Stormwater Runoff – Toxicity and Treatment

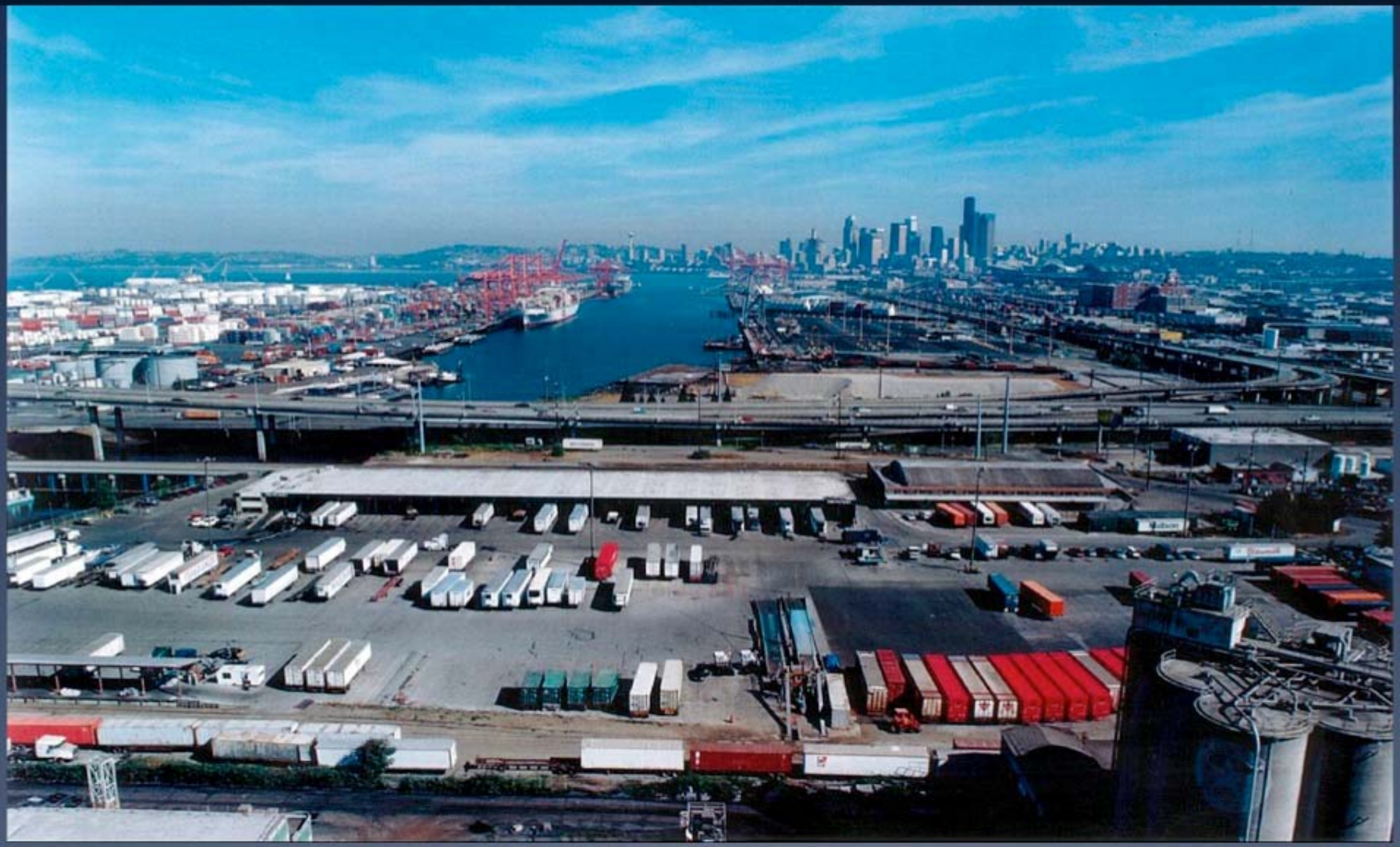
Jen McIntyre WSU | October 21, 2015

WASHINGTON STATE UNIVERSITY

Underwater video of an urban stormwater outfall

West Seattle diving footage by Laura James (www.tox-ick.org)

This is not a forest



Montlake Cut, Seattle

The stormwater pollution you see…

Photo by Blake Feist, NOAA Fisheries

Montlake Cut, Seattle

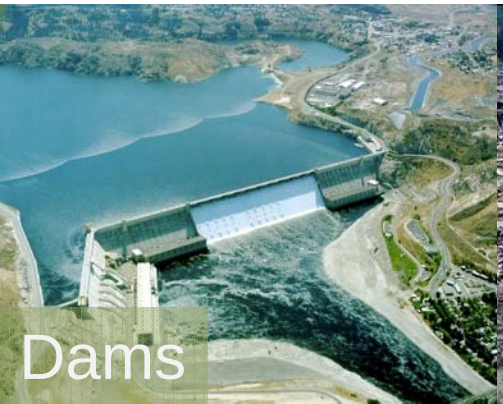
Newly hatched salmon in their gravel redd

Pacific Salmon Declines

* 28 distinct population segments: 5 endangered, 23 threatened

* 176,000 sq. miles in Washington, Oregon, Idaho & California

* 61% of Washington's land area, 55% of Oregon's, 26% of Idaho's, & 32% of California's


Dams


Logging


Hatcheries

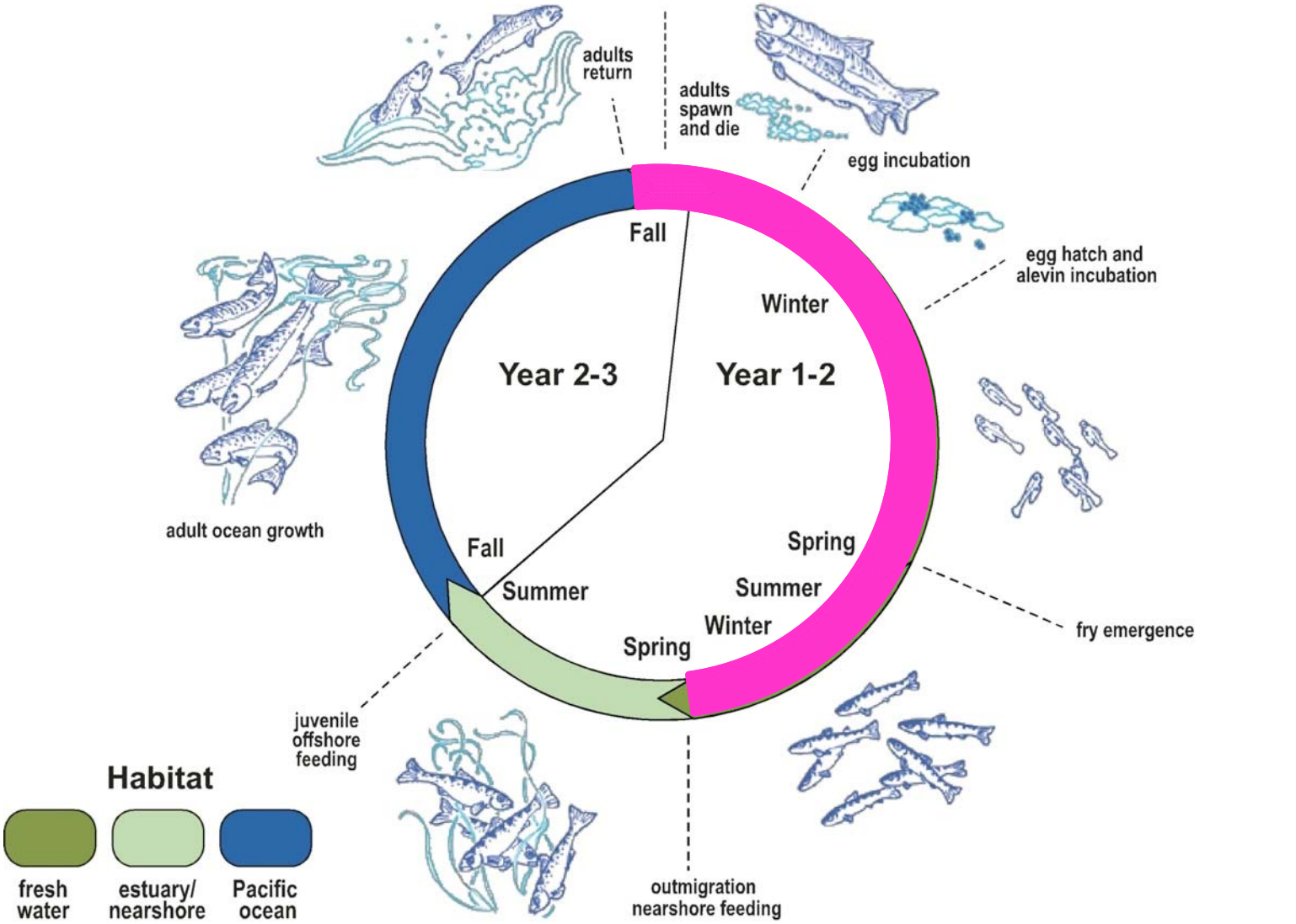

Urbanization

Coho salmon as stormwater sentinel

StreamNet.org

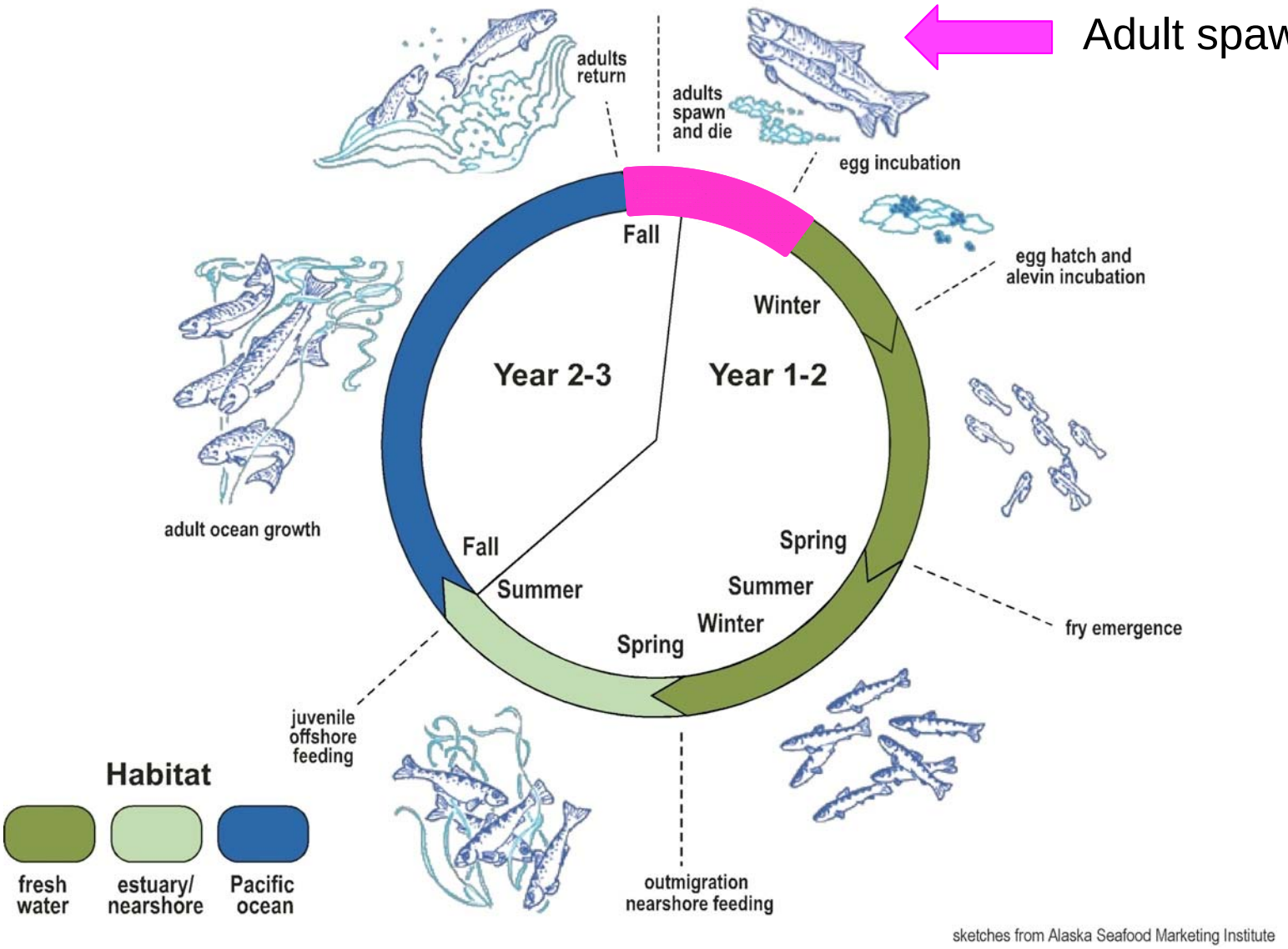
- Widely distributed
- Lowland streams
- > 1 yr in freshwater
- Supported by a diverse food web
- Sensitive to water quantity & quality
- ESA-Listed SOC/ Threatened

Impact of Stormwater on Coho Salmon



sketches from Alaska Seafood Marketing Institute

Impact of Stormwater on Coho Salmon

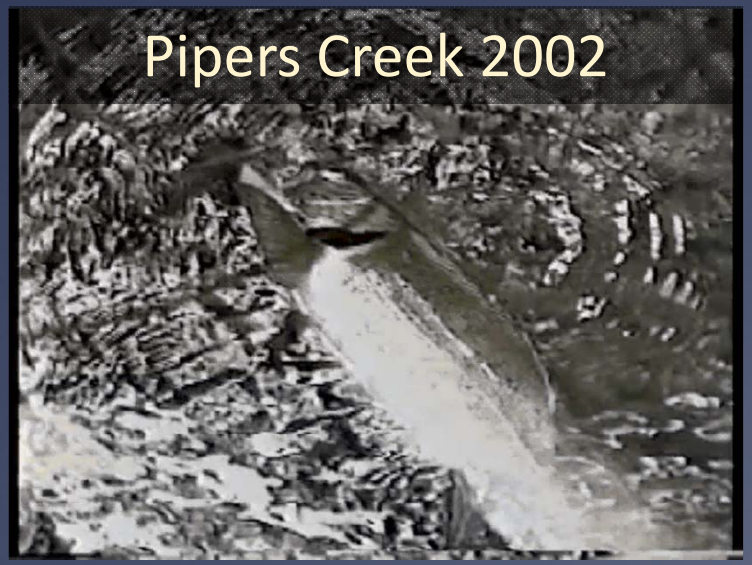


A common suite of PSM symptoms

Longfellow Creek 2002

Longfellow Creek 2005

Pipers Creek 2002



Longfellow Creek 2012

Coho spawner mortality is widespread and recurrent in urban creeks

67%

Longfellow Creek 2003

Des Moines Creek 2004

63%

72%

Longfellow Creek 2005

Longfellow Creek 2012

84%

Coho prespawn mortality findings

Major findings:

- Adult spawners are consistently dying each fall
- The phenomenon is widespread in urban watersheds
- Mortality rates are typically high (60-90% of total run)
- Toxic urban runoff appears to be causal

OPEN ACCESS Freely available online

(2011, 6(8):e28013)

PLoS one

Recurrent Die-Offs of Adult Coho Salmon Returning to Spawn in Puget Sound Lowland Urban Streams

Nathaniel L. Scholz[1]*, Mark S. Myers[1], Sarah G. McCarthy[2], Jana S. Labenia[1], Jenifer K. McIntyre[1], Gina M. Ylitalo[1], Linda D. Rhodes[1], Cathy A. Laetz[1], Carla M. Stehr[1], Barbara L. French[1], Bill McMillan[3], Dean Wilson[2], Laura Reed[4], Katherine D. Lynch[4], Steve Damm[5], Jay W. Davis[5], Tracy K. Collier[1]

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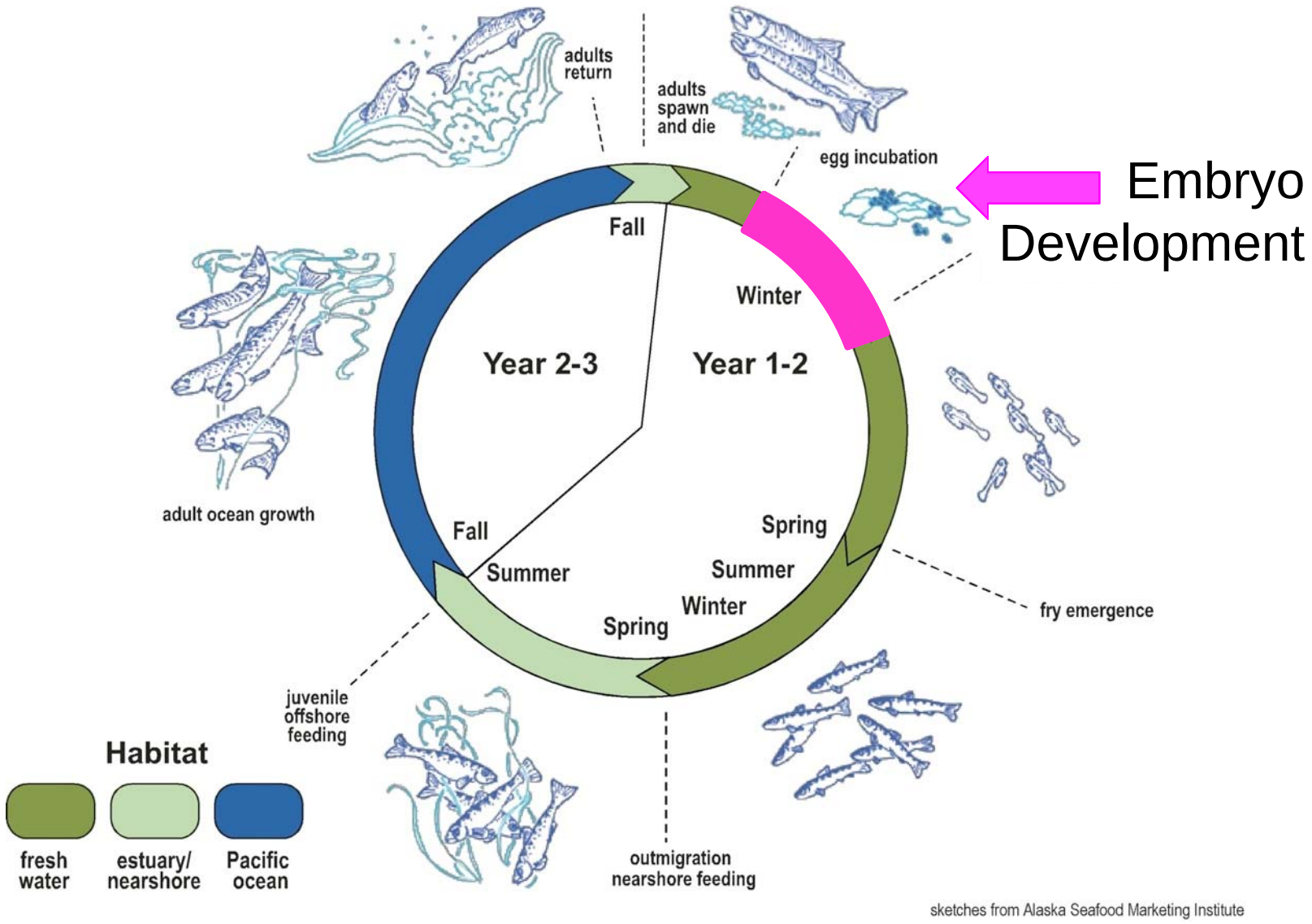
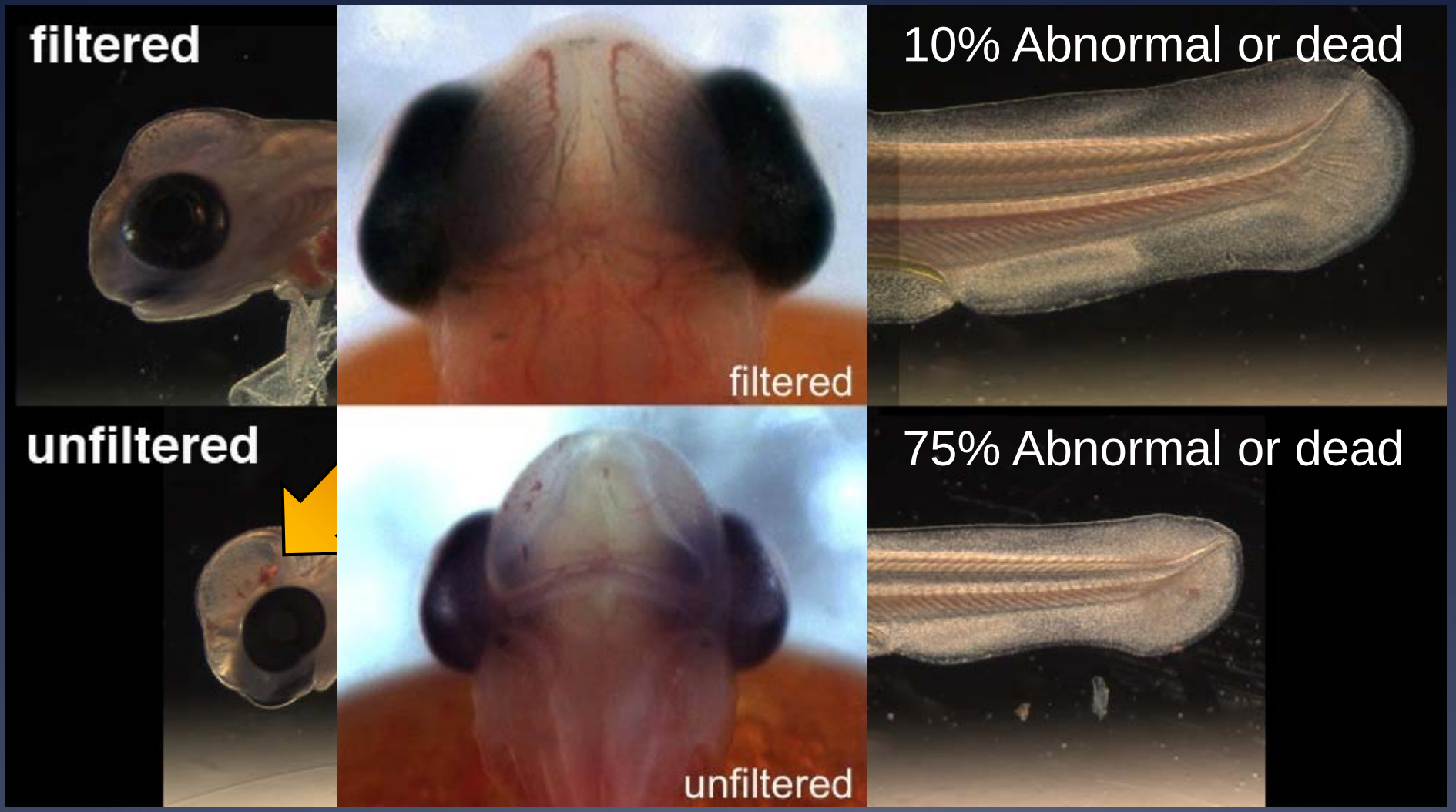
Impacts of Stormwater on Coho Salmon



Experimental filtration of urban runoff

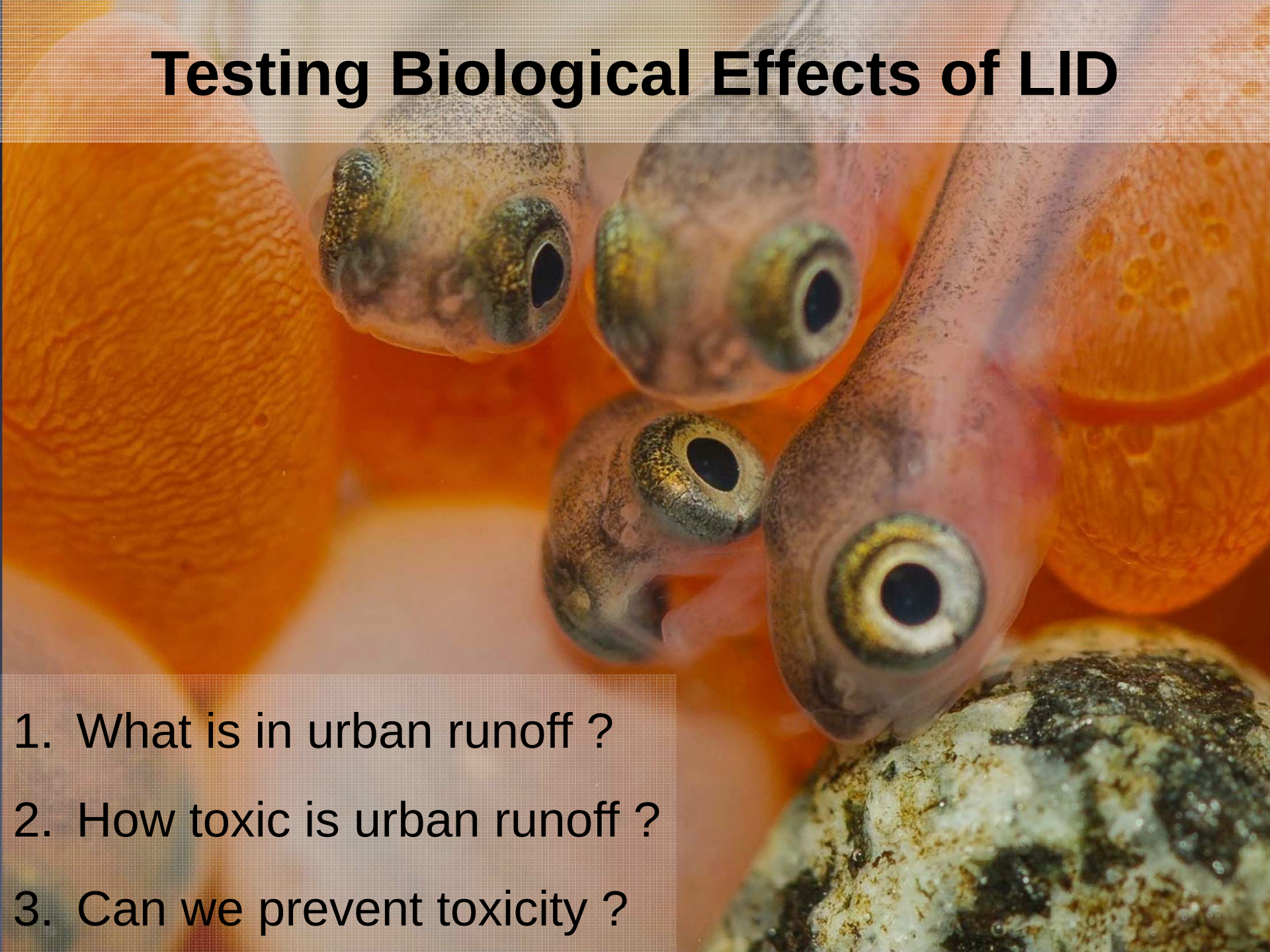
Stormwater research on urban Longfellow Creek, Seattle

Urban runoff is toxic to coho embryos



Longfellow Creek experimental facility, ~ 50 days of development

Testing Biological Effects of LID



1. What is in urban runoff ?
2. How toxic is urban runoff ?
3. Can we prevent toxicity ?

Highway Stormwater Runoff

Urban highway, Seattle, >60,000 AADT

Highway Stormwater Runoff

Downspout from highway

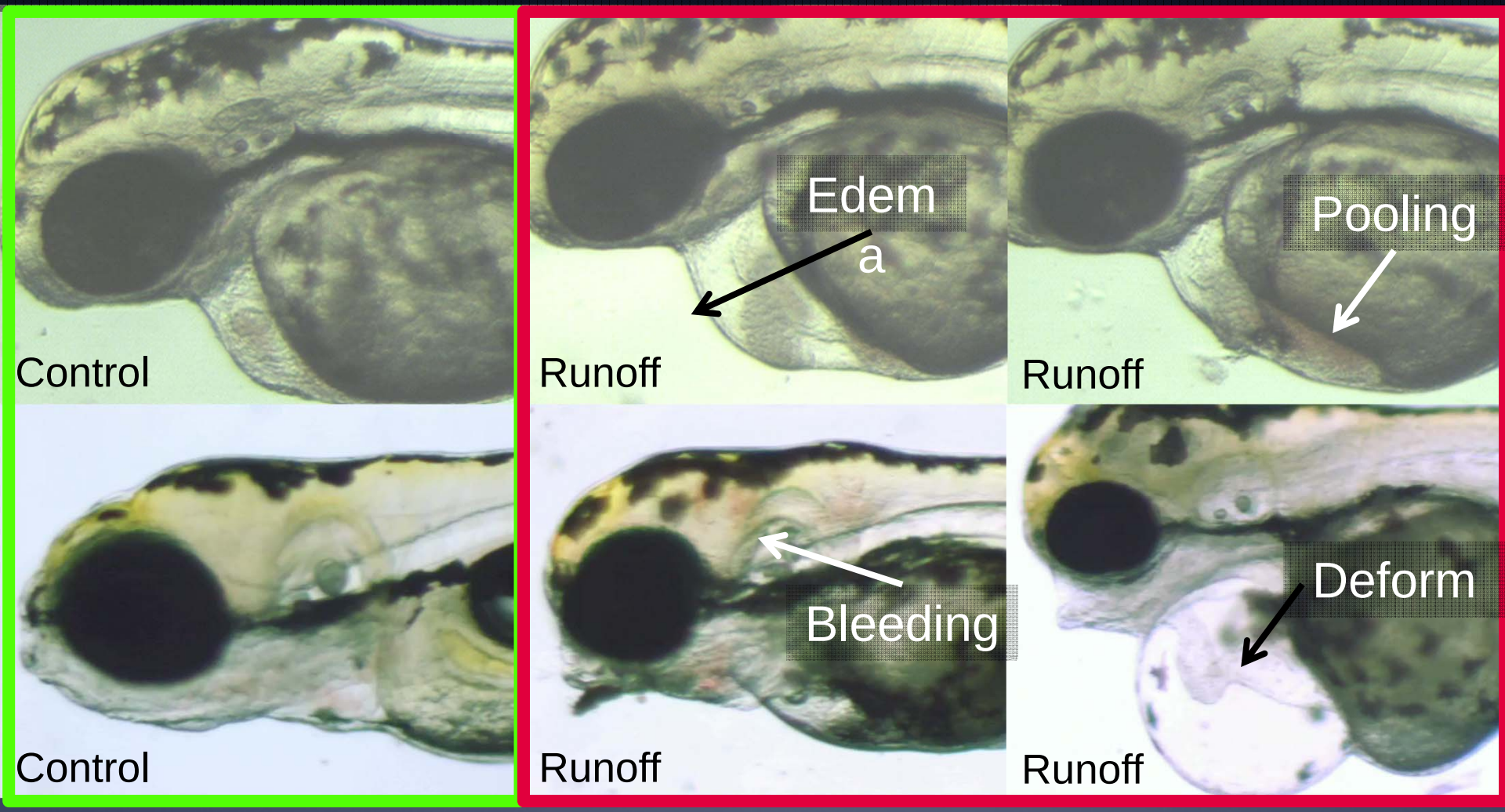
Captured first flush

Sublethal effects of runoff on developing fish

Sublethal effects of runoff on developing fish include:

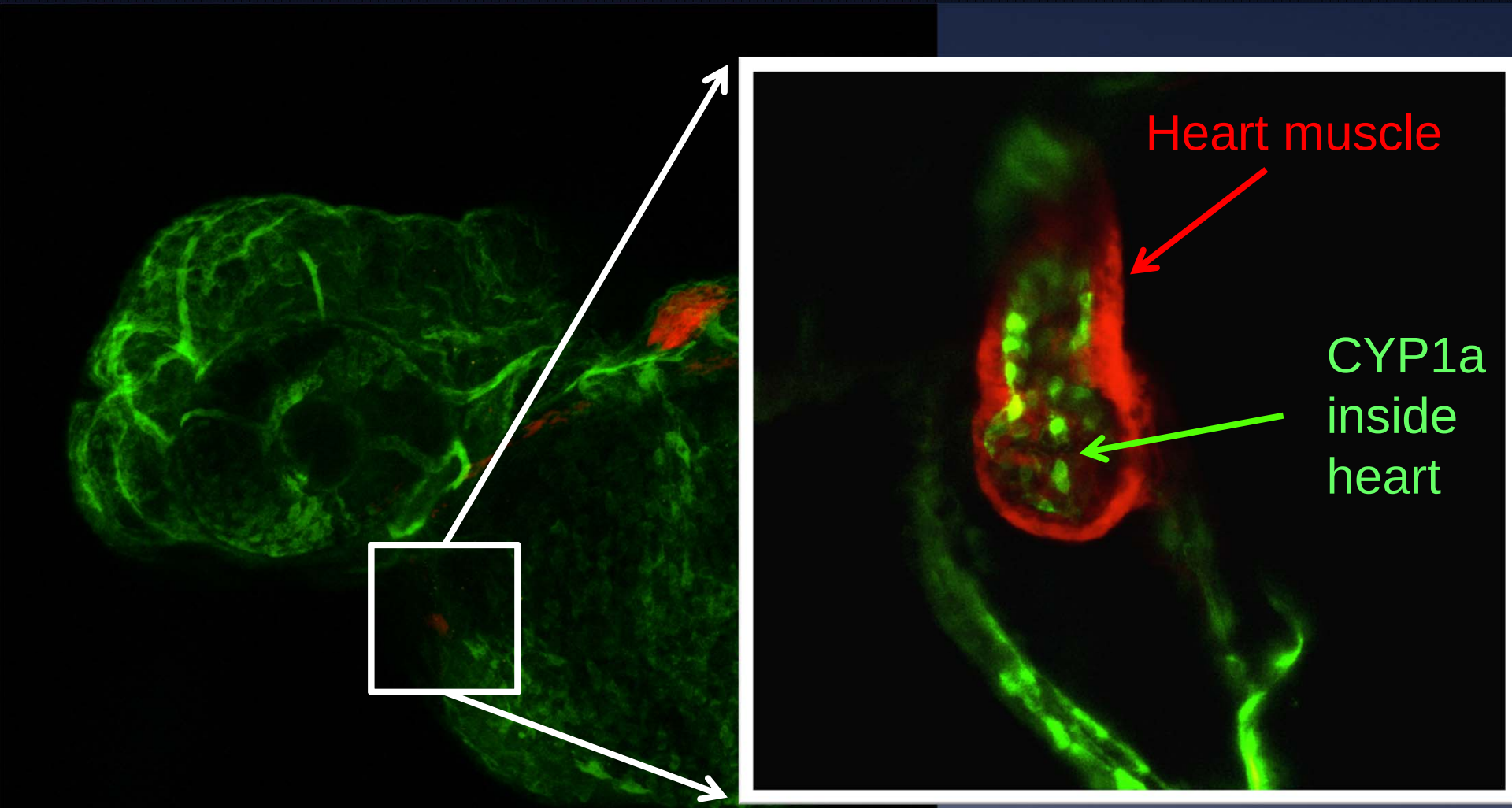
- Inability/delay to hatch
- Developmental delays
- Small eye phenotype (*)
- Pericardial edema (yellow arrow)
- Deformed jaws and hearts (black arrows)

Cardiac abnormalities from runoff



Urban runoff gives zebrafish bad hearts

Heart is a target for road runoff contaminants



CYP1a = Detox gene for PAHs

McIntyre et al. Env Sci Technol. Submitted

Recreating Coho Salmon PSM

Is exposure to urban runoff sufficient to cause coho pre-spawn mortality?

Grover’s Creek facility, Suquamish Tribe

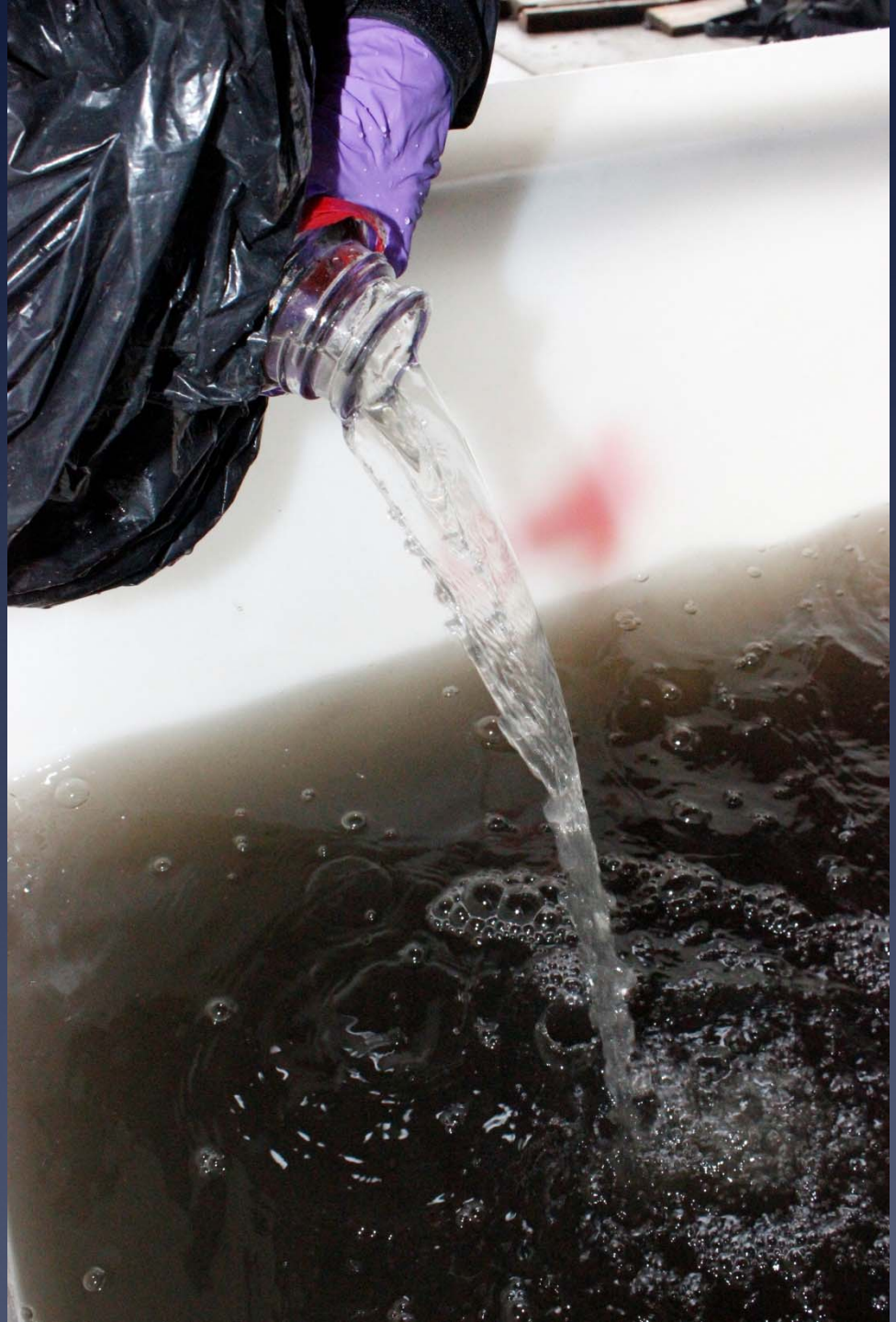


Photo: Tiffany Royal

Exposing adult coho spawners to stormwater under controlled experimental conditions

clean well water

stormwater

Exposure to urban runoff is sufficient to cause adult coho pre-spawner mortality

unexposed (3.5 hrs)

stormwater-exposed (3.5 hr)

November 11th, 2012

Evolving science, from…

“What’s the problem?”

to

“What’s the solution?”

Green Stormwater Infrastructure

Bioretention

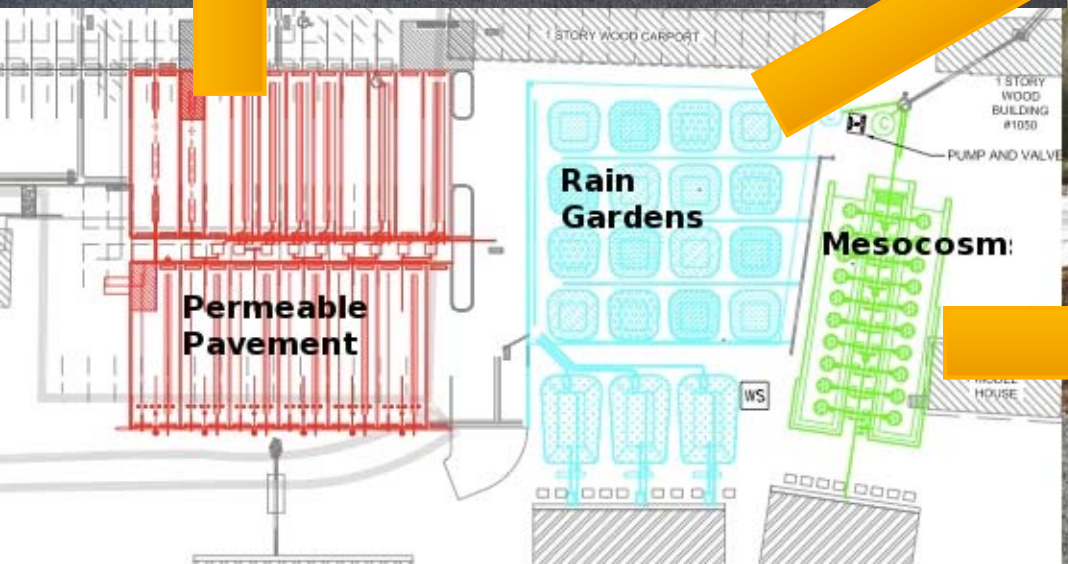
Green roof

Pervious pavement

Emerging technologies for the built landscape may be less harmful to salmon and other aquatic animals

WSU Puyallup GSI Facility

Permeable Pavement



B)

Rain Gardens

C)

Mesocosms

WASHINGTON STATE UNIVERSITY

WSU Puyallup GSI Facility


HAULER


HAULER
HAULER
HAULER

Test with Target Organisms

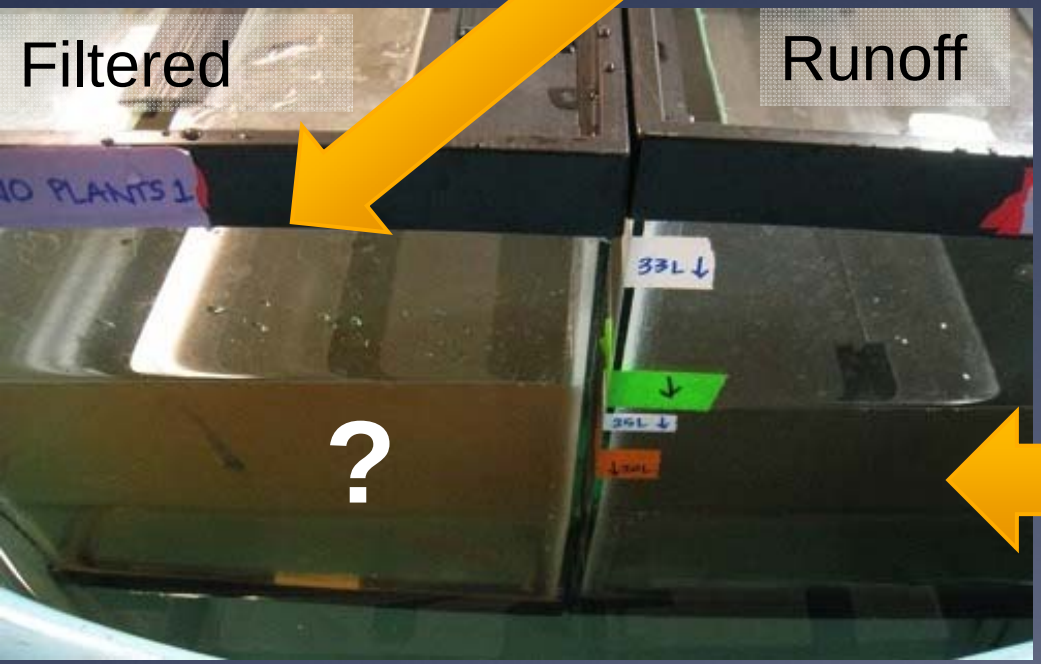
Did bioretention filtration prevent toxicity?

Juvenile coho - controls

100% Survival

Filtered

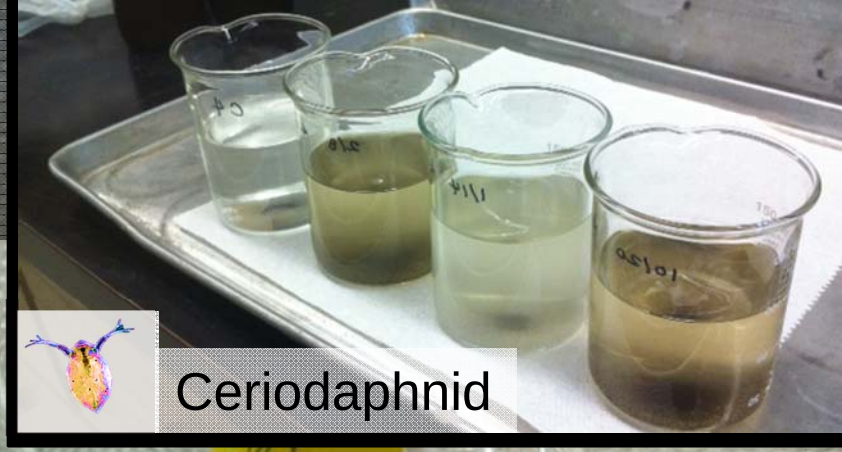
Runoff



?

100% Mortality

Invertebrate Tests



Ceriodaphnid

Control

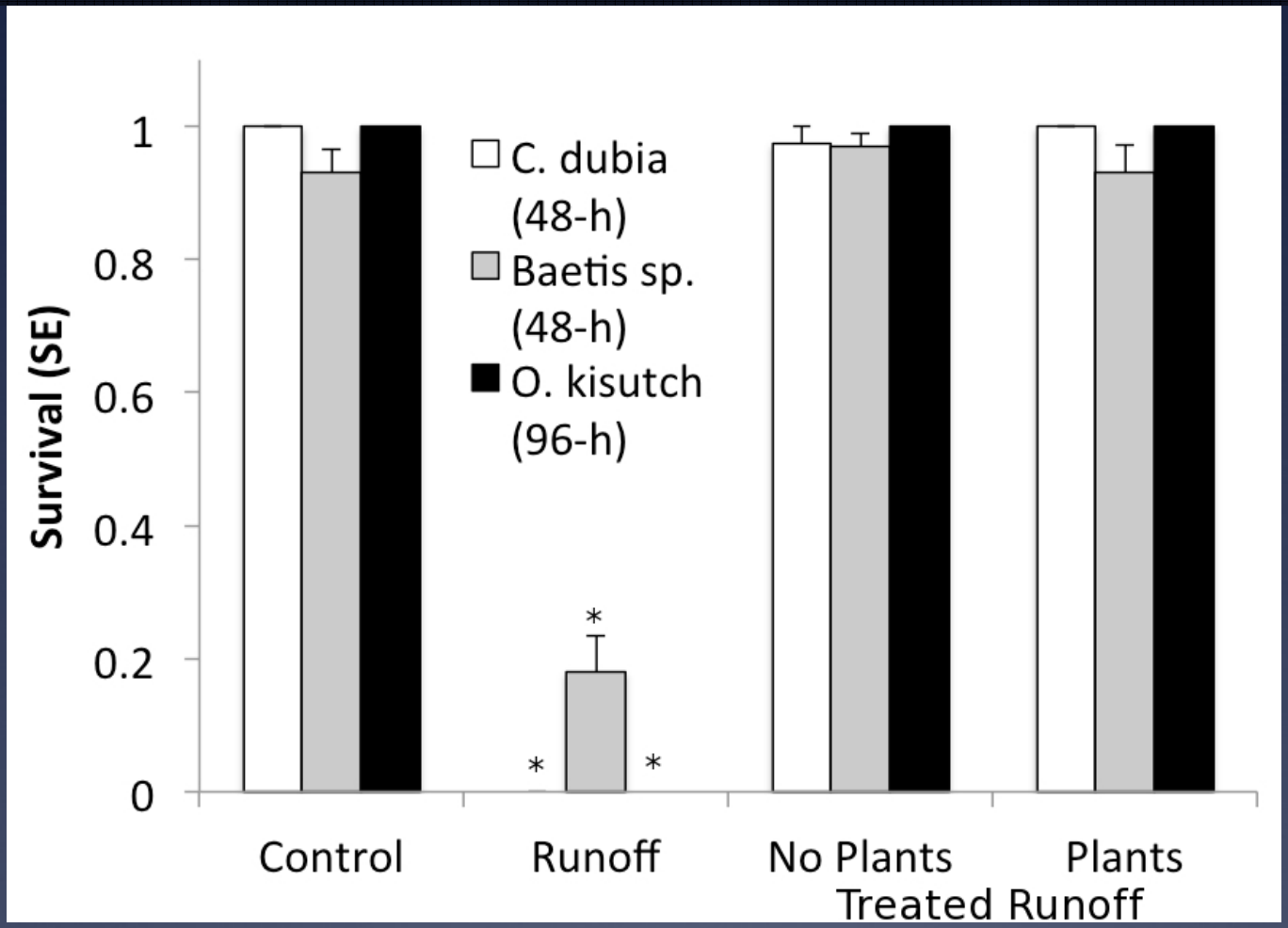
Plants

No Plants

Untreated Runoff

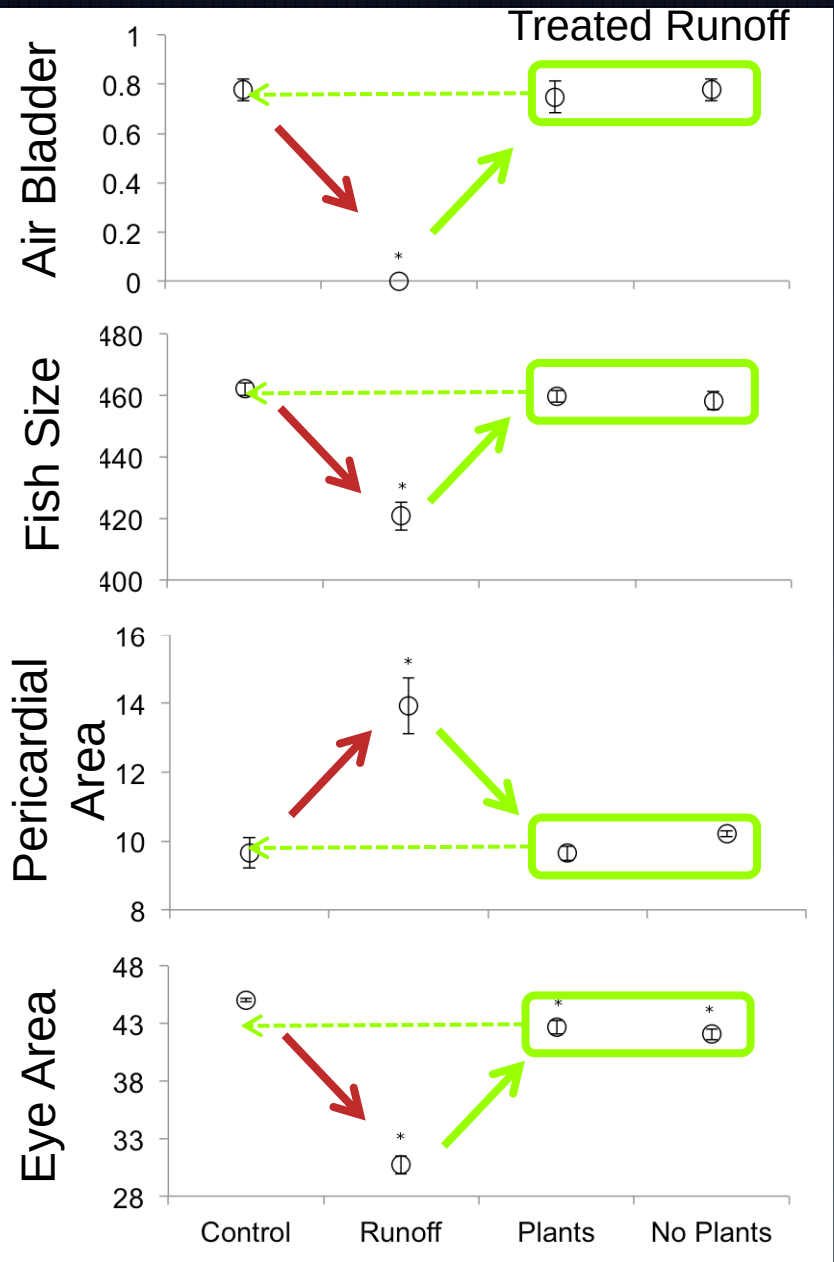
Mayfly larvae

Bioretention Prevents Mortality



Lethal response abolished by soil bioretention treatment

No sublethal toxicity in zfish embryos!



Normal Air Bladders

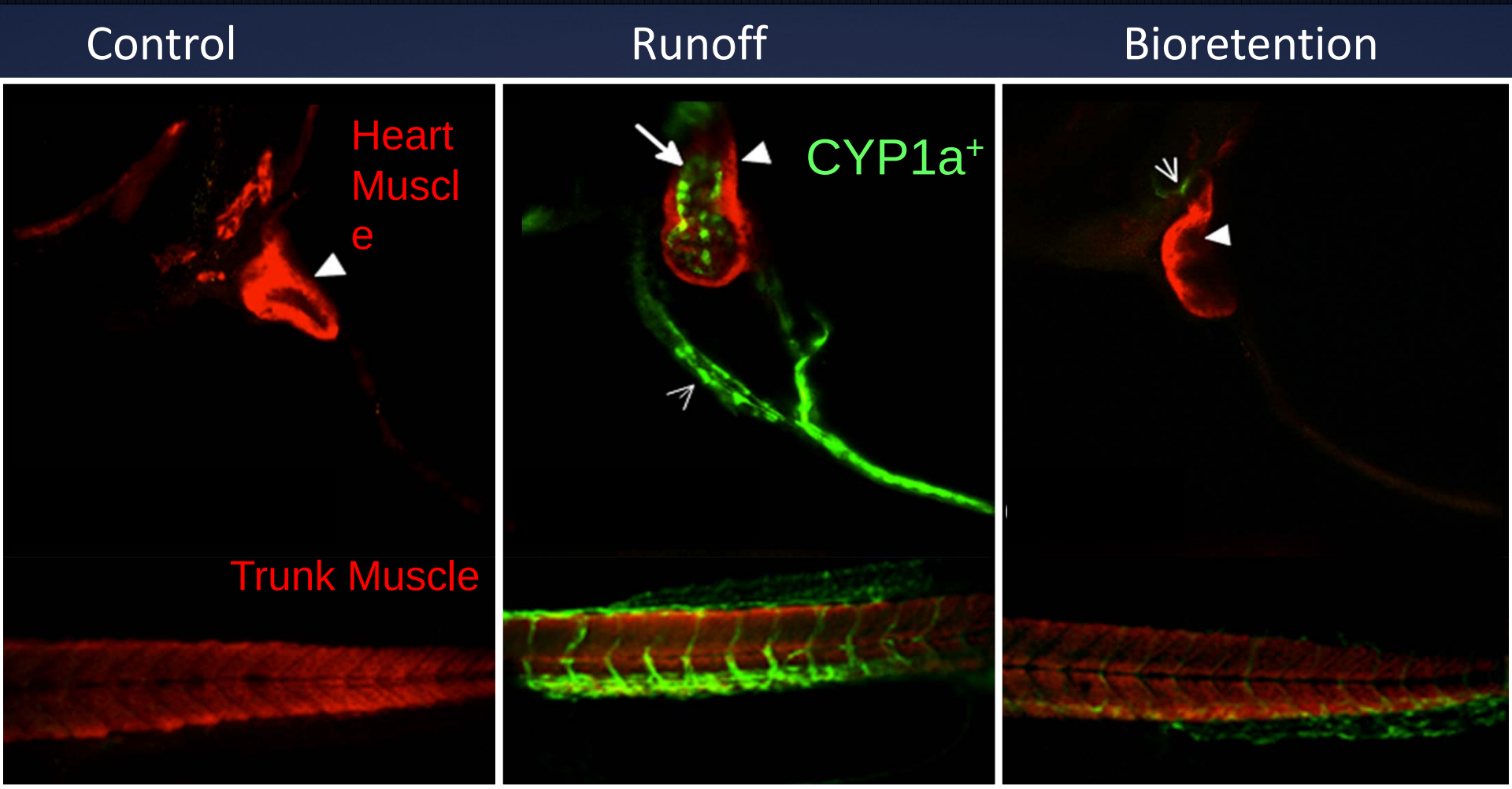
Normal Length

Normal Hearts

Normal Eyes (Almost)

McIntyre et al. 2014. STOTEN.

Cardiotoxicity lost after bioretention



Filtering runoff through bioretention eliminates induction of detox enzyme (CYP1A) in skin and heart of zebrafish

Summary of Bioretention Effectiveness

Animal Model	Effect	Exposure	Eliminated	Reduced
Juv. coho	Mortality	96 h	✓	
Mayfly nymph	Mortality	48 h	✓	
Zebrafish	Mortality	96 h	✓	
Daphnid	Mortality	48 h	✓	
	Reproductive Impairment	7 d	✓	
Zebrafish	Cardiac dysfunction	48 h	✓	
	Growth impairment	96 h	✓	
	Cardiac edema	96 h	✓	
	Swim bladder	96 h	✓	
	Microphthalmia	96 h		✓
	Detox enzymes	48 h		✓
	Cardiac injury genes	48 h	✓	

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Contents lists available at ScienceDirect

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journal homepage: www.elsevier.com/locate/scitotenv

Zebrafish and clean water technology: Assessing soil bioretention as a protective treatment for toxic urban runoff

J.K. McIntyre [a,*], J.W. Davis [b], J.P. Incardona [c], J.D. Stark [a], B.F. Anulacion [c], N.L. Scholz [c]

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Soil bioretention protects juvenile salmon and their prey from the toxic impacts of urban stormwater runoff

J.K. McIntyre [a,*], J.W. Davis [b], C. Hinman [a], K.H. Macneale [c], B.F. Anulacion [c], N.L. Scholz [c], J.D. Stark [a]

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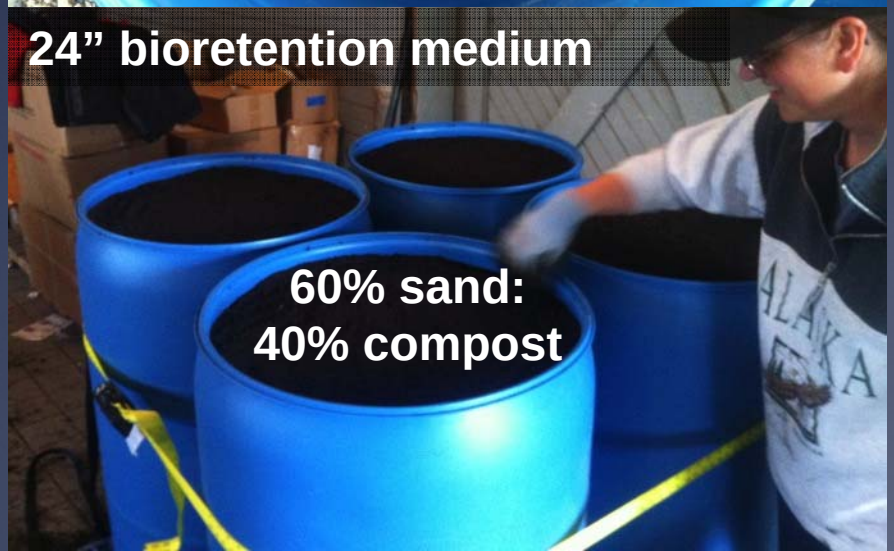
[c] National Ocean and Atmospheric Administration, National Marine Fisheries Service, Northwest Fisheries Science Center, Seattle, WA, USA

Can bioretention prevent coho PSM?

Constructing portable bioretention



Exposures and treatment at Suquamish Hatchery on Grover's Creek

Can bioretention prevent coho PSM?

Clean well water

100% Normal

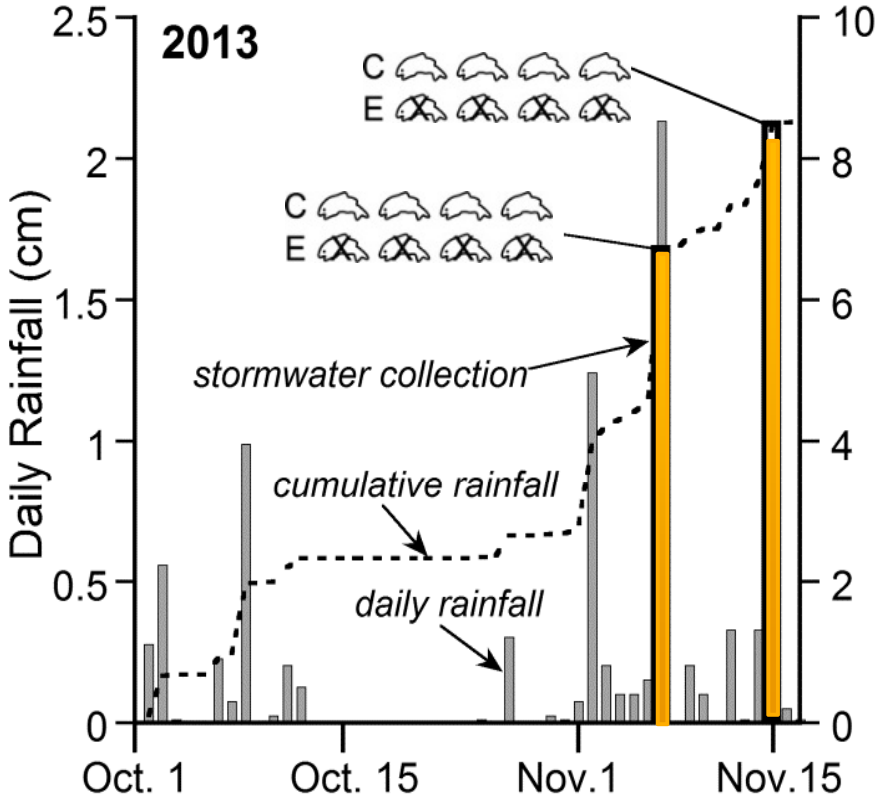
Untreated runoff

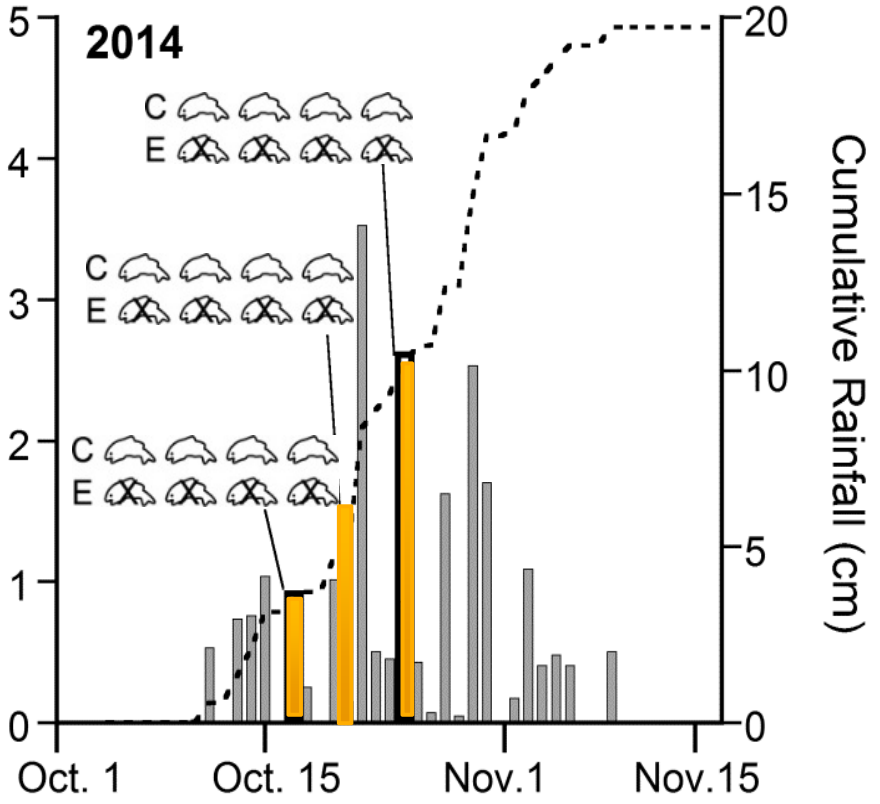
100% Symptomatic

Treated runoff

??????

Stormwater runoff collections 2013 & 2014





Spromberg et al. 2015. J Ecol Applications

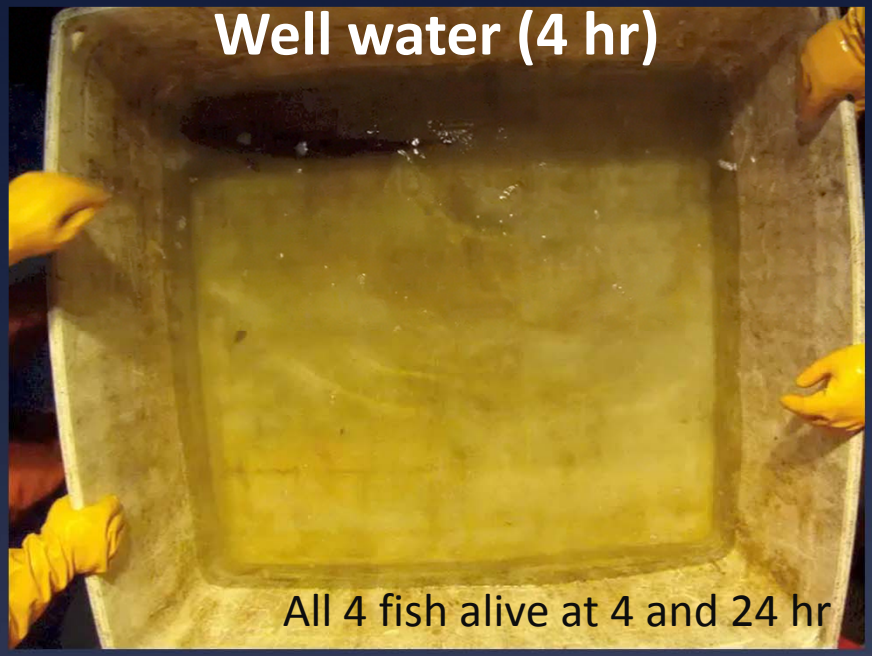
Adult Stormwater Filtration Exposures

Study Year	Test Date	Exposure (hours)	Control Water	Untreated Runoff	Treated Runoff
2013	Nov 8	4	100 % Live	50% Dead; 50% Symptomatic	100% Live
2013	Nov 18	24	100% Live	100% Dead	100% Live
2014	Oct 20	24	100% Live	100% Dead	100% Live
2014	Oct 22	24	100% Live	100% Dead	100% Live
2014	Oct 27	24	100% Live	100% Dead	100% Live

- All fish exposed to Untreated Runoff were symptomatic or dead at <24 h
- All Control and Treated fish alive & asymptomatic at 24 h

Spromberg et al. 2015. J Ecol Applications

Pre-spawn mortality symptoms in coho spawners before and filtering runoff through bioretention



Spromberg et al. 2015. J Ecol Applications

Green Stormwater Effectiveness Summary

- Soil bioretention can prevent acute toxicity of highway runoff
  - Invertebrates
  - Developing fish
  - Juvenile and adult salmon

- Outstanding research questions:
  - Performance longevity
  - Effective sizing
  - Optimal media




How to clean up stormwater runoff?

- Green stormwater infrastructure
- Non-point pollution source controls

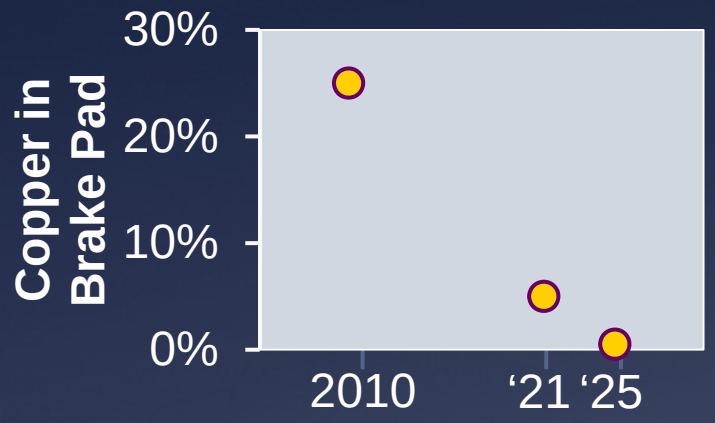
Source Control: Street Sweeping

Seattle Public Utilities Street Sweeping Pilot Project

- Regenerative air sweepers
- 48-90% reduction in street dirt
- No effect on sediment accumulation rate in catch basins

Kim et al. 2014. Environ Technol 35(20):2546
Effectiveness tied to frequency: Need weekly on busy roads

Source Control: Legislation



<5% copper by 2021

<0.5% copper by 2025

PASSED

Washington:
SB6557 3/2010

California:
SB346 9/2010

INTRODUCED

New York:
S1356A 4/2010

Oregon:
SB945 10/2010

JAN 21, 2015

National Brake Pad Initiative

Source Control: Consumer Habits

Public education campaigns

- raise awareness about pollution
- reduce pollution by changing individual actions

What YOU Can Do!

- Pick up pet waste
- Properly dispose of waste
- Practice natural yard care
- Protect & foster wild spaces
- Keep water in your yard with rain barrels, rain gardens, and porous surfaces
- Use car wash facilities
- Walk, bike and ride public transit
- **Support and implement LID**
- **Support legislation to control contaminant sources**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Emma Mudrock

Suquamish Tribe
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