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

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

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Urban stormwater runoff
& Green infrastructure

Fish Barrier Removal Board, Feb 21, 2017

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National Oceanic and Atmospheric Administration, U.S. Department of Commerce (NOAA)

United States Environmental Protection Agency

National Oceanic and Atmospheric Administration, U.S. Department of Commerce (NOAA)

U.S. Fish & Wildlife Service, Department of the Interior

THE SUQUAMISH TRIBE

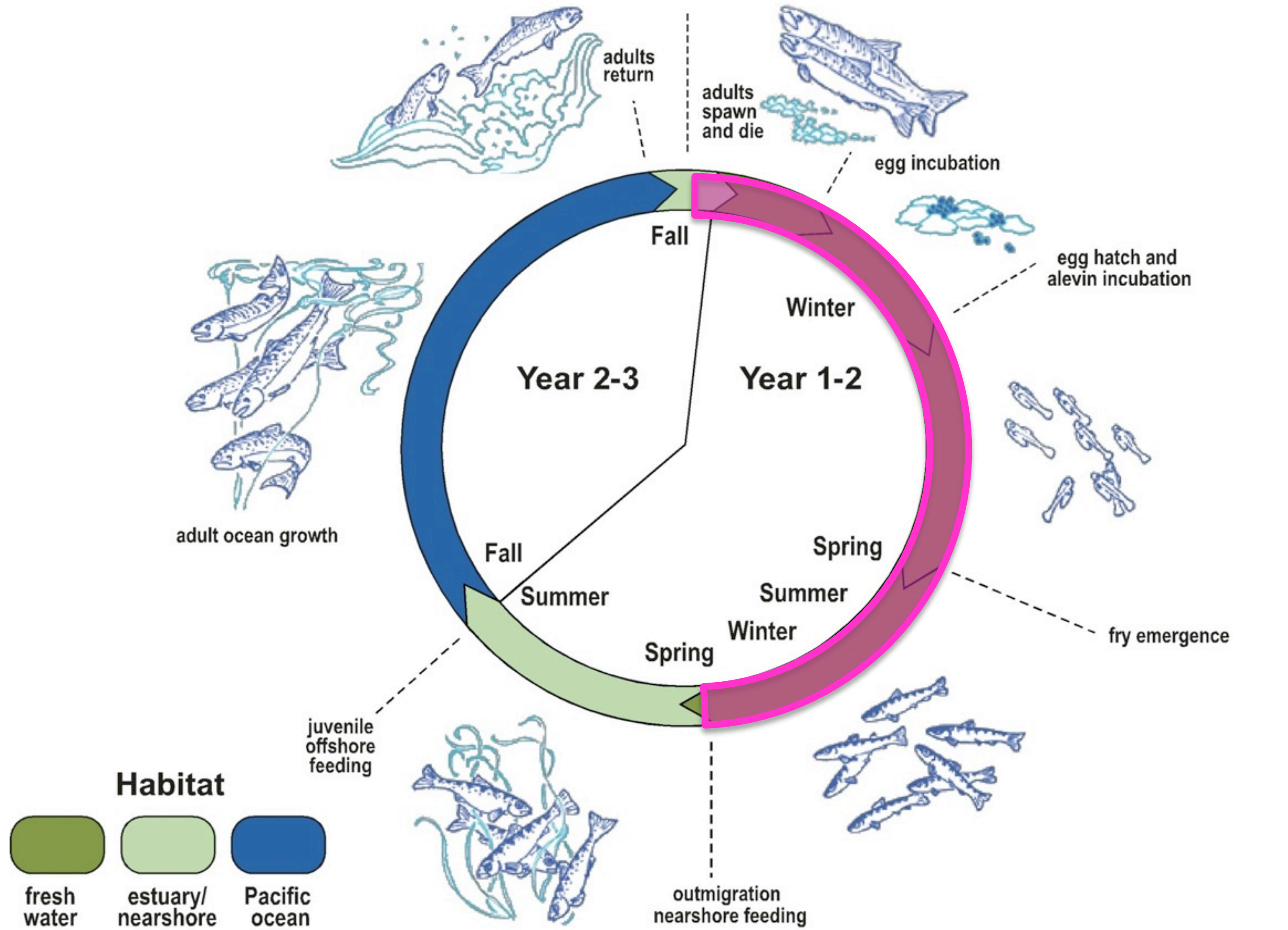
Sea Grant Washington

DEPARTMENT OF ECOLOGY State of Washington

Coho salmon as stormwater sentinel

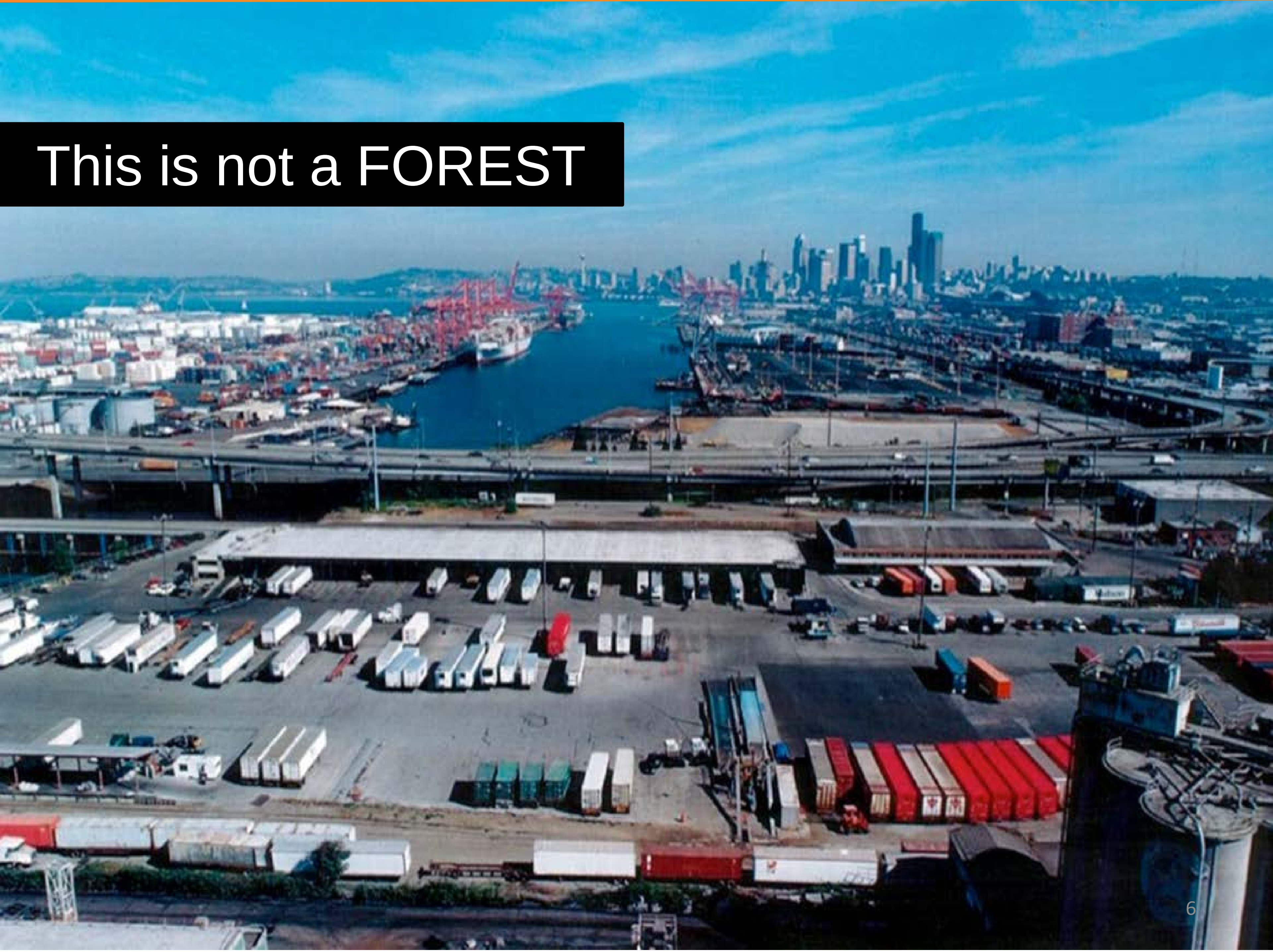
- Widely distributed
- Lowland streams
- Sensitive to water quantity & quality
- Supported by a diverse food web
- More than 1 year in freshwater

Impact of stormwater on coho salmon



sketches from Alaska Seafood Marketing Institute

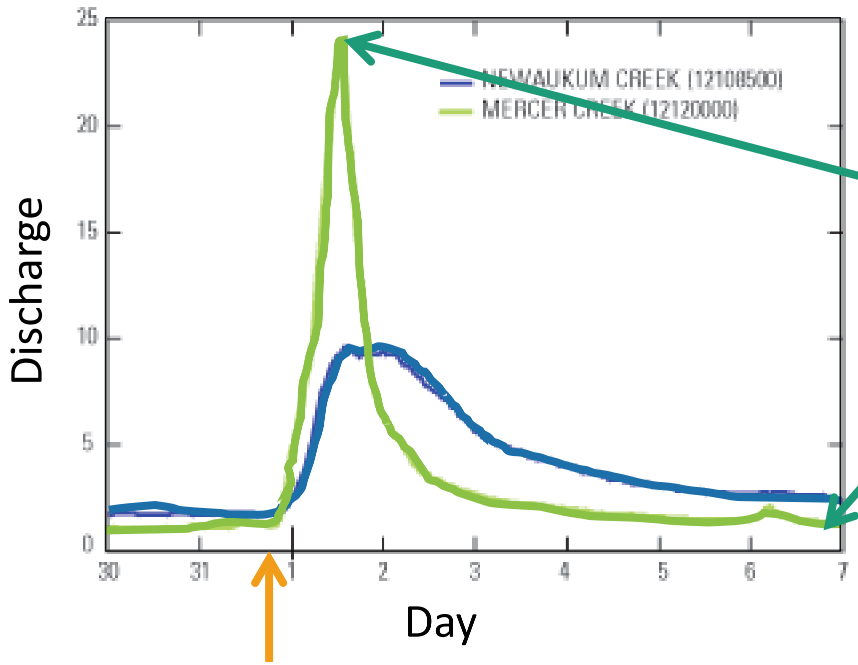
This is not a FOREST



An urban stormwater outfall

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

Urban Runoff: Water Quantity

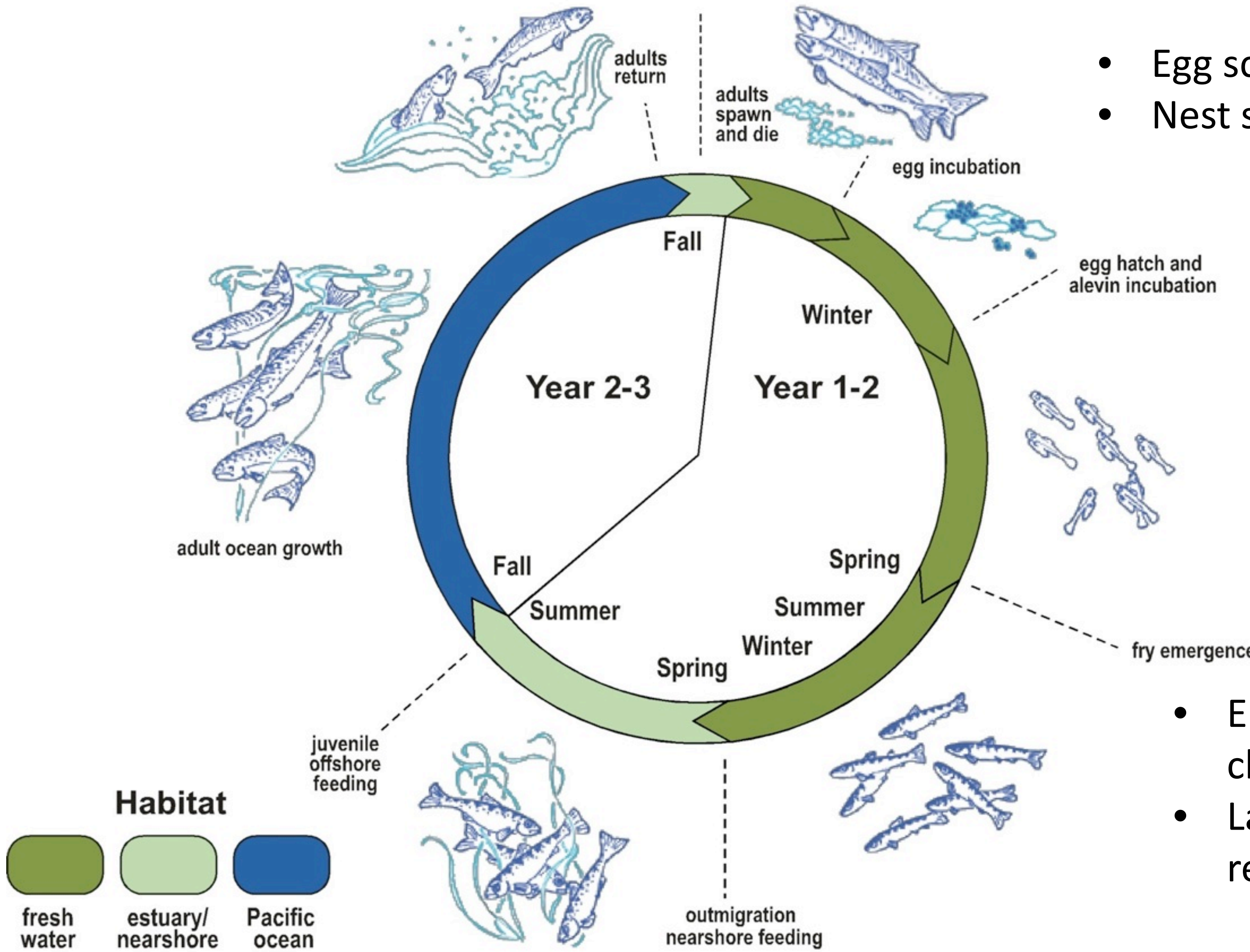


Urban streams:

- Higher peak flow
- Lower baseline flow
- Shorter time to peak flow
- Shorter return to baseline

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

Impact of stormwater on coho salmon



sketches from Alaska Seafood Marketing Institute

- Egg scour
- Nest suffocation

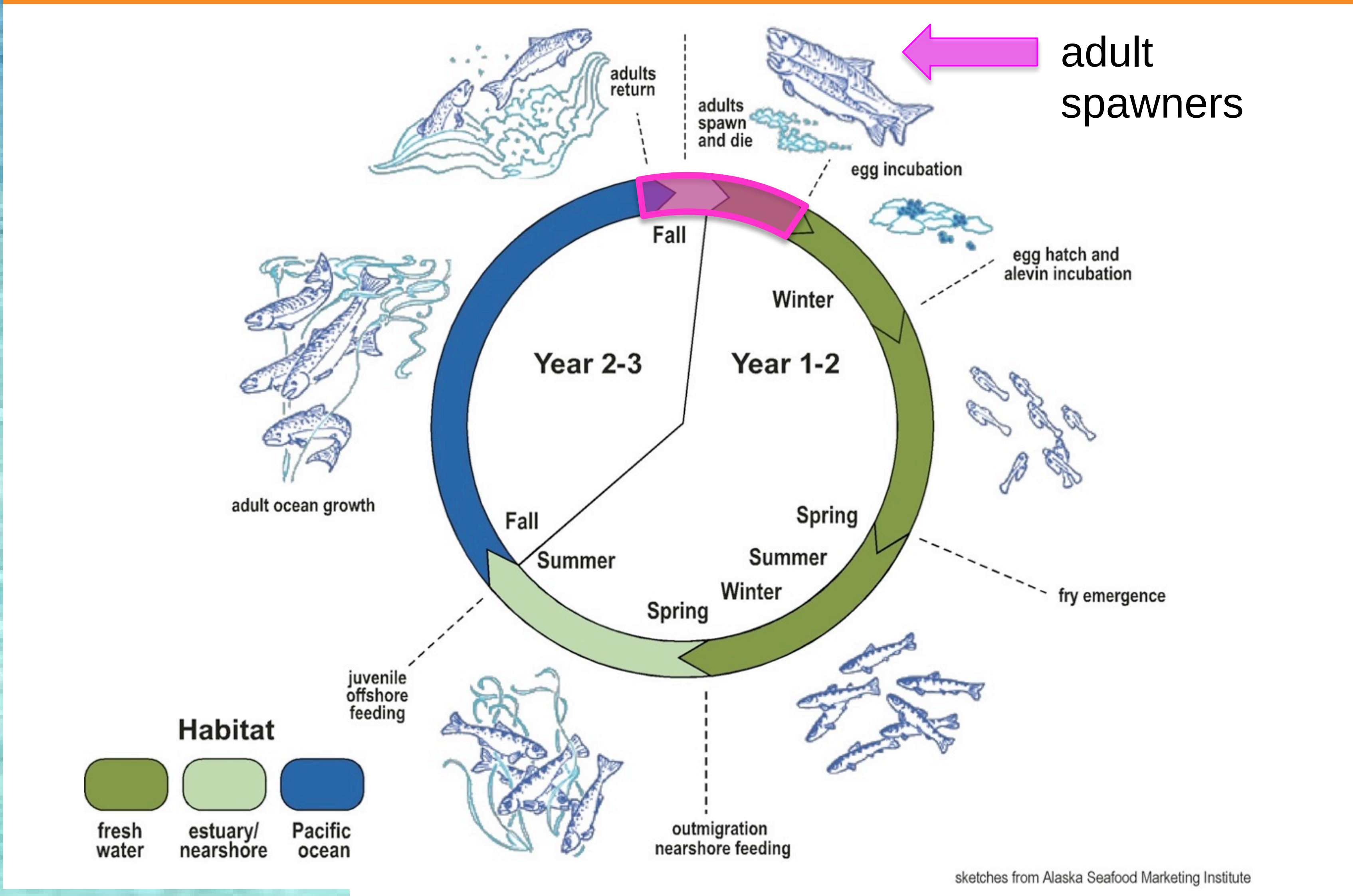
- Energetic challenge
- Lack of flow refugia

The pollution you see….

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

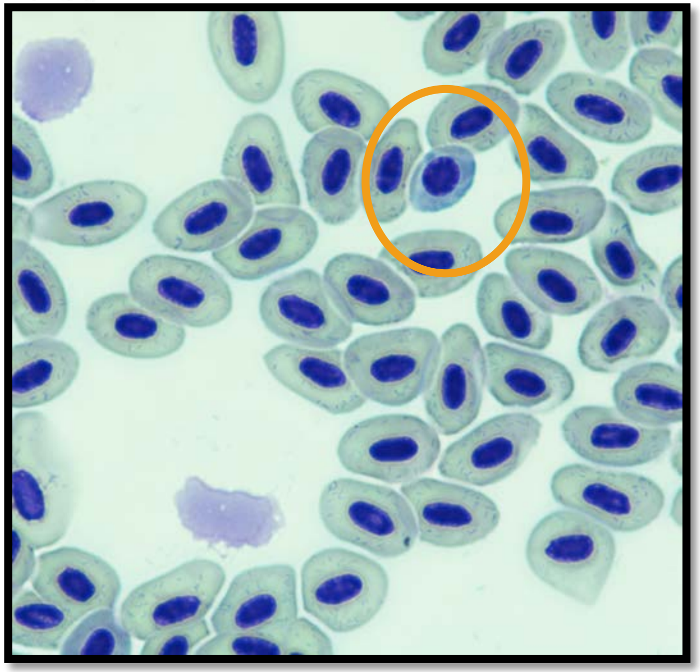
Adult coho exposures

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

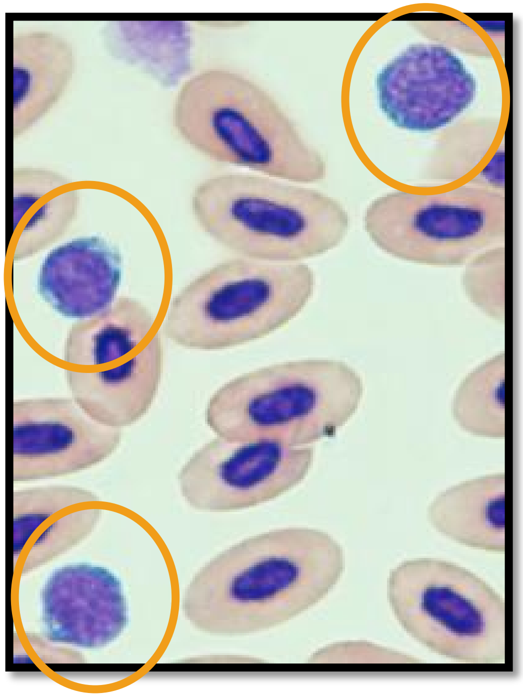
Unexposed (3.5 hrs)	Stormwater-exposed (3.5 hrs)

Spromberg et al. 2015. J. Applied Ecology

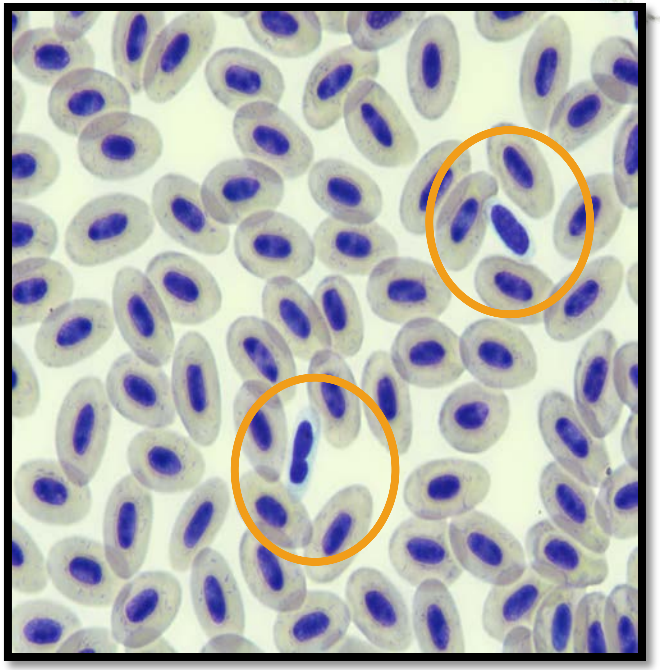
Pathophysiology: Blood cells of coho exposed to runoff



More immature RBCs (hypoxia)



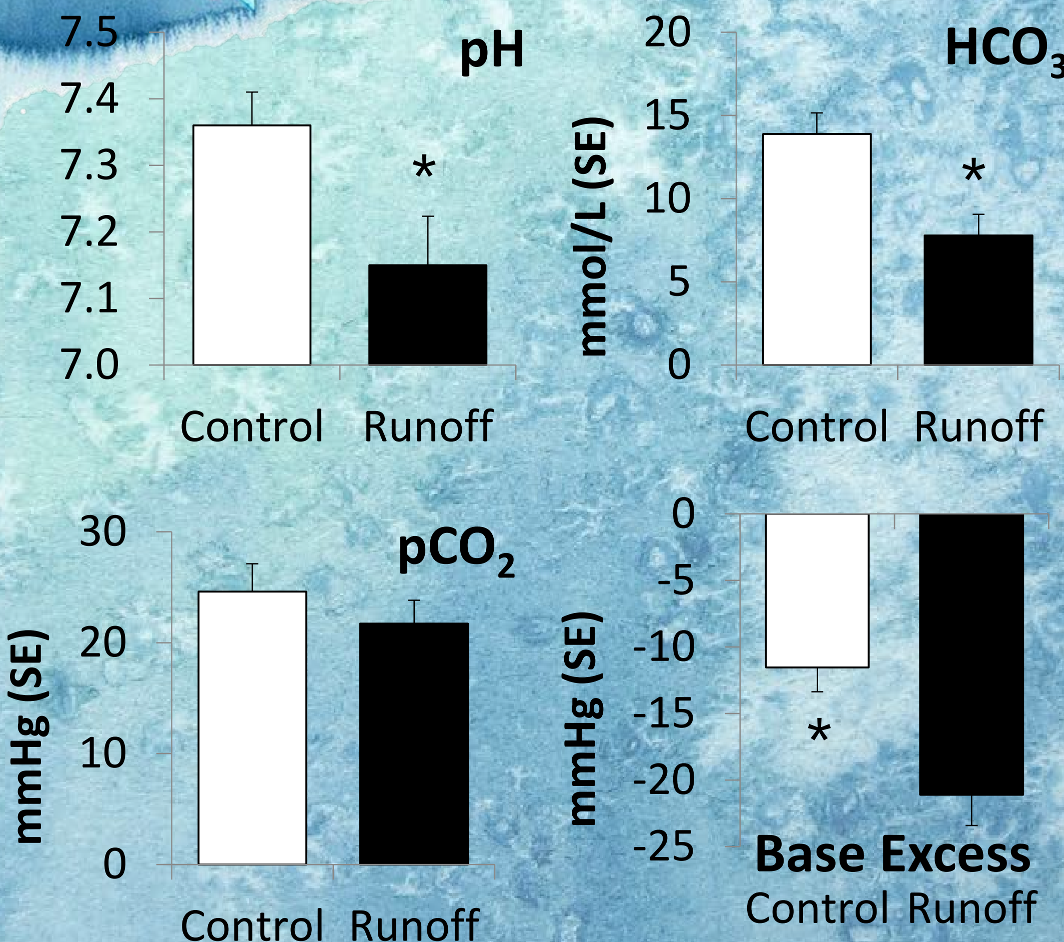
More WBCs (immune response)

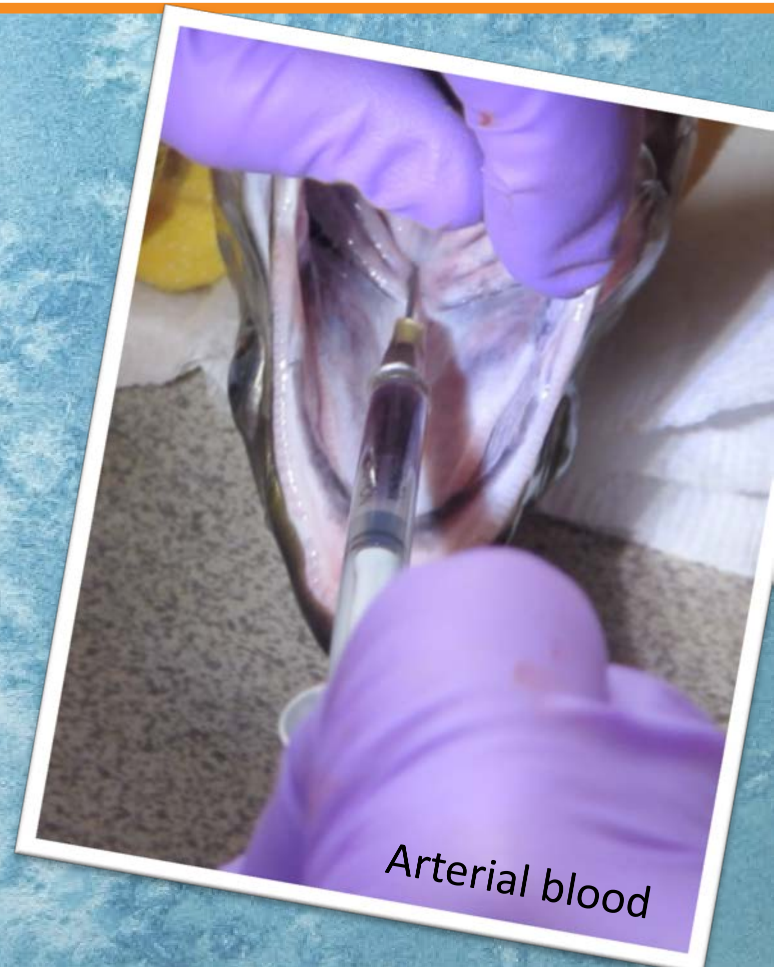


Fewer thrombocytes (coagulation response)

iSTAT point-of-care blood analyzer

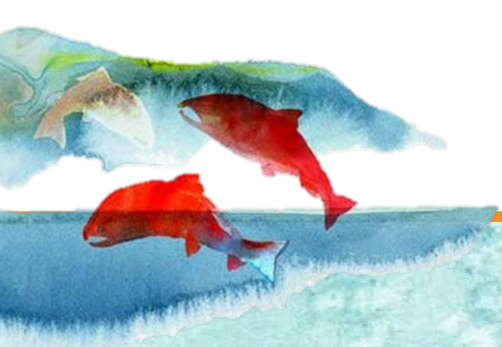
Arterial blood gas analysis

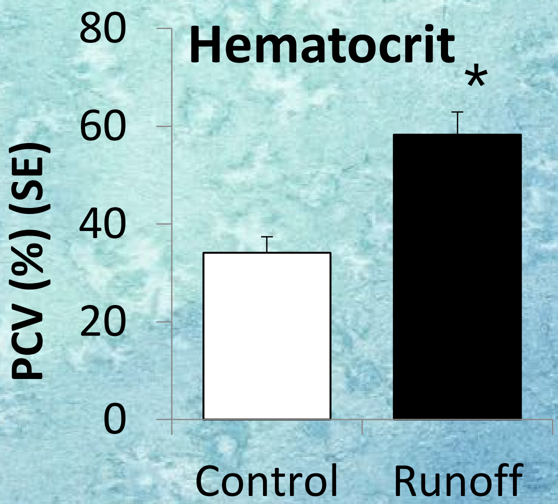




Diagnosis: Metabolic acidosis

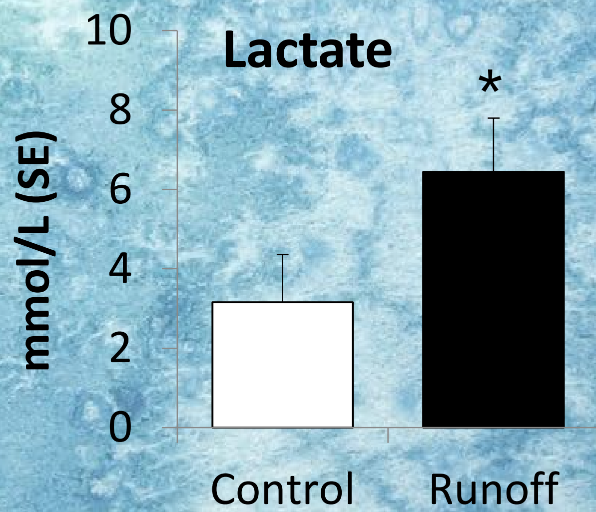
Arterial blood chemistry analysis





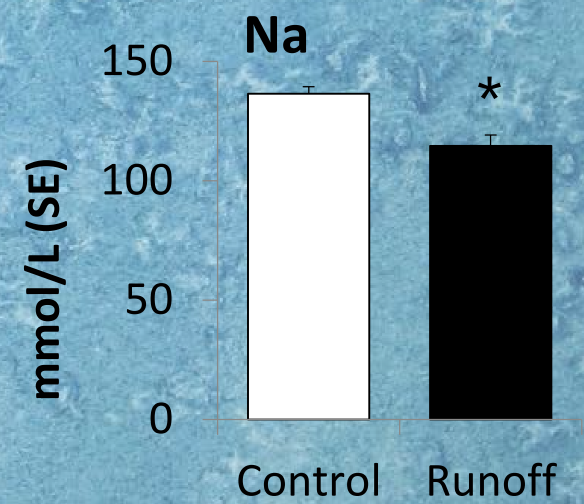
Increased blood cells and/or decreased plasma

Hypoxia



Anaerobic cellular respiration

Hypoxia



Hyponatremia

- Diuresis
- Heart failure
- Kidney failure

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

Adult Chum Salmon

Run Timing: Oct-Dec

Run timing: Nov-Jan

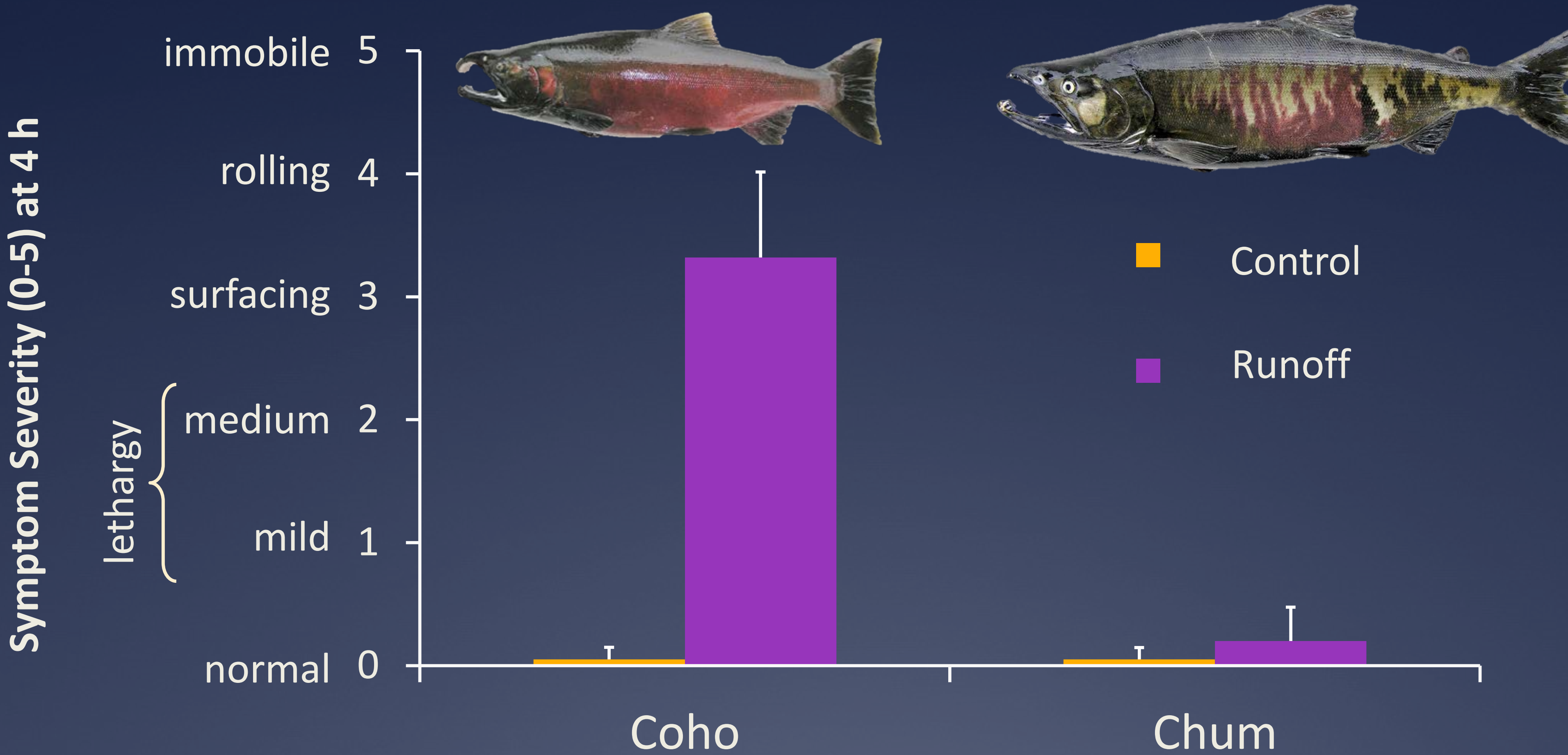
Are other salmon as vulnerable as coho?

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

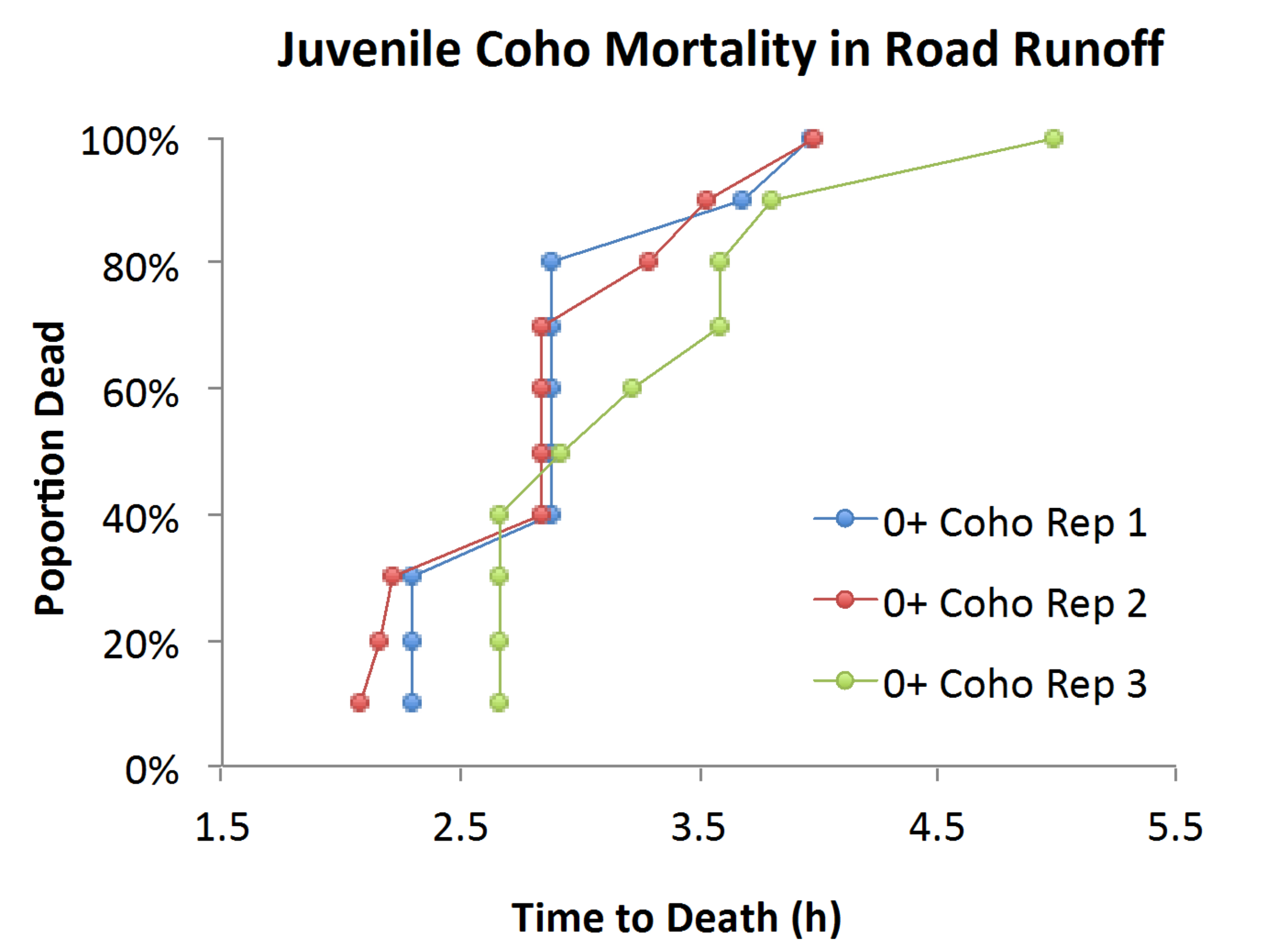
Coho and chum in Pipers Creek (2006)

Sensitivity of juvenile salmon?

Juvenile coho show PSM symptoms

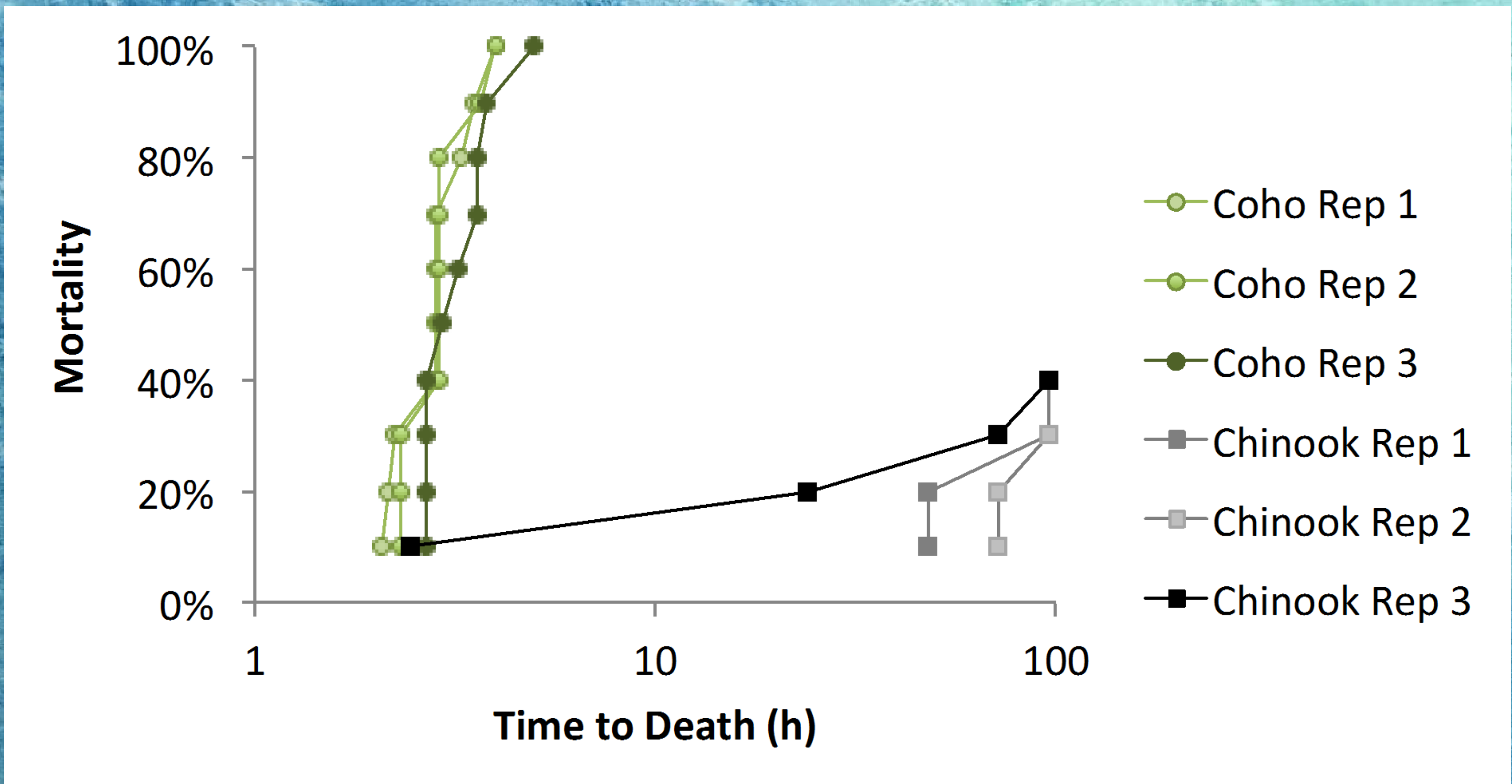
Stage 4: Loss of equilibrium

Sensitivity of juvenile coho?



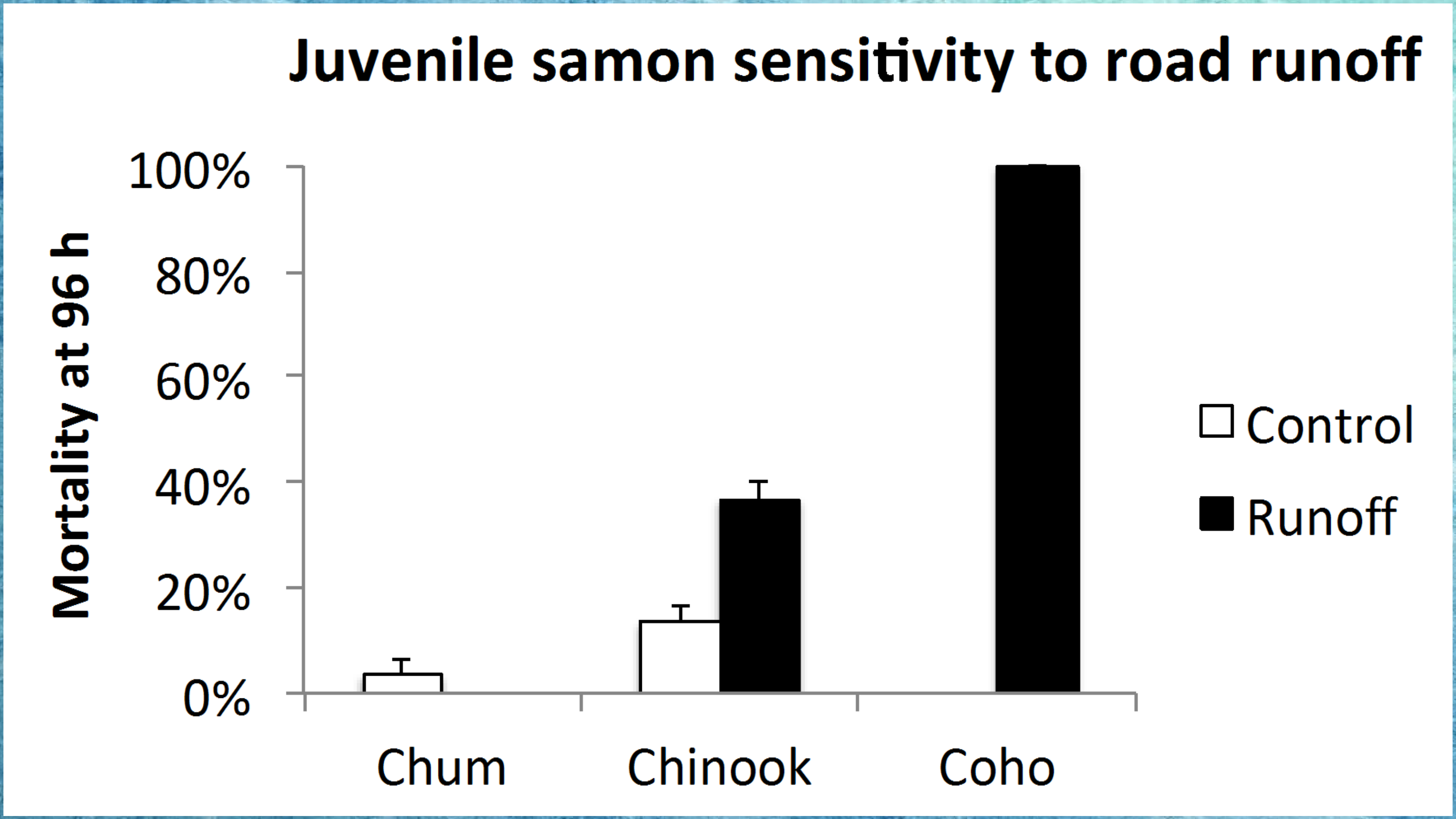
Juvenile coho very sensitive

Juvenile coho vs Chinook salmon?



Coho are by far more sensitive

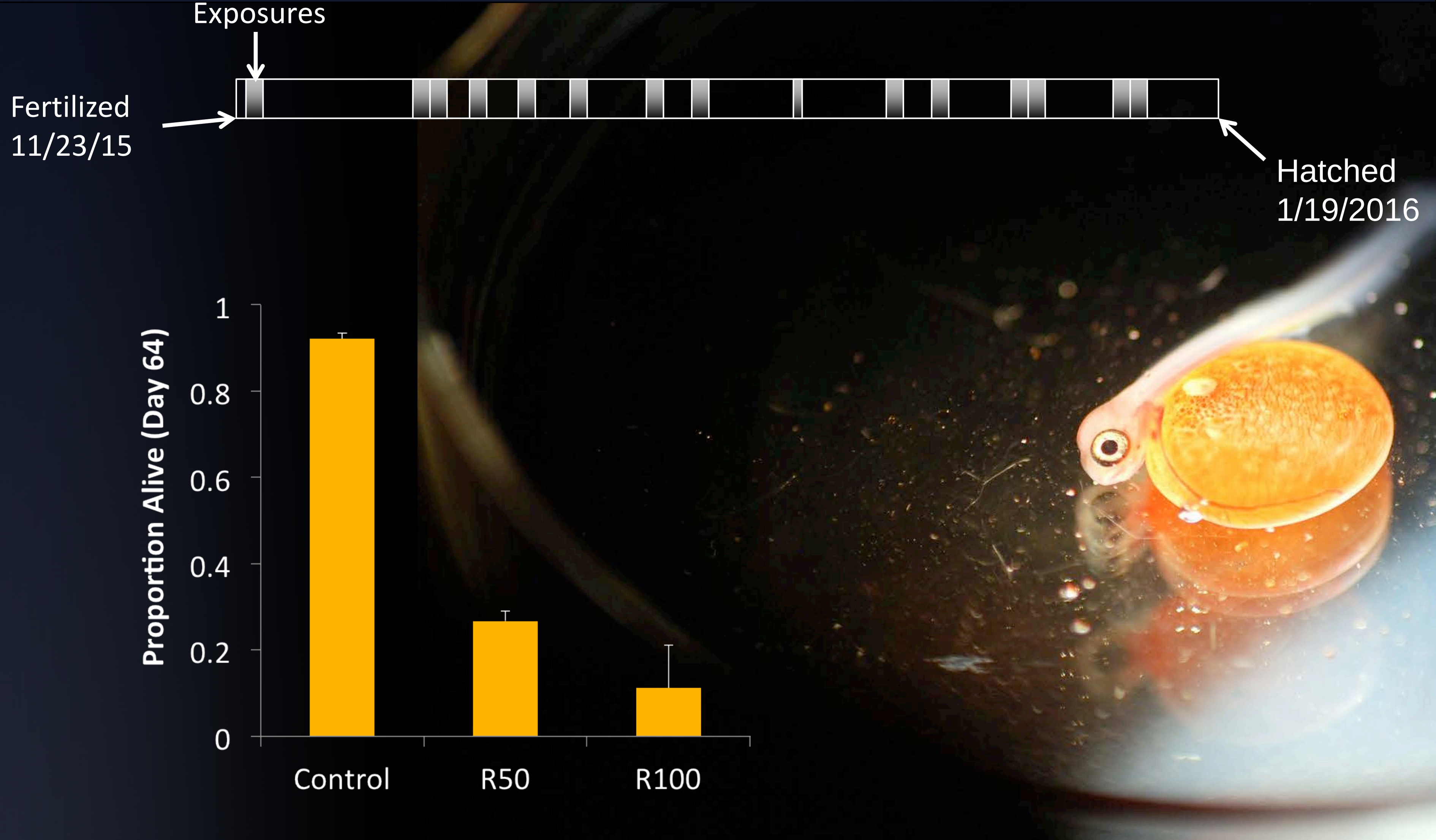
Juvenile chum vs Chinook vs coho salmon?



Coho are by far more sensitive to urban runoff

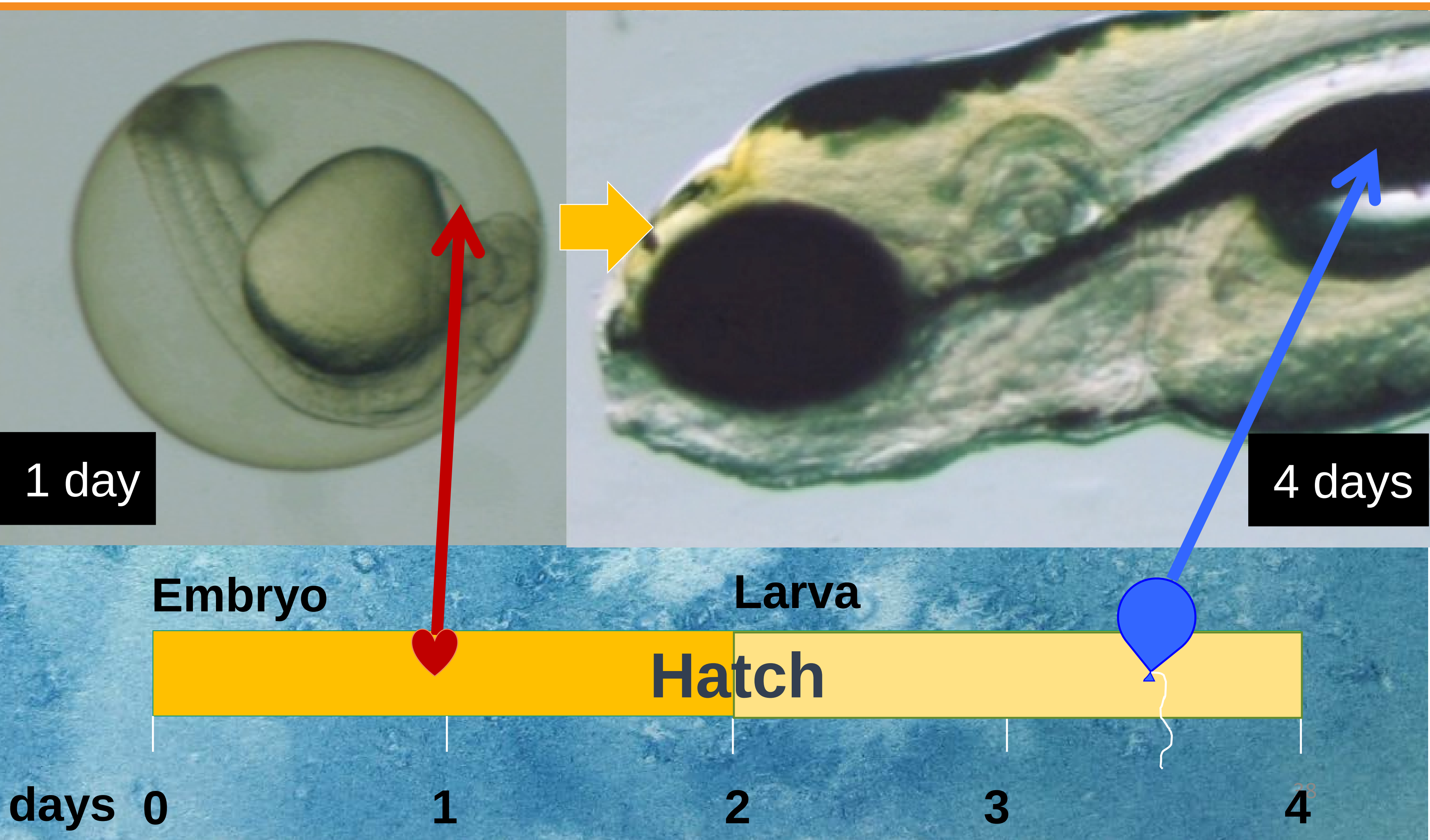
Coho embryo-larval development

Coho Embryos: Episodic Exposure to Runoff

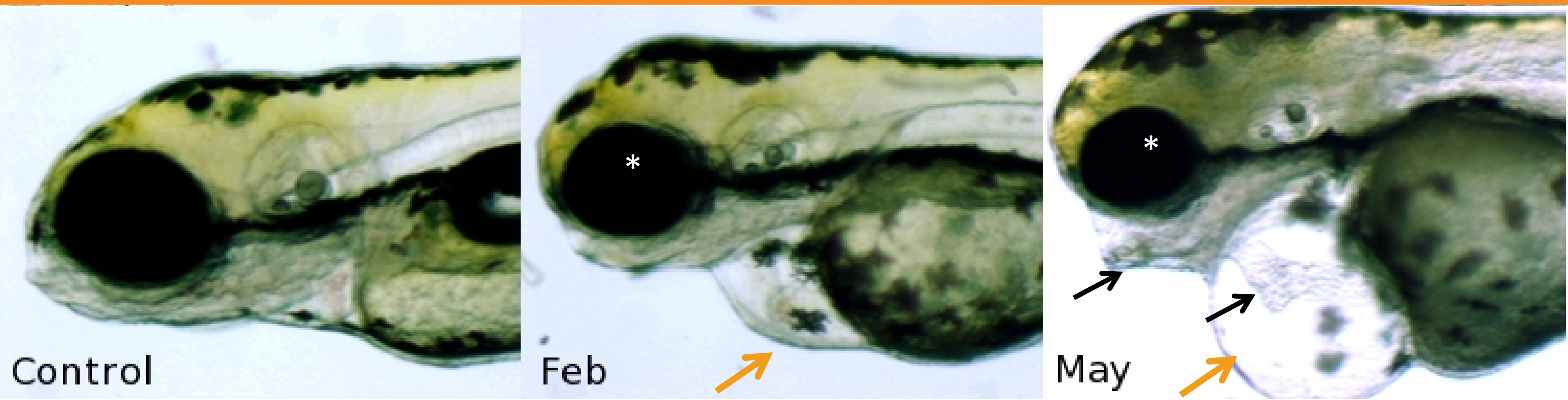


Acute lethal response upon hatching

Zebrafish research model



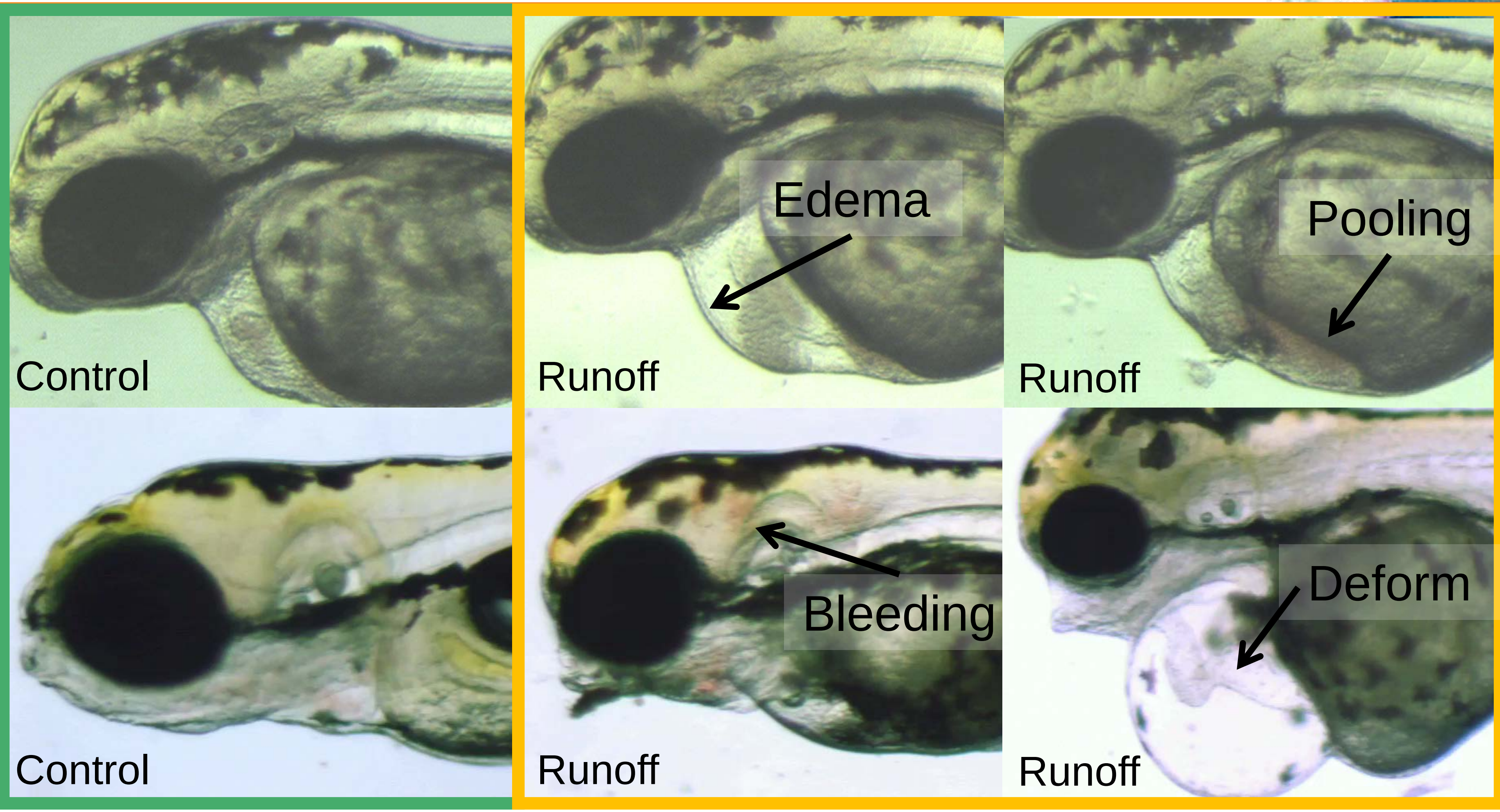
Sublethal effects in zebrafish



Sublethal effects of runoff on developing fish include:

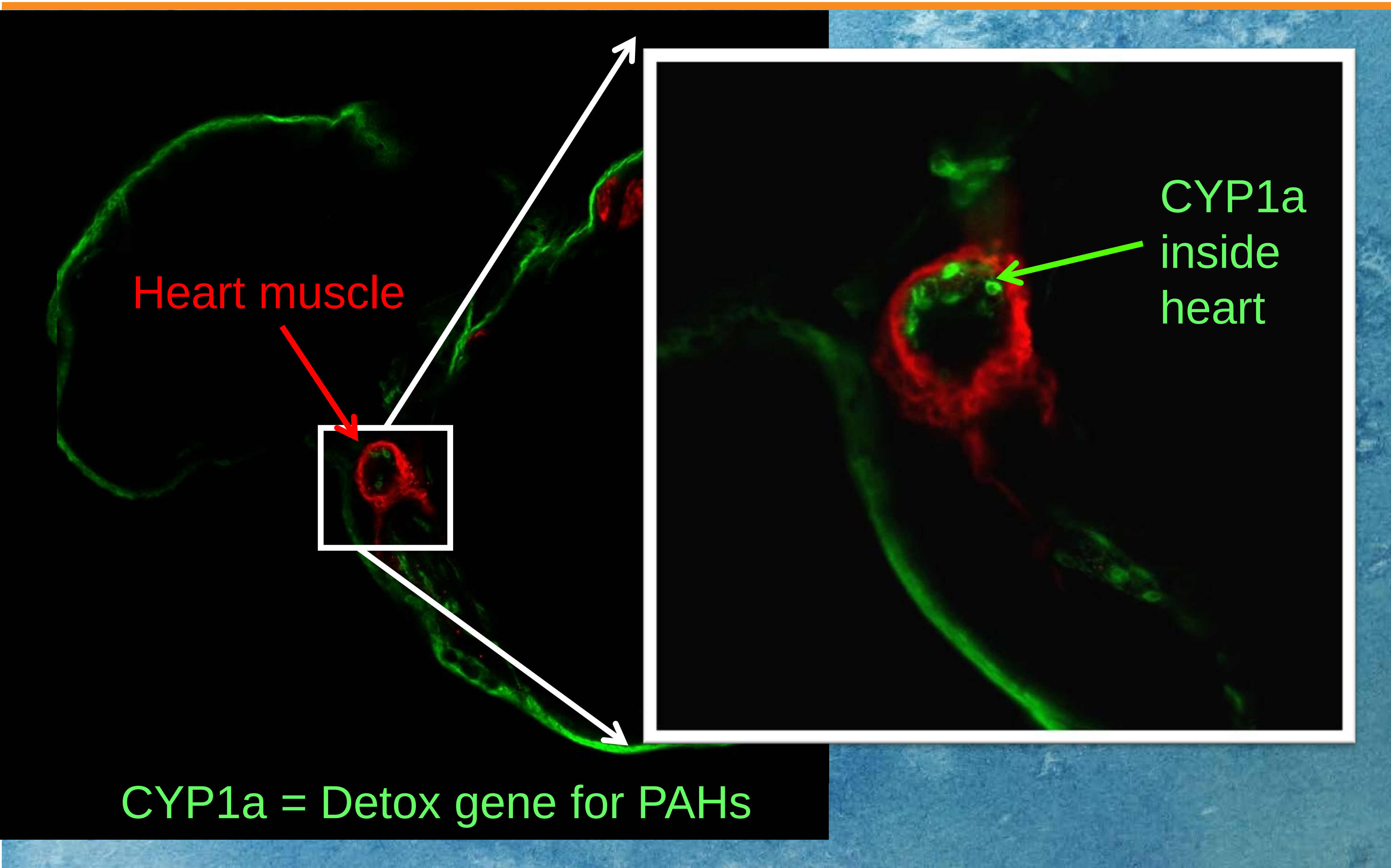
- Inability/delay to hatch
- Developmental delays
- Small eye phenotype (*)
- Pericardial edema (yellow arrow)
- Deformed jaws and hearts (black arrows)

Cardiac abnormalities from runoff

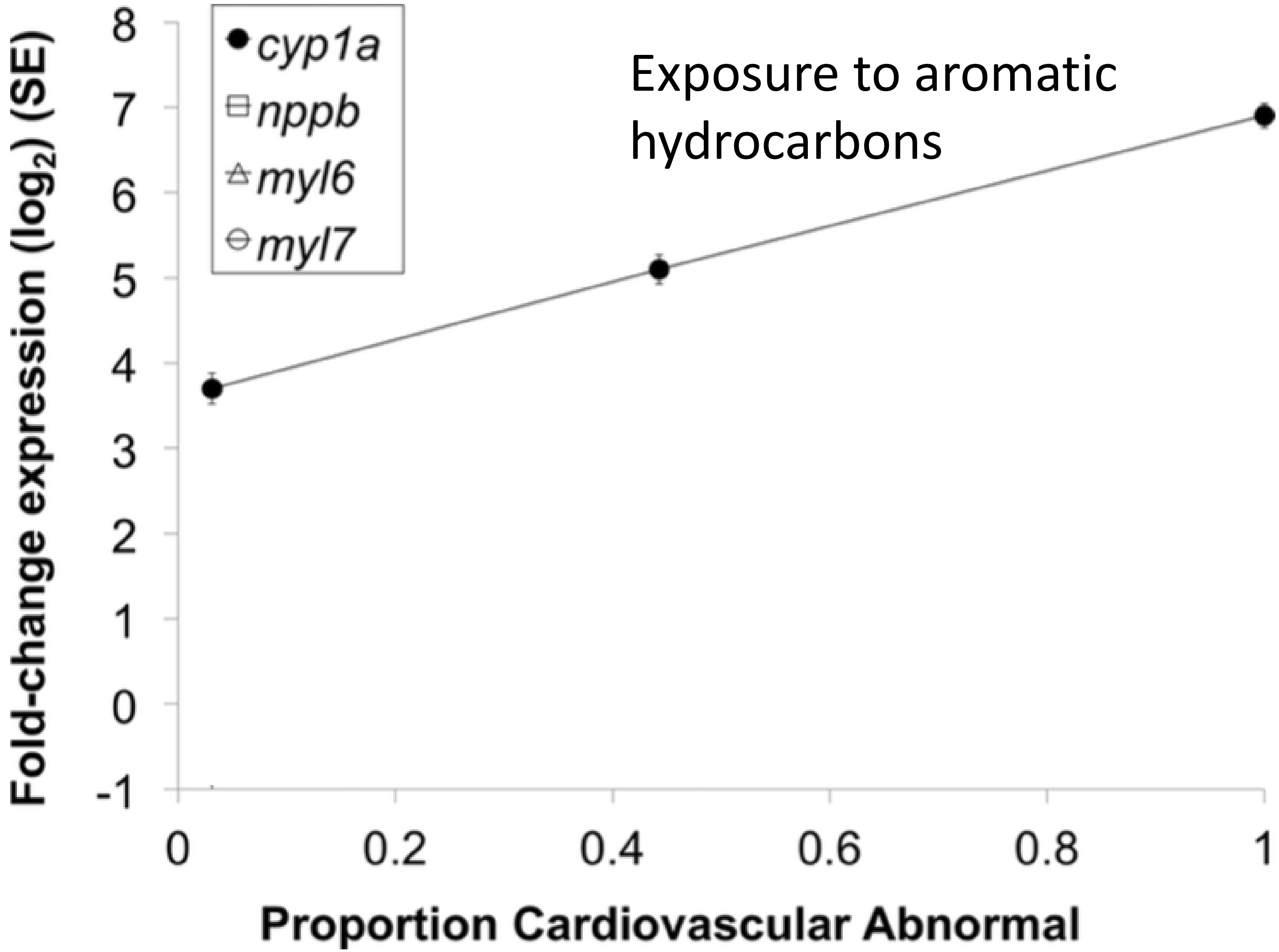


Urban runoff gives zebrafish bad hearts.

The heart is a target for road runoff contaminants



Genes that scale with heart effects



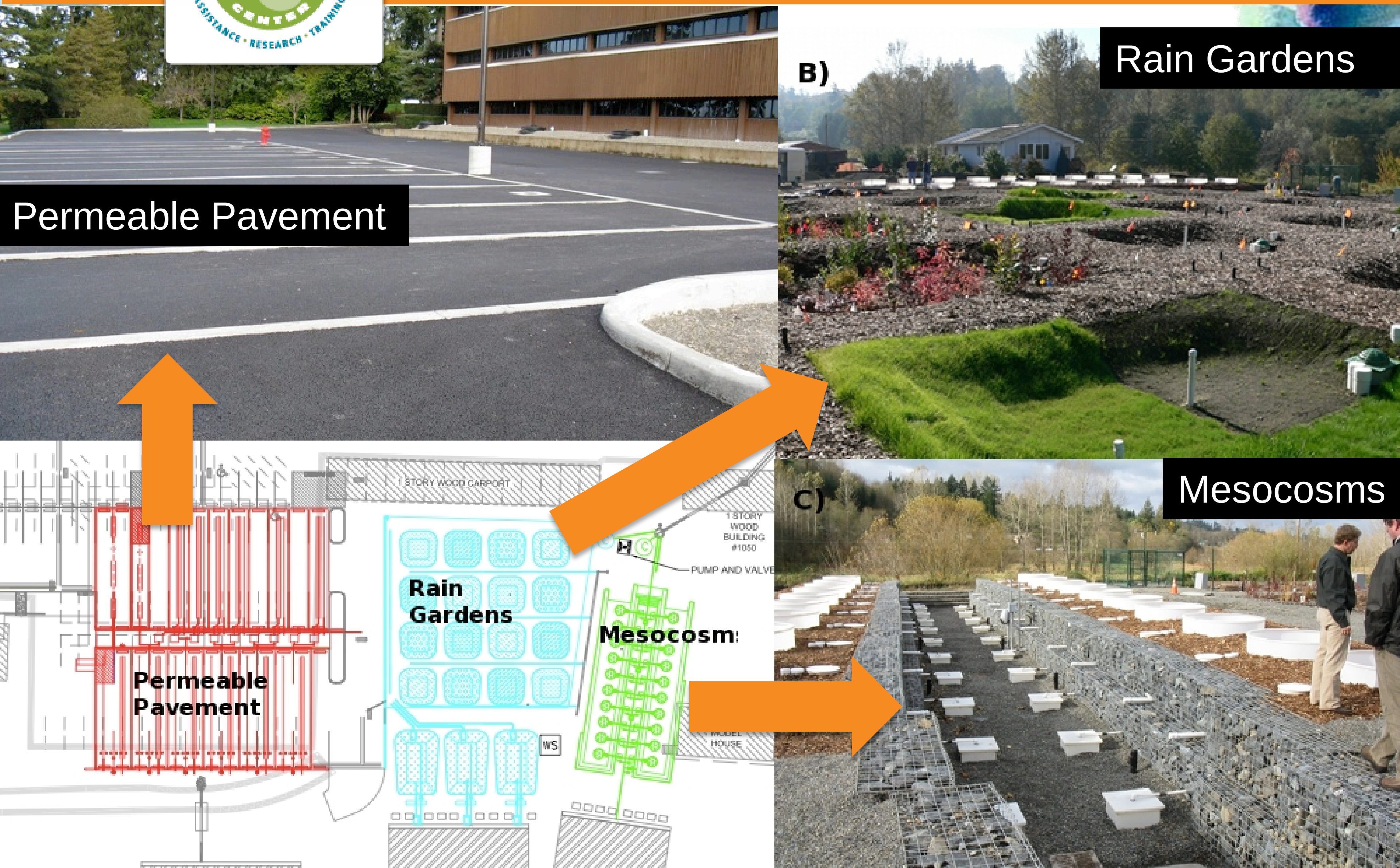
Exposure to aromatic hydrocarbons

Toxicology evolving from:

Green Stormwater Infrastructure

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

WSU Puyallup GSI Facility



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

Constructing
portable bioretention cells

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

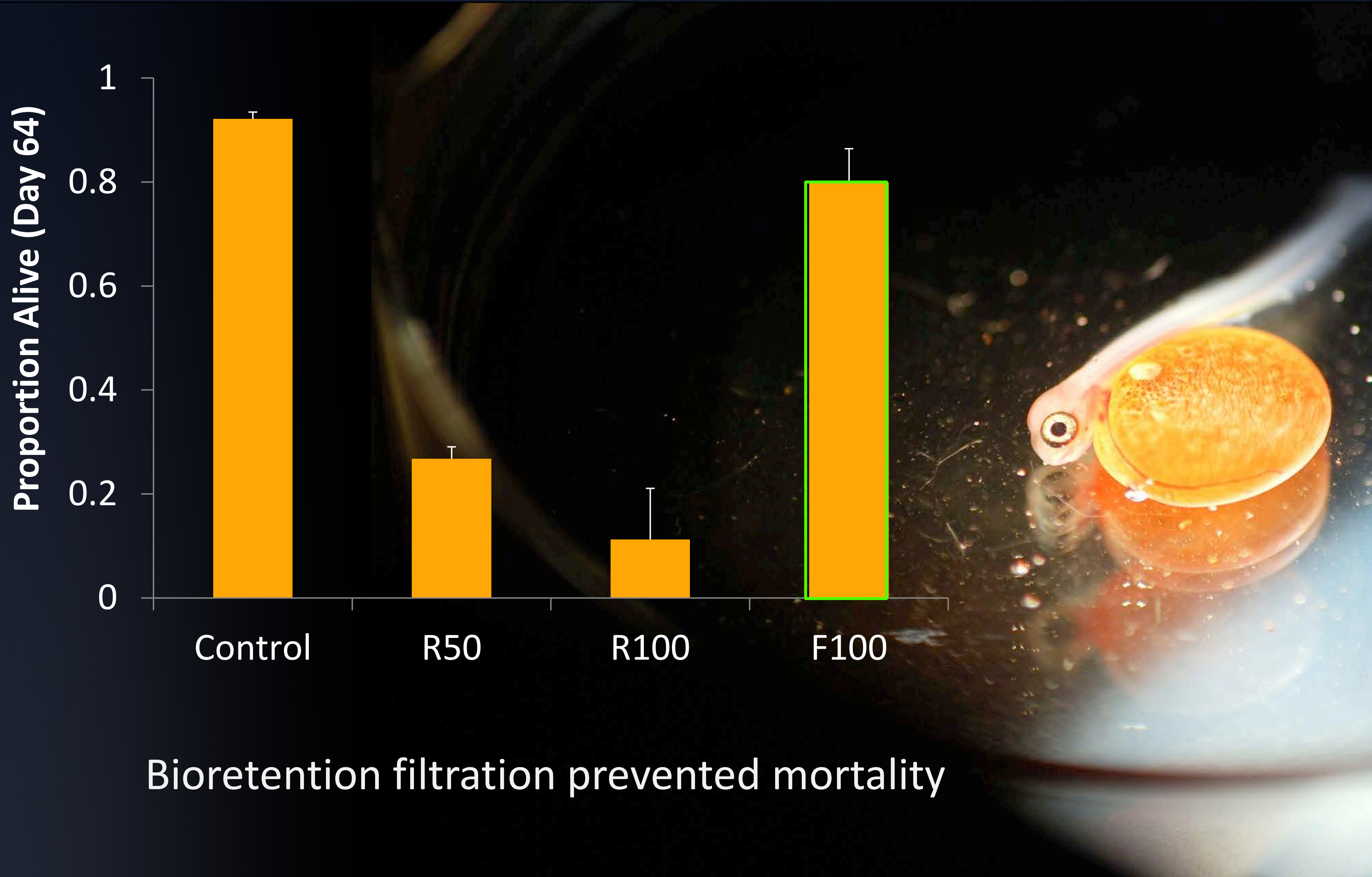
Study Year	Test Date	Exposure (hours)	Control Water	Untreated Runoff	Treated Runoff
2013	Nov 8	4	100 % Live	50% Dead; 50% Symptomatic	100% Live
2013	Nov 18	24	100% Live	100% Dead	100% Live
2014	Oct 20	24	100% Live	100% Dead	100% Live
2014	Oct 22	24	100% Live	100% Dead	100% Live
2014	Oct 27	24	100% Live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

Coho spawners before and after filtering runoff through bioretention

Spromberg et al. 2015. J Ecol Applications

Coho Embryos: Episodic Exposure to Runoff

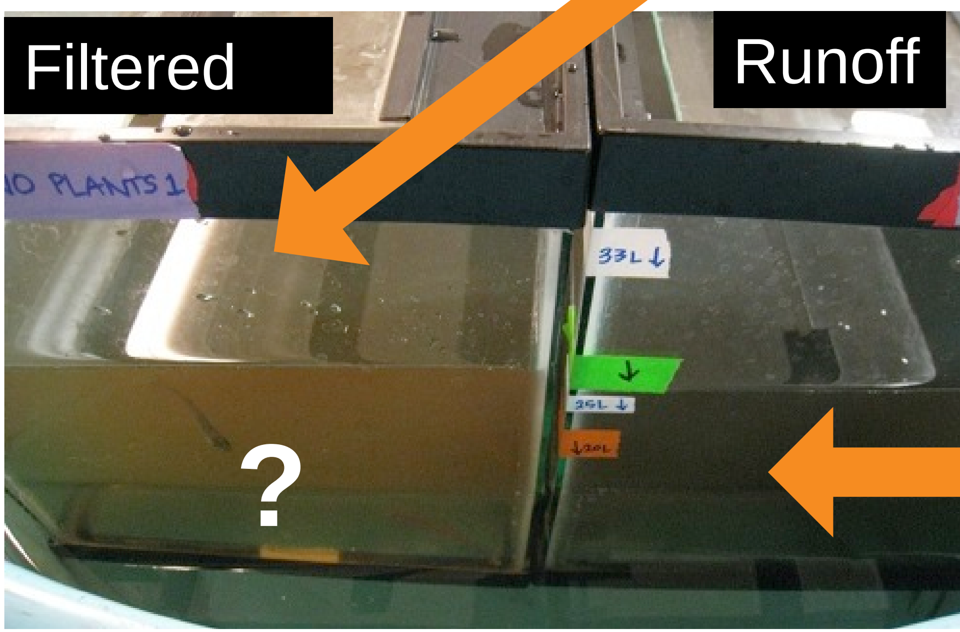


Bioretention filtration prevented mortality

Can bioretention prevent toxicity?

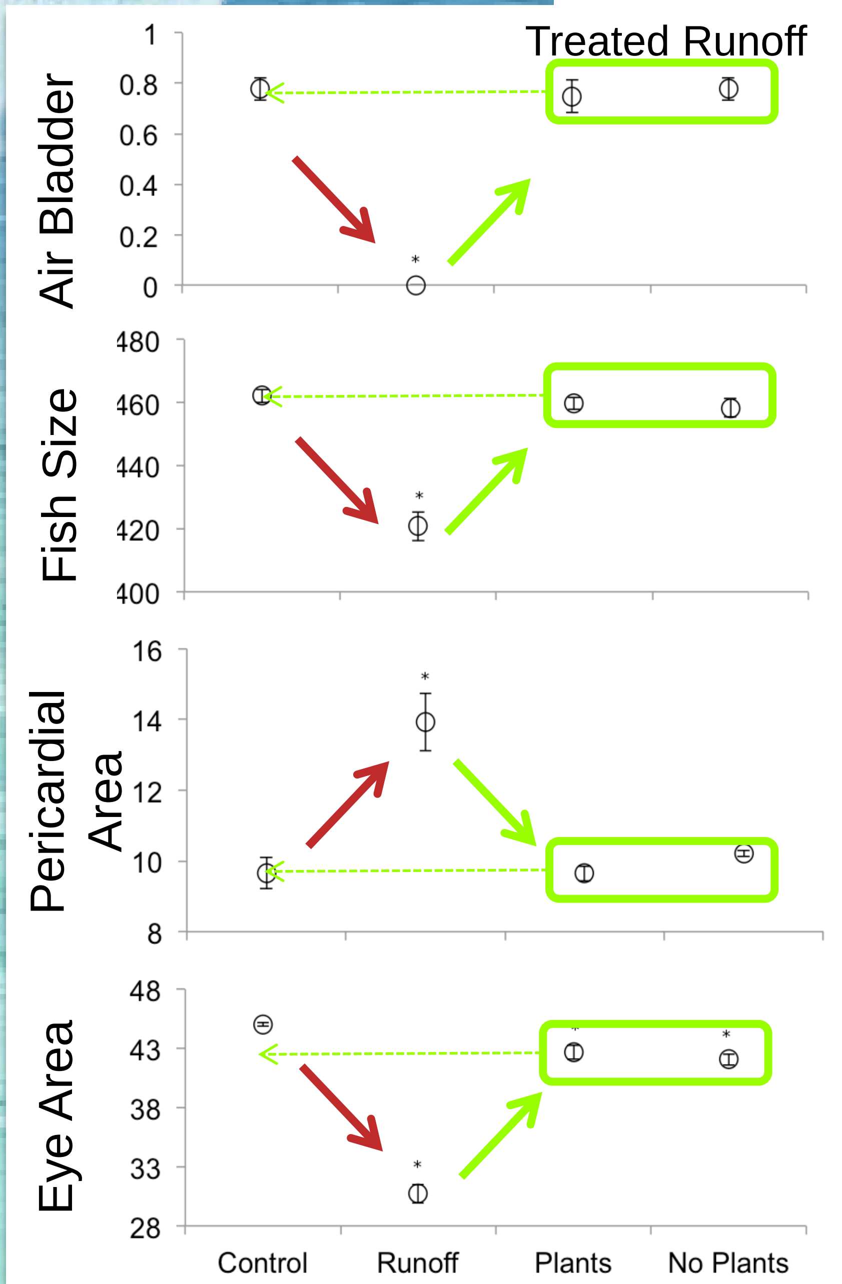
100% Survival

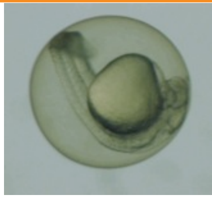
100% Mortality



McIntyre et al. 2015. Chemosphere

Sublethal toxicity in zebrafish embryos





normal air bladders

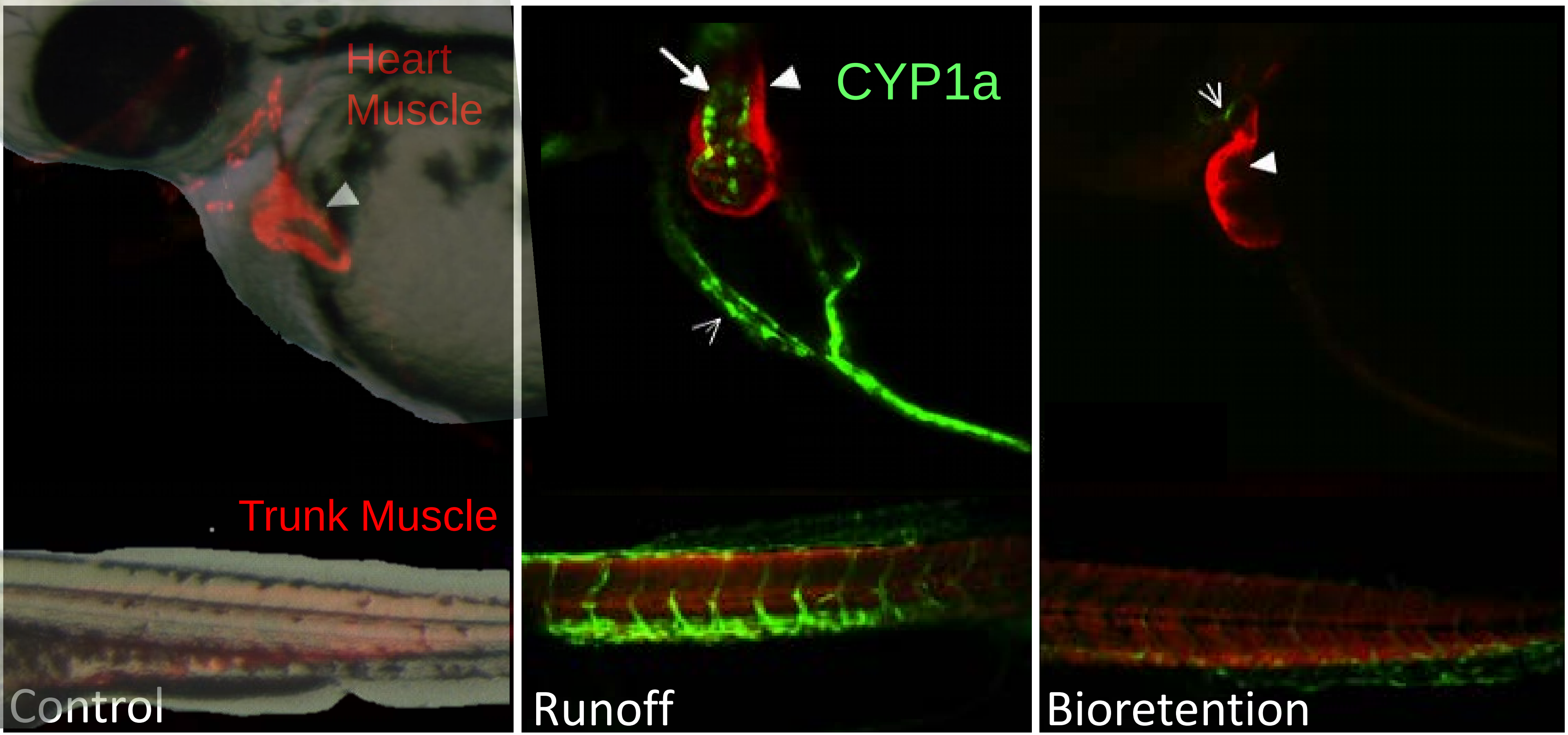
normal length

normal hearts

normal eyes (almost)

McIntyre et al. 2014. STOTEN.

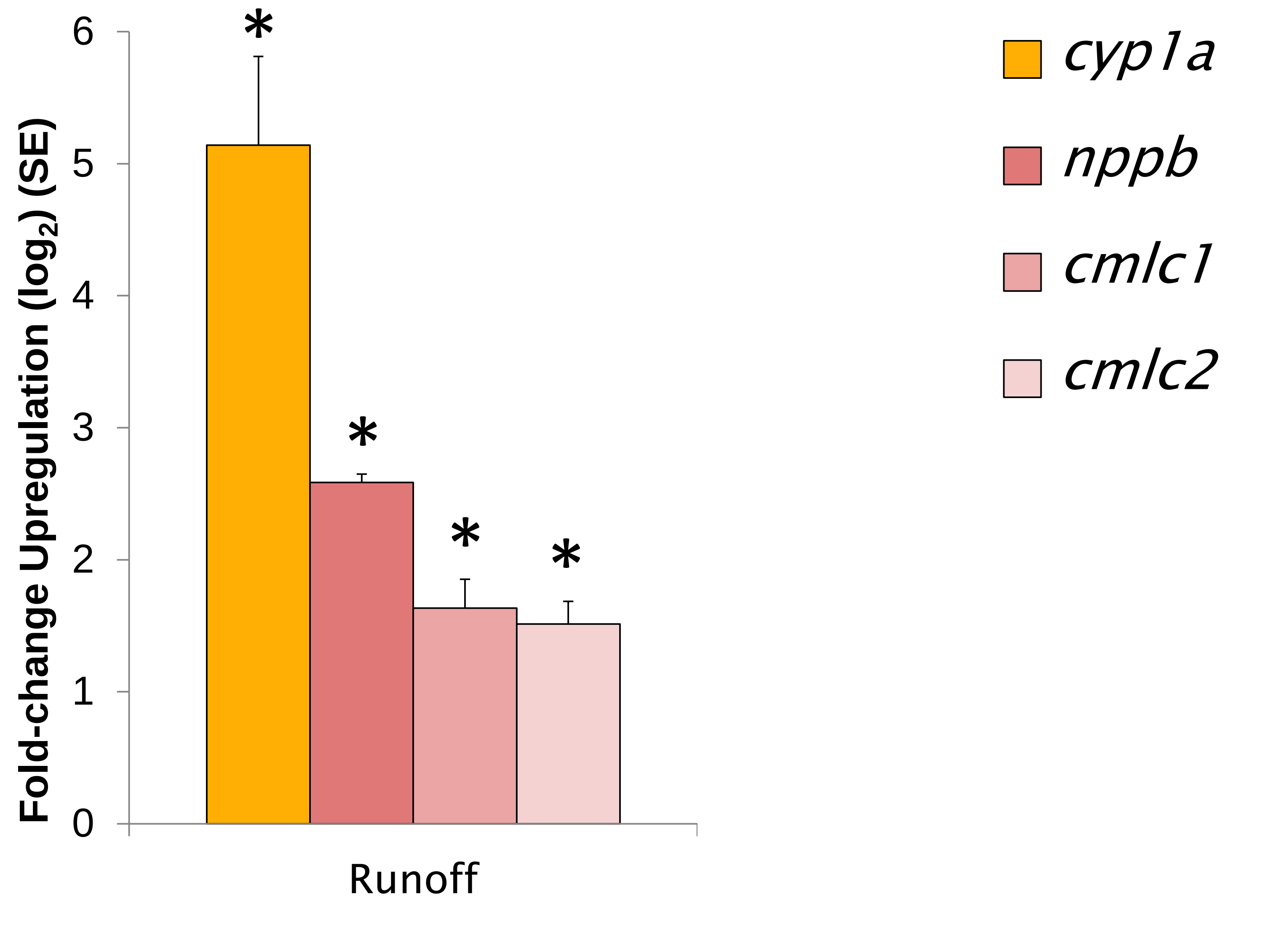
Cardiotoxicity lost after bioretention



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

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 (*cyp1a*)	48 h		✓
	Cardiac injury gene (*nppb*)	48 h	✓	

Upcoming projects runoff impacts to salmon

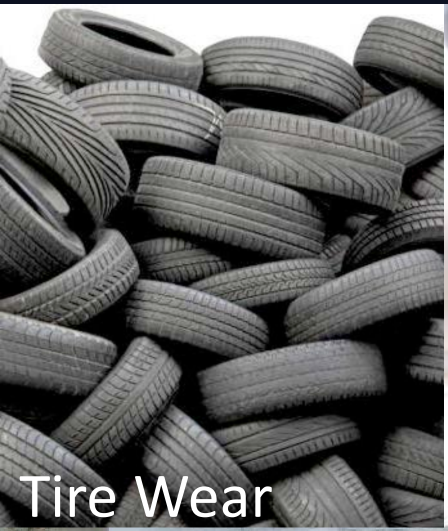
Relative species sensitivity

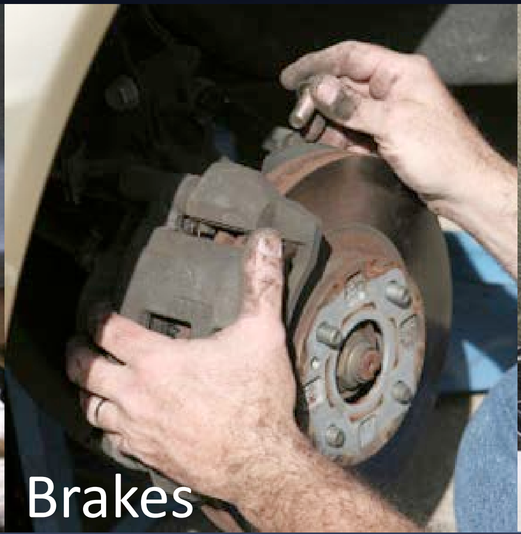
- Testing other species of Pacific salmon

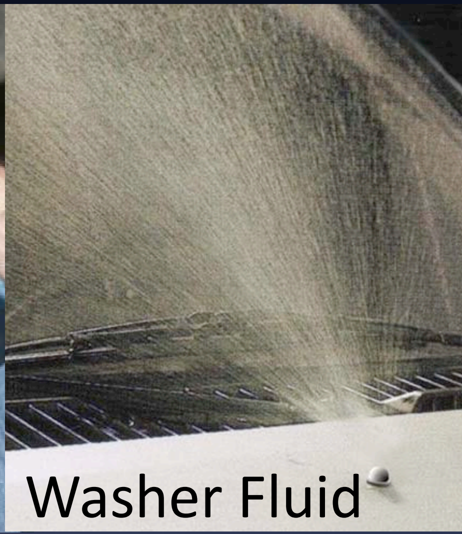
Coho pre-spawn mortality

- 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







<u>Automobile Leaks:</u>

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

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

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

Suquamish Tribe
Mike Huff et al.

Puyallup Tribe
Blake Smith et al.

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