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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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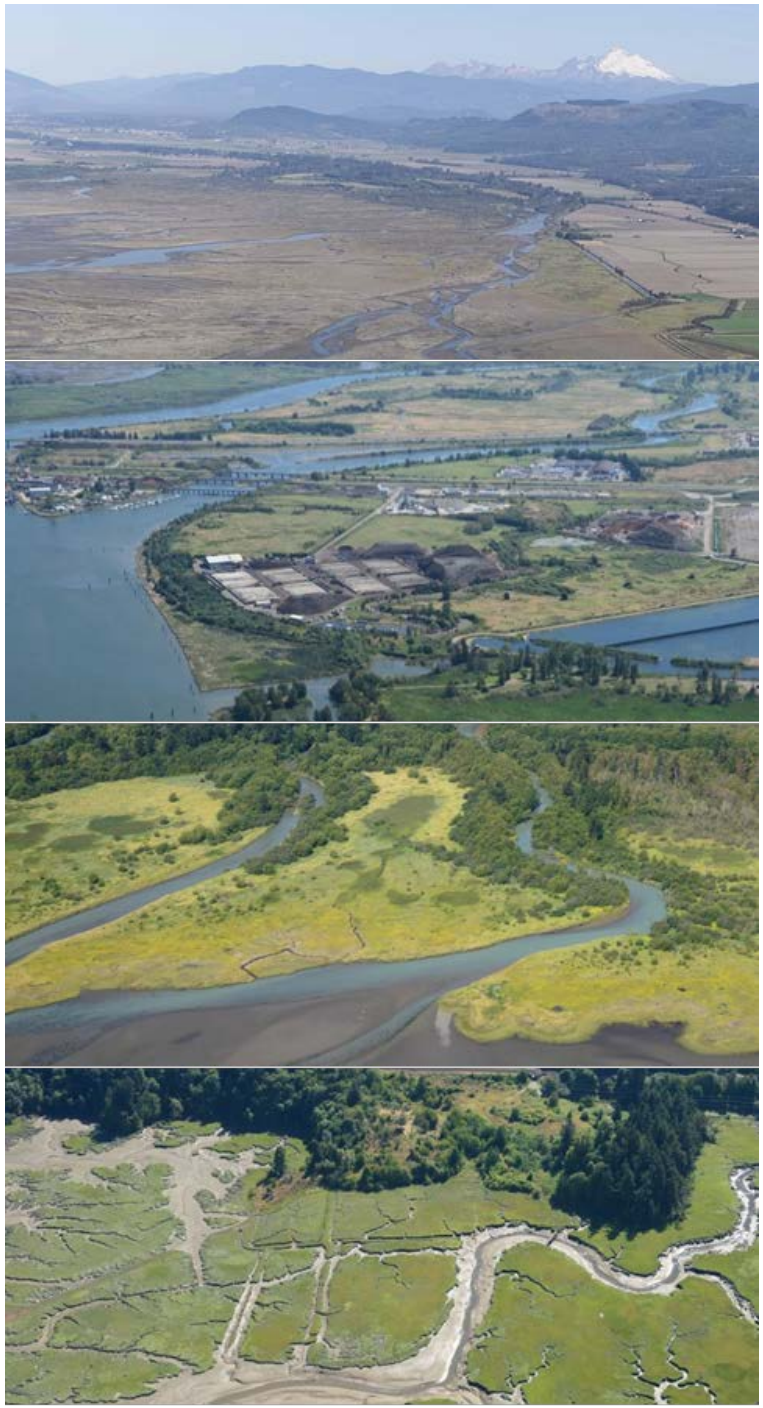

Density-dependent and landscape effects upon estuary rearing in Chinook salmon: Insights from long-term monitoring in four Puget Sound estuaries

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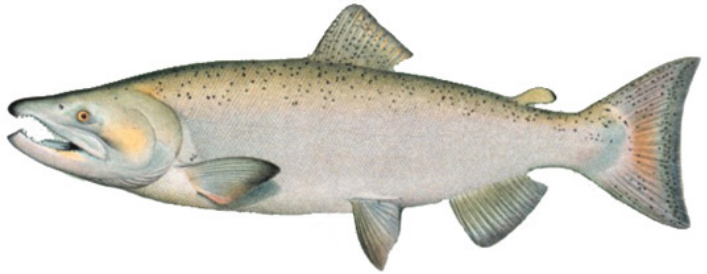
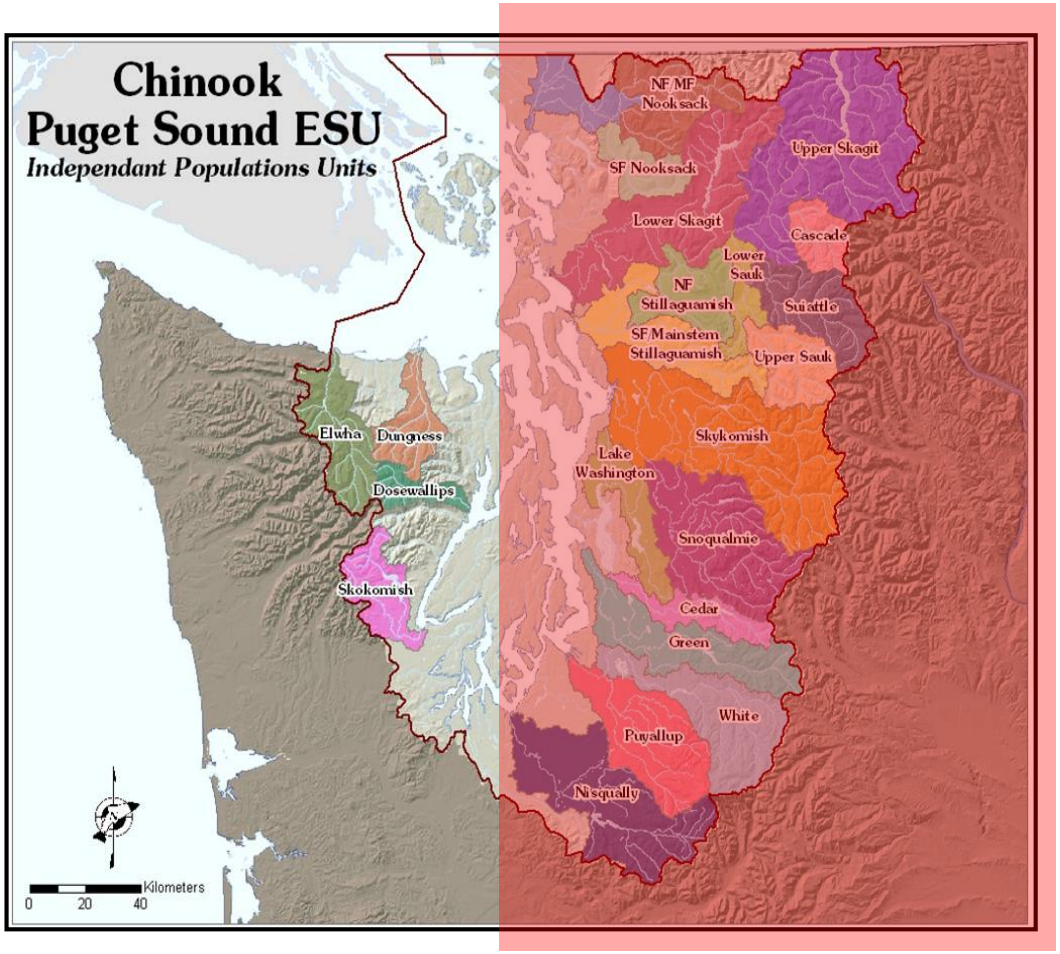
Chinook salmon and estuary habitat loss



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

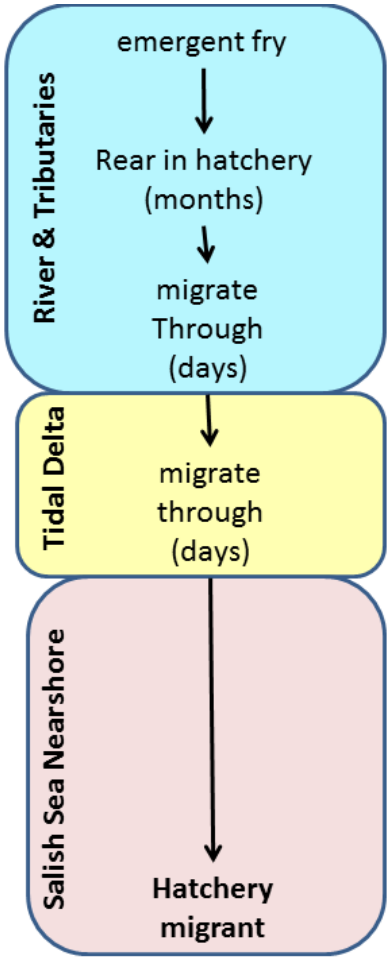
Extensive use of estuaries by juveniles



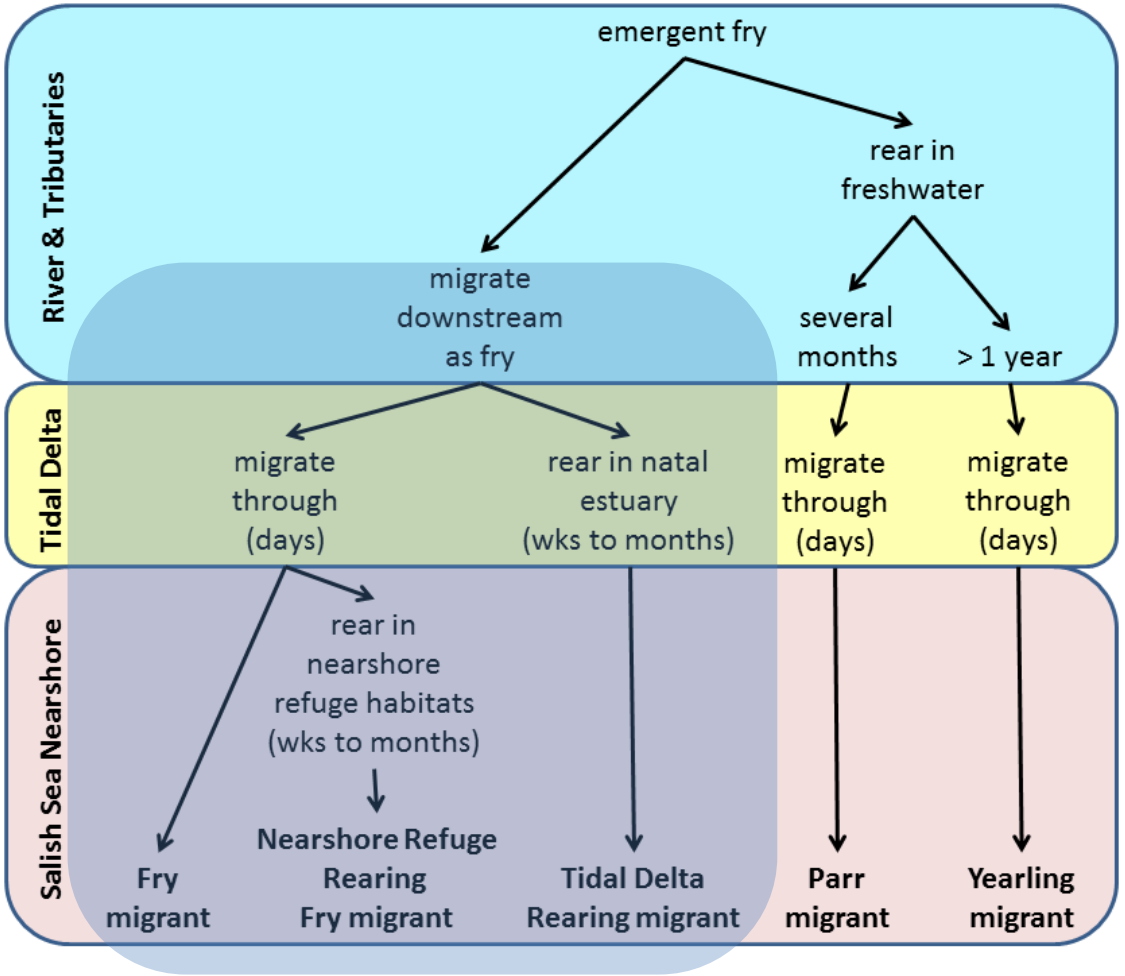
Current area = 1-55% of historical (PSNERP Change Analysis 2011)

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

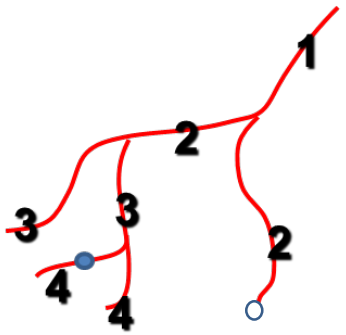
Nooksack
Skagit
Snohomish
Nisqually

Landscape features

Estuary system

Nooksack
Skagit
Snohomish
Nisqually

Landscape connectivity



Channel type

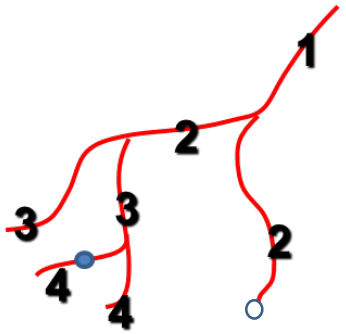
Wetland habitat type

Landscape features

Estuary system

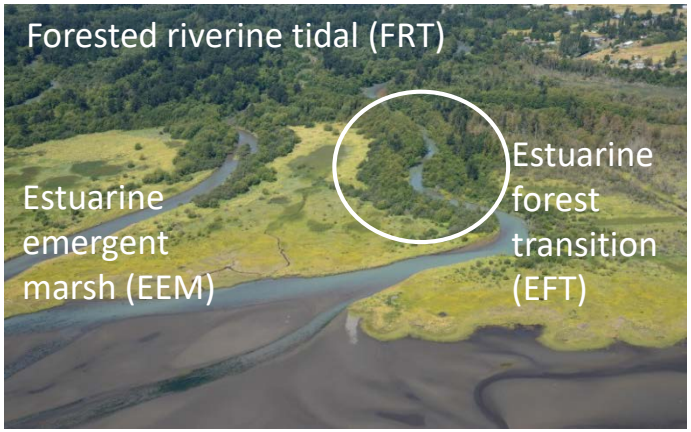
Nooksack
Skagit
Snohomish
Nisqually

Landscape connectivity

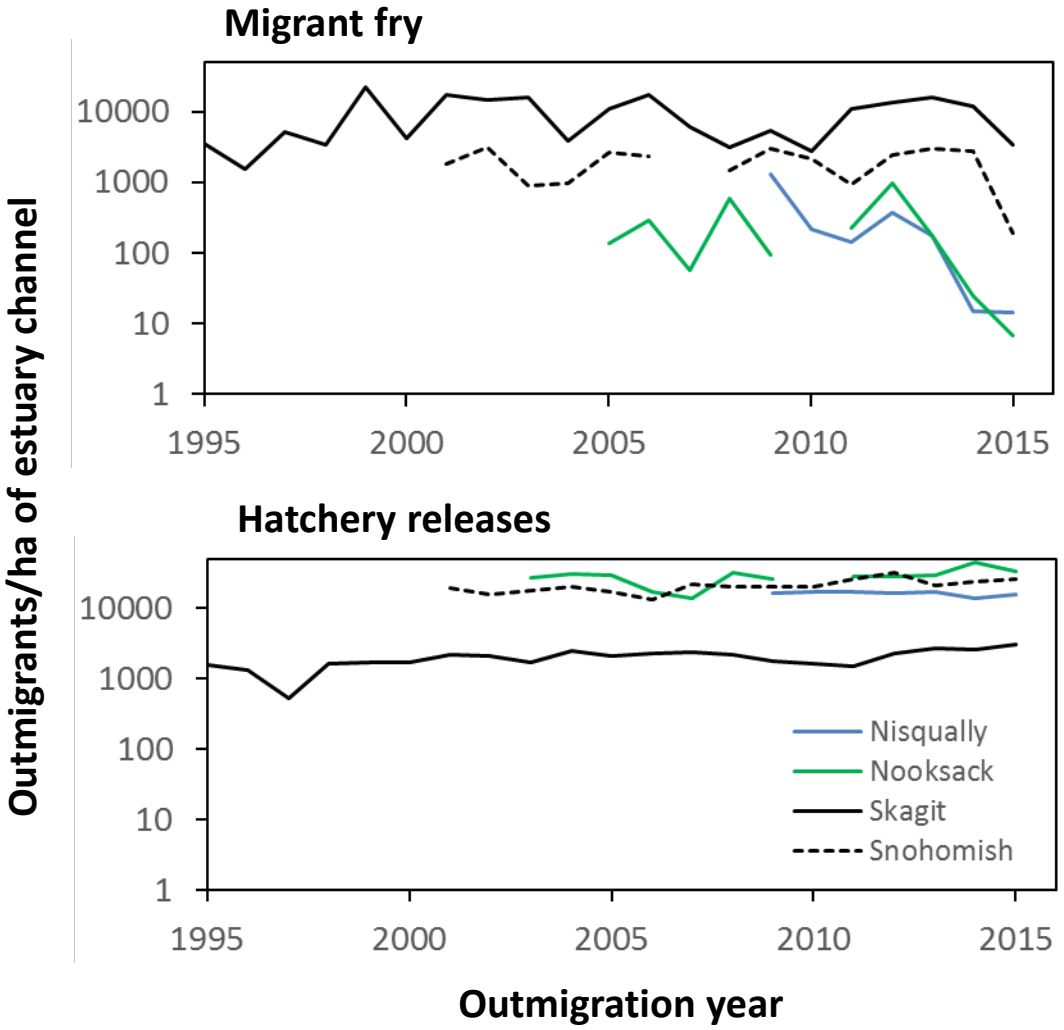


Channel type

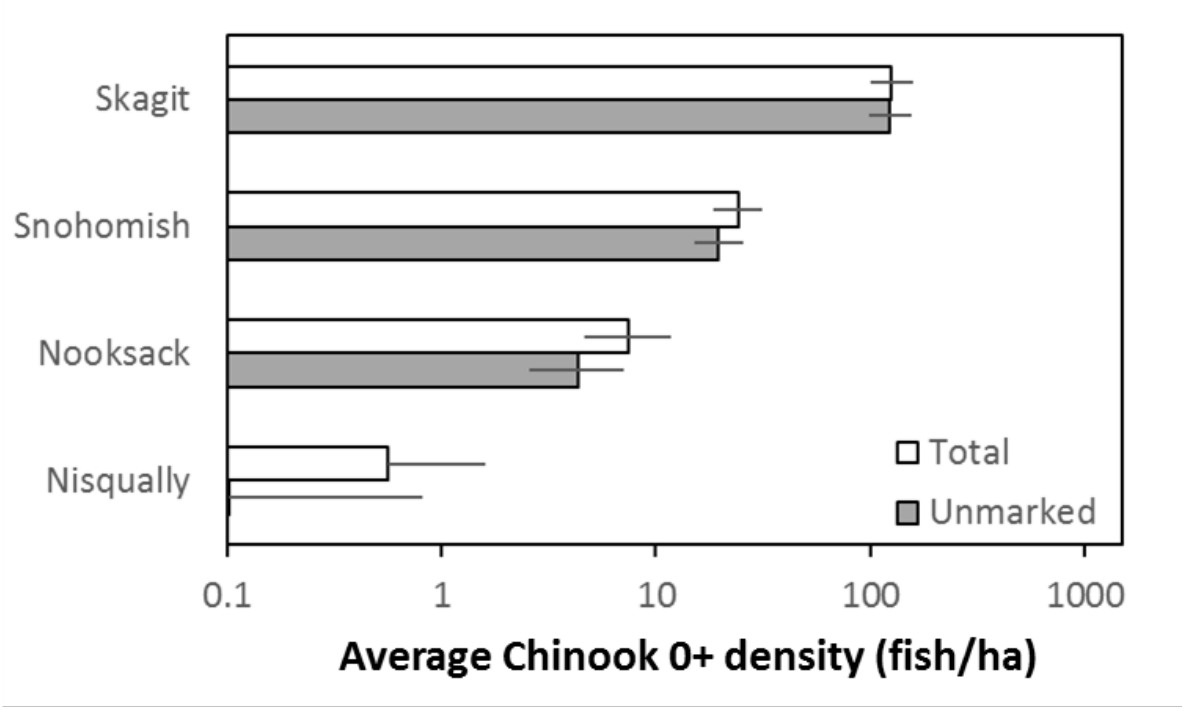
Wetland habitat type



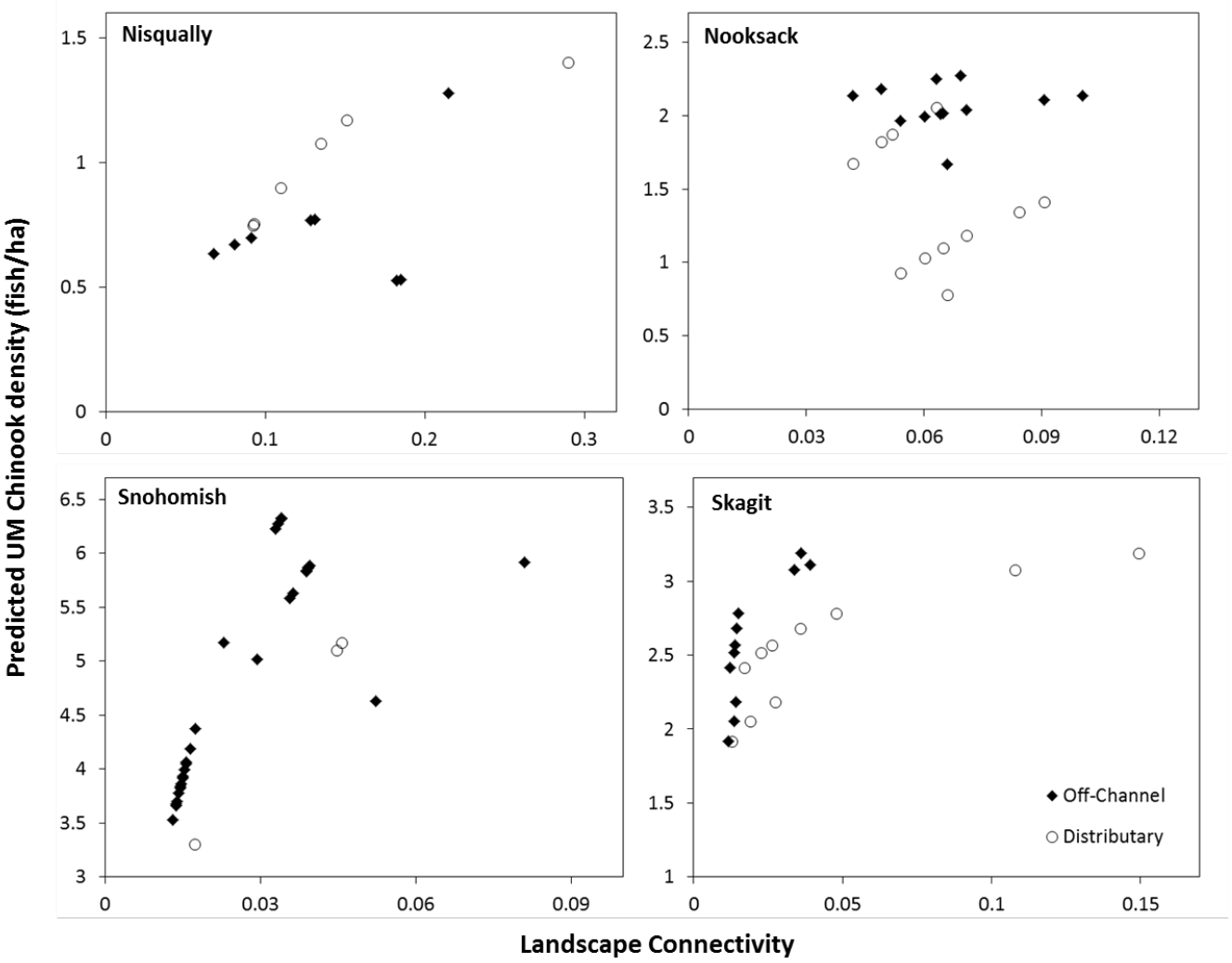
Hatchery vs natural origin fish



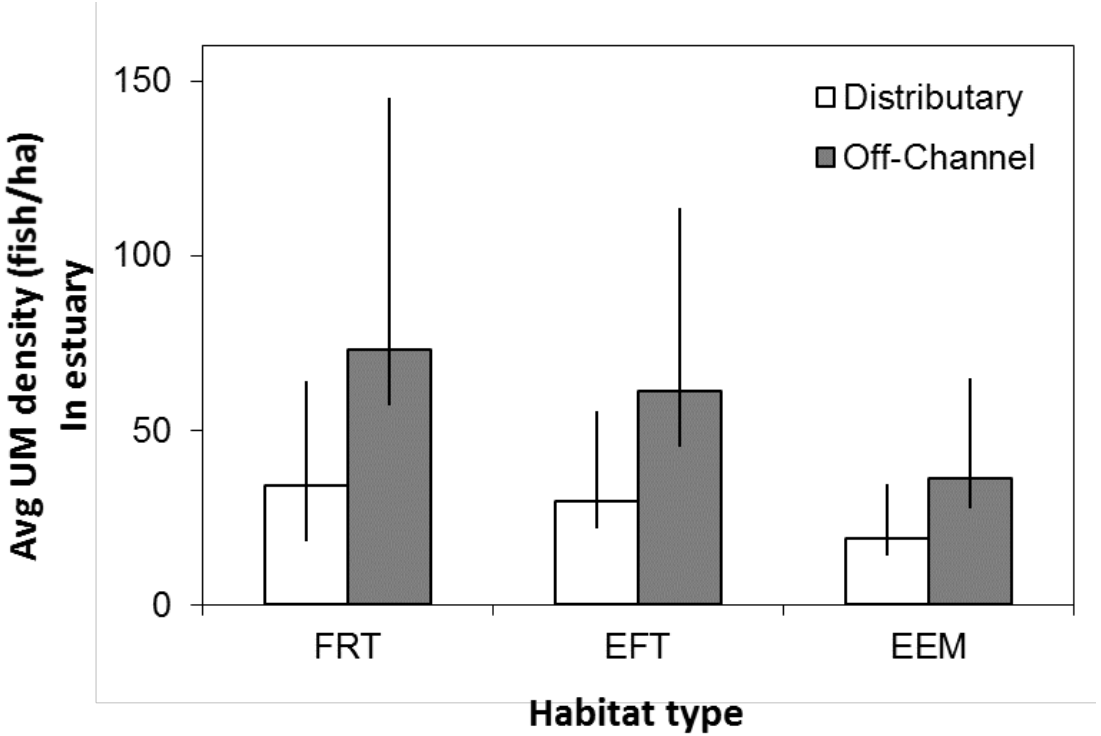
System differences



Landscape connectivity

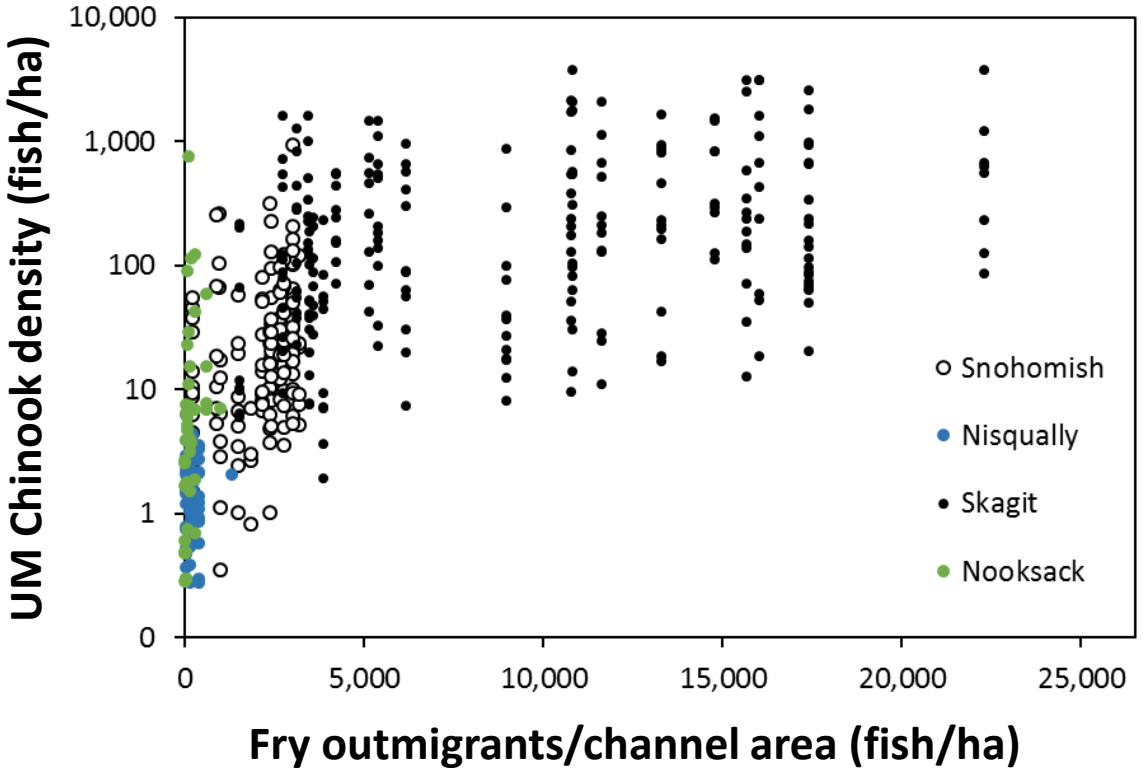


Channel & habitat types



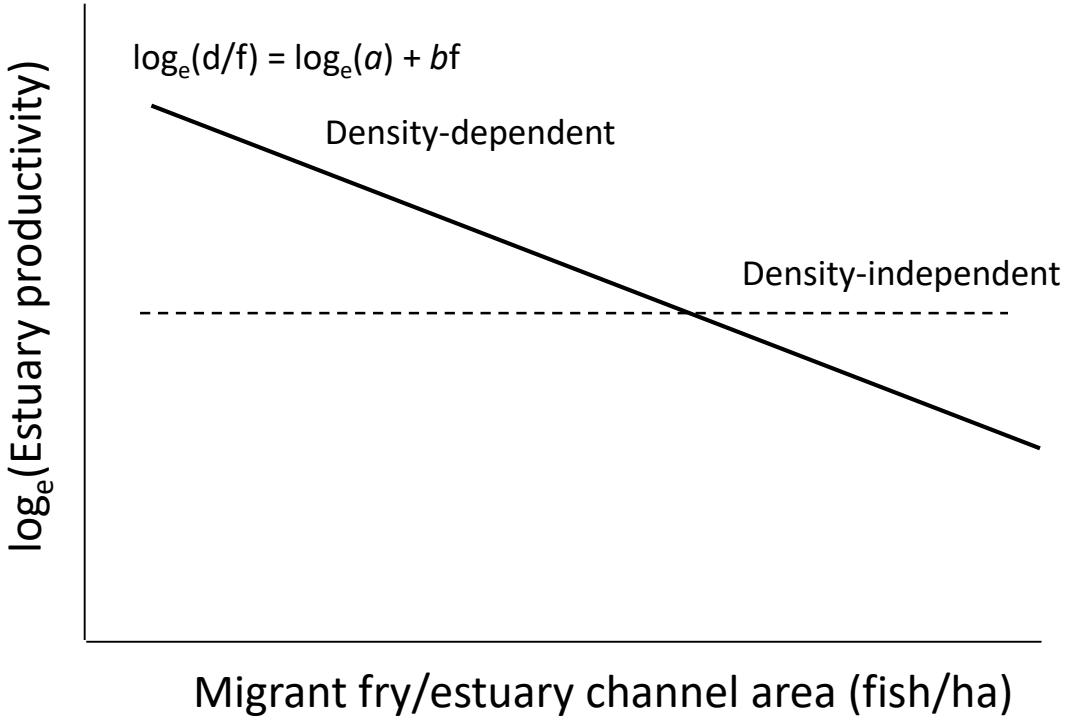
FRT = Forested riverine tidal
EFT = Estuarine forest transition
EEM = Estuarine emergent marsh

Density-dependent relationships

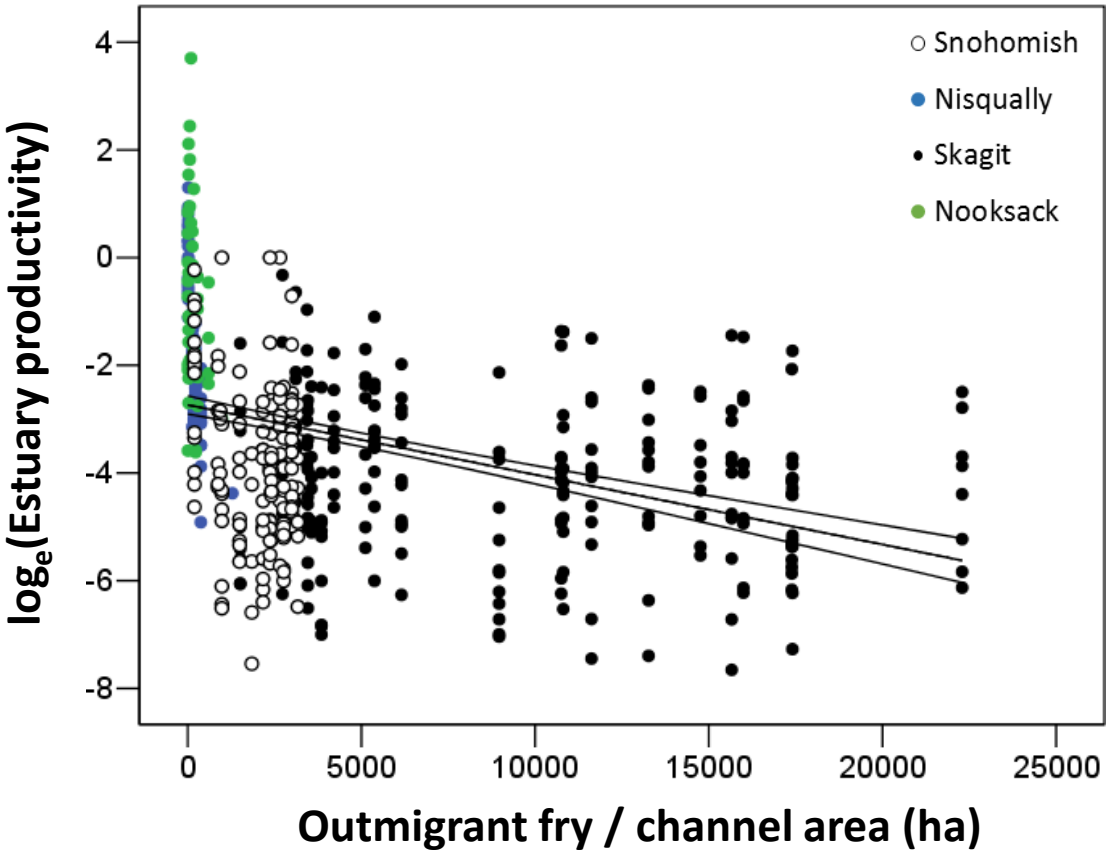


Testing for density dependence

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



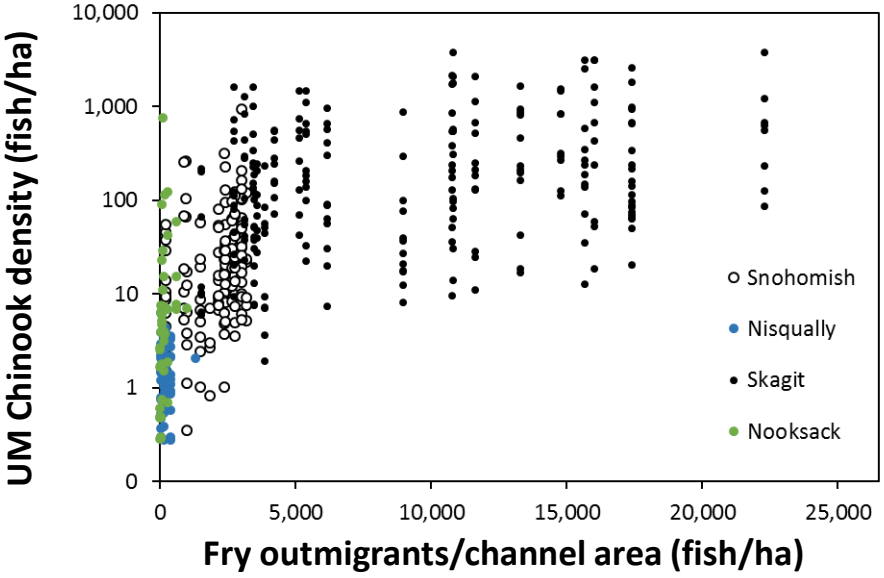
Density-dependent relationships

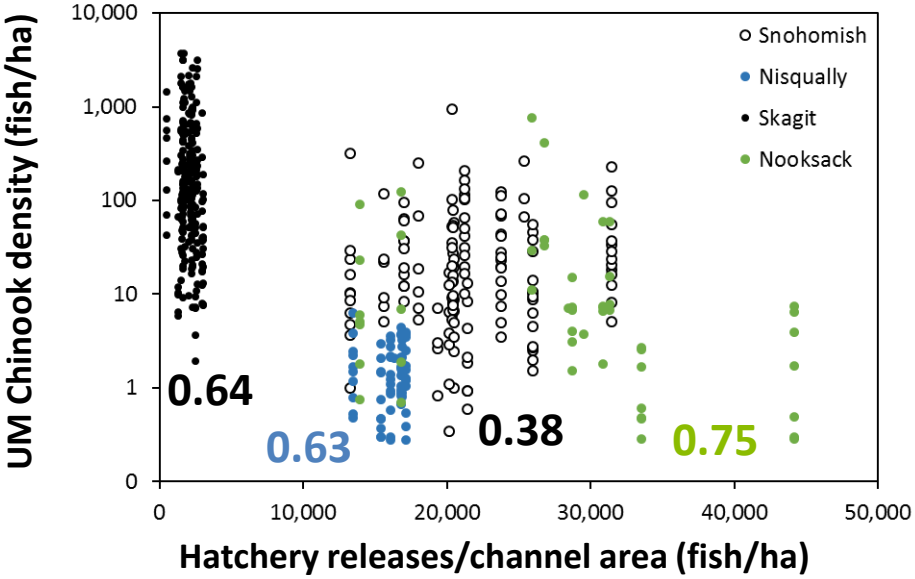


Other population traits exhibiting density dependence in the Skagit:

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

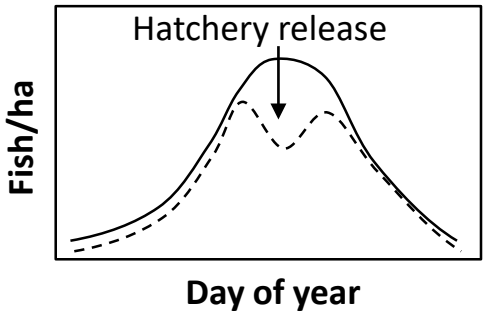
Potential interactions with hatchery fish





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?

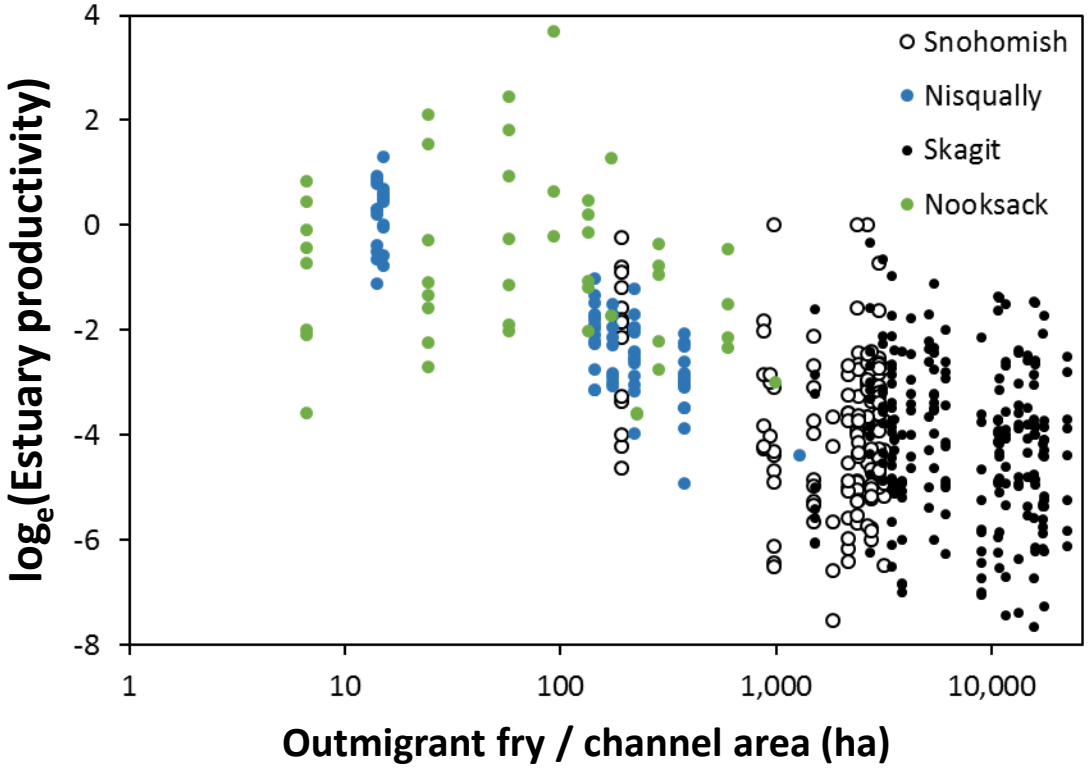
Remove landscape effects:

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

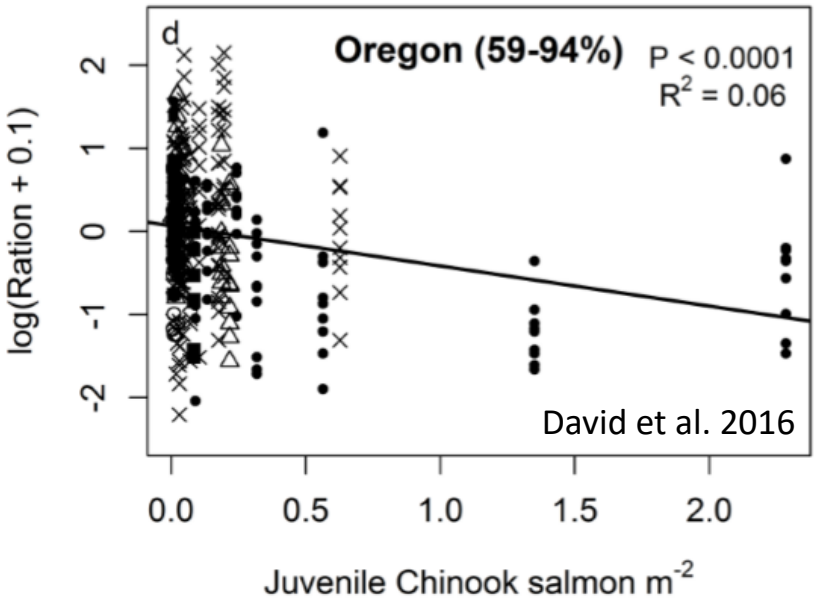
Density-dependent relationships

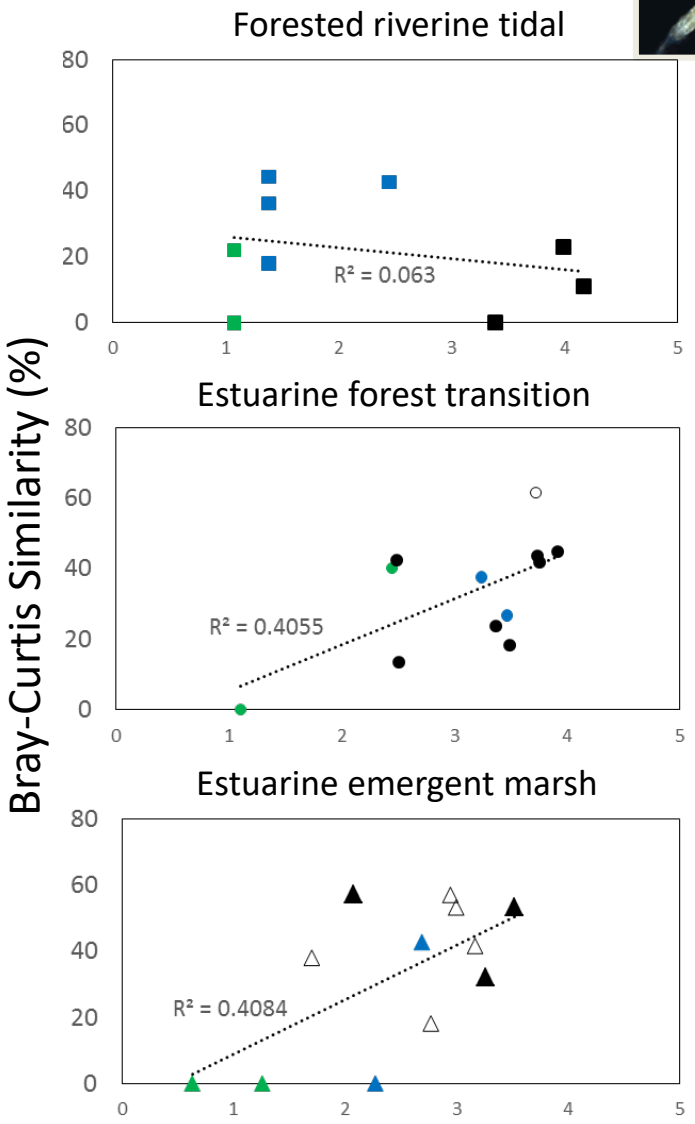


Competition for food?

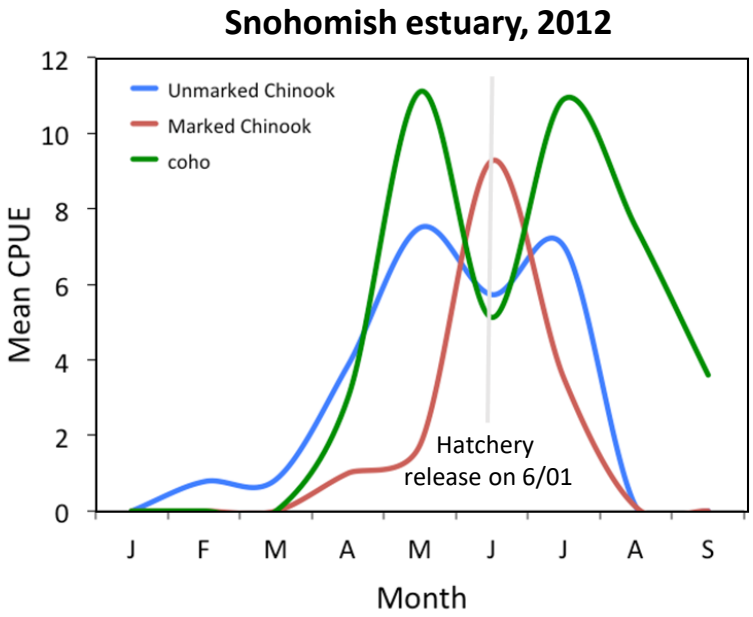
Prediction: if there is competition, fish should become less selective at higher fish densities

Test: Similarity of diet composition and prey availability





Potential interactions with hatchery fish

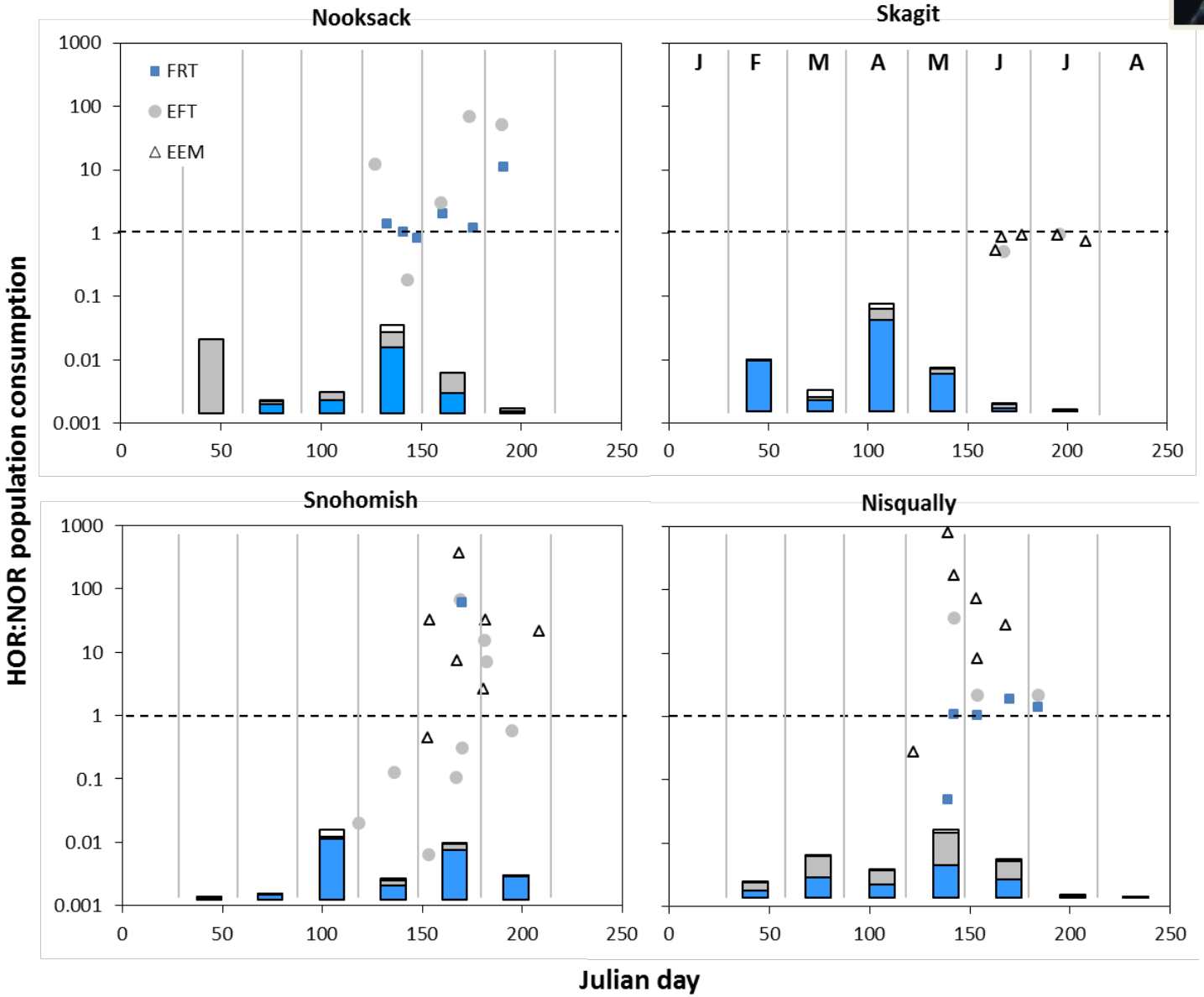


Possible causes

- "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