Large River Habitat Complexity and Productivity of Puget Sound Chinook salmon

Jason Hall*, Correigh Greene[1], Alex Stefankiv[1], Joe Anderson[2], Britta Timpane-Padgham[1], Tim Beechie[1], George Pess[1]

*Work completed with NOAA NWFSC, Now with Cramer Fish Sciences

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[2]WDFW

Presentation Outline

1. Chinook salmon and their habitats
2. PSHSTM Program
3. Large rivers and floodplains
4. Habitat complexity and salmon productivity
5. Habitat complexity and restoration
6. Next steps and implications

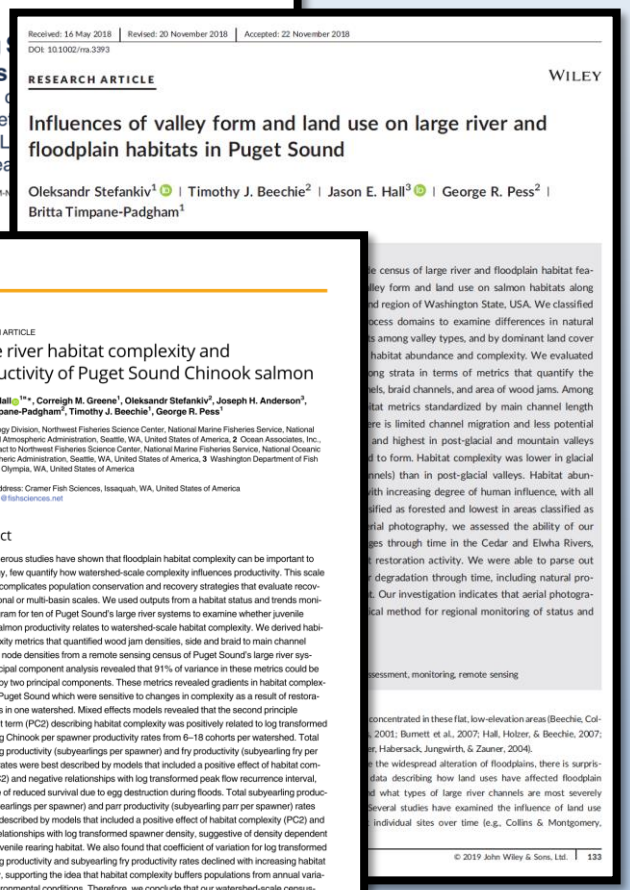
Beechie et al. 2017

NOAA Technical Memorandum NMFS-NWFSC-137

Monitoring S and Trends

Development o Monitoring Me Protocols for L Delta, and Nea

https://doi.org/10.7289/V5/TM-N



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RESEARCH ARTICLE

WILEY

Influences of valley form and land use on large river and floodplain habitats in Puget Sound

Oleksandr Stefankiv[1] | Timothy J. Beechie[2] | Jason E. Hall[3] | George R. Pess[2] | Britta Timpane-Padgham[1]

e census of large river and floodplain habitat fea-
lley form and land use on salmon habitats along
nd region of Washington State, USA. We classified
ocess domains to examine differences in natural
s among valley types, and by dominant land cover
habitat abundance and complexity. We evaluated
ong strata in terms of metrics that quantify the
els, braid channels, and area of wood jams. Among
tat metrics standardized by main channel length
re is limited channel migration and less potential
and highest in post-glacial and mountain valleys
d to form. Habitat complexity was lower in glacial
nnels) than in post-glacial valleys. Habitat abun-
ith increasing degree of human influence, with all
sified as forested and lowest in areas classified as
rial photography, we assessed the ability of our
es through time in the Cedar and Elwha Rivers,
restoration activity. We were able to parse out
degradation through time, including natural pro-
. Our investigation indicates that aerial photogra-
al method for regional monitoring of status and

essment, monitoring, remote sensing

concentrated in these flat, low-elevation areas (Beechie, Col-
2001; Burnett et al., 2007; Hall, Holzer, & Beechie, 2007;
r, Habersack, Jungwirth, & Zauner, 2004).
the widespread alteration of floodplains, there is surpris-
data describing how land uses have affected floodplain
d what types of large river channels are most severely
Several studies have examined the influence of land use
individual sites over time (e.g., Collins & Montgomery,

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Stefankiv et al. 2019

PLOS | ONE

RESEARCH ARTICLE

Large river habitat complexity and productivity of Puget Sound Chinook salmon

Jason E. Hall[1]*, Correigh M. Greene[1], Oleksandr Stefankiv[2], Joseph H. Anderson[3], Britta Timpane-Padgham[2], Timothy J. Beechie[1], George R. Pess[1]

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Check for updates

OPEN ACCESS

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Data Availability Statement: Geospatial data have been uploaded to Open Science Framework and are available at: https://osf.io/ygcgv/?view_only=5364ed7be39f4c7ebbcb0be8b5ccab4b. All other supporting data are included in the tables or supplemental materials.

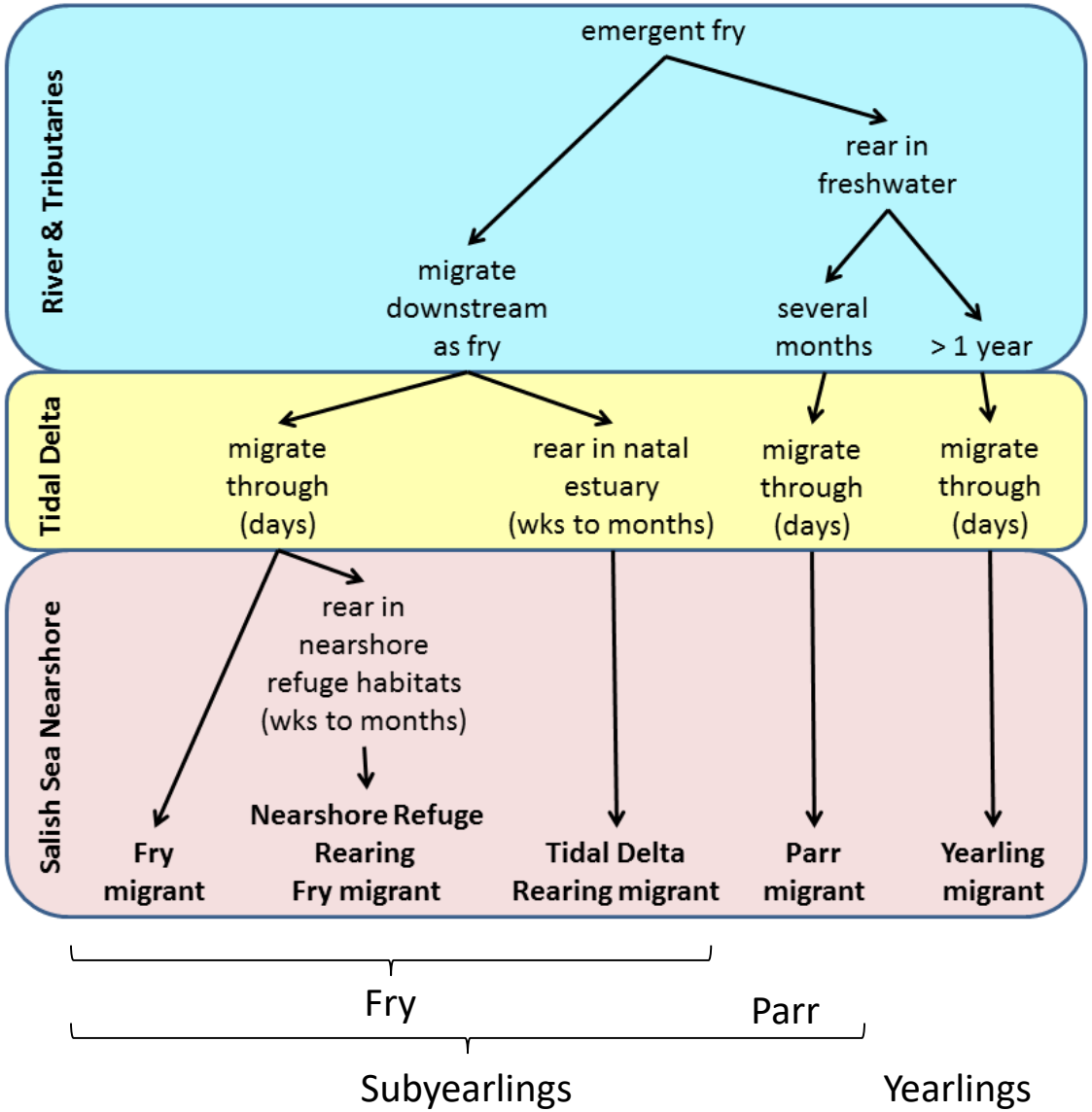
Funding: Funding for this research was primarily provided by the National Oceanic and Atmospheric Administration (NOAA) Northwest Regional Office, and work was completed by Northwest Fisheries Science Center's Watershed Program staff and

Abstract

While numerous studies have shown that floodplain habitat complexity can be important to fish ecology, few quantify how watershed-scale complexity influences productivity. This scale mismatch complicates population conservation and recovery strategies that evaluate recovery at regional or multi-basin scales. We used outputs from a habitat status and trends monitoring program for ten of Puget Sound's large river systems to examine whether juvenile Chinook salmon productivity relates to watershed-scale habitat complexity. We derived habitat complexity metrics that quantified wood jam densities, side and braid to main channel ratios, and node densities from a remote sensing census of Puget Sound's large river systems. Principal component analysis revealed that 91% of variance in these metrics could be explained by two principal components. These metrics revealed gradients in habitat complexity across Puget Sound which were sensitive to changes in complexity as a result of restoration actions in one watershed. Mixed effects models revealed that the second principle component term (PC2) describing habitat complexity was positively related to log transformed subyearling Chinook per spawner productivity rates from 6–18 cohorts per watershed. Total subyearling productivity (subyearlings per spawner) and fry productivity (subyearling fry per spawner) rates were best described by models that included a positive effect of habitat complexity (PC2) and negative relationships with log transformed peak flow recurrence interval, suggestive of reduced survival due to egg destruction during floods. Total subyearling productivity (subyearlings per spawner) and parr productivity (subyearling parr per spawner) rates were best described by models that included a positive effect of habitat complexity (PC2) and negative relationships with log transformed spawner density, suggestive of density dependent limits on juvenile rearing habitat. We also found that coefficient of variation for log transformed subyearling productivity and subyearling fry productivity rates declined with increasing habitat complexity, supporting the idea that habitat complexity buffers populations from annual variation in environmental conditions. Therefore, we conclude that our watershed-scale census-based approach provided habitat complexity metrics that explained some of the variability in productivity of subyearling juveniles among Chinook salmon populations. Furthermore, this

Hall et al. 2018

Chinook salmon habitats and life histories



Habitat Functions

Spawning capacity (all)
Flood refuge (all)
Growth opportunity (parr & 1+)

Predator refuge (fry)
Growth opportunity (fry)
Osmotic transition (all)

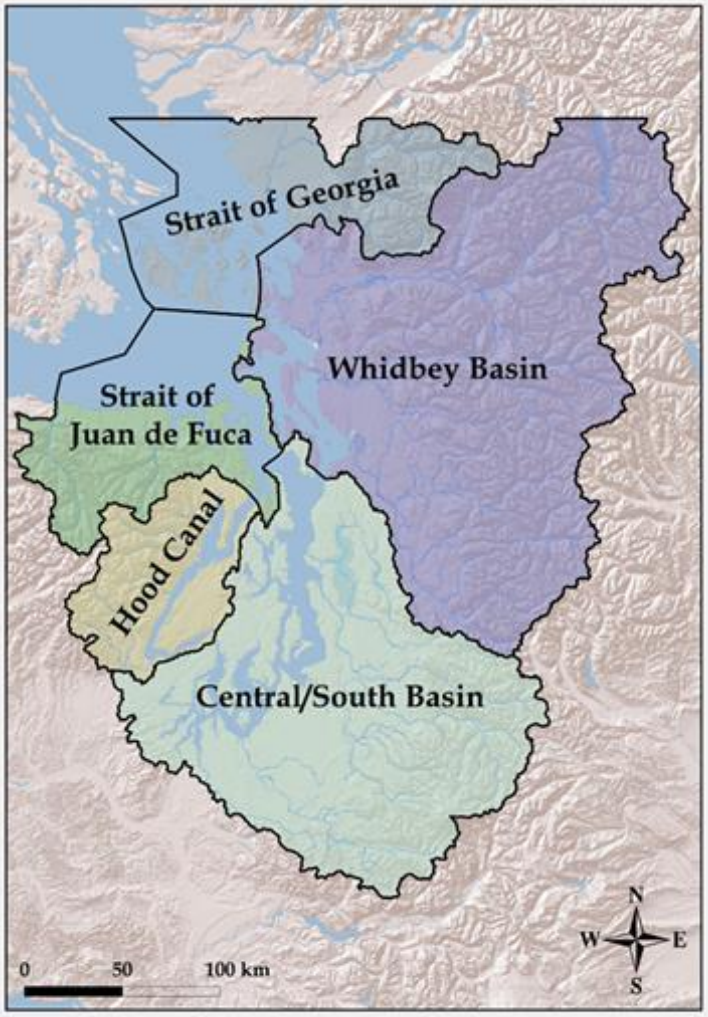
Predator refuge (fry)
Growth opportunity (all)

Consistent monitoring needed across habitats and life stages!

Puget Sound Salmon Habitat Status and Trends Monitoring Program (PSHSTMP)

Objectives:

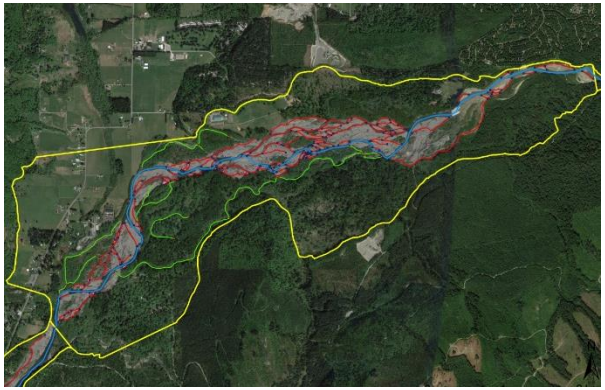
1. **Consistent habitat metrics at MPG scales for major habitat strata**
   - ***Large river and floodplains***
   - *Large river deltas*
   - *Nearshore*
2. **Census-based metrics using readily available remote sensing data**
3. **Detect habitat status AND trends**
4. **Metrics related to VSP parameters**
5. **Support regional recovery efforts and programs**
   - *ESA recovery evaluations*
   - *PSP Vital Signs and Indicators*



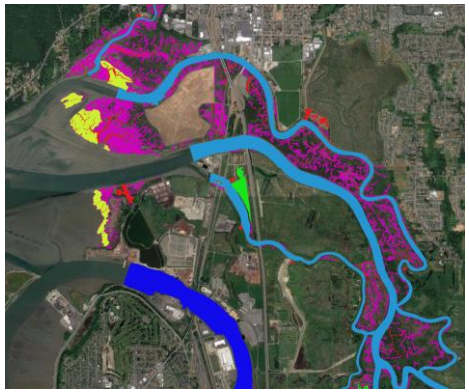
Chinook major population groups

PSHSTMP and Regional Salmon Recovery

Large River & Floodplain

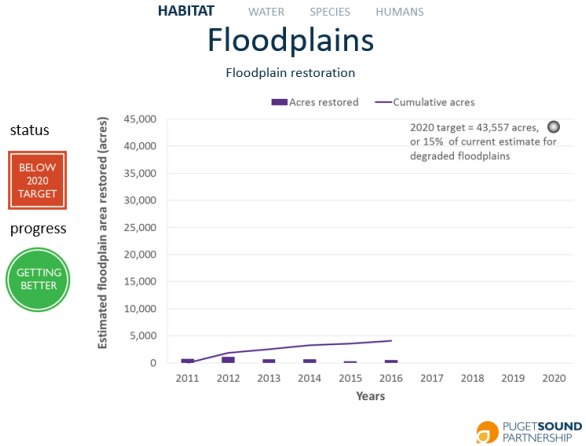


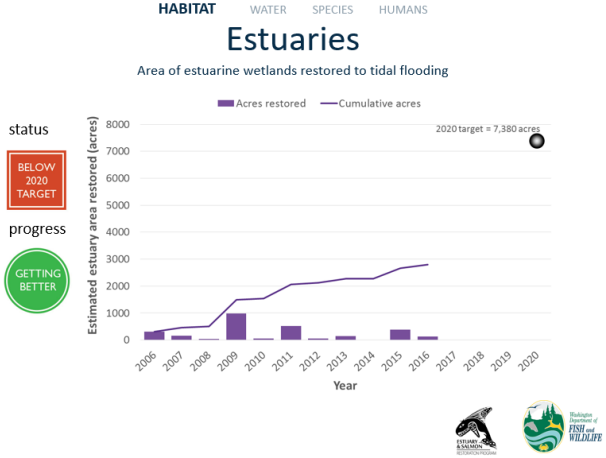
Large River Deltas

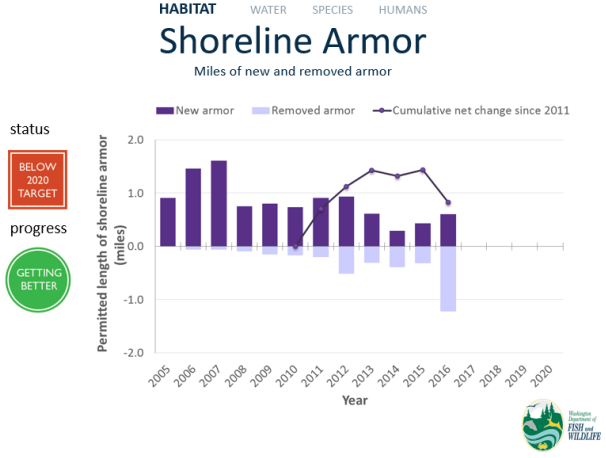


Nearshore

PUGETSOUND PARTNERSHIP

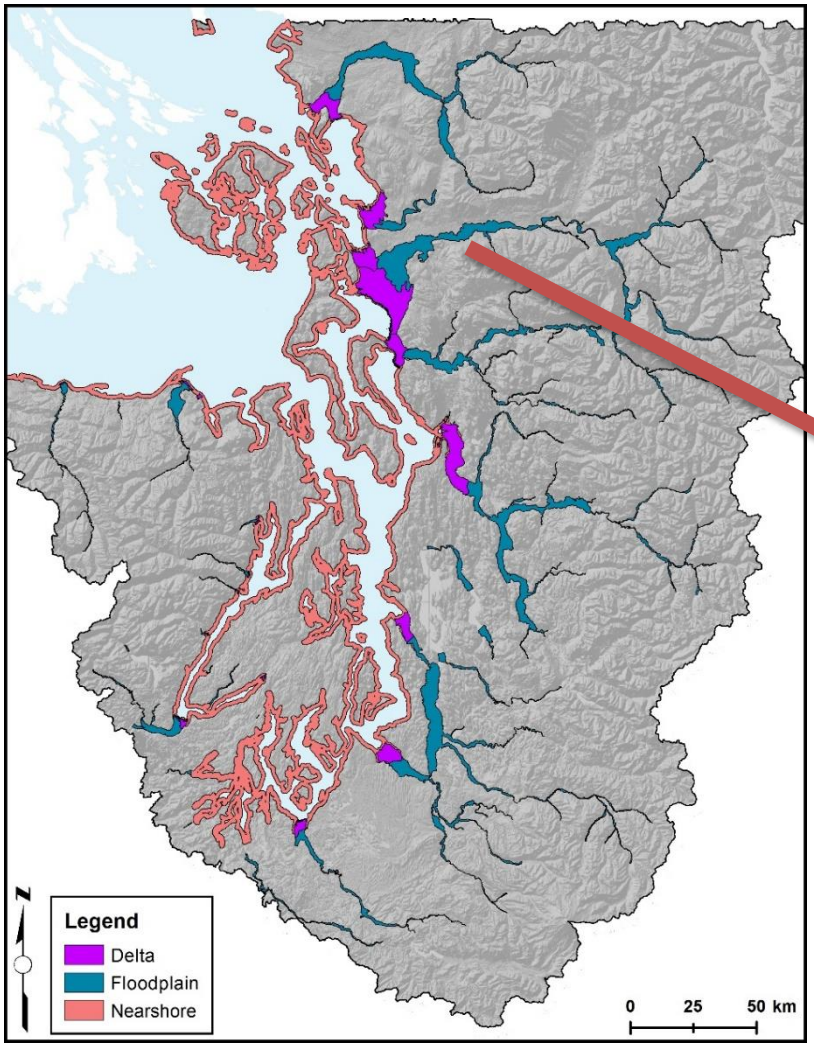




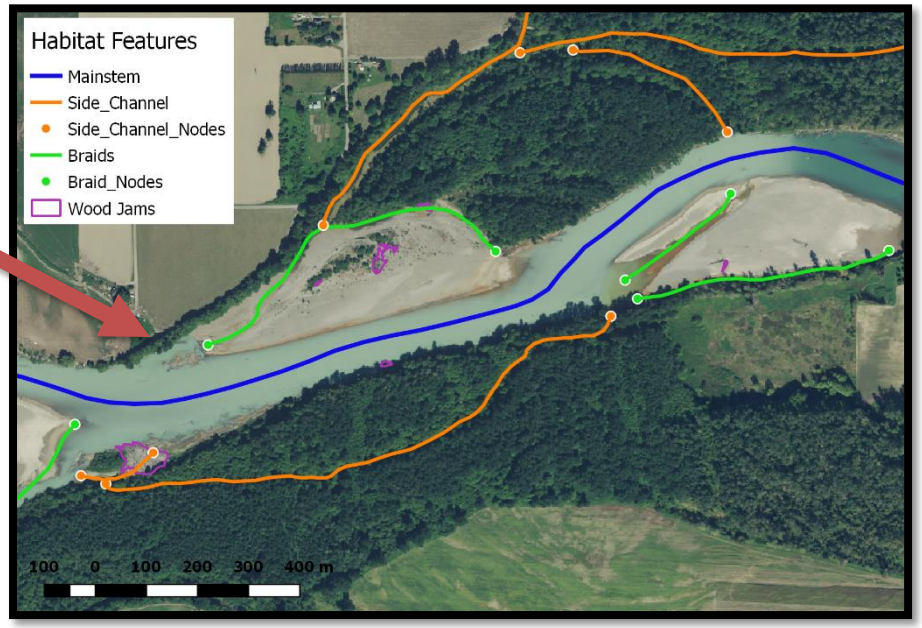


Large River and Floodplain Mapping

PSHSTM Program Sampling Strata



Example of digitized habitat features in the mainstem and floodplain of a large river

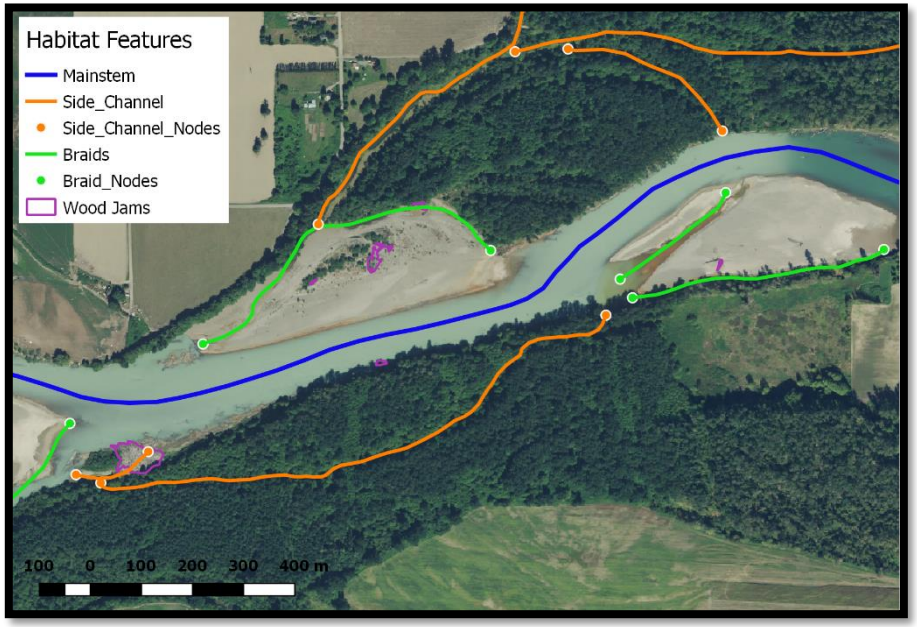


First large river and floodplain mapping completed!

Large River and Floodplain Strata

- **Habitat Quantity:**
  - *Main channel*
  - *Side channel*
  - *Braid channel*
  - *Large wood jams*
- **Habitat Complexity:**
  - *Side & braid : mainstem*
  - *Side & braid node densities*
  - *Wood jam density*

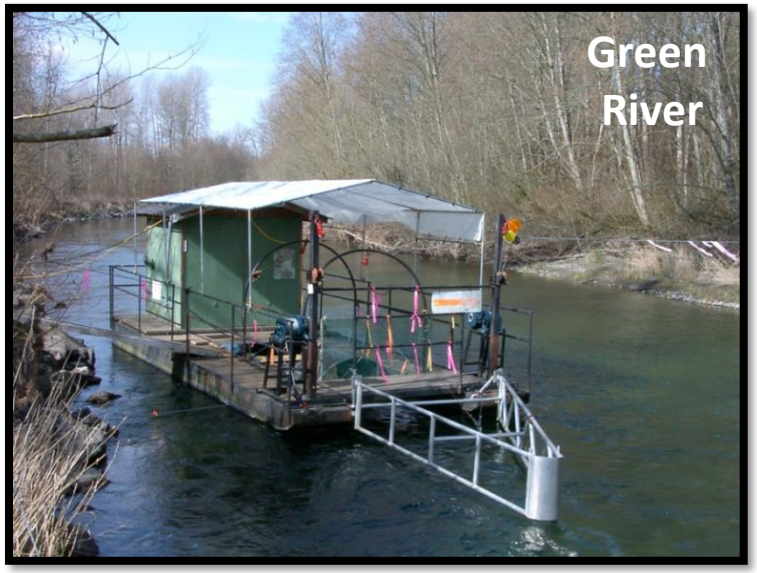
Example of digitized habitat features in the mainstem and floodplain of a large river



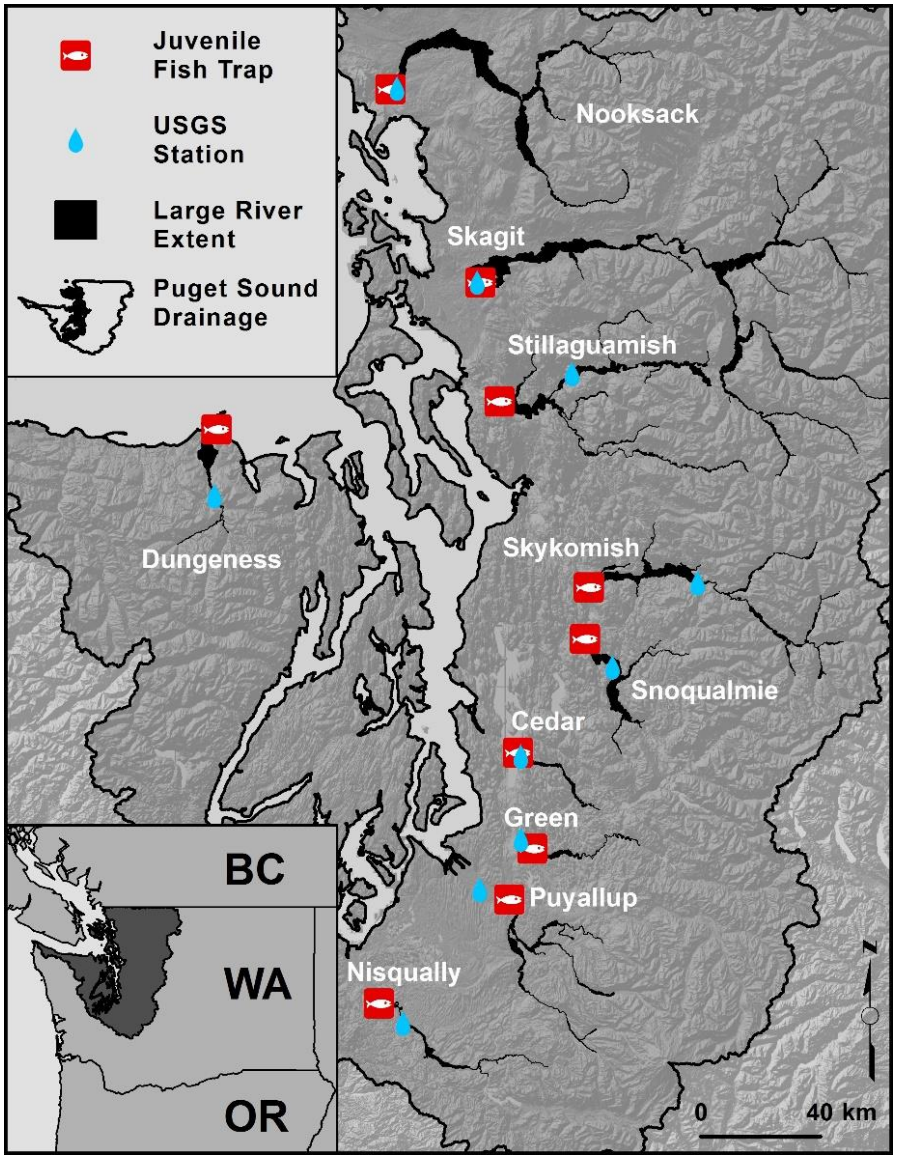
Metrics related to VSP parameters?

Habitat complexity and salmon productivity?

Smolt traps (*J. Anderson*)



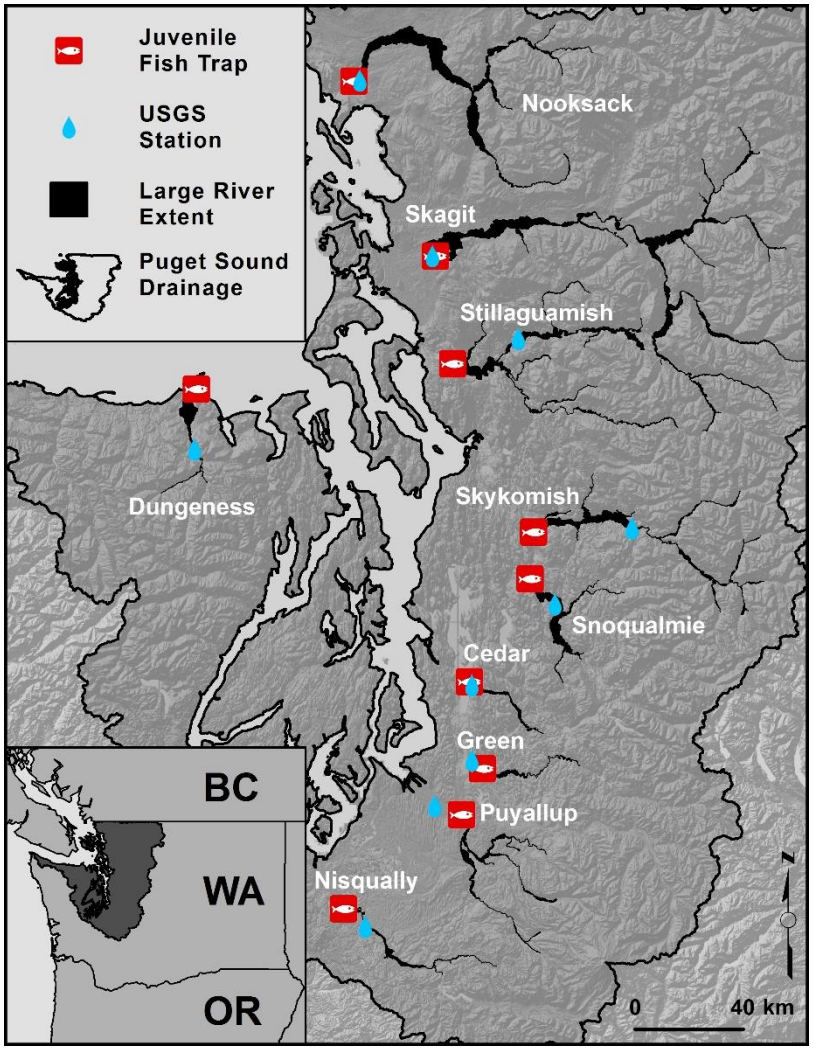
Smolt traps and analysis extent



Habitat complexity and salmon productivity?

- **Exploratory approach**
  - Full subsets LMER regressions
  - AICc model selection
- **Subyearling productivity**
  - Fry per Spawner (FpS)
  - Parr per Spawner (PpS)
  - Total subyearling per Spawner (SpS)
- **Factors**
  - **<u>Habitat complexity</u>**
  - Peak flow Recurrence Interval (RI)
  - Spawner density (SD)
  - Broodyear

Smolt traps and analysis extent



Habitat Complexity Metrics

- **Metrics highly correlated**
- **Habitat Quantity ≠ Complexity**
- **Use PCA approach**
  - Non-correlated PCs
  - Describes most variation
  - Captures complexity patterns

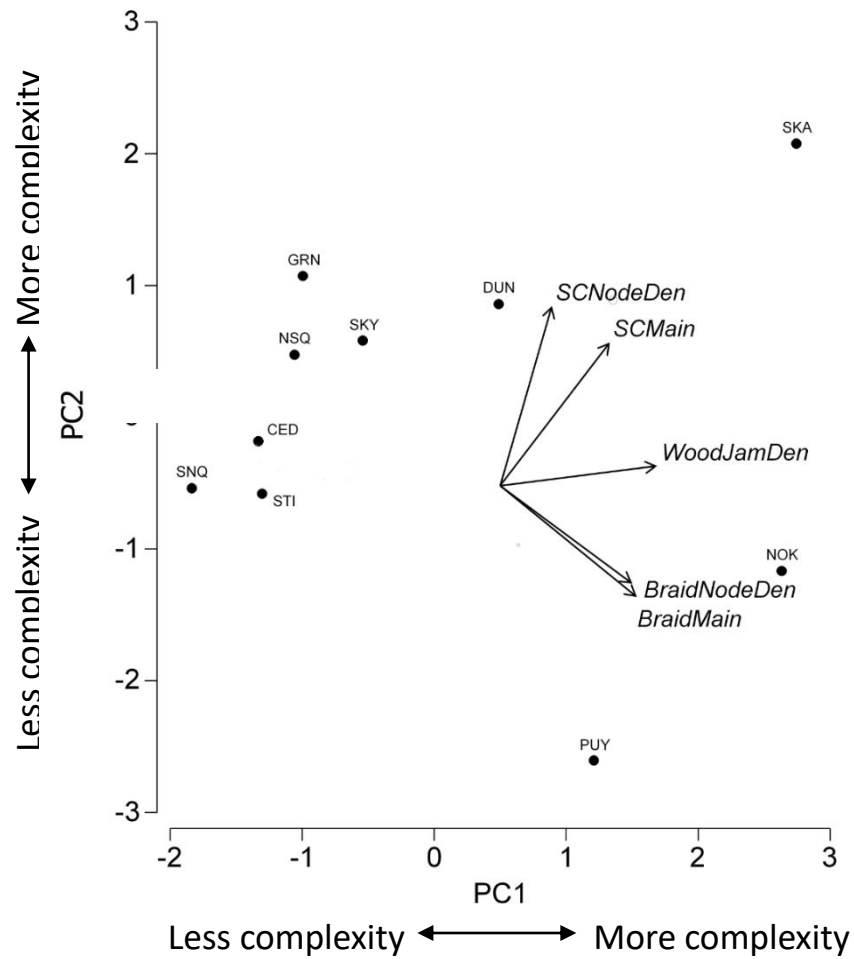
Correlation matrix for habitat complexity metrics (Pearson's *r*)

SC : Main				
0.21	**BR : Main**			
0.70	-0.21	**SC Node Density**		
0.13	**0.91**	-0.02	**BR Node Density**	
0.75	**0.76**	0.30	**0.65**	**Wood Jam Density**

Habitat Complexity PCA:
Strong spatial gradients in habitat complexity

- **Metrics highly correlated**
- **Quantity ≠ complexity**
- **PCA approach**
  - **PC1** (56%): wood & braids
  - **PC2** (35%): side channels
- **Describes regional gradients**
- **PC1 and PC2 as predictors**

PCA biplot of habitat complexity metrics

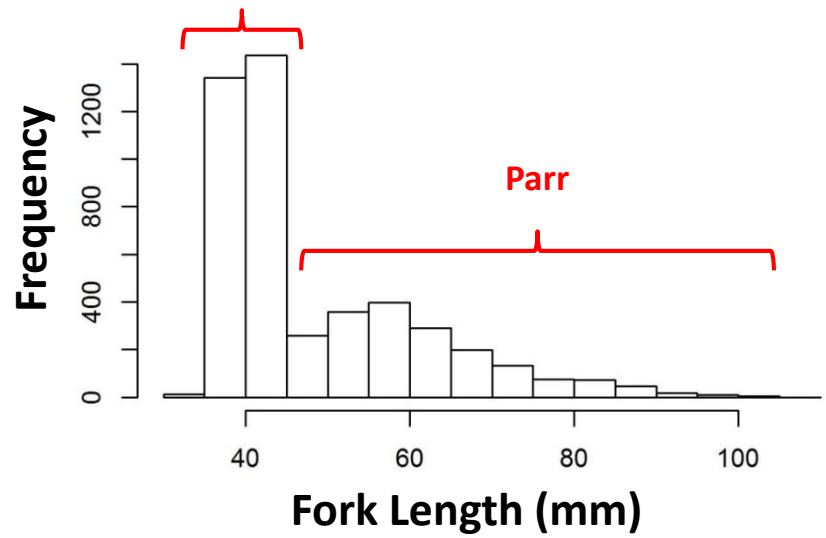


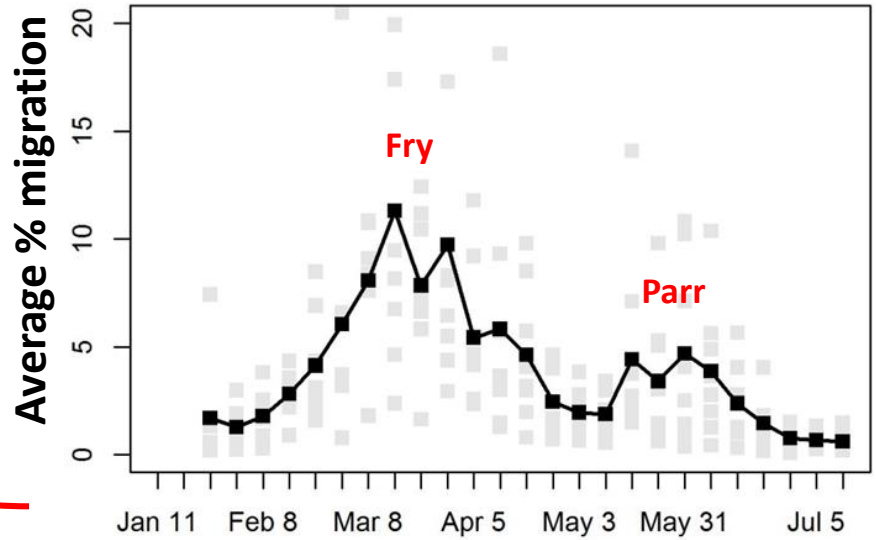
Subyearling Chinook Production Rates

Smolt traps (*J. Anderson*)

Annual Productivity Rates:
Fry per Spawner (**FpS**)
Parr per Spawner (**PpS**)
Total subyearling per Spawner (**SpS**)

Skagit River Example
(*J. Anderson*)



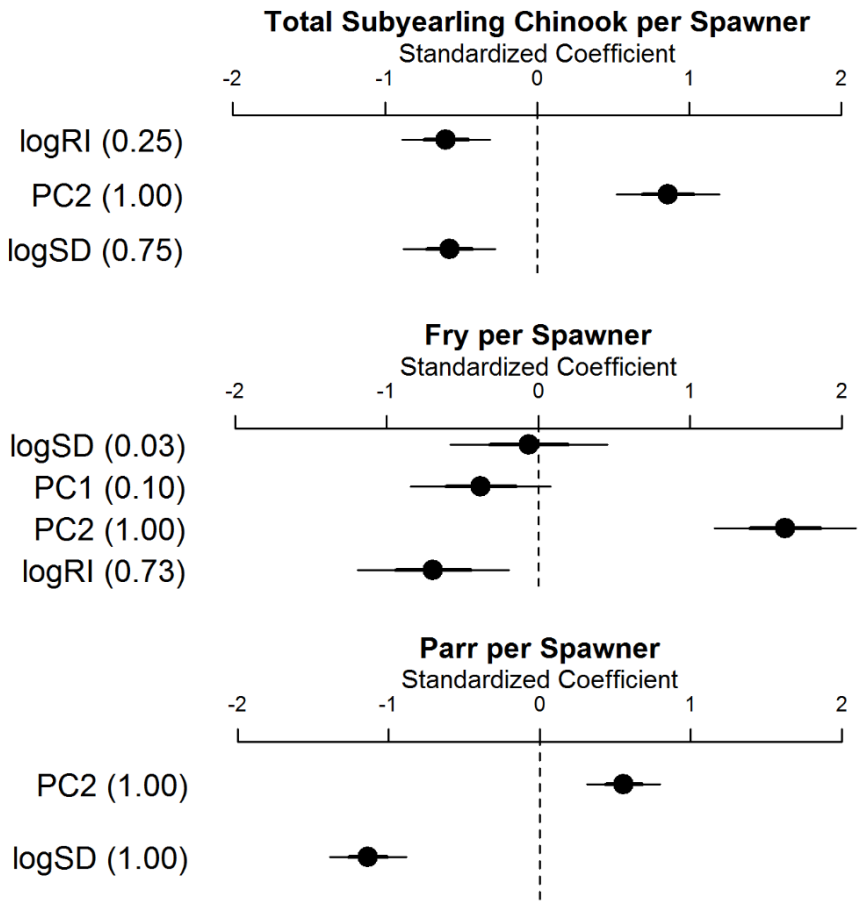


Model Selection Results:

Habitat complexity was a strong predictor of productivity

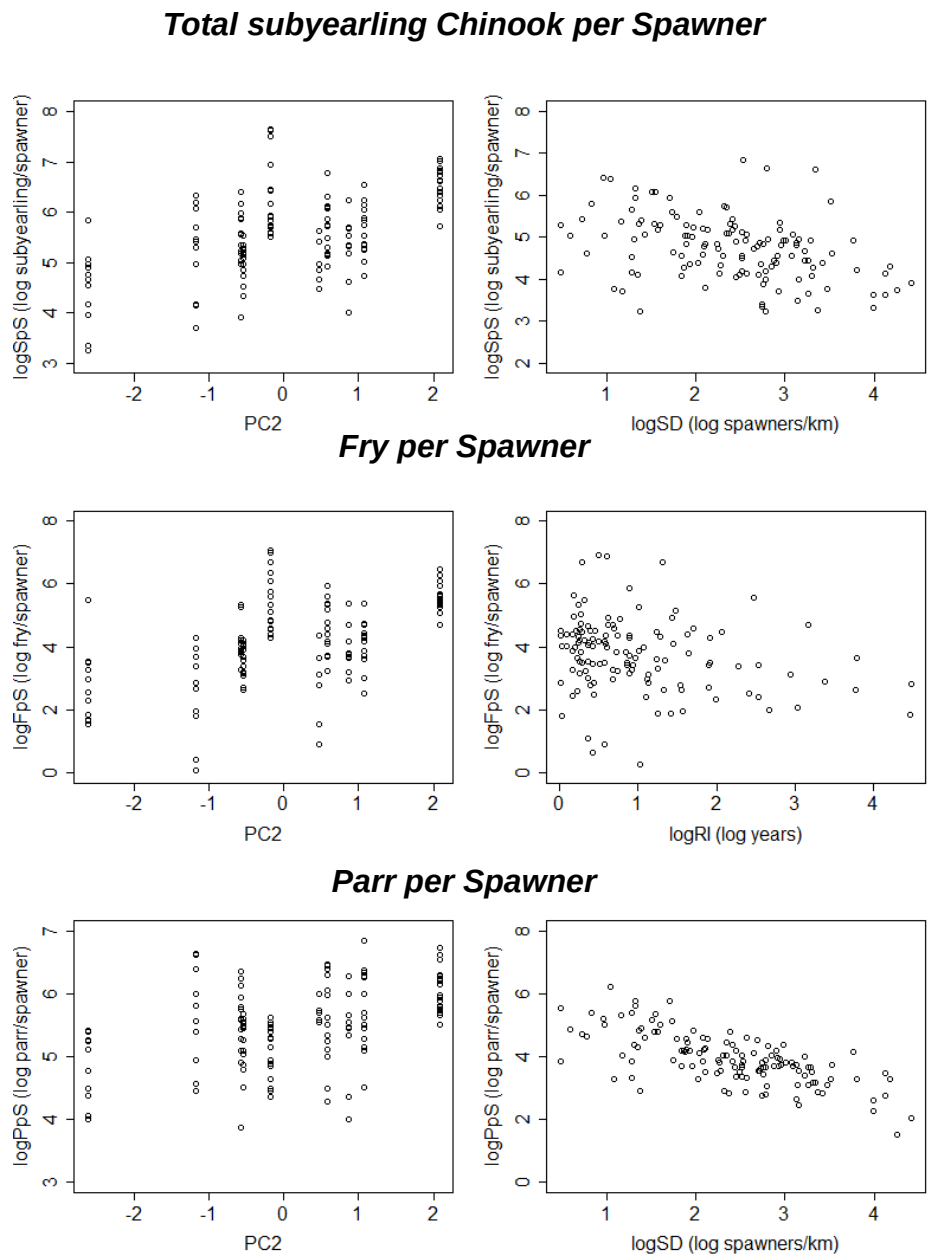
- Model selection ΔAICc < 7
- All selected models included PC2 (+)
- Best models: PC2 with SD (-) or RI (-)
- PC2 effect strongest with FpS

Standardized coefficient plots from selected model sets



Partial Regression Plots from Top Models

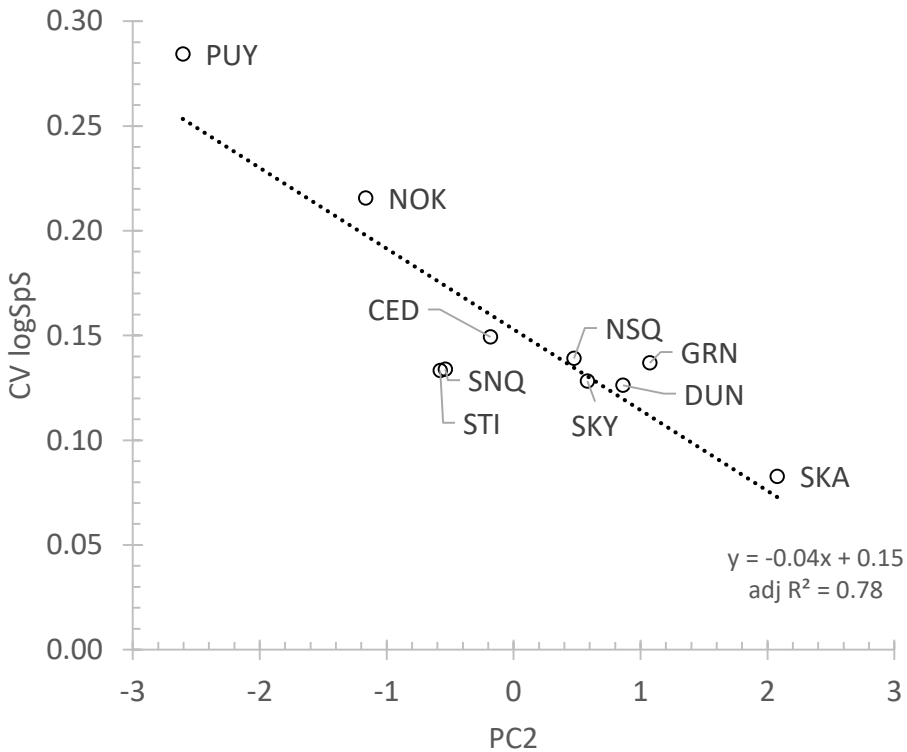
- **Controlling for other factors…**
  - See strong relationships
  - Differences in variance
- **PC2 effect strongest with FpS**
- **SD strong negative predictor for PpS**



Model Selection Results:

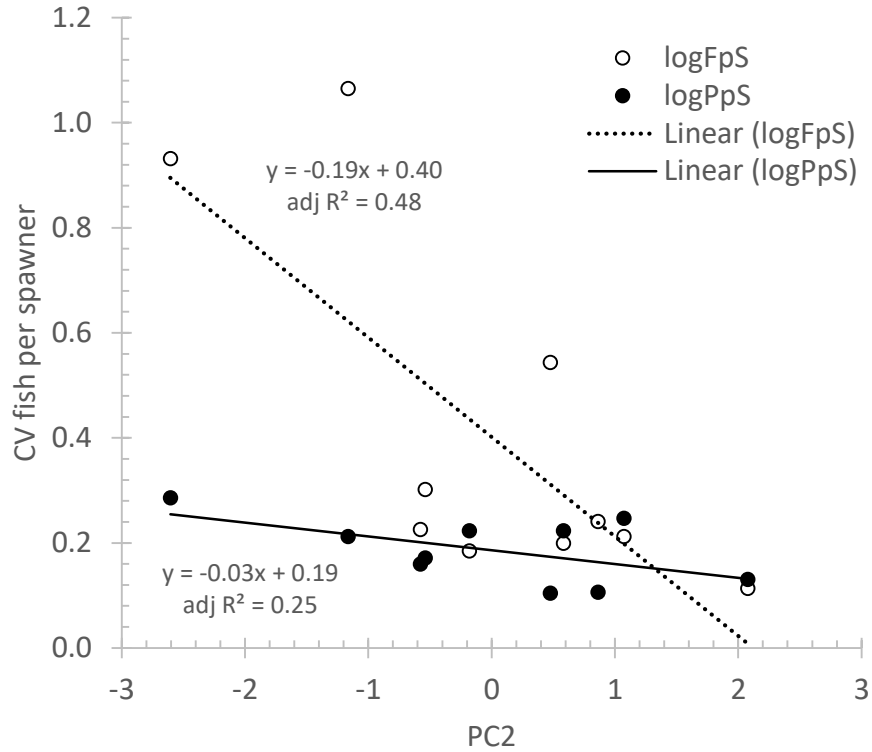
Does habitat complexity buffer productivity?

CV of SpS with habitat complexity



Less complexity ⟷ More complexity

CV of FpS and PpS with habitat complexity



Less complexity ⟷ More complexity

Higher complexity = less variation in productivity!

Habitat Complexity and Restoration:
Does PSHSTMP approach detect change from restoration?

Cedar River example of floodplain restoration

Pre-restoration

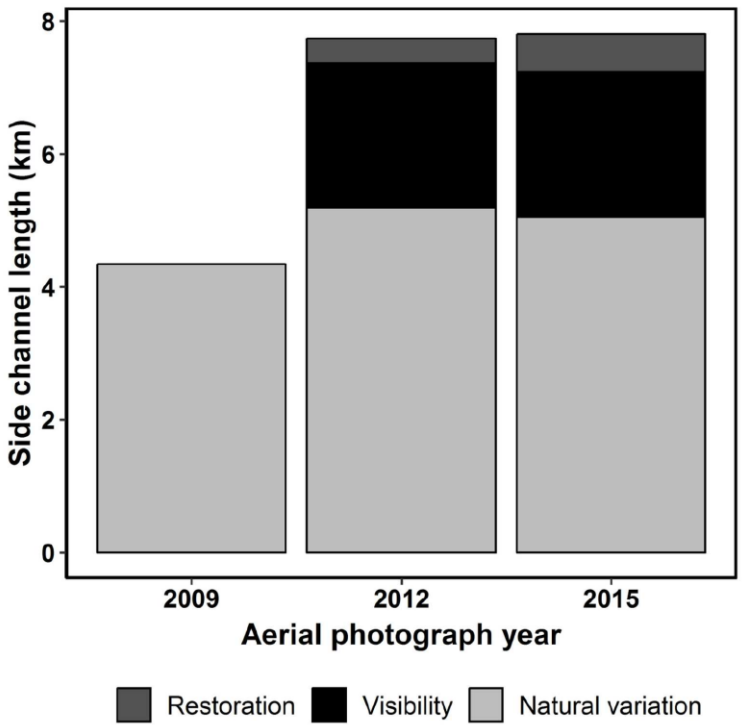
Floodplain restoration creates new features

Map features from archived and future imagery to evaluate change

Post-restoration

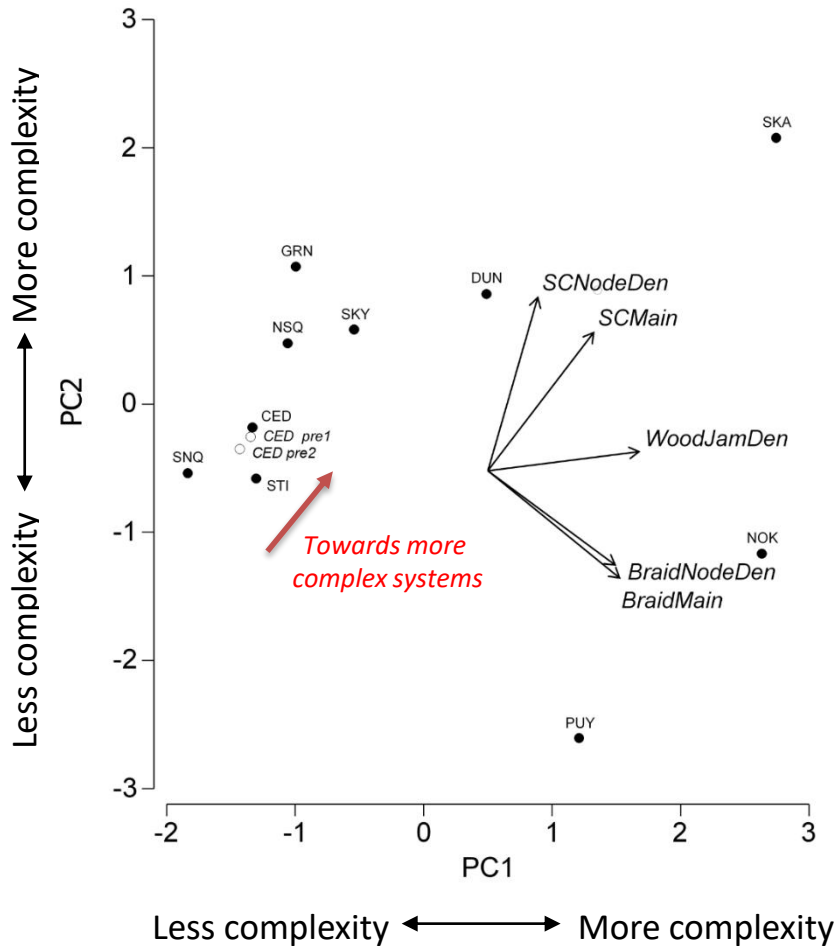
Habitat Complexity and Restoration:
Cedar River Example

Map change in habitat over time



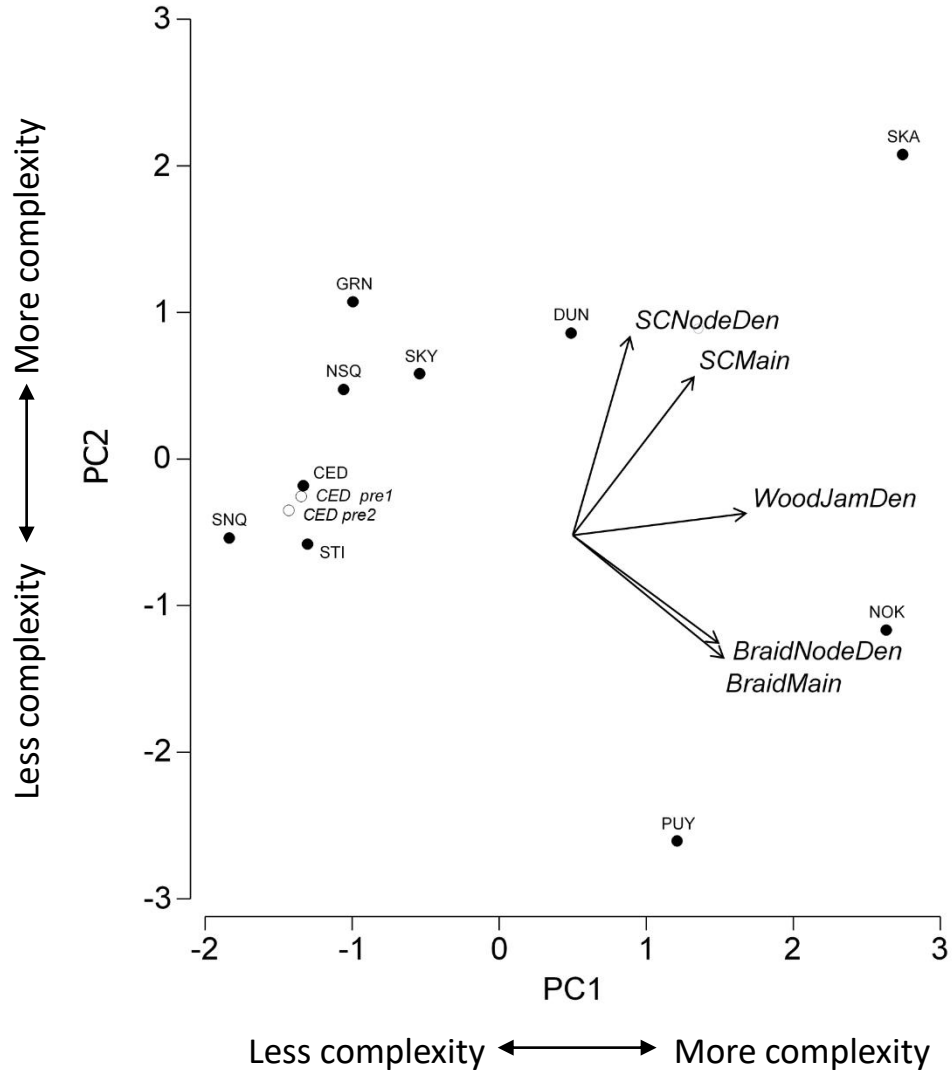
From: Stefanki et al. (In Press). Proof of concept for the SHSTMP status and trends monitoring.

Measurable change in PC scores attributed to restoration



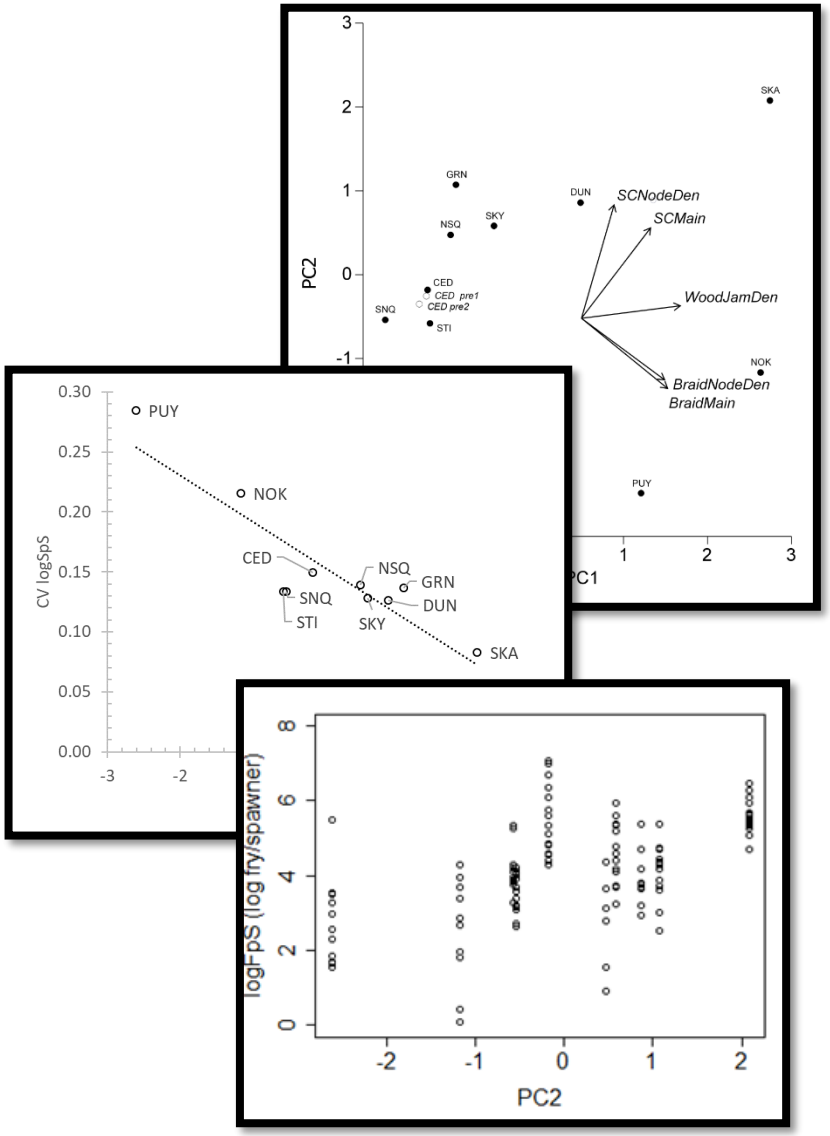
Habitat Complexity and Restoration:
Cedar River Example

- **Predicted impact on productivity?**
  - ↑0.4 - 1.8% FpS
  - ↑1.7 - 17.9% PpS
- **Predicted buffering impacts?**
  - ↓RI 13.5 – 10-year event
  - ↓4.4% SD



Summary of Findings

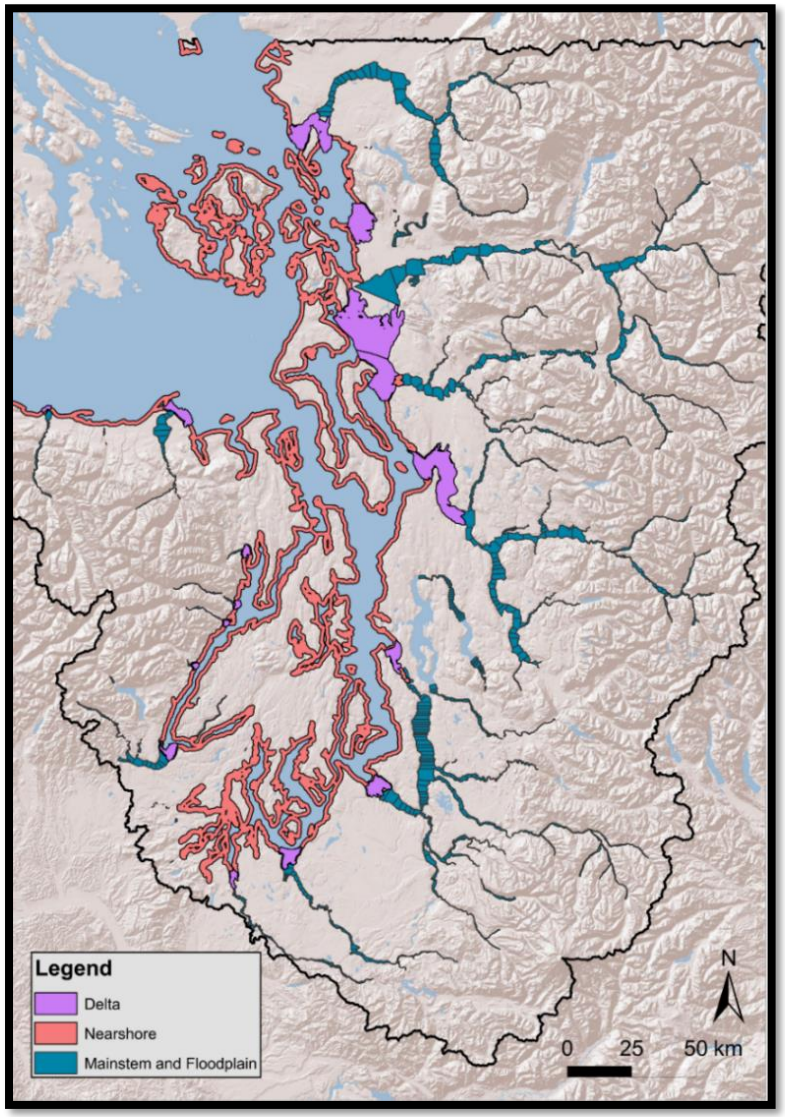
- **Supports hypotheses that higher habitat complexity…**
  - Increases productivity
  - Reduces annual variation
- **Proof of concept for PSHSTMP**
  - Repeatable and scalable
  - Detects system-scale patterns
  - Metrics linked to VSP parameters
  - Detects habitat change
- **Next steps and implications…**



Next Steps and Implications

- **Complete mapping other strata**
  - *Deltas*
  - *Nearshore*
- **Link to other VSP parameters**
  - *Smolt to adult return rates*
  - *Spawner to spawner rates*
  - *Spawner abundance*
  - *Life history attributes*
- **Complete trends analysis**
  - *Natural change?*
  - *Restoration?*

PSHSTM Program Sampling Strata



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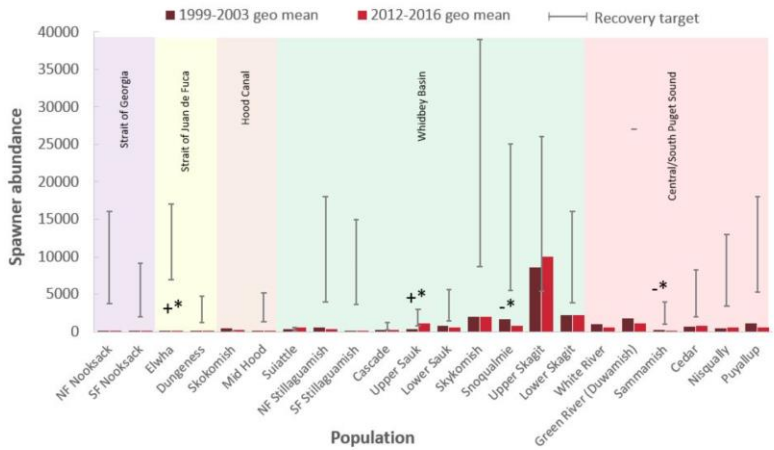
  - *Natural change?*
  - *Restoration?*

Chinook Vital Sign Indicator analysis (Kendall et al.)

FIGURE 1. MEAN CHINOOK SALMON SPAWNER ABUNDANCE IN EACH POPULATION IN PUGET SOUND, SHOWN BY GEOGRAPHIC REGION

1999-2003 vs 2012-2016



The gray vertical lines show the recovery target ranges from National Marine Fisheries Service's Final Supplement to the Shared Strategy's Puget Sound Recovery Plan (2006). There are no targets available for Skokomish, White, and Green rivers. The +* and -* symbols indicate that the population statistically significantly increased or declined, respectively, over the time period.

Source: Washington Department of Fish and Wildlife, SaSI database

Next Steps and Implications

- **Complete mapping other strata**
  - *Deltas*
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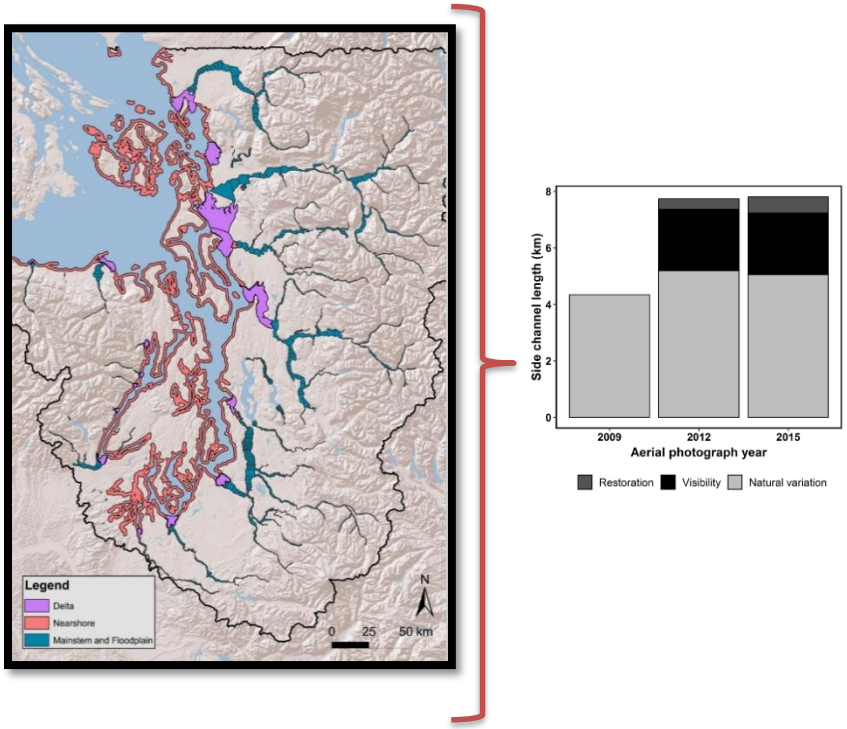
  - *Natural change?*
  - *Restoration?*

Trends analysis for all MPGs and Strata

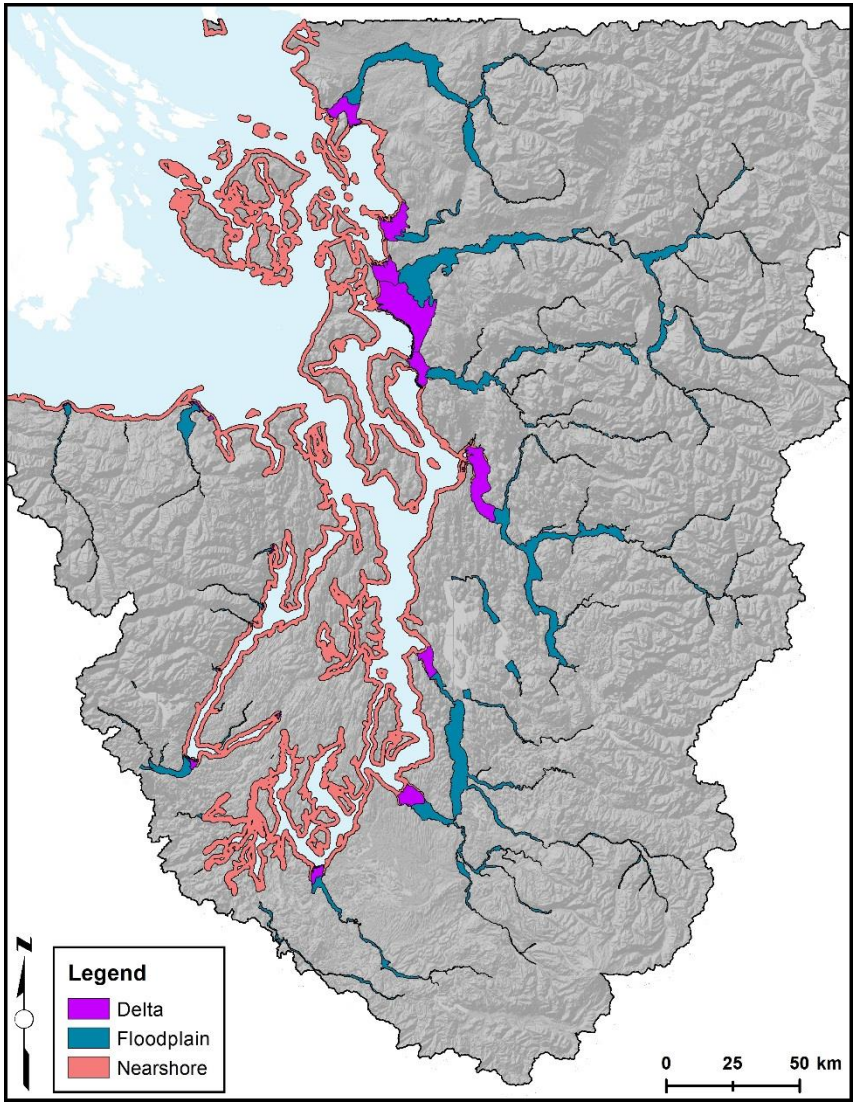


Conclusions

- **PSHSTMP should be a high priority for the Puget Sound region**
  - *Funding uncertain for FY2019*
  - *Some components with ESRP?*

- **Fills major regional data gaps and supports regional recovery efforts…**
  - *ESA recovery evaluations*
  - ***PSP Vital Signs***
  - ***PSP Common Chinook Indicators***
  - *Recovery targets and prioritization*

PSHSTM Program Sampling Strata



Supporting Slides