Youngs Bay – A Tidal Wetland Restoration Story

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LCEP Science Work Group

March 28th 2017

Dissertation Studies:

Advisor: Alan Yeakley

1. **Evaluating Trajectories Tidal Wetland Ecosystem Recovery (2 years of Field work)**

2. **Tidal Wetland Restoration and Sea-level Rise: Seed Bank Response to Changes in Tidal Flooding and Salinity (1 field season and 5 months of greenhouse monitoring)**

Planned Defense – April 28th!

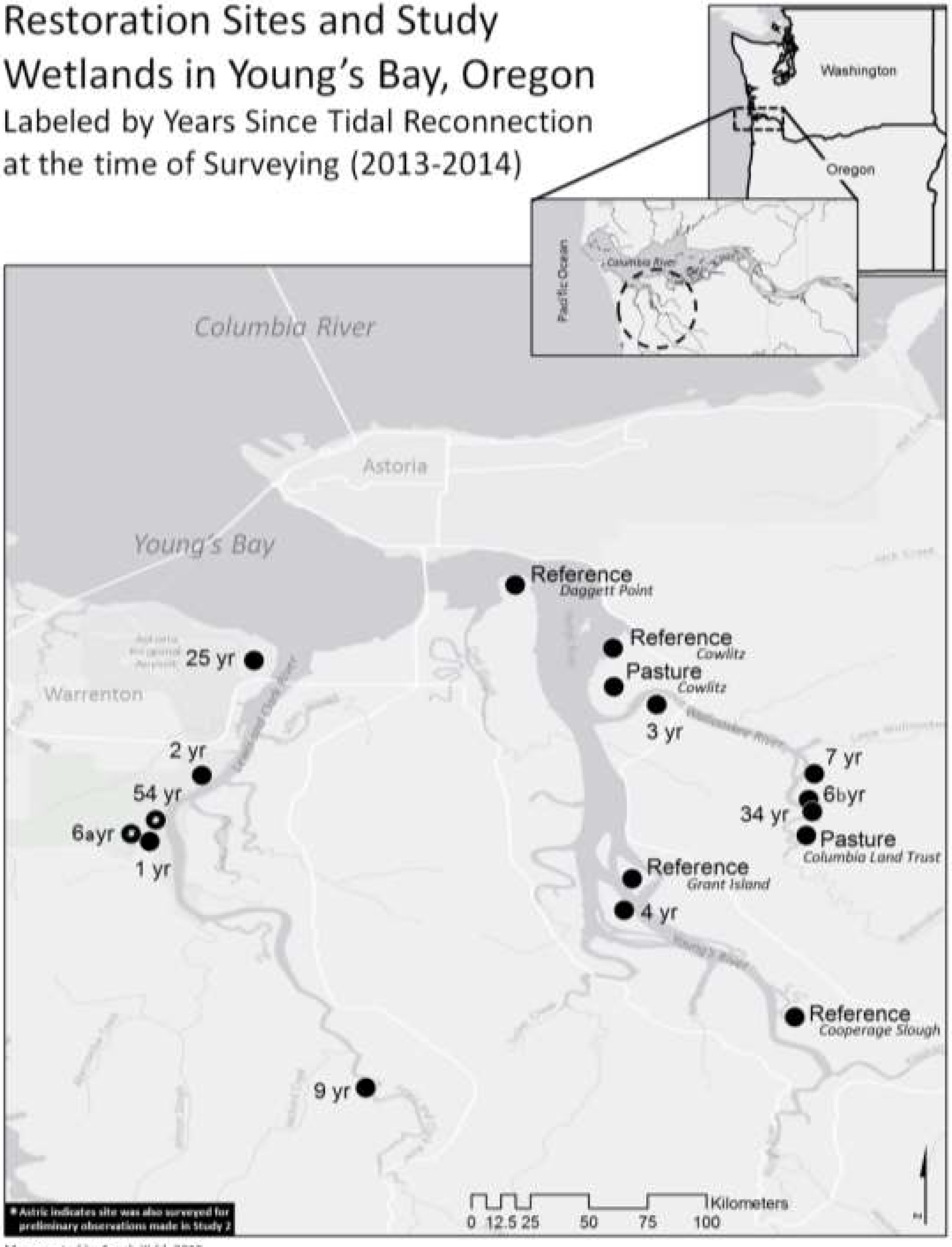
Columbia River Estuary USA

Map created by Sarah Kidd, 2015

Columbia River Basin

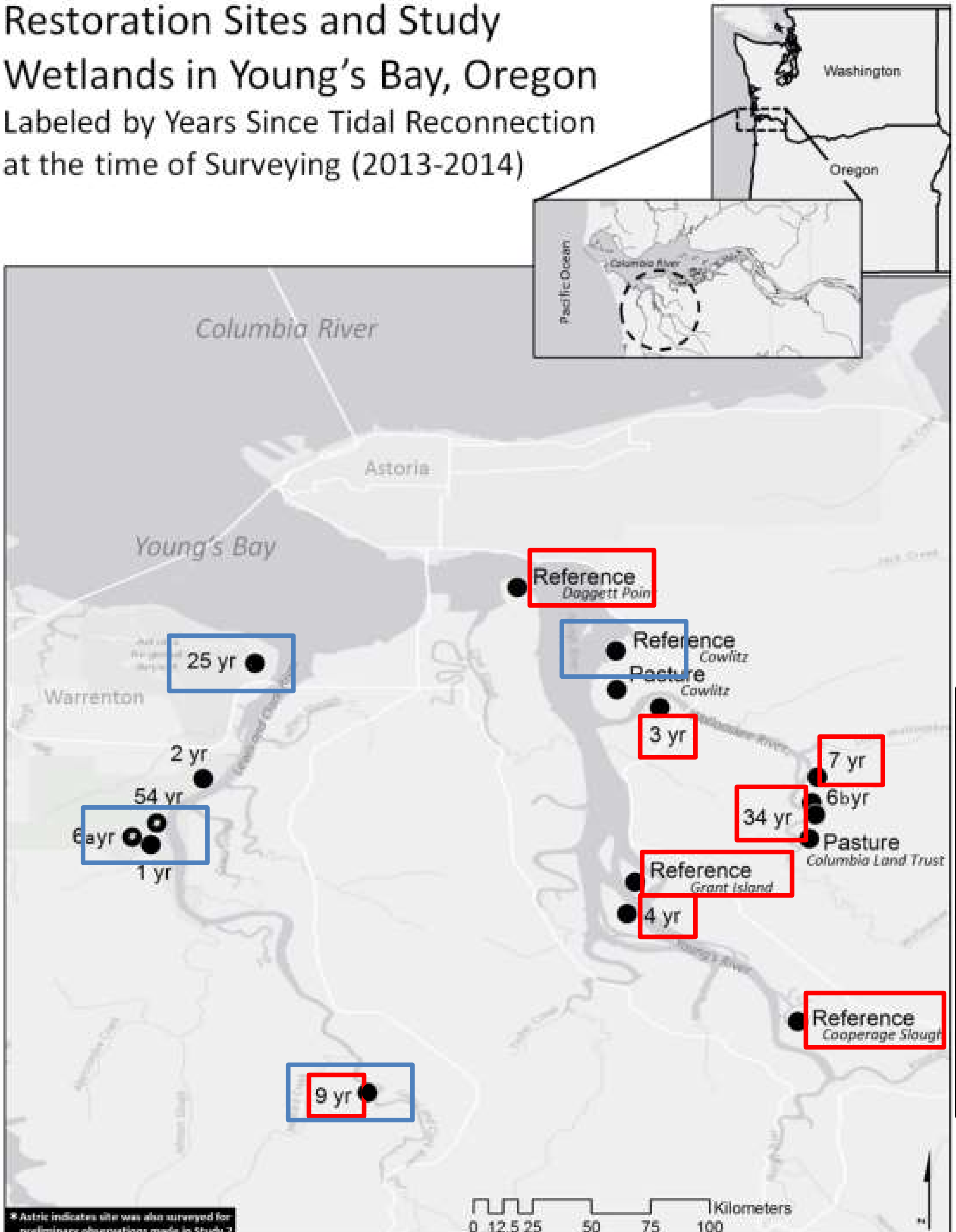
Youngs Bay is oligohaline - low salinity (0.5-5ppt)

Tidal Reconnection



Restoration Sites and Study Wetlands in Young's Bay, Oregon

Labeled by Years Since Tidal Reconnection at the time of Surveying (2013-2014)



METHODS: FIELD SURVEY

Research Sites Include:

11 Restored: 1-54yr Chronosequence

4 Reference Wetlands

2 Pasture (pre-restoration sites)

Half of the sites surveyed in 2013 and half in 2014

Total Data Acquired:

- **17 Sites**
- **254 Soil and Biomass Samples**
  - **n=12-18 a site**
- **1,020 Veg Quads**
  - **n= ~60 a site**

Data logging –

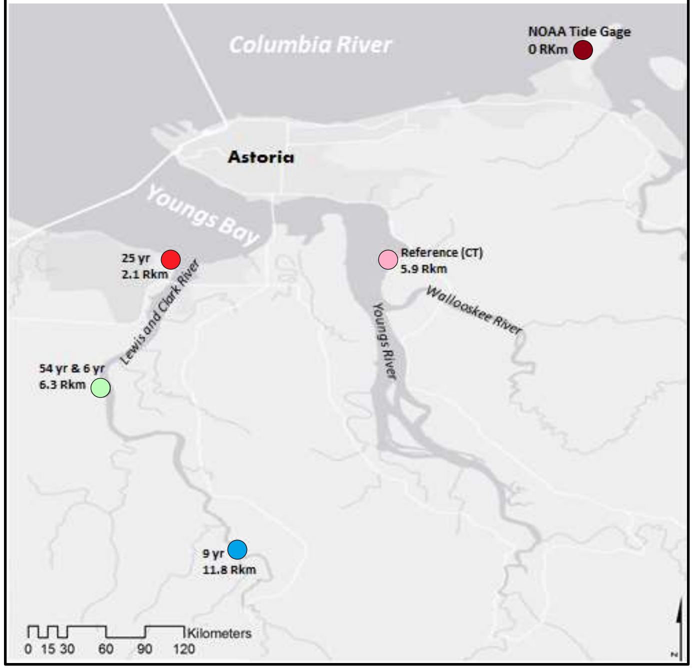
- **Water Level and Salinity Data**

>900 hours of wetland surveying

Range of Maximum Daily Salinities and Water Elevations (Tides)
September 2014-2015

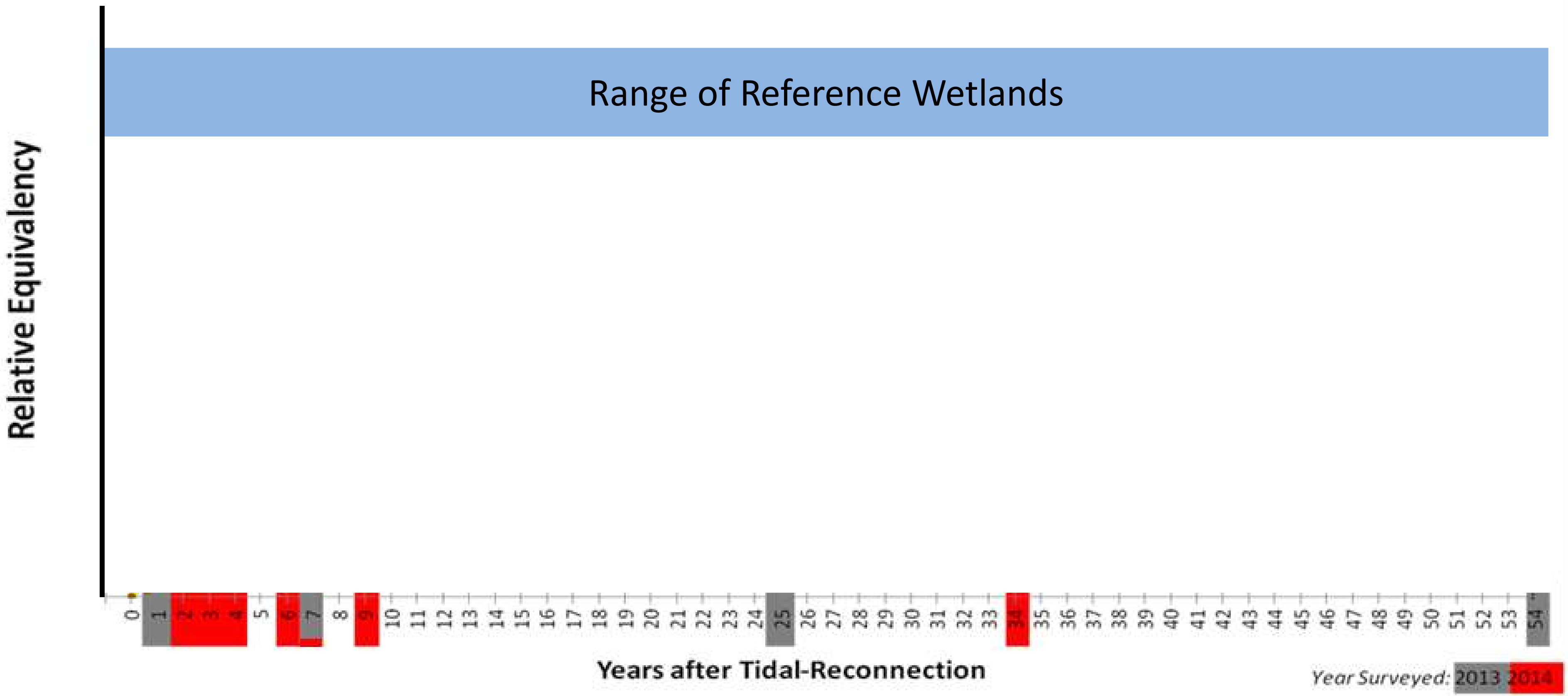
Youngs Bay - Monitoring Locations

- 0 RKm - Tongue Point NOAA Tide Gage
- 2.1 RKm - 25 yr site - Youngs Bay
- 5.9 RKm - Reference (CT) - Youngs Bay
- 6.3 RKm - Lewis & Clark River
- 6.3 RKm - 54 yr site - Alder Creek
- 6.3 RKm - 6 yr site - Colewort Creek
- 11.8 RKm - 9 yr site - Lewis & Clark River



River Distance from the Columbia River (km)

Hypothesized Restoration Trajectories of Tidal Wetland Ecosystems

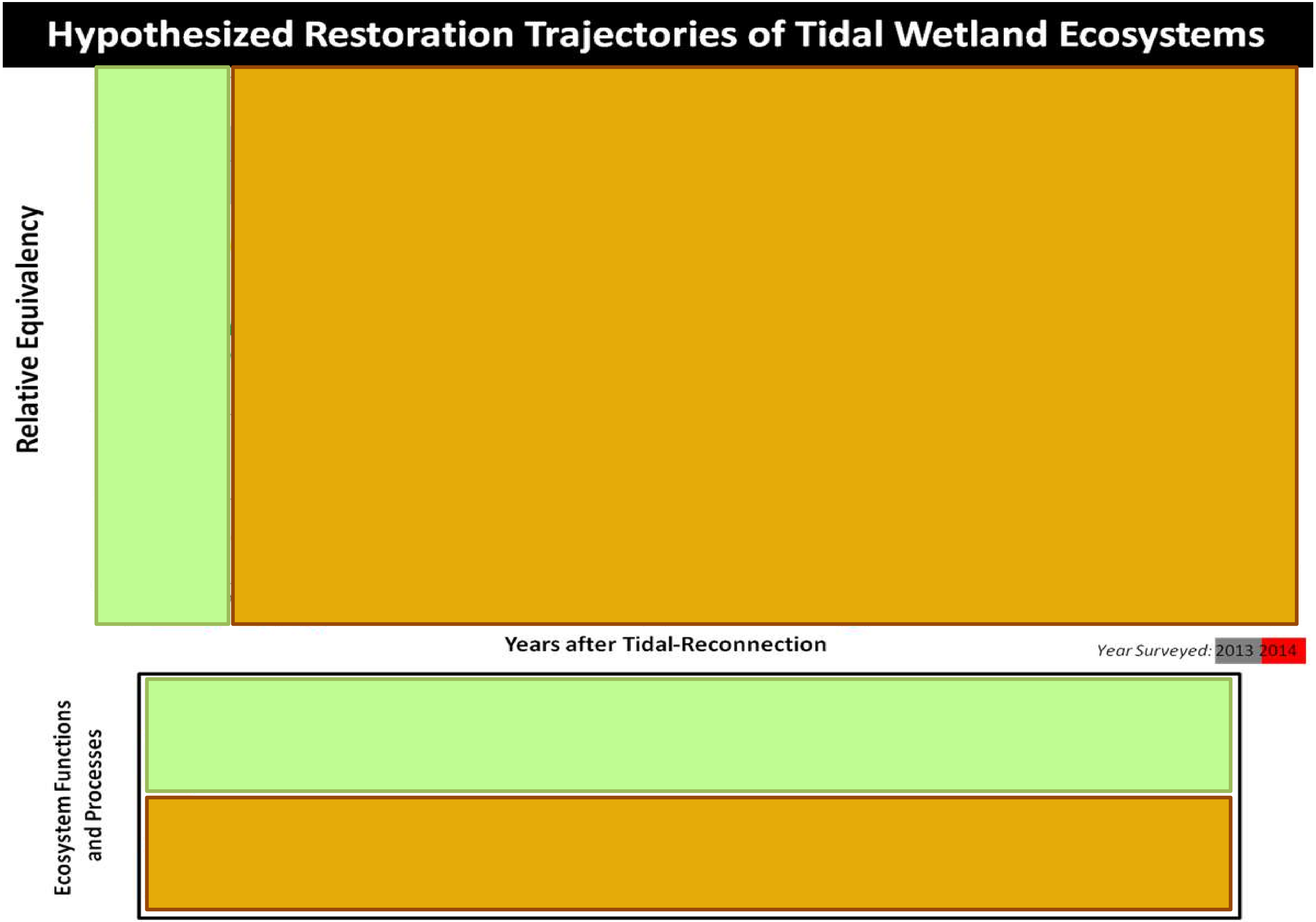


Using a Chronosequence "space for time" Approach

(Gray et al. 2002, Morgan and Short 2002, Warren et al 2002)

Hypotheses based on existing literature:

(e.g. Simenstad and Thom 1996, Zedler and Callaway 1999, Craft et al. 2002, Gray et al. 2002, Morgan and Short 2002, Thom et al. 2002, Warren et al. 2002, Tanner et al. 2002, Ardón et al. 2010, Burden et al. 2013)

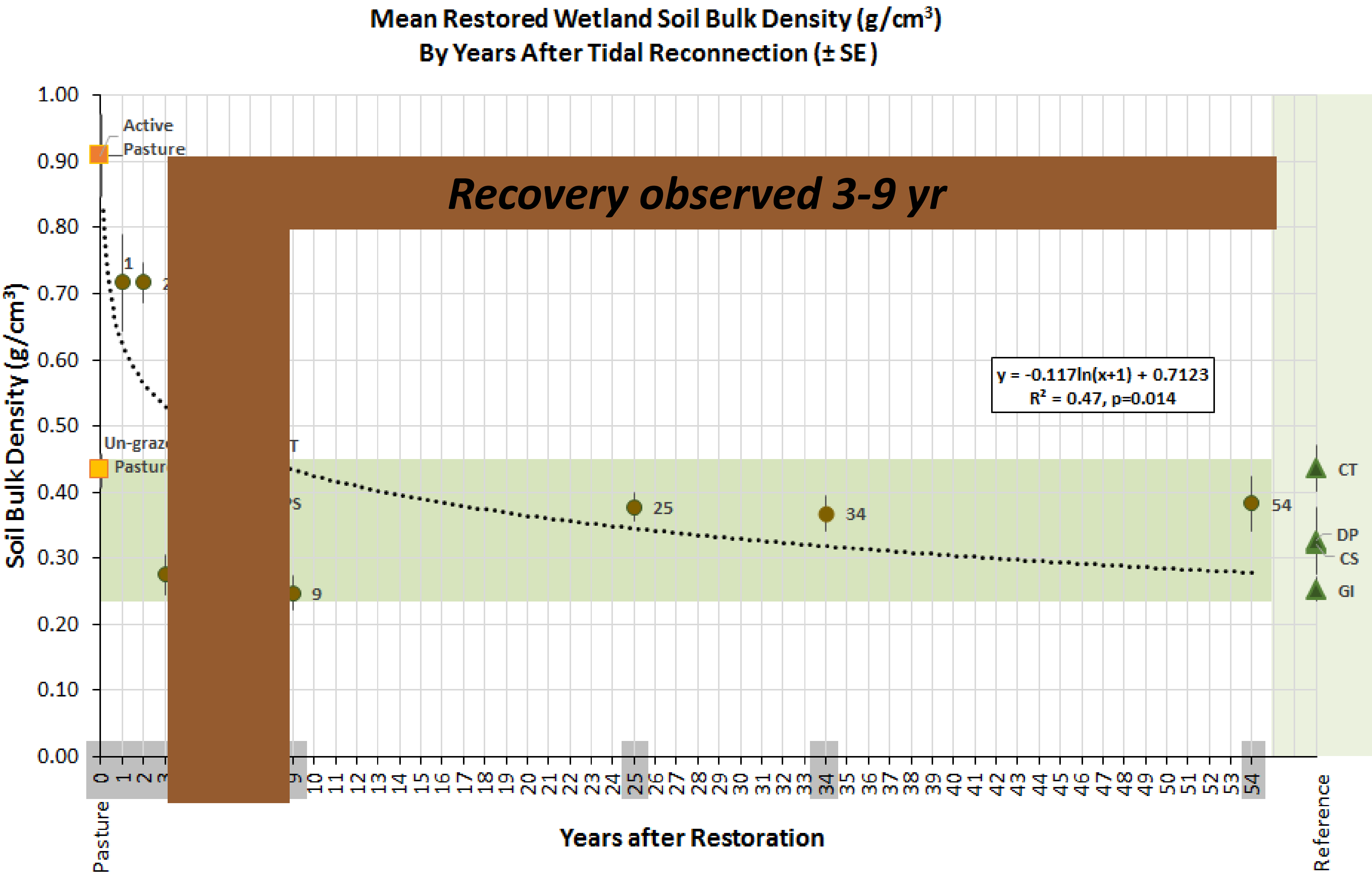

Hypothesized Restoration Trajectories of Tidal Wetland Ecosystems
Relative Equivalency
Years after Tidal-Reconnection
Year Surveyed: 2013 2014
Ecosystem Functions and Processes

Restoration Trajectories

Soil Bulk Density ……………… Predicted >20 yr

Good News: Restoration Trajectories

Soil Bulk Density ………………. Predicted >20 yr

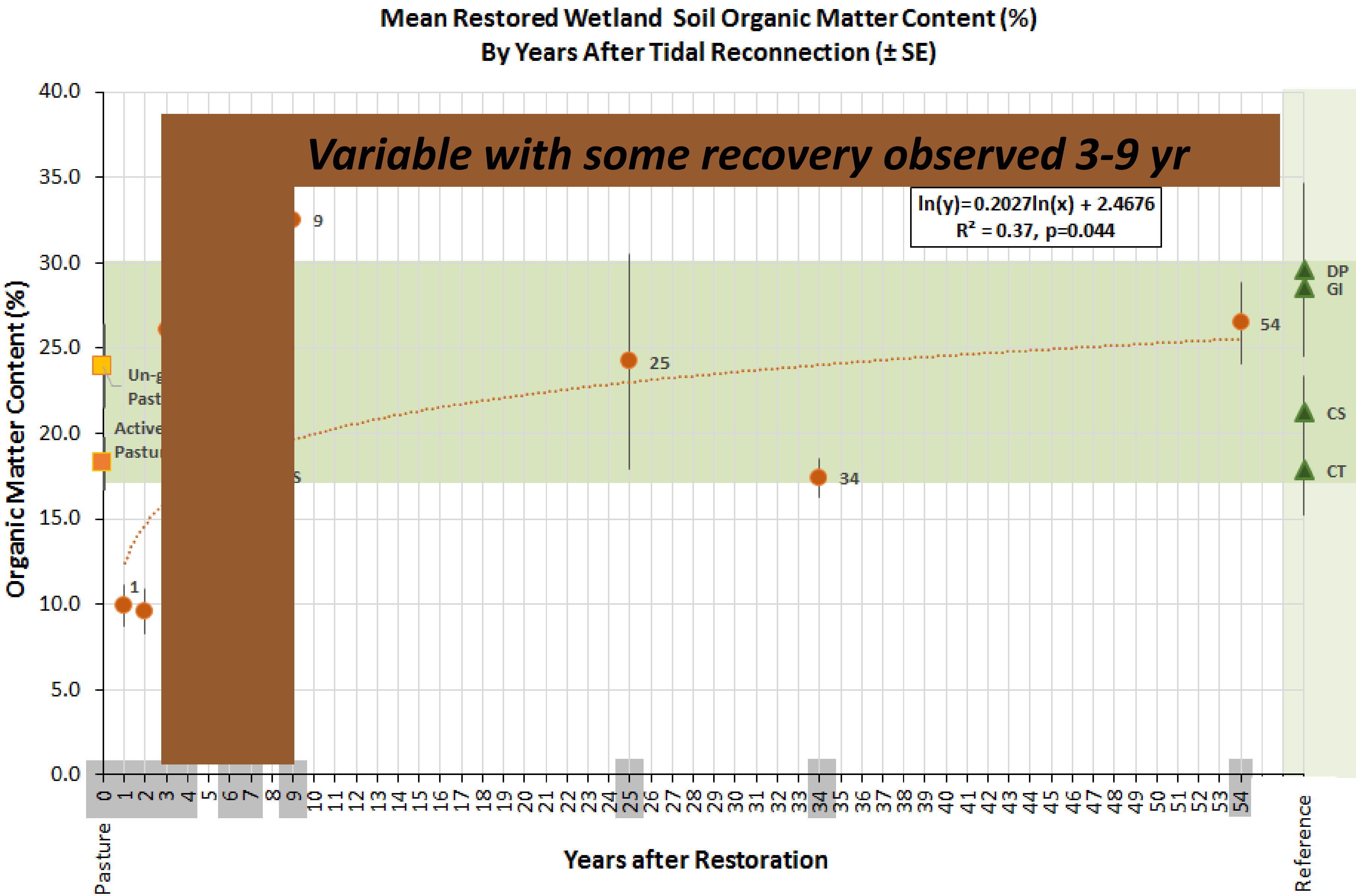


Good News: Restoration Trajectories

Soil Organic Matter……………… Predicted >20 yr

Restoration Trajectories

Soil Organic Matter……………… Predicted >20 yr



Soil Trajectory Conclusions

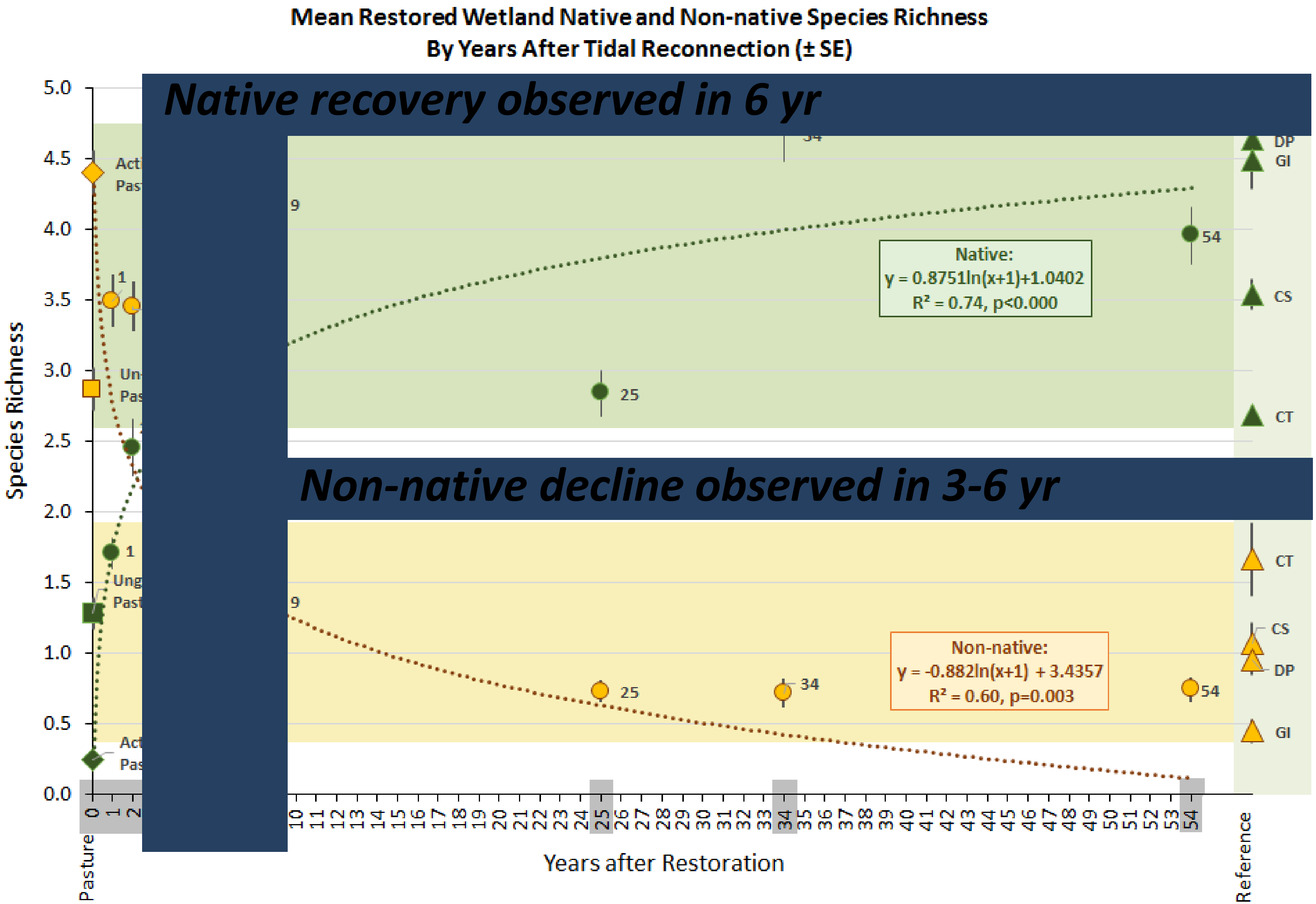
- Bulk Density and Organic Matter Content
  - **Recovery observed within 6-9 yrs!**
- Soil Total N and P
  - <u>**Slight increase**</u> in N across the chronosequence
  - <u>**No pattern**</u> observed in P across the chronosequence
  - Both N and P were <u>**highly variable**</u> in the restored and reference sites

Restoration Trajectories

Native Species Richness…… Predicted 5-10 yr

Restoration Trajectories

Native/Non-native Species Richness…… Predicted 5-10 yr



Restoration Trajectories

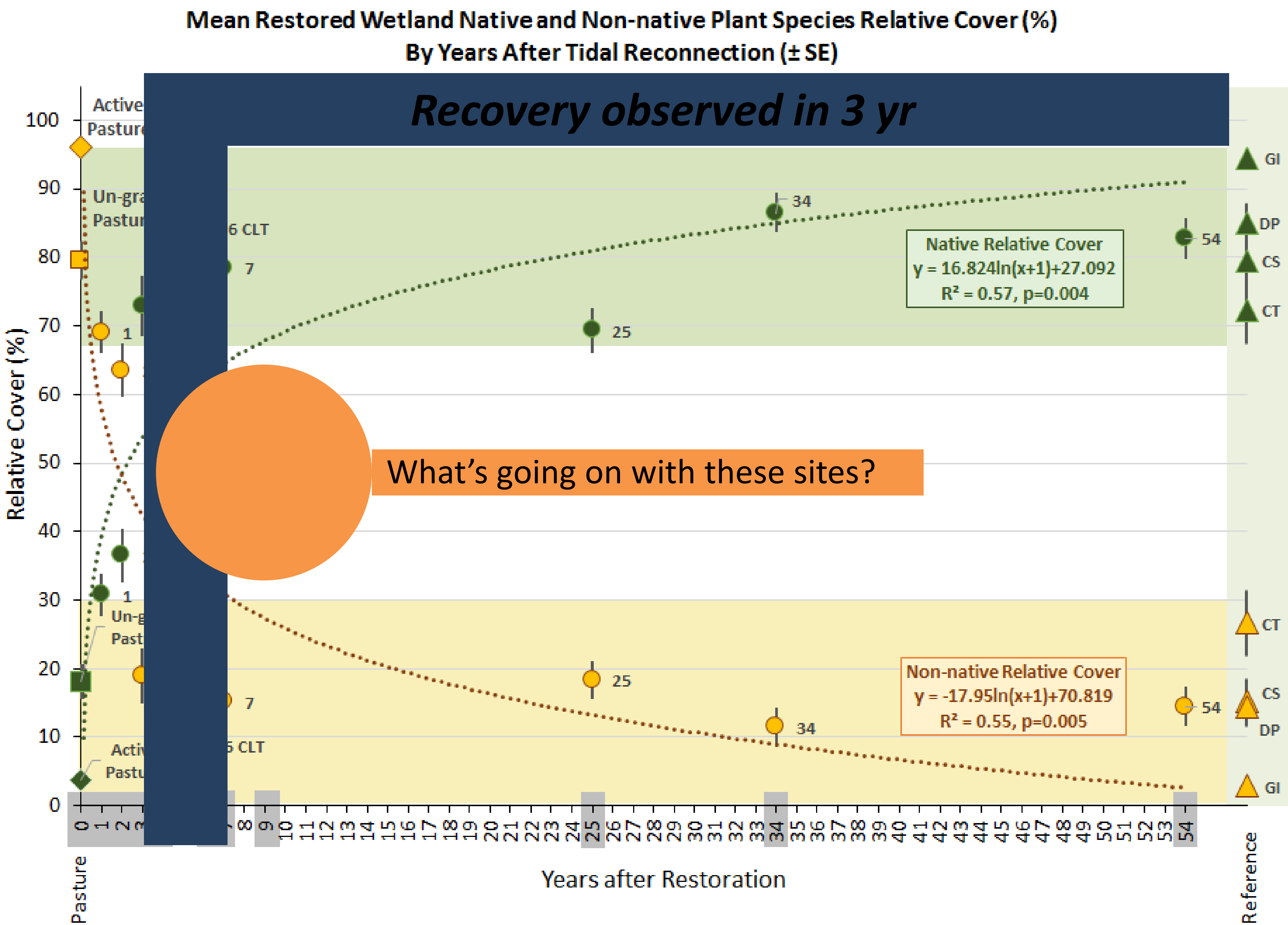
Native/Non-native Cover ………………………. Predicted 5-10 yr

Non-native

Native

Restoration Trajectories

Native/Non-native Cover ……………………. Predicted 5-10 yr

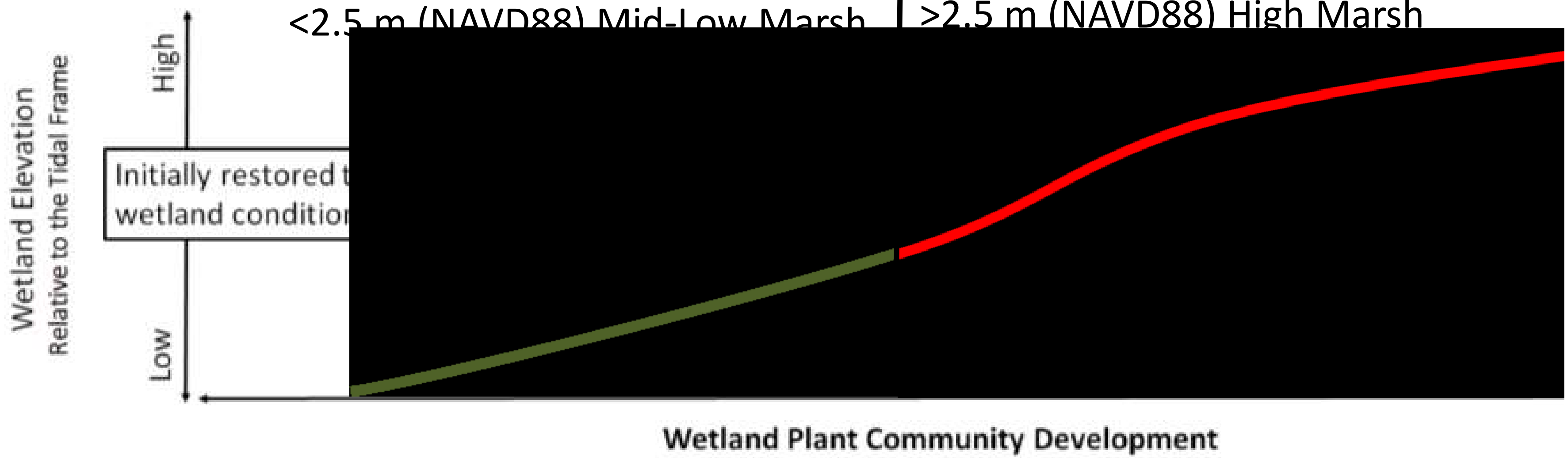


Restoration Trajectories of Tidal Wetland Ecosystems

Plant Community Recovery

Reference Level Recovering ≤ 5 years | NO Recovery ~ 54 years

<2.5 m (NAVD88) Mid-Low Marsh | >2.5 m (NAVD88) High Marsh



2.5 m (NAVD88) ~ 2.4 m (MLLW)

Native low marsh

Carex lyngbyei Hornem., lyngbye's sedge, *and Schoenoplectus lacustris* (L.) Palla, bulrush

Non-native high marsh

Phalaris arundinacea, reed canarygrass, and *Juncus effusus subsp. effusus,* common rush

Conclusions - Restoration Trajectories

- >2.5 m (NAVD88) High Marsh (**<u>all Sites</u>**)

  Locations above mean high water
  - Retaining Non-native Plant Community
  - Lower soil pH
  - Lower soil salinities

All characteristic of pre-restoration wet pasture conditions

Native low marsh | **Non-native high marsh**


Carex lyngbyei **Hornem.*, lyngbye's sedge,***
and Schoenoplectus lacustris **(L.) Palla, bulrush**


Phalaris arundinacea**, reed canarygrass,**
and *Juncus effusus subsp. effusus,* common rush

Restoration Trajectories of Tidal Wetland Ecosystems

What are the mechanisms driving these patterns of plant community recovery?

Native low marsh

Non-native high marsh

Carex lyngbyei **Hornem.*, lyngbye's sedge, and Schoenoplectus lacustris* (L.) Palla, bulrush**

Phalaris arundinacea**, reed canarygrass, and *Juncus effusus subsp. effusus,* common rush**

Drivers of Restoration Trajectories - Tidal Wetland Ecosystems

Major Restoration Impacts

Tidal Wetland Flooding
- Frequency
- Duration
- Salinity

Soil Conditions
- Oxygen
- Salinity
- Nutrients
- Composition

Plant Community
- Species existing and introduced
- Species requirements & tolerances
- Competition

Restoration Outcomes

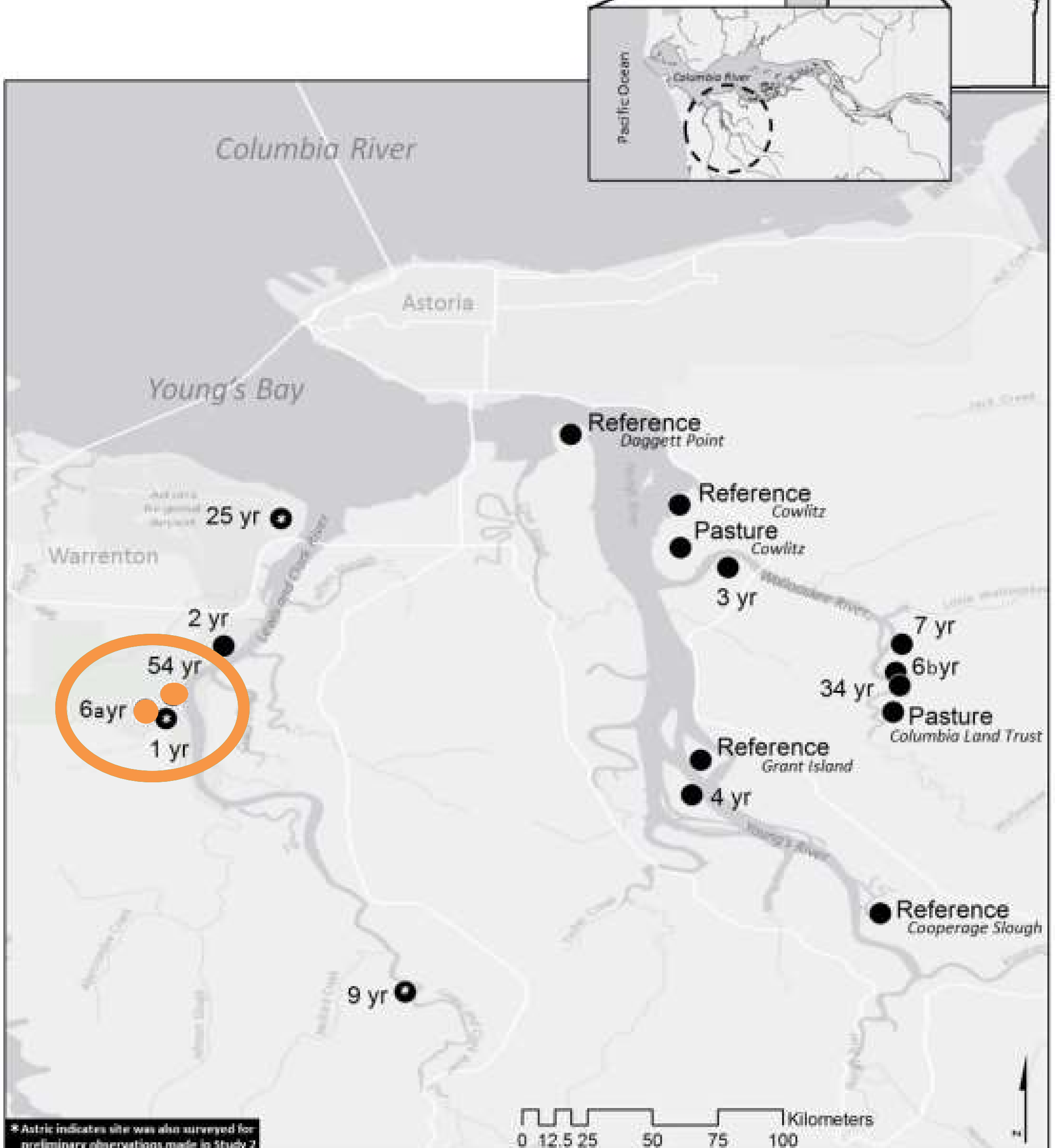
Seed Bank Study

- How do **seed bank compositions** of restored **native and non-native** plant communities compare?
- How do these **seed banks** respond to different **tidal flooding and salinity** conditions?

SEED BANK SAMPLING

Restoration Sites and Study Wetlands in Young's Bay, Oregon

Labeled by Years Since Tidal Reconnection at the time of Surveying (2013-2014)



Seed Bank Sampling – April 2015

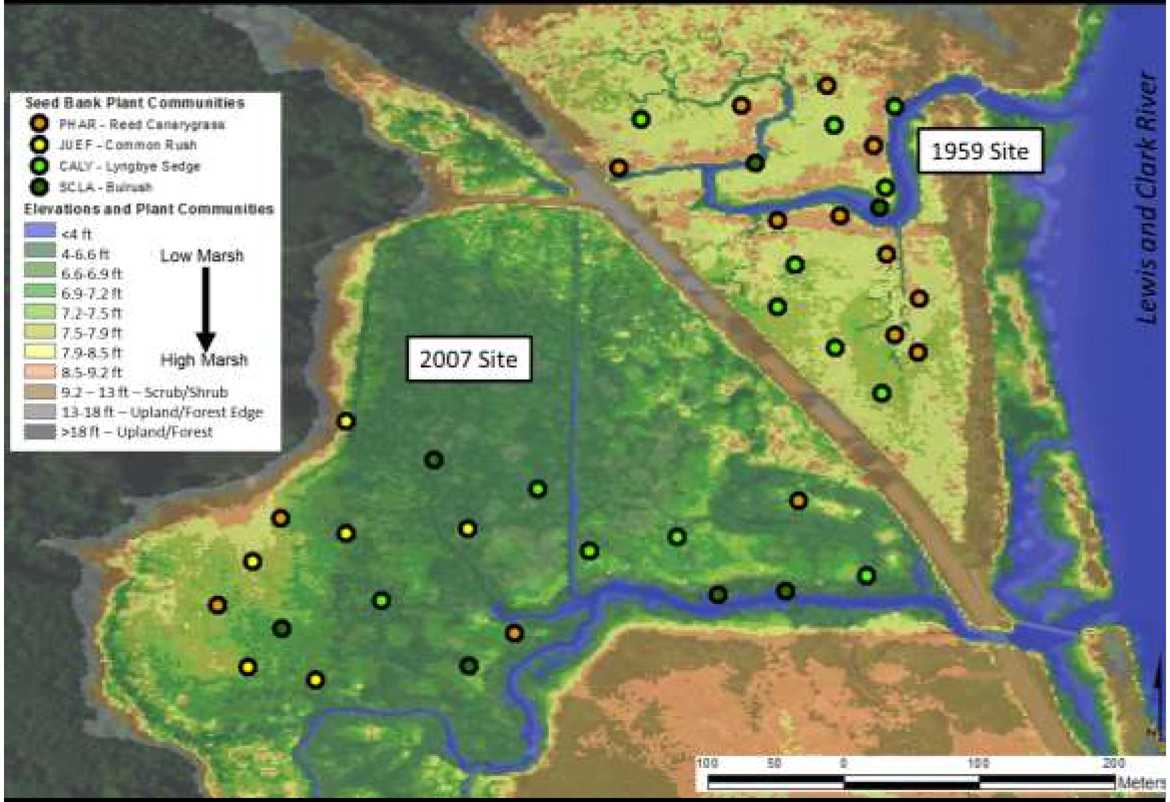
Dominant Native and Non-native Plant Communities Across 2 Restored Sites (1959, 2007)

Thanks Mom!

METHODS: SEED BANK PROCESSING & GREENHOUSE

Collection: 20 Native and 20 Non-native Seed Bank Samples from Dominant Plant Communities

Lewis & Clark National Historical Park Restoration Sites
Seed Bank Sampling Locations & Elevation Map (2009 LiDAR - NAVD88)

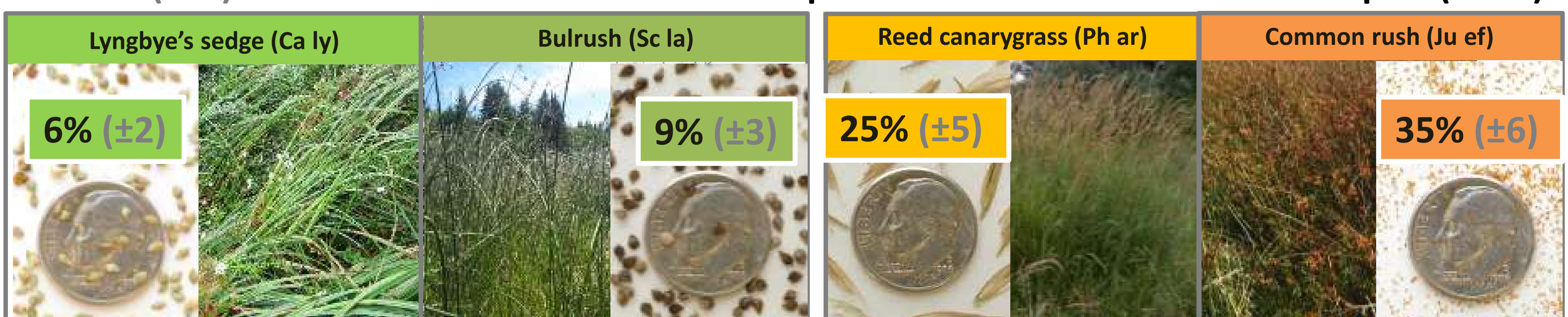


Distributed across 3 salinity treatments: fresh (0 ppt), oligohaline (3 ppt), brackish (10 ppt) and 3 flooding treatments: high marsh (1 hr x 1 day), mid-marsh (3 hr x 2 day), low marsh (6 hr x 2 day)

Monitored for 5 months: Counted a total of 23,920 seedlings from 43 species!

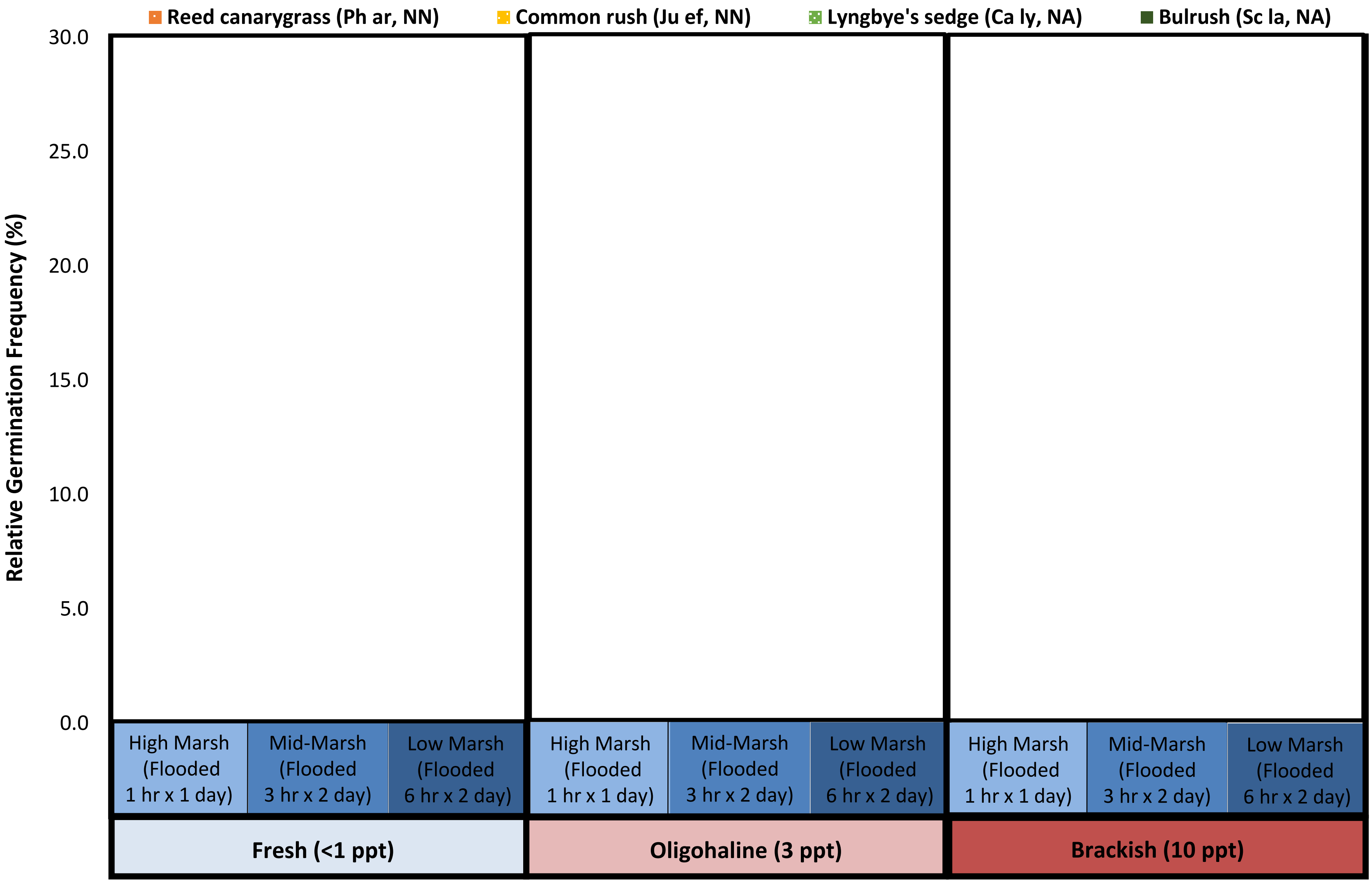
Direct Seed Counts: How do **seed bank compositions** of restored **native and non-native** plant communities compare?

Mean (±SE) relative distribution of dominant species across each seed bank samples (n=40):

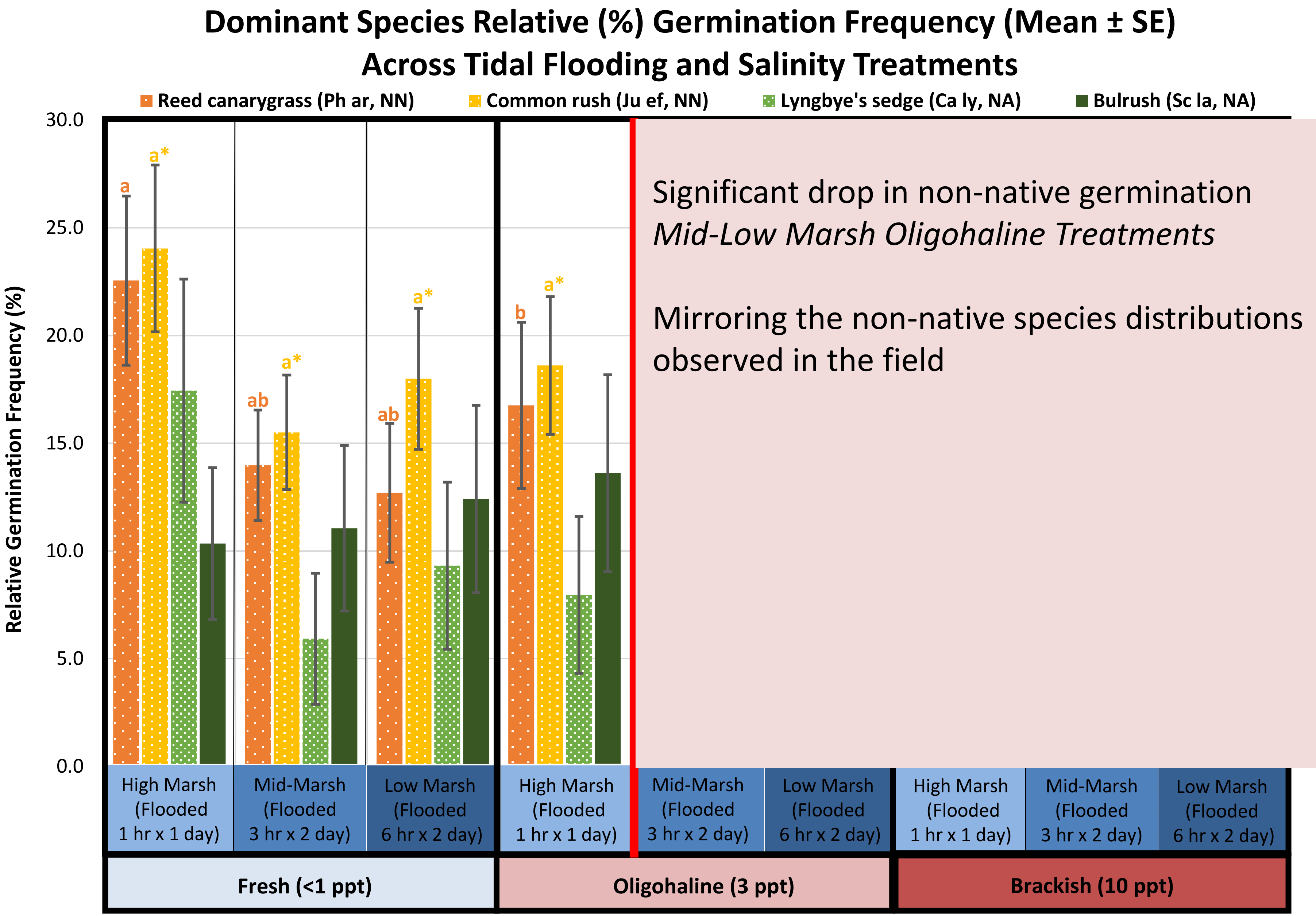


GERMINATION: How do these seed banks/species respond to **different tidal flooding and salinity conditions?**

Dominant Species Relative (%) Germination Frequency (Mean ± SE) Across Tidal Flooding and Salinity Treatments



GERMINATION: How do these seed banks/species respond to **different tidal flooding and salinity conditions?**



Significant drop in non-native germination *Mid-Low Marsh Oligohaline Treatments*

Mirroring the non-native species distributions observed in the field

Seed Bank Conclusions

What are the mechanisms driving these patterns of plant community recovery?

Reed canarygrass (Ph ar)

Common rush (Ju ef)

- **<u>Ubiquitous</u>**/abundant in the seed bank
- **<u>Germination suppressed</u>** by small increases in salinity and flooding!

Lyngbye's sedge (Ca ly)

Bulrush (Sc la)

- **<u>Overall low seed bank abundance</u>** relative to non-native species
- **<u>No germination suppression</u>** observed - similar under high to low marsh flooding and fresh to brackish salinity conditions.

High Marsh invasions – likely driven by competition with non-natives.
Who gets established first **wins in the High Marsh!**

Overall Management Implications

- Understand the **<u>environmental thresholds</u>** of expected native and non-native species
- **<u>Seed banks matter</u>** – Seeding/Planting in High Marsh Zones may help!
- Monitor **<u>within all flooding/elevation classes</u>** – to see the full picture of recovery
- **Adaptive management** may be needed if you don't see ***<u>trends towards reference levels</u>*** *of plant community and soil development within* ***<u>3-6</u>*** *years of restoration*
- Sea level rise (increases in flooding and salinity) may reduce PHAR and JUEF dominance – ***but at the cost of high marsh habitat***
- Other more ***salinity tolerant non-native invasive species are laying in wait***! *Such as Phragmites australis and Narrowleaf Cattial*

QUESTIONS?

THANK YOU FOR LISTENING!

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Research Support

NSF

SWS

SER SOCIETY FOR ECOLOGICAL RESTORATION

NATIONAL PARK SERVICE

Land Owners & Partners

COWLITZ INDIAN TRIBE

NATIONAL PARK SERVICE

Columbia LAND TRUST

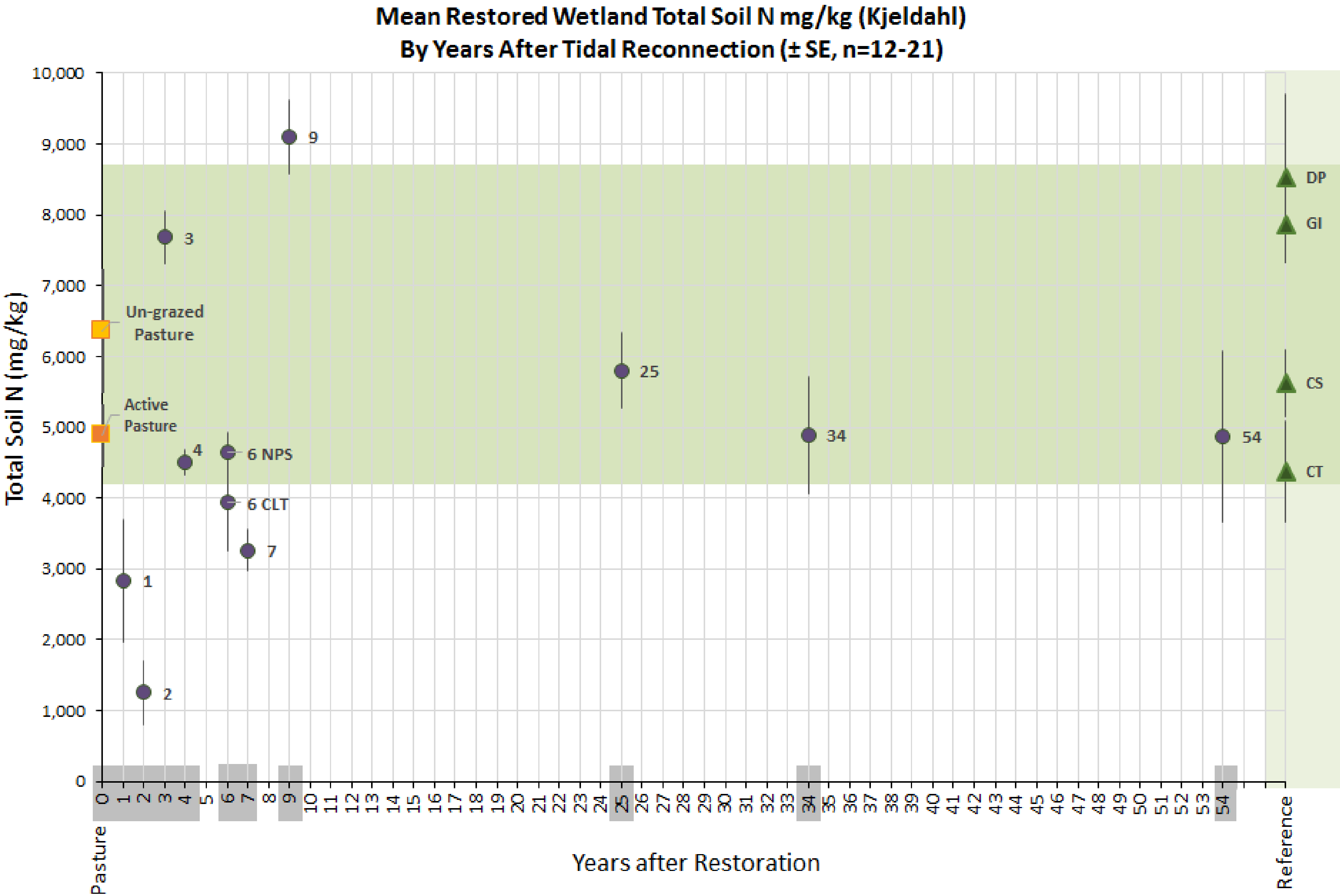
PORT OF ASTORIA

crest

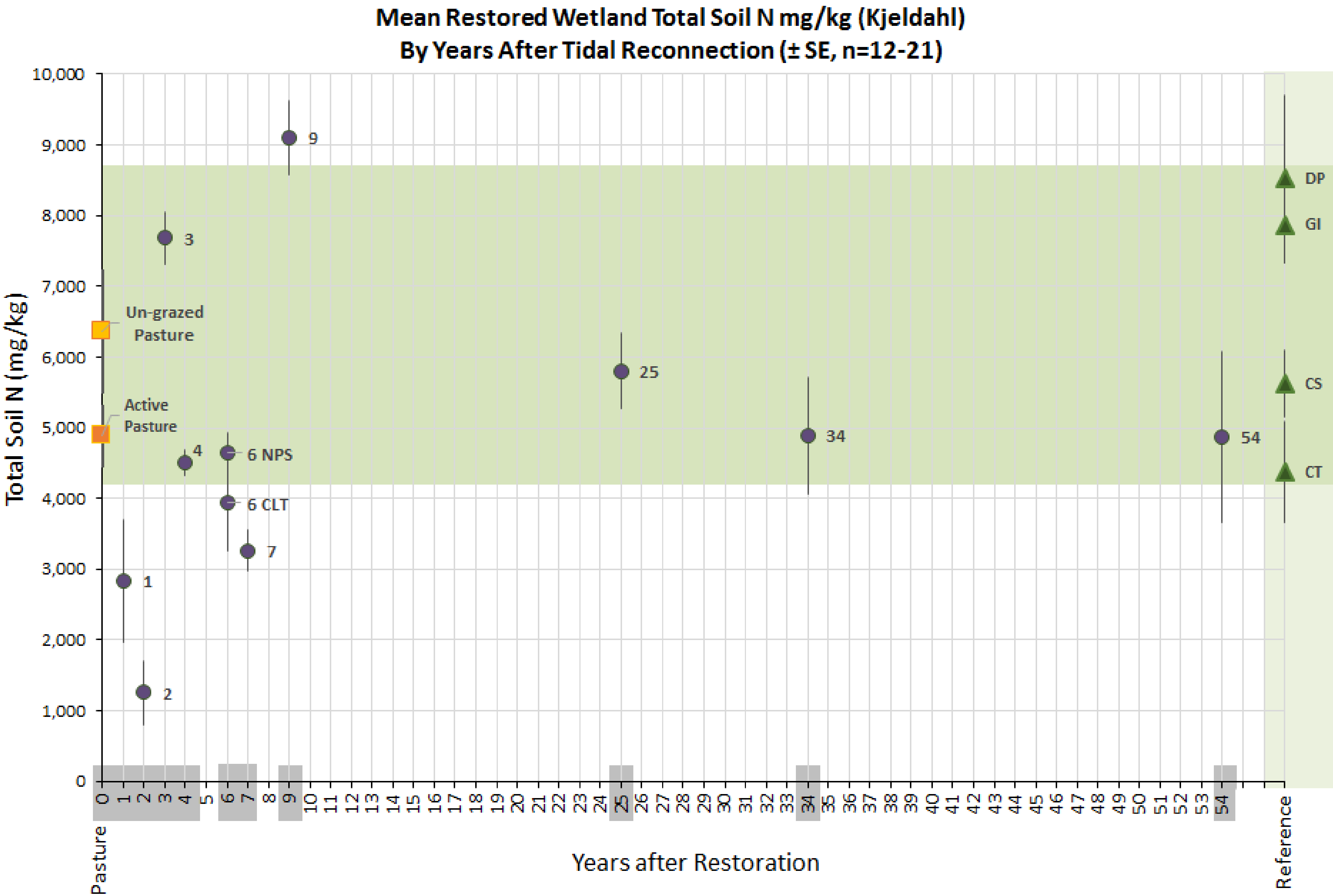
City of Seaside

Lower Columbia Estuary Partnership

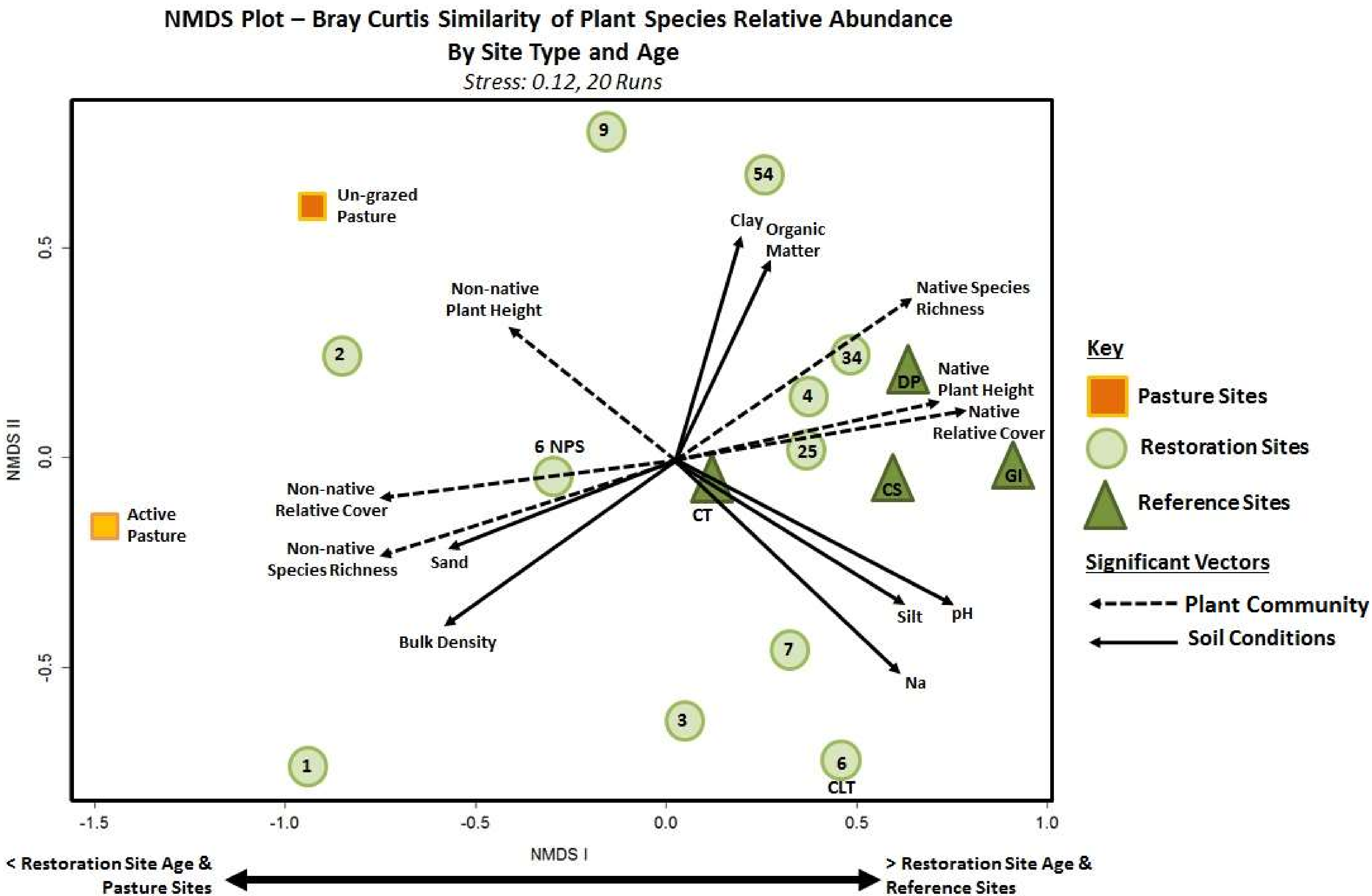
Ecosystem Recovery	Parameters Measured	Expected Recovery	Observed Recovery
H1) Plant Community Composition	Native & Non-native Abundance (% Cover)	5-10 yrs	3-6 yrs
	Native & Non-native Species Richness		3-6 yrs
	BCI –Multivariate Similarity		4 yrs
H2) Plant Productivity	Native & Non-native Plant Height	4-14 yrs	3 yrs
	Native & Non-native Plant Biomass		2 yrs*
H3) Soil Development	Soil Bulk Density (compaction)	> 20 yrs	3-9 yrs
	Soil Organic Matter (OM) Content		3-9 yrs
H4) Soil Nutrients	Soil Phosphorus (P)	3-15 yrs	Variable
	Soil Nitrogen (N)		3-9 yrs*



Mean Restored Wetland Total Soil N mg/kg (Kjeldahl)
By Years After Tidal Reconnection (± SE, n=12-21)
Total Soil N (mg/kg)
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
Un-grazed Pasture
Active Pasture
1
2
3
4
6 NPS
6 CLT
7
9
25
34
54
DP
GI
CS
CT
Pasture
Reference
Years after Restoration

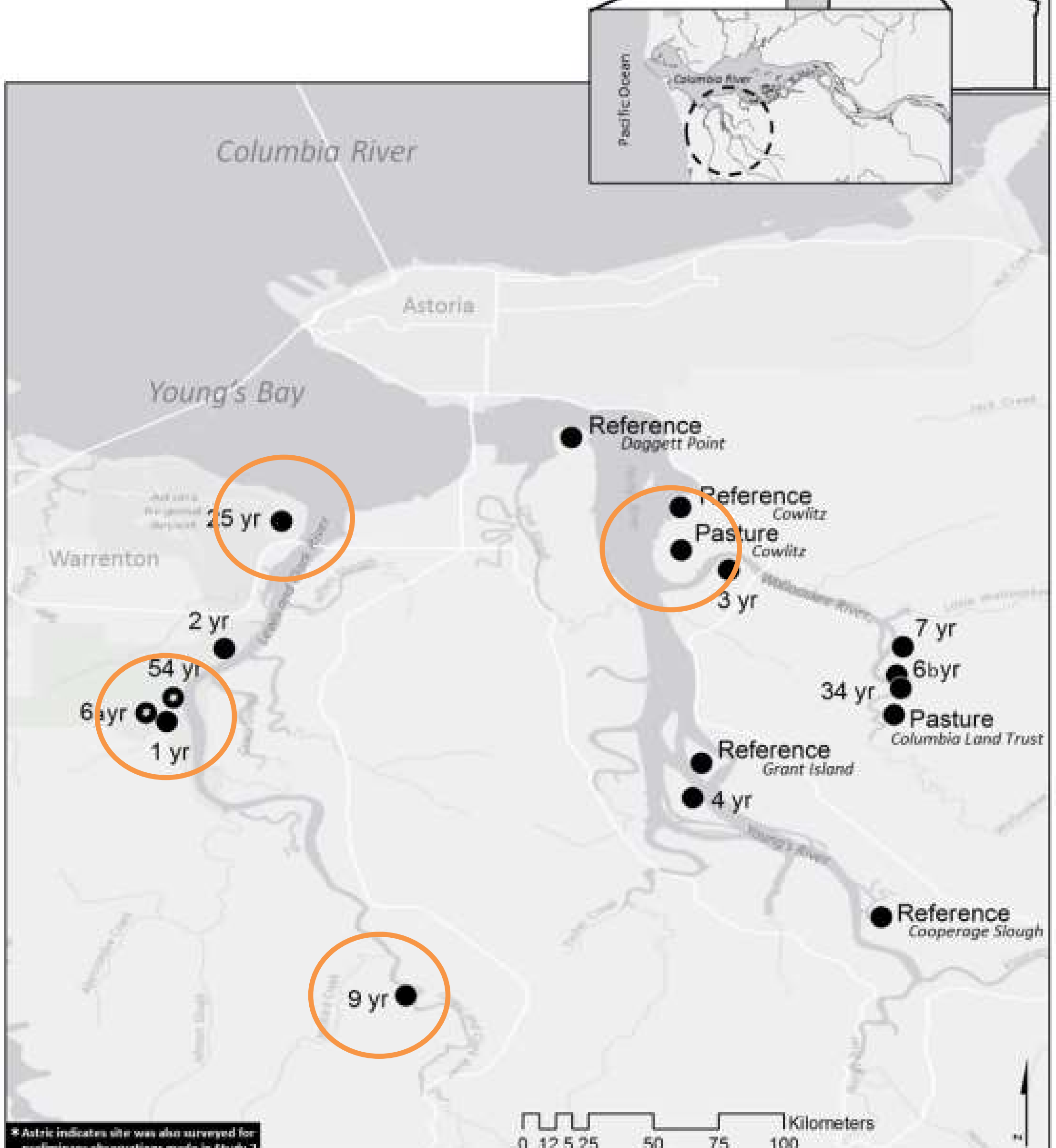


Mean Restored Wetland Total Soil N mg/kg (Kjeldahl)
By Years After Tidal Reconnection (± SE, n=12-21)
Total Soil N (mg/kg)
Years after Restoration
Pasture
Reference
Un-grazed Pasture
Active Pasture
1
2
3
4
6 NPS
6 CLT
7
9
25
34
54
DP
GI
CS
CT


NMDS Plot – Bray Curtis Similarity of Plant Species Relative Abundance
By Site Type and Age
Stress: 0.12, 20 Runs
9
54
Un-grazed Pasture
Clay
Organic Matter
Native Species Richness
Non-native Plant Height
2
34
DP
Native Plant Height
4
Native Relative Cover
6 NPS
25
GI
CS
Non-native Relative Cover
CT
Active Pasture
Non-native Species Richness
Sand
Silt
pH
Bulk Density
7
Na
3
1
6
CLT
0.5
0.0
-0.5
NMDS II
-1.5
-1.0
-0.5
0.0
0.5
1.0
NMDS I
Key
Pasture Sites
Restoration Sites
Reference Sites
Significant Vectors
Plant Community
Soil Conditions
< Restoration Site Age & Pasture Sites
> Restoration Site Age & Reference Sites

Restoration Sites and Study Wetlands in Young's Bay, Oregon

Labeled by Years Since Tidal Reconnection at the time of Surveying (2013-2014)



GENERAL OBSERVATIONS SALINITY

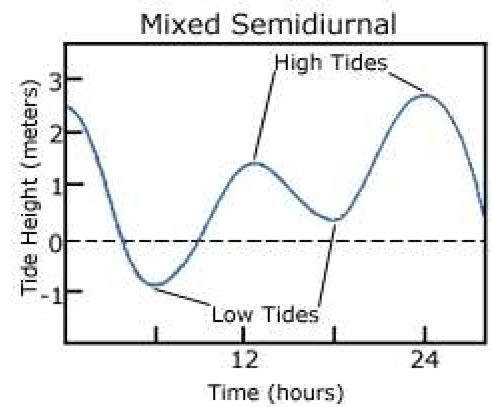
Winter - Spring (2014-2015)

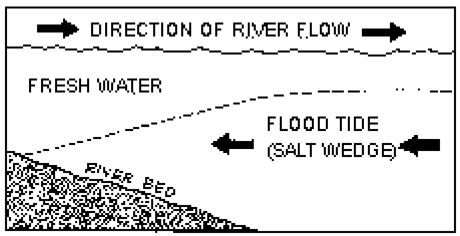
Nov-May Salinity Ranged **0 - 3 ppt**

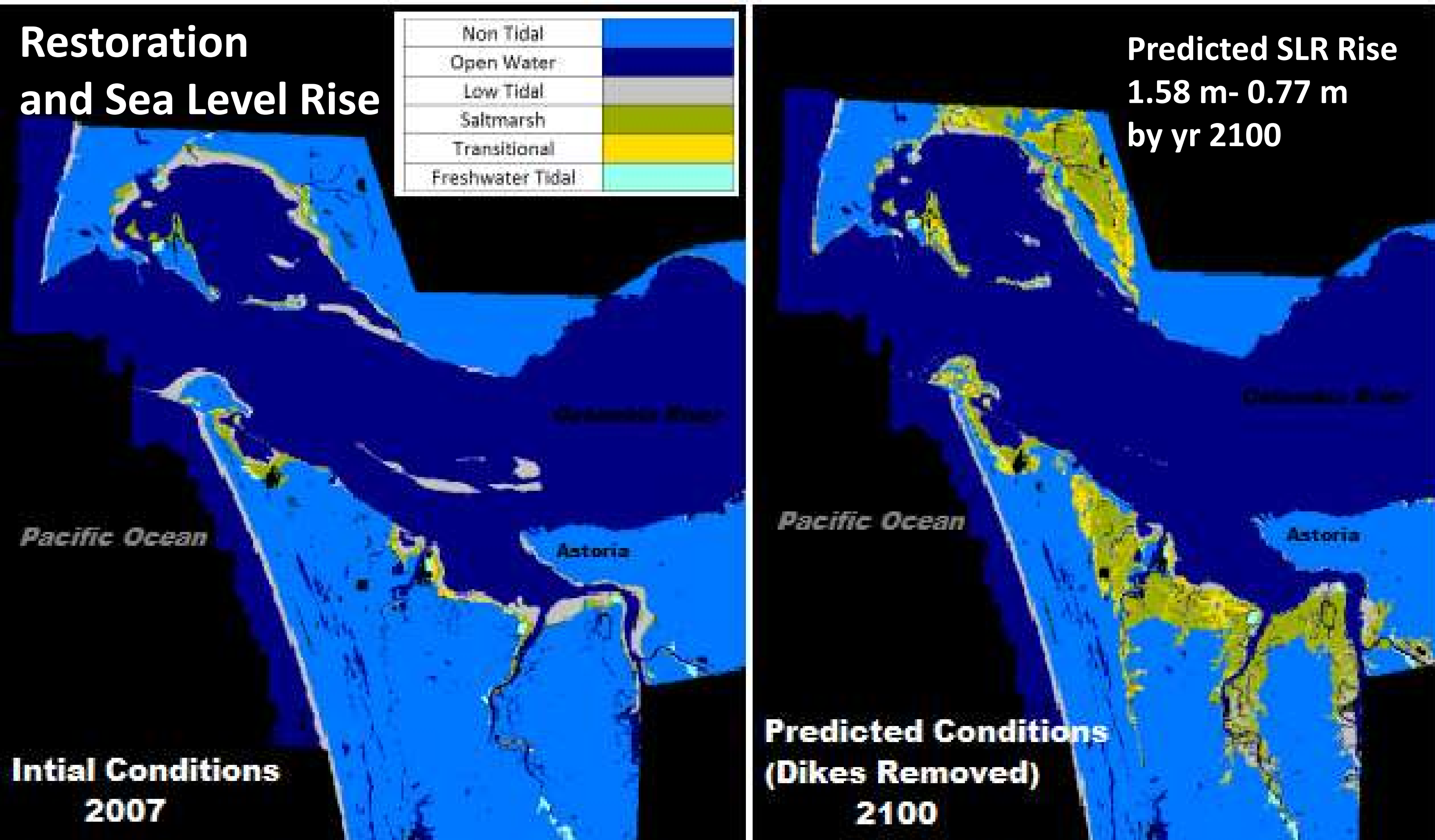
Summer – Fall (2015)

June – Oct Salinity Ranged **3 - 7 ppt**

During dry late summer periods salinities did spike up to 10 ppt



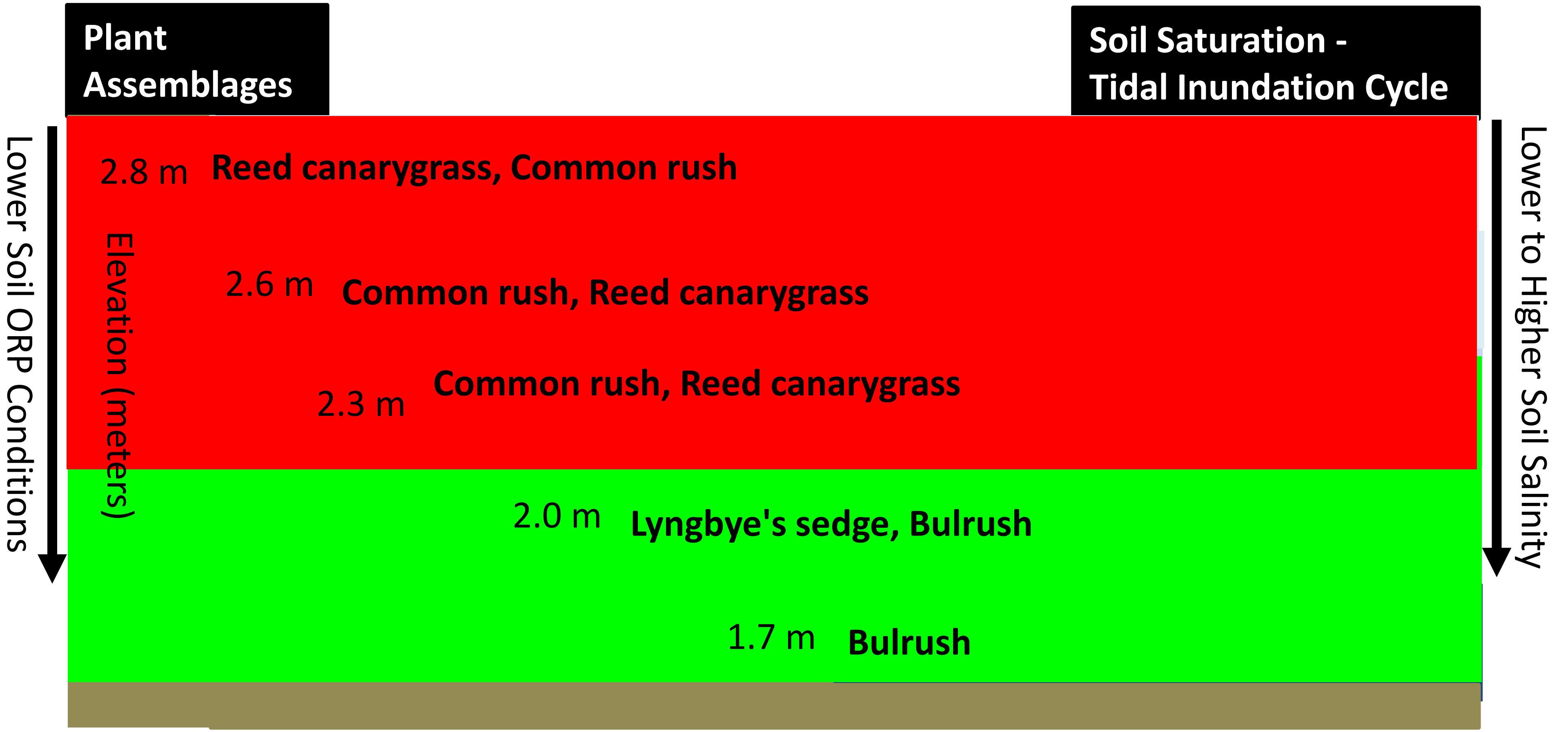




- Restoration actions manipulate tidal flooding conditions and sea level rise will shift tidal flooding and increase wetland salinity
- 2.5 fold shift in tidal wetland distributions with restoration potential increasing by 5 times the current area in Youngs Bay by the year 2100 (Glick et al. 2007, SLAM Model)
- ***Tebaldi et al. (2012) only predicts 0.19 m increase in sea level rise by 2050***

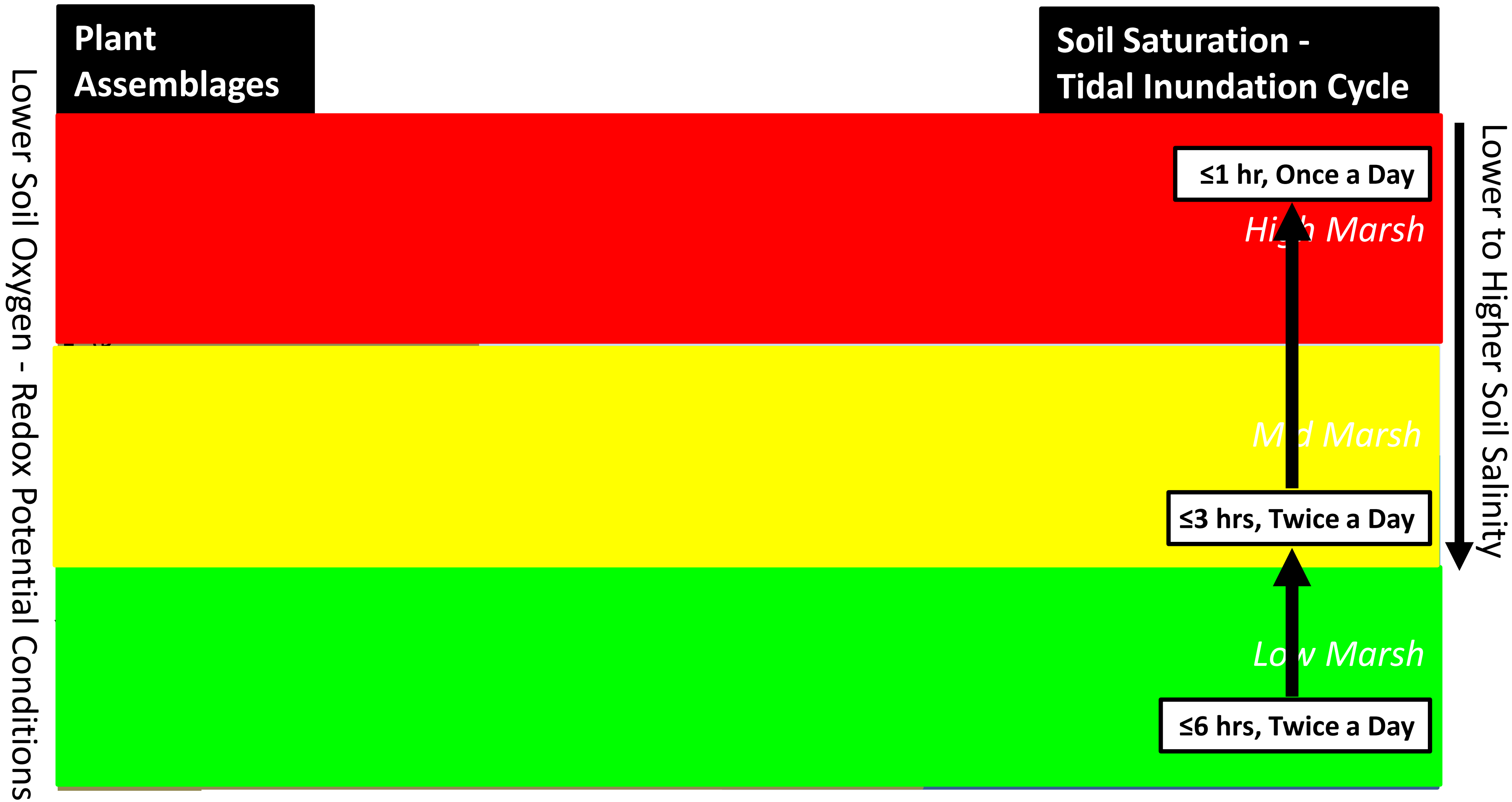
Observed Plant Assemblage Elevation Ranges and Flooding Cycles

Frequency Analysis: Daily Mean Tidal Flooding Conditions from July 15- Sept 15, 2014



Plant Assemblage Elevation Ranges

Frequency Analysis: Daily Mean Tidal Flooding Conditions March 2015



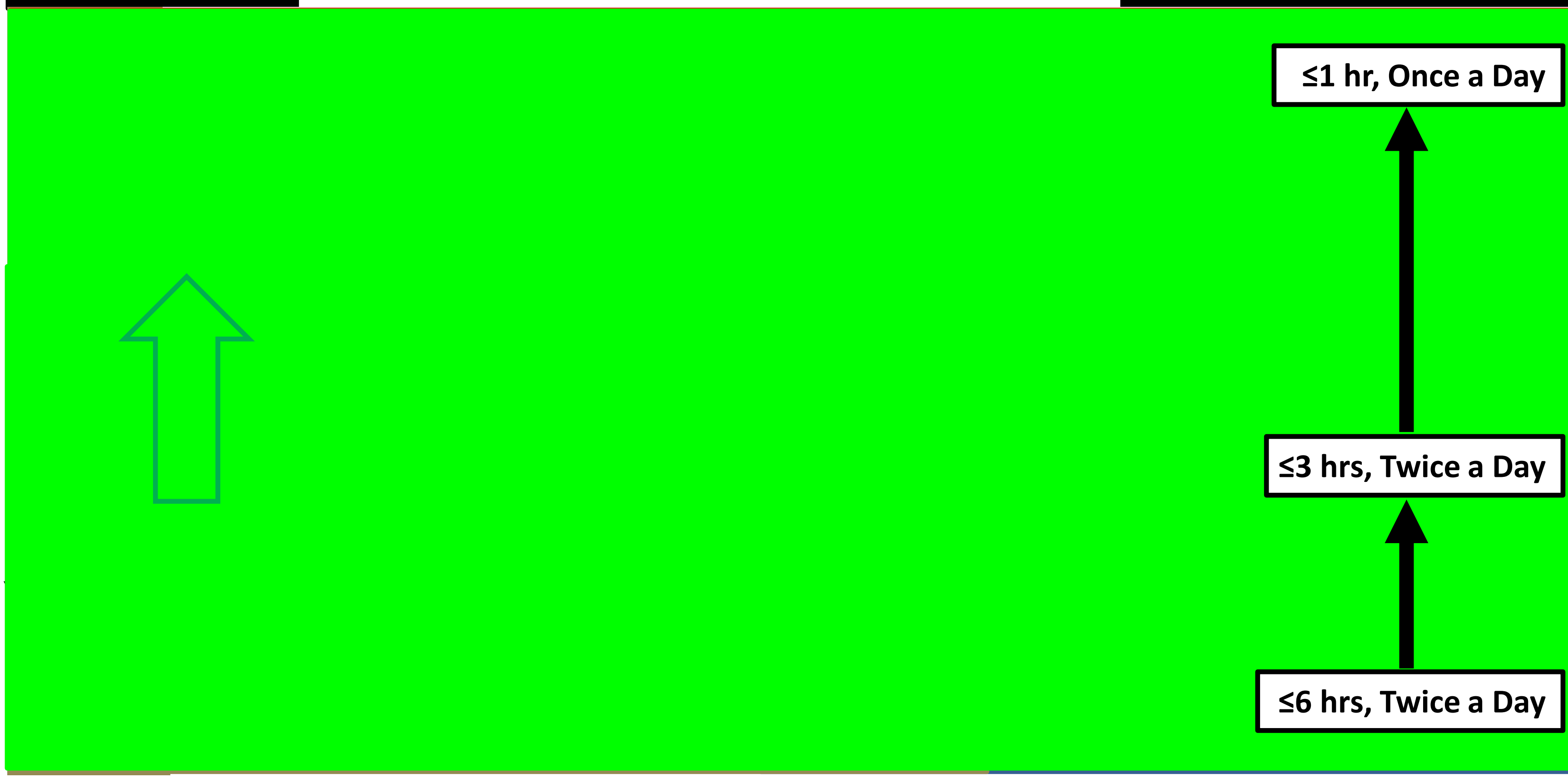
Plant Assemblage Elevation Ranges

Frequency Analysis: Daily Mean Tidal Flooding Conditions March 2015

Plant Assemblages

Soil Saturation - Tidal Inundation Cycle

Lower Soil Oxygen - Redox Potential Conditions



Lower to Higher Soil Salinity

By 2050 SLR is predicted to <u>increase local water levels up</u> to 1.12 ft (0.10-0.34 m) (Glick et al. 2007, Tebaldi et al. 2012)

Seed Bank Composition and Viability

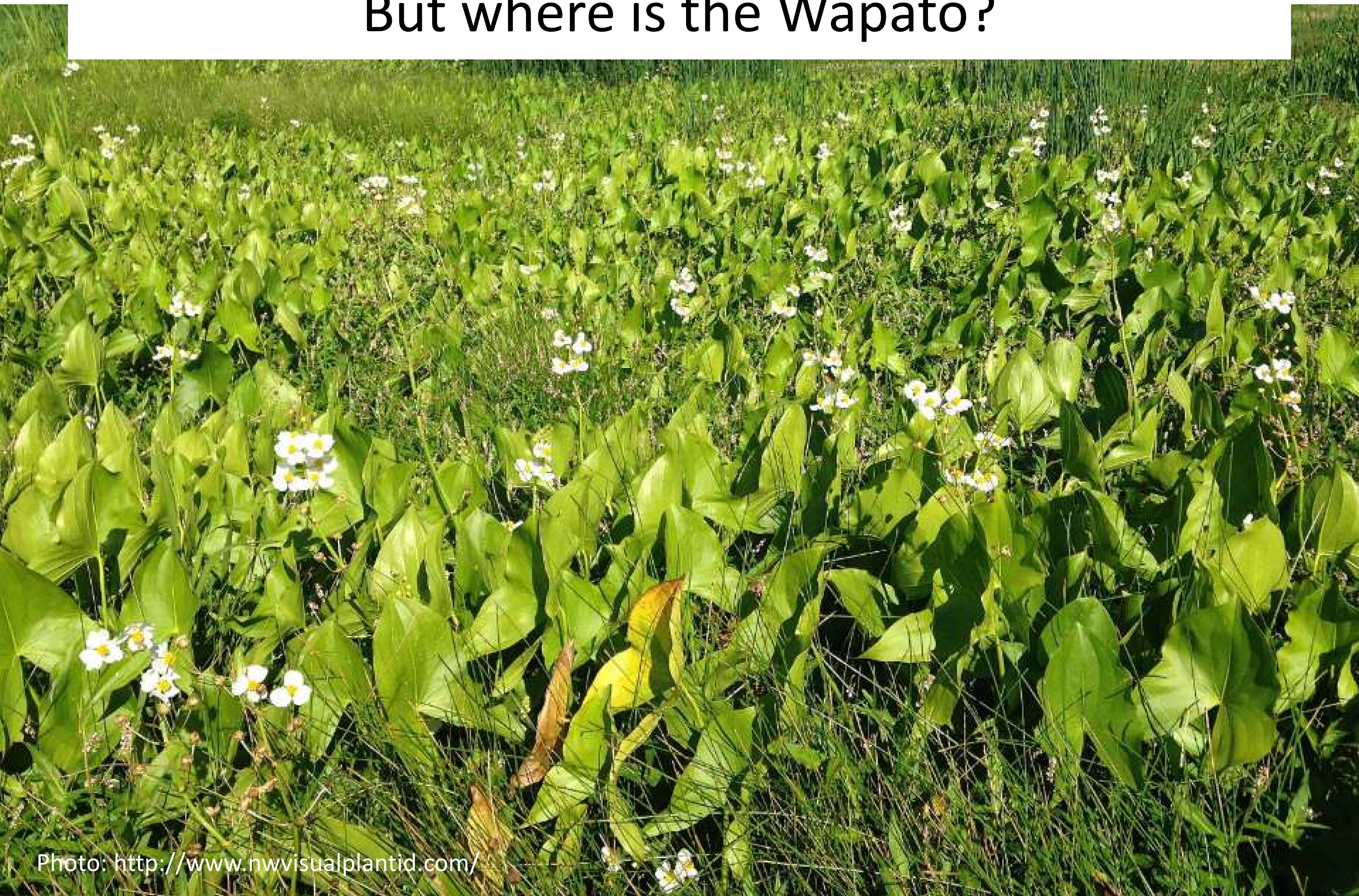
Plant Community Groupings

Reed canarygrass (Ph ar)	Common rush (Ju ef)	Lyngbye's sedge (Ca ly)	Bulrush (Sc la)
			
			

Range limited by flooding and salinity,
Seeds well distributed

Range limited by competition,
Low abundance

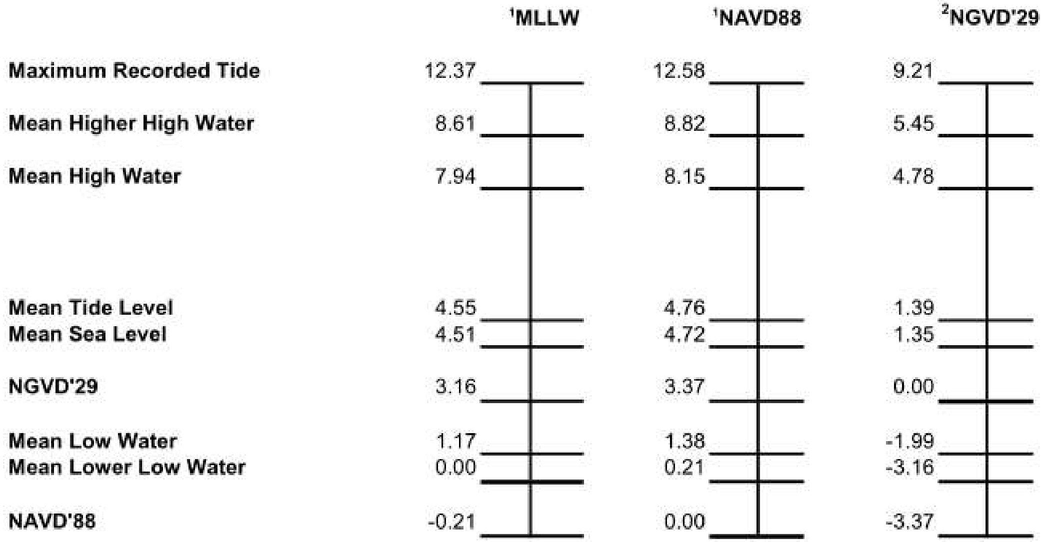
Future Questions:
But where is the Wapato?



Future Questions:
But where is the Wapato?

- Lewis and Clark talk about the abundance of Wapato in Youngs Bay – but where is it today?
  - Loss of the Seed Bank
  - Climate Change, River Regulation
    - Shift in Columbia River Hydrology
    - Shift in Columbia River Salinity
  - Competition with invasive species
- ***<u>Youngs Bay will continue to change</u>***

Photo: http://www.nwvisualplantid.com/



Notes:

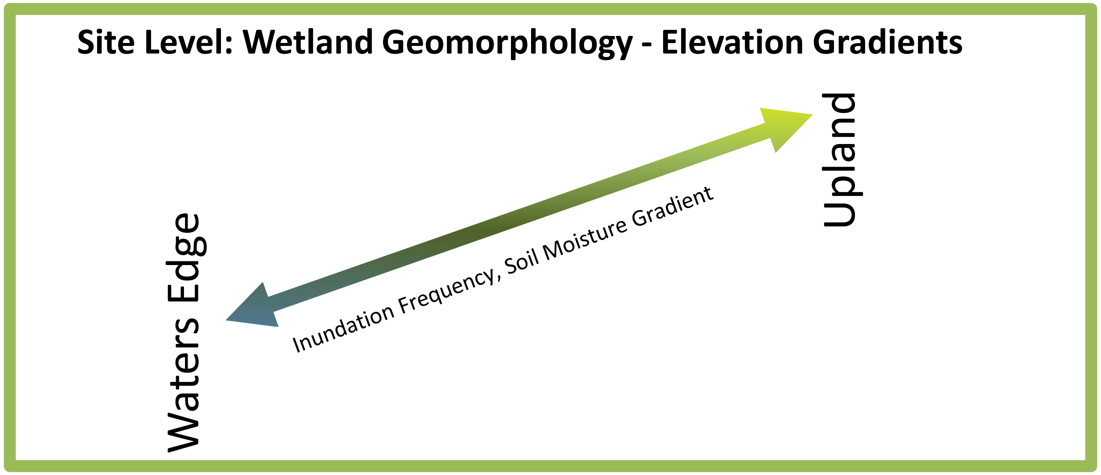
1. Datums published by NOAA Station 9439040, Epoch 1983-2001, retrieved Sept 1, 2010.
2. Conversion to NGVD'29 approximate, determined using VERTCON at the tide gage, not project site.

NAVD88
3.8 (max tide)
2.7 Mean higher high water
2.5 Mean high water
1.45 Mean Tide level
1.44 Mean Sea level
1.03 29' (0)
0.42 Mean low water
0.06 Mean lower low water
0 MLLW (-0.21)

https://tidesandcurrents.noaa.gov/benchmarks/benchmarks_old/9439026.html

METHODS: FIELD SURVEY

3 - 6, 100 m Transects were randomly established along the elevation gradient of each site



Every 5 meters along each transect (n= 60-120 per site):

- ***1m² quadrats: species cover, richness & height, elevation***

Every 20-30 meters (n=12-16 per site):

- ***Dominant plant biomass, soil samples***

Every site's main tidal channel:

- ***Hydrology & water conditions: water surface level elevations***

National Parks Service Restoration Sites

Sites labeled by years after tidal reconnection during the 2013 survey