Toxic of Stormwater Runoff: Aquatic Pollution and Solutions

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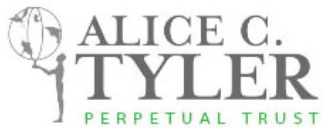
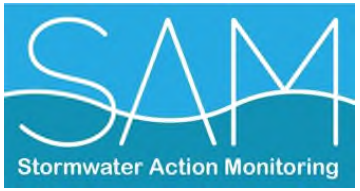
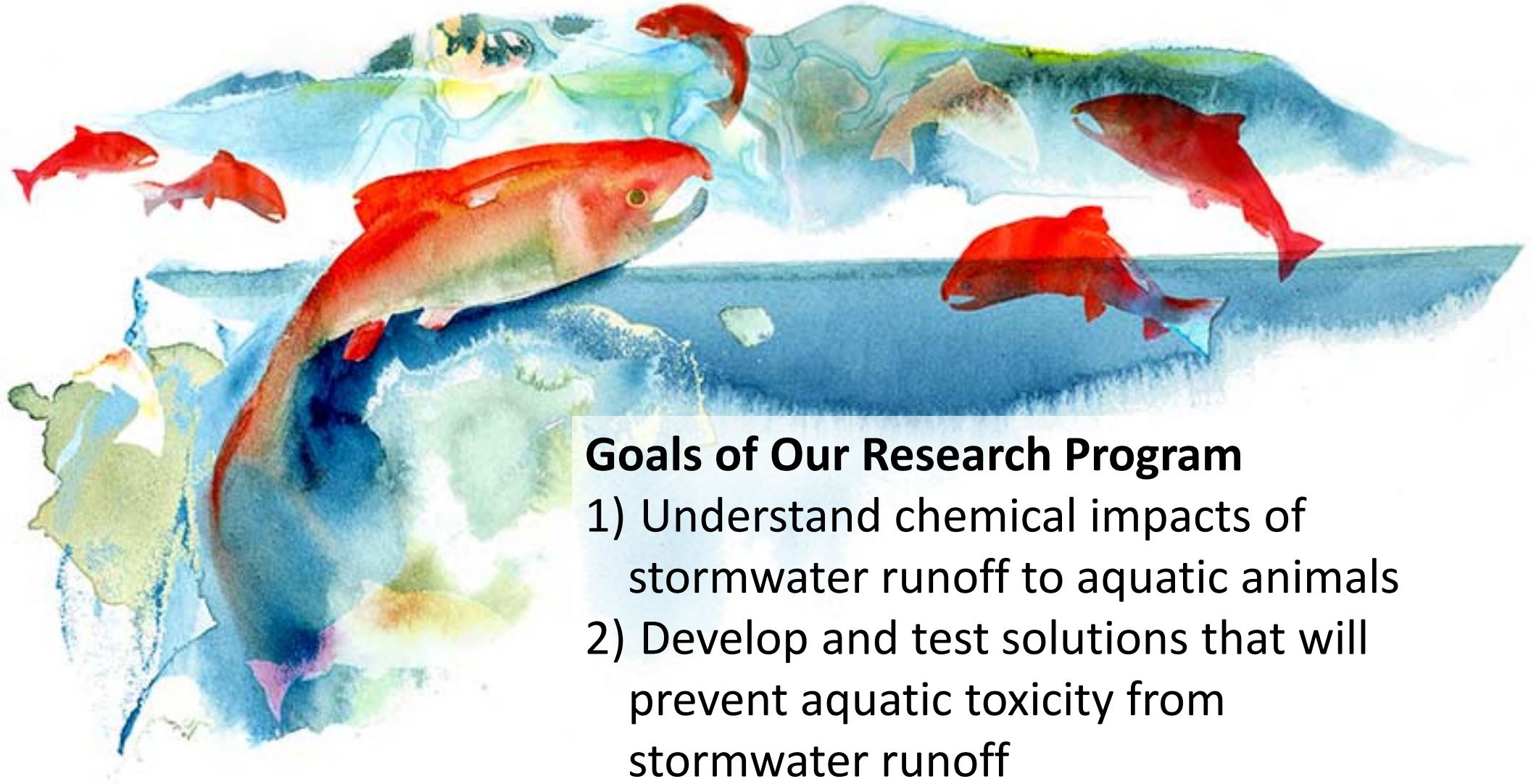
CRBWG| webmtg | May 20, 2020

Puget Sound Stormwater Science Team

Research PARTNERS & SUPPORTERS







Goals of Our Research Program

1) Understand chemical impacts of stormwater runoff to aquatic animals
2) Develop and test solutions that will prevent aquatic toxicity from stormwater runoff

Urban stormwater runoff kills coho salmon spawners

Widespread & recurrent

High rates of pre-spawn mortality in urban creeks (60-90%)

Scholz et al. 2011. PLoS ONE

Weight-of-evidence points to stormwater runoff

Longfellow Creek 2003 Des Moines Creek 2004 Longfellow Creek 2012

OPEN ACCESS Freely available online

(2011, 6(8):e28013)

PLoS one

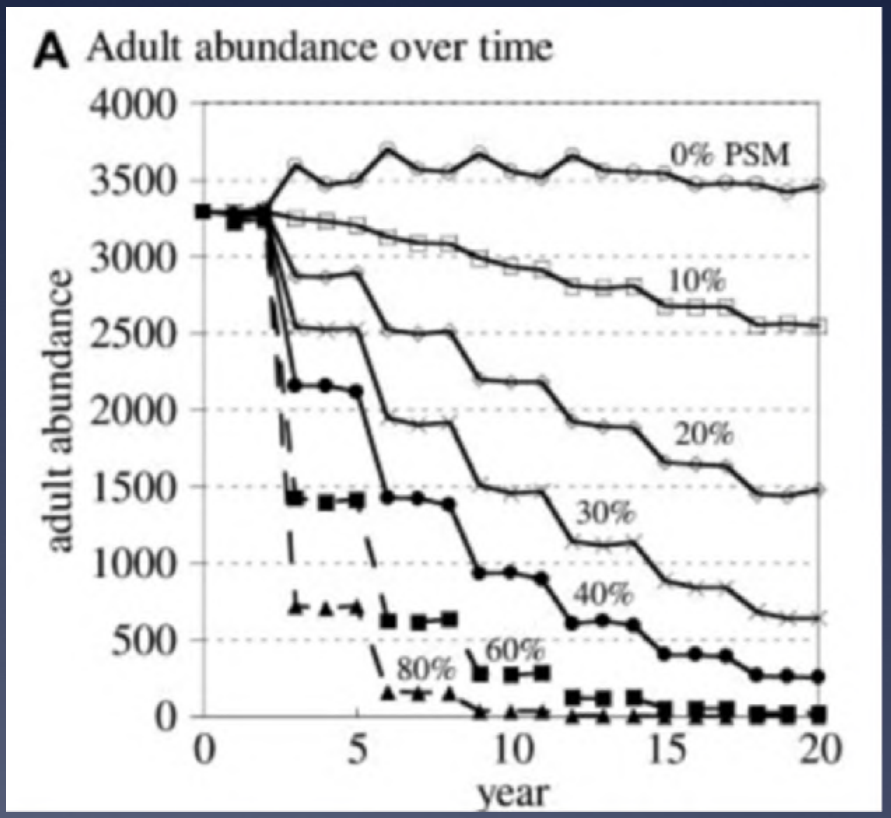
Recurrent Die-Offs of Adult Coho Salmon Returning to Spawn in Puget Sound Lowland Urban Streams

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]

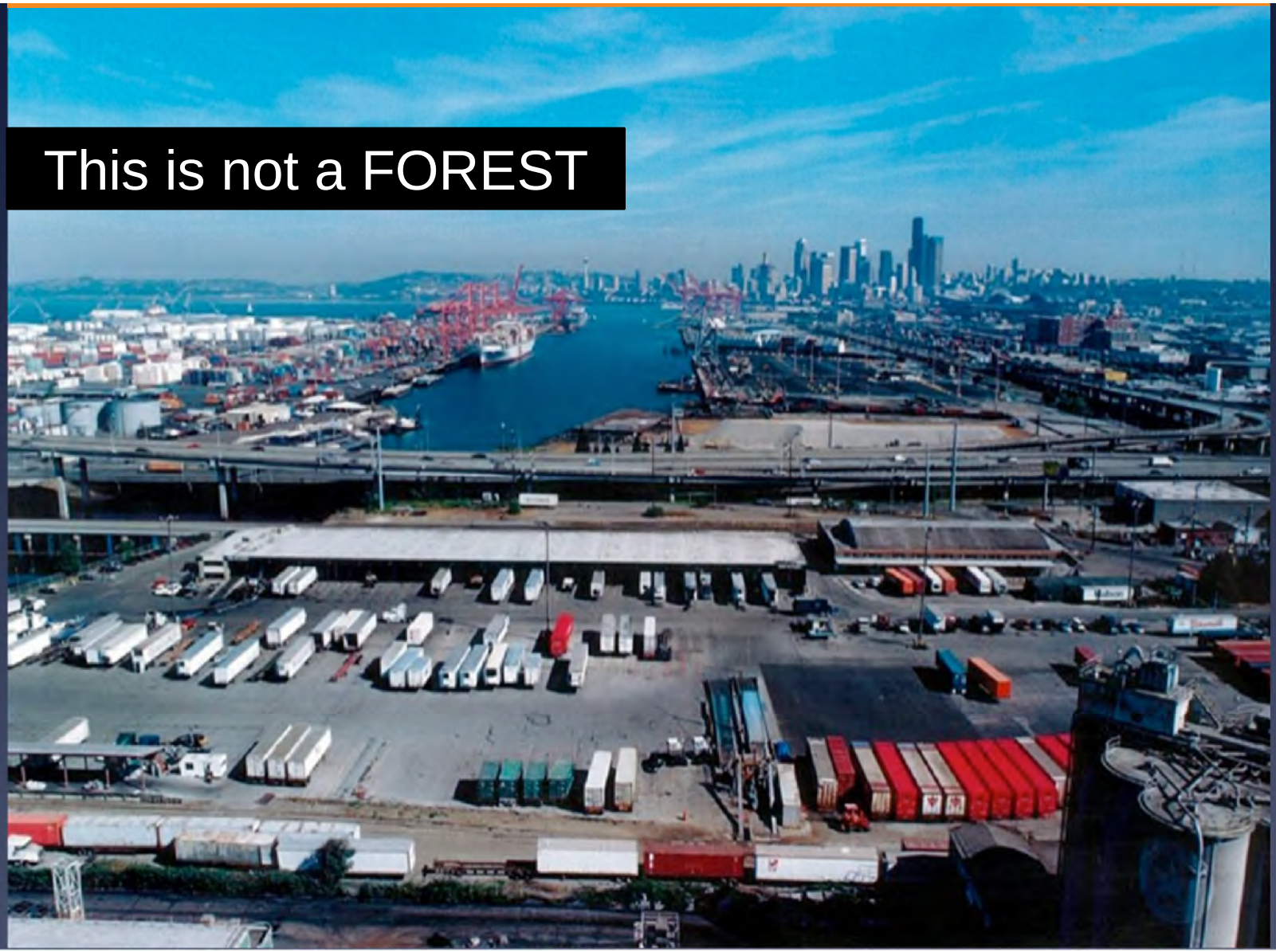
1 Northwest Fisheries Science Center, NOAA Fisheries, Seattle, Washington, United States of America, 2 Department of Natural Resources and Parks, King County, Seattle, Washington, United States of America, 3 Wild Fish Conservancy, Duvall, Washington, United States of America, 4 Seattle Public Utilities, City of Seattle, Seattle,

Rapid extirpation predicted for coho salmon

Even low rates of pre-spawning mortality projected to cause local population extirpation



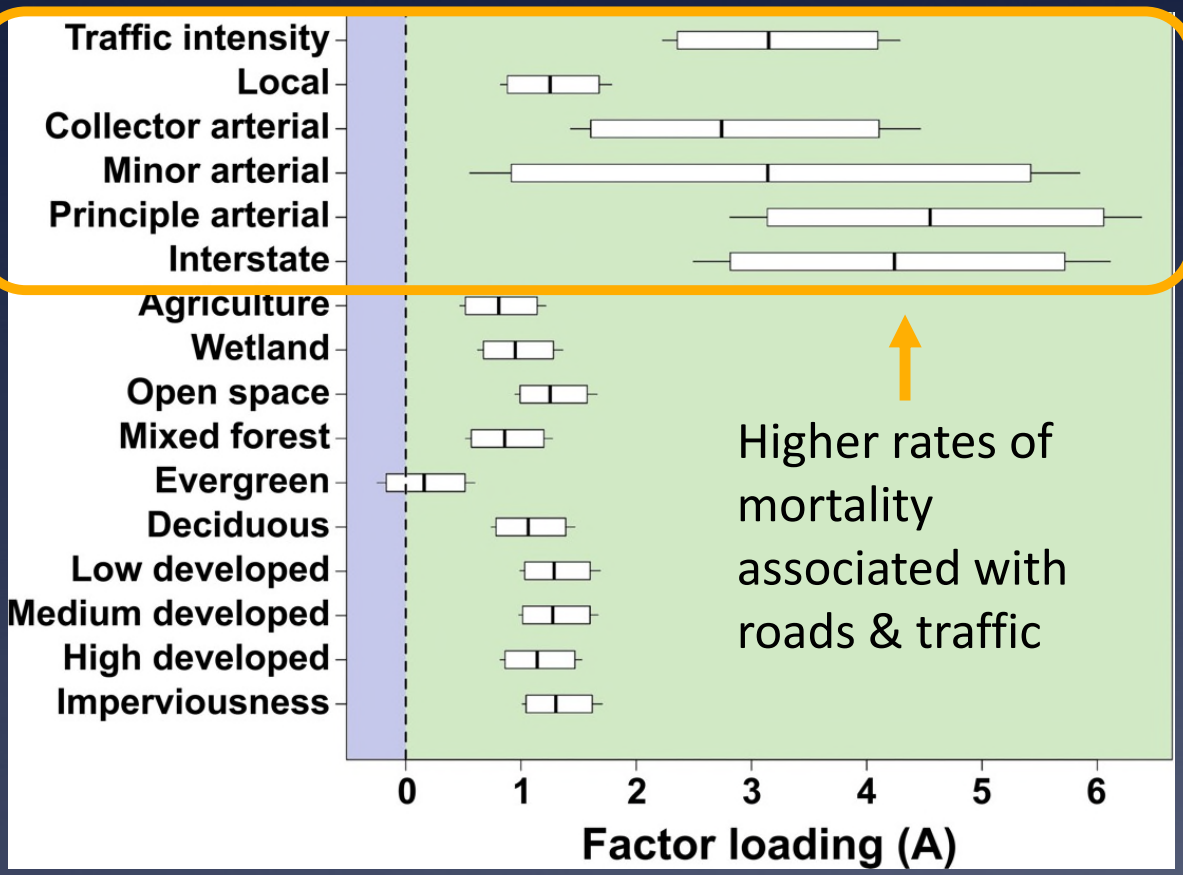
Spromberg & Scholz. 2011. Integrated Env. Assess.Manag.


This is not a FOREST

What is urban stormwater runoff?

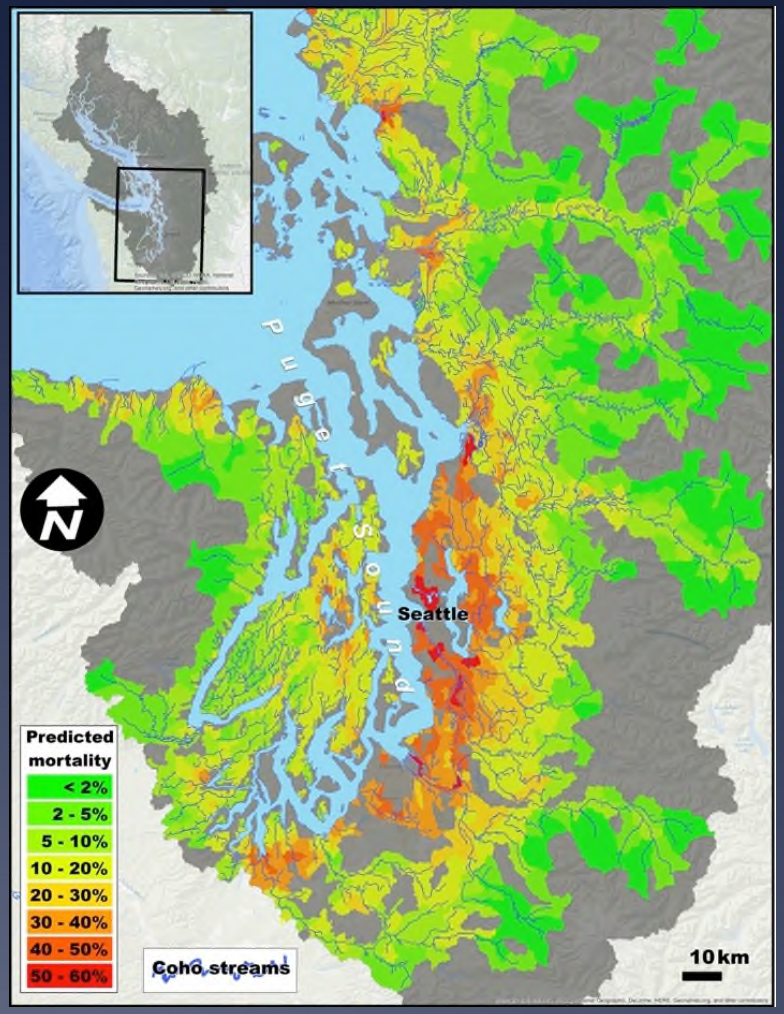
Stormwater entering Puget Sound in West Seattle (www.diverlaura.me)

Contributing Land Uses



Increasing PSM ⟶

Predictive Mapping



Feist et al. 2017. Ecol Applications

Road Runoff

Collecting Road Runoff

Experimentally exposing coho spawners to road runoff

… Induces pre-spawn mortality

Unexposed (3.5 h)

Stormwater-exposed (3.5 h)

Spromberg et al. 2016. J. Applied Ecology

Urban road runoff is sufficient to kill coho salmon

Adult spawners

Alevin

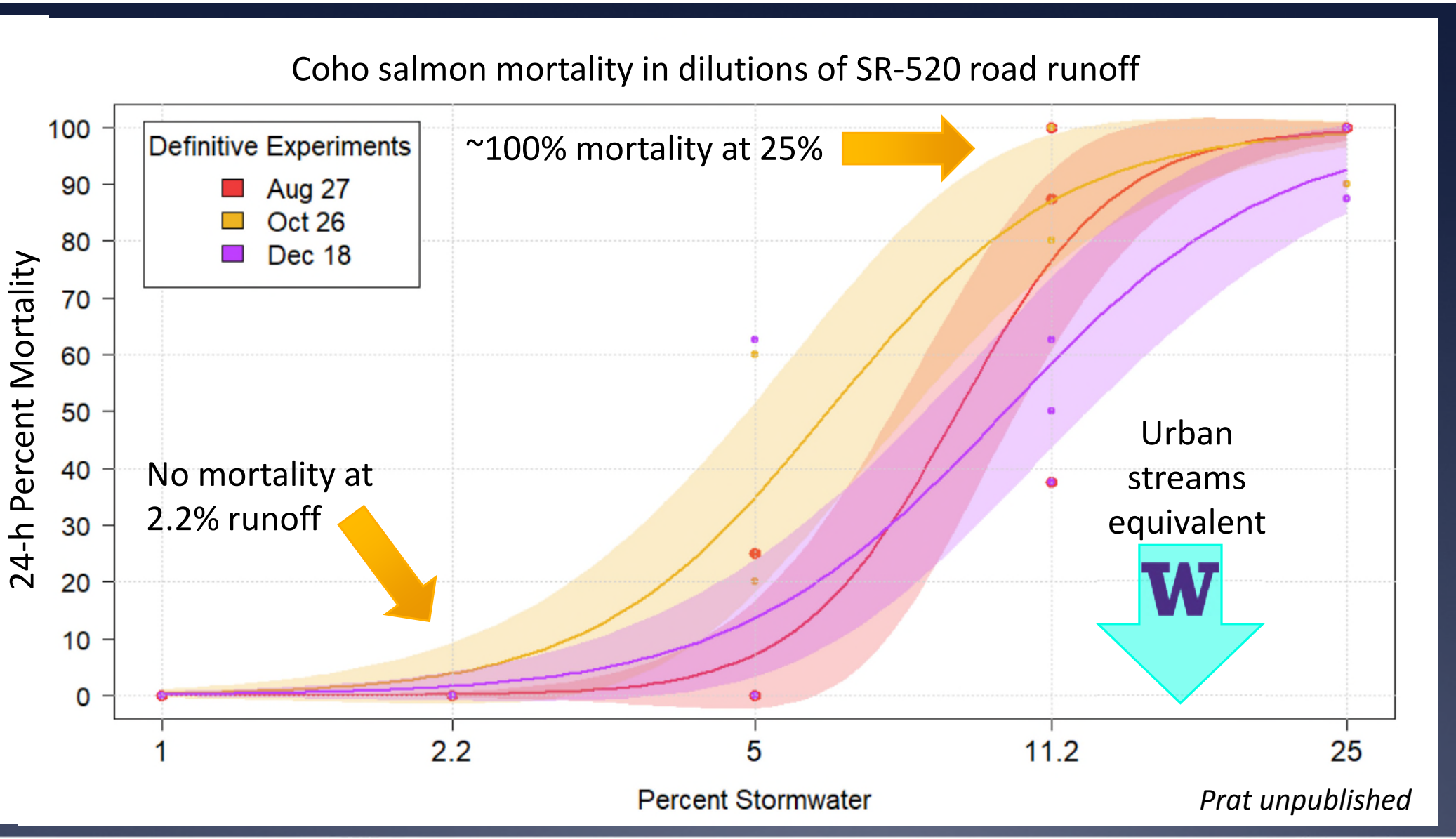
Juveniles

Road runoff: All die within 24 h of exposure

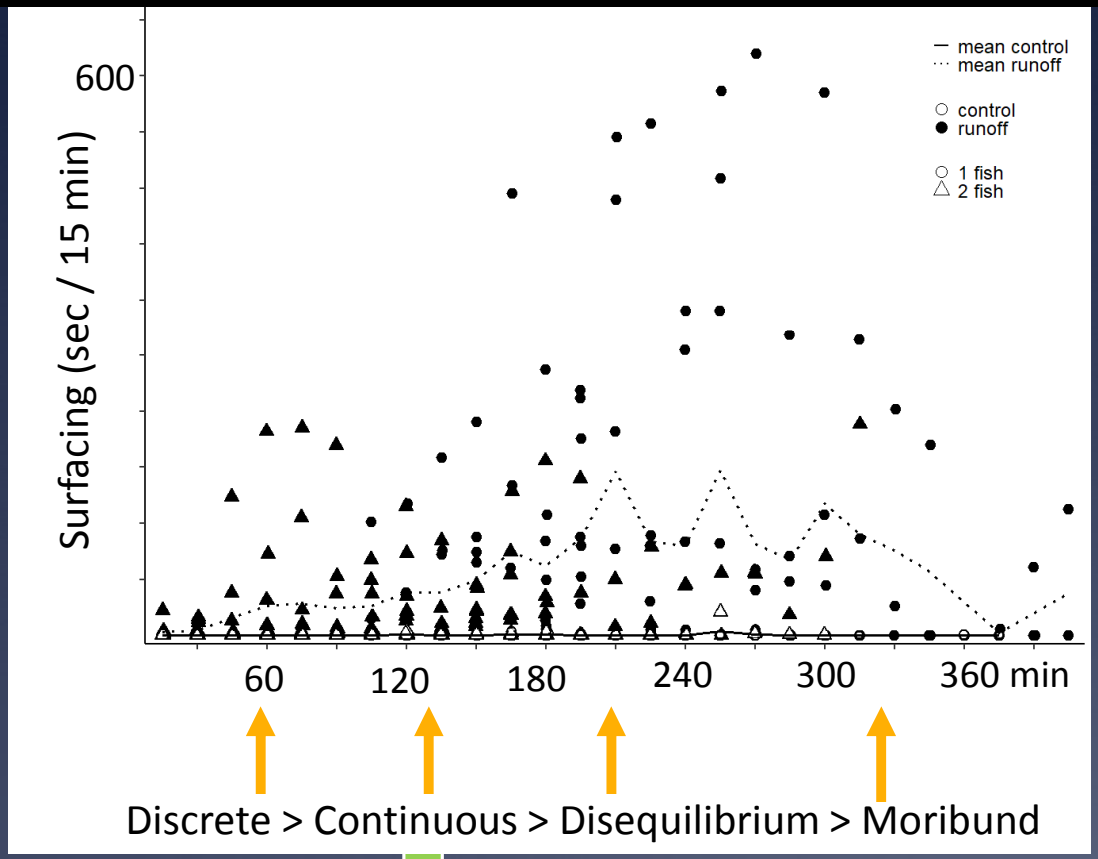
McIntyre et al. 2015. STOTEN

Spromberg et al. 2016. J Appl. Ecol.

Chow et al. 2019. Aquat Tox.


Coho salmon mortality in dilutions of SR-520 road runoff
Definitive Experiments
Aug 27
Oct 26
Dec 18
~100% mortality at 25%
No mortality at
2.2% runoff
Urban
streams
equivalent
24-h Percent Mortality
100
90
80
70
60
50
40
30
20
10
0
1
2.2
5
11.2
25
Percent Stormwater
Prat unpublished

Urban stormwater runoff affects coho behavior

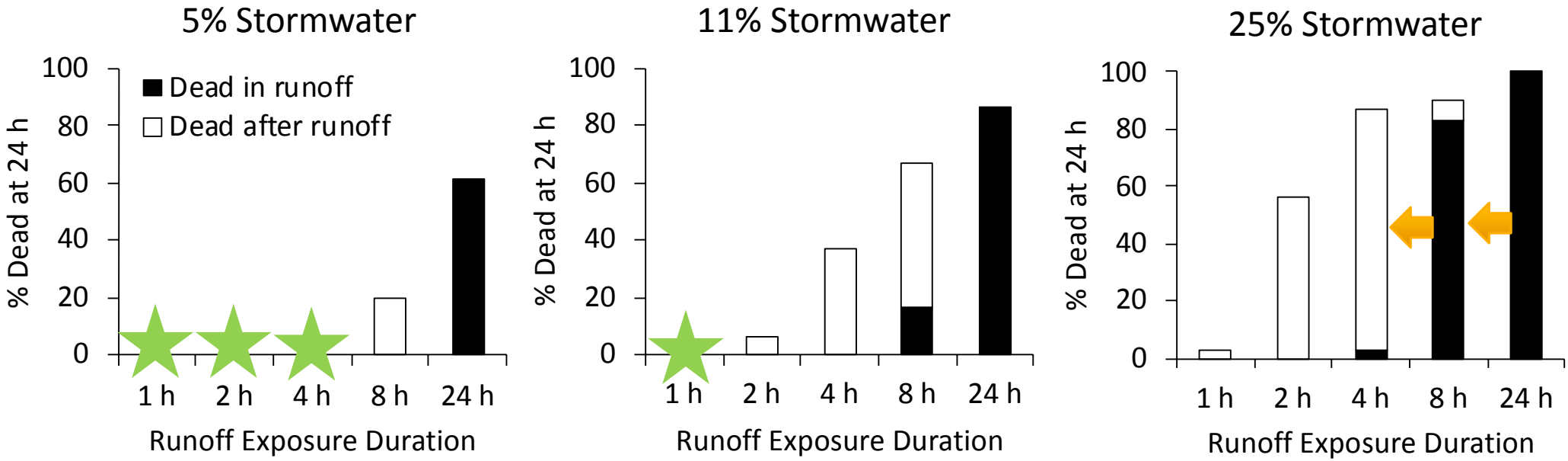


Juveniles

Transfer to clean water does NOT prevent mortality

Chow et al. 2019

What durations of urban runoff exposure kill coho?

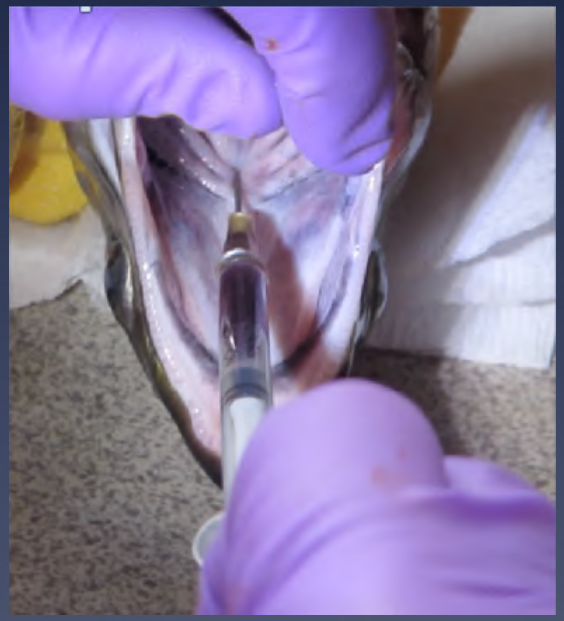


Brief exposures caused delayed mortality

Prat unpublished

Urban stormwater runoff affects coho blood

Adult spawners



Symptomatic fish: Osmoregulatory imbalance & hemoconcentration

McIntyre et al. 2018. Environ. Pollution

Resilience to runoff varies among species

O. kisutch

O. keta

McIntyre et al. 2018. Environ. Pollution

O. nerka

O. mykiss

O. kisutch

O. tshawytscha

Coho > Steelhead > Chinook > Sockeye = Chum


What in road runoff is lethal to coho?

The chemistry of stormwater runoff

Thousands of unique chemicals are present in urban road runoff

Du et al. 2017. Env. Sci. Processes and Impacts

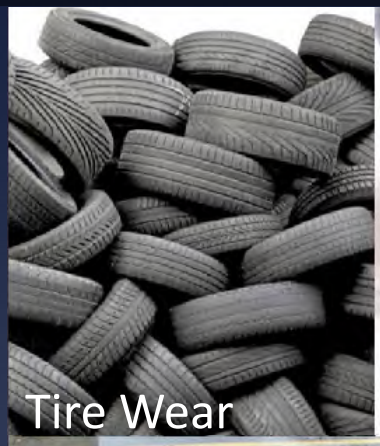
Relatively few of them are identified

Peter et al. 2018. ES&T

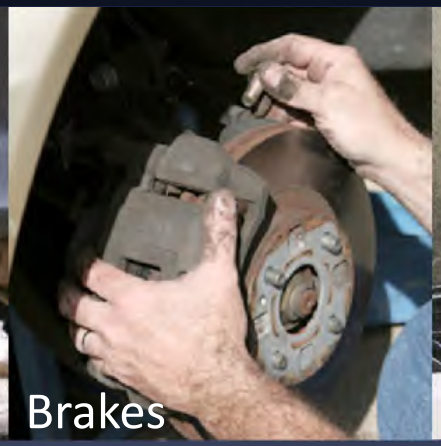
The chemicals that we know don't appear to cause the observed toxicity

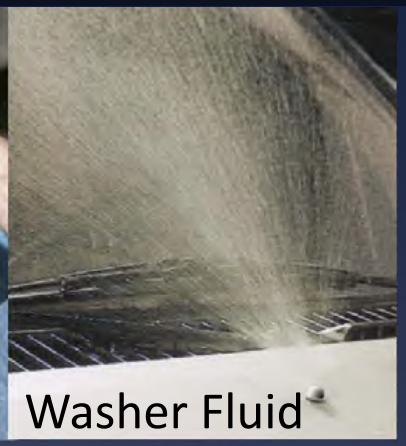
Spromberg et al. 2016. J. Appl. Ecol.

What are vehicle sources of chemicals in road runoff?


Tire Wear


Exhaust


Brakes


Washer Fluid

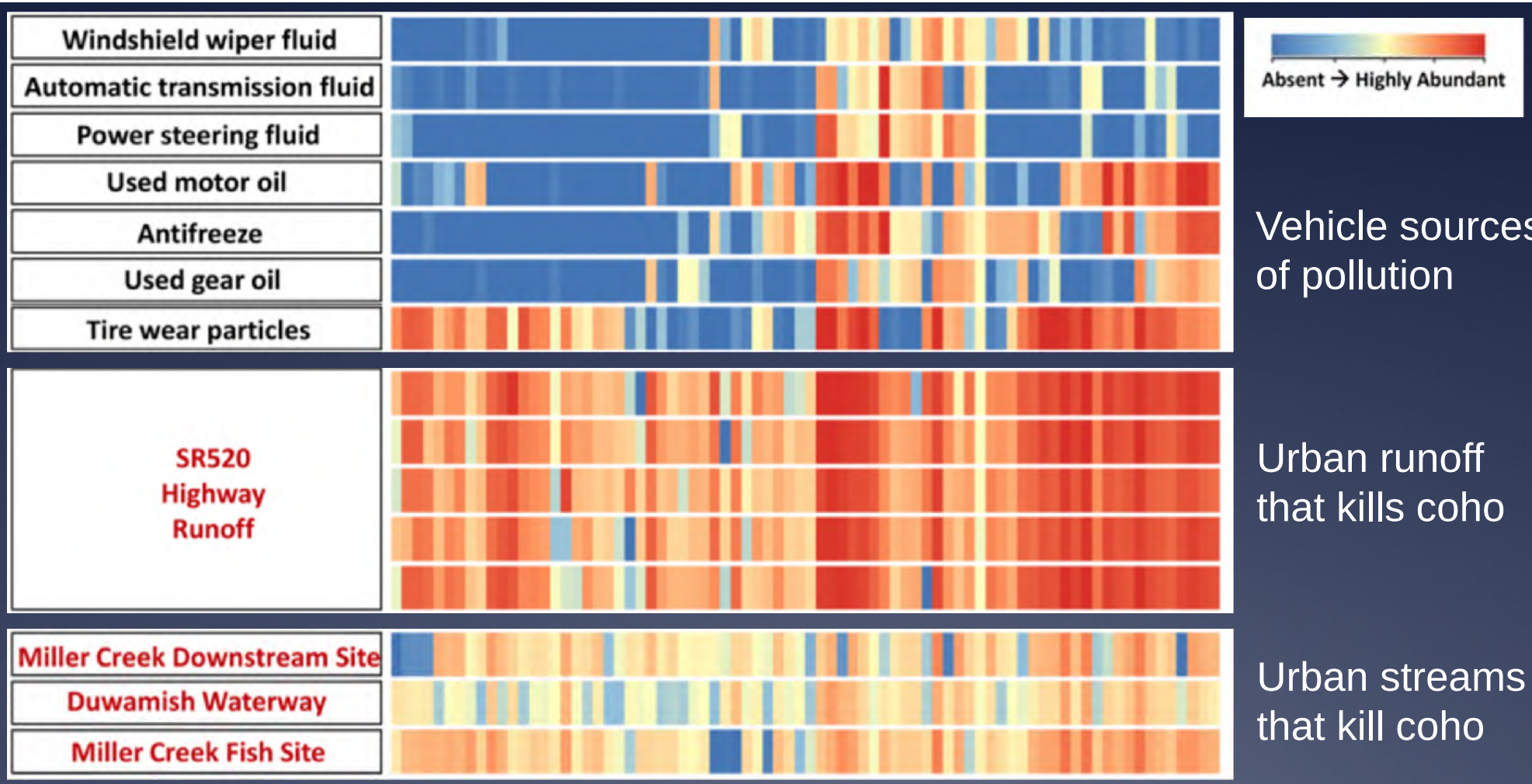

Leaks

Automobile Leaks:

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

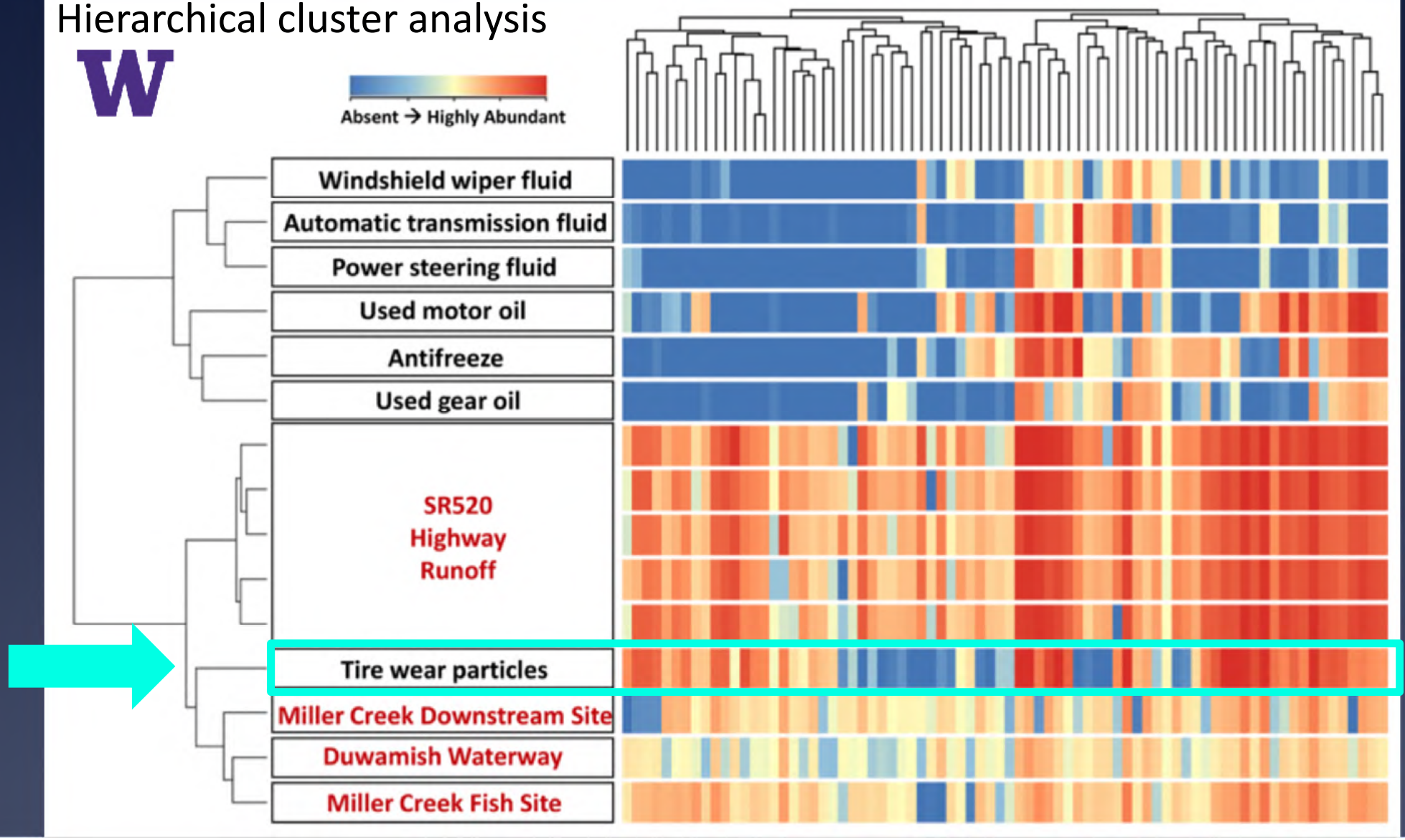
Relative contributions? Most toxic? Contribute most to toxicity?

Non-target high resolution mass spectrometry time-of-flight



Peter et al. 2018. ES&T

Hierarchical cluster analysis



Peter et al. 2018. ES&T

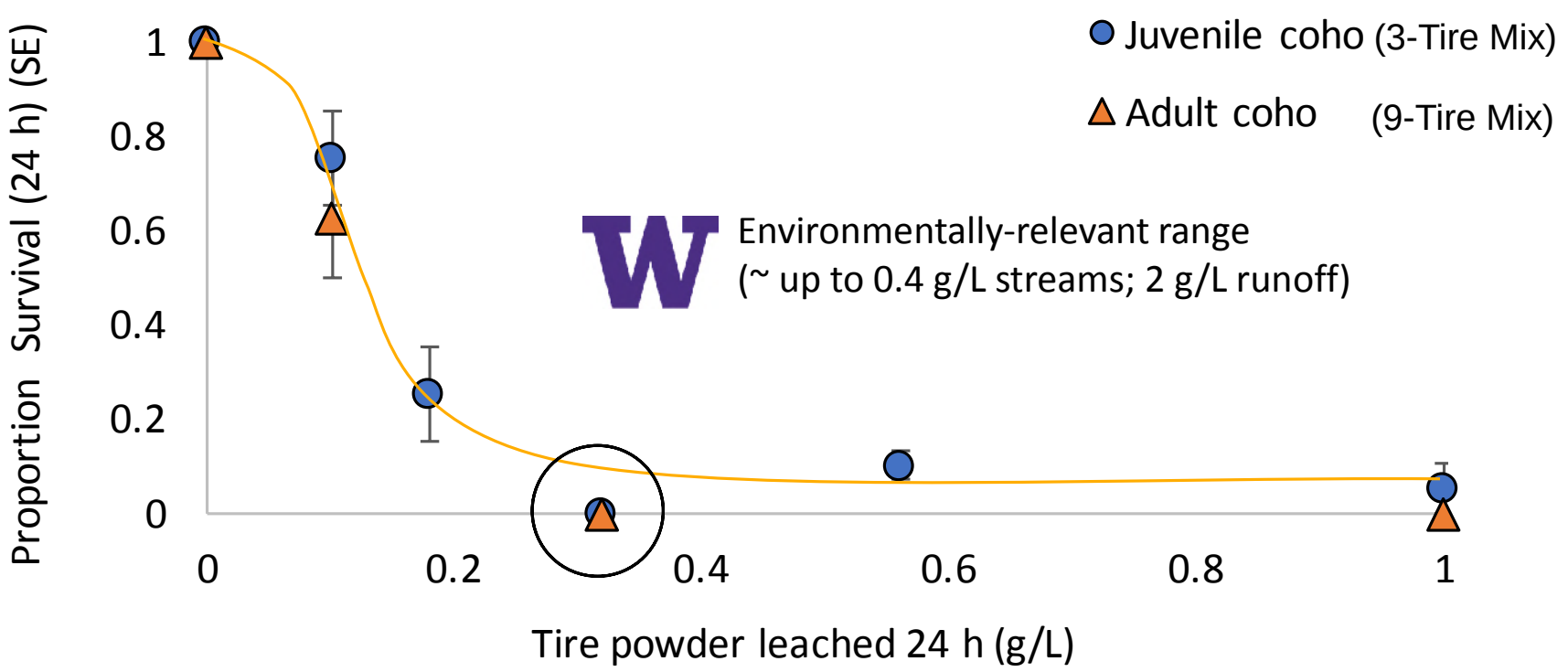
Are tire particles an important source of toxicity?

Are tires an important source of toxicity in urban runoff?

Compare effects of stormwater and chemicals leaching from tires:

1. Does tire leachate cause acute mortality in coho?
2. Coho uniquely sensitive (chum NOT affected)?
3. Similar pathophysiology for tire leachate as stormwater?

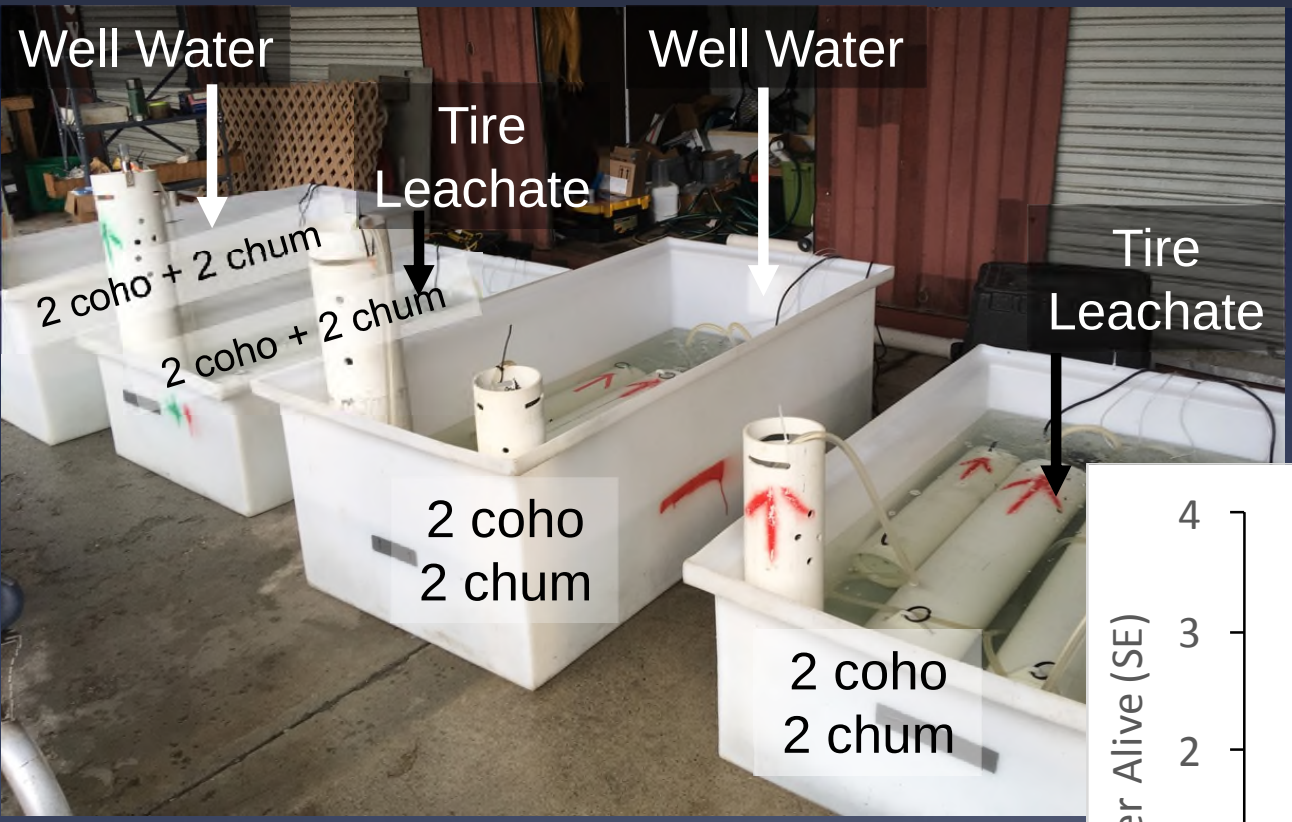
1. Does tire leachate cause acute mortality in coho?



Acute lethality to tire leachate was similar in juveniles and adults

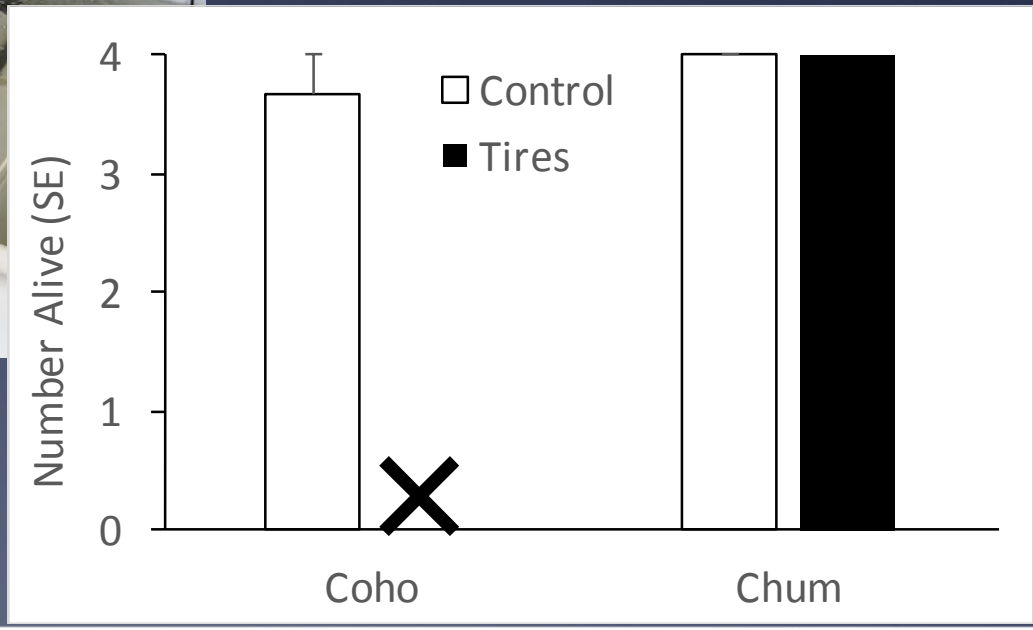
McIntyre et al. unpublished data

2. Are coho salmon uniquely sensitive?

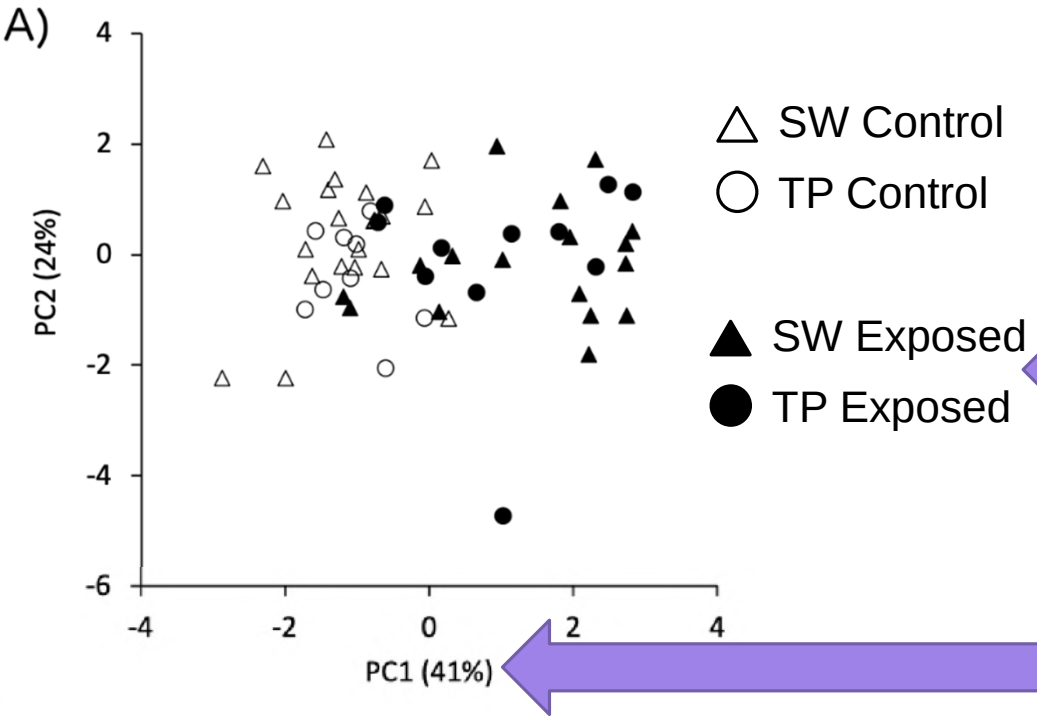


November 2017
Repeated 4x

- Tire Leachate = 320 mg/L
- 24 h exposure
- Expect 100% mortality in coho

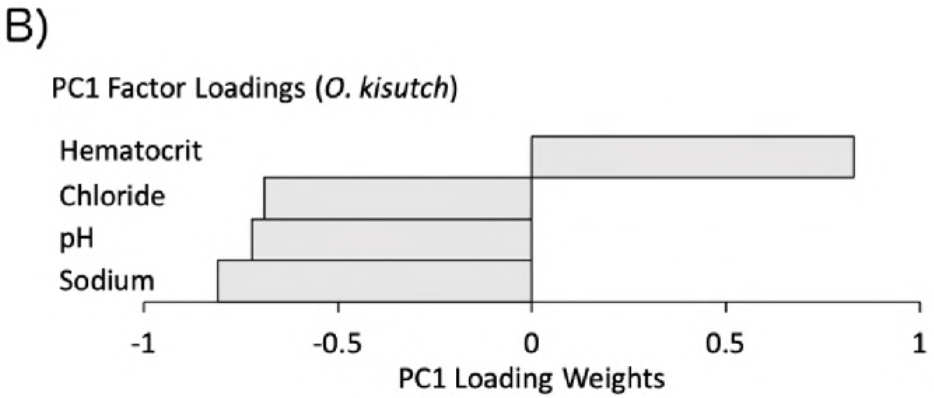


3. Pathophysiology same as for stormwater?



No difference between stormwater and tire leachate ($p = 0.392$)

Treatment significantly associated with PC1 ($p<0.001$)



Same blood parameters affected

Tire particle leachate study summary

1. Chemicals that leach from tires can be acutely lethal to juvenile and adult coho salmon
2. At lethal concentrations of tire leachate, chum salmon spawners were not affected
3. Tire leachate caused an acute increase in hematocrit, decrease in plasma ions and pH in coho, not chum
4. Tire particles are present in road runoff at concentrations similar to those that are acutely lethal to coho salmon
5. Tire particles appear to be an important contributor to the acute lethality of road runoff

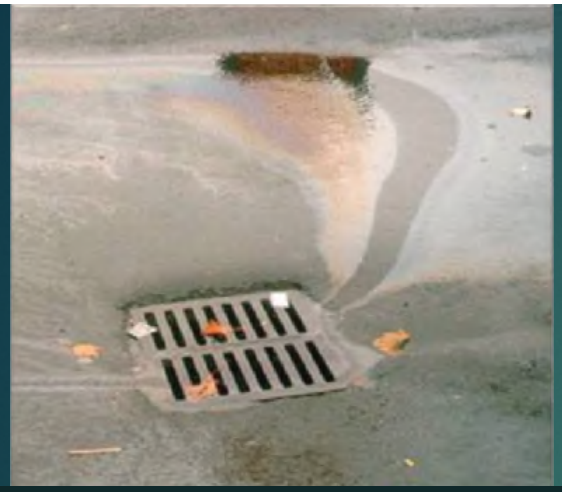
Similar to road runoff


What do we
do about it?

Solutions to stormwater pollution: Source Control

Ongoing collaboration to identify the responsible contaminant(s)

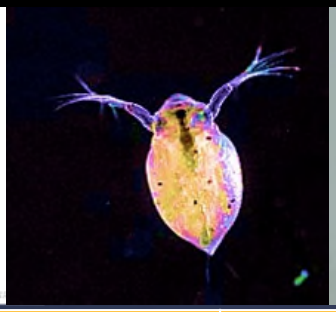
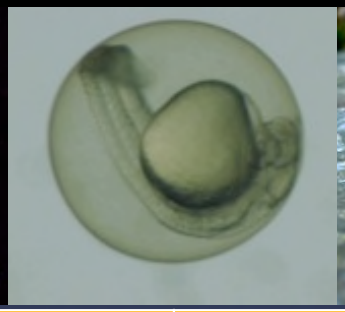
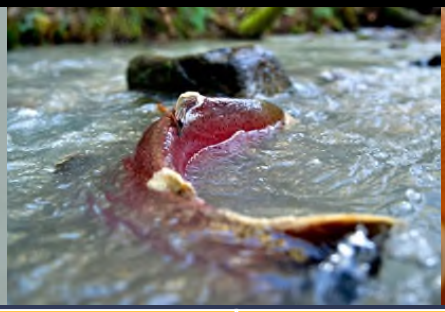
Ongoing conversation with USTMA about whether chemical(s) can be replaced



Solutions: Green Stormwater Infrastructure

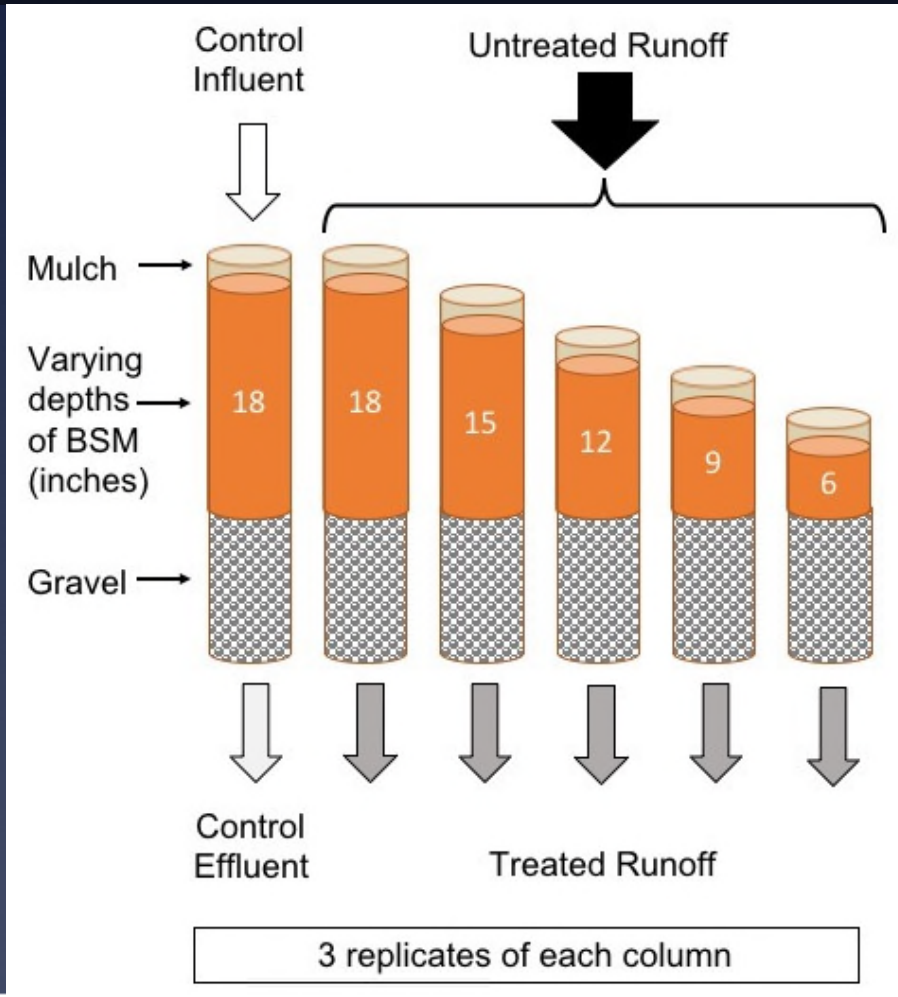
Bioretention treatment prevents acute toxicity




Author	Year	Journal	Runoff	Species	Endpoint	n
McIntyre	2014 2015 2016	STOTEN Chemosphere ES&T	SR520	Zebrafish Water fleas Mayfly nymphs Juvenile coho	Lethal & sub-	1x
McIntyre	2016	ES&T	CTSC	Zebrafish	Lethal & sub-	4x
Spromberg	2016	J. Appl. Ecol.	SR520	Adult coho	Lethal	2-3x
McIntyre	-	In Prep	SR520	Coho alevin	Lethal	22x
Taylor	2017	Water	I-5	Zebrafish	Sub-lethal	365 d

Bioretention Performance: Longevity



Research questions:

- What depths of bioretention are necessary to treat runoff?
- For how long are they effective?

Accelerated Aging:

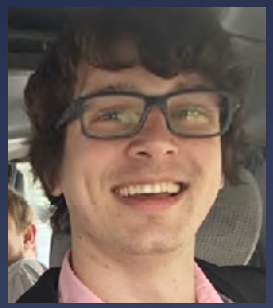
- 10 water years across 2-yr study
- Assess chemical and biological performance at end of every water year

SAM Stormwater Action Monitoring

Lane Maguire
M.S. Student
SOE
Fall 2018

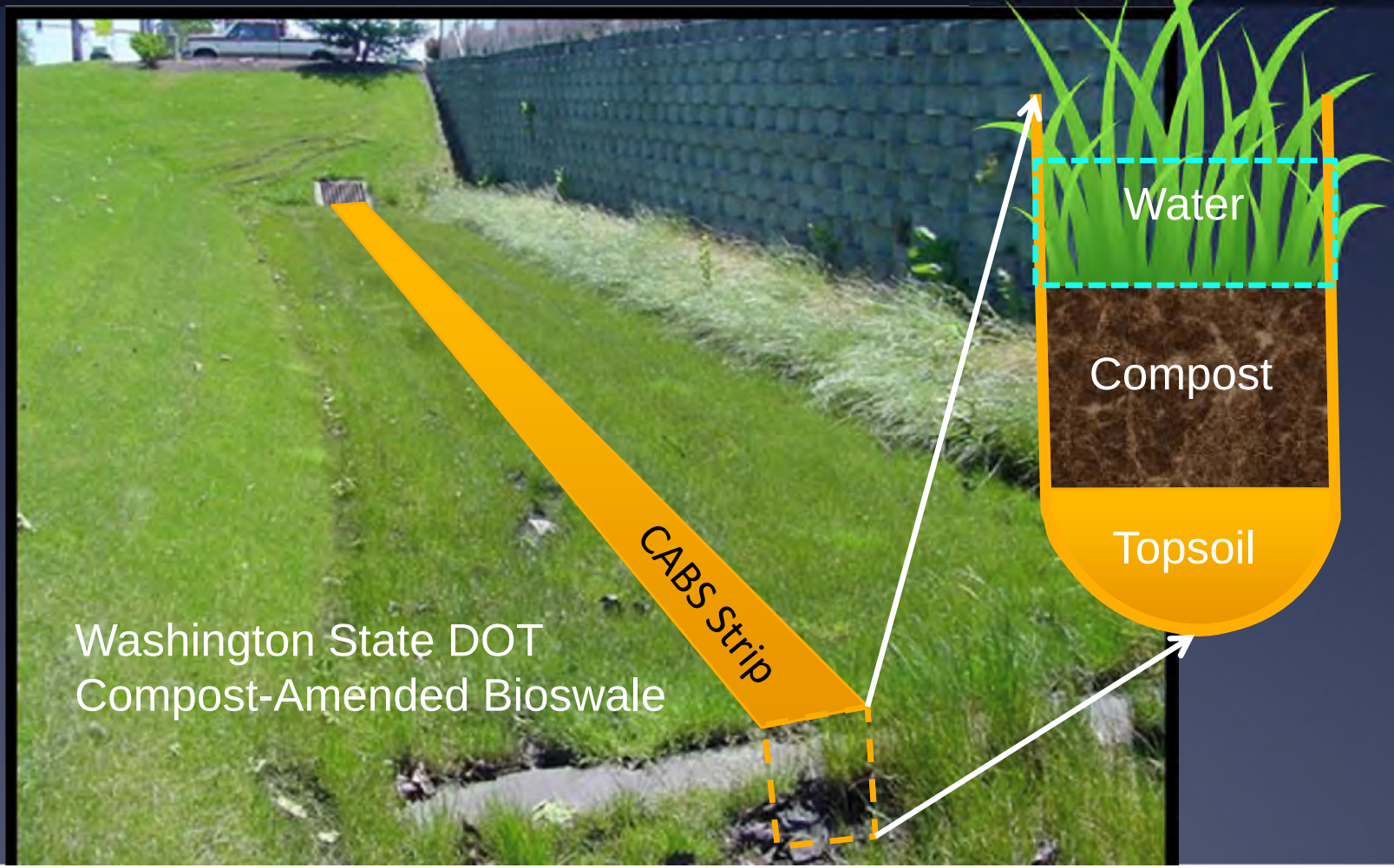
Biofiltration Performance: Roadside Treatments

<u>WSU</u>
Ben Leonard
Ph.D. student
SOE



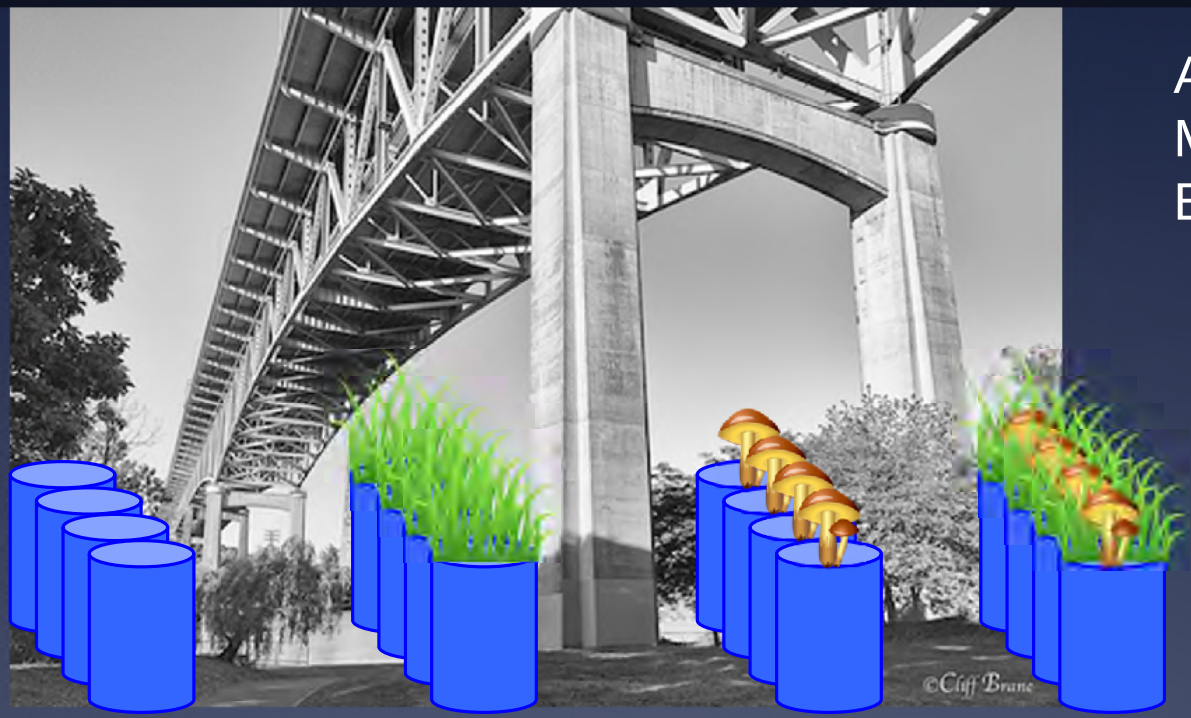
<u>UW</u>
Ed Kolodziej
+ 2 postdocs

WSDOT



Bioretention Performance: Amendments

- What is the role of plants?
- Do fungi provide additional benefits?



Alex Taylor
M.S. 2018
BSysE

- Alex Taylor – WSU M.S.
- 2-yr installation
- BSM + Plants + Fungi
- Real-time input from I-5

- Quarterly monitoring:
- Hydrology
- Chemistry
- Toxicology

SAM
Stormwater Action Monitoring

PAH and bacteria treatment in bioretention

Chelsea J. Mitchell
PhD student, SOE

Objectives:

1) Evaluate novel bioretention amendments (biochar and fungi) to improve removal of organic contaminants:

- Polycyclic aromatic hydrocarbons
- Bacterial pathogens

2) Investigate fate and biodegradation of PAHs in bioretention columns with and without amendments

Biochar
(Pine & fir
feedstock)

Permeable Pavements: Asphalt and Concrete

With and without reinforcing carbon fiber waste from Boeing 767

Do pavements release toxicants into water?

Do pavements provide any water quality treatment?

Changes over time?

Summary – Pollution and Solutions

- Coho salmon spawners die prematurely at high rates in urban creeks
- Road runoff is sufficient to cause the acute mortality
- Pacific salmon sensitivity: coho > steelhead > chinook
- Very high dilutions of road runoff are necessary to prevent mortality
- Affected fish die quickly of unknown causes (active areas of research)
- Coho juveniles and alevin sensitivity similar to adults
- Coho embryos show sublethal effects, similar to other developing fish
- Urban stormwater runoff is a very complex chemical mixture
- High-traffic roads are the best correlated land use with coho urban PSM
- Tire wear particles appear to be an important source of toxicity
- Bioretention is a green stormwater infrastructure that can prevent toxicity
- More work is needed before we can best answer ‘how much and where’?

Puget Sound Stormwater Science Team