The Biological Condition Gradient

By Susan P. Davies
and
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1 Native or natural condition

2 Minimal loss of species; some density changes may occur

3 Some replacement of sensitive-rare species; functions fully maintained

4 Some sensitive species maintained but notable replacement by more tolerant taxa; altered distributions; functions largely maintained

5 Tolerant species show increasing dominance; sensitive species are rare; functions altered

6 Severe alteration of structure and function
2001 ALUS Meeting Data Exercise

33 biologists from 21 states

six BioAxis categories

82% concurrence

four regions of the U.S.

74 stream samples
Purpose

♦ To disclose and document current bioassessment observations and interpretations
  ♦ Enable hypothesis testing
  ♦ Highlight emerging research needs
  ♦ Build upon areas of consistent interpretation
  ♦ Disclose discrepancies in interpretation and explain or resolve through research
OBSERVATION & MEASUREMENT

Making meaning
Making ecological sense

Methods-driven

Yields data

Information, knowledge and experience-driven

Yields pattern recognition

Socially and legally-driven

Yields rules for fairness and balance

Susan P. Davies Maine DEP
Characteristics

- A conceptual model
  - *not a scientific hypothesis*
- A common observational scale
  - *not a roadmap*
- A heuristic (tool for learning and communication)
  - *not a formula*
- A quality gradient
  - *not a “classification of data”*
ALUS Tiers Provide Consistency

Local State/Tribal Bioassessment methods

1. Descriptive
2. Biological Condition
3. Axis

Numeric Criteria=IBI
- Florida
  - Metric 1
  - Metric 2
  - Metric 3

Numeric Criteria=% O/E
- Oregon
  - RivPacs Predictive Model

Numeric Criteria=P(Class X)
- Maine
  - Multivariate Predictive Model

Susan P. Davies, MDEP
Overview of the Attributes

- Taxonomic composition and tolerance
  - Attributes I-V
  - *Regionally Endemic* through *Tolerant*
- Non-native taxa
  - Attribute VI
- Organism condition
  - Attribute VII
- Ecosystem function
  - Attribute VIII
- Physical: Biological interactions
  - Attributes IX and X
  - Expands the interpretation to larger spatio-temporal scales
  - Provides linkage to the “Disturbance Axis”
  - Informs the management perspective (e.g., prioritization)
Fish Metric Behavior Along the Stressor Gradient

METRIC VALUE

Native Taxa
Highly Tolerant Taxa
Intolerant Taxa

DELT Anomalies

LOW Stressor Gradient [Effect of Human Activity] HIGH

Courtesy of Chris Yoder, CABB
Overview of Attributes

I - Historically documented, sensitive, long-lived, regionally endemic taxa
- documented presence prior to CWA
- unique life history requirements
- may be a listed RTE or Special Concern species
- ex: Brook Floater mussel; Bull trout

II - Sensitive - rare or specialist taxa
- may require special habitats;
- intolerant of disturbance in environmental conditions
- naturally low densities;
- commonly k-strategists (slow development, longer lifespan, stable population density over time)
- ex: Taeniopteryx; Slimy sculpin
Maine Macroinvertebrate Monitoring Data

Impaired sites

Least disturbed sites

MODELREC_C

A
B
C
NA
Overview of Attributes (cont.)

- **III - Sensitive - ubiquitous taxa**
  - ordinarily common and abundant
  - broader range of thermal and habitat tolerance; mild pollution loads have a negative effect on populations;
  - ex: *Acroneuria; Baetidae; Ephemerellidae; Brook trout*

- **IV - Taxa of intermediate tolerance**
  - may have generalist feeding strategies
  - densities commonly increase in response to nutrient enrichment
  - may be r-strategists (early colonizers with rapid turnover times and boom/bust populations)
  - ex: *Hydropsychidae; Polycentropodidae; Common shiner*
Ohio Fish Monitoring Data

Minnow Species Occurrence vs Total Copper

- Bluntose Minnow
- Creek Chub
- Striped Shiner
- Sand Shiner
- Silver Shiner
- Hornyhead Chub

Number of Occurrences vs Total Recoverable Copper (ug/l)

- Intolerant
- Intermediate/Facultative
- Sensitive
- Highly Tolerant

Courtesy of Chris Yoder, CABB
Maine Macroinvertebrate Monitoring Data

Least disturbed sites

Impaired sites

Expected Fraction of Data for Normal Distribution

Relative Abundance Chironomidae
Overview of Attributes (cont.)

- **V - Tolerant Taxa**
  - often tolerant of a broad range of environmental conditions
  - often r-strategists or opportunist taxa; densities may increase greatly in absence of competition and predation
  - ex: leeches; gastropods; white sucker

- **VI - Non-native taxa**
  - species that do not naturally occur in a given locale or ecosystem
  - ex: *Corbicula*; zebra mussels; rudd

- **VII - Organism condition**
  - DELT anomalies and parasites of fish;
  - evidence of reproduction; sex ratios; biomass of YOY

- **VIII - Ecosystem function**
  - respiration, primary and secondary production
Overview of Attributes (cont.)

- **Ecosystem Function**
  - processes required for normal performance of a biological system
  - may be applied to any level of biological organization
  - Not commonly measured directly by state/tribal programs
  - **Examples:**
    - **Individual**- % organisms with ...(anomalies, disease, parasites, etc.)
    - **Population**- fecundity, age class distributions, sex ratios, presence/absence
    - **Community**- structural composition and complexity
    - **Ecosystem**- Primary and secondary production, P/R, immigration and emigration, trophic complexity, resource leakage
Overview of Attributes (cont.)

- IX - Spatial and temporal extent of detrimental impacts
  - near-field to far-field range of observable effects of human disturbance (*extent increases with increased severity of disturbance*)
  - patchy islands or periods of unsuitable conditions, within generally suitable conditions, progressing to patchy islands or periods of suitable conditions within generally degraded conditions
  - expands the scale perspective beyond the reach
  - linkage to the stressor-axis - (physical:biological interactions)
  - linkage to the management axis- (level of urgency or severity; ameliorating influences like BMPs)
Overview of Attributes (cont.)

- **X - Ecosystem Connectance**
  - access or linkage (in space/time) to materials, locations, and conditions required for maintenance of interacting populations of aquatic life;
  - the opposite of fragmentation;
  - necessary for meta-population maintenance and natural flows of energy and nutrients across ecosystem boundaries
  - informs the management perspective - recovery potential, recruitment and maintenance of populations into a restored environment
Relation to ME Designated Uses

Stressor Gradient

Biological Condition

Natural

Degraded

Low

Stressor Gradient

High

A

B

C

NA
**Relation to VT Designated Uses**

- **Excellent** (Near-natural)
- **Very Good** (minor changes in S&F)
- **Good** (moderate changes in S&F)
- **Non-supporting** (not sustainable)

The graph shows the relationship between biological condition and stressor gradient. The horizontal axis represents the stressor gradient ranging from low to high, while the vertical axis represents the biological condition ranging from natural to degraded.

- **1. Excellent** (Near-natural)
- **2. Very Good** (minor changes in S&F)
- **3. Good** (moderate changes in S&F)
- **4. Non-supporting** (not sustainable)

The graph illustrates how the biological condition changes as the stressor gradient increases, moving from natural to degraded conditions.
Relation to OH Designated Uses

Biological Condition

- Natural
- Degraded

Stressor Gradient

- Low
- High

Unacceptable

EWH

[ORW]

State-wide

WAP

ECBP

IP

EOLP

HELP

Non-HELP

State-wide

NA
1. Native or natural condition

2. Minimal loss of species; some density changes may occur

3. Some replacement of sensitive-rare species; functions fully maintained

4. Some sensitive species maintained but notable replacement by more tolerant taxa; altered distributions; functions largely maintained

5. Tolerant species show increasing dominance; sensitive species are rare; functions altered

6. Severe alteration of structure and function
ME Example
ALUS Tier 1
Intact watershed

- **Generic Richness**
  - Total = 51
  - EPT = 25 (49%)
  - Mayfly = 8
  - Stonefly = 6
  - Caddisfly = 11
  - Midges = 10

- **Abundance**
  - Total = 312
  - Mayfly = 157
  - Stonefly = 57

- **II - Sensitive - rare, specialist**
  - Taeniopteryx 48
  - Epeorus 13
  - Hexatoma 8
  - Probezzia 8
  - Isoperla 7
  - Pteronarcys 1
  - Capniidae 1
  - Chloroperlidae 1
  - Glossosoma 1
  - Brachycentrus 1

- **III - Sensitive - ubiquitous, generalist**
  - Ephemerella 127
  - Acentrella 13
  - Stenonema 8

- **IV - Intermediate tolerance, opportunistic**
  - Hydropsyche 24
  - Cheumatopsyche 5

- **V - Tolerant Taxa**
  - Polypedilum 8
1. Native or natural condition

2. Minimal loss of species; some density changes may occur

3. Some replacement of sensitive-rare species; functions fully maintained

4. Some sensitive species maintained but notable replacement by more tolerant taxa; altered distributions; functions largely maintained

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6. Severe alteration of structure and function
### ME Example

#### ALUS Tier 3

**Agricultural NPS**

<table>
<thead>
<tr>
<th>Category</th>
<th>Taxa</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>II - Sensitive- rare, specialist</td>
<td>Serratella</td>
<td>8</td>
</tr>
<tr>
<td>III - Sensitive - ubiquitous, generalist</td>
<td>Leucrocuta</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Ephemeraella</td>
<td>67</td>
</tr>
<tr>
<td></td>
<td>Acroneuria</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>Acentrella</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Stenonema</td>
<td>5</td>
</tr>
<tr>
<td>IV - Intermediate tolerance, opportunistic</td>
<td>Simulium</td>
<td>203</td>
</tr>
<tr>
<td></td>
<td>Hydropsyche</td>
<td>92</td>
</tr>
<tr>
<td></td>
<td>Rheotanytarsus</td>
<td>62</td>
</tr>
<tr>
<td></td>
<td>Chirarrera</td>
<td>40</td>
</tr>
<tr>
<td>V - Tolerant Taxa</td>
<td>Cricotopus</td>
<td>33</td>
</tr>
<tr>
<td></td>
<td>Polypedilum</td>
<td>32</td>
</tr>
</tbody>
</table>

#### Generic Richness
- Total = 58
- EPT = 21 (36%)
- Mayfly = 7
- Stonefly = 1
- Caddisfly = 13
- Midge = 12

#### Abundance
- Total = 835
- Mayfly = 220
- Stonefly = 16
Biological Condition

1. Native or natural condition

2. Minimal loss of species; some density changes may occur

3. Some replacement of sensitive-rare species; functions fully maintained

4. Some sensitive species maintained but notable replacement by more tolerant taxa; altered distributions; functions largely maintained

5. Tolerant species show increasing dominance; sensitive species are rare; functions altered

6. Severe alteration of structure and function

Stressor Gradient

Low | High
ME Example
ALUS Tier 6

**Toxic discharge**

**Generic Richness**
- Total = 8
- EPT = 0 (0%)
- Mayfly = 0
- Stonefly = 0
- Caddisfly = 0
- Midges = 3
- Snails = 2

**Abundance**
- Total = 74
- Mayfly = 0
- Stonefly = 0
- Snail = 52

**II - Sensitive - rare, specialist**
- none

**III - Sensitive - ubiquitous, generalist**
- none

**IV - Intermediate tolerance, opportunistic**
- none

**V - Tolerant Taxa**
- Helisoma 48
- Thienemannimyia 16
- Physa 4
- Cricotopus 2
- Ablabesmyia 1
- Helobdella 1
Summary of 2001 Group Consensus

- Tiers 1 & 2 meet CWA biointegrity goal
- Tiers 3 & 4 meet Interim Goal
  - S&F maintained by replacement and redundancy;
  - some sensitive taxa still supported
  - balanced distribution of major groups
- Tiers 5 & 6 do not meet the Interim Goal
  - loss of function
  - sensitive taxa lost
  - hyperdominance or ‘unnatural’ distributions
- High importance attributes should be retained (function, connectance, etc) even if not well-assessed now.

SP Davies, MDEP
Summary of Outstanding Issues

- Should non-native taxa be allowed in Tier 1?
- How can we create a “crosswalk” between the Biocondition Gradient and the Endangered Species Act?
- How can Attribute VIII, Ecosystem Function, be made clearer and more useful?
- How do we transition from describing what we see to establishing management thresholds?
Conclusions

- Near-universal interpretive Gestalt exists among biologists
  - based on First Principles of Ecology, independent of methods
  - highly internalized and under-communicated
- Disclosure and documentation provides an important tool for learning, communication, and management
Additional supporting slides
Maine’s Aquatic Life Management Classes

Class A
- As naturally occurs; Habitat: Natural
- No detrimental change; support all indigenous spp. Habitat: “unimpaired”
- Maintain structure & function; support all indigenous fish (salmonids)
- Habitat for fish and Aquatic Life

Class B
- Maintain structure & function; support all indigenous fish (salmonids)
- Habitat for fish and Aquatic Life

Class C
- Maintain structure & function; support all indigenous fish (salmonids)
- Habitat for fish and Aquatic Life

Non-Attainment of Minimum Standards

Maine’s Water Quality Management Classes

CLASS AA
- Zero Discharge;
- No hydrologic alteration

CLASS A
- No alternatives;
- D/C Equal to or Better; hydro allowed

CLASS B
- D/C with ample dilution;
- DO: 7ppm/75% saturation;
- 9 ppm for salmonid spawning; Bacteria: 64/100 mil in the Summer

CLASS C
- DO: 5 ppm/60% Sat.;
- Water Quality sufficient to ensure salmonid spawning/survival;
- Bacteria: 142/100 mil

Non-Attainment

Susan P. Davies MDEP
Maine Tiered Uses Based on Measurable Ecological Values

<table>
<thead>
<tr>
<th>Narrative Standard</th>
<th>Ecological Value</th>
<th>Quantifiable Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CLASS A</strong></td>
<td>Taxonomic and Numeric Equality; Presence of Indicator Taxa</td>
<td>Similarity, Richness, Abundance, Diversity; EPT, Indicator Taxa, Biotic Index</td>
</tr>
<tr>
<td>Natural</td>
<td>Retention of taxa and numbers; Absence of hyperdominance; Presence of sensitive taxa</td>
<td>Community loss; Richness; Abundance; diversity; equitability; evenness; EPT; Indicator Taxa, Biotic Index</td>
</tr>
<tr>
<td><strong>CLASS B</strong></td>
<td>Resistance, Redundancy; Resilience; Balanced Distribution</td>
<td>Richness; Diversity; Equitability; Evenness</td>
</tr>
<tr>
<td>Unimpaired, maintain indigenous taxa</td>
<td>Energy Transfer; Resource assimilation; Reproduction</td>
<td>Trophic groups; Richness; abundance; community loss; fecundity; colonization rate</td>
</tr>
<tr>
<td><strong>CLASS C</strong></td>
<td>Maintain structure and function</td>
<td></td>
</tr>
</tbody>
</table>
Future Needs - Definitions

- Clear operational definitions of terms used in the BioCondition Gradient are ultimately dependent on clarifying multiple, specific contexts
  - ecoregion context
  - taxonomic context
  - stressor context
  - sampling methods context
  - level of effort context
  - regulatory context

Conclusion:
States and tribes need to refine the definitions in order for them to have a clear and specific meaning within in a given state program.
1. Native or natural condition

2. Minimal loss of species; some density changes may occur

3. Some replacement of sensitive-rare species; functions fully maintained

4. Some sensitive species maintained but notable replacement by more tolerant taxa; altered distributions; functions largely maintained

5. Tolerant species show increasing dominance; sensitive species are rare; functions altered

6. Severe alteration of structure and function

Stressor Gradient

Degraded

Native

Natural
ME Example

ALUS Tier 2

- **Generic Richness**
  - Total = 62
  - EPT = 26 (42%)
  - Mayfly = 9
  - Stonefly = 2
  - Caddisfly = 15
  - Midges = 19

- **Abundance**
  - Total = 585
  - Mayfly = 77
  - Stonefly = 18

- **II - Sensitive - rare, specialist**
  - Psilotreta = 8
  - Serratella = 6
  - Leucrocuta = 5
  - Promoresia = 4
  - Brachycentrus = 1

- **III - Sensitive - ubiquitous, generalist**
  - Helicopsyche = 159
  - Isonychia = 37
  - Acroneuria = 17
  - Stenonema = 17
  - Baetis = 7

- **IV - Intermediate tolerance, opportunistic**
  - Rheotanytarsus = 54
  - Hydropsyche = 52
  - Cheumatopsyche = 11

- **V - Tolerant Taxa**
  - Polypedilum = 8
1. Native or natural condition

2. Minimal loss of species; some density changes may occur

3. Some replacement of sensitive-rare species; functions fully maintained

4. Some sensitive species maintained but notable replacement by more tolerant taxa; altered distributions; functions largely maintained

5. Tolerant species show increasing dominance; sensitive species are rare; functions altered

6. Severe alteration of structure and function
<table>
<thead>
<tr>
<th>Tier</th>
<th>Category</th>
<th>Example Taxa</th>
</tr>
</thead>
<tbody>
<tr>
<td>II</td>
<td>Sensitive - rare, specialist</td>
<td>Serratella 1</td>
</tr>
<tr>
<td>III</td>
<td>Sensitive - ubiquitous, generalist</td>
<td>Tricorythodes 107, Stenonema 101, Baetis 59, Acroneuria 4</td>
</tr>
<tr>
<td>IV</td>
<td>Intermediate tolerance, opportunistic</td>
<td>Cheumatopsyche 896, Hydropsyche 245, Microtendipes 141, Simulium 12</td>
</tr>
<tr>
<td>V</td>
<td>Tolerant Taxa</td>
<td>Cricotopus 469, Polypedilum 84, Physella 45</td>
</tr>
</tbody>
</table>

**Generic Richness**
- Total = 48
- EPT = 12 (25%)
- Mayfly = 6
- Stonefly = 1
- Caddisfly = 5
- Midges = 21

**Abundance**
- Total = 2470
- Mayfly = 295
- Stonefly = 4
Natural or natural condition

Minimal loss of species; some density changes may occur

Some replacement of sensitive-rare species; functions fully maintained

Some sensitive species maintained but notable replacement by more tolerant taxa; altered distributions; functions largely maintained

Tolerant species show increasing dominance; sensitive species are rare; functions altered

Severe alteration of structure and function
### ME Example

**ALUS Tier 5**

<table>
<thead>
<tr>
<th>Tier</th>
<th>Description</th>
<th>Taxa</th>
</tr>
</thead>
<tbody>
<tr>
<td>II</td>
<td>Sensitive - rare, specialist</td>
<td>None</td>
</tr>
<tr>
<td>III</td>
<td>Sensitive - ubiquitous, generalist</td>
<td>None</td>
</tr>
<tr>
<td>V</td>
<td>Tolerant Taxa</td>
<td>Isopoda: 412, Hayesomyia: 185, Polypedilum: 40</td>
</tr>
</tbody>
</table>