Development of Sediment Quality Guidelines Based on Benthic Macrofauna Response

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Background

• California is developing a sediment quality assessment framework focused on protection of the benthic macrofaunal community
  – Regulatory incorporation of sediment quality triad
  – Specific tools for implementation statewide
• Toolbox of indicators for chemistry, toxicity, and benthic community disturbance under development
• Sediment Quality Guidelines (SQGs) will be used to interpret chemistry measurements
Sediment Quality Guidelines

- Most SQGs are based on empirical relationships between individual chemical contaminants and toxicity
  - Probability of toxicity (logistic regression)
  - Effects range median (ERM)

- Approaches that integrate multiple chemicals perform best
  - Maximum probability (Pmax)
  - Mean SQG quotient (mERMq)
Toxicity vs. Benthos

• Want to protect benthos, but most SQGs based on toxicity data

• Are SQGs based on toxicity accurate predictors of benthic impact?

• Benthos may have a differential response to individual chemicals and/or chemical mixtures
  – Laboratory vs. field
  – Single animal vs. population
  – Short-term vs. long-term exposure
Research Questions

• How do chemical relationships between toxicity and benthos compare?

• Can the predictive ability of SQGs be improved by developing a benthos-specific SQG?
Comparison of Chemical Relationships

- Matched chemistry, toxicity, and benthos data
  - Southern California embayments (N=441)
  - **Toxicity:** 10 day amphipod survival
  - **Benthos:** Abundance across multiple benthic organisms

- Correlations between individual chemicals and toxicity/benthos

- Cumulative distribution functions of affected samples
Spearman’s Correlation

The diagram shows the Spearman’s correlation coefficients for various chemicals, including Cadmium, Copper, Lead, Mercury, Zinc, HPAH, LPAH, PCB, DDD, DDE, DDT, a-Chlordane, and g-Chlordane, with respect to Toxicity and Benthos. The x-axis represents the chemicals, while the y-axis represents the Spearman’s correlation coefficient range from 0.0 to 0.5.
Chemical Response Ranges

Apparent response thresholds for toxicity and benthos disturbance were similar for all chemicals.
Measuring SQG Agreement with Toxicity and Benthos

- **Four levels of biological response**
  - Reference, low, moderate, high

- **Two measures of response**
  - Toxicity (amphipod mortality)
  - Benthos (benthic community disturbance)

- **SQG thresholds for predicting biological response were selected by statistical optimization**
Predictive Ability Comparison

• Compared agreement predicting biological response using tox-based SQGs and a new benthos-based SQG

• Toxicity-based SQGs
  – **ERM**: mean ERMq across all chemicals
  – **Logistic Regression**: maximum probability of toxicity (Pmax)

• Benthos-based SQG
  – **Chemical Score Index (CSI)**: mean score (mCSI)
Chemical Score Index

• Reflects association between chemicals and magnitude of response (BRI) of California benthos

• Two types of data are combined
  – Set of predicted benthic response categories based on individual chemical concentrations
  – Set of weighting factors for each of the chemicals based on strength of association.
Chemical Response Categories

Concentration

Benthic Community Disturbance

Reference

Low

Moderate

High

T1

T1

T1
### Calculating mCSI

**Data**

<table>
<thead>
<tr>
<th>Chem</th>
<th>Conc</th>
</tr>
</thead>
<tbody>
<tr>
<td>[Cu]</td>
<td>22</td>
</tr>
<tr>
<td>[Pb]</td>
<td>29</td>
</tr>
<tr>
<td>[Zn]</td>
<td>250</td>
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<tr>
<td>[Hg]</td>
<td>0.44</td>
</tr>
<tr>
<td>[DDT]</td>
<td>90.02</td>
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</table>

**Apply thresholds**

<table>
<thead>
<tr>
<th></th>
<th>Min</th>
<th>Low</th>
<th>Mod</th>
<th>High</th>
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<tbody>
<tr>
<td>T1</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T2</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
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<tr>
<td>T3</td>
<td></td>
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</table>

**Predicted Category**

<p>| |</p>
<table>
<thead>
<tr>
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<tbody>
<tr>
<td>1</td>
</tr>
<tr>
<td>2</td>
</tr>
<tr>
<td>3</td>
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<tr>
<td>4</td>
</tr>
</tbody>
</table>

**Average across all chemicals**

```
0.70  1.5  2.7  1.9  3.8
```

**mCSI**

```
X
```
Agreement with Respect to Toxicity (n=146)

<table>
<thead>
<tr>
<th>SQG</th>
<th>Agreement</th>
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<tbody>
<tr>
<td>mERMq</td>
<td>38%</td>
</tr>
<tr>
<td>Pmax</td>
<td>40%</td>
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</table>

No statistically significant differences
Agreement with Respect to Benthic Response (n=146)

<table>
<thead>
<tr>
<th>SQG</th>
<th>Agreement</th>
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<tbody>
<tr>
<td>mERMq</td>
<td>43%</td>
</tr>
<tr>
<td>Pmax</td>
<td>31%</td>
</tr>
<tr>
<td>mCSI</td>
<td>52%*</td>
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</tbody>
</table>

* Statistically different from other SQGs
Application to San Pedro Bay
n=67
Application to San Pedro Bay

N = 67

mCSI more accurate at the extremes
Summary

- Benthos and toxicity test responses appear to have differential associations with chemistry
- Toxicity-based SQGs are useful for predicting benthos
- Benthos-based SQGs show improvement in predicting response of benthos, particularly at the extremes
- Merit to using both types of SQGs in sediment quality assessments