



State of Washington
DEPARTMENT OF FISH AND WILDLIFE

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February 19th, 2017

TO: Whom it May Concern

FROM: Thomas P. Jameson, Washington Department of Fish and Wildlife, Habitat Program, Fish Passage and Screening Division Manager, Chairman Fish Barrier Removal Board

SUBJECT: Resolution Honoring Mr. Brain Abbott

Whereas the Fish Barrier Removal Board lost a valued member and leader on December 31, 2016, with the passing of Brian Abbott;

Whereas Brain Abbott was a tireless and outspoken advocate of salmon recovery and environmental stewardship, whose dedication paved the way for the founding of the Fish Barrier Removal Board within the state of Washington.

Whereas Brian Abbott served with distinction as the executive director of the Governor's Salmon Recovery Office, fundamentally changing how Washington State manages its salmon recovery efforts.

Whereas Brain Abbott initiated the first salmon recovery conference and helped create the Kennedy Creek Salmon Trail.

Whereas Brain Abbott was much loved and respected by his family, friends, co-workers, his sense of humor, kindness, energy and graciousness enriched those fortunate enough to know and work with him, therefore, be it

Resolved that the members of the Fish Barrier Removal Board recognize the significant contributions of Brain Abbott over the course of his distinguished career, mourn his passing and extend our sincere condolences to his family and friends.

Moved by: Mr. Thomas P Jameson, FBRB Chairman, Fish Passage Division Manager, Habitat Program, Washington Department of Fish and Wildlife, 360-902-2612

Seconded by: Mr. Gary Rowe, FBRB Member, Managing Director, Washington State Association of County Engineers, 360-489-3014



Urban stormwater runoff & Green infrastructure

Fish Barrier Removal Board, Feb 21, 2017

Puget Sound Stormwater Science Team



Nat Scholz
Julann Spromberg
David Baldwin
John Incardona
James Cameron
Jessica Lundin
Cathy Laetz
Jana Labenia
Barb French



Jay Davis
Ken King



Jen McIntyre
John Stark
Emma Mudrock
Jill Wetzel



Research PARTNERS & SUPPORTERS



WASHINGTON STATE
UNIVERSITY



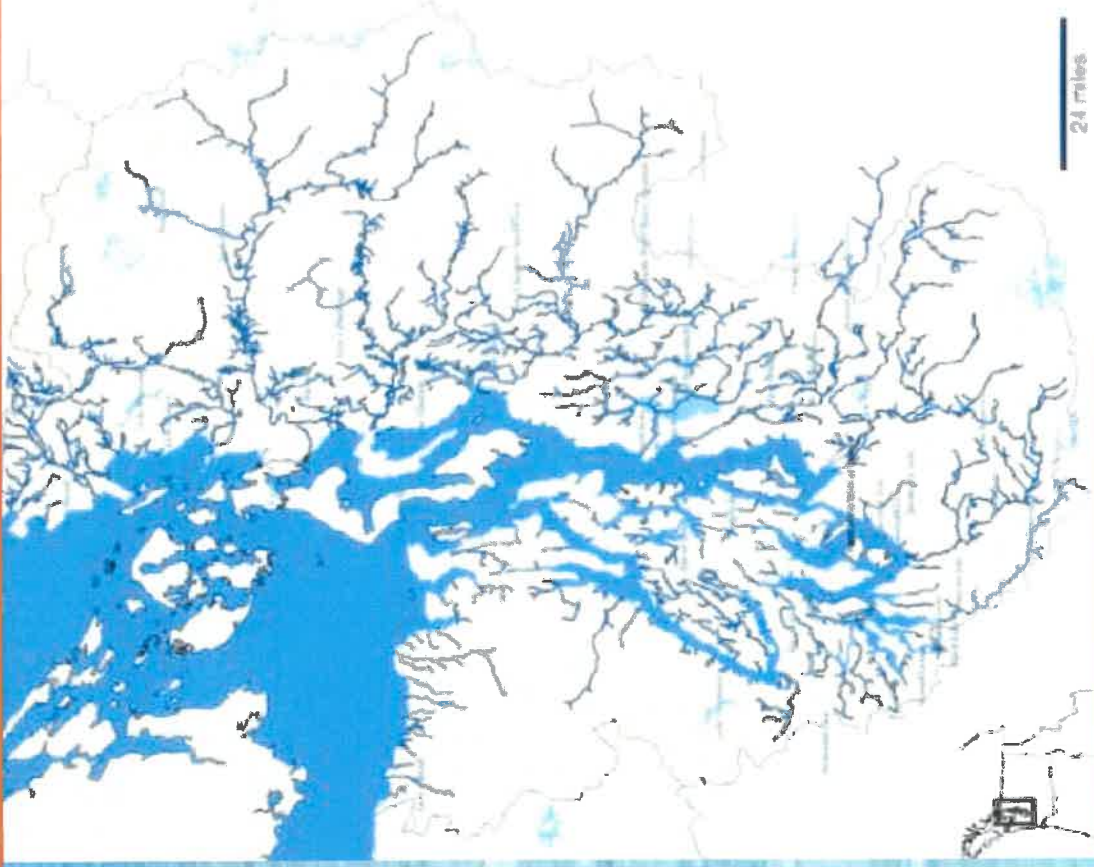
THE
SUQUAMISH
TRIBE





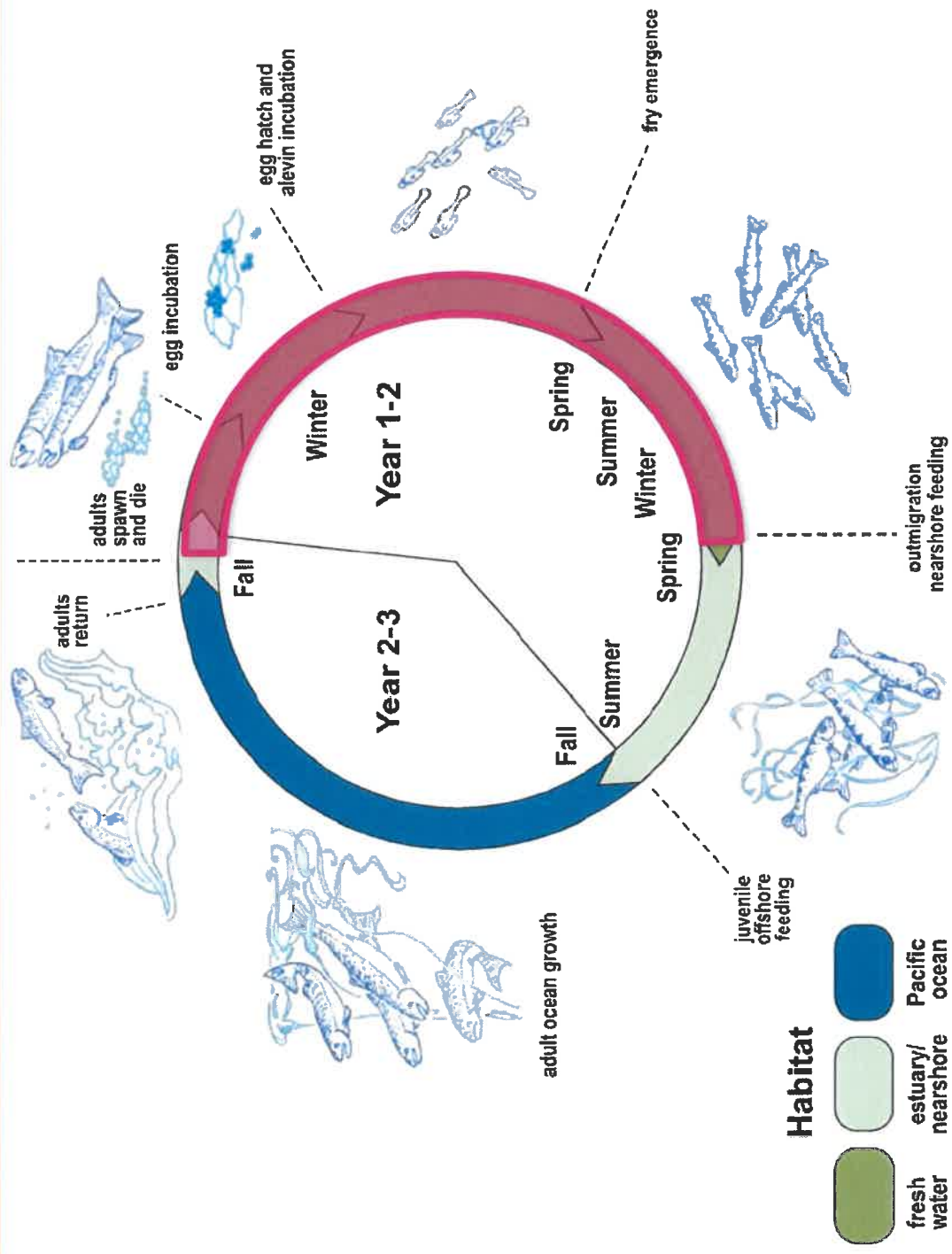
Coho salmon as stormwater sentinel

- Widely distributed
- Lowland streams
- Sensitive to water quantity & quality
- Supported by a diverse food web
- More than 1 year in freshwater





Impact of stormwater on coho salmon



This is not a FOREST

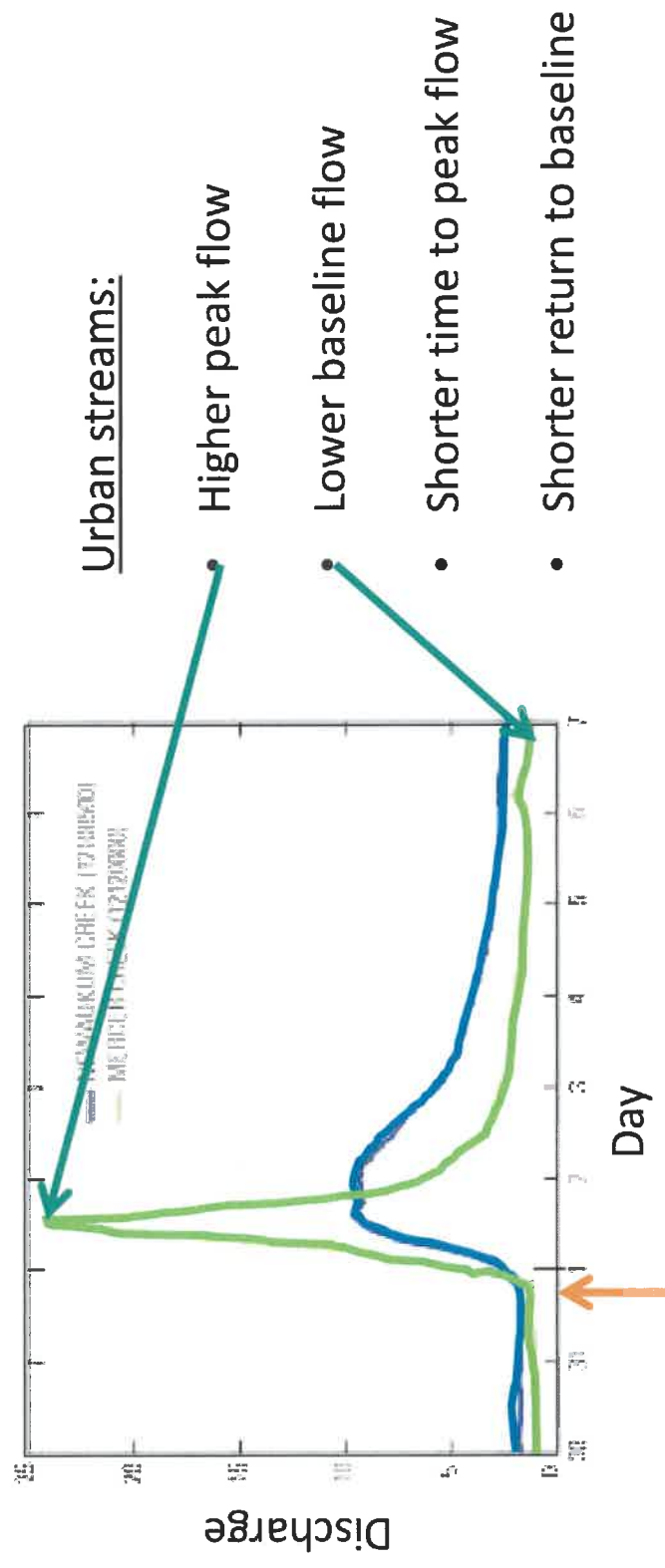


An urban stormwater outfall



West Seattle underwater footage by Laura James (www.diverlaura.me) ⁷

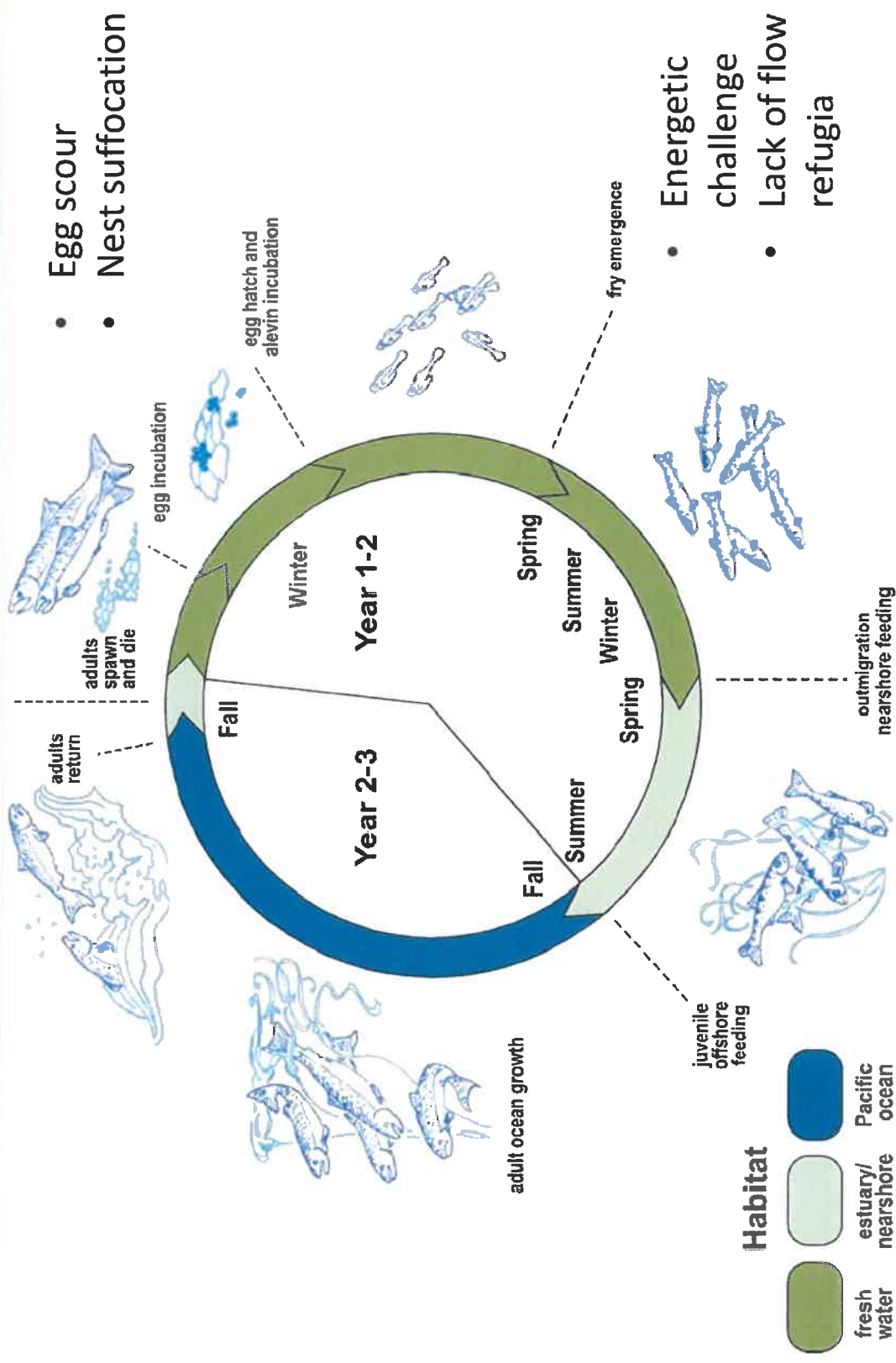
Urban Runoff: Water Quantity



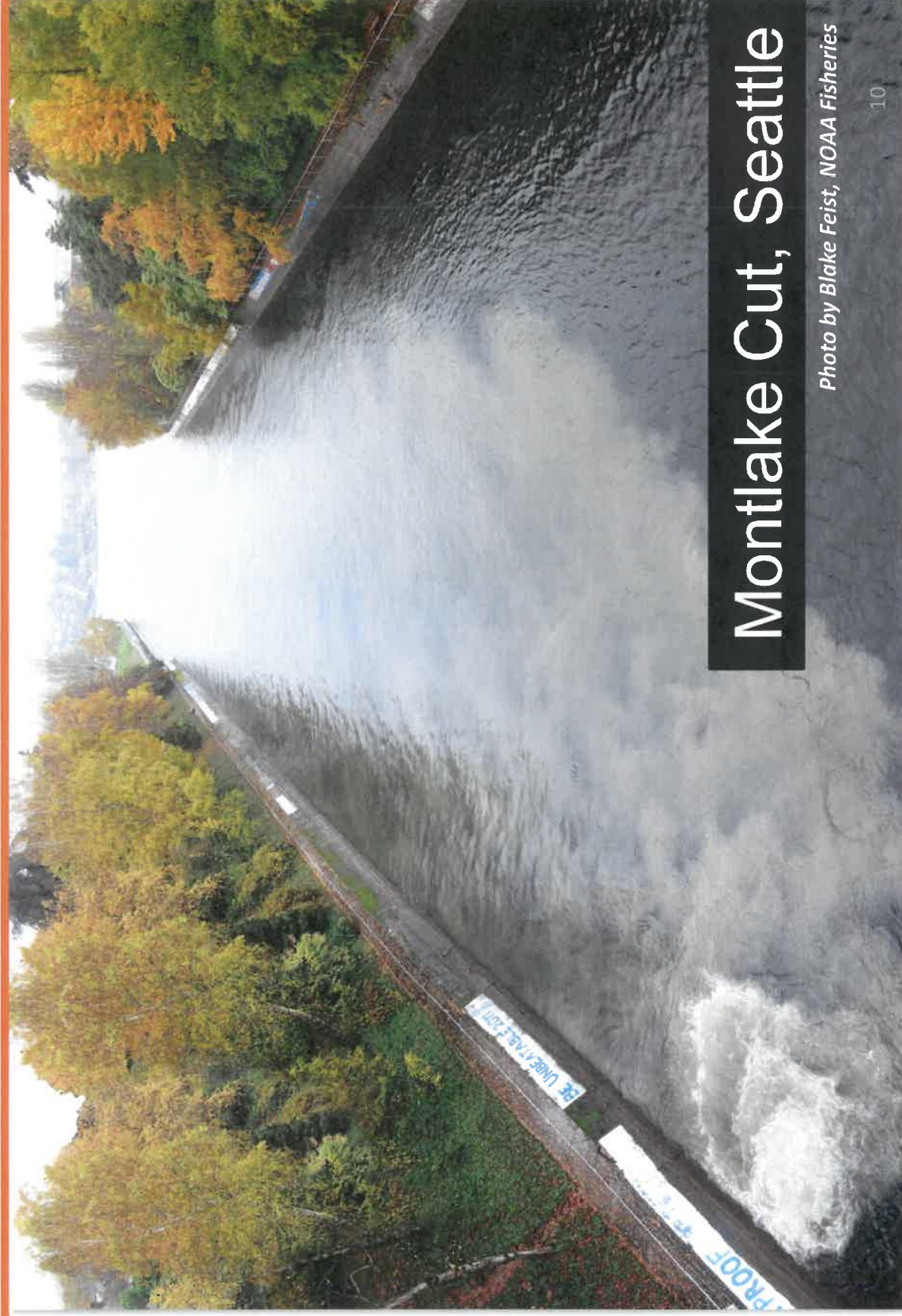
- Urban systems are 'flashy'
- For aquatic animals, the rapid and intense change in water flow is a problem



Impact of stormwater on coho salmon



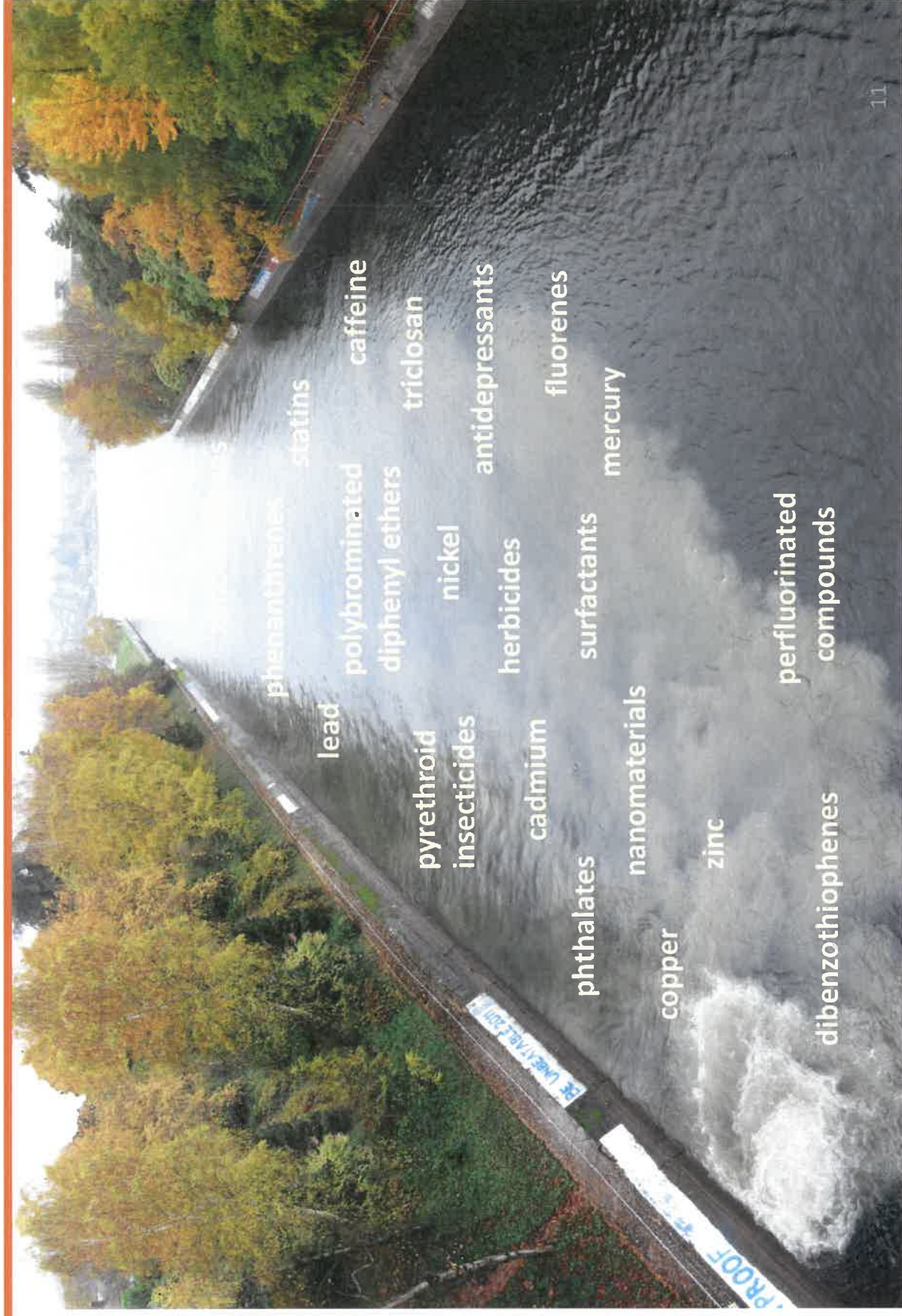
The pollution you see....



Montlake Cut, Seattle

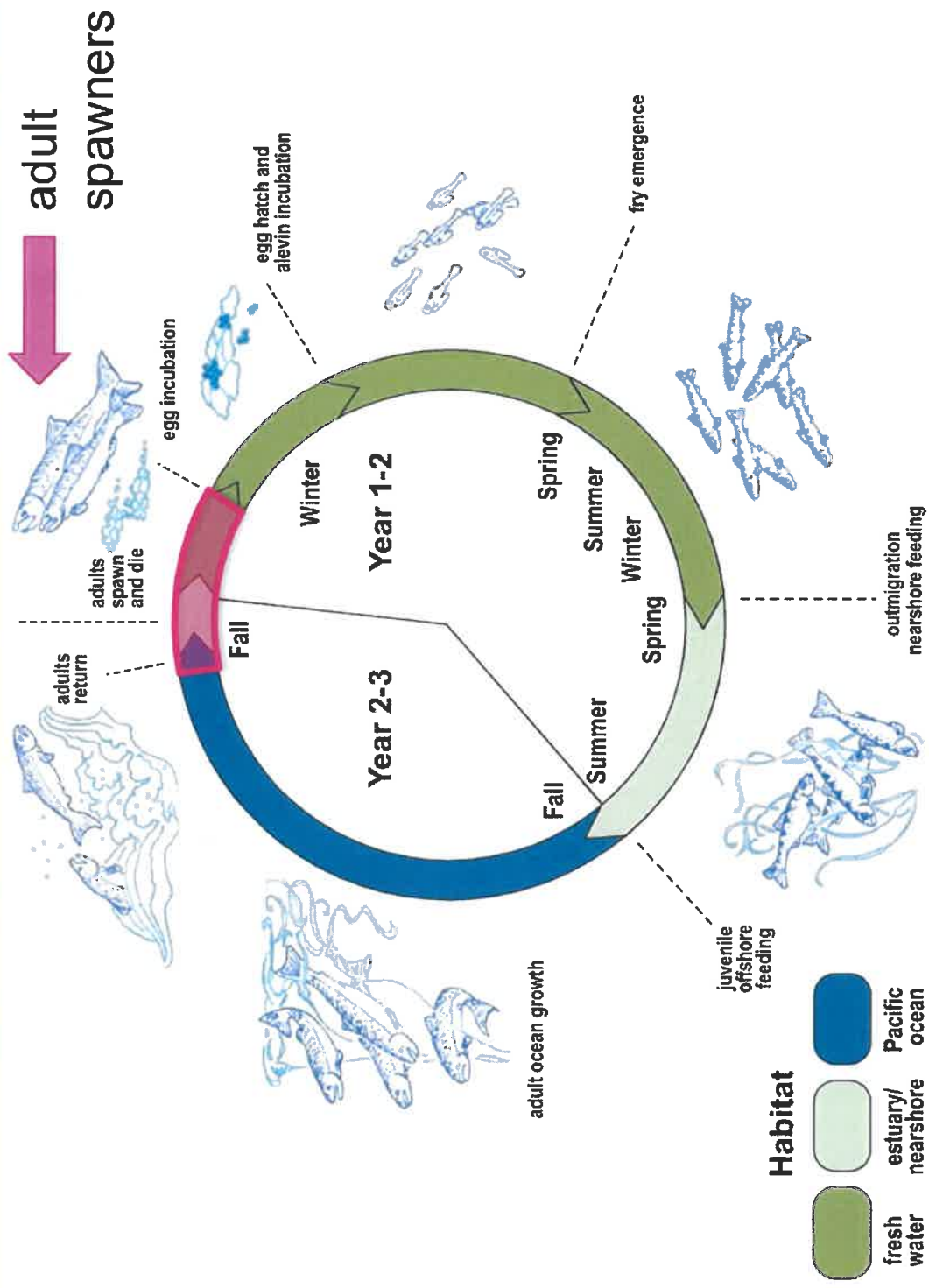
Photo by Blake Feist, NOAA Fisheries

...& the pollution you don't see





Impact of stormwater on coho salmon



A common suite of symptoms



Longfellow Creek, 2002



Longfellow Creek, 2005



Pipers Creek, 2002



Longfellow Creek, 2012

Coho pre-spawn mortality is widespread & recurrent in urban creeks



67%

Longfellow Creek, 2003



63%

Des Moines Creek, 2004



72%

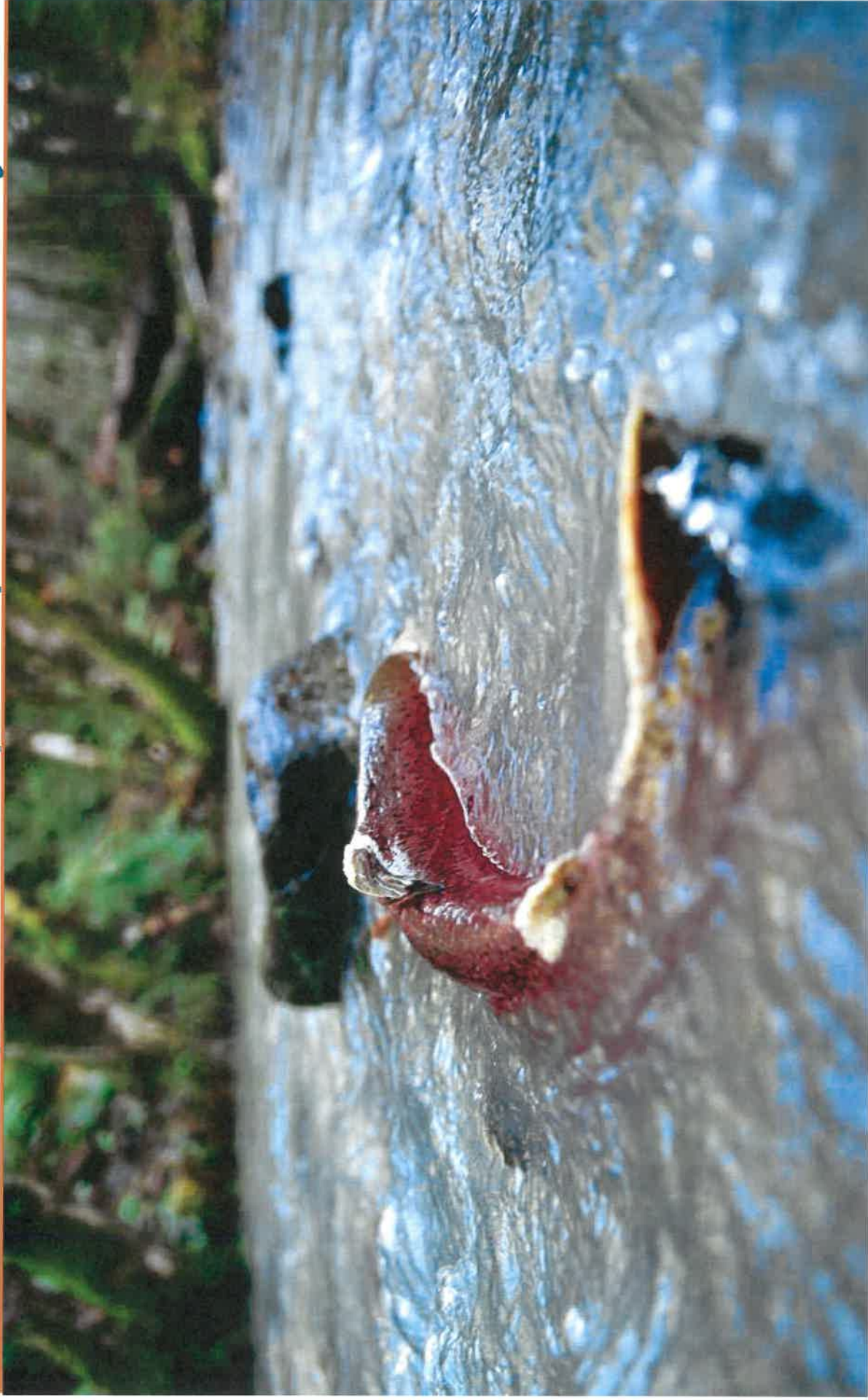
Longfellow Creek, 2005



84%

Longfellow Creek, 2012

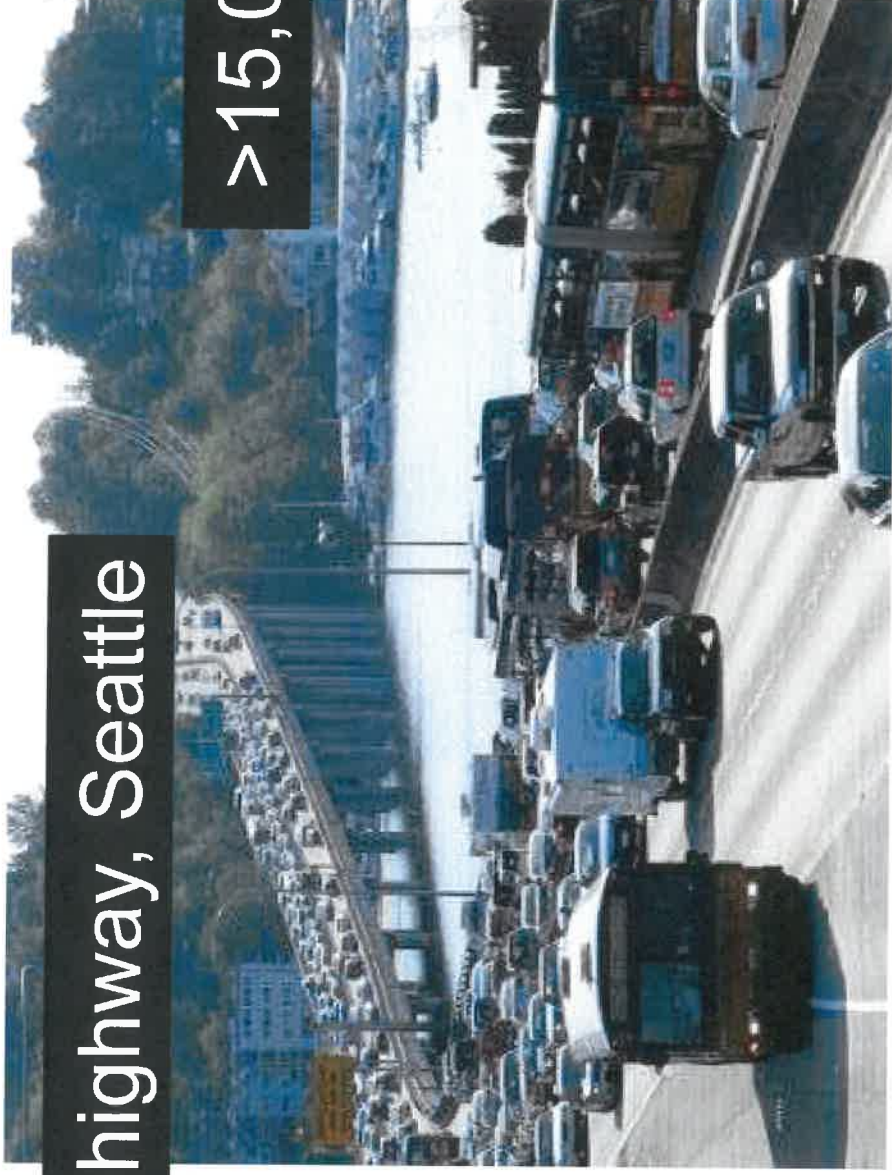
Could we recreate the symptoms & mortality of coho pre-spawn mortality?

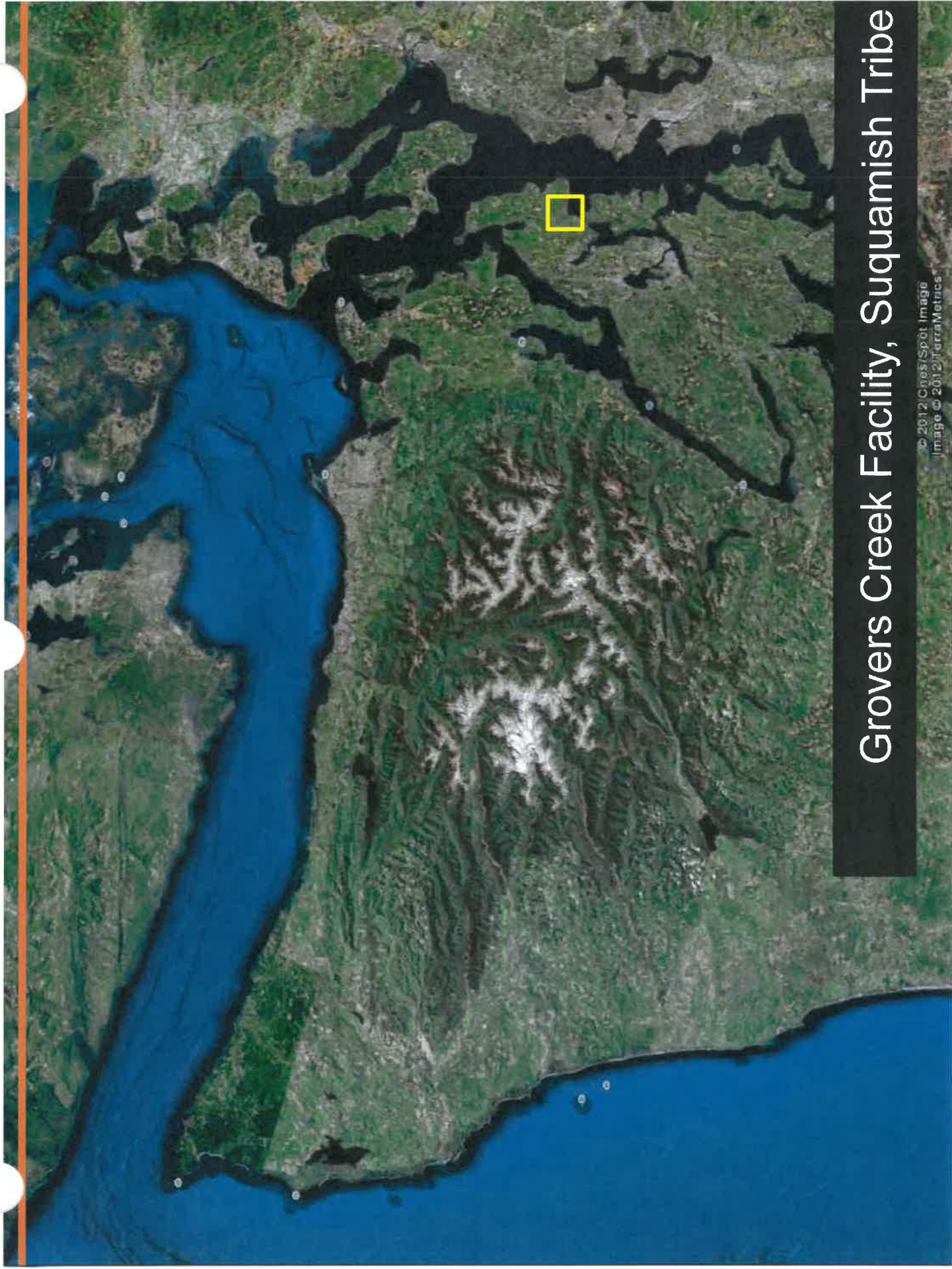


Collect stormwater runoff

Urban highway, Seattle

>15,000 AADT





Grovers Creek Facility, Suquamish Tribe

© 2012 Cnes/Spot Image
Imago © 2012 TerraMetrics

Adult coho exposures



clean well water



stormwater

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

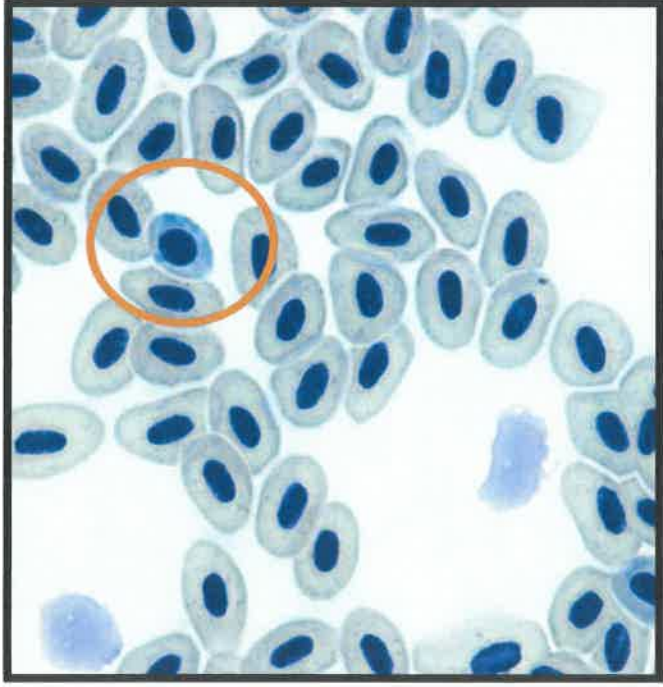
Unexposed (3.5 hrs)



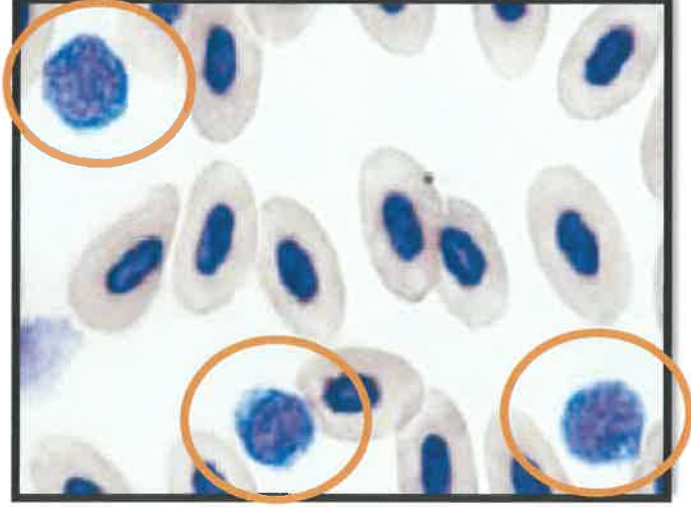
Stormwater-exposed (3.5 hrs)



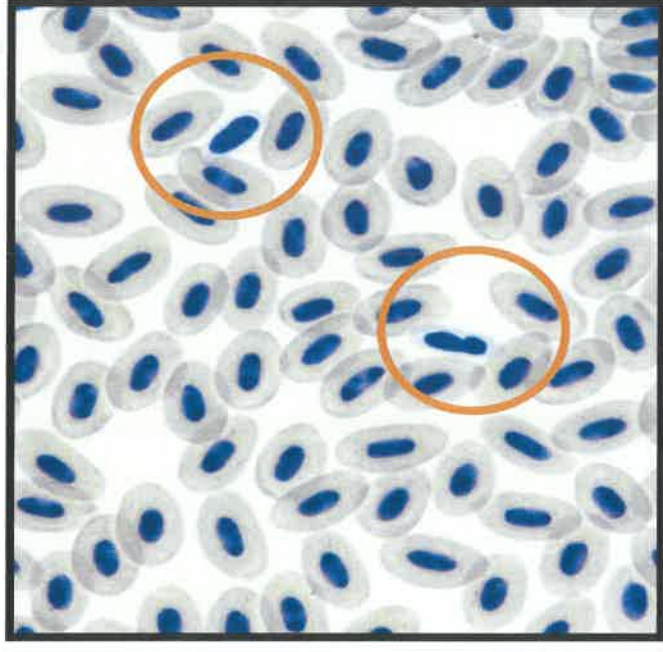
Pathophysiology: Blood cells of coho exposed to runoff



More immature RBCs
(hypoxia)

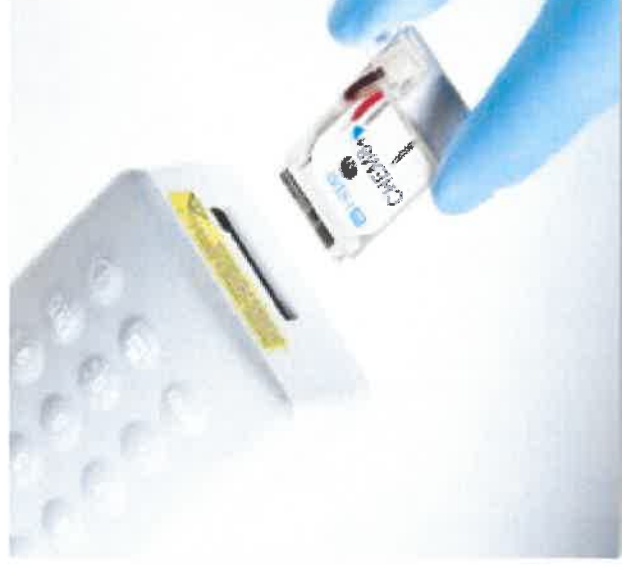


More WBCs
(immune response)

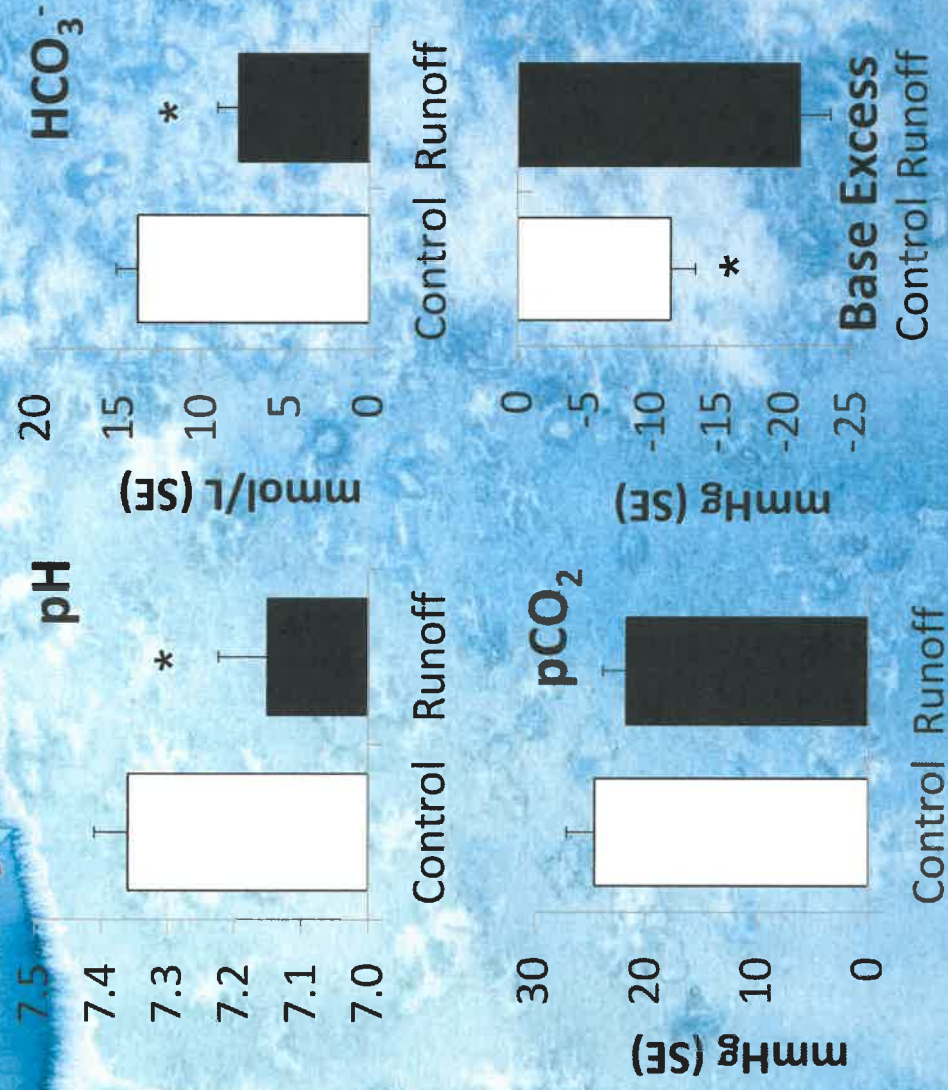


Fewer thrombocytes
(coagulation response)

iSTAT point-of-care blood analyzer

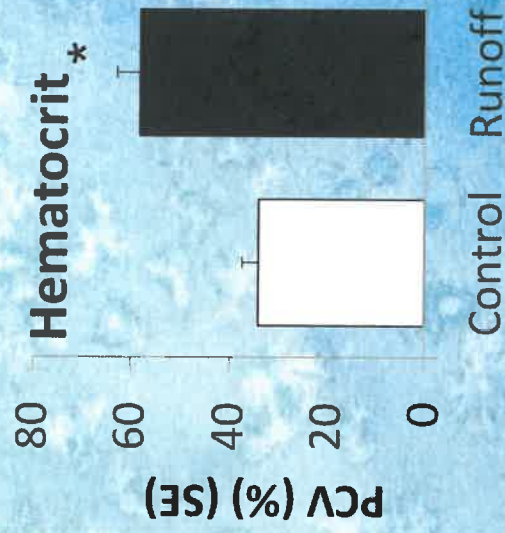


Arterial blood gas analysis



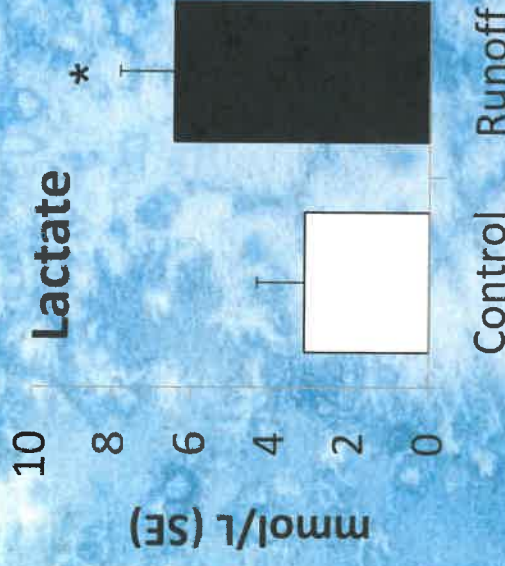
Diagnosis: Metabolic acidosis

Arterial blood chemistry analysis



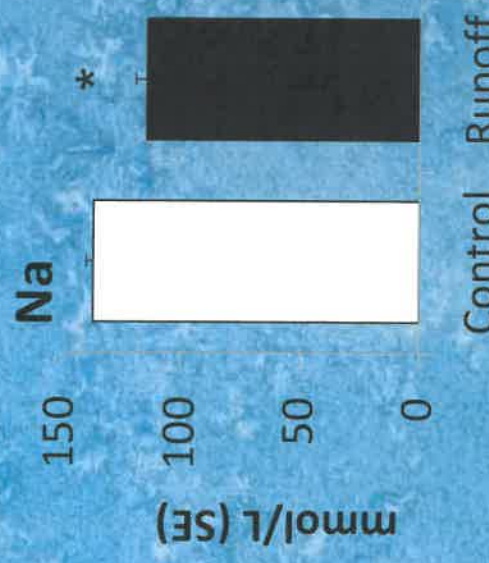
**Increased blood cells
and/or decreased plasma**

Hypoxia



**Anaerobic cellular
respiration**

Hypoxia



Hyponatremia

- Diuresis
- Heart failure
- Kidney failure²³

Evidence for Hypoxia in Adult Coho



- Behavioural
 - Increased gilling
 - Surface gaping
- Hematological
 - **↑** HCT (Higher RBC counts / cell swelling)
 - Metabolic acidosis (low pH, low bicarb, base deficit)
 - Lactate production (anaerobic cellular respiration)

Types of hypoxia

Hypoxia Type	Caused by
Hypoxic	Insufficient O ₂ in environment e.g., low dissolved oxygen
Anemic	Insufficient RBC or Hb e.g., nitrate poisoning - methemoglobinemia
Stagnant	Insufficient blood flow e.g., cardiovascular failure, hypotension
Histotoxic	Tissues cannot access/use O ₂ e.g., metabolic poisons

2016
Field Season

Are other salmon as sensitive as coho?

Adult Coho Salmon



Run Timing: Oct-Dec

Adult Chum Salmon



Run timing: Nov-Jan

Are other salmon as vulnerable as coho?



10.30.2015

Coho salmon

Runoff 2 h

Are other salmon as vulnerable as coho?

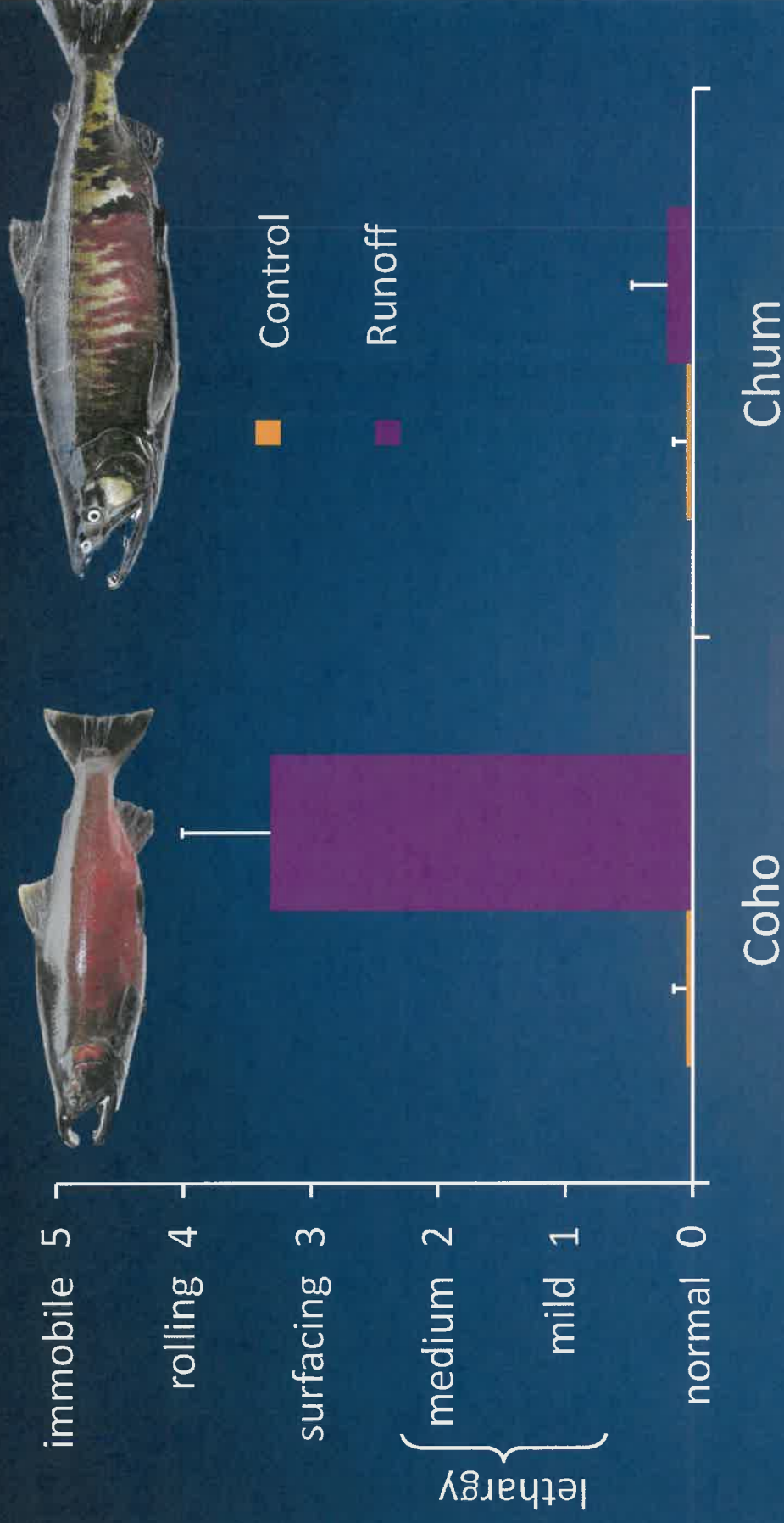


10.30.2015

Chum salmon

Runoff 4 h

Are chum as vulnerable as coho?



Chum did not develop pre-spawn mortality behavioral symptoms

Coho and chum in Pipers Creek (2006)



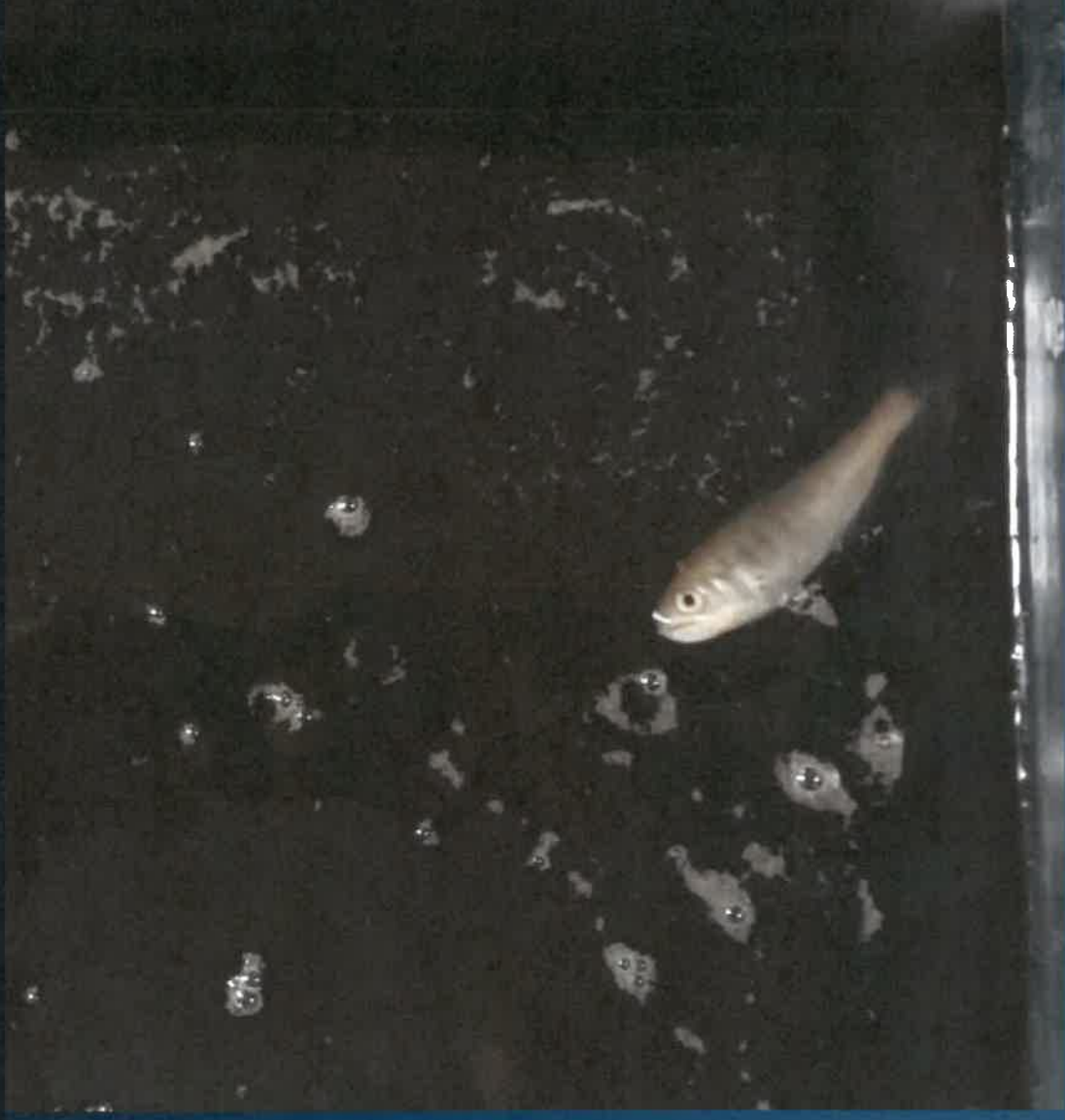
Sensitivity of juvenile salmon?

Juvenile coho salmon



O. kisutch

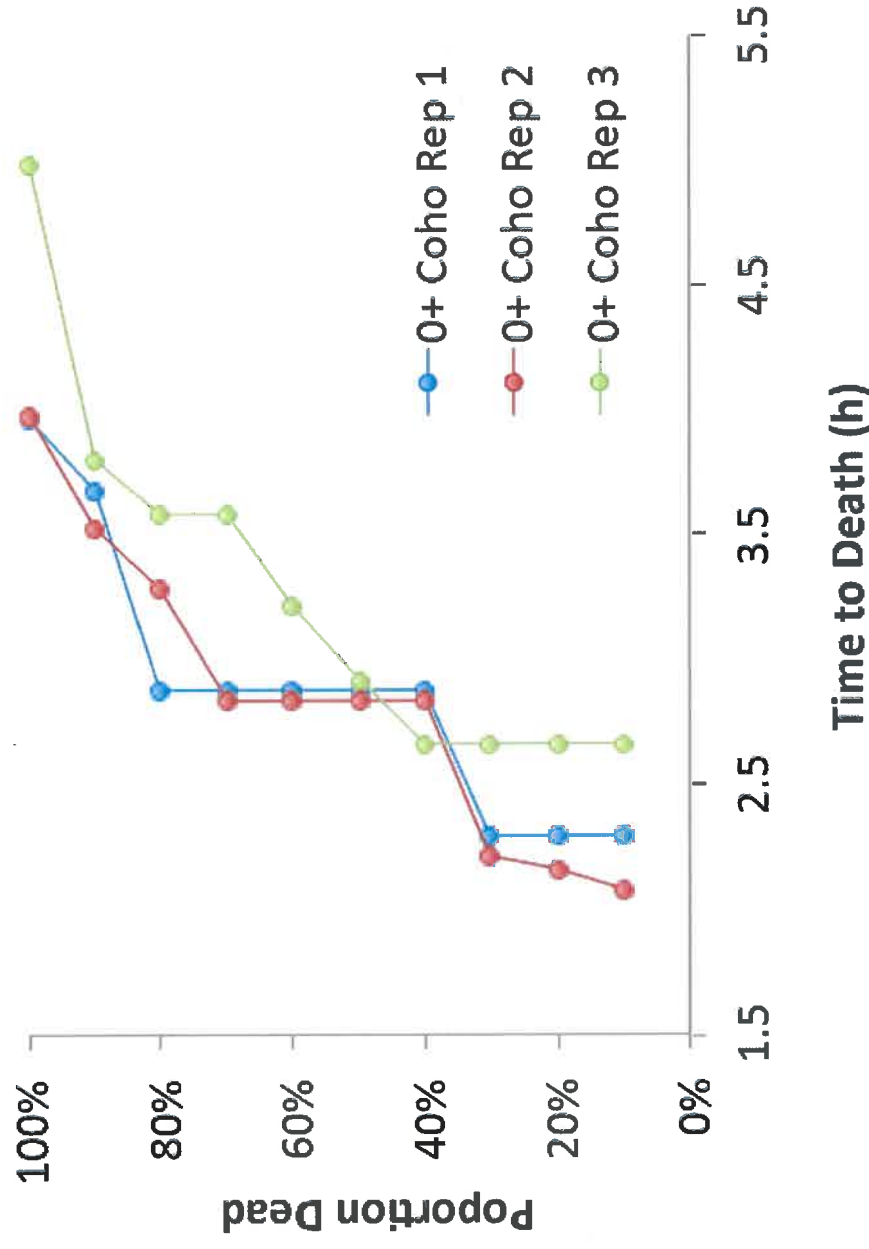
Juvenile coho show PSM symptoms



Stage 4: Loss of equilibrium

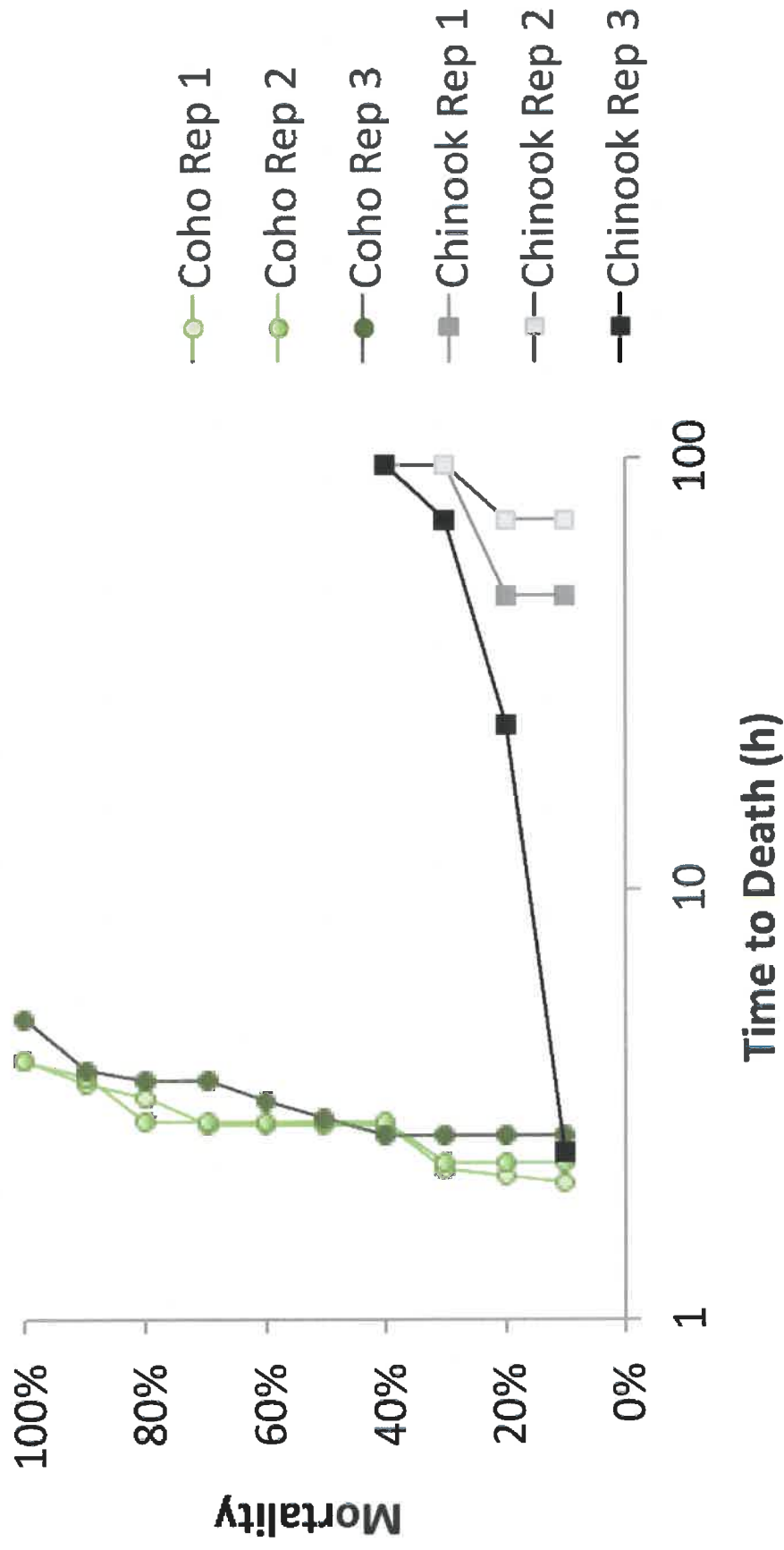
Sensitivity of juvenile coho?

Juvenile Coho Mortality in Road Runoff



Juvenile coho very sensitive

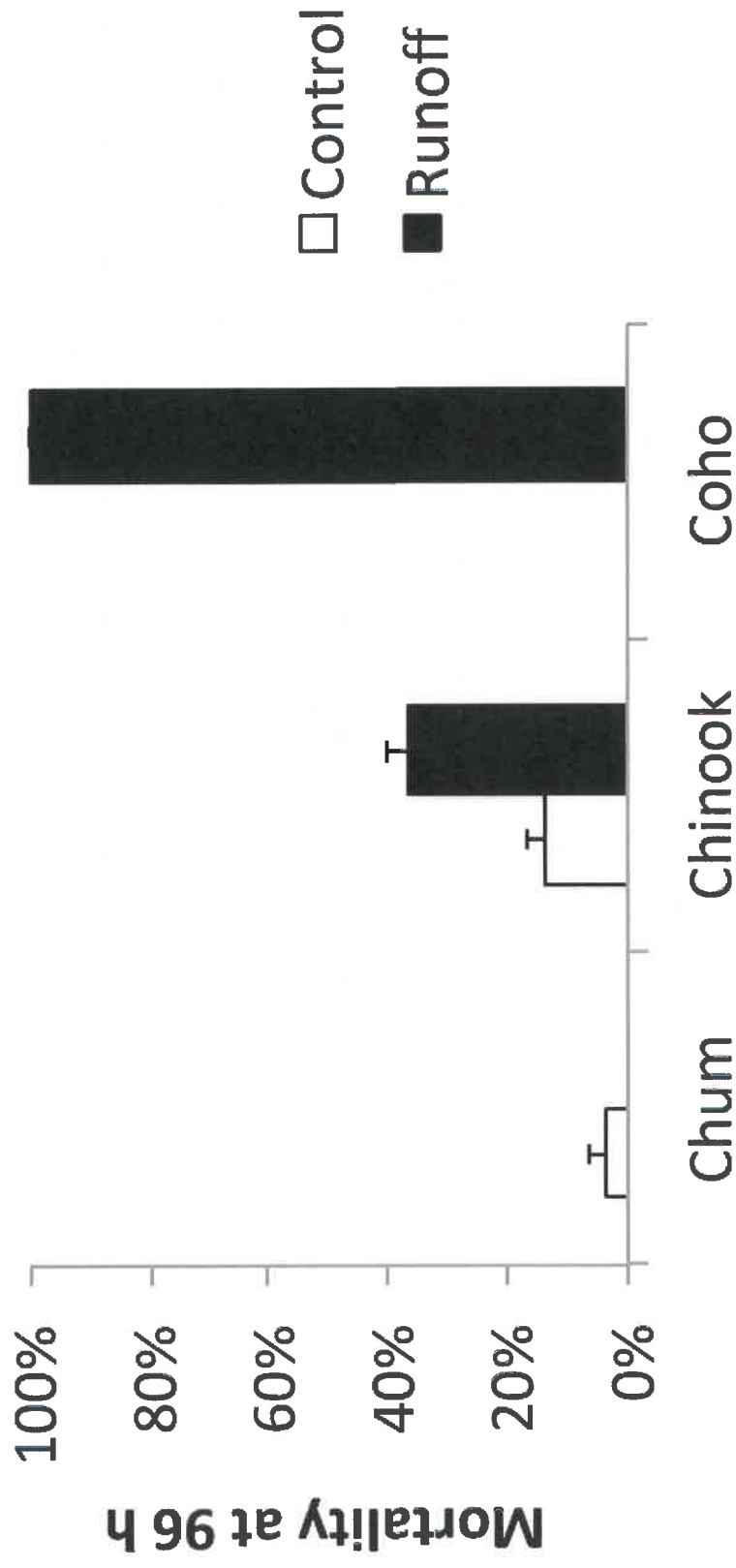
Juvenile coho vs Chinook salmon?



Coho are by far more sensitive

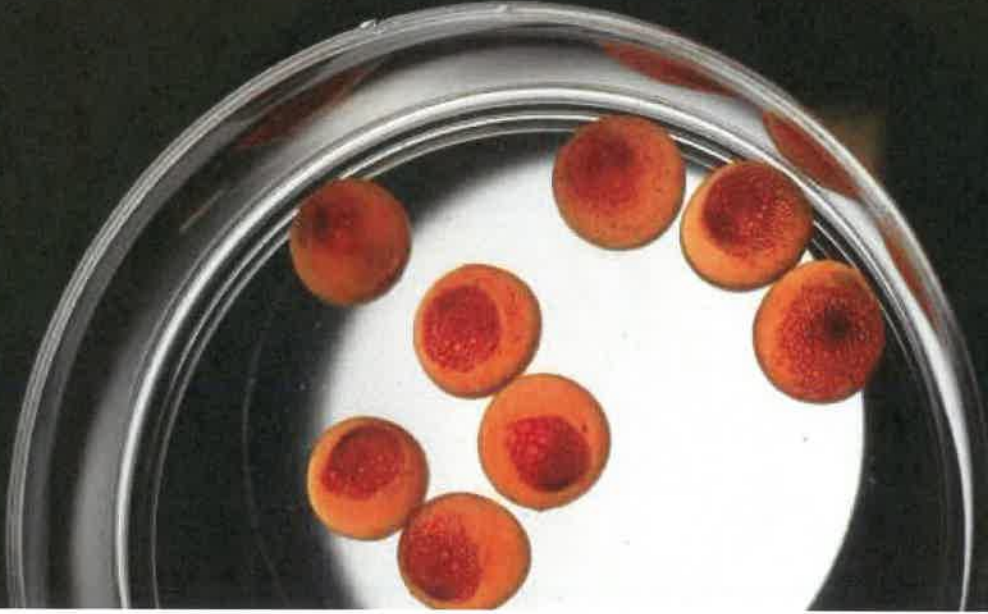
Juvenile chum vs Chinook vs coho salmon?

Juvenile salmon sensitivity to road runoff

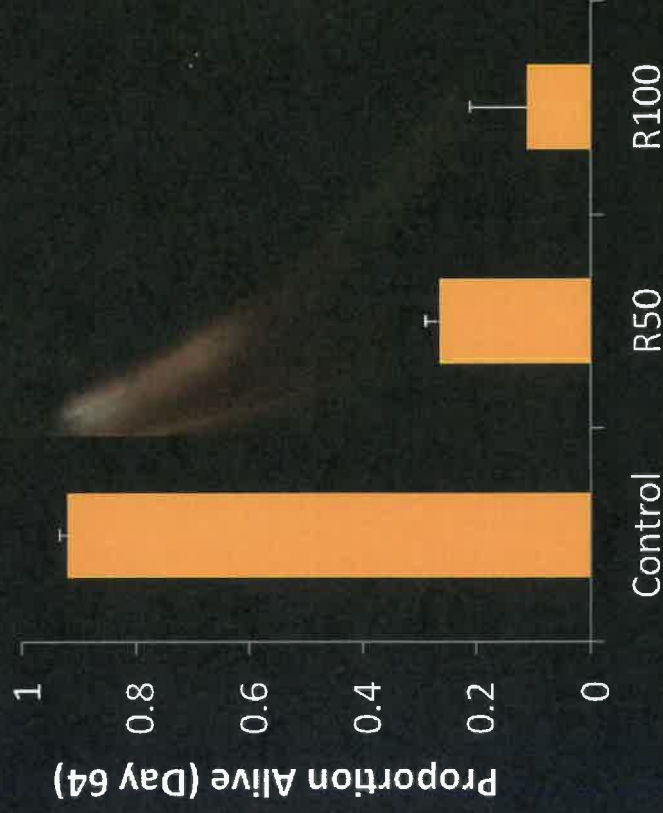
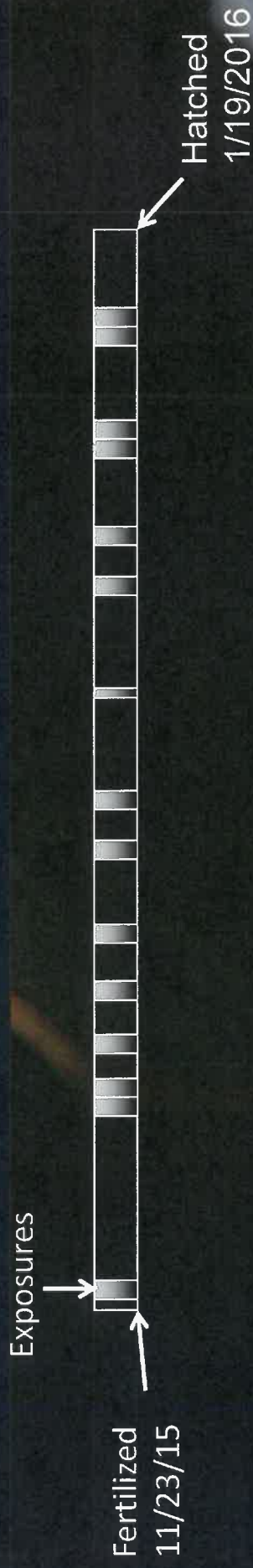


Coho are by far more sensitive to urban runoff₃₅

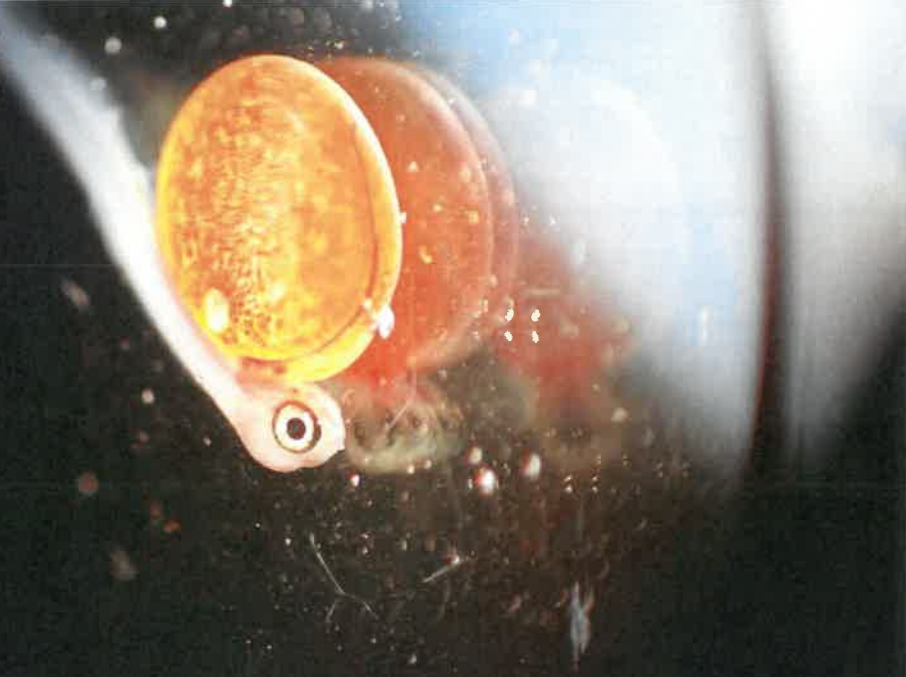
Coho embryo-larval development



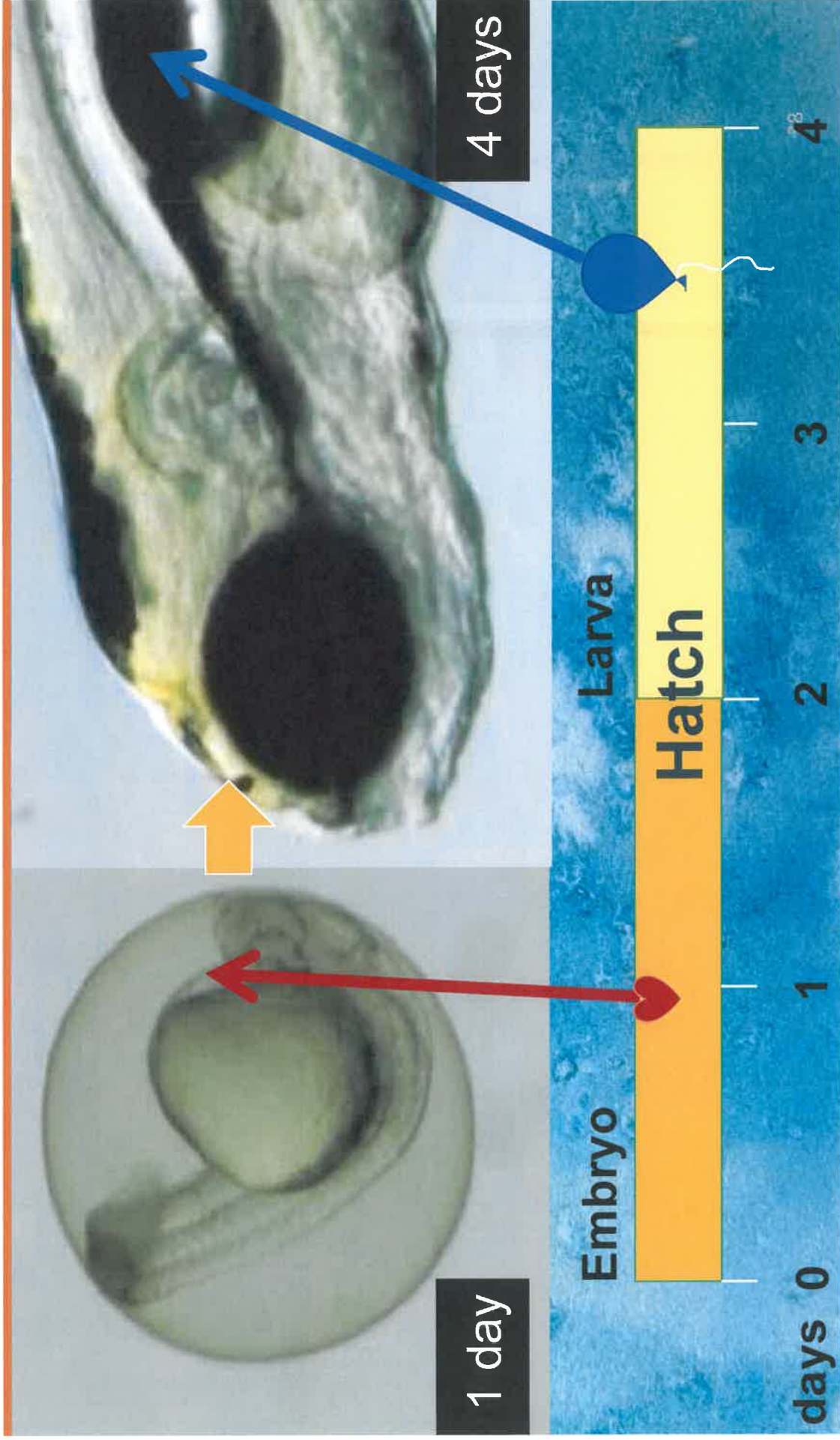
Coho Embryos: Episodic Exposure to Runoff



Acute lethal response upon hatching



Zebrafish research model



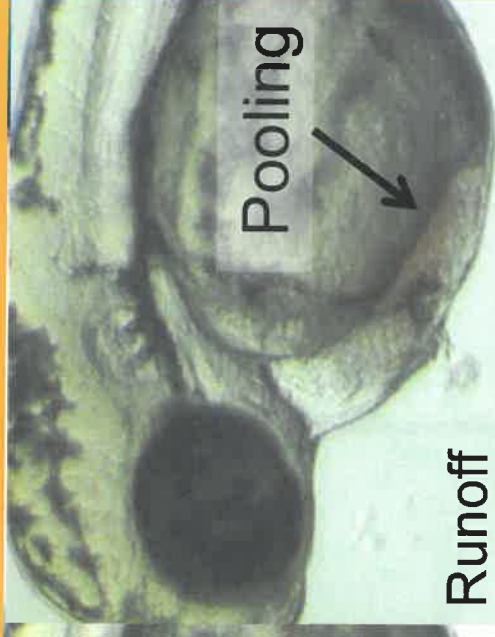
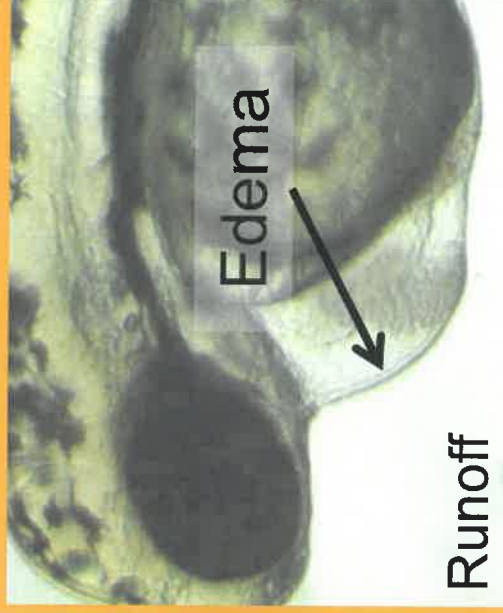
Sublethal effects in zebrafish



Sublethal effects of runoff on developing fish include:

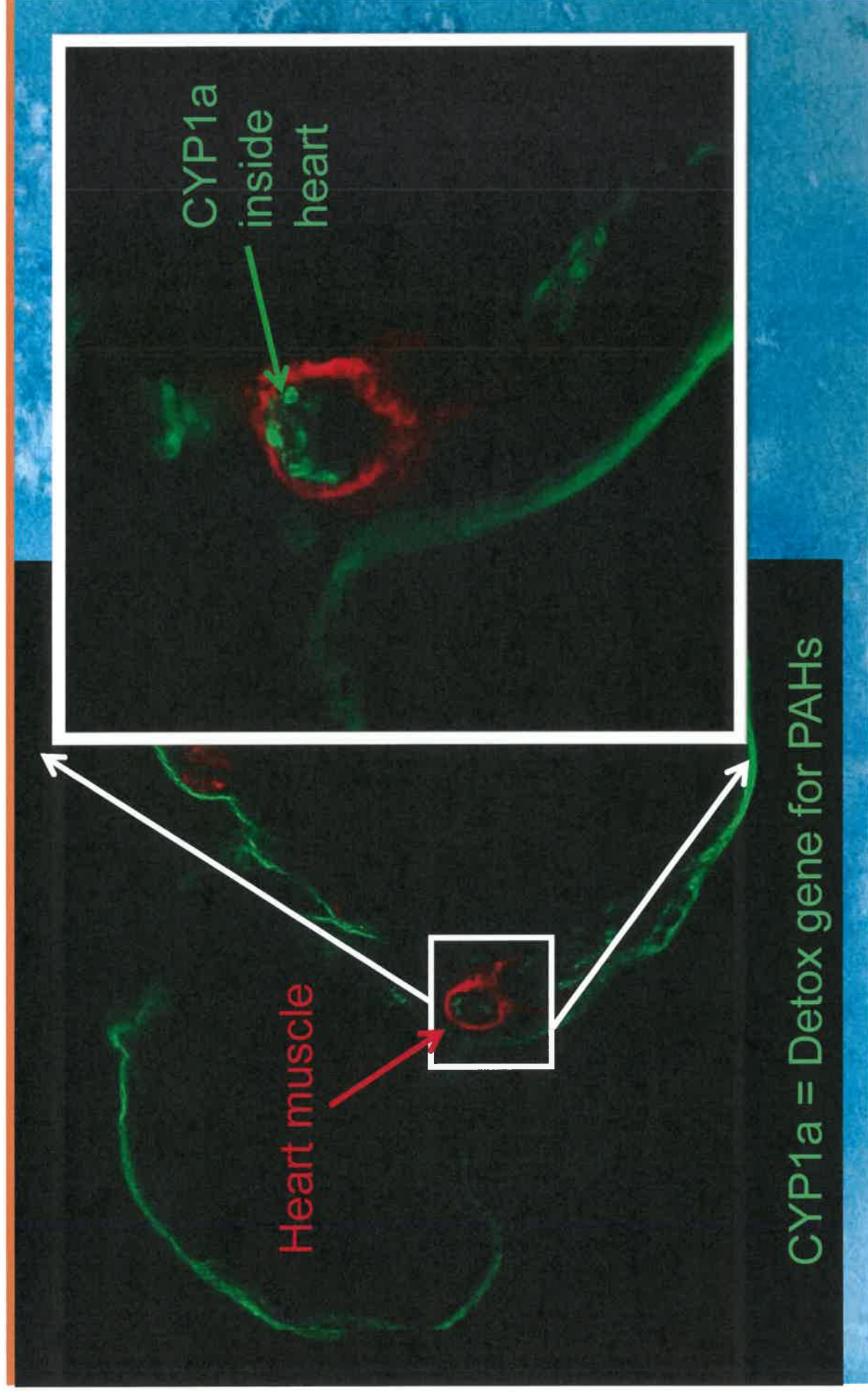
- Inability/delay to hatch
- Developmental delays
- Small eye phenotype (*)
- Pericardial edema (yellow arrow)
- Deformed jaws and hearts (black arrows)

Cardiac abnormalities from runoff

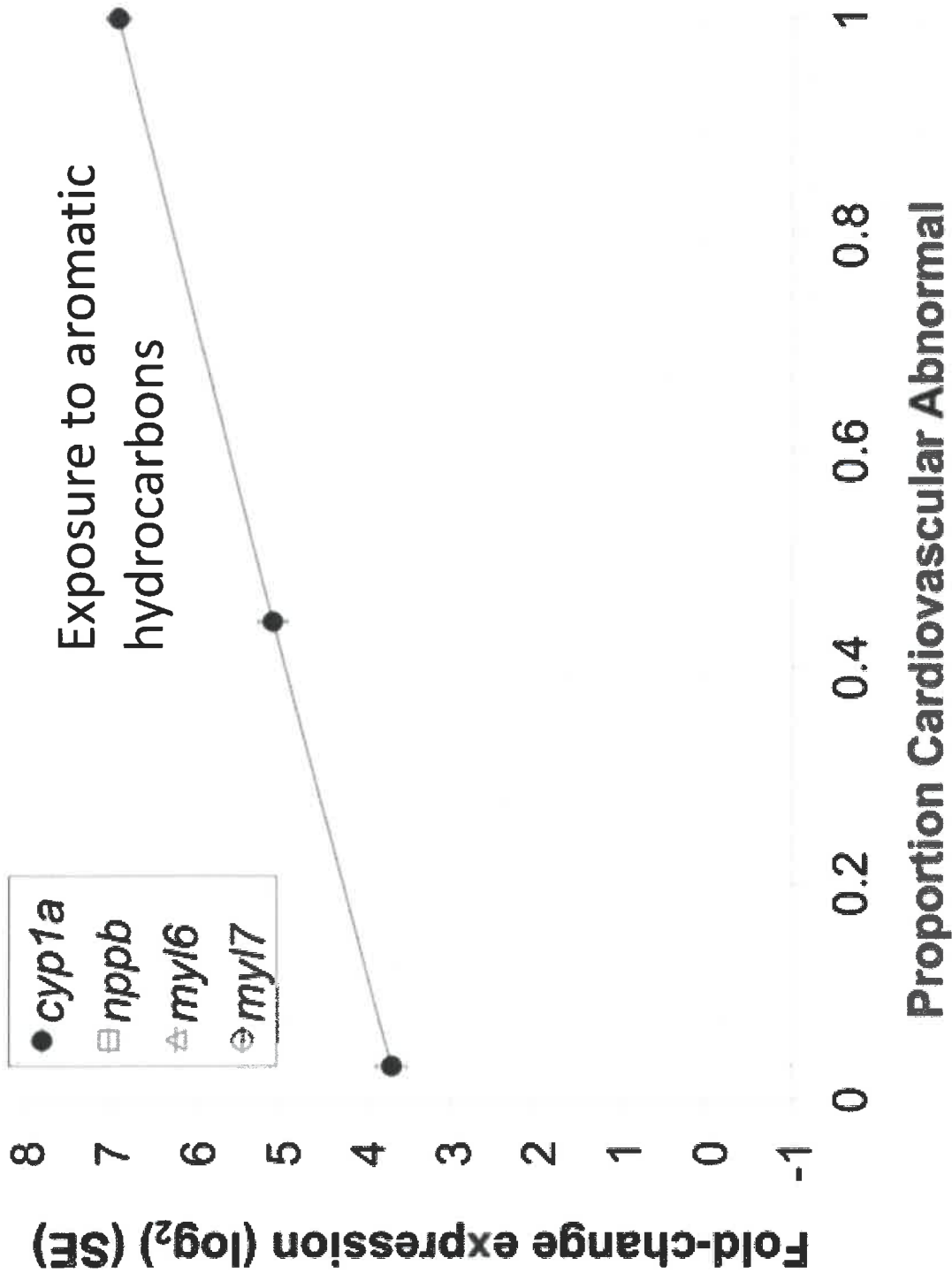


Urban runoff gives zebrafish bad hearts.

The heart is a target for road runoff contaminants



Genes that scale with heart effects

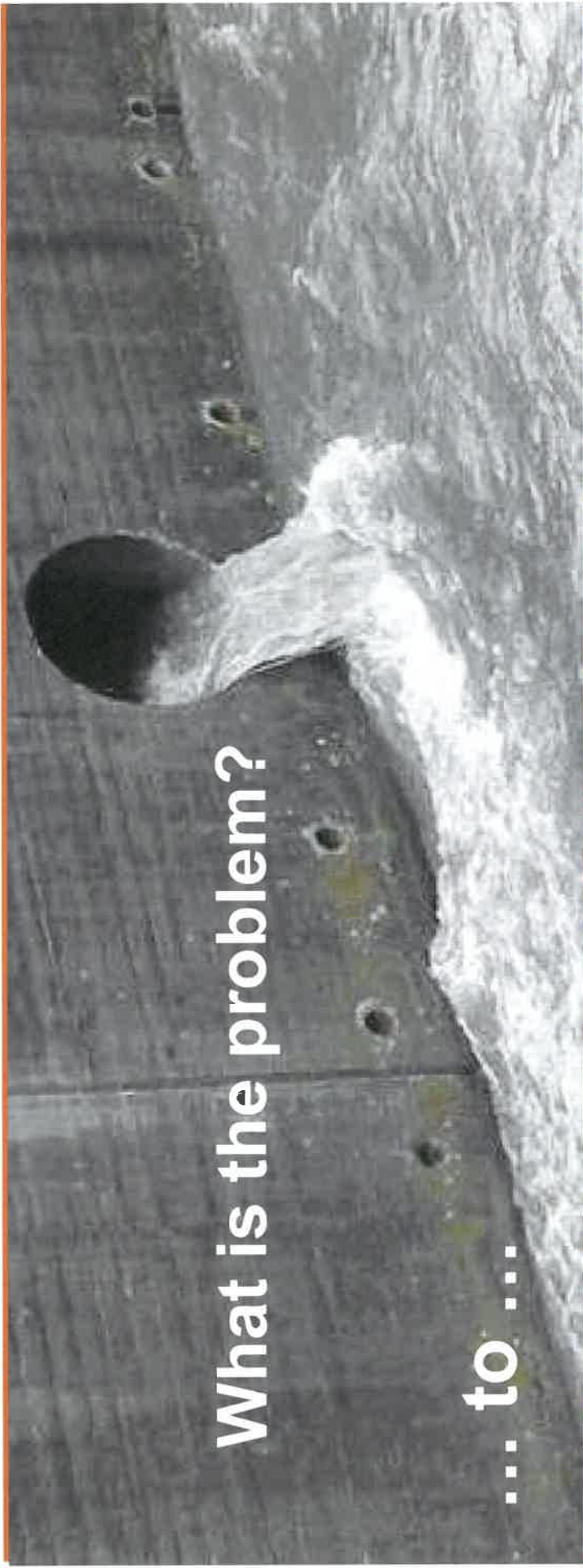


Toxicology evolving from:

What is the problem?

... to ...

What is the
solution?



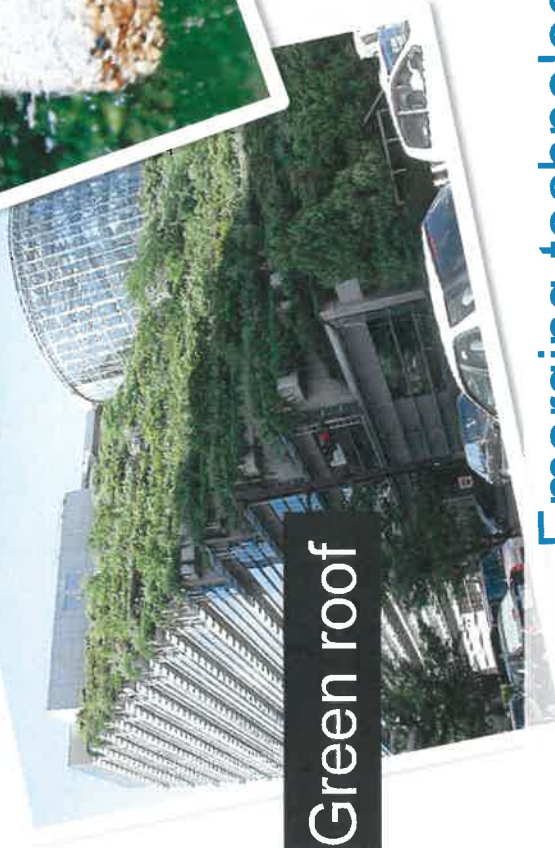
Green Stormwater Infrastructure



Bioretention



Pervious pavement



Green roof

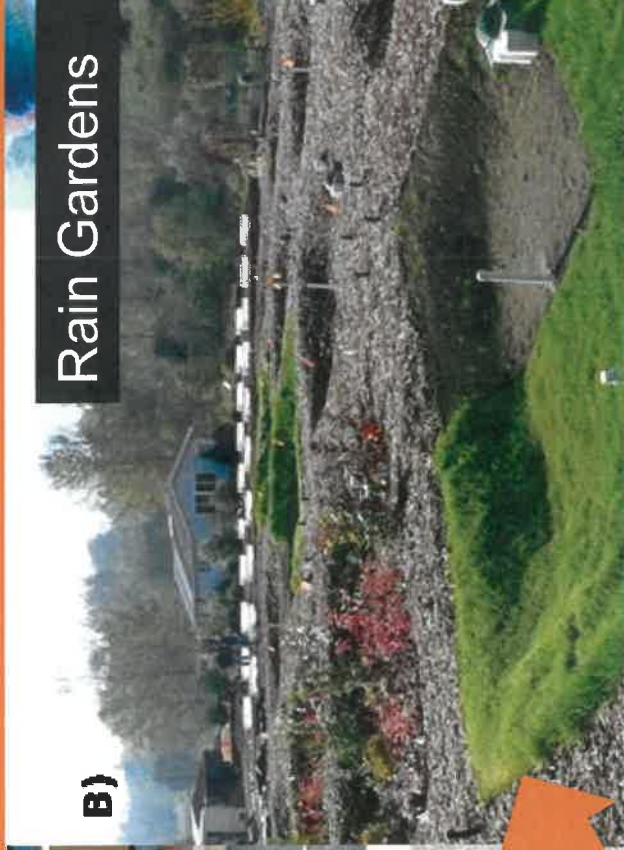
Emerging technologies for the built landscape may be less harmful to salmon and other aquatic animals



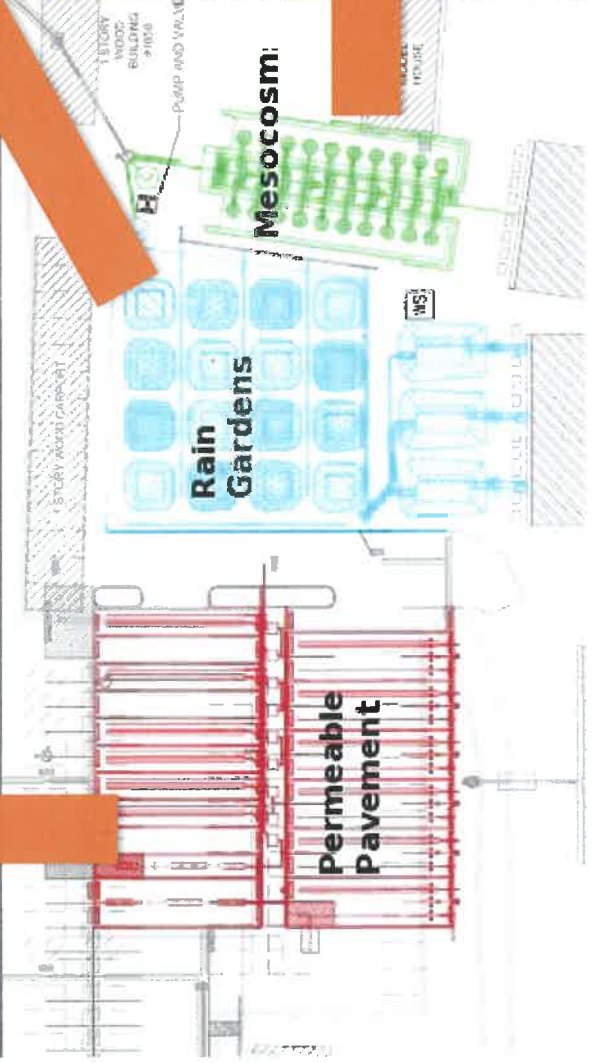
WSU Puyallup GSI Facility



Permeable Pavement

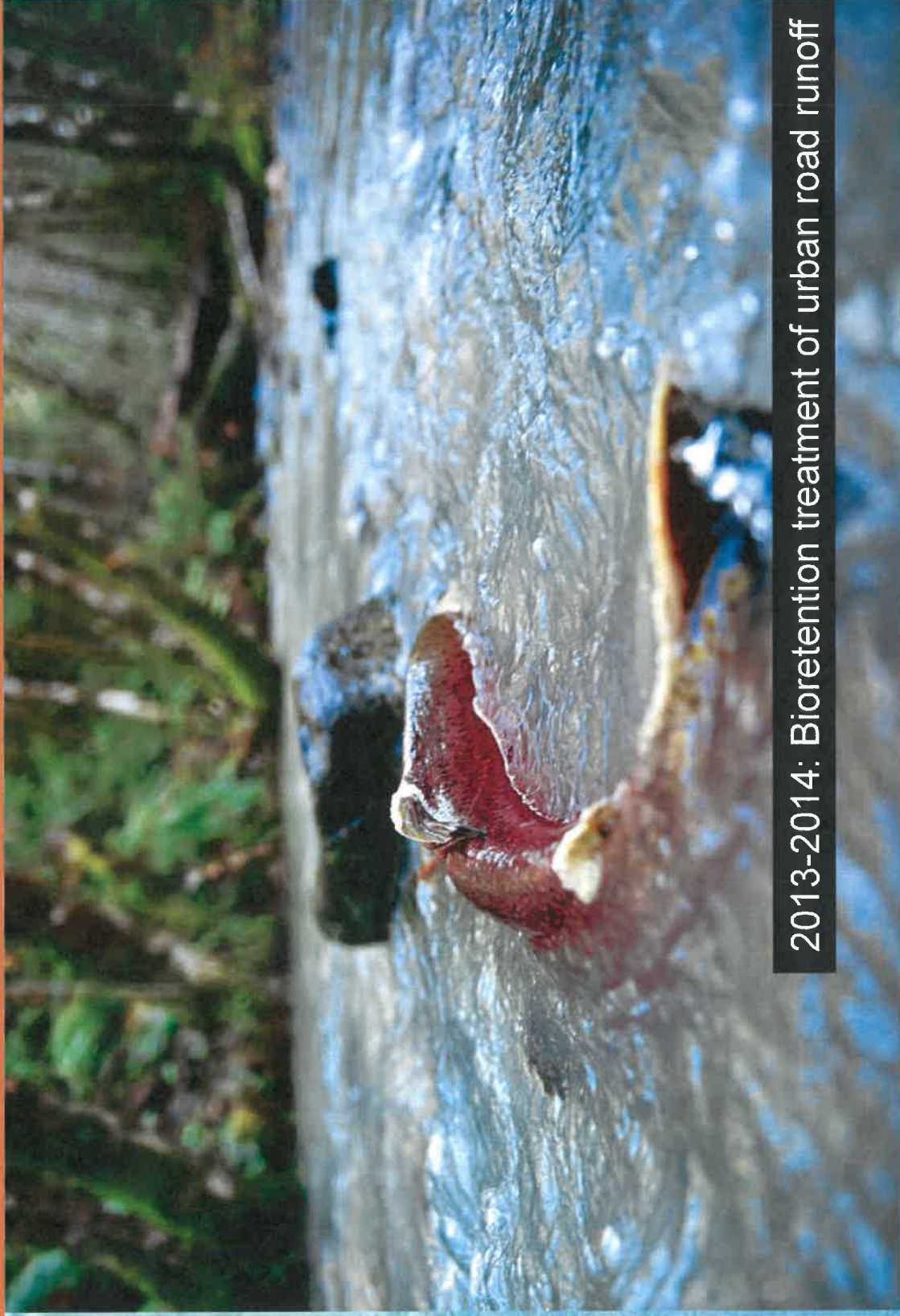


Rain Gardens



Mesocosms

Could bio-retention treatment prevent coho pre-spawn mortality?



2013-2014: Bioretention treatment of urban road runoff

Constructing portable bioretention cells



55 gal. drum

Slotted underdrain



12" drainage layer



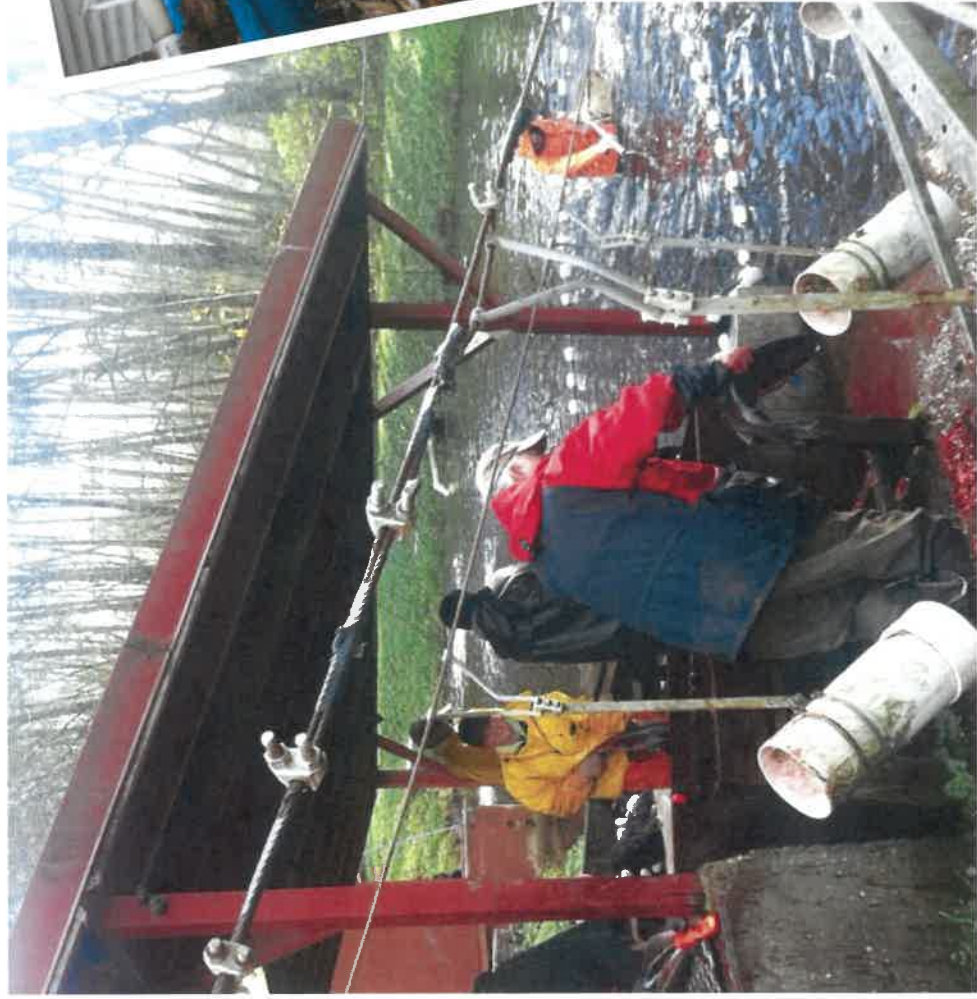
24" bioretention medium

60% sand:
40% compost



mulch

Exposures & treatment at Suquamish Hatchery on Grover's Creek



Can bioretention prevent coho prespawner mortality?

Clean well water



100% Normal

Untreated runoff



100% Symptomatic

Treated runoff



?????

Stormwater runoff exposures 2013/14

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 hours
- All control & treated fish were alive at 24 hours

Well water (4 hr)



All 4 fish alive at 24 hr

Unfiltered stormwater (4 hr)



0 of 4 fish alive at 24 hr

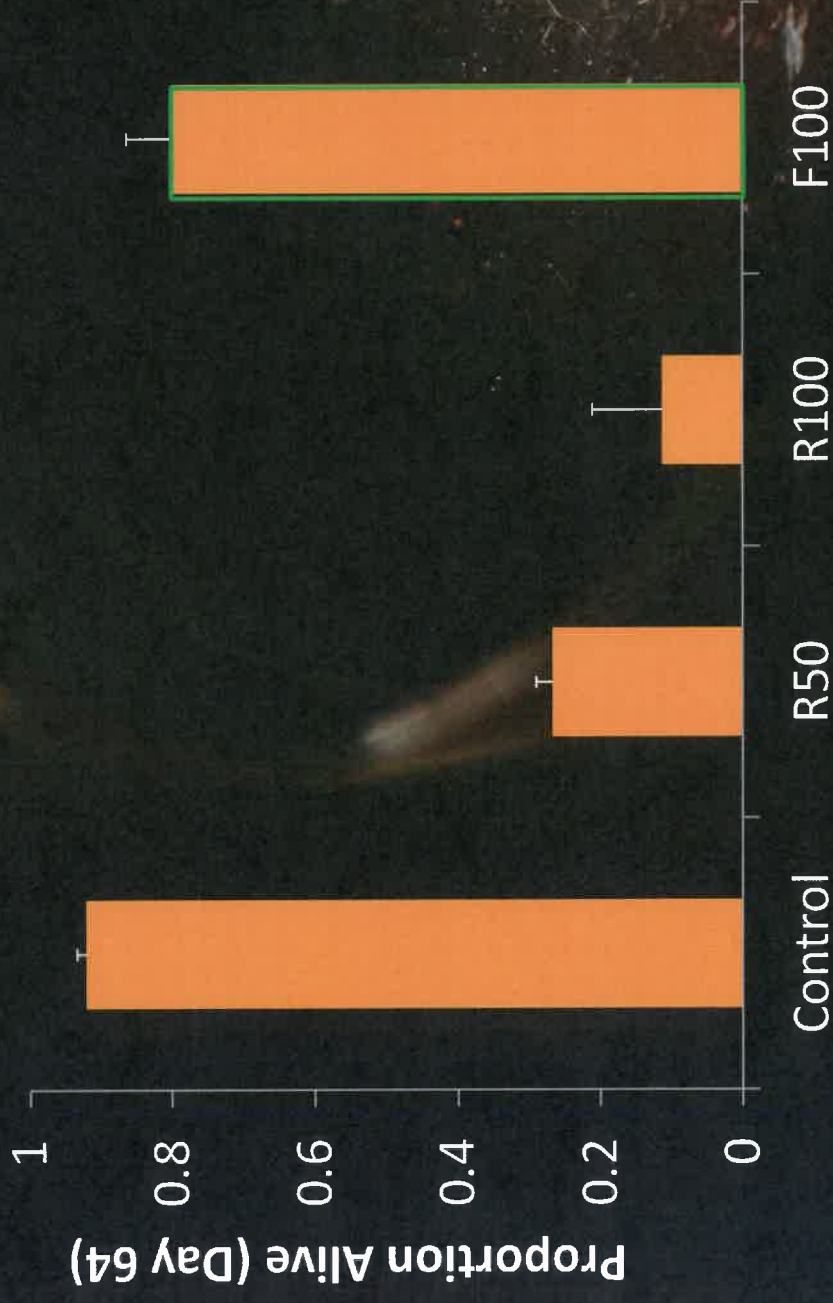
Coho spawners before and after filtering runoff through bioretention

Filtered stormwater (4hr)

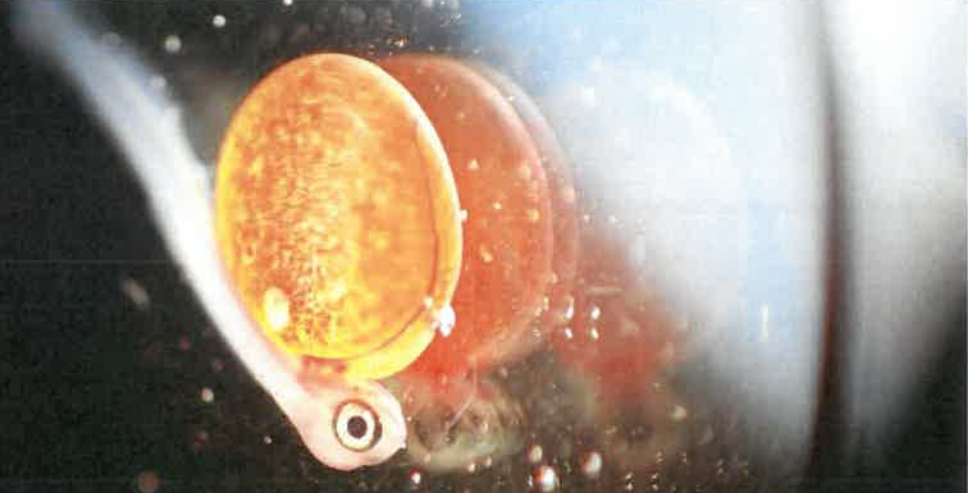


**All 4 fish alive
at 4 & 24 hr**

Coho Embryos: Episodic Exposure to Runoff



Bioretention filtration prevented mortality



Can bioretention prevent toxicity?



Juvenile coho - controls

100% Survival

100% Mortality

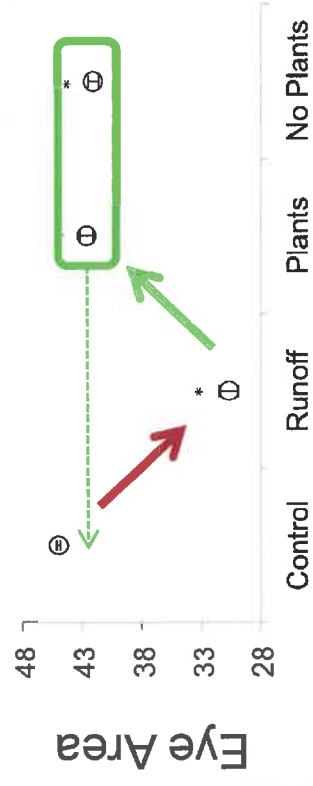
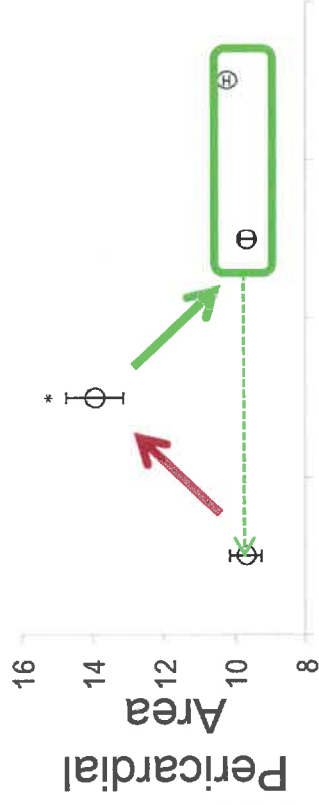
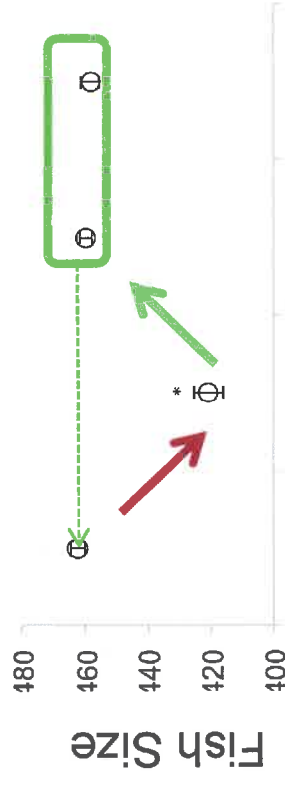
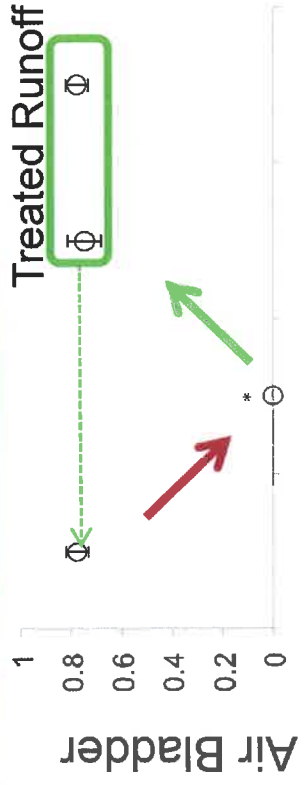
Filtered

Runoff

?



Sublethal toxicity in zebrafish embryos

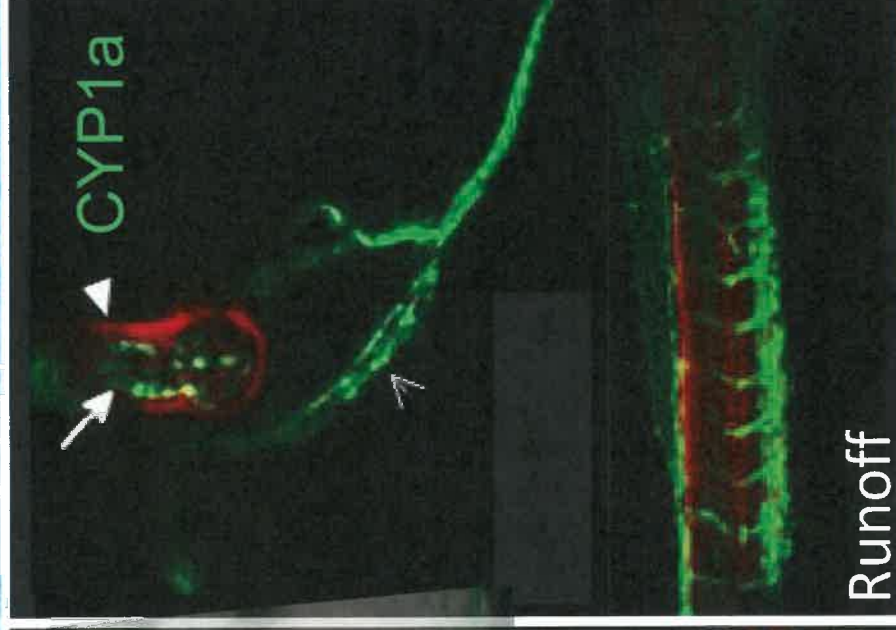
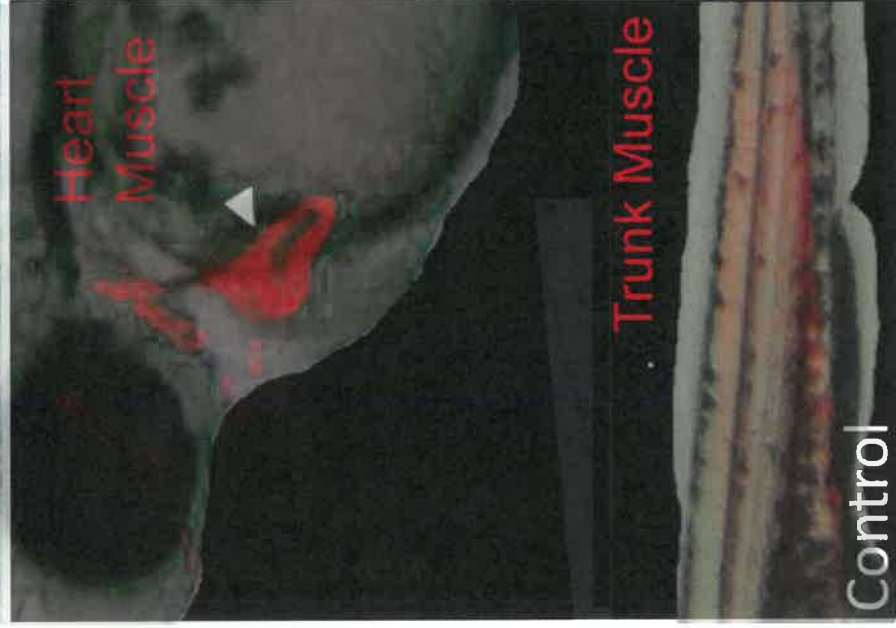


normal length

normal hearts

normal eyes (almost)

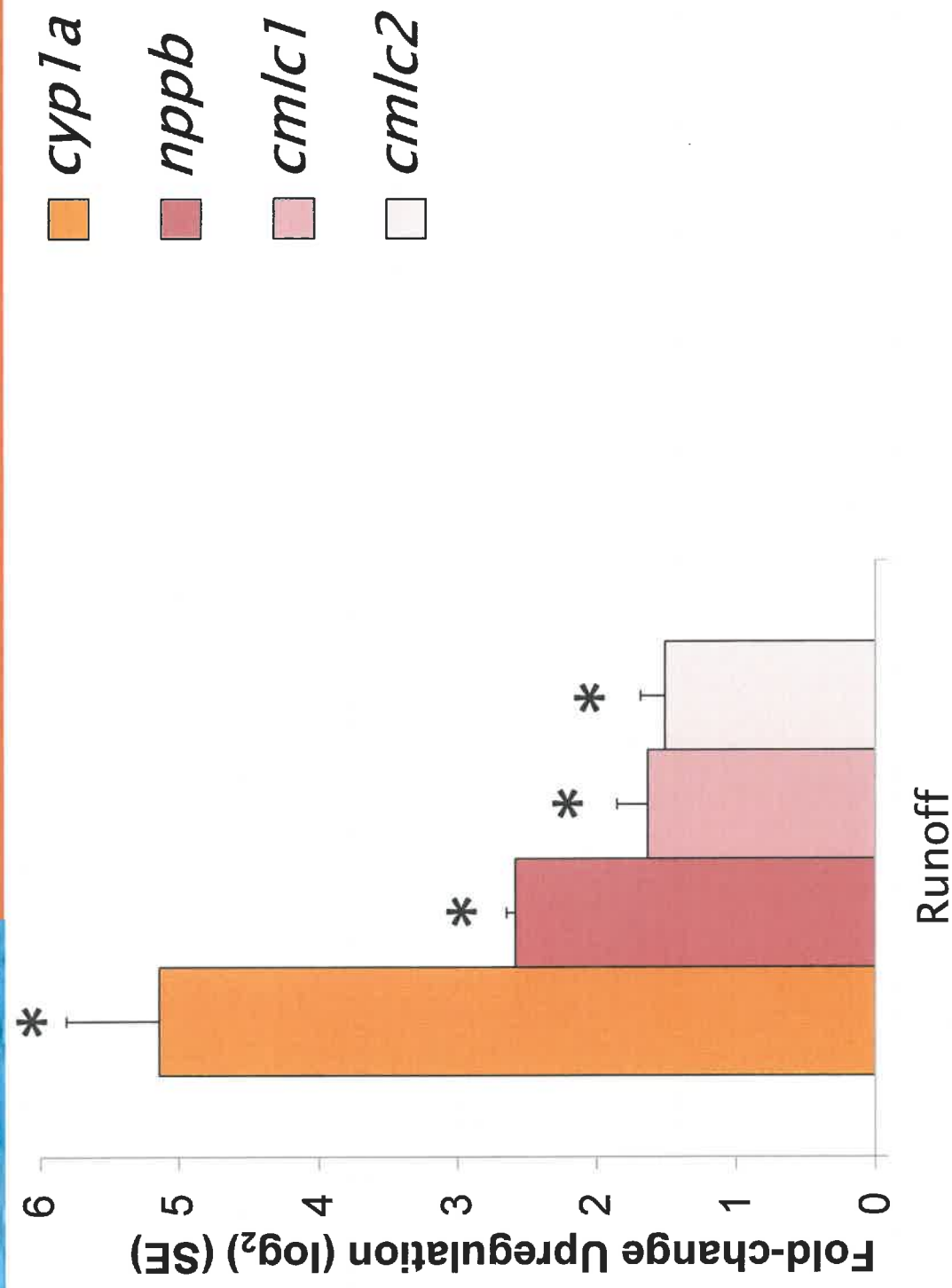
Cardiotoxicity lost after bioretention



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

McIntyre et al. 2016. ES&T

Molecular markers in runoff exposed zebrafish



Summary of bioretention effectiveness

Animal Model	Effect	Exposure	Eliminated	Reduced
Juv. coho	Mortality	96 h	✓	
Adult coho	Mortality	24 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		✓
	PAH exposure gene (<i>cyp1a</i>)	48 h		✓
	Cardiac injury gene (<i>nppb</i>)	48 h	✓	

Upcoming projects runoff impacts to salmon

Relative species sensitivity

- Testing other species of Pacific salmon

Coho pre-spawn mortality

- Uncover primary source of hypoxia
- Phenotypic anchoring of physiology to behaviour in coho
- Validating juvenile salmon as a model for adult pre-spawn mortality



Sources of Toxics in Road Runoff



Tire Wear



Exhaust



Brakes



Washer Fluid

Automobile Leaks:

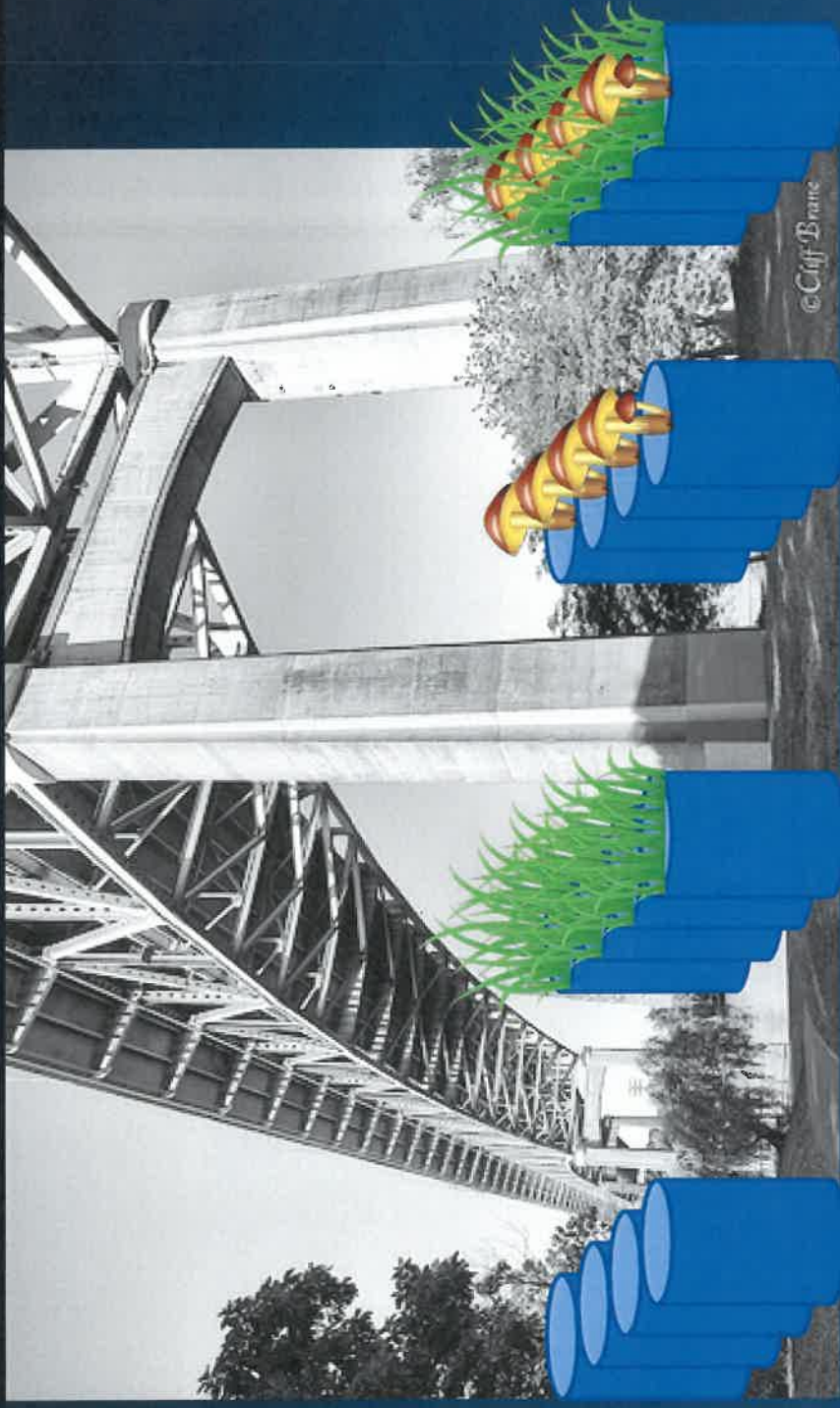
- Fuel
- Engine Oil
- Brake Fluid
- Engine Coolant
- Transmission Fluid



Leaks

Which are most toxic? Which contribute most to toxicity?

Bioretention Performance 2016-2018



- Alex Taylor – WSU M.S.
- 2-yr installation
- BSM + Plants + Fungi
- Real-time input from I-5
- Quarterly monitoring:
- Hydrology
- Chemistry
- Toxicology

Acknowledgments



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WSU-Puyallup REC
FMO Crew
Oriki Jack
Curtis Hinman
Richard Bembenek
Emma Mudrock

Suquamish Tribe
Mike Huff et al.

Puyallup Tribe
Blake Smith et al.

US Fish & Wildlife Service:

Steve Damm

WASHINGTON STATE
UNIVERSITY



