Adult coho salmon pre-spawn mortality and urban stormwater runoff: what’s sufficient, what isn’t, and what can prevent it

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Introducing... coho salmon

• Widely distributed
• Lowland streams
• > 1 yr in freshwater
• Supported by a diverse food web
• Sensitive to water quality & quantity
• Species of Concern

StreamNet.org
Coho pre-spawn mortality is widespread and recurrent (60-90% of total fall runs)
Previous PSM forensics results

- Conventional water quality parameters (temperature, dissolved oxygen, sediment, etc) do not appear to be causal.
- Chemical contaminants are present in urban stormwater, but at levels lower than those expected to cause acute mortality.
- There is no evidence of disease or pathology, and dying fish appear to be in good physical condition (ocean bright, good condition index).
- All affected fish exhibit consistent symptomology before they die.
- Most fish in Longfellow Creek appear to be hatchery strays. Annual returns to other streams have typically been low.
Predictive Model of Pre-spawn Mortality

Land Use drivers:
- Impervious Surface
- Roads
- Commercial Land Use

Feist et al., 2011
The stormwater pollution you see...
Combined Sewer Overflow, November 19th 2012

... and the pollution you don’t see.

Photo by Blake Feist, NOAA Fisheries
Combined Sewer Overflow, November 19th 2012

... and the pollution you don’t see

PAHs
phenanthrenes
lead
polybrominated diphenyl ethers
nickel
herbicides
surfactants
PAHs
xenoestrogens
statins
caffeine
triclosan
antidepressants
fluorenes
dibenzo thiophen es

copper

copper

Metals

n nanomaterials
mercury
perfluorinated compounds
zinc

... and the pollution you don’t see

Photo by Blake Feist, NOAA Fisheries
Are major components of urban stormwater runoff sufficient or necessary to cause coho pre-spawn mortality?

**Approach:**
Use a controlled setting to expose adult coho spawners to:
- chemical mixtures,
- urban runoff, and
- filtered urban runoff.

**Endpoints:**
PSM symptomatology or mortality.
Adult coho spawner exposures

Performed at Grovers Creek Salmon Hatchery

**Exposures:**

Static, recirculated, aerated

Overnight duration (some 4 hr or 48 hr)

Separate tanks (4 fish per), control and exposures

Different exposures:

- PAH/metal mixture
- metal mixture
- unfiltered runoff
- filtered runoff
Adult coho spawner exposures

Measurements:
Mortality: number alive following exposure
Behavior: observe any symptomatic behavior
Tissue Analysis: samples of gill, bile, and liver
Water Analysis: metals, PAHs, and conventionals
PAHs/Metals Mixture

- Concentrations starting at high values from in-stream monitoring for 24-48 hours.
- **PAHs** (petro- and pyrogenic):
  - Water accommodated fraction (WAF) of ANSCO e.g. Phenanthrene (0.240 – 0.384 µg/L)
    - Pyrene (0.365 – 0.584 µg/L)
    - Fluoranthene (0.365 – 0.584 µg/L)
- **Metals**:
  - Cadmium (0.3 – 1.8 µg/L)
  - Copper (7.0 – 42.0 µg/L)
  - Lead (1.0 – 6.0 µg/L)
  - Nickel (2.0 – 12.0 µg/L)
  - Zinc (9.0 – 54.0 µg/L)
24-hour exposures to concentrations of 5 metals approximating 5X and 10X higher values than those observed in stream monitoring.
Stormwater Runoff Collection

Collection devices placed at bottom of downspouts from an elevated highway. Water was collected in glass carboys wrapped in black plastic or a stainless steel tank.
Filtered Runoff

Bioretention Drums at Grovers Creek Hatchery

Washington State Department of Ecology

- 2” mulch
- 24” bioretention soil media (60% sand : 40% compost)
- 12” drainage layer (gravel aggregate)
- Cap
- Slotted 2” PVC
- Bulkhead
- 2” ball valve
- Underdrain
Grovers Creek Salmon Hatchery
Grovers Creek Salmon Hatchery
Grovers Creek Salmon Hatchery
Hatchery Pond
Salmon holding tubes in exposure tanks showing recirc flow hoses.
Testing bioretention

Clean well water

Untreated runoff

Treated runoff
Mixture Exposures

**PAHs/Metals Mixture**
   2011: 8 trials (2 for 48 hours)

**Metals only mixture**
   2012: 4 trials

**Results:**

**Behavior**
   No symptoms of PSM

**Mortality**
   No different than controls

**Bile FACs and Gill Metal Analyses**
   Demonstrated uptake of both PAHs and metals
   Tissue levels similar to field collected PSM fish
## Runoff Exposures 2012

**2012: 4 trials**

<table>
<thead>
<tr>
<th>Date</th>
<th>Collection</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nov 2, 2012</td>
<td>Collection: Oct 31-Nov 2</td>
<td>4 hour exposure</td>
</tr>
<tr>
<td>Nov 14, 2012</td>
<td>Collection: Nov 11-13</td>
<td>4 hour exposure</td>
</tr>
</tbody>
</table>

All control fish were alive and behaving normally.

All runoff exposed fish were symptomatic or dead.
<table>
<thead>
<tr>
<th>Study Year</th>
<th>Test Date</th>
<th>Exposure (hours)</th>
<th>Control Water</th>
<th>Untreated Runoff</th>
<th>Treated Runoff</th>
</tr>
</thead>
<tbody>
<tr>
<td>2013</td>
<td>Nov 8</td>
<td>4</td>
<td>100 % Live</td>
<td>50% Dead; 50% Symptomatic</td>
<td>100% Live</td>
</tr>
<tr>
<td>2013</td>
<td>Nov 18</td>
<td>24</td>
<td>100% Live</td>
<td>100% Dead</td>
<td>100% Live</td>
</tr>
<tr>
<td>2014</td>
<td>Oct 20</td>
<td>24</td>
<td>100% Live</td>
<td>100% Dead</td>
<td>100% Live</td>
</tr>
<tr>
<td>2014</td>
<td>Oct 22</td>
<td>24</td>
<td>100% Live</td>
<td>100% Dead</td>
<td>100% Live</td>
</tr>
<tr>
<td>2014</td>
<td>Oct 27</td>
<td>24</td>
<td>100% Live</td>
<td>100% Dead</td>
<td>100% Live</td>
</tr>
</tbody>
</table>

100% of fish exposed to Untreated Runoff were symptomatic or dead by end of exposure.

100% of Control and Treated fish lived
Metals

& PAHs

open symbols = normal/live

closed symbols = symptomatic/dead

Artificial Stormwater

Well Water

Highway Runoff

Filtered Runoff
The tested PAH and metal cocktail was not sufficient to produce PSM symptomology.

The metal cocktail (Cd, Cu, Ni, Pb, Zn) was not sufficient to cause PSM symptomology.

Tested PAHs and metals may still be components necessary to cause PSM.
Adult Exposure Summary

- Stormwater runoff is a complex mixture of contaminants.
- Stormwater runoff contains contaminants sufficient to cause PSM symptomology.
- Treating runoff removed contaminants necessary to cause PSM symptomology.
Stormwater science: a regional collaboration

Research:
NOAA Fisheries, Northwest Fisheries Science Center
U.S. Fish and Wildlife Service, Washington Office
Washington State University, Puyallup Extension

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USFWS National Contaminants Program
Washington State Department of Ecology
City of Seattle
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Mark Tagal
Frank Sommers
Jana Labenia
Kate Macneale
Bernadita Anulacion
Gina Ylitalo
Barb French
Coho PSM Publications

FORENSICS:

http://www.plosone.org/article/info%3Adoi%2F10.1371%2Fjournal.pone.0028013

Contact: Nathaniel.Scholz@noaa.gov

POPULATION MODEL:

DOI: 10.1002/ieam.219.


Contact: Julann.Spromberg@noaa.gov

LAND USE MODEL:
doi:10.1371/journal.pone.0023424.

http://www.plosone.org/article/info%3Adoi%2F10.1371%2Fjournal.pone.0023424

Contact: Blake.Feist@noaa.gov
Stormwater Runoff Exposures 2012

**October 15, 2012**  
*Collection*: October 12-14  
*Controls*: 4 Jacks  
*Exposed*: 3 Jacks, 1 F  
Max exposure 4 hours, Air added

**October 29, 2012**  
*Collection*: October 27, 2012  
*Controls*: 3 M, 1 F  
*Exposed*: 1 M, 3 F  
Max exposure 2 hours, Air added

**November 2, 2012**  
*Collection*: Oct 31-Nov 2  
*Controls*: 4 F  
*Exposed*: 4 F  
Max exposure 4 hours, O₂ added

**November 14, 2012**  
*Collection*: November 11-13  
*Controls*: 4 F  
*Exposed*: 4 F  
Max exposure 4 hours, O₂ added

All Exposed fish symptomatic by end of exposure.  
All Control fish lived and exhibited normal behavior at end of exposure.
Stormwater Runoff Exposures 2013

**November 8, 2013** Collection: November 7, 2013
- Controls: 4 F  Untreated: 4 F  Treated: 1 M 3 F
- Exposure 4 hours: C & Tr All normal Un 2d, 2symptomatic

**November 18, 2013** Collection: Nov 15, 2013
- Controls: 4 F  Untreated: 4 F  Treated: 4 F
- Max exposure 24 hours, C all normal, Un all dead, Tr all alive 3 normal behavior

**December 2, 2013** Collection: Nov 29-Dec 1, 2013, 40% dilution
- Controls: 3 F 1M  Untreated: 3 F 1M  Treated: 4 F
- Max exposure 24 hours  C Normal, Un all dead, Tr lethargic

100% of fish exposed to Untreated Runoff were symptomatic or dead by end of exposure.

100% of Control and Treated fish lived
## Results - Water

<table>
<thead>
<tr>
<th></th>
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<tbody>
<tr>
<td>pH</td>
<td>6.73</td>
<td>7.47</td>
<td>7.22</td>
<td>7.06</td>
<td>7.78</td>
<td>7.9</td>
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<tr>
<td>Alkalinity (mg/L CaCO3)</td>
<td>68.2</td>
<td>36.5</td>
<td>32.1</td>
<td>37.4</td>
<td>93.85</td>
<td>95.8</td>
</tr>
<tr>
<td>Carbonate (mg/L CaCO3)</td>
<td>&lt;1.0 U</td>
<td>&lt;1.0 U</td>
<td>&lt;1.0 U</td>
<td>&lt;1.0 U</td>
<td>&lt;1.0 U</td>
<td>&lt;1.0 U</td>
</tr>
<tr>
<td>Bicarbonate (mg/L CaCO3)</td>
<td>68.2</td>
<td>36.5</td>
<td>32.1</td>
<td>37.4</td>
<td>93.85</td>
<td>95.8</td>
</tr>
<tr>
<td>Hydroxide (mg/L CaCO3)</td>
<td>&lt;1.0 U</td>
<td>&lt;1.0 U</td>
<td>&lt;1.0 U</td>
<td>&lt;1.0 U</td>
<td>&lt;1.0 U</td>
<td>&lt;1.0 U</td>
</tr>
<tr>
<td>TSS (mg/L)</td>
<td>80.9</td>
<td>48.2</td>
<td>58.8</td>
<td>37.6</td>
<td>&lt;1.0 U</td>
<td>&lt;1.0 U</td>
</tr>
<tr>
<td>N-Ammonia (mg-N/L)</td>
<td>3.02</td>
<td>0.749</td>
<td>0.319</td>
<td>0.862</td>
<td>0.2925</td>
<td>0.264</td>
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<tr>
<td>Ortho-Phosphorus (mg-P/L)</td>
<td>0.066</td>
<td>0.037</td>
<td>0.246</td>
<td>0.014</td>
<td>0.24</td>
<td>0.011</td>
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<tr>
<td>TOC (mg/L)</td>
<td>106</td>
<td>15.1</td>
<td>8.84</td>
<td>20.8</td>
<td>&lt;1.50 U</td>
<td>&lt;1.50 U</td>
</tr>
<tr>
<td>DOC(mg/L)</td>
<td>91.6</td>
<td>11.8</td>
<td>5.41</td>
<td>15.4</td>
<td>&lt;1.50 U</td>
<td>&lt;1.50 U</td>
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<tr>
<td>Hardness (mg/L CaCO3)</td>
<td>130</td>
<td>47</td>
<td>35</td>
<td>57</td>
<td>70.5</td>
<td>61</td>
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<tr>
<td>Calcium (mg/L)</td>
<td>45.3</td>
<td>16.2</td>
<td>12.4</td>
<td>20.1</td>
<td>17.05</td>
<td>14.6</td>
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<tr>
<td>Magnesium (mg/L)</td>
<td>4.02</td>
<td>1.65</td>
<td>0.97</td>
<td>1.64</td>
<td>6.7625</td>
<td>5.91</td>
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</table>