Stream Amphibians as Metrics of Ecosystem Stress: A Case Study From California's Redwoods Revisited

Hartwell H. Welsh, Jr., Garth R. Hodgson and Adam K. Cummings
Redwood Sciences Laboratory, Arcata, California
Control  Set 1 from 1990
Treatment I  Set 2 from 1990
Treatment II  Set 1 from 1996
Treatment III  Set 2 from 1996
Event

Highway construction of the Prairie Creek Redwoods State Park bypass resulted in a storm-driven accidental infusion of exposed sediments into pristine streams in Prairie Creek Redwoods State Park, California in October 1989.
Suspended sediment from gauging stations

Prairie Creek Suspended Sediment by Water Year

Unit Suspended Sediment Flux (tons/sq.mi.)


1990 herp sample 1996 herp sample
Measured sediment depths at Bottom, Middle, Top.

Graph a: Mean Sediment Depth (cm) vs. Control, Treatment I, Treatment II, Treatment III.

Graph b: Pool Tail Embeddedness (%) vs. Control, Treatment I, Treatment II, Treatment III.

Diagram: Residual pool, fine bed material, riffle crest depth.

Cobble Embeddedness: <25%, 25-50%, 50-75%, >75%
Amphibian Sampling (Belts)

715 belts total.

1990
130 Control
137 Impacted
267 Total

1996
219 Control
229 Impacted
448 Total
Mesohabitat Use by Species

The diagram illustrates the captures per square meter across different mesohabitat groups for three species:

- Tailed frog
- Torrent salamander
- Giant salamander

The mesohabitat groups are:

- Riffle
- Gld/Run
- Allpool
- Steepool
- Steprun

The data shows the variability in mesohabitat use for each species across these groups.
Captures by Treatment

### Density

<table>
<thead>
<tr>
<th></th>
<th>Control</th>
<th>Treatment I</th>
<th>Treatment II</th>
<th>Treatment III</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tailed frog</td>
<td>0.8</td>
<td>0.4</td>
<td>0.2</td>
<td>0.1</td>
</tr>
<tr>
<td>Torrent salamander</td>
<td>0.3</td>
<td>0.1</td>
<td>0.1</td>
<td>0.05</td>
</tr>
<tr>
<td>Giant salamander</td>
<td>2.0</td>
<td>1.5</td>
<td>1.0</td>
<td>0.75</td>
</tr>
</tbody>
</table>

### Total Captures

<table>
<thead>
<tr>
<th></th>
<th>Control</th>
<th>Treatment I</th>
<th>Treatment II</th>
<th>Treatment III</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>125</td>
<td>65</td>
<td>90</td>
<td>38</td>
</tr>
<tr>
<td></td>
<td>30</td>
<td>9</td>
<td>21</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>152</td>
<td>145</td>
<td>676</td>
<td>547</td>
</tr>
</tbody>
</table>
Mixed effects models – A two pronged approach

<table>
<thead>
<tr>
<th>Mesohabitat Occupancy:</th>
<th>Mesohabitat Density:</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Response:</strong> binomial</td>
<td><strong>Response:</strong> counts</td>
</tr>
<tr>
<td><strong>Random effects:</strong> Creek/Mesohabitat</td>
<td><strong>Random effects:</strong> Creek</td>
</tr>
<tr>
<td><strong>Fixed effects:</strong> Treatment</td>
<td><strong>Fixed effects:</strong> Treatment*MesoHab interaction, %Fines, %Embedded</td>
</tr>
<tr>
<td><strong>Single model</strong></td>
<td><strong>8 models/species; top model selected using AICc</strong></td>
</tr>
</tbody>
</table>
Mesohabitat Density: Model selection

|M   |   count ~ (Treatment + Mesohabitat)²  + Embedded + Fines + offset(LBeltArea) |
|M1: |   ~ (Treatment + Mesohabitat)² + Embedded + Fines + offset(LBeltArea)       |
|M2: |   ~ (Treatment + Mesohabitat)² + Embedded + Fines + offset(LBeltArea)       |
|M3: |   ~ (Treatment + Mesohabitat)² + Embedded + Fines + offset(LBeltArea)       |
|M4: |   ~ (Treatment + Mesohabitat)² + Embedded + Fines + offset(LBeltArea)       |
|M5: |   ~ (Treatment + Mesohabitat)² + Embedded + Fines + offset(LBeltArea)       |
|M6: |   ~ (Treatment + Mesohabitat)² + Embedded + Fines + offset(LBeltArea)       |
|M7: |   ~ (Treatment + Mesohabitat)² + Embedded + Fines + offset(LBeltArea)       |
|M8: |   ~ (Treatment + Mesohabitat)² + Embedded + Fines + offset(LBeltArea)       |
## Mesohabitat Density:

### Model selection

<table>
<thead>
<tr>
<th></th>
<th>Tailed frog</th>
<th>Torrent salamander</th>
<th>Giant salamander</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>AICc</td>
<td>Rank</td>
<td>AICc</td>
</tr>
<tr>
<td><strong>M5:</strong> Embedded &amp; Fines</td>
<td>2.2</td>
<td>2</td>
<td>2.0</td>
</tr>
<tr>
<td><strong>M6:</strong> Embedded</td>
<td>0.0</td>
<td>1</td>
<td>1.5</td>
</tr>
<tr>
<td><strong>M7:</strong> Fines</td>
<td>15.1</td>
<td>4</td>
<td>0.0</td>
</tr>
<tr>
<td><strong>M8:</strong> NULL</td>
<td>14.0</td>
<td>3</td>
<td>0.3</td>
</tr>
</tbody>
</table>

**Tailed frog**
- Top model: **M6**
- Environmental parameter: **Embeddedness**

**Torrent salamander**
- Top model: **M7**
- Environmental parameter: **Fines**

**Giant salamander**
- Top model: **M6**
- Environmental parameter: **Embeddedness**
Tailed Frog Density

- For every 10% increase in embeddedness, frog density declined 30%
Torrent Salamander Density

- For every 10% percent increase in *fine sedimentation*, salamander density declined 29%
Giant Salamander Density

- For every 10% increase in *embeddedness*, salamander density declined 11%
Conclusions

The storm that followed the initial highway construction increased sediment loads and reduced aquatic amphibian densities in the five affected streams in 1990.

A second larger storm events delivered considerably more fine sediment in 1996, further reducing tailed frog and torrent, but not giant salamander, densities.

It is apparent that sediment events, both natural or anthropogenic, can have cumulative effects on the stream system and its biotic assemblages, but not all organisms respond in the same way. This is true even in one of the most stable ecosystems in the world, the old growth coast redwoods.
APPLIED ISSUES

Amphibians as metrics of critical biological thresholds in forested headwater streams of the Pacific Northwest, U.S.A.

HARTWELL H. WELSH JR AND GARTH R. HODGSON
USDA Forest Service, Pacific Southwest Experiment Station, Redwood Sciences Laboratory, Arcata, CA, U.S.A.
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