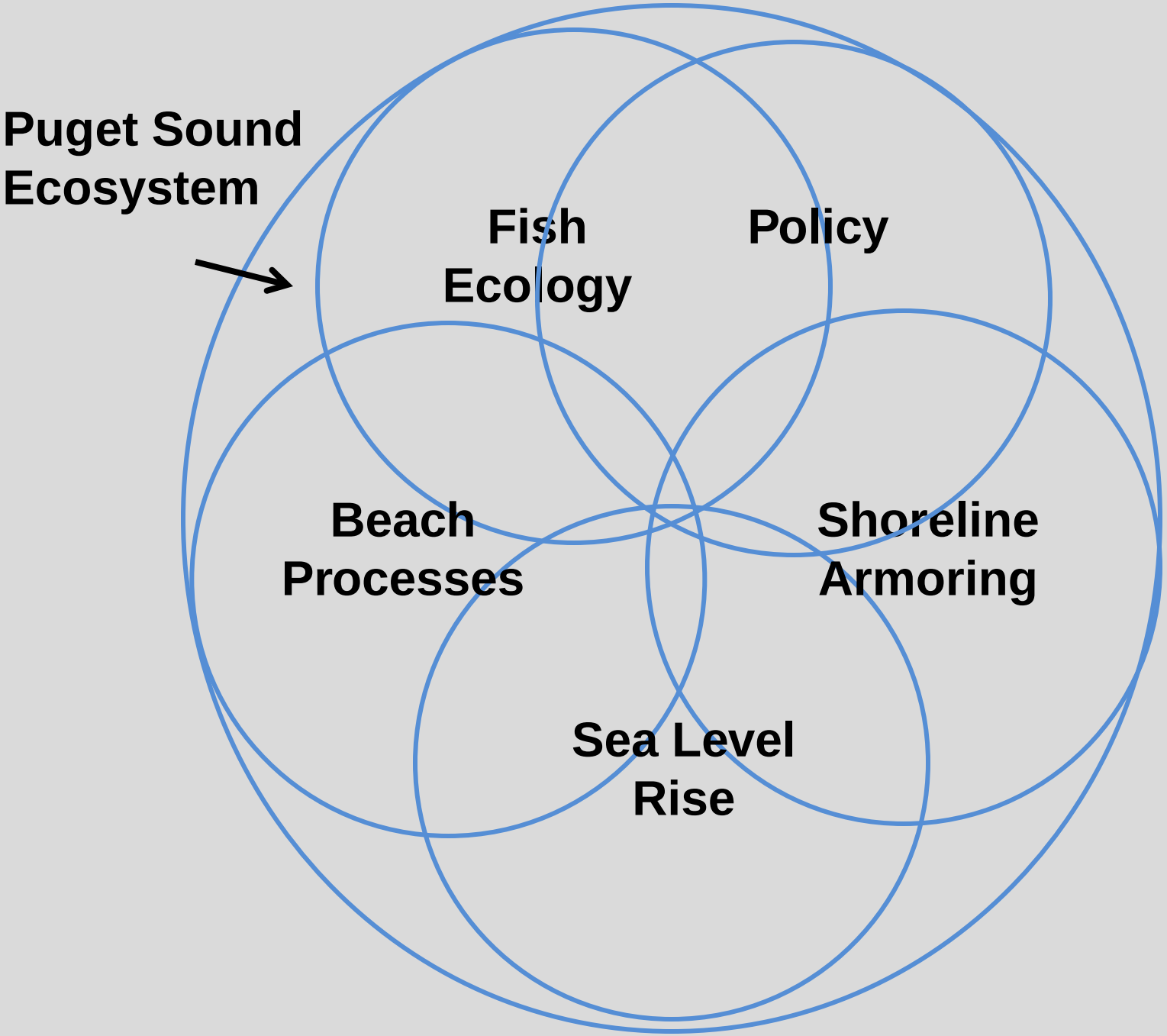
Presented at Puget Sound Shorelines and the Impacts of Armoring Workshop,
May 12-14 2009.
This presentation not peer reviewed.

Anticipated Effects of Sea Level Rise in Puget Sound on Beach-spawning Fishes

Kirk Krueger, Ken Pierce, Timothy Quinn and Dan Penttila

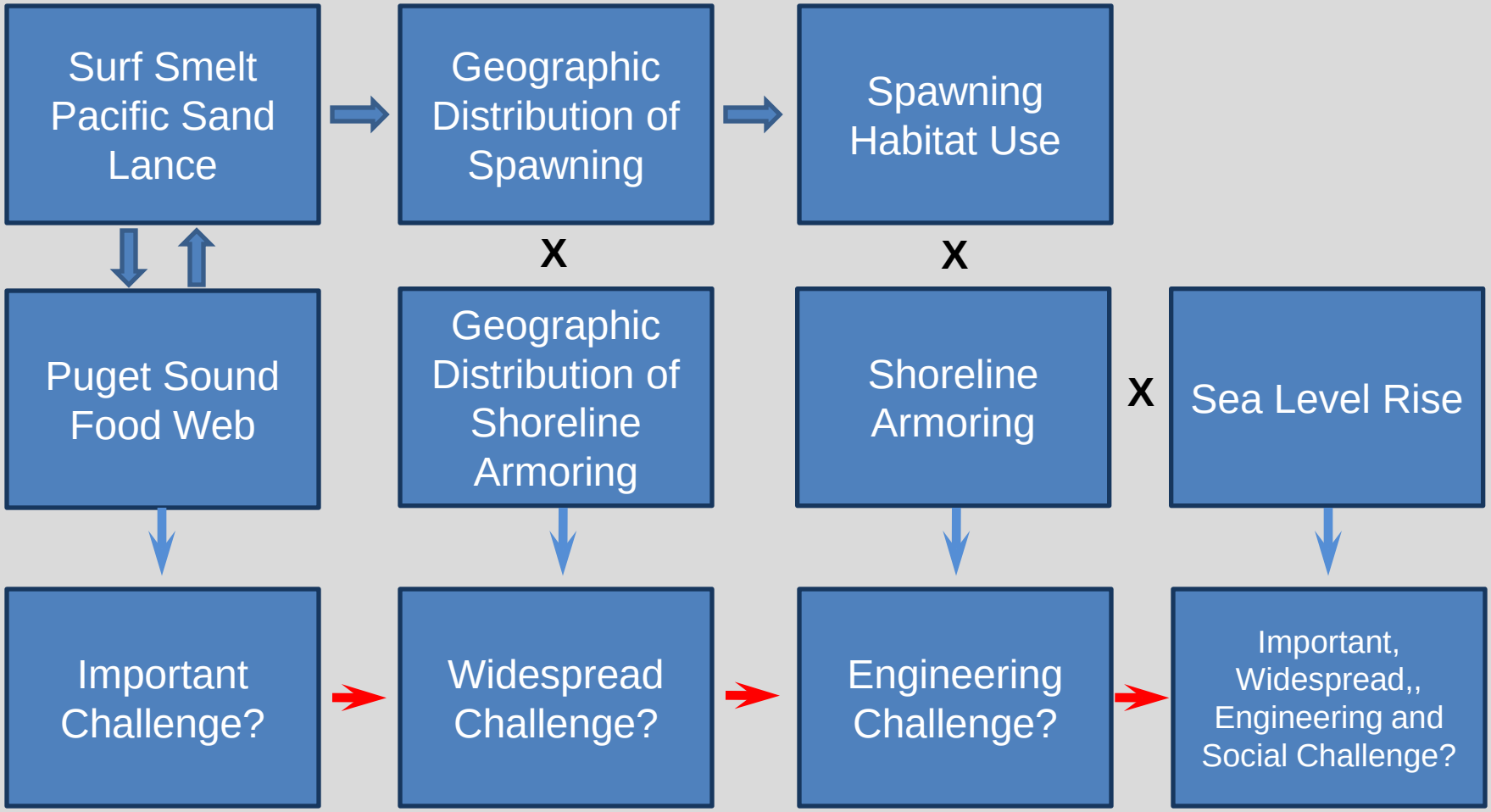
Washington Dept. of Fish and Wildlife

Habitat Program


Puget Sound Ecosystem
Fish Ecology
Policy
Beach Processes
Shoreline Armoring
Sea Level Rise

Question

- Given shoreline armoring and expectations of sea level rise, should we be especially concerned for surf smelt and Pacific sand lance?
  - Can we avoid substantial impacts or identify conservation priorities?
  - Can we use this information to plan for change instead of reacting to it?


Surf Smelt Pacific Sand Lance
Geographic Distribution of Spawning
Spawning Habitat Use
X
X
Puget Sound Food Web
Geographic Distribution of Shoreline Armoring
Shoreline Armoring
X
Sea Level Rise
Important Challenge?
Widespread Challenge?
Engineering Challenge?
Important, Widespread,, Engineering and Social Challenge?

Focal Species

- Length 30 cm
- Live to 5 years
- Oviparous, with demersal eggs and planktonic larvae
- Year-round Spawning?

Surf Smelt (*Hypomesus pretiosus*)

- Length 30 cm
- Live to 11 years
- Oviparous, with demersal eggs and planktonic larvae
- Winter Spawning?

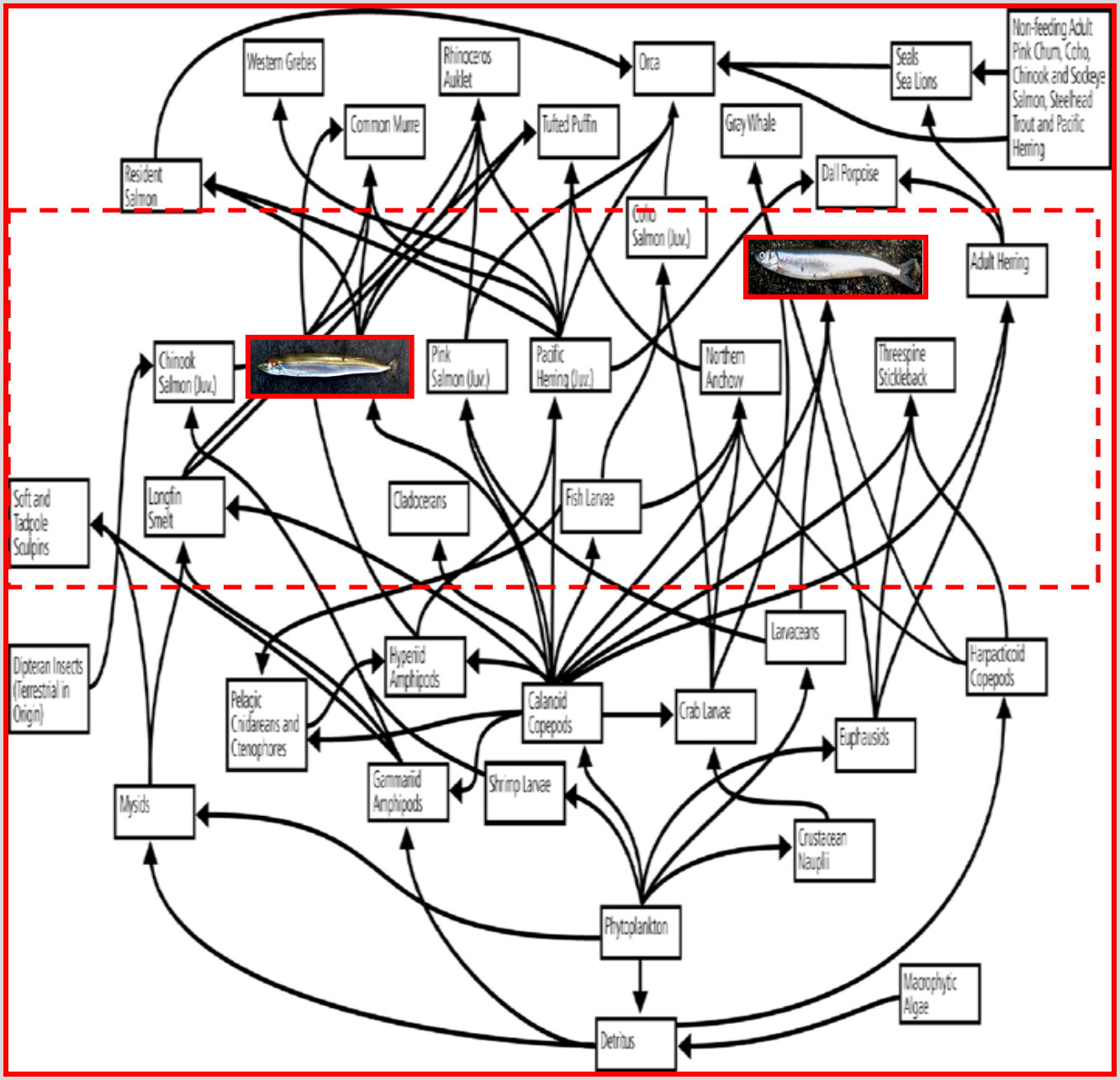
Pacific Sand Lance (*Ammodytes hexapterus*)

Little commercial importance – little information.

Nearshore open water food web

Note positions between macro-zooplankton and secondary predators

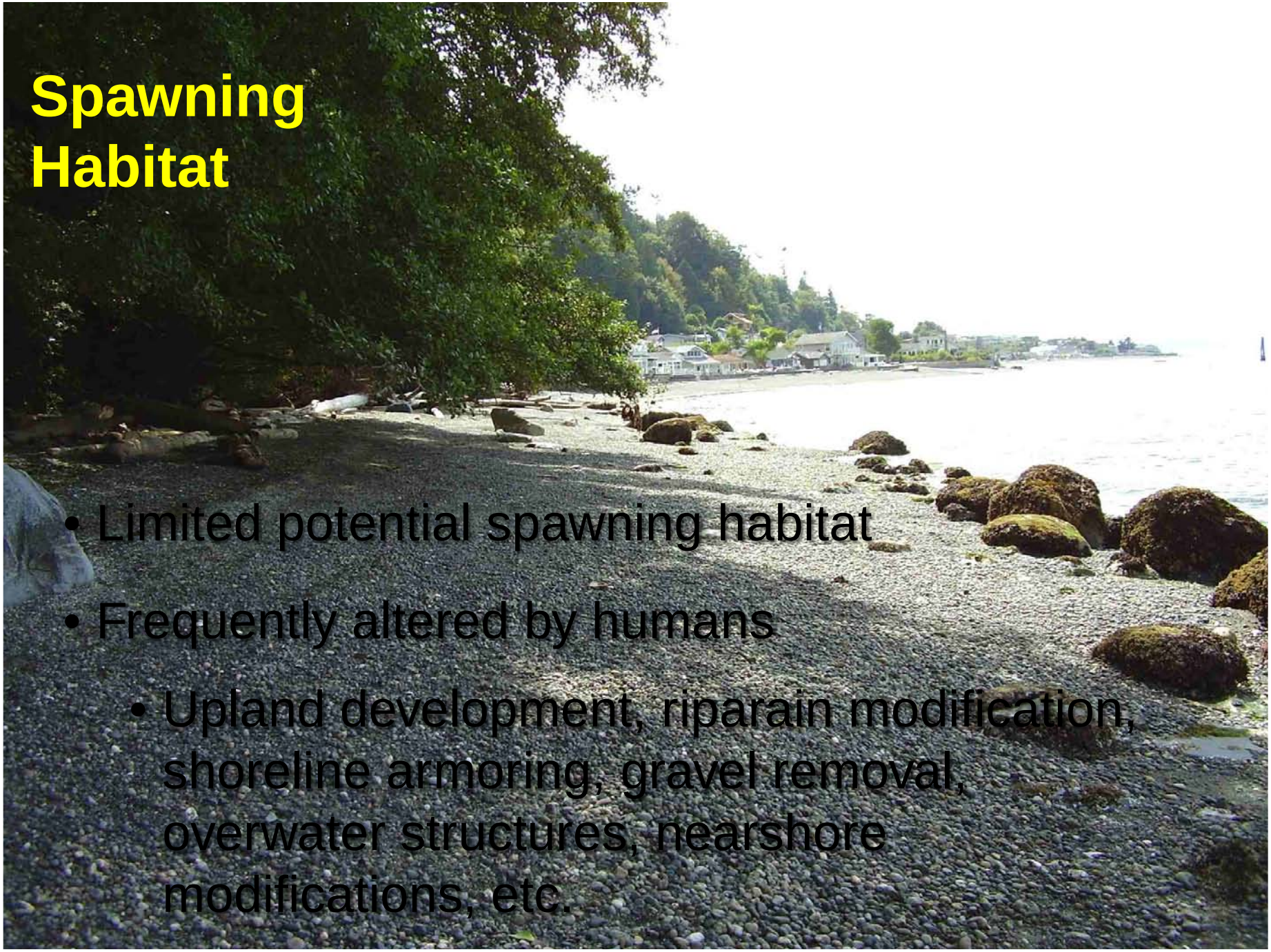
Few likely replacement species?



adapted from Simenstad et al. 1979 and Penttila 2007

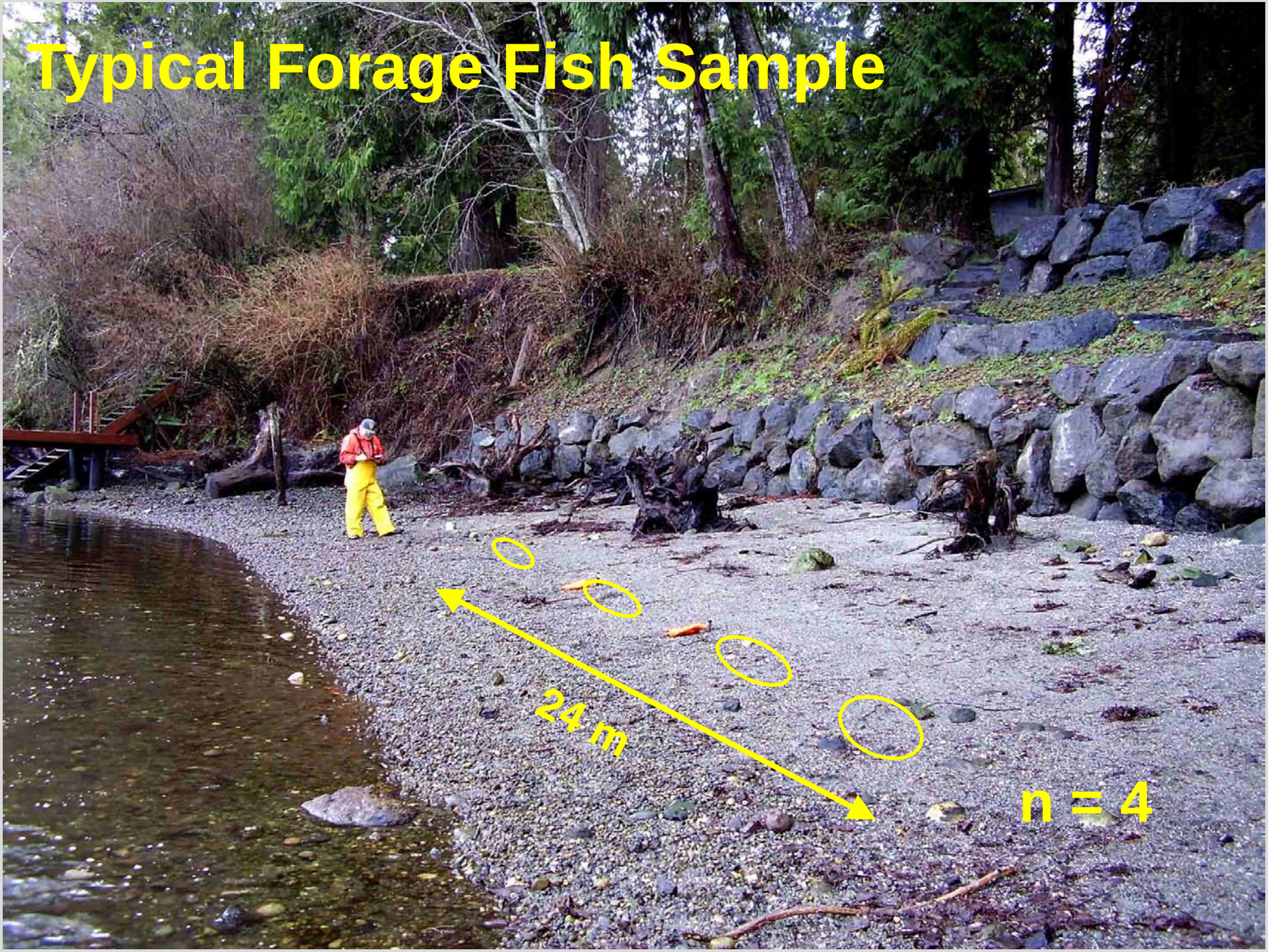
Photos: Peter Hodum
Photo: Peter Hodum
Photo: Peter Hodum
Photo: Peter Hodum
Photo: Peter Hodum

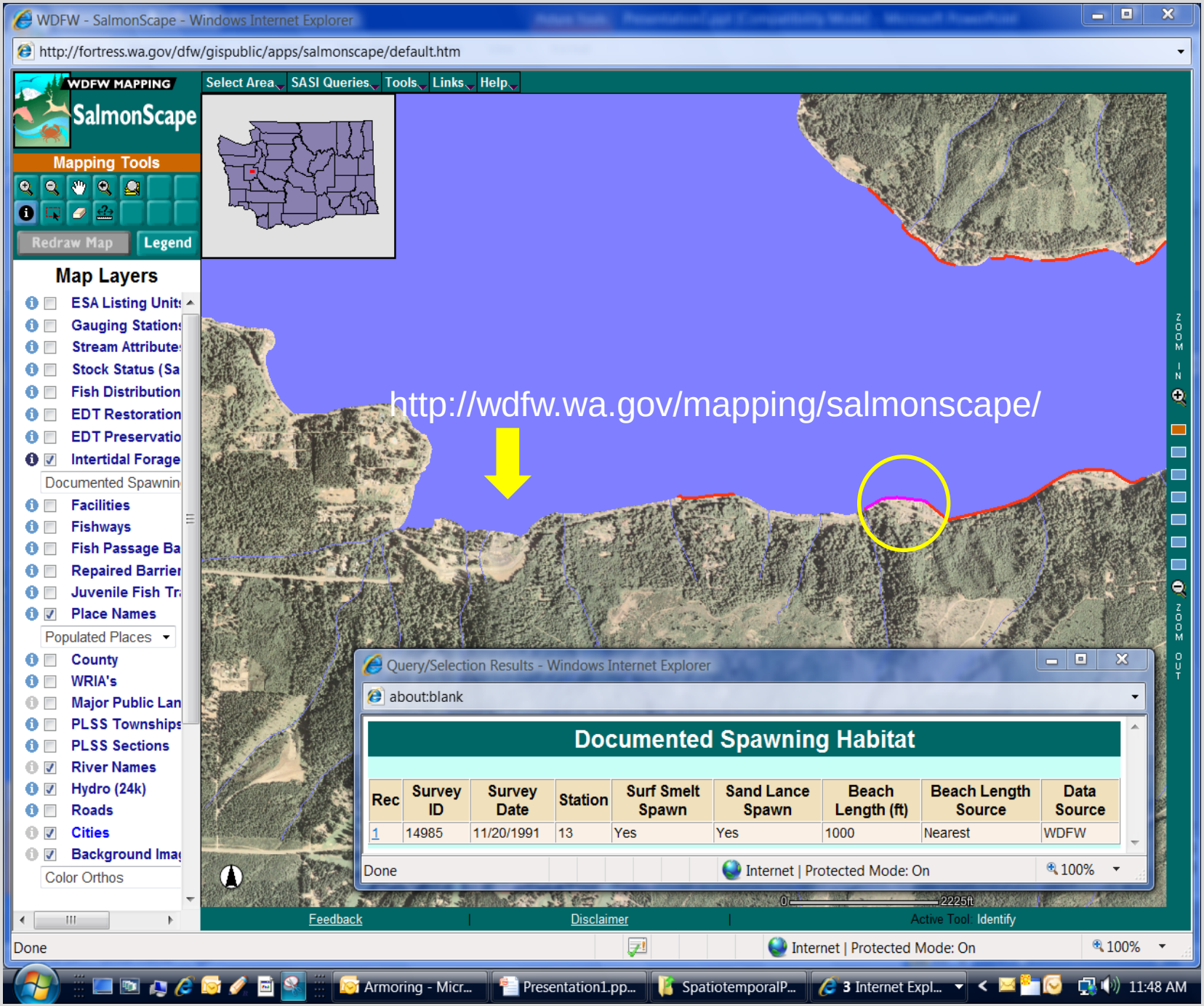
Spawning Habitat

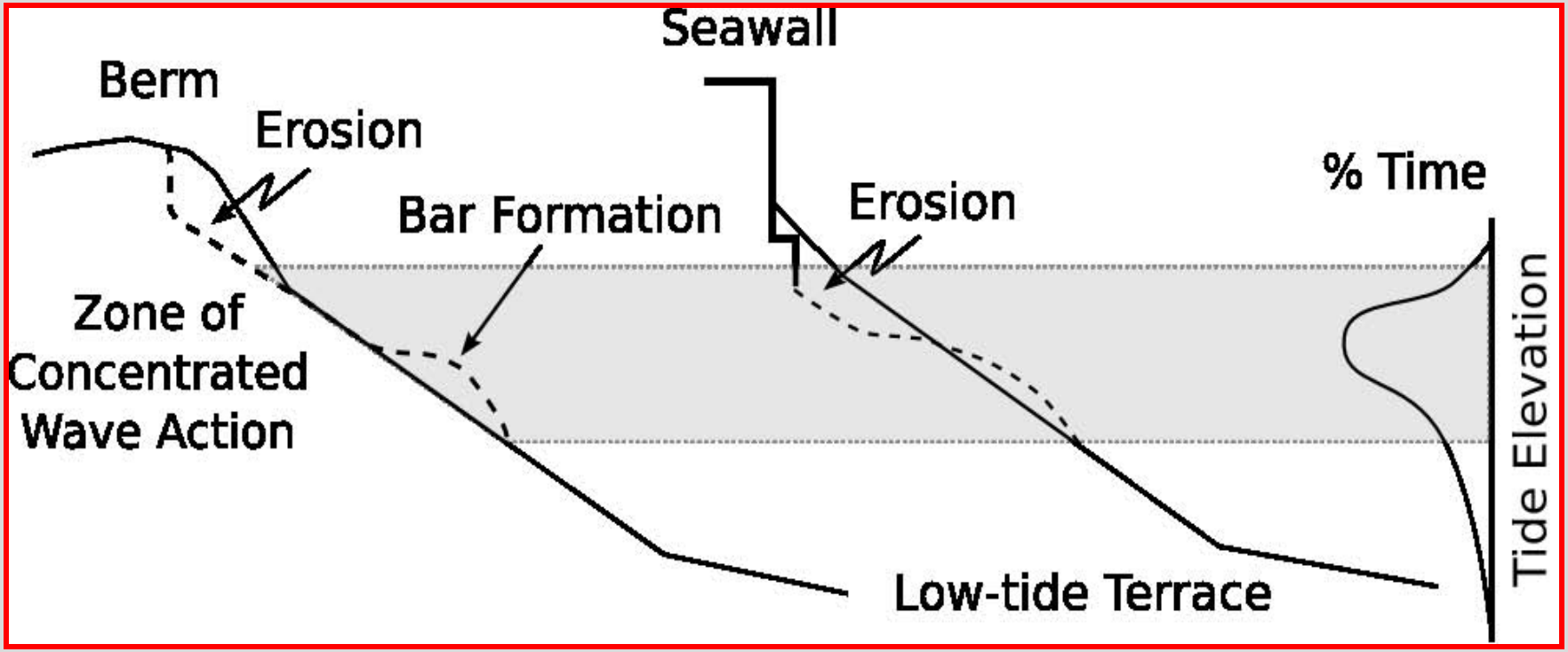


- Limited potential spawning habitat
- Frequently altered by humans
  - Upland development, riparain modification, shoreline armoring, gravel removal, overwater structures, nearshore modifications, etc.

Typical Forage Fish Sample

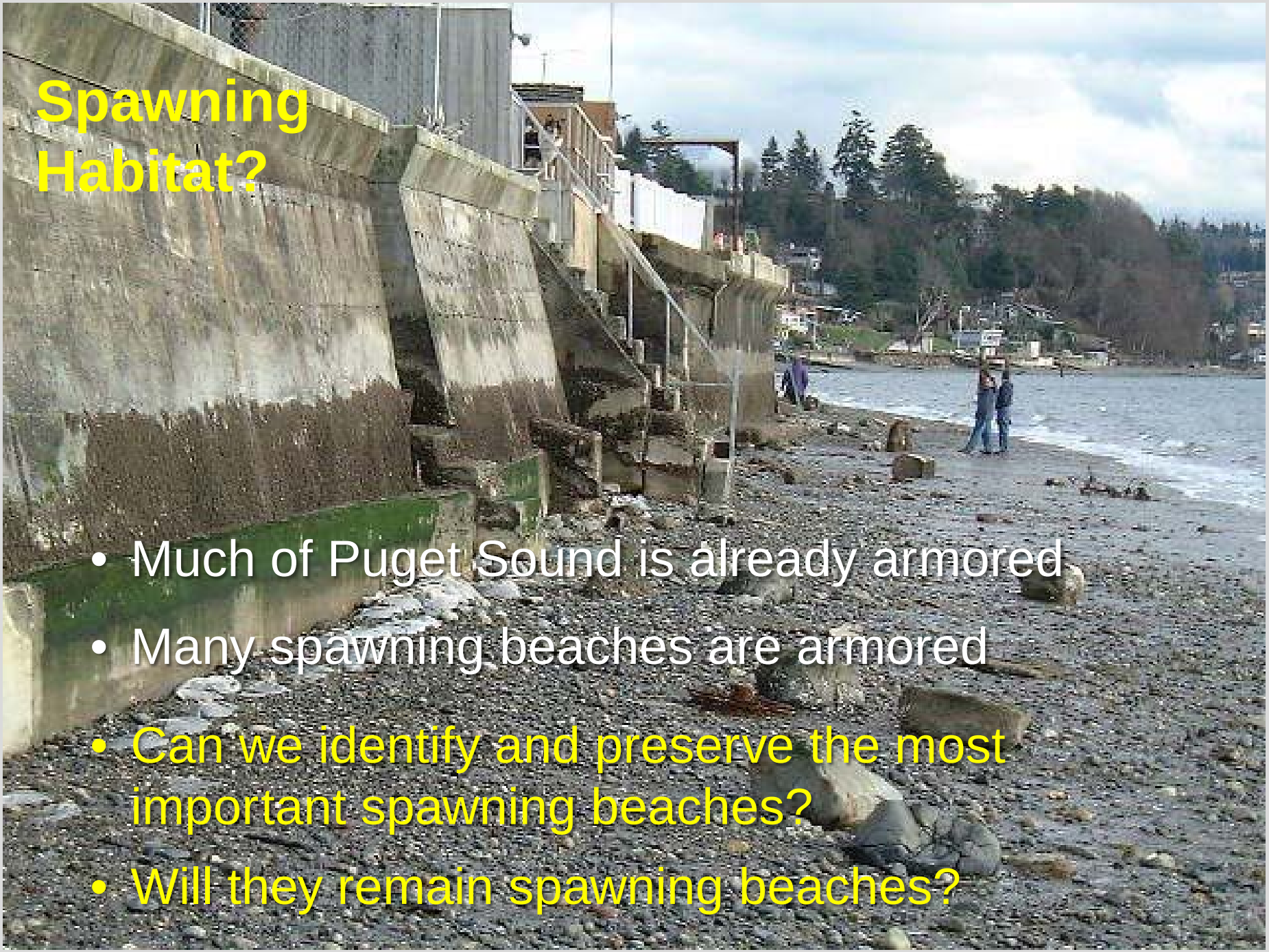



WDFW - SalmonScape - Windows Internet Explorer
http://fortress.wa.gov/dfw/gispublic/apps/salmonscape/default.htm
WDFW MAPPING
SalmonScape
Select Area
SASI Queries
Tools
Links
Help
Mapping Tools
Redraw Map
Legend
Map Layers
ESA Listing Units
Gauging Stations
Stream Attributes
Stock Status (Sa
Fish Distribution
EDT Restoration
EDT Preservatio
Intertidal Forage
Documented Spawnin
Facilities
Fishways
Fish Passage Ba
Repaired Barrier
Juvenile Fish Tr
Place Names
Populated Places
County
WRIA's
Major Public Lan
PLSS Townships
PLSS Sections
River Names
Hydro (24k)
Roads
Cities
Background Imag
Color Orthos
http://wdfw.wa.gov/mapping/salmonscape/
ZOOM IN
ZOOM OUT
Query/Selection Results - Windows Internet Explorer
about:blank
Documented Spawning Habitat
Rec | Survey ID | Survey Date | Station | Surf Smelt Spawn | Sand Lance Spawn | Beach Length (ft) | Beach Length Source | Data Source
1 | 14985 | 11/20/1991 | 13 | Yes | Yes | 1000 | Nearest | WDFW
Done
Internet | Protected Mode: On
100%
0
2225ft
Feedback
Disclaimer
Active Tool: Identify
Done
Internet | Protected Mode: On
100%
Armoring - Micr...
Presentation1.pp...
SpatiotemporalP...
3 Internet Expl...
11:48 AM



Profile response to erosional conditions on macro-tidal, low-energy beaches. Model shown for both natural and modified beaches as observed at Cama Beach, WA.

Adapted from Figure 4.12 *in* Finlayson, D. P. 2006. Geomorphology of Puget Sound Beaches. Doctoral Dissertation, University of Washington.



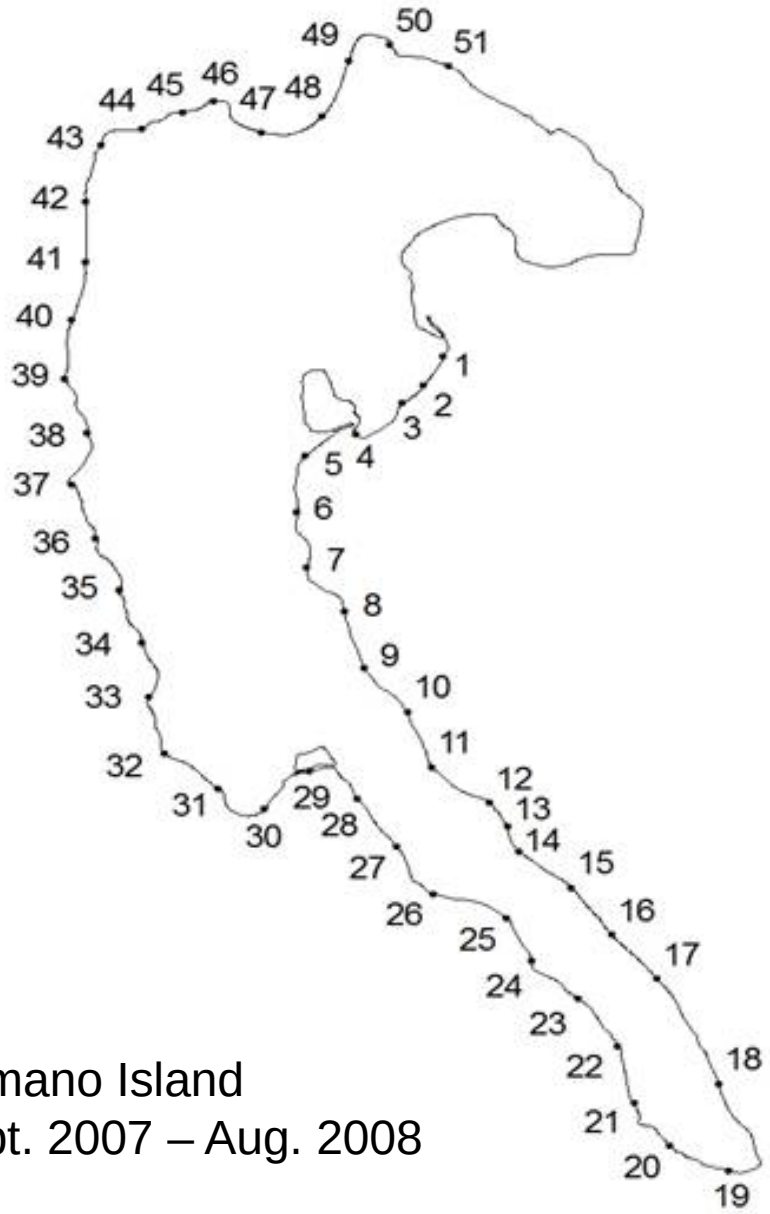
Spawning Habitat?

- Much of Puget Sound is already armored
- Many spawning beaches are armored
- Can we identify and preserve the most important spawning beaches?
- Will they remain spawning beaches?

Each beach was sampled approximately every two weeks for one year.

Surf smelt and Pacific sand lance egg occurrence was identified.

Armored and unarmored beaches were surveyed.

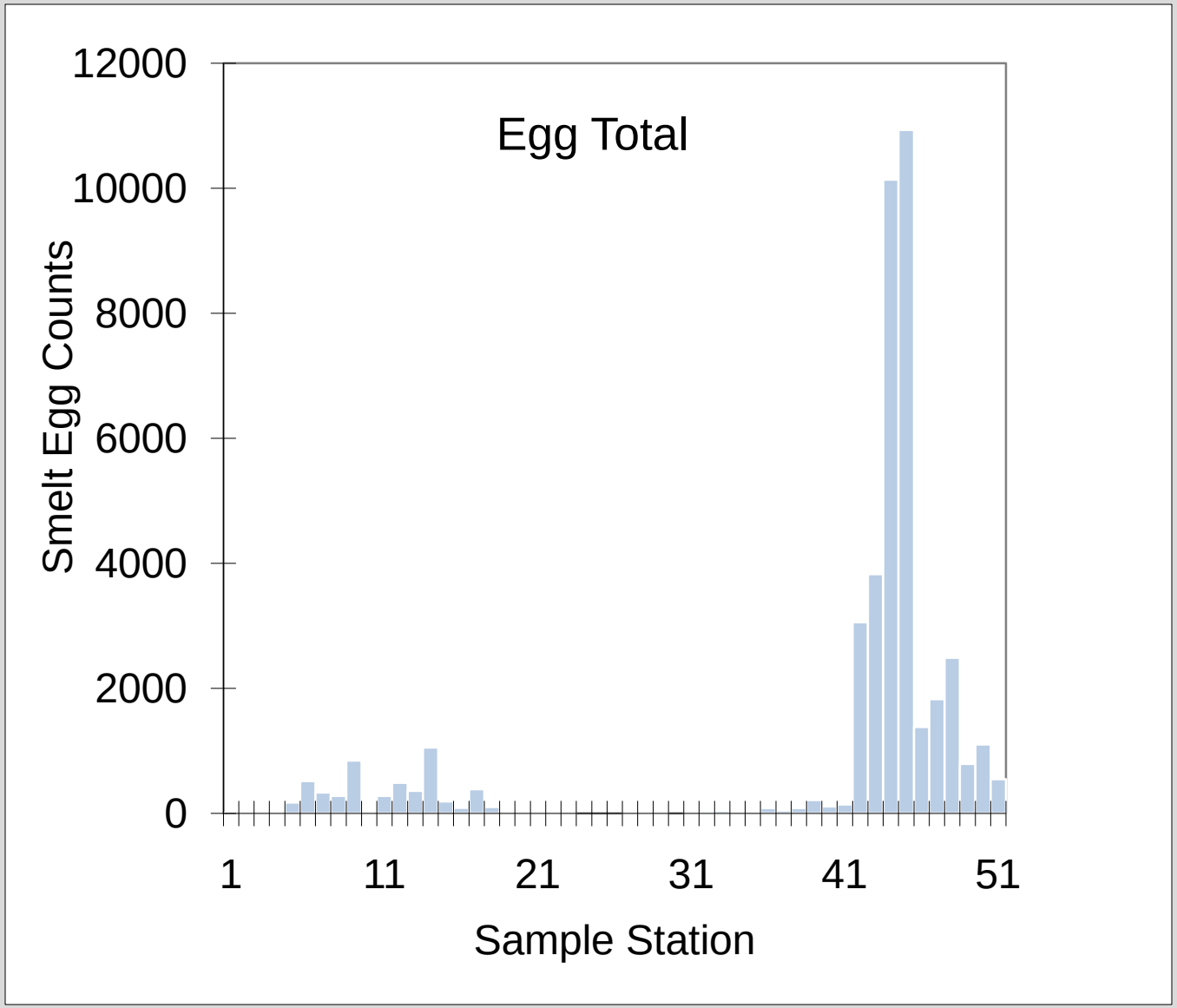


Camano Island
Sept. 2007 – Aug. 2008

Surf Smelt egg density is spatially variable – not all beaches are of similar value.

Differences among years is unknown.

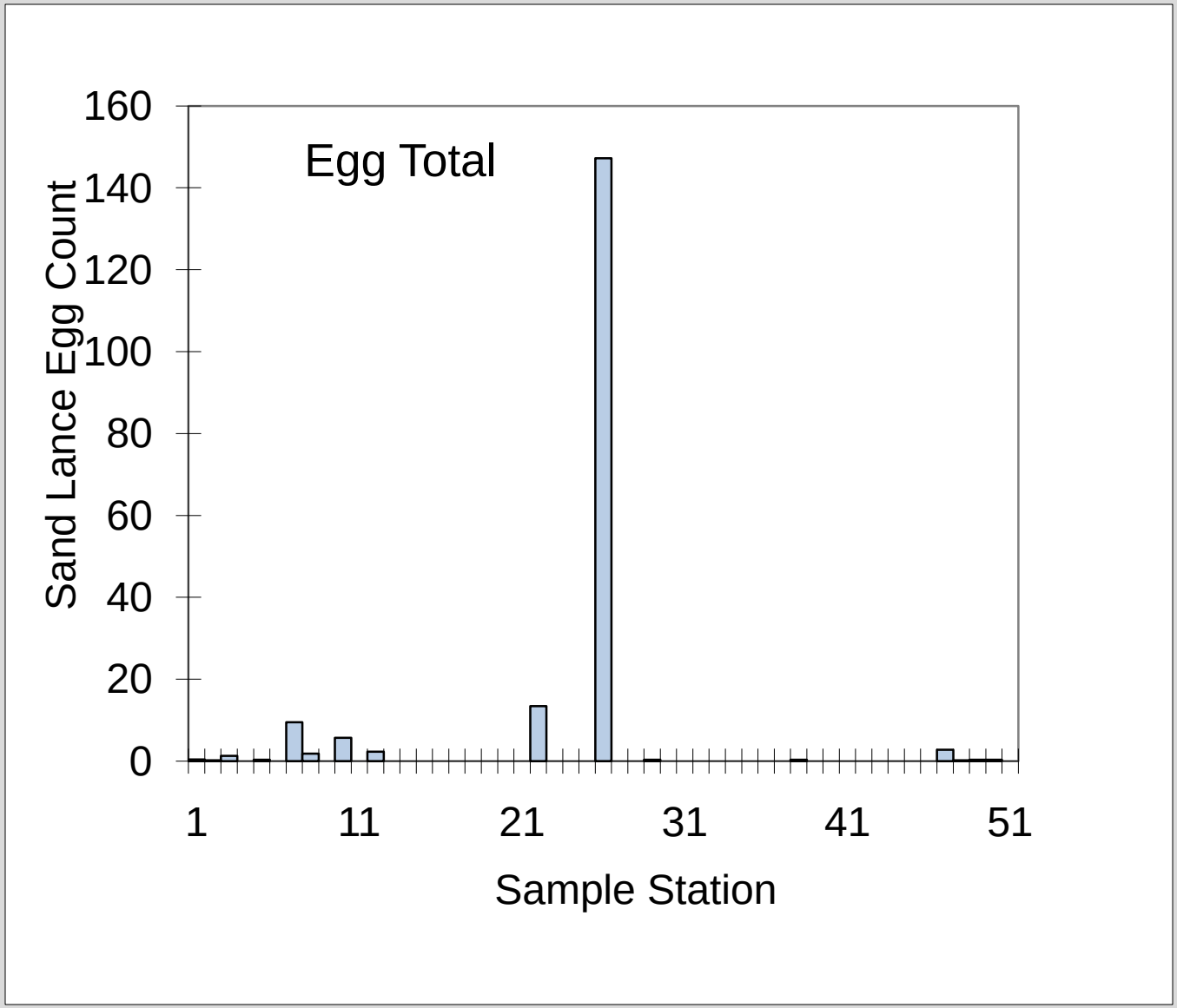
Difficult to identify most important beaches.



Sand lance egg density is also spatially variable – not all beaches are of similar value.

Differences among years is unknown.

Difficult to identify most important beaches.

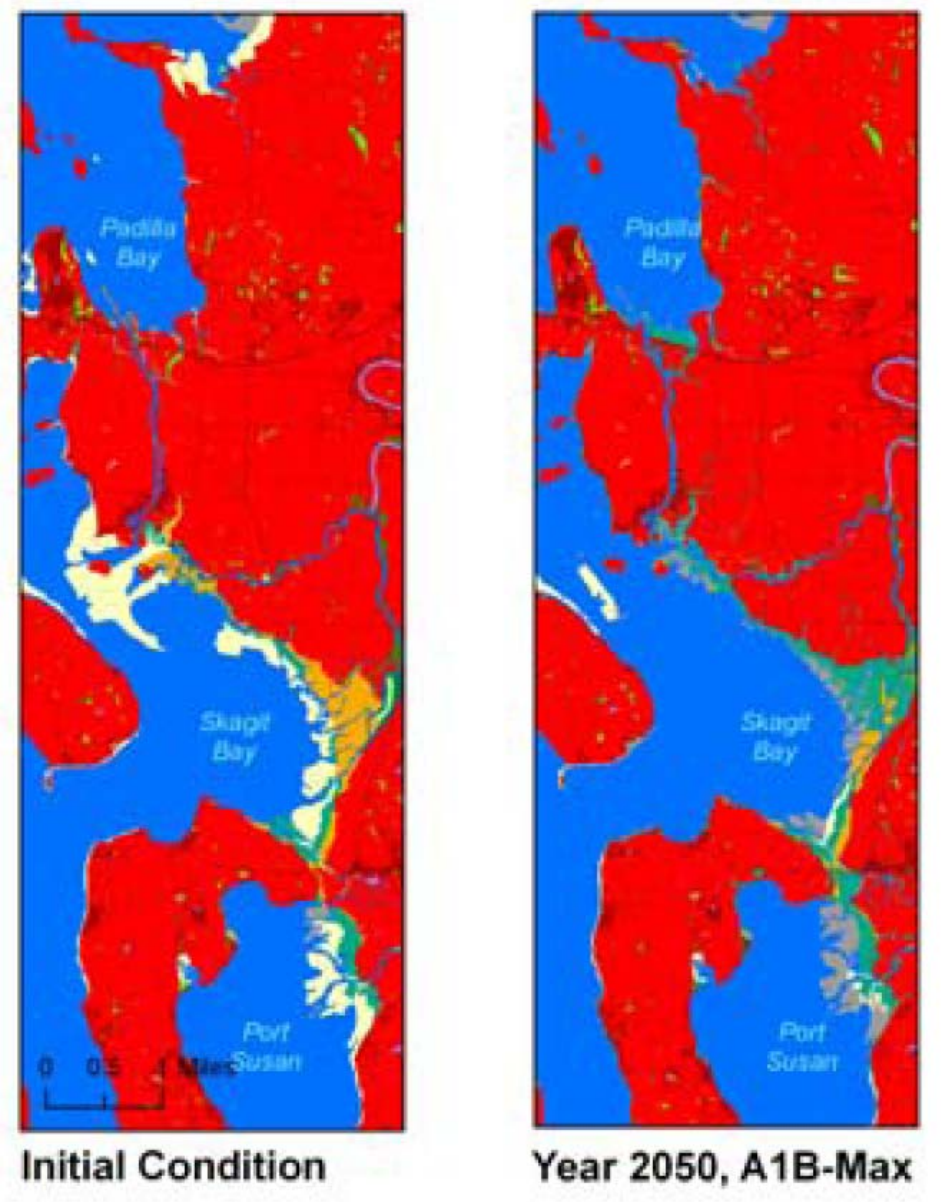


Surf Smelt and Pacific Sand Lance Spawn on Many Armored Beaches

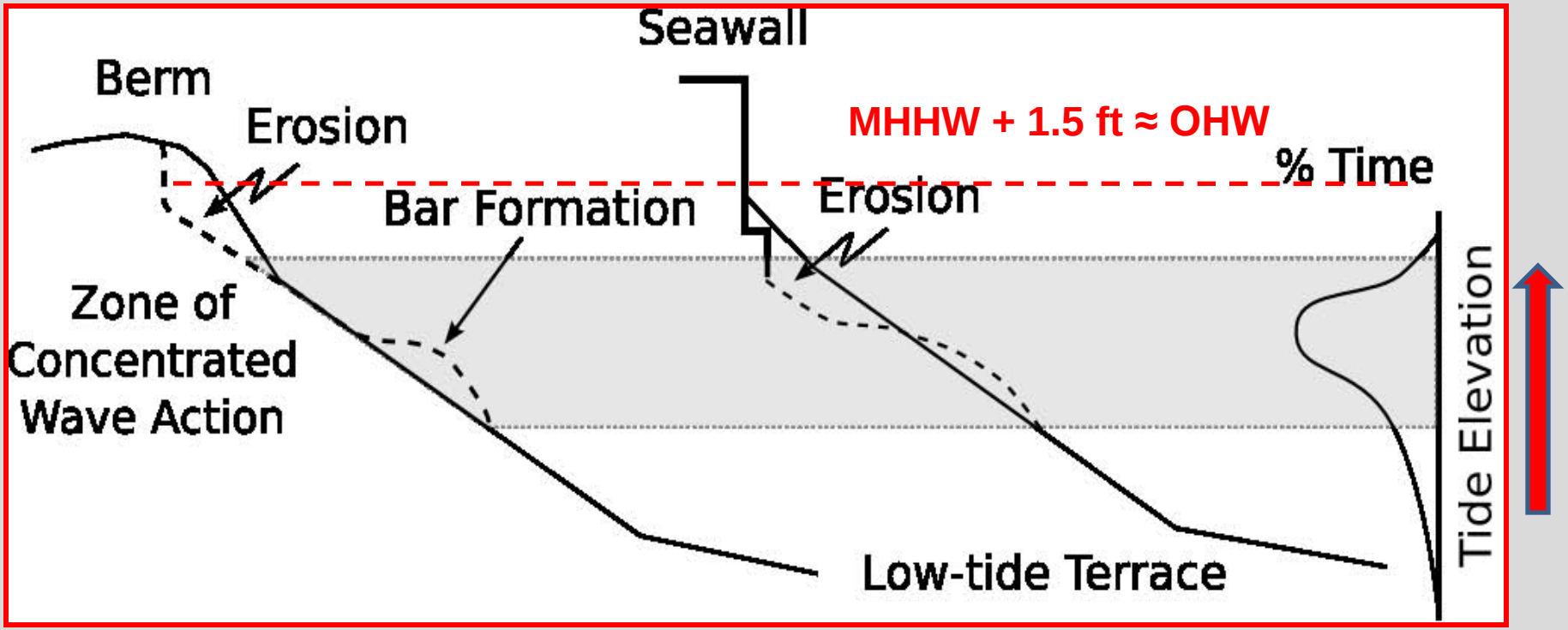
- Disturbance due to armor is likely, but we've not detected it often.
- Difficult to identify the most important spawning beaches – they are discontinuous and differ among species, but...we'd better figure out how.
- Suggests a need to be cautious and to set conservation priorities.

Sea Level Rise

- Across the study sites, estuarine beach is projected to decline by 65 percent by 2100 under the 0.69-meter (27.3-inch sea-level) rise scenario.
- Estuarine and ocean beaches decline by 87 and 98 percent, respectively, if sea-level rise reaches 1.5 meters (59.1 inches).



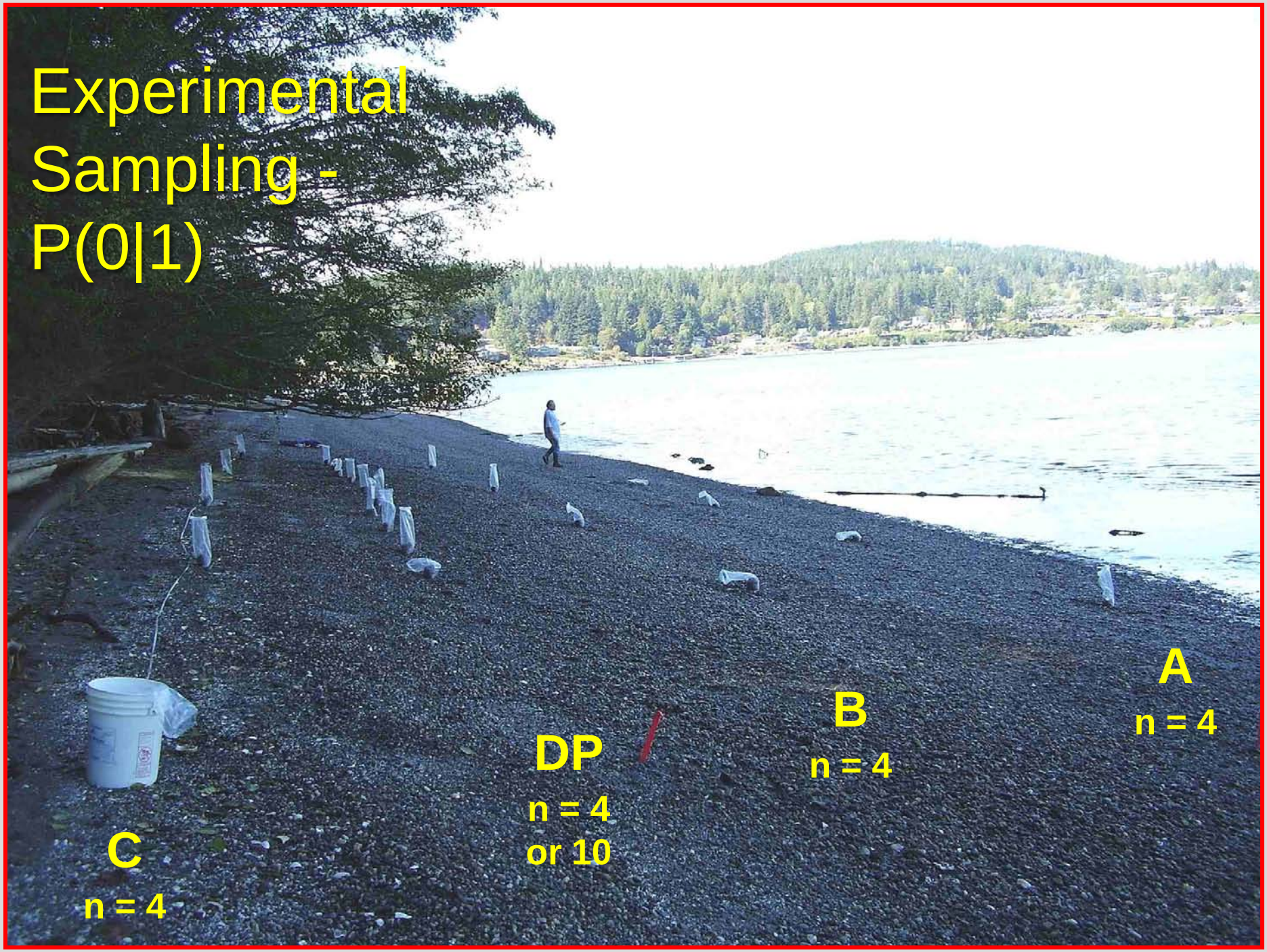
National Wildlife Federation. 2007. Sea-level Rise and Coastal Habitats in the Pacific Northwest.



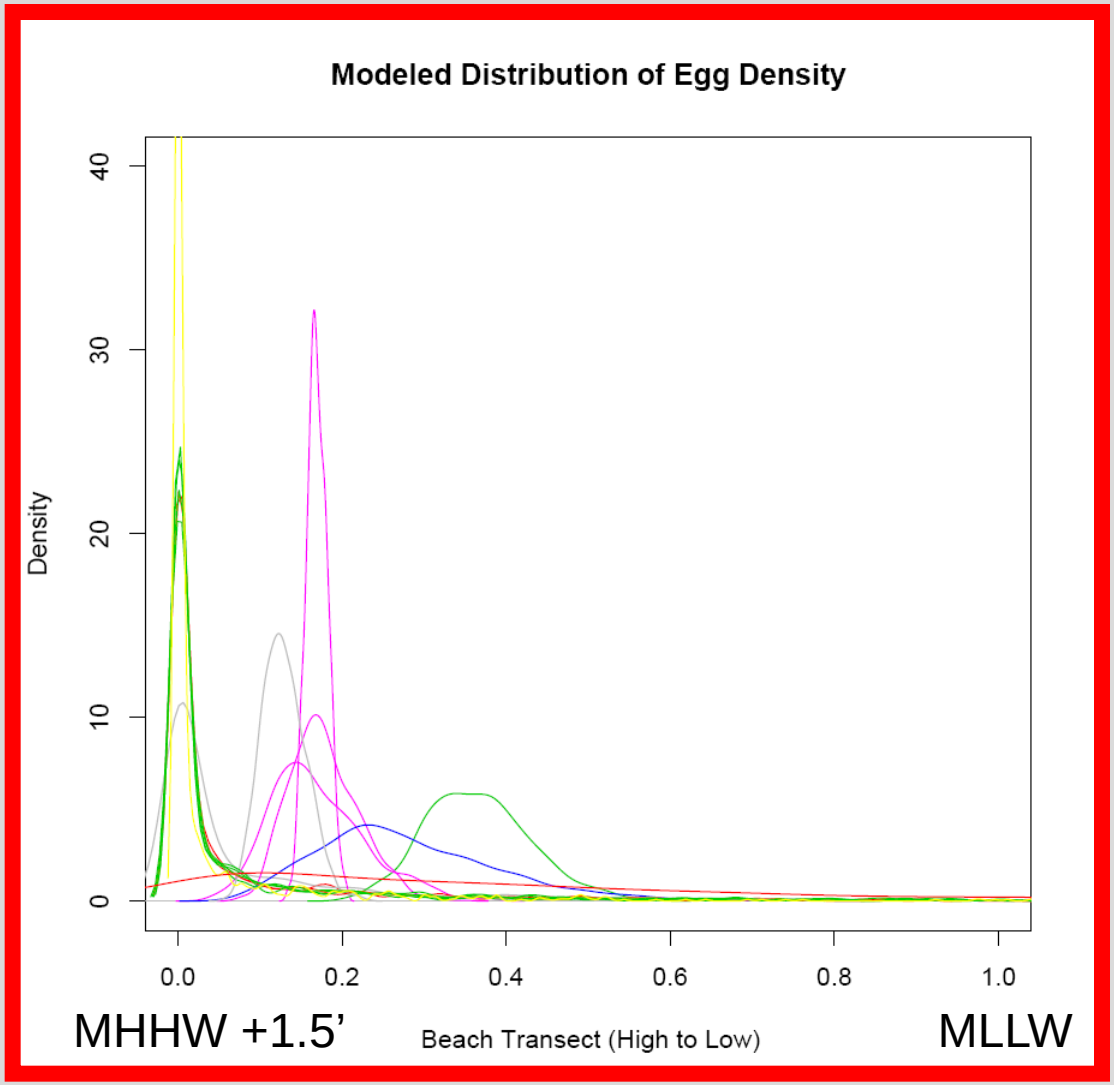
Profile response to erosional conditions on macro-tidal, low-energy beaches. Model shown for both natural and modified beaches as observed at Cama Beach, WA.

Adapted from Figure 4.12 *in* Finlayson, D. P. 2006. Geomorphology of Puget Sound Beaches. Doctoral Dissertation, University of Washington.

Experimental Sampling - P(0|1)



- Fit Gamma distributions to surf smelt egg data to describe the spatial distribution of eggs in relation to beach elevation.
- Insufficient sand lance data.
- They have a spawning elevation (depth) preference



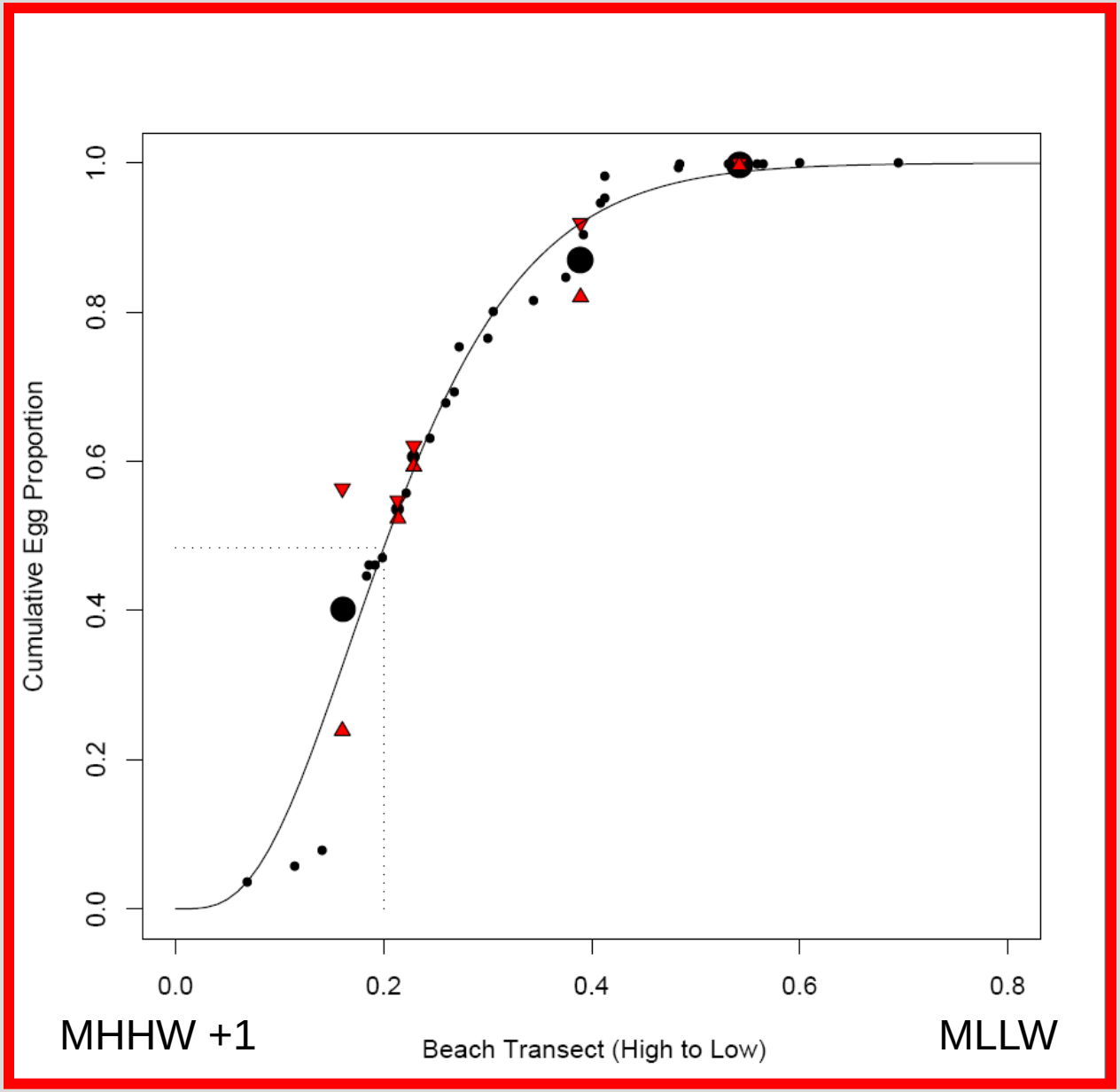
Cumulative gamma distribution - proportion of Surf Smelt eggs vs. beach elevation.

Points are samples, large points are several samples at an elevation.

Triangles mark one standard deviation.

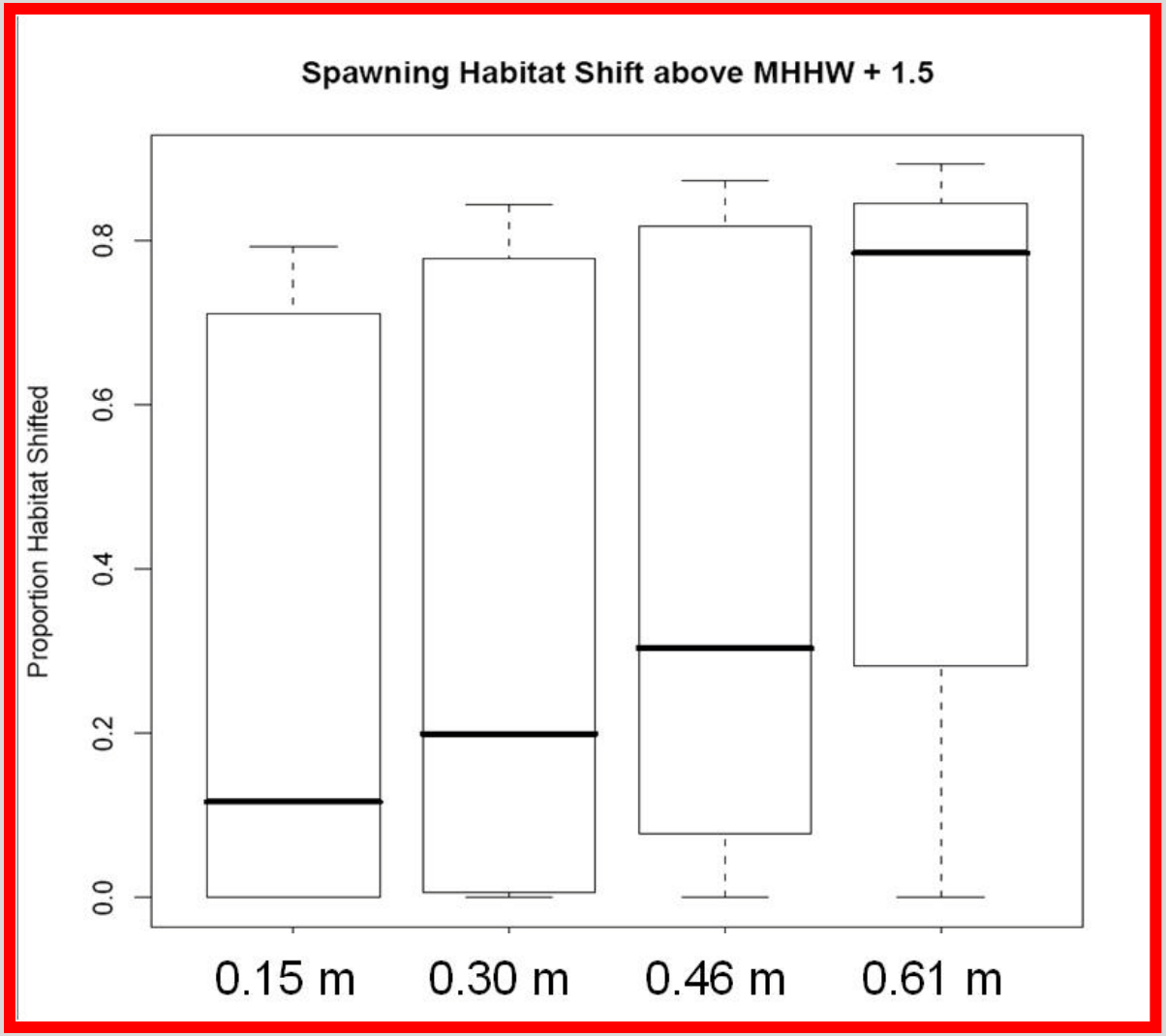
The broken line show the proportion of eggs lost due to a sea level rise.

A small loss of beach can have a large effect.



Effects of sea level rise on beach spawning habitat differ among beaches.

Even a relatively small rise in sea level can result in the loss of a large percentage of spawning habitat.



Conclusions

- Concern for species is warranted.
- Loss of habitat due to armoring is likely.
- Loss of habitat due to sea level rise is likely.
- Shoreline armoring and sea level rise might interact to exacerbate loss of habitat.
- The need for engineering and social solutions is urgent.

Conclusion: Indicator Species?

- Although low on the warm and fuzzy sliding scale, at least they are vertebrates!
- Constantly “sample” the ecosystems conditions and use a limited, important, often disturbed ecotone or boundary.
- Already have some regulatory protection.
- We have some data – a place to start.

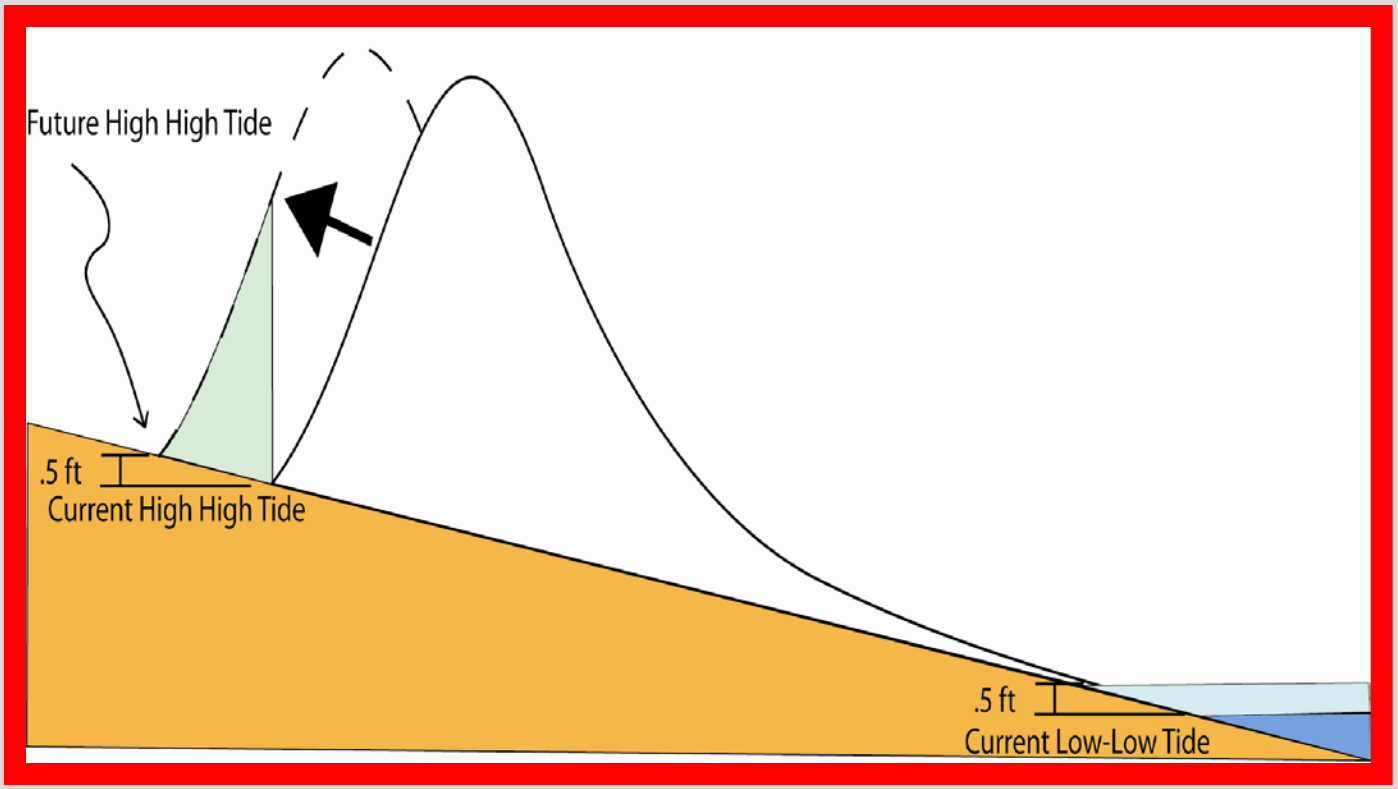
Policy Challenge

Cleared Riparian

Uncleared Riparian

Desire to clear riparian areas and armor

Conceptual model of forage fish egg distribution with sea level rise on an unarmored beach.



Lots of armor and lots of spawning beaches armored. Use doesn’t see to differ, yet.

Upland
Conditions
Overland Flow

Upland

overland and lotic flow

Nearshore

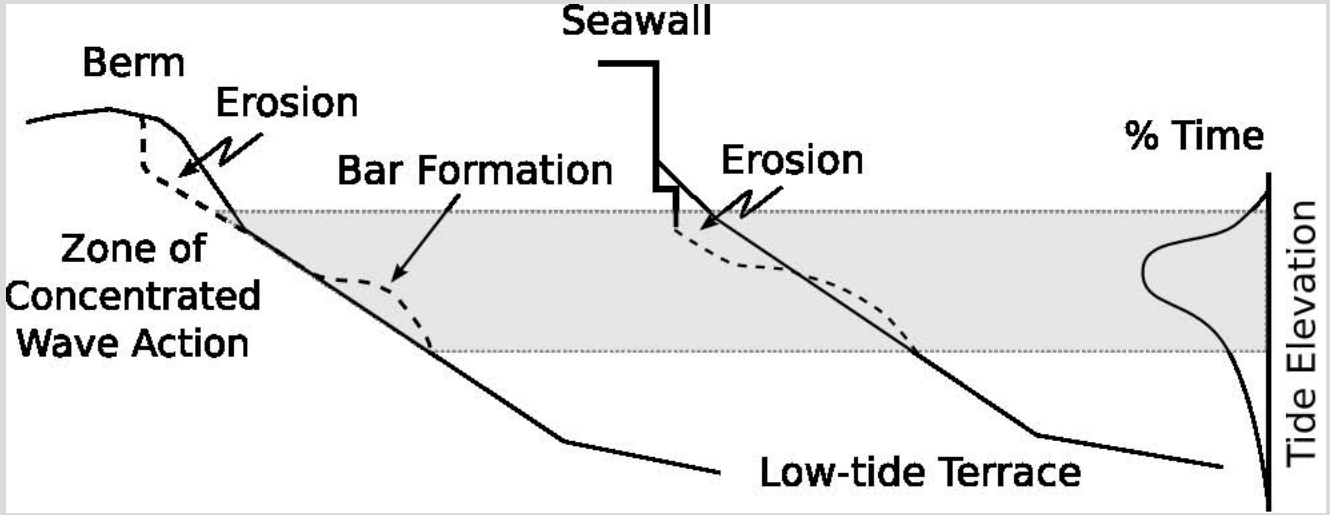


Figure 4.12: Profile response to erosional conditions on macro-tidal, low-energy beaches. Model shown for both natural and modified beaches as observed at Cama Beach. Finlayson, D. P. 2006.

Questions Addressed

1. Why we're concerned about these species
    1. Importance (literature)
    2. Species Replacements (literature)
    3. Habitat Specialization (field surveys)
2. Why shoreline armoring is a concern
    1. Habitat loss (theoretical model)
    2. Conservation options (field study)
3. Why sea level rise is a concern
    1. Habitat loss (literature)
    2. Exacerbated effects of armor (survey and model)

Survey Results

- More than 30 years of surveys
- Thousands of samples
- Hundreds of miles of beaches sampled
- Many spawning beached identified