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Critical Habitat in the Salish Sea – Understanding Eelgrass for Restoration and Resilience

May 19, 2020

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Marine Ecologist

U.S. DEPARTMENT OF ENERGY BATTELLE

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U.S. DOE Labs

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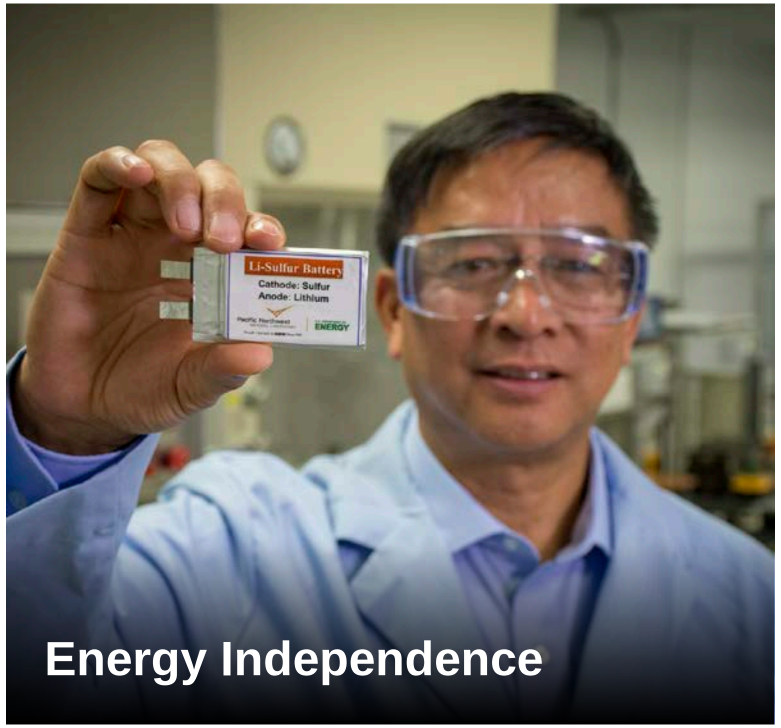
PNNL is Focused on **DOE’s MISSIONS** and Addressing Critical **NATIONAL NEEDS**



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PNNL is an ECONOMIC ENGINE

4,722
Employees

265
Inventions

$1.46B
Total Economic Output

$1.01B
Annual Spending

88
Patents

7,180
Jobs Generated
in Washington

$465M
Total Payroll

34
Licenses

193
Companies
with PNNL Roots

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50+ Years

Developing Goodwill

	Philanthropic Investments	Team Battelle Volunteer Hours	Community Organizations
Decades	$28.5M	347,000	>120
FY19	$0.52M	30,000	56

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Marine Sciences Laboratory

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Marine Sciences Lab

Colleagues:
Ron Thom, Emeritus
Amy Borde
Lara Aston
Kate Hall
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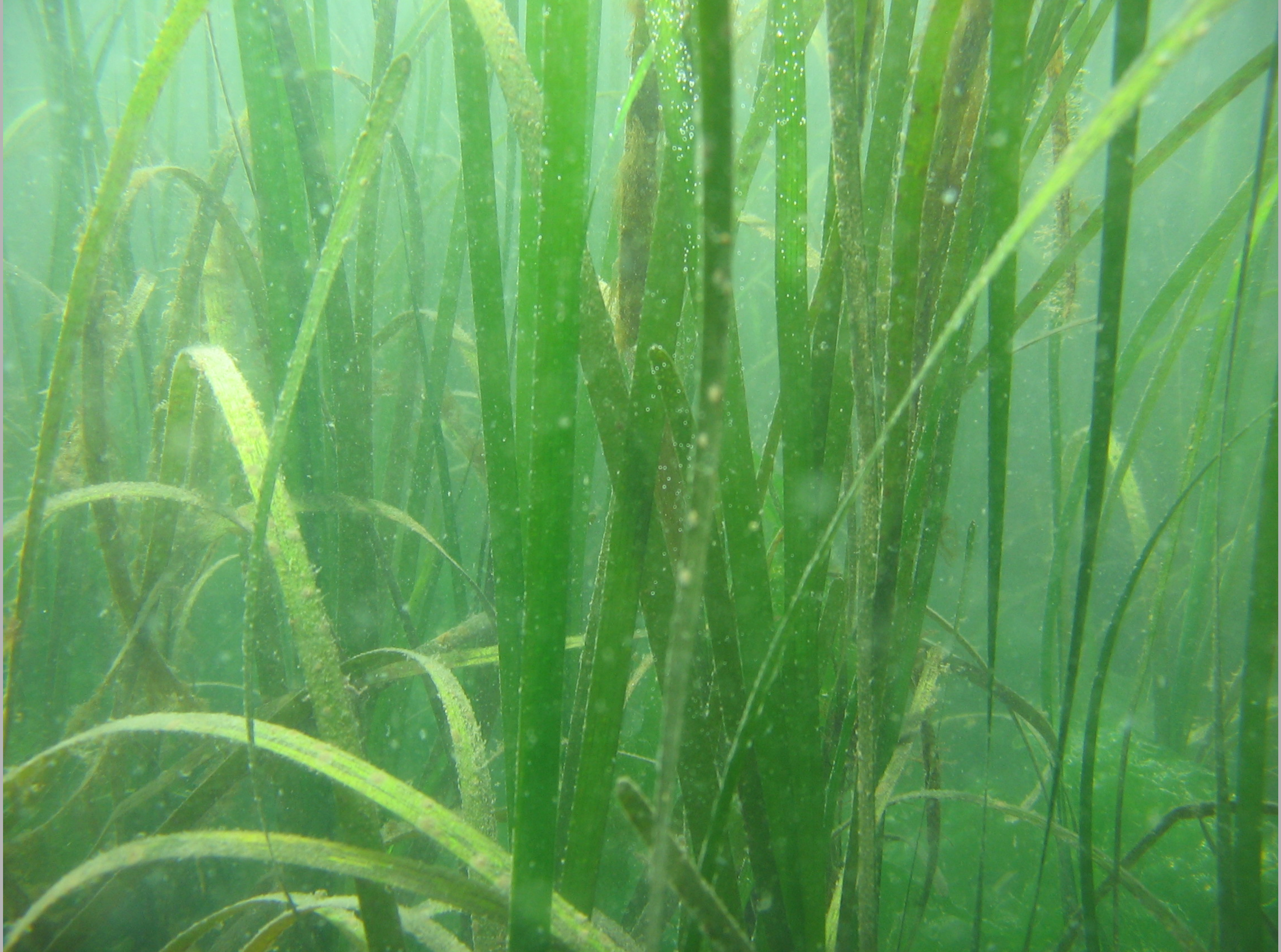
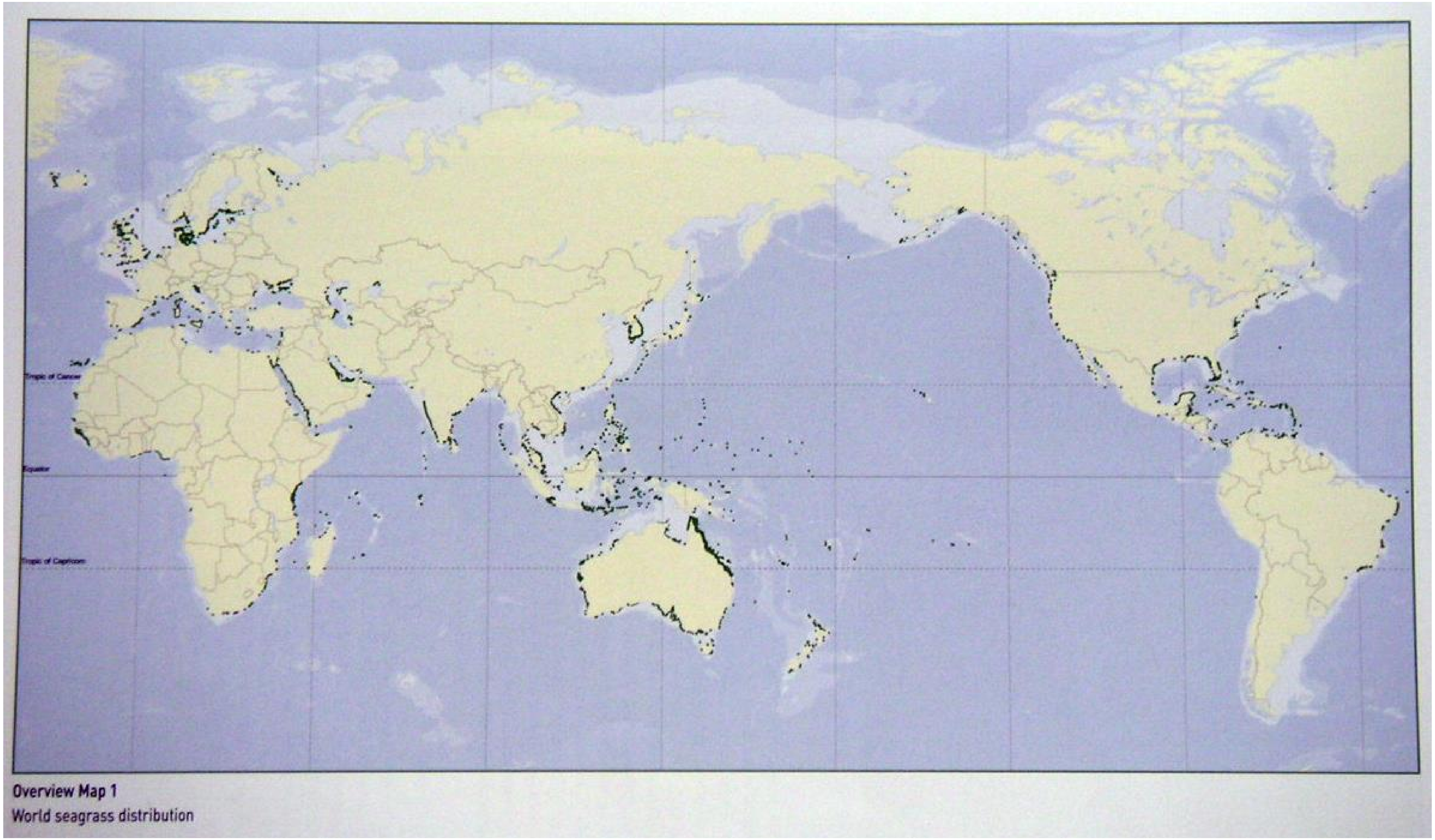
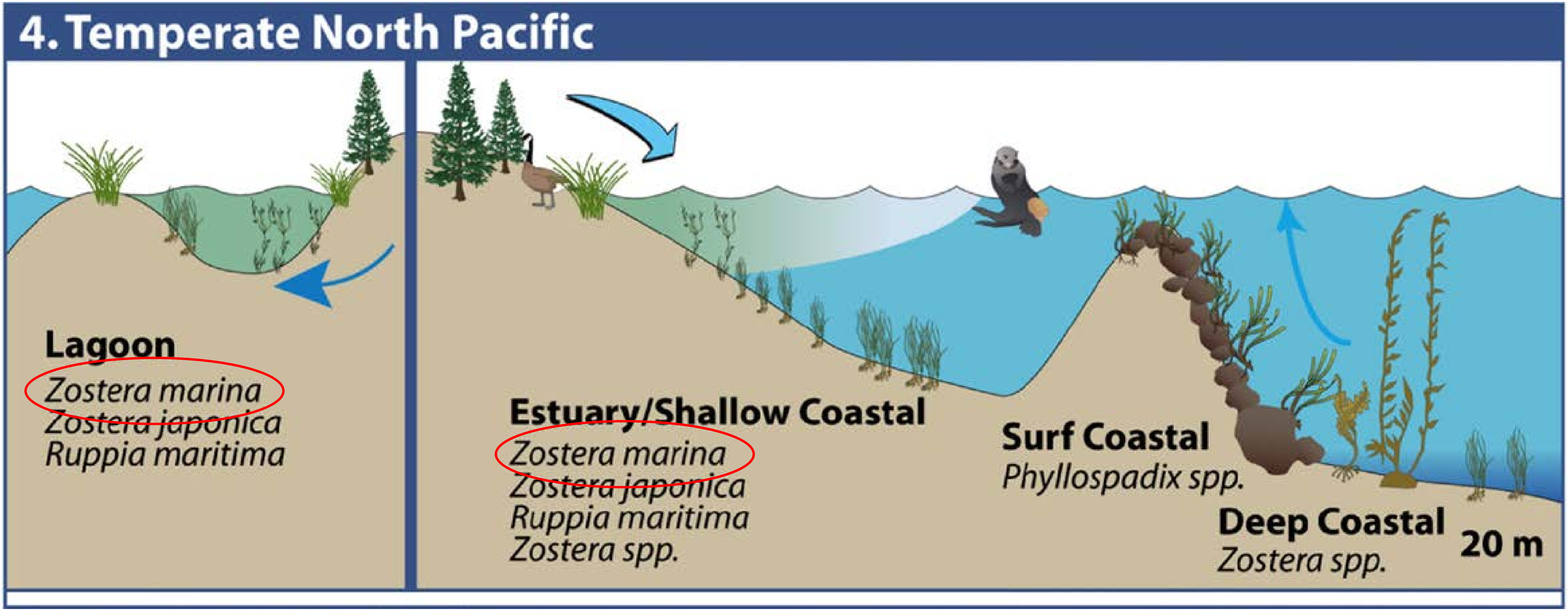




Green and Short. 2003. World Atlas of Seagrasses.

Local seagrass

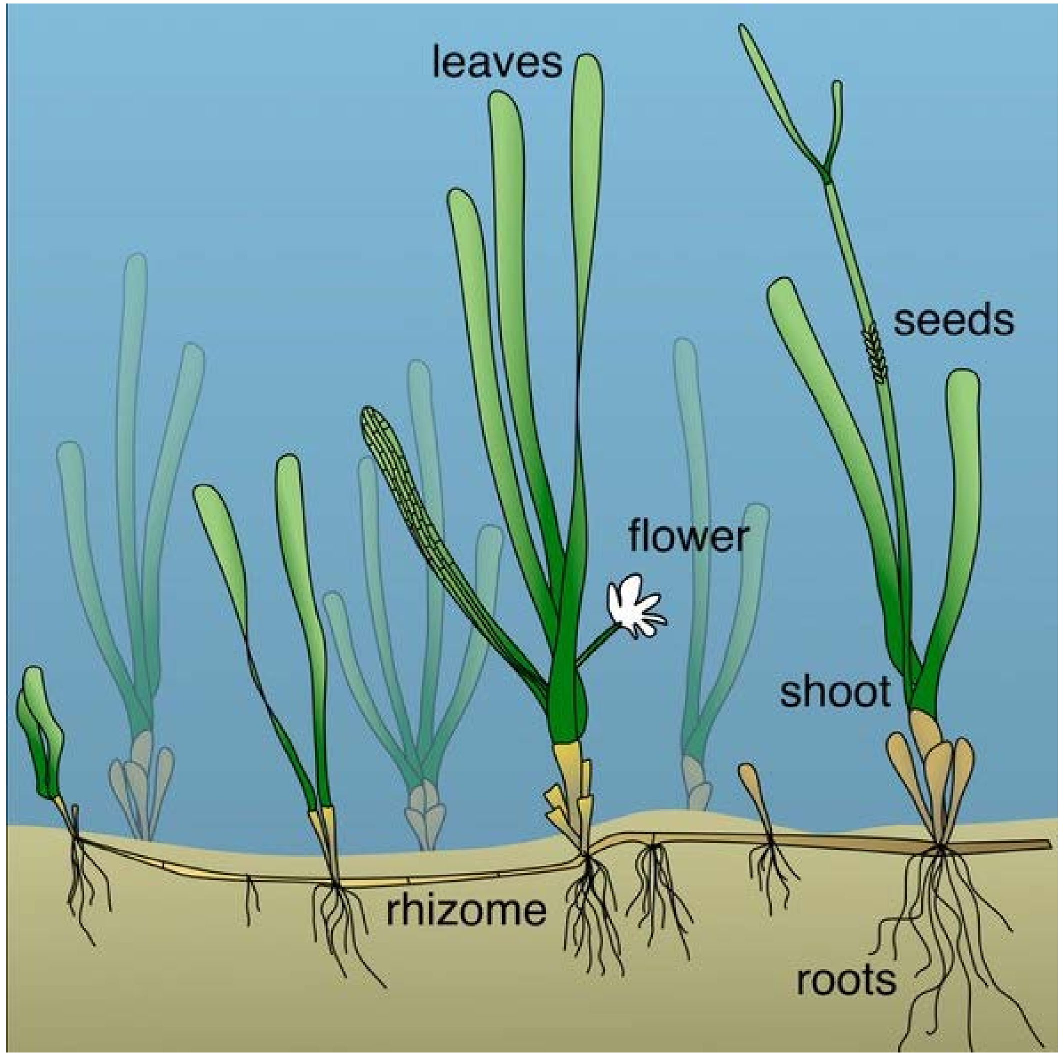


Short et al. 2007

Zostera marina (eelgrass)

http://www.seagrassli.org/ecology/eelgrass/taxonomy.html

- Most widespread of ~60 seagrass species
- Grows in northern hemisphere
- 3 – 7 ribbon-like leaves
  - 0.3 – 1.3 cm wide
  - 7 – 160 cm long
- Rhizomes
- Monoecious
- Water pollinated



Project Seagrass

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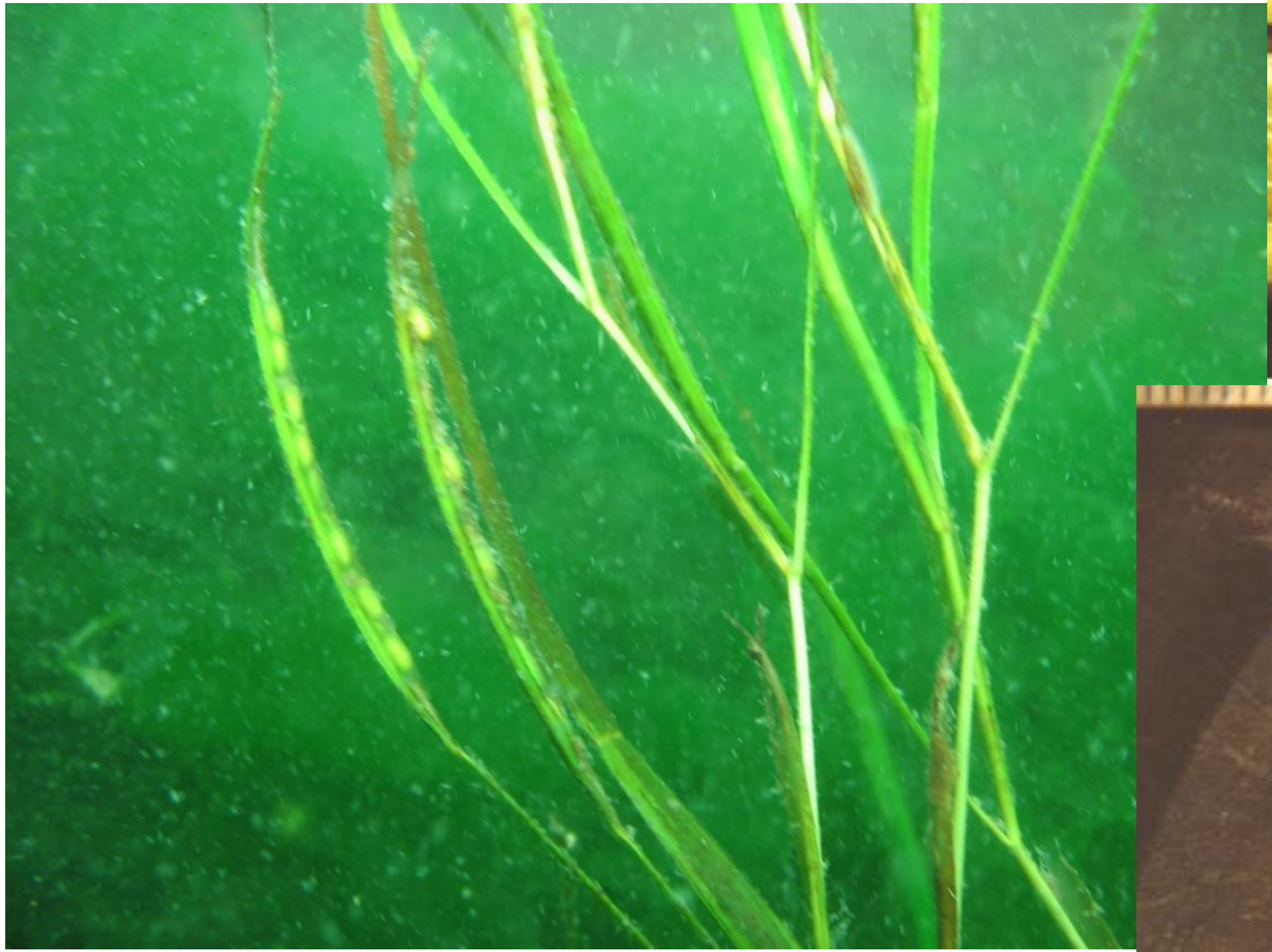
Sexual reproduction



Asexual reproduction

Eelgrass functions

- Provides food for coastal food webs
- Juvenile salmon feed & find refuge in eelgrass meadows
- Provides habitat for microbes, invertebrates, & vertebrates (often endangered or commercially important finfish or shellfish)
- Provides natural nursery & spawning areas for some finfish (e.g. herring) & shellfish (e.g. Dungeness crab)
- Provides storm & shoreline protection (reduces nearshore erosion by lessening the impact of waves on shoreline)
- Stabilizes sediment & prevents sediment resuspension, can improve water clarity
- Provides oxygen to water and sediment, reduce acidification
- Traps and cycles nutrients through the ecosystem
- Sequesters carbon from the atmosphere
- May kill pathogens and diseases in water

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The Eelgrass Meadow — A World of Microhabitats

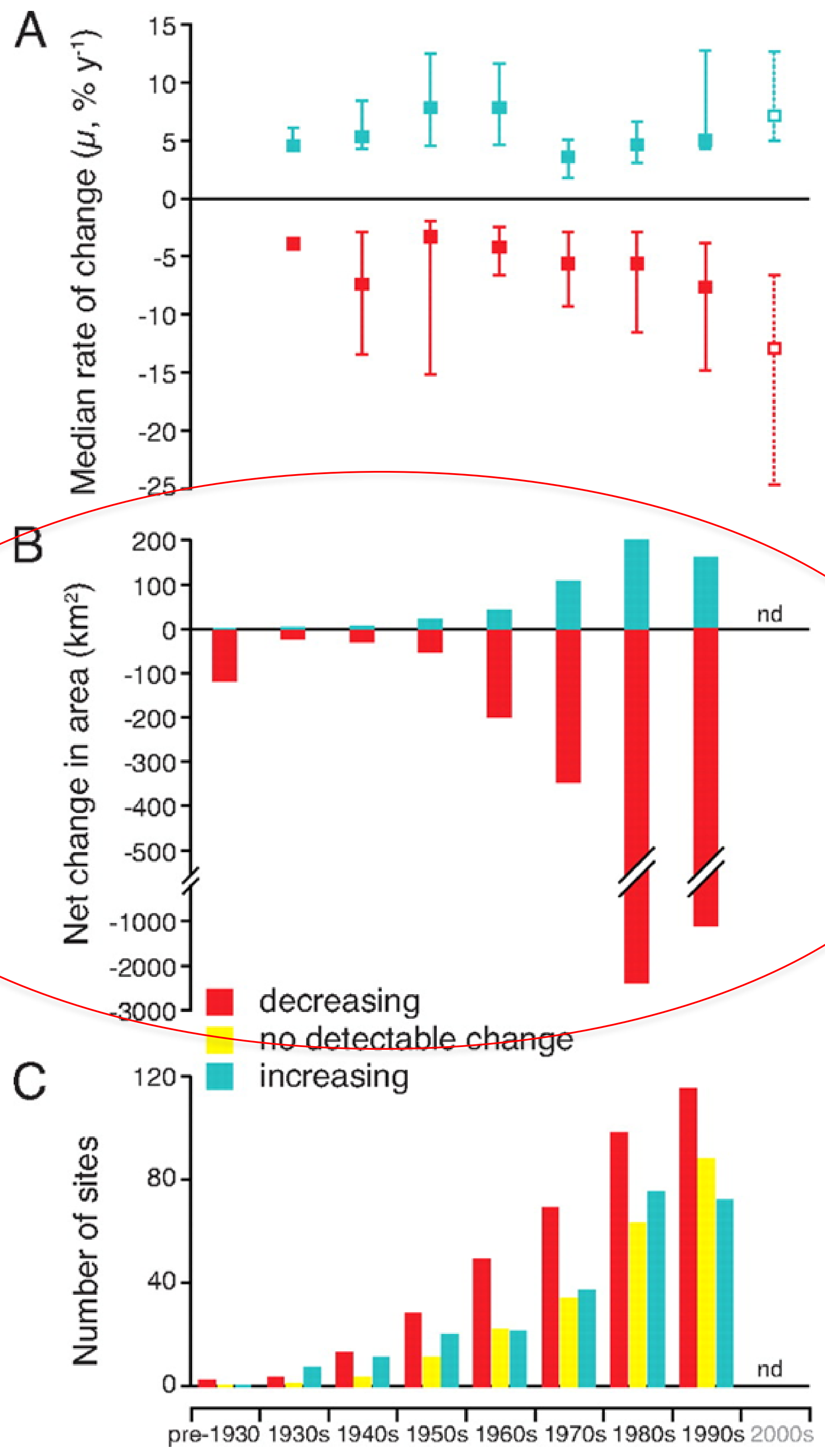
1. Zooplankton
2. Larval crab
3. Salmon
4. Herring
5. Epiphytic macroalgae
6. Epiphytic microalgae, Hydozoa, and bryozoa
7. Sea cucumber
8. Dungeness crab
9. Octopus
10. Sand dollars
11. Clams and cockles
12. Pacific spiny Lumpsucker
13. Caprellid amphipod
14. Stalked jellyfish
15. Eelgrass isopod
16. Juvenile salmon
17. Bubble shell
18. Opalescent nudibranch
19. Perch
20. Juvenile kelp crab
21. Alabaster nudibranch
22. Scallop
23. Gunnel
24. Bay pipefish
25. Sea urchin
26. Juvenile sculpin
27. Decorator crab
28. Juvenile clams
29. Juvenile flounder And sole
30. Juvenile crab
31. Geoduck
32. Sediment microfauna
33. Snail and snail eggs
34. Juvenile cod, tomcod And wall-eyed pollock
35. Herring eggs
36. Jellyfish
37. Larval fish
38. Melibae-hooded nudibranch
39. Tubesnout
40. Shrimp
41. Brooding anemone
42. Prickleback
43. Sculpin
44. Bacteria on detritus
45. Moonsnail
46. Sunflower seastar
47. Sea pen
48. Red rock crab
49. Hermit crab
50. Worms
51. Ghost shrimp
52. Sand lance
53. Black Brant
54. Canada Goose
55. Bufflehead

Figure 2. The eelgrass meadow: A world of microhabitats (© permission Port Townsend Marine Science Center, Port Townsend, WA).

Mumford 2007

Worldwide declines

Increasing loss in area



Waycott et al. 2009

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Regional Declines

- In Puget Sound, eelgrass is considered a critical habitat for fisheries support and is protected at the federal, state, and local levels.
- In the early 1990’s, Washington State established a “no net loss” policy for eelgrass
- Declines occurring in Puget Sound, particularly in back bay areas (DNR 2005), likely due to combined effects of urban development, loss of water clarity, nutrient enrichment, and other effects.
- In 2010, DNR and the Puget Sound Partnership set action item to increase eelgrass 20% by 2020 (~4,000 ha)

What’s the problem?

What can we do?

- Protect existing plants
- Improve water quality
- Restore habitat

Approach to Restoration

1. Model shorelines
2. Identification of potential areas
3. Field surveys
4. Test plots / evaluation
5. Full restoration planting
6. Evaluate and apply to next effort

Thom et al., 2018

Restoration Ecology
THE JOURNAL OF THE SOCIETY FOR ECOLOGICAL RESTORATION

TECHNICAL ARTICLE

Eelgrass (*Zostera marina* L.) restoration in Puget Sound: development of a site suitability assessment process

Ronald Thom[1,2], Jeffrey Gaeckle[3], Kate Buenau[1], Amy Borde[1], John Vavrinec[1], Lara Aston[1], Dana Woodruff[1], Tarang Khangaonkar[1], James Kaldy[4]

The restoration of eelgrass (*Zostera marina* L.) is a high priority in Puget Sound, Washington, United States. In 2011, the state set a restoration target to increase eelgrass area by 4,200 ha by 2020, a 20% increase over the 21,500 ha then present. In a region as large, dynamic, and complex as Puget Sound, locating areas to restore eelgrass effectively and efficiently is challenging. To identify potential restoration sites we used simulation modeling, a geodatabase for spatial screening, and test planting. The simulation model of eelgrass biomass used time series of water properties (depth, temperature, and salinity) output from a regional hydrodynamic model and empirical water clarity data to indicate growth potential. The geographic information system-based analysis incorporated results from the simulation model, historical and current eelgrass area, substrate, stressors, and shoreline manager input into a geodatabase to screen sites for field reconnaissance. Finally, we planted eelgrass at test sites and monitored survival. We screened 2,630 sites and identified 6,292 ha of highly to very highly suitable conditions for eelgrass—ample area for meeting the 20% target. Test plantings indicated that fine-scale data are needed to improve predictive capability. We summarized the results of our analysis for the majority of the approximately 3,220 km of shoreline in Puget Sound on maps to support restoration site selection and planning. Our approach provides a process for identifying and testing potential restoration sites and highlights information needs and management actions to reduce stressors and increase eelgrass area to meet restoration objectives.

Key words: eelgrass model, eelgrass transplanting, nearshore restoration, Puget Sound, *Zostera marina*

Implications for Practice

- Simulation models in combination with a geodatabase and test plantings provided a comprehensive yet efficient approach for identifying sites suitable for restoring eelgrass in a large and complex estuary.
- Our analysis showed that eelgrass restoration of 4,200 ha is achievable pending site-specific assessments, possible reduction in stressors, and following prudent restoration procedures.
- The modeling and test planting identified fine-scale light attenuation data and improved physiological data, particularly in regard to low-light conditions and phenotypic or genotypic adaptations, as critical information needs to improve this method of restoration planning.
- The model and database provide a methodology for assessing effects of climate and land use changes on species distributions and identify mitigation for these changes through stressor reduction and improved site selection.

Introduction

Recent global declines in seagrasses have been attributed to anthropogenic stressors (Orth et al. 2006; Waycott et al. 2009), triggering the World Conservation Union (IUCN) to list nearly 25% of the world's seagrass species as endangered or threatened (Short et al. 2011). In Puget Sound, Washington, United States, declines in eelgrass meadows and localized extinctions have been attributed to anthropogenic shoreline modifications, periodic disturbances, and degradation in water quality (Dowty et al. 2010; Thom et al. 2011). In 2011, the Puget Sound Partnership (PSP) established a challenging recovery goal of increasing eelgrass area by 20% by 2020, an approximate 4,200 ha increase from the 2000–2008 baseline of 21,500 acres (Christiaen et al. 2017).

Author contributions: RT, JG, KB, AB designed the research and analyzed the data; JG, AB, JV conducted assessments and plantings; KB refined and ran eelgrass model; LA, JG conducted planner surveys; DW analyzed light data; TK contributed hydrodynamic modeling results; JK contributed initial model; KB, RT, JG, AB, JV, LA, DW wrote the manuscript.

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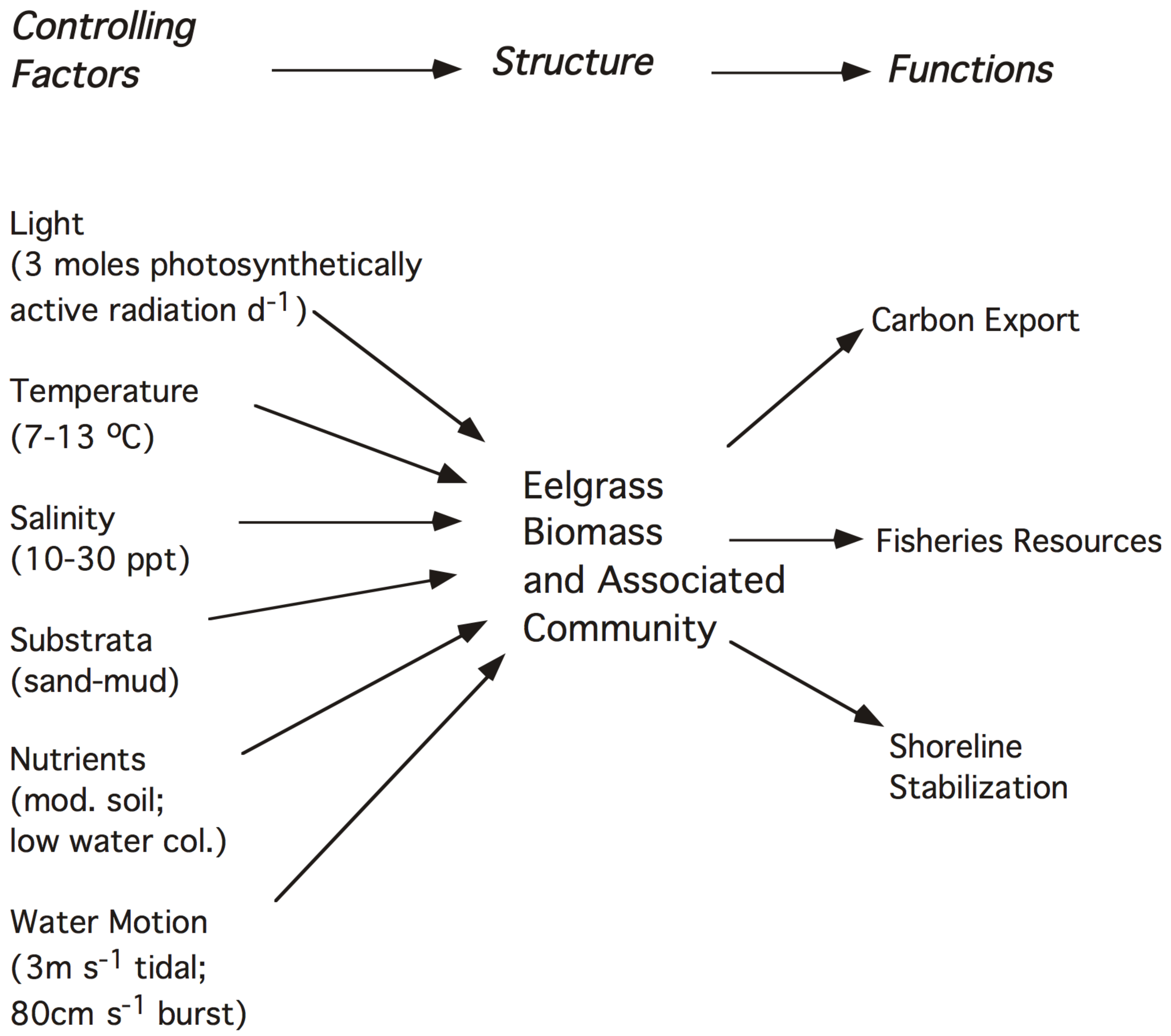
doi: 10.1111/rec.12702

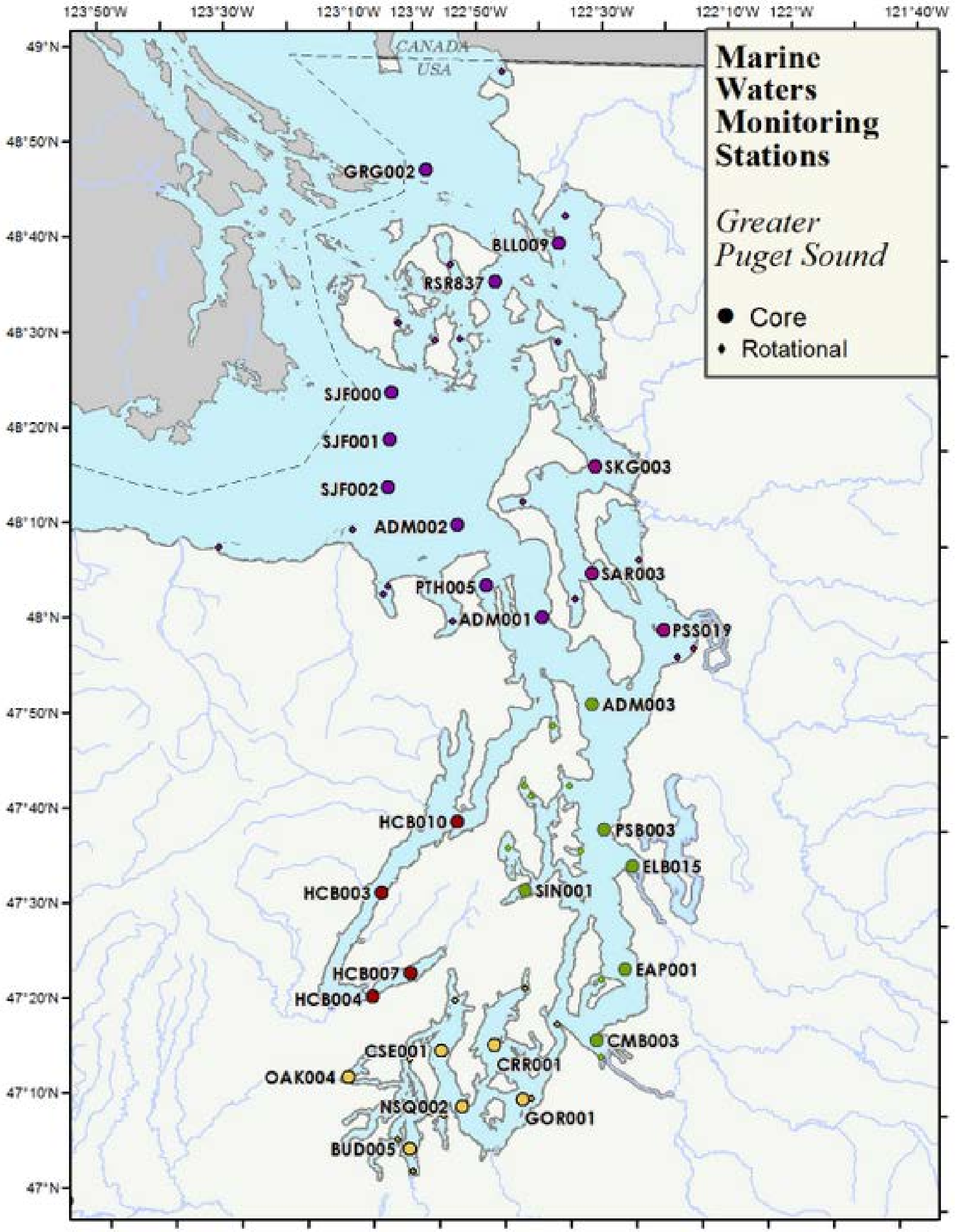
Modeling

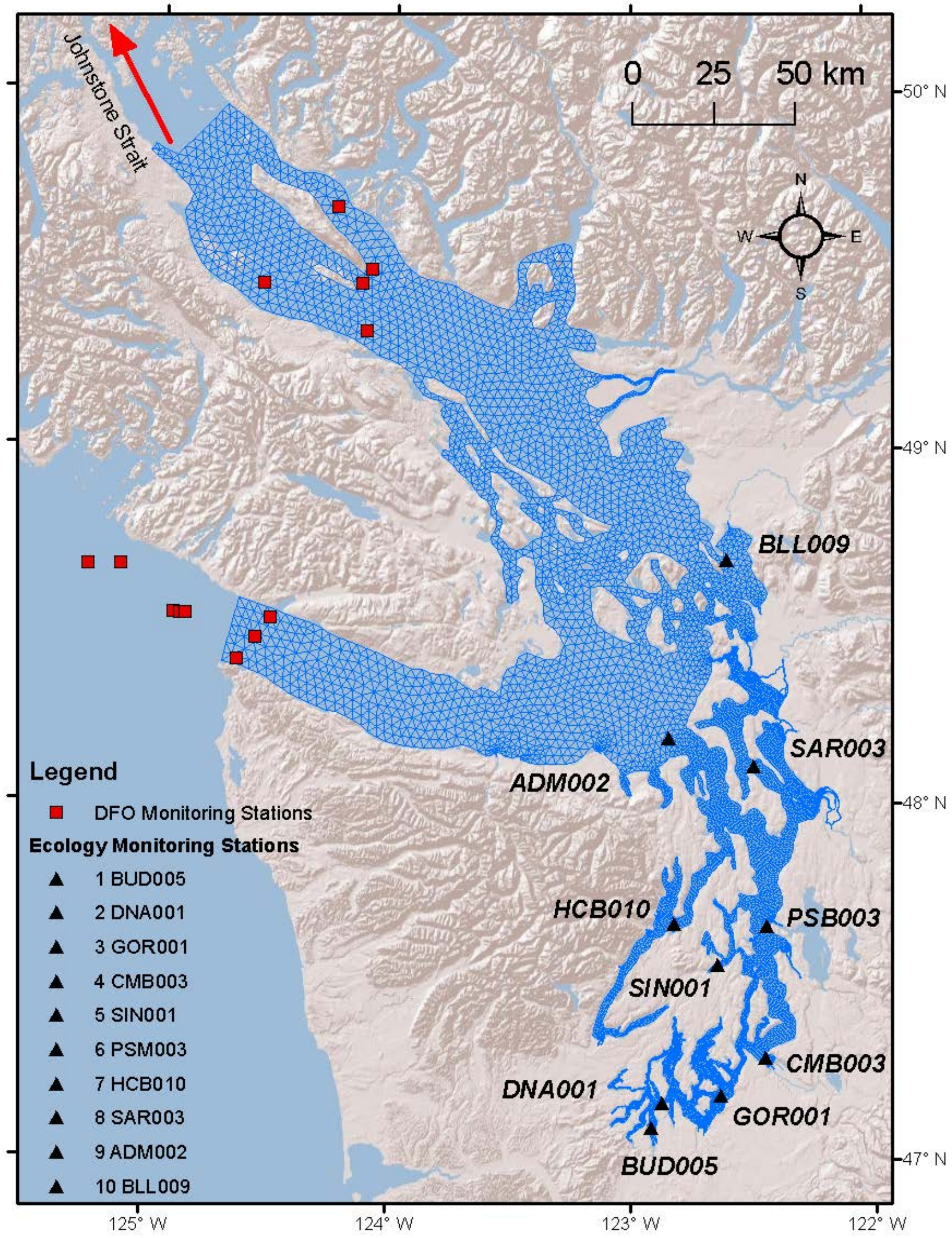
- Can provide general idea of processes and effects

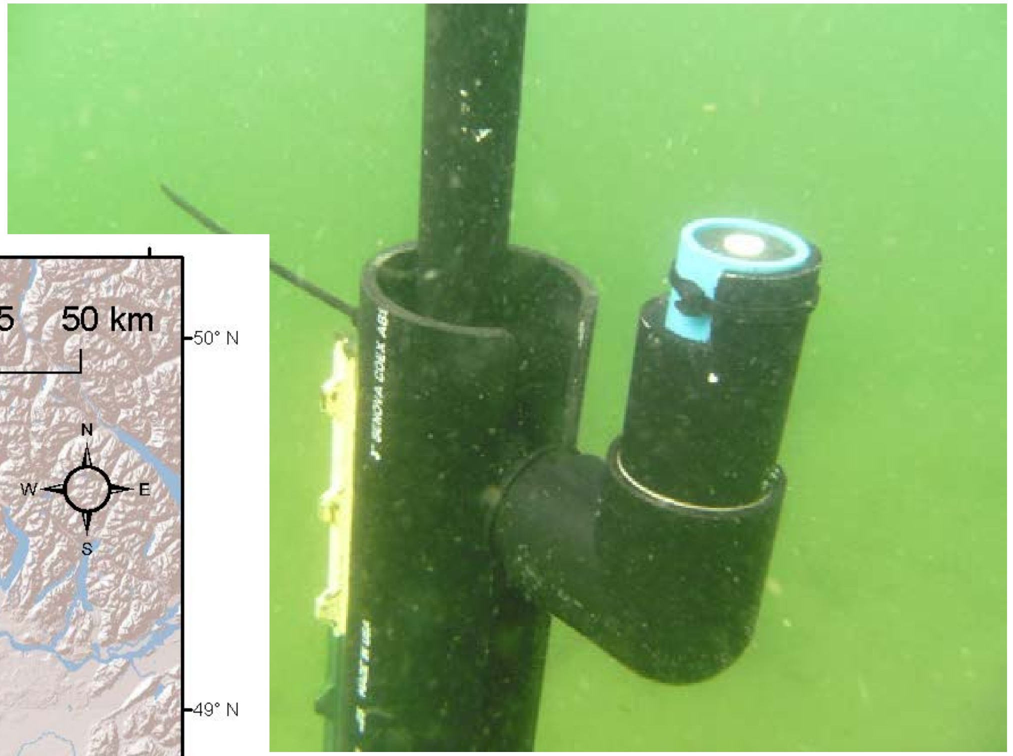
- Saves:
  - Time
  - Money
  - Exposure
  - Wear and tear

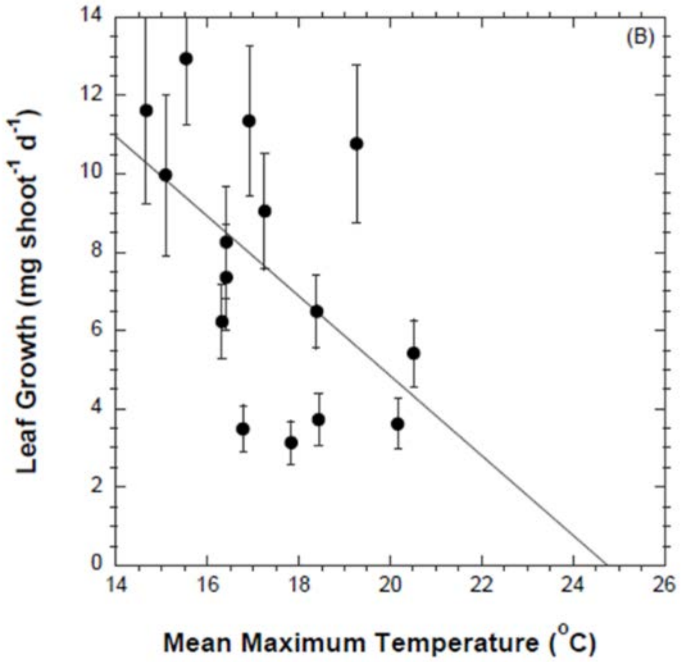


Data Sources

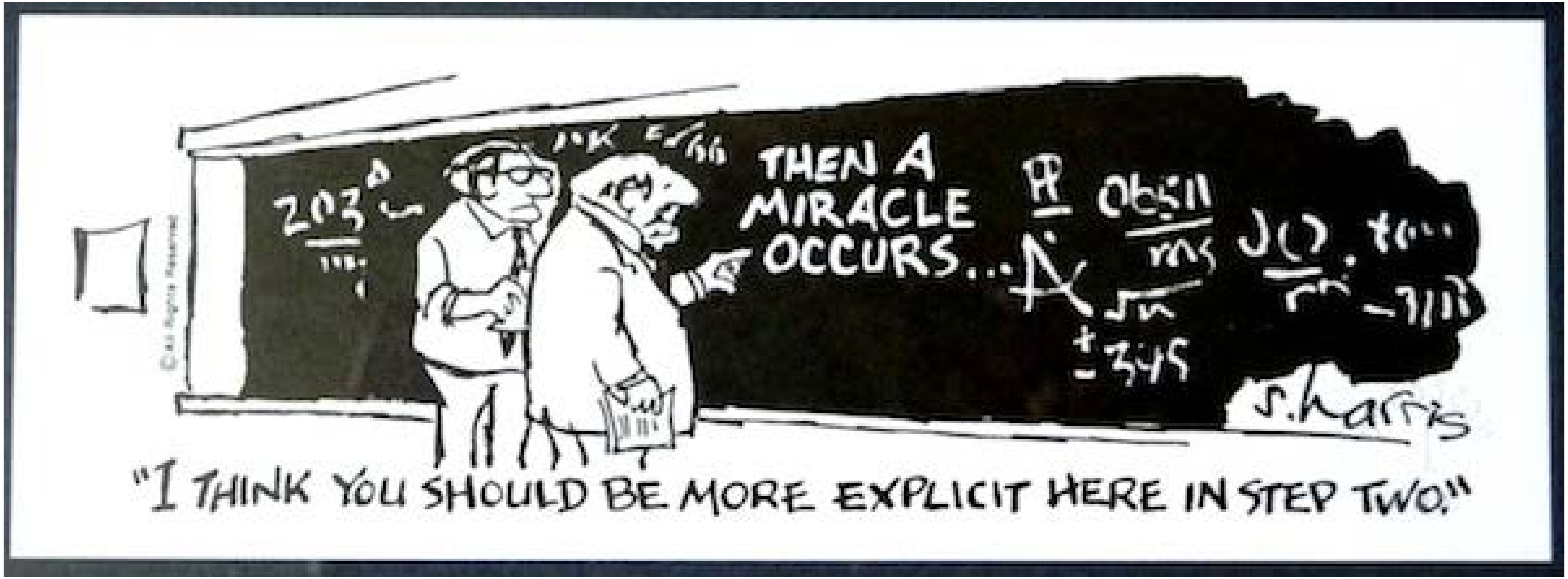








Khangaonkar et al., 2011


THEN A MIRACLE OCCURS...
S.Harris
"I THINK YOU SHOULD BE MORE EXPLICIT HERE IN STEP TWO."

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Eelgrass Biomass Model

Aboveground biomass (mol C/m^2)

Photosynthesis

Respiration

$$C_{a,t+1} = C_{a,t} + \Delta t \left[(1-\tau) P(I_z, T, S) C_{a,t} \left(1 - \frac{C_{a,t}}{\kappa}\right) - R_a(T) C_{a,t} - M_a C_{a,t} \right]$$

$$C_{b,t+1} = C_{b,t} + \Delta t \left[(\tau-\delta) P(I_z, T, S) C_{a,t} \left(1 - \frac{C_{a,t}}{\kappa}\right) - R_b(T) C_{b,t} - M_b C_{b,t} \right]$$

Belowground biomass (mol C/m^2)

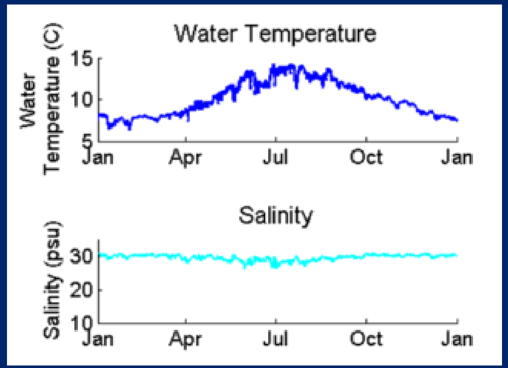
Translocation and exudation of carbon

Density dependence

Mortality

Adapted from: Burd and Dunton 2001, Eldridge et al. 2004, Kaldy and Eldridge 2006

Eelgrass Growth Model for Puget Sound



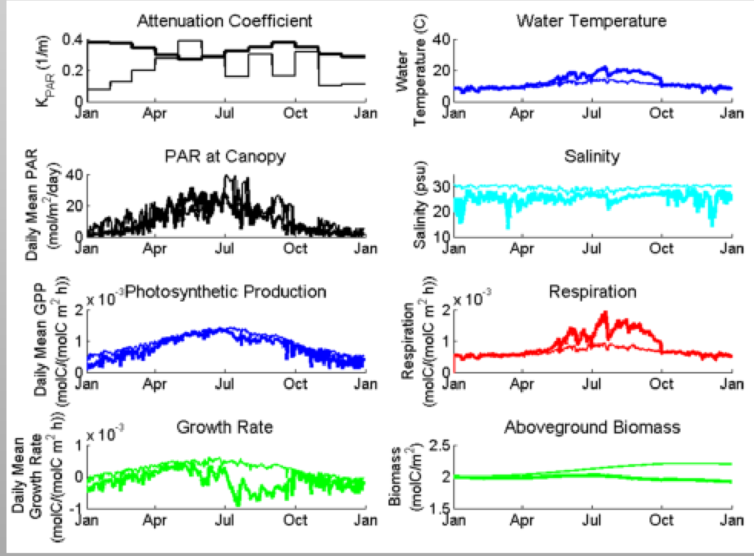
Puget Sound Hydrodynamic Model

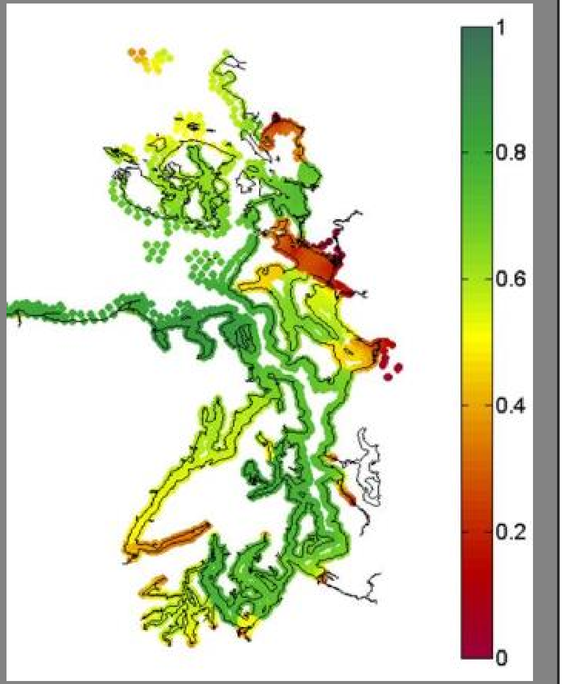
Light Data

Physiological Response

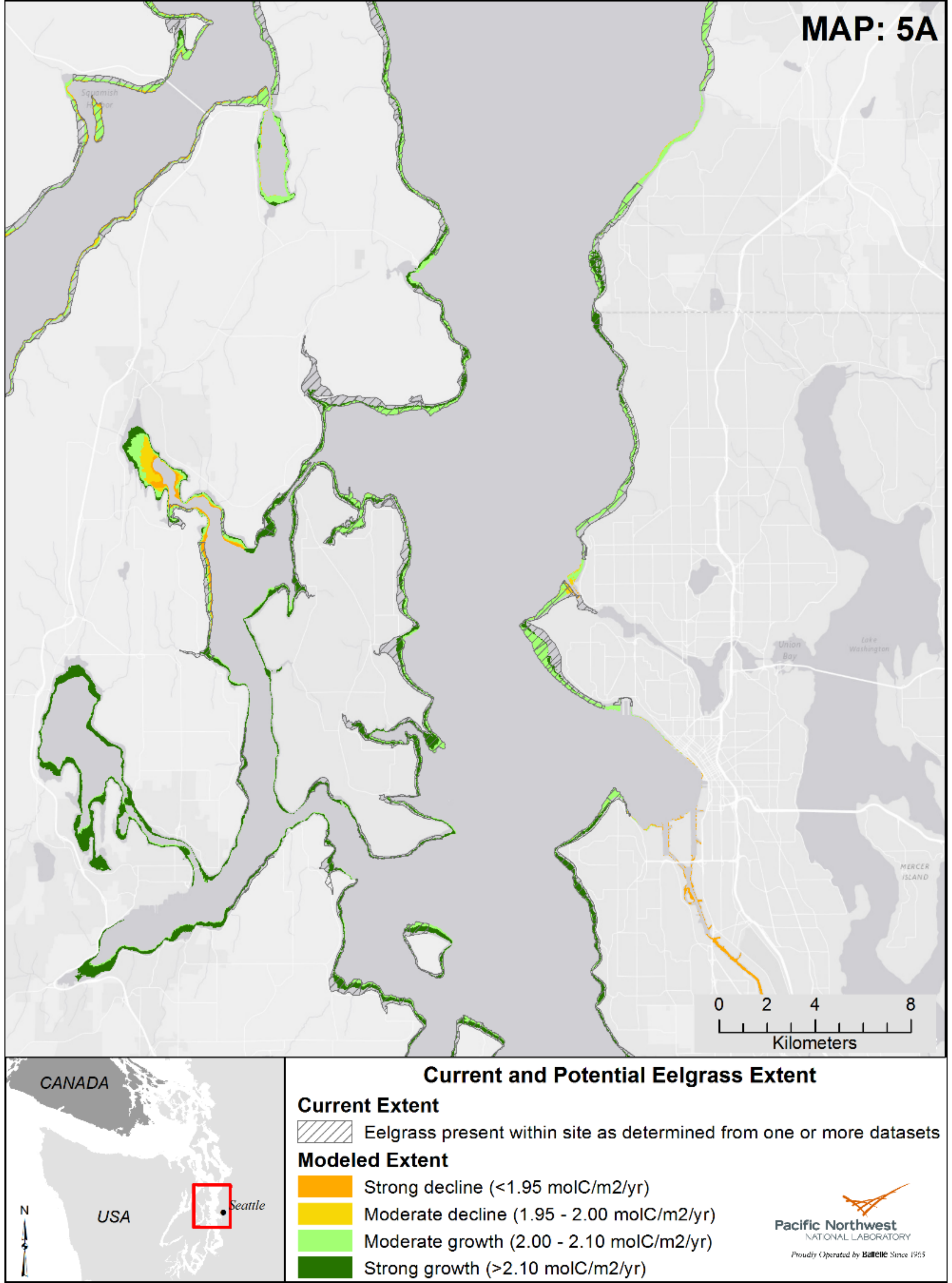
Density dependence
Photosynthesis
Respiration

Eelgrass Model Output (numerical data)





Model output for -5m depth (point data)


MAP: 5A
0 2 4 8
Kilometers
CANADA
USA
N
Seattle
Current and Potential Eelgrass Extent
Current Extent
Eelgrass present within site as determined from one or more datasets
Modeled Extent
Strong decline (<1.95 molC/m2/yr)
Moderate decline (1.95 - 2.00 molC/m2/yr)
Moderate growth (2.00 - 2.10 molC/m2/yr)
Strong growth (>2.10 molC/m2/yr)
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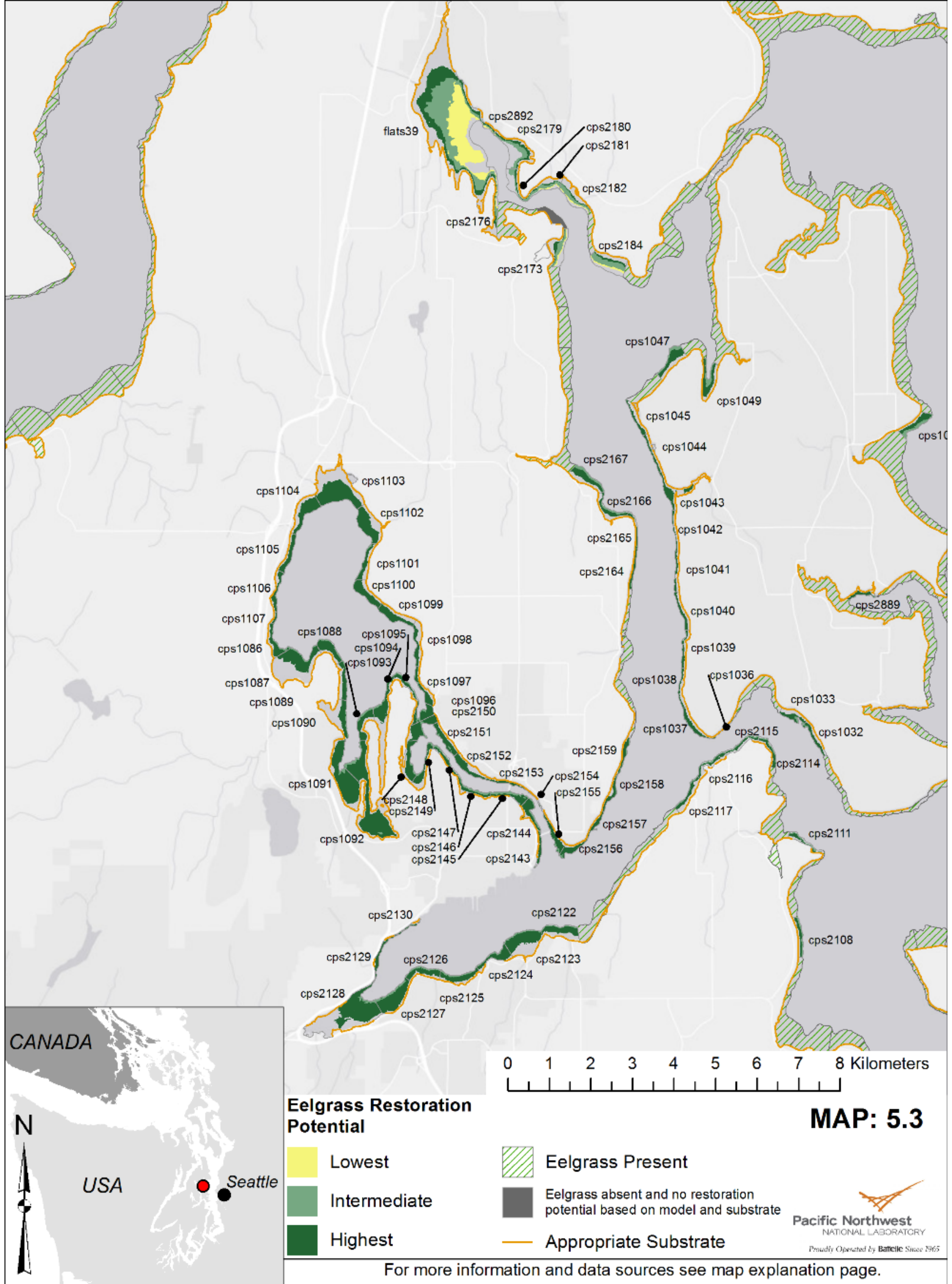
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cps2126
cps2123
cps2124
cps2128
cps2125
cps2127
CANADA
USA
N
Seattle
0 1 2 3 4 5 6 7 8 Kilometers
Eelgrass Restoration Potential
MAP: 5.3
Lowest
Intermediate
Highest
Eelgrass Present
Eelgrass absent and no restoration potential based on model and substrate
Appropriate Substrate
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For more information and data sources see map explanation page.

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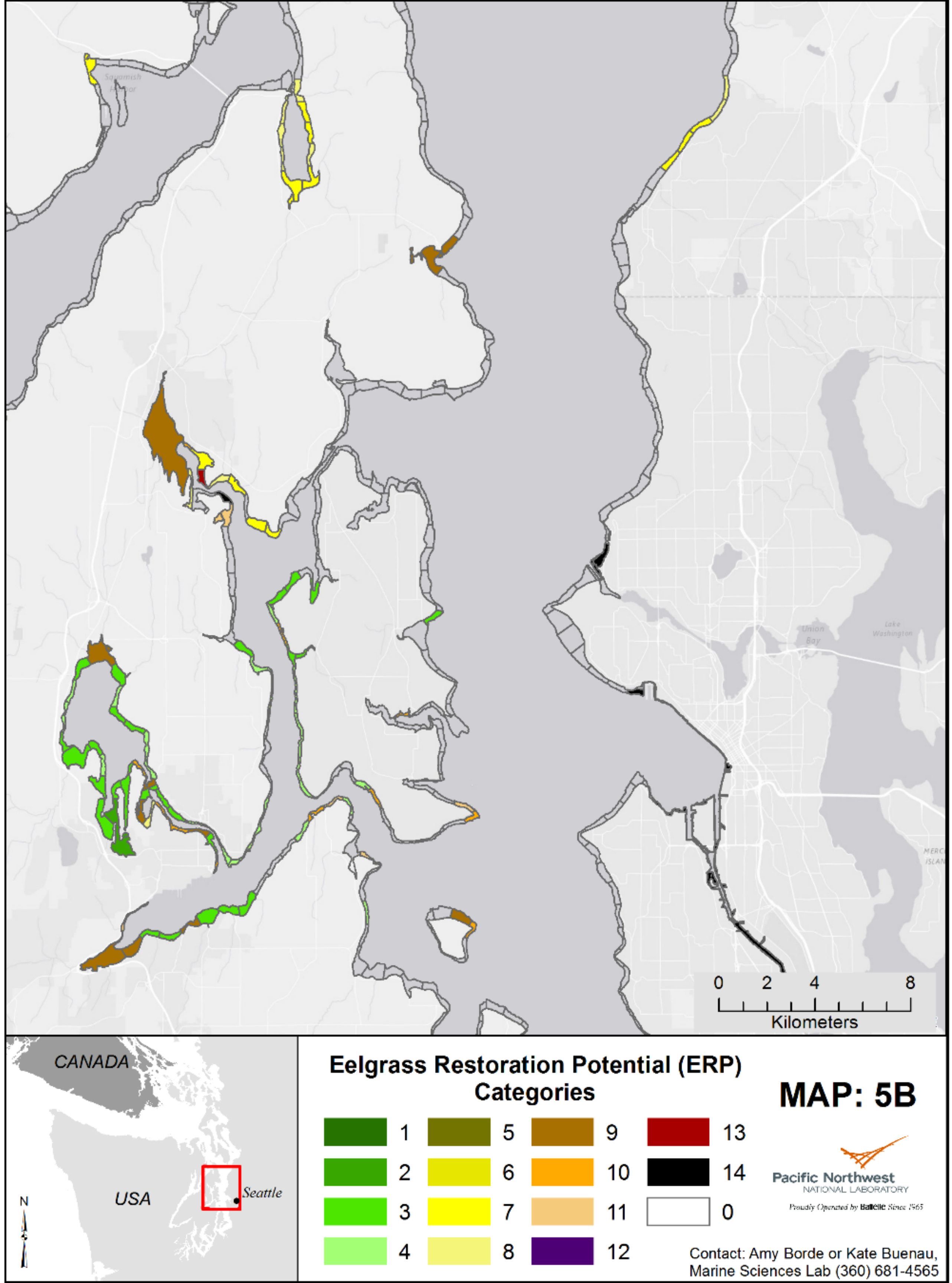
Habitat suitability model

- Biomass model results
- Presence or absence of eelgrass
- Bathymetry / potential area
- Landscape conditions
- Stressors
  - Overwater structures
  - Shoreline armoring



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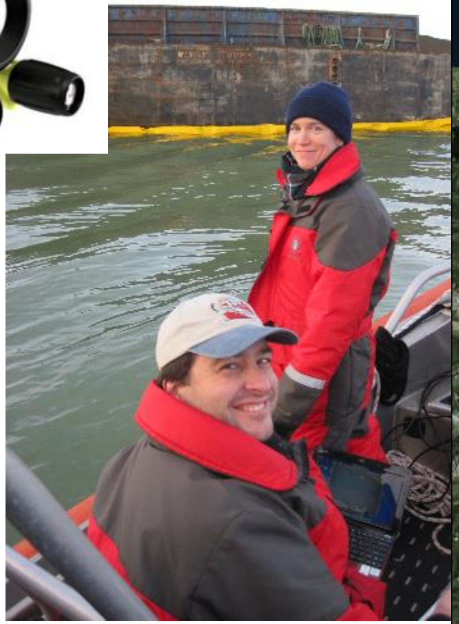
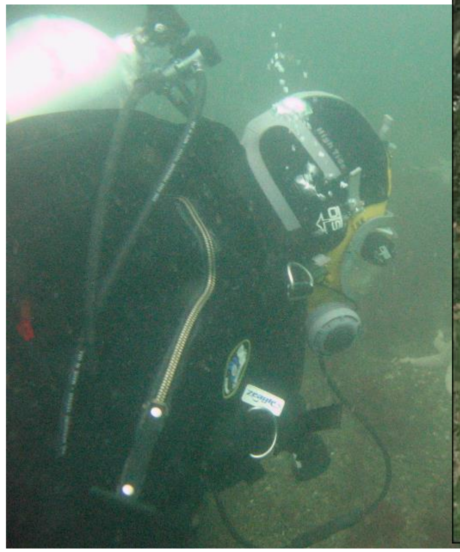
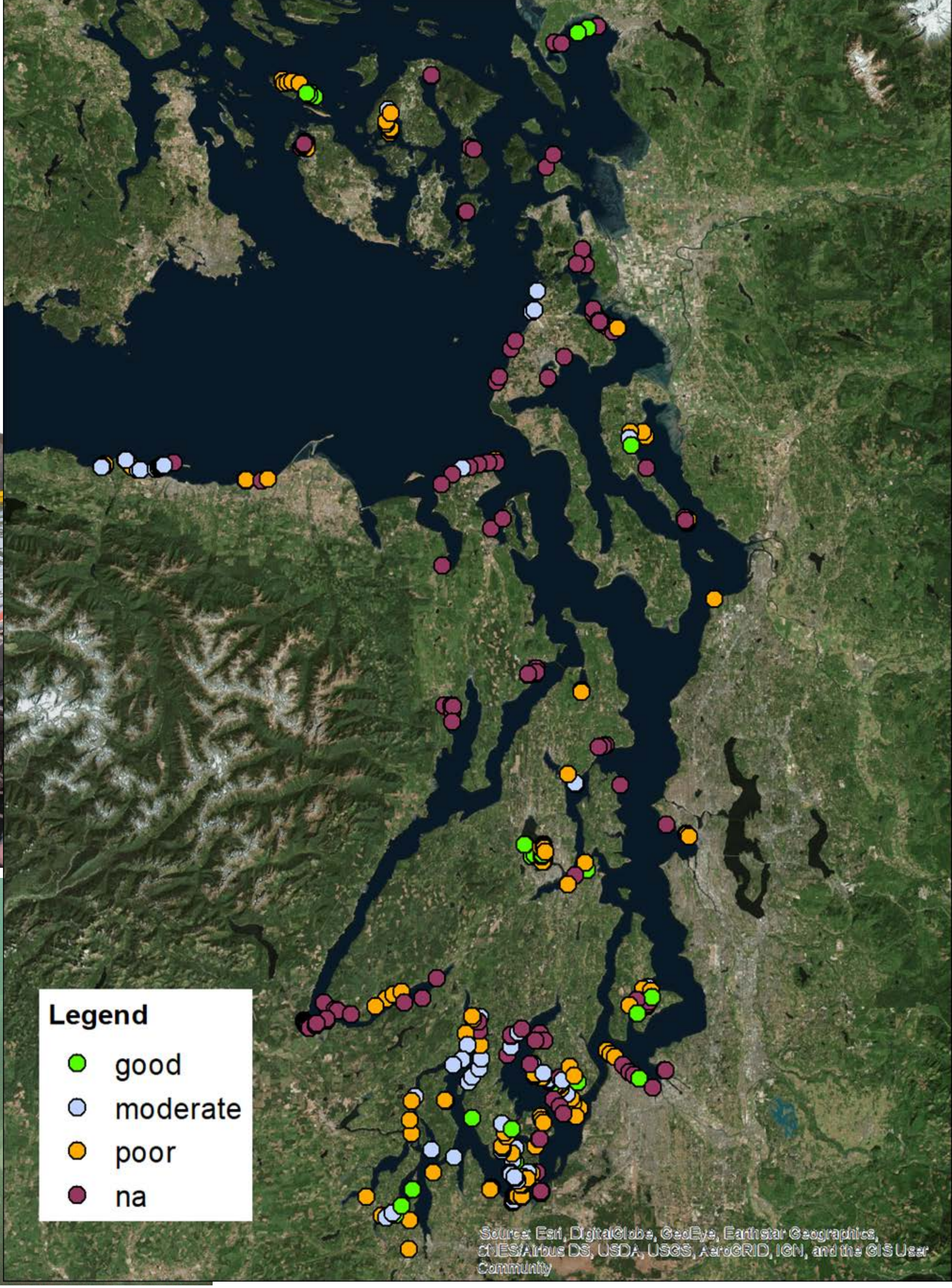
Site Surveys

- Presence of eelgrass
- Appropriate substrate
- Presence of stressors
  - Water clarity
  - Algae presence
  - Shoreline modifications
- Surveyed over 75 areas and ~400 sites







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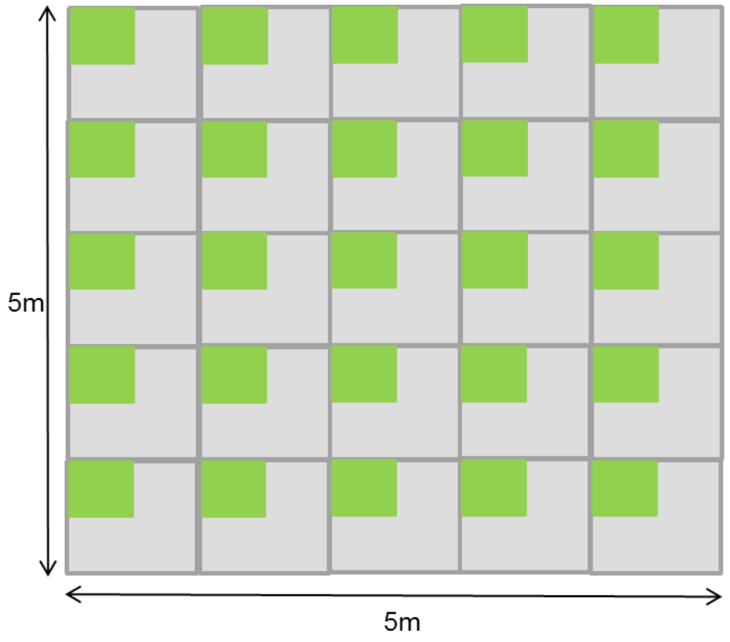
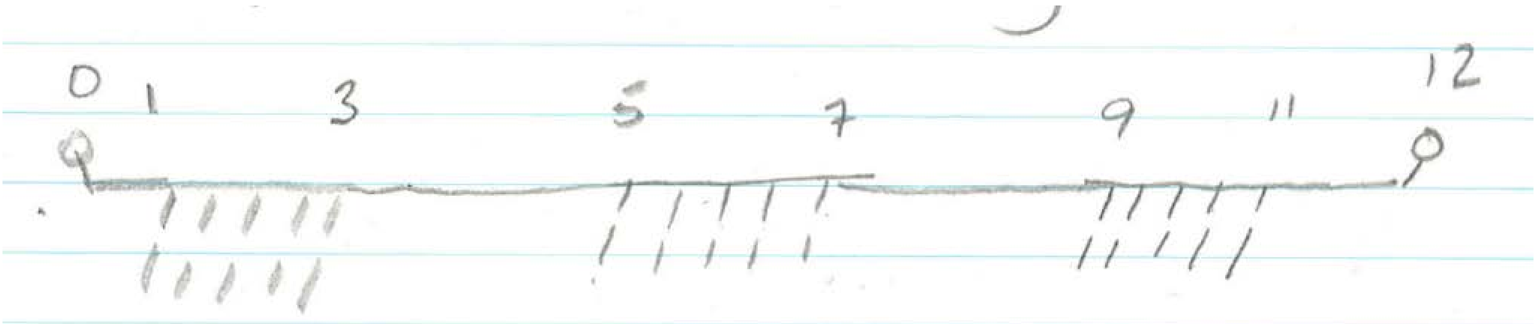
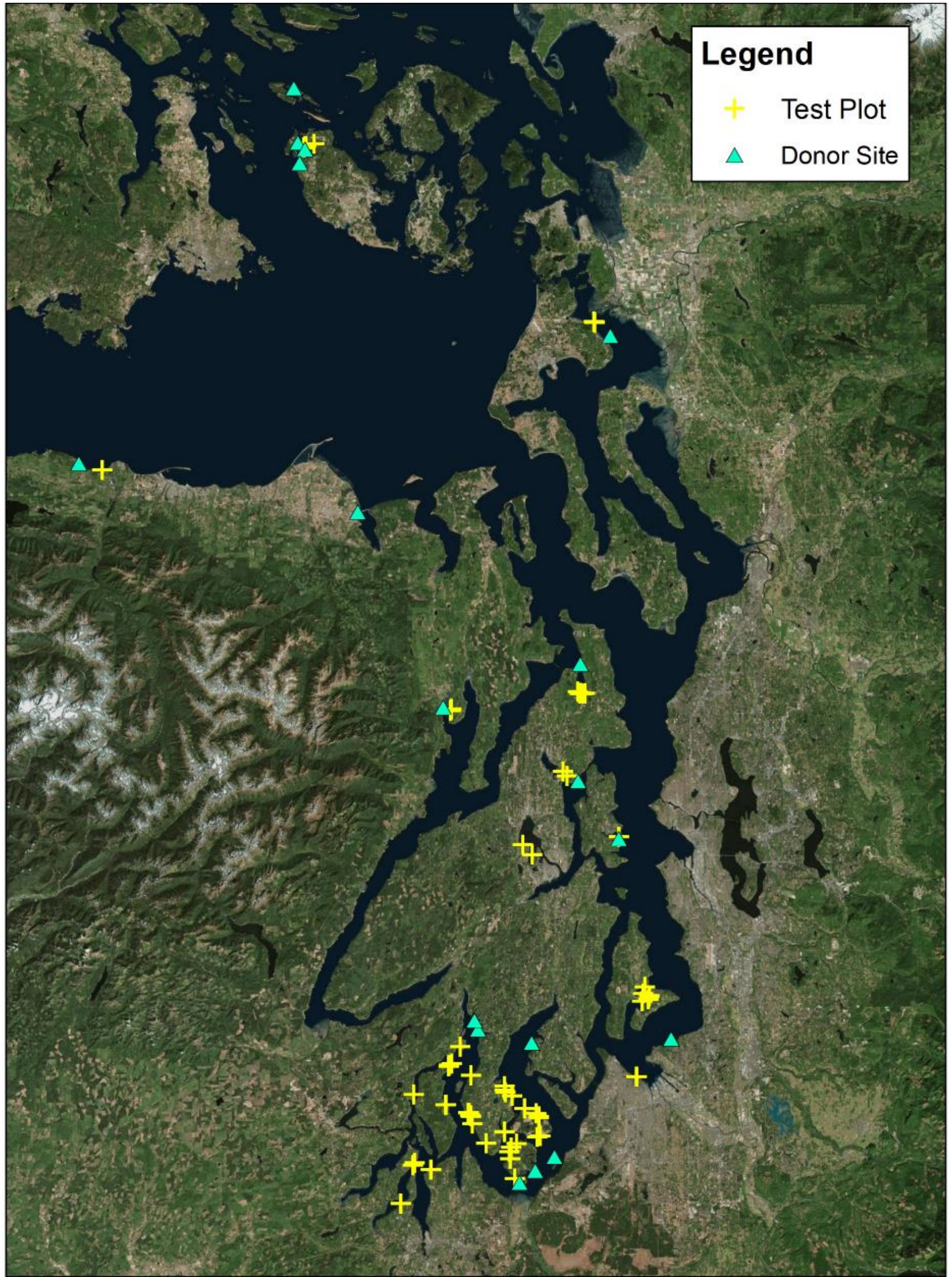
Test Transplants

- 5 x 5 m plot
- Checkerboard planting
- Each 0.25 m^2 has 20 shoots
- 500 shoots per plot





Planted 77 test plots to date



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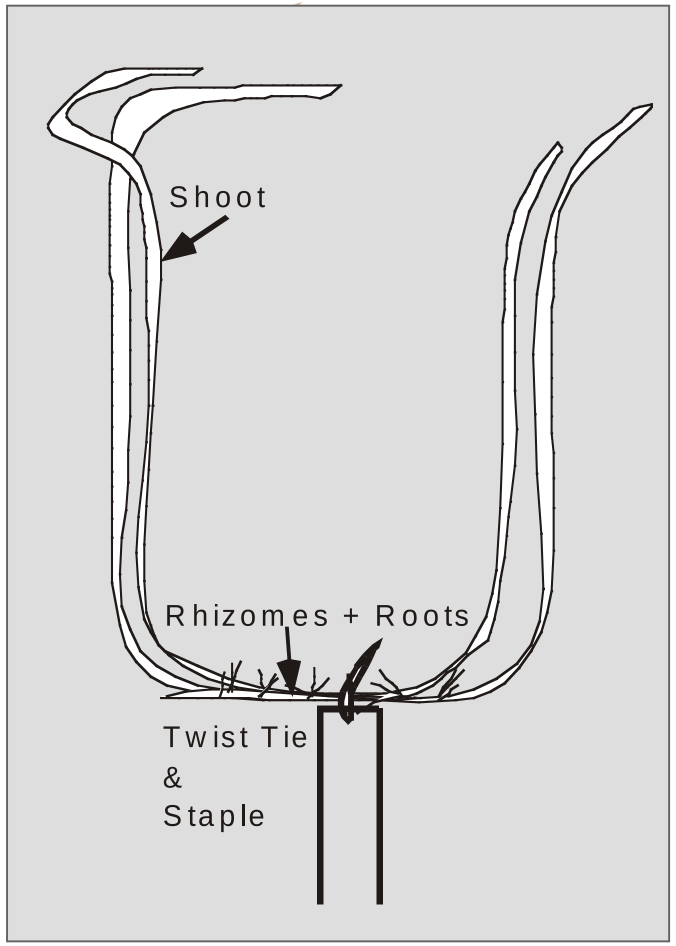
Harvesting

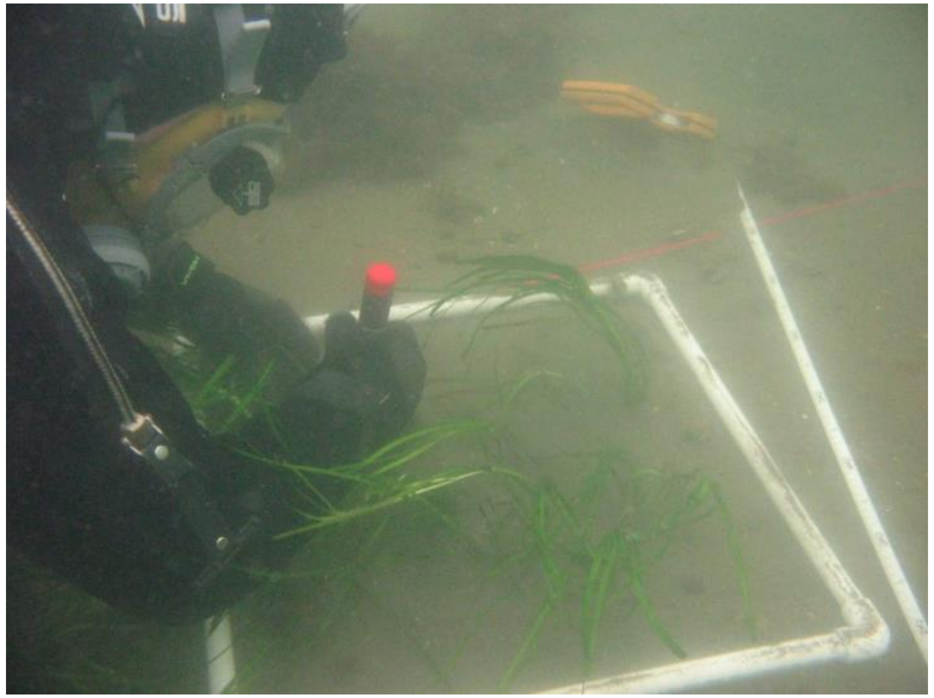
- Tanks at MSL
  - Primarily if salvaged from an area nearby
- 16 donor sites
  - Located near restoration sites
- Conducted donor harvest study to determine effects
  - Preliminary results indicate recovery is rapid and little to no effect is discernable

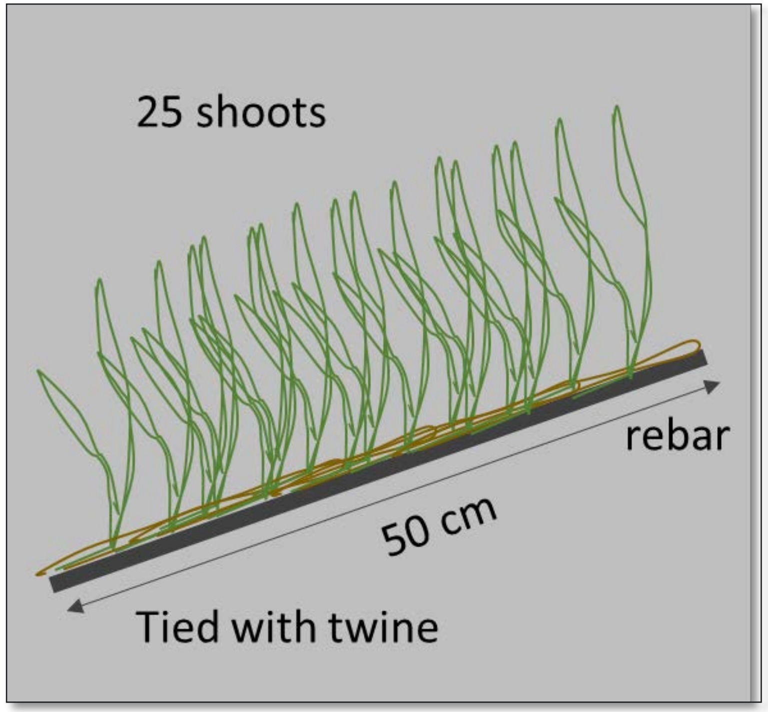
Bundling

Bundling

Planting methods







Planting

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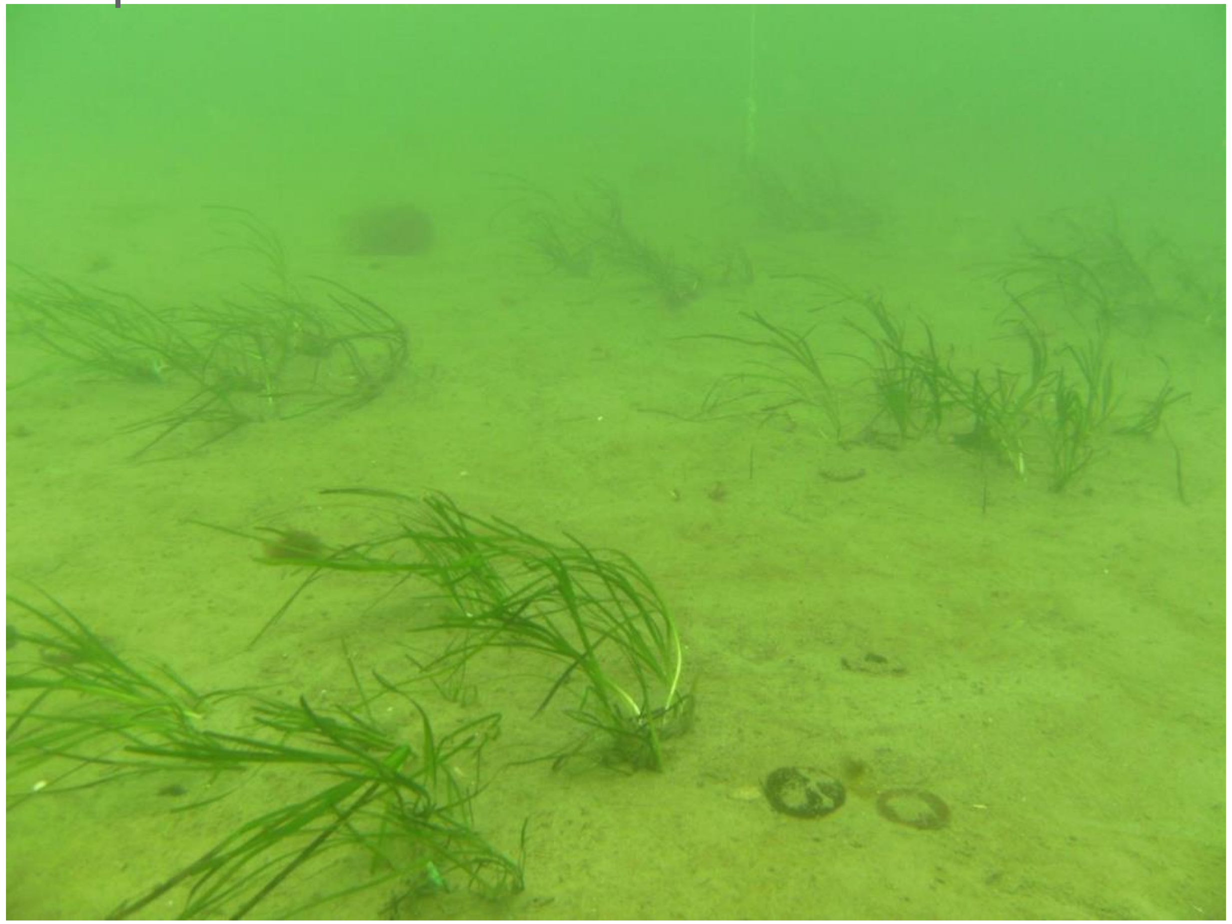
Test Plots

- Planted 78 test plots to date

Staple Method



Rebar Method

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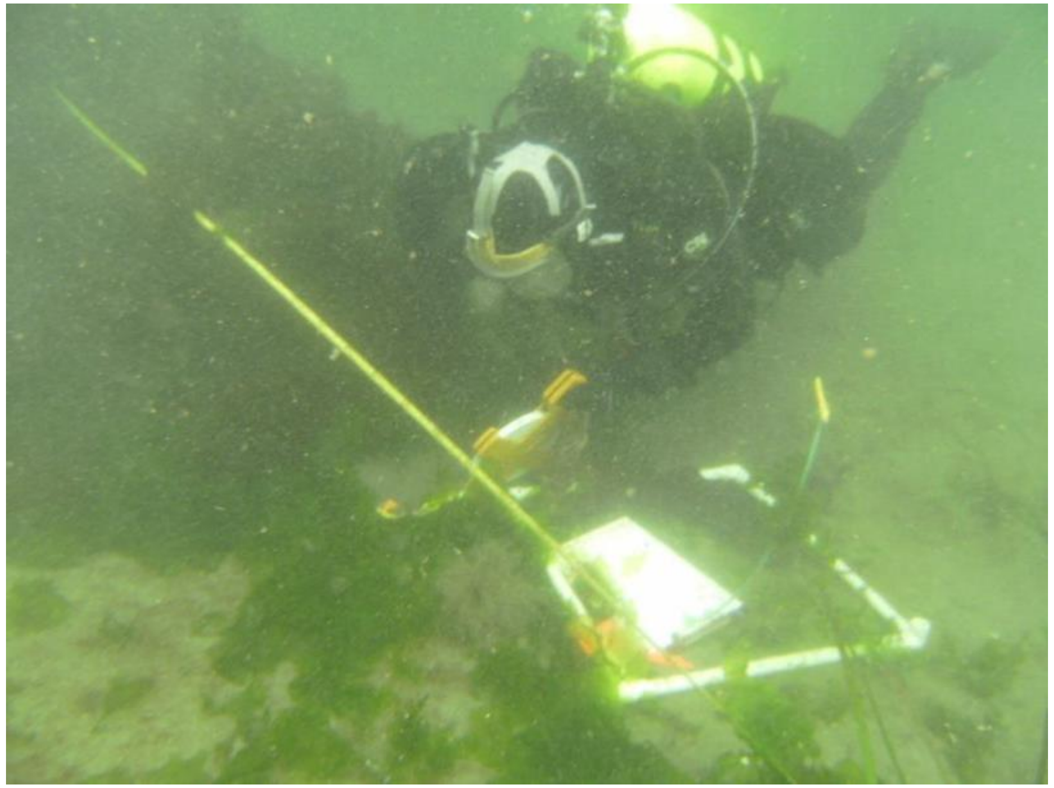
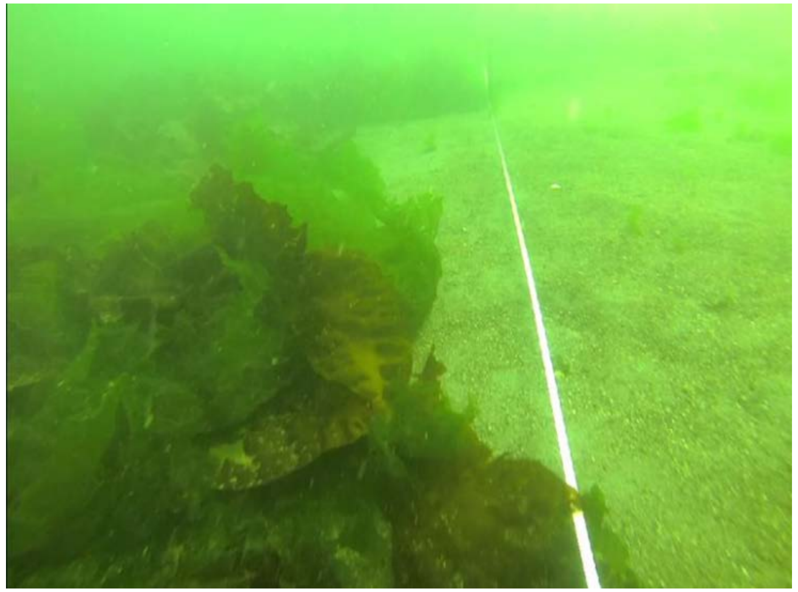
Evaluation of Test Plots



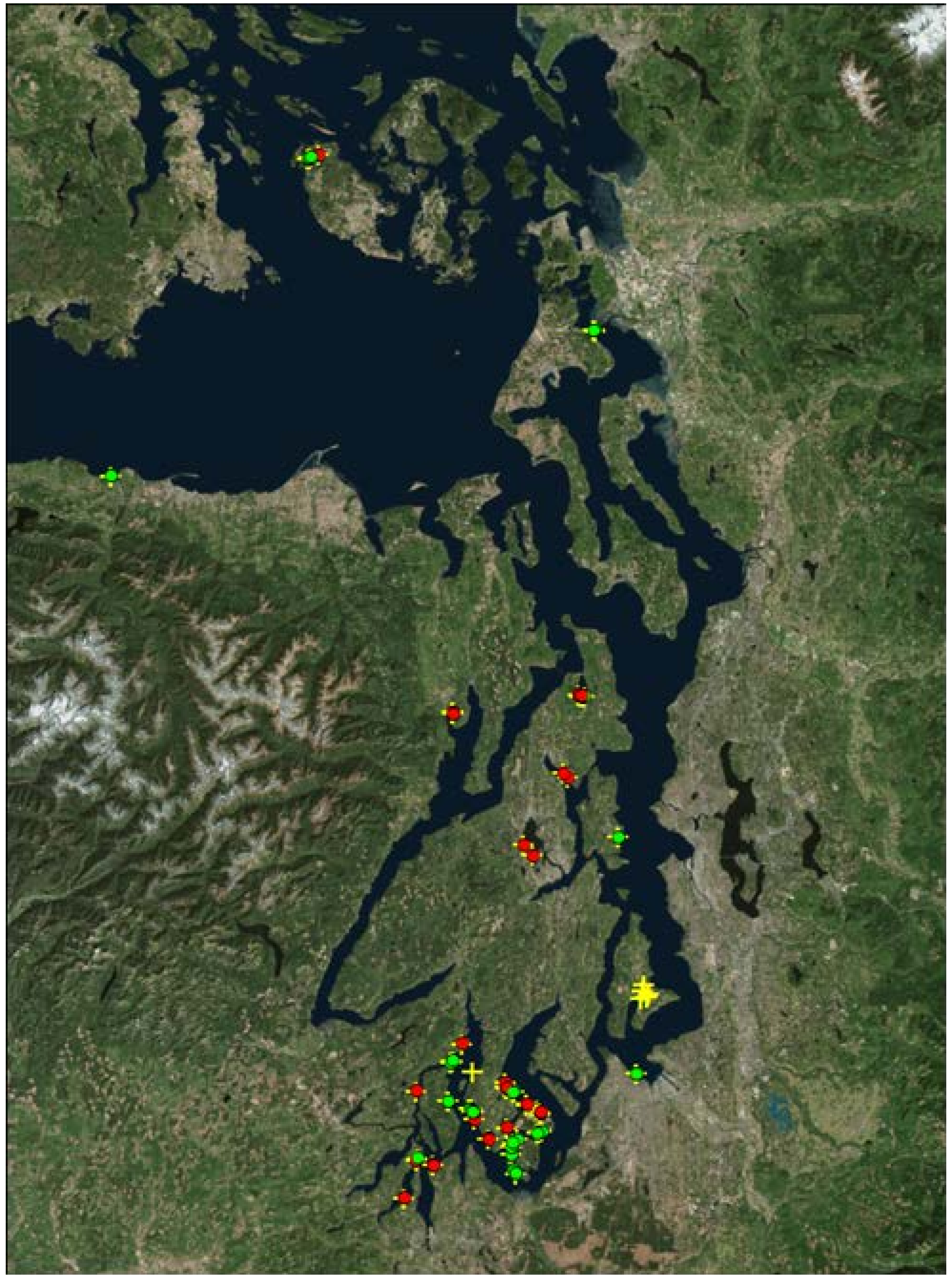
Assessment

Planted 77 test plots to date

- 49 Absent

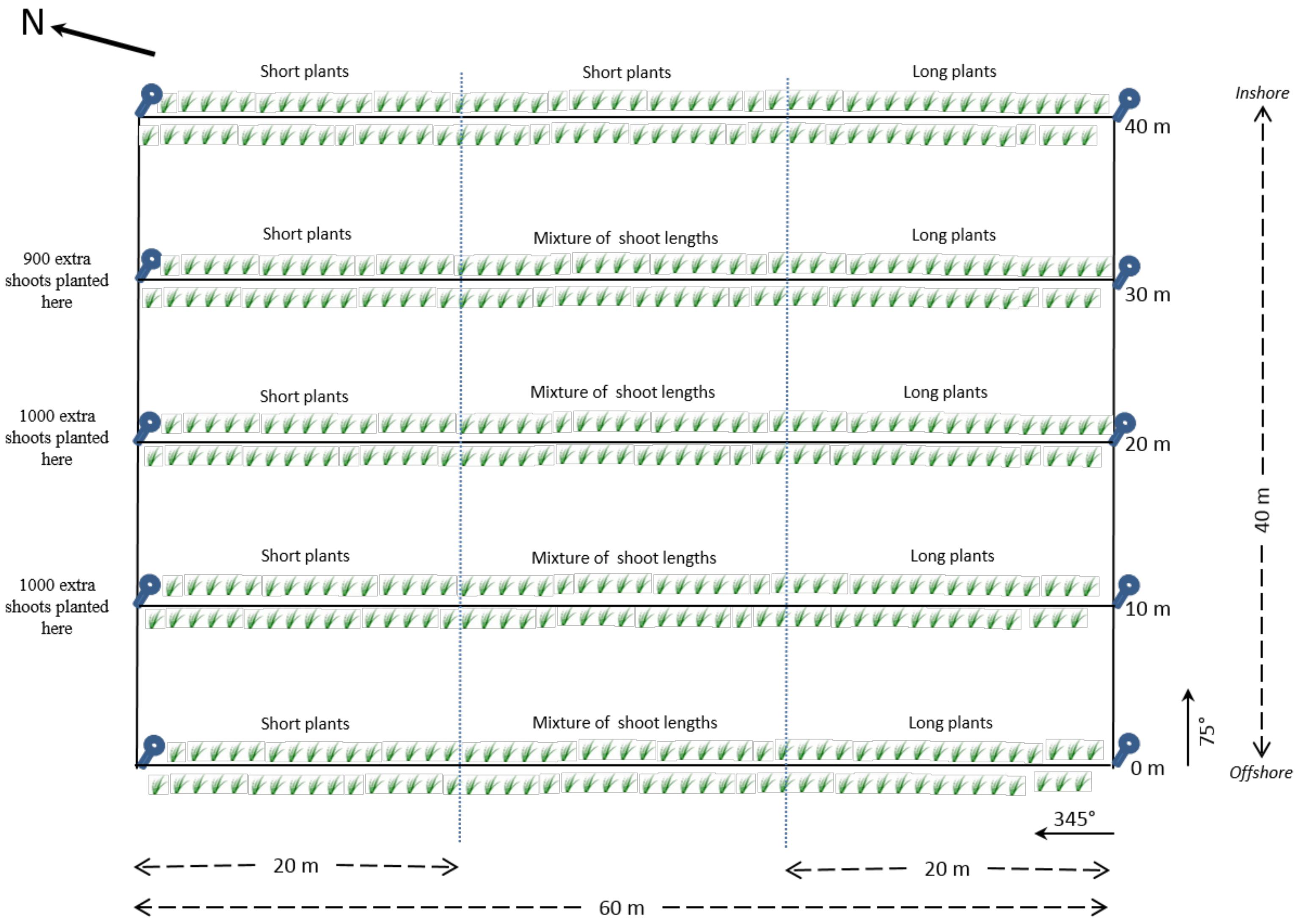


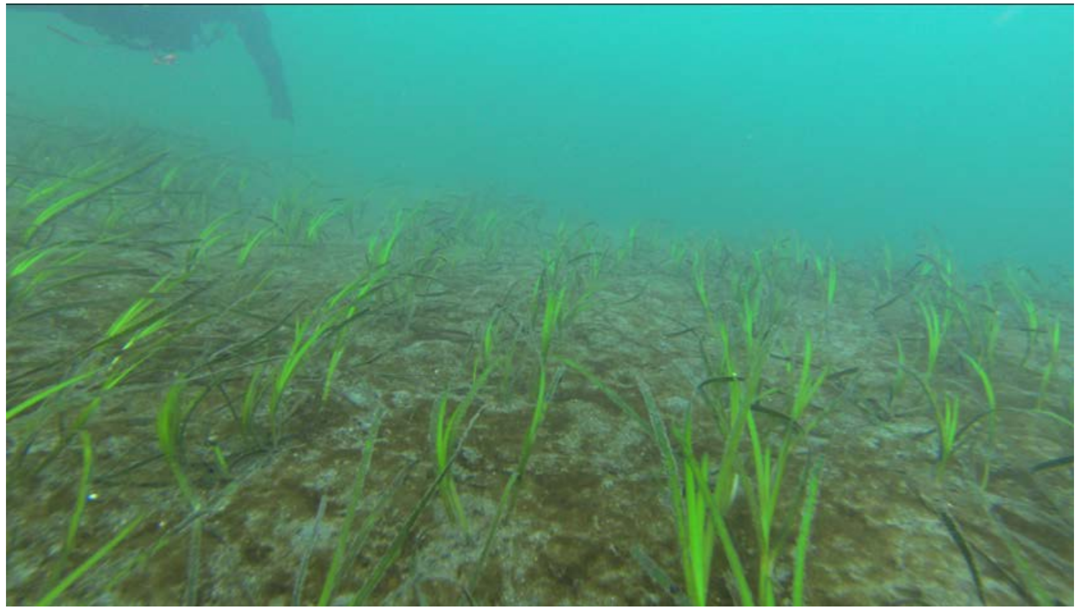
- 28 Present



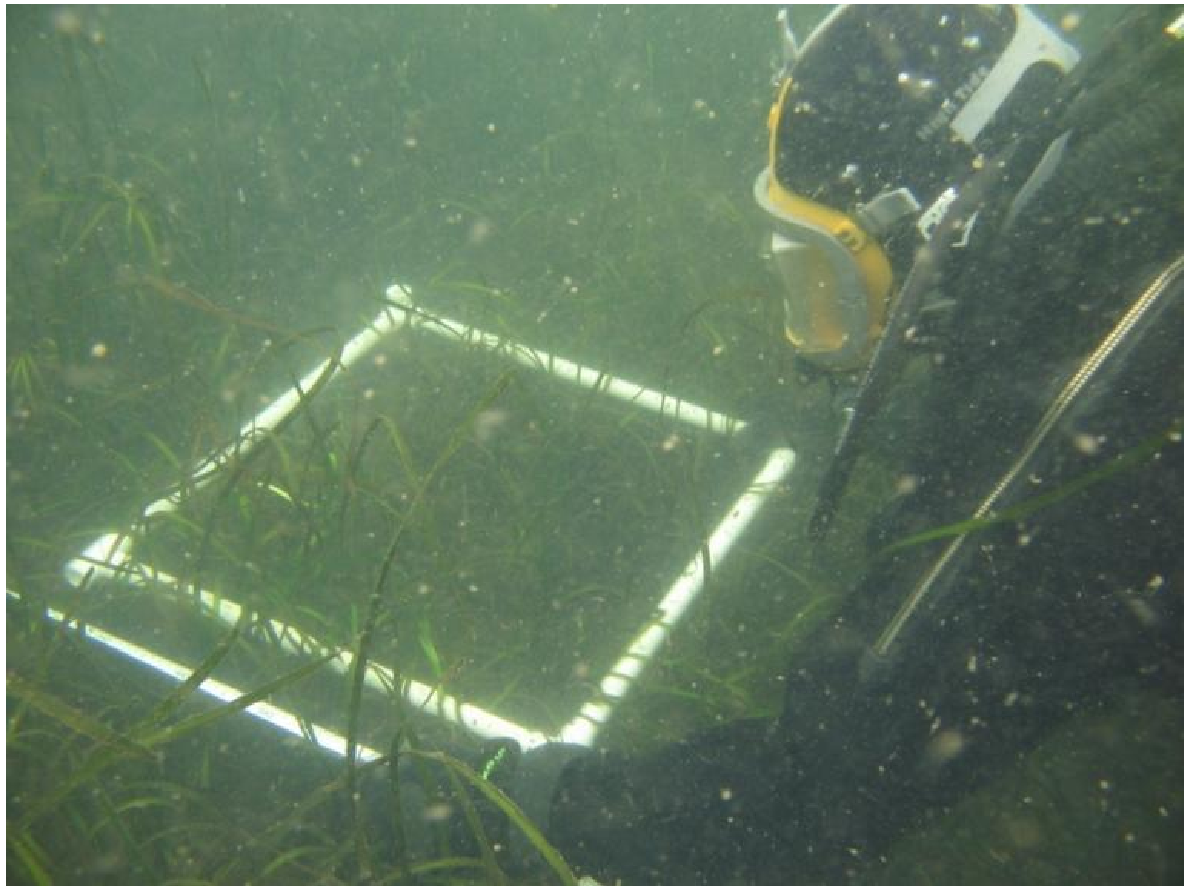
Full planting

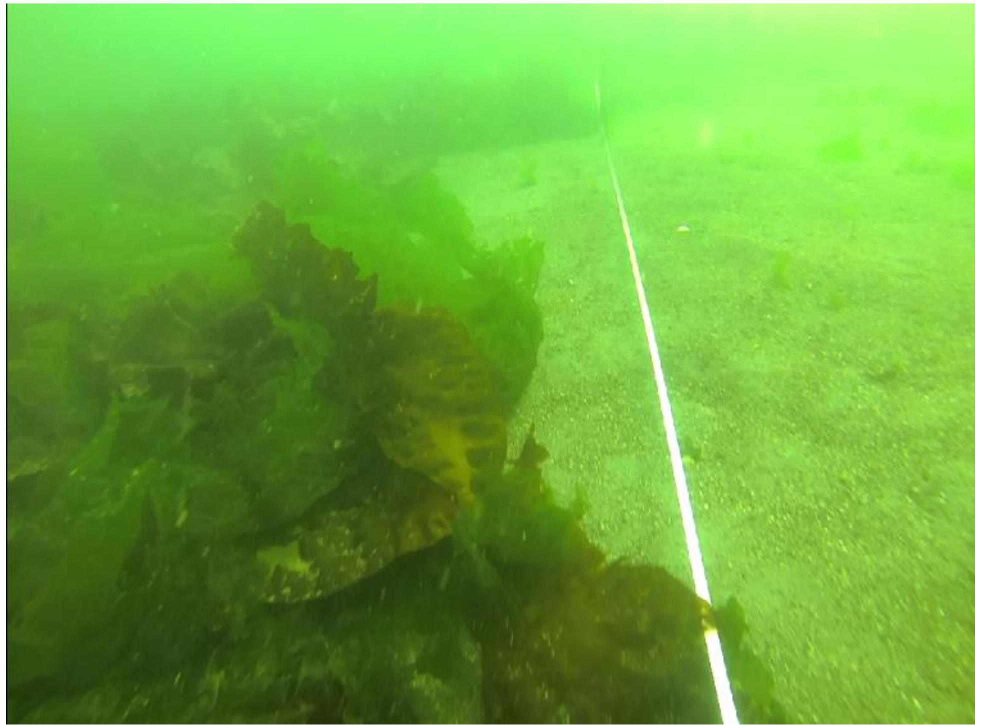
Mid-North Joemma PNNL 2015





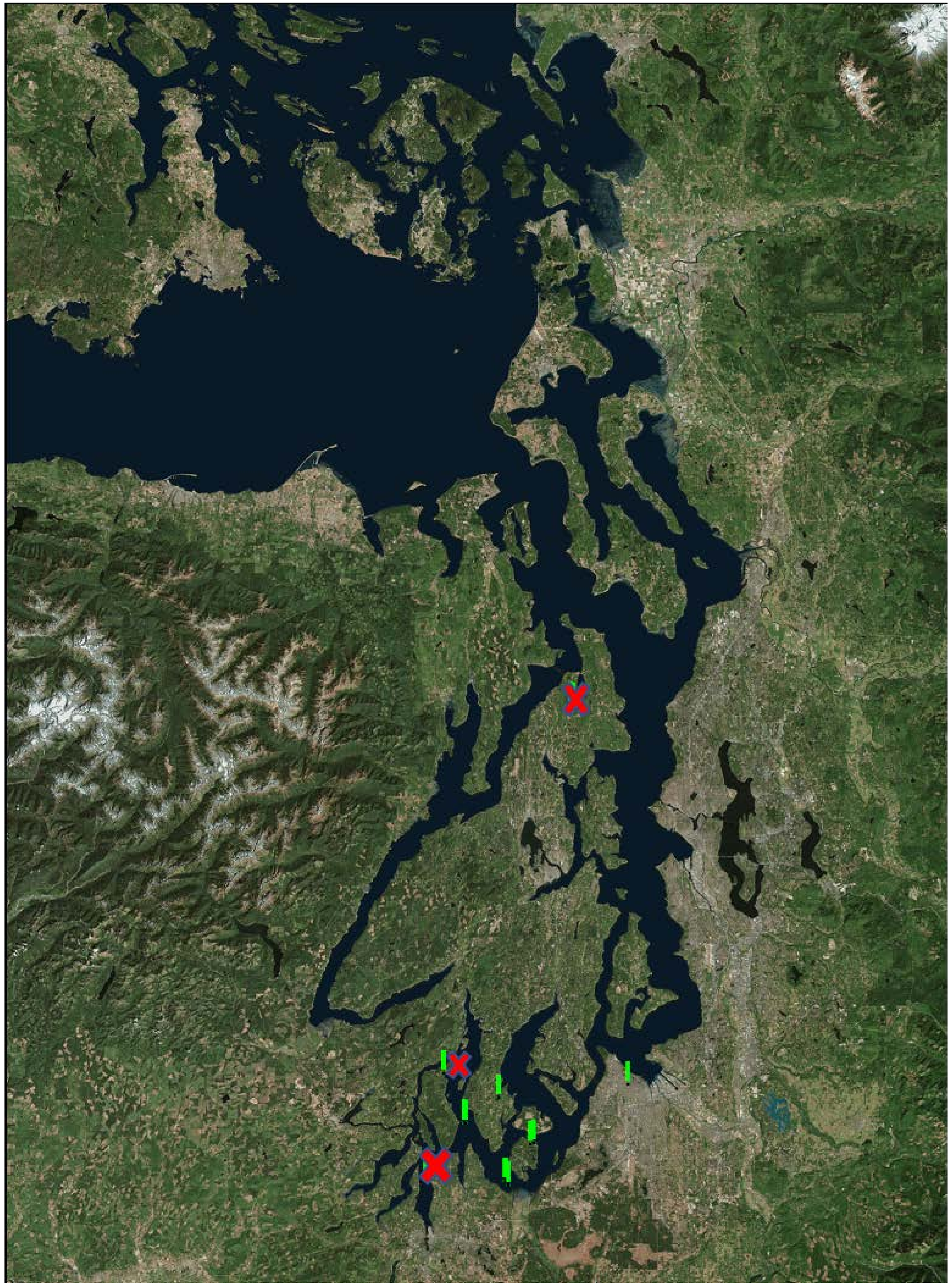
Evaluation





11 Large-scale Plantings

- 3 unsuccessful
- 8 successful



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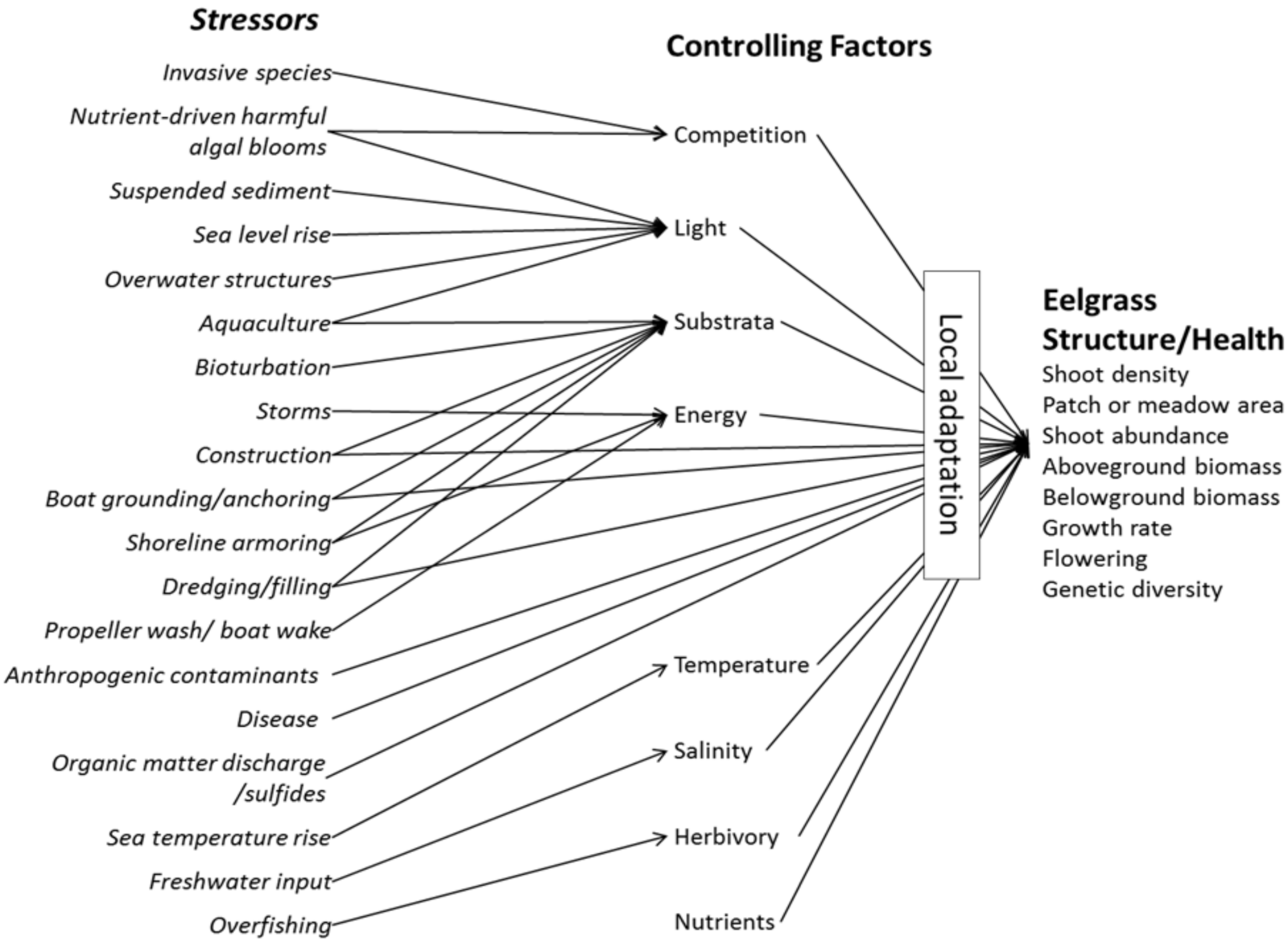
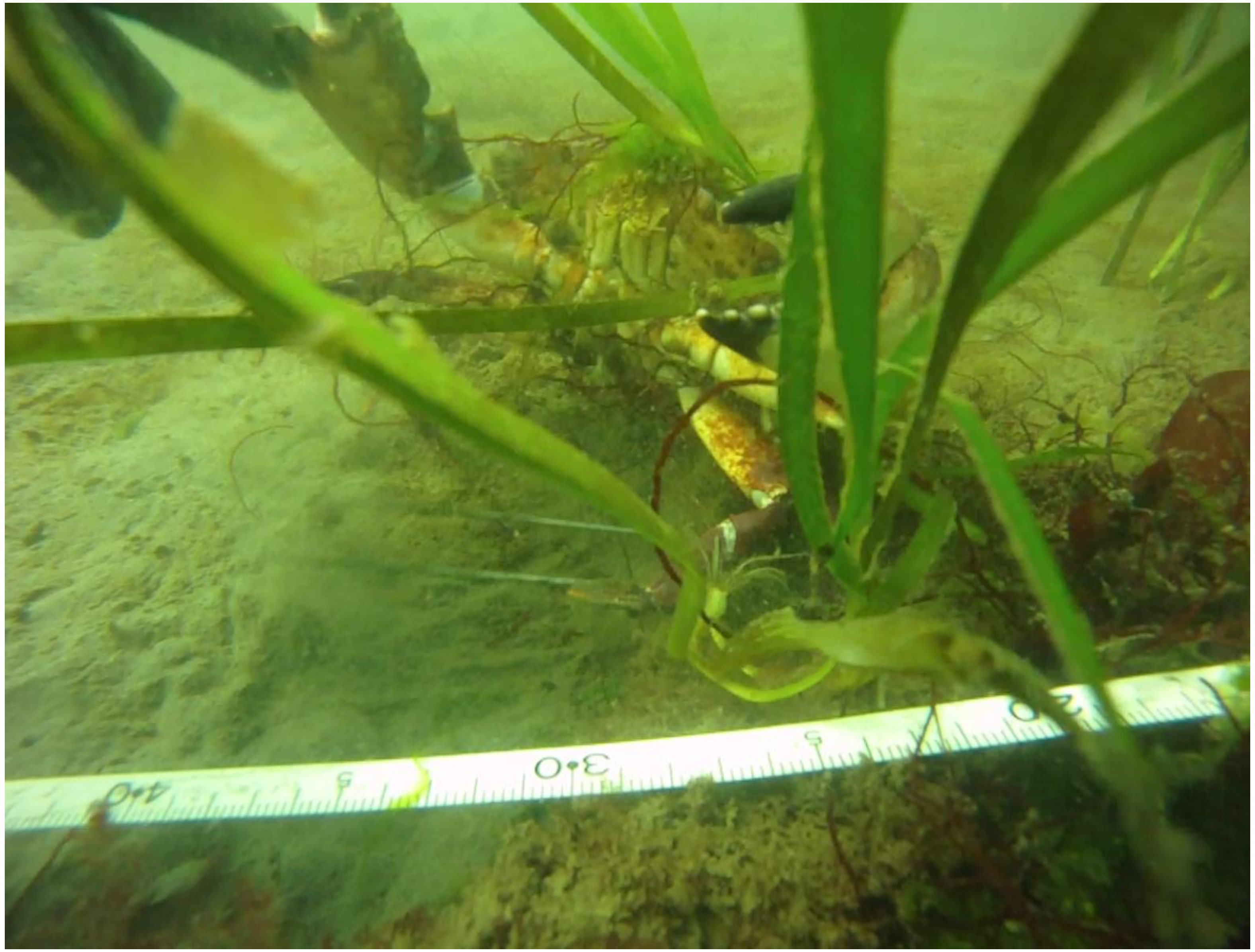
Science is iterative

- Learn from our results
- Apply lessons to next efforts



Thom et al. 2011

Biological disturbances



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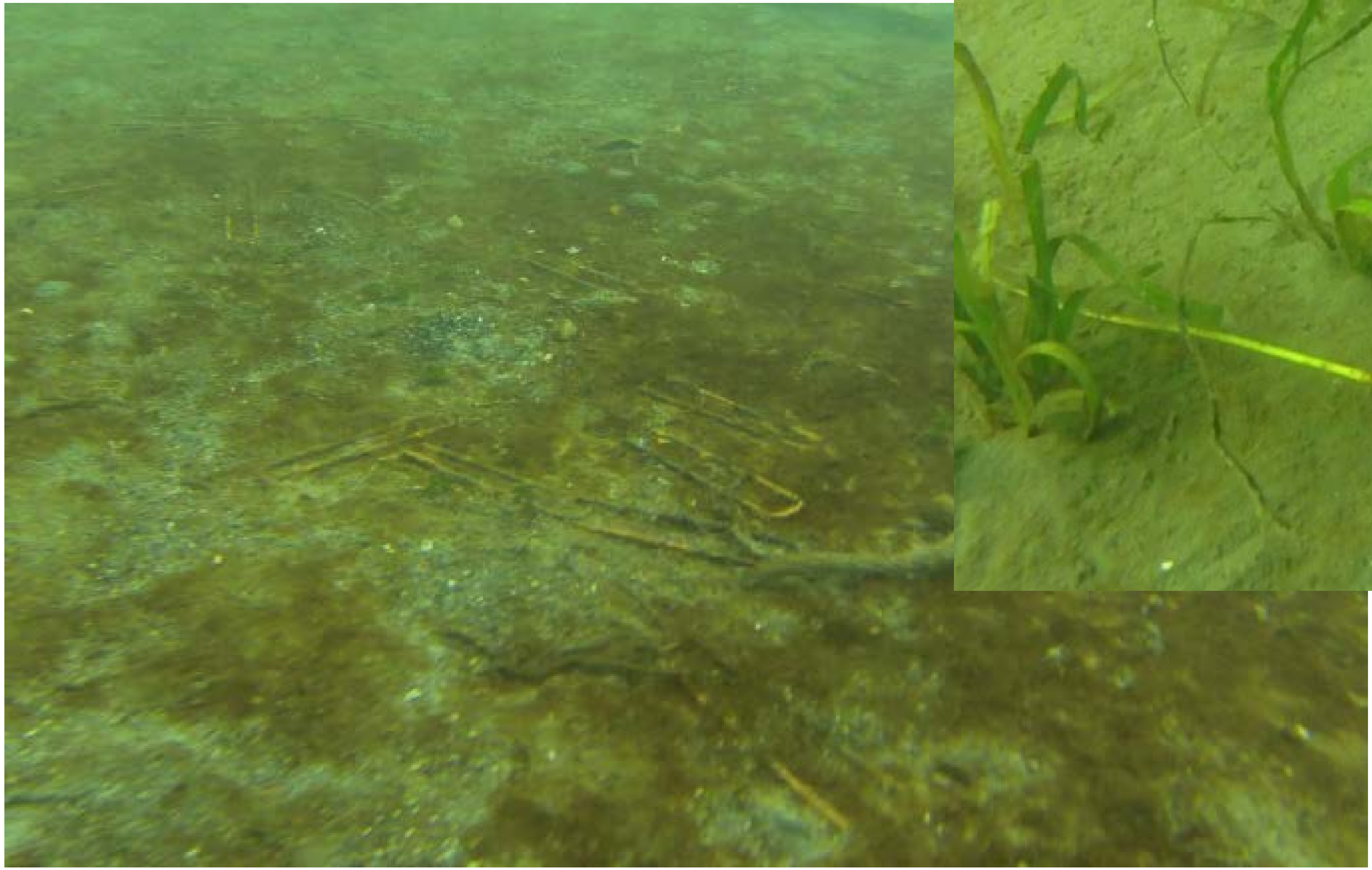
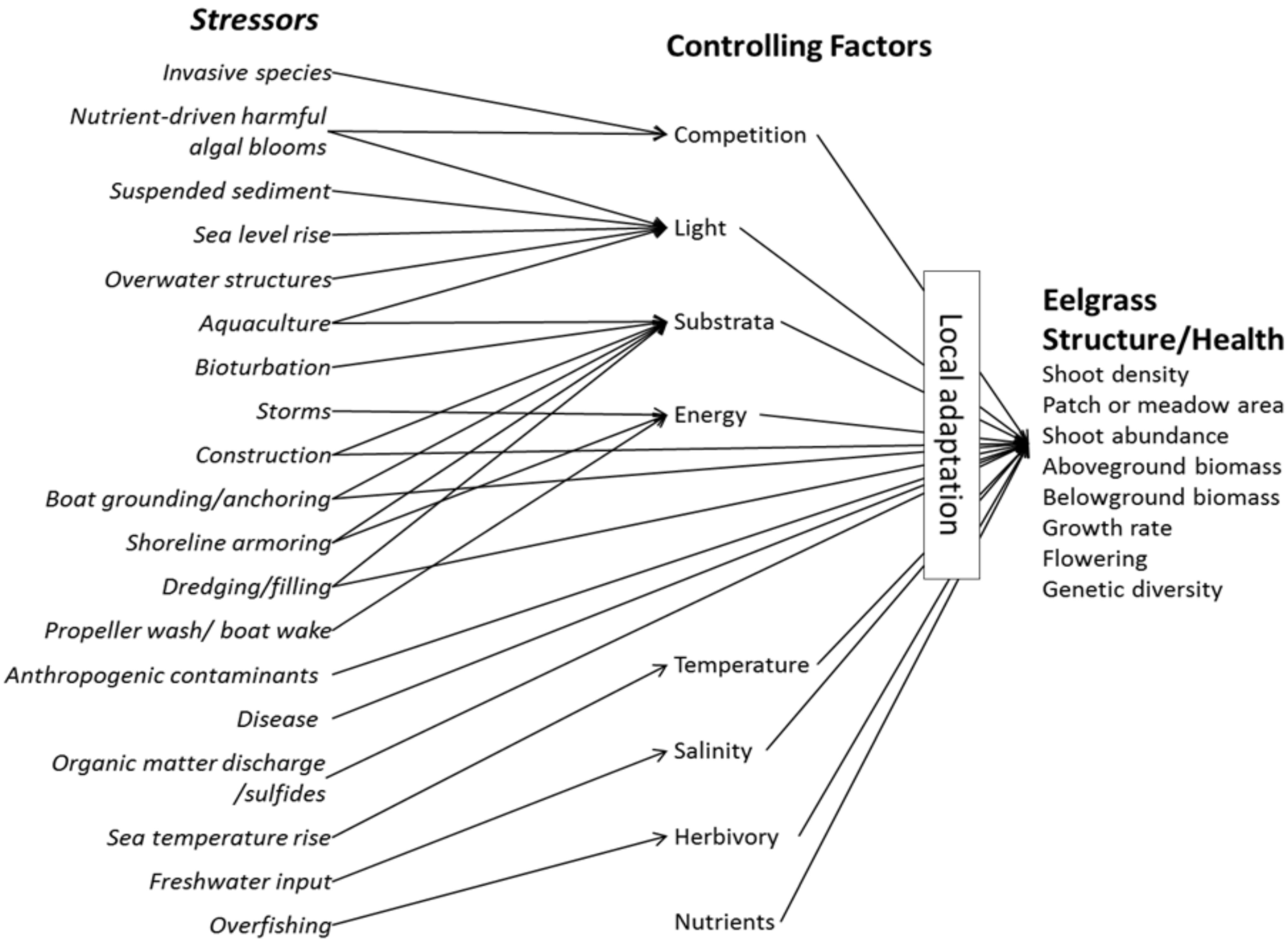
Macroalgal deposition

Unconsolidated sediment





Thom et al. 2011

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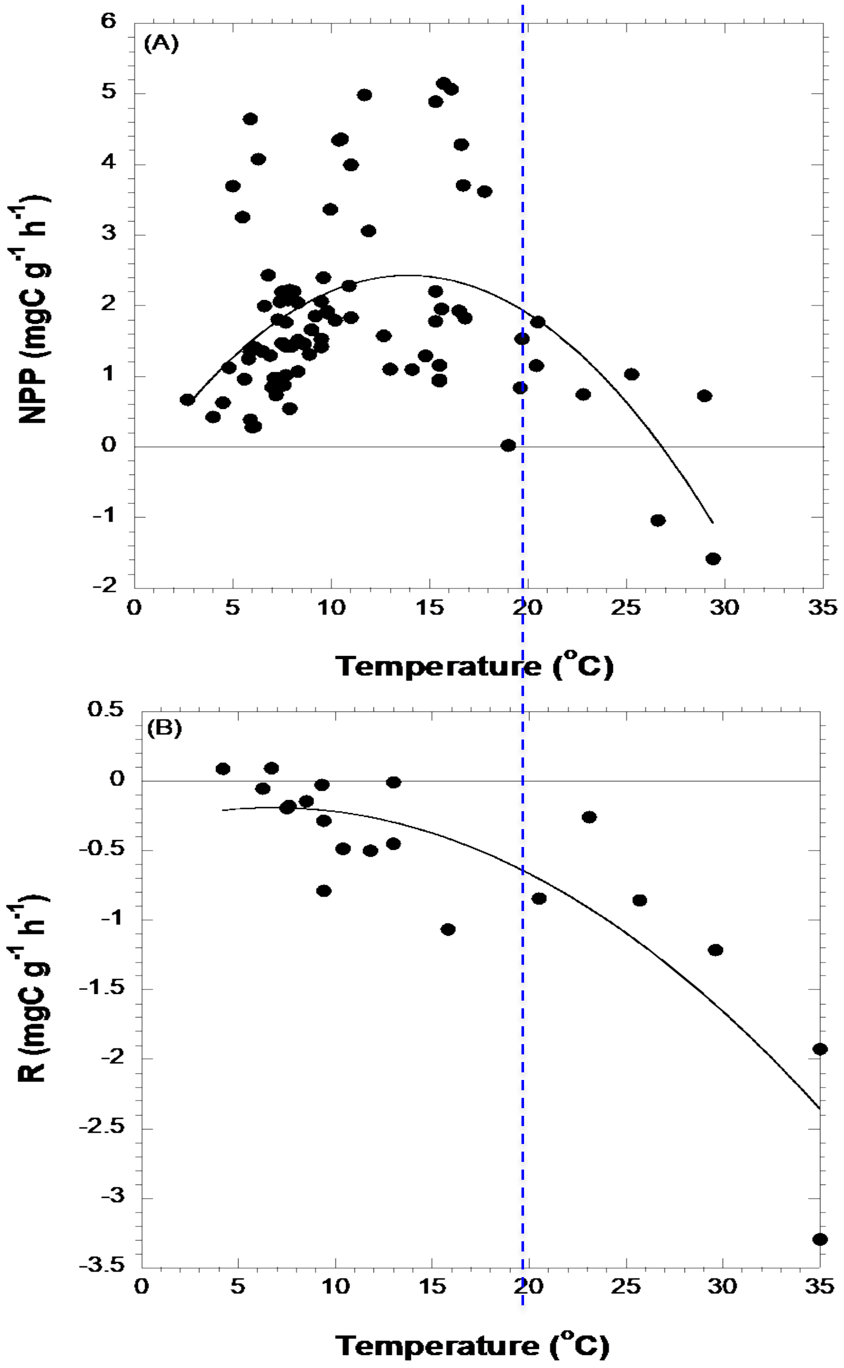
Impacts to Donor Sites

Mouth of Sequim Bay, WA

(Eelgrass growth rate in 21 of 24 summers since 1991)

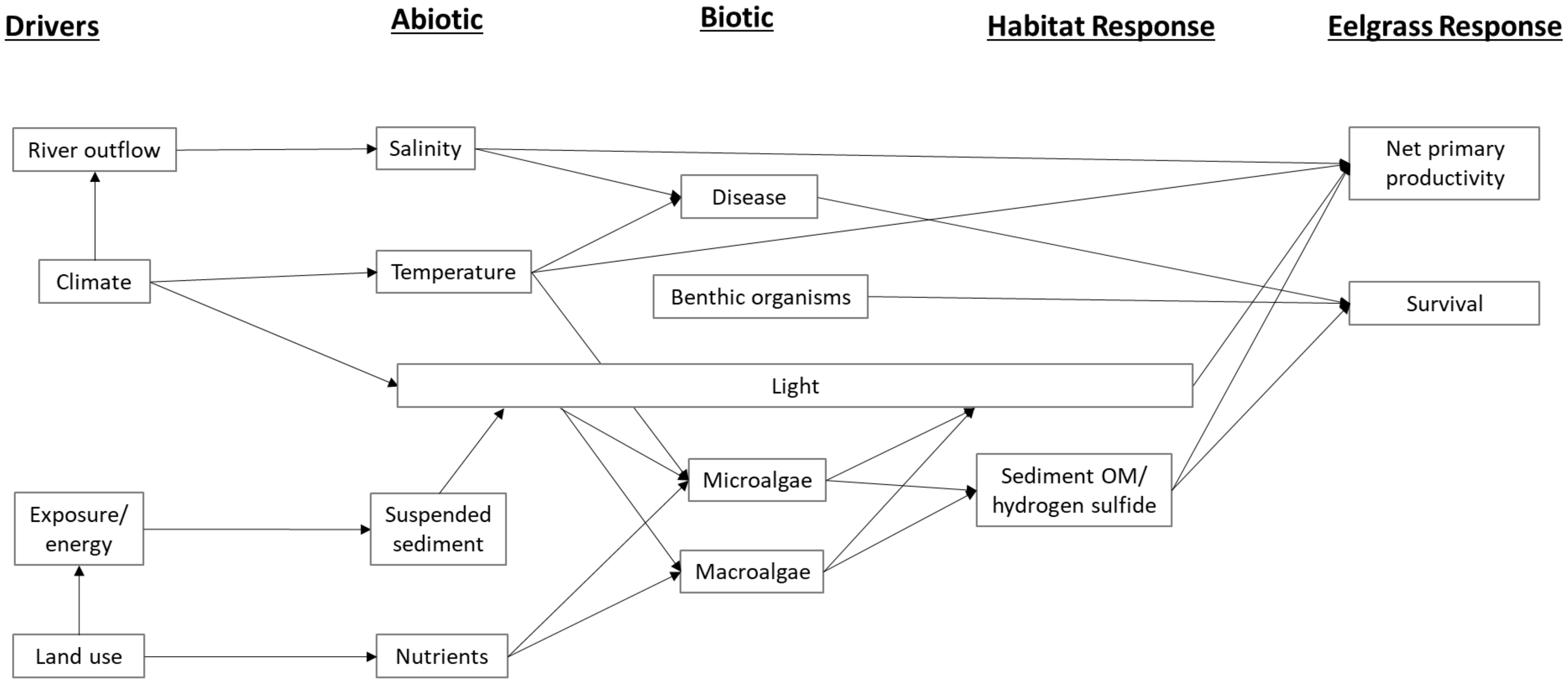
Temperature



Thom et al., 2014

What's Next?

- Continued restoration in Puget Sound
  - 2 large scale sites this year based on test plot results
- Continue climate related research including new mesocosm tanks
  - Temperature response of different populations from Puget Sound
  - Evaluation of eelgrass wasting disease
  - Metabelomics



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THANK YOU!

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Glass: A Common Material Solving An Uncommon Problem – How Do We Immobilize Nuclear Waste?
Jaime George
Tuesday, May 26
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Joseph Laureanti
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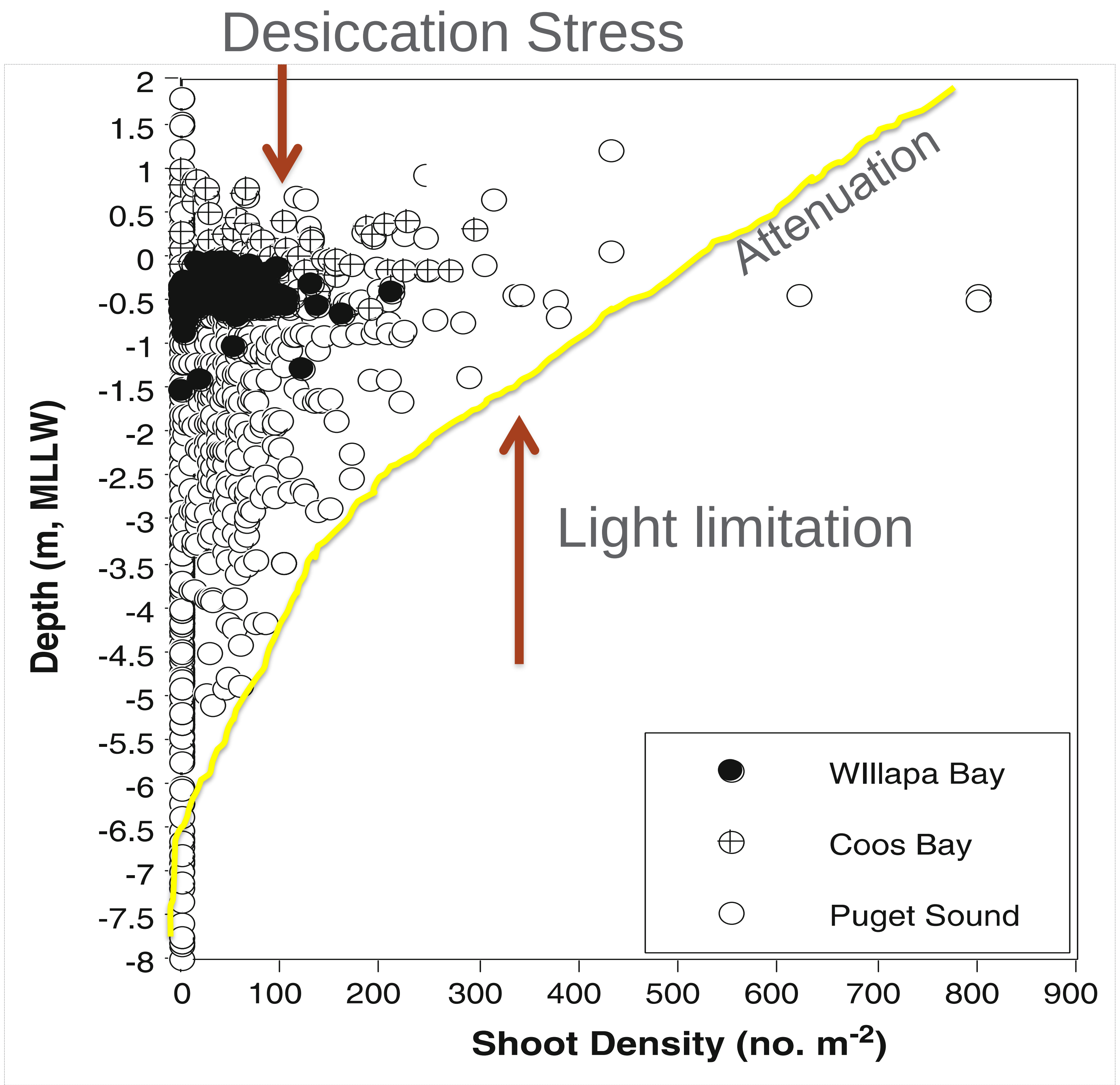
Monitoring Results

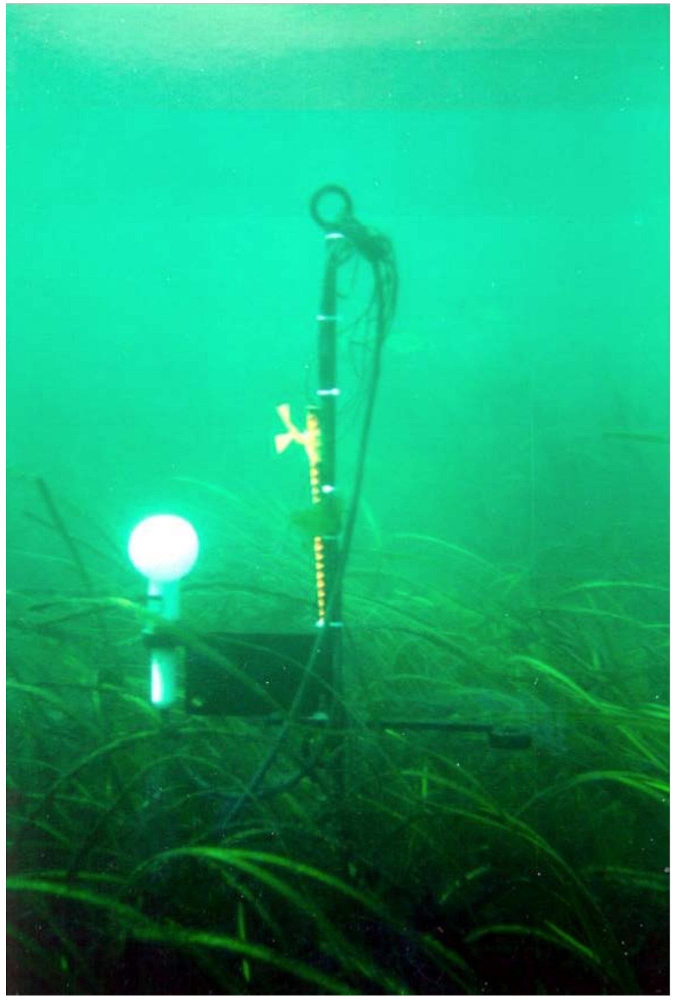
	Joemma North	Joemma South	Anderson	CBay-West	CBay-East	Harstine South	Harstine North
Planted year	**2015**	**2015**	**2017**	**2018**	**2019**	**2018**	**2019**
# Planted	12,000	10,200	10,525	10,825	16,400	9,688	13,320
Year 1	2,286	4,326		6,950	14,892	13,252	35,065
Year 2	37,078	80,680	4,770	10,170		66,057	
Year 3	5,769	62,649	20,682				
Year 4	7,340	246,003					

Monitoring Results (% of planted)

	Joemma North	Joemma South	Anderson	CBay-West	CBay-East	Harstine South	Harstine North
Planted year	**2015**	**2015**	**2017**	**2018**	**2019**	**2018**	**2019**
# Planted	12,000	10,200	10,525	10,825	16,400	9,688	13,320
Year 1	19%	42%		64%	91%	137%	263%
Year 2	309%	791%	45%	94%		682%	
Year 3	48%	614%	197%				
Year 4	61%	2412%					

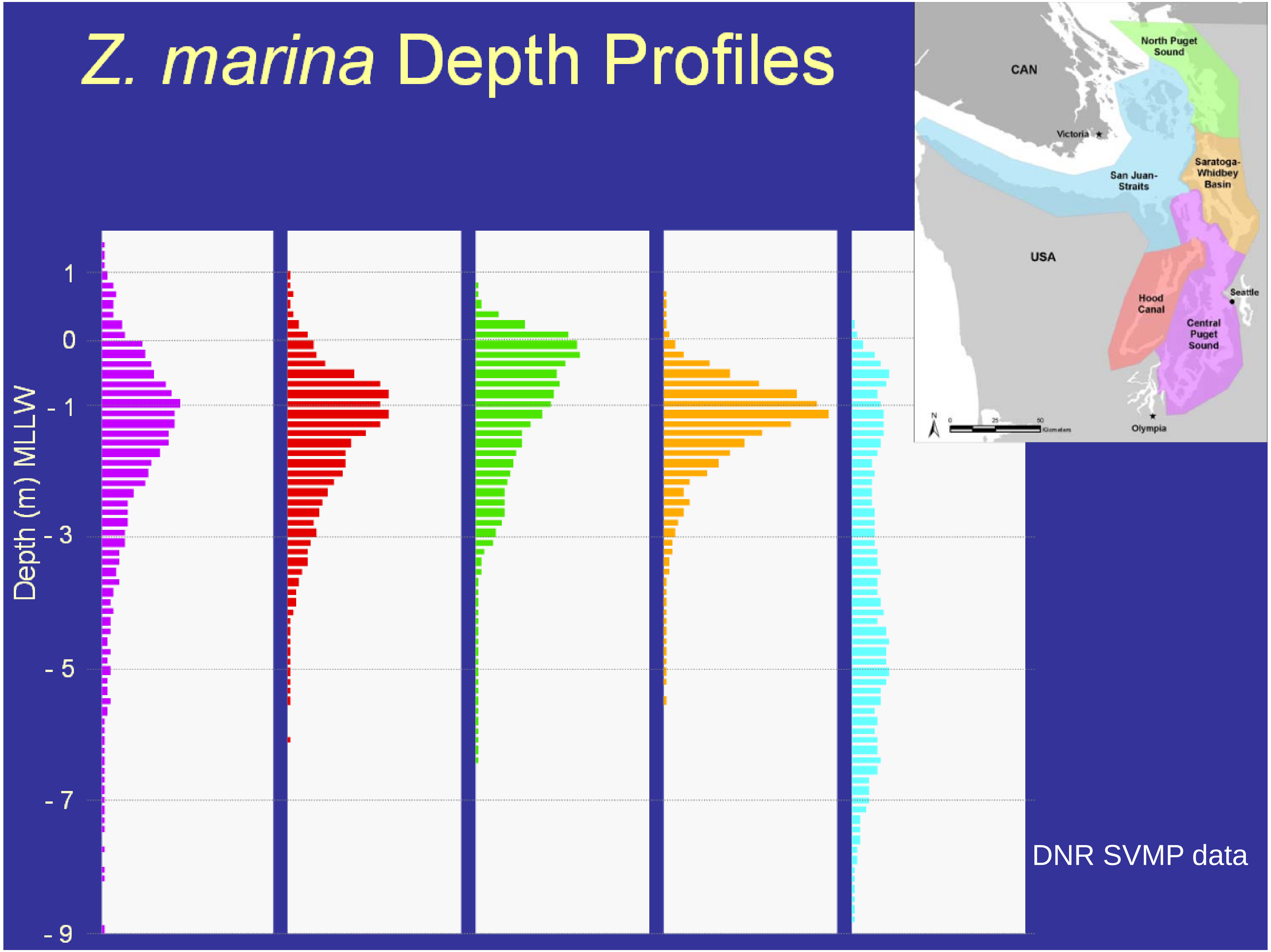
Depth Distribution





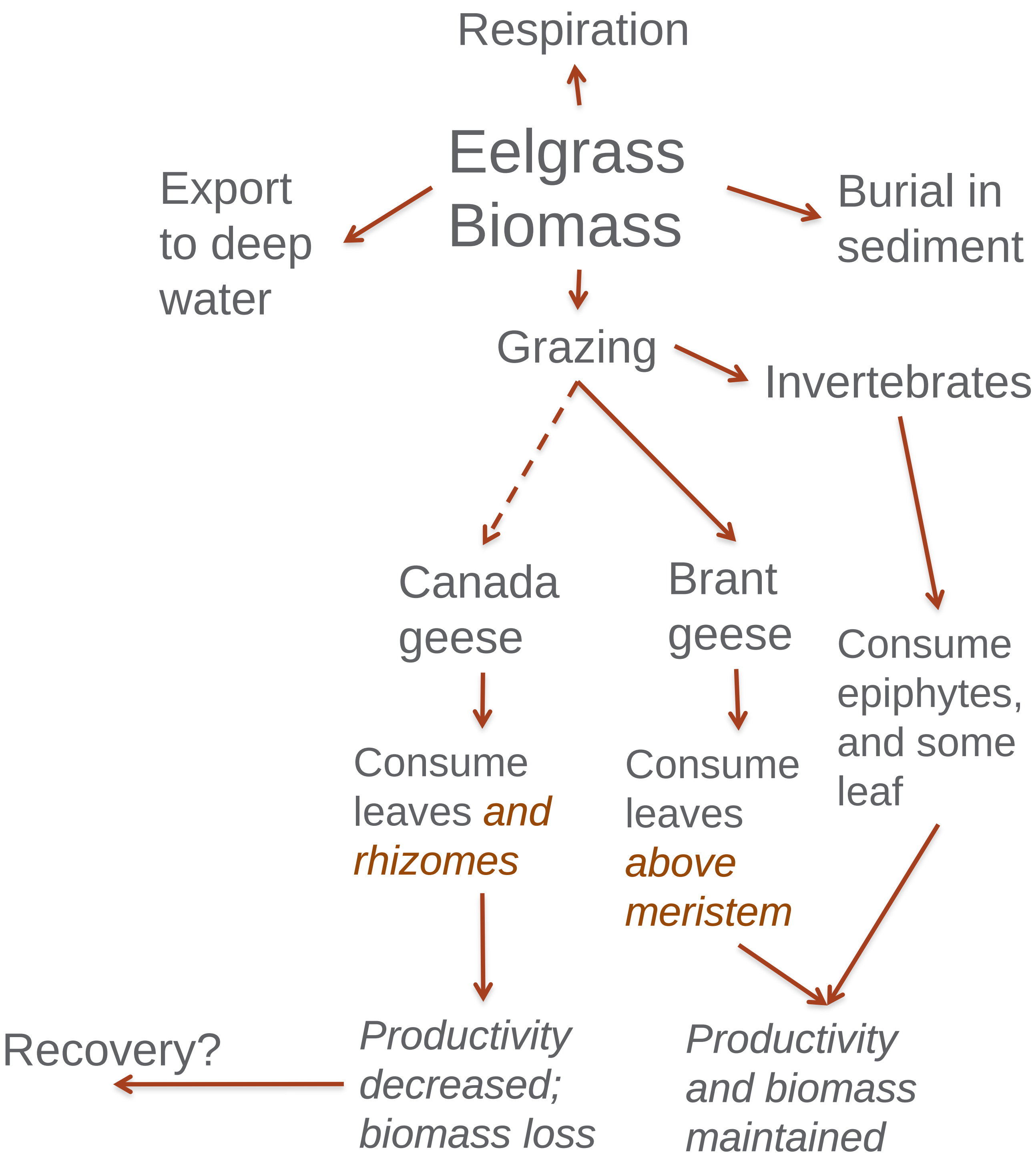
Thom et al. 2003 and 2008

Z. marina Depth Profiles



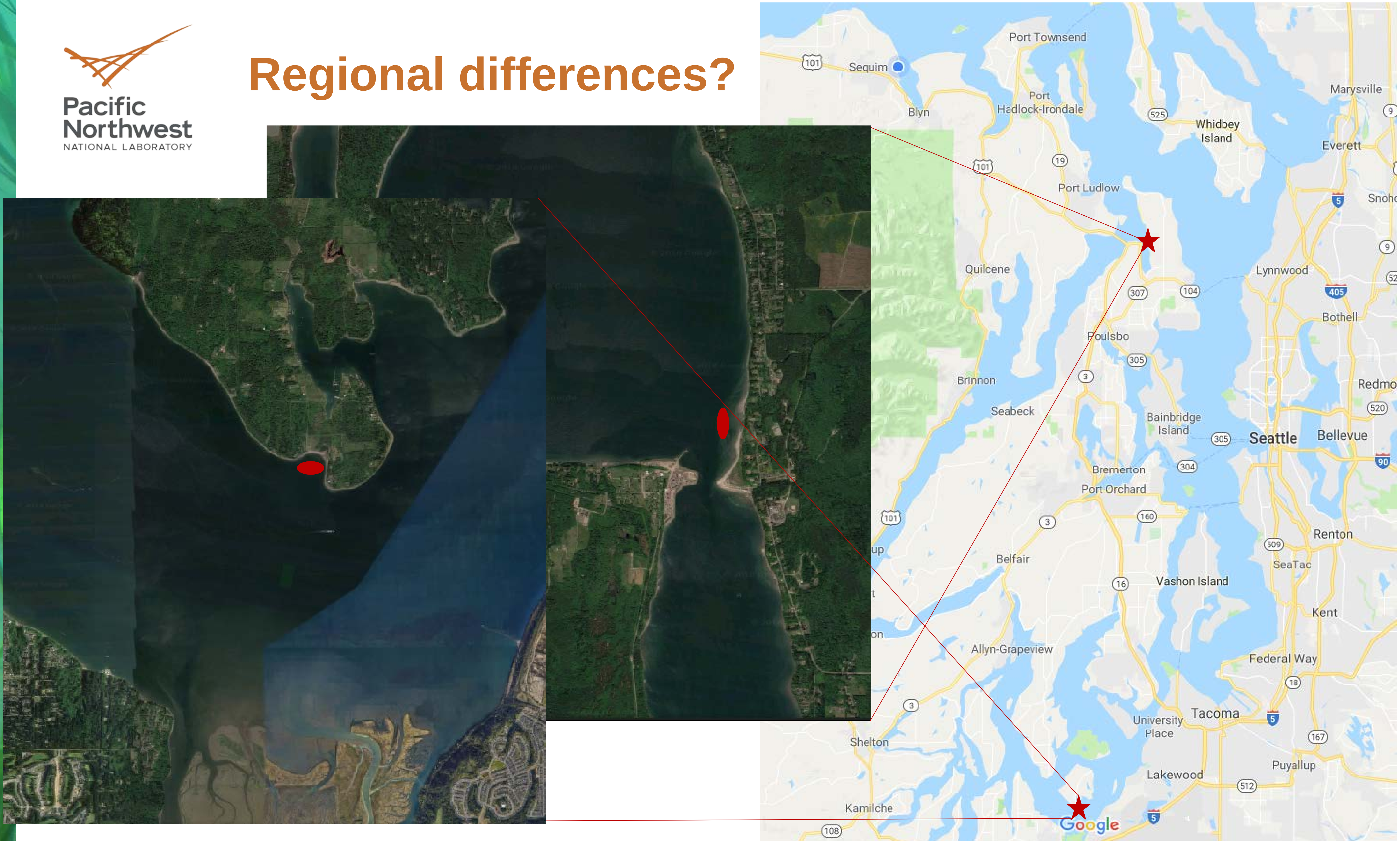
DNR SVMP data

***Hypothesis*: Drought induced diet switch from terrestrial grasses to eelgrass**



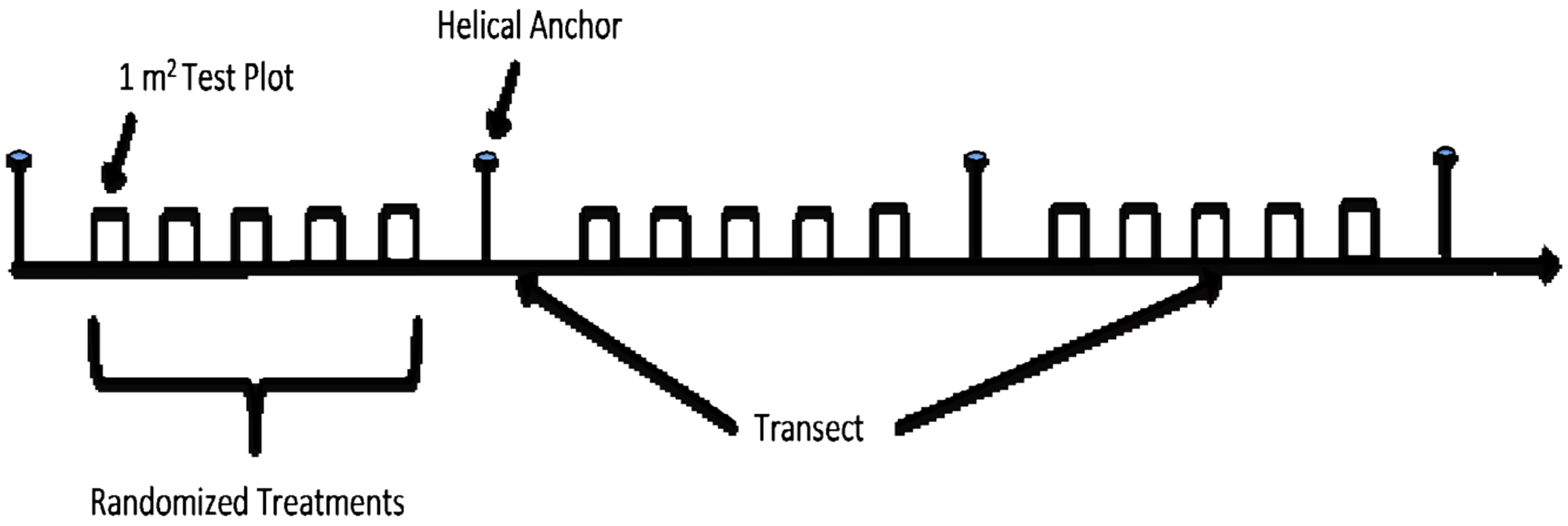
Rivers and Short 2007 documented similar Canada geese grazing effects

Regional differences?



Donor impact experiment

- Randomized block design
- 5 blocks per site
- 5 harvest levels (0, 10, 20, 30, and 50%)



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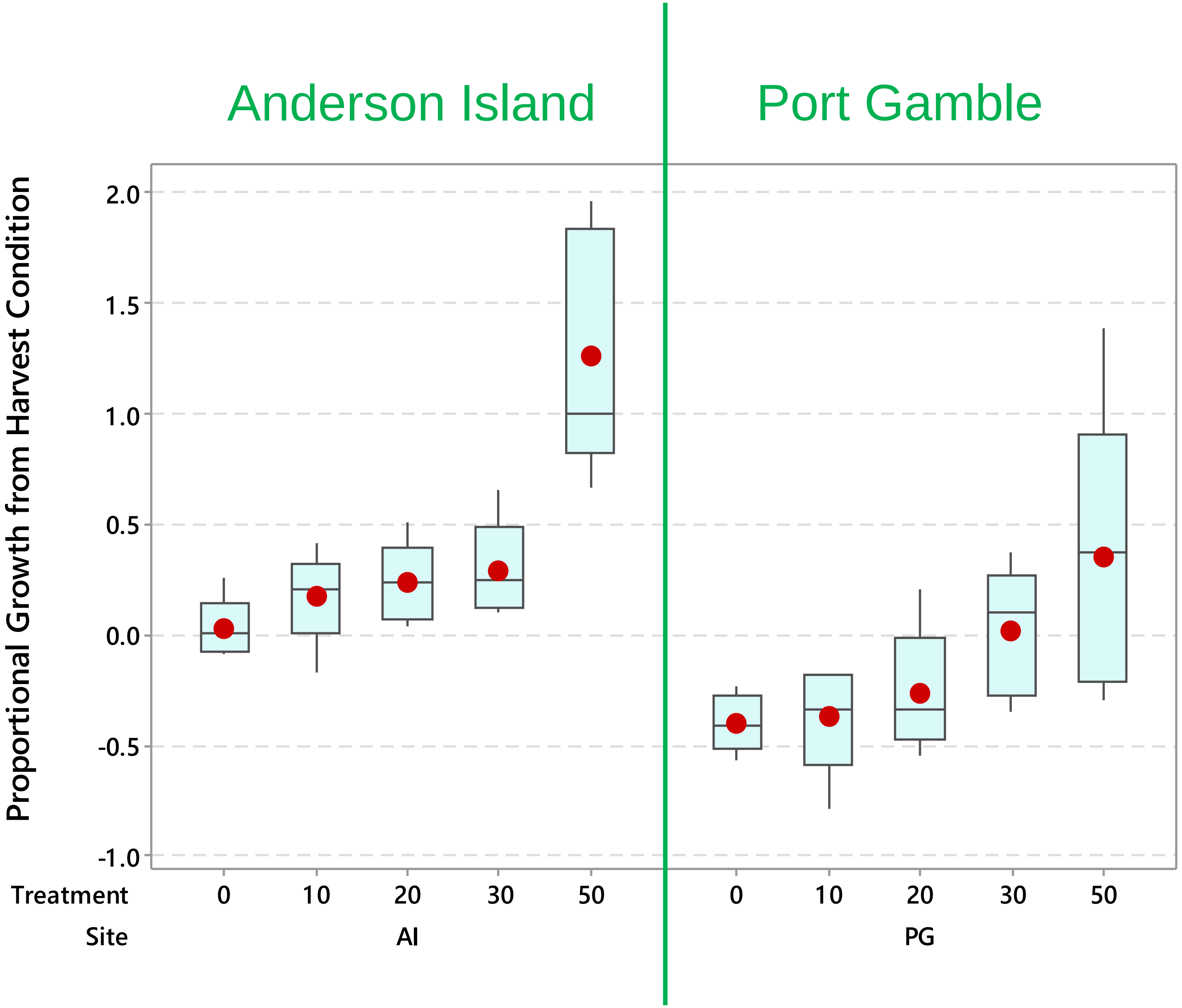
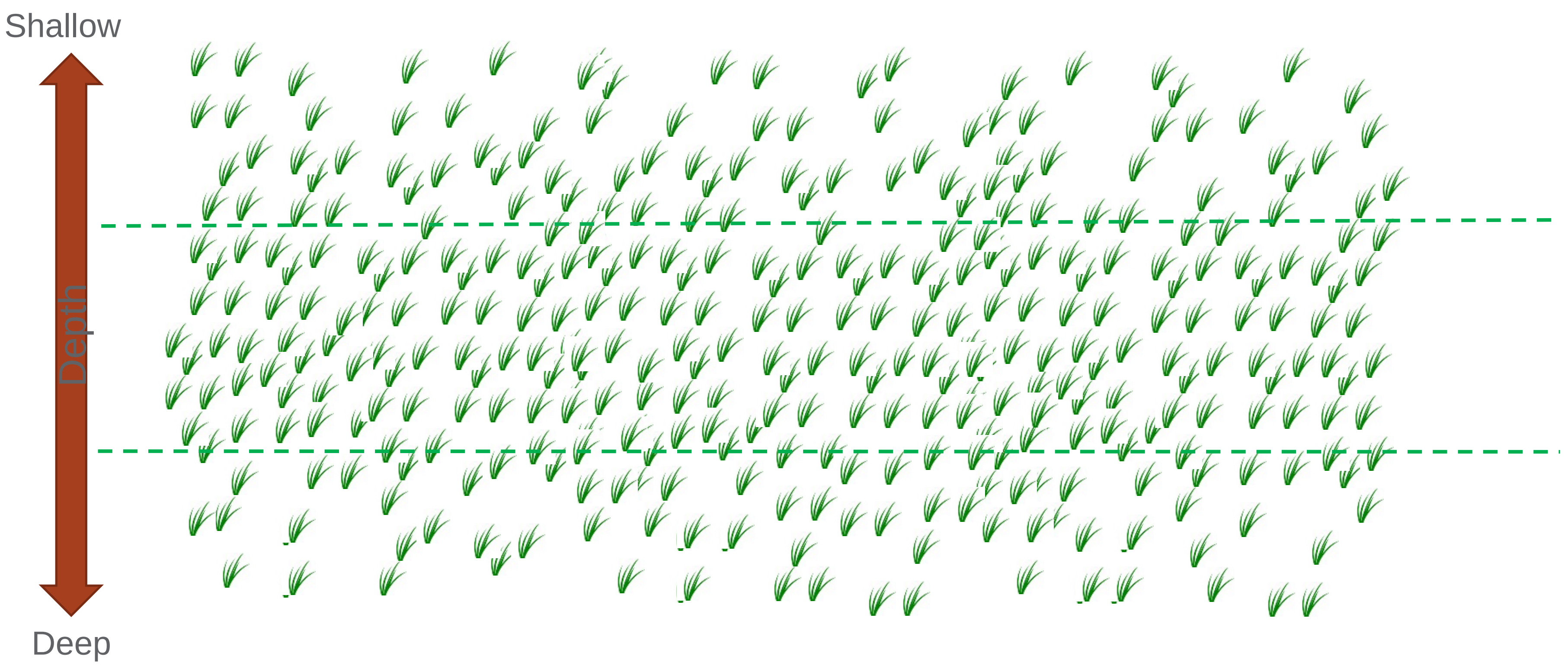
Methodology

Proportional change from harvest (T_2)



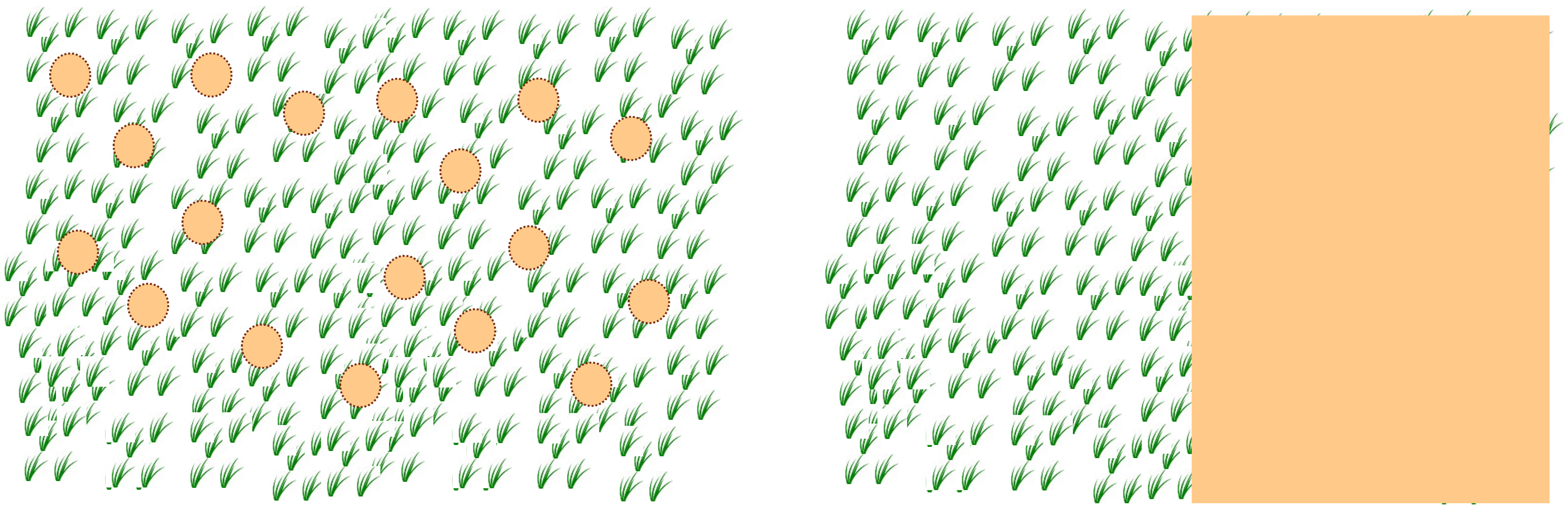
Caveats

- We chose sites with higher densities



Caveats

- We harvested small patches



Conclusions

- Donor sites can probably recover quickly at moderate harvest rates
- Should conservatively harvest no more than 15 or 20% in dense areas
- Use best practices:
  - Remove small patches
  - Do not harvest the edges
  - Avoid low density areas

Clinton Ferry Dock

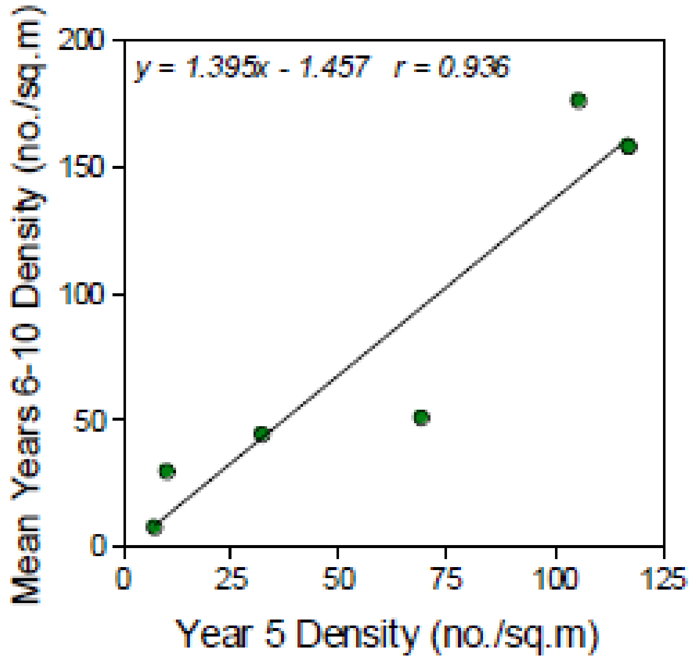


Figure 30. Correlation between the densities of plots (>5 years old) at Year 5 and the average density during Years 6 to 10

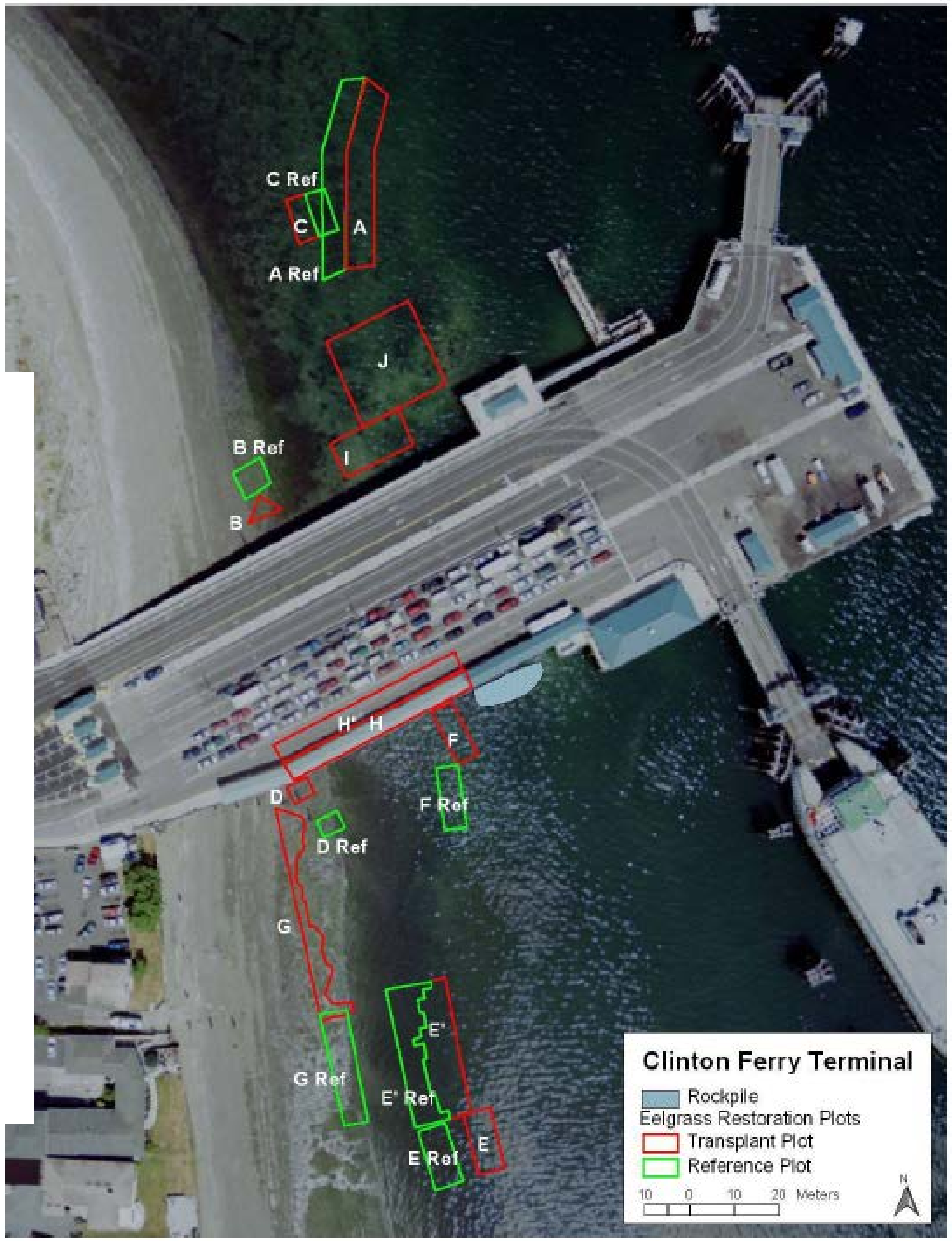


Figure 1. Clinton Ferry Terminal area showing transplant plots, new dock footprint, reference plots, and the rock pile (photograph taken summer 2003; WSDOT)

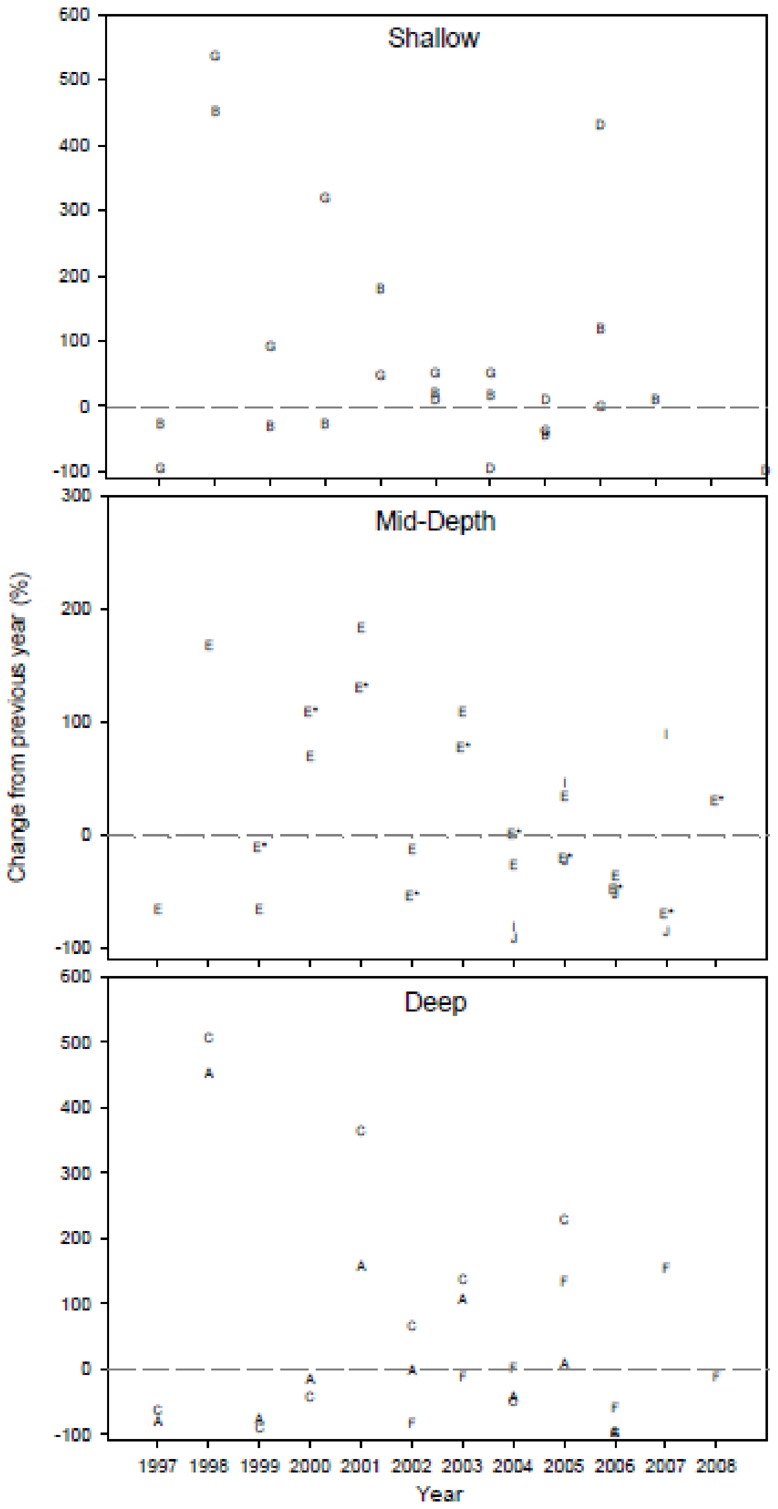


Figure 33. Percent change from the previous year in transplanted plots (separated by depth). Letters indicate plot location.

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