

# Forecasting Sea Level and Climate Change Impacts to Large River Deltas in Puget Sound - "Estuarine Squeeze"

Eric Grossman

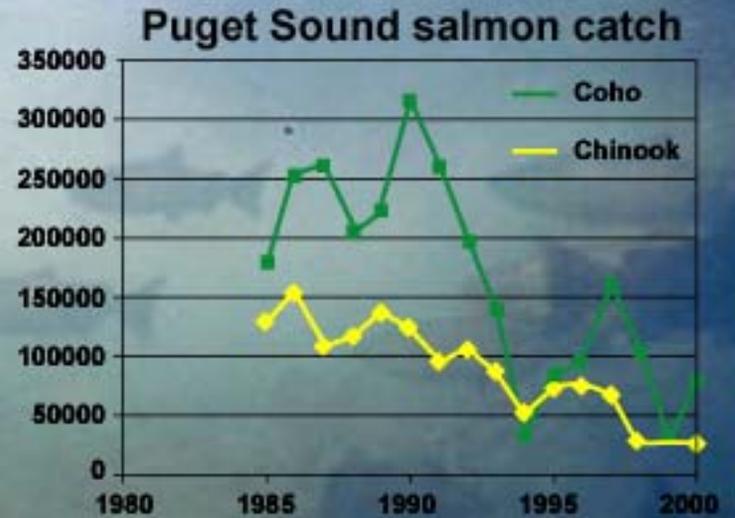
USGS Coastal and Marine Geology Program

*egrossman@usgs.gov*



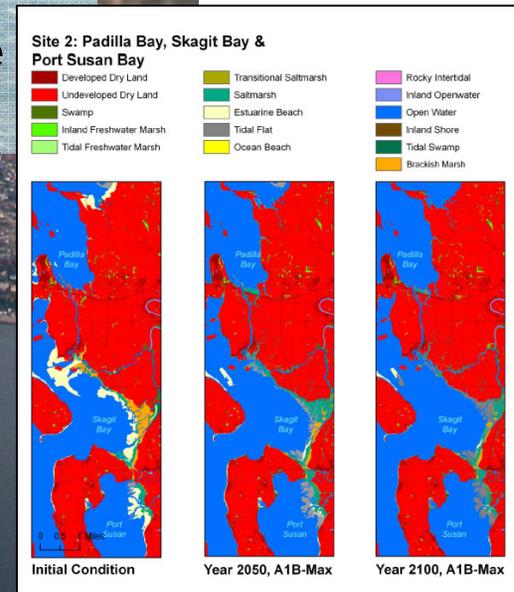
# Salmon Recovery

>80% loss of PS tidal habitat  
 - limiting *Chinook*/salmonids survival  
 Data gap nearshore habitat structure/function



Extensive habitat restoration planned  
 Climate/sea-level change expected  
 - lack predictions of complex/cumulative nearshore ecosystem responses

SKAGIT CHINOOK RECOVERY PLAN  
 2005



# CHIPS - Coastal Habitats in Puget Sound Project

## Interdisciplinary Studies to Support Restoration of Large River Deltas



### BIOLOGY

Steve Rubin  
 Reg Reisenbichler  
 Michael Hayes  
 Collin Smith  
 Kim Larsen

### GEOGRAPHY

Bill Labiosa

### GEOLOGY

Eric Grossman  
 Andrew Stevens  
 Bob Rosenbauer  
 Ralph Haugerud  
 Peter Swarzenski  
 Mary McGann

### WATER

Chris Curran  
 Mark Mastin  
 Ed Josberger  
 Mark Savoca  
 Tony Paulson



Greg Hood  
 Eric Beamer  
 Steve Hinton



Todd Mitchell  
 Charles O'Hara

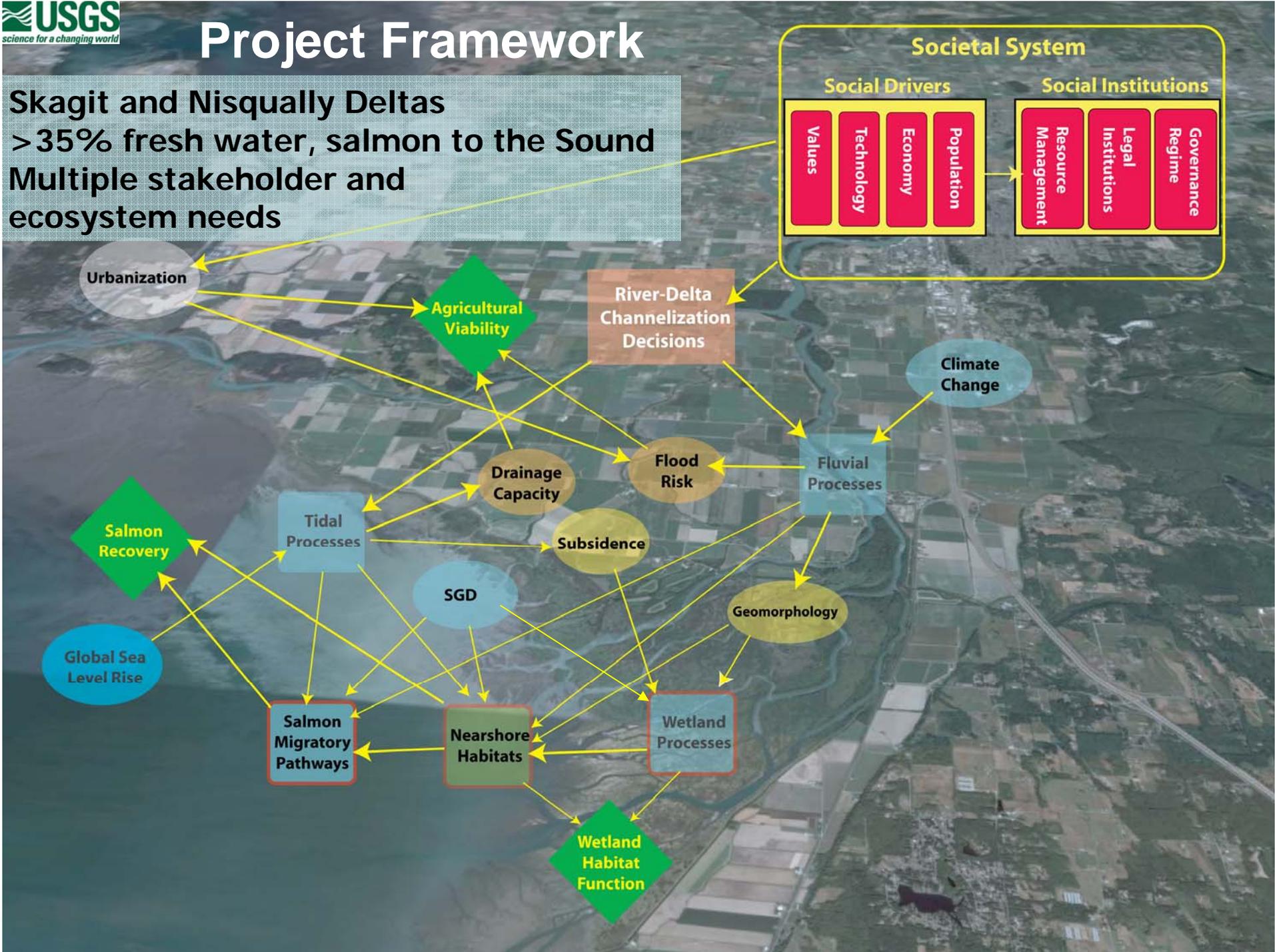


Northwest Fisheries  
 Science Center



# Project Framework

**Skagit and Nisqually Deltas**  
 > 35% fresh water, salmon to the Sound  
 Multiple stakeholder and ecosystem needs



# Talk Outline

Issues facing restoration of Puget Sound deltas

Highlights of years 1-3 Large River Deltas Study

Conceptual model of “Estuary Squeeze”

Climate Impacts Studies

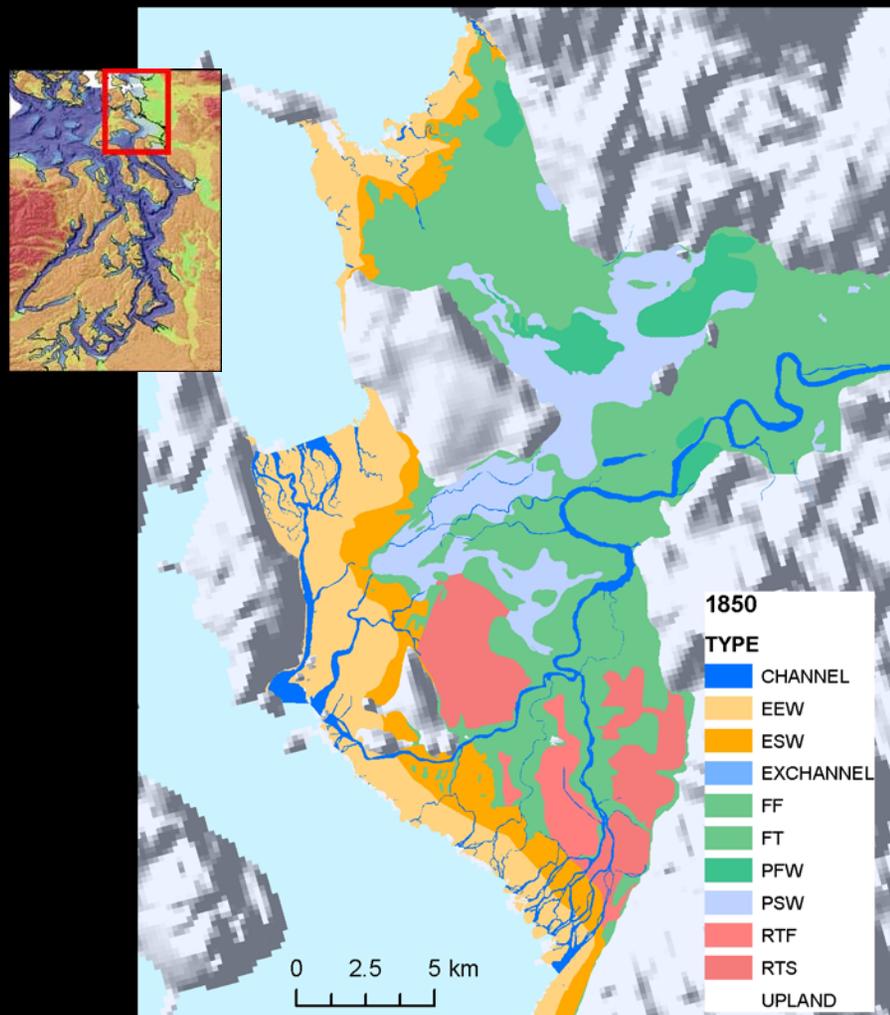
Fluvial inputs and estuarine responses

- Salmon habitat connectivity
- Structure and recent change to nearshore habitats
- Geomorphic changes affecting restoration

Future Directions

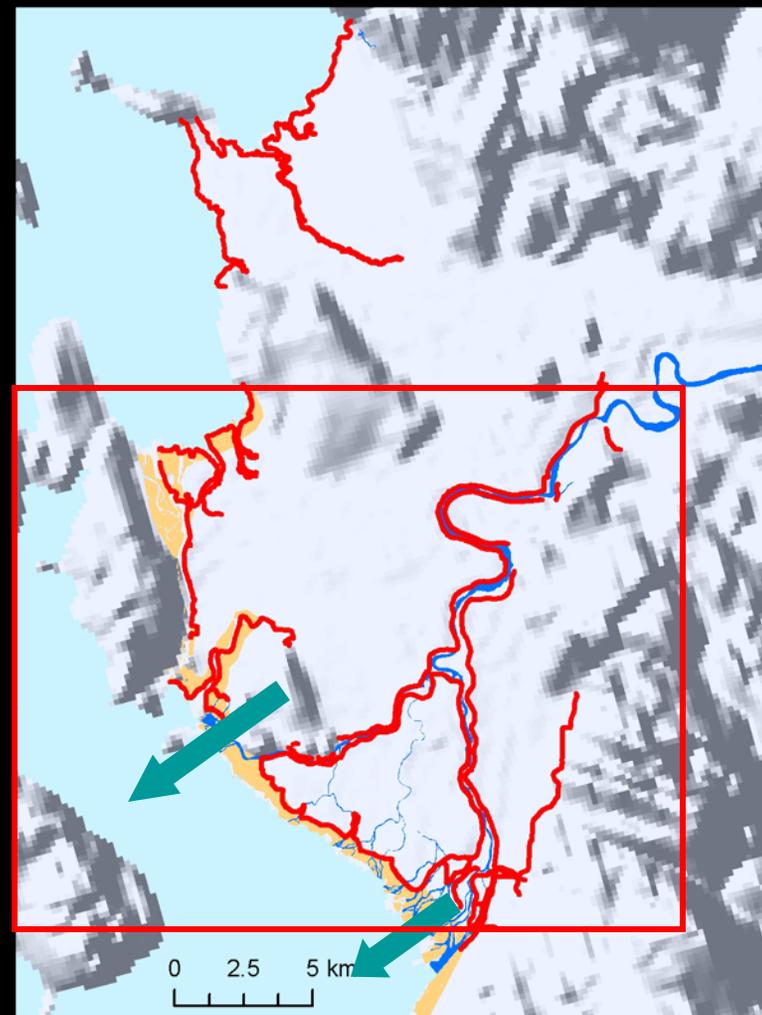
# Principal Issues

## Habitat Loss



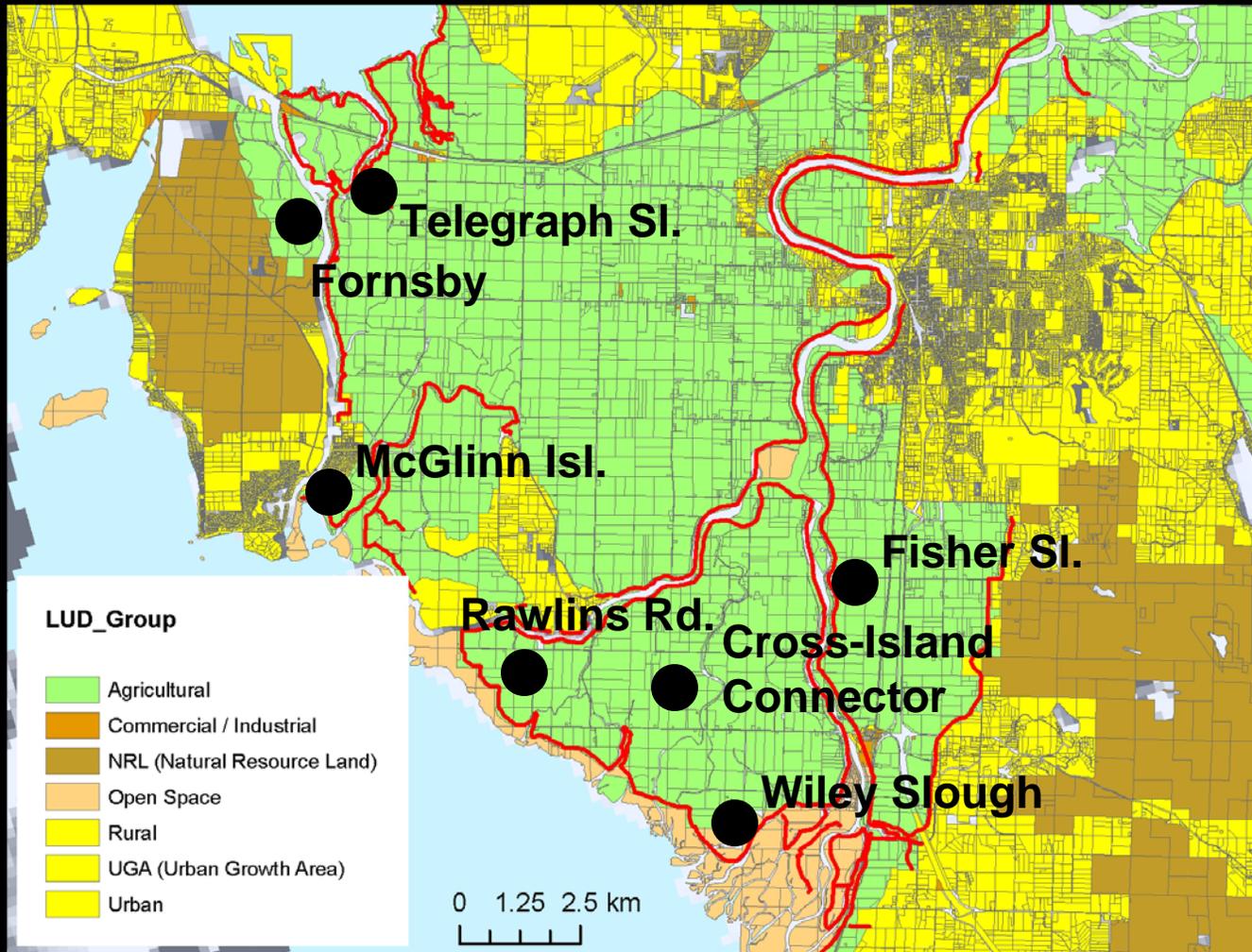
*After Collins 2000*

Focused flow and freshwater, higher velocities into estuary altered sediment pathways



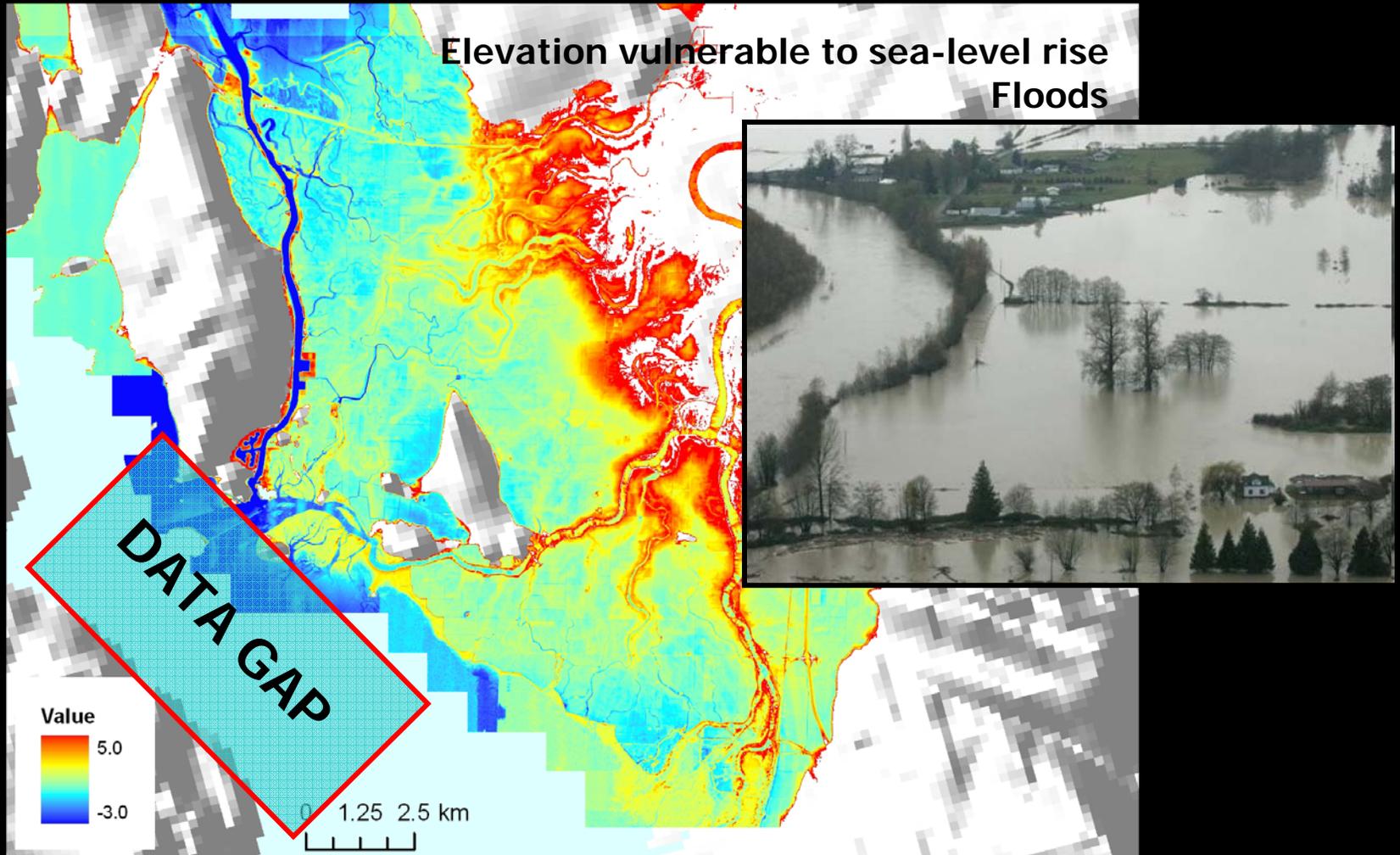
# Restoration Challenges: competing interests

Habitat restoration intersecting agricultural/urban interests  
Need decision support to balance needs of salmon recovery, bountiful agriculture, urbanization, and flood hazard mitigation



# Decision Support: complex feedbacks

Need ability to forecast changes to estuarine quality, geomorphology, flood hazards and costs

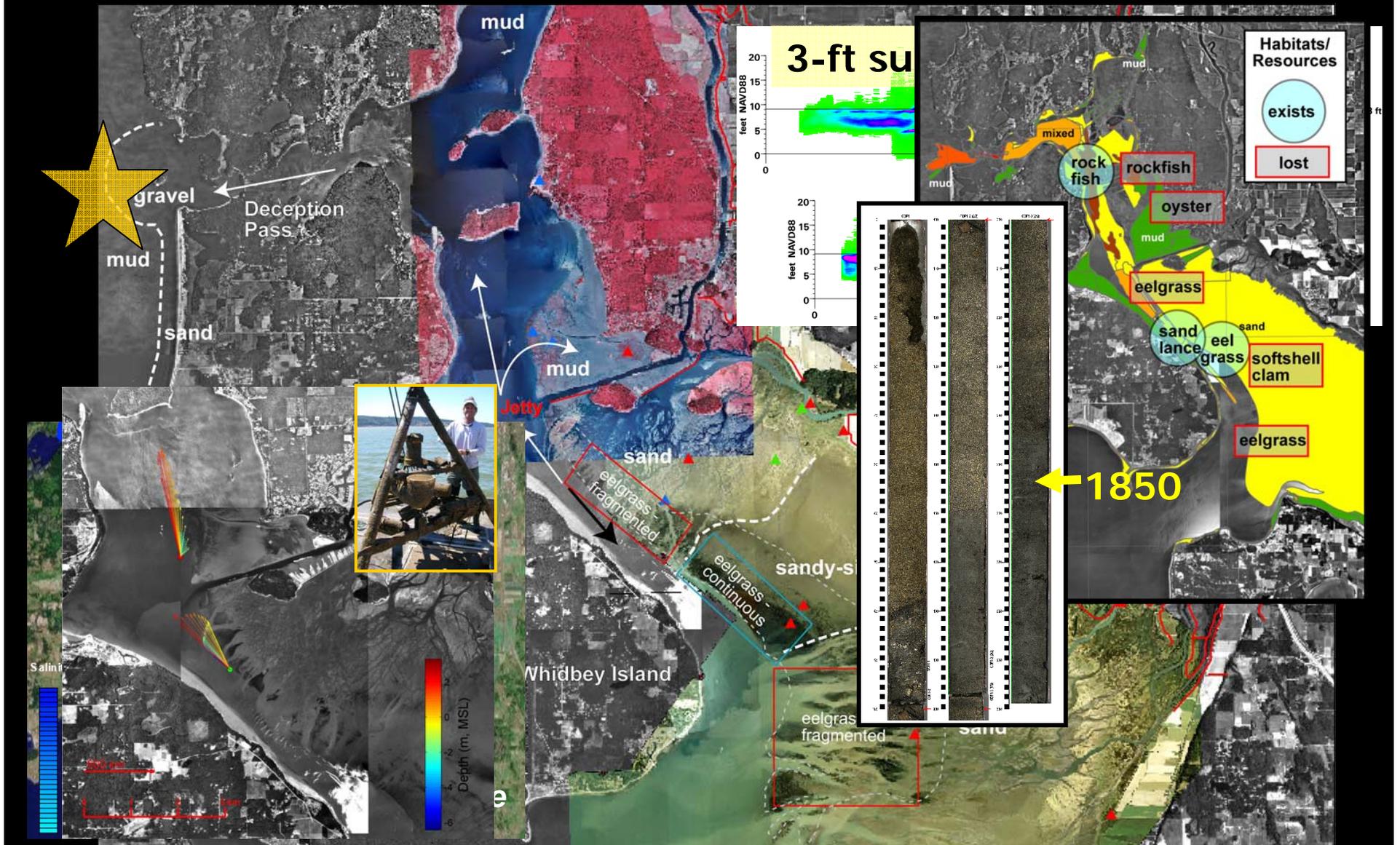


# Highlights: Nearshore "downstream" ecosystem responses

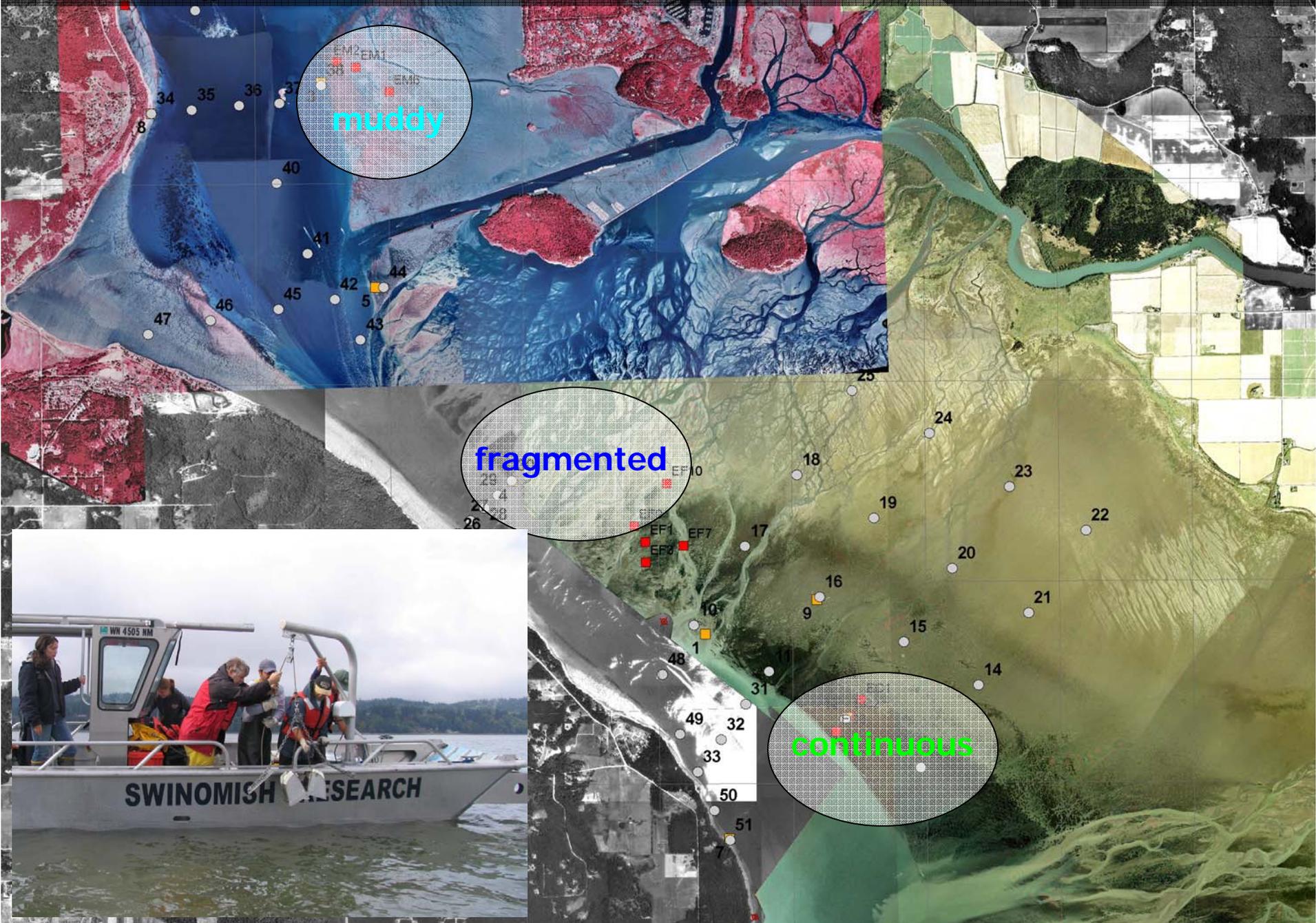
Focused FW mixing, restricted alongshore habitat connectivity

Sediment bypassing/partitioning, delta "footprint" outside Deception pass

Fragmented benthic habitats and lost resources since 1850

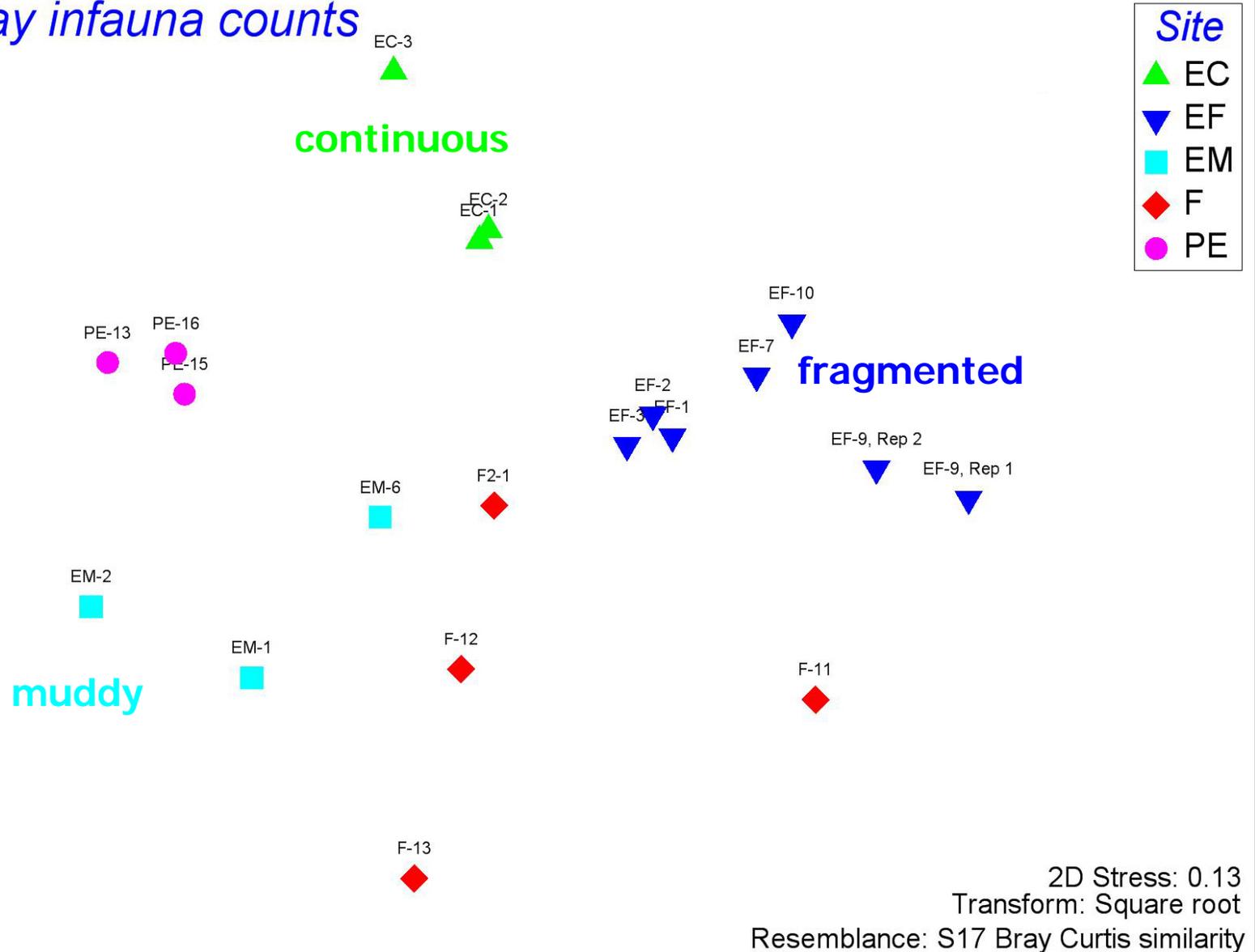


# Importance of eelgrass, ecosystem services, vulnerability

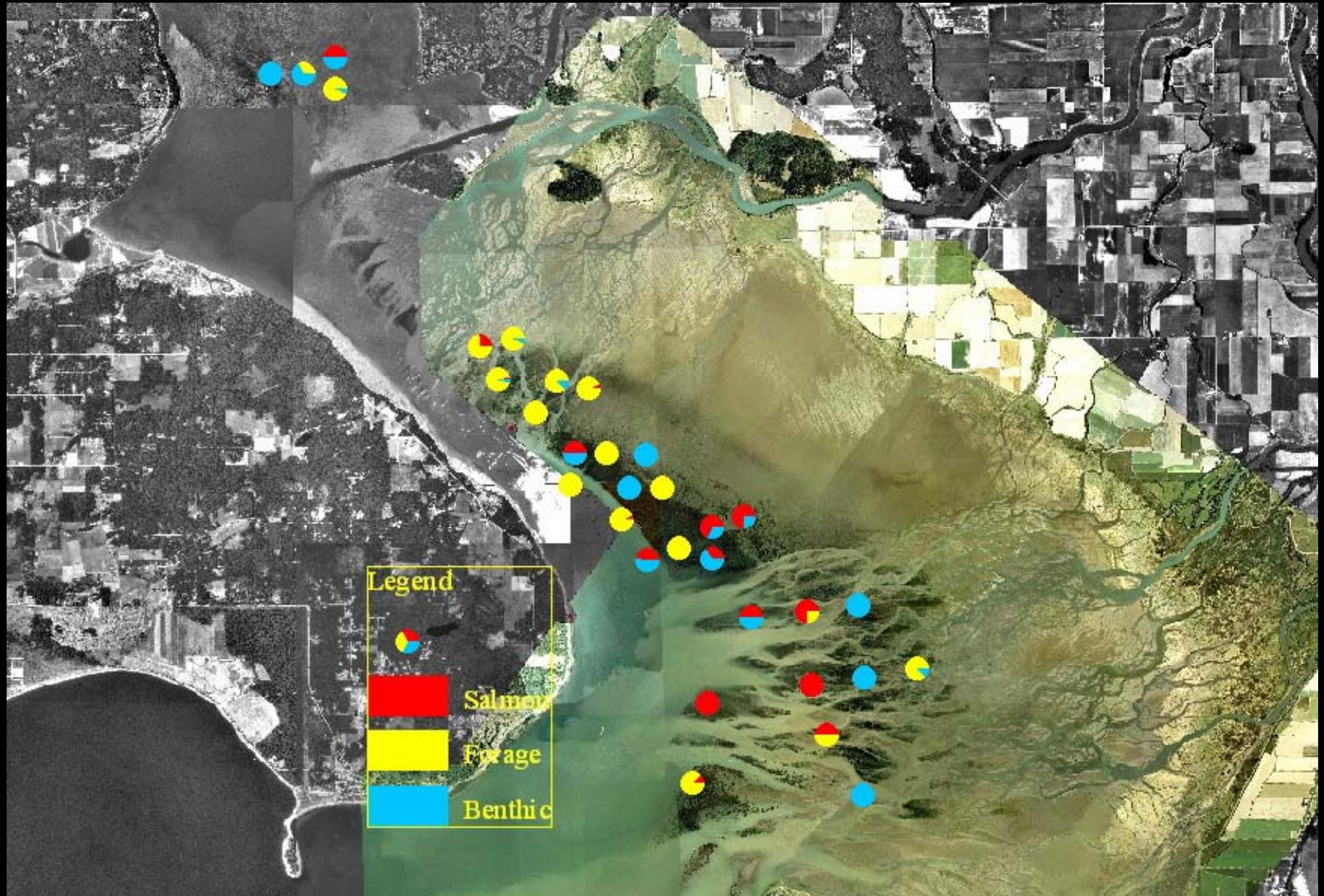


# Distinct community structure, trophic relationships

## Skagit Bay infauna counts



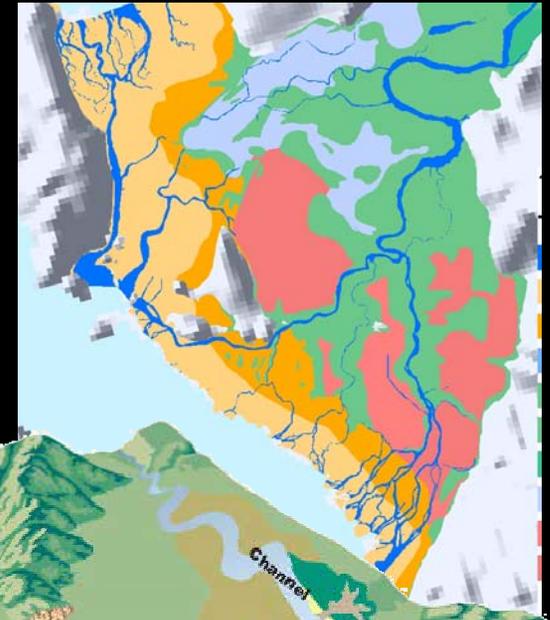
# Distinct patterns of fish use of eelgrass



# Estuary Squeeze between sea-level rise and urbanization

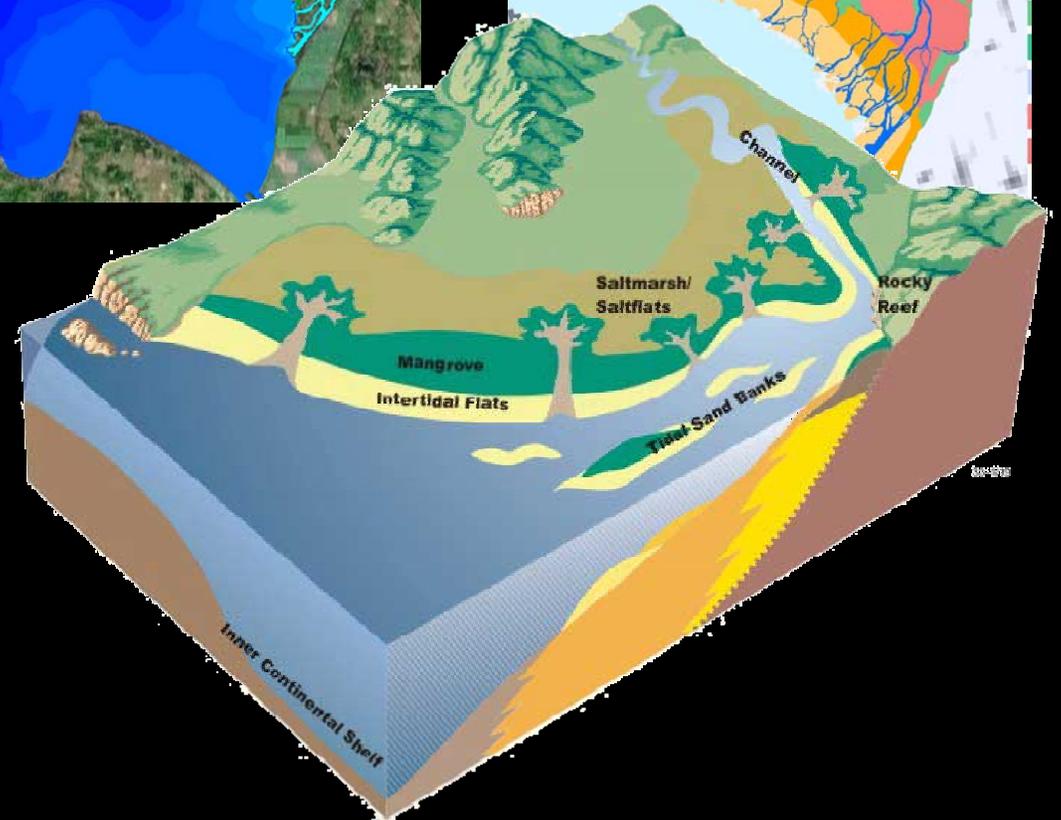
## Lateral

Transgression  
Backwater  
ETZ landward  
Migratory paths  
truncated



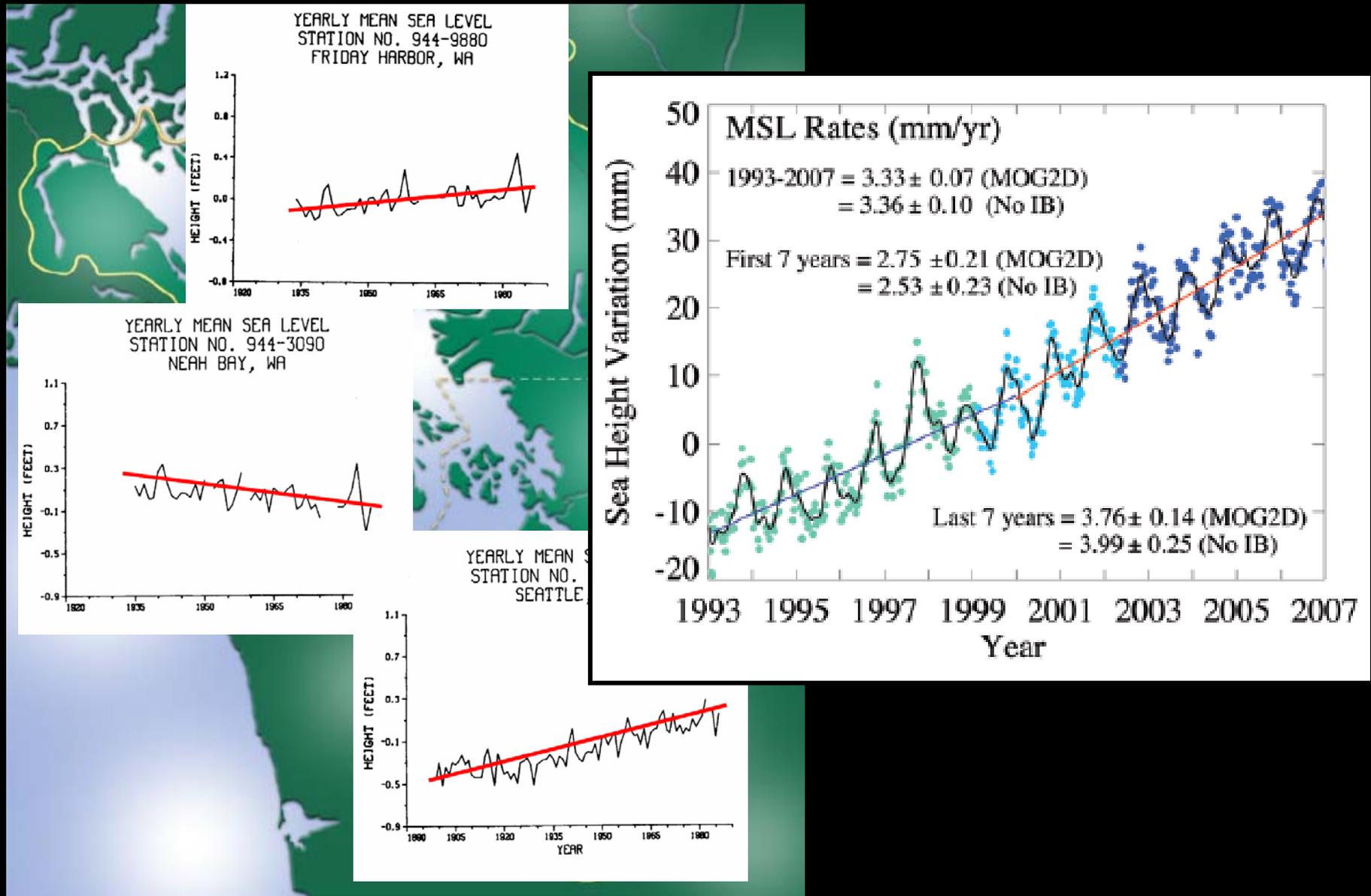
## Vertical

Reduced plume thickness  
Increased salinity wedge



# Puget Sound Sea Level Rise

## Gradient in relative rise due to subsidence



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Fluvial inputs and estuarine responses

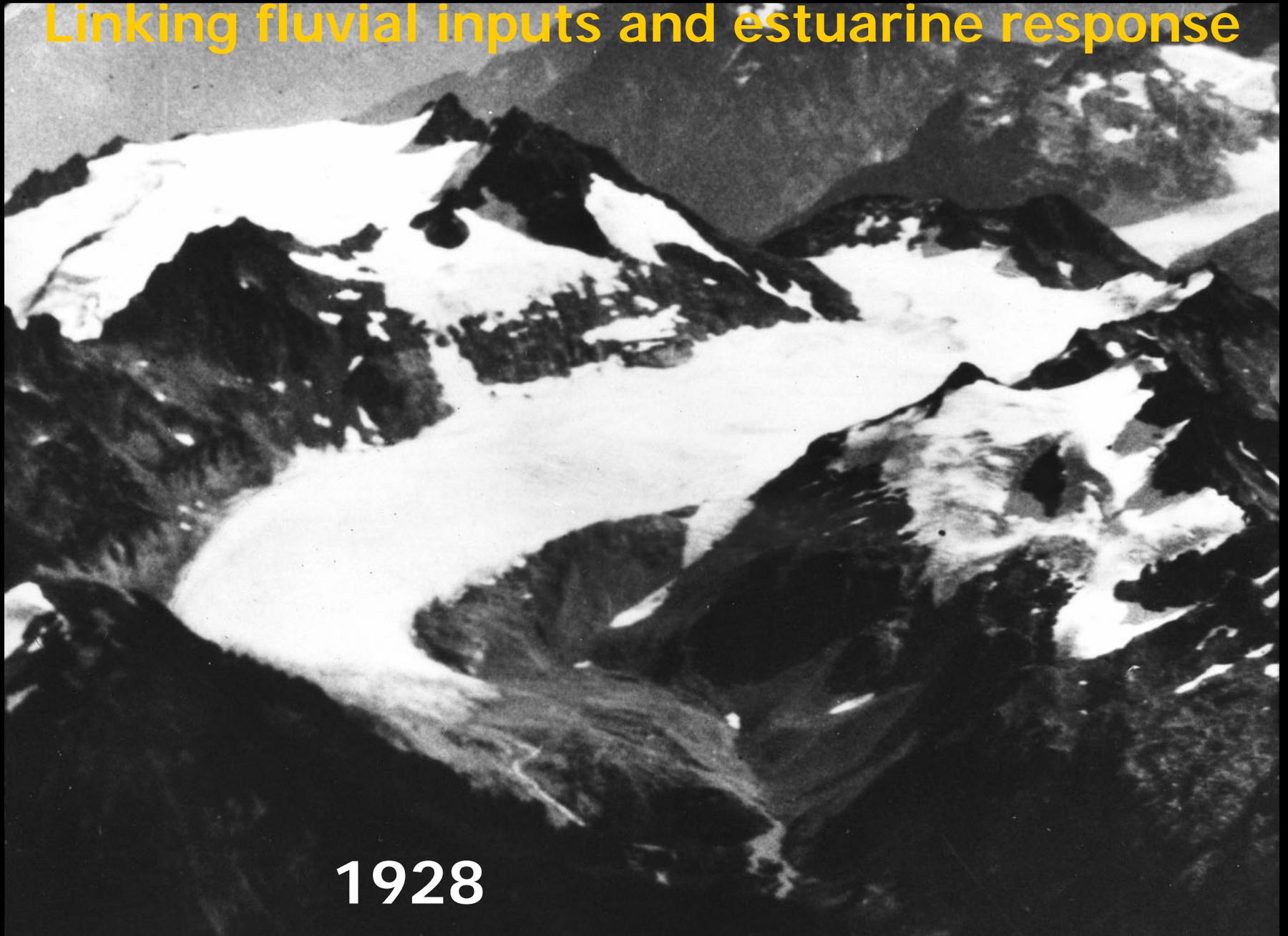
Salmon habitat connectivity

Structure and recent change to nearshore habitats

Geomorphic changes affecting restoration

Future Directions

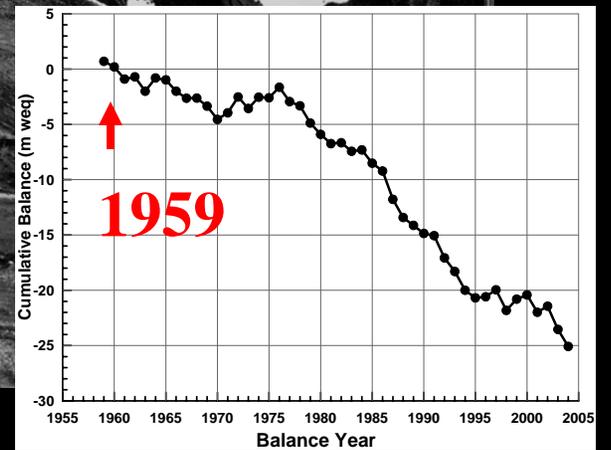
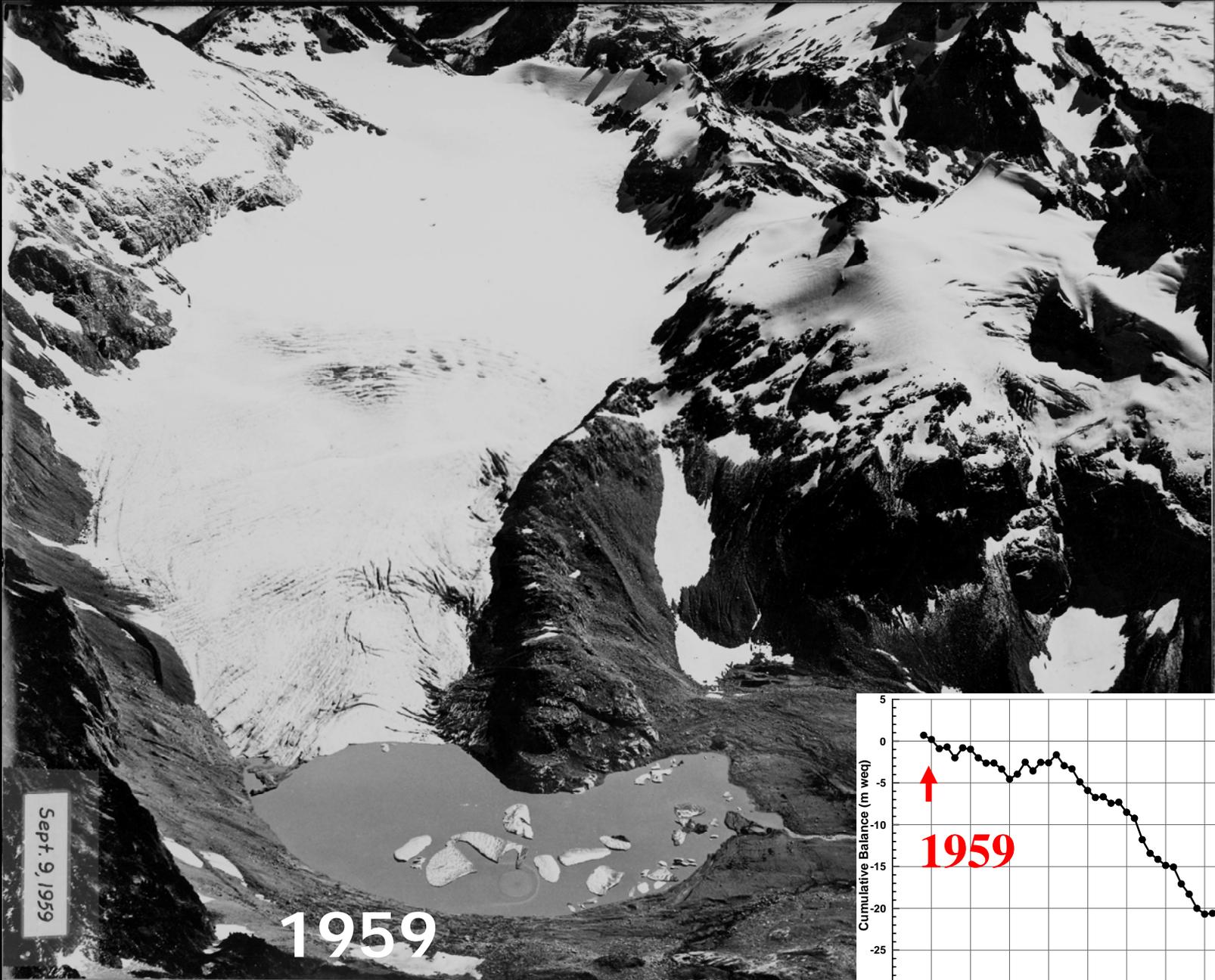
Linking fluvial inputs and estuarine response

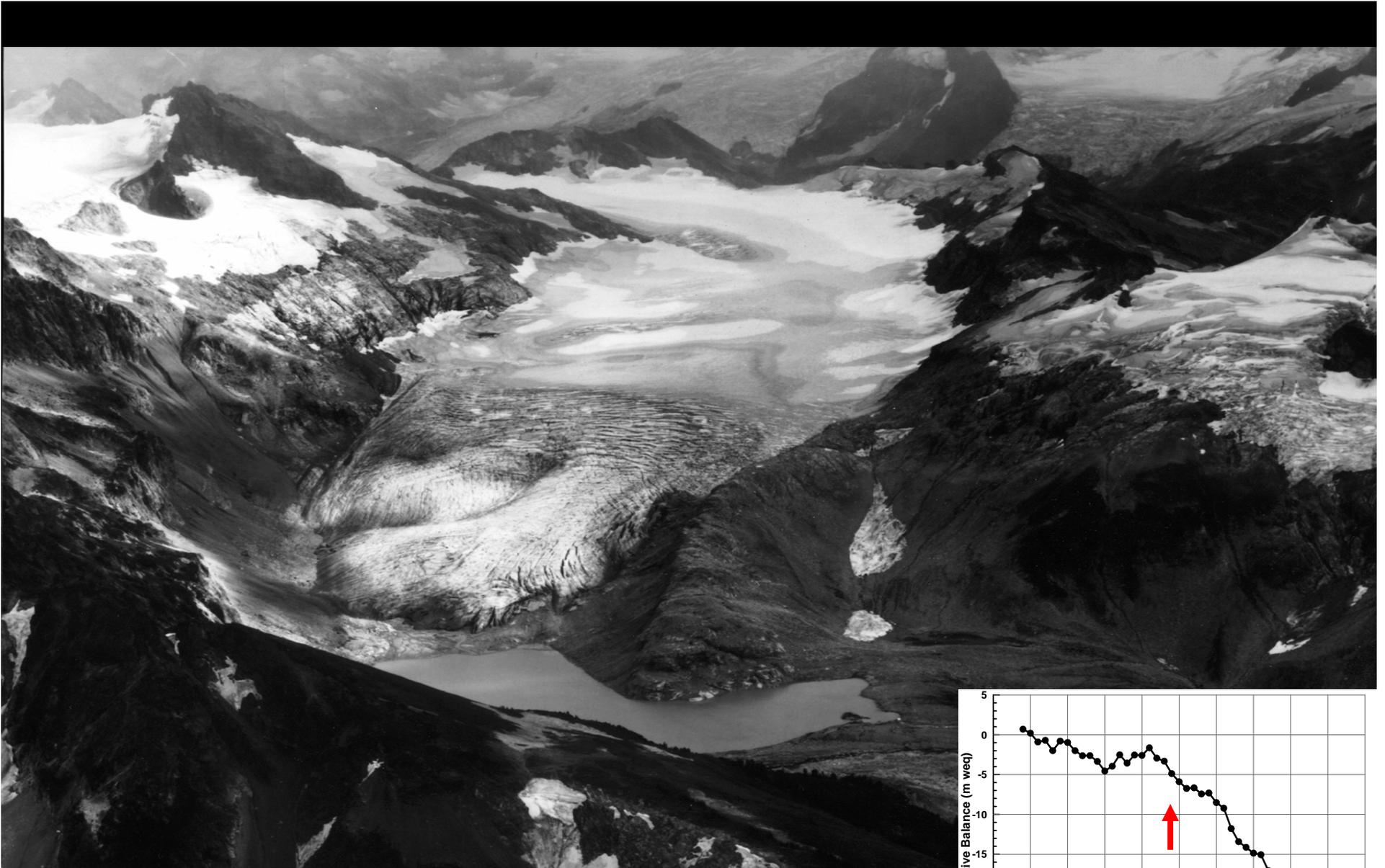


1928

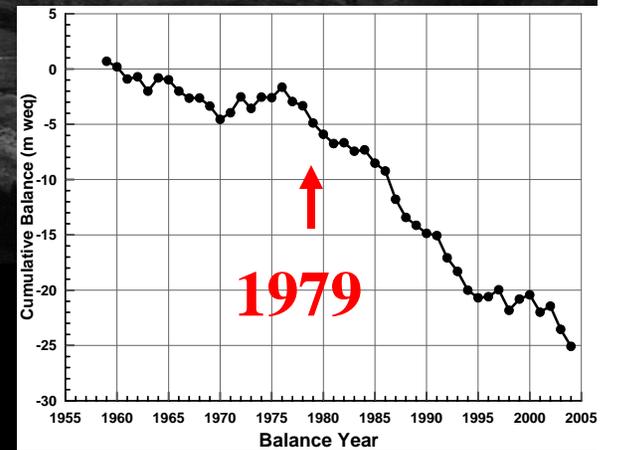
Cascade "USGS Benchmark" Glacier

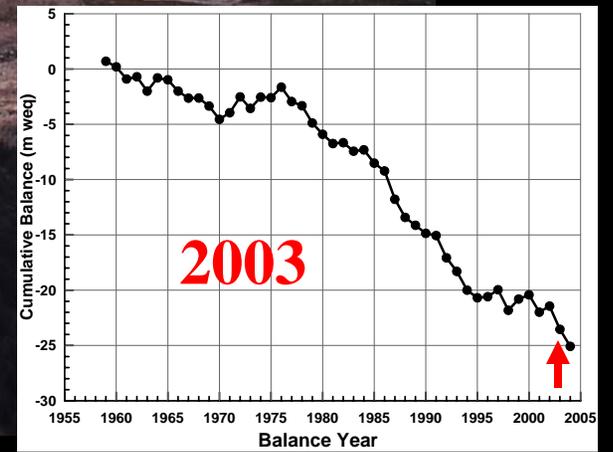
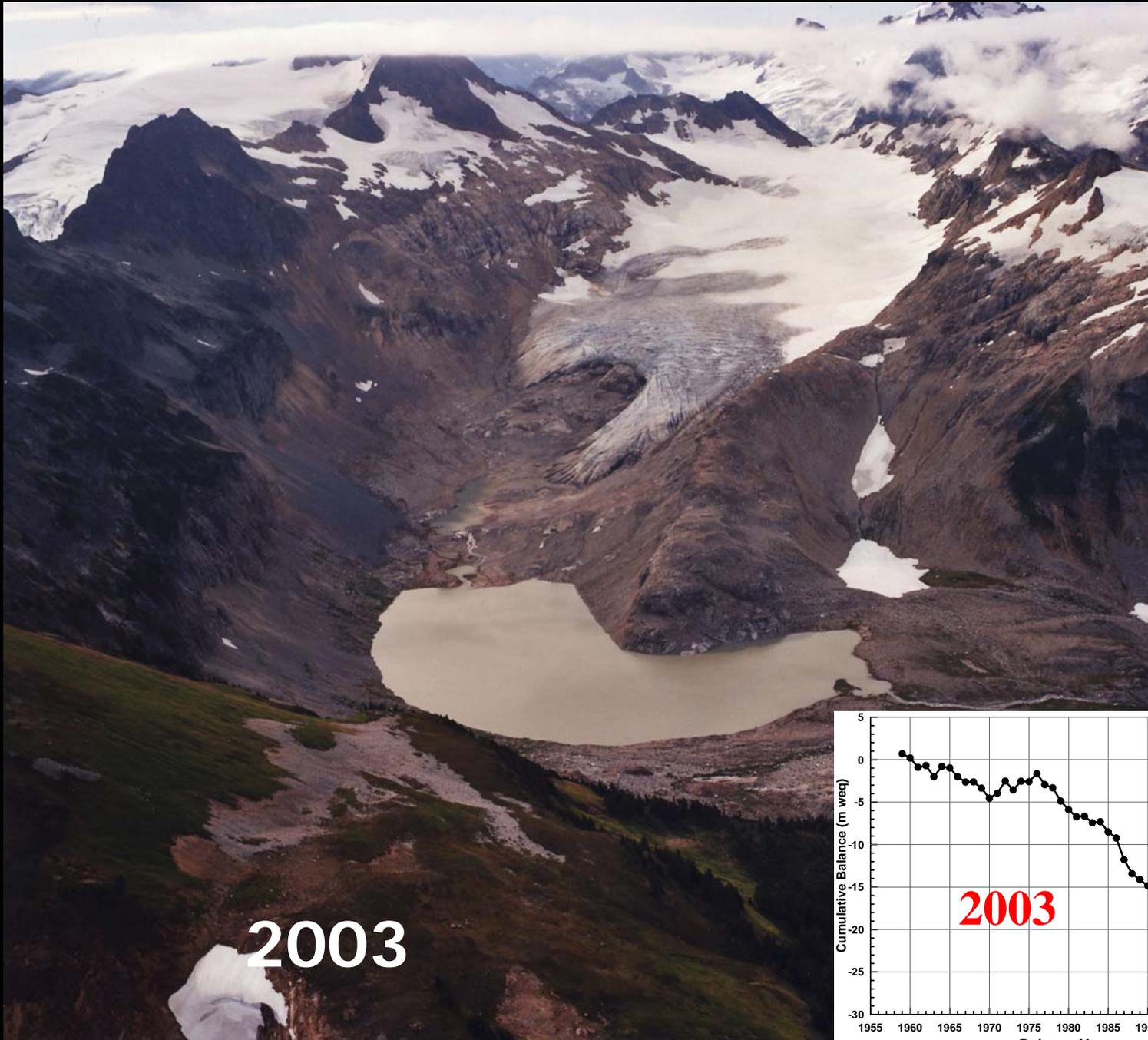
Josberger and others





1979





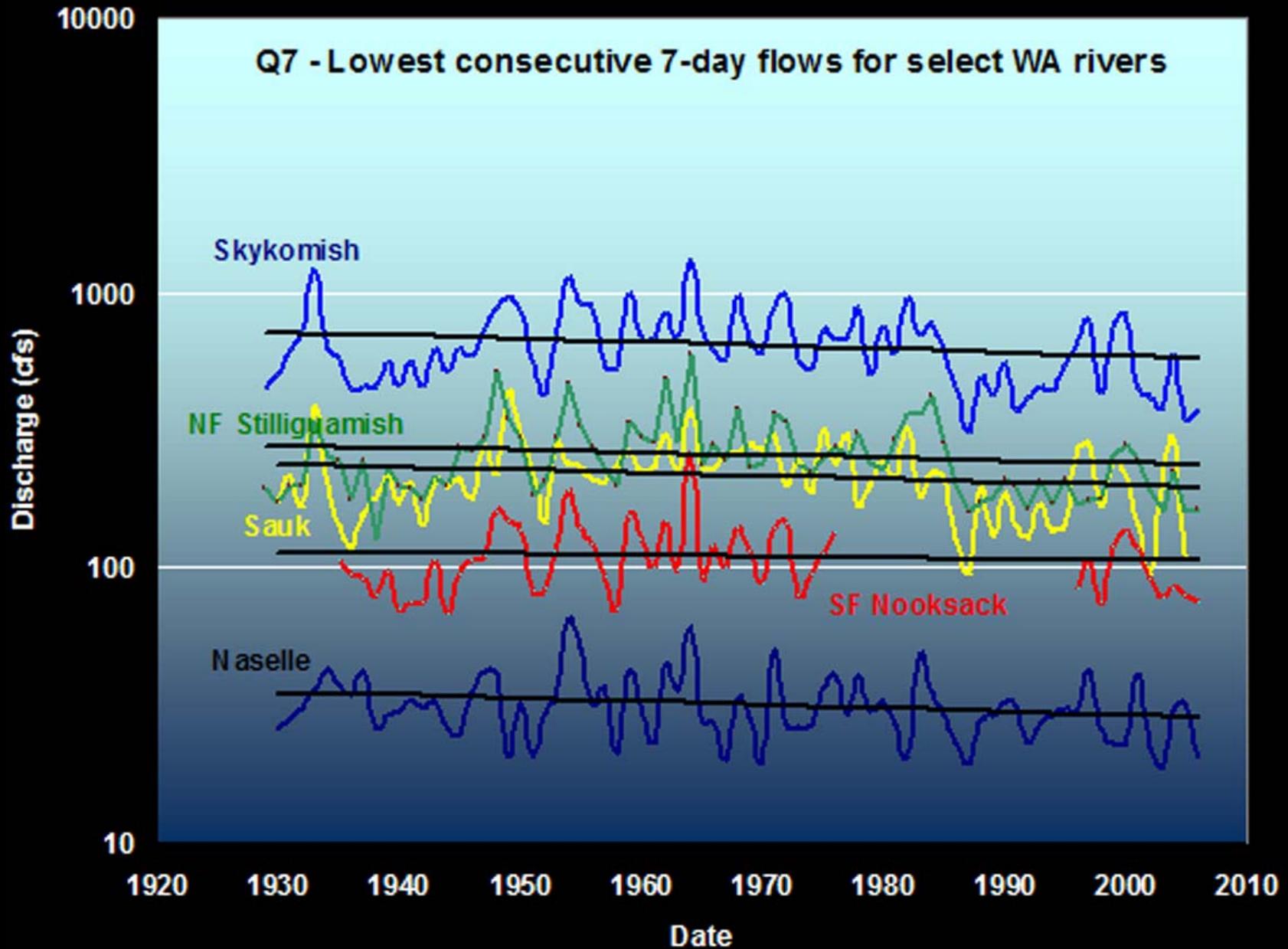


2006

## Volume Estimates (water equivalent)

YR	km <sup>3</sup>
1650	0.49
1890	0.49
1928	0.32
1958	0.24
1970	0.22
1985	0.19
2001	0.16

# Decreasing Low Flows?



# Freshwater/sediment partitioning, estuary response



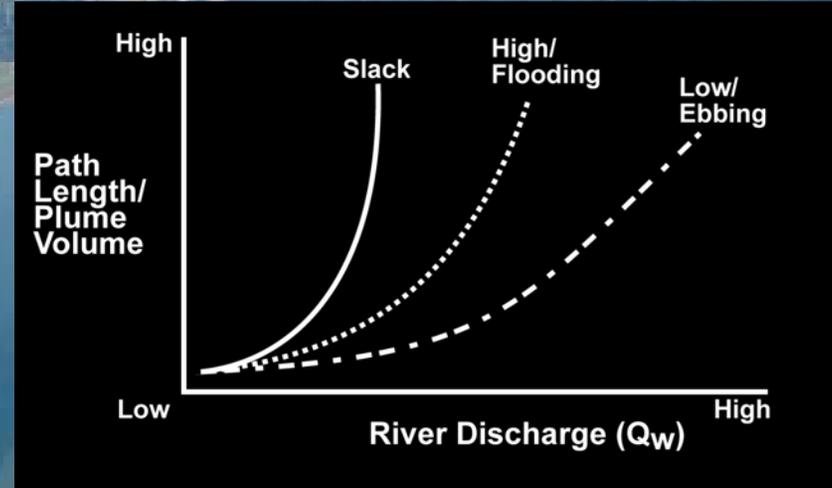
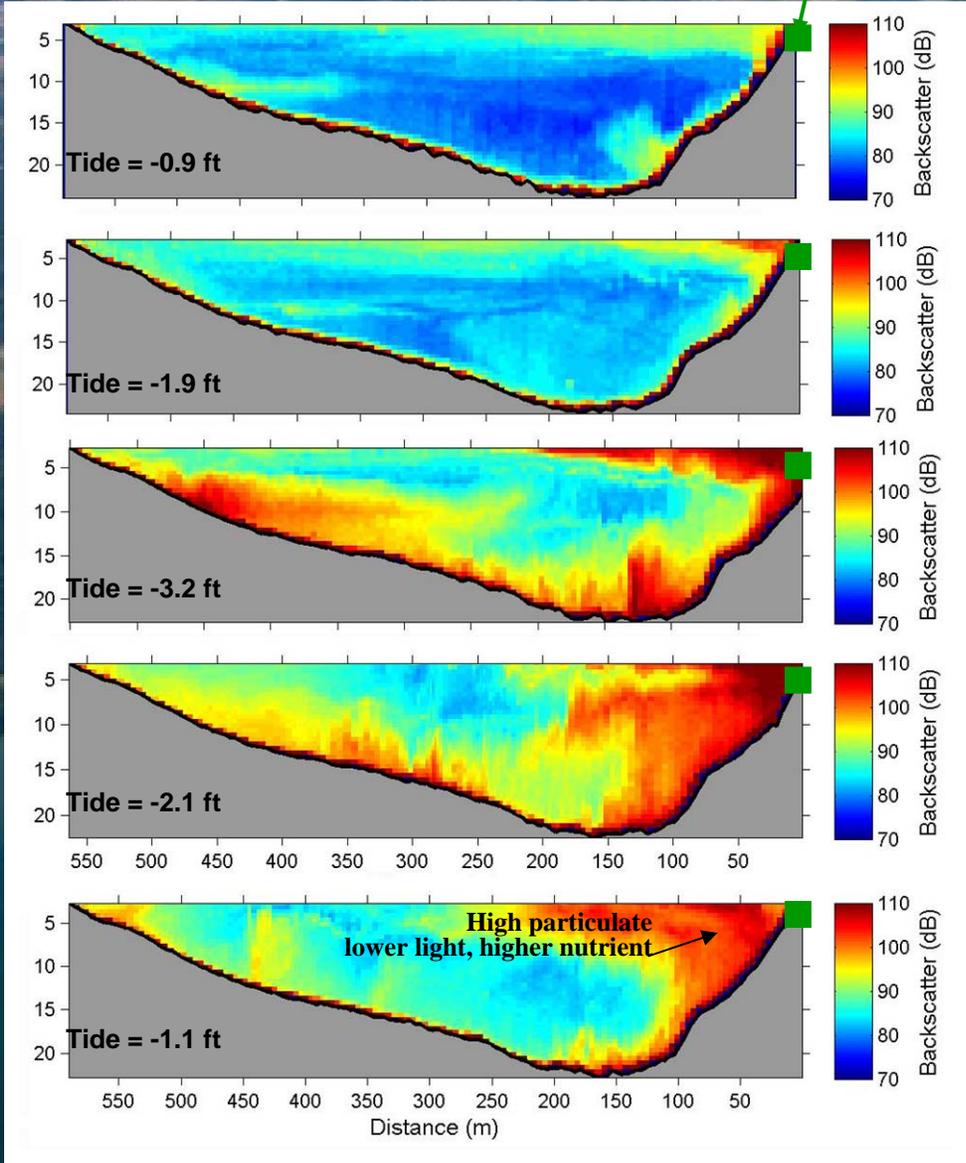
# Estuarine properties - Habitat Connectivity

*Z. marina*

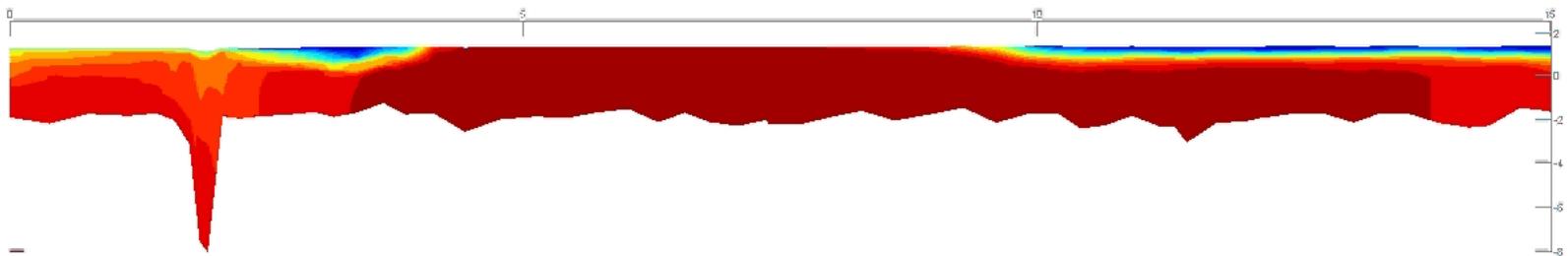
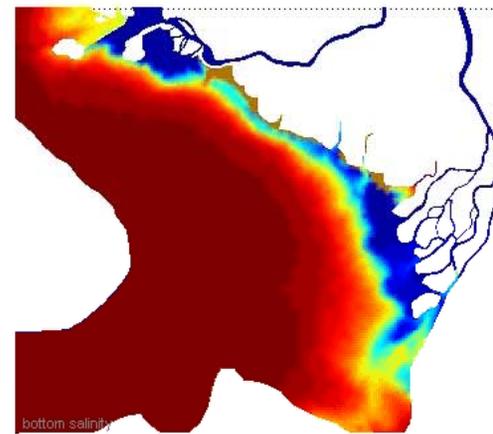
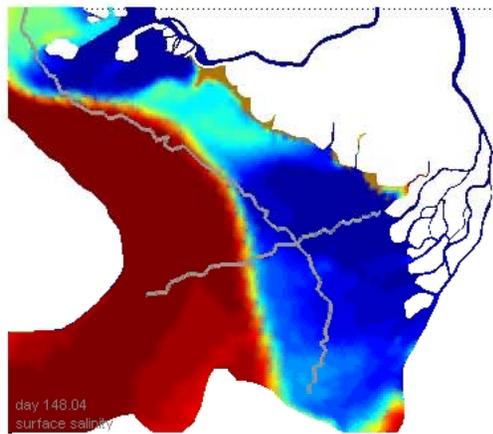
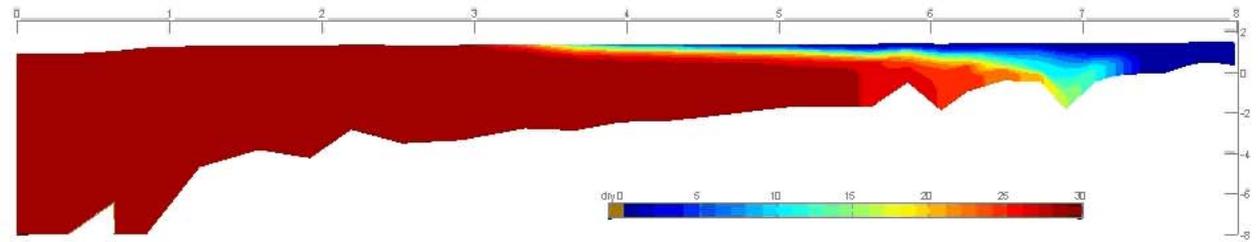
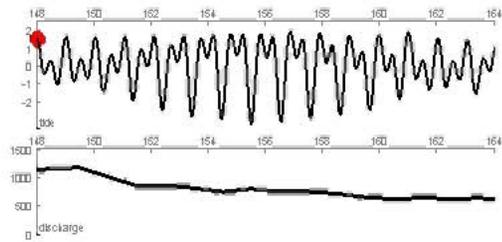
Whidbey Isl.

June 14, 2006

N. Fork Skagit R.



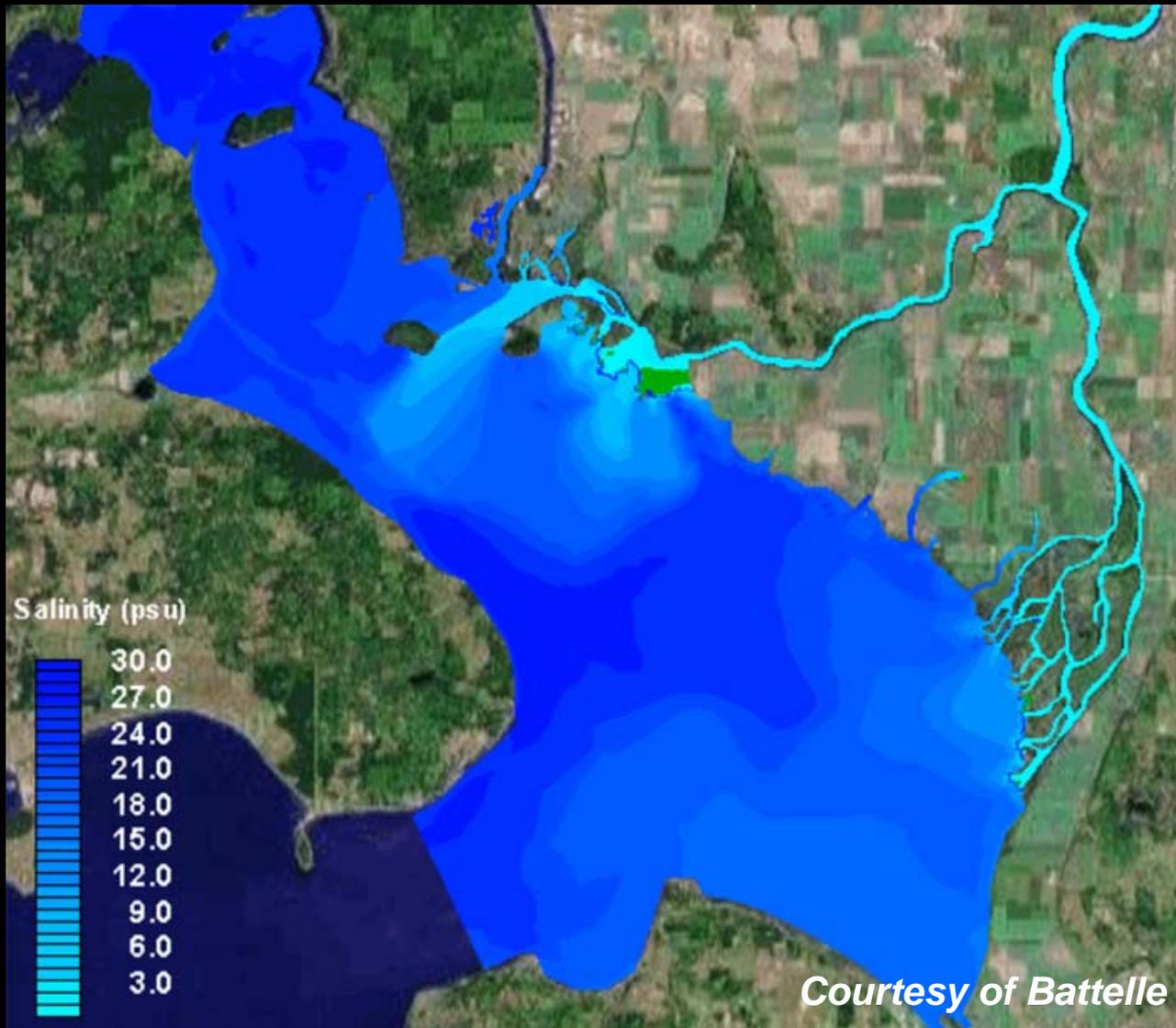
# Forecasting Estuarine Transition Zone



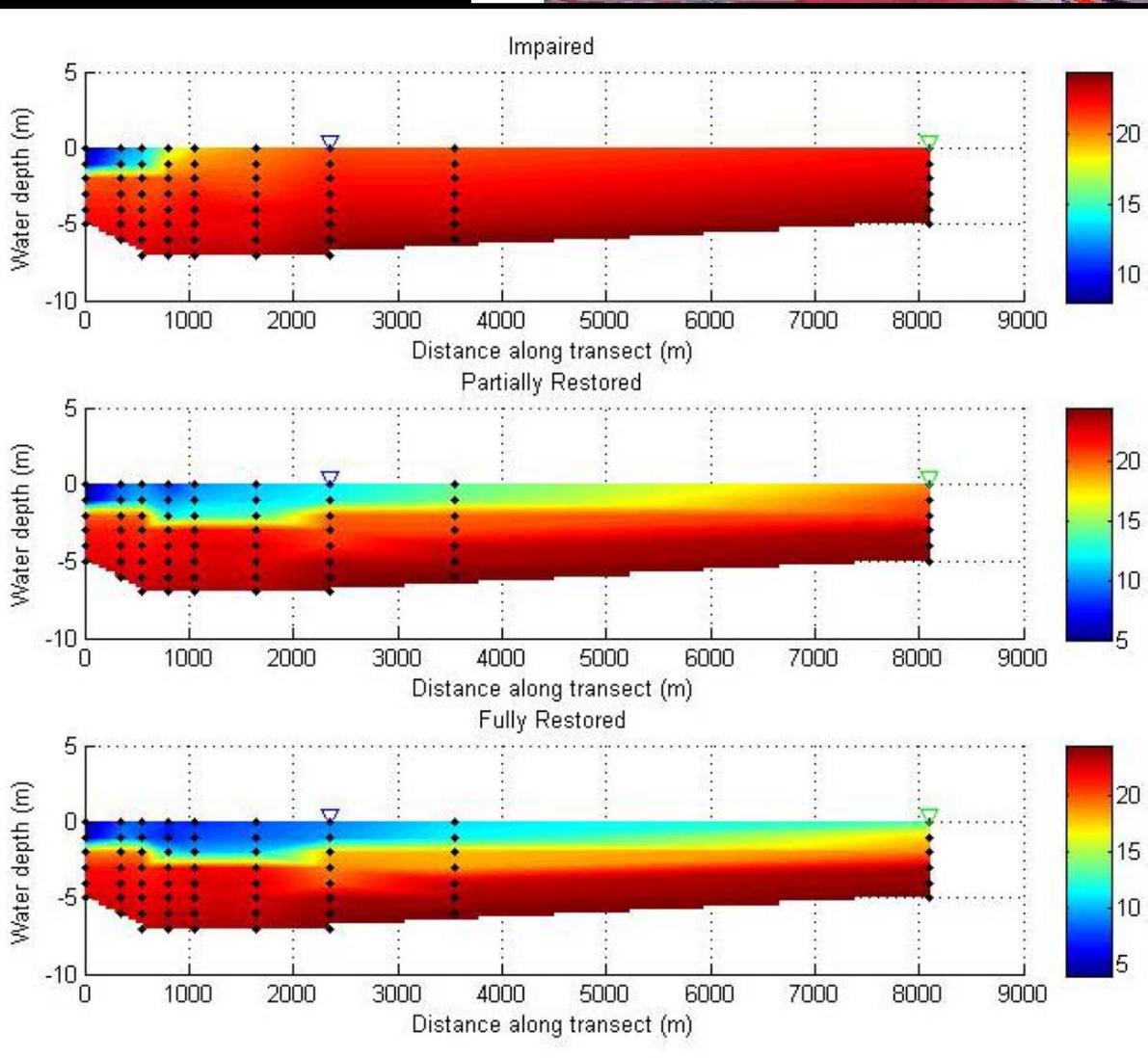
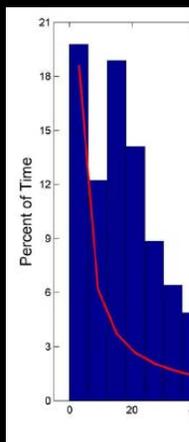
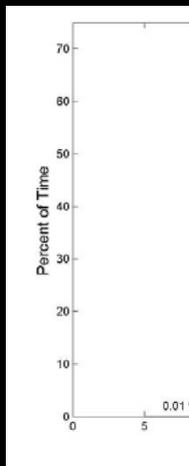
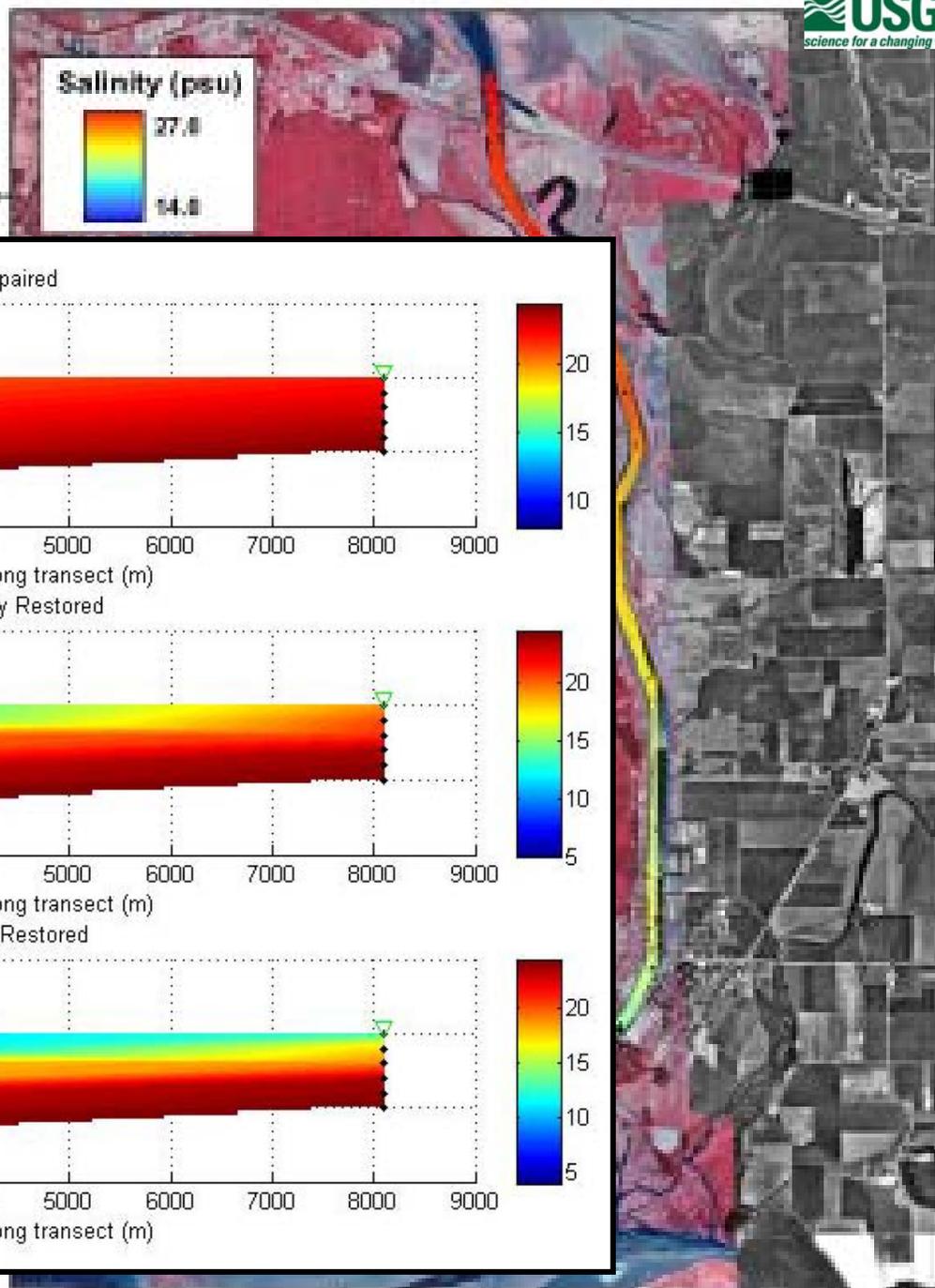
*Courtesy Dave Ralston (WHOI)*

# Case Study: Restoring habitat connectivity

## Sharp salinity fronts limit alongshore connectivity

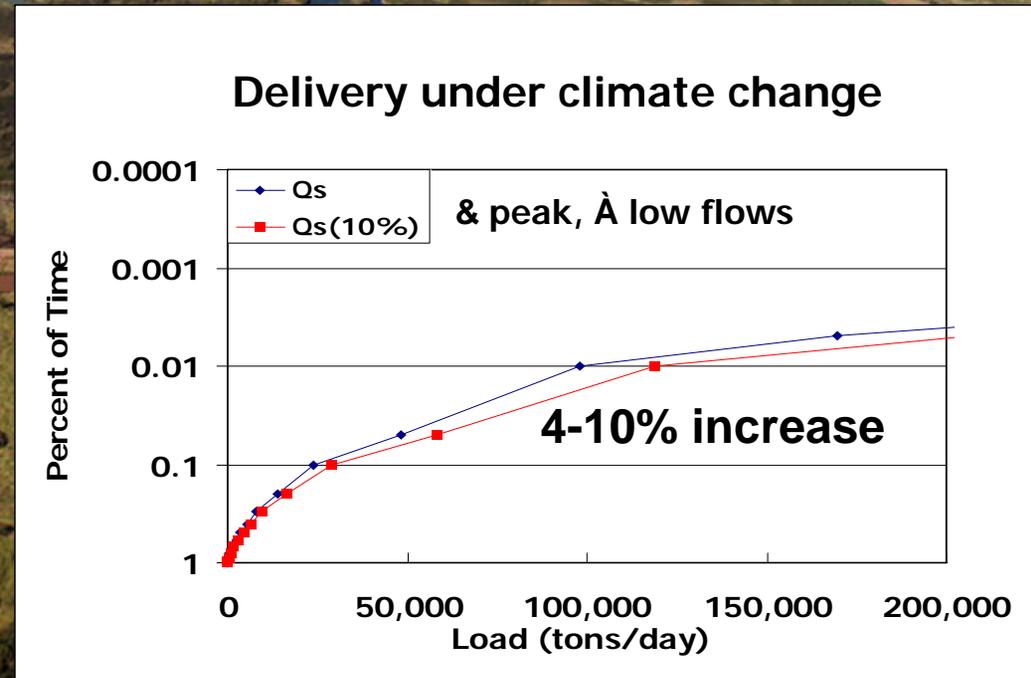
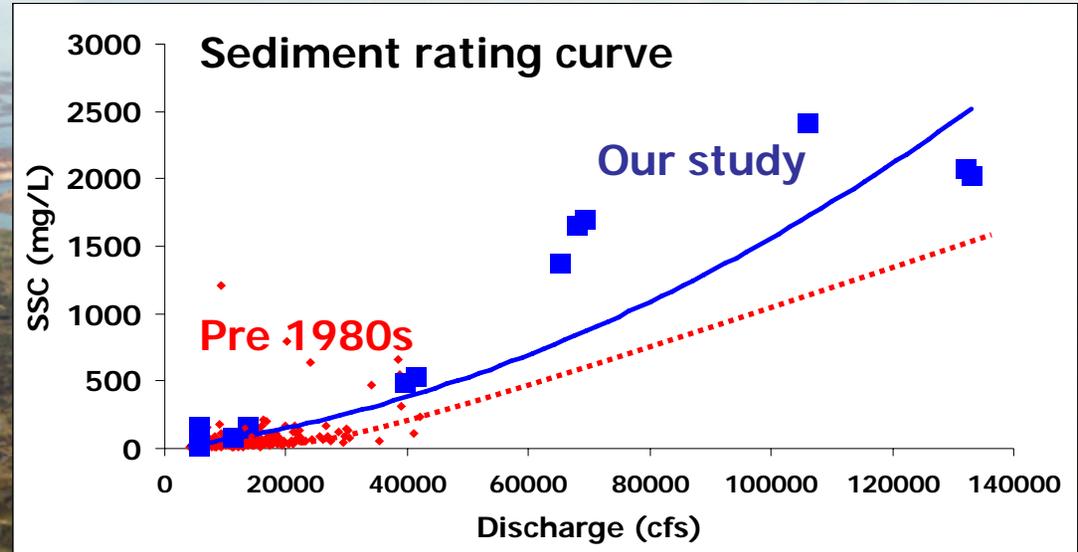
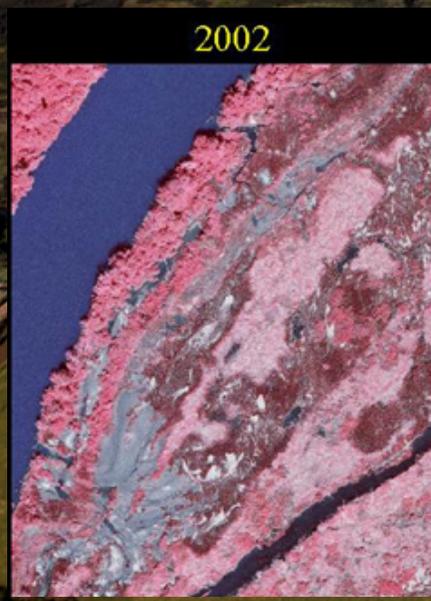
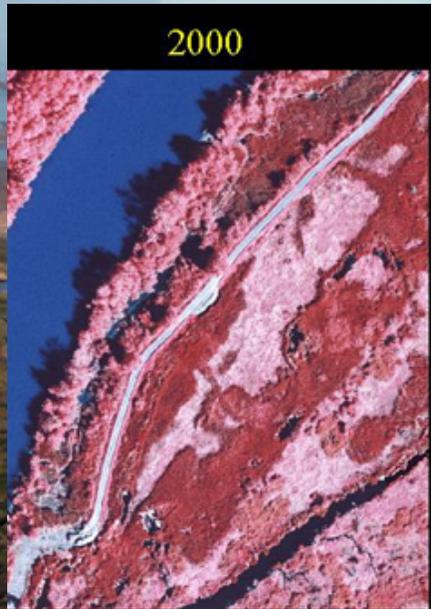


# Forecast change and Restoration Success - changing inputs



Grossman et al. 2007

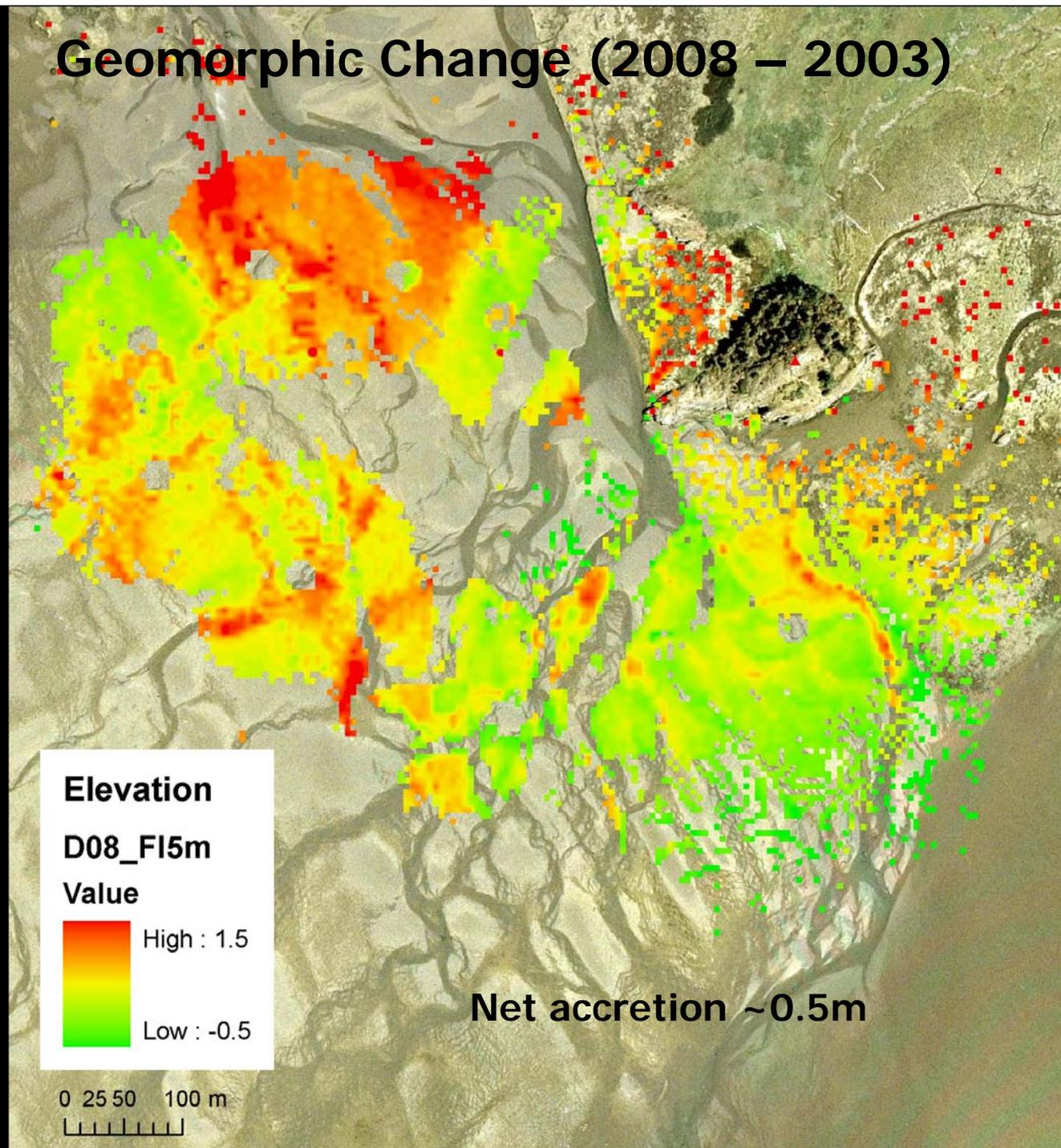
# Sediment budget to guide restoration response



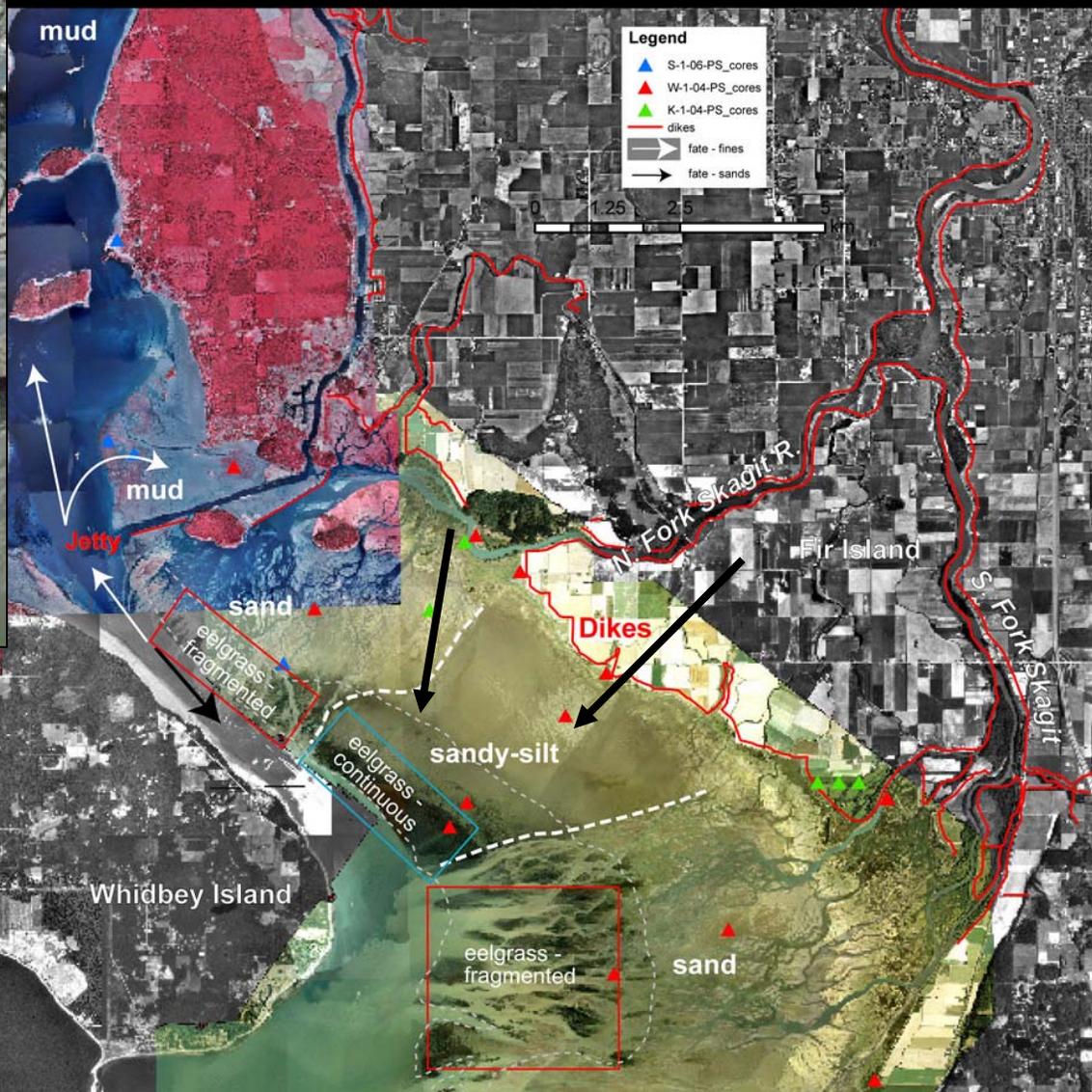
# Sedimentation and delta evolution



# Geomorphic Change (2008 – 2003)

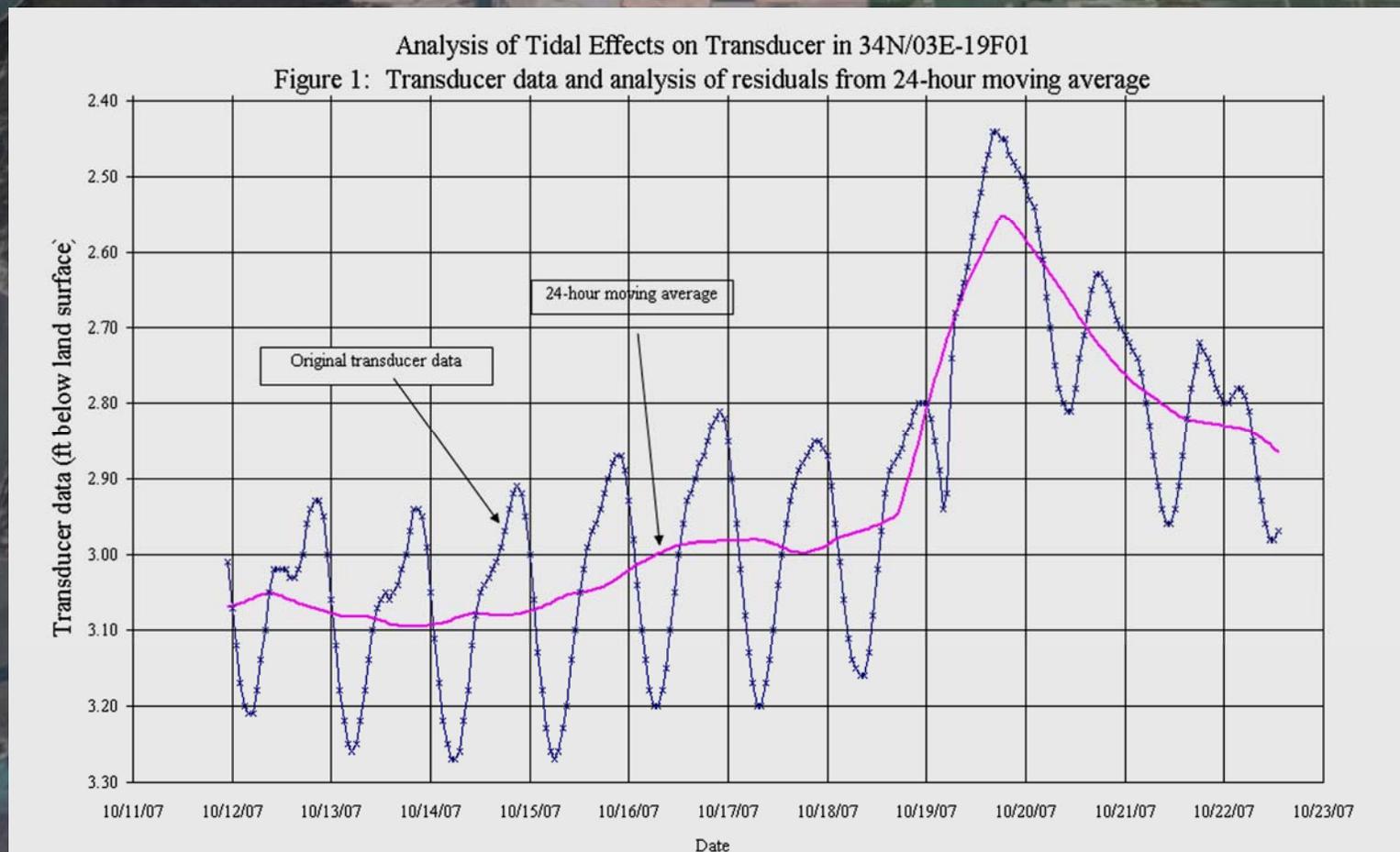


# Positive feedback to impairing connectivity alongshore or proposed restoration and to eelgrass impacts



# Groundwater Issues and Sea-Level Rise

Ground-water elevation and salinity impacts to crop success, drainage need for risk assessments and trade-off analyses



# Conclusions

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**Estuarine habitats and processes already perturbed by land use activities and SLR/climate change likely to restrict habitat availability because of estuary squeeze**

**Impacts to important, remaining nearshore habitat structure and function should be assessed in “wetland” restoration because of uncertain “downstream” affects**

**Strategic collaborative studies required to better forecast estuarine changes and develop decision-support tools:**

- guide science**
- assess uncertainty**
- forecast future outcomes**
- inform resource management**

