Use of biological indicators in hydromodification monitoring

Peter Ode
Water Pollution Control Laboratory
Aquatic Bioassessment Laboratory
California Department of Fish and Game
• Bioassessment fundamentals
• Biological responses to hydromodification
• Current research priorities
**Bioassessment** – assessment of the health of a waterbody from its resident biota
Why Develop Ecological Indicators?

• Global paradigm shift toward ecological indicators
• Provide direct evidence about resources we are trying to protect
• Integrate information about chemical and non-chemical stressors over time
• Links resource protection across multiple agencies by focus on ultimate policy goals
CA’s Ecological Indicators

Multiple Indicators – BMIs, algae, (fish), riparian vegetation

Multiple waterbody types – large rivers, non-perennial streams, lakes, wetlands

Start with invertebrates and perennial streams
invertebrates: the backbone of bioassessment

- Abundant
- Diverse
- Informative
Standardized Bioassessment Infrastructure Elements

Surface Water Ambient Monitoring Program (SWAMP)
Regulatory Biological Objectives

How do we convert a list of species into a condition score?

- Midges
- Caddisflies
- Mayflies
- Dragonflies
- Stoneflies
- Beetles
Scoring Tools Depend on Reference Sites
(sites with low levels of disturbance)
“What should the biology look like at a test site?”
Reference site selection

Screened > 2400 candidate reference sites

Objectives:

1. Reference pool represents CA stream diversity
2. Biological at reference sites is minimally influenced by stress
Reference sites have few sources of human stress

- **Infrastructure**: roads, railroads
- **Population**
- **Hydromodification**
  - manmade channels, canals, pipelines
- **Landuse**
  - Ag/Urban development
  - Timber Harvest, Grazing
- **Fire history, dams, mines**
- **303d list, known discharges**
- **Invasive invertebrates, plants**
- **Instream and riparian habitat**
- **Water chemistry**
Very good geographic coverage

<table>
<thead>
<tr>
<th>REGION</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>North Coast</td>
<td>75</td>
</tr>
<tr>
<td>Central Valley</td>
<td>1</td>
</tr>
<tr>
<td>Coastal Chaparral</td>
<td>57</td>
</tr>
<tr>
<td>Interior Chaparral</td>
<td>33</td>
</tr>
<tr>
<td>South Coast Mountains</td>
<td>85</td>
</tr>
<tr>
<td>South Coast Xeric</td>
<td>34</td>
</tr>
<tr>
<td>Western Sierra</td>
<td>131</td>
</tr>
<tr>
<td>Central Lahontan</td>
<td>114</td>
</tr>
<tr>
<td>Deserts + Modoc</td>
<td>27</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>586</strong></td>
</tr>
</tbody>
</table>
Multivariate view of natural diversity

Temperature, Conductivity

Stream Size, Precipitation
Reference sites cover most stream types

Stream Size, Precipitation

Temperature, Conductivity
California Stream Condition Index (CSCI)

Part A: Ecological Structure Component (pMMI)
Part B: Taxonomic Loss Component (O/E)

BMI Species List from Sample

<table>
<thead>
<tr>
<th>Taxon</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mayfly species 1</td>
<td>43</td>
</tr>
<tr>
<td>Mayfly species 2</td>
<td>12</td>
</tr>
<tr>
<td>Mayfly species 3</td>
<td>2</td>
</tr>
<tr>
<td>Beetle species 1</td>
<td>1</td>
</tr>
<tr>
<td>Beetle species 2</td>
<td>1</td>
</tr>
<tr>
<td>Midge genus 1</td>
<td>65</td>
</tr>
<tr>
<td>Midge species 1</td>
<td>3</td>
</tr>
<tr>
<td>Midge species 2</td>
<td>10</td>
</tr>
<tr>
<td>Midge genus 2</td>
<td>3</td>
</tr>
<tr>
<td>Dragonfly species</td>
<td>2</td>
</tr>
<tr>
<td>Stonefly species</td>
<td>1</td>
</tr>
<tr>
<td>Stonefly species</td>
<td>14</td>
</tr>
<tr>
<td>Worm species 1</td>
<td>9</td>
</tr>
<tr>
<td>Worm species 2</td>
<td>2</td>
</tr>
</tbody>
</table>

Ecological Function Metrics

- # mayfly taxa
- # predator taxa
- % sediment tolerant taxa
- % non-insect taxa

Scores are adjusted to account for major natural gradients

- Elevation
- Latitude
- Longitude
- Conductivity
- PPT, Temp
- Mineral Content

• Both components adjust for environmental setting
• CSCI is a simple average of the two scores
Distribution based thresholds:

Mean = 1.01
SD = 0.13

CA Stream Condition Index Value

1st %
10th %

very likely altered
likely altered
likely intact
Probability surveys and reference data provide context for interpreting targeted monitoring data.
The diagram illustrates the distribution of a stressor variable. It compares the reference distribution (low disturbance) with the standard monitoring distribution. The diagram shows how the stressor variable affects two sets of data labeled 'A' and 'B', indicating a shift or change in the distribution due to stressor influence.
Hydromod has multiple effects on biology

Changing from complex dynamic systems to simpler static systems

- alterations of hydrology and physical structure tend to reduce habitat diversity

Changing the hydrograph and temperature regime

- flow magnitude/timing and temp drive life history strategies
- alterations limit ability of streams to support native biota
Physical stressors are among the most significant impacts to biology.

Relative Risk:
Increased risk of biological impairment in presence of high stressor levels

(analogous to medical risk advisories – e.g., 10x higher risk of emphysema associated with smoking)

Data from SMC probability survey (Mazor et al. 2011)
Biological Responses to Hydromodification

Physical changes to channel

• Habitat is a primary driver of species distributions
  - Filling interstitial spaces
  - Channel modification usually results in reduced habitat diversity
  - Fine sediment smothering
Responses to associated environmental changes

- Flow (magnitude, timing, duration, )
- Water source (surface: groundwater ratio)
- Temperature, DO
Hydromodification stressors interfere with physical requirements and life history strategies

- **Smothering** (not just fish!)
- **Loss of interstitial spaces/habitat diversity** – competition for space and food
- **Thermal impacts** - life history timing, resting stages, reproduction, dispersal, egg-laying preferences, etc.
Response to fine sediment

Hydroptila

Optioservus

Abundance vs. Percent Fines and Sand

Relative Bed Stability
Sediment intolerant vs. sediment tolerant

**Epeorus**

- E. longimanus
- E. deceptivus
- E. grandis
- E. albertae

**Caenis**

- C. latipennis
- C. bajaensis

The graphs show the abundance of these taxa at different log relative bed stability levels, with the x-axis representing log relative bed stability and the y-axis representing abundance.
Species level IDs matter in some cases

In some cases, genus level ID is OK for tolerance values, in others it is misleading.
Fine sediment thresholds differ regionally
(data from SWAMP’s Perennial Streams Assessment)
Biological Monitoring Research Priorities

Emphasis on tools for supporting long term monitoring strategies

- Biology can help focus these and give intermediate feedback
- We’ve built tools and a framework for this kind of monitoring, but most tools are general ... need more stressor-specific focus

- How much resilience/resistance to different modifications
- What aspects of hydromod matter most to biota?
Current priorities

1. **Support for Causal Analysis**
   
   * (stressors are multivariate and span multiple spatial scales)*
   
   - Stressor-specific analyses
   - Functional group indicators
   - Improved relative risk models

2. **Adapting bioassessment for non-perennial streams**

3. **Bioassessment and flow alteration**
Majority of stream length is non-perennial

- ~75% of CA stream length is non-perennial
- current maps are frequently inaccurate
- neglected target for monitoring and protection
Non-perennial streams

Non-perennial streams are the primary interface between downstream perennial streams and the activities on the landscape.

Intense seasonality (Gasith & Resh 1999)
- Flooding/Drying
- Increased chemical concentrations
- Increased biotic interactions

Susceptible to hydromodification
Non-perennial streams

Initial studies designed to ask whether bioassessment tools for perennial streams work in intermittent streams

Initial results are very promising

New SCCWRP/ABL studies sponsored by San Diego RB designed to expand upon this work
Numeric Flow Metrics to Support Freshwater Bio-objectives, Hydromodification Management, and Nutrient Numeric Endpoints

ERIC STEIN
BIOLOGY DEPARTMENT

Colorado State University

USGS
science for a changing world
Objectives

Develop an approach for establishing instream environmental flow requirements necessary to meet ecological benchmarks

1. How should streams in California be grouped or classified for the purposes of establishing environmental flow requirements

2. What are the key hydrologic variables that should be used for environmental flow requirements

3. What are the key biological response variables that should be used when establishing environmental flow requirements

4. What is the appropriate framework/approach for setting actual flow requirements for specific stream types.
Predicting Flow in California Streams
(Daren Carlisle – USGS, Jeanette Howard – TNC)
Bear Creek above diversion

Bear Creek below diversion
Predicting monthly mean flows
(modeled from landscape, landuse, withdrawals, diversions, etc.)

- If we can predict normal flow, we can measure deviation from normal conditions
- Use to identify best biotic indicators of hydrologic alteration
Predicted monthly mean flows
Key Messages

Altering complex dynamic systems affects many variables that biota respond to.

Stream biota are reliable indicators of deviation from normal hydrology and physical characteristics of streams:
- “how much change is too much”
- recovery measures

Watershed monitoring approach is ideal for biological indicators, especially in a screening/integrative role.
Questions?
Intermittent **obligates and specialists:**
*how do they survive?*

1. **Diapausing egg or larva**
   - **Stoneflies**
   - **Dobsonflies**

2. **Vagile adults & rapid development time**
   - **Diving beetles**

3. **Unknown: diapause & rapid development?**
   - **Midges**
   - **Blackflies**