

Habitat loss and restoration of ecosystem processes in Puget Sound

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Estuary and Salmon Restoration Program
Washington Department of Fish and Wildlife



Washington
Department of
**FISH and
WILDLIFE**

Habitat loss and restoration of ecosystem processes in Puget Sound

- I. How Puget Sound shorelines have changed
- II. Guiding principles for restoration
- III. Restoration actions in Puget Sound
- IV. Research and adaptive management

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Puget Sound



We are here

How to approach restoration at the Puget Sound scale?

The Puget Sound Nearshore Ecosystem Restoration Project (PSNERP)

What should our guiding philosophy of restoration be?

Goetz et al. 2004
Simenstad et al. 2006
Grenier 2010

How might future growth and development affect the nearshore?
(Bolte and Vache 2010)

Feasibility Report and new Congressional Approval for 12 Projects

What has changed in the nearshore?
Where?
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Which of these changes are problems and why?
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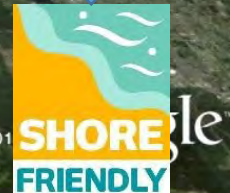
In what ways will we improve the nearshore?
(Cereghino et al. 2012)

Estuary and Salmon Restoration Program

Implications of change

Fresh et al. 2011

What types of actions can protect and restore the nearshore?
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Puget Sound



We are here

How to approach restoration at the Puget Sound scale?

We organize the landscape by shoreform

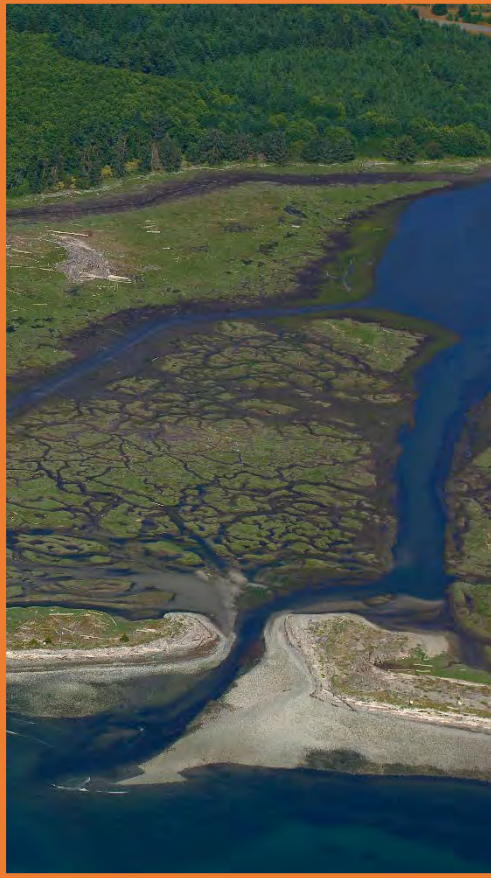
Deltas



Coastal
Inlets



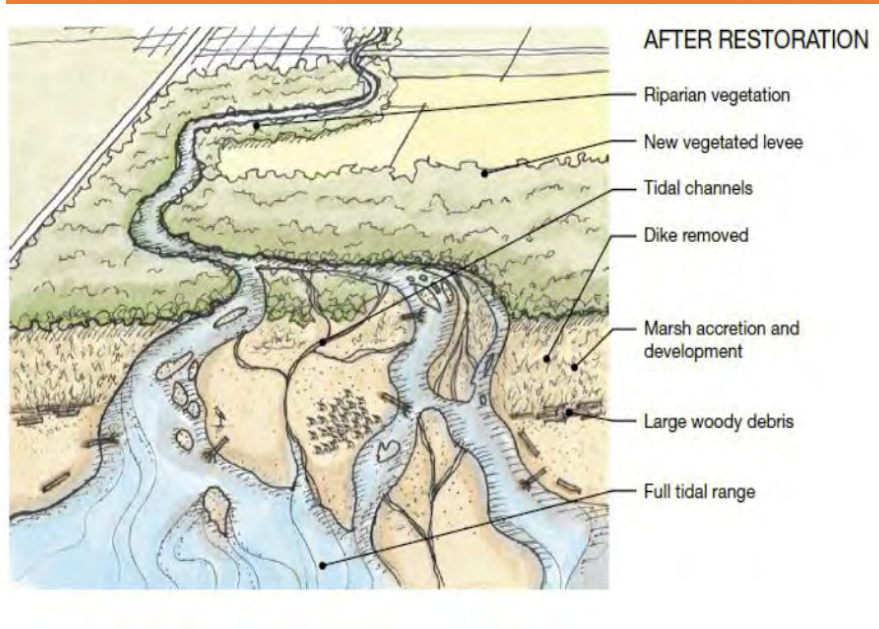
Barrier
Embayments



Beaches

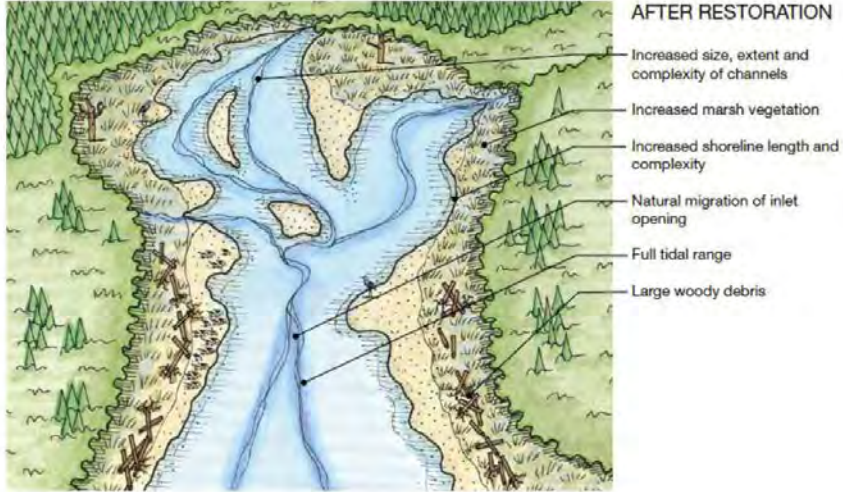


Deltas



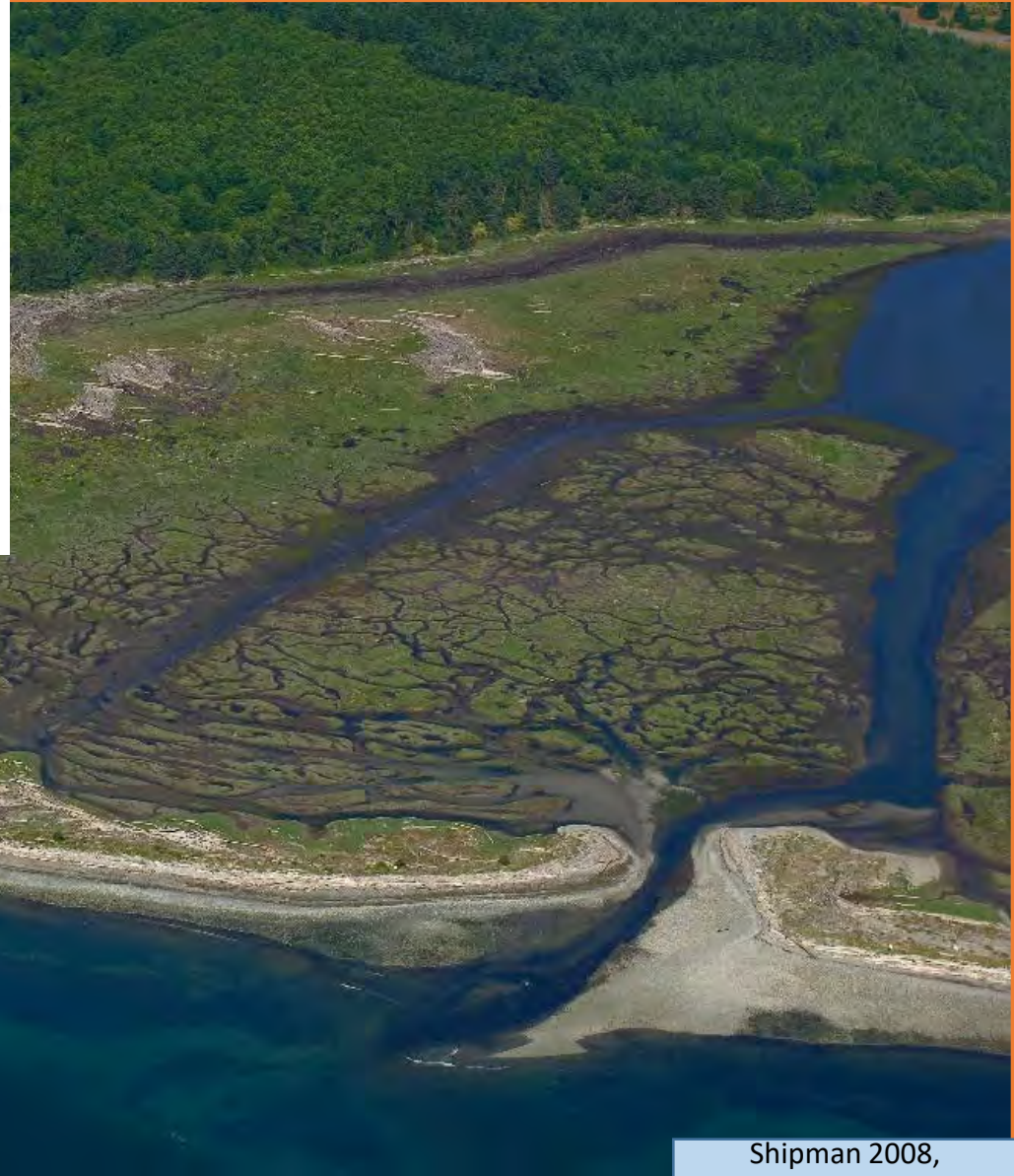
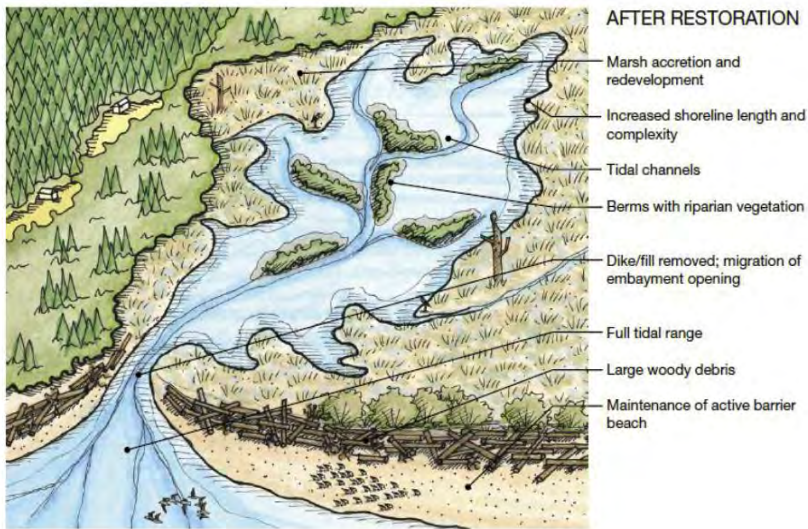
Shipman 2008,
Schlenger et al. 2011
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Coastal Inlets



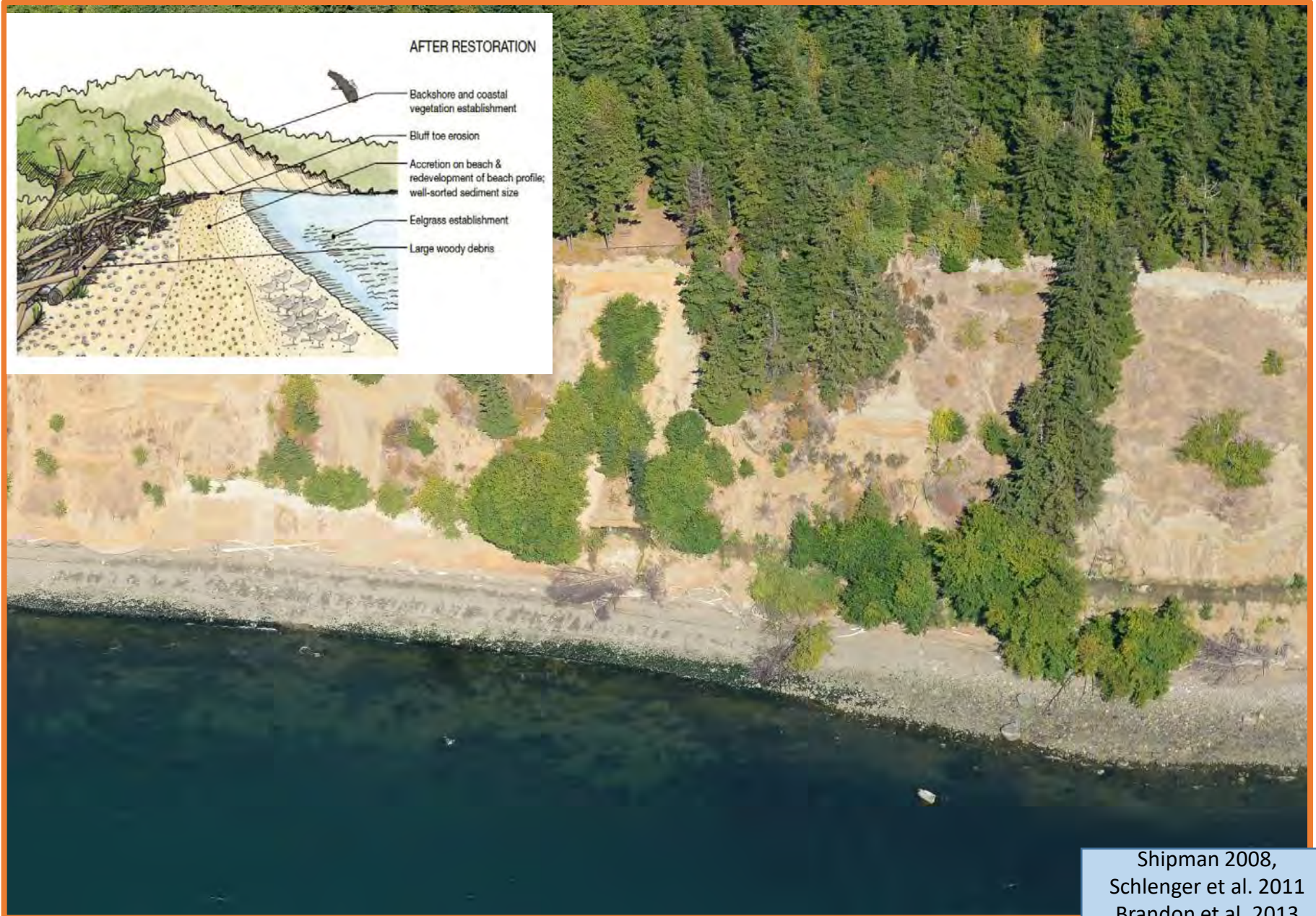
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Barrier Embayments



Shipman 2008,
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Beaches



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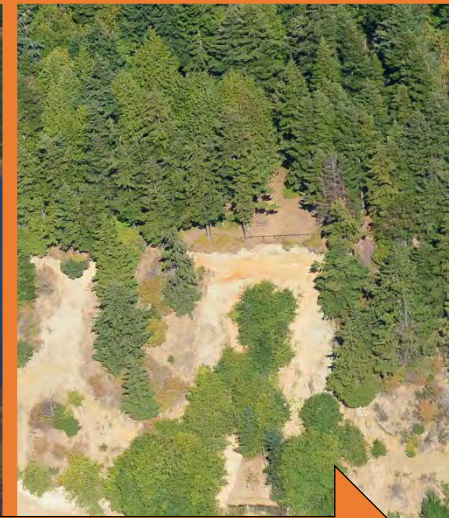
Shaped by different processes

Deltas

Coastal
Inlets

Barrier
Embayments

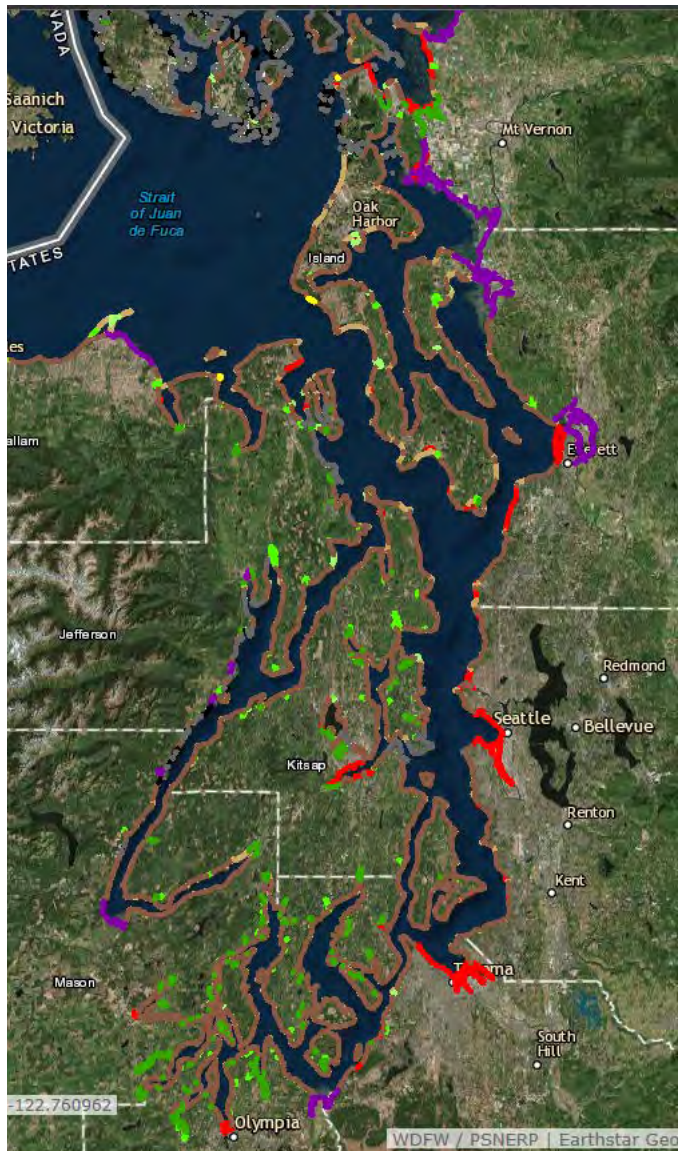
Beaches



Sediment Supply and Transport

Freshwater Inputs

Categorize Puget Sound by shoreform



- Delta
- Bluff Backed Beach
- Barrier Beach
- Open Coastal Inlet
- Barrier Estuary
- Barrier Lagoon
- Closed Lagoon Marsh
- Plunging Rocky
- Rocky Platform
- Pocket Beach
- Artificial

- River Delta
- Beaches
- Open Coastal Inlet
- Barrier Embayments

Nearshore Process Units

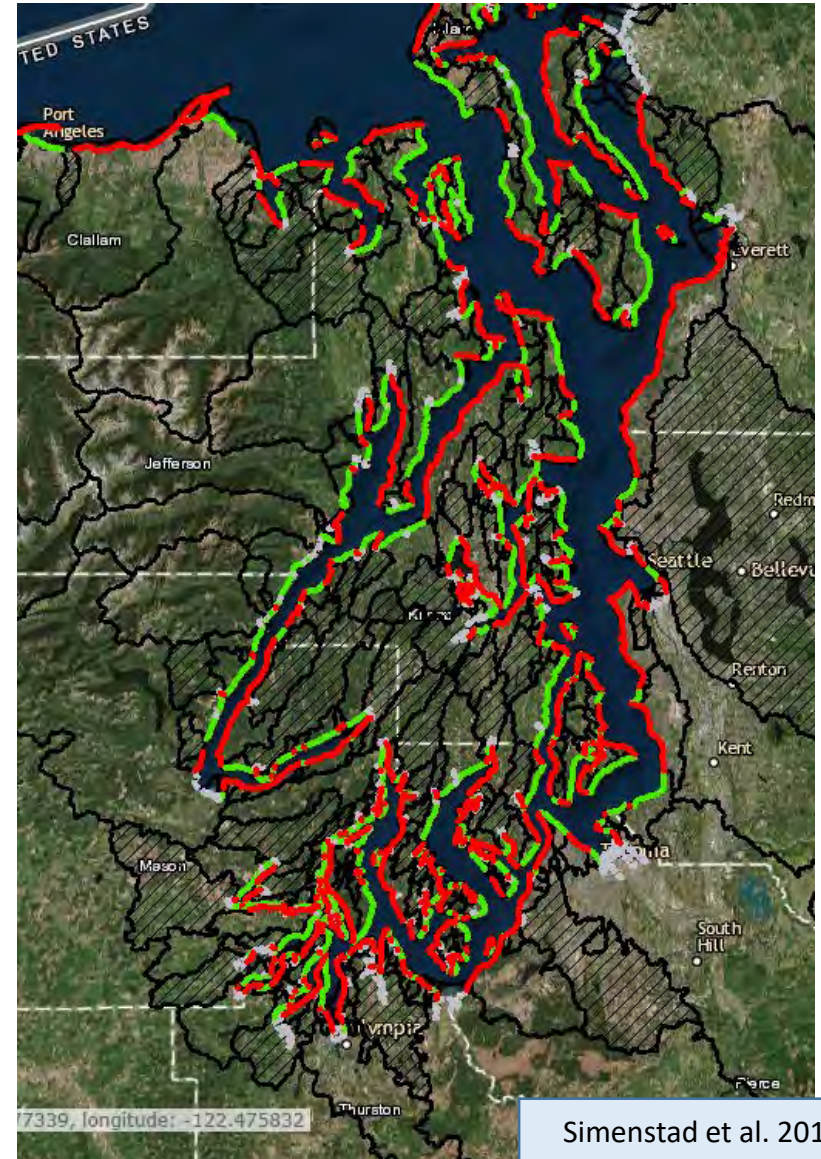
Nearshore Process Unit

Watershed

Adjacent Upland

Shoreforms

- 812 Shoreline Process Units (SPU)
- 16 Delta Process Units (DPU)
- SPU's defined by **net sediment drift**



How sediment moves through drift cells



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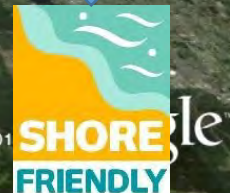
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Assessing change at multiple spatial scales

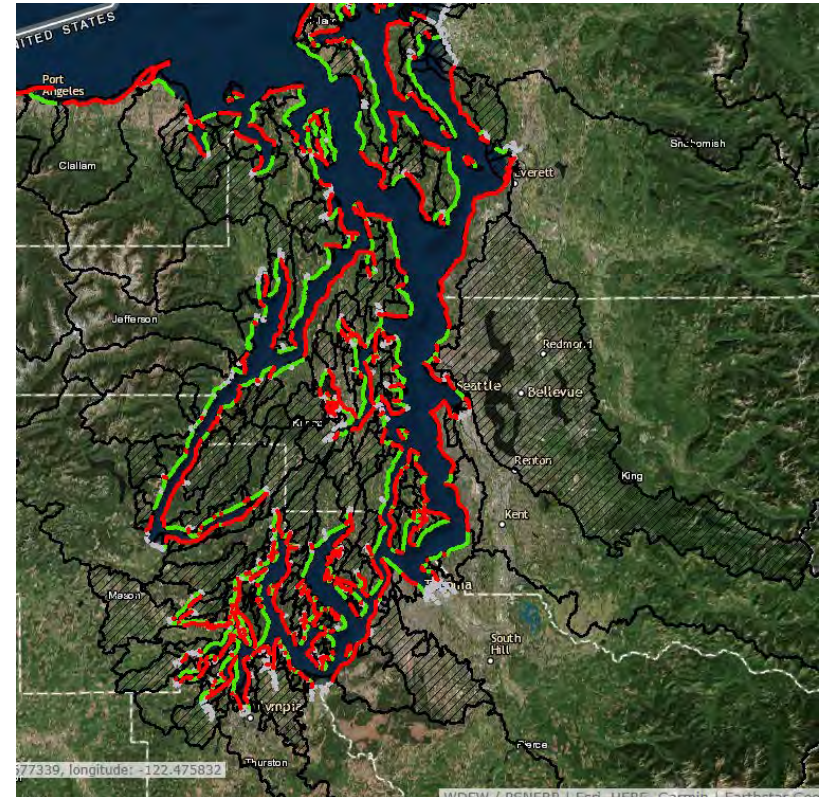
1852-1926 to 2000-2006

Nearshore Process Unit

Watershed

Adjacent Upland

Shoreforms



Big Data Compilation Effort!

Assessing change at multiple spatial scales

1852-1926 to 2000-2006

Nearshore Process Unit

Watershed

Adjacent Upland

Shoreforms



Historic



Current



Big Data Compilation Effort!

Assessing change at multiple spatial scales

1852-1926 to 2000-2006

Nearshore Process Unit

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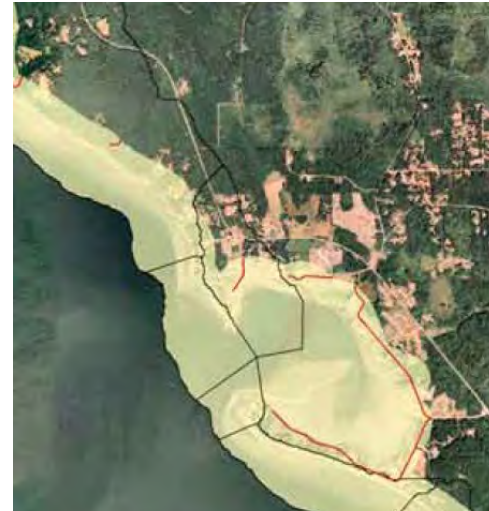
Roads

Railroads

Land Cover

Impervious Surfaces

Stream Crossings



Big Data Compilation Effort!

Assessing change at multiple spatial scales

1852-1926 to 2000-2006

Nearshore Process Unit

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Roads

Railroads

Land Cover

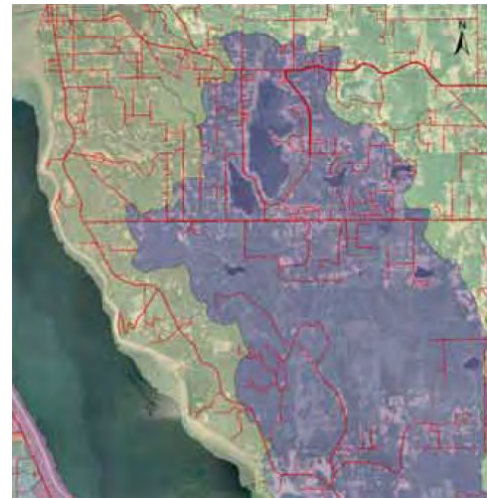
Impervious Surfaces

Stream Crossings

Drainage Area

Impoundment by dams

Big Data Compilation Effort!



Assessing change at multiple spatial scales

1852-1926 to 2000-2006

Nearshore Process Unit

Watershed

Adjacent Upland

Shoreforms



Loss/gain of intertidal wetlands

Armoring

Tidal Barriers

Breakwaters/jetties

Overwater structures

Nearshore Fill

Marinas

Big Data Compilation Effort!



Simenstad et al. 2011

Shoreforms: then and now

Historic



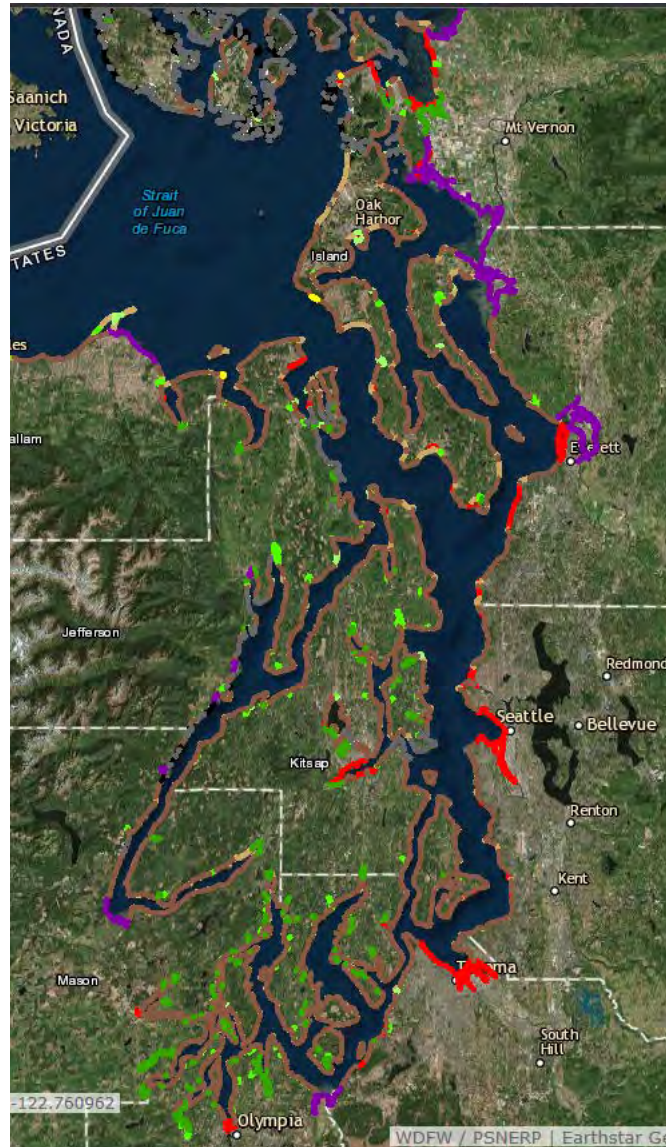
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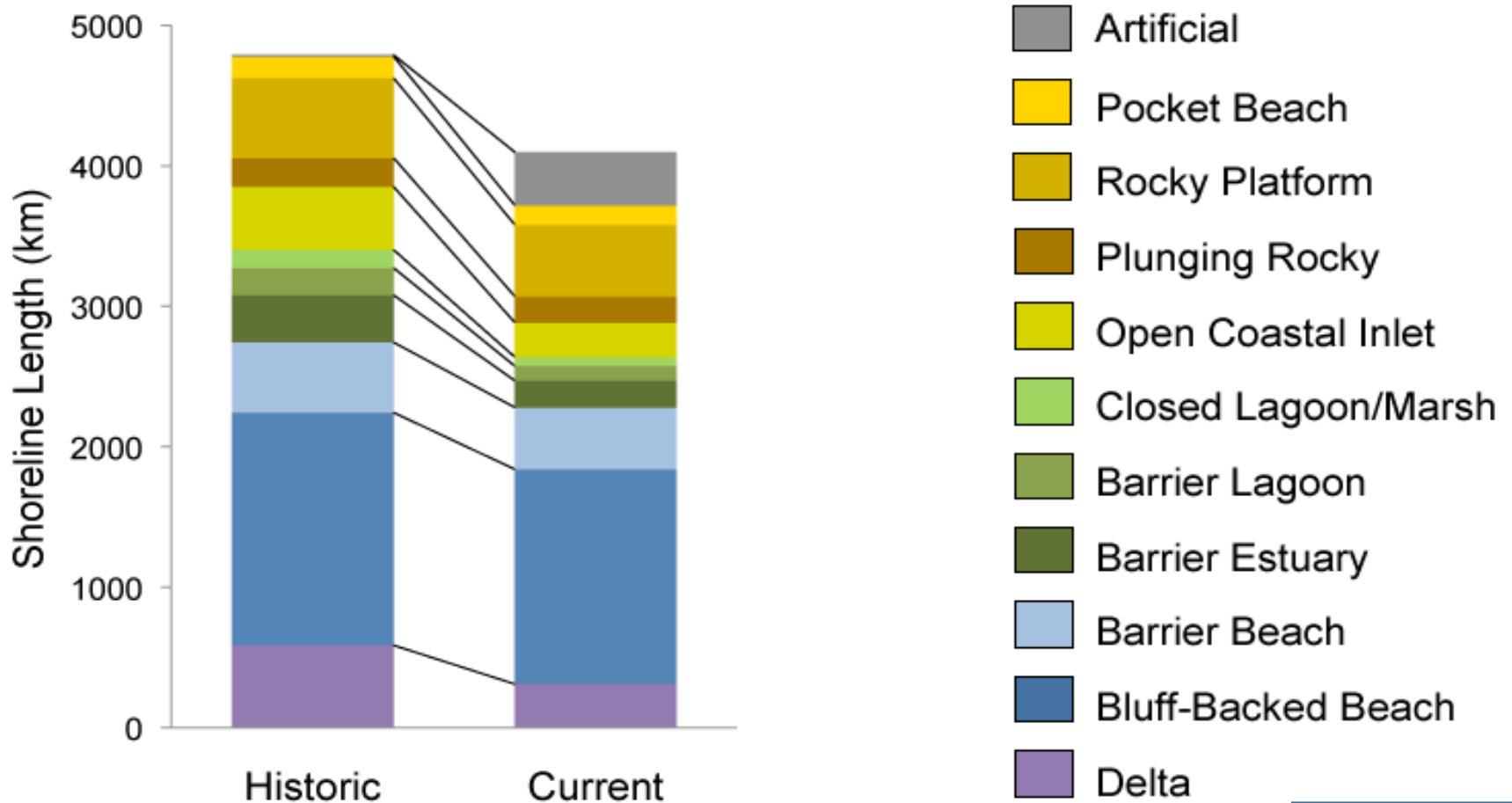


Current

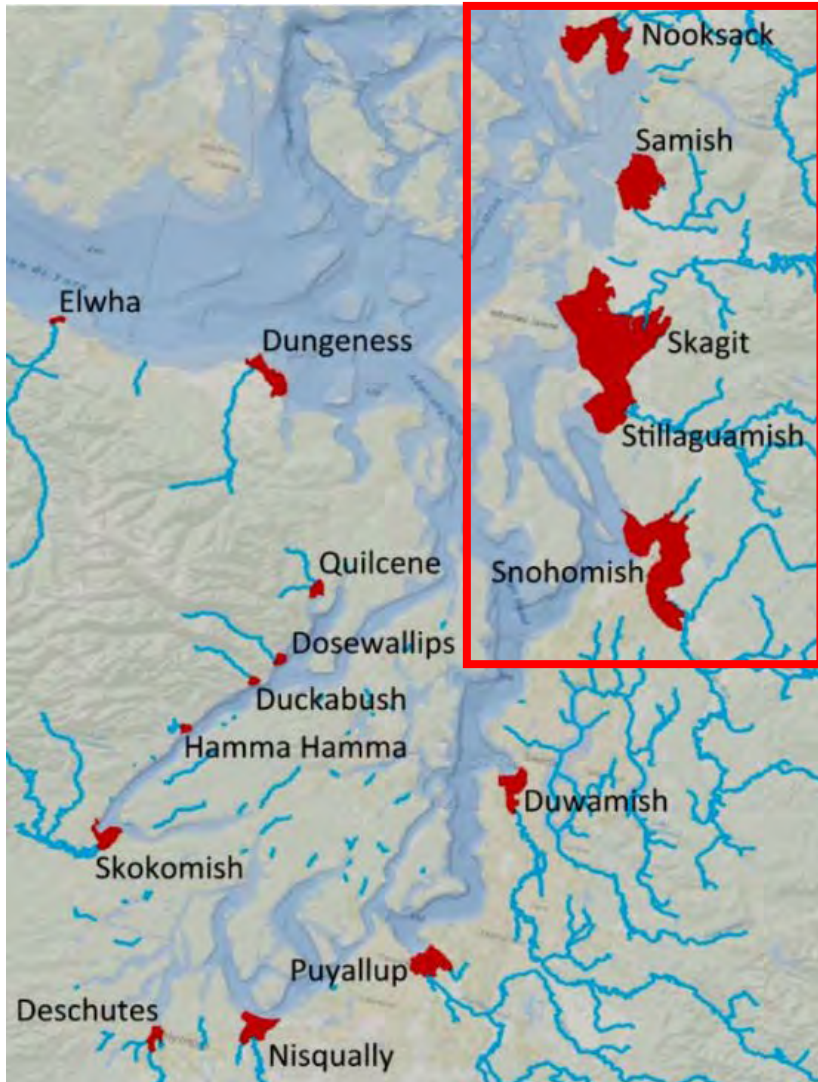


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Shorter, simpler, more artificial shorelines



Loss of tidal wetlands in Puget Sound



77% loss of vegetated wetlands from 16 largest river deltas



PLOS ONE

Insights into estuary habitat loss in the western United States using a new method for mapping maximum extent of tidal wetlands

Laurel S. Brophy^{1,2}, Corinne M. Swenson^{1,3}, Eric C. Merritt^{1,4}, Brooke Johnson¹, Josh Lauer¹, Bruce H. Kinsley¹, Kevin O'Connor¹, Matthew J. Templeton¹, Sheng Chen¹

Abstract

Effective conservation and restoration of estuarine habitats require accurate maps of their location and extent. We present a new method for mapping maximum extent of tidal wetlands in the western United States using a new method for mapping maximum extent of tidal wetlands. This method uses satellite imagery to map the maximum extent of tidal wetlands in the western United States. The new method is based on an elevation-based method that uses satellite imagery to map the maximum extent of tidal wetlands. This method is based on an elevation-based method that uses satellite imagery to map the maximum extent of tidal wetlands. This method is based on an elevation-based method that uses satellite imagery to map the maximum extent of tidal wetlands.

Introduction

Estuarine ecosystems are important for many reasons, including their role in providing habitat for many species of fish and wildlife, their role in filtering pollutants from the water, and their role in providing a natural barrier against storms and tsunamis. However, estuarine ecosystems are being lost at an alarming rate due to human activities such as agriculture, urban development, and industrial activities. This loss of estuarine ecosystems is a major threat to the health of our planet and the well-being of our society.

Methods

We used satellite imagery to map the maximum extent of tidal wetlands in the western United States. We used a new method for mapping maximum extent of tidal wetlands that uses satellite imagery to map the maximum extent of tidal wetlands. This method is based on an elevation-based method that uses satellite imagery to map the maximum extent of tidal wetlands.

Results

We found that the maximum extent of tidal wetlands in the western United States is much larger than previously estimated. This is due to the use of satellite imagery to map the maximum extent of tidal wetlands. This method is based on an elevation-based method that uses satellite imagery to map the maximum extent of tidal wetlands.

Conclusions

Our results show that the maximum extent of tidal wetlands in the western United States is much larger than previously estimated. This is due to the use of satellite imagery to map the maximum extent of tidal wetlands. This method is based on an elevation-based method that uses satellite imagery to map the maximum extent of tidal wetlands.

References

1. Simenstad TA, et al. (2011) Tidal wetlands in Puget Sound: A review of their distribution, ecology, and management. *Wetlands* 31: 1-15.

2. Brophy LS, et al. (2019) Insights into estuary habitat loss in the western United States using a new method for mapping maximum extent of tidal wetlands. *PLOS ONE* 14: 1-15.

3. Swenson CM, et al. (2019) A new method for mapping maximum extent of tidal wetlands in the western United States. *Wetlands* 39: 1-15.

4. Merritt EC, et al. (2019) A new method for mapping maximum extent of tidal wetlands in the western United States. *Wetlands* 39: 1-15.

5. Johnson B, et al. (2019) A new method for mapping maximum extent of tidal wetlands in the western United States. *Wetlands* 39: 1-15.

6. Lauer J, et al. (2019) A new method for mapping maximum extent of tidal wetlands in the western United States. *Wetlands* 39: 1-15.

7. Kinsley B, et al. (2019) A new method for mapping maximum extent of tidal wetlands in the western United States. *Wetlands* 39: 1-15.

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10. Chen S, et al. (2019) A new method for mapping maximum extent of tidal wetlands in the western United States. *Wetlands* 39: 1-15.

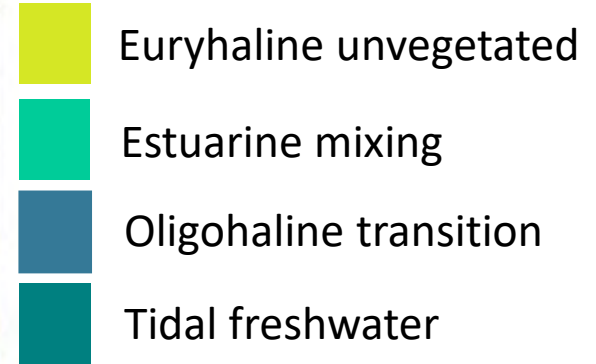
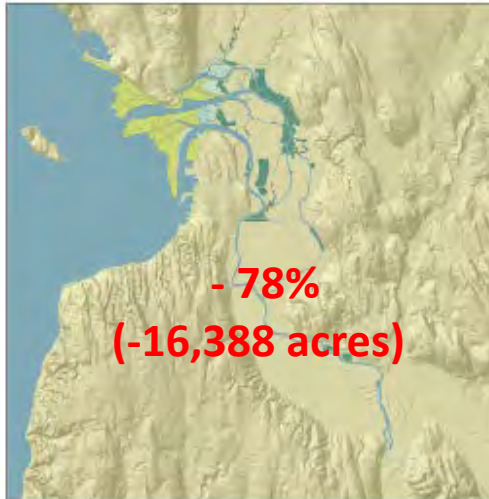
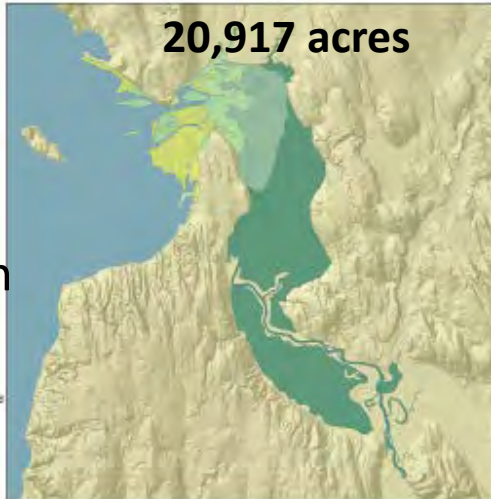
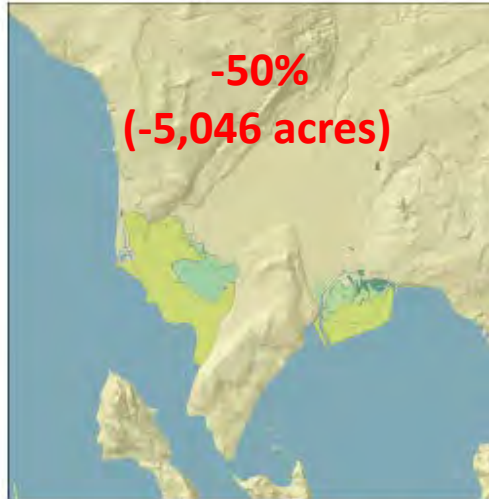
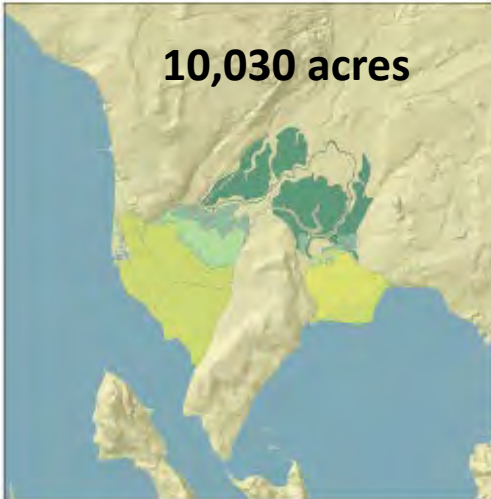
Recent paper →
Brophy et al. 2019,
similar results



Loss of tidal wetlands in Puget Sound

Historic

Current



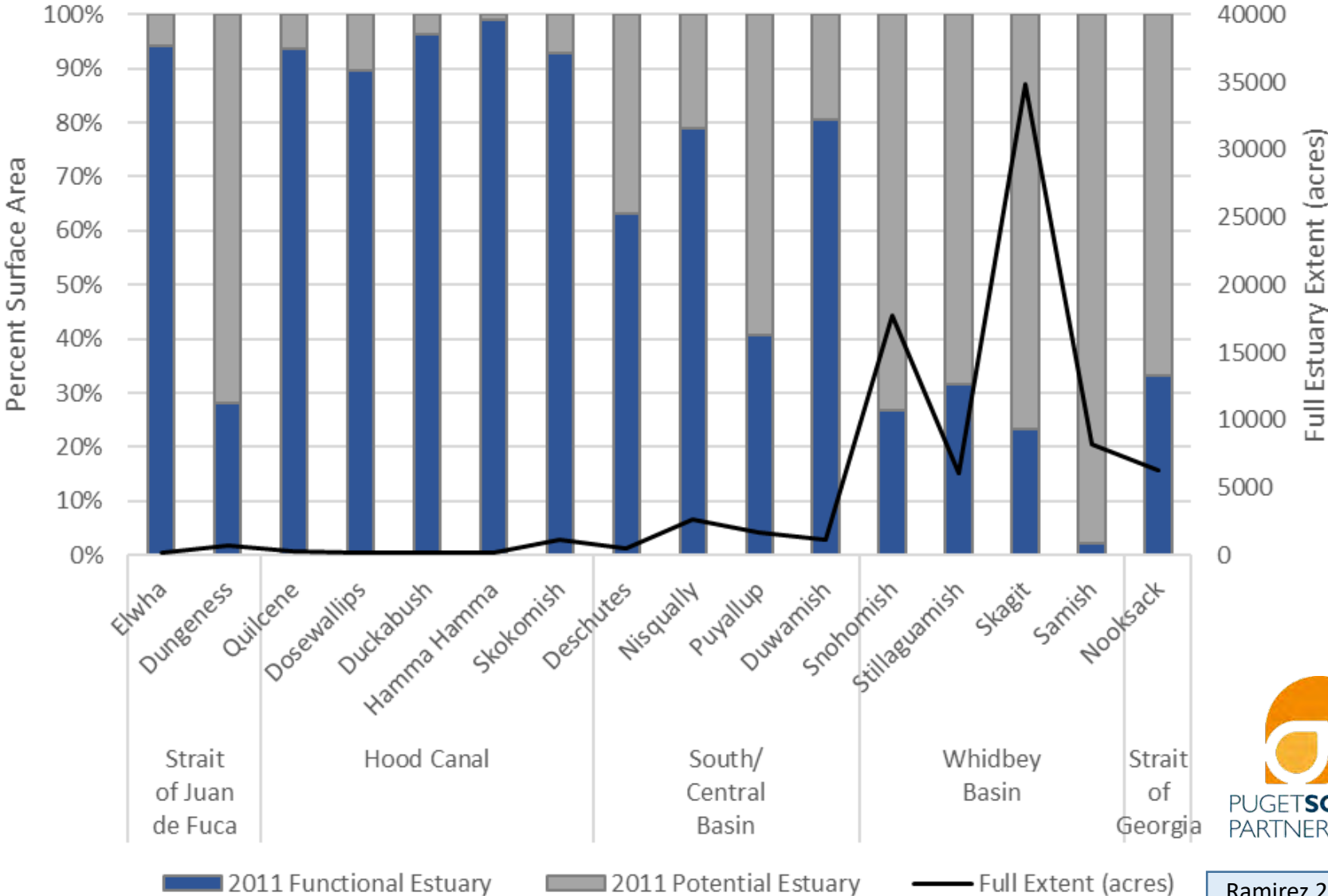
Disproportionate loss of some habitats → Tidal Freshwater



Nooksack
Delta

Snohomish
Delta

Recent Puget Sound Analysis



Nearshore habitat degradation in Puget Sound

~77% of large river estuaries are diked or filled ~1/3 of beaches are armored



Riprap on Ediz Hook in Port Angeles



Elliott Bay Marina and Magnolia neighborhood in Seattle



Aerial of Duwamish Spit and Burlew Lagoon



Highway across Purdy Spit



Pier at Redondo Beach



Railroad grade and isolated tidal wetland in Woodway, south of



Drift logs accumulated on beach at Elger Bay, Camano Island

PSNERP Process Unit 2 Pagers



Process Unit Overview

The table below summarizes the current and future scenarios for the process unit. The process unit is defined by the following characteristics:

- Process Unit Size: 16.6 km²
- Shoreline Type: 5.5 km
- Shoreline Length: 11.9 km

WQI-QI-QII Composition

Composition	10%
Transport	60%
Convergence	0%
No appreciable flow	15%

Research Process Degradation Summary

Degradation categories affect the extent to which anthropogenic stressors affect 1) resource processes, in both current and future scenarios, relative to other process units. As noted, degradation group assignment is made from best, best, moderate, worst and worst for each scenario. High degradation may indicate areas suitable for restoration while low degradation may indicate areas suitable for protection. Future degradation conditions were projected into 2040 assuming current land development trends. See publication 2011-01 (Schlager et al.) for more information.

Research Process	Current	Scenario
Sediment Input	Medium	Medium
Sediment Transport	High	High
Sediment Deposition	Medium	Medium
Tide Flats	Medium	Medium
Wetlands (Tidal)	Low	Low
Tide Channels	Low	Low
Proximal Input	Medium	Medium
Distal Input and Output	Medium	Medium
Exchange of Aquatic Organisms	Medium	Medium
Physical Disturbance	Medium	Medium
WQI	Low	Low
QII	Low	Low

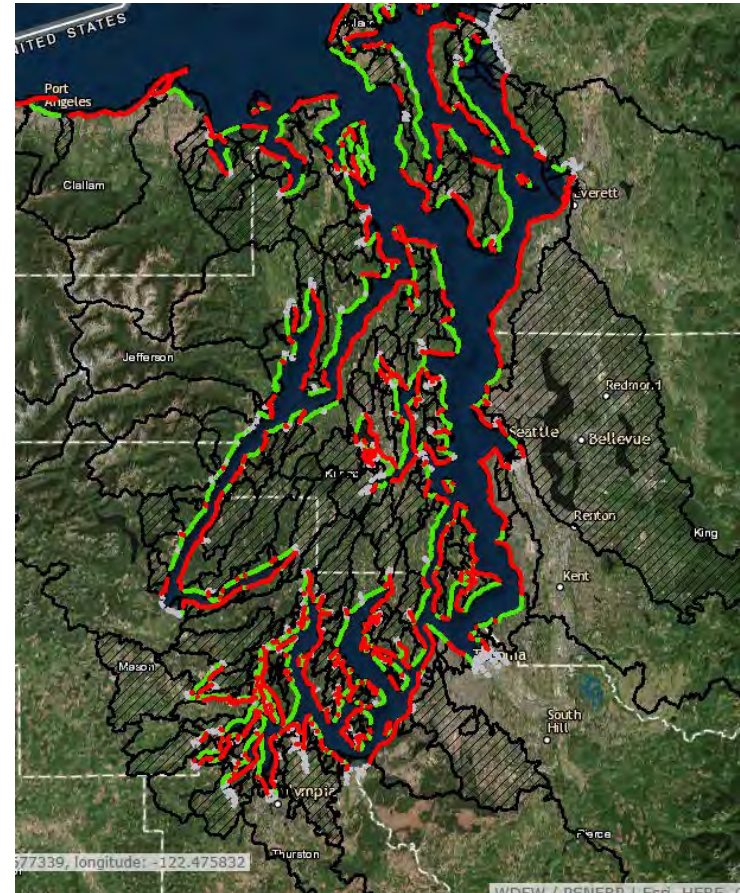
Landform Composition

Medium to Large (1000-10000) and Small (100-1000)

Landforms are a dominant landscape feature and a primary predictor of sediment input. The difference between future and current conditions are assumed to be due to shoreline alterations that result in wetland change. Wetland loss/gain is reported in the following table. See publication 2011-01 (Schlager et al.) for more information.

Landform Type	Current	Scenario	Change	Relative	Current	Change (%)
Small Wetland	2	1	-1	0.2	0.2	-50
Large Wetland	1	1	0	0.1	0.1	0
Small Upland	1	1	0	0.1	0.1	0
Upland	0	0	0	0.0	0.0	0

- Sediment dynamics
- Process degradation
- Shoreforms present
- Upland and watershed features
- Shoreline modifications
- Wetland loss/gain



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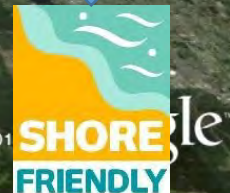
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Estuary and Salmon Restoration Program

Implications of change

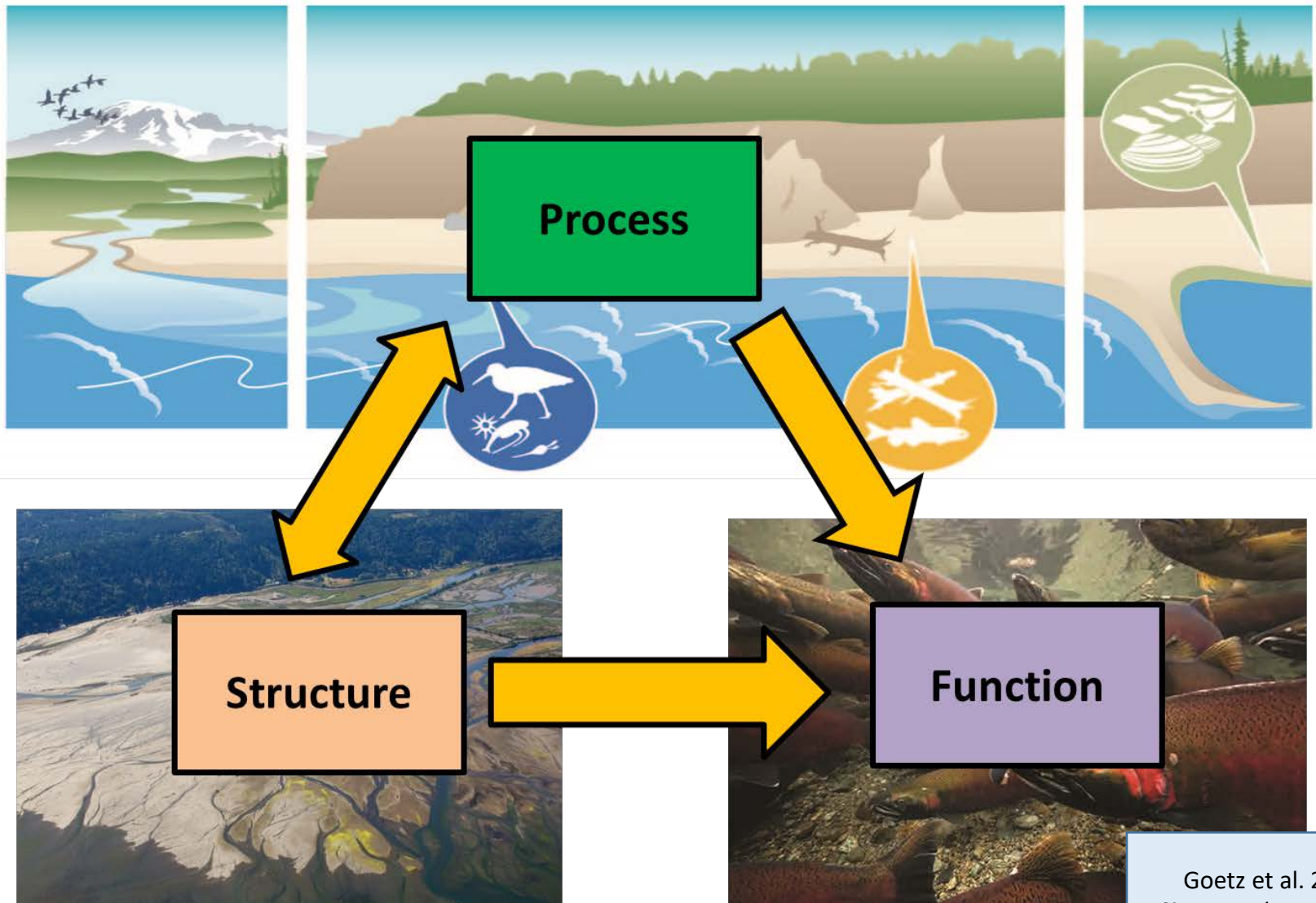
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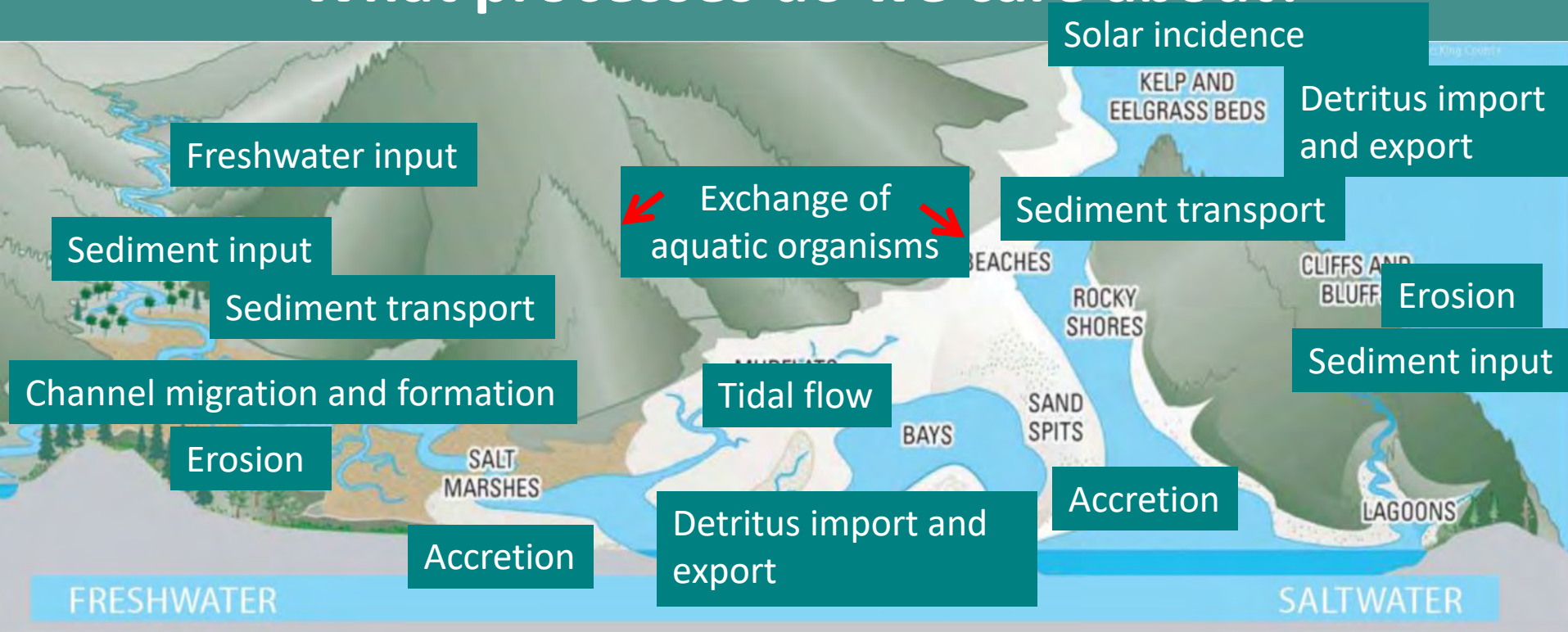
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Process-based restoration



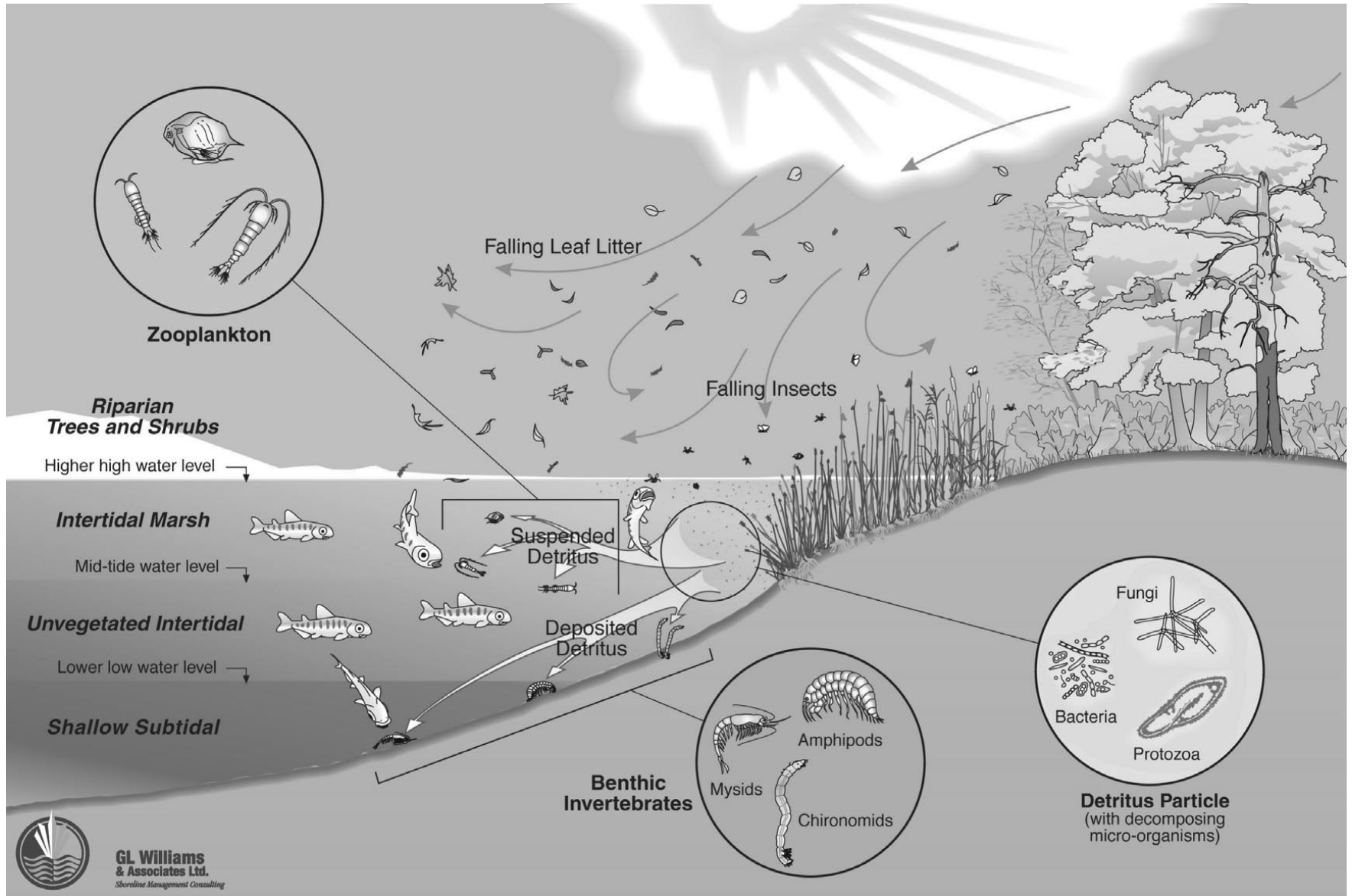
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What processes do we care about?



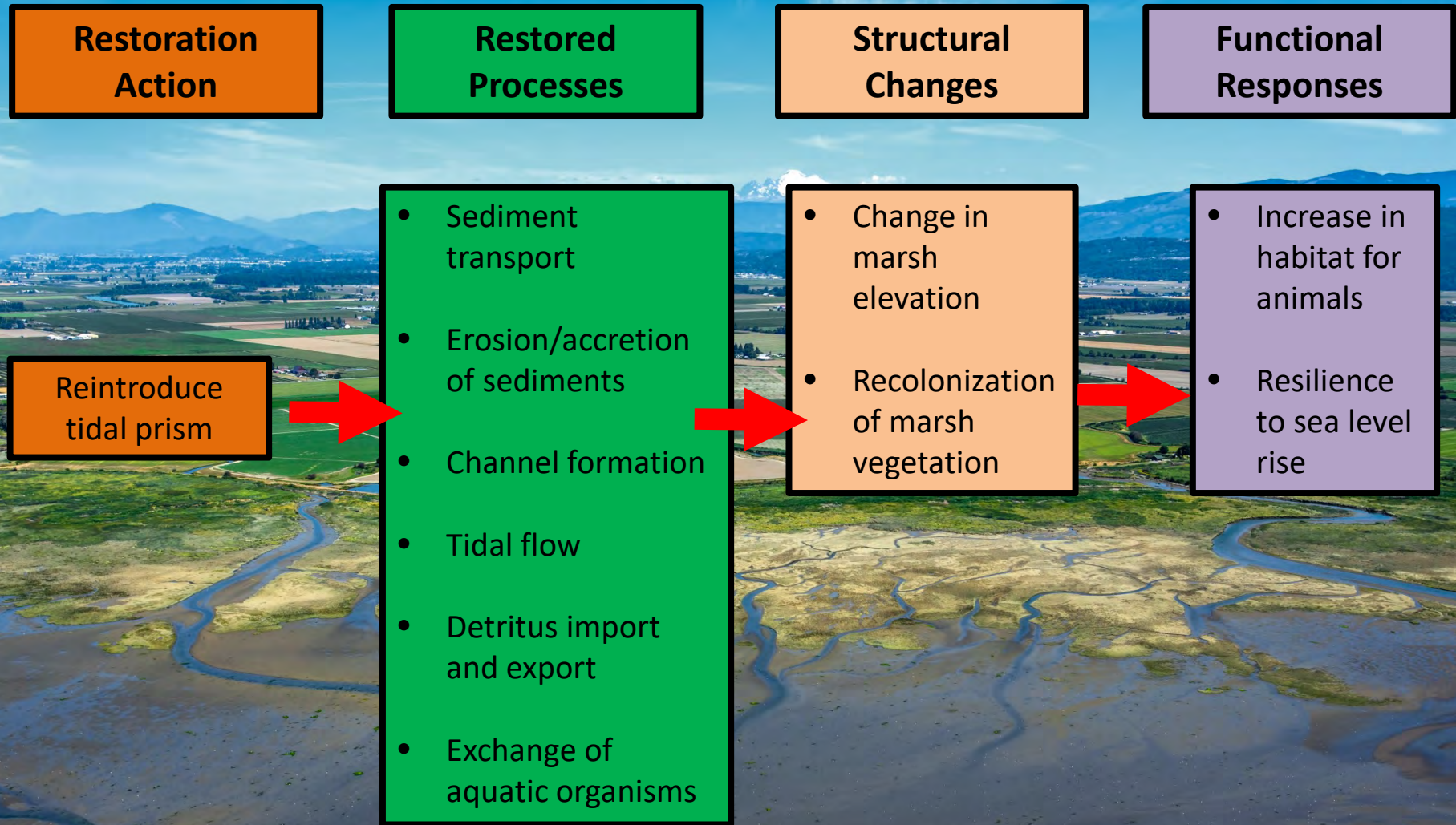
What processes maintain this physical landscape?

Detrital inputs to marine systems



GL Williams & Associates Ltd.
Shoreline Management Consulting

Example for delta restoration



Example for beach restoration

Restoration Action

Bulkhead removal

Restored Processes

- Sediment supply
- Sediment dynamics
- Accumulation of wood and detritus
- Wave dissipation
- Moisture retention

Structural Changes

- Beach profile
- Sediment composition
- Substrate heterogeneity

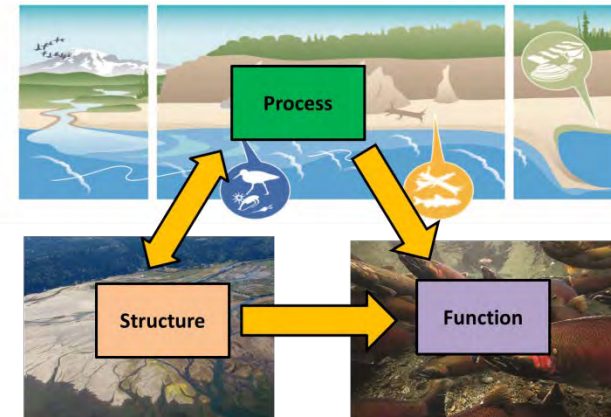
Functional Responses

- Increase in habitat for animals
- Resilience to sea level rise

PSNERP Guiding Principles for restoration

Derived from landscape, conservation, and estuarine ecology

- Conserve **what is intact**
- **Ecosystem-based** approach
- **Physical processes**
- **Habitat heterogeneity**
- **Landscape context**
- **Connectivity**
- **Large areas**
- **Rare or vulnerable** components of the ecosystem
- **Ecological importance**
- **Cumulative** impacts



Goetz et al. 2004
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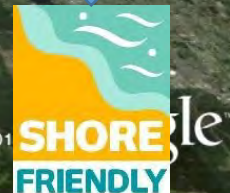
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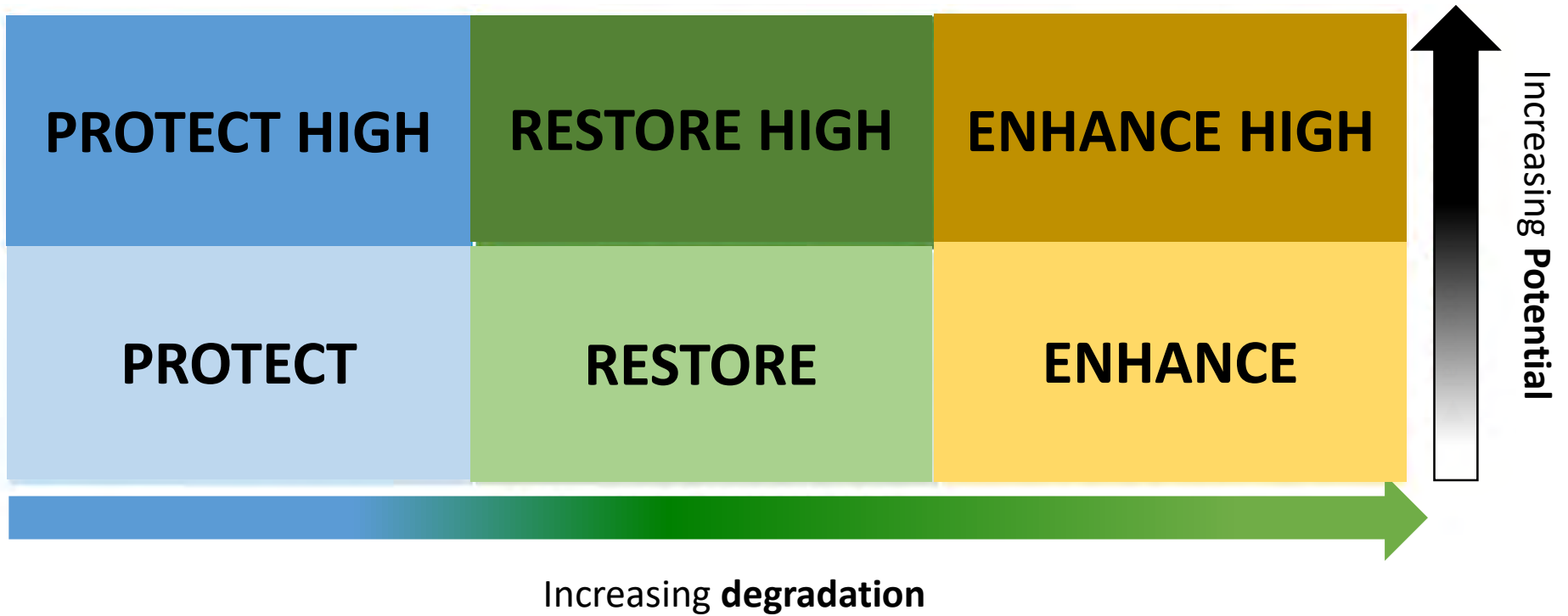


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Methods for deriving strategies

- I. Calculate **Anthropogenic Degradation and Restoration Potential** for each process unit
- II. Assign a strategy (**Protect, Restore, Enhance**) based on **Degradation**
- III. Assign category of High/Low for based on **Potential**

Methods for deriving restoration strategies



Deriving restoration strategies: Deltas



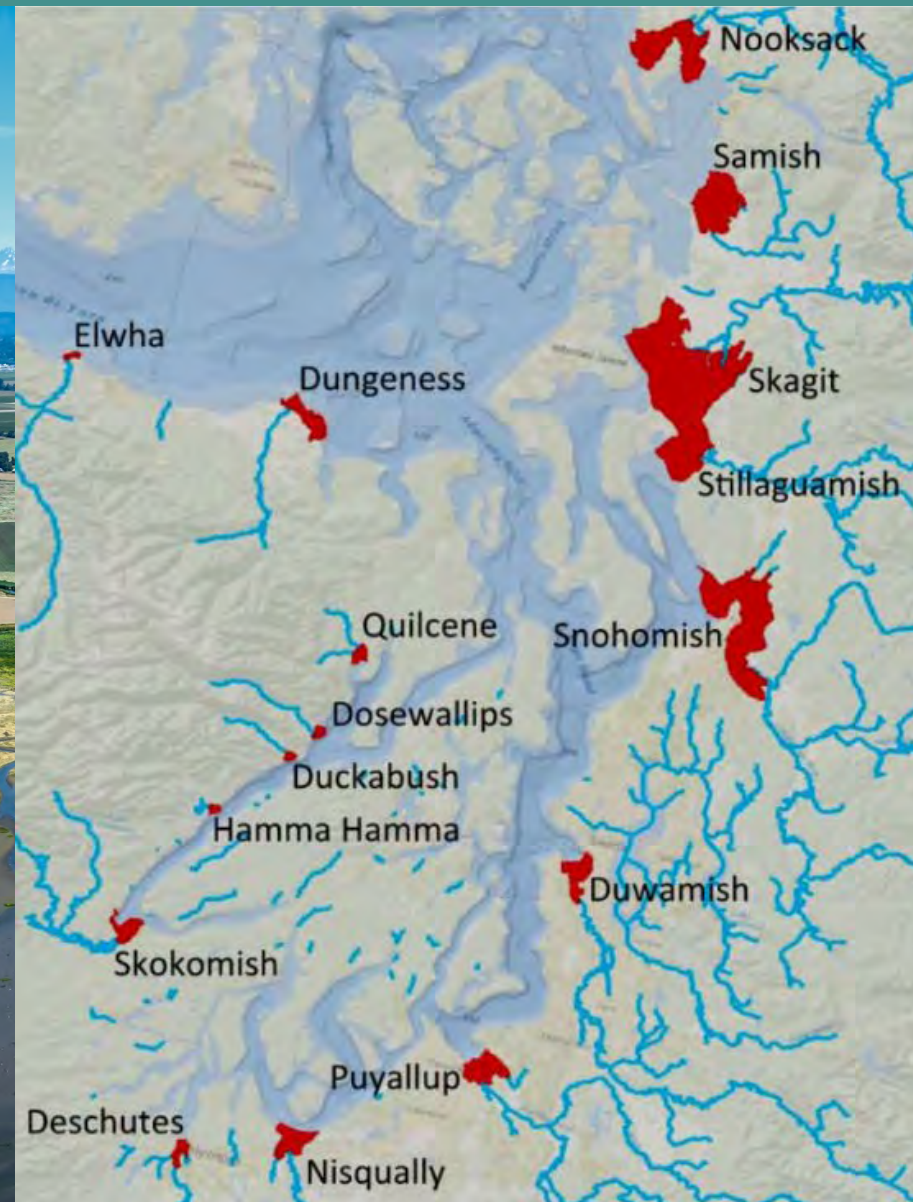
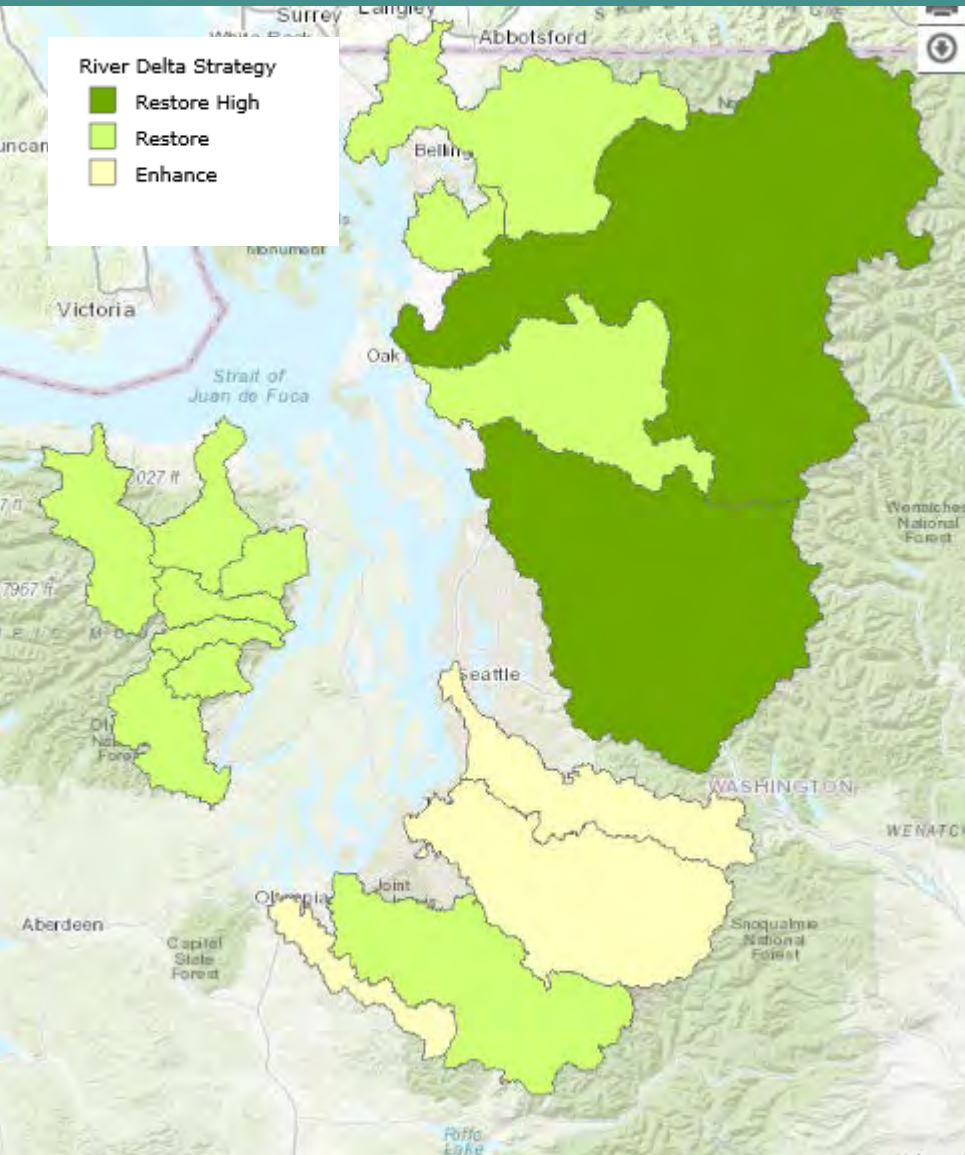
Restoration Potential

- Size
- Complexity
- Diversity of habitats

Degradation

- Habitat Loss
- Impervious surface

River delta strategy recommendations across Puget Sound



Beach strategy recommendations across Puget Sound



Coming in 2020!
New Beach
Strategies based
on updated data

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Restoration Programs in Puget Sound



PUGET SOUND
PARTNERSHIP

PSAR FUND

Puget Sound Acquisition and Restoration



DEPARTMENT OF
ECOLOGY
State of Washington



Floodplains by Design

· REDUCING RISK, RESTORING RIVERS ·



**ESTUARY & SALMON
RESTORATION PROGRAM**



WASHINGTON STATE
RECREATION AND CONSERVATION OFFICE

**Salmon Recovery
Funding Board**



Washington
Department of
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WILDLIFE**



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SERVICE

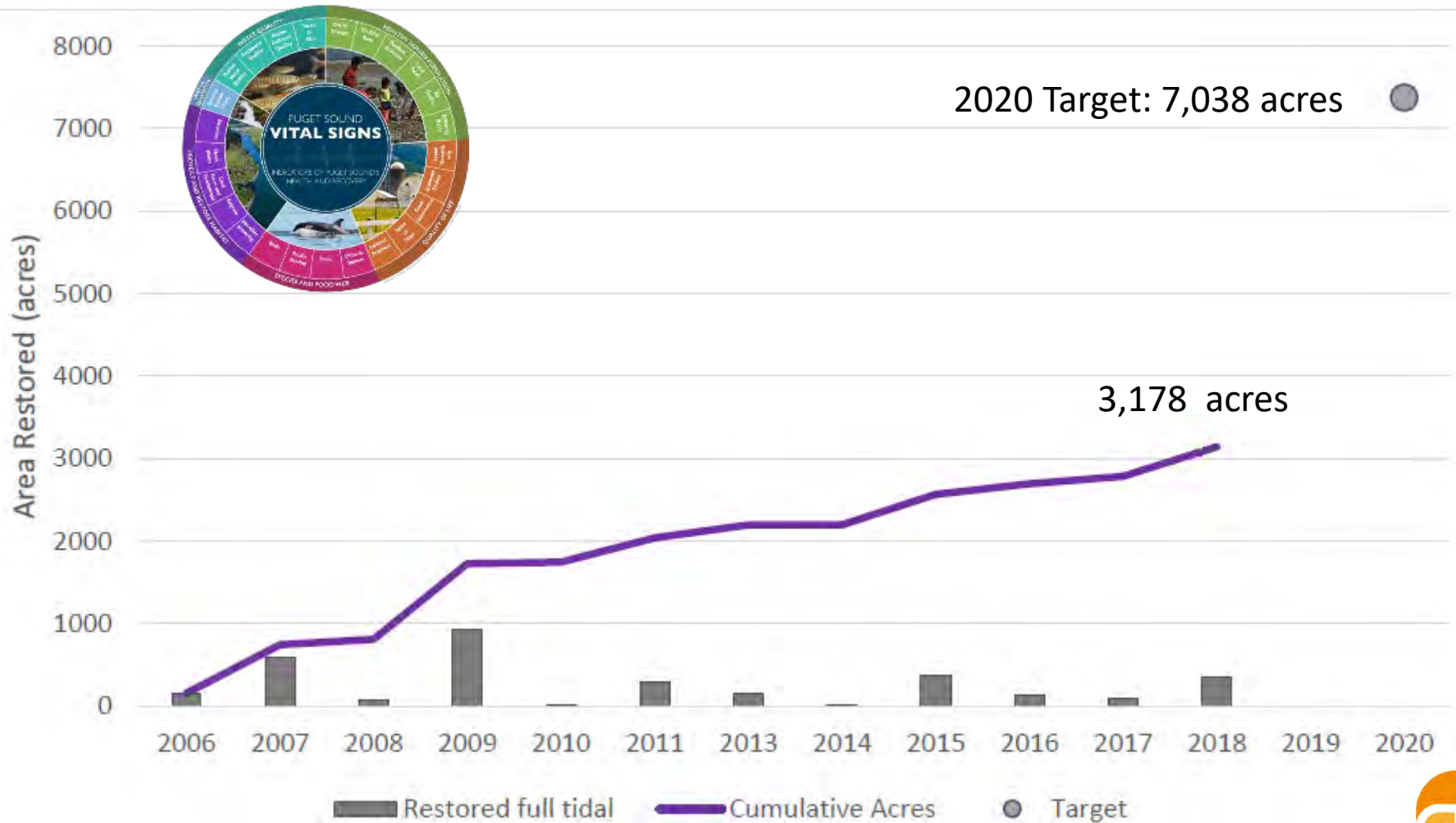
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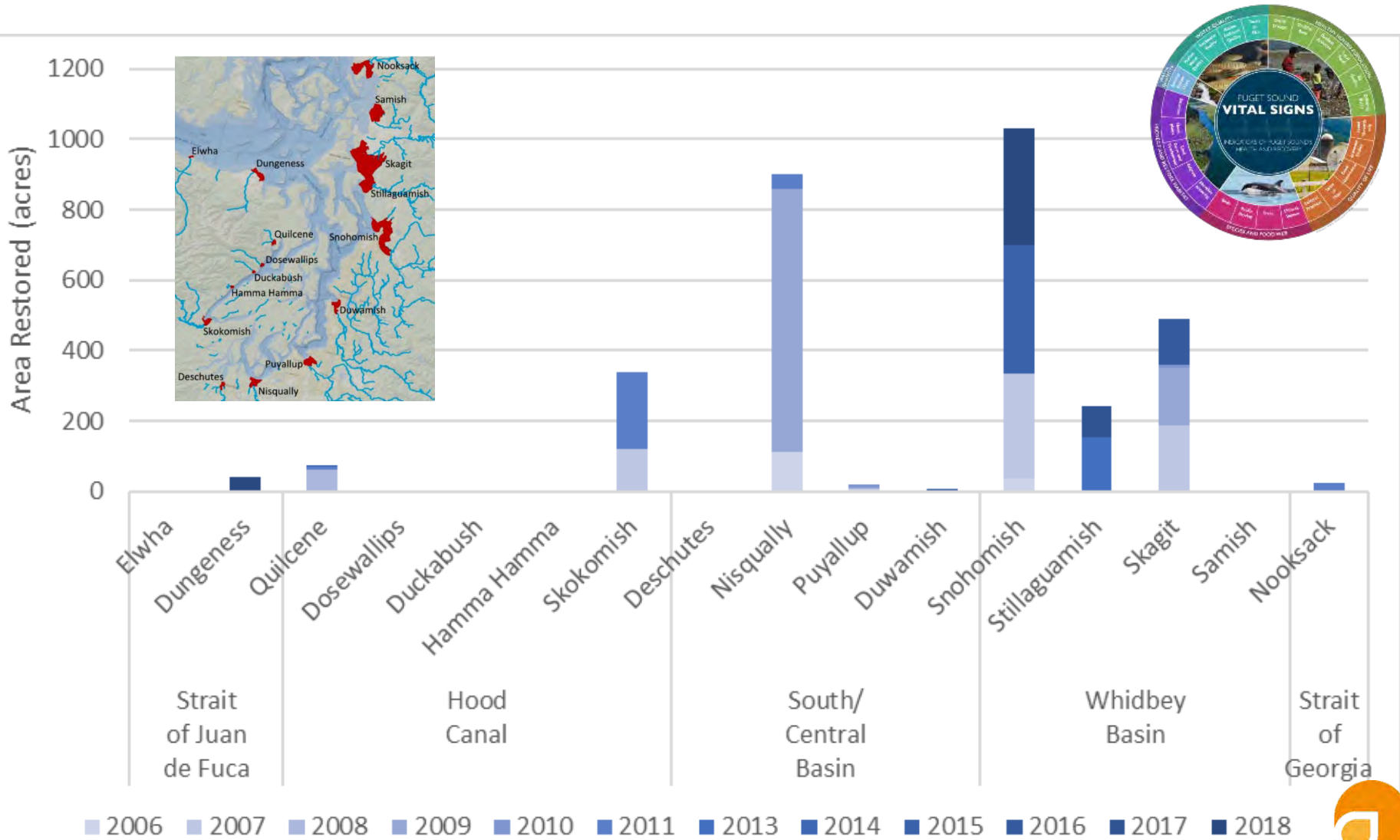
UNITED STATES
ENVIRONMENTAL PROTECTION AGENCY



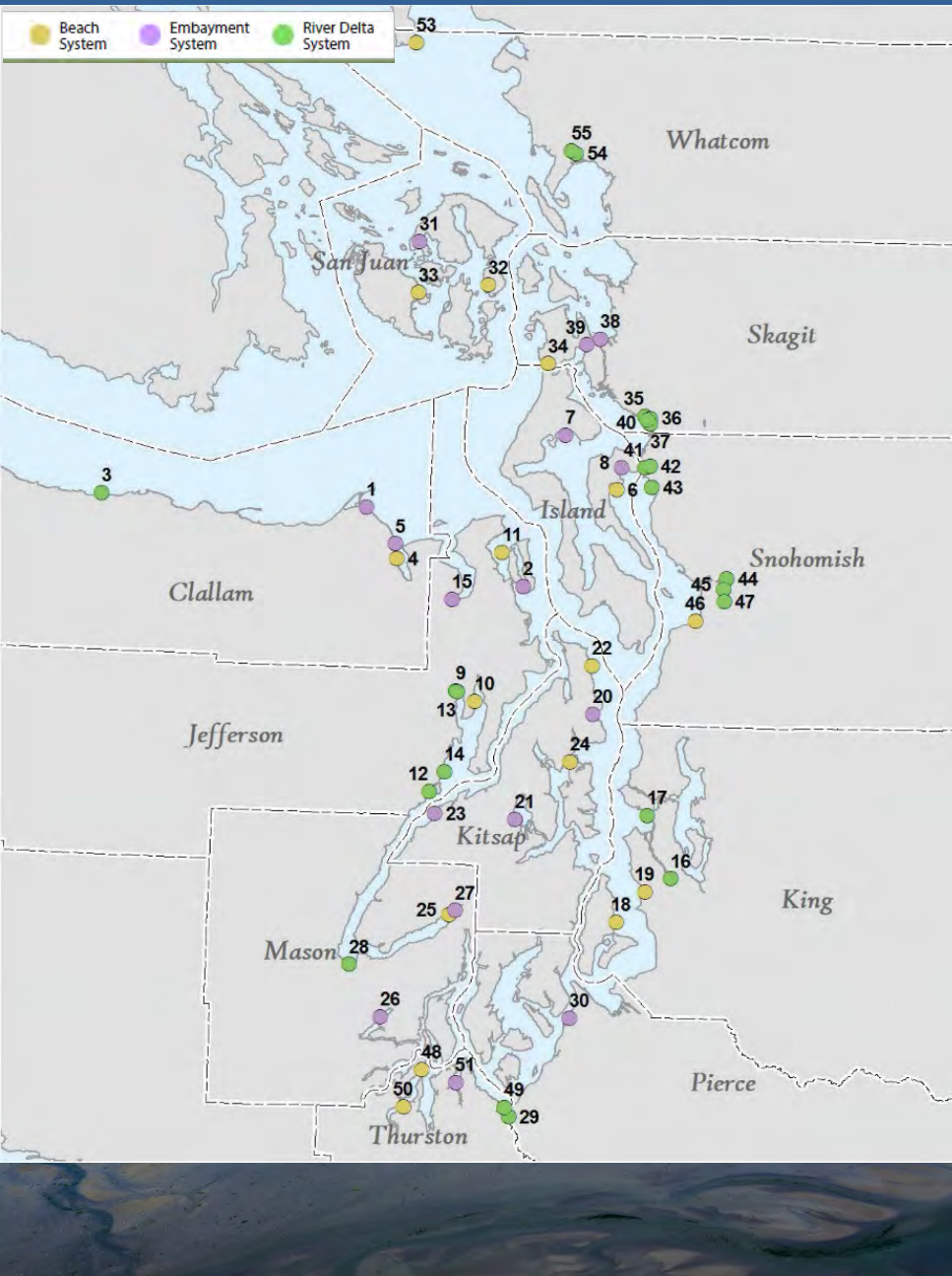
Estuary restoration in Puget Sound



Estuary restoration in Puget Sound



Estuary and Salmon Restoration Program



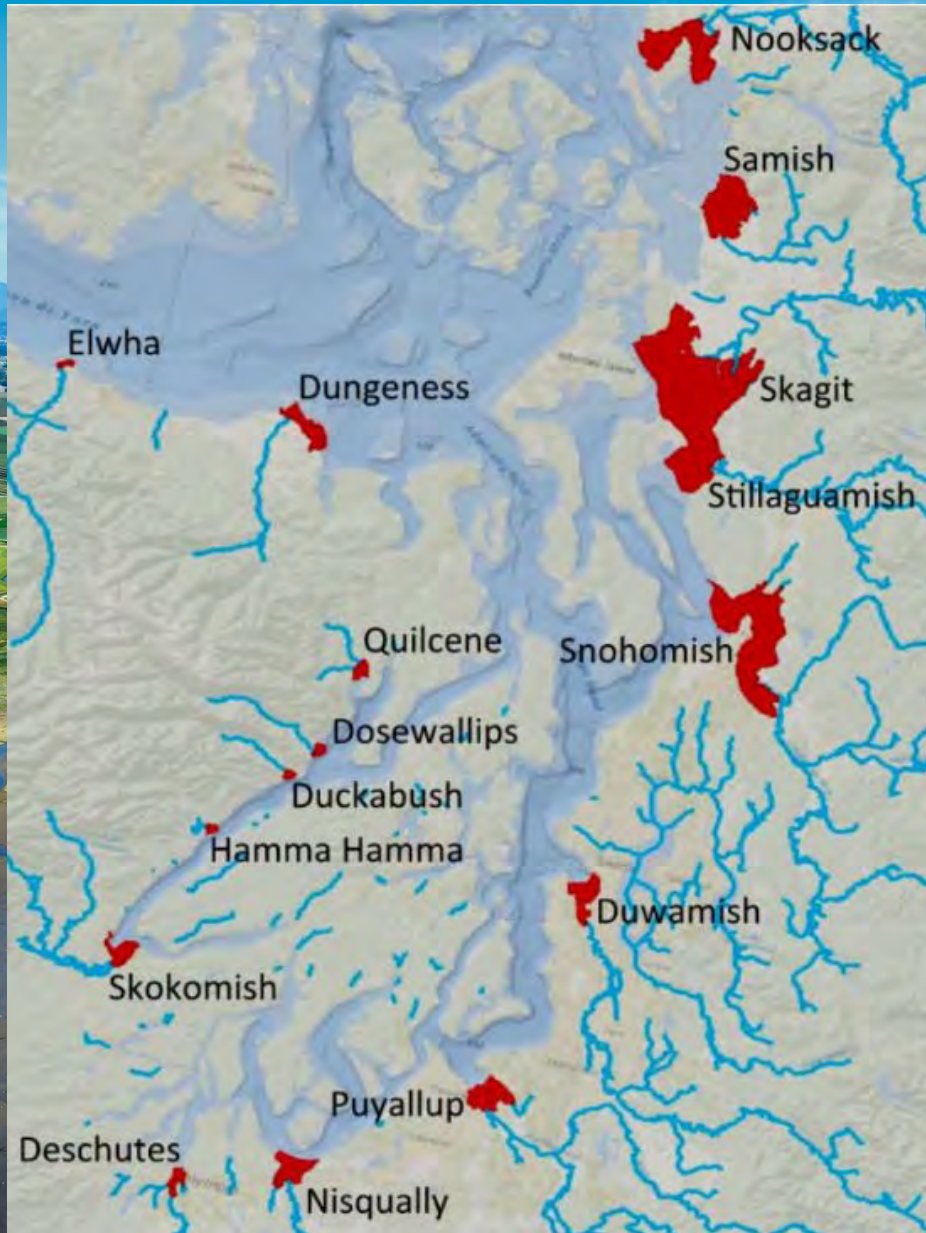
Estuary and Salmon Restoration Program

- Created in 2006
- Implementing nearshore ecosystem restoration projects ~100 completed to date
- Advancing adaptive management
- State capital budget appropriation
- \$5-12.5 million for restoration projects

Estuary and Salmon Restoration Program (ESRP) Objectives

1. Restore and/or protect large river delta estuaries
2. Restore and/or protect coastal embayments
3. Restore and/or protect beaches and bluffs
4. Increase understanding of natural process restoration to improve effectiveness of project actions

Program Objective: Restore and protect river deltas



Project Example: Skokomish Estuary Restoration

Skokomish Estuary Restoration Sponsor: Skokomish Tribe & Mason Conservation District

Phase I (2007) - 108 acres completed

Phase II (2010) - 216 acres completed

Phase III (2011) - 525 acres completed

Phase IIIc(2014) - 330 acres underway

Total: 1,179 acres / 377 tidal acres \$3.7 Million in ESRP



**SKOKOMISH
INDIAN TRIBE**

SqWuqWu'b3sh "People of the River"

Project Example: Leque Island Restoration



Restored to tides in October 2019

Skagit Bay

Camano Island

Stanwood

Stillaguamish River

Port Susan Bay



Program Objective: Restore and Protect Beaches and Embayments

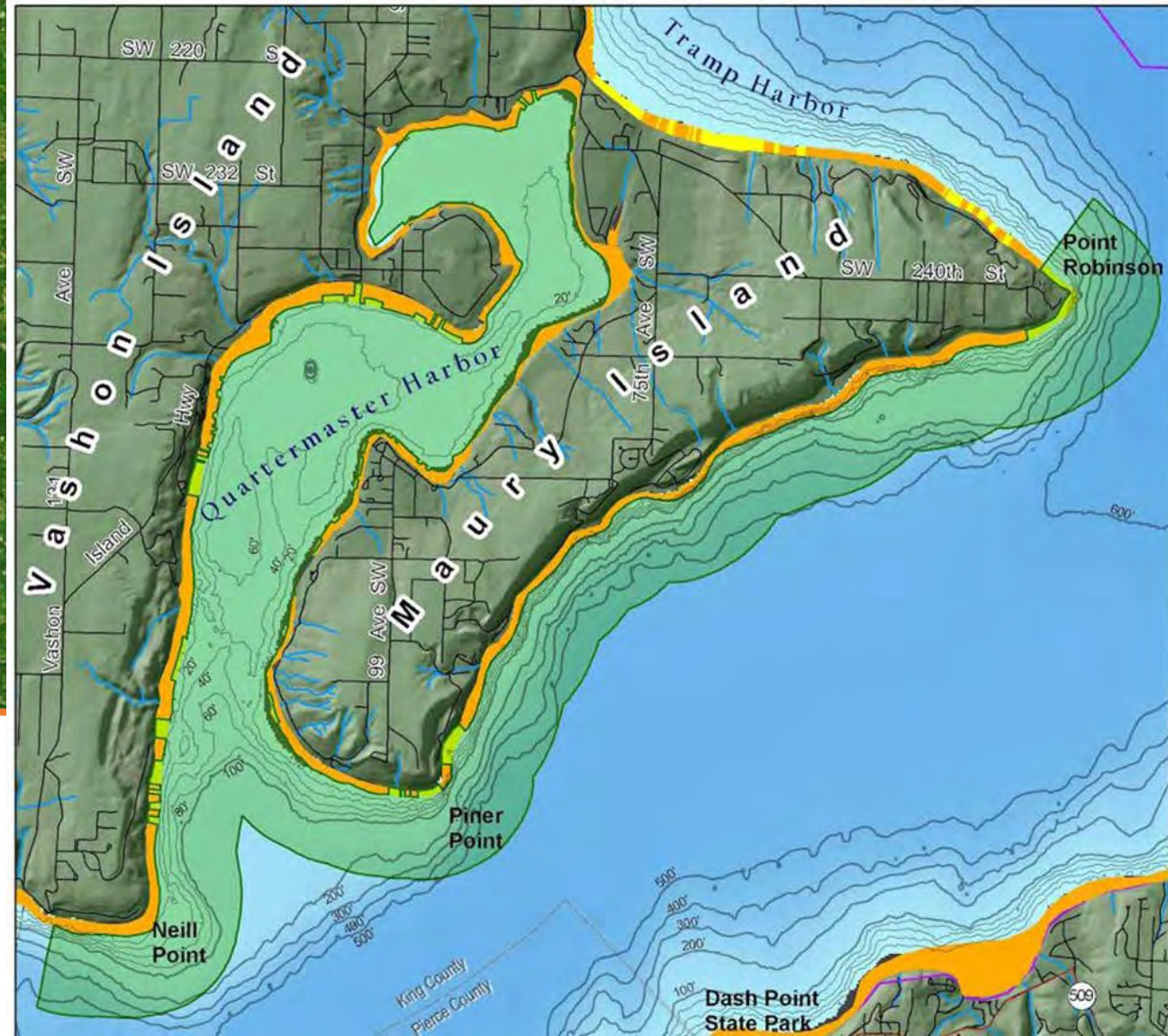


Before



After

Project Example: Maury Island Aquatic Reserve



King County

Project Example: Maury Island Aquatic Reserve



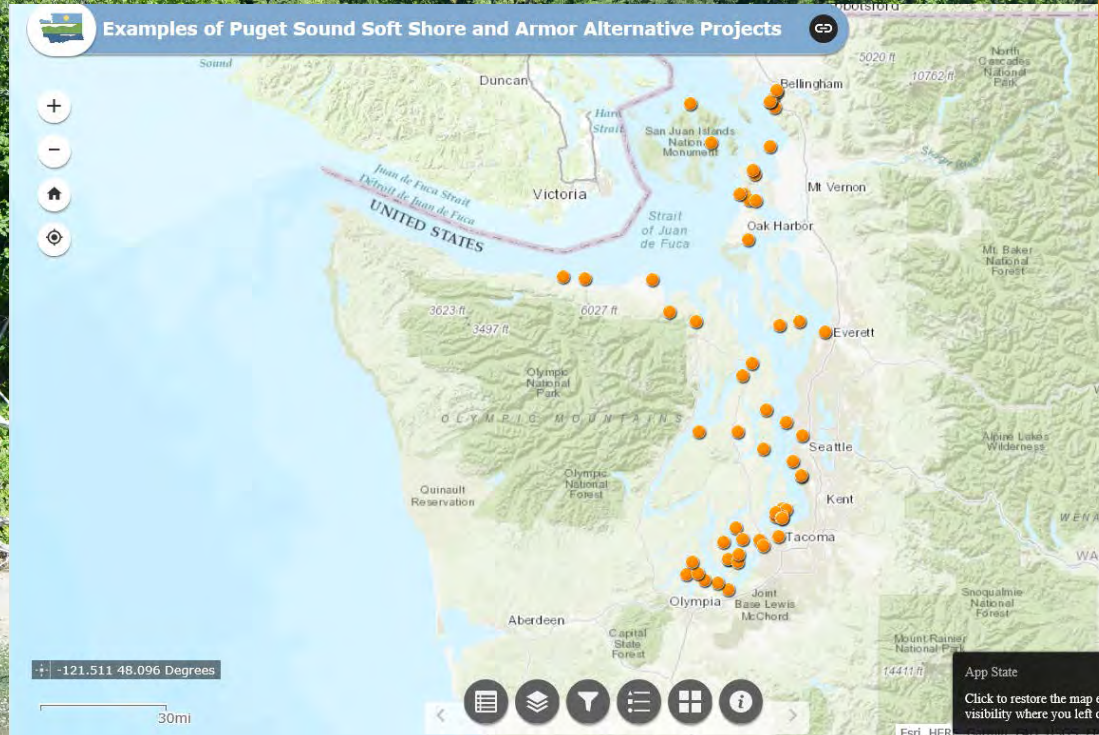
King County

Project example: Edgewater Beach



Project example: Edgewater Beach

- New Tool!
- Department of Ecology Project cataloguing armor removal and soft shore projects in Puget Sound



Kelly's Point Feeder Bluff Protection



Habitat loss and restoration of ecosystem processes in Puget Sound

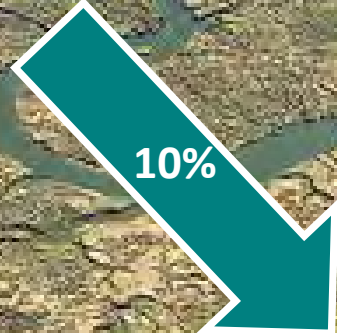
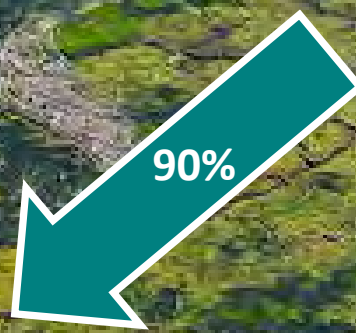
- I. How Puget Sound shorelines have changed
- II. Guiding principles for restoration
- III. Restoration actions in Puget Sound
- IV. Research and adaptive management

Estuary and Salmon Restoration Program (ESRP) Objectives

1. Restore connectivity and size of large river deltas
2. Restore sediment input, transport and accretion processes
3. Restore shoreline complexity and length
4. Increase understanding of natural process restoration to improve effectiveness of project actions

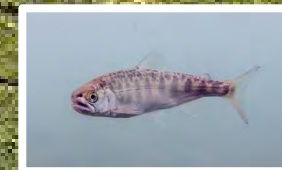
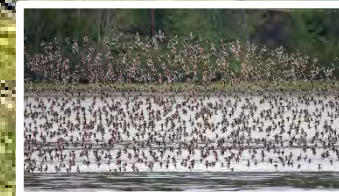
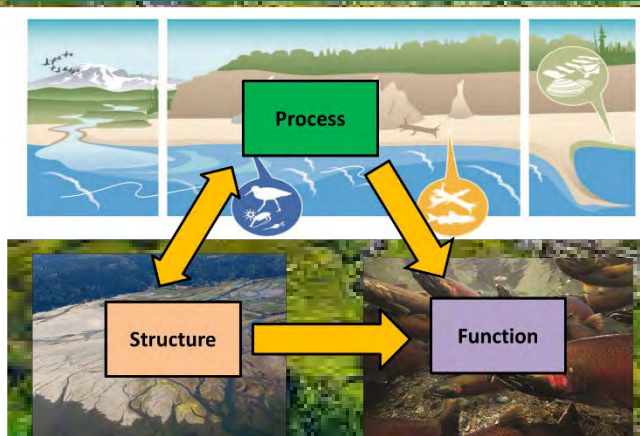
WDFW's Estuary and Salmon Restoration Program

Founded on scientific principles of the Puget Sound Nearshore Ecosystem Restoration Project (PSNERP)



Process-based restoration in Puget Sound

Research projects to inform restoration



Project Example: Snohomish Beach Nourishment

Assessing ecosystem response to beach nourishment on shorelines occupied by railroad.

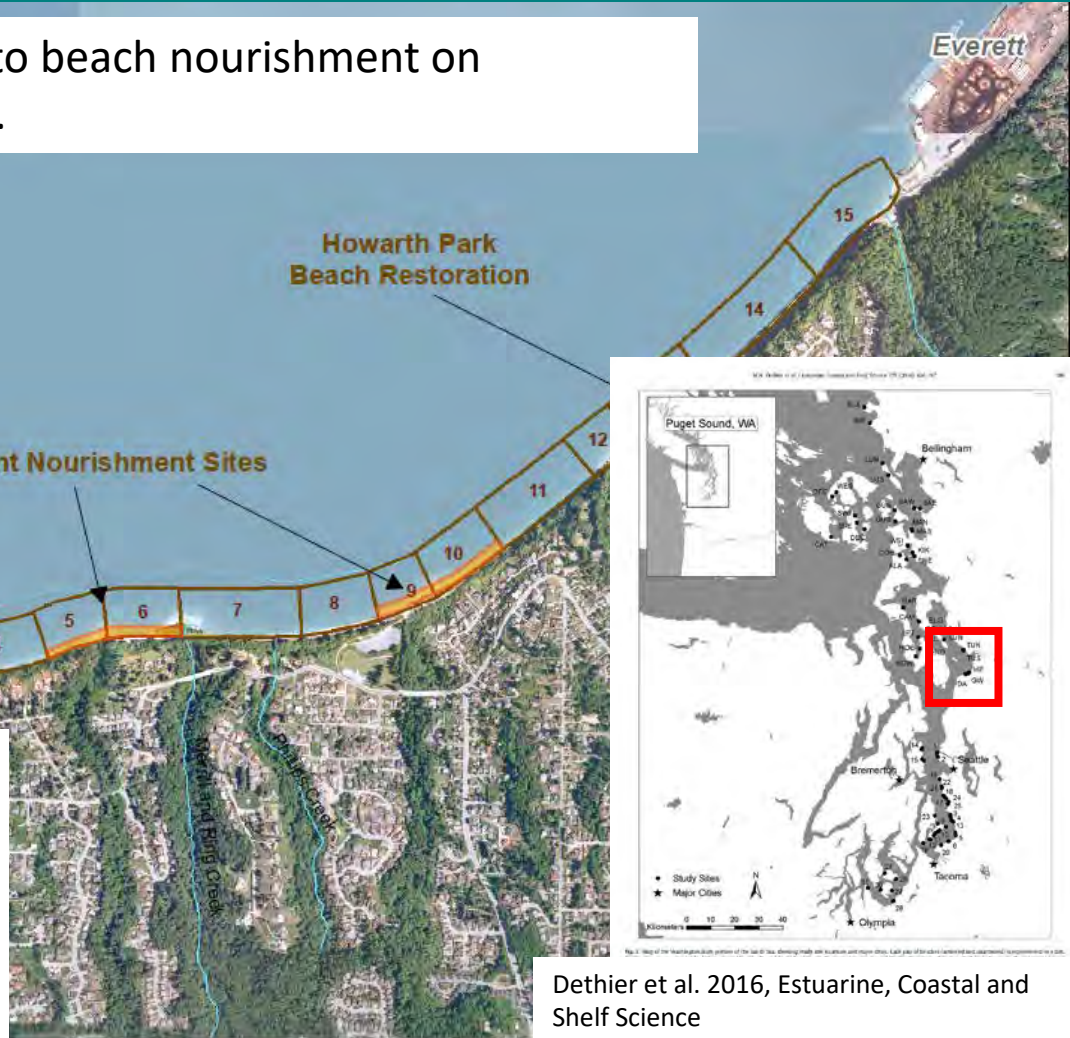


Howarth Park Beach Restoration

Sediment Nourishment Sites

Beach ecosystem response

- Beach wrack accumulation
- Invertebrates in wrack
- Forage fish eggs
- Sediment accumulation



Dethier et al. 2016, Estuarine, Coastal and Shelf Science



Nearshore Beach Nourishment
Figure 1



PUBLIC WORKS
SURFACE WATER MANAGEMENT
(425) 388-3454

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Project Example: Edgewater Beach

Ecosystem responses to restoration

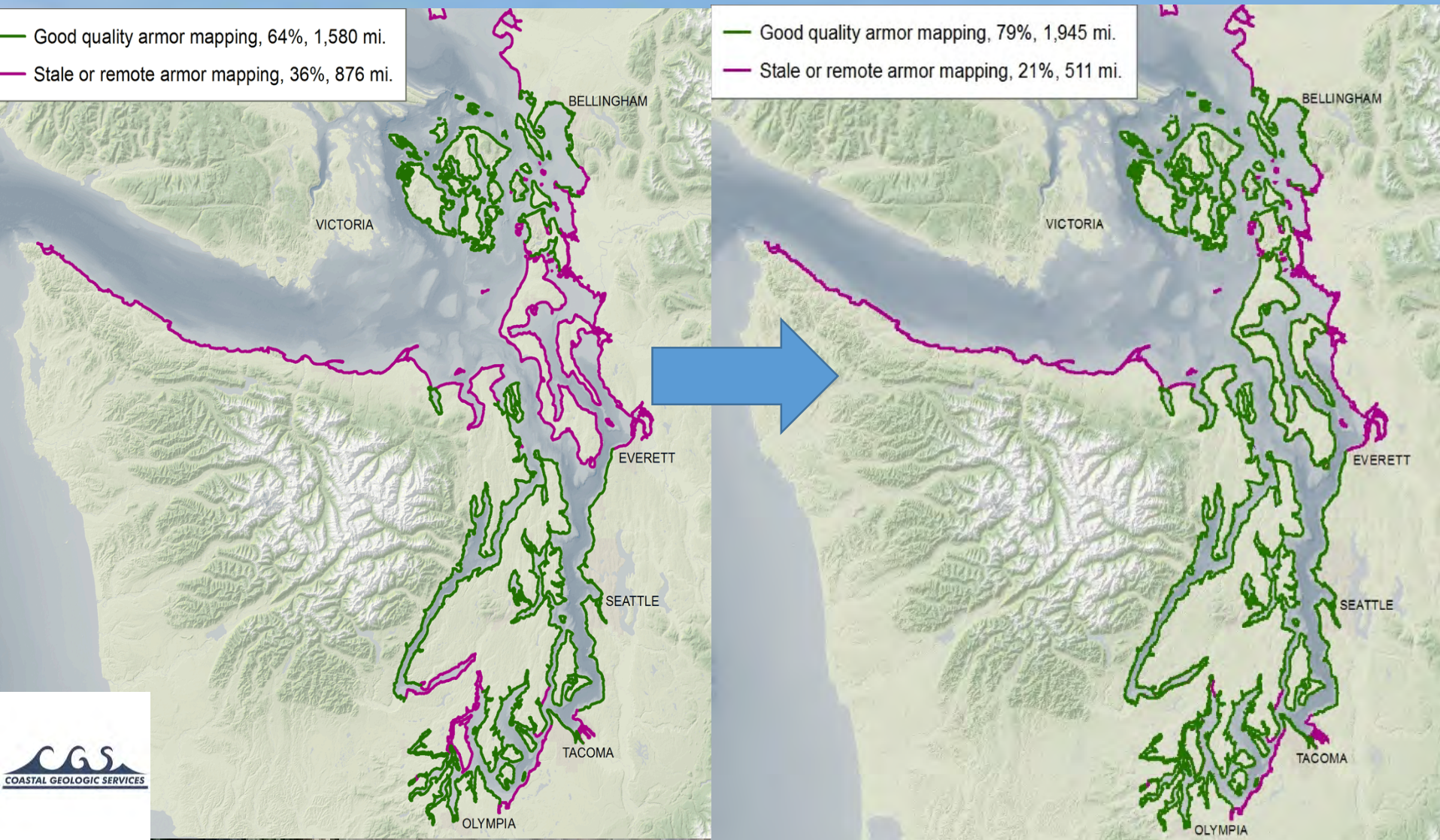
- Sediment transport
- Beach wrack
- Beach profile
- Invertebrate community
- Fish and crab community



Project Example: Beach Strategies Project

1. Improve geospatial data for shorelines (armor extent/condition/feeder bluff mapping)
2. Develop new strategies based on new data
3. Incorporate into online interactive geodatabase

Project Example: Beach Strategies Project



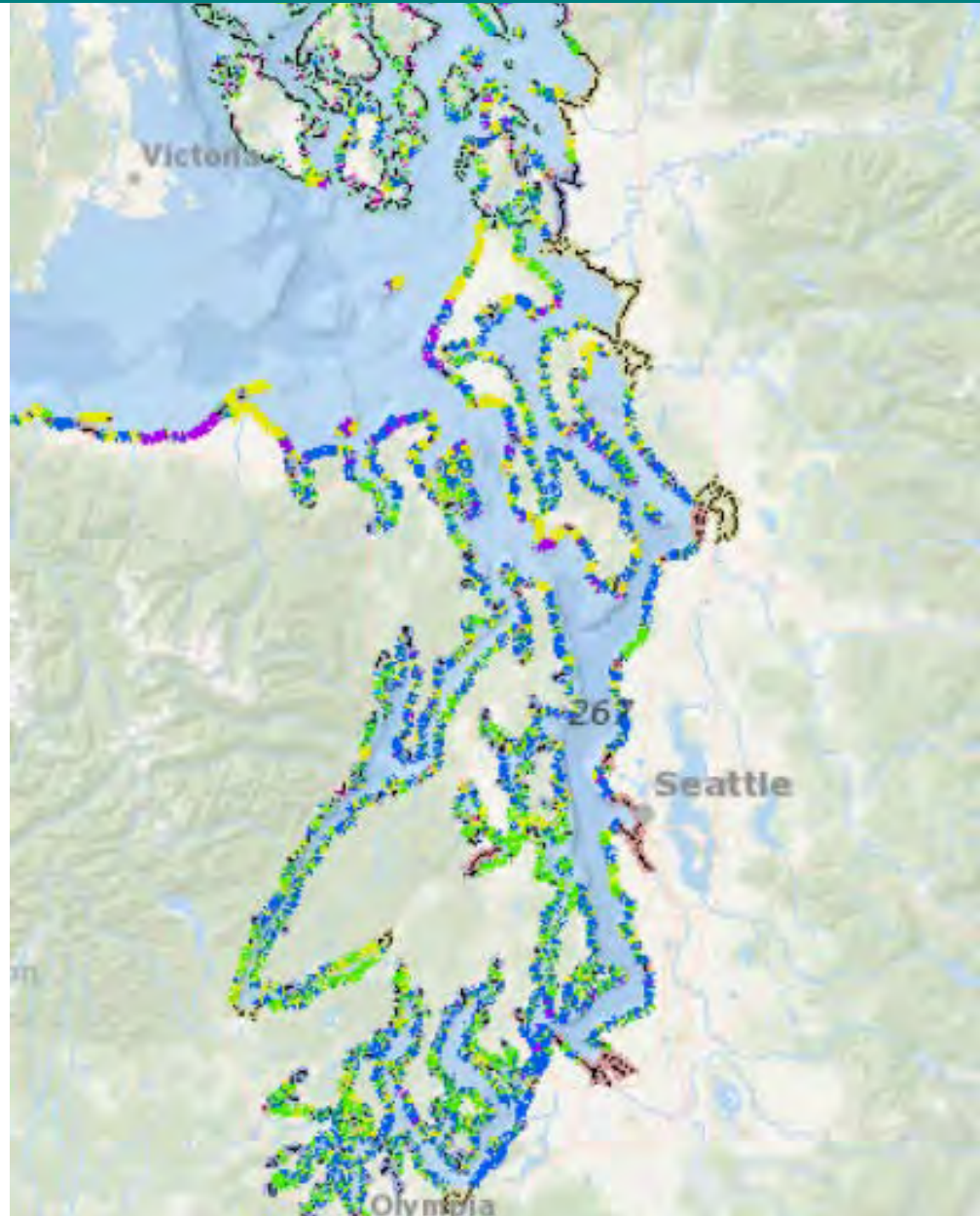
Project Example: Beach Strategies Project

New Shoretype Mapping

Beach Strategies

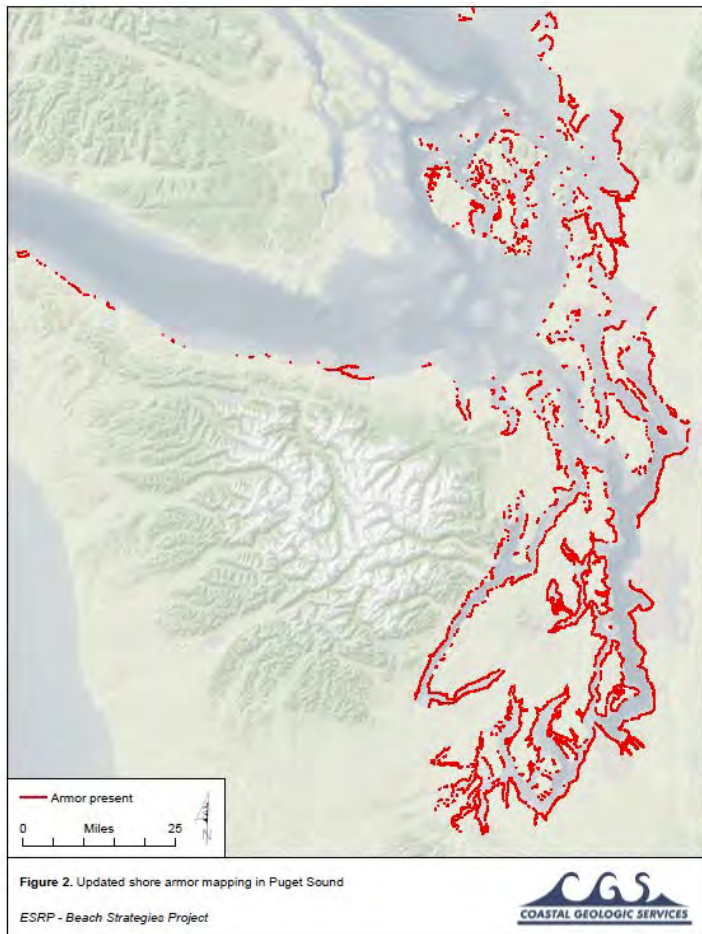
Shoretype

- Pocket Beach
- Pocket Beach - Artificial
- Feeder Bluff Exceptional
- Feeder Bluff
- Feeder Bluff, Tallus
- Transport Zone
- Accretion Shorform
- No Appreciable Drift - Artificial
- No Appreciable Drift - Bedrock
- No Appreciable Drift - Delta
- No Appreciable Drift - Low Energy



Project Example: Beach Strategies Project

New Armor Mapping

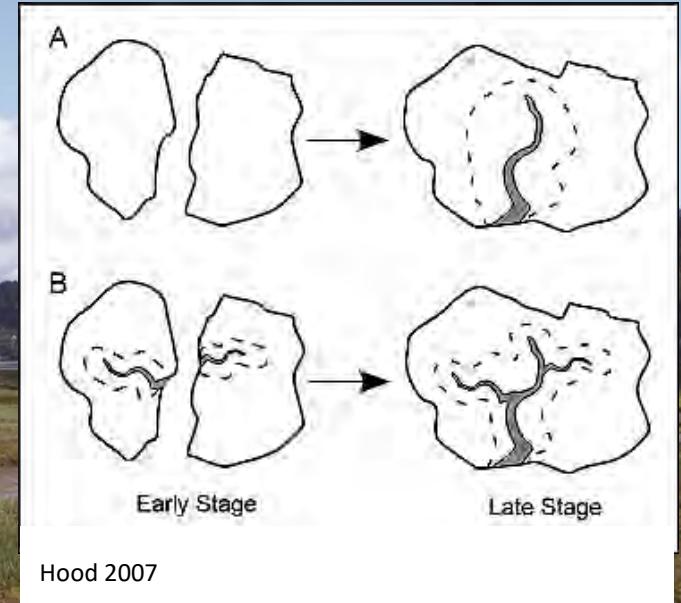


County	Unarmored, miles	Armored, miles	Total, miles	Percent Armored
Clallam	128	31	159	20
Island	163	54	217	25
Jefferson	173	28	202	14
King	56	67	123	55
Kitsap	132	122	254	48
Mason	158	74	232	32
Pierce	114	127	240	53
San Juan	382	26	408	6
Skagit	155	74	229	32
Snohomish	96	37	133	28
Thurston	71	45	116	39
Whatcom	115	31	146	21
Sound-wide	1745	715	2,460	29

Coming in 2020!
New Beach
Strategies based
on updated data

Project example: Scaling tidal geometry with marsh island area for Puget Sound

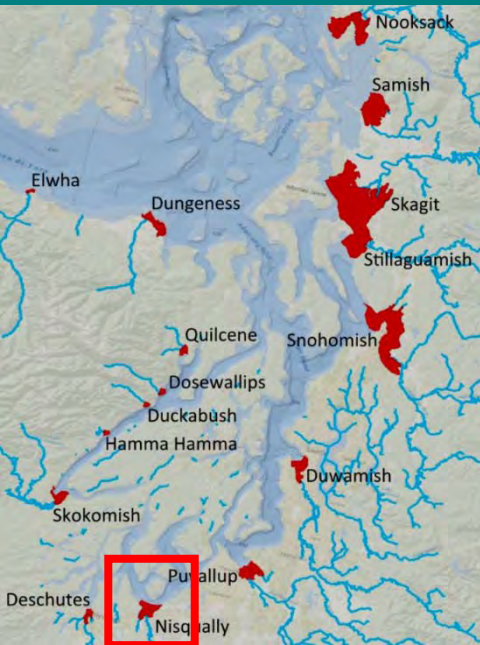
Design Guidance:
Number of Channels
Number of Outlets
Channel Area



Hood 2007 Scaling tidal channel with marsh island area: A tool for habitat restoration, linked to channel formation processes. Water resources research

Hood 2015 Geographic variation in Puget Sound tidal channel planform. *Geomorphology*.230.98-108

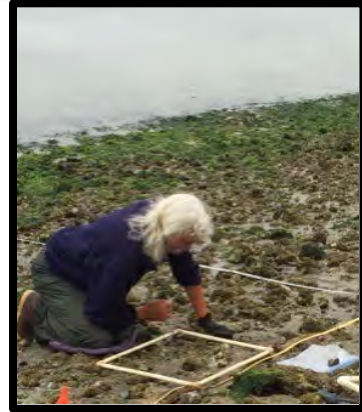
Project example: Nisqually response to restoration



- Juvenile Chinook access to restored site
- Colonization by juvenile salmonid prey
- Habitat-specific prey energy density

Ellings et al. 2016
Davis et al. 2017
Davis et al. 2018
Woo et al. 2018
Woo et al. 2019

Adaptive Management Cycle



Ecosystem response

Tools

Communication

Nearshore
Restoration Summit
and Synthesis!
Fall 2020



Incorporation into
restoration
projects



Summary

- Puget Sound shorelines and estuaries have changed dramatically
- We are working to improve habitat function by restoring the processes that shape the landscape
- We are making good progress, but lots of work to do
- We are learning as we go

WDFW Conservation Initiative and Guiding Principles

- *“We practice conservation by managing, protecting and restoring ecosystems for the long term benefit of people, and for fish, wildlife and their habitat”*



“There can be no purpose more enspiriting than to begin the age of restoration, reweaving the wondrous diversity of life that still surrounds us . . . The next century will, I believe, be the era of restoration in ecology. “

– E.O. Wilson, *The Diversity of Life*

“Science alone does not hold the power to achieve the goal of greater sustainability, but scientific knowledge and wisdom are needed to help inform decisions that will enable society to move toward that end.”

– Jane Lubchenco

Acknowledgements

ESRP Team: Jay Krienitz, Kay Caromile, Jenna Jewett

PSNERP Nearshore Science Team

ESRP Learning Project Sponsors

Thank you!

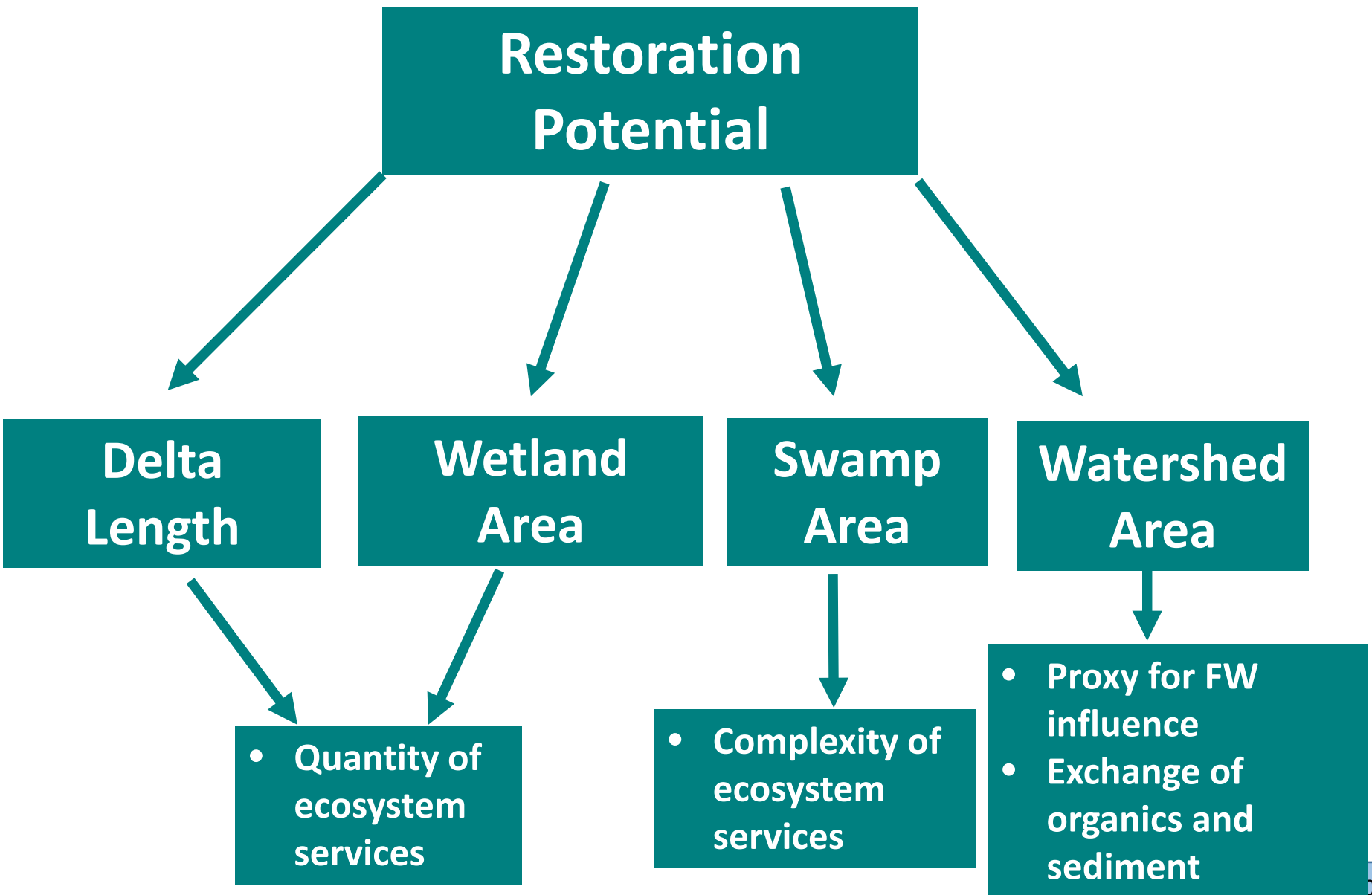


ESTUARY & SALMON
RESTORATION PROGRAM



Washington
Department of
**FISH and
WILDLIFE**

Calculation of Restoration Potential: Deltas



Calculation of Degradation: Deltas

**Relative Degradation
of Historic Potential**

```
graph TD; A[Relative Degradation of Historic Potential] --> B[Lost Delta Length]; A --> C[Tidal Flow Degradation]; A --> D[Wetland Loss]; A --> E[Nearshore Impervious]; A --> F[Watershed Impervious];
```

**Lost Delta
Length**

**Tidal Flow
Degradation**

**Wetland
Loss**

**Nearshore
Impervious**

**Watershed
Impervious**

Risk Factors: Deltas

Risk Factors

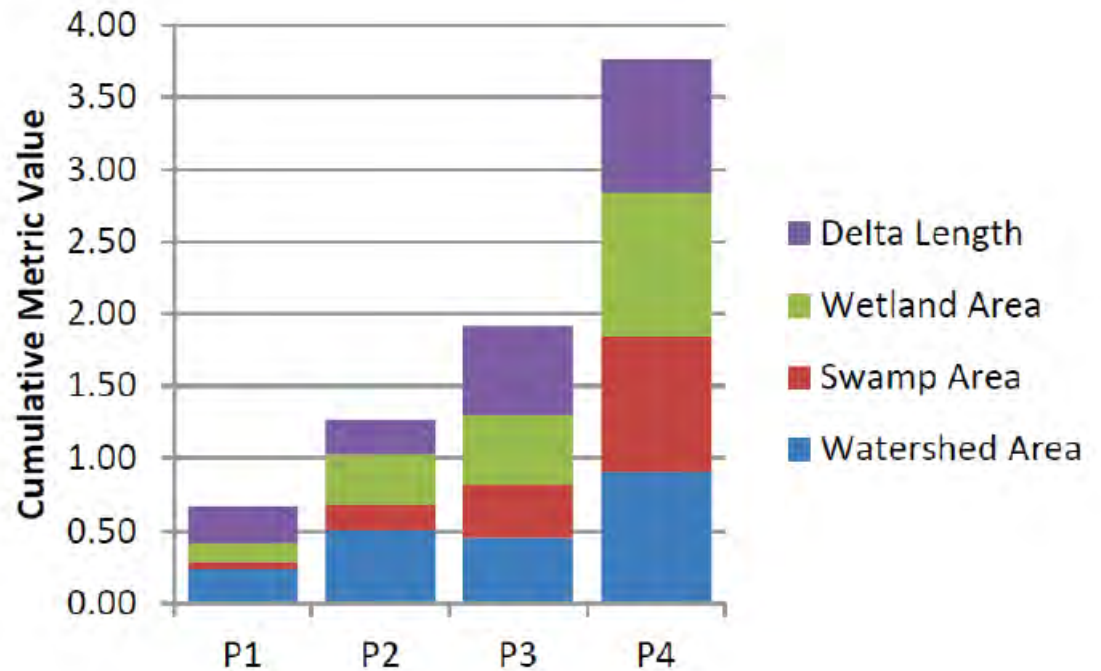
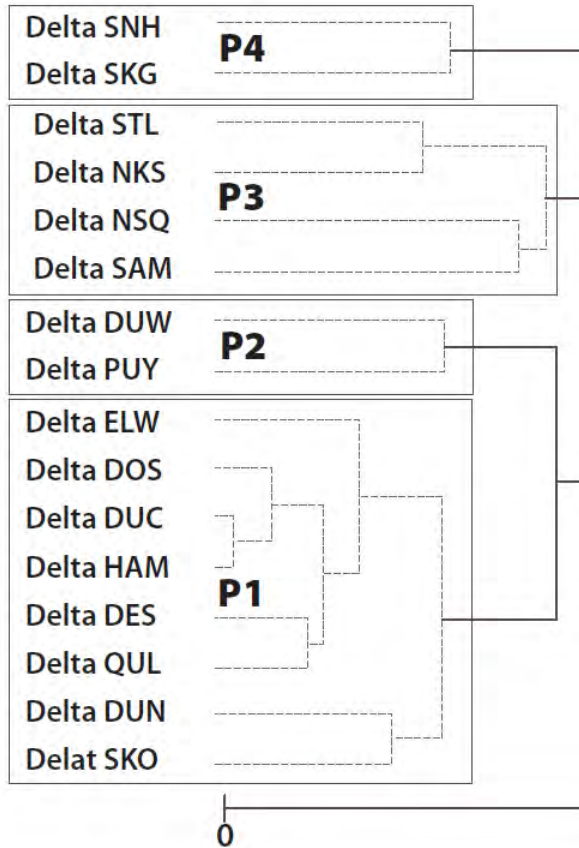
```
graph TD; A[Risk Factors] --> B[Future Nearshore Development]; A --> C[Future Watershed Development]; A --> D[Dam Impoundment];
```

**Future Nearshore
Development**

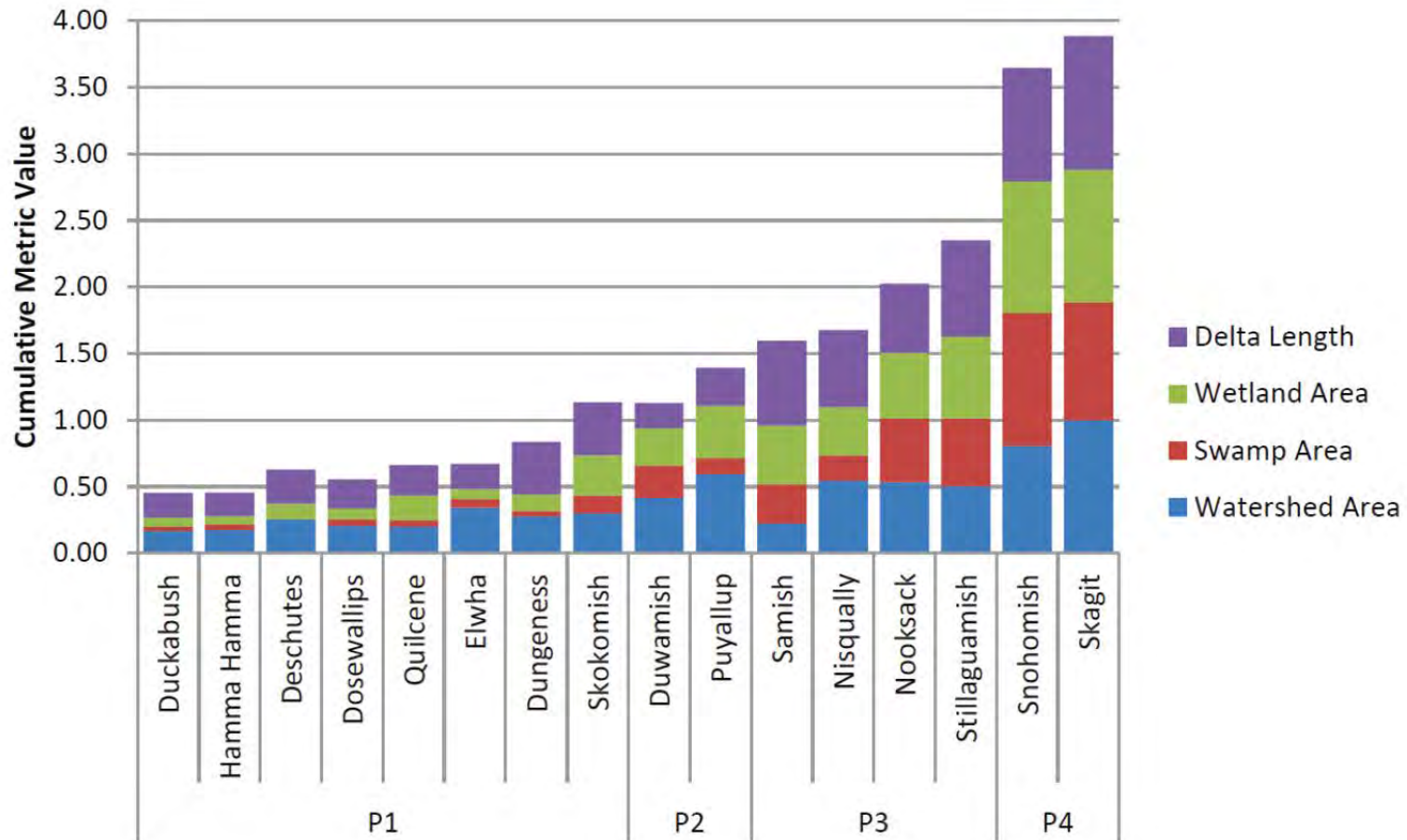
**Future
Watershed
Development**

**Dam
Impoundment**

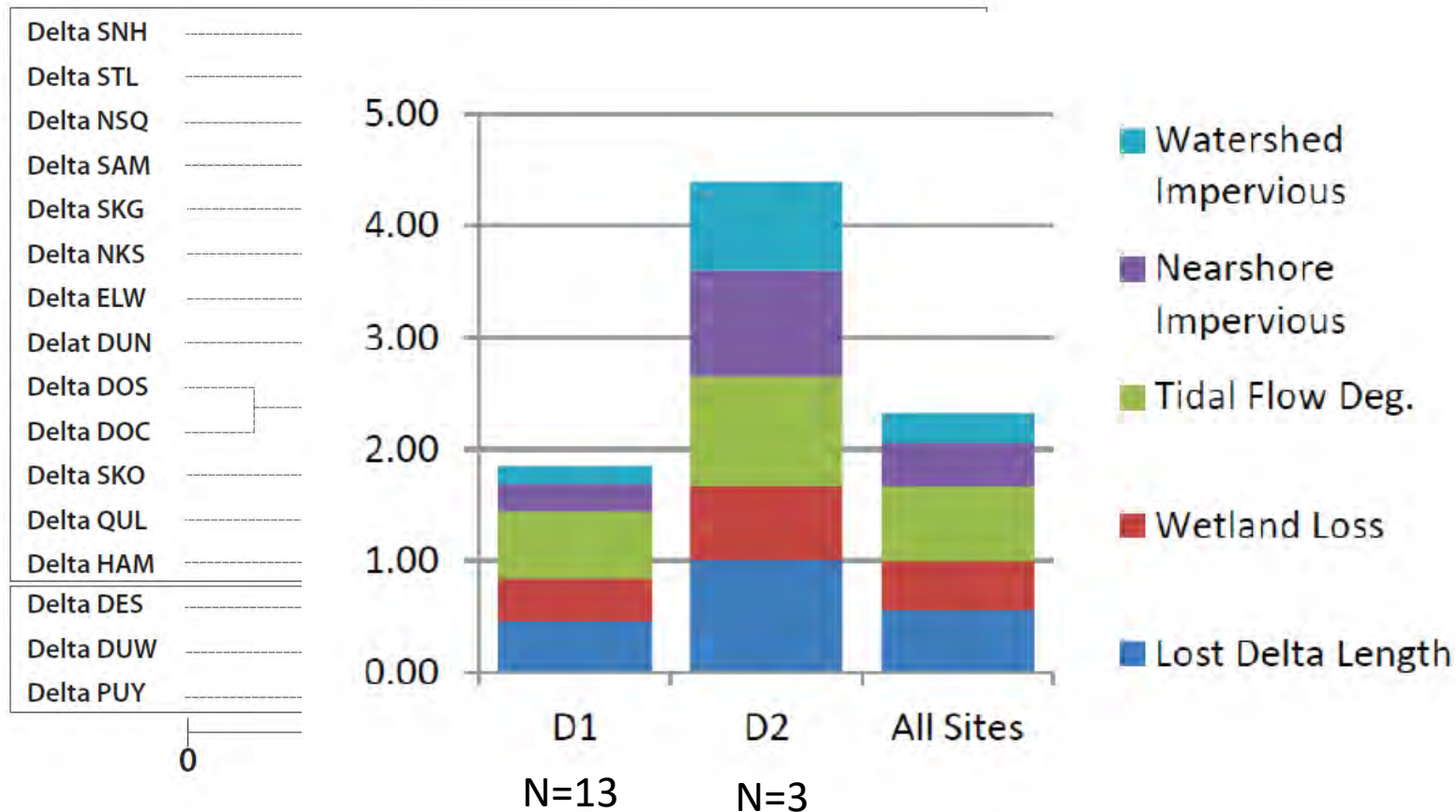
Delta Potential Groupings: Cluster analysis



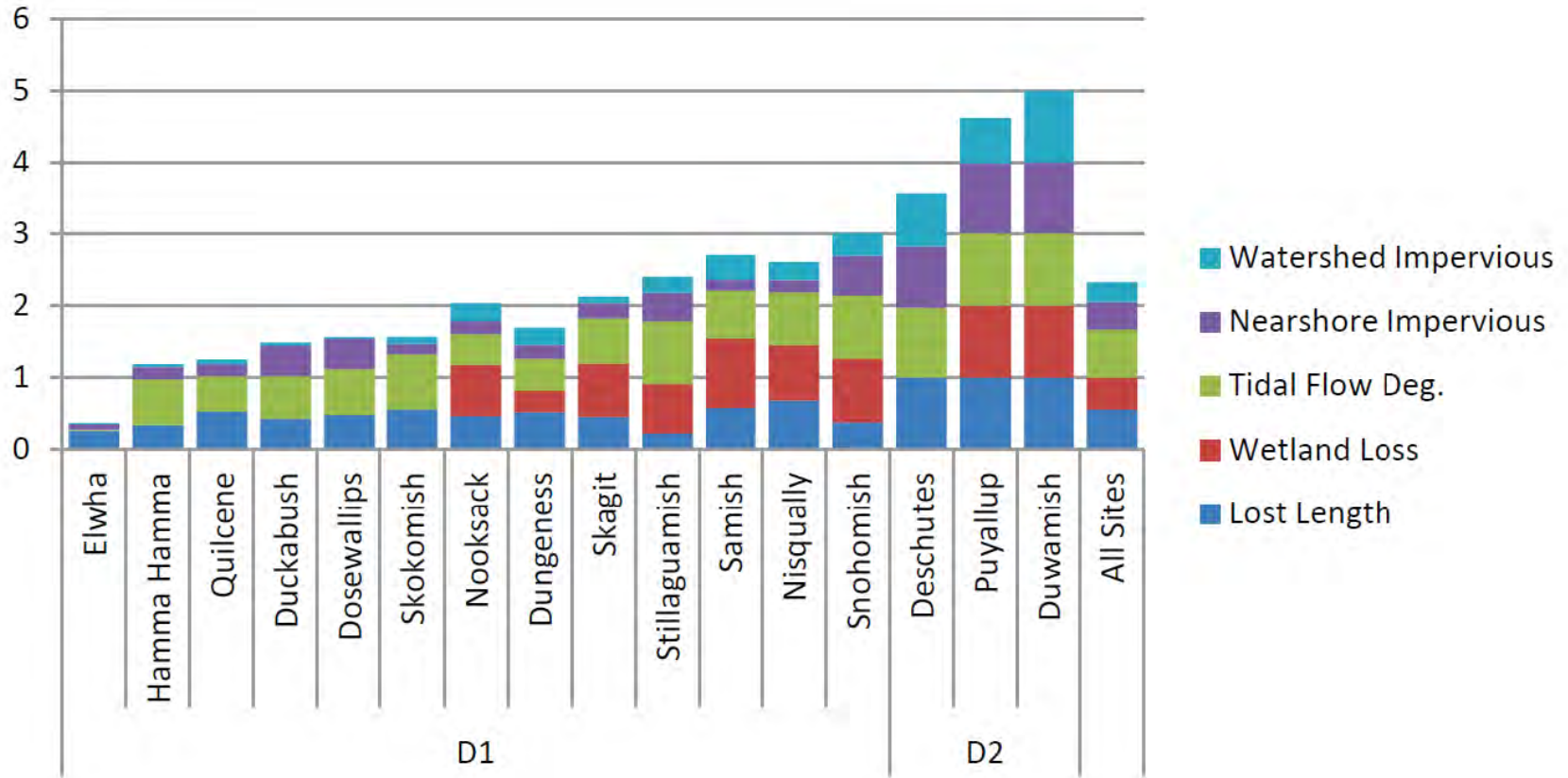
Features of Delta Potential Groups



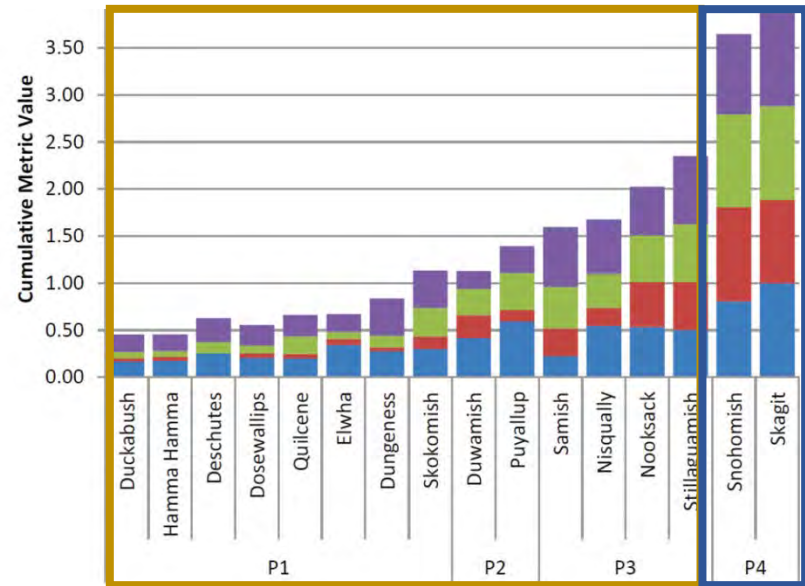
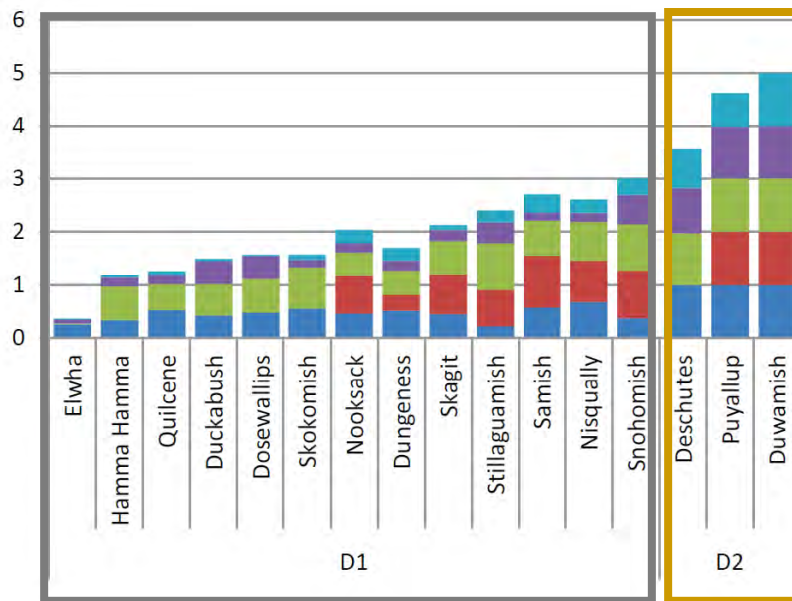
Delta Degradation Groupings: Cluster Analysis



Features of Delta Degradation Groups



Delta Management Strategy



Group	D1	D2	Total
P1	7	1	8
P2	0	2	2
P3	4	0	4
P4	2	0	2
Total	13	3	16

Low

High

Restore Enhance