May 1st, 10:30 AM - 12:00 PM

# Symptoms of adult coho salmon pre-spawn mortality are not produced by exposures to artificial mixtures of metals and PAHs.

David Hugh Baldwin
*United States. National Marine Fisheries Service*, David.Baldwin@noaa.gov

Julann Spromberg
*United States. National Marine Fisheries Service*

Jay W. Davis
*U.S. Fish and Wildlife Service*

Steven Damm
*U.S. Fish & Wildlife Service*

Jenifer K. McIntyre
*Washington State University*

*See next page for additional authors*

## Speaker

David Hugh Baldwin, Julann Spromberg, Jay W. Davis, Steven Damm, Jenifer K. McIntyre, and Nathaniel L. Scholz

# Symptoms of adult coho salmon pre-spawn mortality are not produced by exposure to artificial mixtures of metals and PAHs

David Baldwin, Julann Spromberg, Steve Damm, Jenifer McIntyre, Jay Davis, Nat Scholz




# Coho pre-spawn mortality (PSM) is widespread and recurrent in urban streams

Longfellow Creek 2003

Des Moines Creek 2004

Longfellow Creek 2005

Coho PSM rates measured in Seattle-area urban streams have ranged from ~ 40 – 90% of the total run (2002-2009, 2012)

# 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.

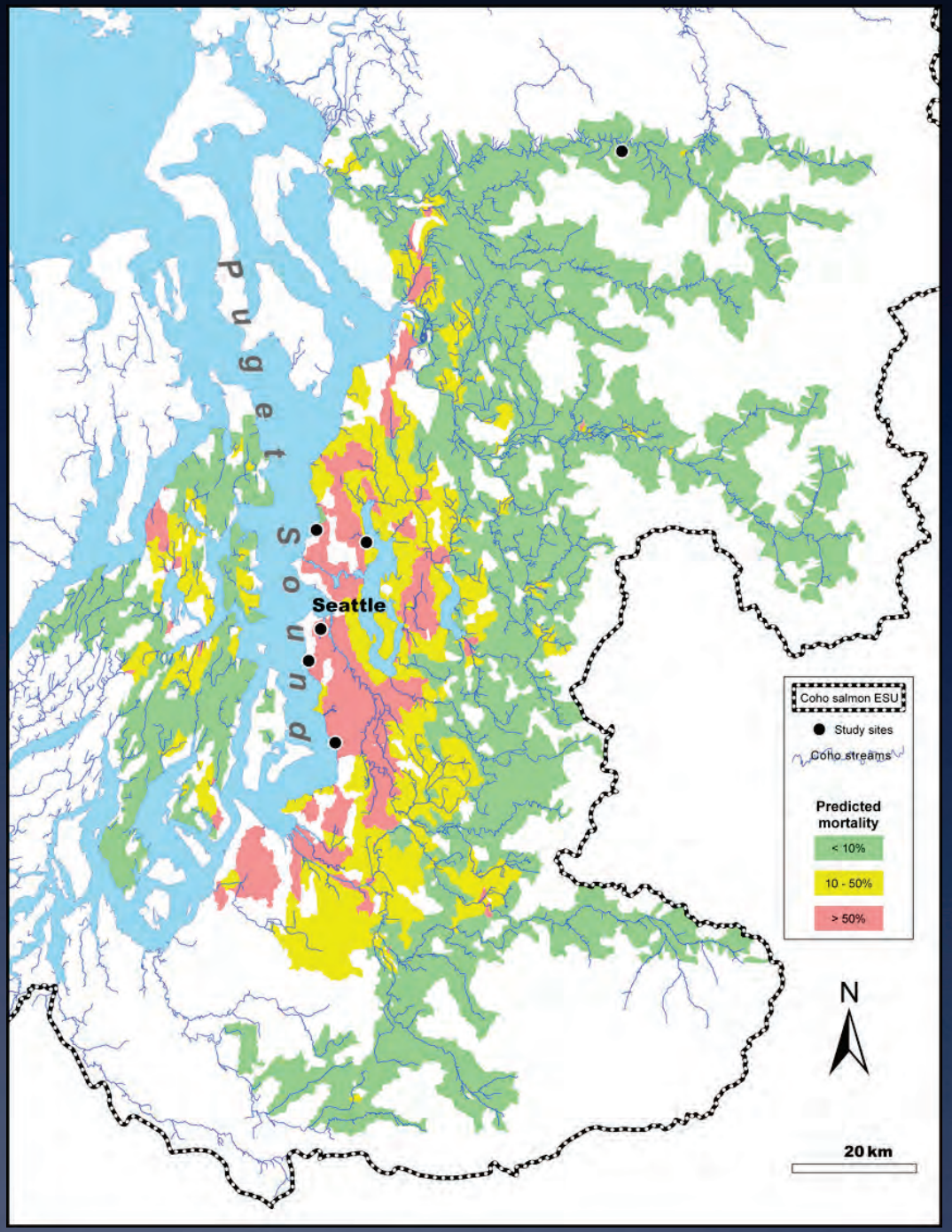
# Predictive Model of Pre-spawn Mortality

**Land Use drivers:**

**Impervious surface**

**Roads**

**Commercial Land Use**




*Feist et al., 2011*

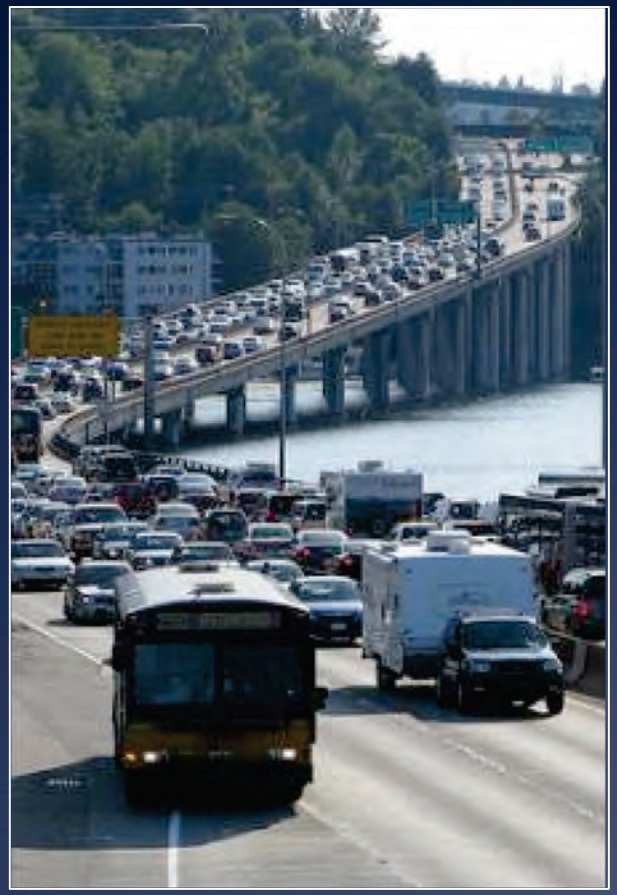
# Urban Stormwater Runoff: an important source of contaminants

Contaminants include:

- **Petroleum products** (PAHs)
- **Metals** (e.g. zinc, copper, lead)
- Pesticides
- PCBs
- Soaps
- Fertilizers
- Cyanide
- Others…

Rapidly being acknowledged as major source of habitat degradation in coastal areas
(PEW Oceans Commission. 2003. Report to U.S. Congress)

# Are major components of urban stormwater runoff sufficient to cause coho pre-spawn mortality?



**Approach:**

Expose adult coho spawners recently returned to freshwater to urban stormwater or chemical mixtures in a controlled setting.

**Endpoints**:

PSM symptomology or mortality.

# Adult coho spawner exposures

Performed at Grover's Creek Salmon Hatchery

**Exposures:**

Static, recirculated, aerated

Overnight duration (some 4 hr or 48 hr)

Two tanks (4 fish per), control and one exposure

Three different exposures:

- PAH/metal mixture,
- metal mixture, or
- stormwater

# 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)

concentrated mixture

# Metals Only Exposures

- 24-hour exposures to concentrations of 5 metals approximating 5X and 10X higher values than those observed in stream monitoring

| metal | 5X Nominal Conc (ug/L) | 10X Nominal Conc (ug/L) |
|---|---|---|
| Cd | 1.5 | 3 |
| Cu | 50 | 100 |
| Pb | 10 | 20 |
| Ni | 20 | 40 |
| Zn | 150 | 300 |

# 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.

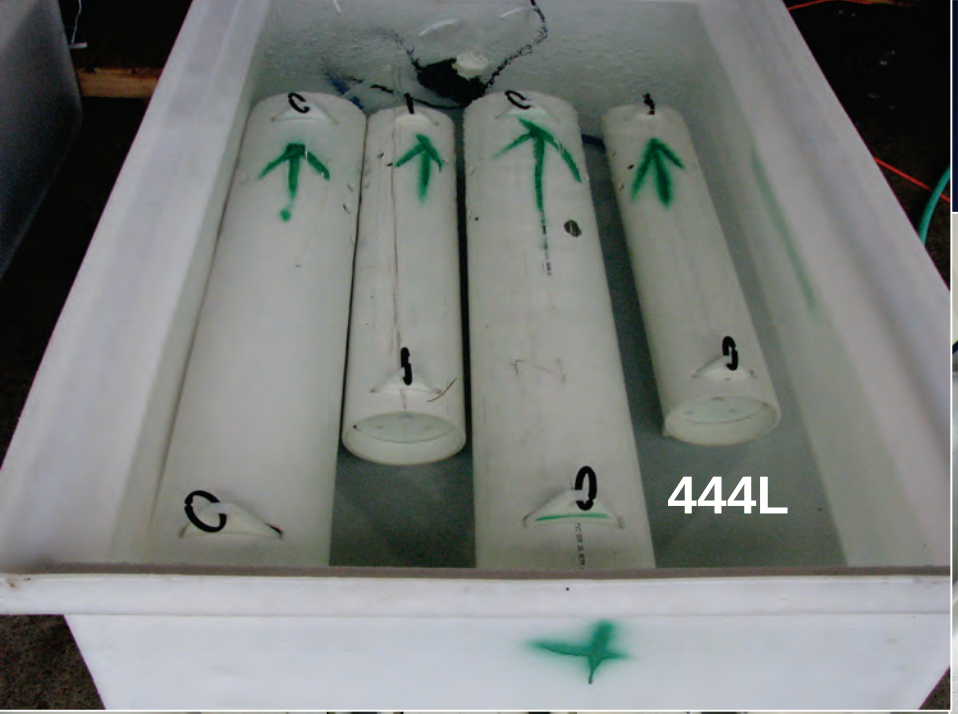
# Grover's Creek Salmon Hatchery

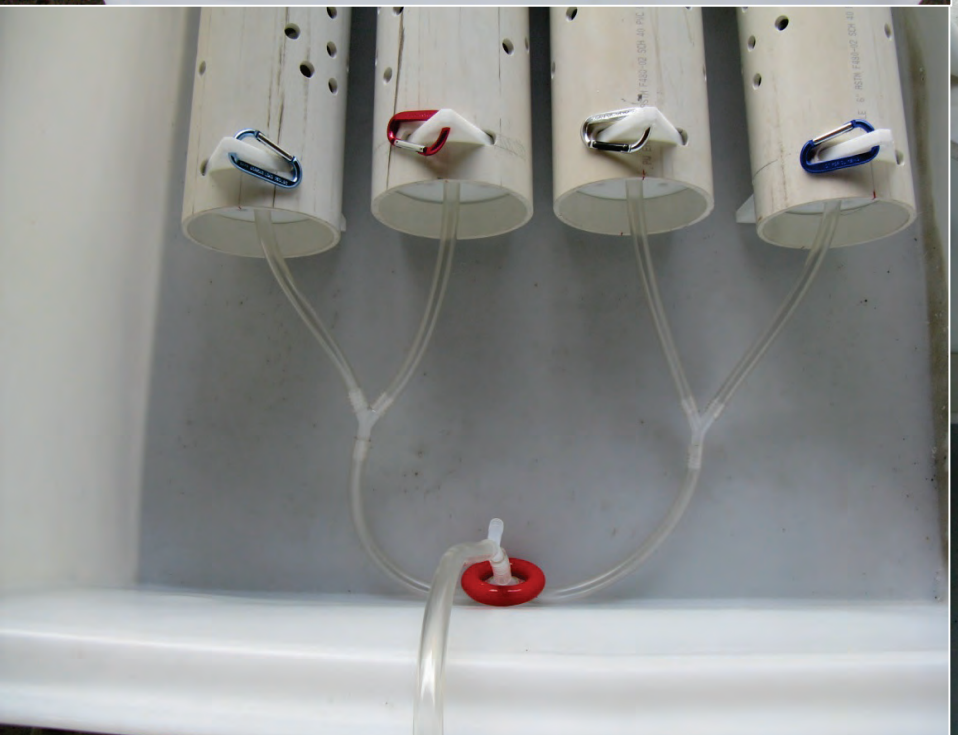
# Grover's Creek Salmon Hatchery

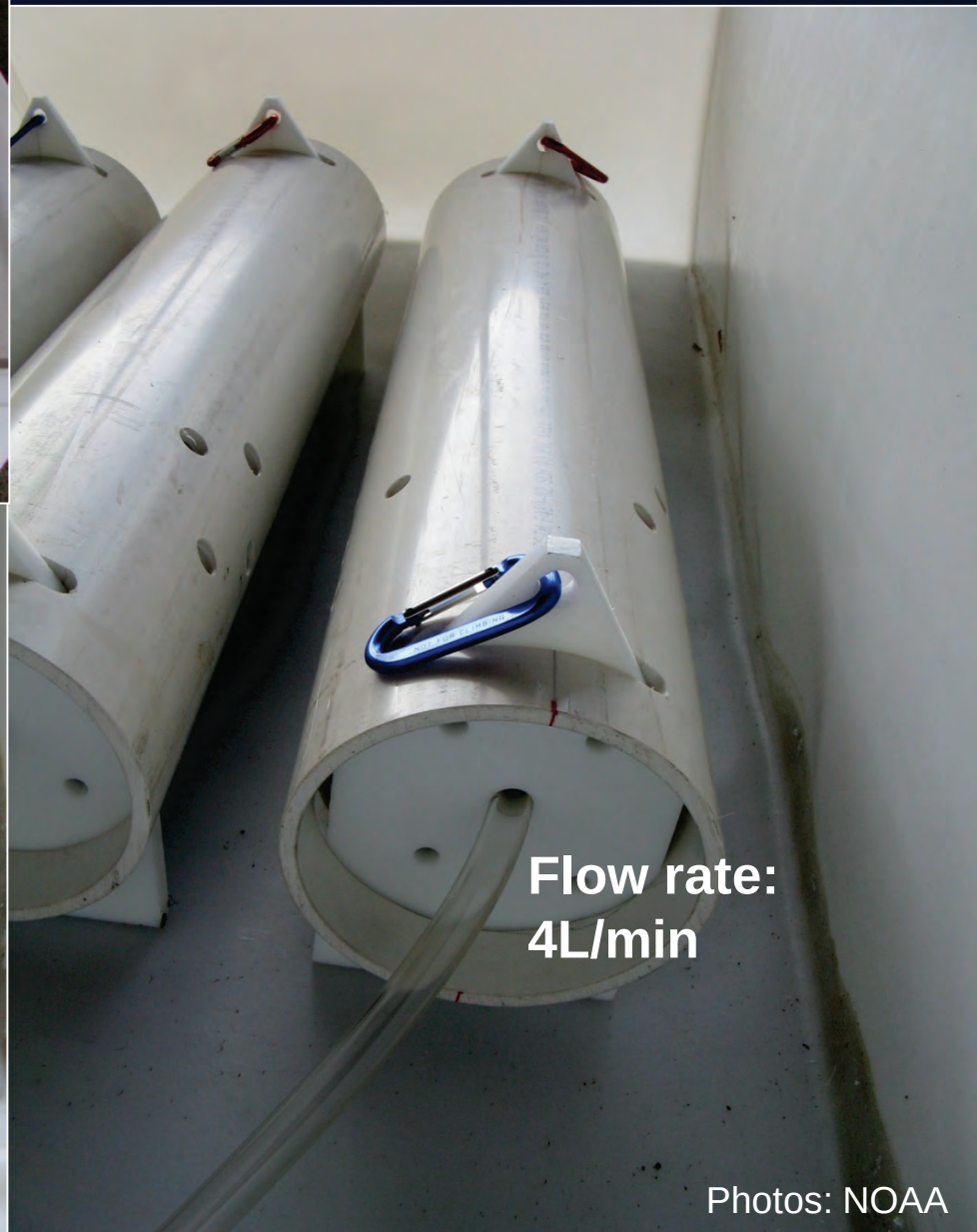
# Grover's Creek Salmon Hatchery
# Hatchery Pond

Photo: NOAA

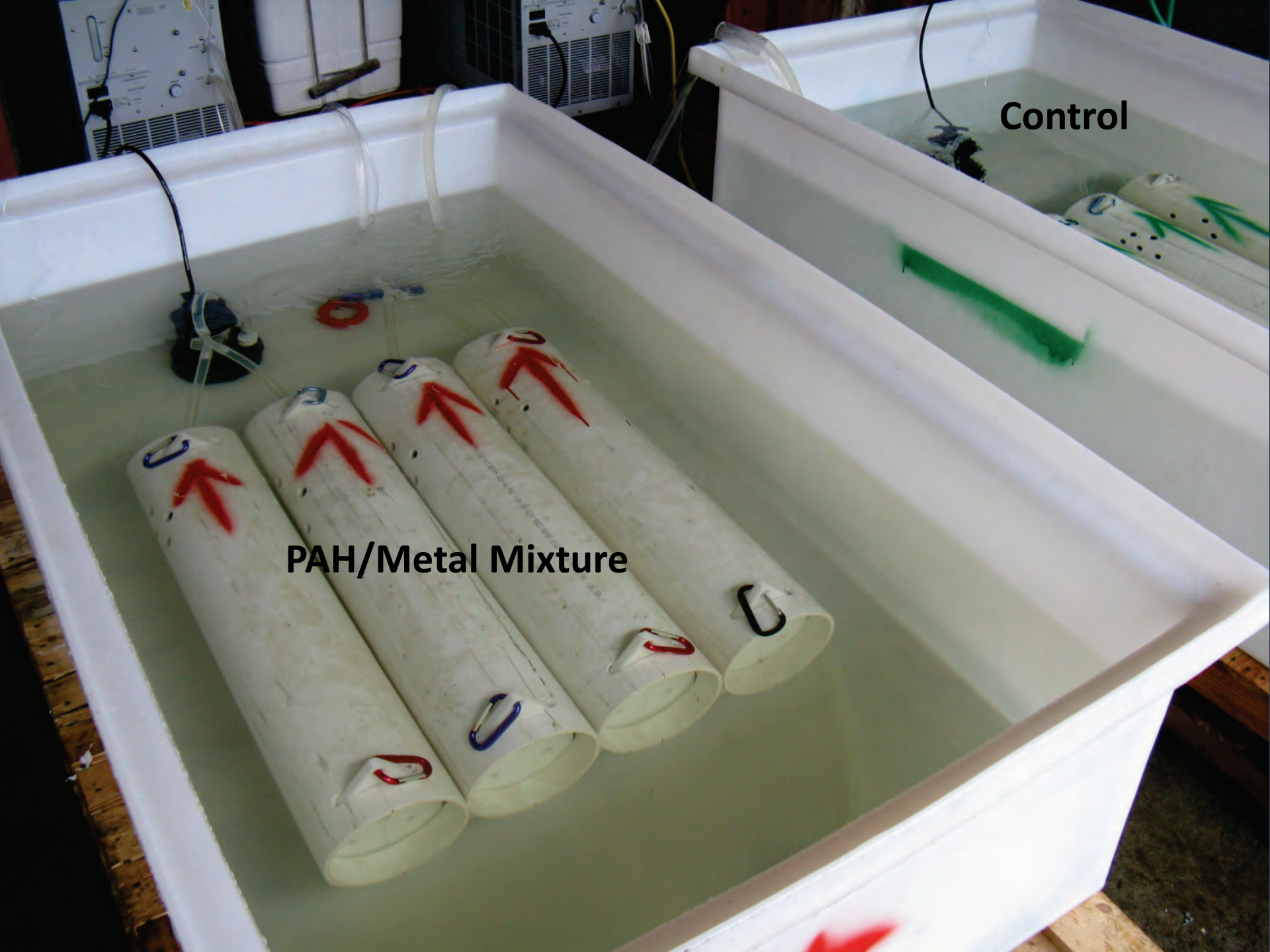
Salmon holding tubes in exposure tanks showing flow hoses.

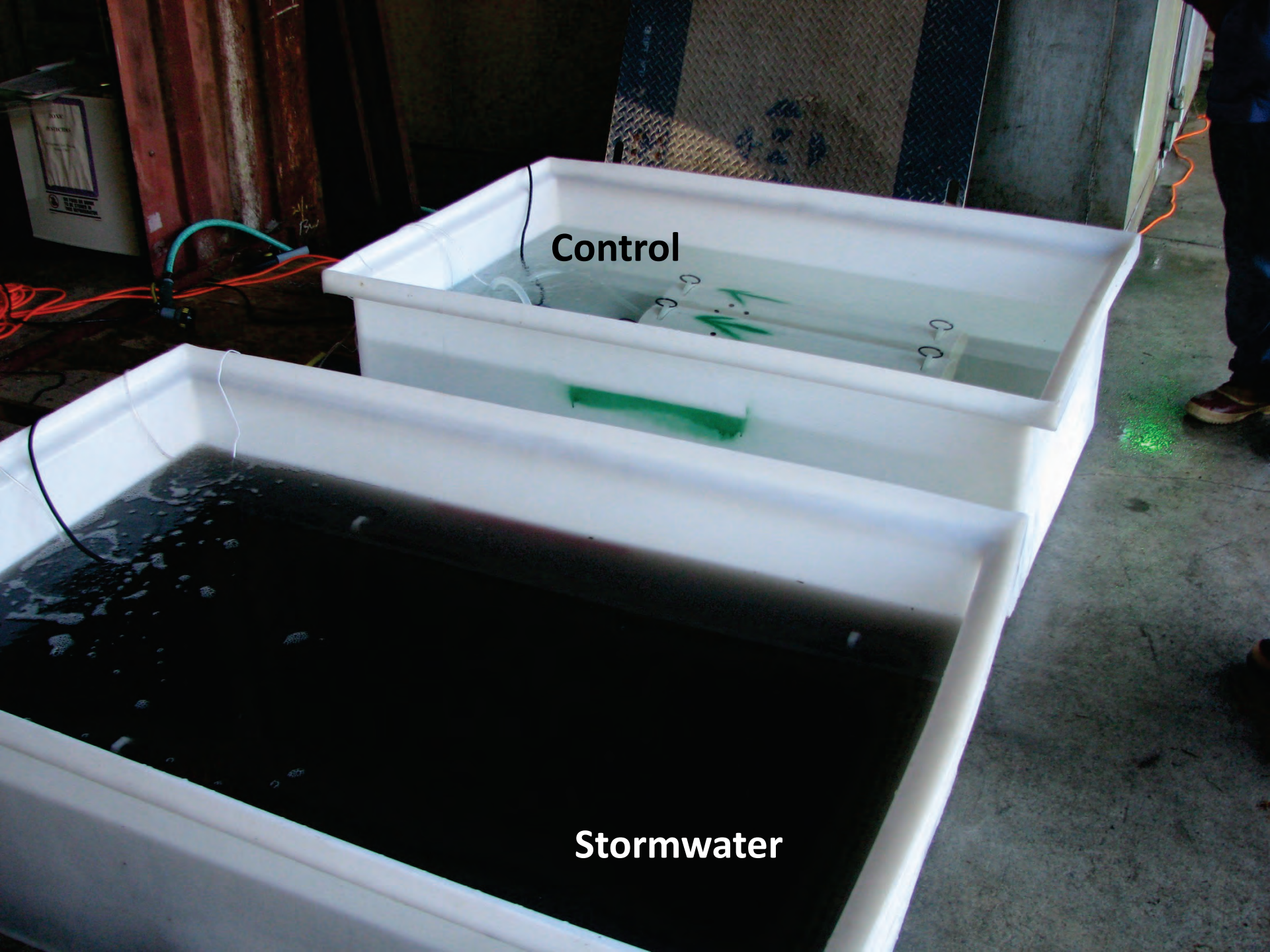





Photos: NOAA


Control
PAH/Metal Mixture


Control
Stormwater

# Stormwater Runoff Exposures

2012-2013: 7 trials

| | | | |
|---|---|---|---|
| Oct 15, 2012 | Collection: Oct 12-14 | 4 hour exposure | 4s |
| Oct 29, 2012 | Collection: Oct 27 | 2 hour exposure | 4s |
| Nov 2, 2012 | Collection: Oct 31-Nov 2 | 4 hour exposure | 4s |
| Nov 14, 2012 | Collection: Nov 11-13 | 4 hour exposure | 4s |
| Nov 8, 2013 | Collection: Nov 7 | 4 hour exposure | 2s/2d |
| Nov 18, 2013 | Collection: Nov 15 | 24 hour exposure | 4d |
| Dec 2, 2013 | Collection: Nov 29-Dec 1 | 24 hour exposure (40% dilution) | 4d |

All Control fish were alive and behaving normally following exposure.

All Exposed fish were symptomatic or dead by end of exposure.

# Cocktail Exposures

***PAHs/Metals Mixture***

2011: 8 trials (2 for 48 hours)

***Metals only mixture***

2012: 4 trials

**Results:**

***Behavior***

No symptoms of PSM

***Mortality***

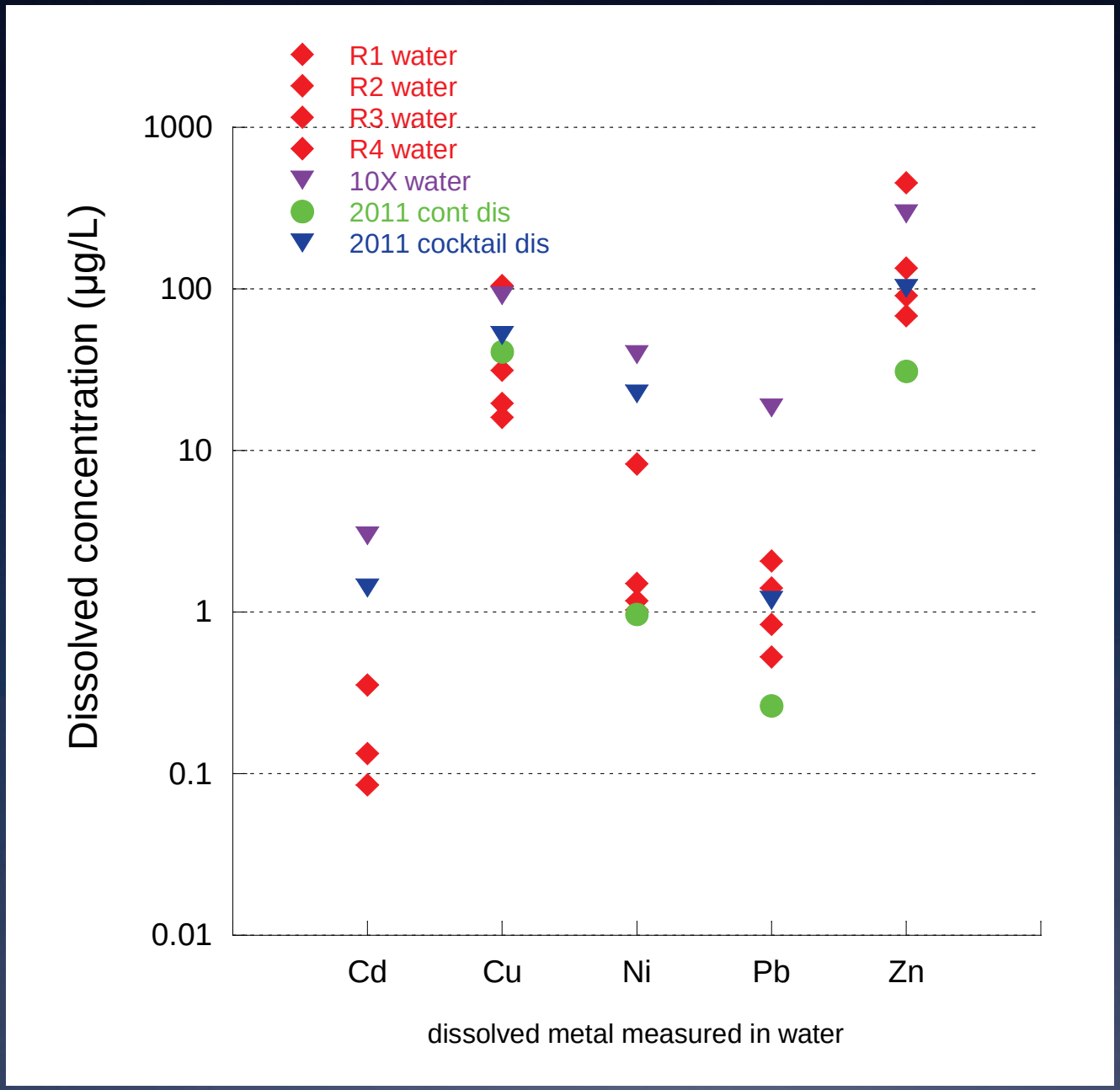
No different than controls

***Bile FACs and Gill Metal Analyses***

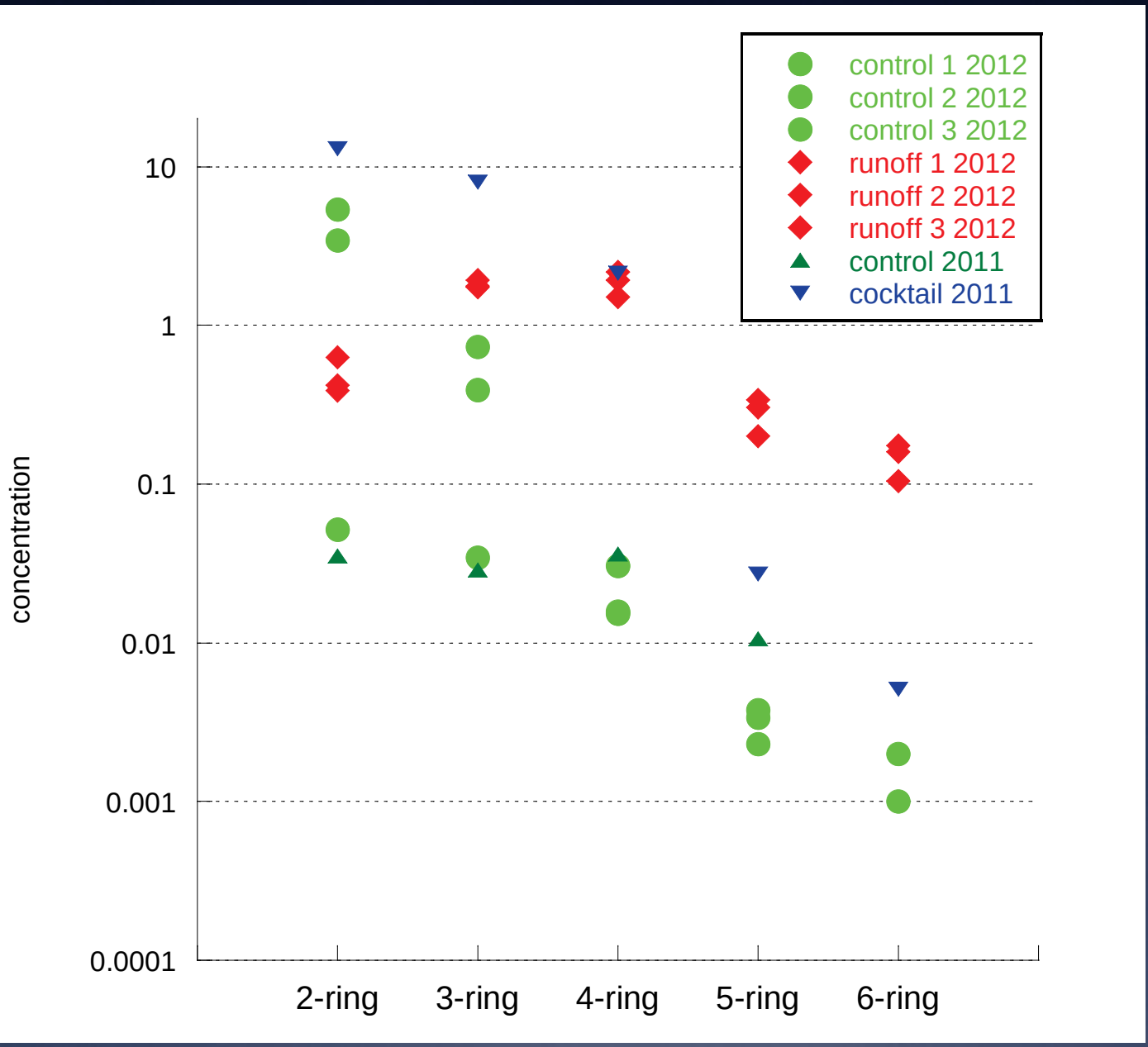
Demonstrated uptake of both PAHs and metals

Tissue levels similar to field collected PSM fish

# Results – Water Metals



# Results – Water PAHs



# Adult Exposure Summary

- Stormwater runoff contains contaminants sufficient to cause PSM symptomology.
- The metal cocktail (Cd, Cu, Ni, Pb, Zn) was not sufficient to cause PSM symptomology.
- The tested PAH and metal cocktail was not sufficient to cause PSM symptomology.

# Important Caveats

- Stormwater runoff is a complex mixture of contaminants.
- Untested PAHs and metals are likely to be present in stormwater.
- The tested PAHs and metals may be components of stormwater **necessary** to cause PSM symptomology.

# Acknowledgements

**Suquamish Tribe Grover's Creek Hatchery Staff and Volunteers**

Mike Huff

Jay Zischke

Bill Alexander

Ben Purser

Kitsap Poggie Club

**USFWS**

Joy Evered

Sharon Lutz

**NOAA**

Allisan Aquilina-Beck

Karen Peck

Mark Tagal

Frank Sommers

Jana Labenia

Kate Macneale

Bernadita Anulacion

Gina Ylitalo

Barb French

# Thanks!

# Results - Water

| measured parameters | Runoff #1 10.15.12 | Runoff #2 10.29.12 | Runoff #3 11.2.12 | Runoff #4 11.14.12 | Runoff Controls | 10X metals 10.31.12 |
|---|---|---|---|---|---|---|
| pH | 6.73 | 7.47 | 7.22 | 7.06 | 7.78 | 7.9 |
| Alkalinity (mg/L CaCO3) | 68.2 | 36.5 | 32.1 | 37.4 | 93.85 | 95.8 |
| Carbonate (mg/L CaCO3) | <1.0 U | <1.0 U | <1.0 U | <1.0 U | <1.0 U | <1.0 U |
| Bicarbonate (mg/L CaCO3) | 68.2 | 36.5 | 32.1 | 37.4 | 93.85 | 95.8 |
| Hydroxide (mg/L CaCO3) | <1.0 U | <1.0 U | <1.0 U | <1.0 U | <1.0 U | <1.0 U |
| TSS (mg/L) | 80.9 | 48.2 | 58.8 | 37.6 | <1.0 U | <1.0 U |
| N-Ammonia (mg-N/L) | 3.02 | 0.749 | 0.319 | 0.862 | 0.2925 | 0.264 |
| Ortho-Phosphorus (mg-P/L) | 0.066 | 0.037 | 0.246 | 0.014 | 0.24 | 0.011 |
| TOC (mg/L) | 106 | 15.1 | 8.84 | 20.8 | <1.50 U | <1.50 U |
| DOC(mg/L) | 91.6 | 11.8 | 5.41 | 15.4 | <1.50 U | <1.50 U |
| Hardness (mg/L CaCO3) | 130 | 47 | 35 | 57 | 70.5 | 61 |
| Calcium (mg/L) | 45.3 | 16.2 | 12.4 | 20.1 | 17.05 | 14.6 |
| Magnesium (mg/L) | 4.02 | 1.65 | 0.97 | 1.64 | 6.7625 | 5.91 |
| | | | | | | |
| Cadmium –total (µg/L) | 0.552 | 0.184 | 0.204 | 0.197 | ND | 3.03 |
| Cadmium -dissolved (µg/L) | 0.355 | ND | 0.085 | 0.133 | ND | 2.98 |
| Copper-total (µg/L) | 153 | 54.9 | 66.1 | 61.4 | 0.9775 | 103 |
| Copper - dissolved(µg/L) | 105 | 19.6 | 16.1 | 31.3 | 0.1675 | 91.2 |
| Lead -total(µg/L) | 13.1 | 10.3 | 12.2 | 7.97 | ND | 19 |
| Lead - dissolved(µg/L) | 1.41 | 0.527 | 0.841 | 1.03 | ND | 18.4 |
| Nickel -total(µg/L) | 10.5 | 5.41 | 4.18 | 4.23 | ND | 40.3 |
| Nickel - dissolved(µg/L) | 8.24 | 1.5 | 1.17 | 2.08 | ND | 39.2 |
| Zinc -total(µg/L) | 589 | 189 | 204 | 223 | 1.87 | 302 |
| Zinc -dissolved(µg/L) | 454 | 68.1 | 91 | 135 | 1.32 | 292 |

# Coho PSM Publications

**FORENSICS:**

Scholz, N.L., Myers, M., McCarthy, S., Labenia, J., McIntyre, J., Ylitalo, G., Rhodes, L., Laetz, C., Stehr, C., French, B., McMillan, B., Wilson, D., Reed, L., Lynch, K., Damm, S., Davis, J.W., Collier, T.K. 2011. Recurrent die-offs of adult coho salmon returning to spawn in Puget Sound lowland urban streams, *PLoS ONE. 6(12*): e28013. doi:10.1371/journal.pone.0028013.

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

Contact: Nathaniel.Scholz@noaa.gov

**POPULATION MODEL:**

Spromberg, J.A. & Scholz, N.L. 2011. Estimating the Future Decline of Wild Coho Salmon Populations Resulting from Early Spawner Die-Offs in Urbanizing Watersheds of the Pacific Northwest, USA. *Integrated Environmental Assessment and Management* 7(4):648-656.

DOI: 10.1002/ieam.219.

http://onlinelibrary.wiley.com/doi/10.1002/ieam.219/full

Contact: Julann.Spromberg@noaa.gov

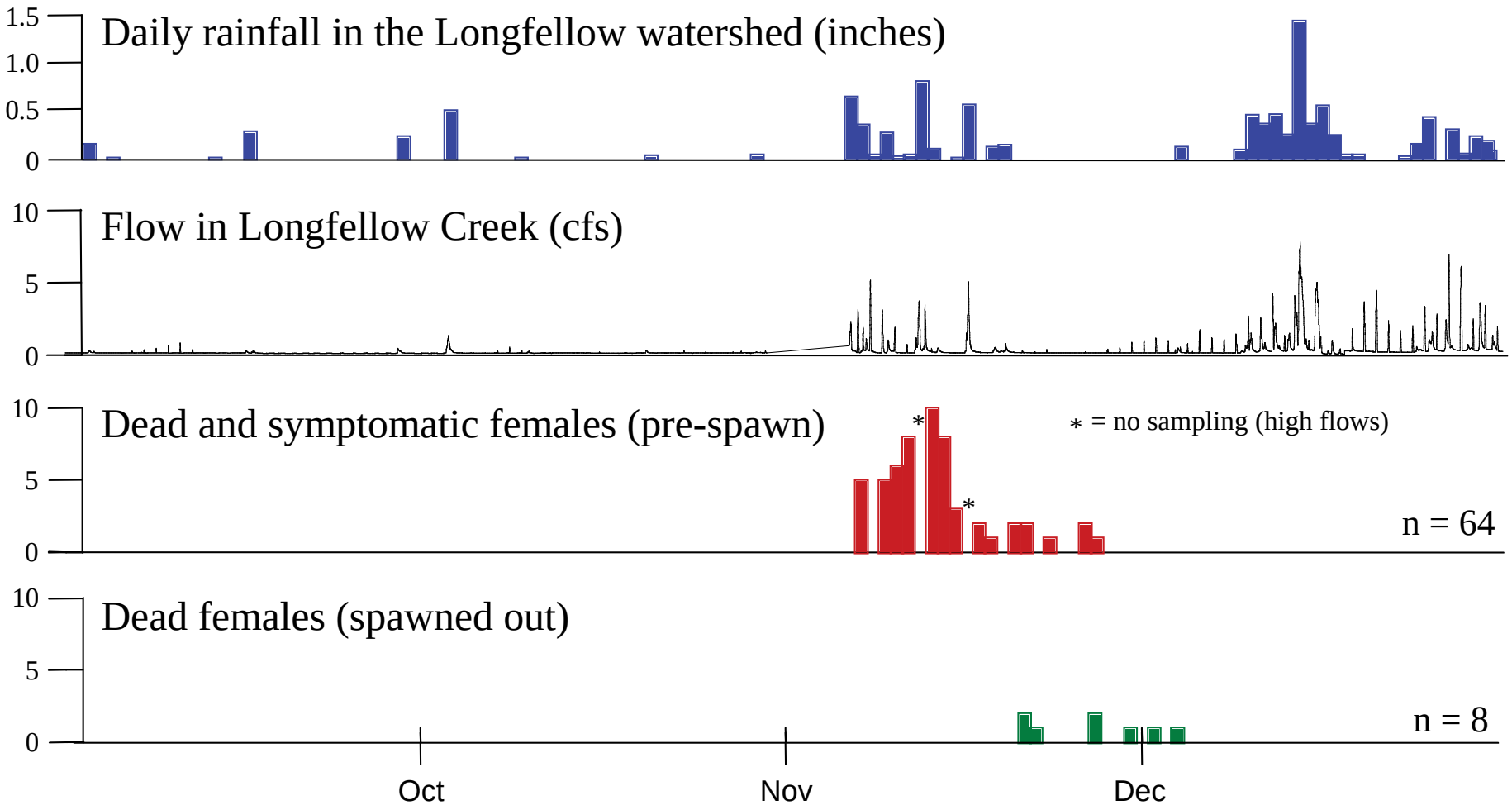
**LAND USE MODEL:**

Feist, B.E., Buhle, E.R., Arnold, P., Davis, J.W., & Scholz, N.L. 2011. Landscape ecotoxicology of coho salmon spawner mortality in urban streams. *PLoS ONE*. 6(8): e23424. doi:10.1371/journal.pone.0023424.

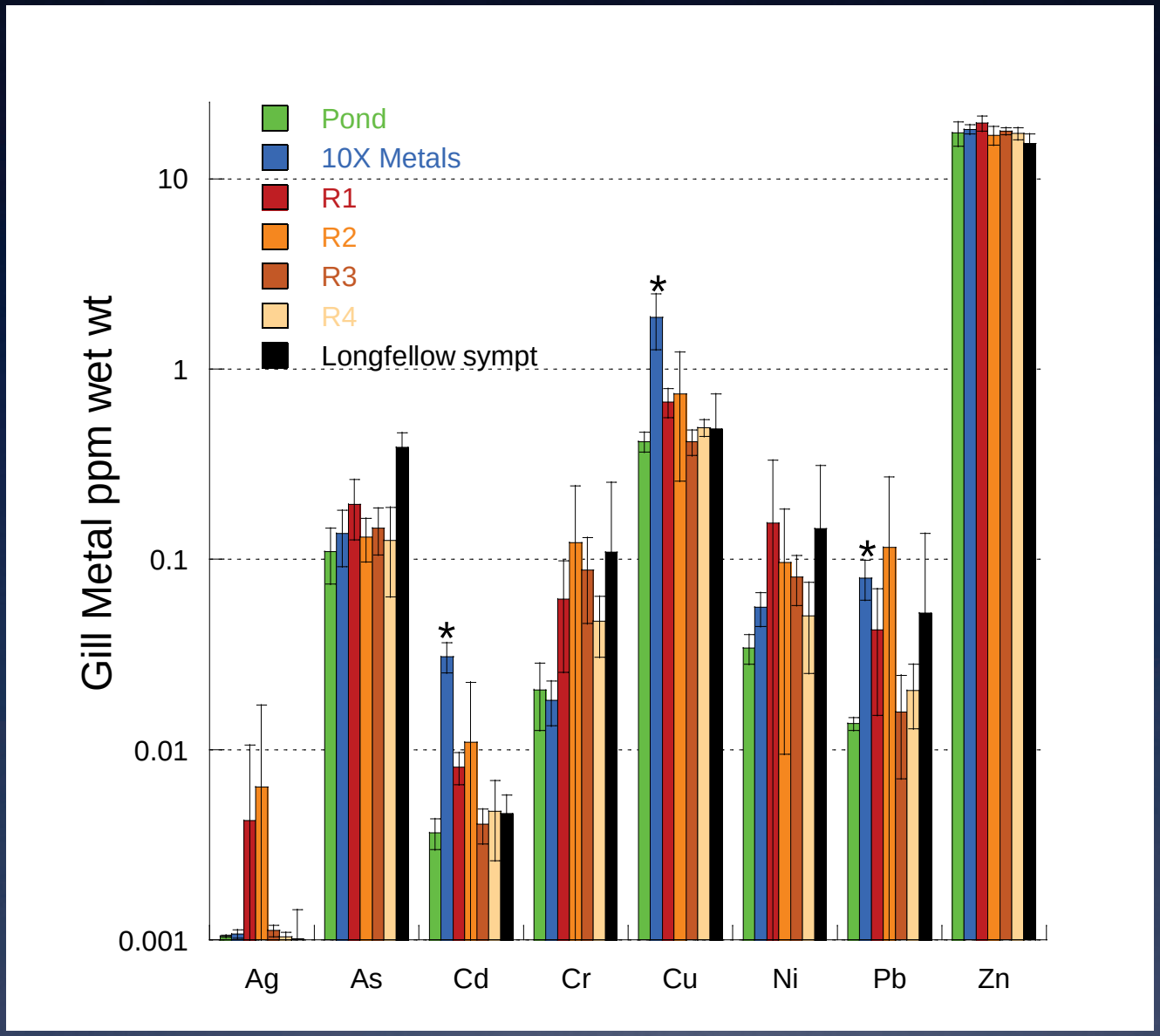
http://www.plosone.org/article/info%3Adoi%2F10.1371%2Fjournal.pone.0023424

Contact: Blake.Feist@noaa.gov

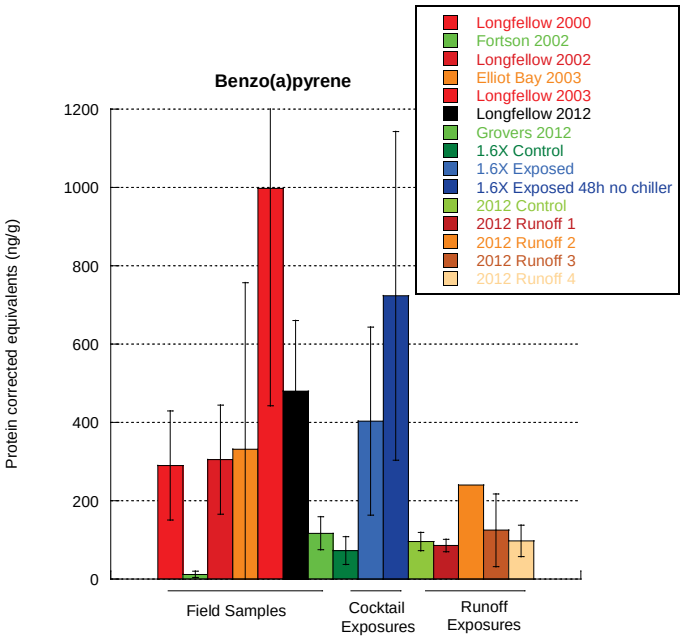
# Documented pre-spawn mortality in Longfellow Creek, Fall 2002

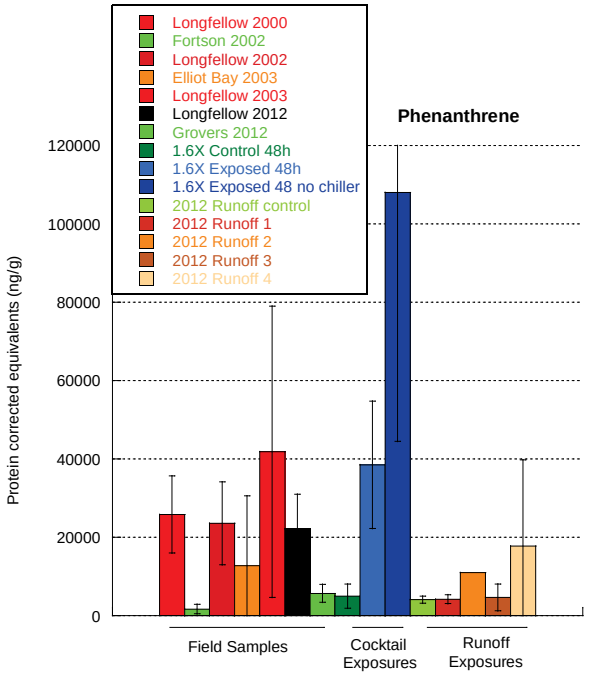


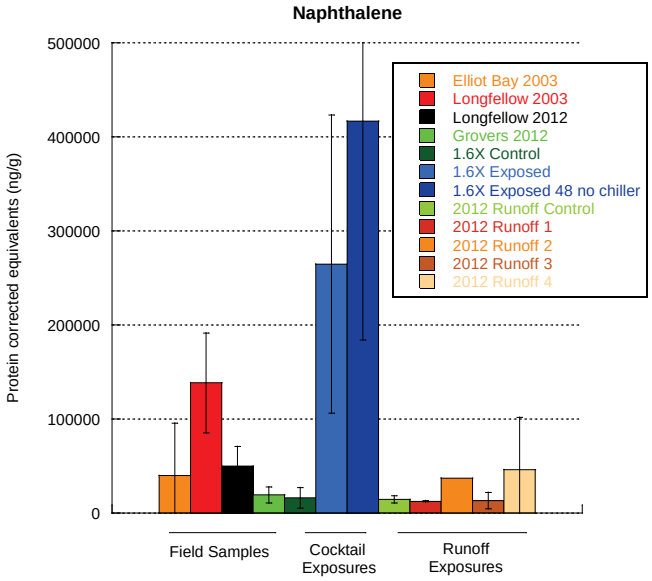
# Results – Gill Metals

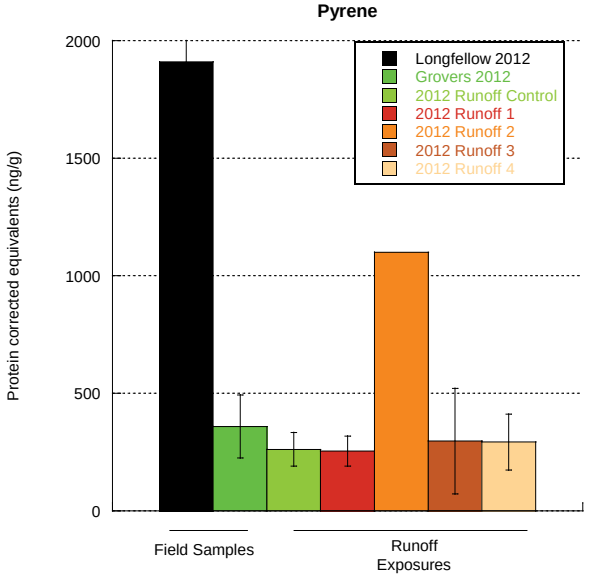


# Results – Bile FACs



# Loading Fish

Photo: Tiffany Royal

# 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, $O_2$ added

*November 14, 2012* *Collection*: November 11-13
*Controls*: 4 F *Exposed*: 4 F
Max exposure 4 hours, $O_2$ 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**