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Plant community and nutrient development within four estuary restoration sites in Kitsap County, Washington

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Plant Community and Nutrient Development within Four Estuary Restoration Sites in Kitsap County, Washington

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Shannon M. Call and Dr. Jenise M. Bauman
April 5th, 2018
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WESTERN WASHINGTON UNIVERSITY

HUXLEY COLLEGE OF THE ENVIRONMENT

1988 2018 30TH ANNIVERSARY SALISH SEA ECOSYSTEM CONFERENCE

Estuaries and Ecosystem Services

Definition

” (a) a semi-enclosed coastal body of water, (b) with a free connection to the ocean, and (c) within which sea water is diluted by freshwater derived from land drainage.” – Cameron and Pritchard (1963)

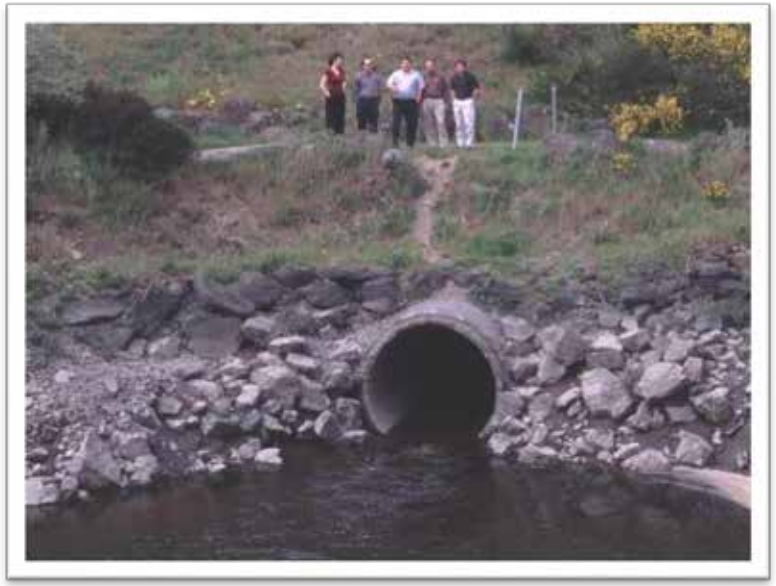
Ecosystem Services

- Nutrient Cycling
- Soil Formation
- Primary Productivity
- Salmon Habitat
- Carbon Sequestration
- Storm Abatement

Degradation of Estuaries:
Structural Degradation

Levee

Agriculture Dike



Culvert

Degradation of Estuaries: Functional Degradation

Soil organic matter input is altered, which restricts microbial communities (Park 2015)

Physically separated animal populations experience a loss of genetic diversity (Horskins, Mather, and Wilson 2006)

Altered hydrology extends drying and flooding periods, which alters microbial communities ability to metabolize organic matter (Flynn 2005; Mitsch and Gosselink 2015; Vincent, Burdick, and Dionne 2013)

Remediation of Estuaries

Process-based restoration is the current focus in restoration ecology

- Biogeochemical Cycling
- Soil Formation
- Primary Productivity

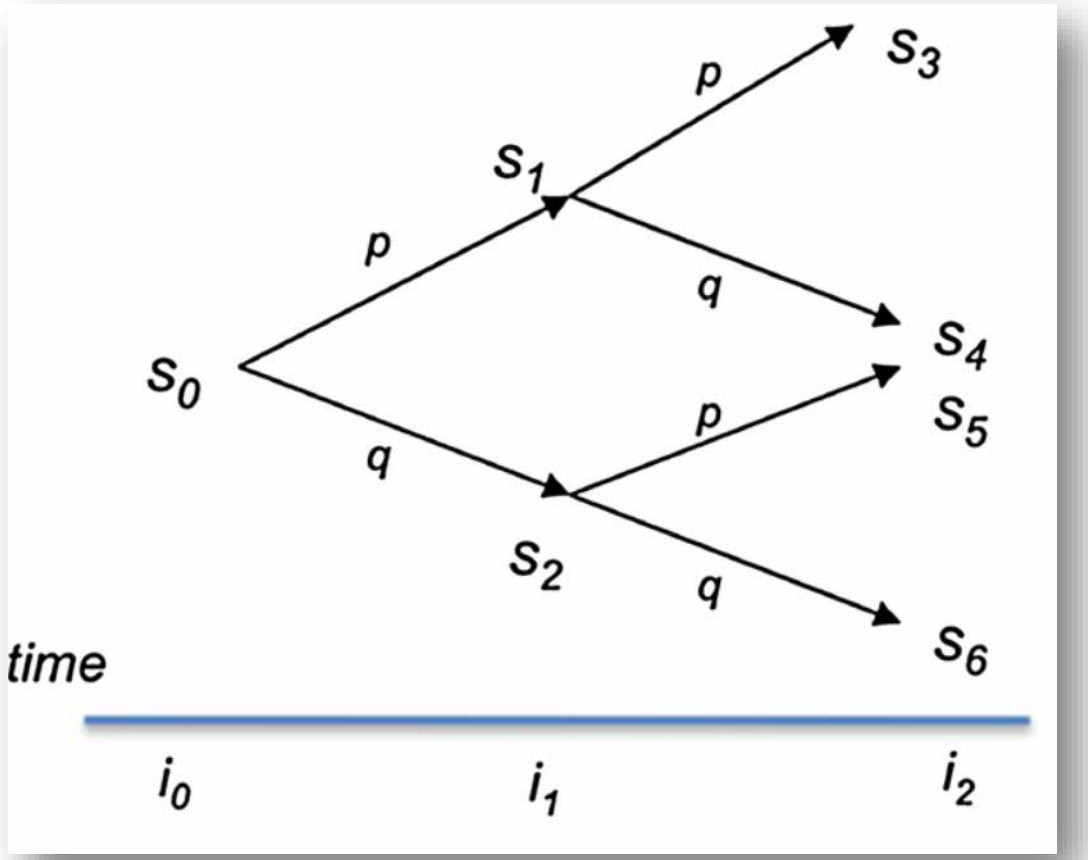
A holistic approach to restoration is considered, including watershed connectivity, energy movement, migration routes, terrestrial vegetation, floodplains, and biophysical processes between abiotic and biotic factors (D'Agostini, Gherardi, and Pezzi 2015; Ward, Malard, and Tockner 2002)

Estuary Restoration via Culvert Removal

Pre-Restoration

Post-Restoration

Path Dependence



State (S) and probabilities (p and q)

The restoration outcome can be defined as a community characterized in terms of species abundance

Priority effects suggests that the first plant species to colonize a restoration site will influence the recruitment of other species. Depending on which species colonizes first, or even later, will affect the trajectory restoration

Difficulties in Path Dependence

If invasive species colonize upon restoration, this could lead to an alternate stable state and lead to a novel system

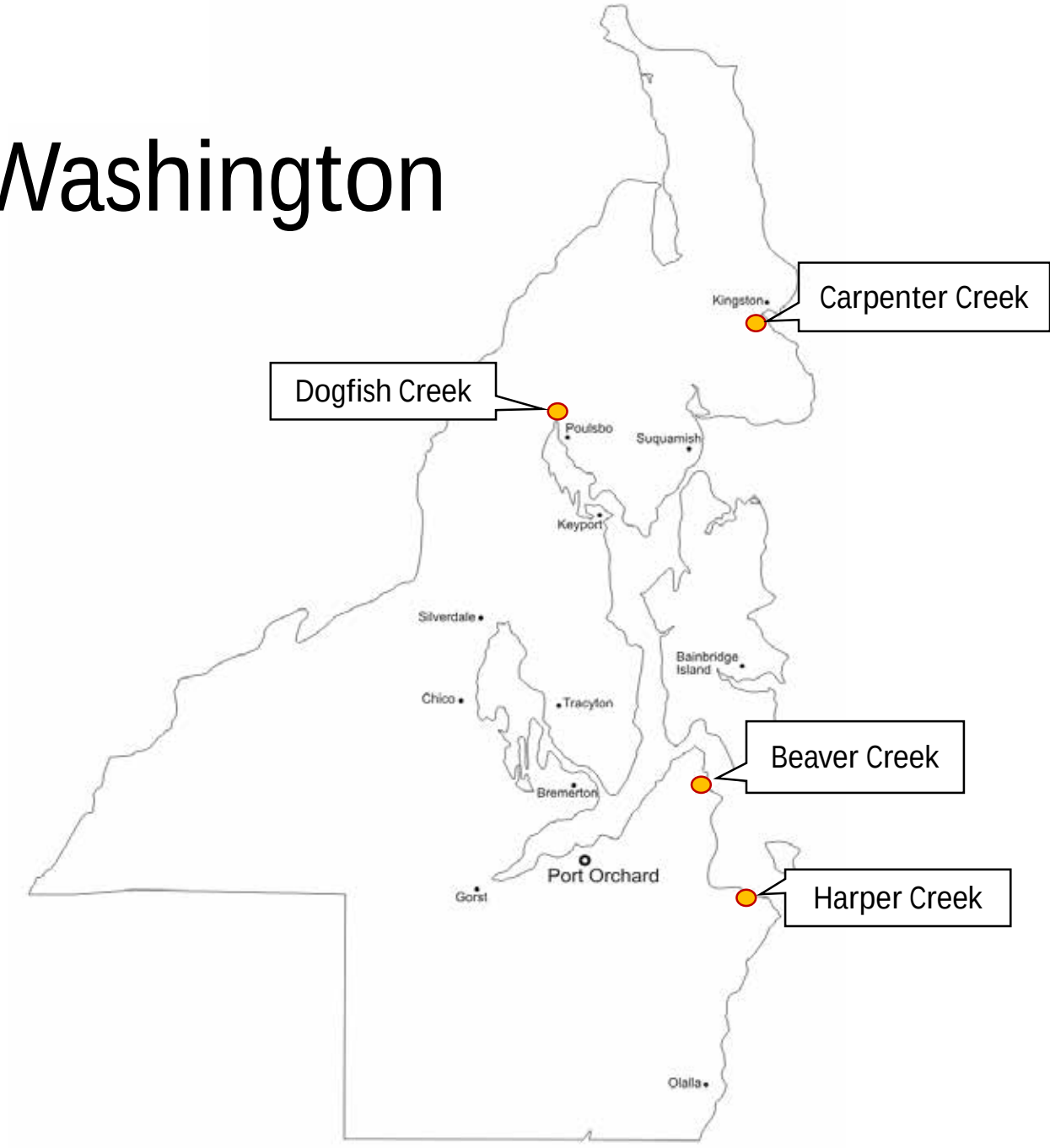
Some species of concern in the PNW include:

- Spartina
- Scotchbroom
- Cordgrass
- Japanese Knotweed
- Reed Canary Grass
- Common Reed

Research Questions

1. Are soil carbon, organic matter, and nutrients increasing?
2. Does plant species diversity increase over time?
3. Will plant communities homogenize between location?
4. Does time since restoration affect plant invasibility?

Site Map: Kitsap County, Washington



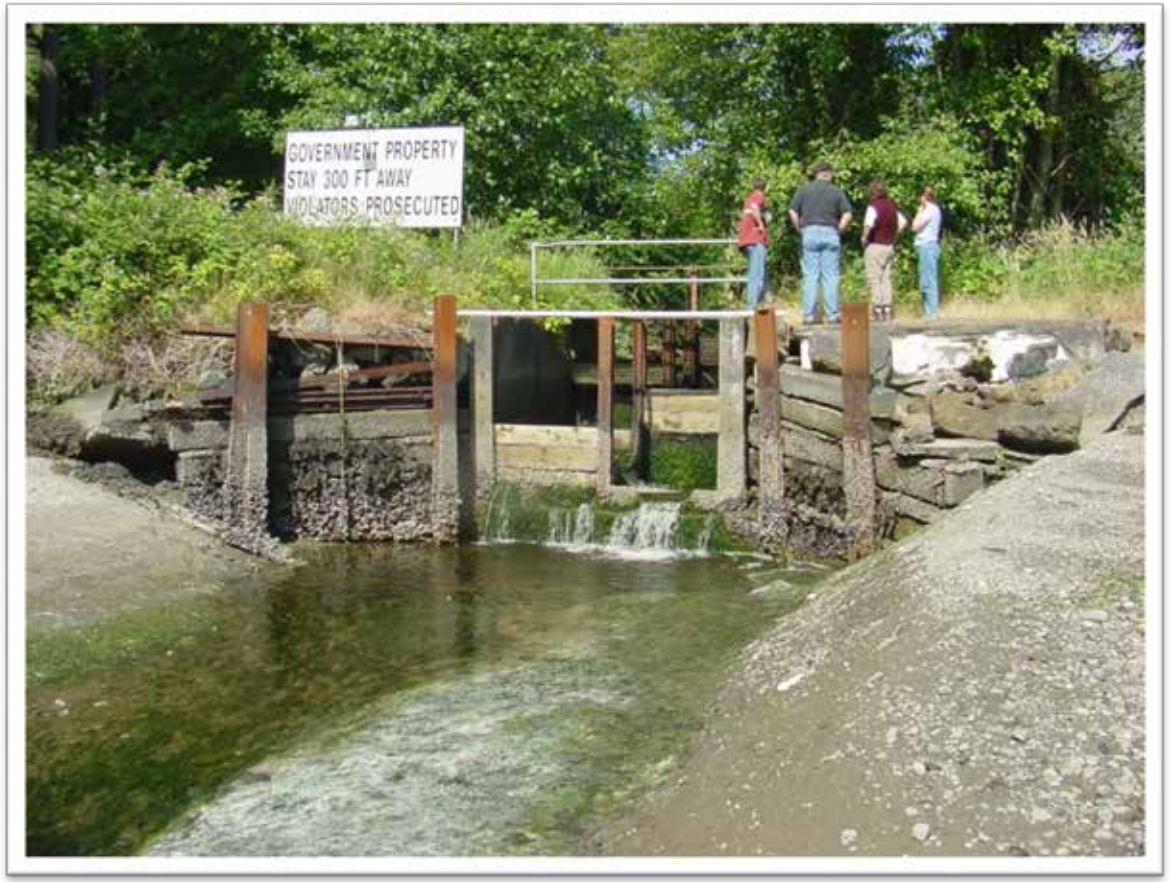
Harper Creek; Port Orchard, WA
Pre-Restoration

Project Supported by: Asarco Mitigation Funds; Salmon Recovery Board; WDFW; West Sound Watersheds Council; Kitsap County DCD and Public Works.
Photos from: Habitat Work Schedule

Carpenter Creek; Kingston, WA
3 Years post-restoration

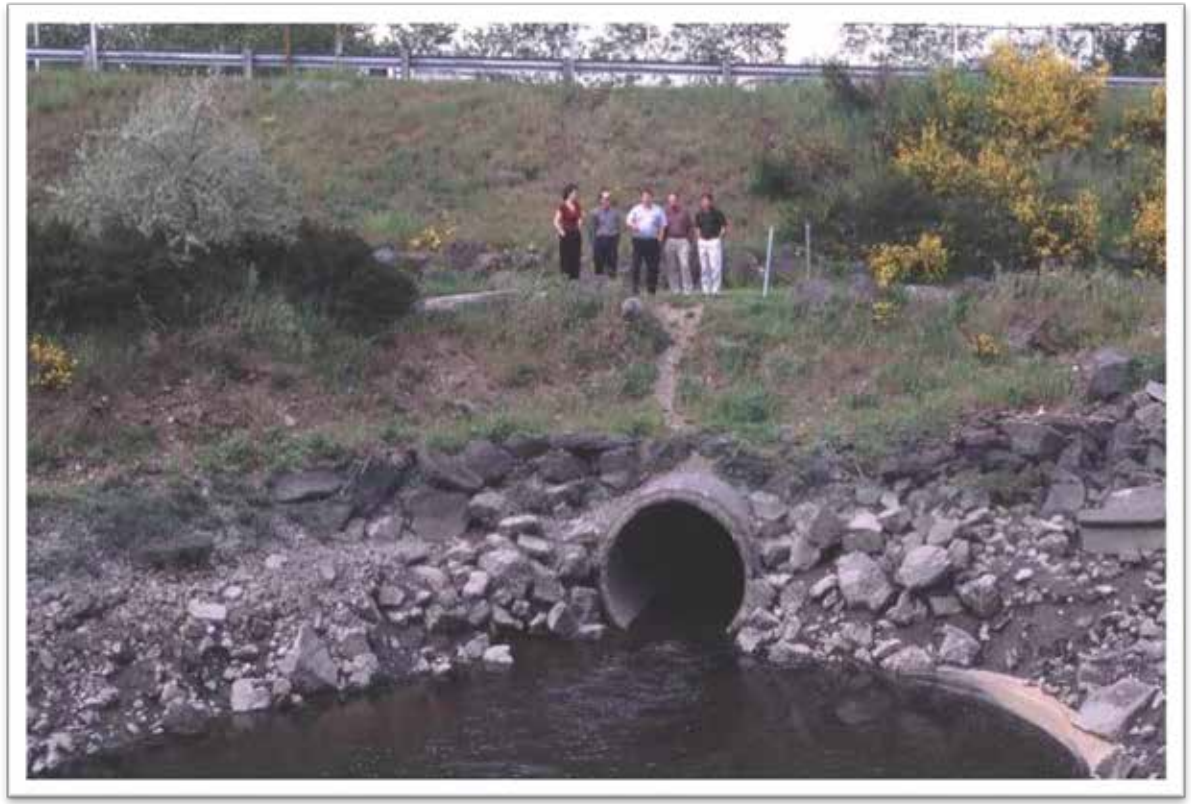
Project Supported by: Kitsap County; Stillwaters Environmental Center; WDFW; West Sound Watersheds Council; Kitsap County DCD and Public Works. Photos from: Habitat Work Schedule 2017

Beaver Creek; Manchester, WA
9 Years post-restoration



Project Supported by: West Sound Watersheds Council; Mid-Puget Sound Fisheries Enhancement Group; Department of Defense – US Navy. Photos from: Habitat Work Schedule 2017

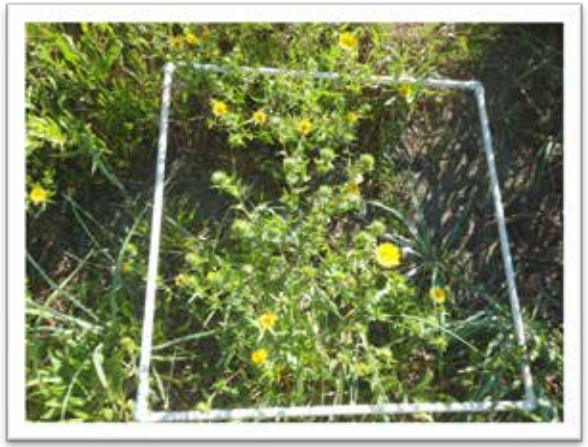
Dogfish Creek; Poulsbo, WA
12 years post-restoration



Project Supported By: West Sound Watersheds Council; Salmon Recovery Funding Board; City of Poulsbo; Suquamish Tribe. Photos from: Habitat Work Schedule 2017

Vegetation Sampling and Soil Collection

- Six, 50-meter transects –
  3 above and 3 below (N=24)
- Three quadrats were randomly placed along each transect for soil collection, biomass, and plant height.
- “Plants of the Pacific Northwest Coast” – Pojar and MacKinnon
- “Flora of the Pacific Northwest” – Hitchcock and Cronquist



Weight Loss-on-Ignition: Soil Organic Matter

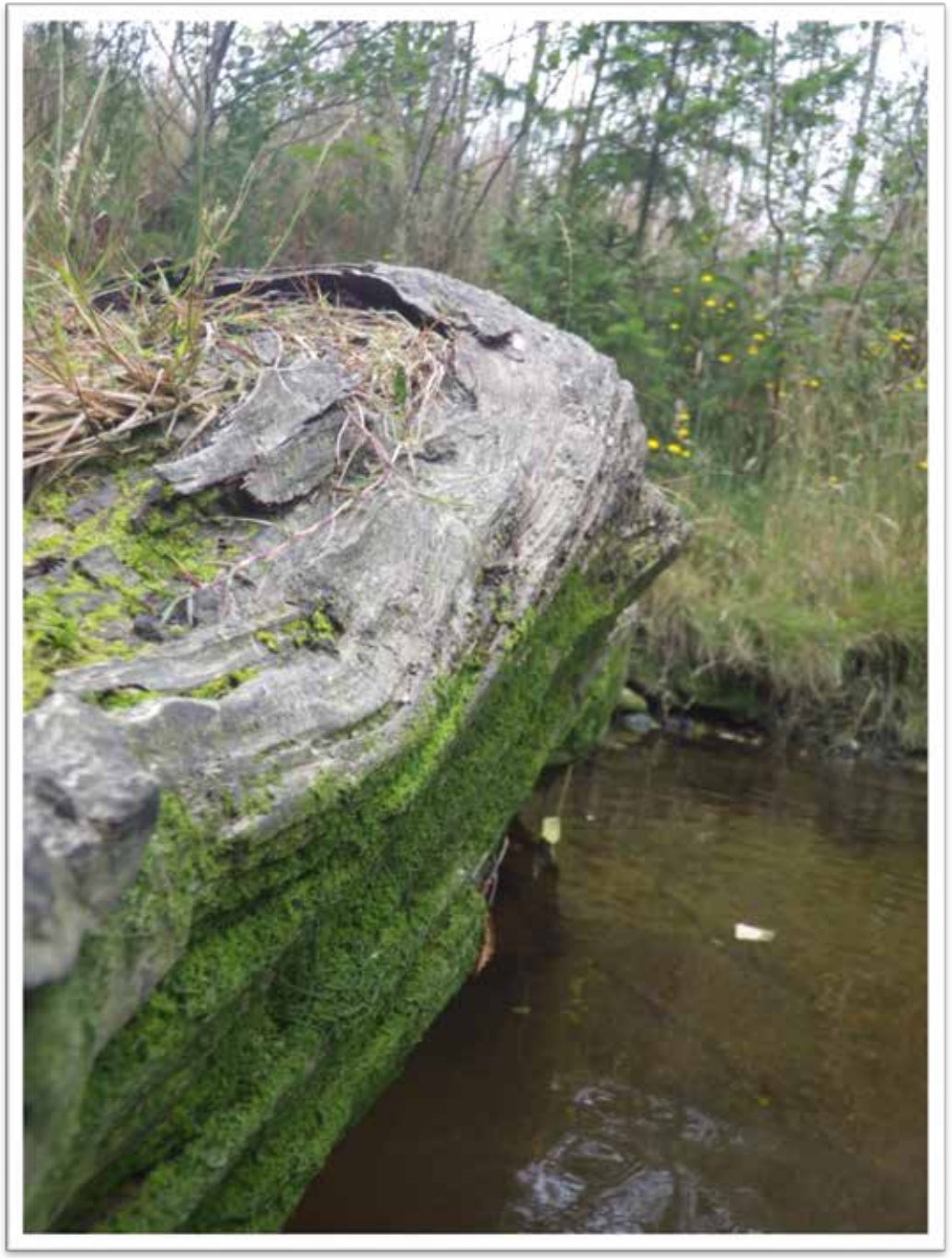
- Soil was dried overnight at 110°C to remove any absorbed water
- 2-3 grams of soil was heated at 550°C for four hours
- The difference in weight after being heated was compared to the pre-heated weight
- This tells us roughly how much organic matter was in the sediment

CN Analysis

- 100 mg was combusted at 950°C
- Percent composition of nitrogen and carbon gas was measured
- Used to determine how much nitrogen and carbon were in samples
- Estuaries sequester large amounts of carbon, CN Analysis assessed a trajectory of carbon sequestration recovery

Soil Nutrients

- Macro- and micronutrients:
  - Phosphorus
  - Potassium
  - Magnesium
  - Calcium
  - Sulfur
  - Boron
  - Copper
  - Iron
  - Manganese
  - Zinc
- Soil samples were sent to Spectrum Analytical for nutrient analysis

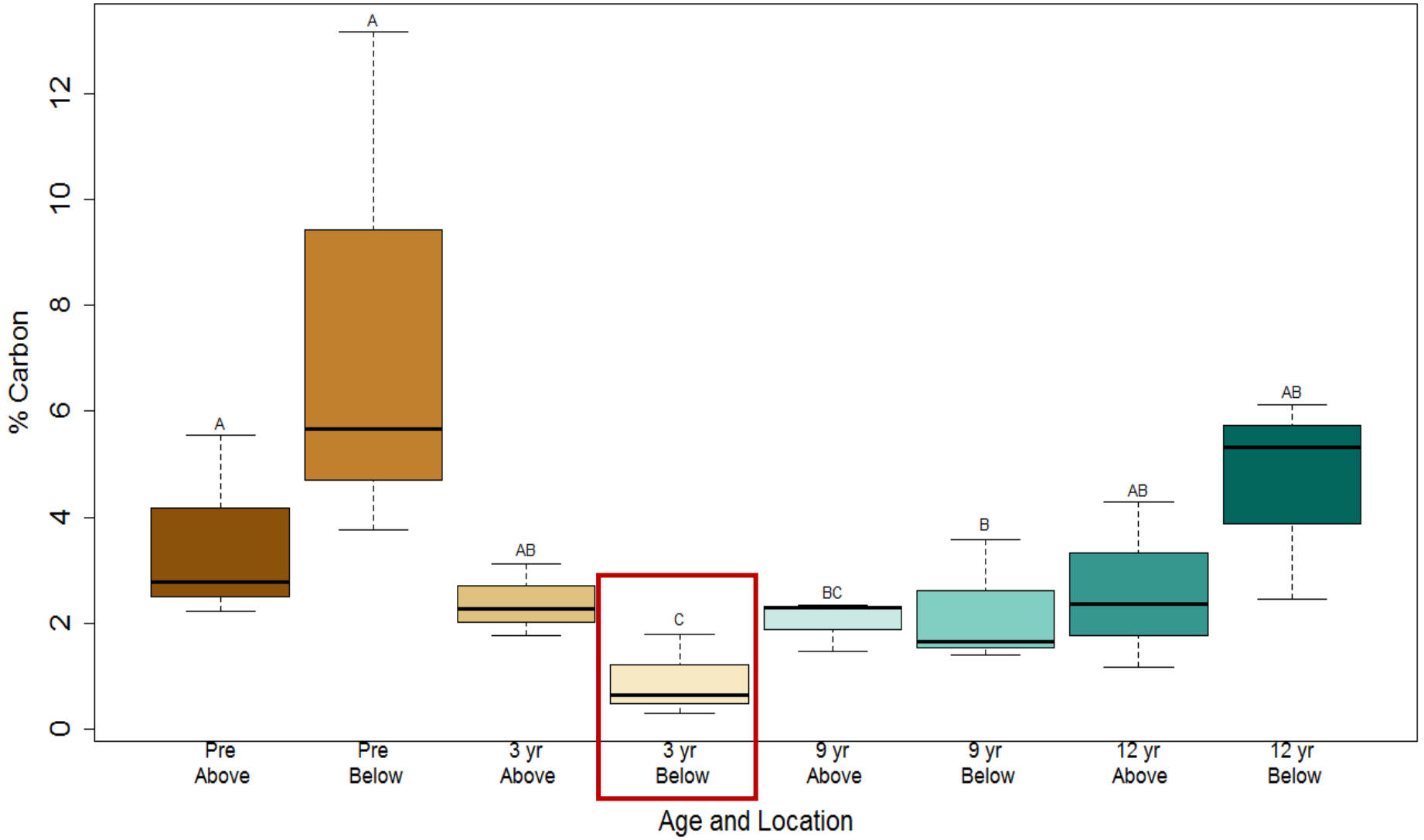


Results

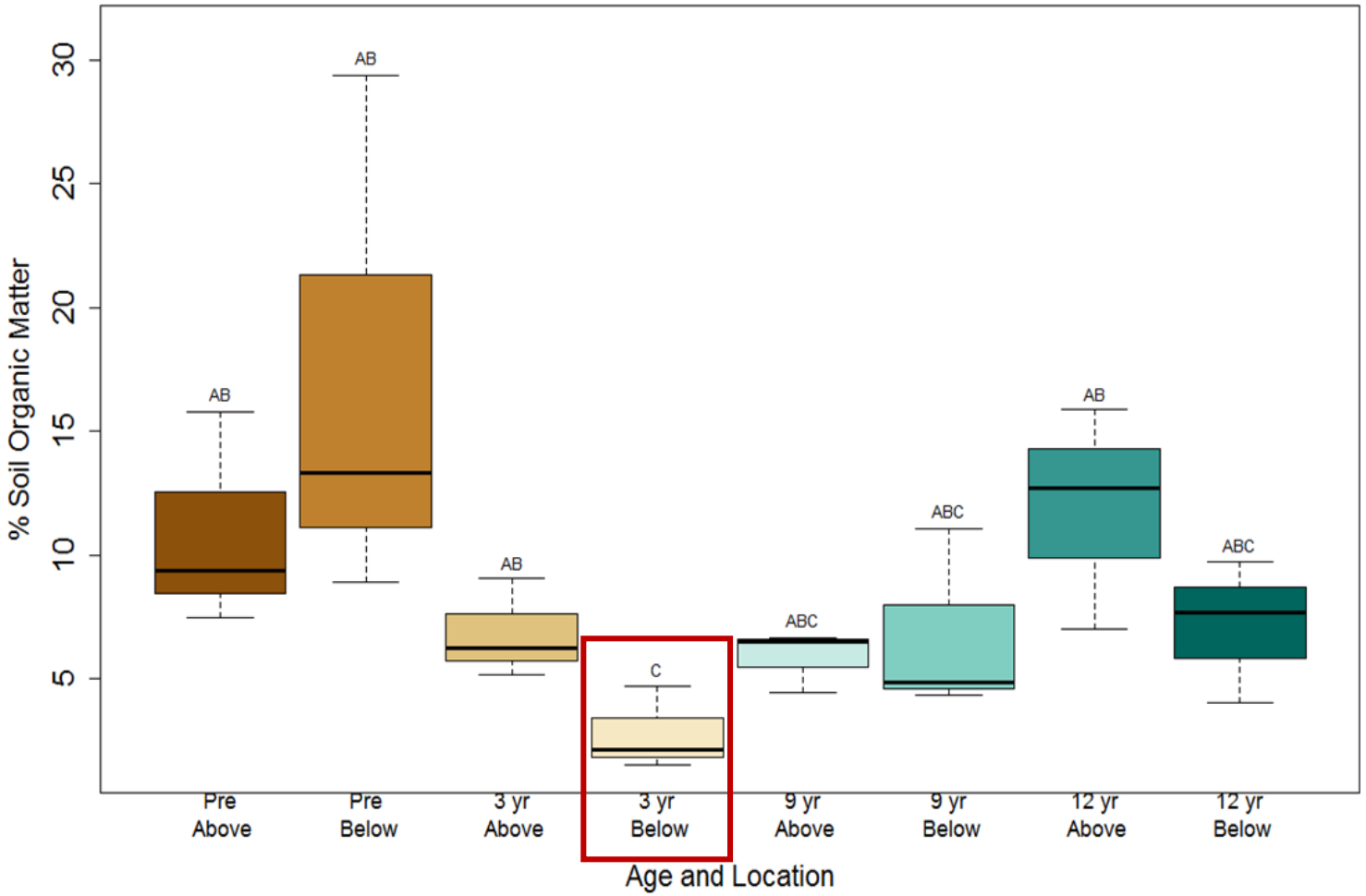
- **Soil**
  - **Carbon**
  - **Organic Matter**
  - **Nutrients Homogenization**
  - **Nutrient Deficiencies**
- Vegetation
  - Native Species
  - Invasive Species
  - Diversity (H‘)
  - Species Assemblages

Soil: Carbon

- There was a significant interaction between site and location (*P*=0.03)
- The newest post-restoration site was significantly lower in soil carbon than most sites



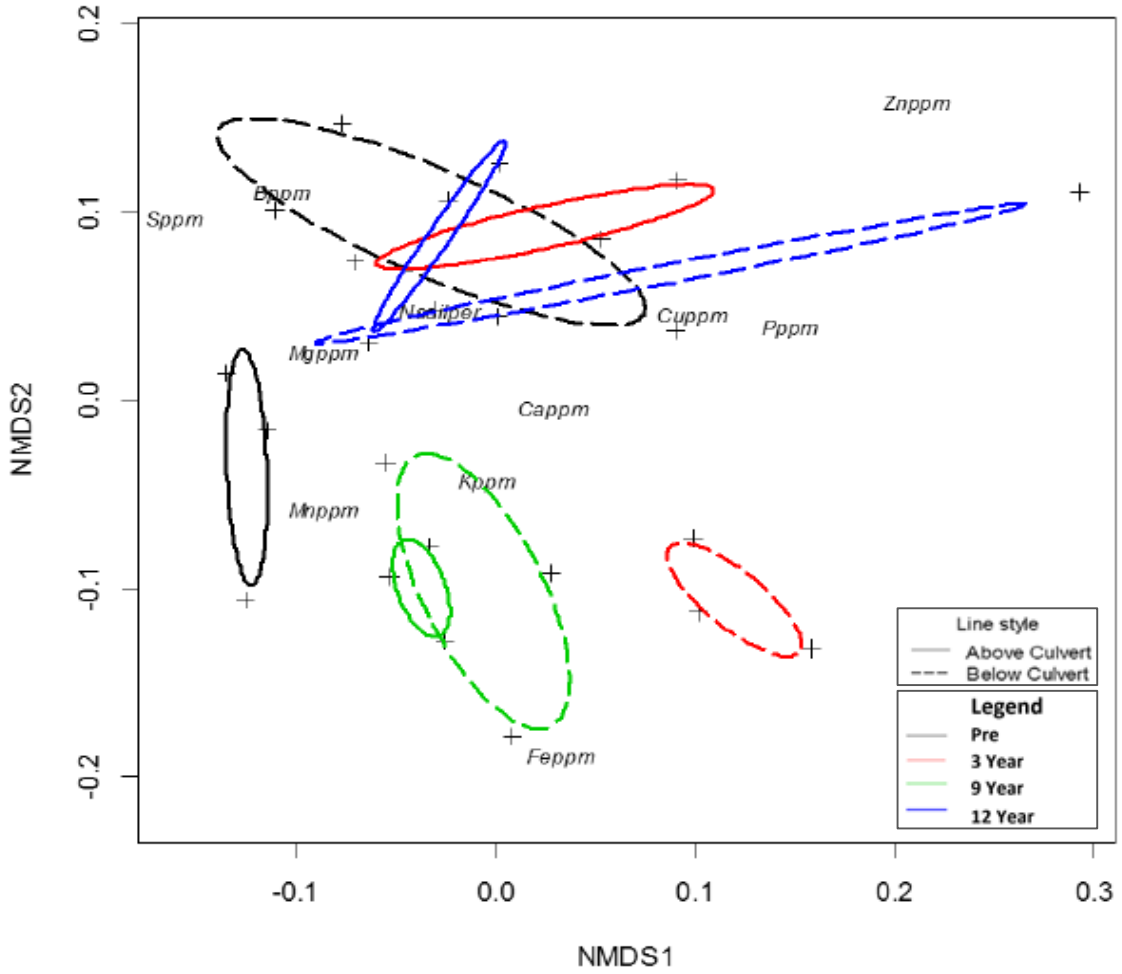
Soil: Organic Matter



- Significant difference in Soil Organic Matter at the newest post-restoration site when compared to the pre-restoration site ($P<0.01$)
- Sites recently restored show lower soil organic matter
- We may be seeing a trend of increasing soil organic matter after restoration

Soil: NMDS Nutrients per Site and Location

- Sites are shown as plus (+) symbols
- Ellipses indicate where 95% of sites are expected to occur
- Differences were noted among sites (P<0.005; N=23; Stress = 0.10)
- Soil nutrients were different between location, above and below, at the newest and pre-restoration sites.



Soil: Nutrient Deficiencies

Site	Nutrient	Site Range (ppm)	Normal Range (ppm[a])
Pre	Potassium (K)[A]	204 - 461	100 - 2,000
	Magnesium (Mg)[A]	600 - 1713	1,200 - 15,000
	Boron (B)[A]	1.6 - 10.9	5 - 150
	Iron (Fe)[AB]	104.9 - 375.9	5,000 - 50,000
	Manganese (Mn)[A]	35 - 189	200 - 10,000
3 yr	Potassium (K)[B]	65 - 305	100 - 2,000
	Magnesium (Mg)[A]	69 - 914	1,200 - 15,000
	Boron (B)[A]	0.2 - 7.8	5 - 150
	Iron (Fe)[B]	110.6 - 212.7	5,000 - 50,000
	Manganese (Mn)[B]	8 - 62	200 - 10,000
9 yr	Potassium (K)[B]	209 - 237	100 - 2,000
	Magnesium (Mg)[A]	205 - 969	1,200 - 15,000
	Boron (B)[A]	0.8 - 2.4	5 - 150
	Iron (Fe)[A]	298.7 - 363.2	5,000 - 50,000
	Manganese (Mn)[B]	17 - 87	200 - 10,000
12 yr	Potassium (K)[AB]	240 - 362	100 - 2,000
	Magnesium (Mg)[A]	441 - 1,180	1,200 - 15,000
	Boron (B)[A]	0.9 - 6.0	5 - 150
	Iron (Fe)[AB]	211.4 - 324.6	5,000 - 50,000
	Manganese (Mn)[AB]	39 - 126	200 - 10,000

[a] Standard soil macro- and micronutrient ranges were drawn from Brady (1974); Letters indicate statistical differences determined by Tukey's HSD.

Summary of Soil Development

- Soil carbon and organic matter are initially lost after restoration, with trends toward increasing over the first 12 years
- Nutrient deficiencies are present in newly restored sites
- No post-restoration site has returned to natural estuarine soil ranges between 12-20% for carbon and 22-35% organic matter (Vincent, Burdick, and Dionne 2013).

Results

- Soil
  - Carbon
  - Organic Matter
  - Nutrients
  - Nutrient Deficiencies
- **Vegetation**
  - **Native Species**
  - **Invasive Species**
  - **Diversity (H‘)**
  - **Species Assemblages**

Vegetation: Native Species

- A total of 65 plant species were sampled
- Bootstrap population estimates an expected population size of 66 (±3)

Most abundant native species:

Pickleweed - 19.2%
Fat hen - 9.5%
Gumweed - 8.0%
Saltgrass - 6.4%
Meadow grass - 4.9%
Dune grass - 4.2%

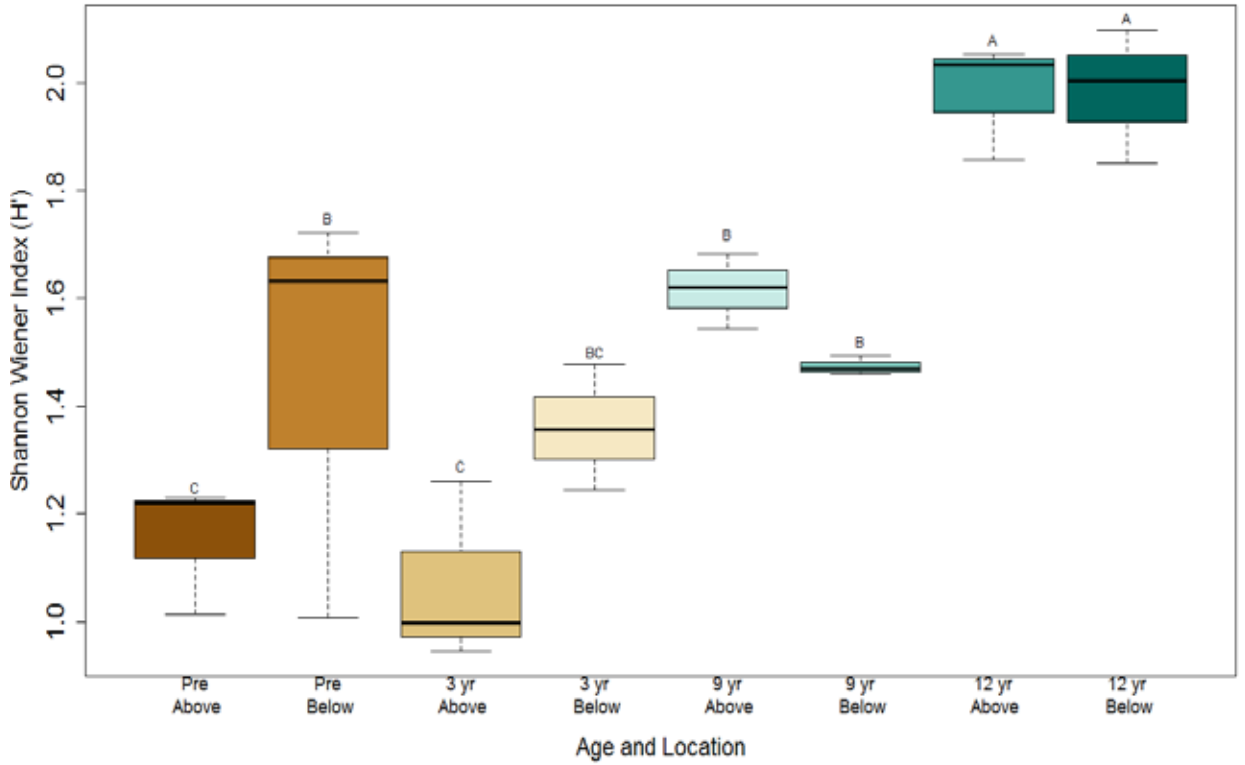
Washington State Noxious Species and Abundance

- Class B
  - Scotchbroom (11)
- Class C
  - Himalayan Blackberry (30)
  - Reed Canary Grass (11)
  - Hairy Cats Ear (3)
  - Canada Thistle (3)
  - Oxeye Daisy (2)
  - Queen Anne's Lace (1)
  - Common Tansy *
  - Bindweed *

* Occurred in a quadrat, but not transects.

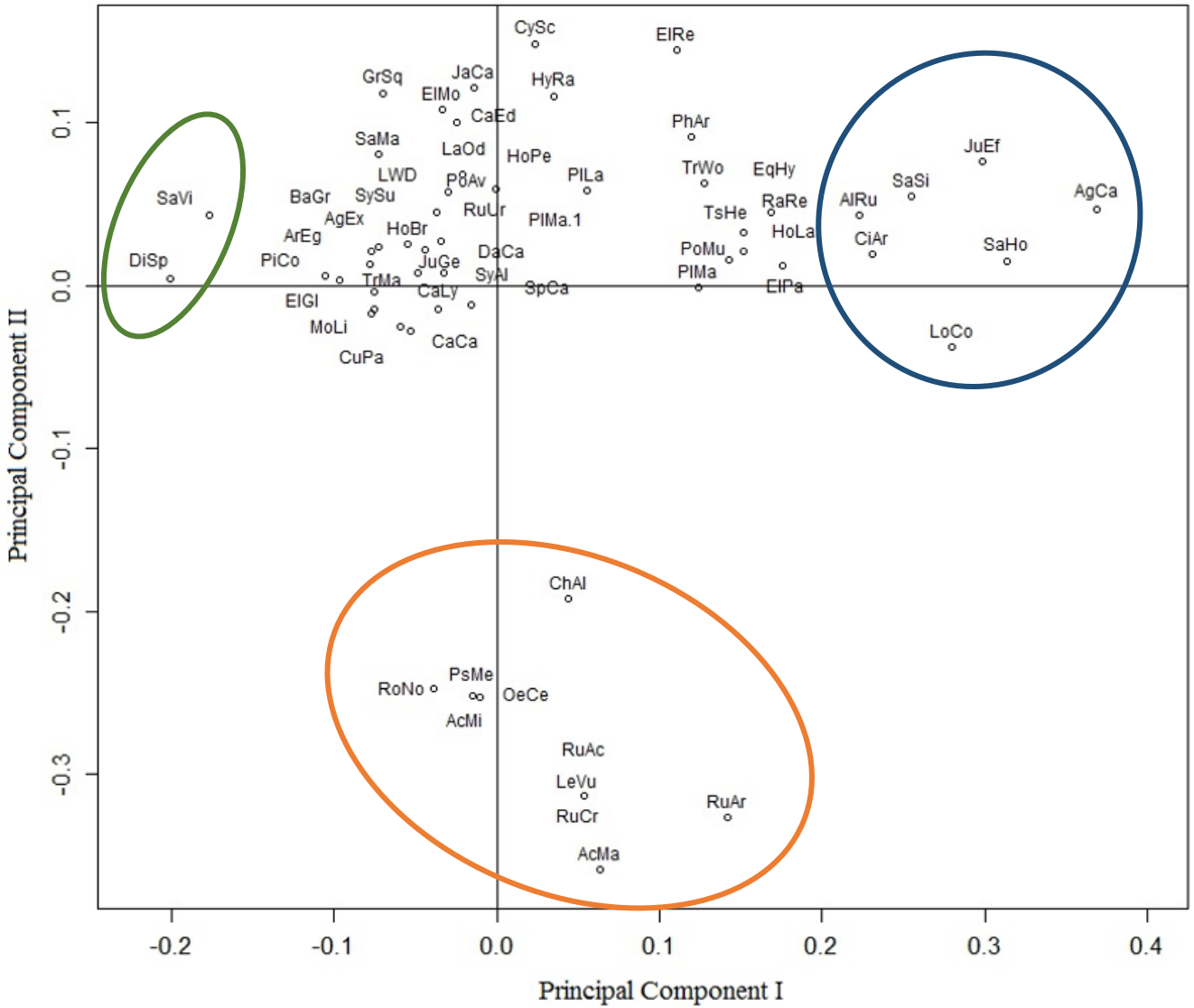
Plant Species Diversity (H′)

- No difference in biomass and height
- A significant difference between site was noted for plant species diversity by site ($F_{(3,16)}$ = 23.58; P< 0.001)
- A similar trend was noted for plant species richness between site and location ($F_{(3,16)}$ = 4.15; P= 0.02).



Variable Ordination of Plant Species

- Principal Component I illustrates a salinity gradient
  - Halophytes
  - Glycophytes
- Principal Component II illustrates a vertical gradient
  - Woody Perennials



Analysis of Similarity and Similar Percentages

	Pre		3 yr		9 yr		12 yr	
ANOSIM R	0.43		0.81		0.56		0.35	
Significance	0.007**		0.005**		0.002**		0.008**	
Composition	Species	P	Species	P	Species	P	Species	P
	Pickleweed	0.01**	Pickleweed	0.02*	Fat Hen	0.003**	Saltgrass	0.003**
	Fleshy Jaumea	0.03*	Dune grass	0.003**	Colonial Bentgrass	0.009**	Coastal Pearlwort	0.05*
			Gumweed	0.007**	Gumweed	0.01**	Gumweed	0.02*
					Common Rush	0.02*	Pacific Silverweed	0.04*

* Significant at $P < 0.05$; ** Significant at $P <= 0.01$

Summary of Vegetation

1. Plant species diversity increases in our older sites, with little colonization from invasive species. Plant species diversity positively affects ecosystem processes such as nutrient cycling, primary productivity and biogeochemical cycling (Cardinale et al. 2007; Tilman et al. 1997; Tilman 1999) which supports increased soil organic matter and carbon results.
2. Plant communities do not appear to homogenize between locations (above and below), due to the development of a salinity gradient.
3. Restoration design appears to restore the salinity gradient, which is a common component of a natural estuary. This is an important component in the recovery pathway, that appears to be selecting against invasive species and for native salt tolerant species.
4. Based on the planting plans provided for each restoration project, all plants planted did not persist, with the exception of Tufted Hairgrass.
5. All common estuarine species native in the Pacific Northwest were encountered in relative proportion to functional group along a salinity and vertical gradient, typical of a temperate estuary (Gabler et al. 2017), therefore the recovery pathway appears to be on a native trajectory.

Implications for Restoration

1. Soil organic matter development is central to vegetation recruitment
    - Incorporating woody debris and organic matter from onsite could enhance sediment with material that may speed up organic matter accretion (e.g. engineer LWD and root-wads into the site).

2. Utilize the development of the salinity gradient
    - Pickleweed, saltgrass, seaside plantain, and Lyngby's sedge should be utilized in re-seeding upon restoration
    - After the development of the salinity gradient, woody plantings (e.g. Ocean Spray, Hooker's Willow, Oregon Ash, Salal, and Shore Pine) should be incorporated along the vertical gradient where inundation is infrequent.

3. It appears the timeline for recovery of soil organic matter to natural levels will take approximately 30-40 years
    - Plant assemblages appear to be on a trajectory for native species recruitment

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Questions?