Skagit Estuary Recovery Plan Implementation Progress: What's Been Completed, How It's Working, & Some Thoughts For The Future

Presentation to the Skagit Watershed Council

May 4, 2022

Eric Beamer & Greg Hood

Skagit River System Cooperative

Presentation Outline

- Reminder of the Skagit Chinook Recovery Plan (SRP) Chapter
- Our monitoring approach (project, population/system)
- Results:
  - What's been restored
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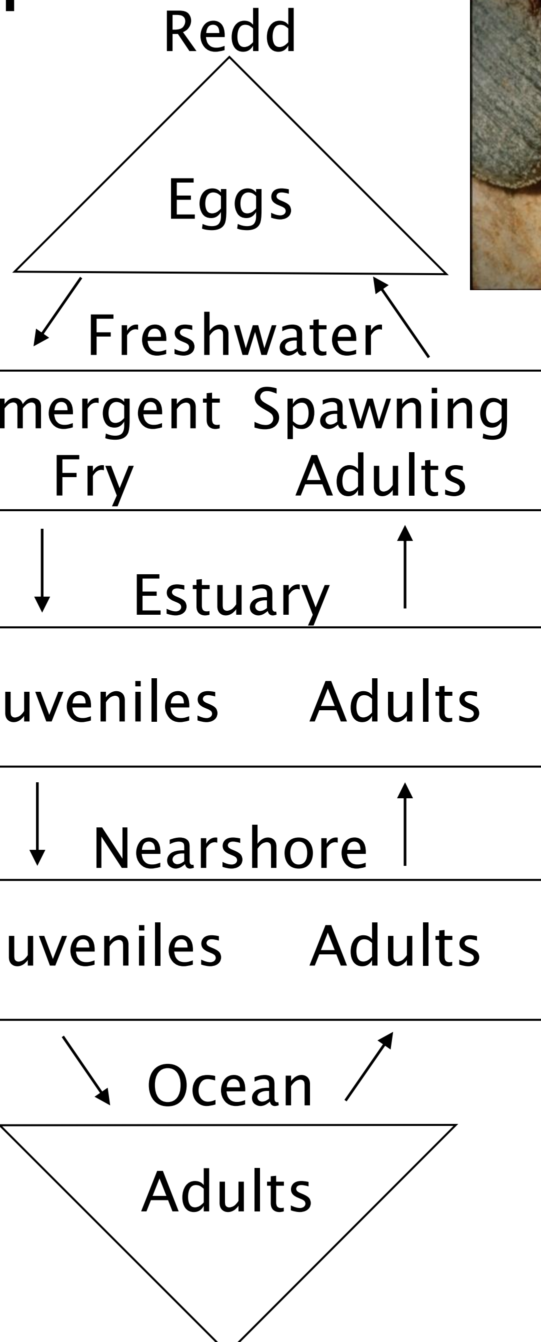
Tidal Delta (Ch. 11) & Nearshore (Ch. 12) Rearing (aka, estuary rearing)

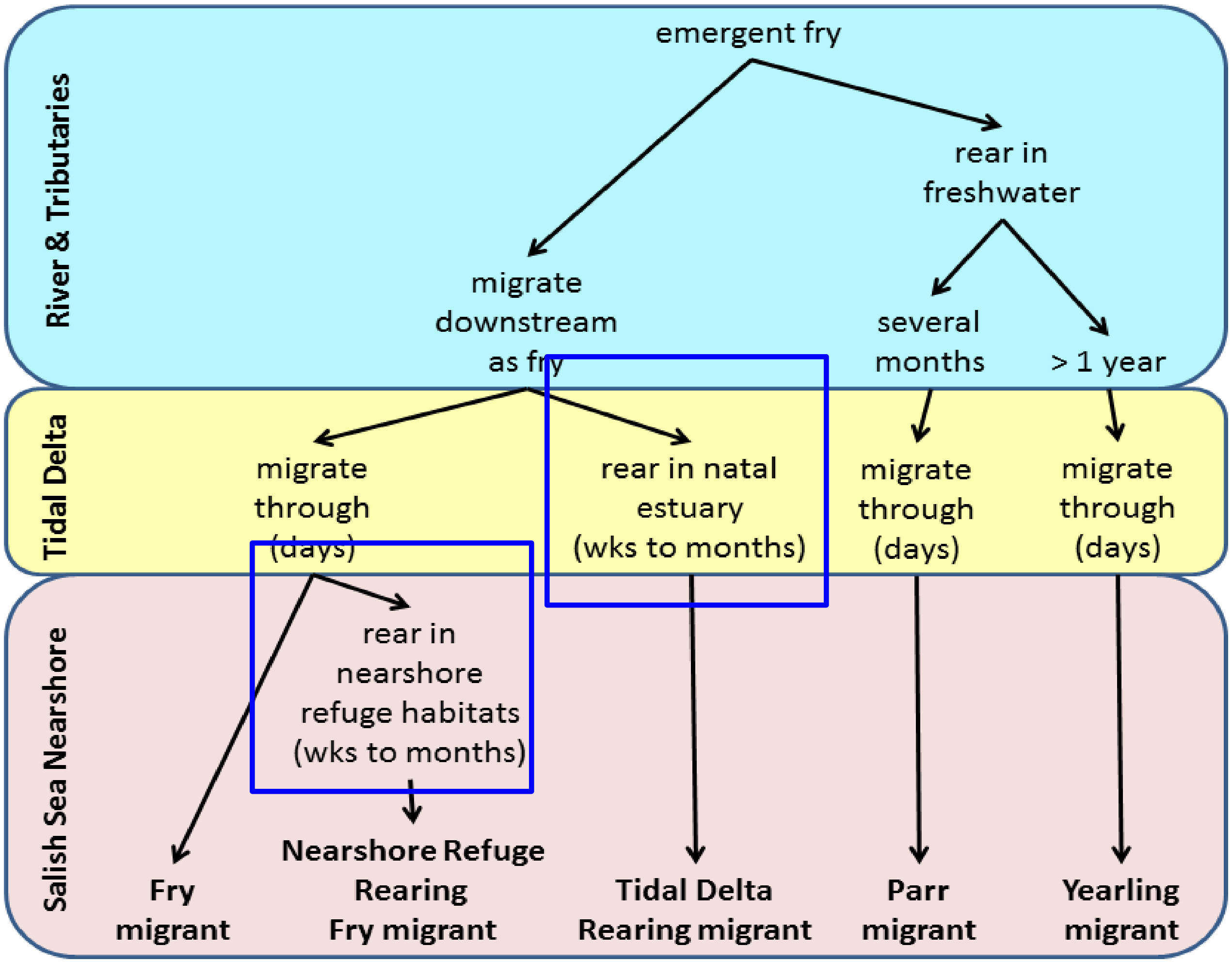
Details in Appendix D of SRP

Chinook salmon life cycle

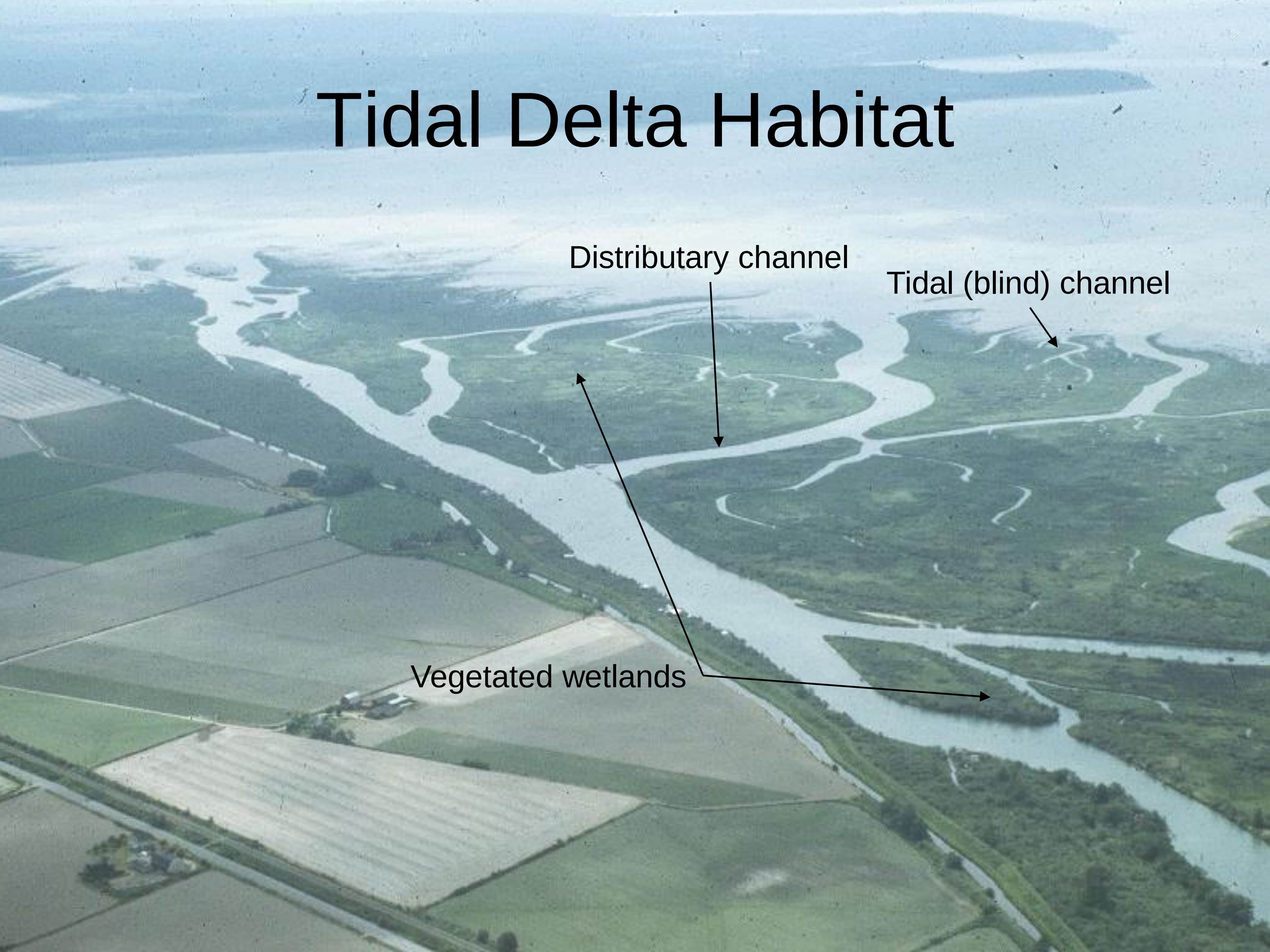


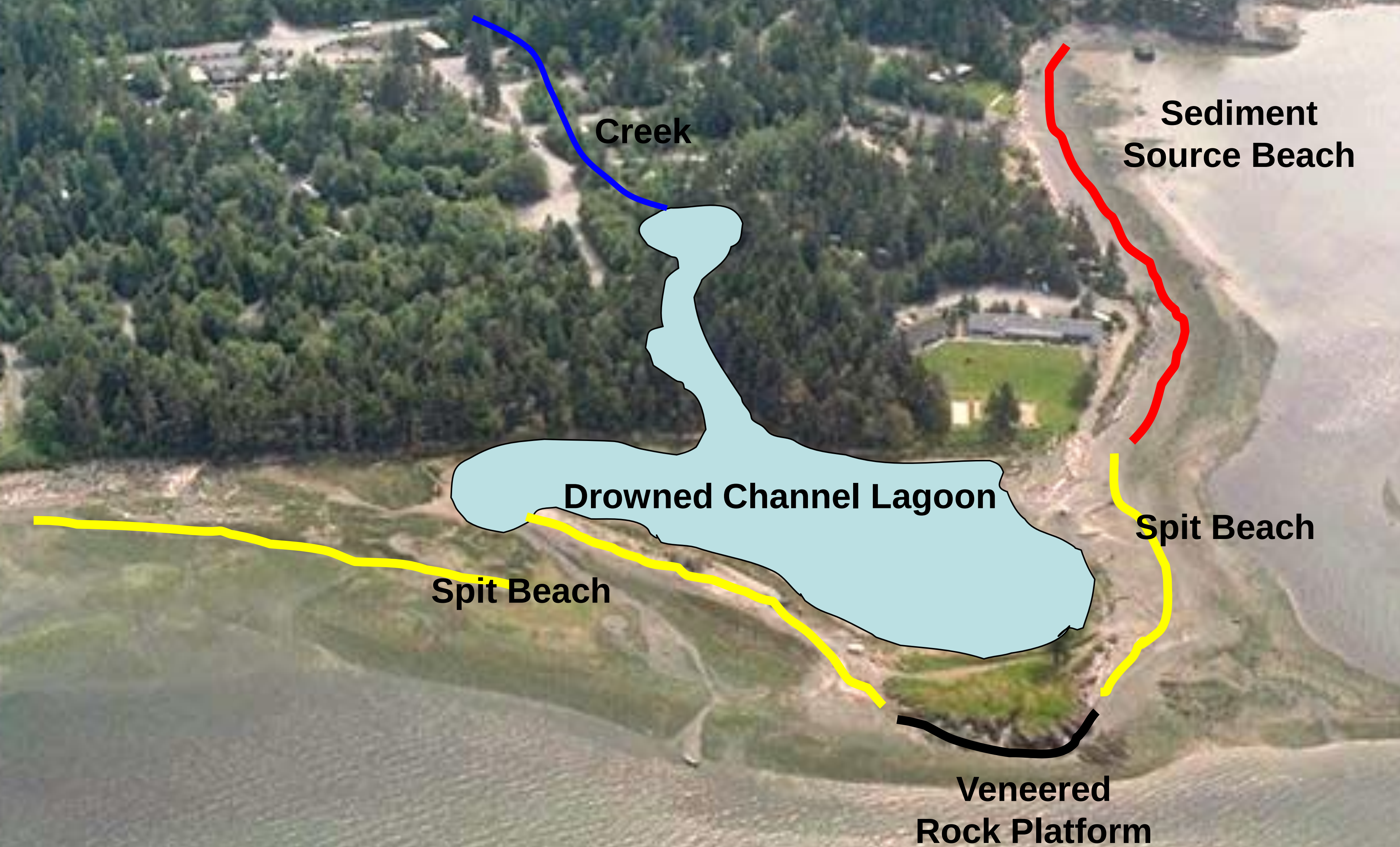
Juvenile Life History Diversity

Skagit Natural Origin Populations



Tidal Delta Habitat





Pocket Estuary Habitat

(example: Lone Tree Lagoon)

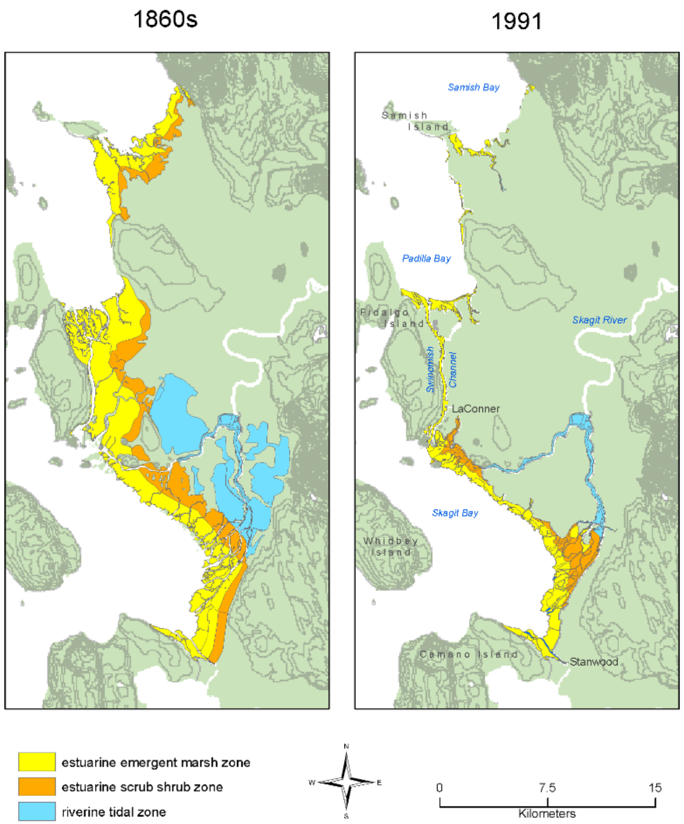
Why do we need Estuary Restoration?

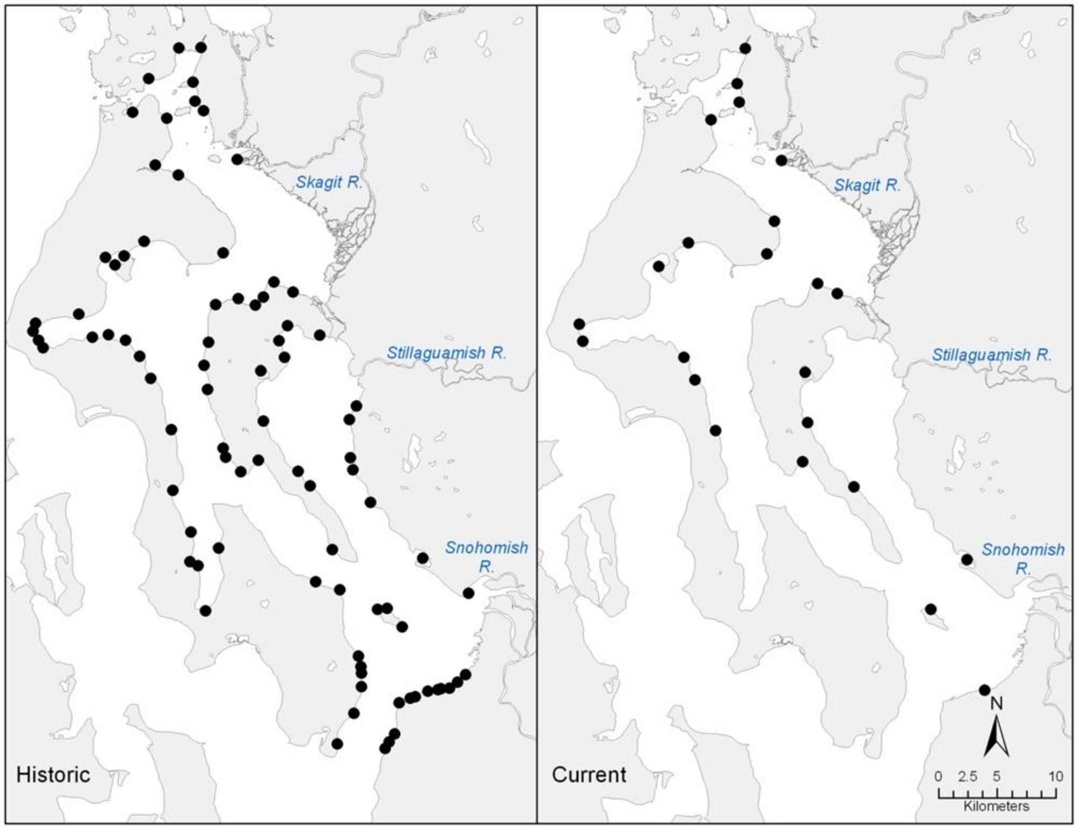
- Current habitat conditions
- Current biological mechanisms
- Unbalanced migration pathways

- Leads to tidal delta and pocket estuary restoration
- Use stock-recruit carrying capacity model to predict benefits of individual candidate restoration projects

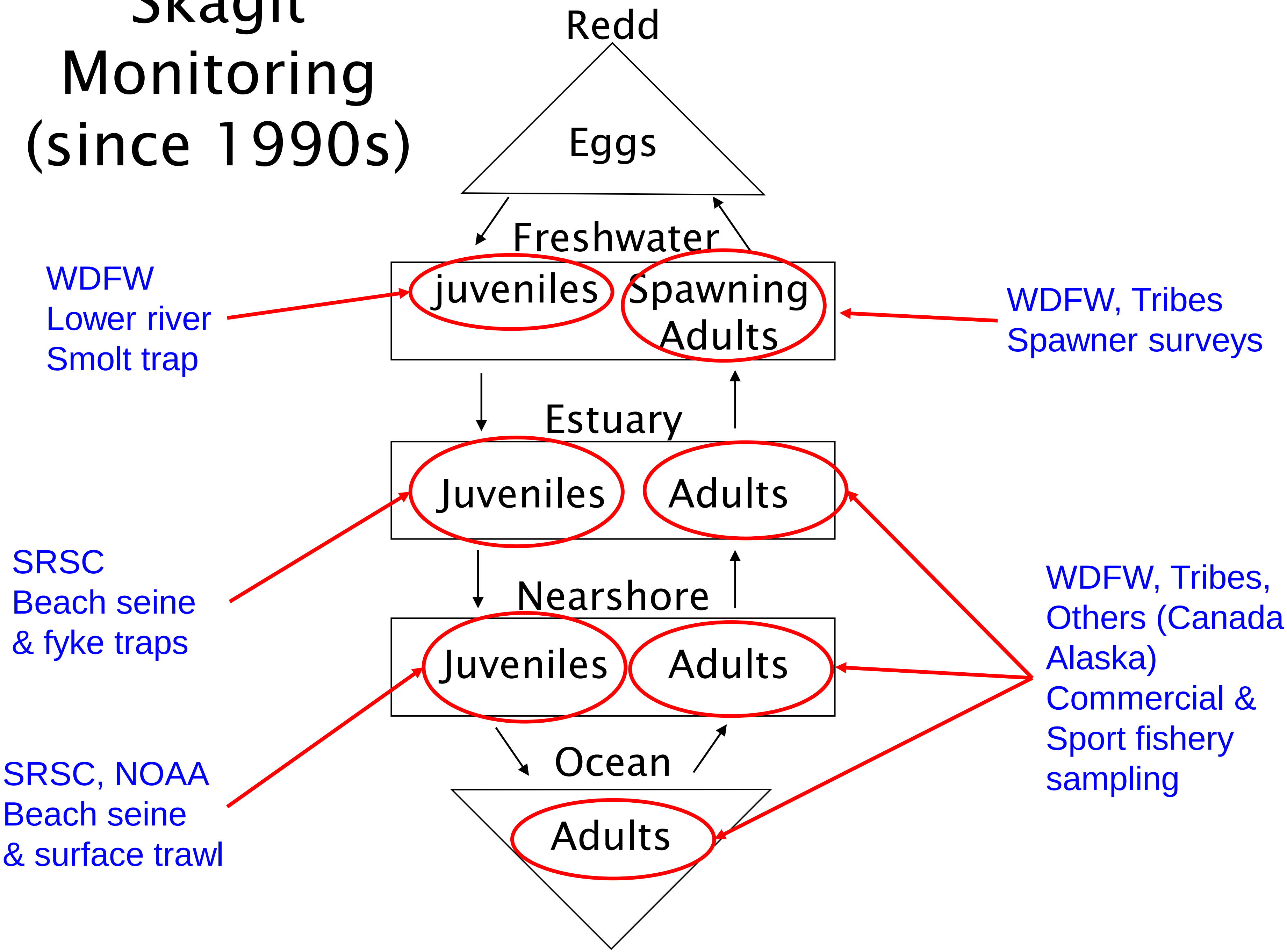
Skagit Tidal Delta & Pocket Estuary Habitat Change

- Both are smaller in area & fragmented
- Tidal delta: 88% loss of habitat fish use directly
- Pocket estuaries: 86% loss in habitat fish use directly





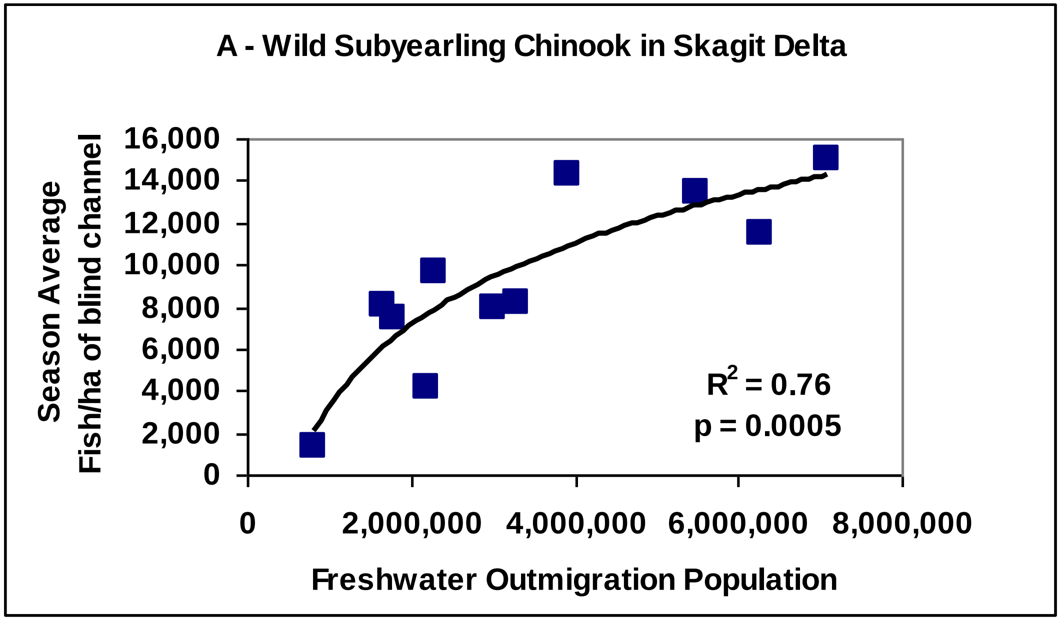
Skagit Monitoring (since 1990s)

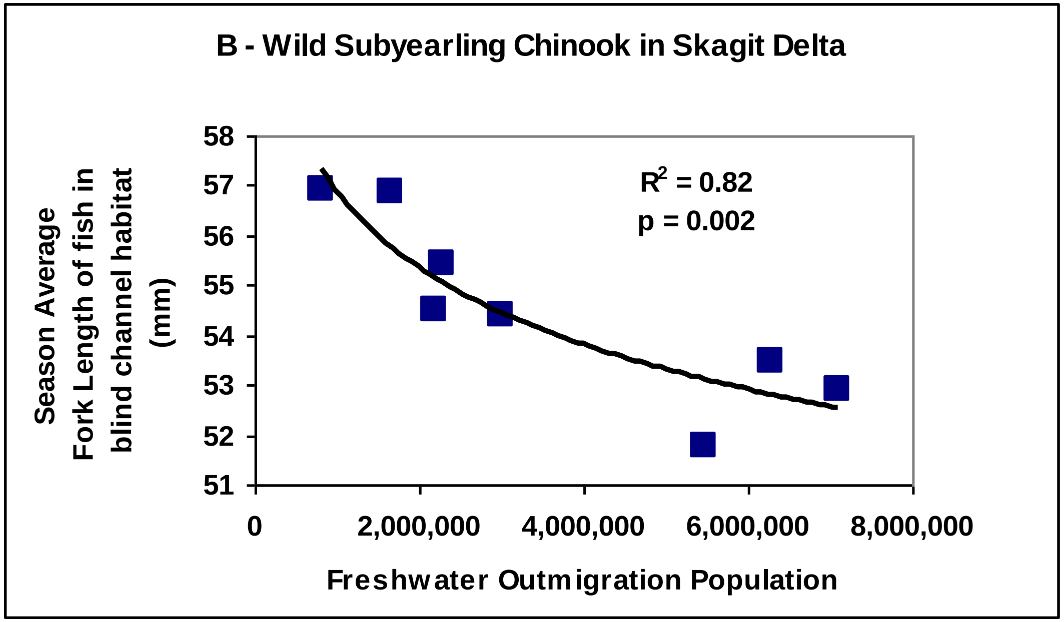


Density dependence in the tidal delta

•The relationship between freshwater outmigration population and juvenile Chinook abundance in delta habitat is asymptotic

•The size of Chinook in delta habitat decreases as a function of freshwater outmigration

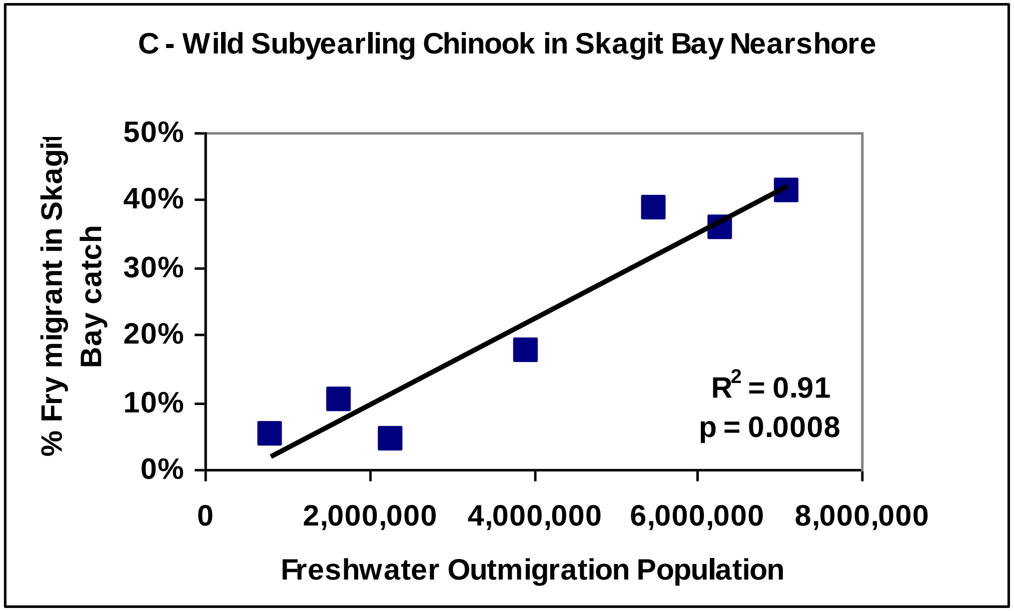




from Beamer et. al. (2005)

Nearshore

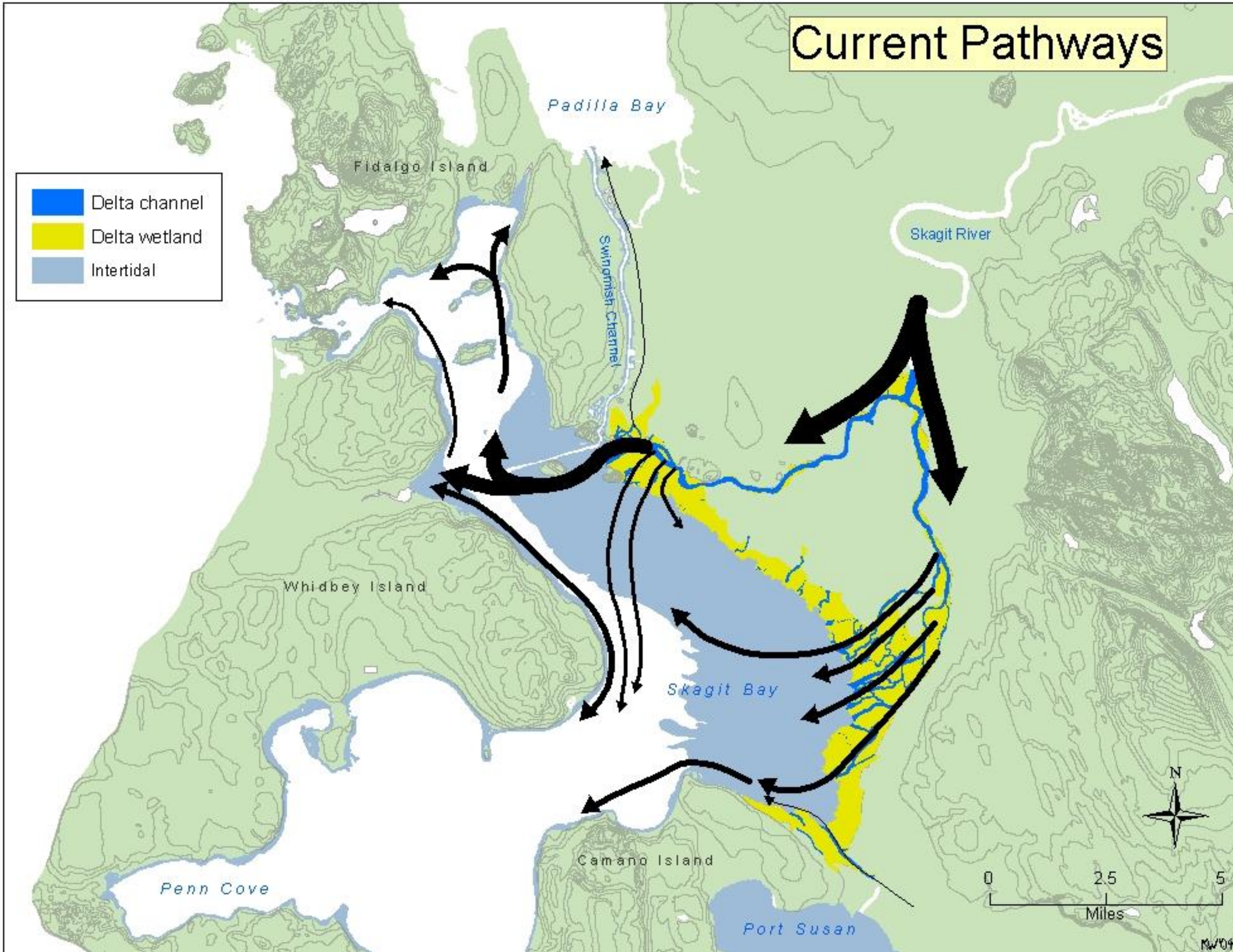
•The proportion of fry migrants increases as a function of freshwater smolt outmigration population size (density dependent movement in the delta)



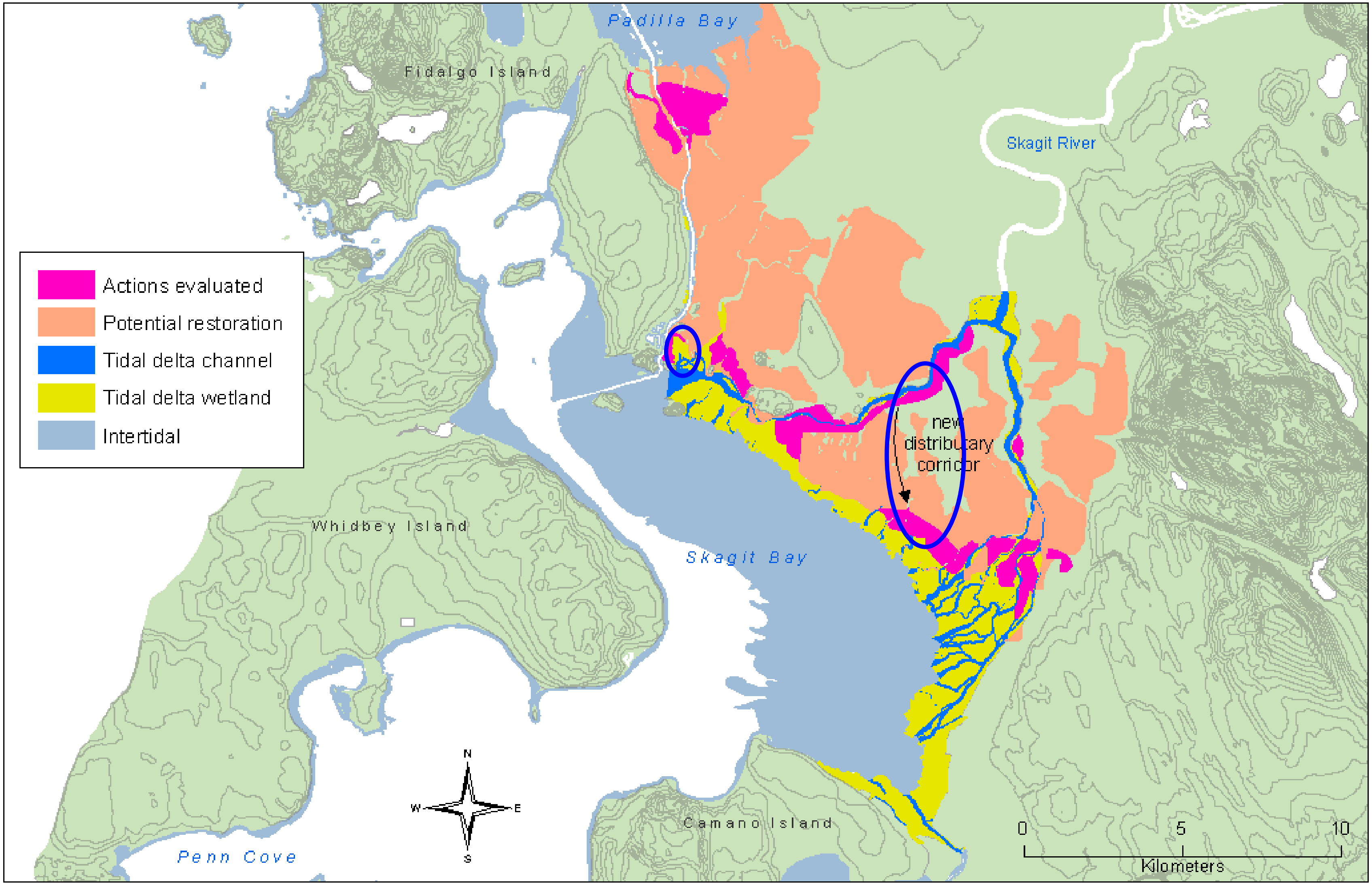
Where do they go in the nearshore?

•Wild Chinook fry accumulate in pocket estuaries (and small streams) from January through May

- increased growth
- refuge from predators


Current Pathways
Delta channel
Delta wetland
Intertidal
Padilla Bay
Fidalgo Island
Swinomish Channel
Skagit River
Whidbey Island
Skagit Bay
Camano Island
Penn Cove
Port Susan
N
0
2.5
5
Miles

Potential Tidal Delta Restoration



Potential Pocket Estuary Restoration

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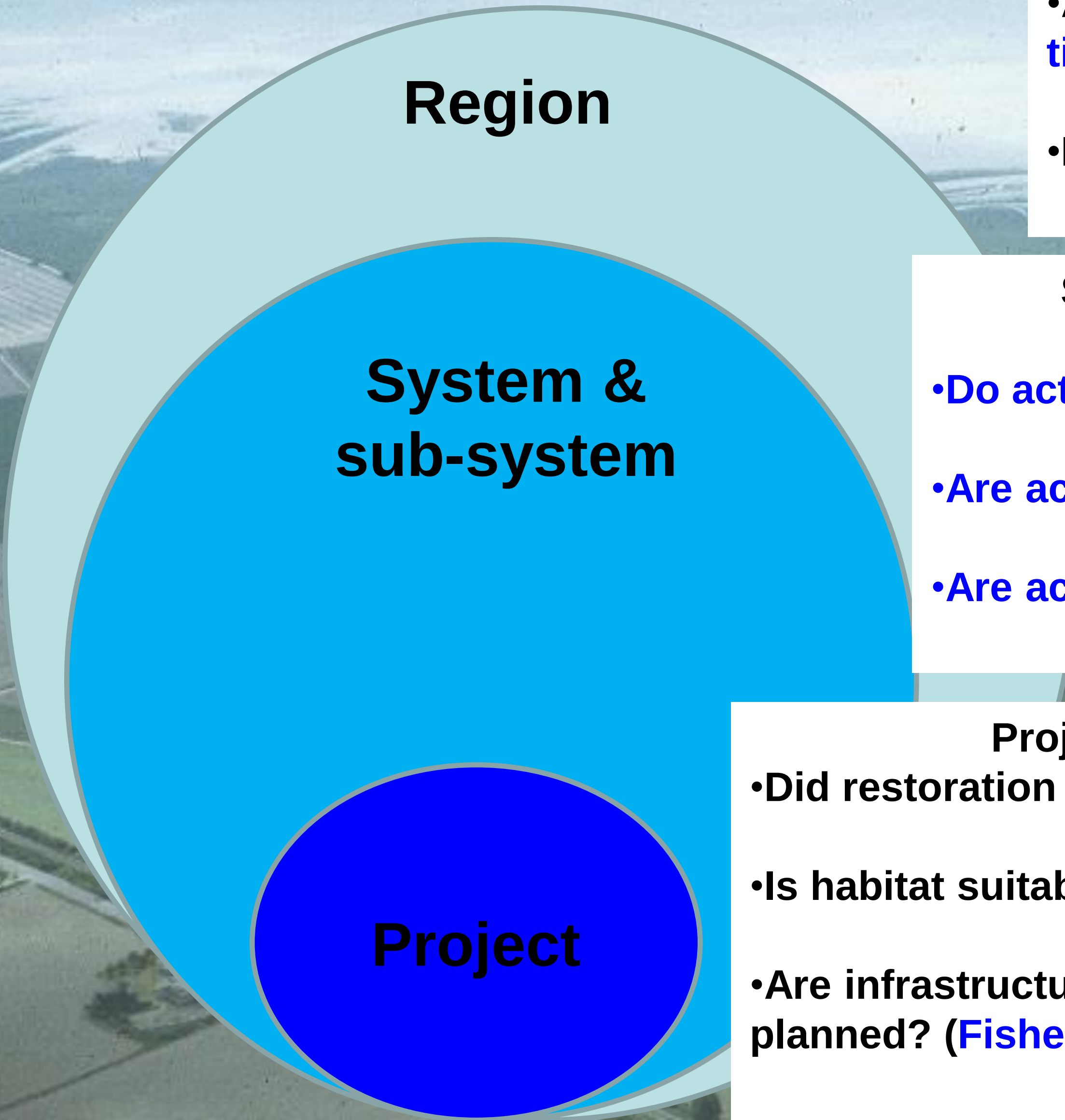
Monitoring is done at nested scales; all scales are important



Puget Sound, PS Chinook Recovery

- **Are the strategies working? (ERSP tidegate study)**
- **Is recovery happening and on pace?**

Skagit Chinook, Skagit estuary

- **Do actions proposed achieve the goal?**
- **Are actions getting done?**
- **Are actions working?**

Project, a restoration project

- **Did restoration occur?**
- **Is habitat suitable? Are fish there and doing fine?**
- **Are infrastructure constraints operating as planned? (Fisher Slough Floodgate)**

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Skagit Estuary Restoration Projects: Built & Planned

	Site	Year completed	Benefit to salmon (connectivity, capacity, or both)	Tidal Footprint Acres	Monitoring design, years monitored
	Deepwater Slough	2000	Both	221	**PT, 2001-2003**
653 acres	**Smokehouse Floodplain**	2005-8	Capacity	67	**BACI, 2004-2011**
	Milltown Island	2006-7	Capacity	0*	**PT, 2012-2013**
	South Fork Dike Setback	2007	Capacity	21	**PT, 2012, 2014**
	Swinomish Ch Fill Removal	2008	Capacity	8	**PT, 2009-2013**
	Wiley Slough	2009	Capacity	160	**Partial BACI, 2003, 2012-2013**
	Fisher Slough	2010-11	Capacity	46	**BACI, 2009-2013 & 2015**
	Fir Island Farms	2016	Capacity	130	**BACI, 2015-2018**
	Britt Slough	2021	Connectivity	0*	**BACI, 2021-2023**
402.4 acres	**Milltown Island Phase 2**	2023	Both	0*	**Not designed or funded**
	Smokehouse Floodplain 2	2023	Capacity	120	**Planned BACI, 2005-present**
	Deepwater Phase 2	2023	Capacity	268	**Not designed or funded**
	North Leque Island	2022	Connectivity	0*	**Not designed or funded**
	S Fork Dike Setback Phase 2	2022	Both	0*	**BACI, 2012,2014,2023-24**
	Swinomish Ch. Phase 3 (Dunlap)	2023/4	Capacity	4.4	**Not designed or funded**
	McGlinn Island Causeway	<5 years	Connectivity	10	**Planned BACI, 2005-present**
	TOTAL			**1055.4**	

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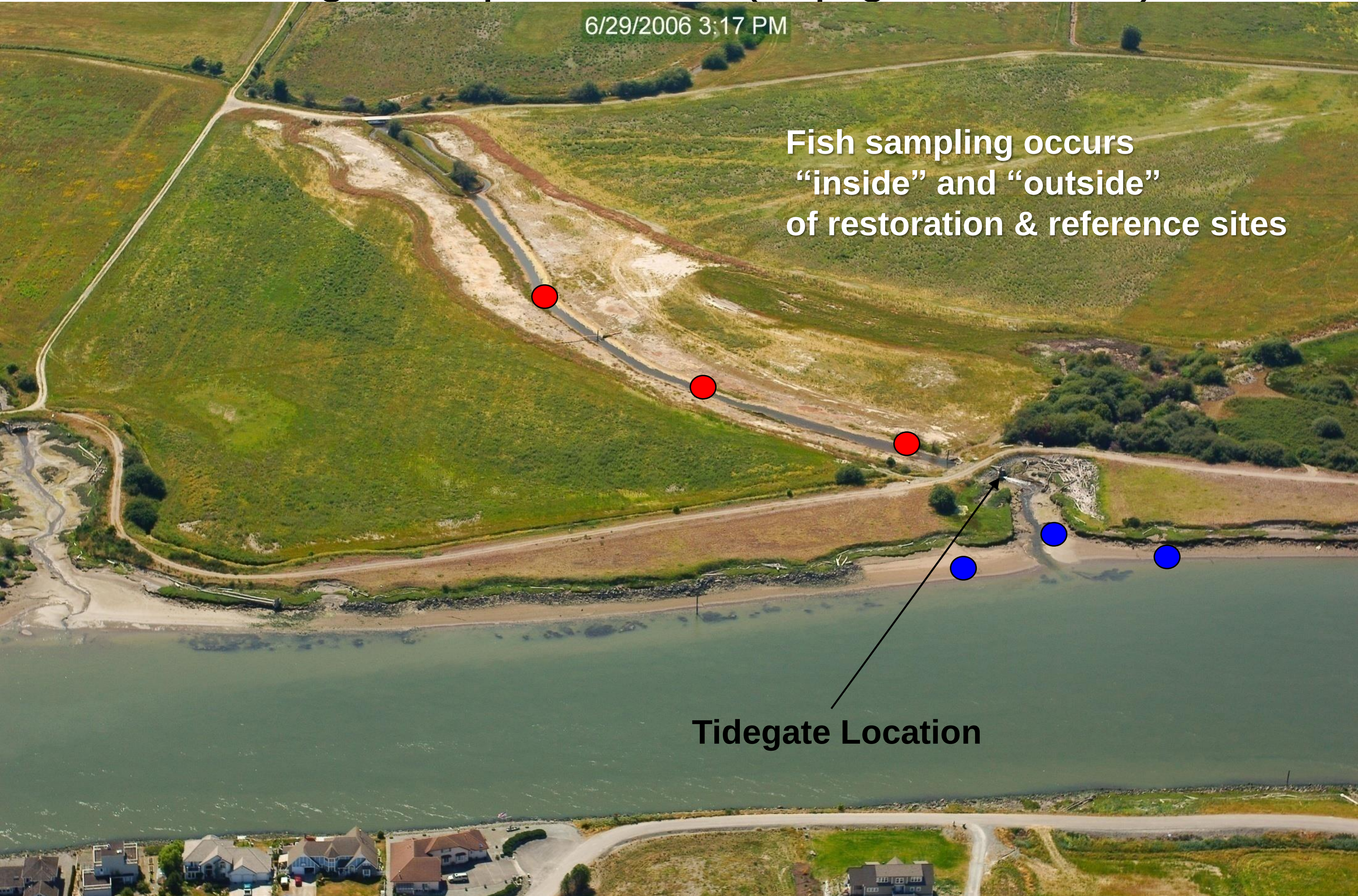
Is restoration working for fish?

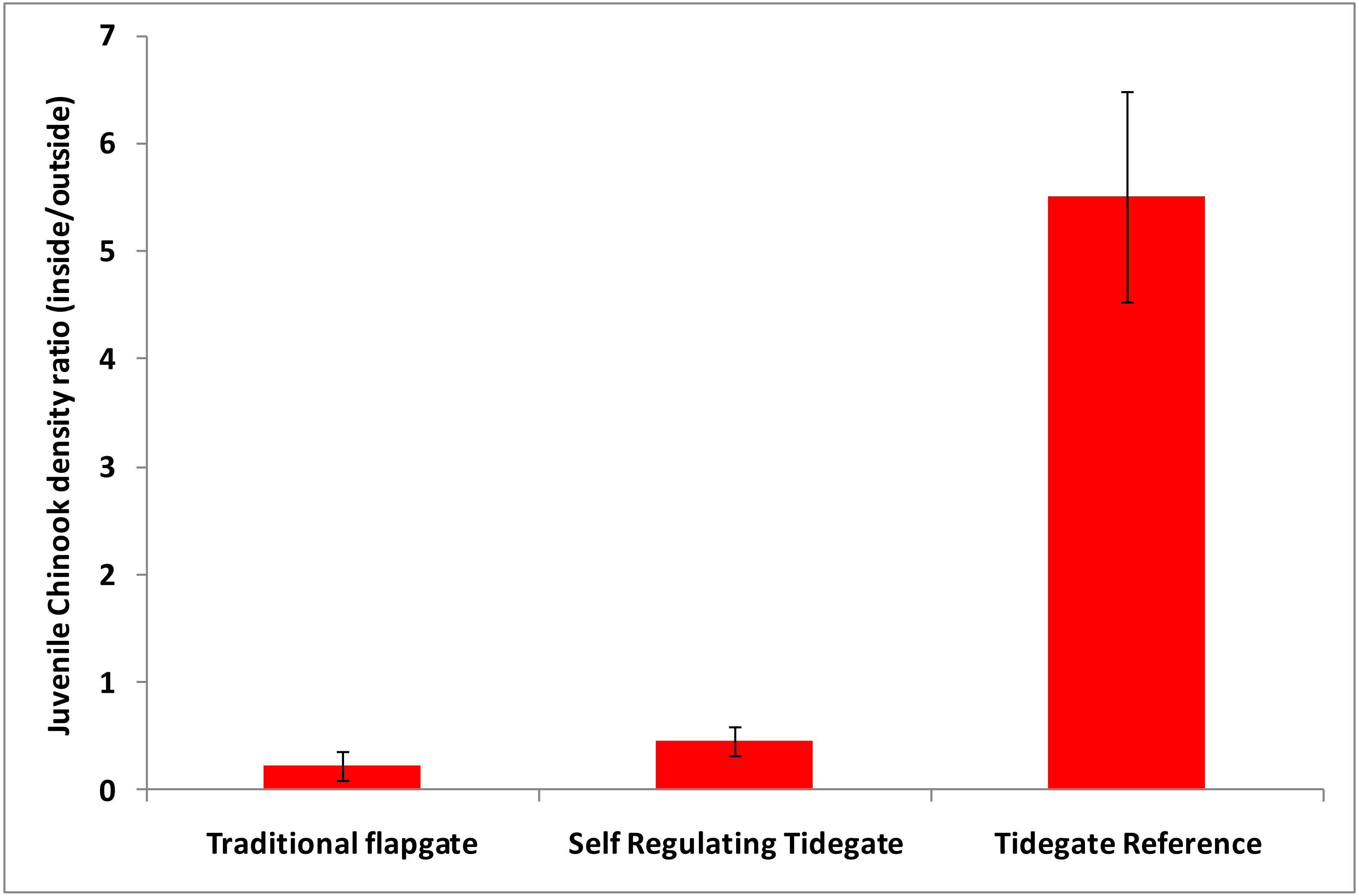
Local (restoration project) response:

- If you build it they will come. Juvenile Chinook used restored habitat generally consistent with reference sites.
- Some restoration designs work better than others for fish. Projects using dike setback, dike breach, or fill removal work best

Smokehouse Restoration Phase 1 example: Tide gate replacement (flap gate to SRT)



Effects of SRT restoration in the Skagit & Samish estuaries for juvenile Chinook salmon (3 sites, 8 years)

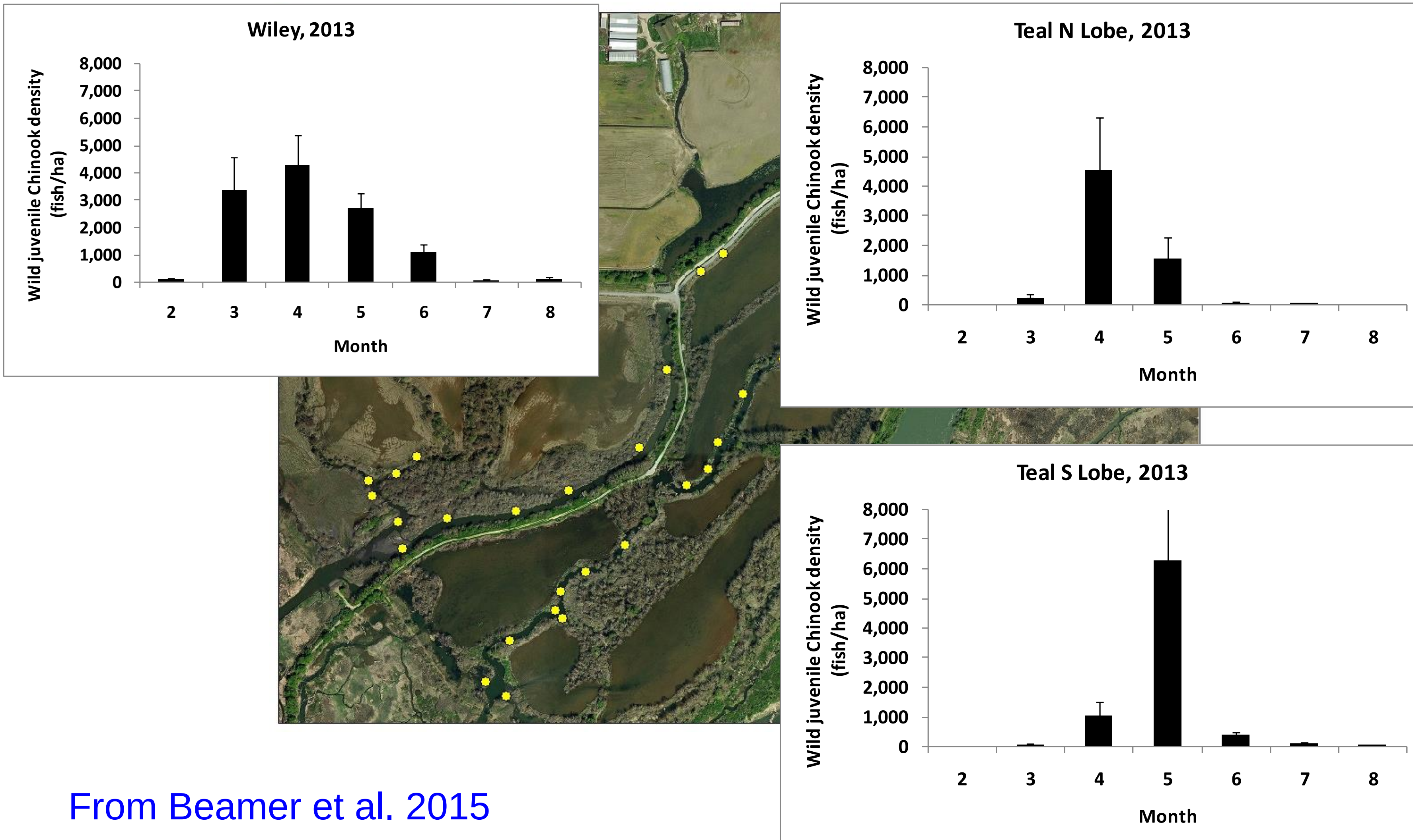


Summarized from Greene et. al. 2012

Wiley Slough Restoration

Juvenile Chinook abundance

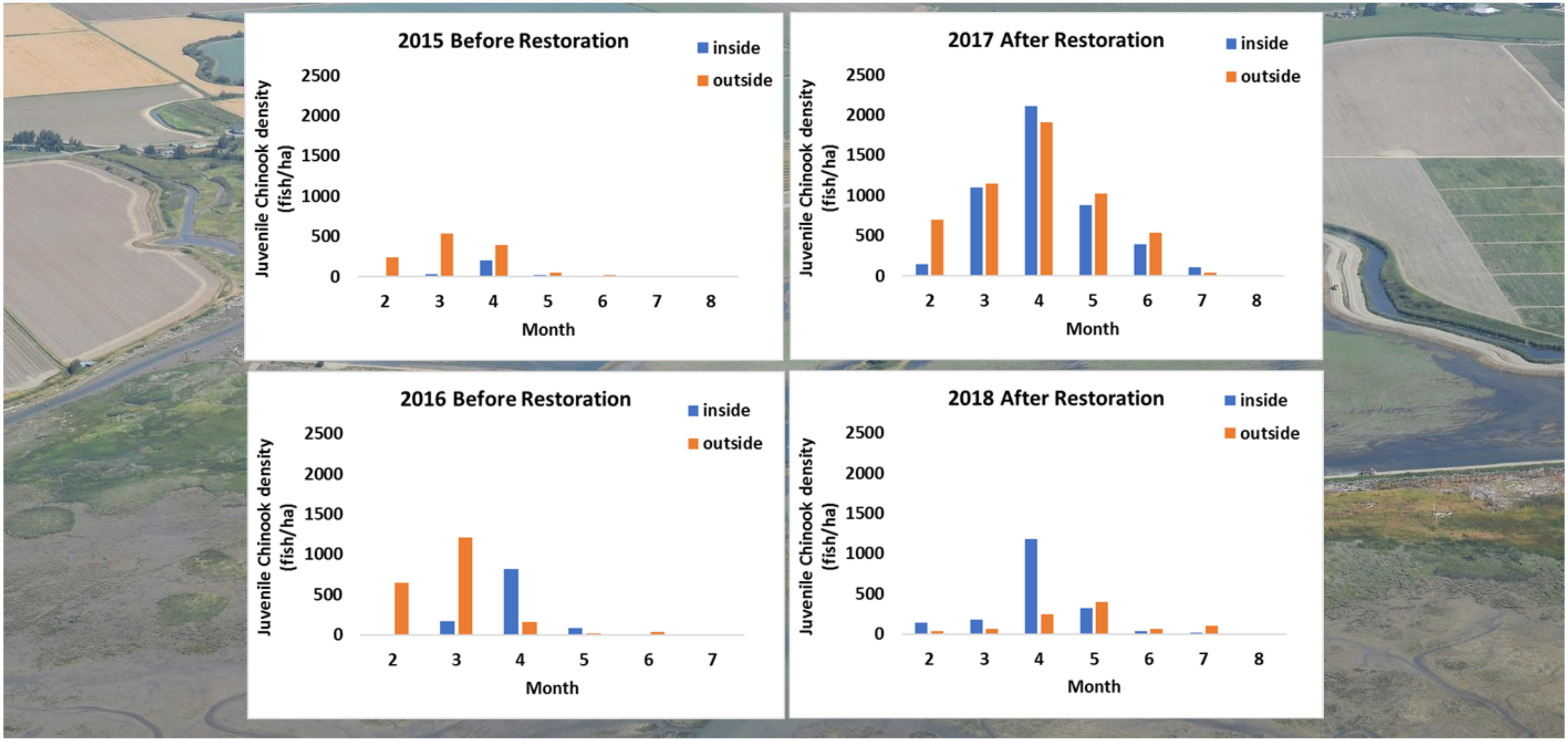
- **No before restoration monitoring (site blocked fish access)**
- **after restoration (88,000 and 248,000 fish)**
- **Carrying capacity estimate 75,000 to 370,000 fish – sustainable fish benefit depends on habitat trajectory (more from Greg)!**



From Beamer et al. 2015

Dike setback/breach design

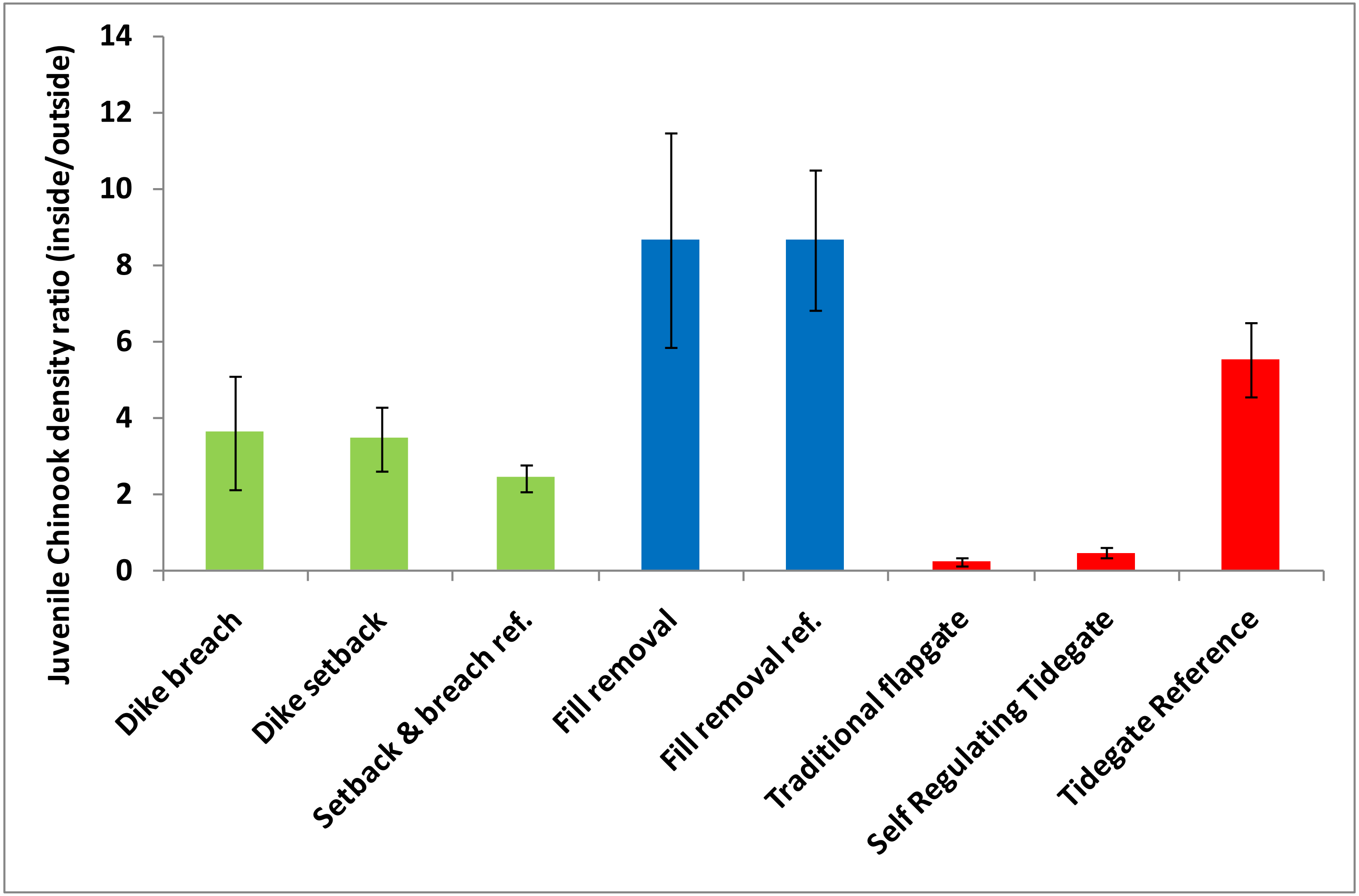
- Fir Island Farms example



Note the one outlet/inlet channel (more from Greg)

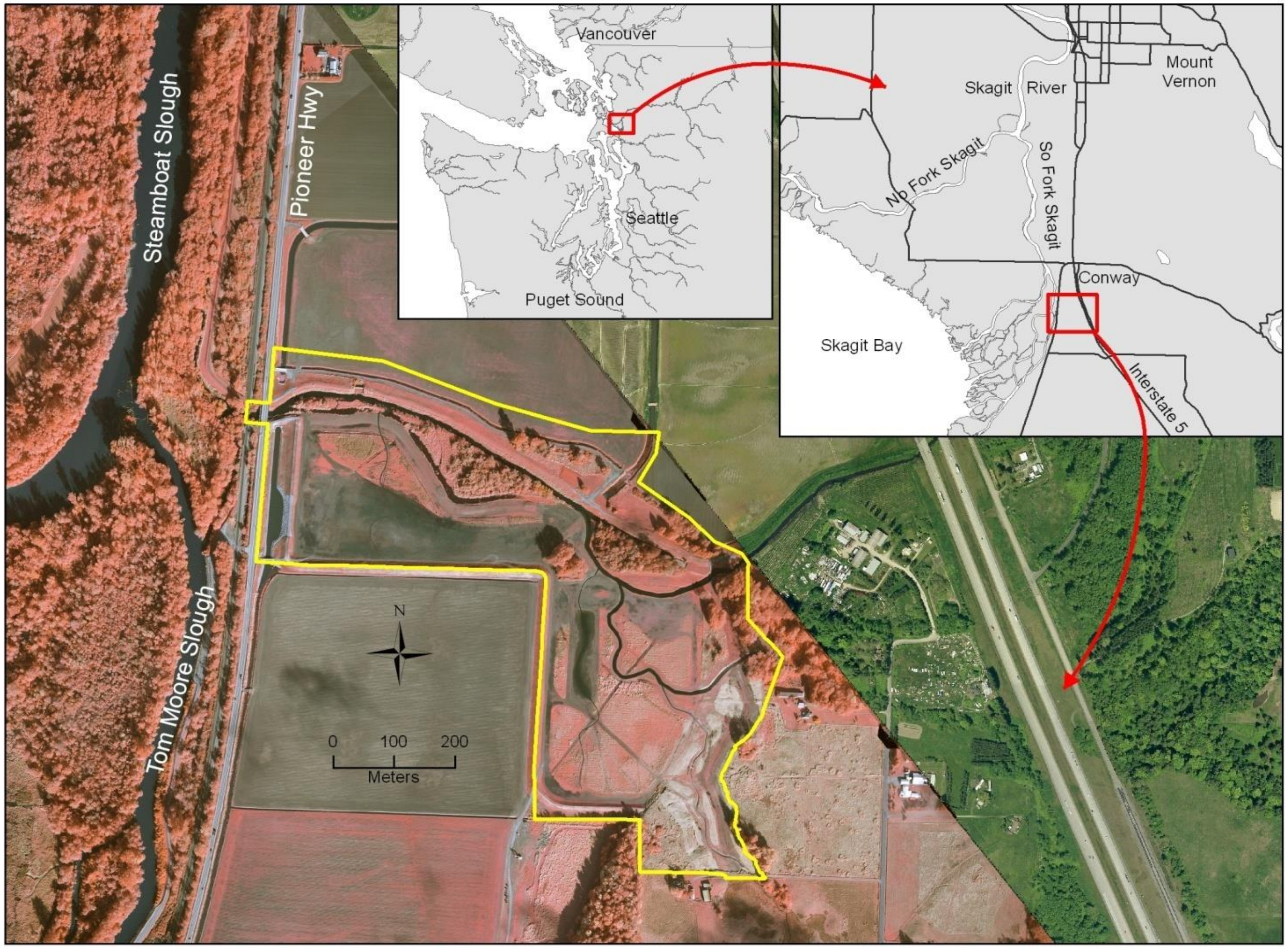
From Beamer et al. 2018

Summary: effects of different types of restoration in the Skagit estuary for juvenile Chinook salmon



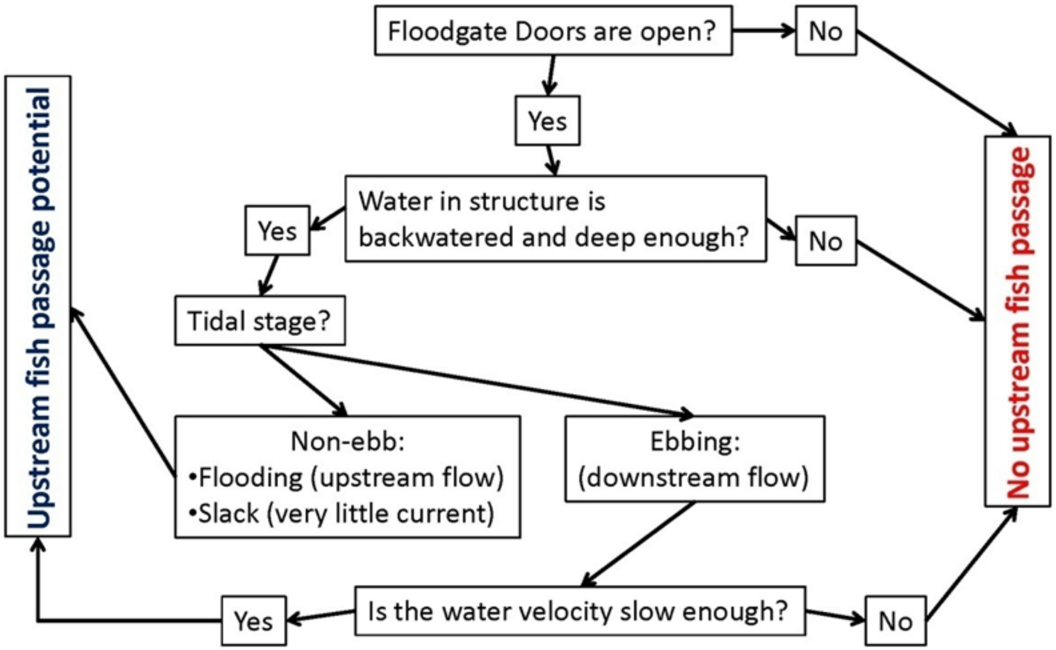
From Greene et al. 2016

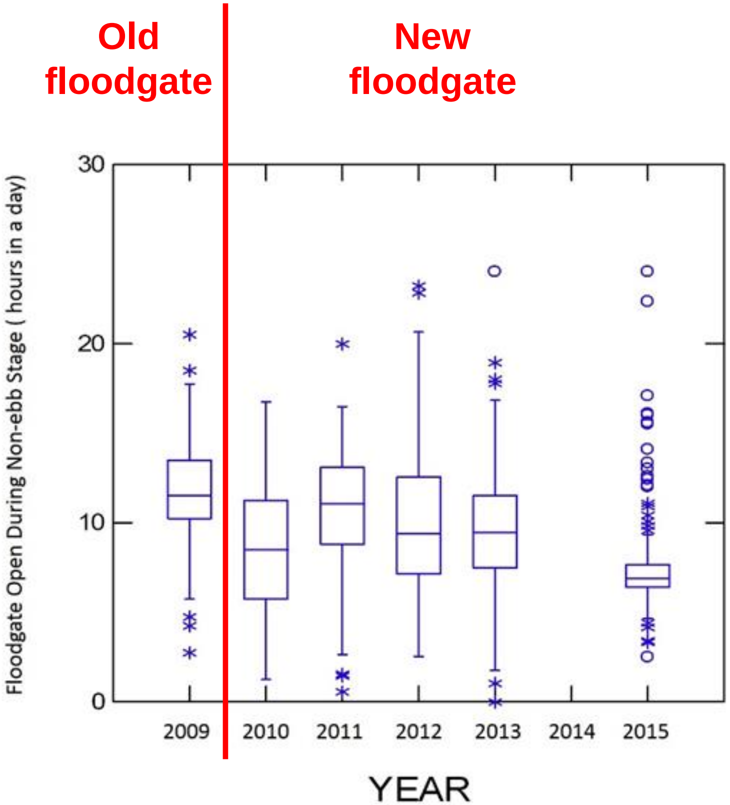
Complex Restoration Project Example: Fisher Slough (floodgate operation & dike setback)



Fisher Slough Floodgate Operation

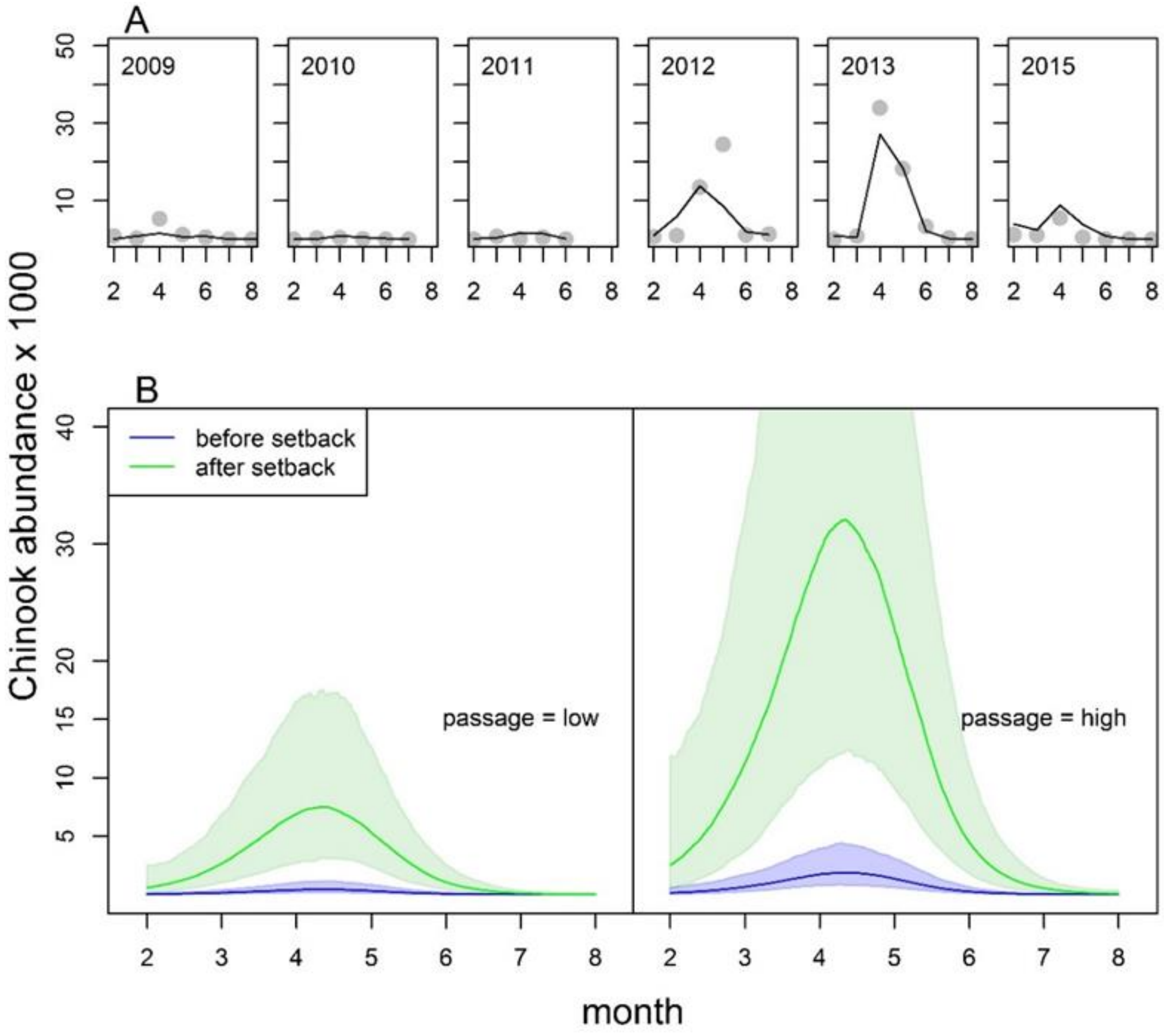
Upstream juvenile Chinook salmon passage potential





From Beamer et al. 2017

Floodgate operation & dike setback



From Beamer et al. 2017

Are the suite of restoration projects working for fish?

System (population) response:

- Juvenile Chinook are less crowded in the estuary as restoration increases habitat opportunity.
- The length of fish residence in the estuary increases as restoration increased.
- More weakly supported include: a) reduced frequency of fry migrants in marine habitats and b) higher smolt-adult return rates as restored area increased

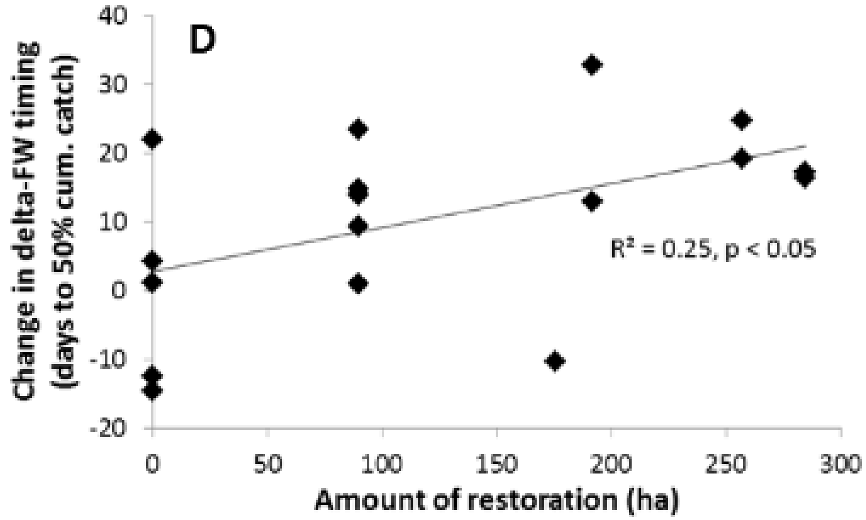
From Greene et al. 2016

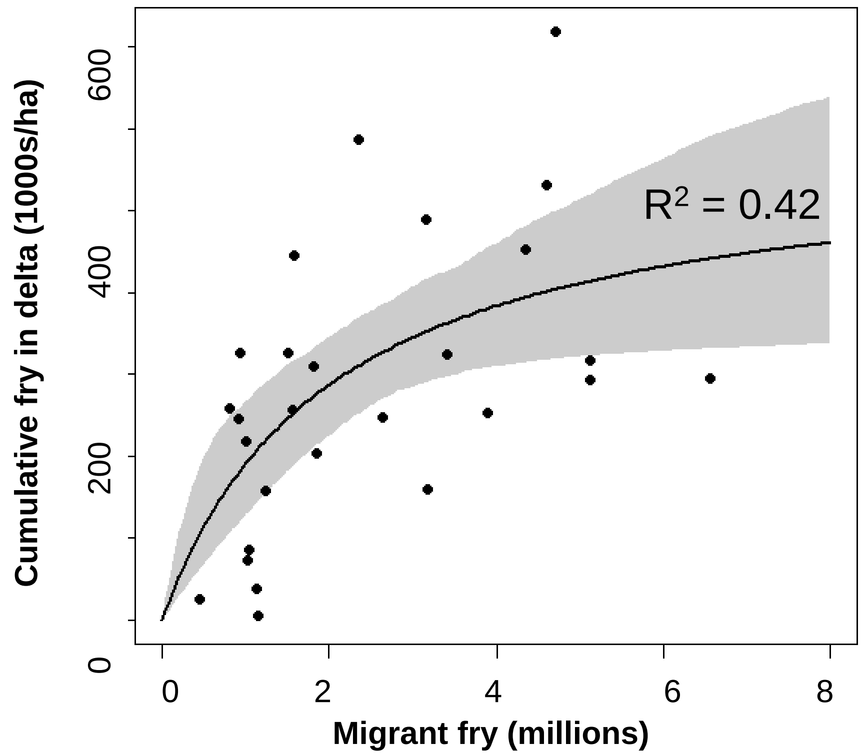
Evidence for Skagit estuary habitat limitation

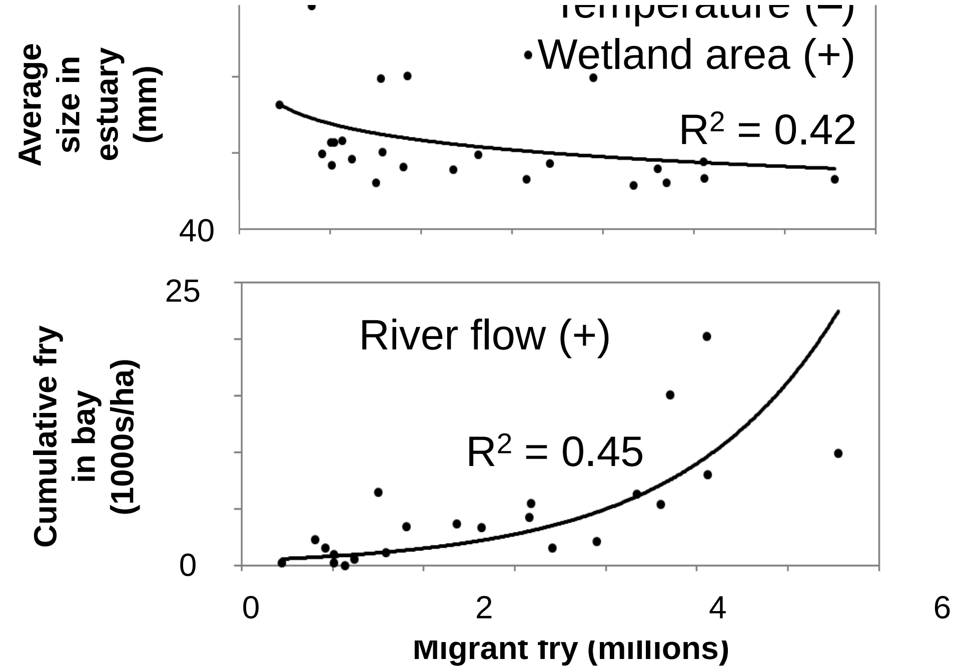
CRP findings still true: a) limit to abundance, b) fish size declines, and c) proportionally more fry are displaced into Skagit Bay as the estuary fills

New:

- **Residence time of fish decreases as the estuary fills up.**
- **Habitat area (restoration) offsets fish size and residence time trends**







1st version: Greene et al 2015; being updated now

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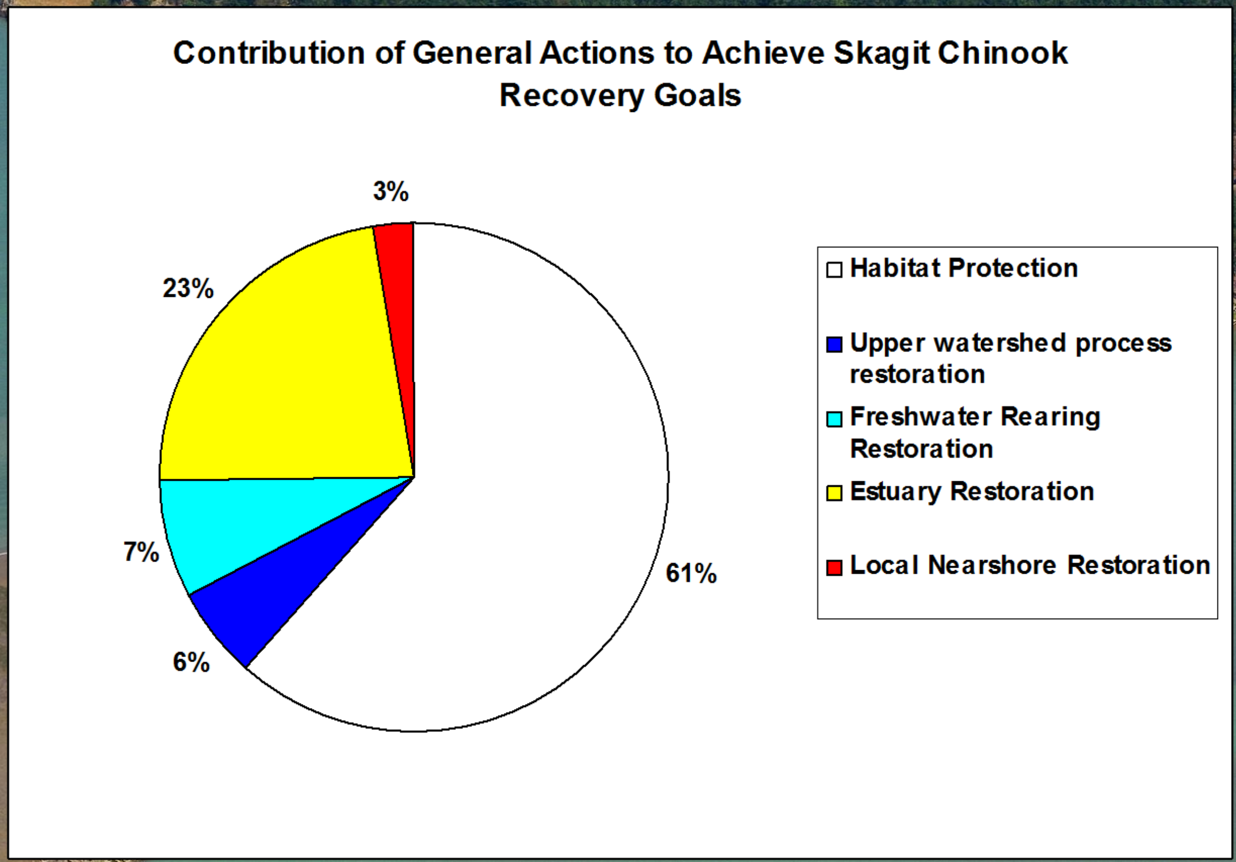
Are the current restoration projects enough?

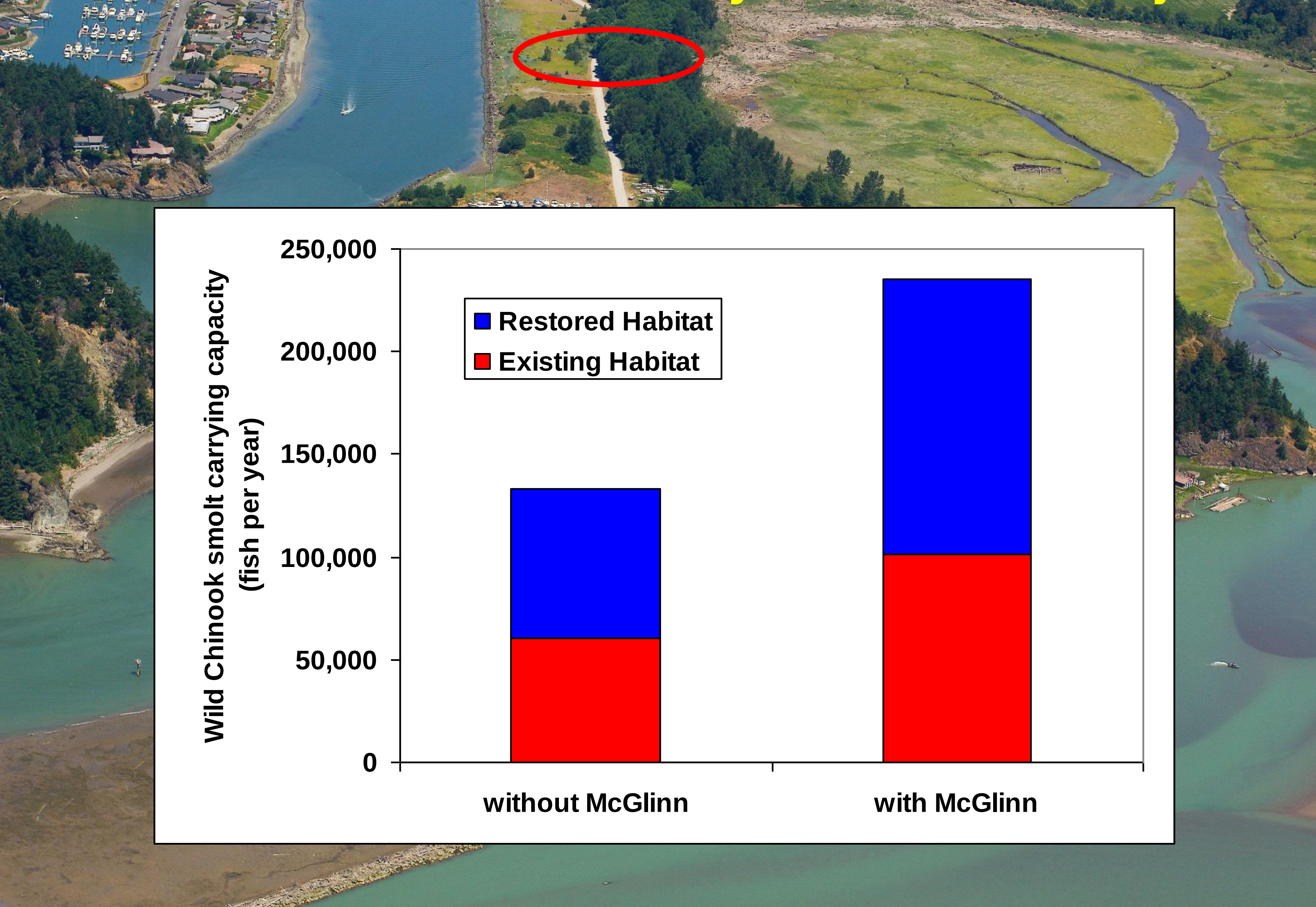
- Habitat Status & Trends Results (Greg)
- Projects in process (Richard)



What the Skagit Chinook Recovery Plan (CRP) says:

Capacity (fish/yr)	Description
3.60 million	CRP Goal for entire estuary
2.25 million	Estimated pre-CRP adoption (<2005)
1.35 million	**CRP goal for restoration**

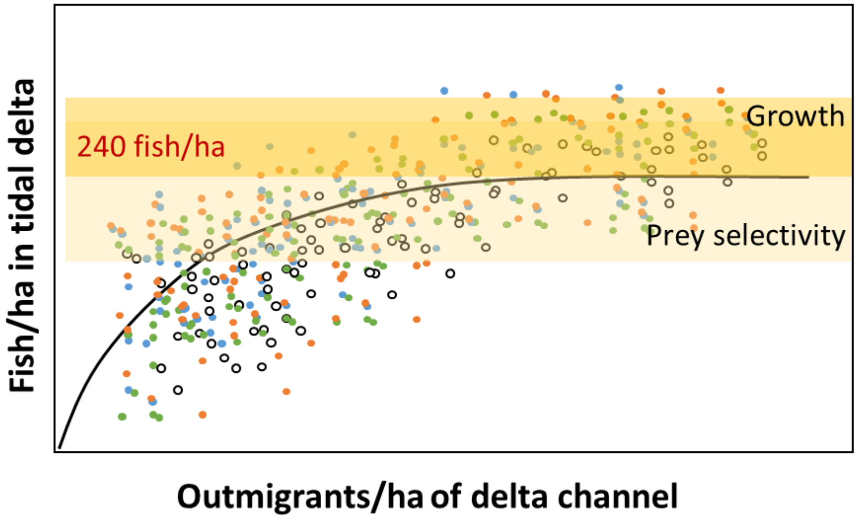
McGlinn Island Connectivity Restoration Project

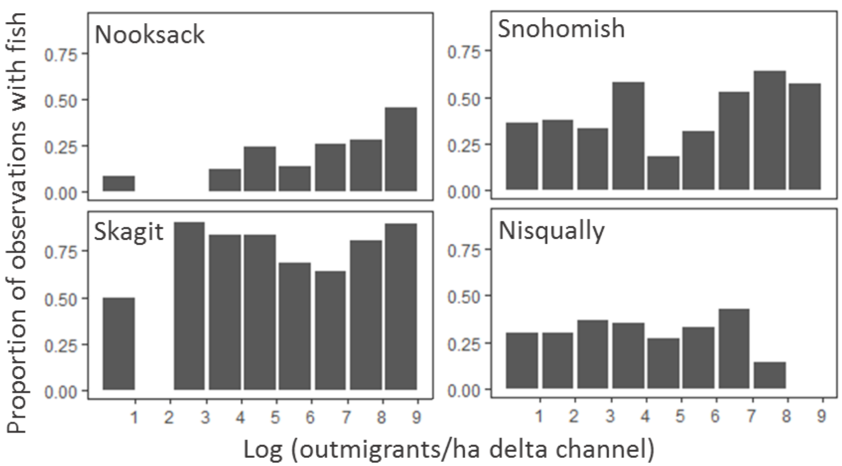


The Future

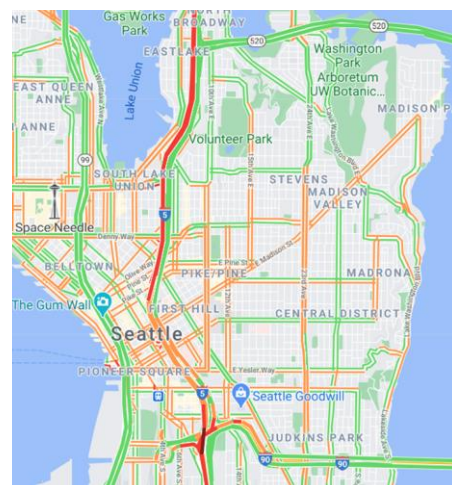
- Continue the long-term population/system monitoring
- Continue restoration effectiveness monitoring
- Continue collaborating
  - regional & local partners

Learn more about how density dependence in estuaries works!



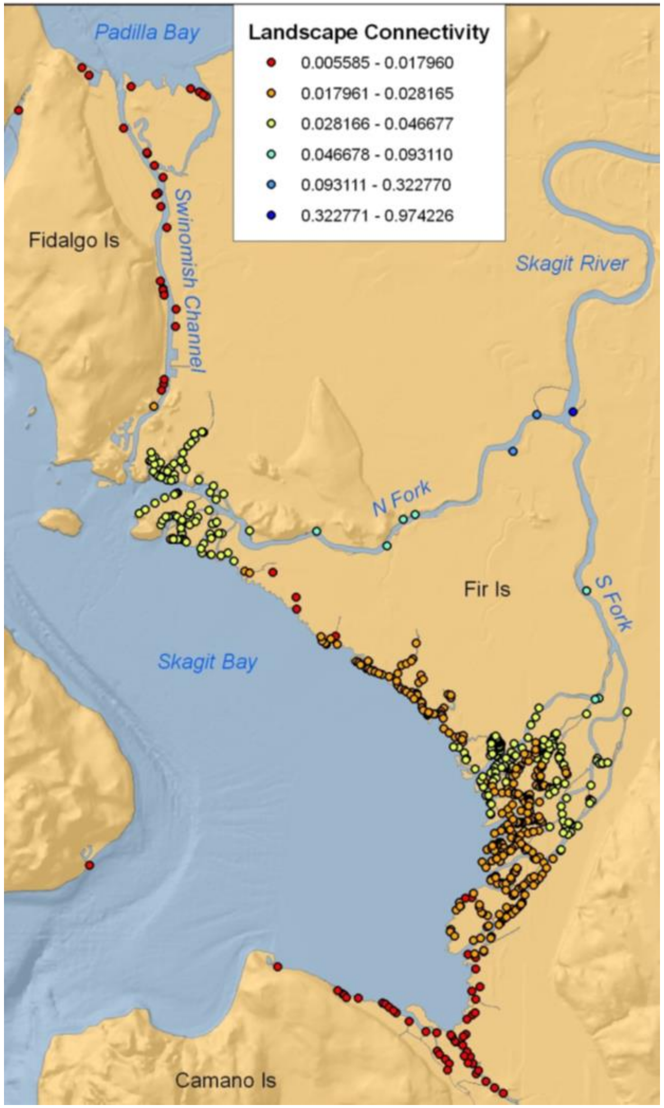


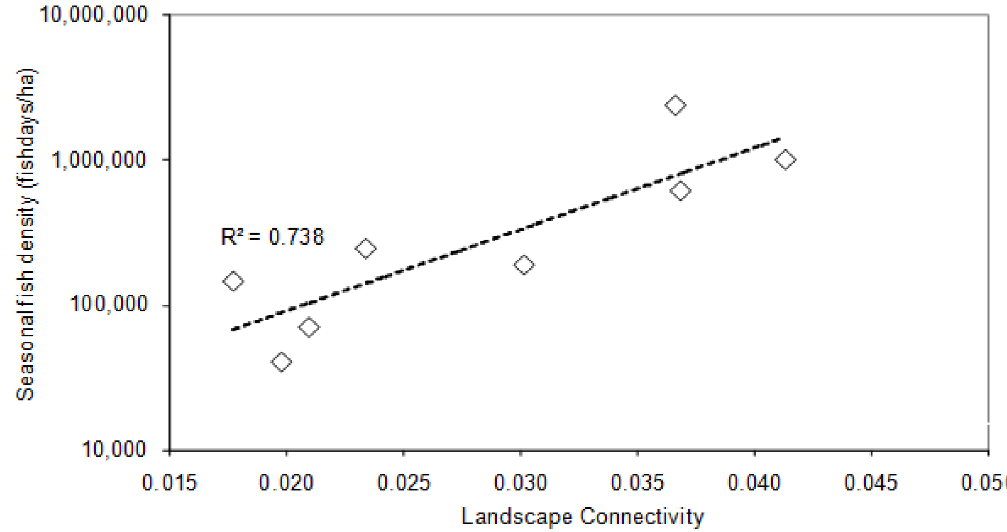
- System and seasonal differences
- Fish responses vary
- Reconsider our concept of "capacity"

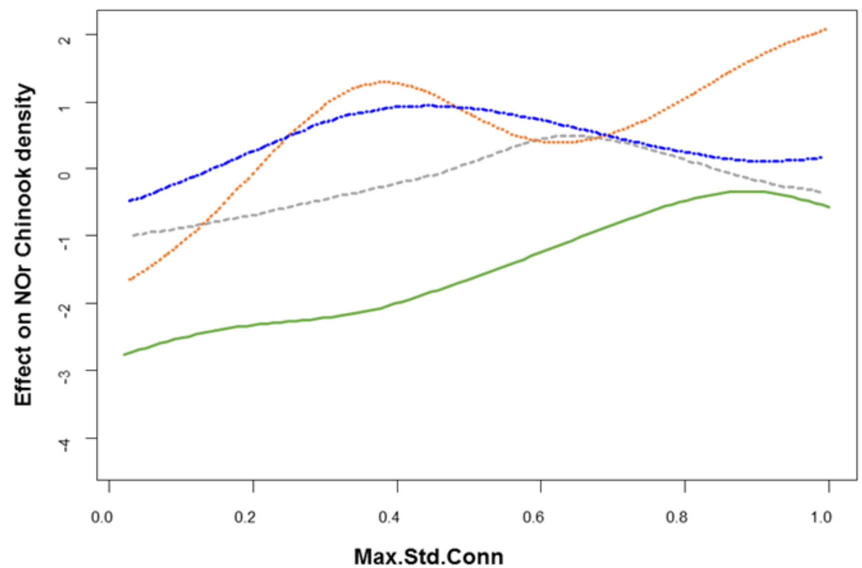


Greene et al. 2021.

Learn more how “location” matters



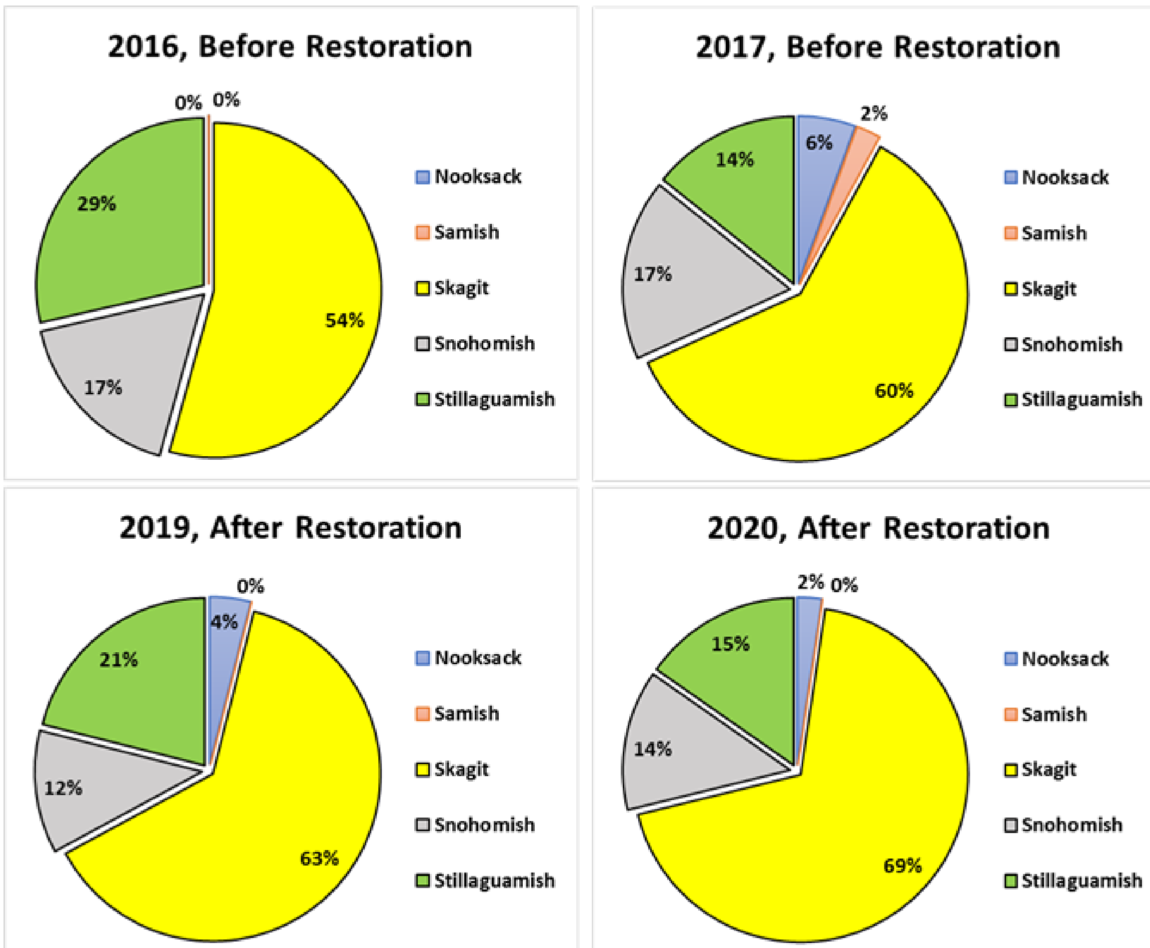




From Beamer & Wolf 2011; Greene et al. 2021

Location matters … it can be a mixture even in a river delta!

Genetic assignment of natural origin juvenile Chinook from the Stillaguamish tidal delta (zis a ba 1 area)



References

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- Greene, C., J. Hall, E. Beamer, R. Henderson, and B. Brown. 2012. Biological and Physical Effects of “Fish-Friendly” Tide Gates. Report to the Estuary and Salmon Restoration Program. Final Report for the Washington State Recreation and Conservation Office, January 2012. https://salishsearestoration.org/images/4/4a/Greene_et_al_2012_effects_of_tidegates_on_fish.pdf

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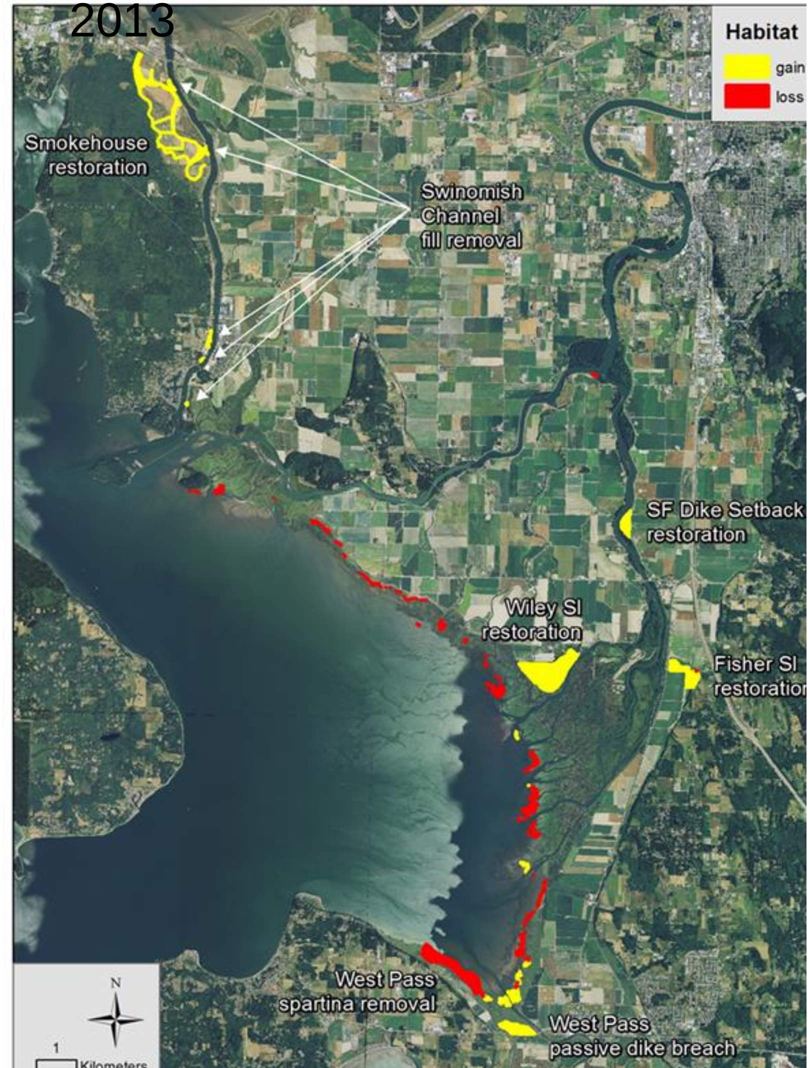
Is there more estuary habitat for fish?

We need a large-scale perspective—Status and Trends Monitoring

Skagit estuary gains/loss 2004-2013

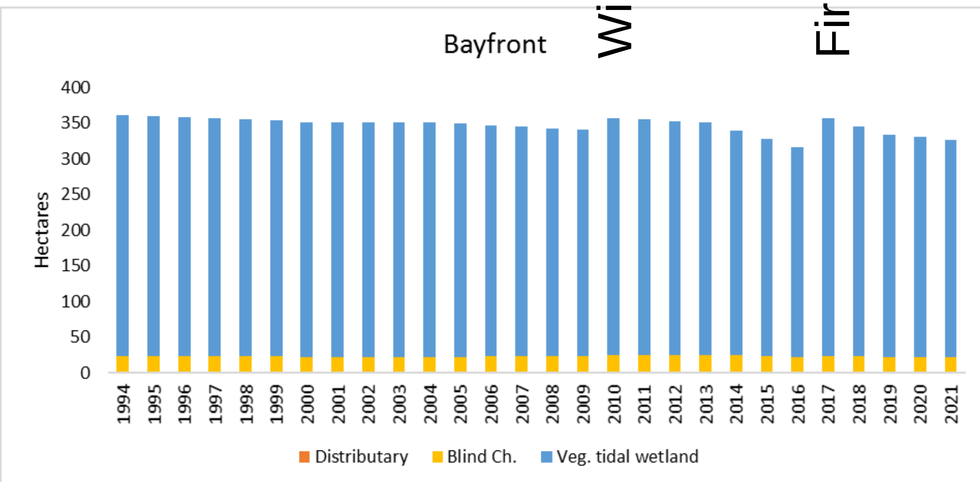


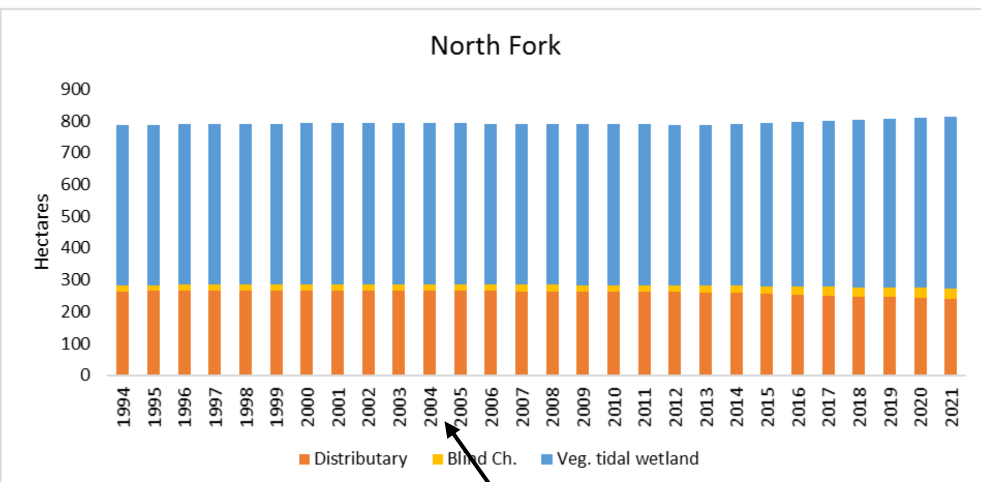
- The Skagit estuary is gaining more habitat than it is losing
- Restoration is the main reason why.
- Natural gains and losses of estuary occur, with a net loss observed from 2004-2013.
- Most loss areas are along the bay front of Fir Island (sheltered from river sediment deposition and more exposed to wave caused erosion)

Beamer and Wolf 2017

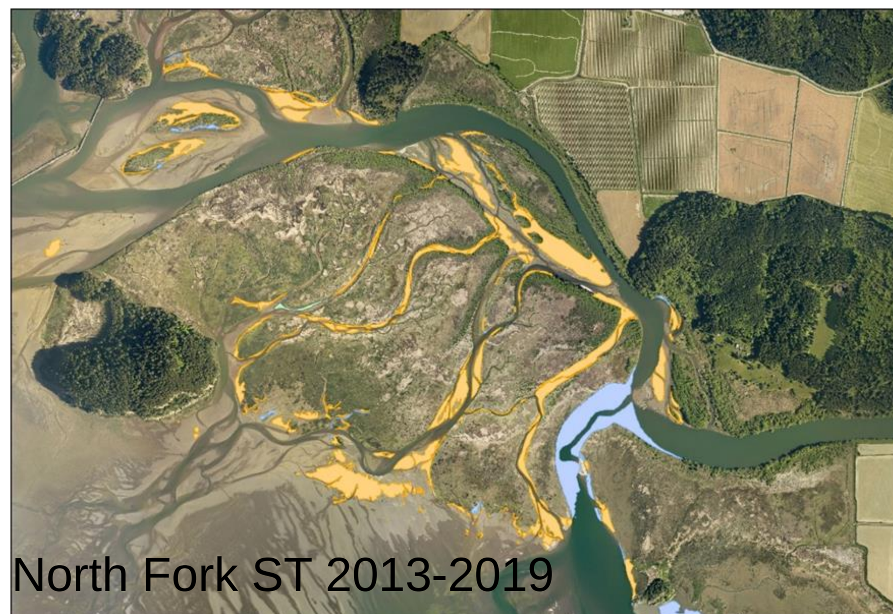
Wiley

Fir Isl. Farms

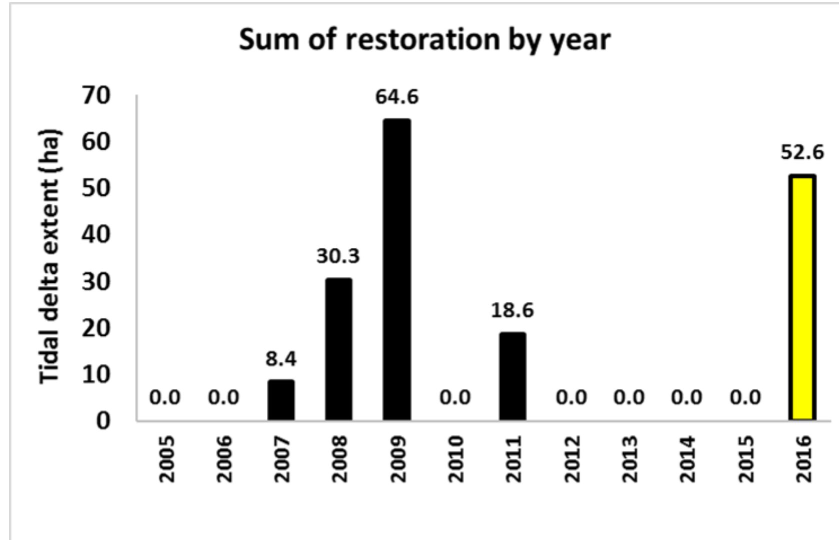


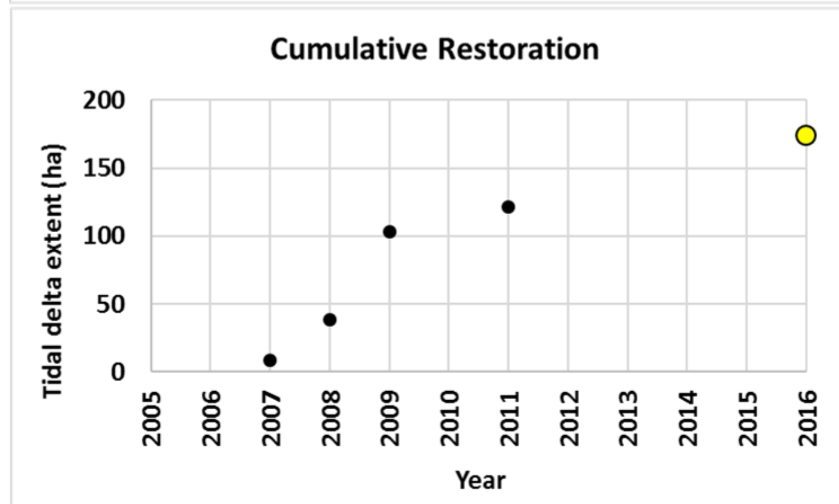


NF Avulsion



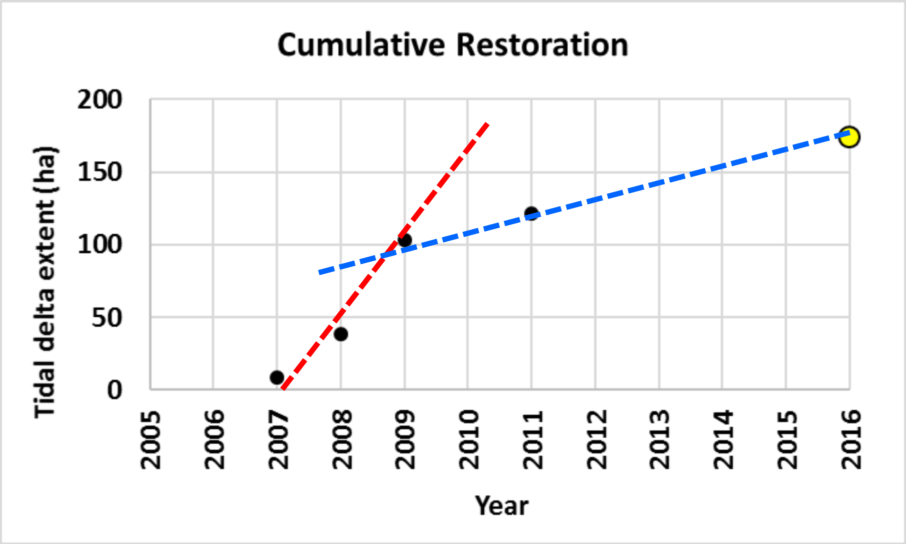
Restoration by year





Restoration project (year completed)	Gain (ha)	Loss (ha)	Net change (ha)
Fisher Sl restoration (2011)	18.657	0.041	18.615
SF Dike Setback restoration (2007)	8.369		8.369
Smokehouse restoration (2008)	26.902		26.902
Swinomish Channel fill removal (2008)	3.366		3.366
Wiley Sl restoration (2009)	64.623		64.623
Total	**121.917**	**0.041**	**121.876**

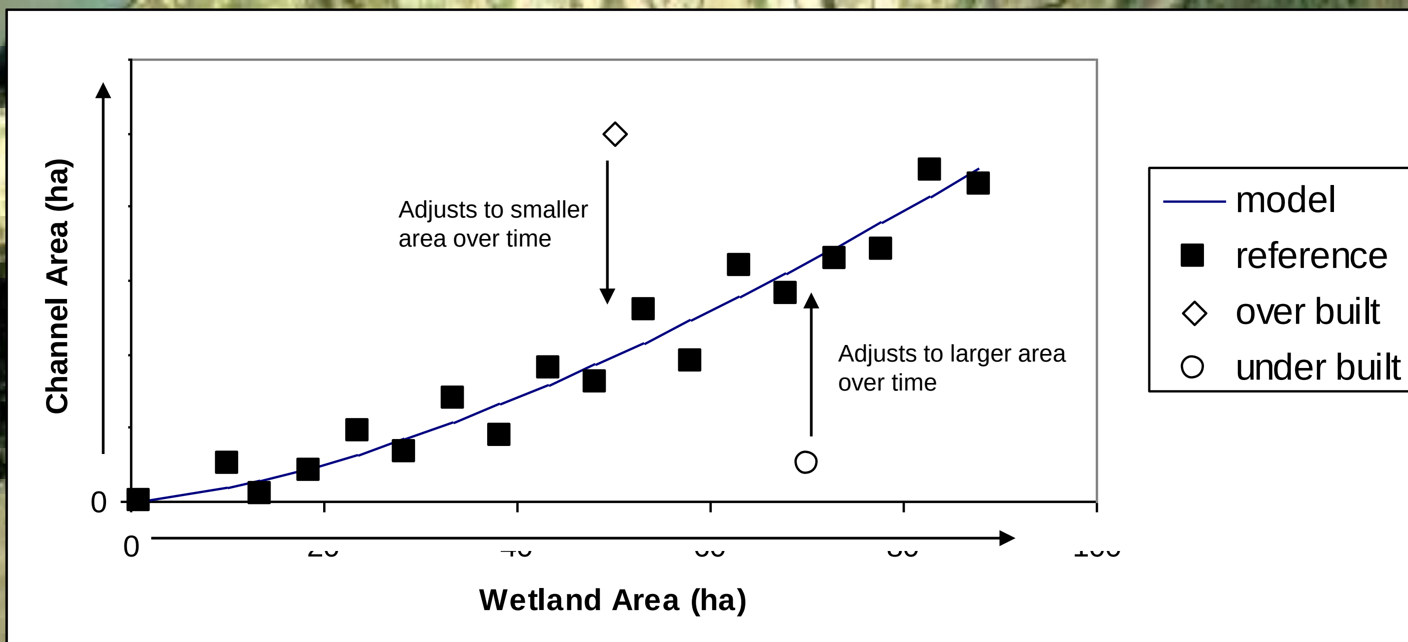
How long will it take to reach Skagit tidal delta desired future condition?



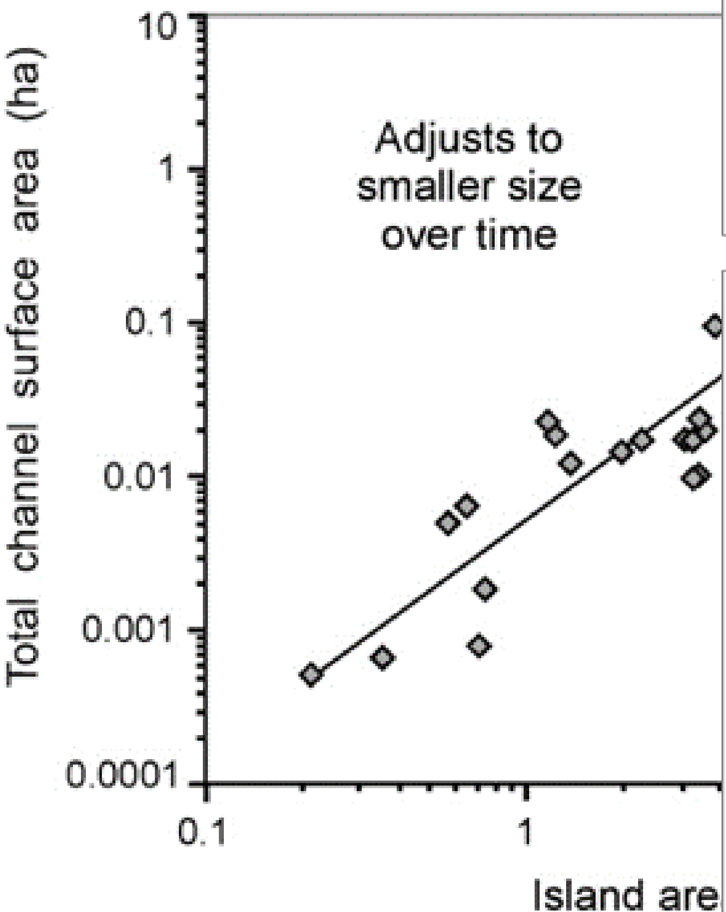
DFC scenario	DFC achieved (year)	Restoration amount needed (2014-DFC)	Additional restoration to maintain DFC though year 2106	Total restoration to achieve and maintain DFC
Scenario 1: Fastest observed restoration pace • Restoration pace = 25.8 ha/yr • Natural gain/loss rate = -1.9 ha/yr	2045	825.6 ha	117.1 ha	942.7 ha
Scenario 2: Slowest observed restoration pace • Restoration pace = 10.2 ha/yr • Natural gain/loss rate = -1.9 ha/yr	2106	948.6 ha	0.0 ha	948.6 ha

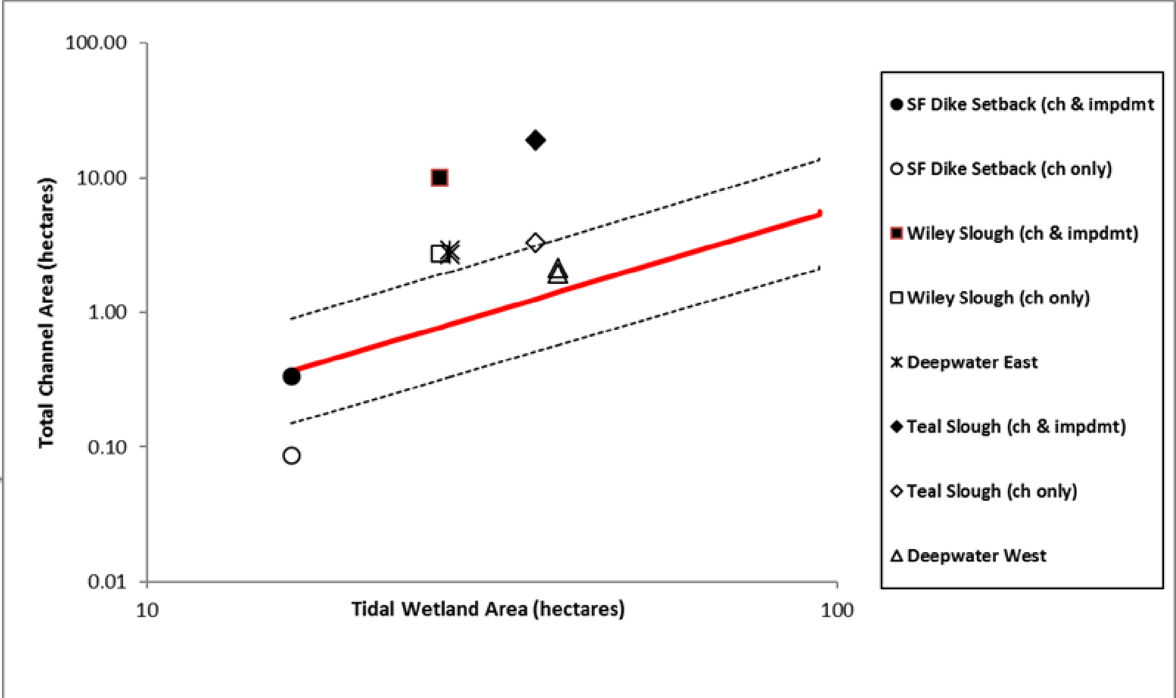
Why is there uncertainty?

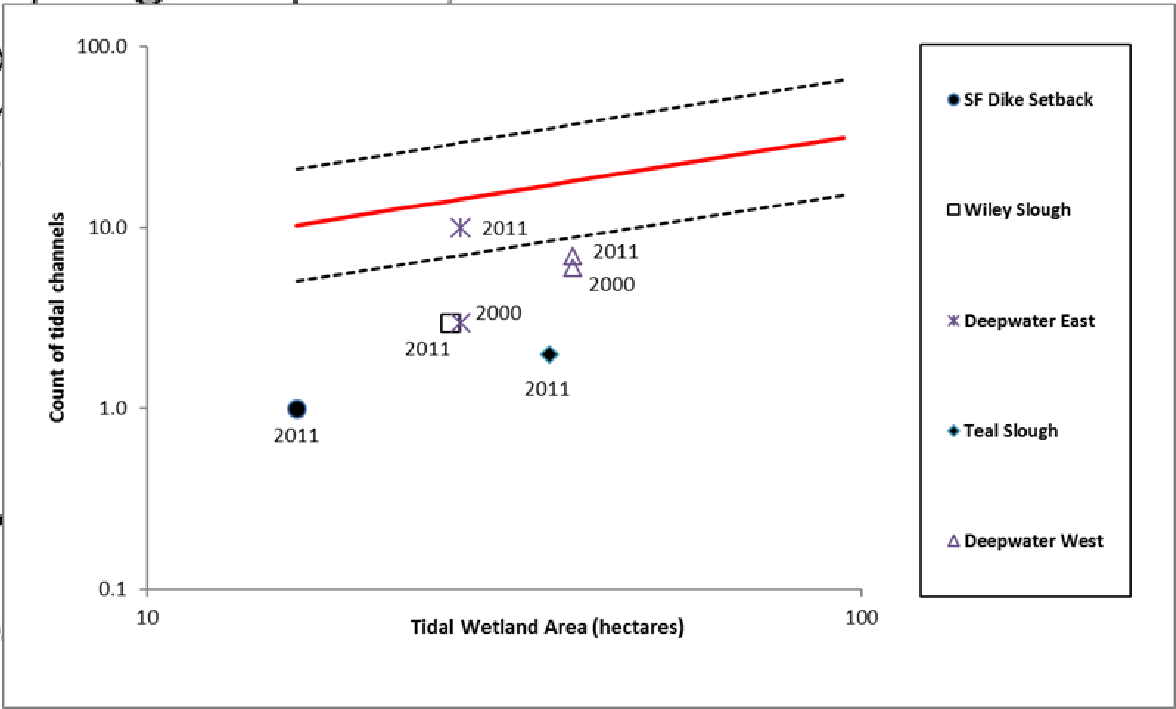
1. **Statistical uncertainty of models**
2. **Habitat is not static**
   - **Considerations:**
     - **Fate of impoundments & development of channels**
     - **Vegetation colonization**



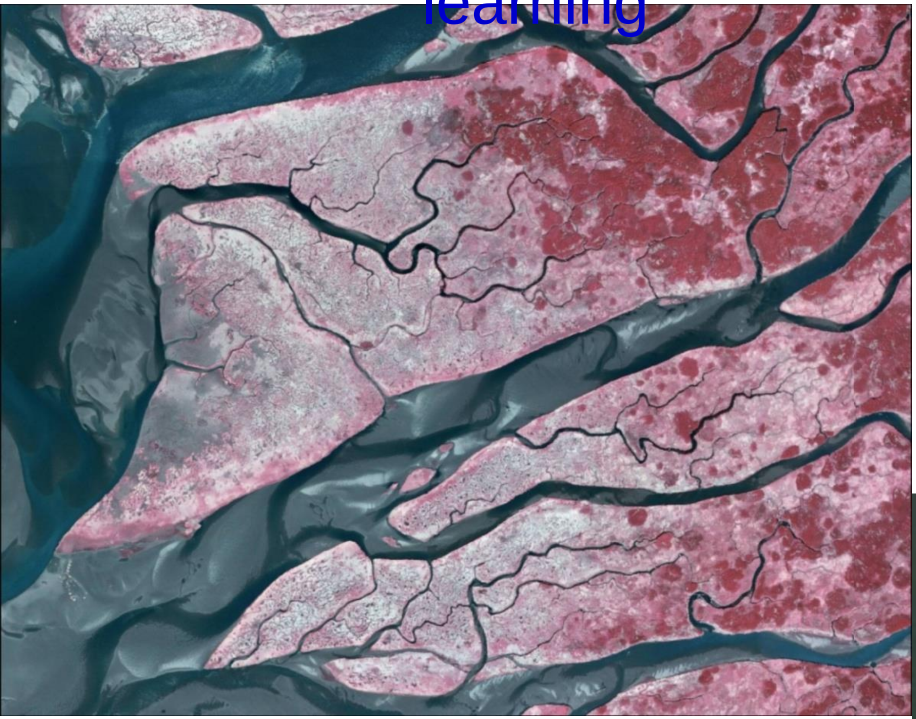
Learn about habitat trajectory







Predictive Models are critical for learning



Prediction is necessary:

for planning and design
to evaluate outcomes (monitoring)
to better understand our system
to advance restoration science and practice

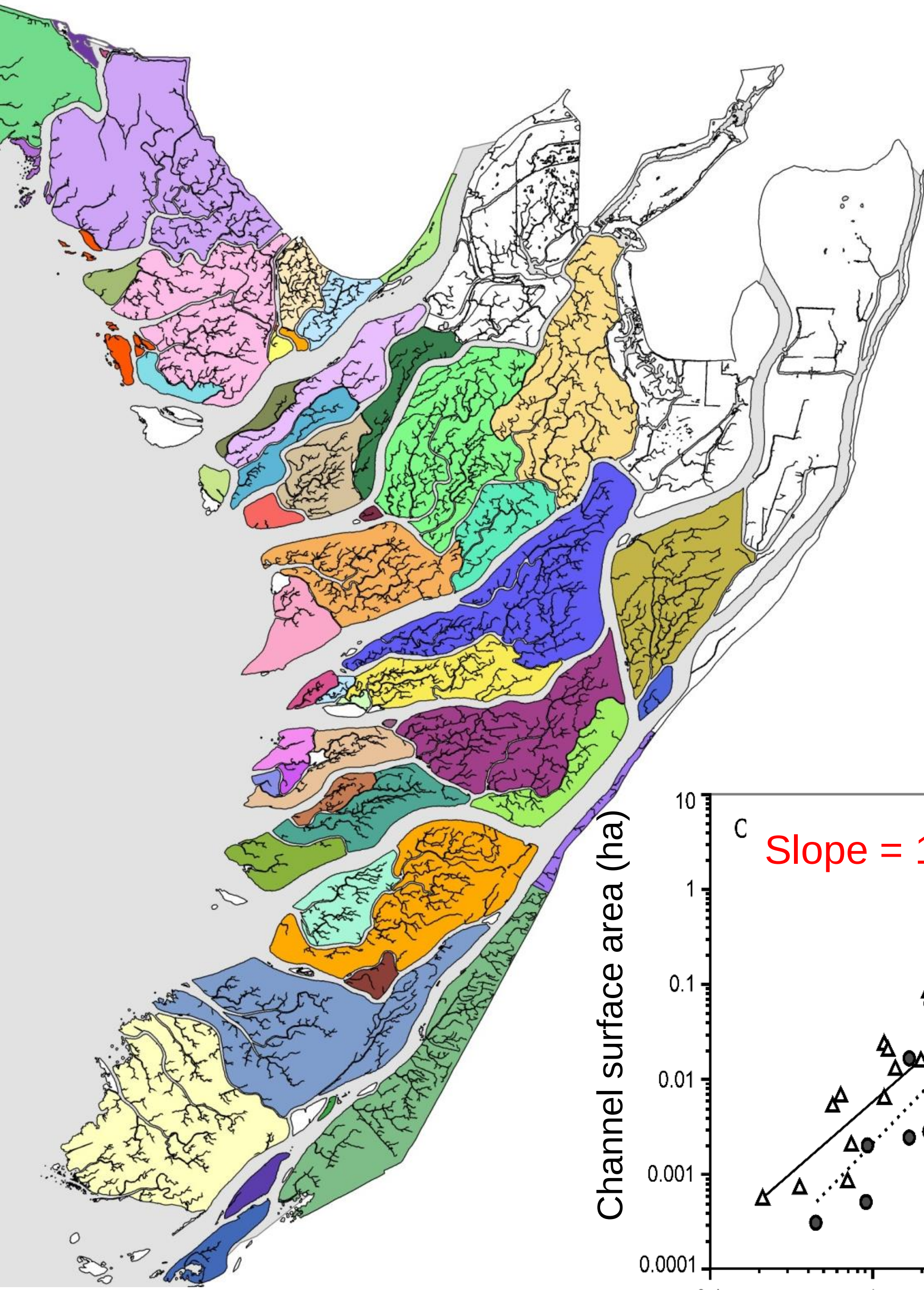
Just winging it is not good enough

Ann's Slough & reference Cosmopolis, WA

30+ years ago restoration predictions were conceptual and qualitative.

The restoration site should look and act something like a reference site.

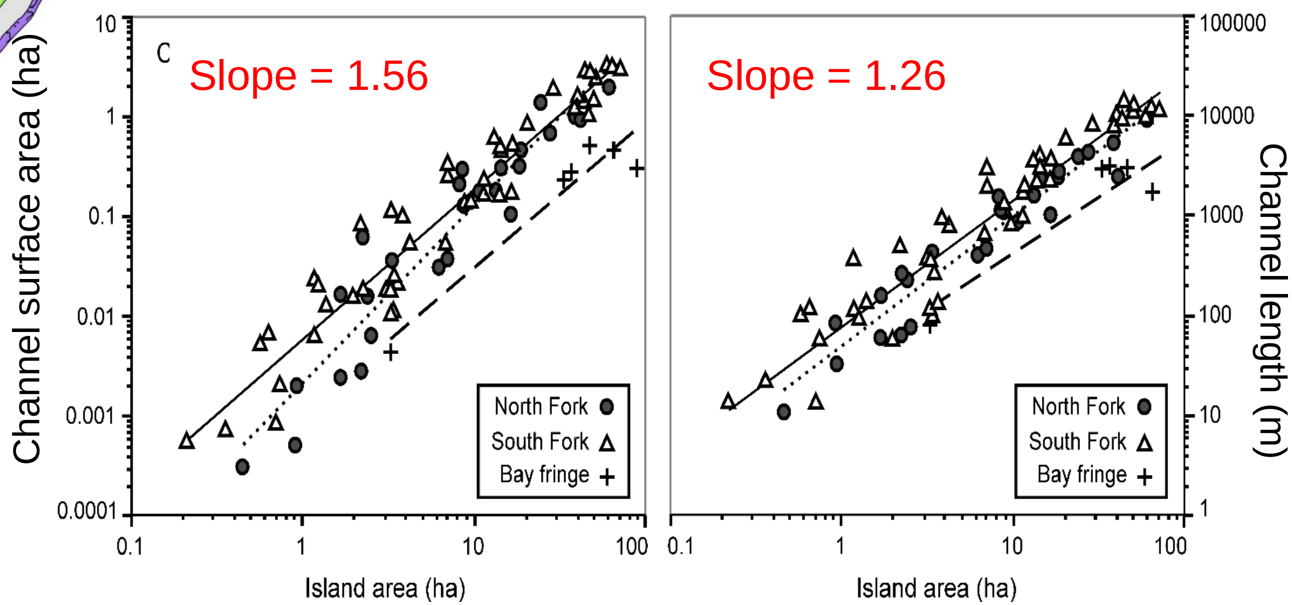
Channel Allometry



Landscapes are fractal, e.g., scaling relationships between marsh islands and tidal channels: Power functions that can be linearized by log transformation,

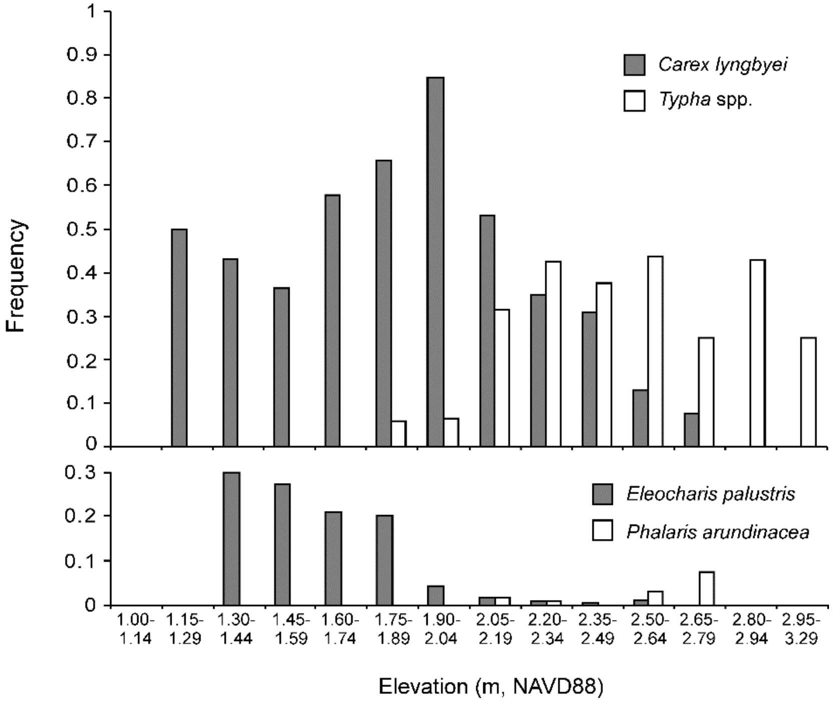
$P = cA^b \rightarrow \log(P) = \log(c) + b \log(A)$

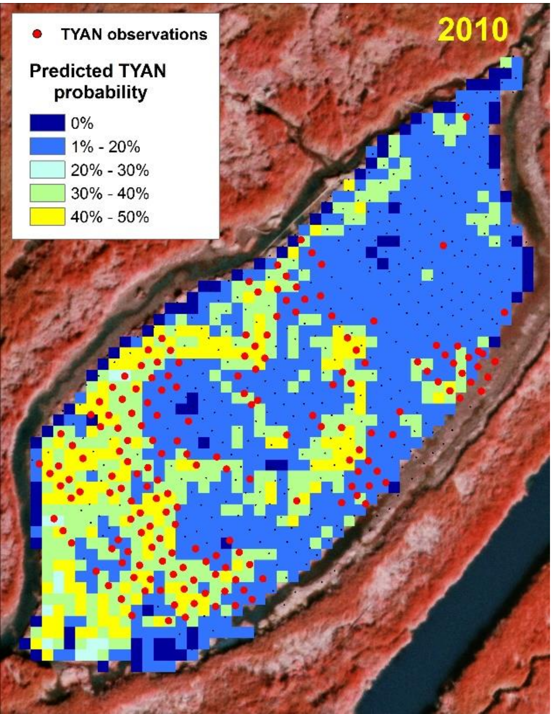
Predict a suite channel geometries, and fish abundance, making assumptions about fish densities.

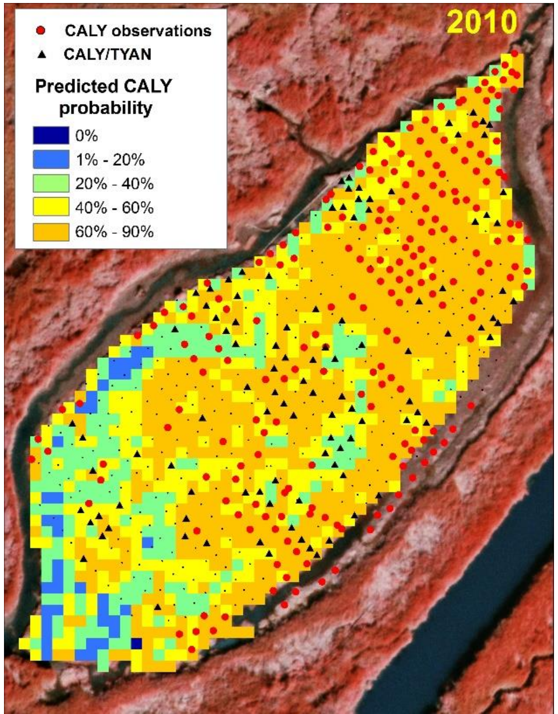


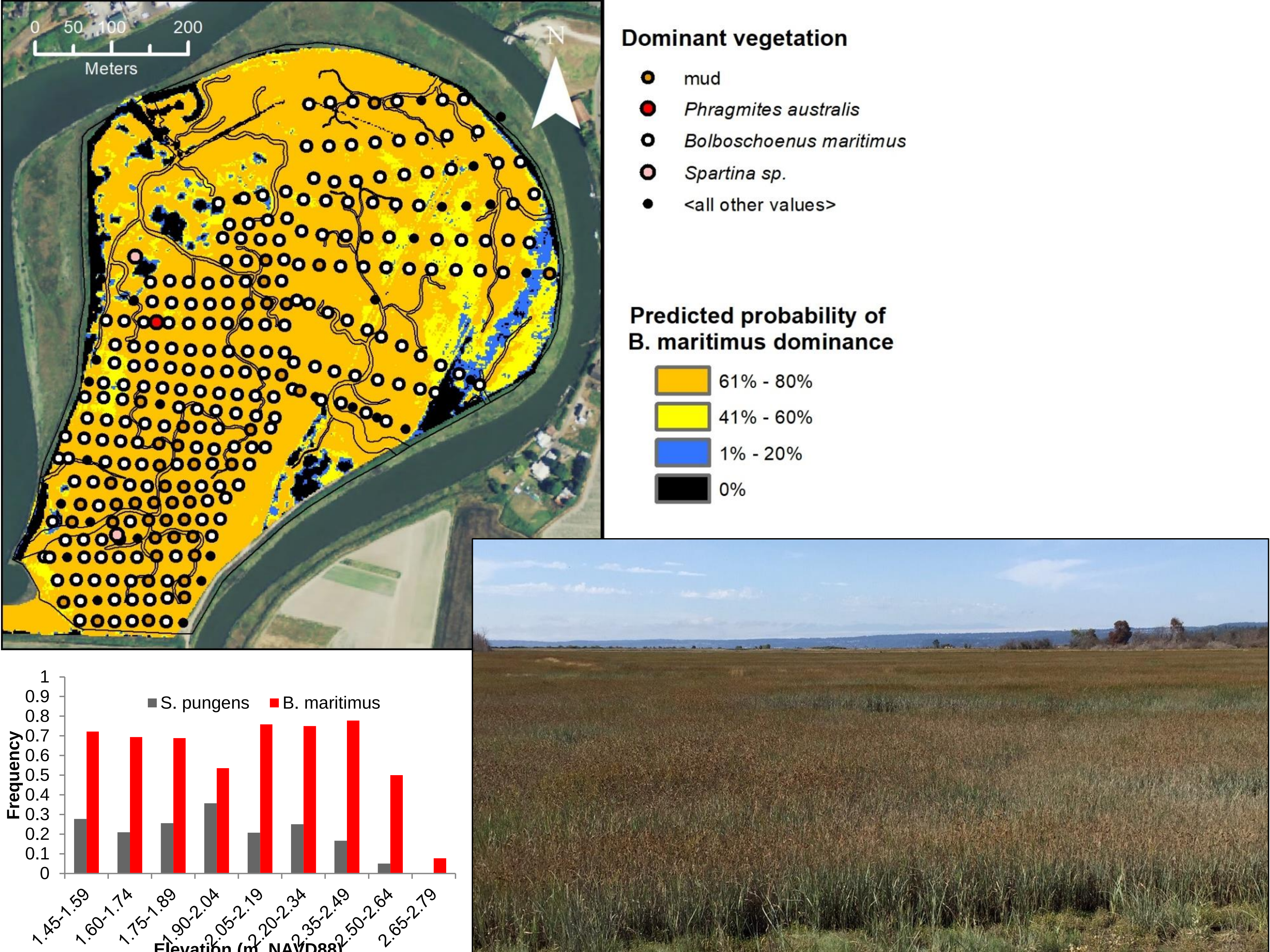
Predictive Vegetation Models (PVMs)

Hood WG. 2013. *Wetlands Ecology and Management* 21: 229-242

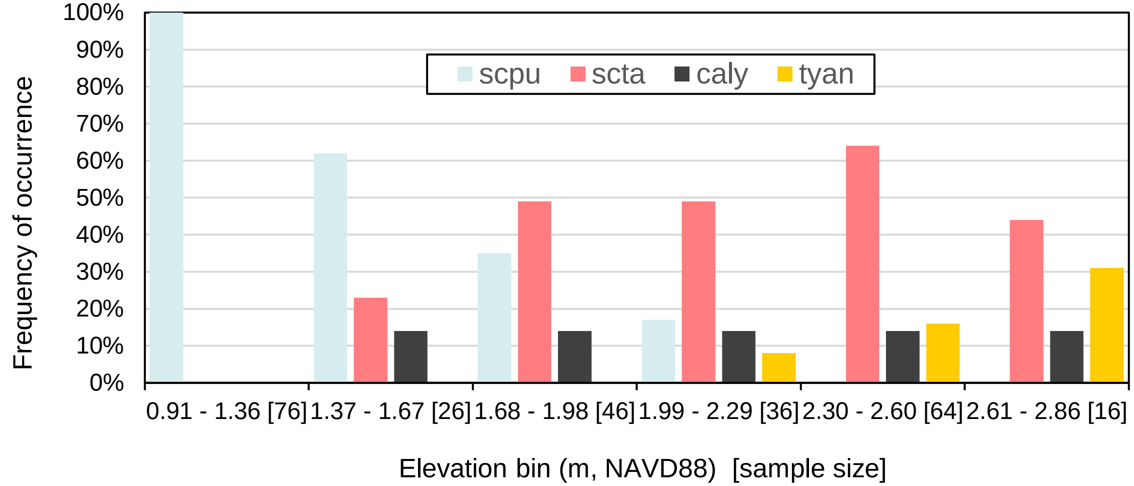








0 50 100 200
Meters
N
Dominant vegetation
mud
Phragmites australis
Bolboschoenus maritimus
Spartina sp.
<all other values>
Predicted probability of
B. maritimus dominance
61% - 80%
41% - 60%
1% - 20%
0%
S. pungens
B. maritimus
Frequency
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1.45-1.59
1.60-1.74
1.75-1.89
1.90-2.04
2.05-2.19
2.20-2.34
2.35-2.49
2.50-2.64
2.65-2.79
Elevation (m, NAVD88)


100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Frequency of occurrence
scpu
scta
caly
tyan
0.91 - 1.36 [76]
1.37 - 1.67 [26]
1.68 - 1.98 [46]
1.99 - 2.29 [36]
2.30 - 2.60 [64]
2.61 - 2.86 [16]
Elevation bin (m, NAVD88) [sample size]

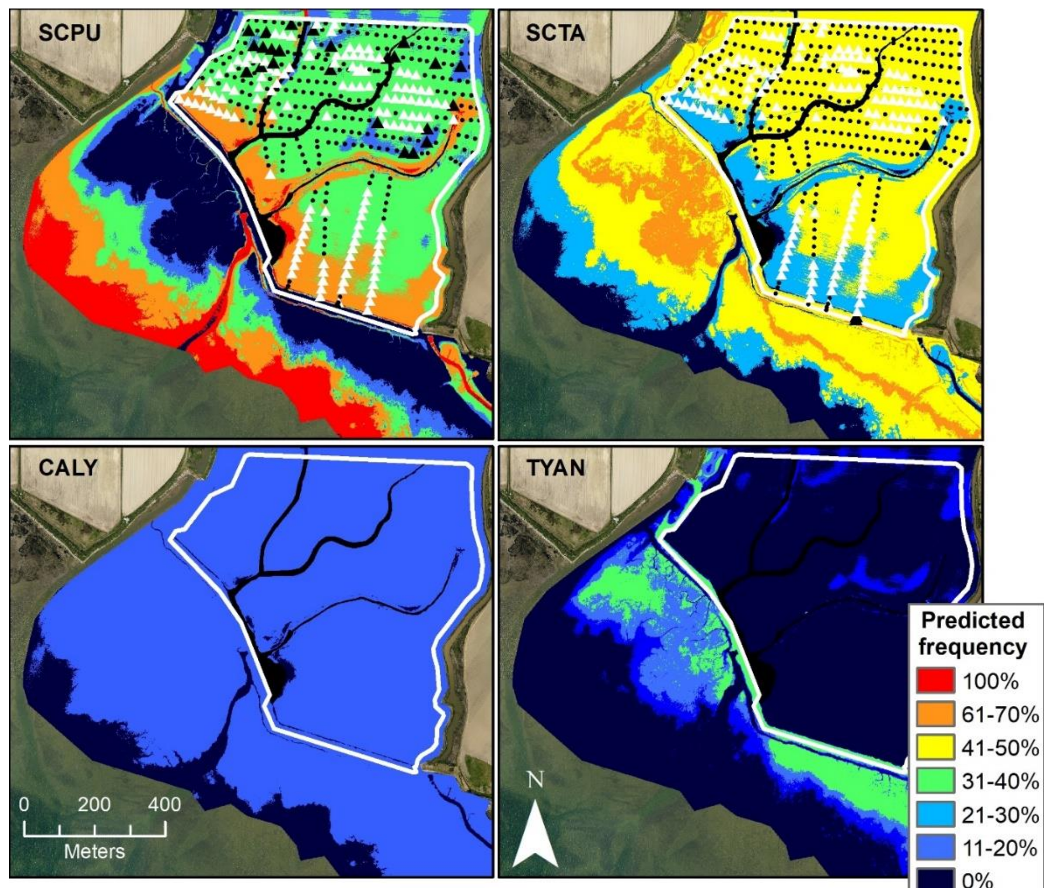
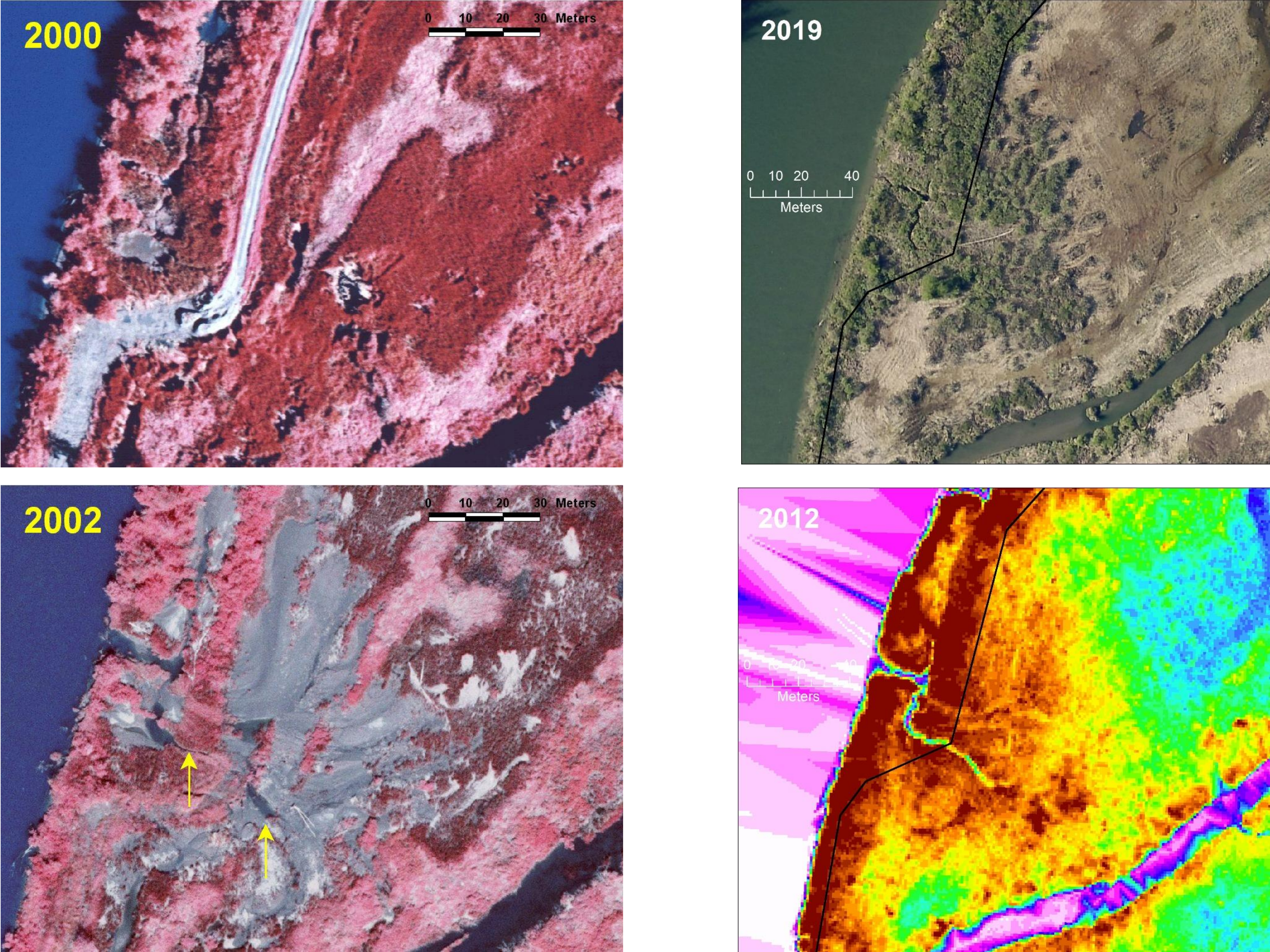
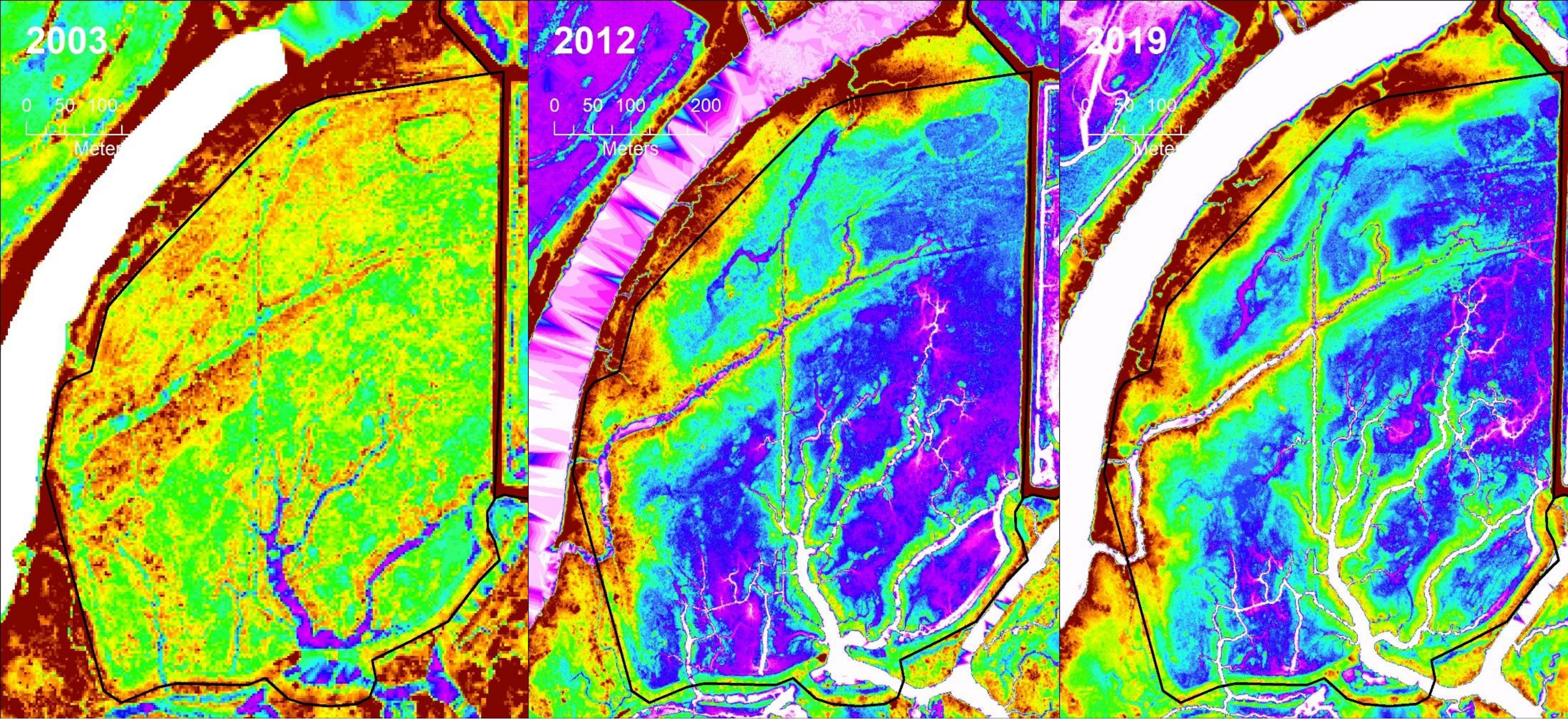

SCPU
SCTA
CALY
TYAN
0
200
400
Meters
N
Predicted frequency
100%
61-70%
41-50%
31-40%
21-30%
11-20%
0%

Table 1. Allometric predictions for tidal channel network geometry versus restoration site excavation. The 80% confidence limits of the predictions are in parentheses.

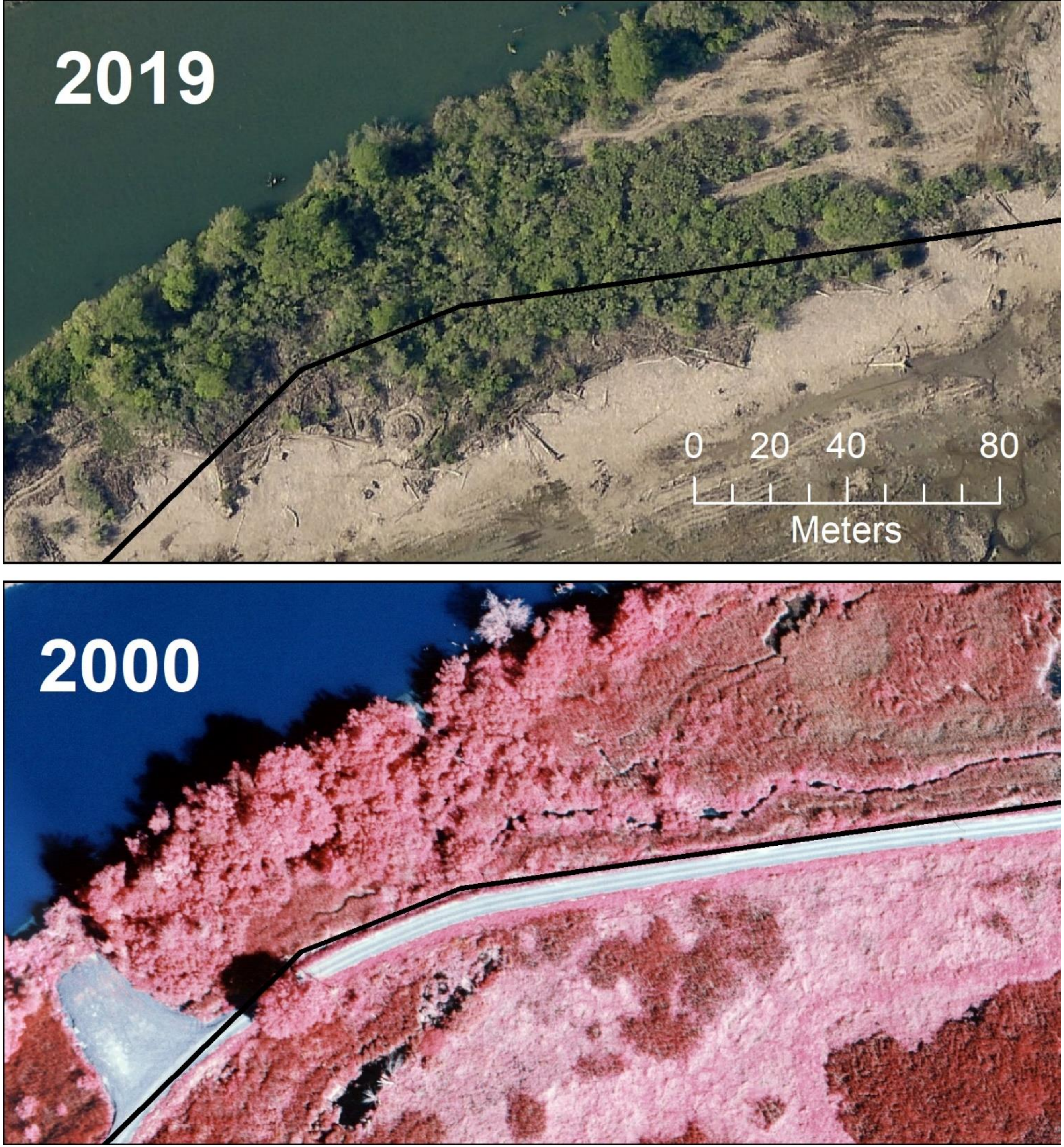
Site	Area	Predicted channel count	Observed channel count	Predicted channel length (m)	Observed channel length (m)
FIF	132 ac (53.4 ha)	22 (11-46)	1	10,965 (4,400 - 27,000)	2,200
zis a ba	90 ac (36.2 ha)	17 (8-34)	7	6,240 (2,550 – 15,280)	5,210

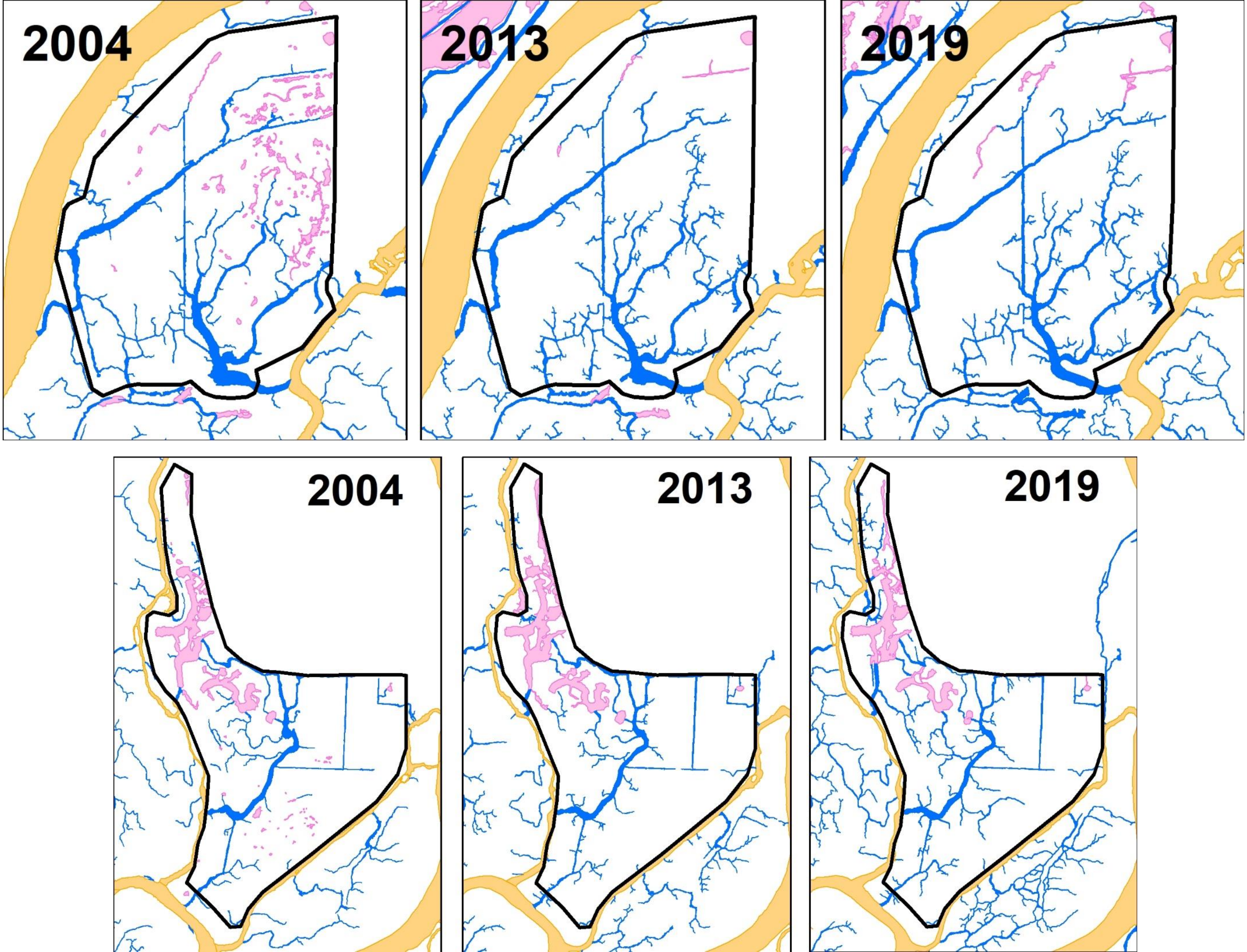

2000
0 10 20 30 Meters
2019
0 10 20 40
Meters
2002
0 10 20 30 Meters
2012
Meters

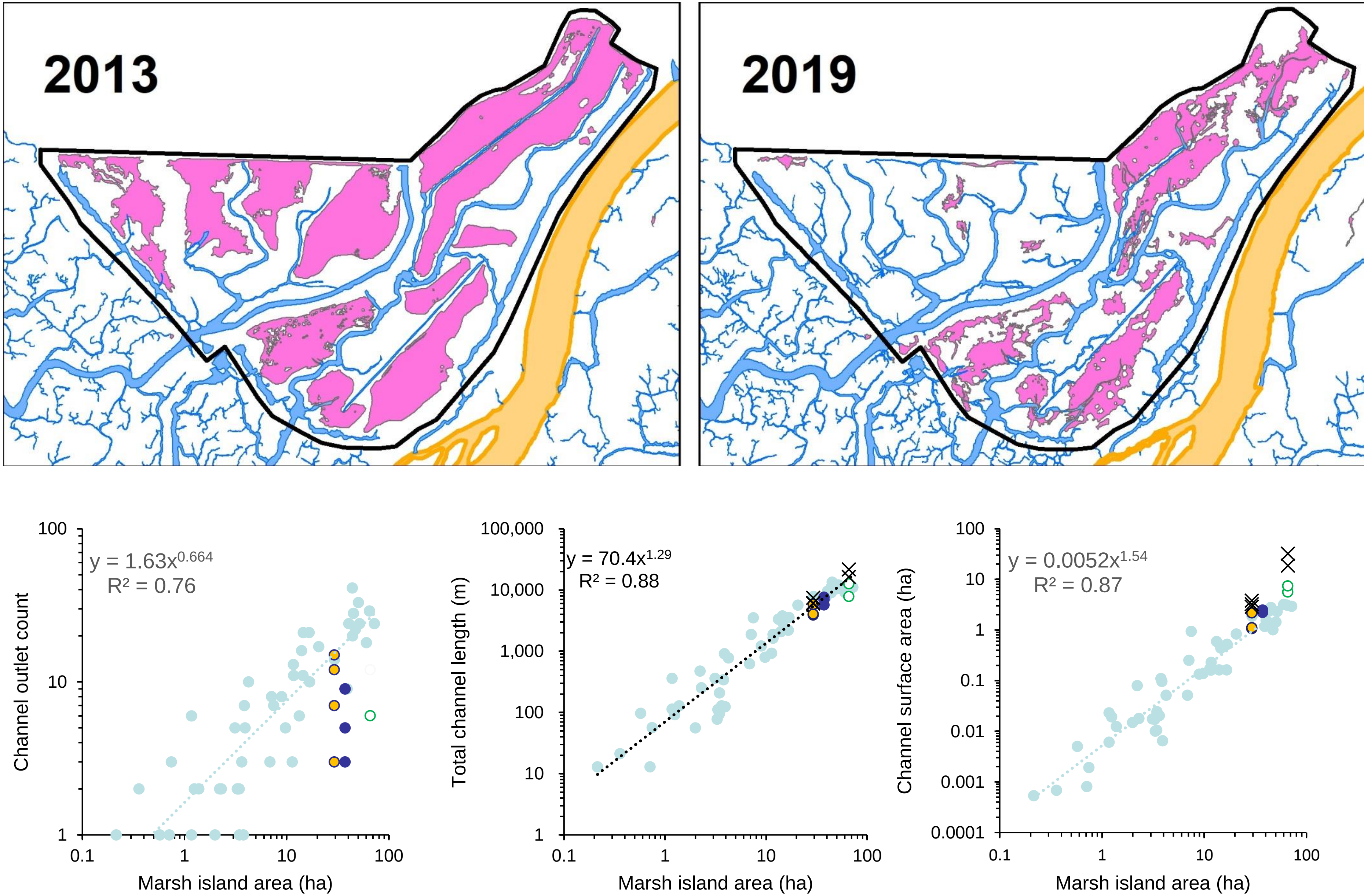


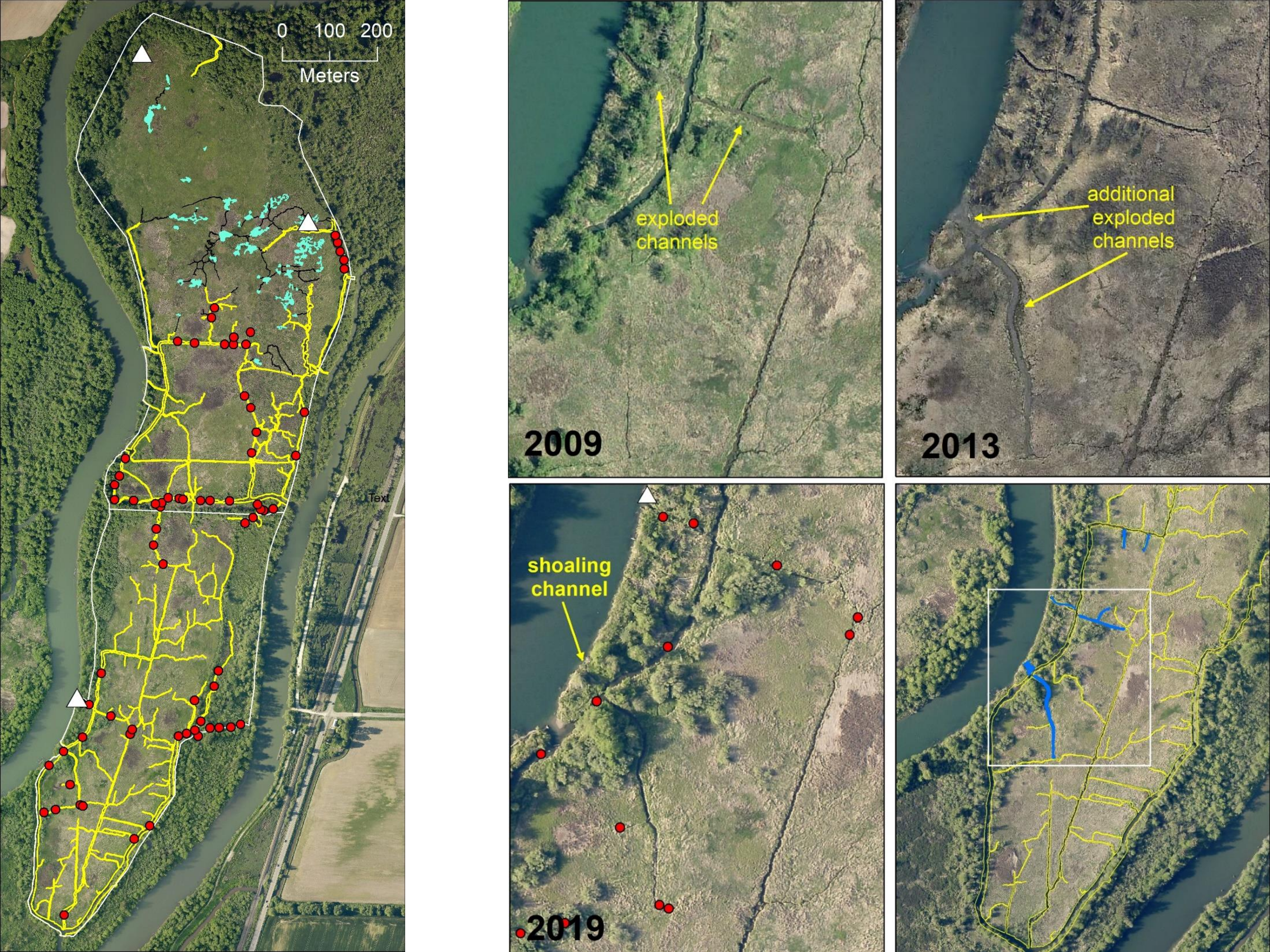
1. Sediment imported via small channels tributary to Freshwater Slough. Compare 2003 with high spots abutting the dike footprint vs. 2012 where high spots spill across the dike footprint

2. Sediment also appears to be filling in the restoration site, especially at the lowest elevation; compare 2012 with 2019, where there is a large decrease in blue and purple elevations. (2012 and 2019 lidars have same color scale)

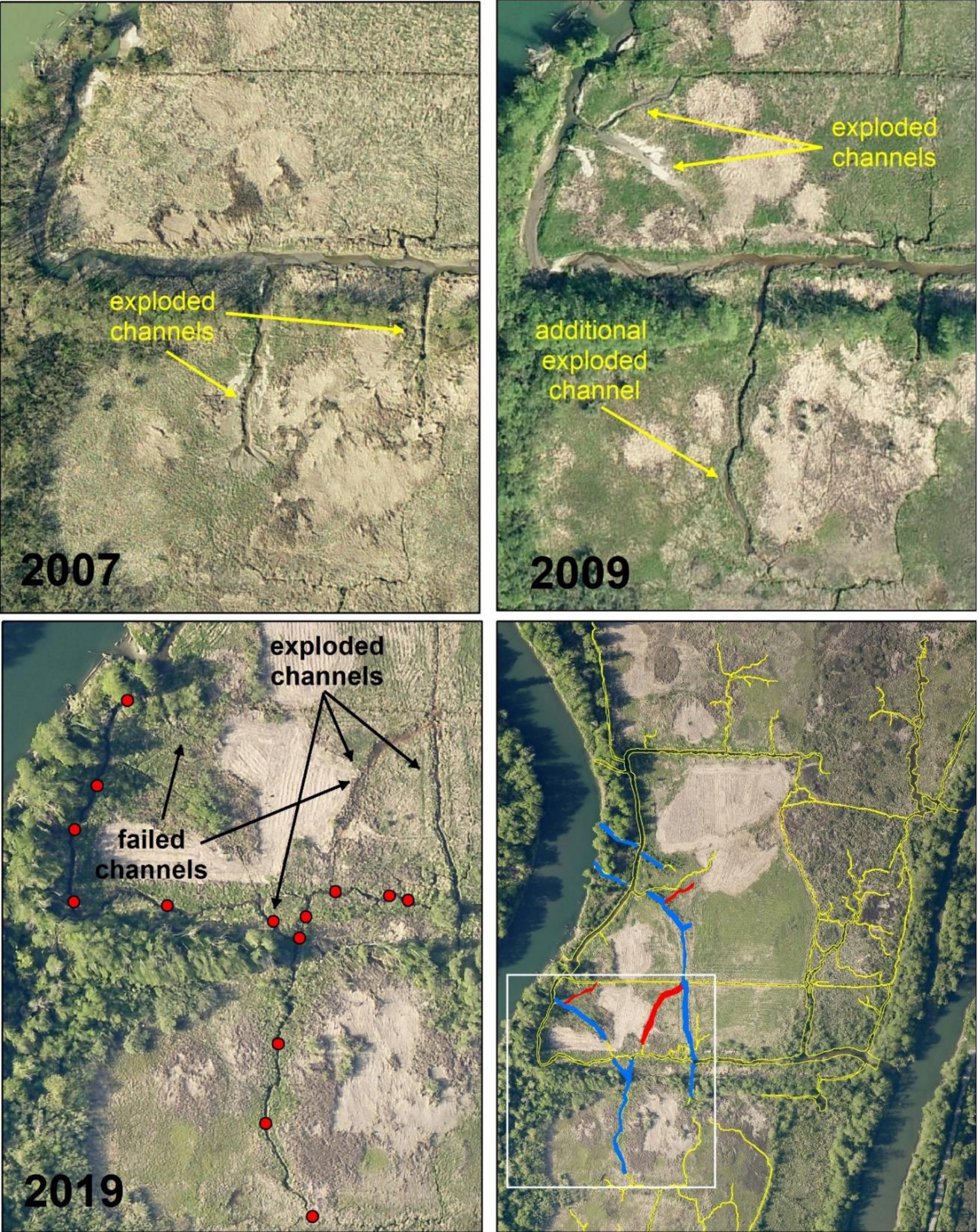

2019
0 20 40 80
Meters
2000


2004
2013
2019
2004
2013
2019


2013
2019
y = 1.63x^0.664
R² = 0.76
Channel outlet count
Marsh island area (ha)
y = 70.4x^1.29
R² = 0.88
Total channel length (m)
Marsh island area (ha)
y = 0.0052x^1.54
R² = 0.87
Channel surface area (ha)
Marsh island area (ha)



0 100 200
Meters
Text
exploded
channels
2009
additional
exploded
channels
2013
shoaling
channel
2019


exploded
channels
2007
exploded
channels
additional
exploded
channel
2009
exploded
channels
failed
channels
2019

Fir Island Farm—(a) vegetation and channels; (b) hard pans.

Deepwater Slough—(a) two few channel outlets initially, but they are developing over time; (b) channel inlets are routes for sediment delivery, topographic change, and vegetation diversity; (c) large remnant channel network, never well drained or farmed site, channels may be forming because no plow pan or new unconsolidated sediments.

Wiley Slough—(a) large ponds were a surprise, unclear why they didn't drain well; (b) large ponds are slowly drying out, either because of improved drainage, sediment deposition, or both; (c) large ponds provide large rearing for small fish, waterfowl, but inhibited vegetation development.

Milltown Island—(a) beaver can colonize restoration sites, extensively; (b) restoring tidal shrub/forest communities requires intervention; (c) exploding tidal channels can be hit or miss, requires better planning (quantify over marsh distance?).

Fisher Slough—"novel" wetland vegetation community, with abundant wapato, bur-reed, *Potamogeton*, soft-stem bulrush, several spikerushes. A missing community that was historically more common? Landward edge of reference tidal marshes; modified hydrology.

Swin Ch. Fill removal sites—(a) marsh elevation prediction was accurate, (b)

Future Directions in Prediction

Further development of predictive models is necessary to evaluate restoration success/failure and to improve design. Predictions provide us with logical expectations, benchmarks, standards, against which to compare project outcomes, and assess restoration of natural processes.

Scope for further refinement of predictive models and for creative application of models to restoration planning, design, monitoring, and adaptive management.

1. Channel allometry
   a. Overmarsh flow distance
   b. Cross-sectional geometry scaling
   c. Scaling of within-channel habitat (node distances, low-tide pool sizes and spacing)
2. PVMs
3. Predicting beaver dam locations (BDAs???); beavers as restoration allies?

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