The Urban Mortality Syndrome: Juvenile Coho Salmon as Surrogates for Adult Spawners

Puget Sound Stormwater Science Team

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What is Stormwater Runoff?

Photo credit: Seattle Municipal Archives

Urban Stream Syndrome

- Physical
- Hydrological
- Biological
- Chemical

Stormwater: Quality

Photo credit: City of Ashland

Physical Habitat Restoration

Longfellow Creek
(urban - restored)
West Seattle

Fortson Creek
(non-urban)
Stillaguamish River

Stream Restoration

Pre-Restoration (1999)

Post-Restoration (2000)

Many Puget Sound area streams restored to enable fish passage starting in 1990's

Post-project monitoring efforts revealed adult coho salmon pre-spawn mortality phenomenon in fish returning to spawn in restored urban streams

Coho salmon dying in urban streams

Longfellow Creek 2002

Longfellow Creek 2005

Coho spawner mortality is widespread and recurrent in urban creeks

67%

Longfellow Creek 2003

Des Moines Creek 2004

63%

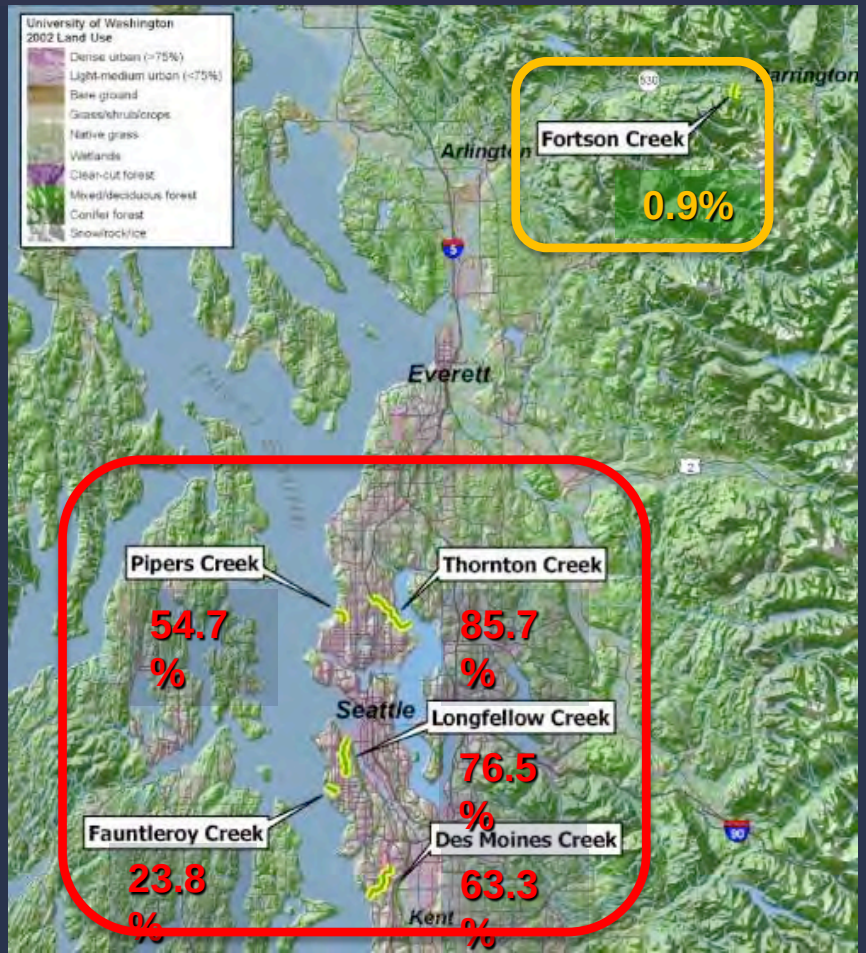
72%

Longfellow Creek 2005

Longfellow Creek 2012

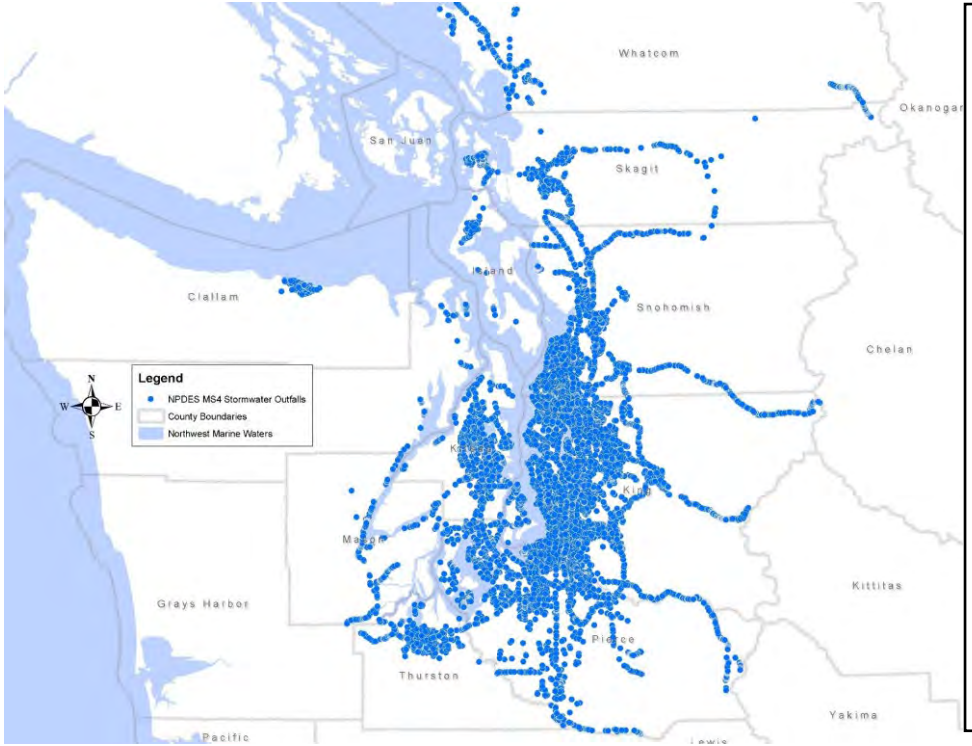
84%

Unexpected Findings



Draining into Puget Sound

~28,862 stormwater outfalls



Source: WA Stormwater Center

Source: Granquist and James

Coho salmon as sentinels for urban stormwater runoff

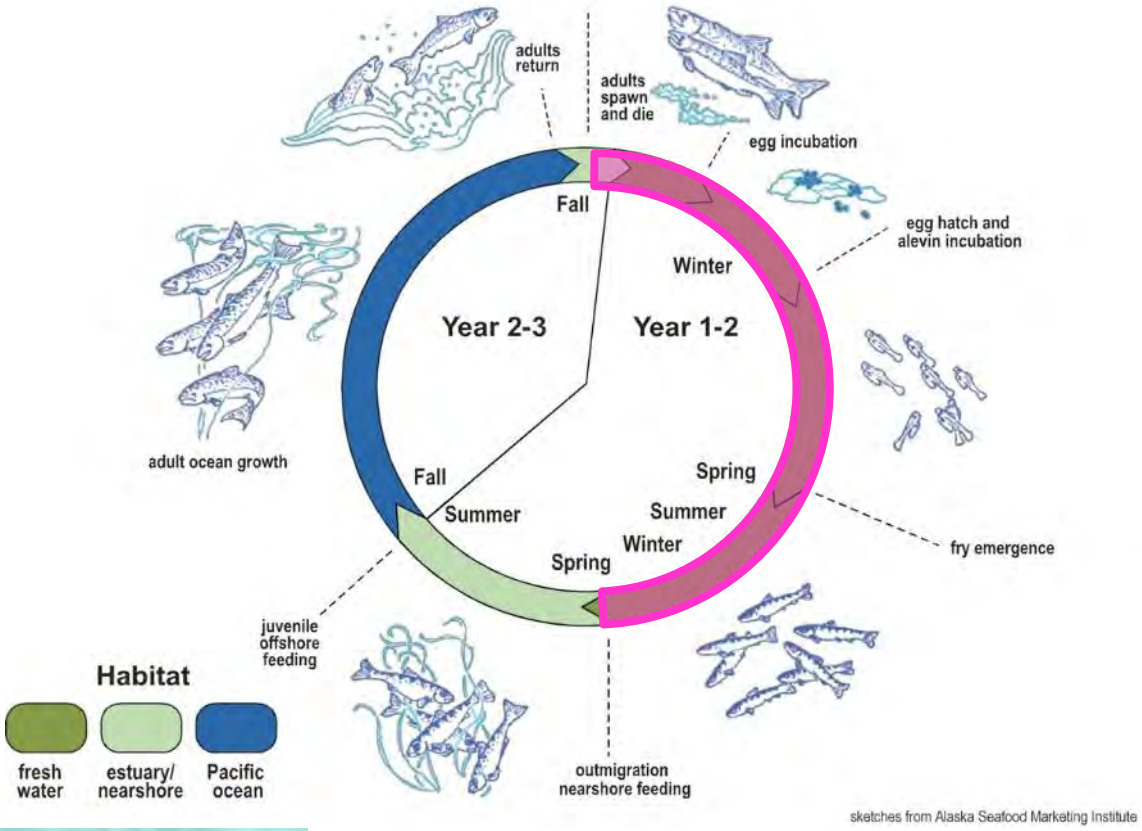
Photo credit: Tim Grams

Coho salmon as stormwater sentinel

StreamNet.org

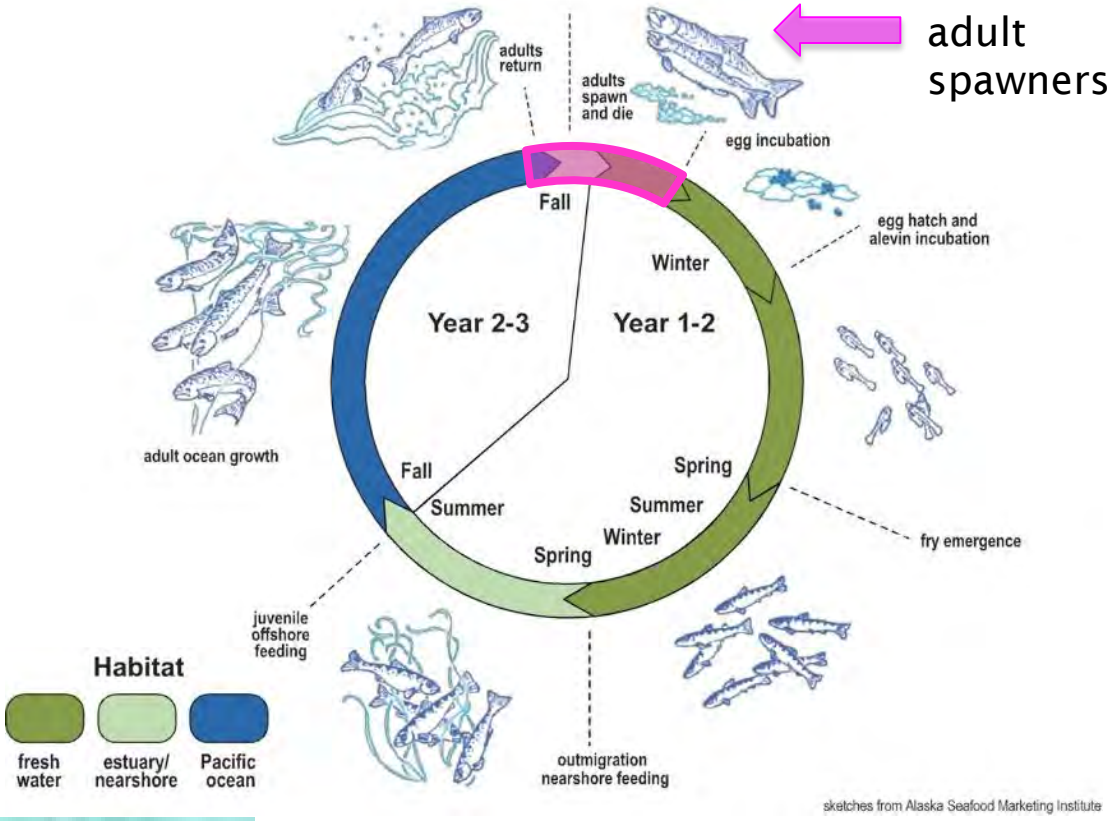
- Widely distributed
- Lowland streams
- > 1 yr in freshwater
- Supported by a diverse food web
- Sensitive to water quantity & quality
- ESA-Listed SOC/ Threatened

Impact of stormwater on coho salmon



Field Observations

Impact of stormwater on coho salmon



THURSDAY, OCTOBER 19, 2017

RAIN, WIND
High, 56. Low, 46. > B10
seattletimes.com/weather

The Seattle Times

WINNER OF 10 PULITZER PRIZES

$1.50

INDEPENDENT AND LOCALLY OWNED FOR MORE THAN 121 YEARS

SEATTLETIMES.COM

Stormwater pollution killing coho before they can spawn

PUGET SOUND BASIN

40% of home range a toxic stew that may drive extinction

By LYNDA V. MAPES
Seattle Times environment reporter

The sweet seep of autumn rain is bringing coho salmon back home to their natal streams all over the Puget Sound basin — where too often they encounter a bitter truth: pollution in a shocking 40 percent of their home range so bad it can inflict a swift death.

The culprit is stormwater, and it is causing death rates so high, some populations of wild coho are at risk of local extinction, researchers found.

Yet there also are surprisingly simple and cheap solutions at hand, the researchers wrote in their paper, published Wednesday by the Ecological Society of America in the scientific journal Ecological Applications.

Researchers at NOAA's Northwest Fisheries Science Center in Seattle worked with collaborators, including the U.S. Fish and Wildlife Service, local tribes and the Wild Fish Conservancy, to survey 51 sites from 2000 to 2011 in streams all over the Puget Sound basin. They used the survey data with a new computer model to map predicted coho death rates. The results show that in an estimated 40 percent of their range in the Puget

See > COHO, A4

NOAA FISHERIES

Coho salmon, including females full of eggs, are dying before they can spawn in Puget Sound streams polluted with stormwater runoff.

Amazon deadline on HQ2 is tonight

BIDDING CONTEST

Will tax breaks, travel time from Seattle or quality of life win out?

By MATT DAY
Seattle Times business reporter

In the six weeks since Amazon said it was seeking a site for a second headquarters, cities have preened. They've sent delegations to Seattle, bragged about their university engineering programs and tried to ship cactuses to Jeff Bezos.

Coho pre-spawning mortality (Urban Runoff Mortality Syndrome)

Pipers Creek, 2017

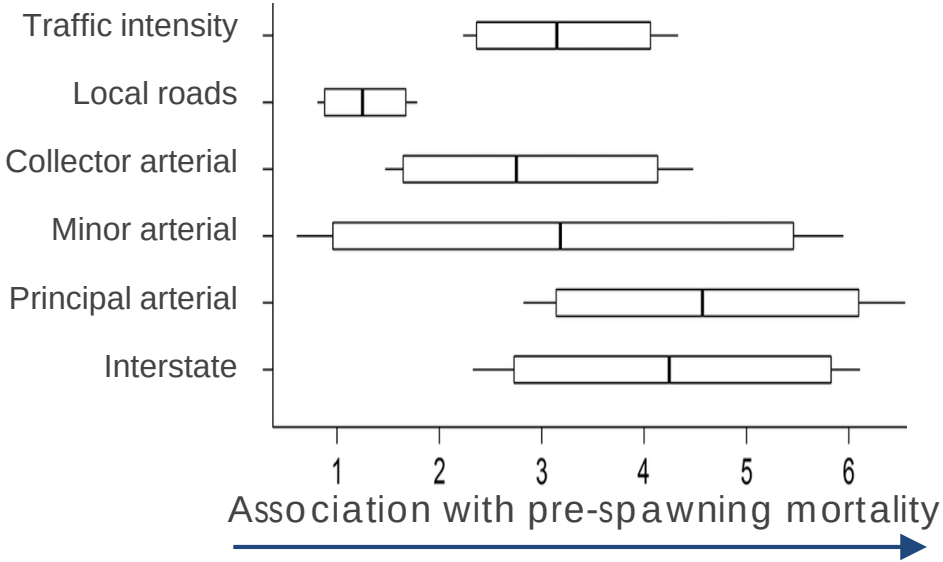
Lower Duwamish, 2017

Coho pre-spawning mortality

Mortality associated with motor vehicles

- Surveyed 51 coho spawning sites along an urban gradient
- Impervious surfaces associated with pre-spawning mortality
- Motor vehicles probable agents

Indicators of impervious surfaces



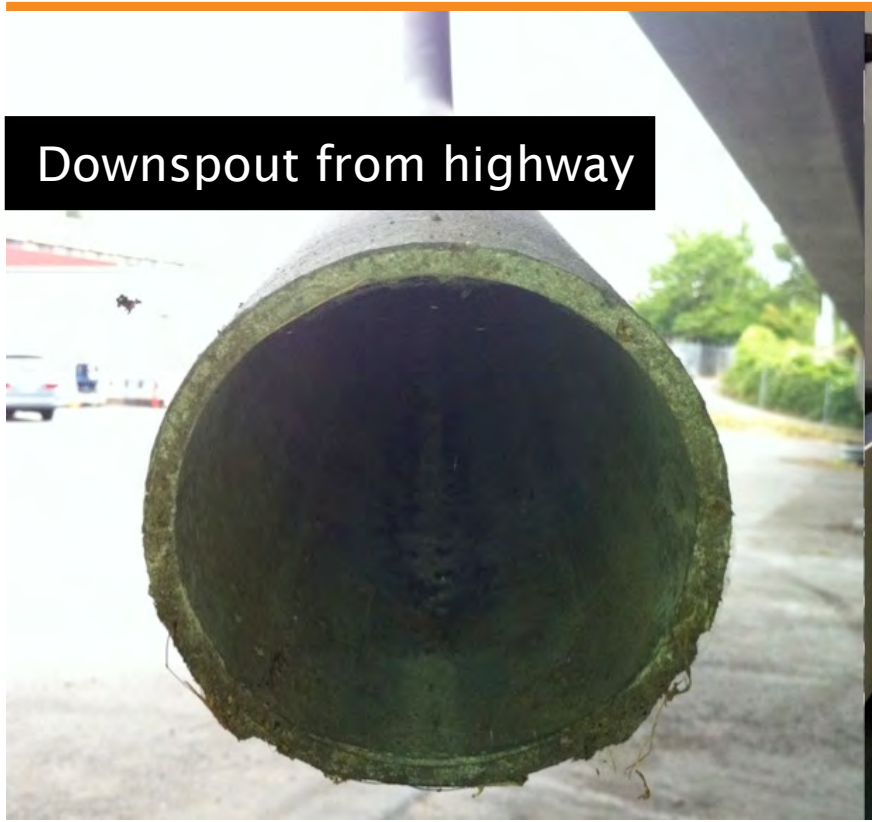
Feist et al. 2017, Ecol Appl

Experimental Studies

Runoff Collection

Urban highway, Seattle, >60,000 AADT,
Onramp Collection: about 15,000 AADT

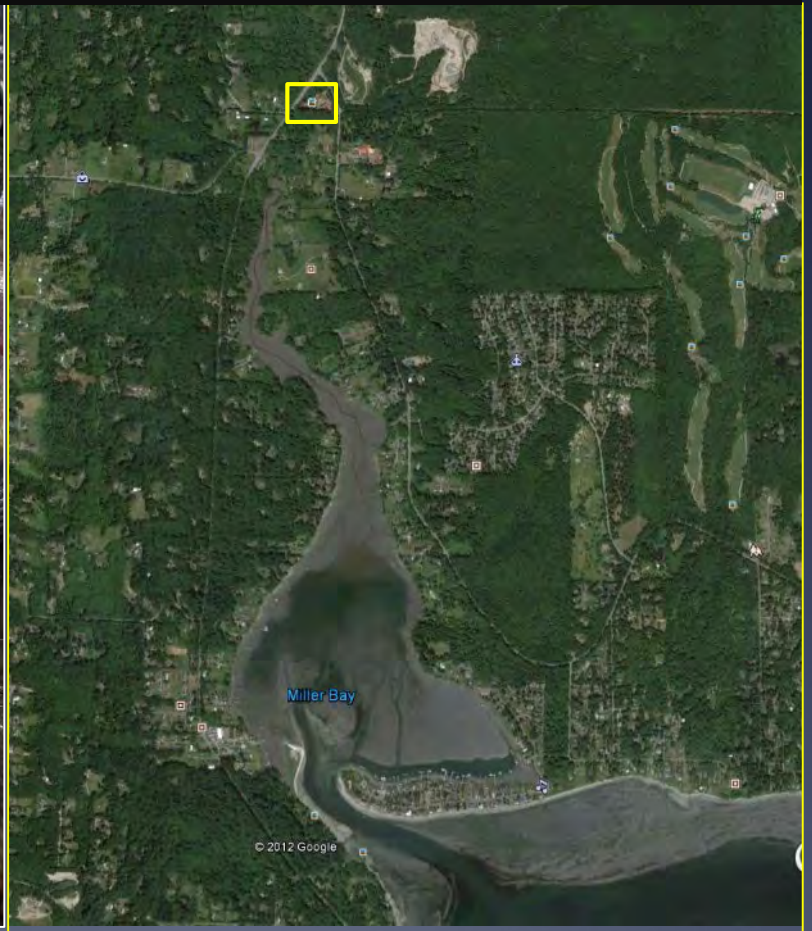
Highway stormwater runoff



THE SUQUAMISH TRIBE
Grovers Creek Facility, Suquamish Tribe
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
© 2012 Cnes/Spot Image
Image © 2012 TerraMetrics

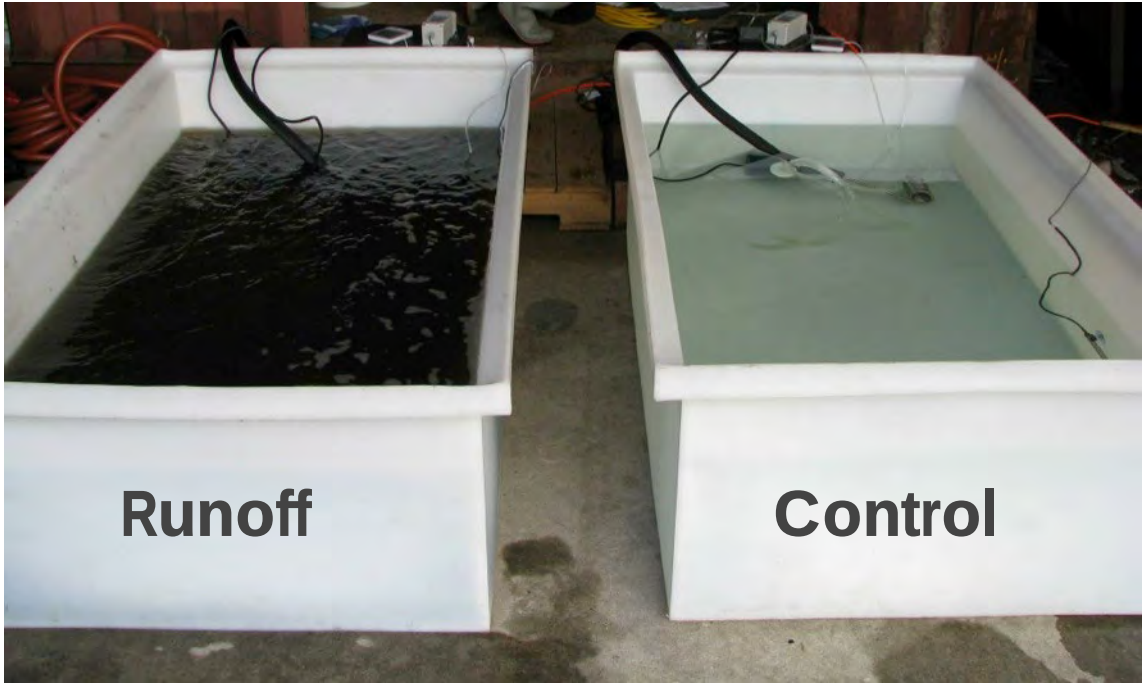
Grovers Creek facility, Suquamish Tribe

Photo: Tiffany Royal



Coho pre-spawning mortality

Highway runoff is toxic to coho

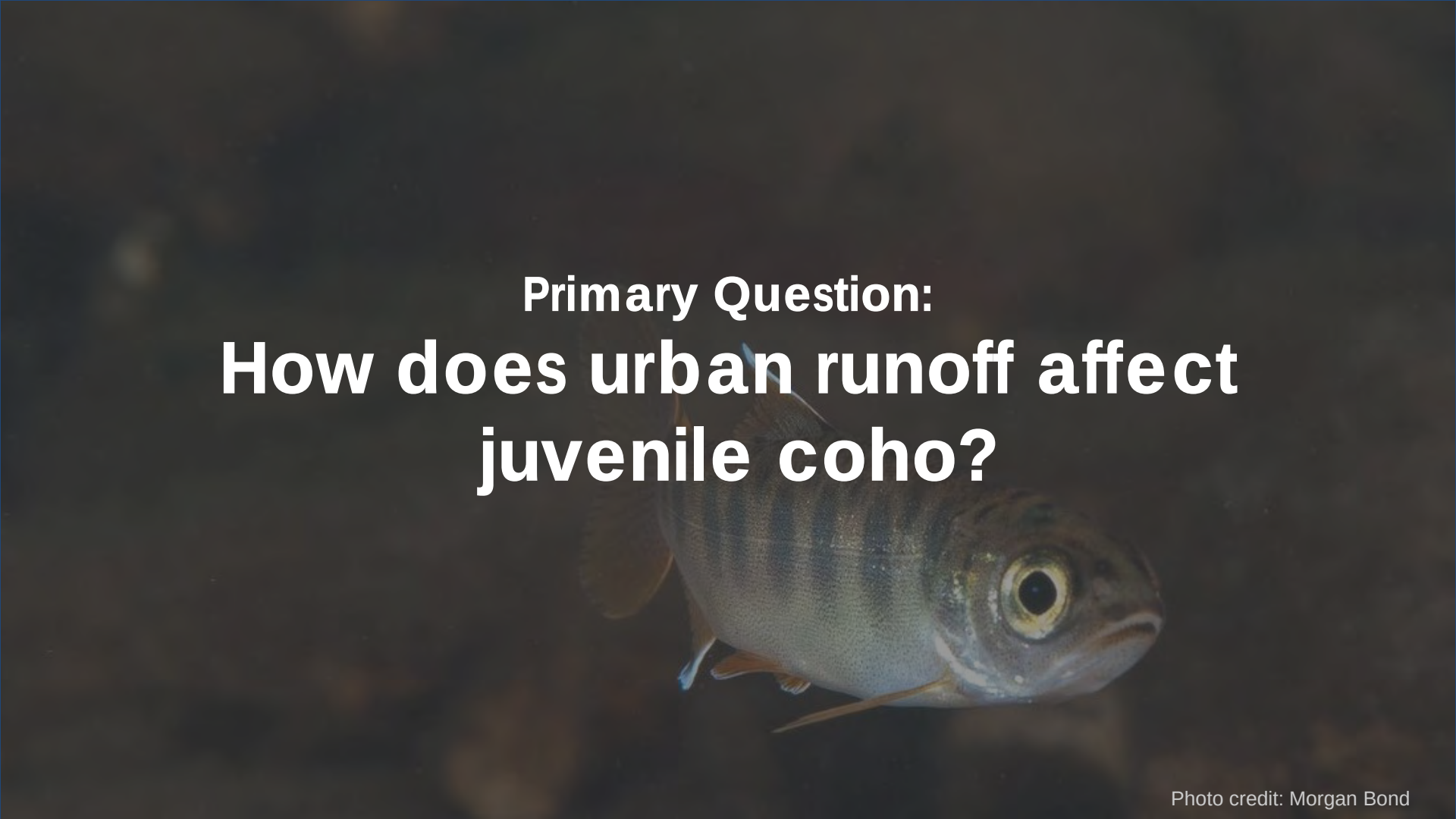


Spromberg et al. 2016, JAE
McIntyre et al. Submitted

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

unexposed
(3.5 hrs)

stormwater-exposed
(3.5 hrs)



Primary Question:

How does urban runoff affect juvenile coho?

Photo credit: Morgan Bond

Main Objectives:

1. Identify the behavioral and physiological effects of urban runoff to juvenile coho salmon

2. Compare between life history stages (compare juvenile response to adults)

Photo Credit: Morgan Bond

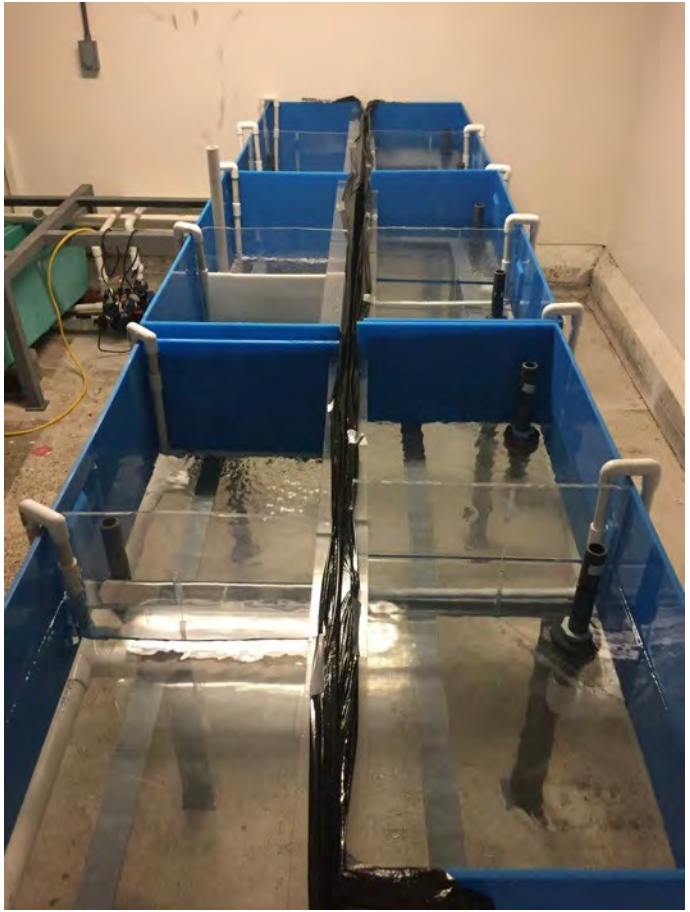
Juvenile coho in urban streams

Longfellow Creek 2012

Video credit: NOAA Fisheries

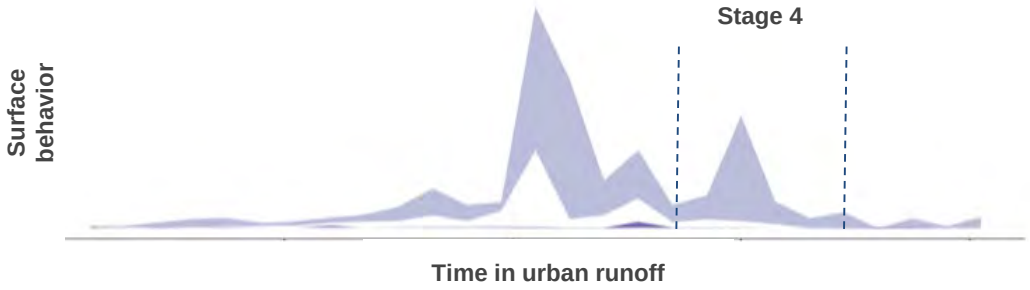
Objective One:

Behavioral characterization



WSU Puyallup Research and Extension Center

Progression of behavioral symptoms



Stage 0: Presymptomatic from the surface

Stage 1: Discrete surfacing events

Stage 2: Short episodes of continuous surface swimming

Stage 3: Sustained continuous surface swimming*

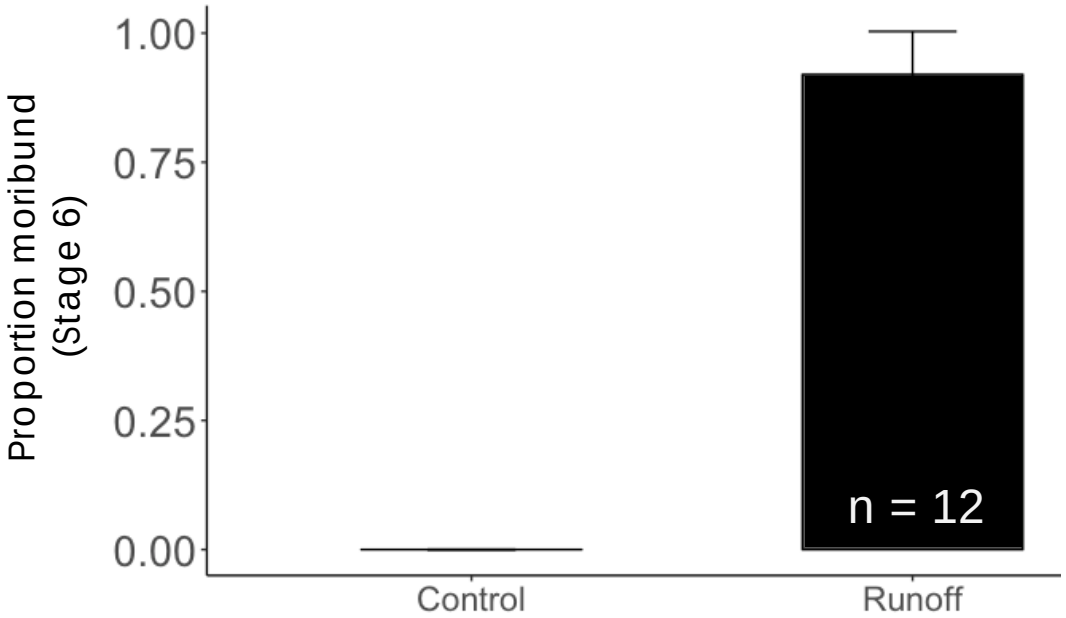
Stage 4: Loss of equilibrium

Stage 5: Loss of buoyancy

Stage 6: Moribund

Urban runoff was acutely toxic to juvenile coho

7 hours continuous exposure



Objective One findings:

Behavioral characterization

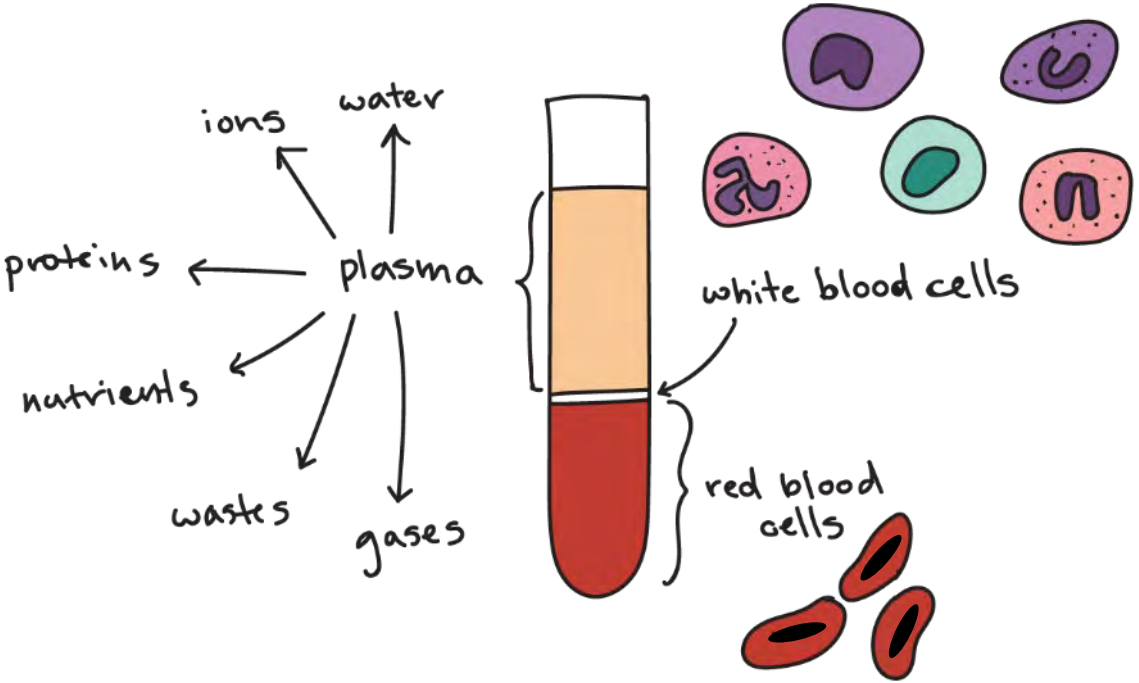
1. Urban runoff is acutely toxic to juvenile coho
2. Similar behaviors as previously observed in adults
3. Consistent progression of behavioral stages
   - Variability in time to effect
4. Transferring to clean water did not reverse the mortality effect
   - Symptomatic fish are on a “one-way” trip

Objective Two:

Physiological impacts

Methods:

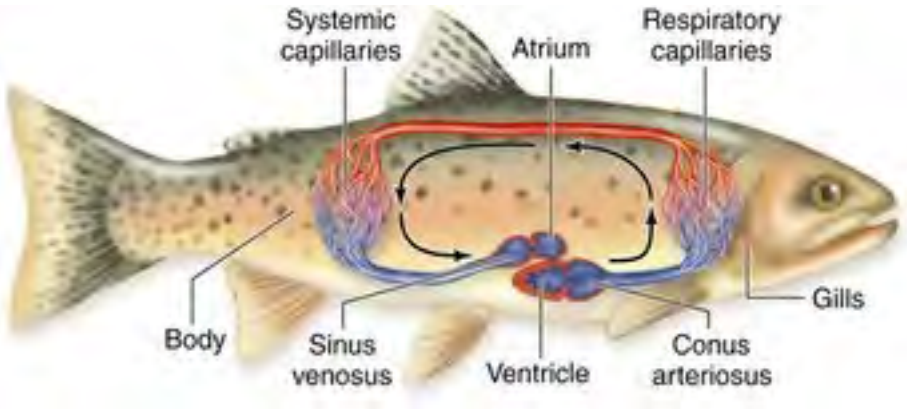
Exploring blood profiles



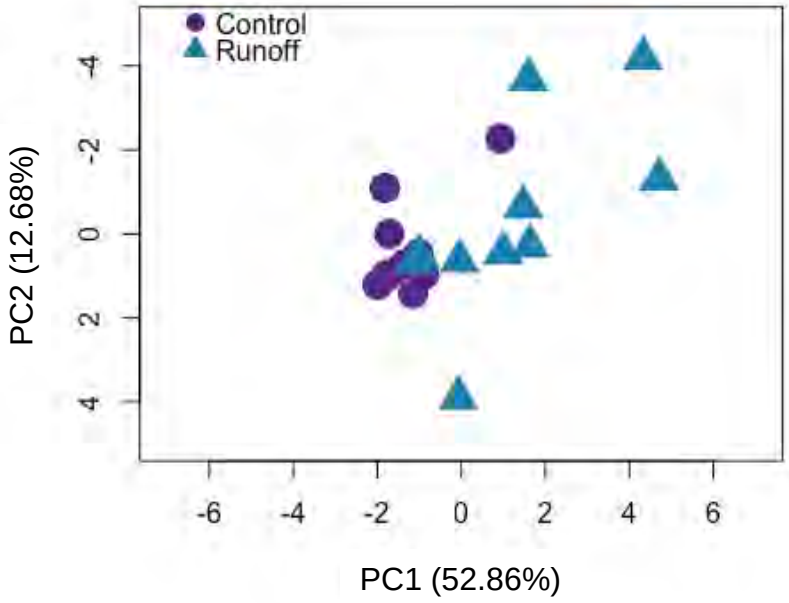
Source: Khan Academy

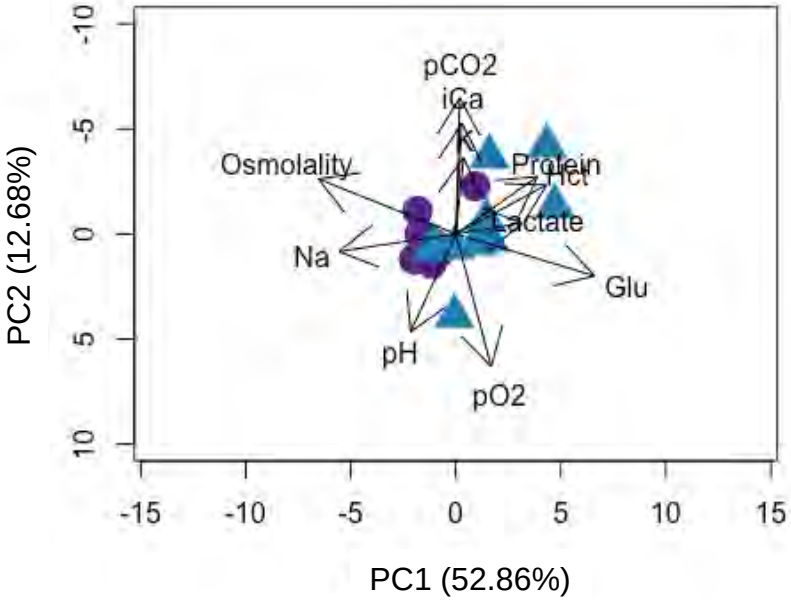
Principal Component Analysis (PCA)

- 11 blood variables
  - pH
  - Gases (pO_2, pCO_2)
  - Ions (Na^+, K^+, iCa^{2+})
  - Glucose and lactate
  - Hematocrit
  - Total protein
- Post hoc analysis to determine treatment differences



PCA: Is there a treatment difference?

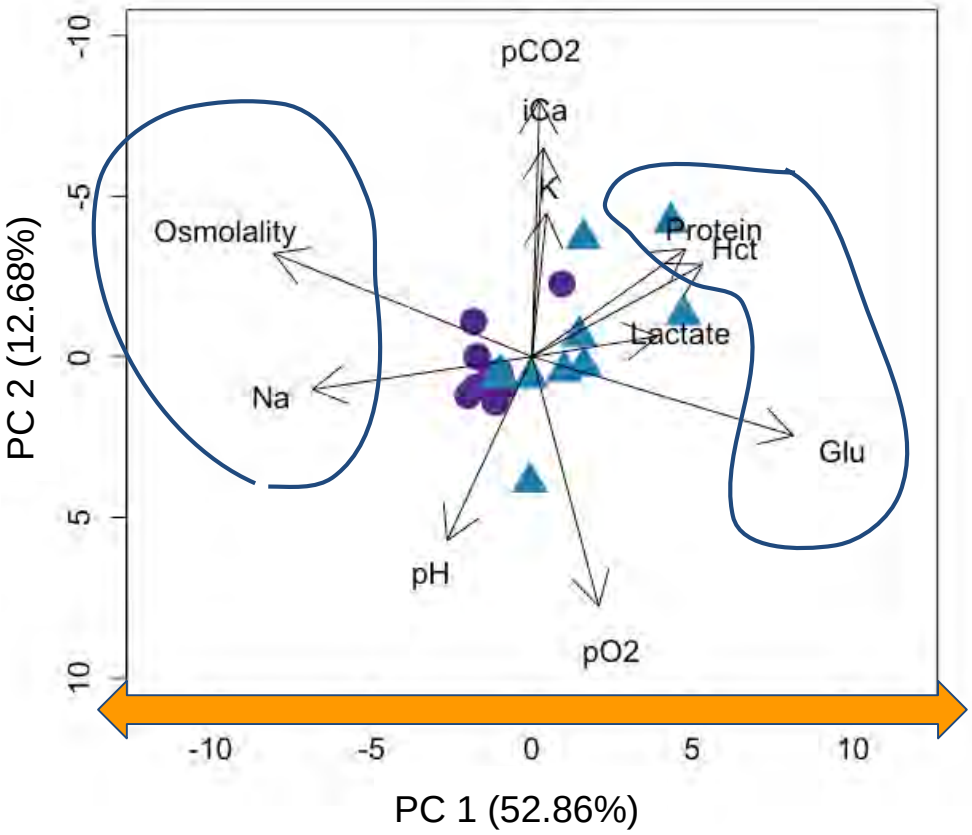




PCA:

Blood profile of runoff-exposed coho

- Stage 4 (loss of equilibrium)
- **Runoff-exposed fish** loaded significantly different along **PC1** compared to controls
- Some variables were more correlated with PC1



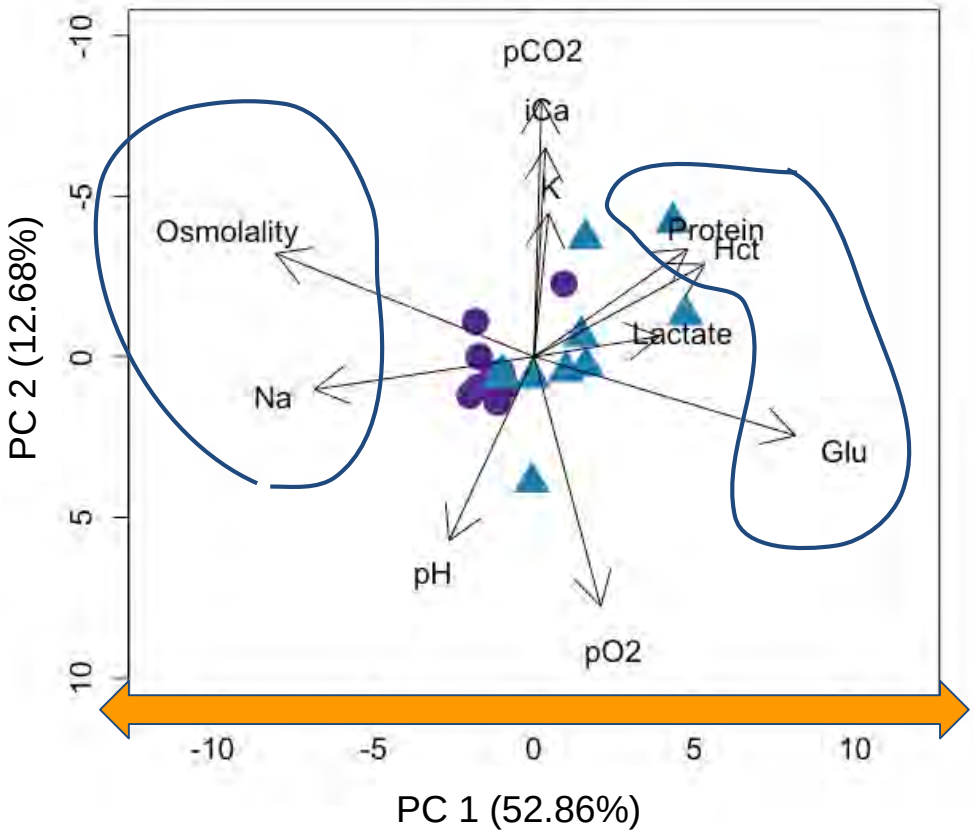
PCA:

Blood profile of runoff-exposed coho

Runoff-exposed fish:

- ⬆ Glucose
- ⬆ Total plasma protein
- ⬆ Osmolality
- ⬇ Na^+
- ⬆ Hematocrit

→ Osmoregulatory disturbance



Can juveniles be used as a model to study the adult spawner effect?

Objective Three:

Comparing life history stages

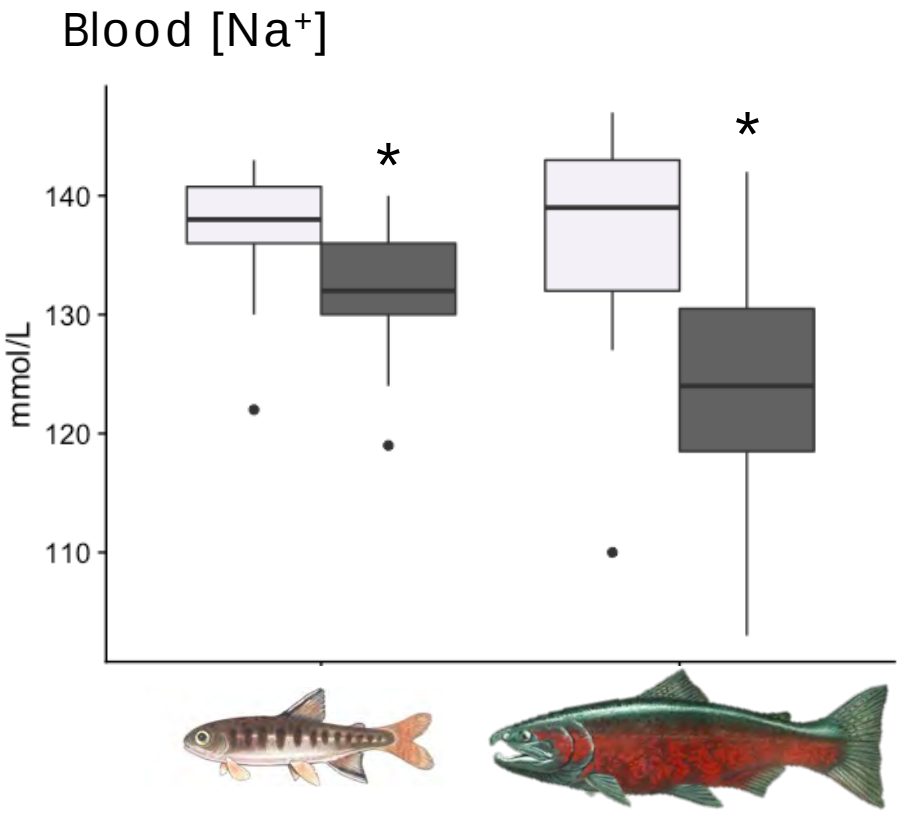
- Acute mortality from highway runoff
- Similar behavioral symptoms in both the field and experimental exposures
- Is there an osmotic disturbance present in spawners?

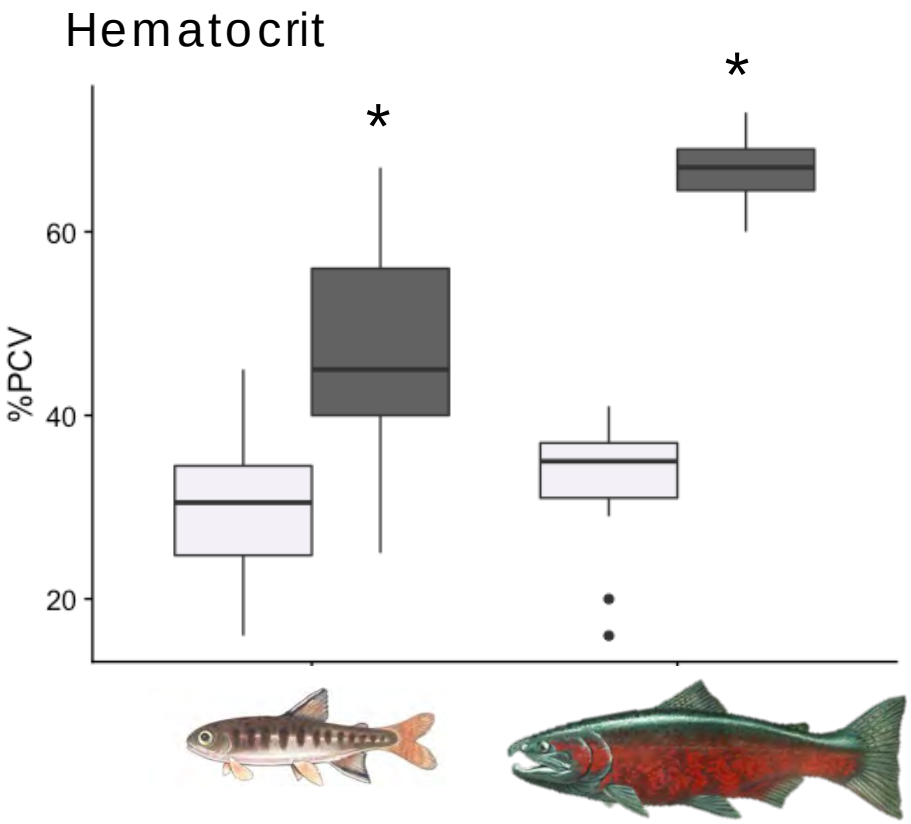
Comparing life history stages:

Consistent osmotic disturbance

Control (time-matched)

Runoff (Stage 4)

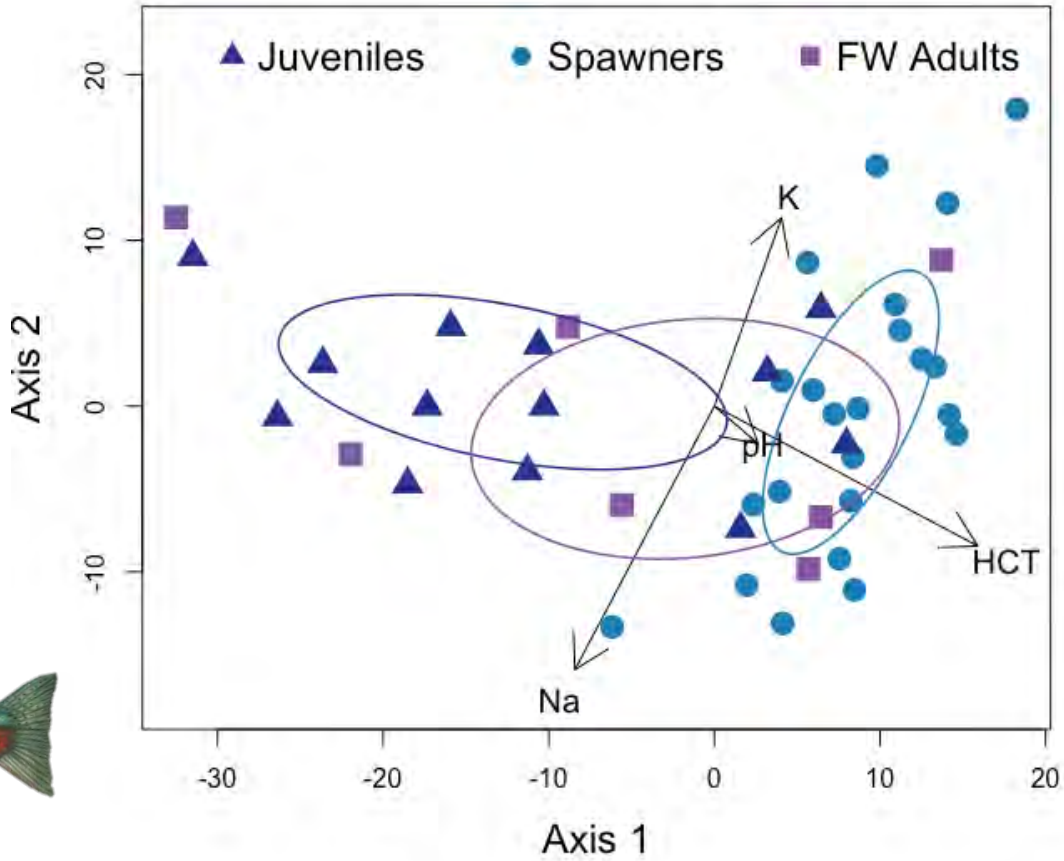




NMDS: Comparing life history stages

Osmoregulatory-related blood metrics

No difference was observed between life history stages (i.e. the runoff effect was similar)



Conclusions:

1. Urban runoff is acutely toxic to juveniles
2. Ion and osmoregulatory disturbance observed in runoff-exposed coho
3. Similar effect on juveniles compared to adults (i.e. good surrogates to study the phenomenon)
   - acute mortality
   - behavioral symptoms
   - physiological impacts

Puget Sound Stormwater Science Team (PSSST)

Washington State University

Puyallup Research & Extension Center

U.S. Fish & Wildlife Service

Stormwater Science: a Regional Collaboration

Sheltering Communities from Coastal Storms

Puyallup Research & Extension Center

Bullitt Foundation

Questions?

... AND THEN, AFTER SPENDING SEVERAL YEARS ABSORBING GOODNESS KNOWS WHAT TOXINS, IN SOME OF THE MOST HEAVILY POLLUTED WATERS ON THE PLANET, I DRAGGED MY MERCURY-LADEN CARCASS BACK UP THIS STREAM TO DIE... BON APPÉTIT.
PTTTOOOO