)
Tiered Aquatic Life Uses

Condition of the Biotic Community
[Specific to Ecotype]

1. Natural structure and function of biotic community maintained

2. Minimal changes in structure & function

3. Evident changes in structure and minimal changes in function

4. Moderate changes in structure and minimal changes in function

5. Major changes in structure & moderate changes in function

6. Severe changes in structure & function

Stressor Gradient

LOW ———— HIGH
Thresholds & Water Quality Criteria

Valued Ecological Attributes

- Aquatic Biodiversity
- Fisheries Production
- Agricultural Production

Nutrient Condition (TP μg/L)

- Algal Blooms
- Anoxia

Graph showing the relationship between nutrient condition and valued ecological attributes.

- Fish
- Algae & Inverts

Values range from 0.0 to 1.0.
Resolving Tradeoffs in Optimization

Old Management Strategy

New Management Plan
Tiered Uses

Ecological Condition

- Good (<10 μg/L)
- Fair (<60 μg/L)
- Poor
Aquatic Resource Management

Old Management Strategy

New Management Plan Tiered Uses

<table>
<thead>
<tr>
<th>Phosphorus Condition</th>
<th>Ecological Condition</th>
<th>Provisioning Services</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 10 μg/L</td>
<td>Good</td>
<td>Fair</td>
</tr>
<tr>
<td>10-60 μg/L</td>
<td>Fair</td>
<td>Good</td>
</tr>
<tr>
<td>&gt; 60 μg/L</td>
<td>Poor</td>
<td>Fair</td>
</tr>
</tbody>
</table>
Aquatic Resource Management

Old Management Strategy

New Management Plan Tiered Uses

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<tbody>
<tr>
<td>&lt; 10 µg/L</td>
<td>Good</td>
<td>Fair</td>
</tr>
<tr>
<td>10-30 µg/L</td>
<td>Fair</td>
<td>Good</td>
</tr>
<tr>
<td>&gt; 30 µg/L</td>
<td>Poor</td>
<td>Unacceptable</td>
</tr>
</tbody>
</table>

Fair (30 µg/L)
Assessment & Management Tools
For States and Tribes

Valued Ecological Attributes
(Aquatic Biodiversity ( ),
C & NP Sequestration ( ),
Agricultural Production ( )

Human Disturbance Gradient

Ecosystem Services
Carbon Sequestration

Pollutant Condition (e.g. TP or TN mg/L)

Anoxia
Cattail Invasion

Number of Reference Sites
Low
High
75th %tiles

e.g. % Non-native Taxa

HSW LSW

Natural

10 30 40

Algae & Plants
Birds

Ground/Surfacewater

% Human Disturbance