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Salish Sea Ecosystem Conference

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Density-dependent and landscape effects upon estuary rearing in Chinook salmon: insights from long-term monitoring in four Puget Sound estuaries

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Speaker

Correigh M. Greene, Eric M. Beamer, Rich Henderson, Joshua Chamberlin, Jason Hall, Joseph H. Anderson, Matthew Pouley, Melanie Davis, Sayre Hodgson, and Christopher Ellings

**Density-dependent and landscape effects upon estuary rearing in Chinook salmon:
Insights from long-term monitoring in four Puget Sound estuaries**



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Todd Zackey (Tulalip Tribes)
Evelyn Brown (Lummi Tribe)
Melanie Davis (USGS)
Sayre Hodgson (Nisqually Tribe)
Christopher Ellings (Nisqually Tribe)
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Susan de la Cruz

WDFW

Clayton Kinsel
Matt Klungle

Others

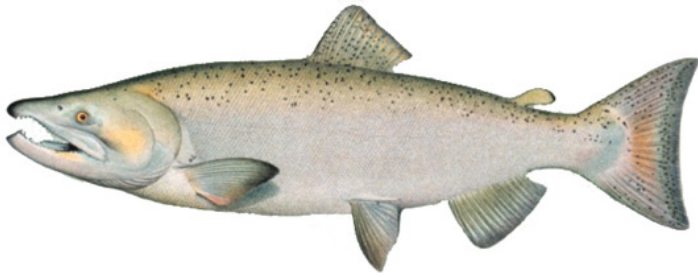
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Many field workers

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Long Live the Kings
Skagit River System Cooperative
Pacific Salmon Implementation
Treaty

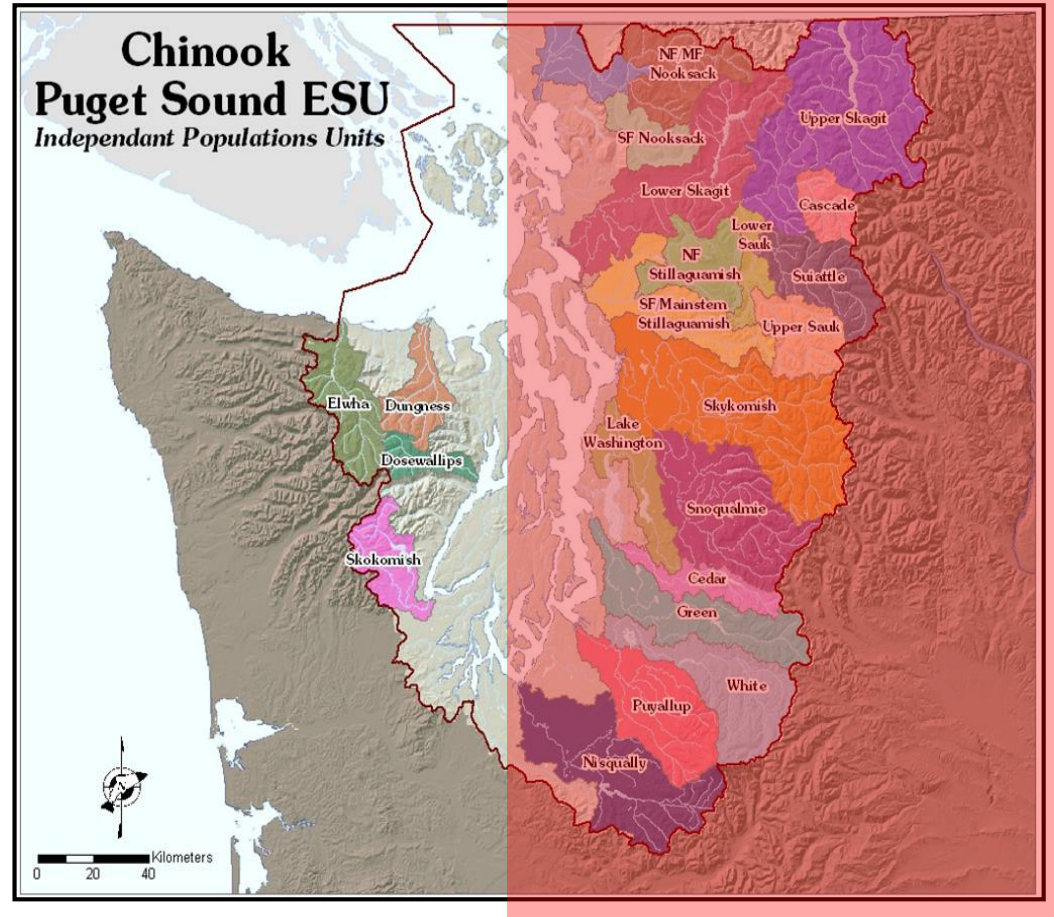
Chinook salmon and estuary habitat loss



ESA listing affects natural resources management:

- Critical habitat issues in US
- Potential to shut down fisheries
- Orca food – proposal to increase hatchery production to boost prey
- PSP Vital Sign – road to recovery by 2020

Extensive use of estuaries by juveniles

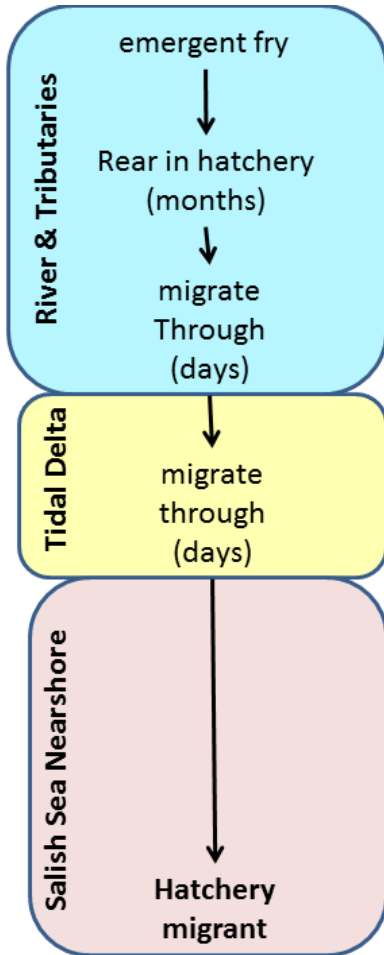


Current area = 1-55% of historical
(PSNERP Change Analysis 2011)

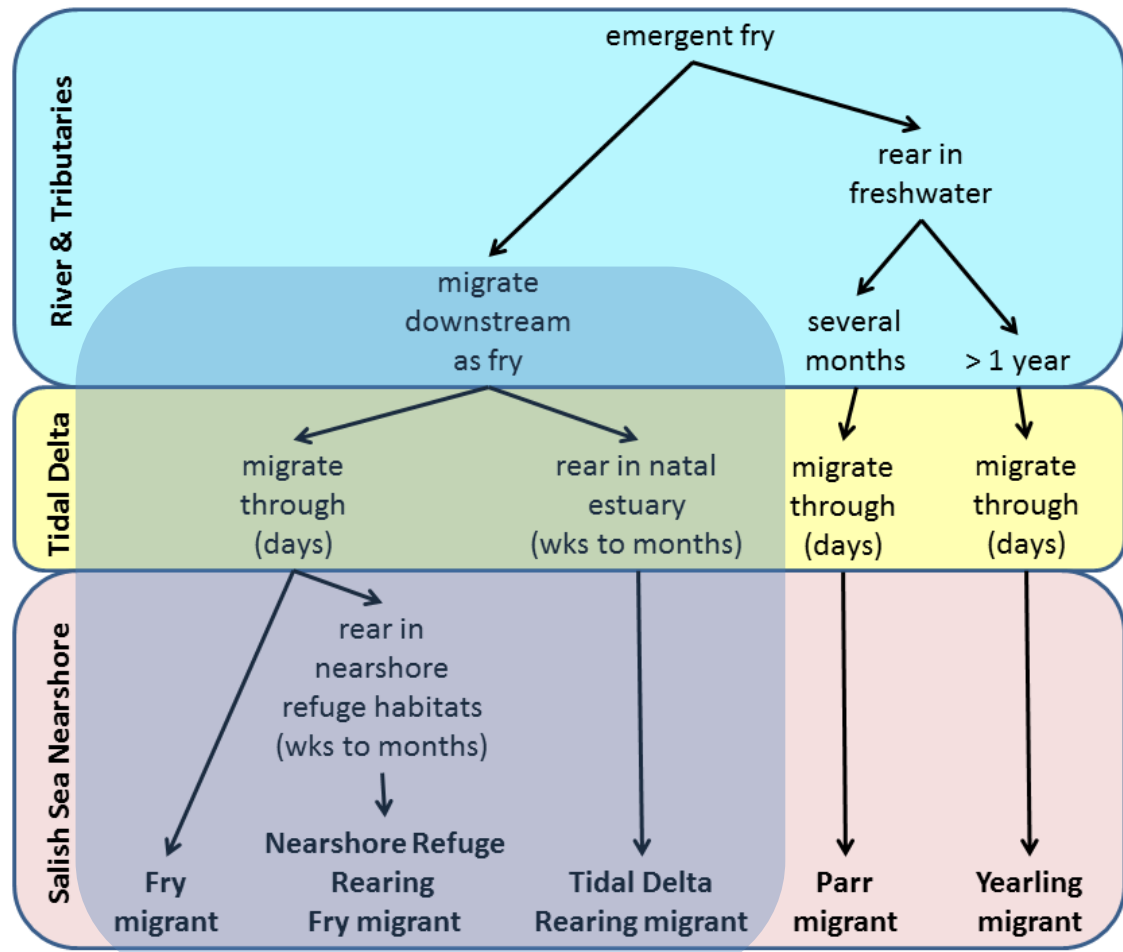
Chinook in estuaries: Which life history types benefit?



Subyearling hatchery (marked) populations



Wild (unmarked) populations



Questions

What landscape features influence distribution and abundance of fish?

- Estuary system
- Landscape connectivity
- Habitat types
- Channel types



Does estuary habitat limit population recovery?

- Evaluating density dependence among populations
- Possible hatchery interactions in estuaries



Landscape features

Estuary system

Landscape connectivity

Channel type

Wetland habitat type

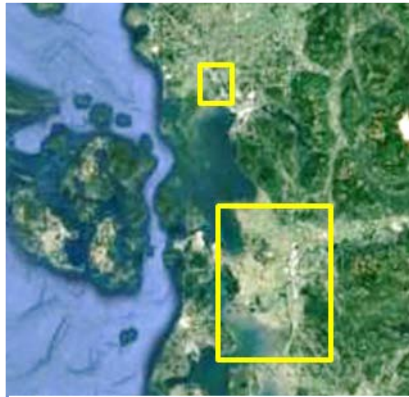


Nooksack
Skagit
Snohomish
Nisqually



Landscape features

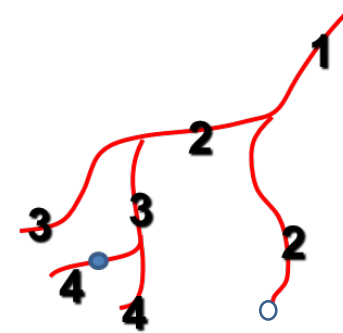
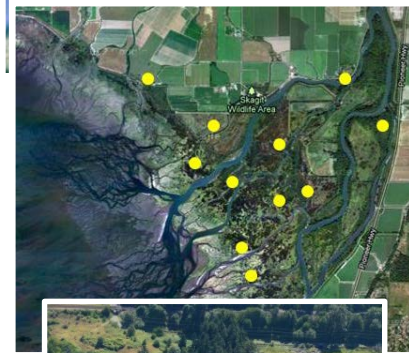
Estuary system



Nooksack
Skagit
Snohomish
Nisqually



Landscape connectivity



Channel type

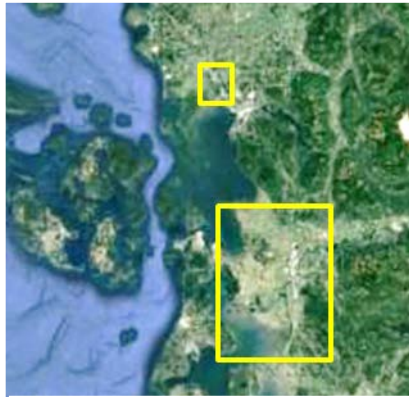


Wetland habitat type



Landscape features

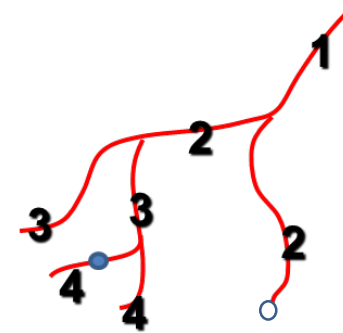
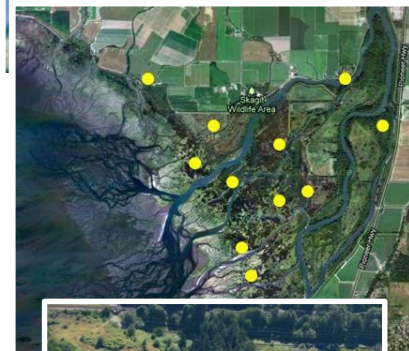
Estuary system



Nooksack
Skagit
Snohomish
Nisqually



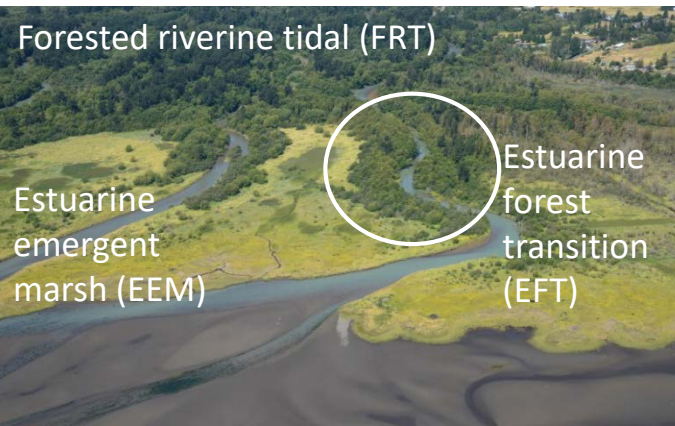
Landscape connectivity



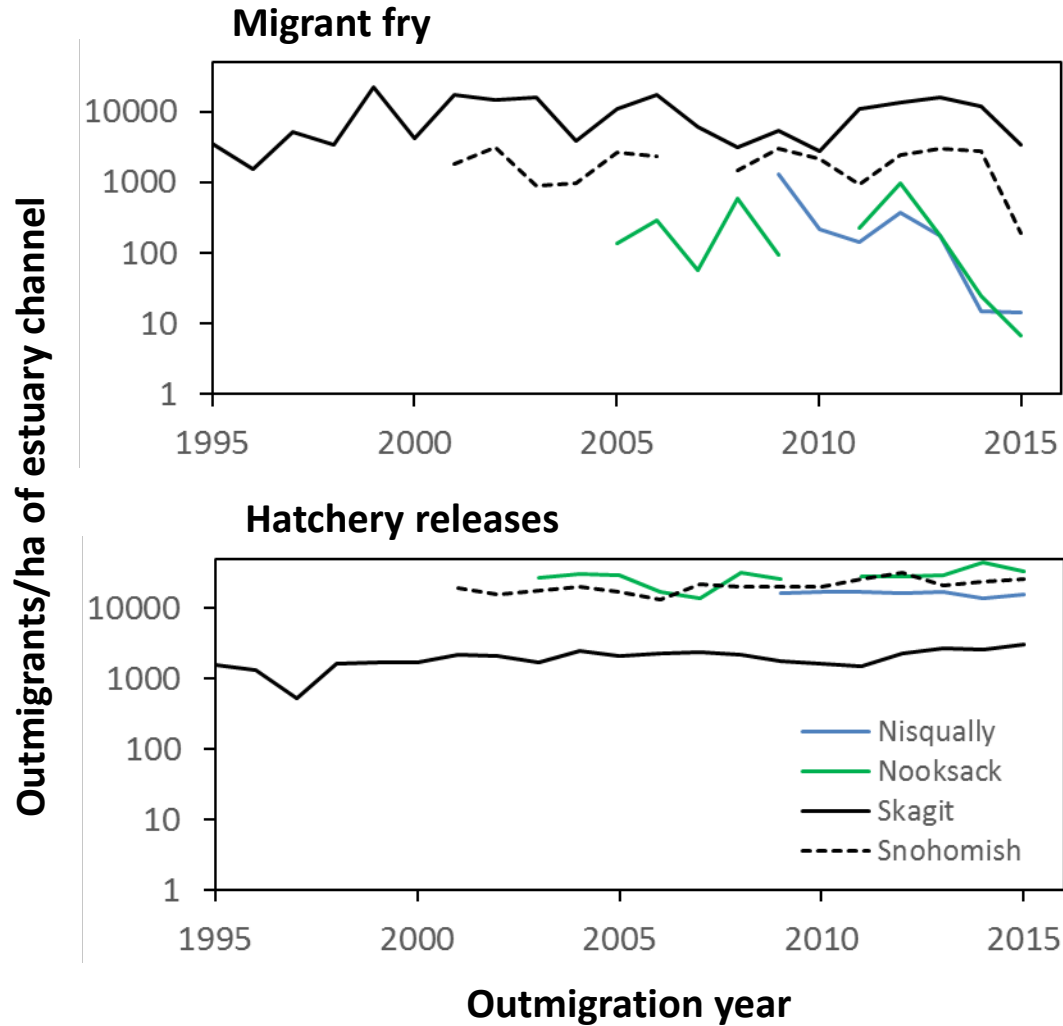
Channel type



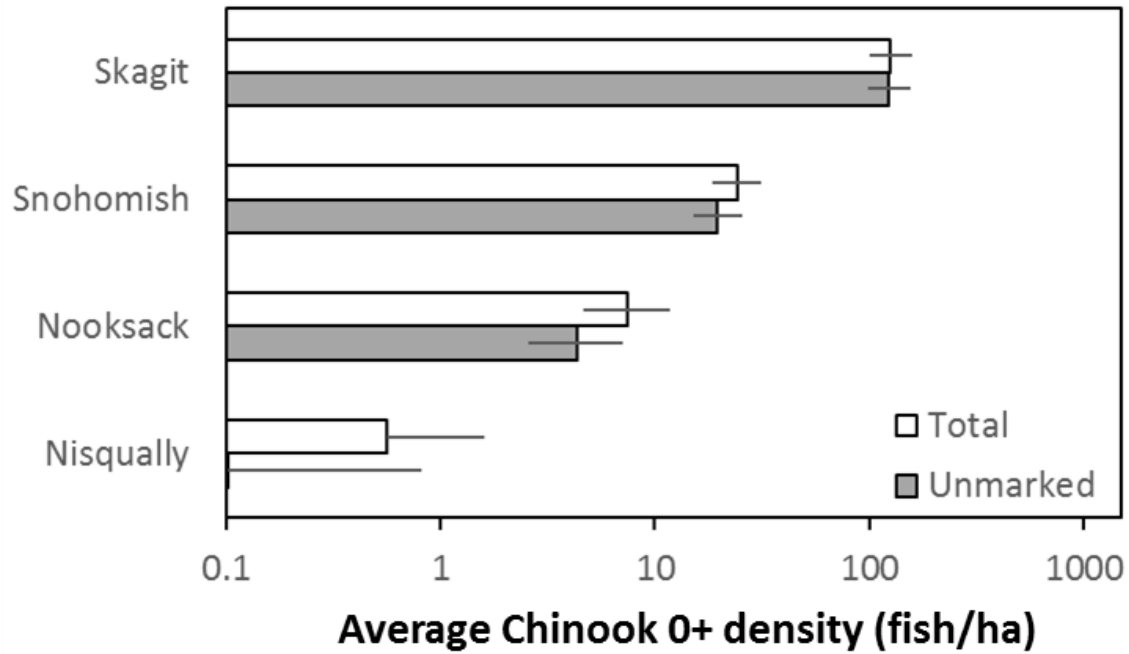
Wetland habitat type



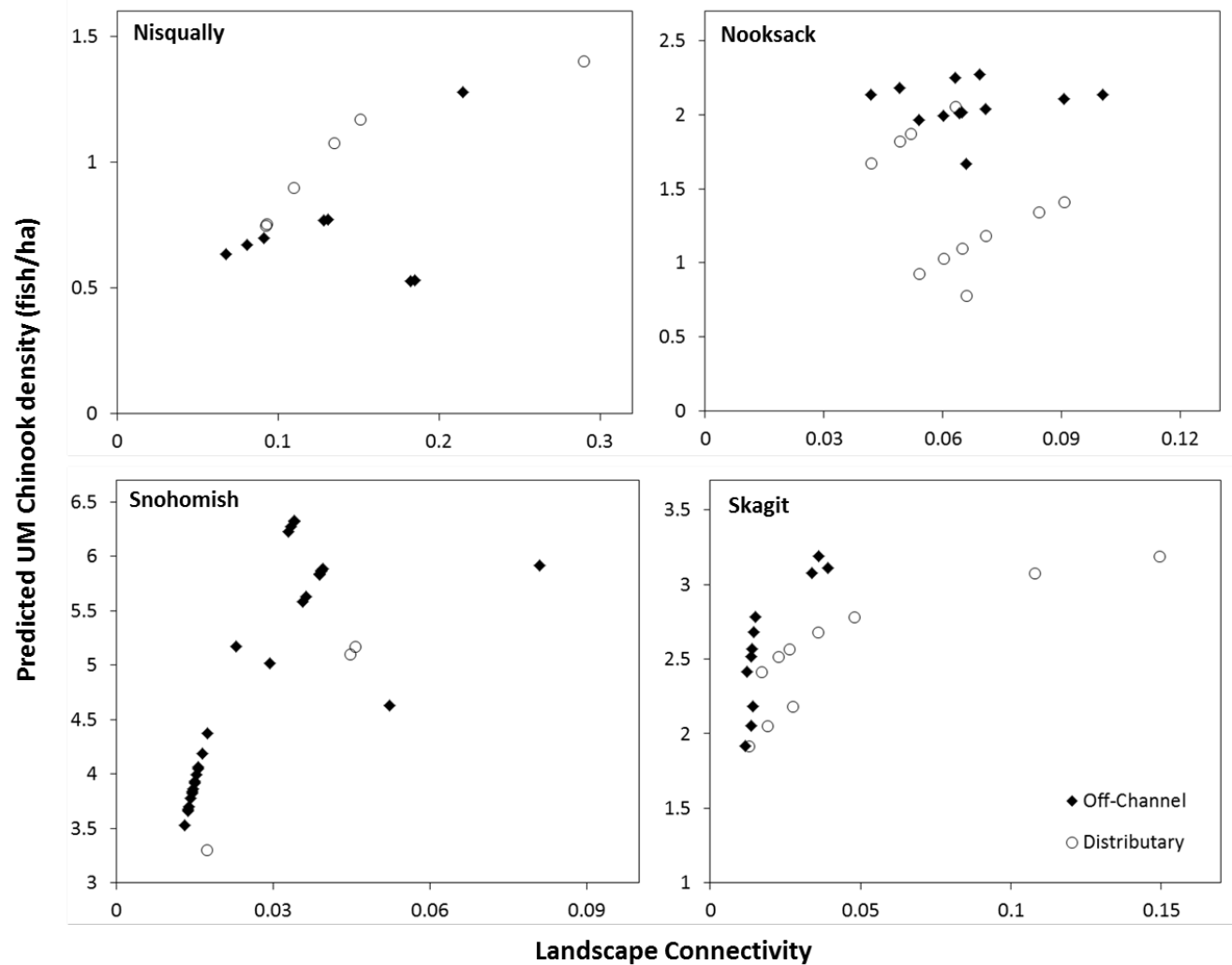
Hatchery vs natural origin fish



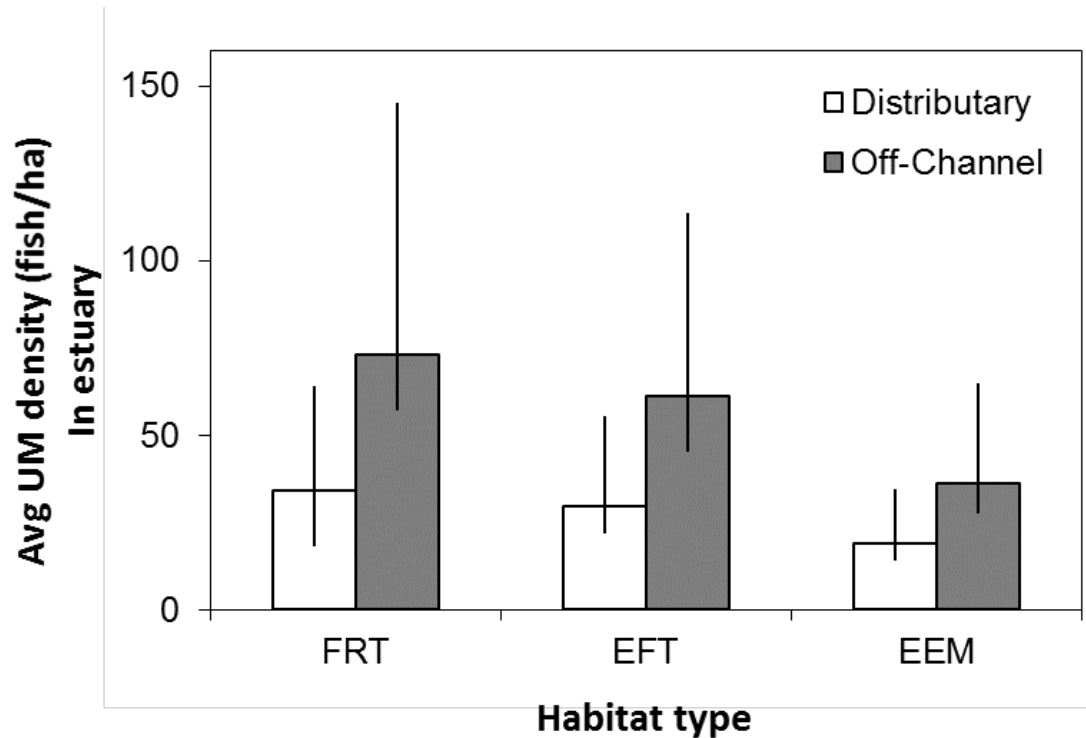
System differences



Landscape connectivity



Channel & habitat types

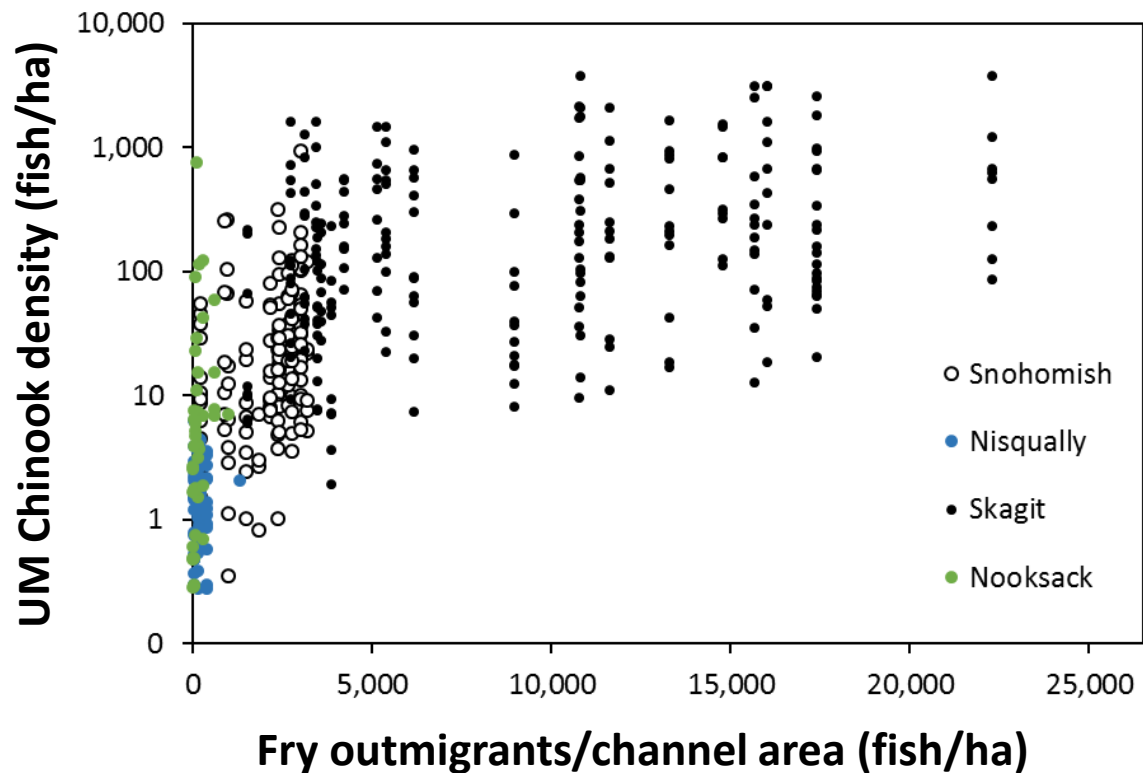


FRT = Forested riverine tidal

EFT = Estuarine forest transition

EEM = Estuarine emergent marsh

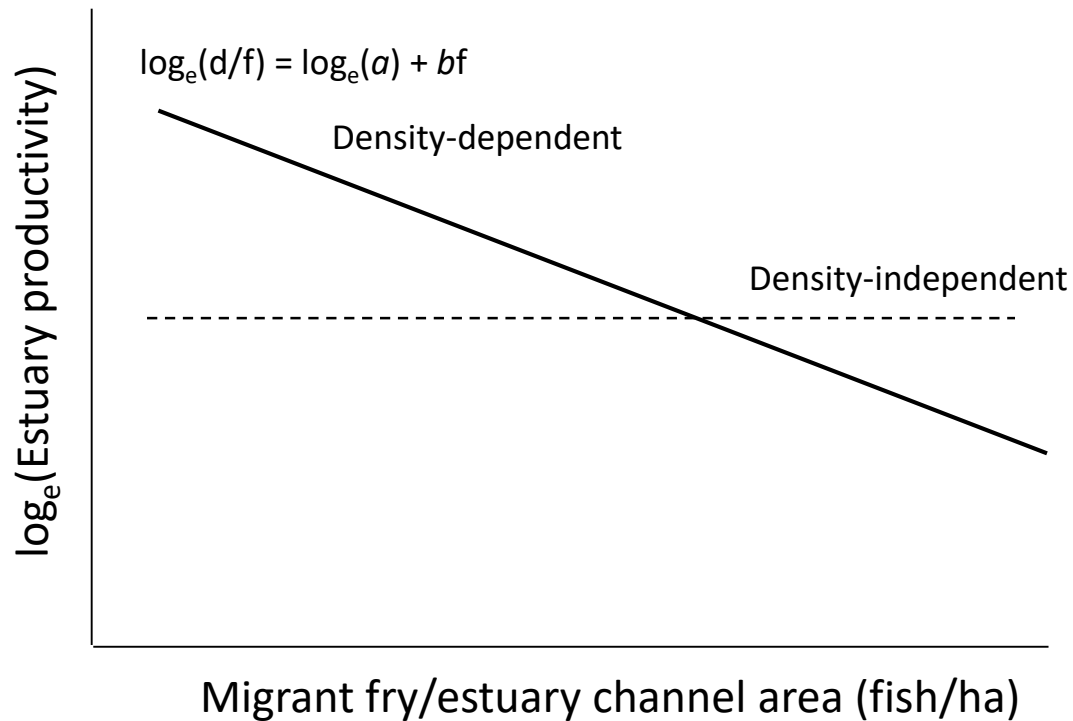
Density-dependent relationships



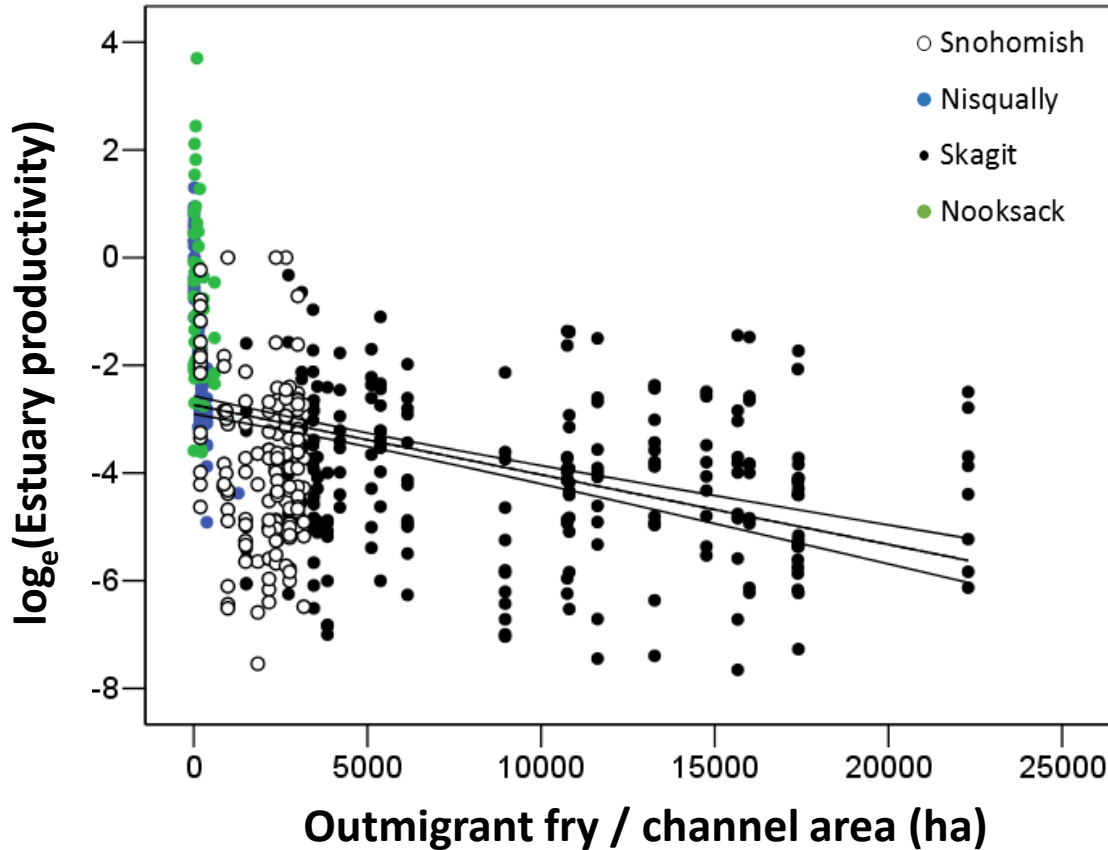
Testing for density dependence



$$\text{Estuary productivity} = \frac{\text{Average annual estuary density}}{\text{Migrant fry/channel area}}$$



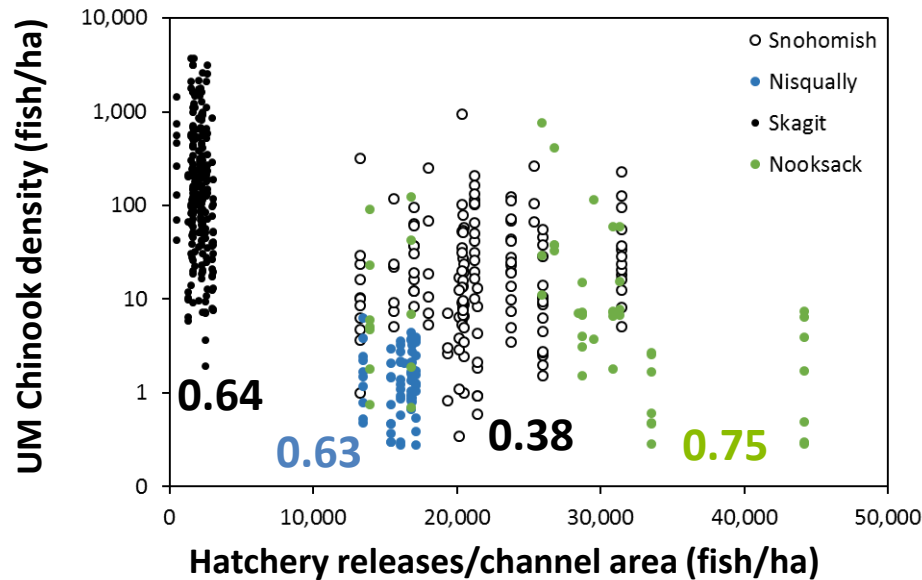
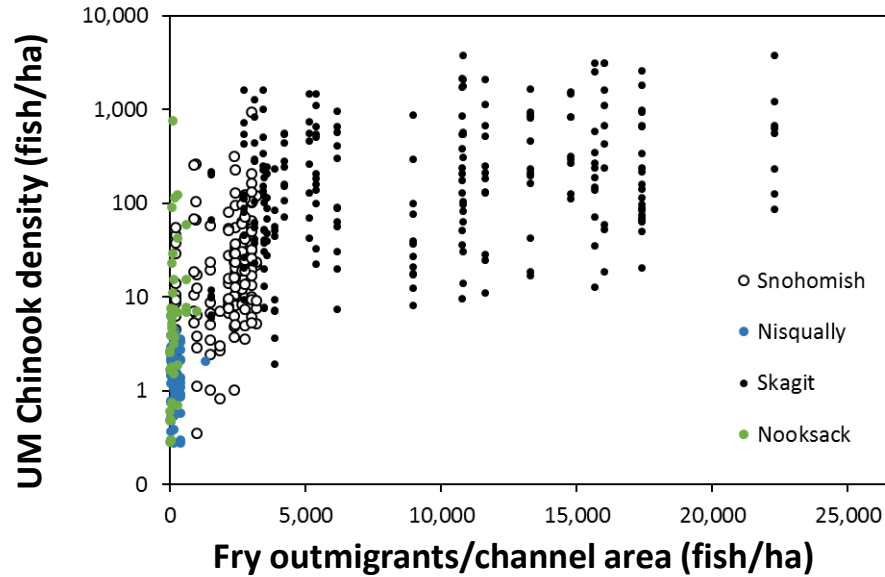
Density-dependent relationships



Other population traits exhibiting density dependence in the Skagit:

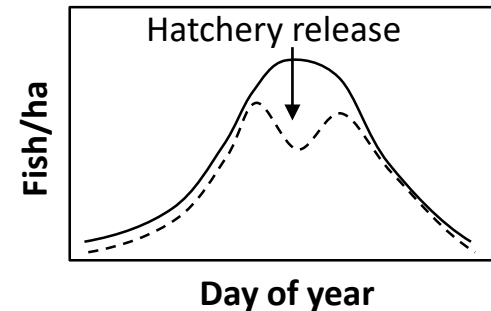
- Estuary growth and size
- Residence time in estuary
- Proportion of migrants entering Puget Sound as fry
- Smolt-adult return rate

Potential interactions with hatchery fish



Additional analyses indicate:

- Bioenergetic models – high consumption demand by hatchery fish in 3 estuaries
- Seasonal declines in unmarked fish after hatchery releases



Conclusions

What landscape features influence distribution and abundance of fish?

- Estuary system
 - Landscape connectivity
 - Habitat types
 - Channel types
 - Context-dependent effects
- } Relevant improving
benefits of restoration



Does estuary habitat limit population recovery?

- Evidence for density-dependent interactions at large outmigrations
- These levels were not observed in 2 populations
- Densities of unmarked fish negatively tracked hatchery releases
- Hatchery releases regularly surpass estimated maximum densities



Thanks!



Statistical analysis



Question:

What landscape features influence annual densities of unmarked salmon?

Four main effects:

Estuary System (Nooksack, Skagit, Snohomish, Nisqually)

Landscape connectivity (covariate)

Habitat type (Forested riverine tidal, estuarine forest transition, estuarine emergent marsh)

Channel type (Off-channel, distributary)

Interactions of main effects:

System * connectivity

System * habitat type

System * channel type

Connectivity * habitat type

Connectivity * channel type

Statistical analysis



Question:

Does estuary habitat limit population recovery?

Remove landscape effects:

Landscape connectivity (covariate)

Channel type (off-channel, distributary)

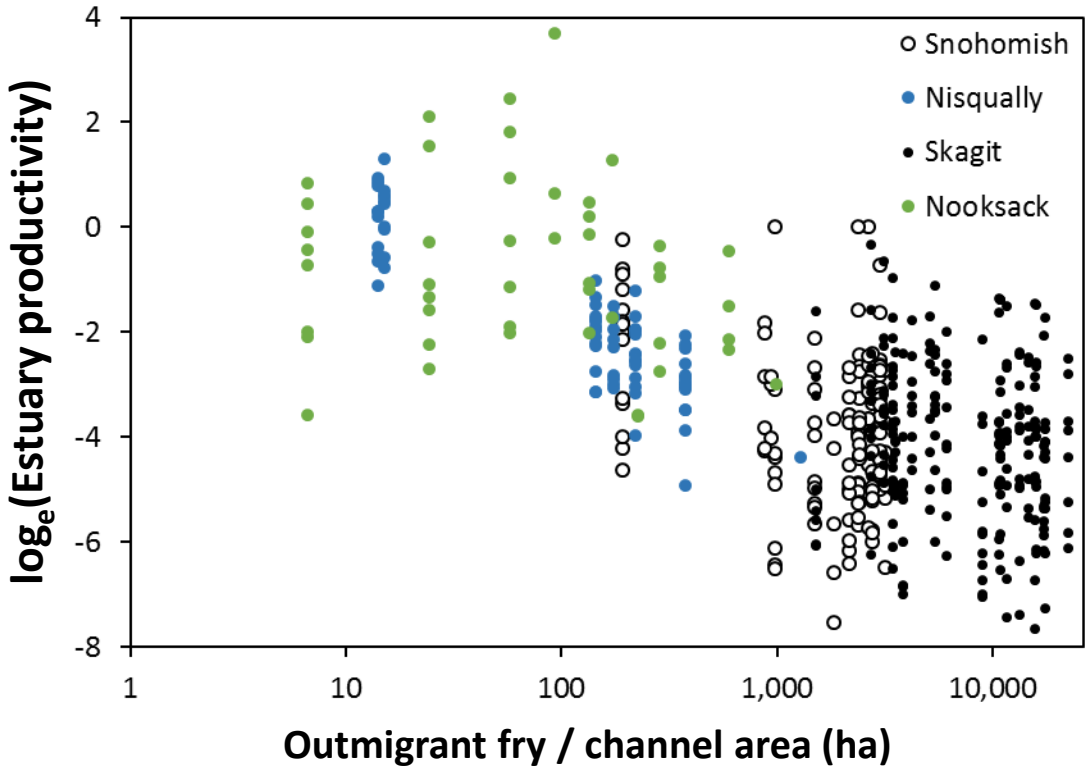
Connectivity * channel type

Retain system and habitat-dependent variation to test for annual effects of:

Migrant fry

Hatchery releases

Density-dependent relationships

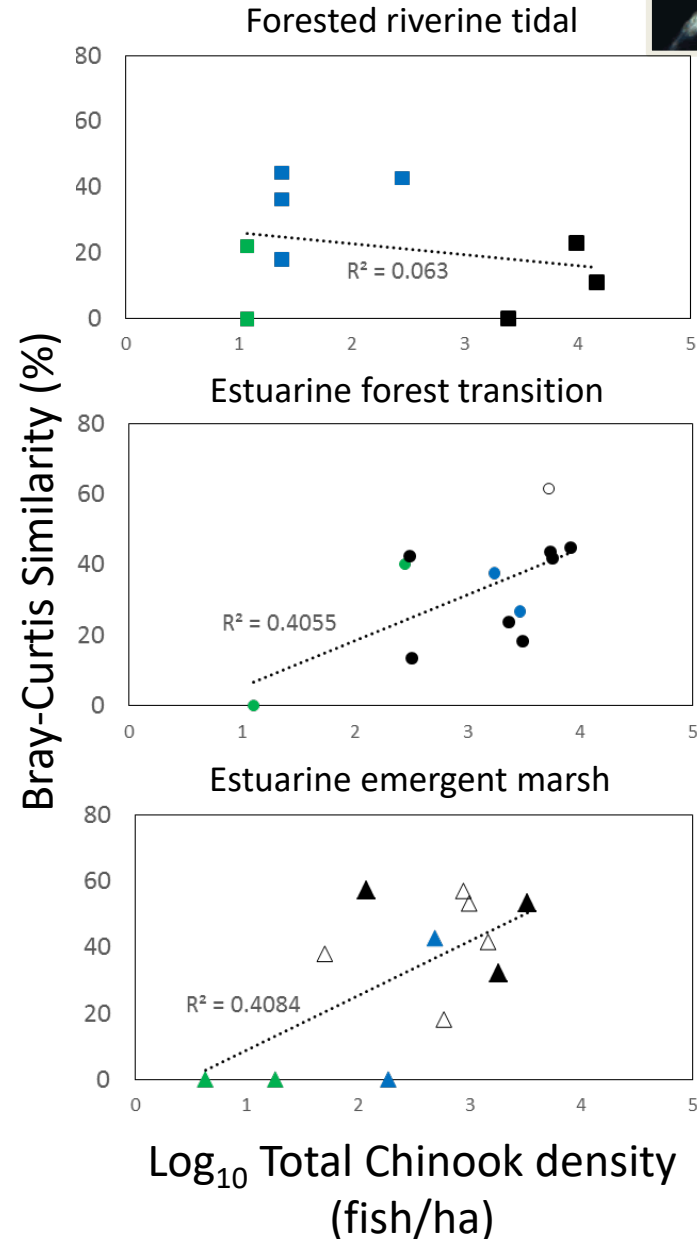
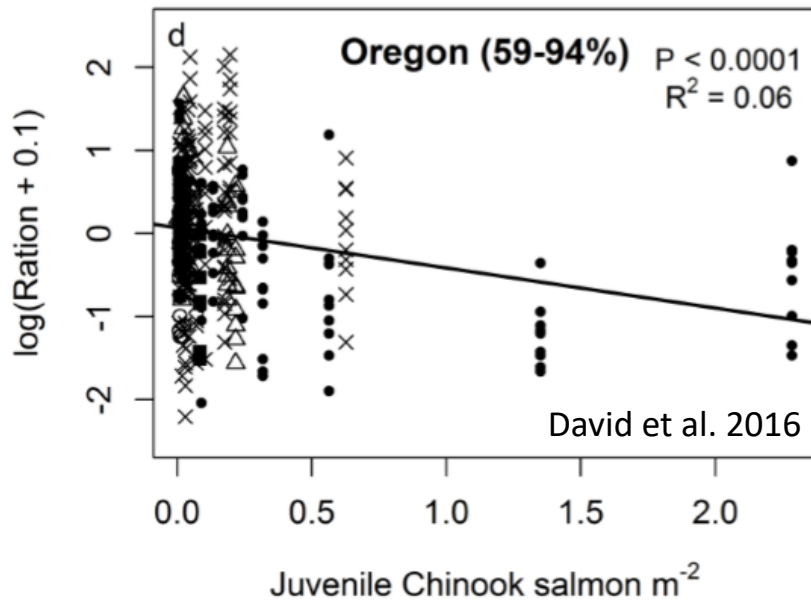


Competition for food?



Prediction: if there is competition, fish should become less selective at higher fish densities

Test: Similarity of diet composition and prey availability

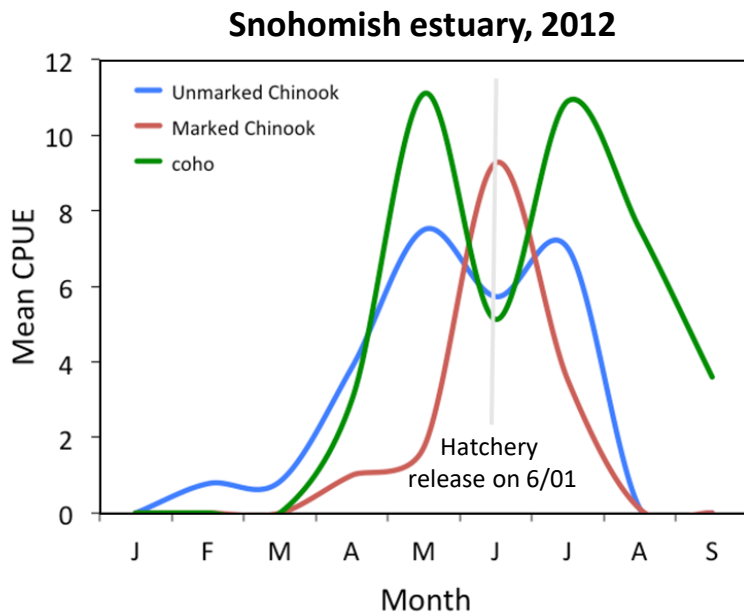


Potential interactions with hatchery fish



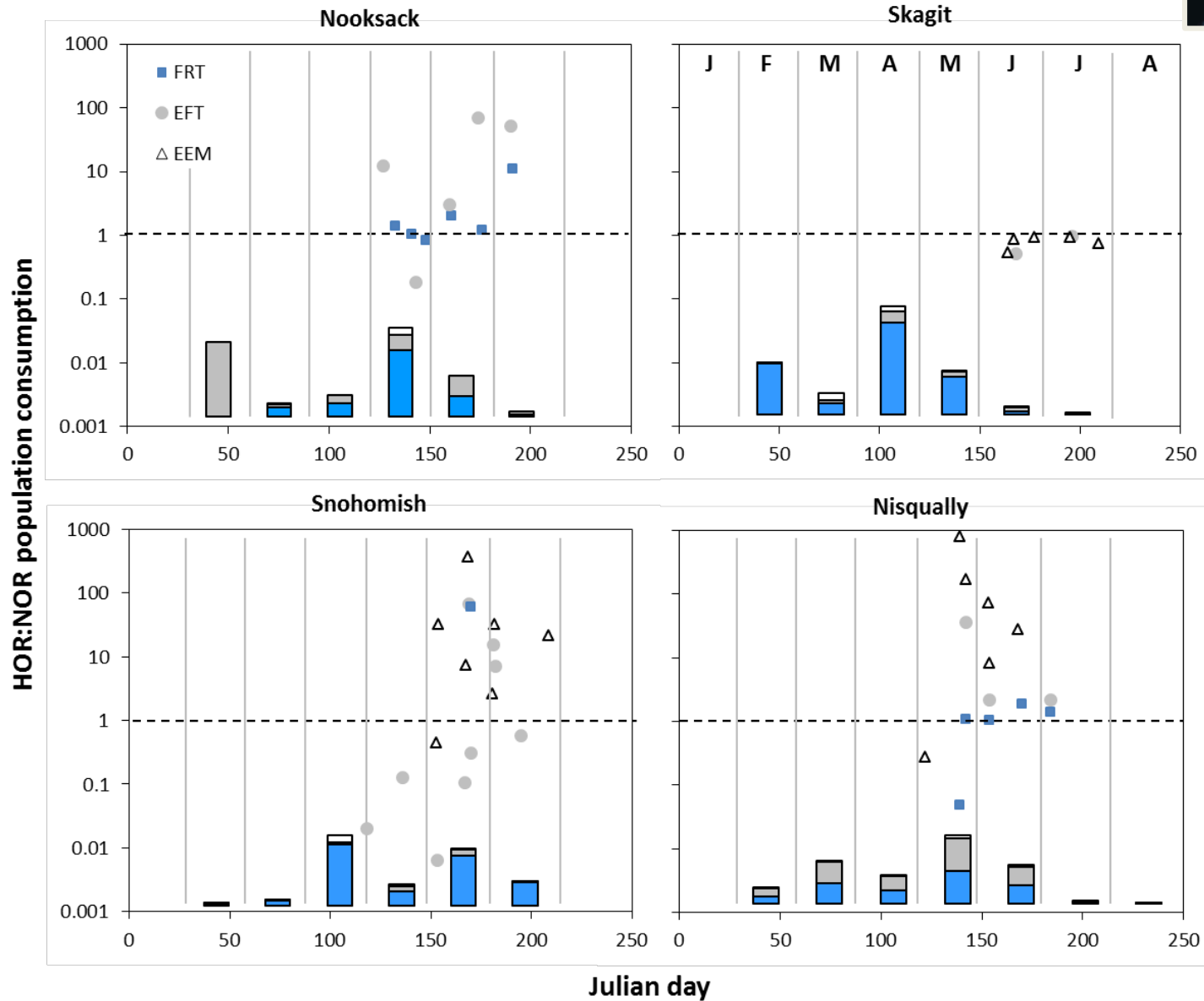
Possible causes

- “Pied-piper effect”: fish follow large migrations
- Pulsed competition for food during hatchery releases induces early migration
- Introgression of genotypes for rapid outmigration
- Down-river transmission of pathogens from hatcheries



Additional research needed

Consumption demand of hatchery fish



Possible Decision Framework

