The Columbia River Estuary & Plume:

what they are, and why they matter to species recovery in the Columbia Basin

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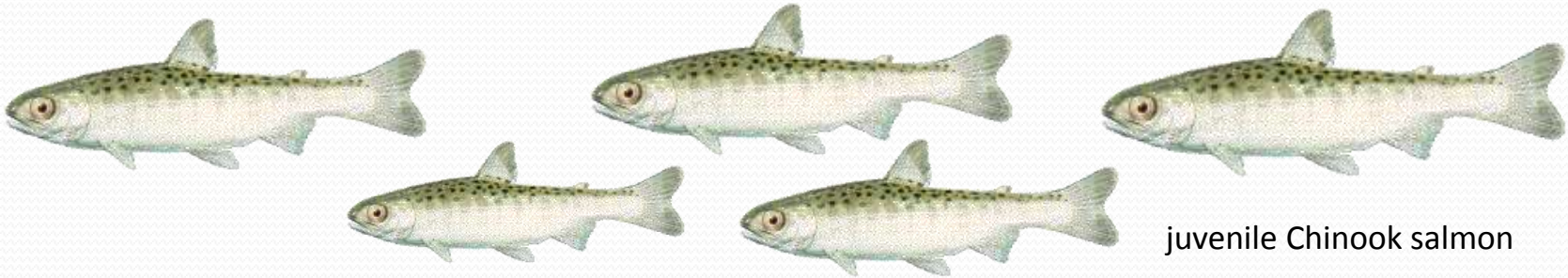
All anadromous fishes make critical transitions between freshwater and saltwater life phases

- Critical transitions take place in estuaries, river plumes
- Survival to spawning age requires fish make this transition at least twice
  - Seaward migration as larvae, fry, or juveniles
  - Spawning migration as adults
- Given the strong effects these transitions can have on population recruitment, species recovery should consider the role of estuary, plume conditions

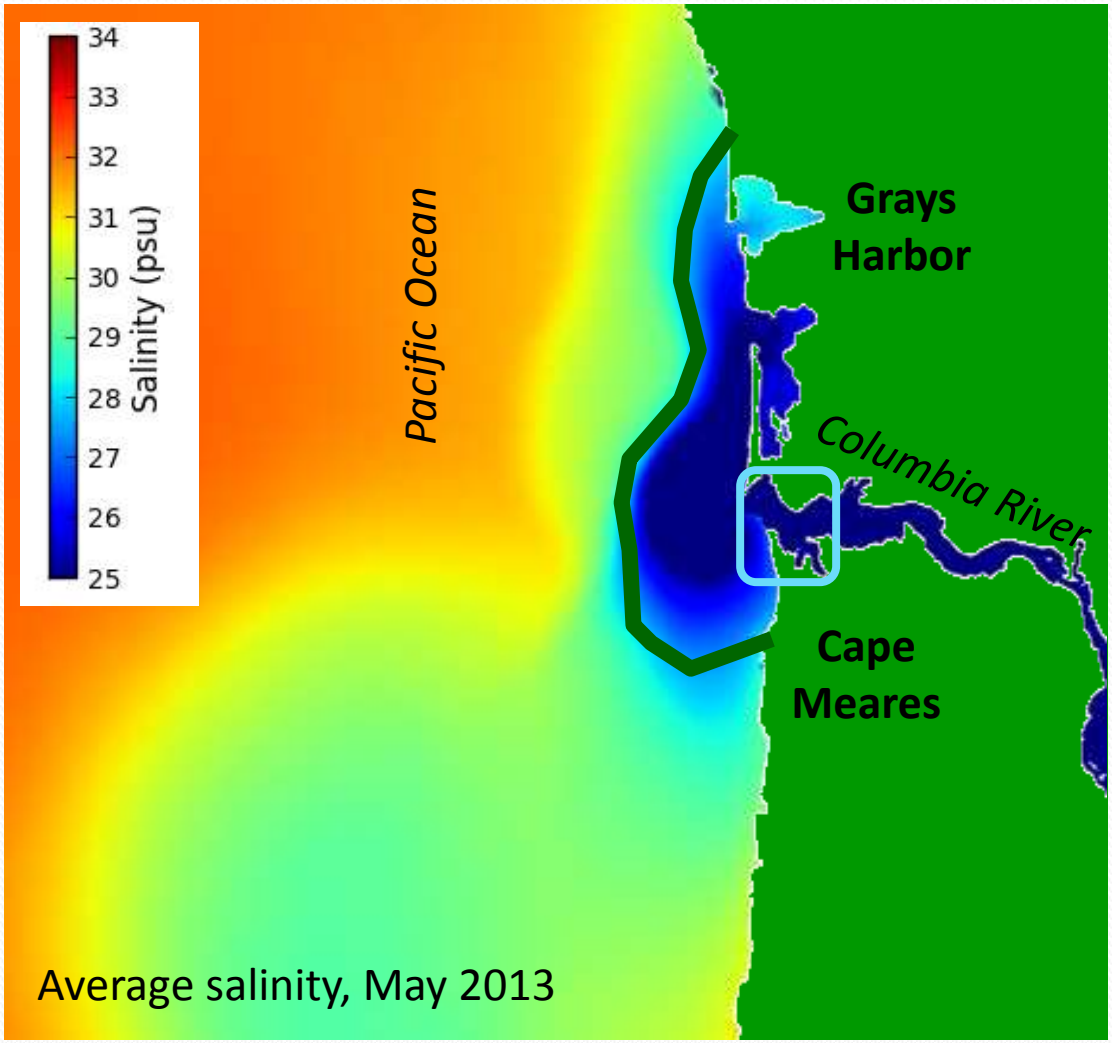


juvenile Chinook salmon

Part 1 – What are the estuary and plume?

- Basic understanding of plume structure – sketch in on a cocktail napkin
- Recognize it when you see it

Estuary, plume as freshwater/saltwater transition zones



The estuary (river): portion of the river where ocean water with salinity >1 psu often occurs on a daily basis (rkm 0 – rkm 45)

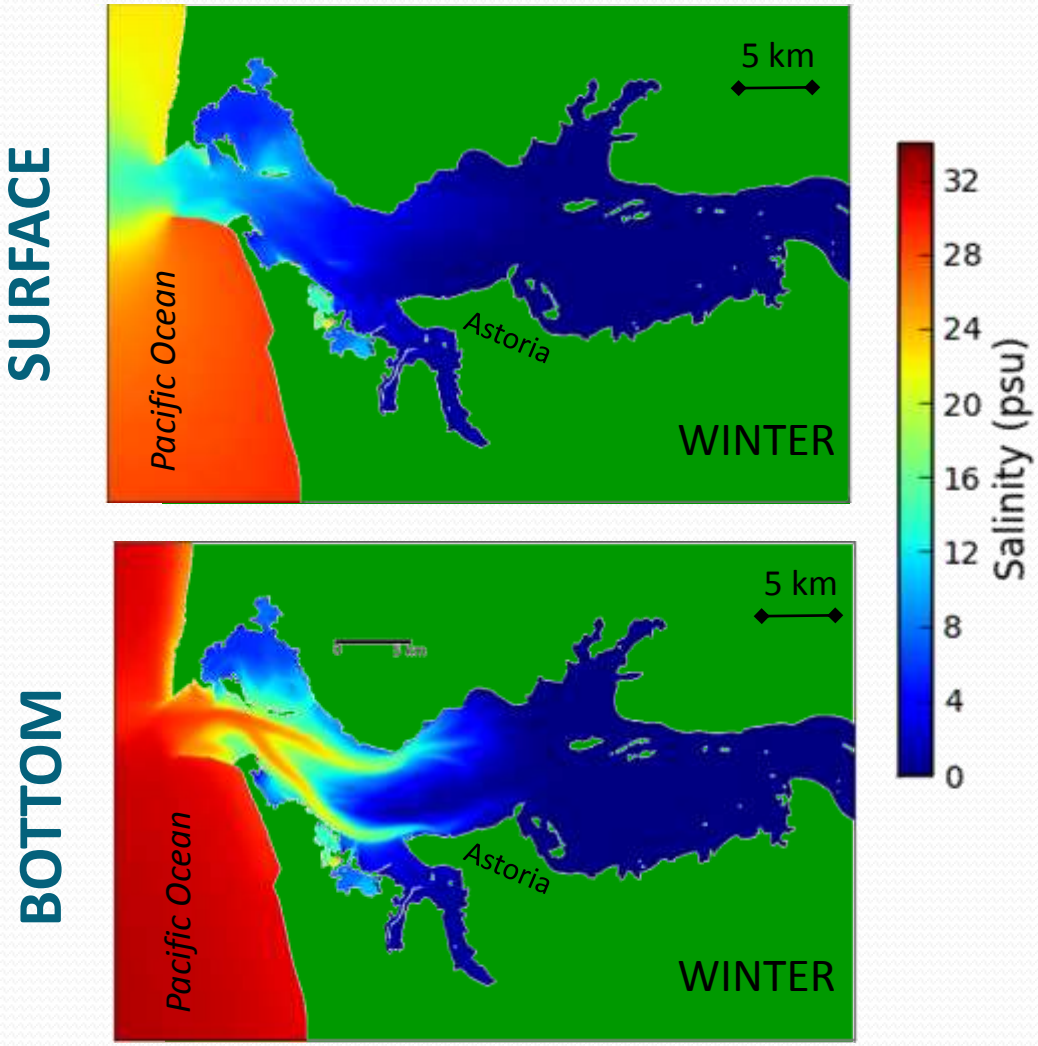
The plume (ocean): highly dynamic inshore zone where near-surface salinity varies between 5-28 psu on a daily basis due to river discharge (0-75 km offshore of river mouth)

- **Pacific Ocean**
- **Plume**
- **Estuary**
- **Tidal freshwater**

Model images courtesy www.stccmop.org

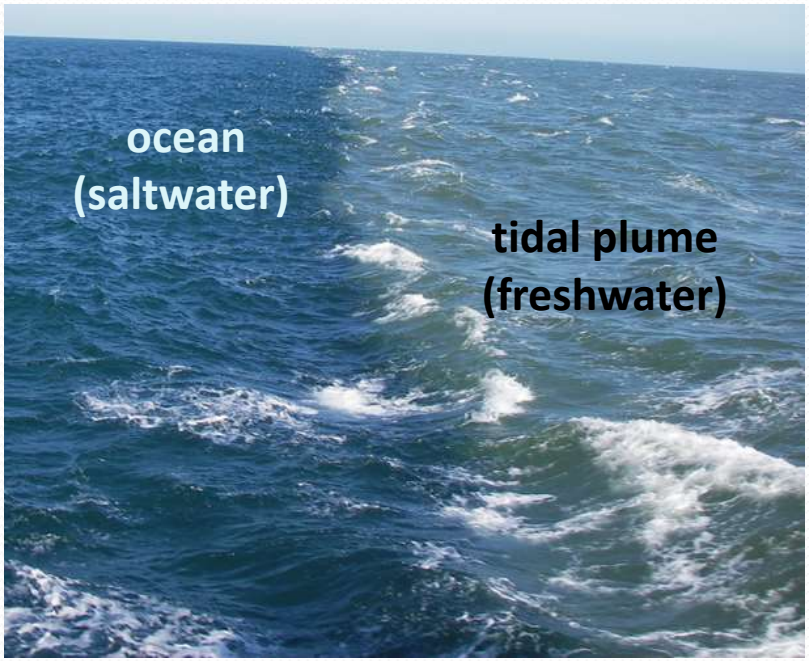
Salinity, temperature, other properties vary in space and time

- Two-layer system
  - Freshwater on top
  - Saltwater on bottom
- This matters to fish, other organisms with temperature, salinity preferences



Model images courtesy www.stccmop.org

Estuary, plume have real, visible features - not just esoteric properties of computer models



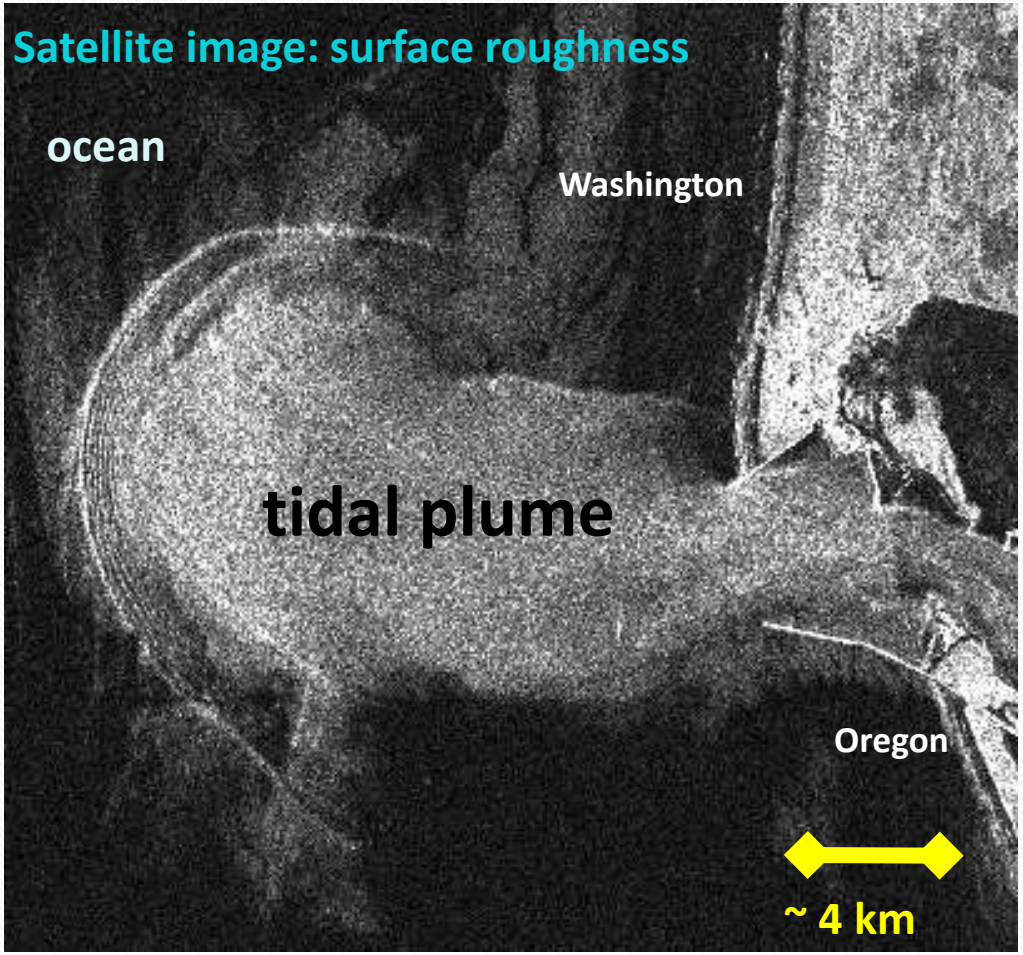
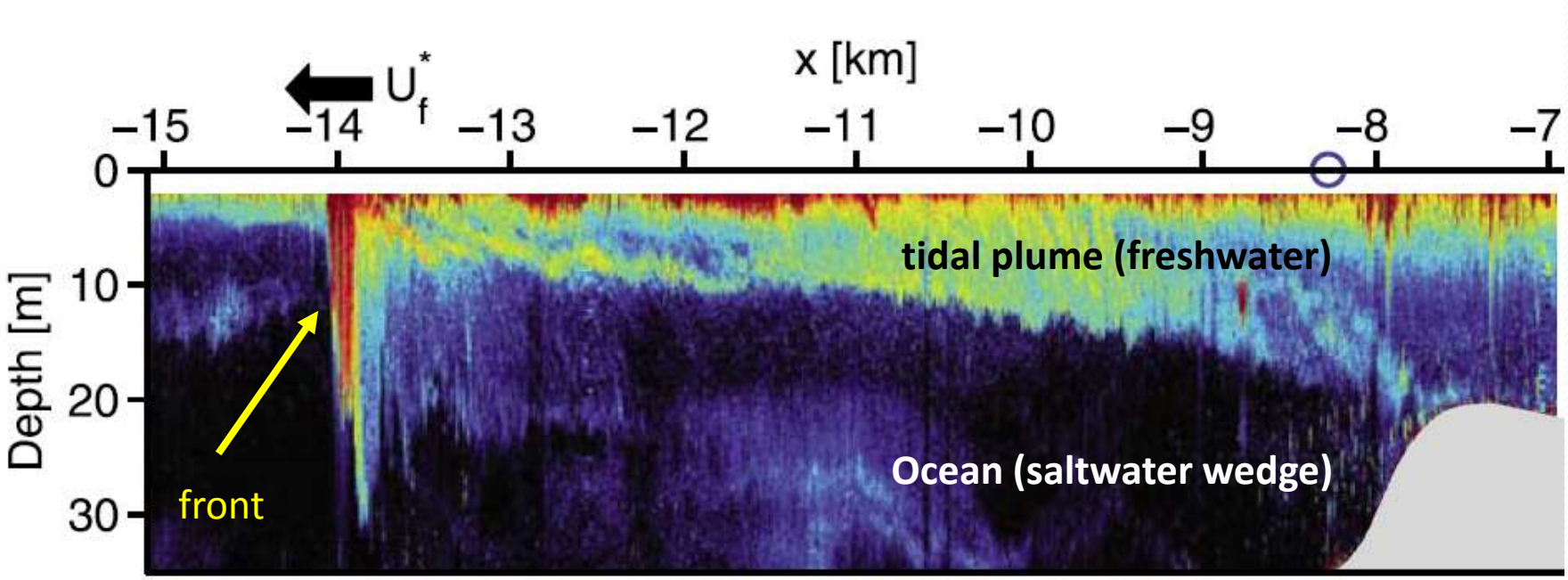


Photo J. Zamon; satellite imagery courtesy of NASA

Profile of Columbia River plume showing two-layer system

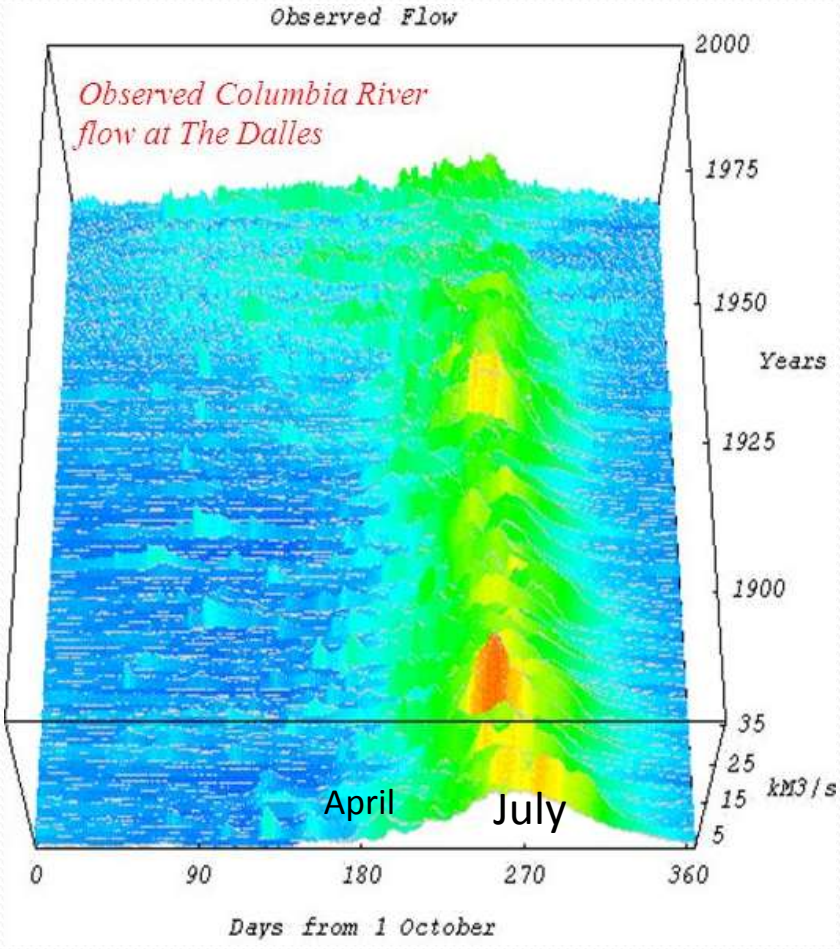


120 kHz acoustic reflection
Ebb tide, 08 Aug 2005

Kichler & Nash 2010 JGR

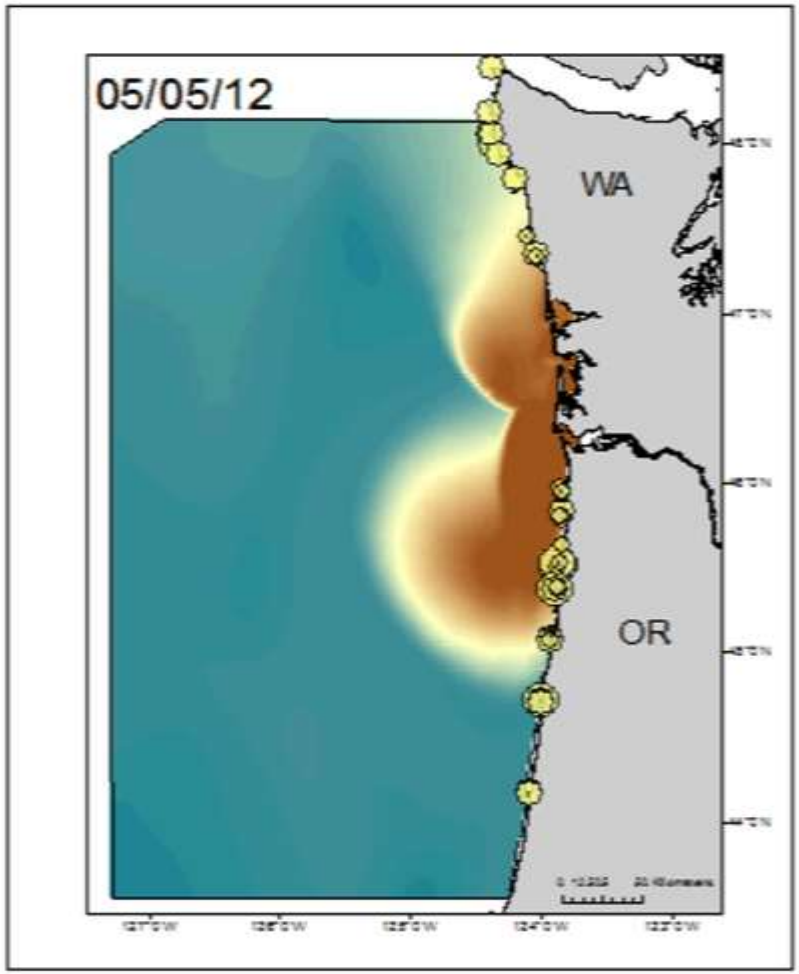
Major factors affecting estuary/plume dynamics

- River flow
  - Hydropower operation
  - Precipitation/snow melt
- Ocean tides
  - New volumes of freshwater discharged into ocean every ~12 hrs on the ebb tide
  - New volumes of saltwater enter the estuary every ~12 hrs on the flood tide
- Wind direction, strength
  - Direction pushes buoyant surface water around
  - Strength affects mixing time of freshwater plume into surrounding ocean waters



Columbia hydrograph courtesy of D. Jay

Estuary, plume are dynamic – they never sit still



Animation courtesy of www.stccmop.org

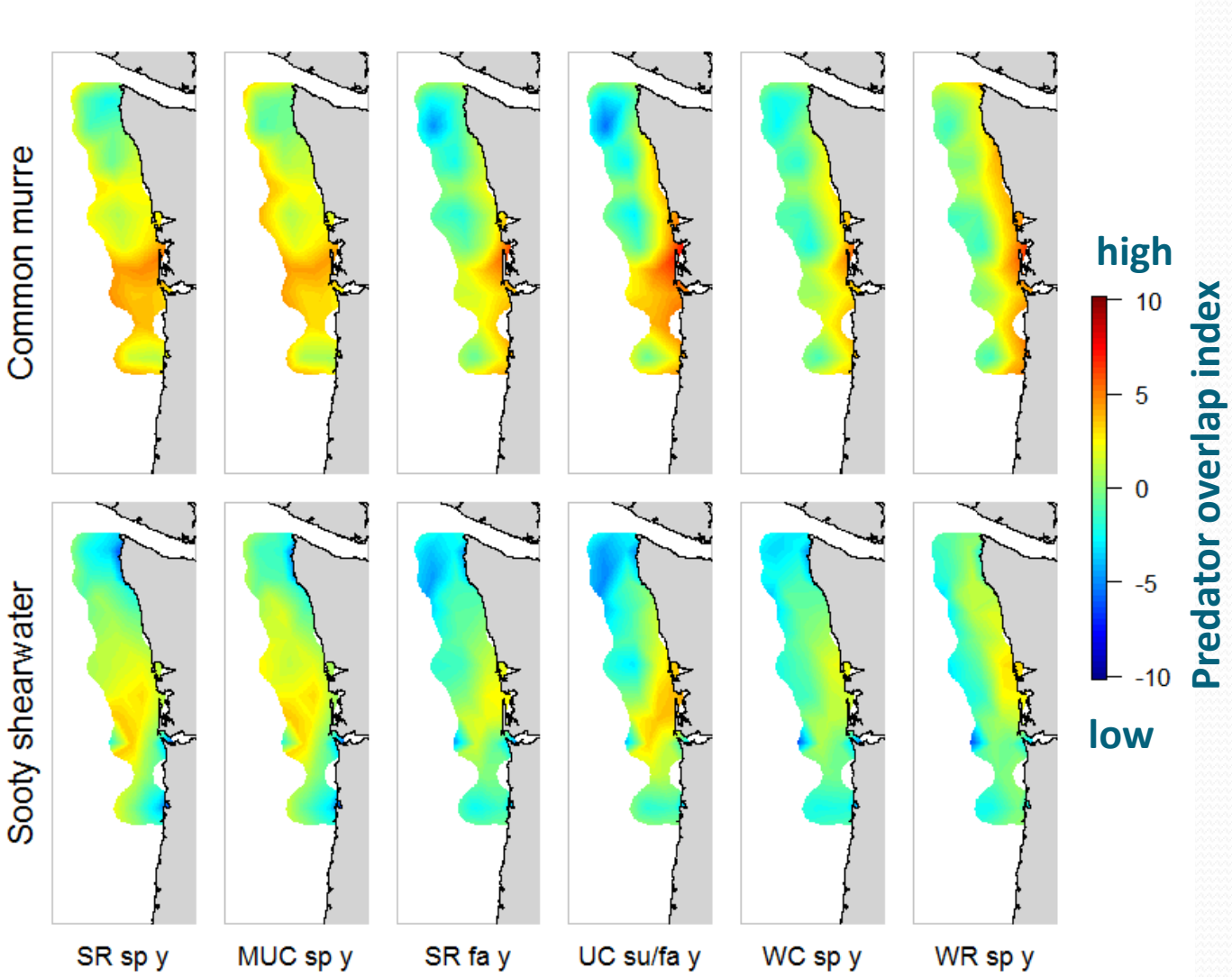
Part 2 - Why do the estuary & plume matter to Columbia Basin species recovery?

- Three examples of ongoing work
- Think about how estuary/plume might affect *your* recovery efforts

Three examples of ongoing research into plume/estuary effects on anadromous ESA-listed species

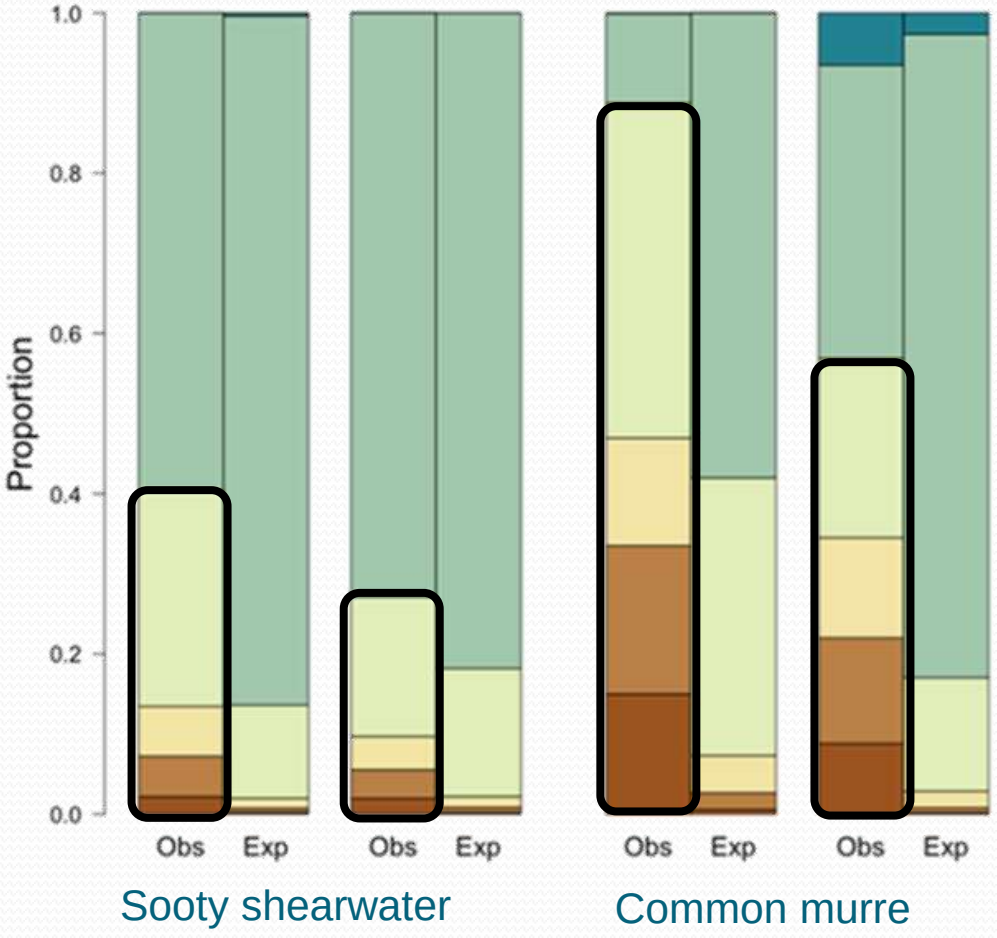
- Early marine survival of juvenile Chinook salmon
- Early marine survival of eulachon larvae
- Estuary survival of adult Chinook salmon and run timing of eulachon

Example 1 –
Early marine survival of Chinook juvenile salmon



Zamon et al. in prep

Predator preference for plume habitat affects predation risk

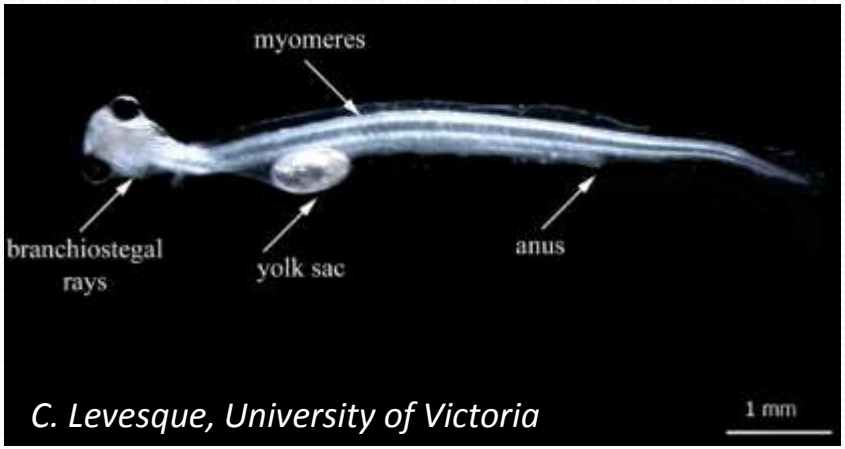


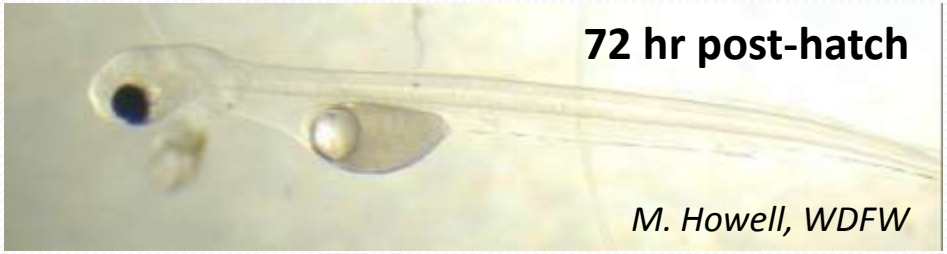
- Compare observed predator locations w/proportion of habitat available
- Significant preference for plume salinities ≤31: goodness-of-fit test, $p < 0.001$ in all years
- Strong evidence birds track plume location, size

Observed vs. expected plume occupancy

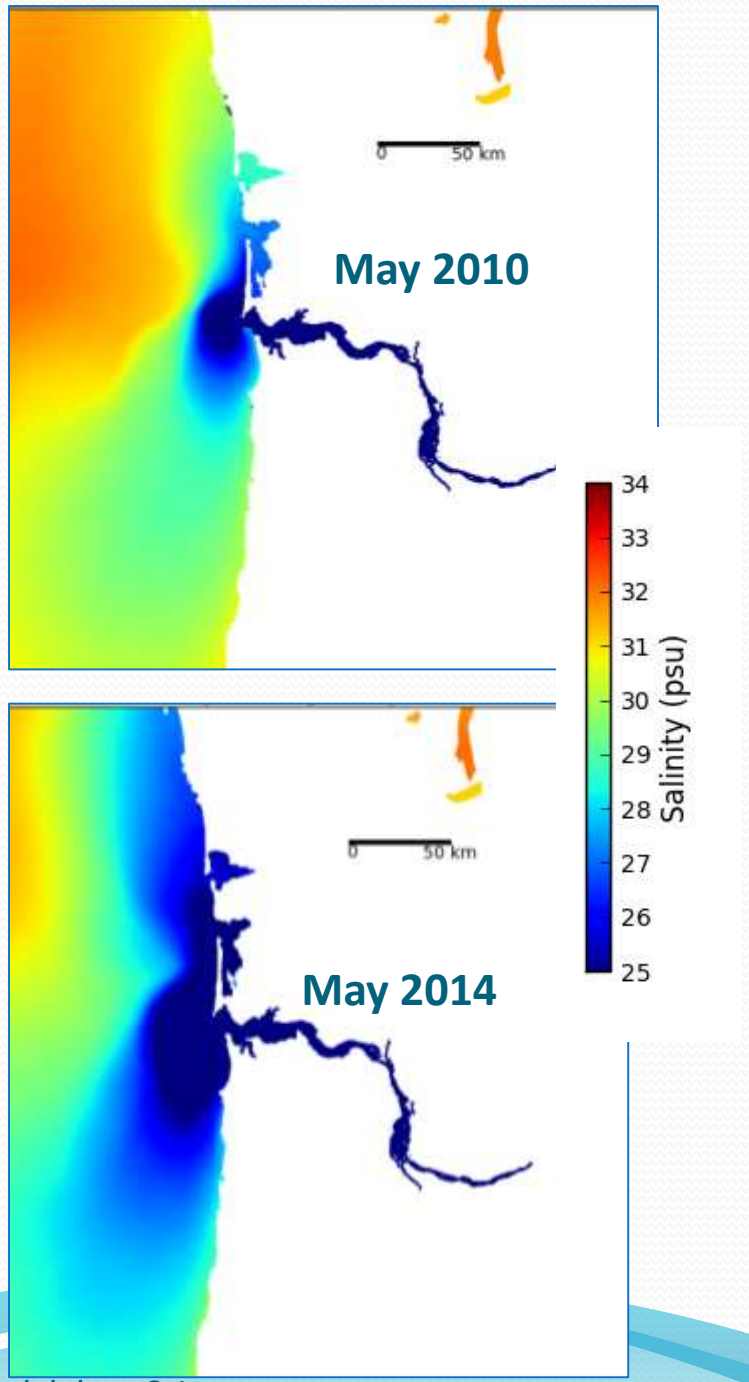
Phillips et al. 2018 MEPS

Example 2 – Early marine survival of larval eulachon





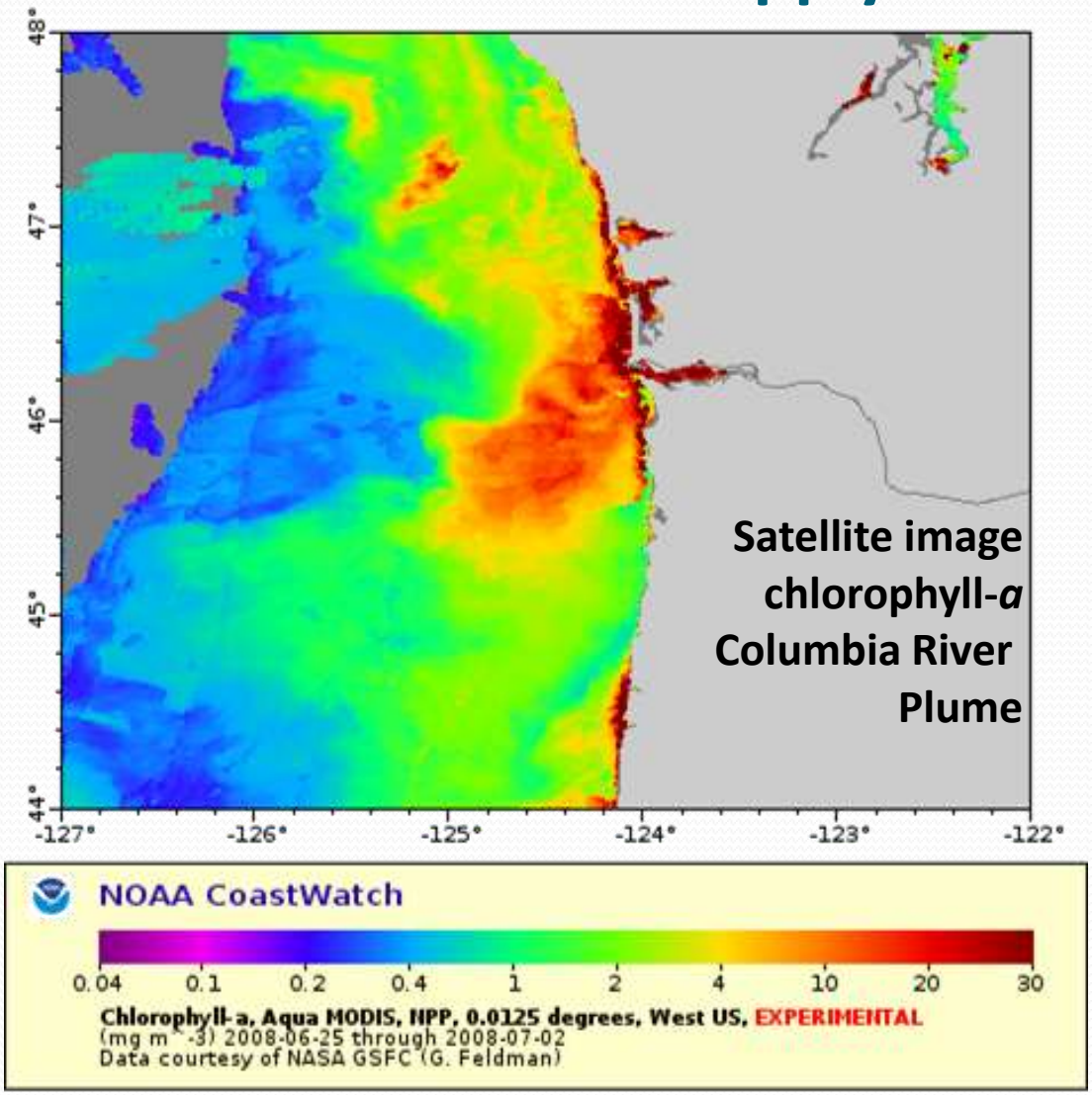
- 4-9 mm yolk-sac larvae transported passively seaward 50-200+ km
- Yolk sac absorbed in ~21 days at 11.6°C



Langness, pers. comm.; model data & images courtesy www.stccmop.org

Estuary & plume conditions affect match-mismatch of larvae with food supply

- Elevated chl-*a*, plankton abundance in plume (e.g. *Morgan et al. 2005 MEPS, Peterson & Peterson JGR)*
- Variation in transport time, estuary/plume conditions encountered after yolk-sac absorption critical to survival at first-feeding

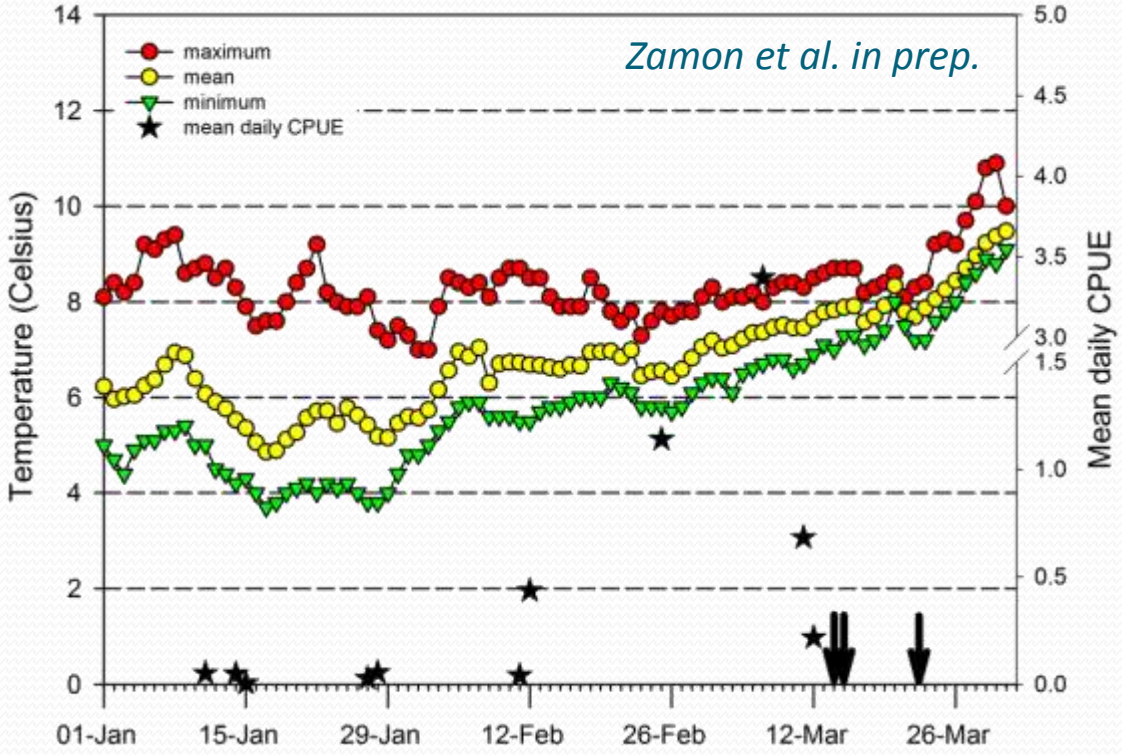


Example 3 – Estuary survival of returning Chinook salmon

- Timing of peak eulachon spawning affected by estuary conditions
- Sea lions eat eulachon, often follow spawning eulachon upstream

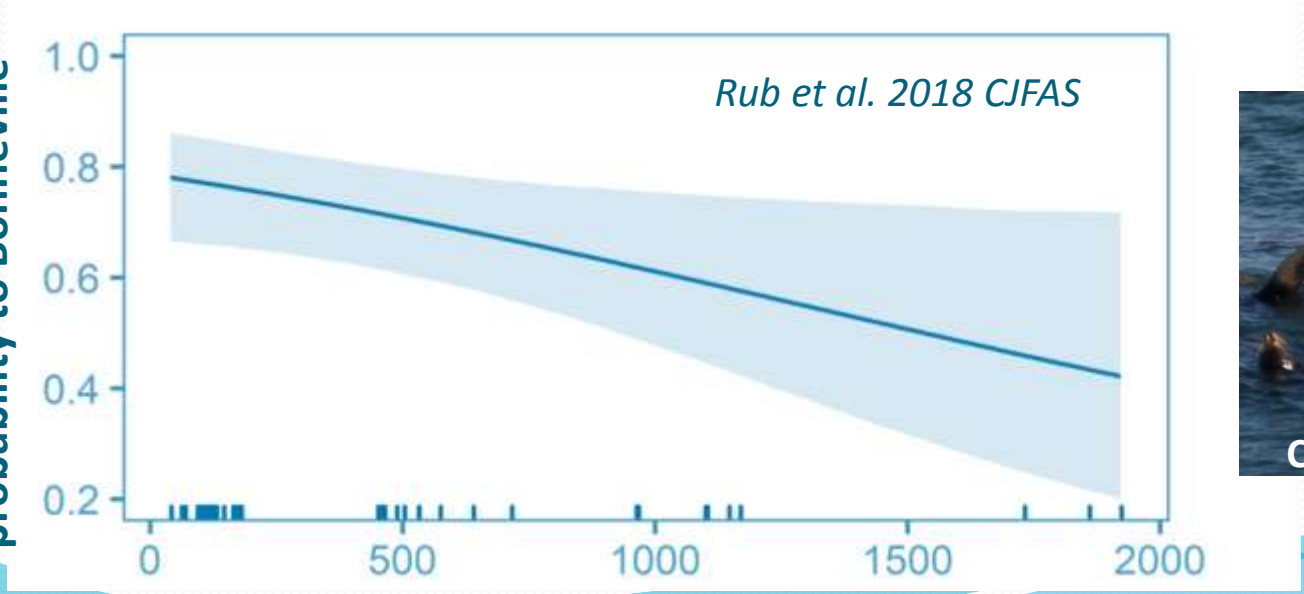

Pacific eulachon

Estuary temperature vs. eulachon catch



Eulachon run timing/strength affects estuary pinniped predation

- Sea lion abundance highly correlated with annual, weekly eulachon abundance
- Adult salmon survival in the estuary decreases as sea lion abundance increases



Many other managed species affected by estuary/plume

- Other anadromous fishes
  - Pacific lamprey
  - White sturgeon
  - Green sturgeon

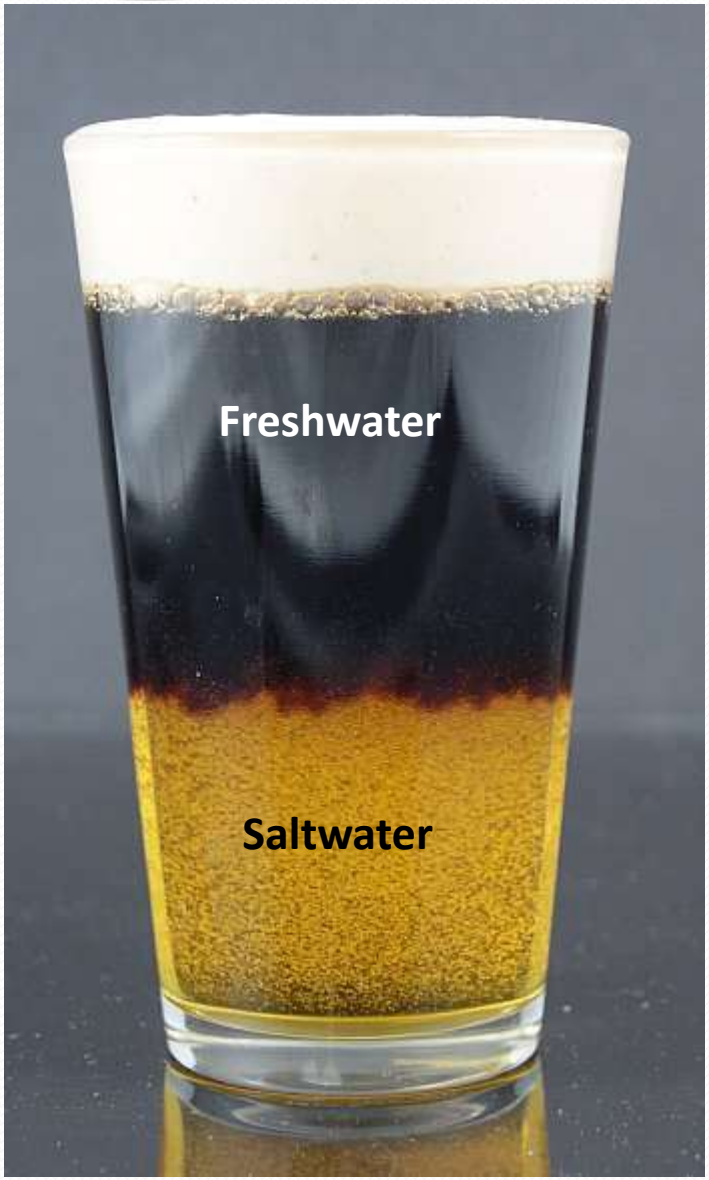

White sturgeon

- Estuary- or plume-dependent species
  - Flatfish
  - Dungeness crab
  - Northern anchovy
  - Pacific sardine
  - Double-crested cormorants
- Marine mammals, sea turtles
  - Killer whales
  - Leatherback turtles


Resident killer whales

Take-home message: Plume in a pint

- Three-dimensional, two-layer region where fluids from different sources interact
- Creates unique, dynamic ecological conditions that attract -- are critical to -- fish & wildlife during important transition events in their lives



Thank you!
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Other questions ? – feel free to contact me

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