Processes affecting prespawn mortality in Chinook salmon throughout the Columbia River Basin

Tracy Bowerman, Chris Caudill, Matt Keefer
Department of Fish and Wildlife Sciences, U. of Idaho
Lisa Crozier
Northwest Fisheries Science Center, NOAA fisheries, Seattle

University of Idaho College of Natural Resources

NOAA

The Seattle Times

Snowpack drought has salmon dying in overheated rivers

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2015

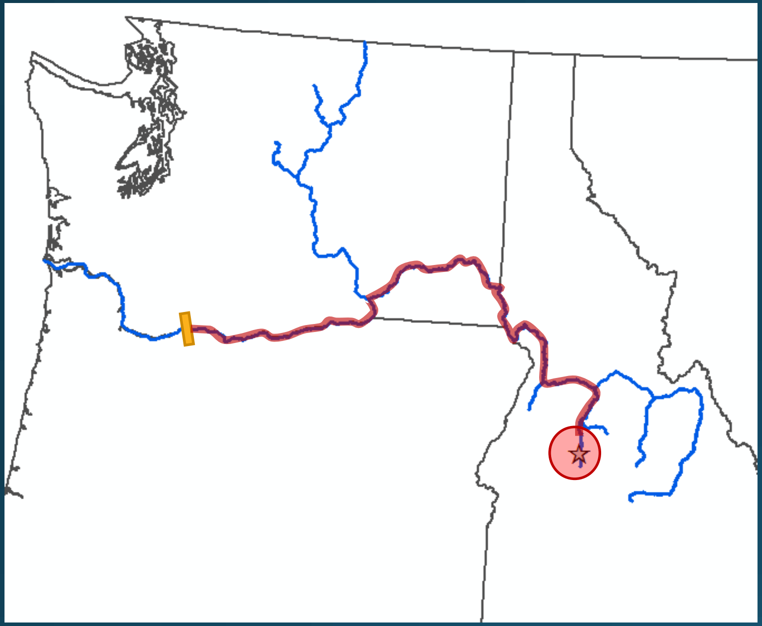
Chris Fisher, Colville Tribes


Steve Ringman/The Seattle Times

Outline

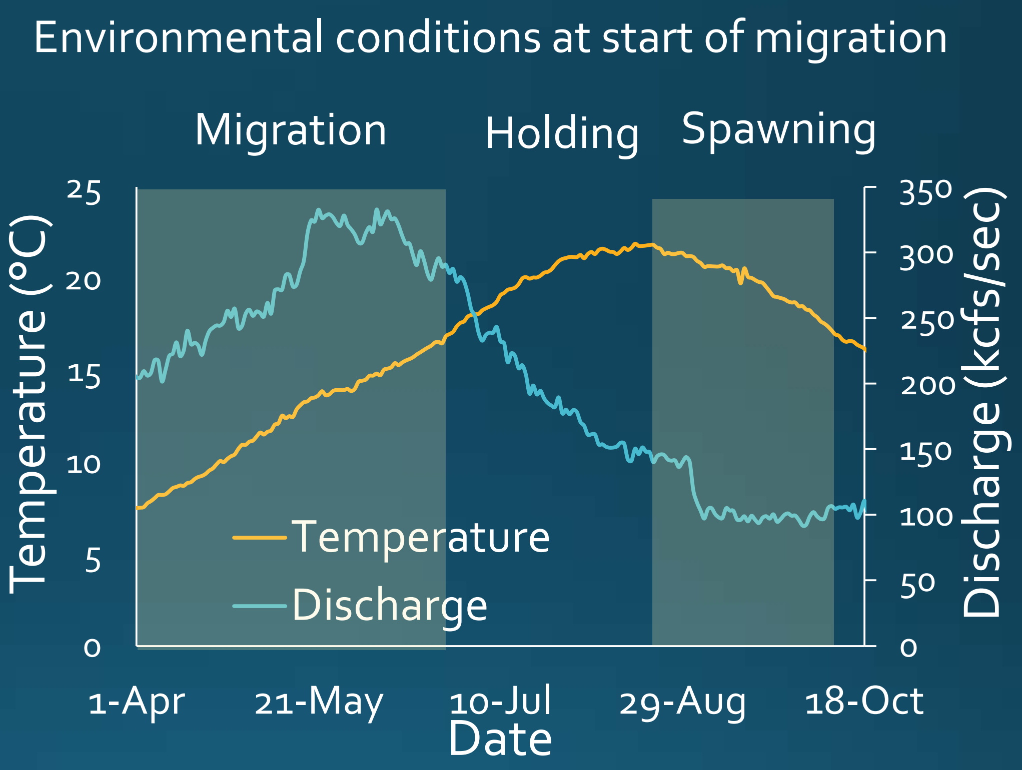
1. Adult salmon mortality and effects on populations
2. Questionnaire to fisheries professionals: methods used to monitor PSM
3. Patterns of PSM across the Columbia Basin
4. Factors related to PSM in Willamette and Columbia
5. Energetics model to evaluate energetic exhaustion as a mechanism for PSM

Adult salmon freshwater mortality



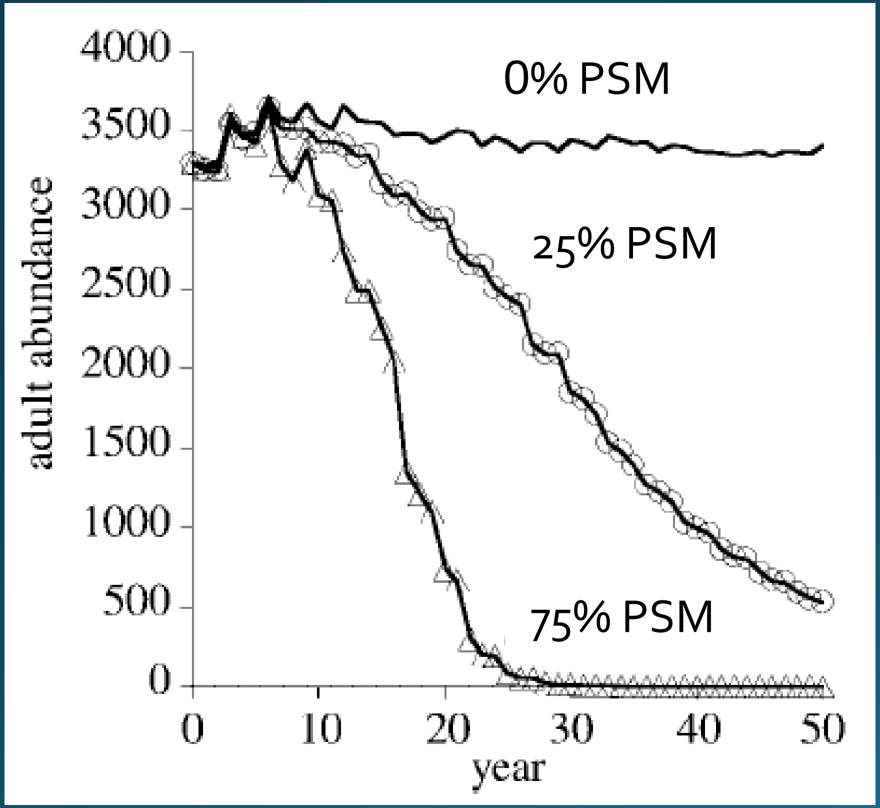
En-route mortality: during upstream migration prior to reaching spawning grounds

Pre-spawn mortality (PSM): after arrival at spawning grounds prior to reproduction



Why should we care about PSM?

Puget Sound Coho salmon



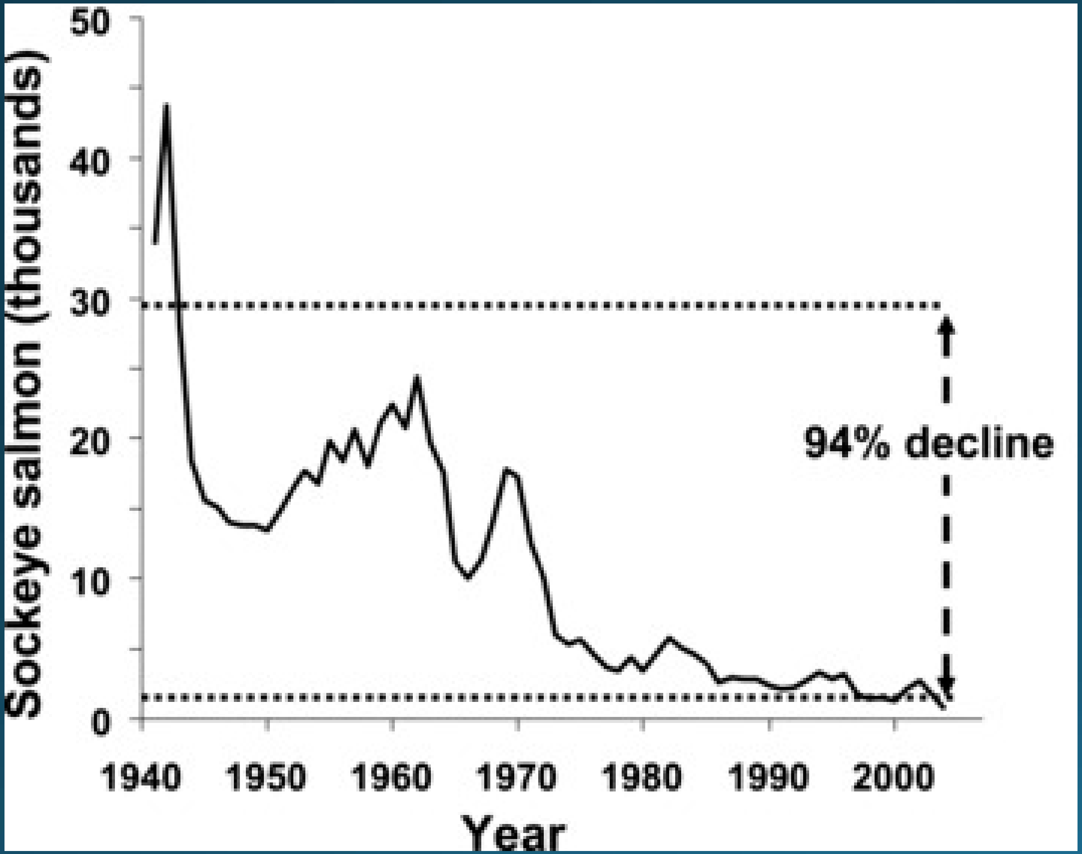
Spromberg and Scholz 2011

30 year projections :

25% PSM → 60% decline

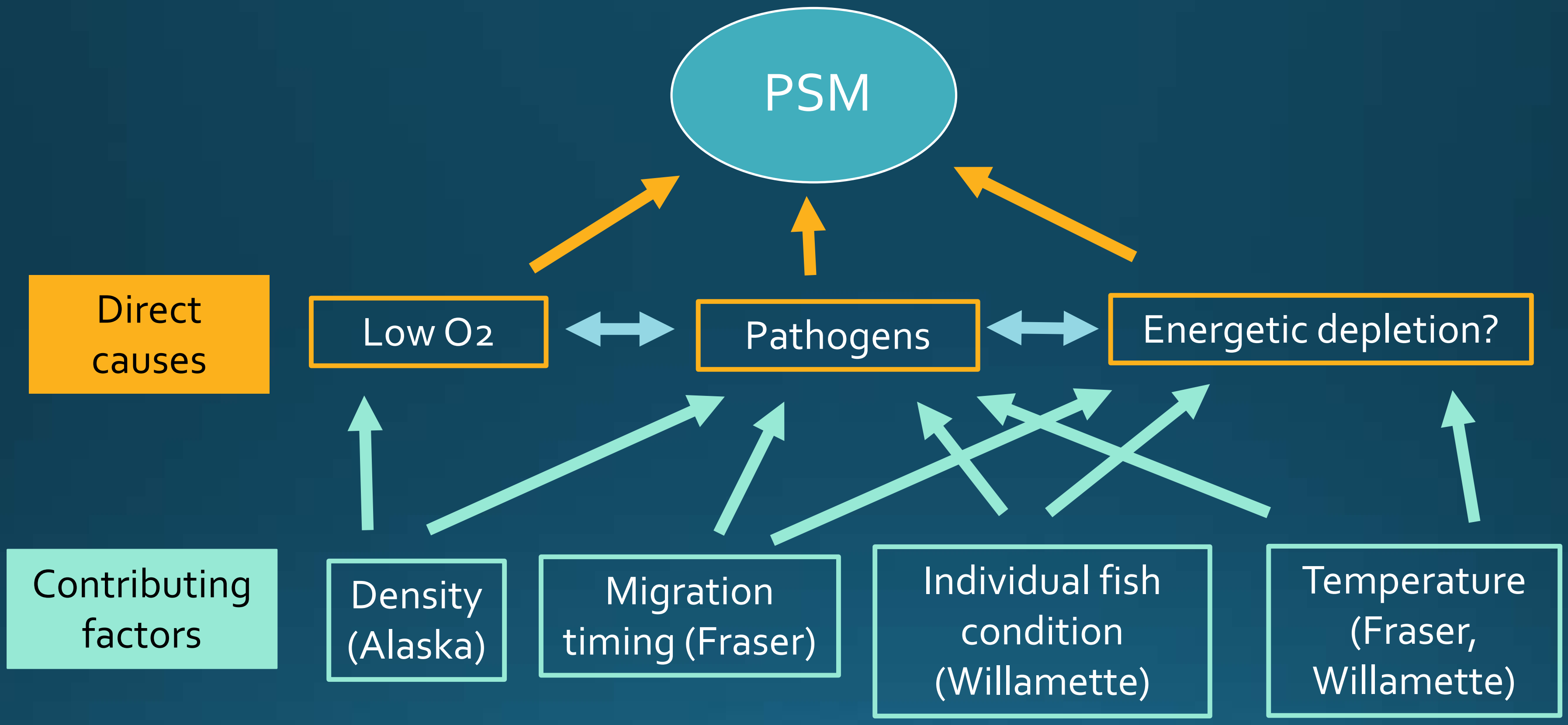
75% PSM → extinction

Why we care about PSM



Increased PSM contributed to collapse of Cultus Lake Sockeye and emergency listing

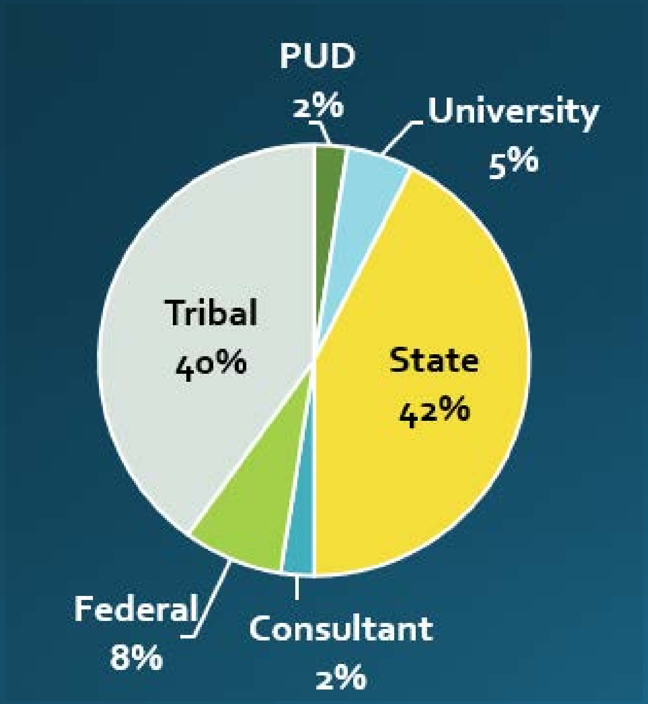
What causes salmon to die prematurely?

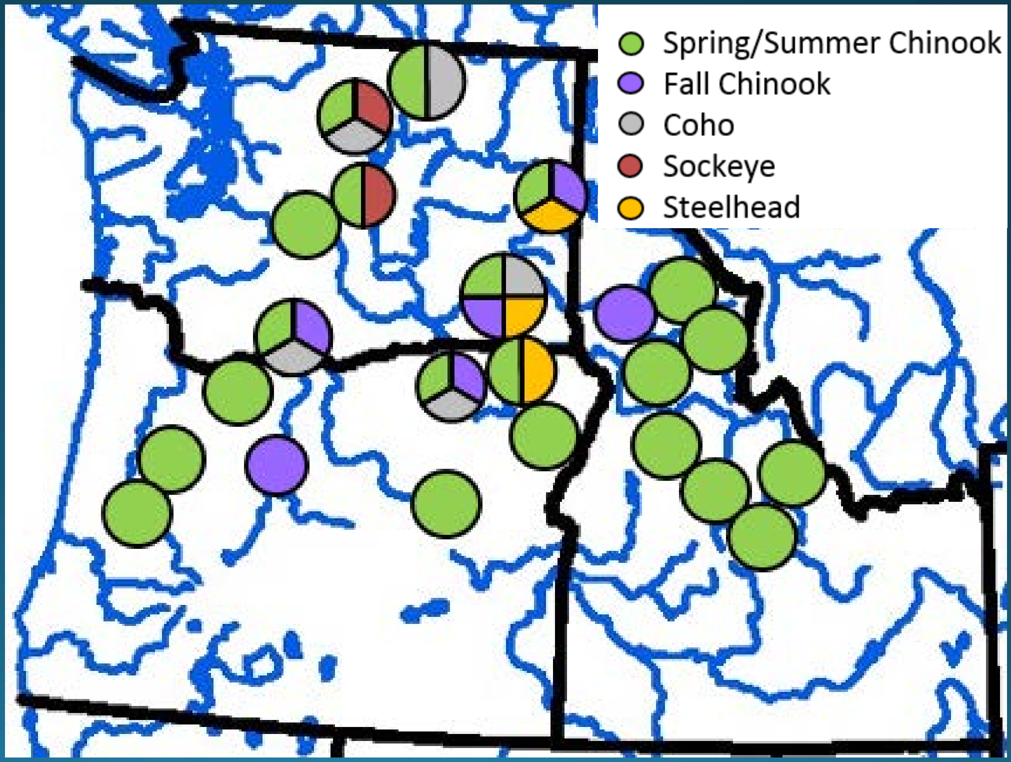


Questionnaire: overview of PSM monitoring

37 Respondents in Columbia
12 different agencies
7000 stream km surveyed

PSM monitoring widespread but considerable variation in data collection and reporting

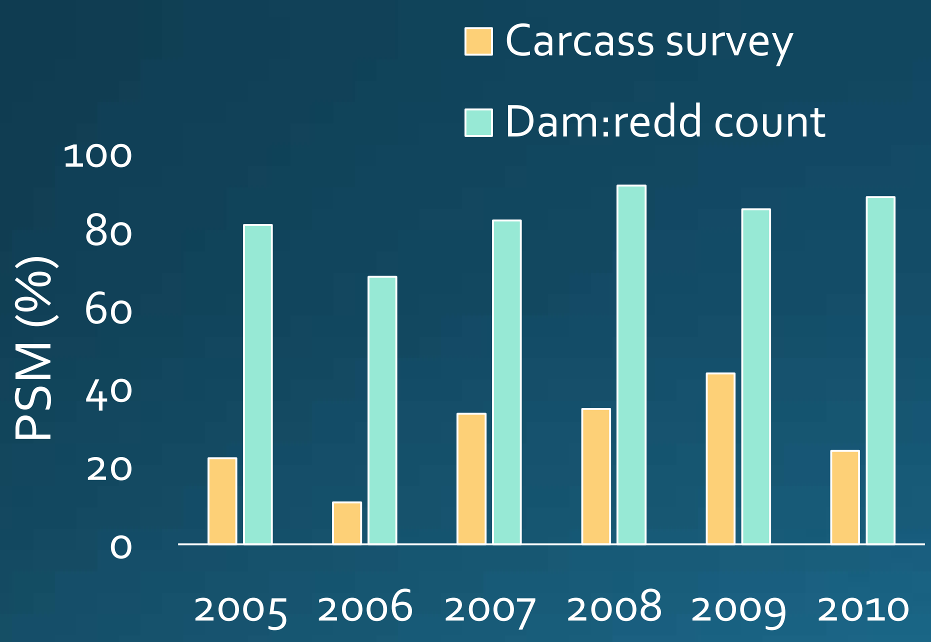




Questionnaire: How is PSM monitored?

Data used to estimate PSM:

- Carcasses collected on spawning grounds assessed for egg retention
- Count at dam or weir relative to redd count



Bowerman et al. 2016 Fisheries;
Shroeder et al. 2005

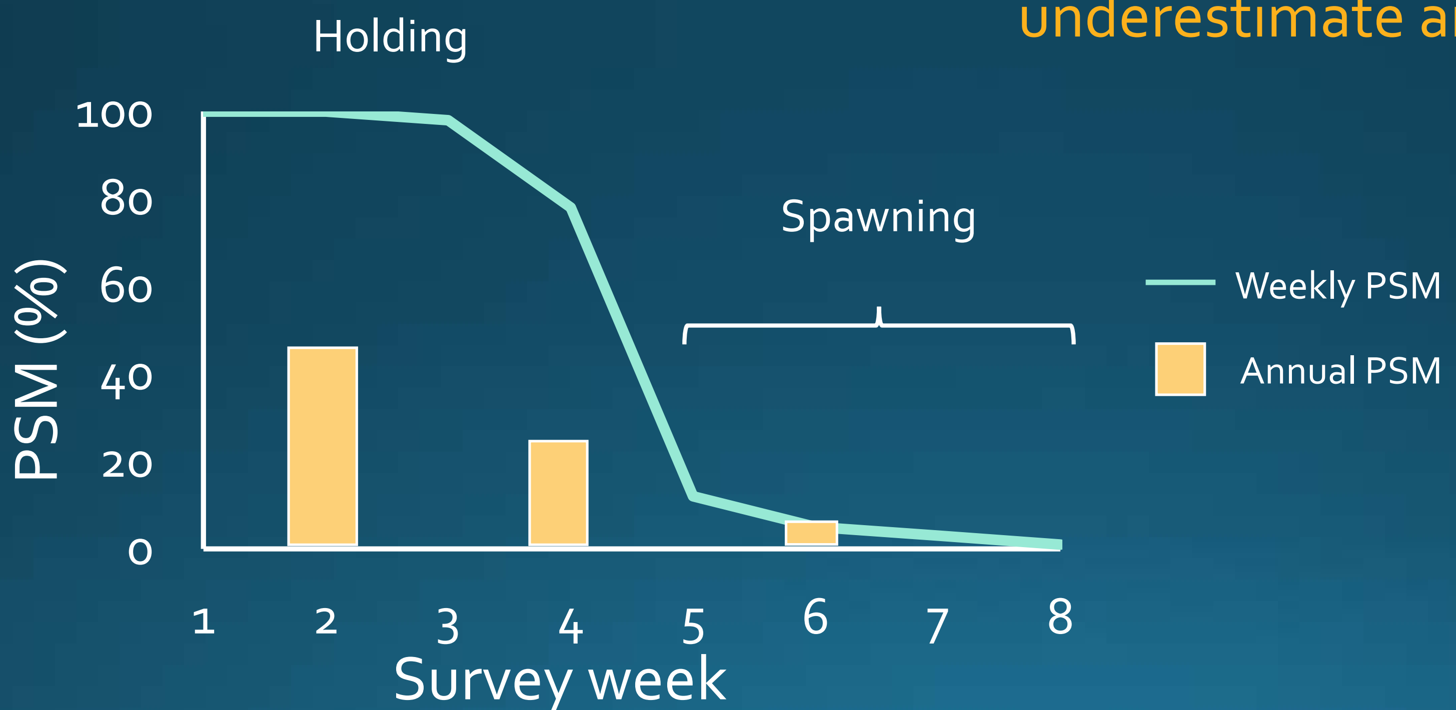
Potential biases with each method:

- Carcass-based counts may miss en route and early season mortality
- Dam:Redd count estimates prone to error associated with redd counts, sex ratios, etc.

Timing of carcass surveys important

In some populations, PSM highest before spawning begins

Carcass counts conducted only during spawning period may dramatically underestimate annual PSM



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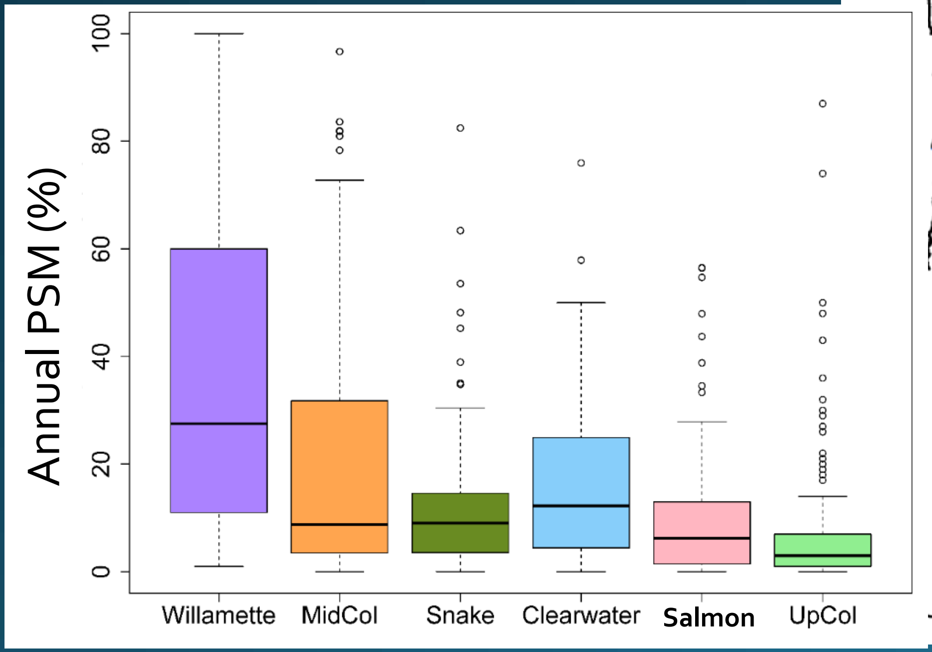
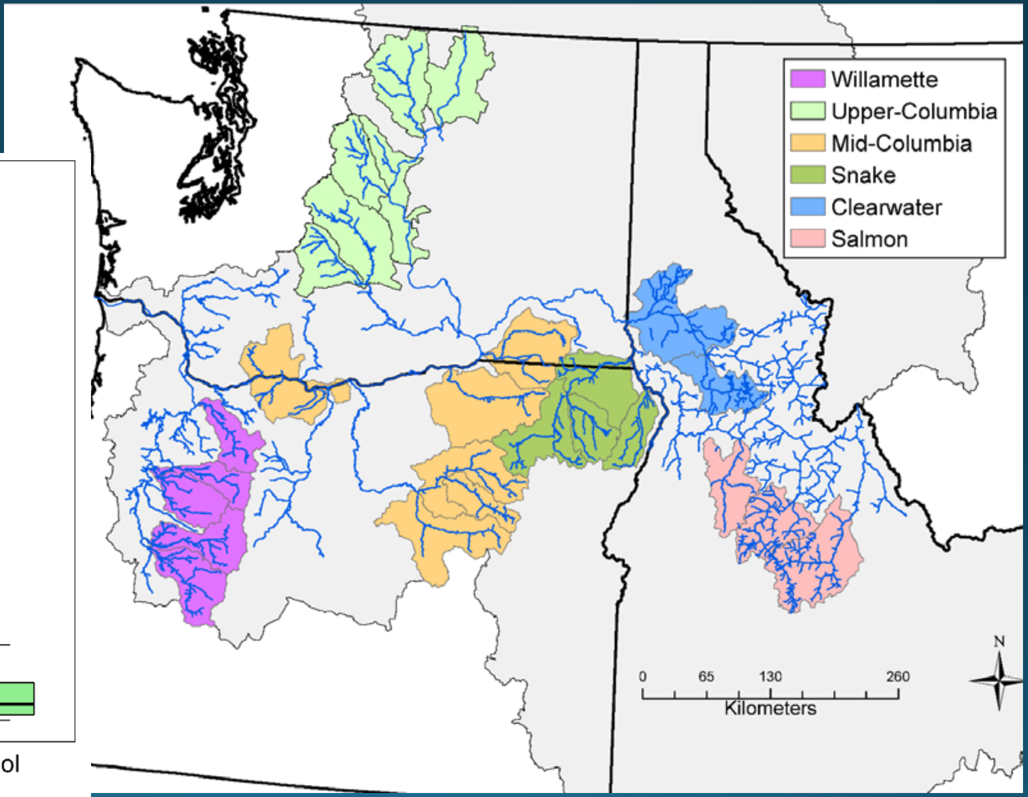
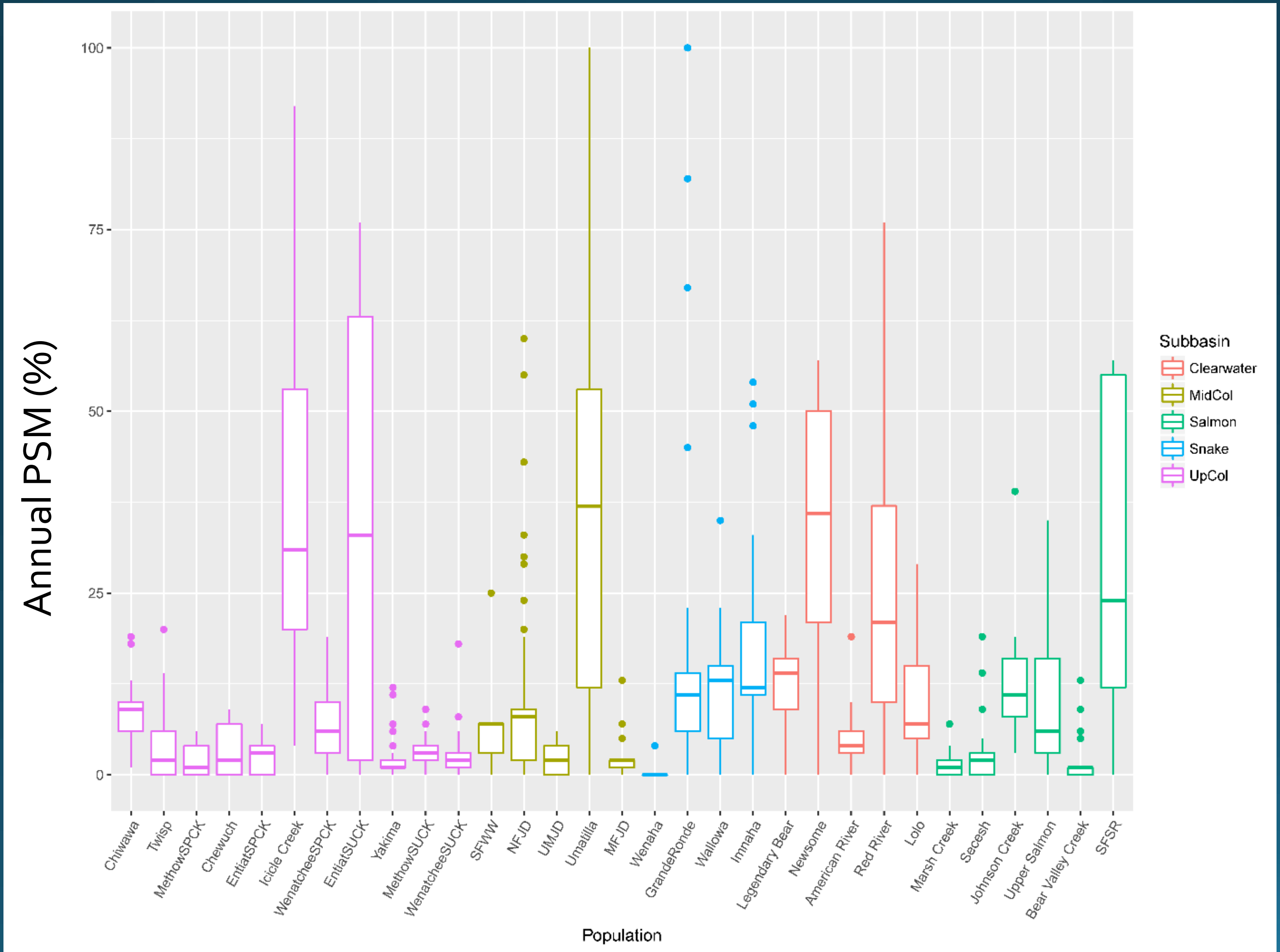
Sp-su Chinook PSM rates in the Columbia Basin

618 site years of carcass data
59 streams

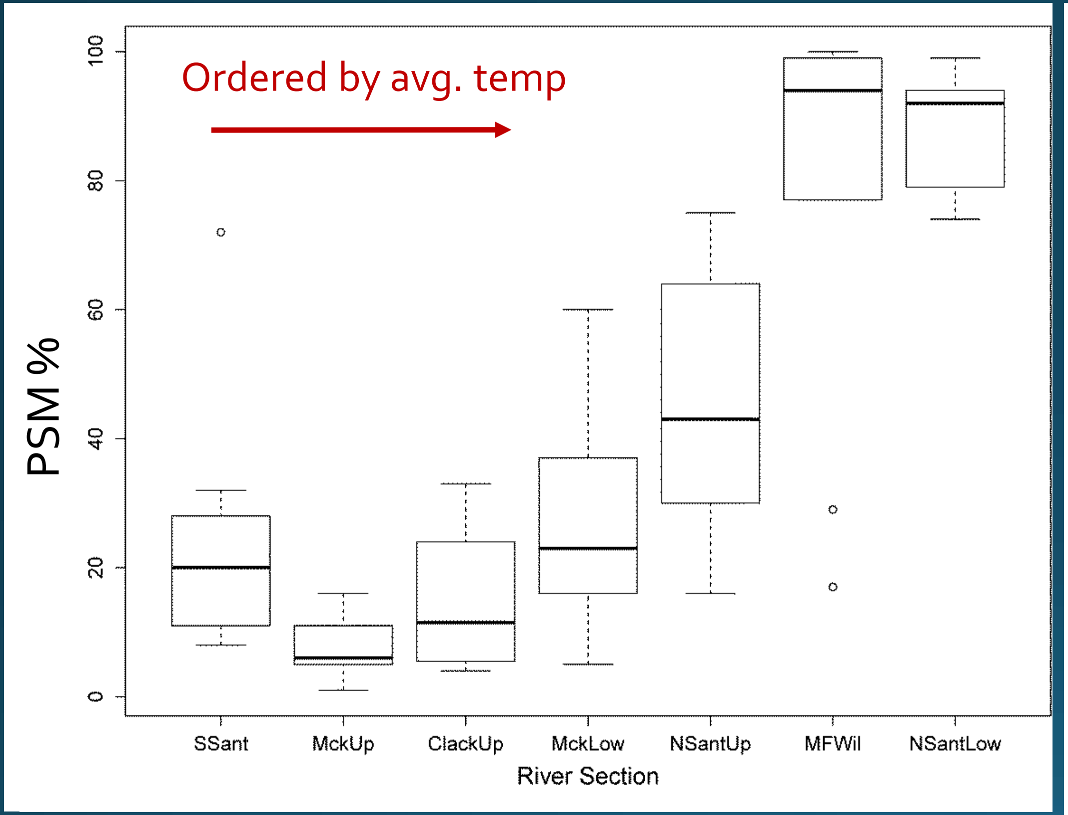


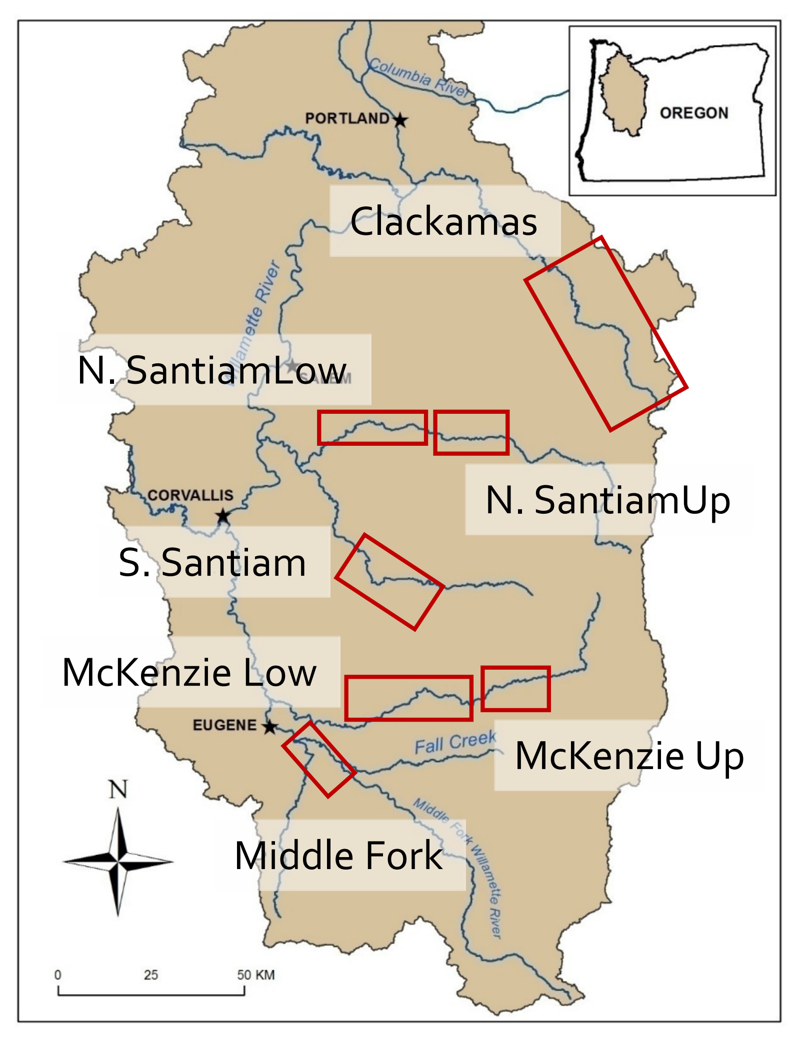


PSM highly variable among populations



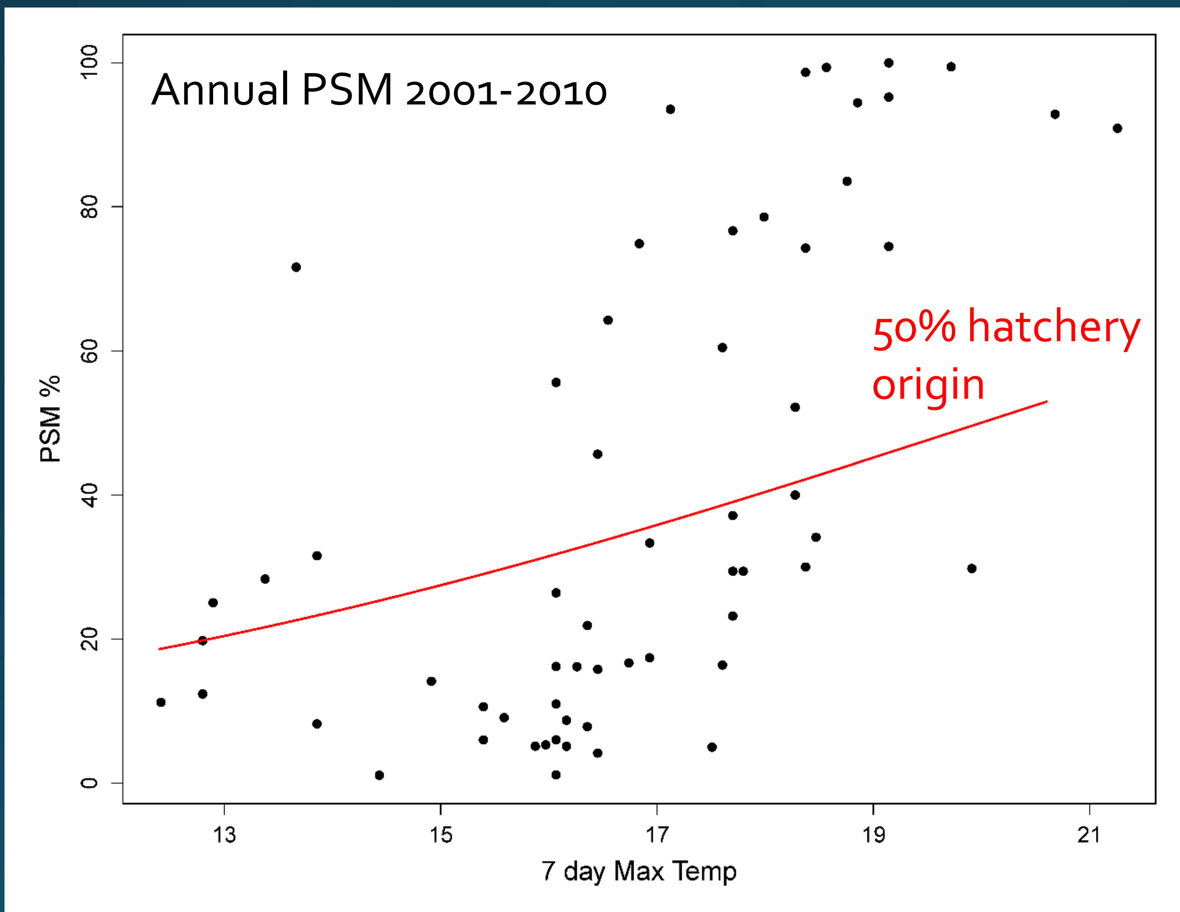
Willamette Basin spring Chinook PSM





Data from annual reports 2001-2010

Factors affecting PSM in Willamette Basin rivers



PSM significantly related to:

1. Temperature
2. Percent hatchery origin (clipped)

Logit $(\mu)_{ij} = \beta_0 + \beta_1 \left(Temp_{ij}\right) +$

$+ \beta_2\left(PctHatchery_{ij}\right) + b_i + b_j + b_{ij}$

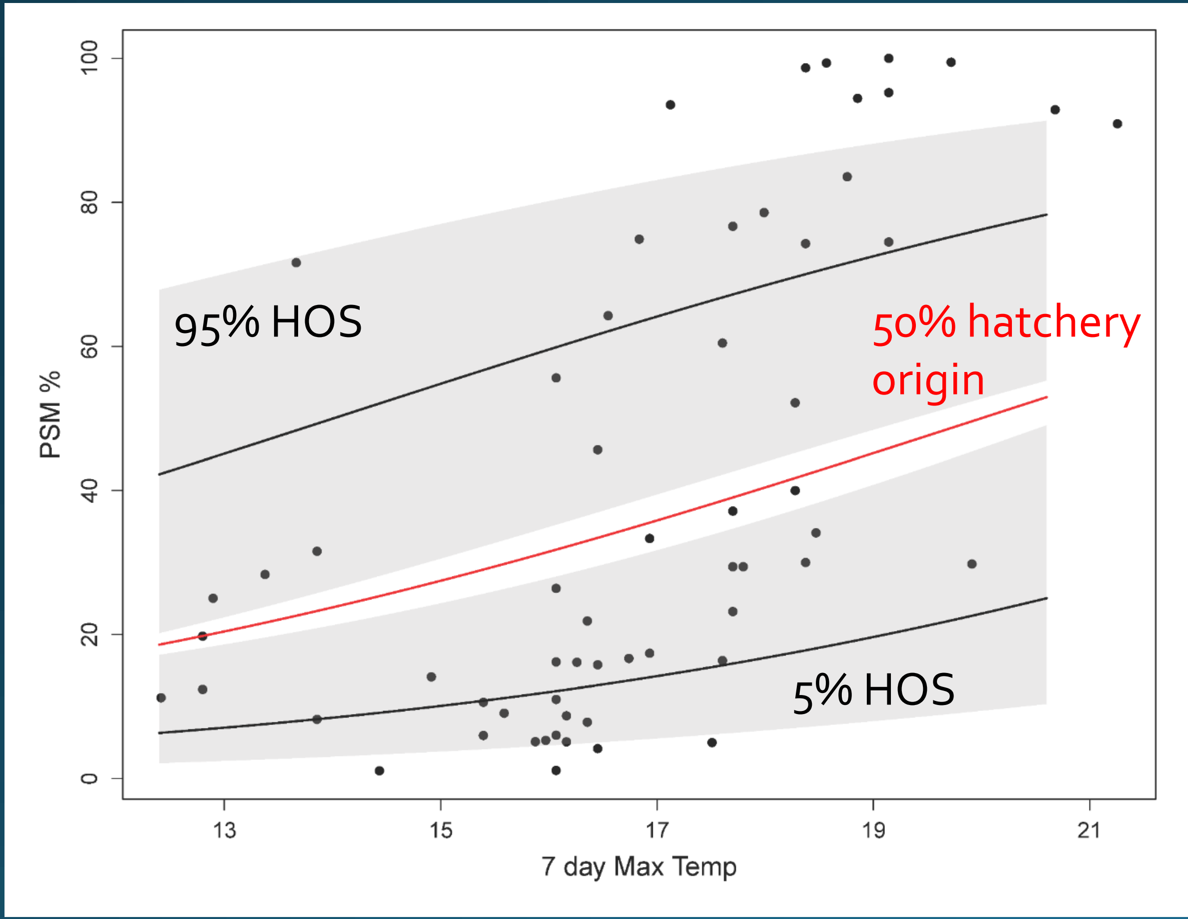
$PSM_{ij} \sim Binomial(\mu_{ij}, \pi_{ij})$

$b_i \sim N(0, \sigma_b{}^2)$ random intercept stream i

$b_j \sim N(0, \sigma_b{}^2)$ random intercept year j

$b_{ij} \sim N(0, \sigma_b{}^2)$ individual-level random intercept

Factors affecting PSM in Willamette Basin rivers



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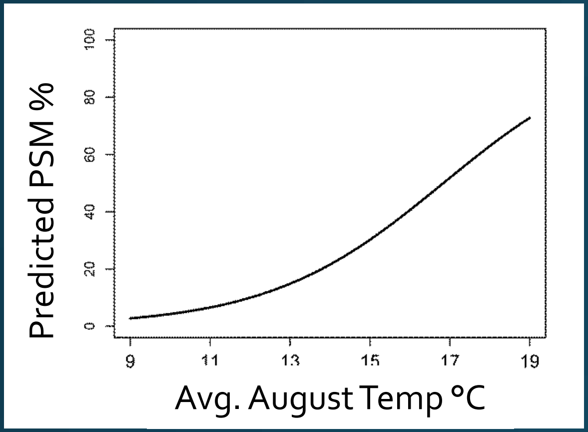
Factors affecting Chinook PSM in the CRB



Probability of PSM:

- Increased with temperature

Temperature decreases with elevation

Logit $(\mu)_{ij} = \beta_0 + \beta_1\,(Temp_{jk}) + \beta_2\,(Origin_{ijk})$

$+ \beta_3(Length_{ijk}) + b_j + \; b_k + \varepsilon_{jk}$

$Mortality_{ijk} \sim Bernoulli(\mu_{ijk})$

$b_j \sim N(0, \sigma_b{}^2)$ random intercept for population j

$b_k \sim N(0, \sigma_b{}^2)$ random intercept for year k

Preliminary results, subject to revision

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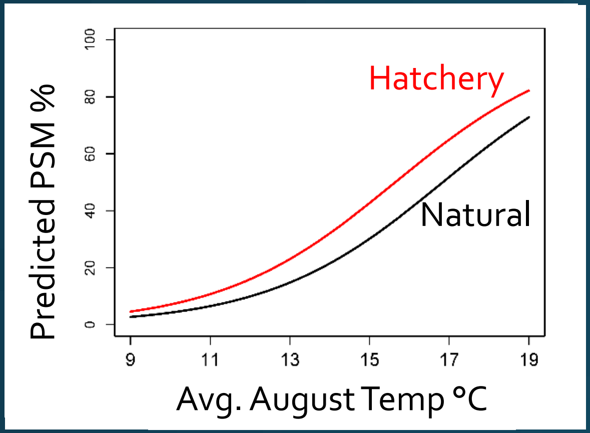

Probability of PSM:

- Increased with temperature
- Higher for hatchery fish

Density increases with percent hatchery origin

Logit $(\mu)_{ij} = \beta_0 + \beta_1 (Temp_{jk}) + \beta_2 (Origin_{ijk})$

$+ \beta_3 (Length_{ijk}) + b_j + b_k + \varepsilon_{jk}$

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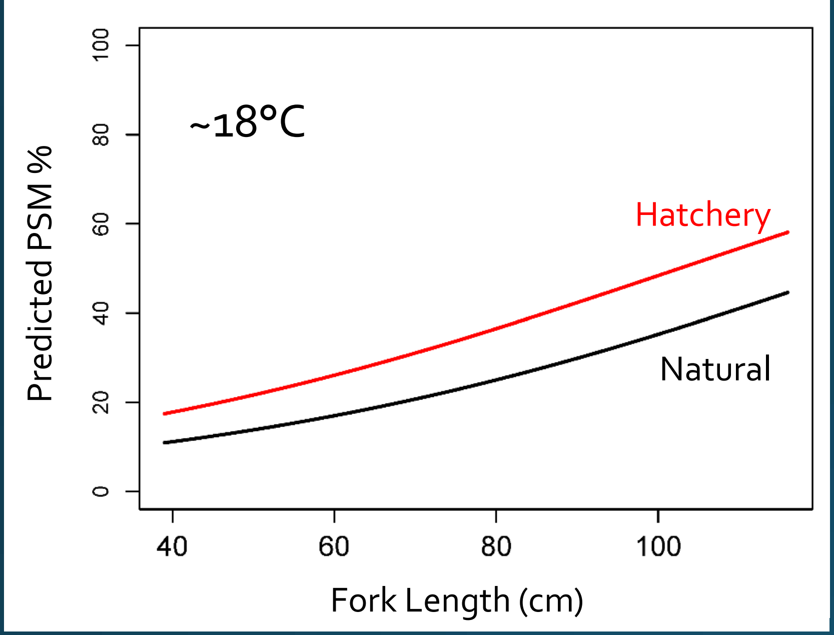

Probability of PSM:

- Increased with temperature
- Higher for hatchery fish
- Increased with length

Migration timing sometimes related to size

Logit $(\mu)_{ij} = \beta_0 + \beta_1\,(Temp_{jk}) + \beta_2\,(Origin_{ijk})$

$+ \beta_3(Length_{ijk}) + b_j + b_k + \varepsilon_{jk}$

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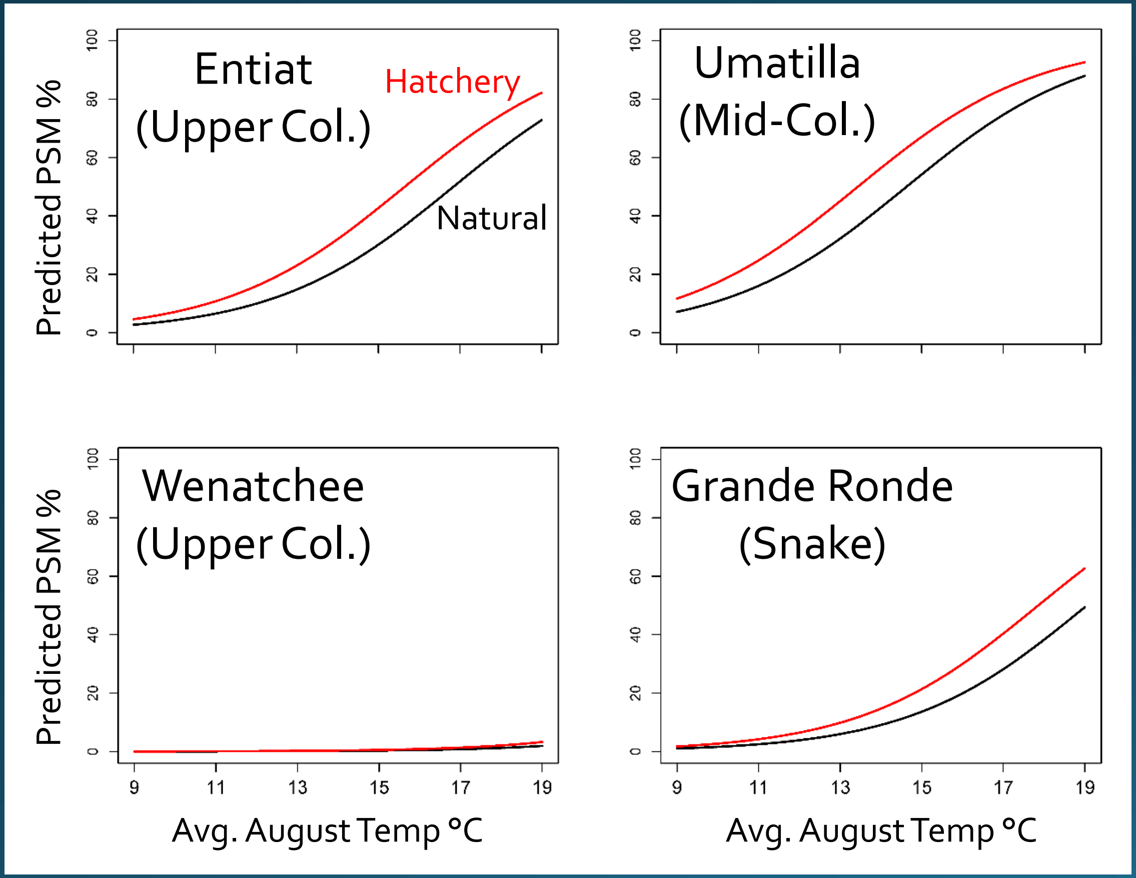
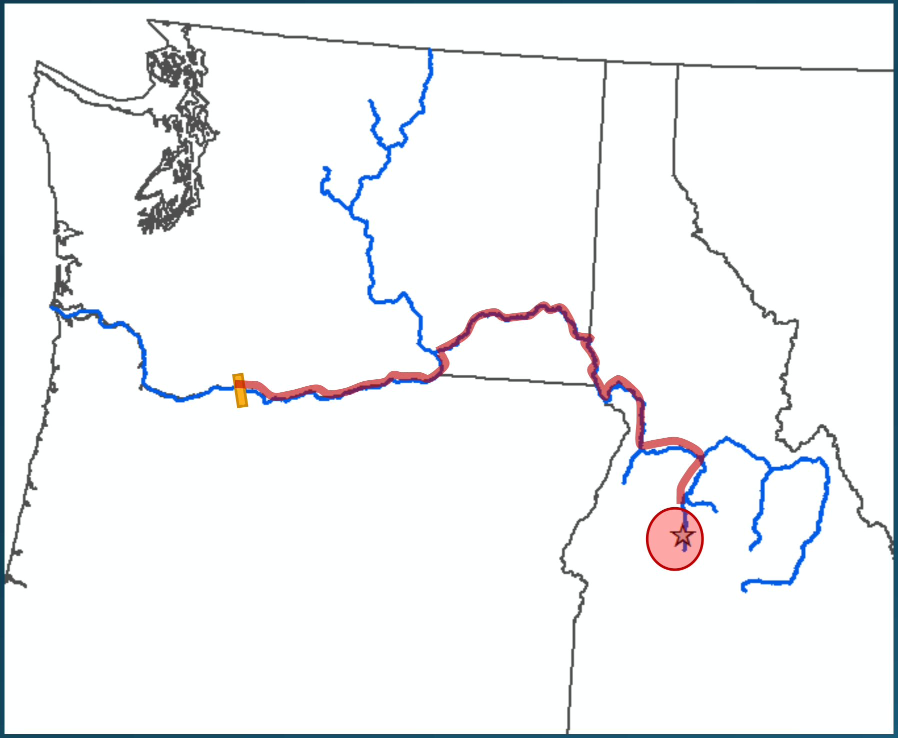


Probability of PSM:

- Increased with temperature
- Higher for hatchery fish
- Increased with length
- Varied among rivers

Preliminary results, subject to revision

Bioenergetics model system



Goals:

Develop model to predict energy use during migration, & holding different environmental conditions

Test theory that energy exhaustion could cause PSM

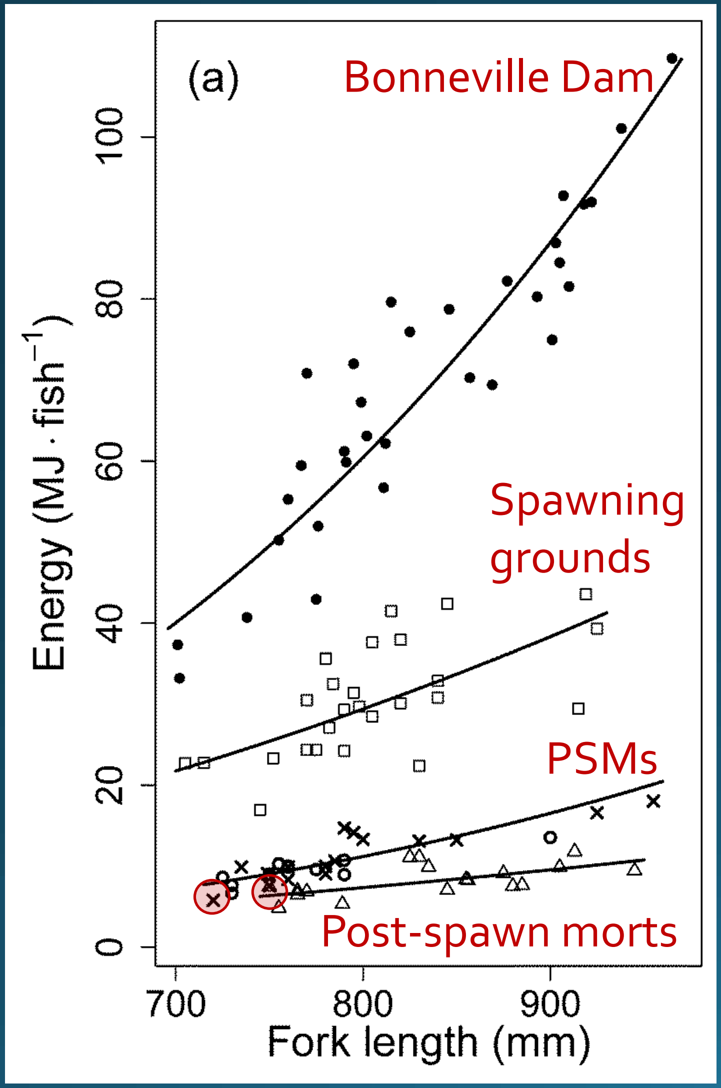
Summer-run Chinook salmon

South Fork Salmon River, Idaho

Migration: >900 km, 1100 m elevation

Holding: 1-2 months

Spring Chinook energy budget



+ gonad development ~14%

Migration ~46%

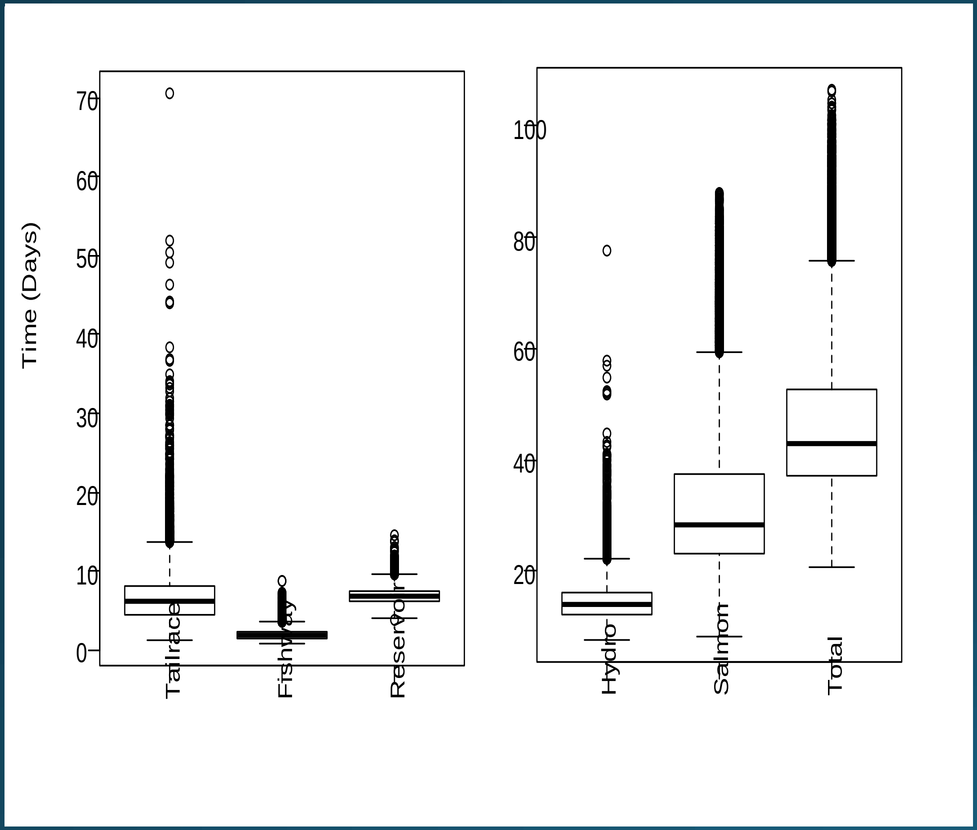
Holding ~25%

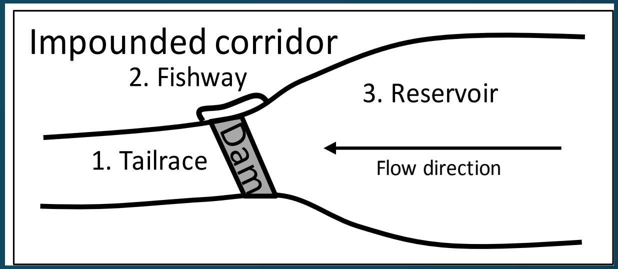
Spawning ~7%

Energetic depletion did not appear to be the primary cause of PSM; however a few PSMs had energy similar to post-spawn mortalities

Bowerman et al. 2017 JFB

Individual-based model to predict travel time





Travel time a function of:

- Discharge
- Water temperature
- Time of day (Impounded)
- Day of year (Snake-salmon)
- Individual variability

Tremendous variability in travel time

- Within each section
- Overall migration

Crozier et al. *In prep.*

Predict holding time and energy use

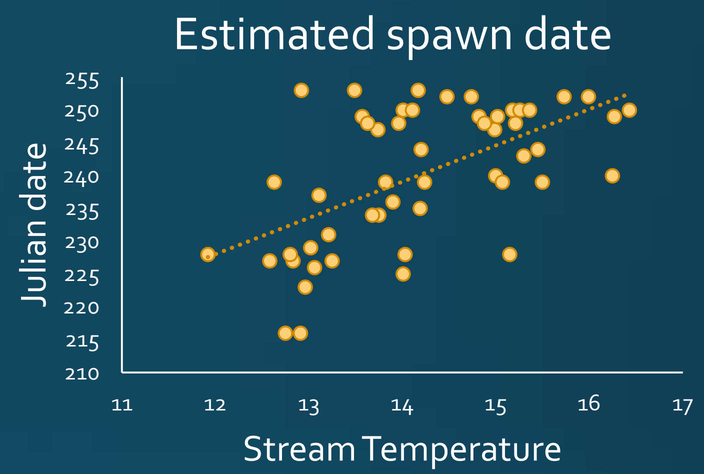
Spawn timing a function of:

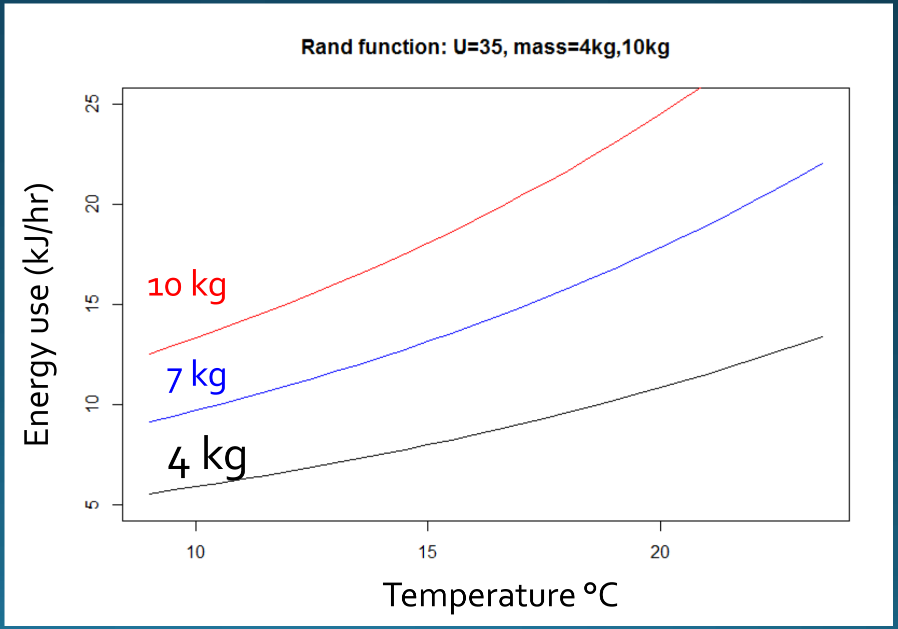
- Stream temperature

Link to energy use via bioenergetics equations

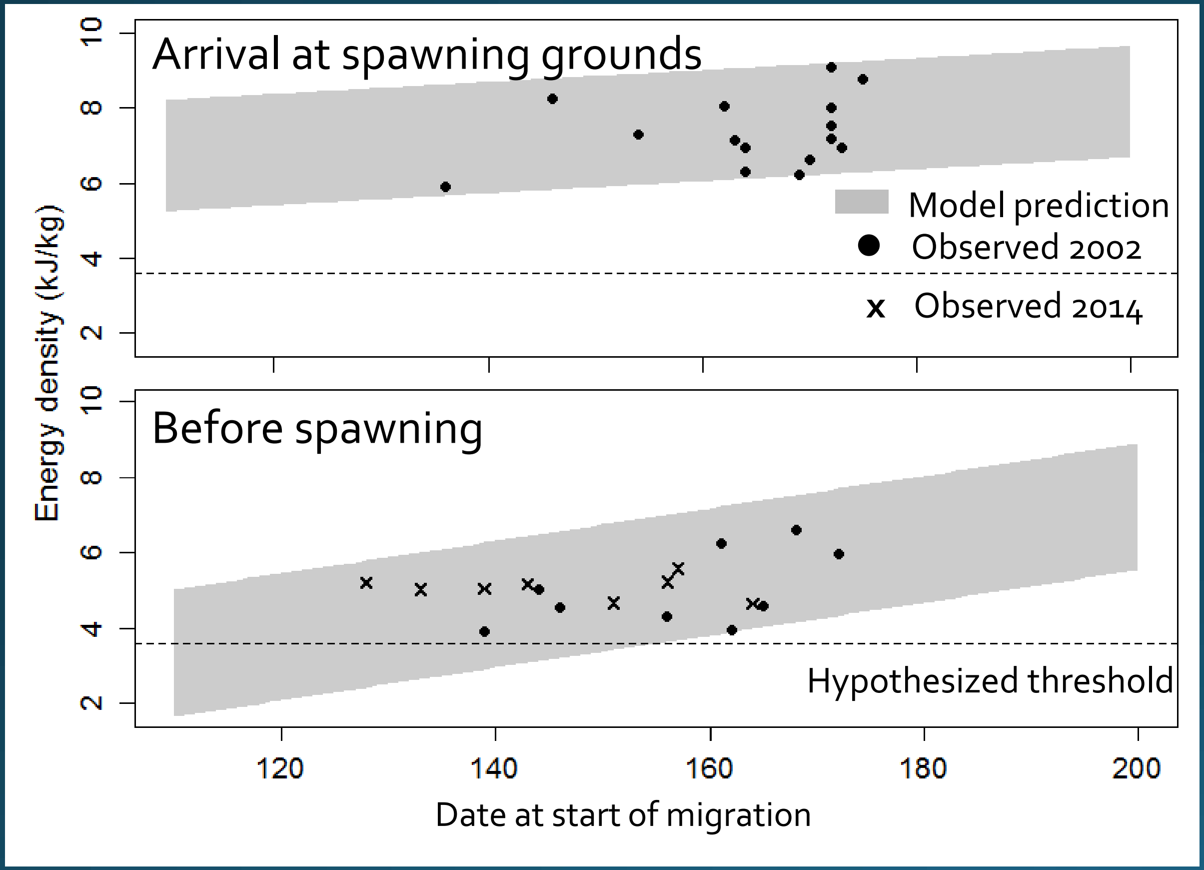
Energy use a function of:

- Fish size
- Water temperature
- Rate of travel
- Time spent at that rate





Model results: Energy remaining



Fish that migrated later had more energy after migration and before spawning

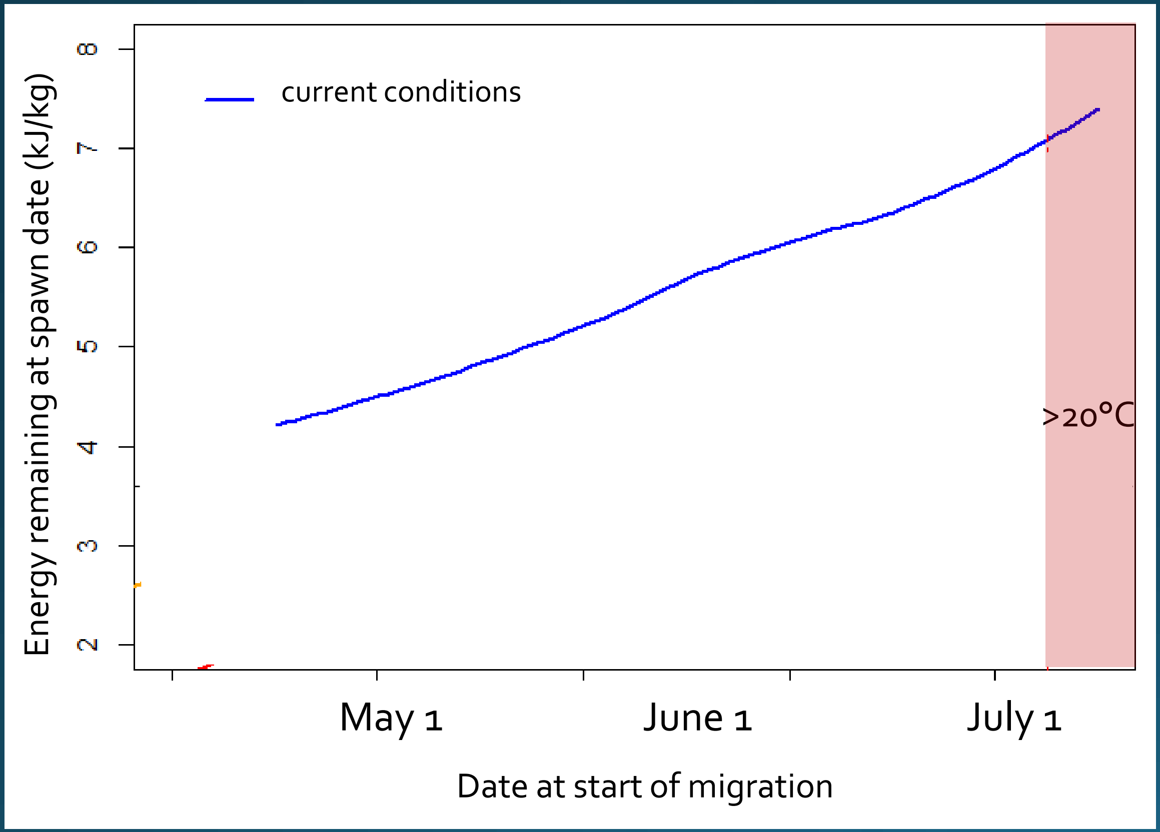
Early migrators were more likely to fall below proposed threshold to sustain life

Crossin et al. 2004
Bowerman et al. 2017

preliminary results, subject to revision

Model results: climate change predictions

Energy density available at spawn date



Late migrators had more energy available

Late migration limited by high water temps in migratory corridor

Preliminary results, subject to revision

Model results: climate change predictions

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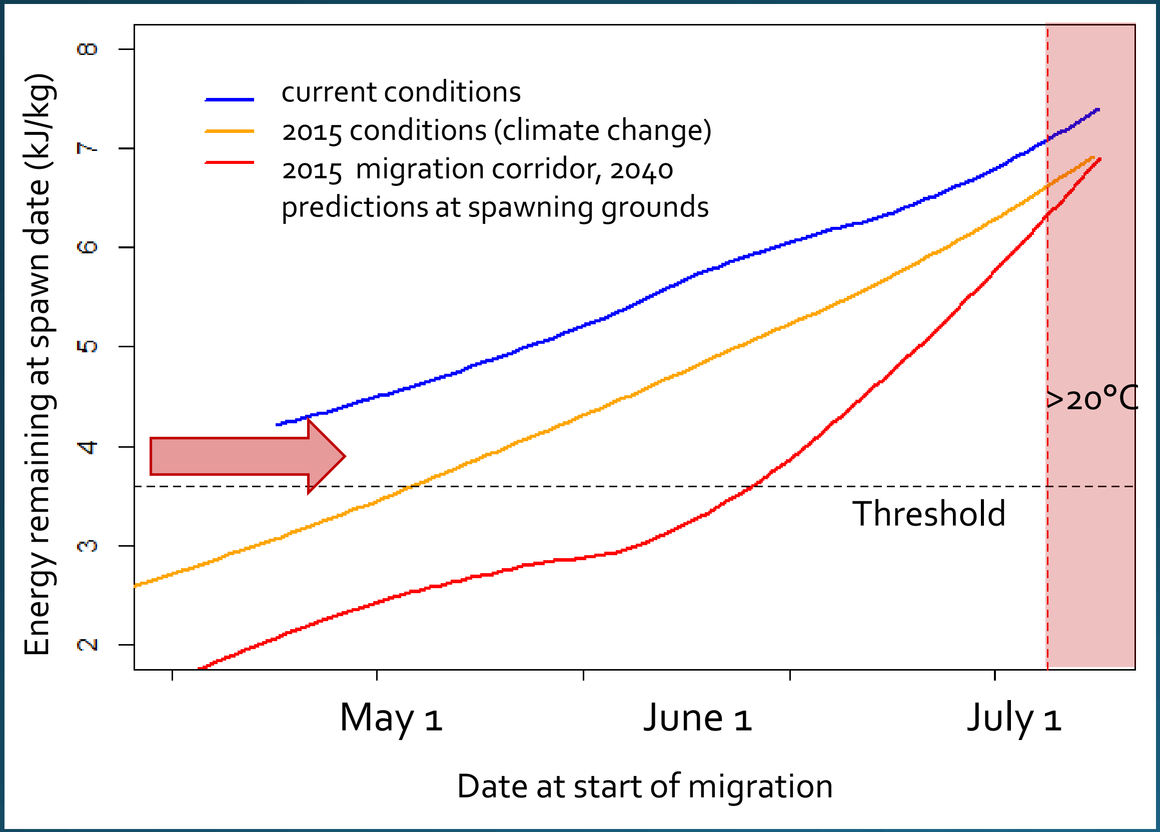

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Under warmer conditions, model predicted energy-depletion for early migrants

Suggests increasingly narrow window of "optimal" migration timing

Climate change predictions from NorWeST model
Preliminary results, subject to revision

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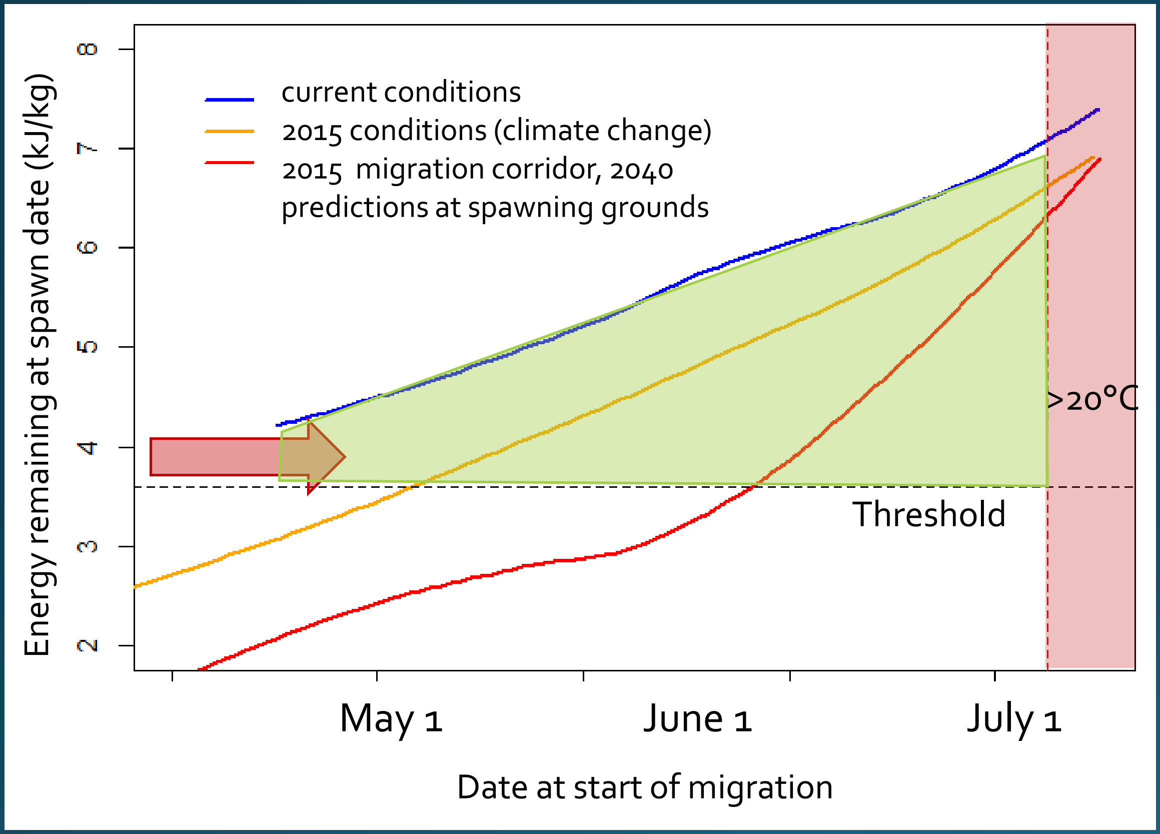

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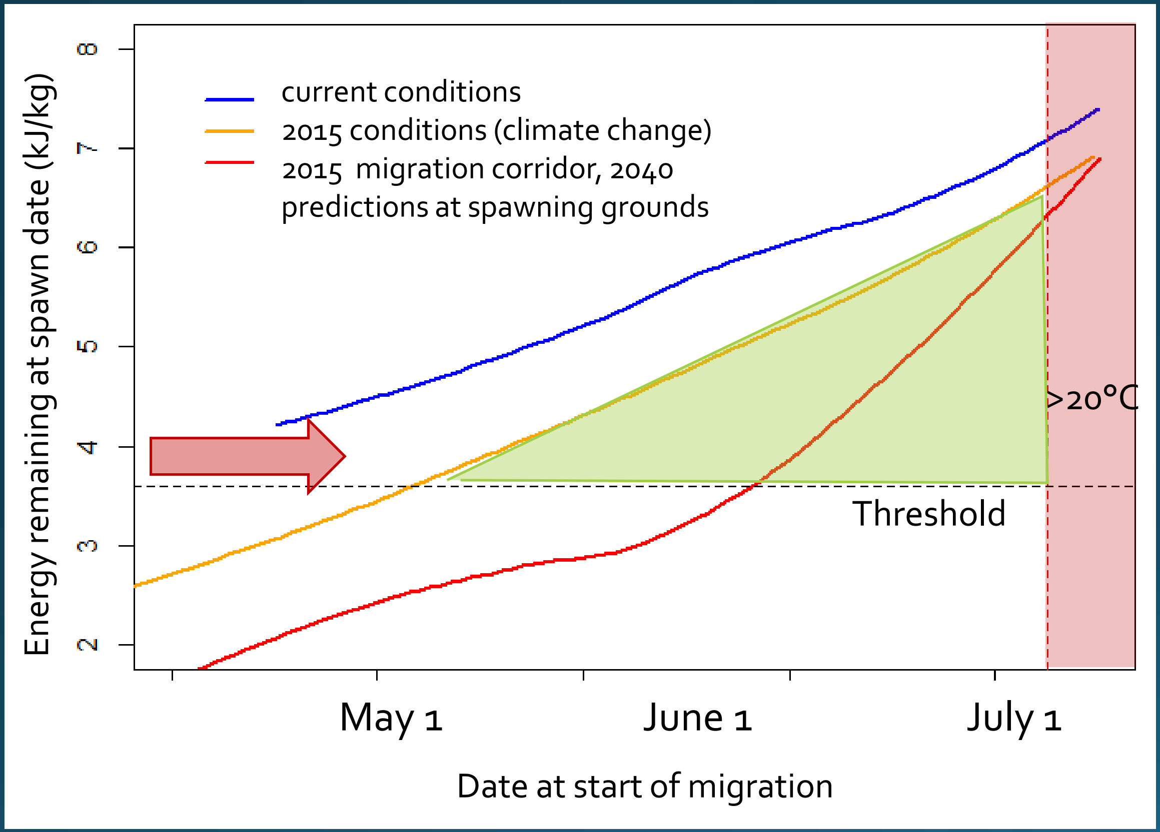

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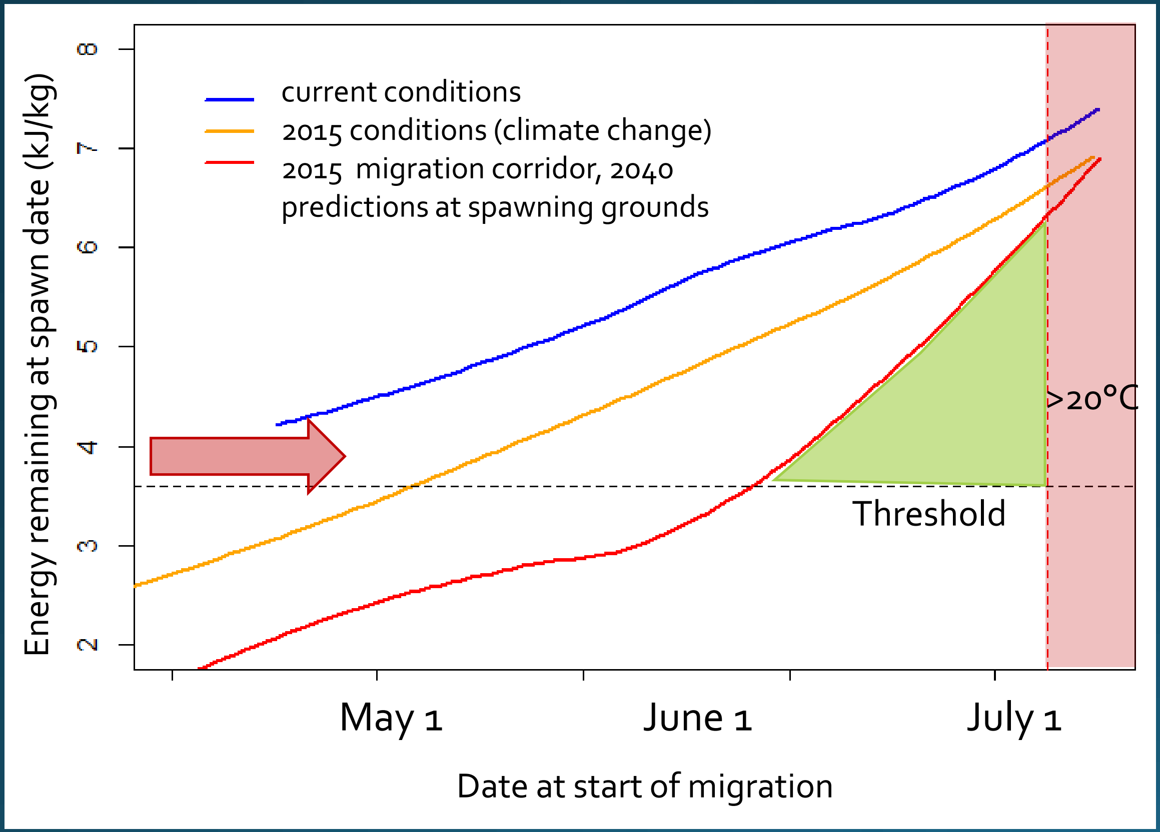

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Summary

- High PSM can lead to population declines
- Need for systematic monitoring
- Variability in PSM among locations and years
- PSM increased with stream temperature
- Probability of PSM higher for hatchery fish, larger fish
- Additional factors not included here, interactions among factors
- Potential for energetic depletion to cause PSM
- Energy expenditure greater for early migrating fish/high temps
- Need to better understand PSM in light of climate change predictions

Acknowledgements

Data from:

- Washington Department of Fish and Wildlife
- Yakama Nation
- Idaho Department of Fish and Game
- Oregon Department of Fish and Wildlife
- Nez Perce Tribes
- Confederated Tribes of Umatilla Indian Reservation
- Confederated Tribes of Warm Springs
- NOAA fisheries
- U.S. Fish and Wildlife Service
- University of Idaho Fish Ecology Research Lab
- US Forest Service Rocky Mountain Research Station

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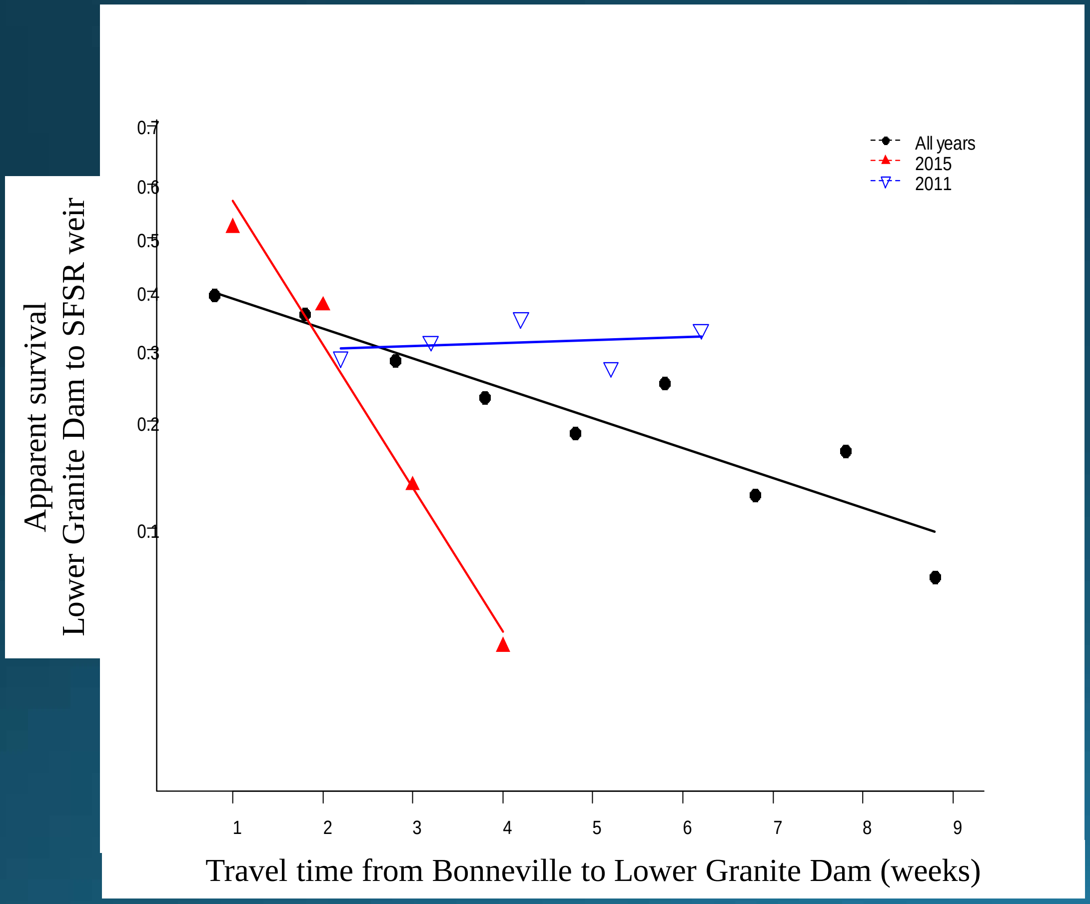
- University of Idaho

Contact info:
tracybowerman@gmail.com
541-915-3910


All years
2015
2011
0.7
0.6
0.5
0.4
0.3
0.2
0.1
1
2
3
4
5
6
7
8
9
Apparent survival
Lower Granite Dam to SFSR weir
Travel time from Bonneville to Lower Granite Dam (weeks)