

Evaluating nature-based shoreline stabilization in a tidal wetland restoration project in the San Francisco Estuary



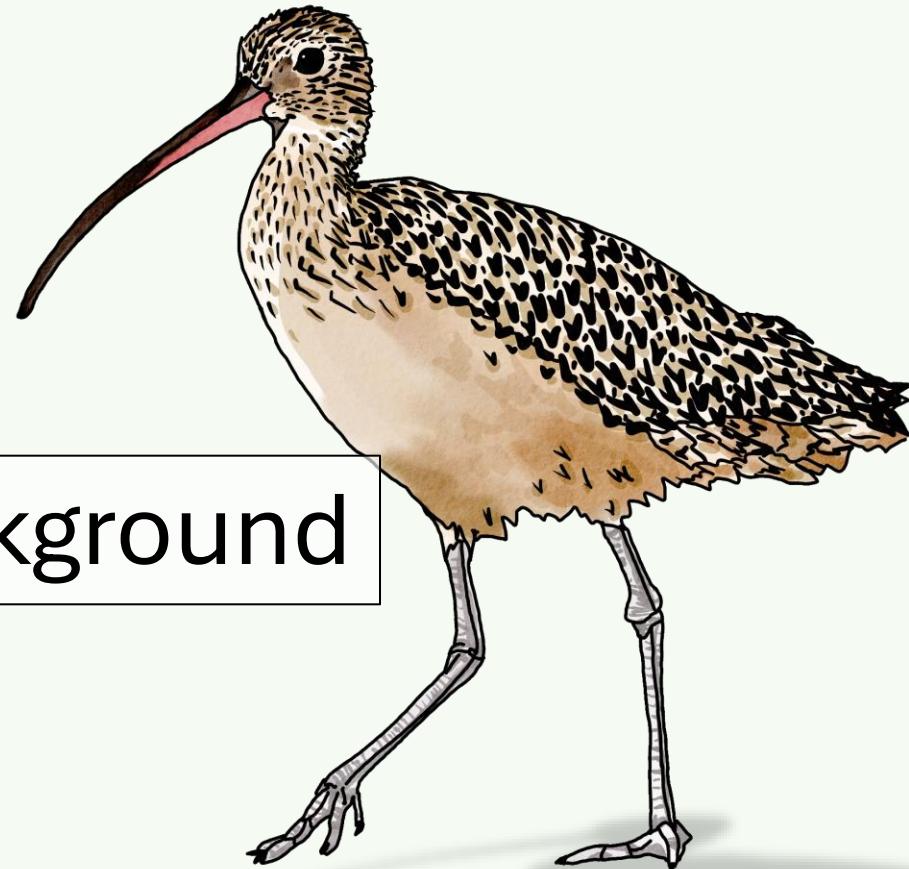
SAN FRANCISCO
STATE UNIVERSITY

ESTUARY & OCEAN
SCIENCE CENTER

AT THE ROMBERG TIBURON CAMPUS

Rebecca Morris
Thesis Defense 11/14/2024
Committee: Dr. Stuart Siegel; SFB NERR
Dr. Peter Baye; Coastal Ecologist
Dr. Katharyn Boyer; SFSU-EOS

Background



What is a tidal salt marsh?



- Coastal wetland
- Found in bays and lagoons
- Flooded and drained by saltwater
- Salt-tolerant plants
- Habitat for many organisms



Background

Image: Rail: Dean LaTry, ebird, 2024; SM Harvest Mouse: GrassrootsEcology, 2024; Bass: MarylandBiodiversity.com, 2024; Delta smelt: CDFW, 2024

ECOSYSTEM SERVICES PROVIDED BY SALTMARSHES.

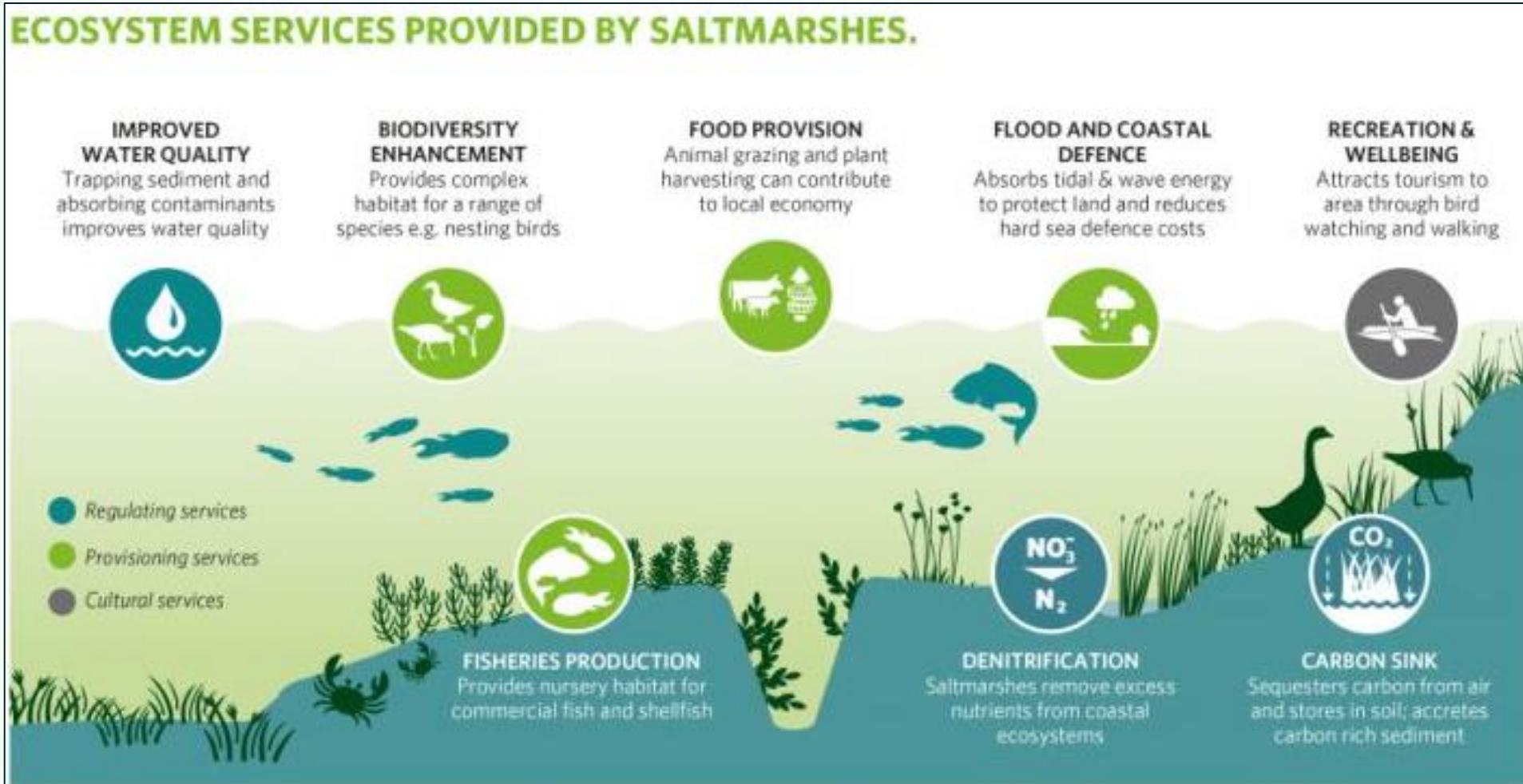


Image: UK Environment Agency, *Saltmarsh Restoration Handbook*, 2021



Image: Harriet Manley, Friends of China Camp, 2024

Sea level rise puts coastal habitats at risk of drowning.

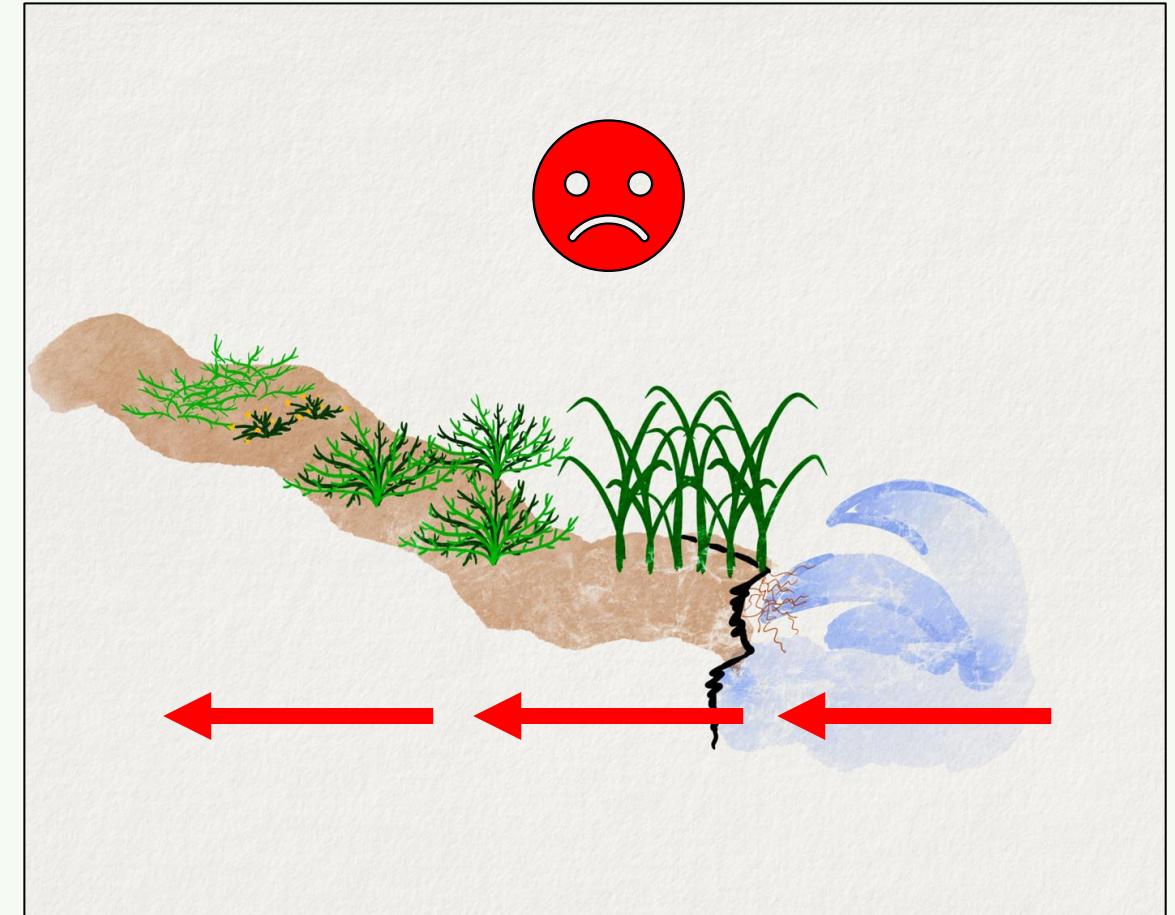
Crosby *et al.*, 2016

Background

Lateral Bay Edge Retreat

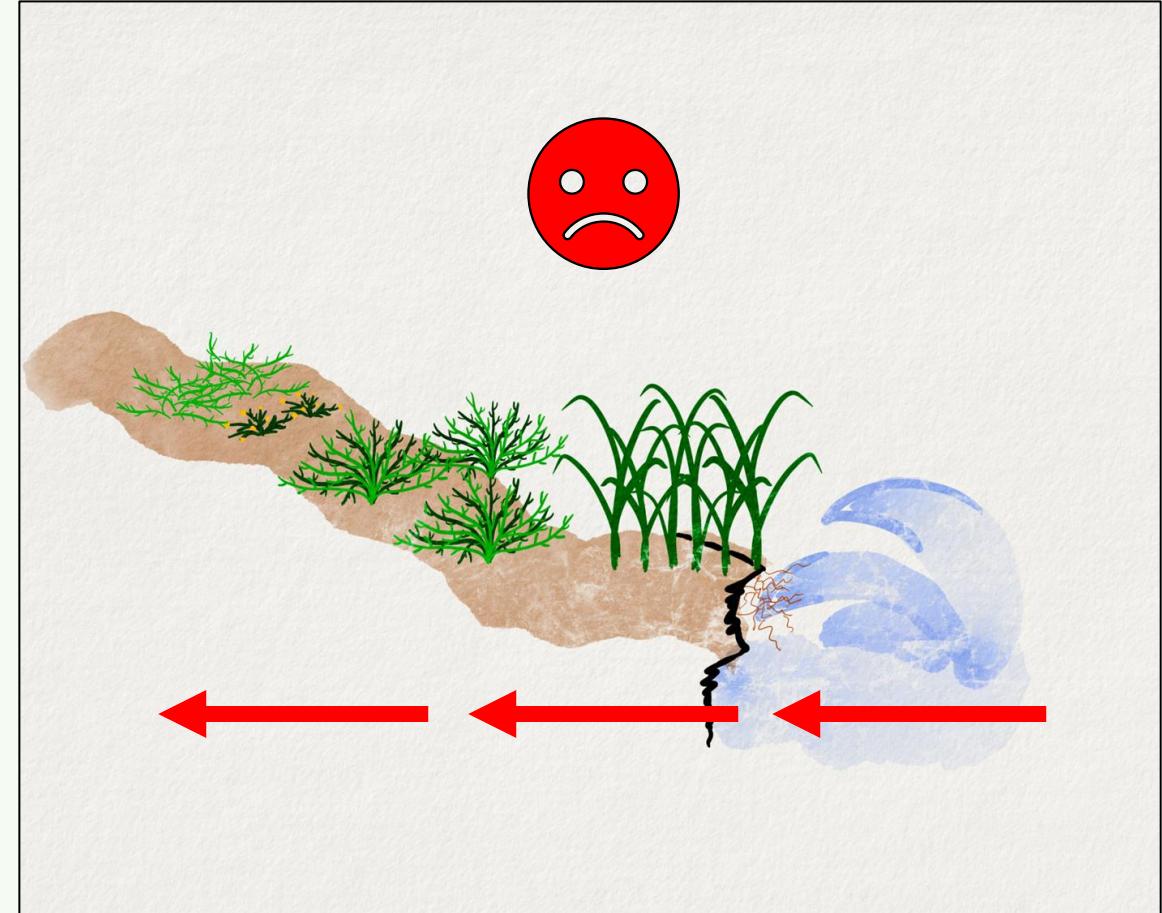
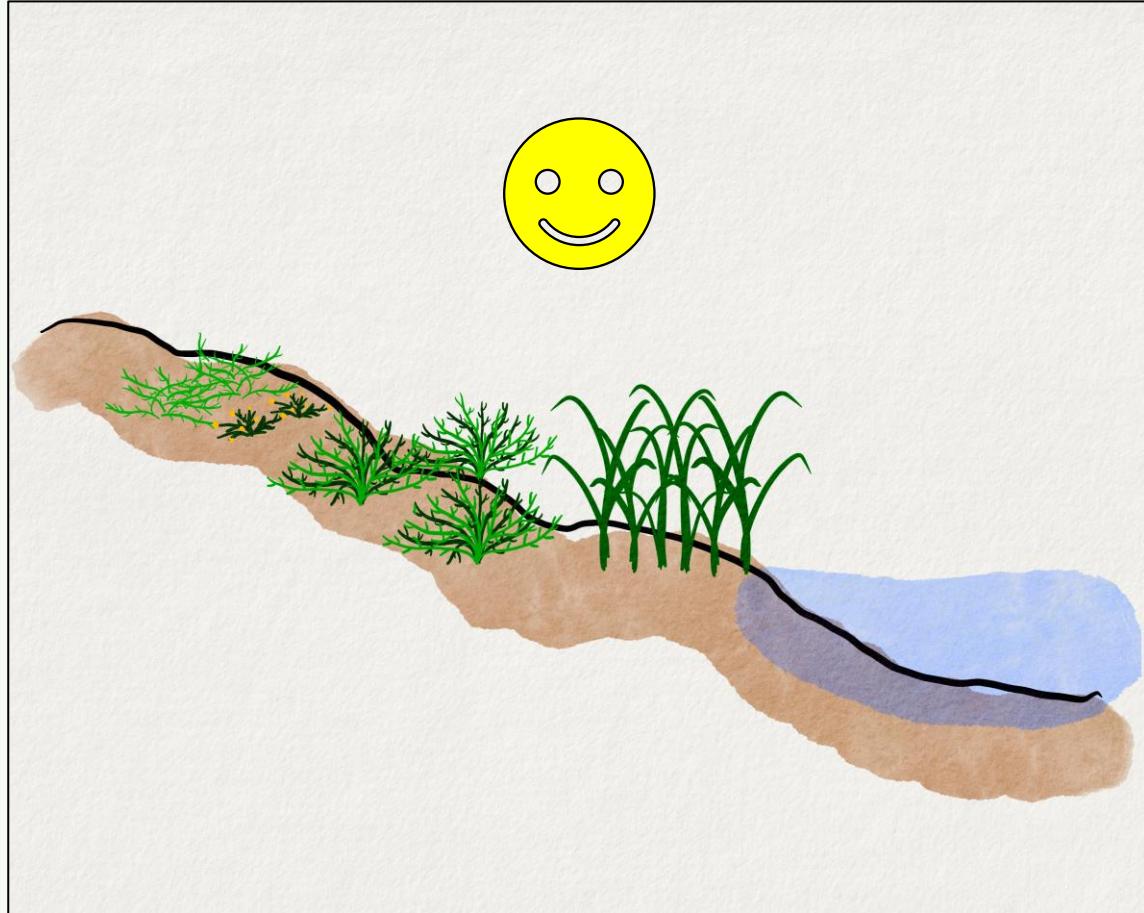
Thought to be main cause
of global marsh loss!!

(Fagherazzi, 2013)



Lateral Bay Edge Retreat

Brinson *et al.*, 1995



Tidal Marshes are Dynamic!

Influences on marsh evolution:

- Elevation with respect to the tide
- Orientation
- Wave energy
- Vegetation type
- Shoreline structure
- Sediment supply
- Land availability

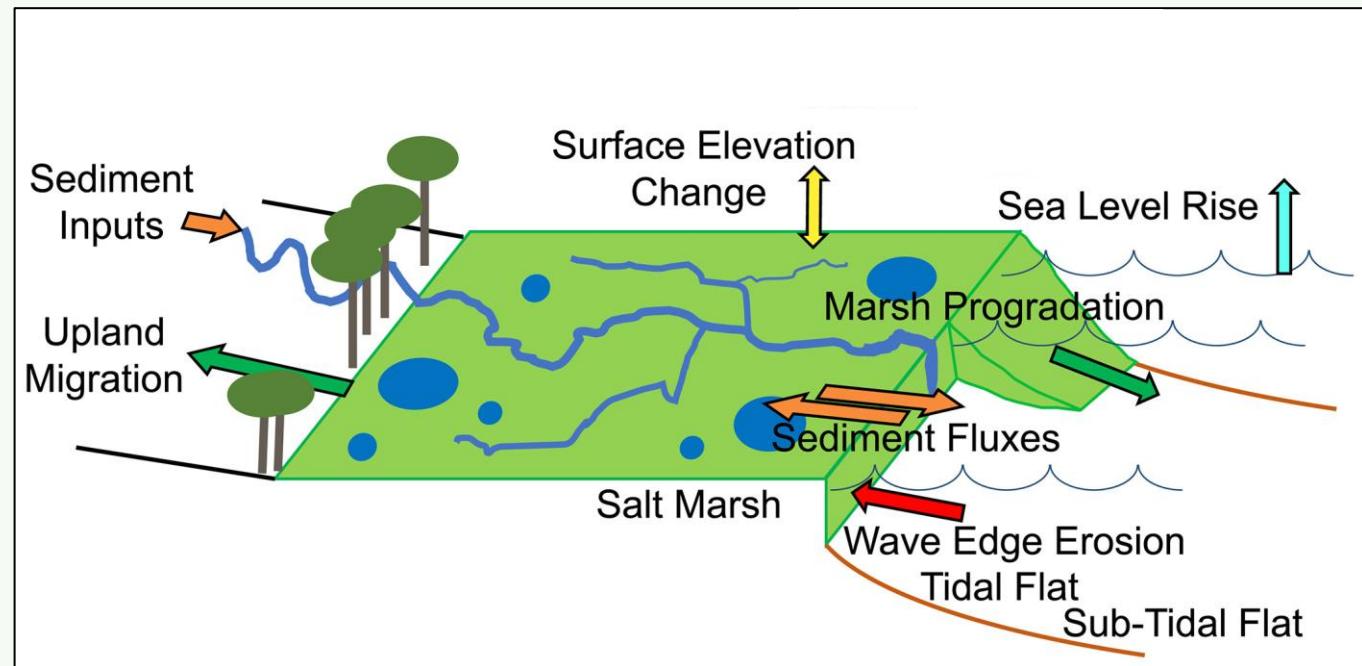


Image: Fagherazzi et al., 2020

Marsh Evolution to Avoid Drowning

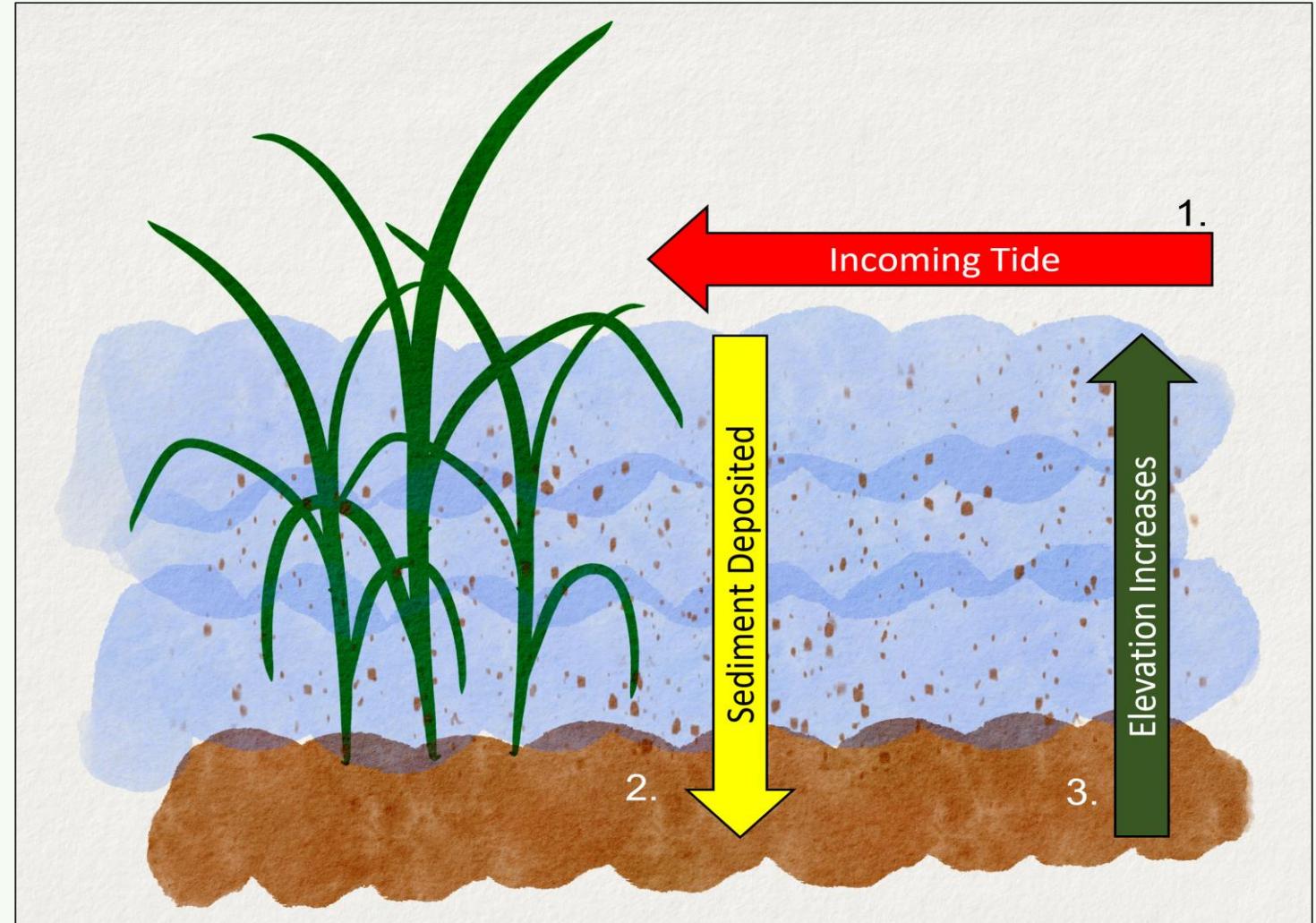
- 1. Vertical Accretion**
- 2. Landward Migration**

Marsh Evolution to Avoid Drowning

1.

Vertical Accretion:
Vegetation-Sedimentation
Feedback Loop

Redfield, A. C., & Rubin, M., 1962



+ plant decaying matter, root/rhizome expansion

Background

Marsh Evolution to Avoid Drowning

2.

Landward Migration

Fagherazzi et al., 2019



King Tide, Sears Point, 2023

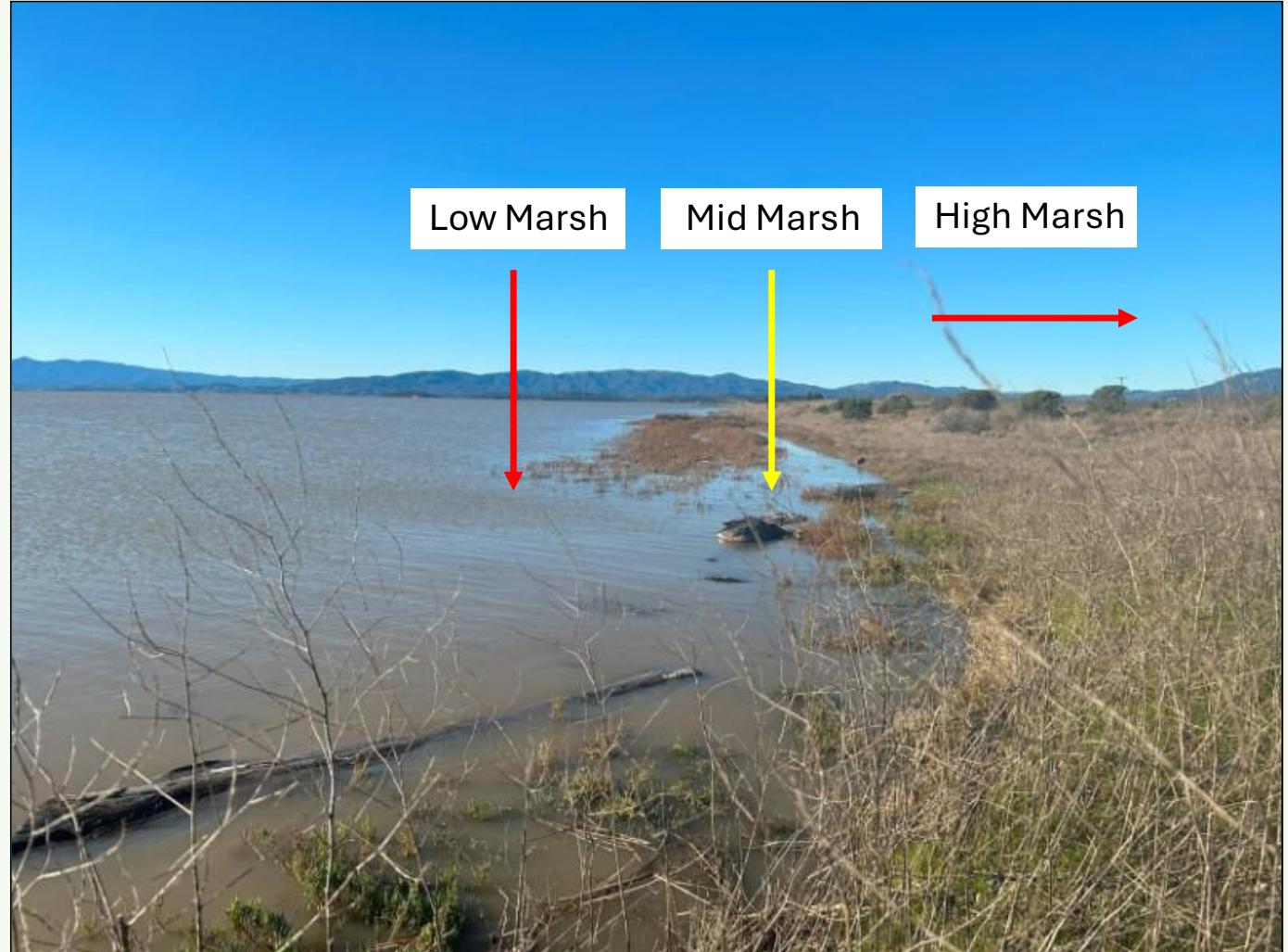
Background

Marsh Evolution to Avoid Drowning

2.

Landward Migration

Fagherazzi et al., 2019



King Tide, Sears Point, 2023

Background

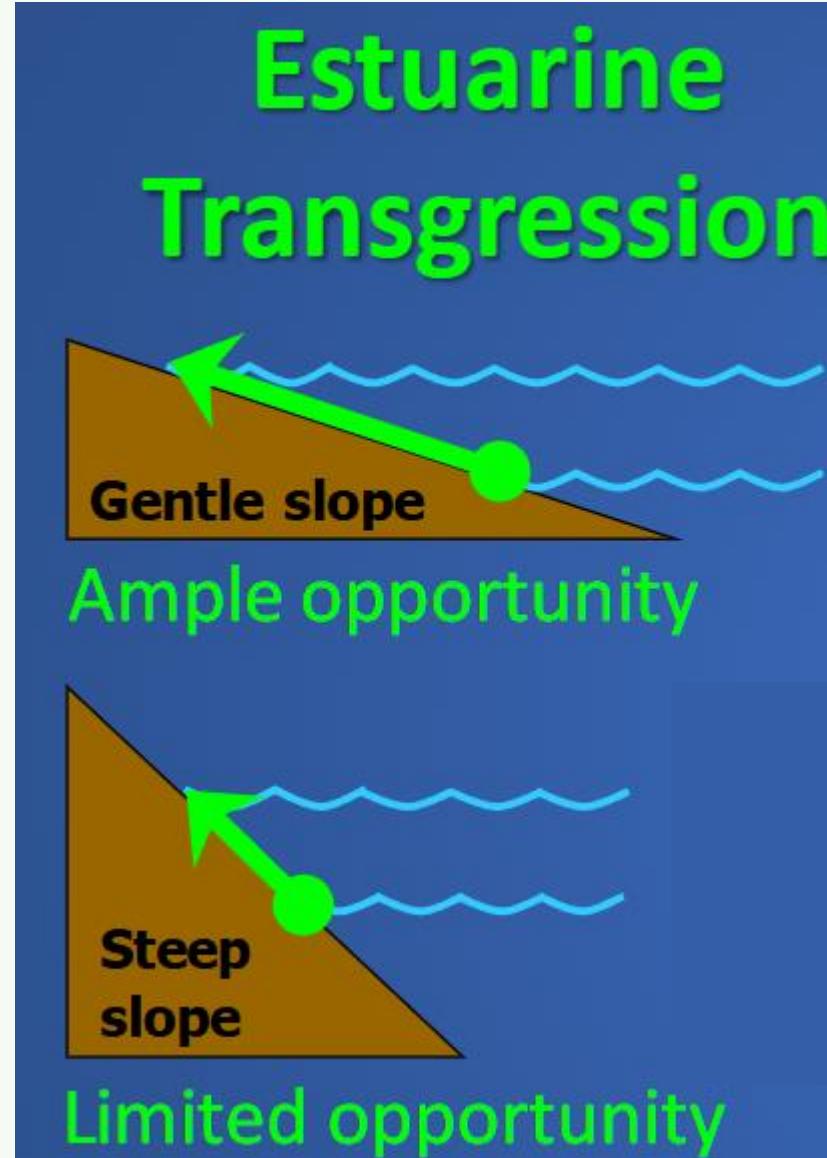
Marsh Evolution to Avoid Drowning

2.

Landward Migration

Fagherazzi et al., 2019

Background



Extend of landward migration potential depends on edge slope:

- Flatter - more
- Steeper - less
- and whether edge blocked by infrastructure.

Marsh Evolution to Avoid Drowning

“Coastal Squeeze”

Doody, 2004



Image: COMPASS Apartment Listing , Seabrook Island, SC, 2024

Background

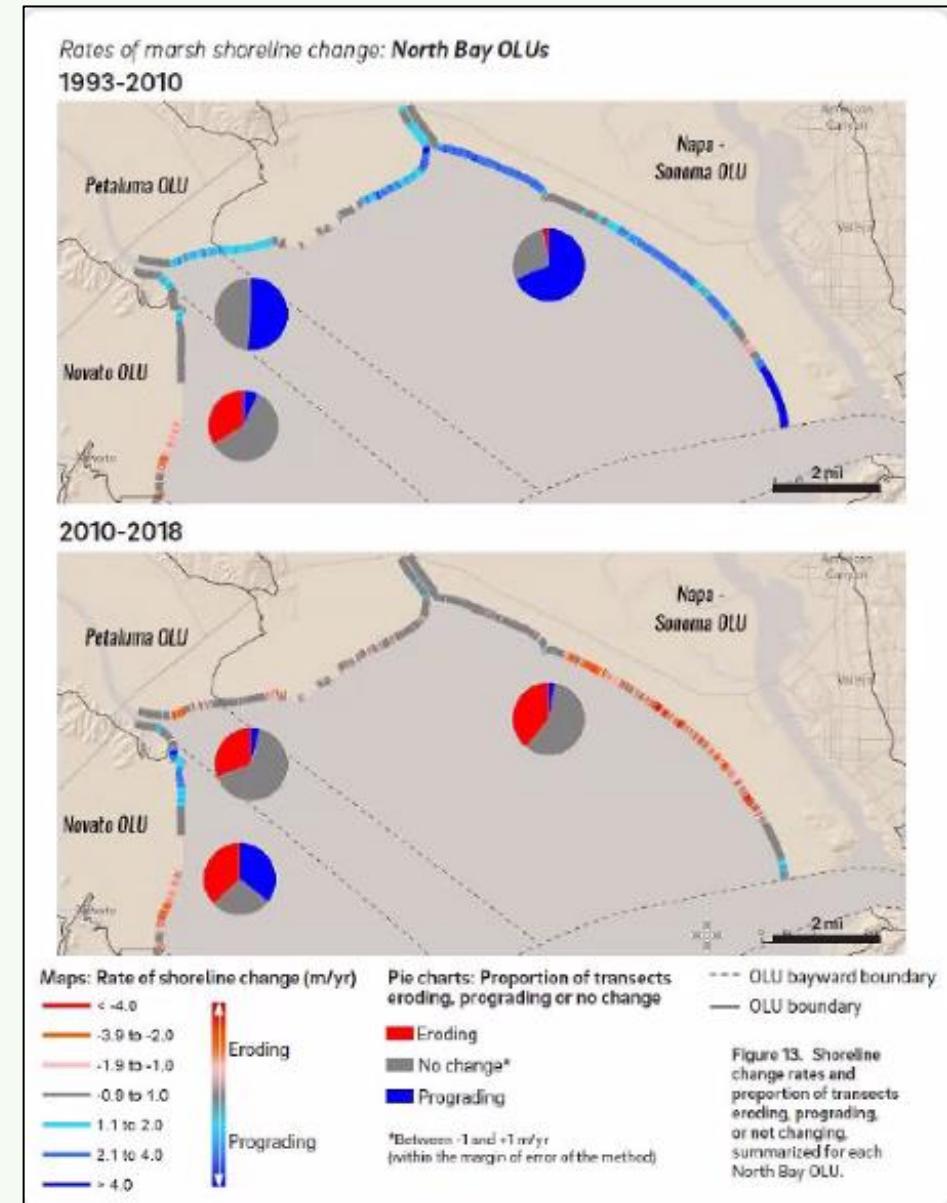
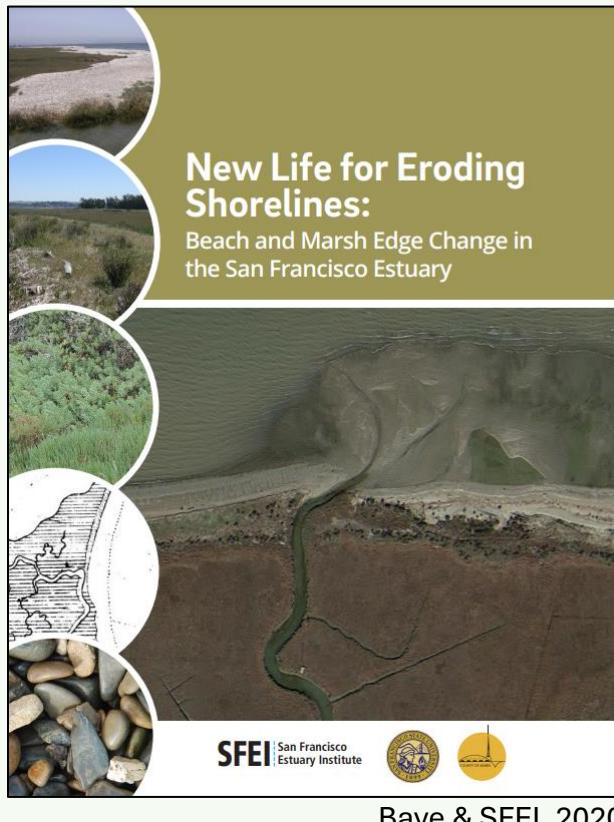
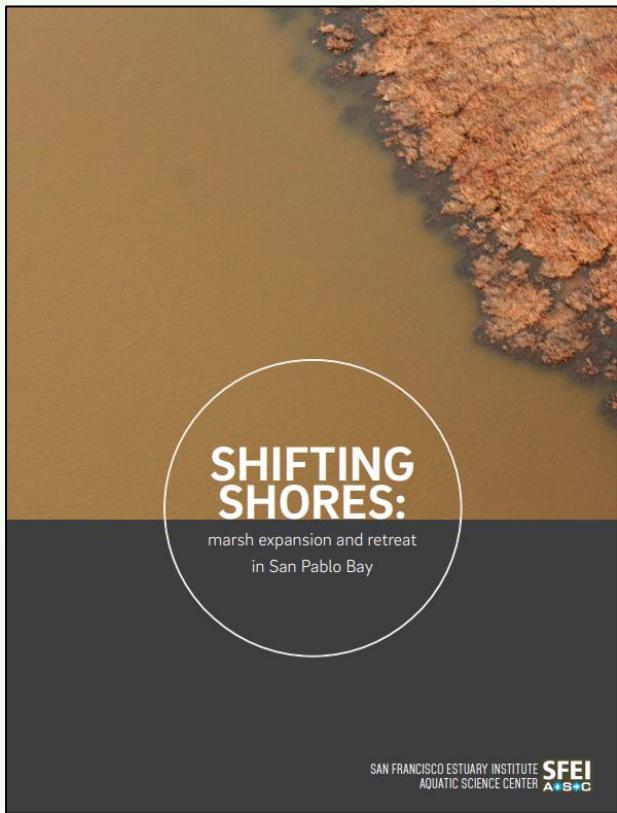
Lateral Bay Edge Retreat

Brinson *et al.*, 1995



Images: Peter Baye, Sears Point, 2019

Lateral Bay Edge Retreat

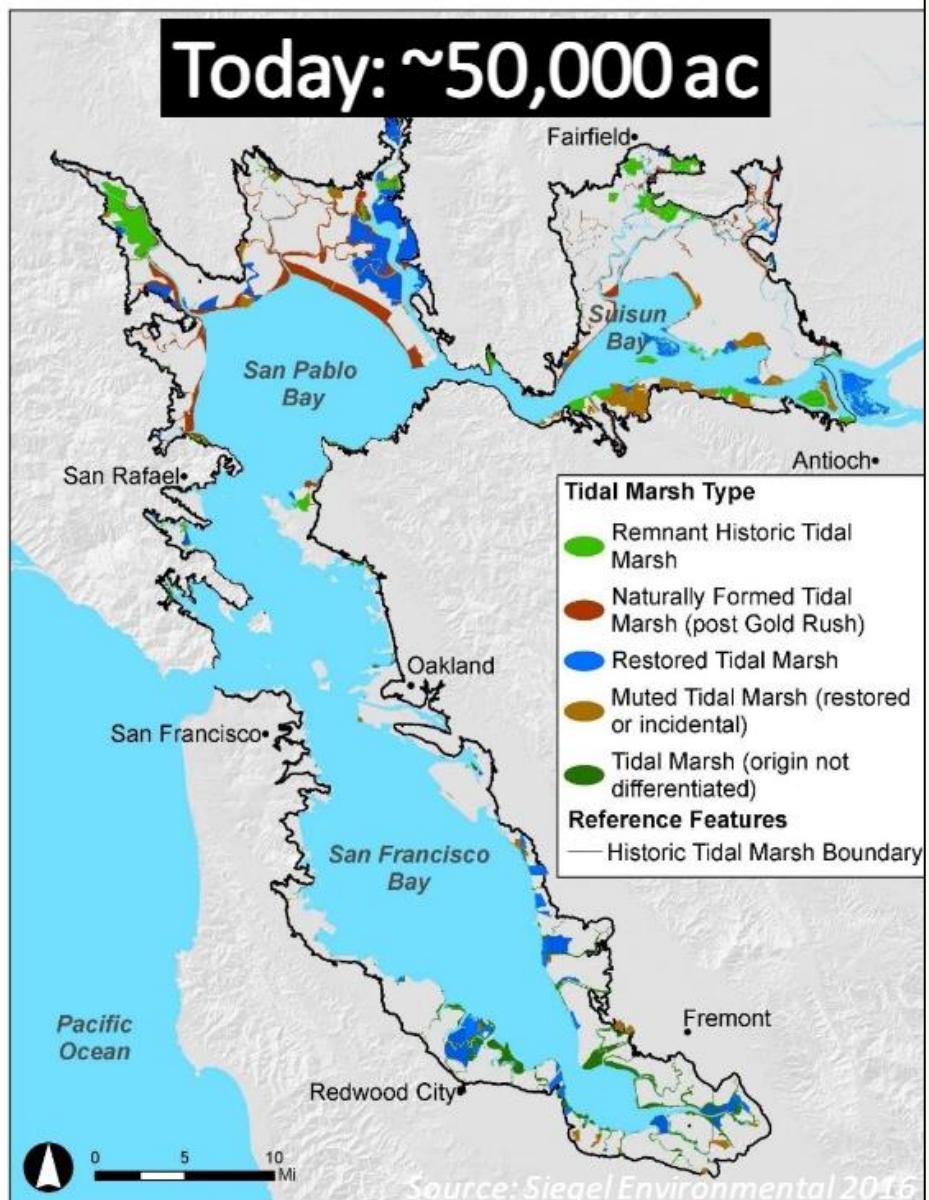
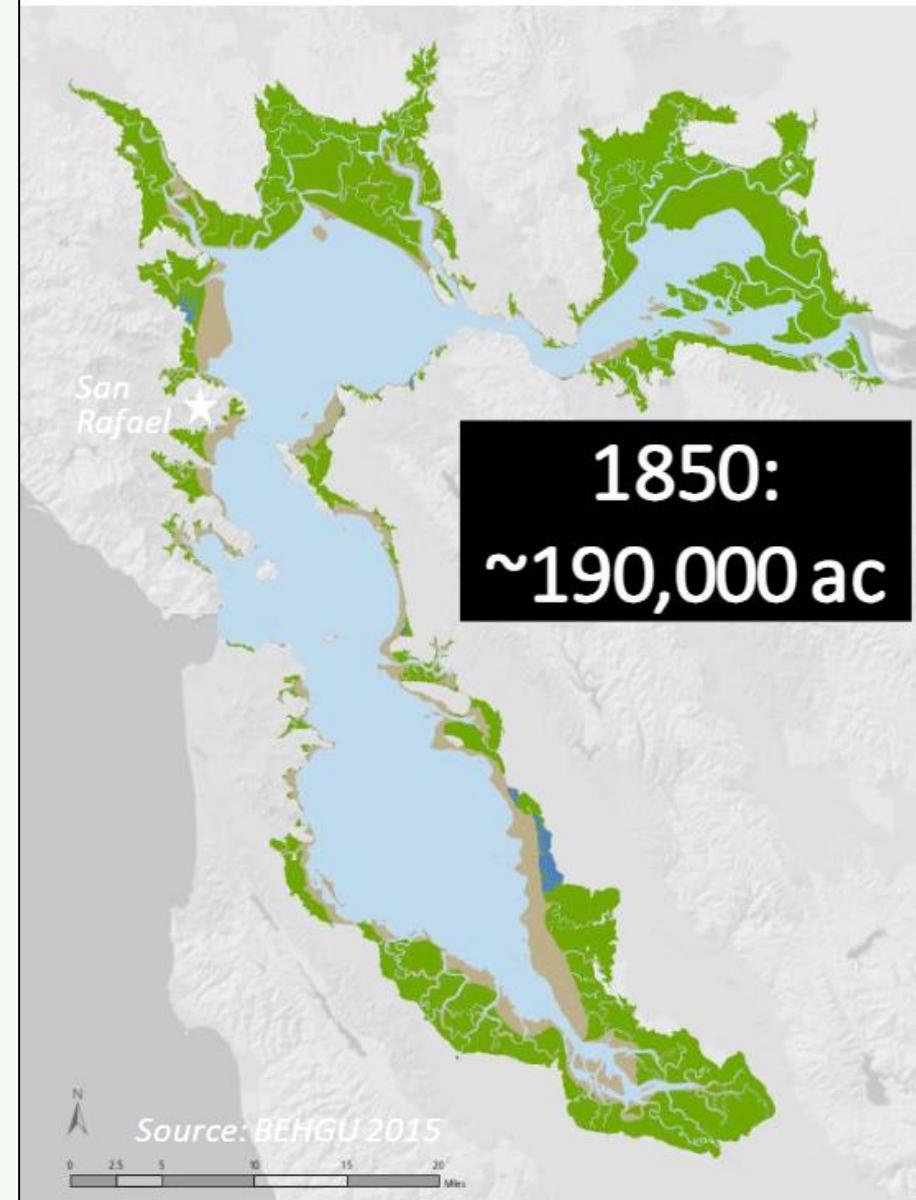


San Francisco Bay Tidal Marsh: Then & Now

90% of SF Bay's historic tidal salt marshes have been lost.

Nichols *et al.*, 1986

Background



Project Aim

To inform future restoration projects on methods that could be beneficial for nature-based shoreline protection strategies.

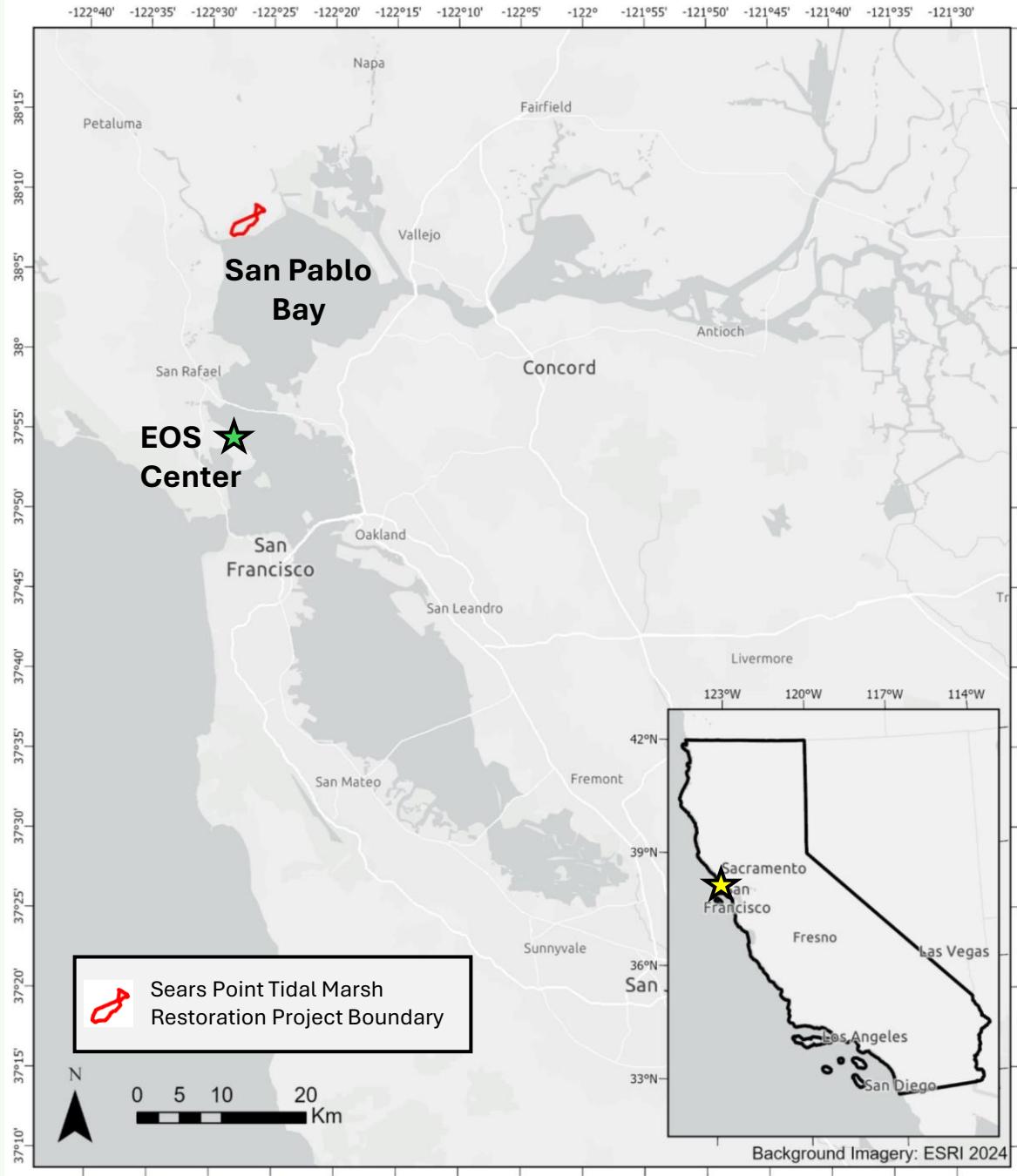


Project Site

Project Site: Sears Point

- San Pablo Bay -- Sonoma, California
- ~380 hectares (939 acres)
- Historic marsh land
- Diked/Farmed for last 150 years
- Subsided ~ 2m (6 ft)
- Acquired by Sonoma Land Trust 2004
- Initial restoration 2015
- Shoreline Repair 2021

Background

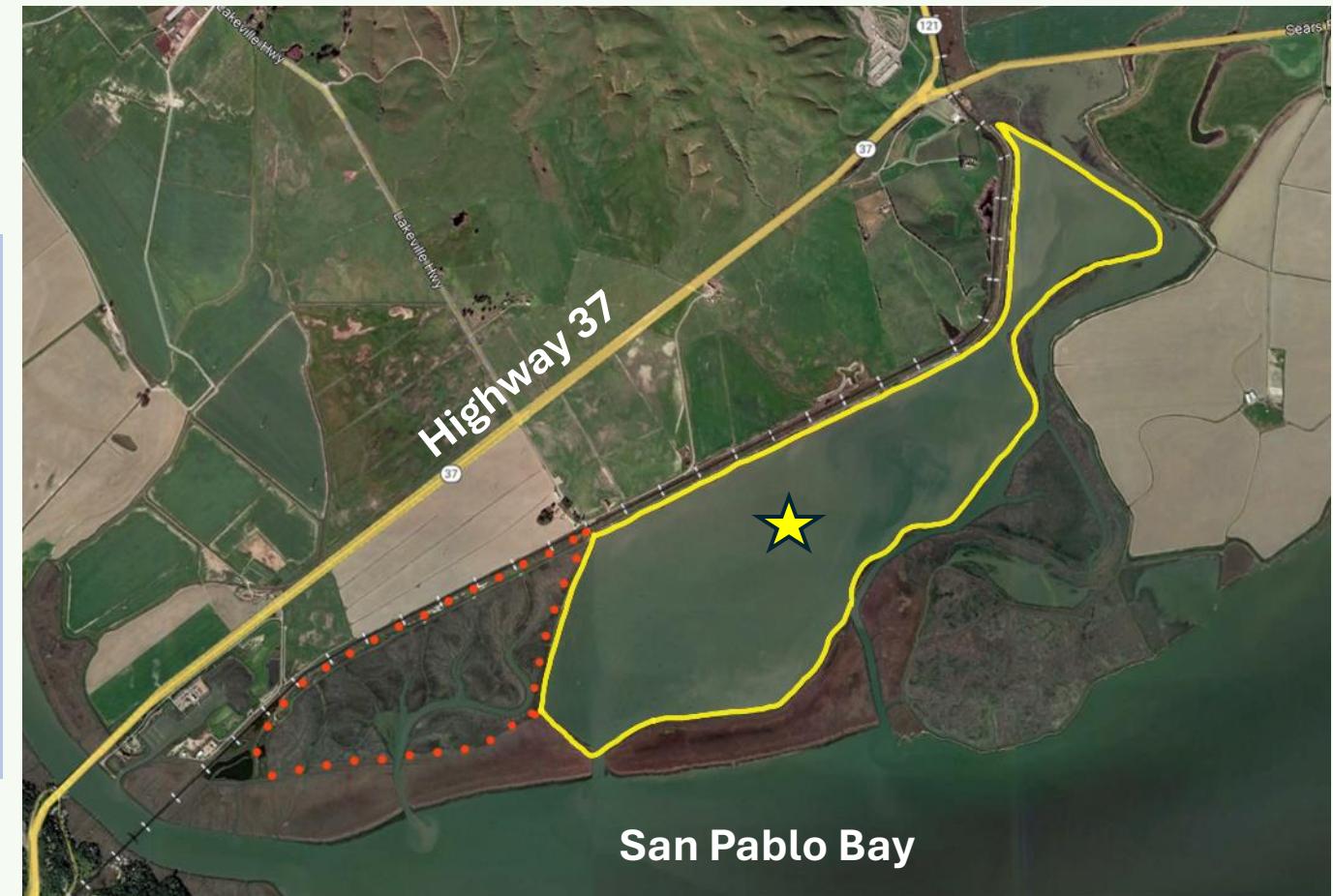


Project Site: Sears Point Tidal Marsh Restoration Project

Initial Restoration 2015:

Goal:

- Protect dike lands to the north including Highway 37.
- Restore tidal marsh habitat for native flora and fauna.
- Provide public recreational access.
- Using nature-based strategies.



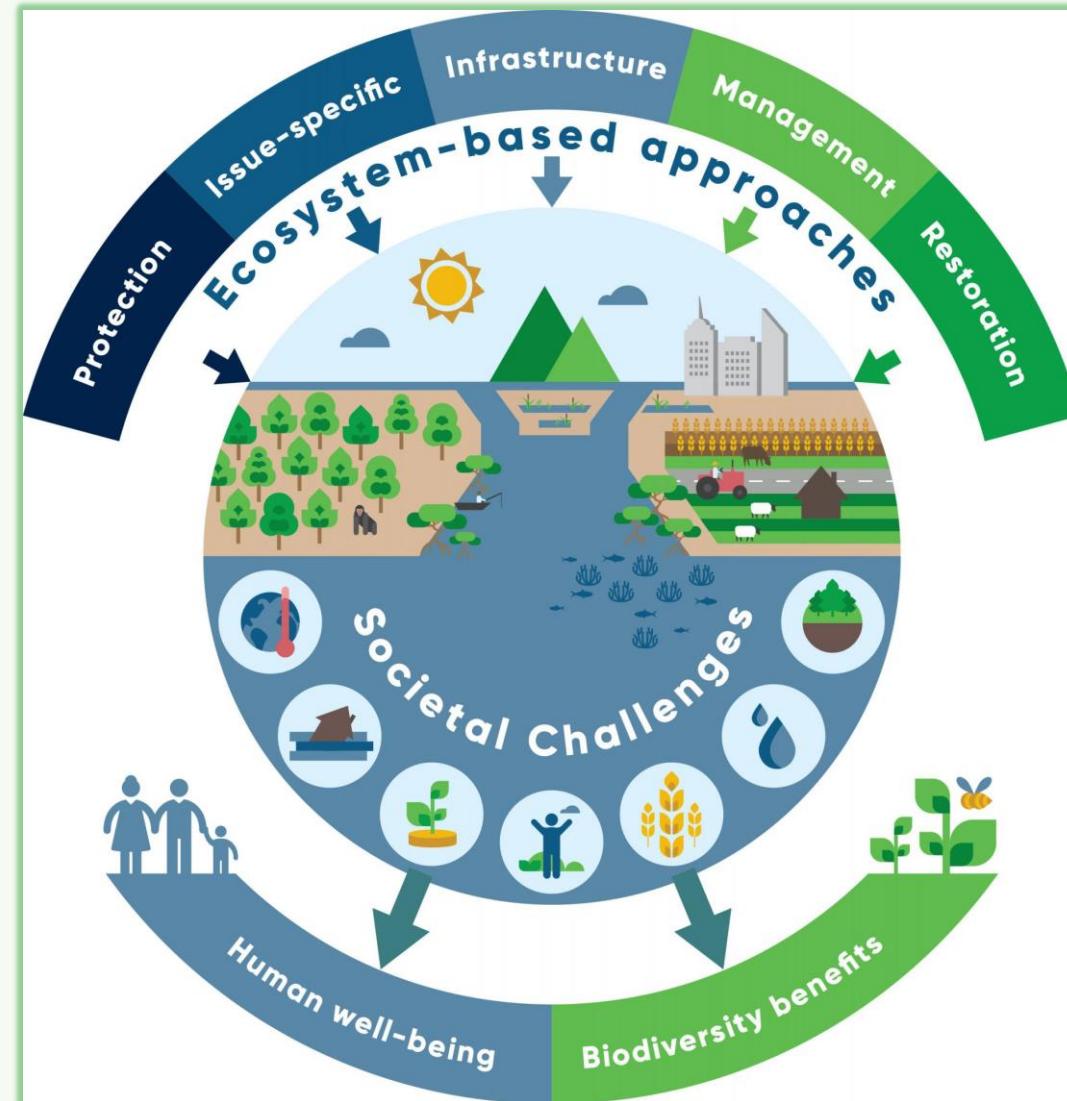
San Pablo Bay

Nature-Based Strategies

Uses nature
AND human-made
structures

KEY: The latter
does NOT
dominate

Bilkovich et al. 2016



Nature-Based Strategies

- Living Shoreline
- Green or blue-green infrastructure
- Soft Structure
- Ecosystem-based adaptation



Image: IUCN World Conservation Congress

Project Site: Sears Point Tidal Marsh Restoration Project

Initial Restoration 2015:

- Habitat control levee
- 500 marsh mounds
- Sacrificial vegetation on mounds and levee



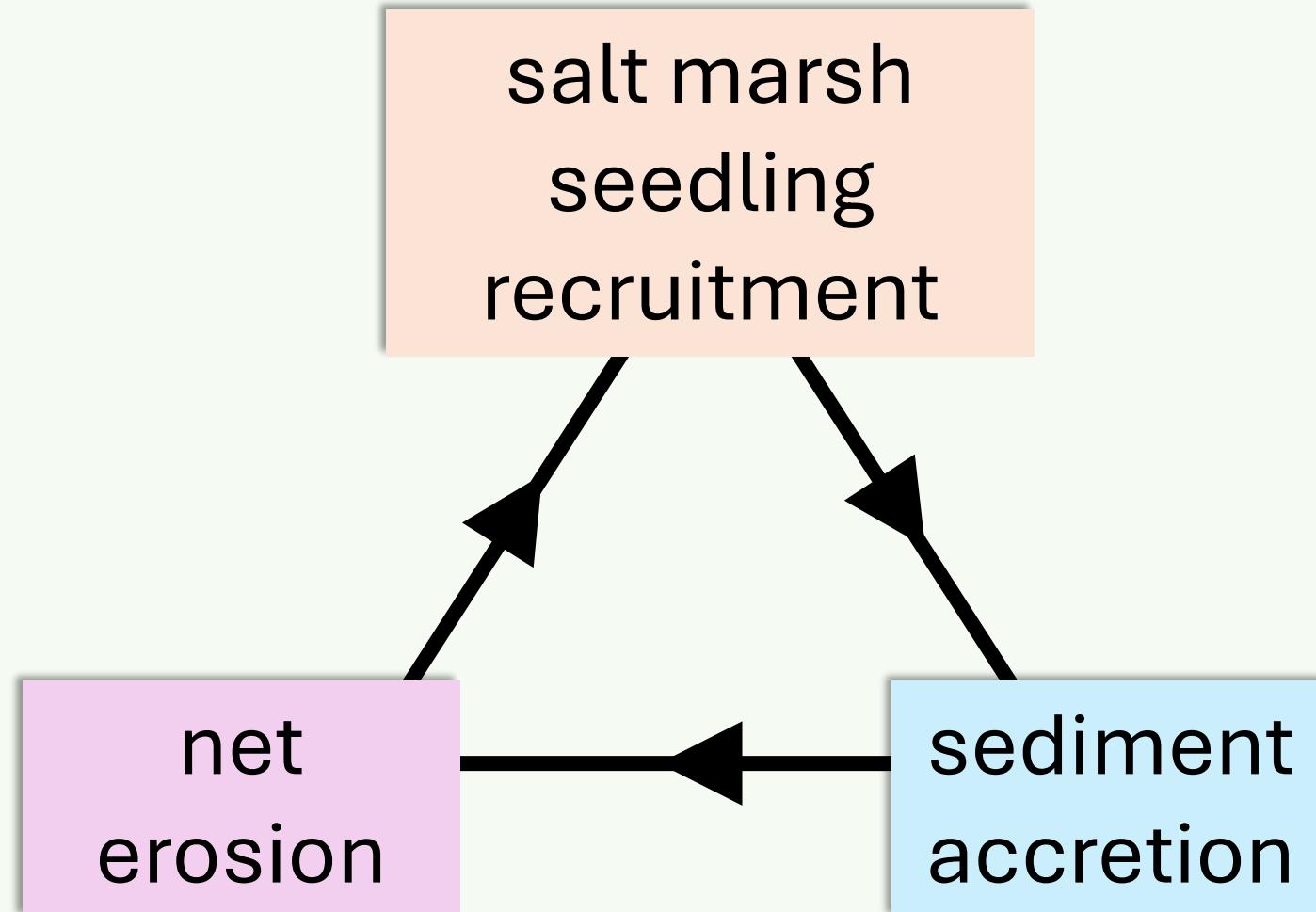
Result:

- Erosion on levee and marsh mounds
- Risk to flood control function
- Failure for habitat to form



Background

The cyclical erosion continued...



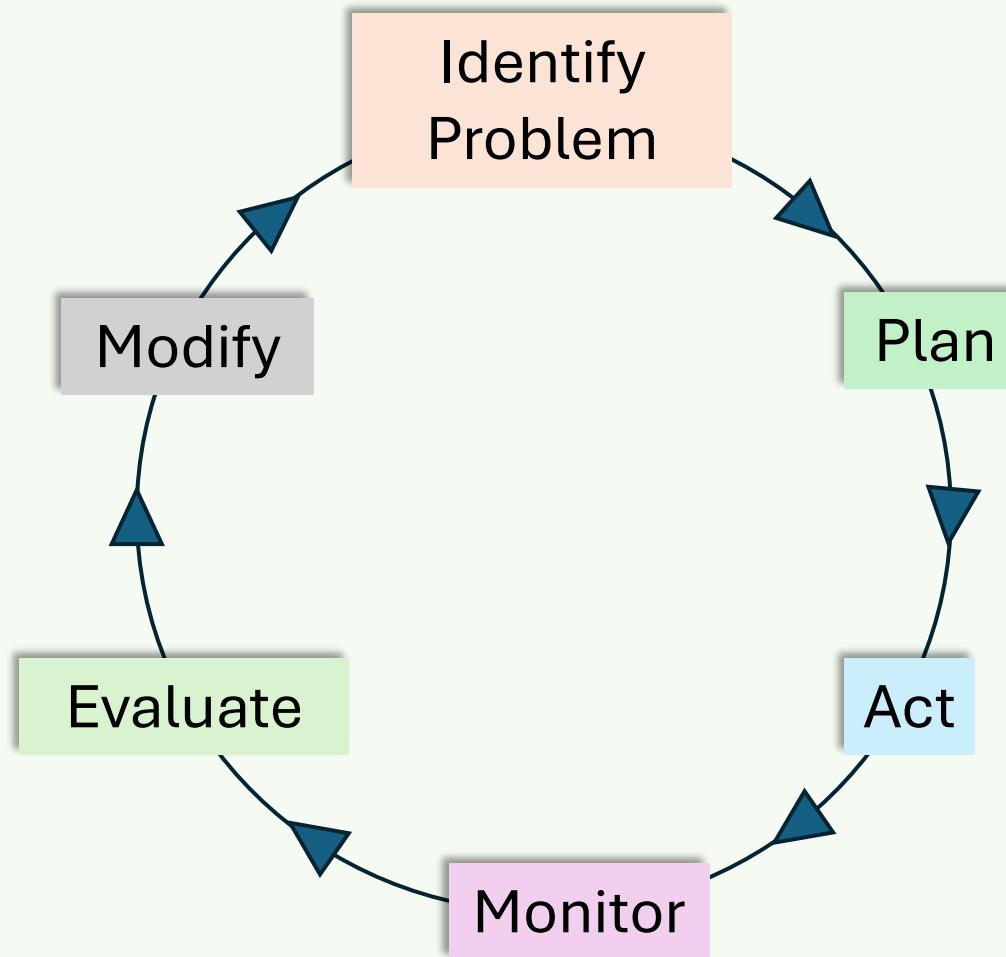


Images: Peter Baye, 2019

An adaptive management approach
was needed...

Adaptive Management Cycle

C.S. Holling, 1973; Lancia *et al.*, 1996



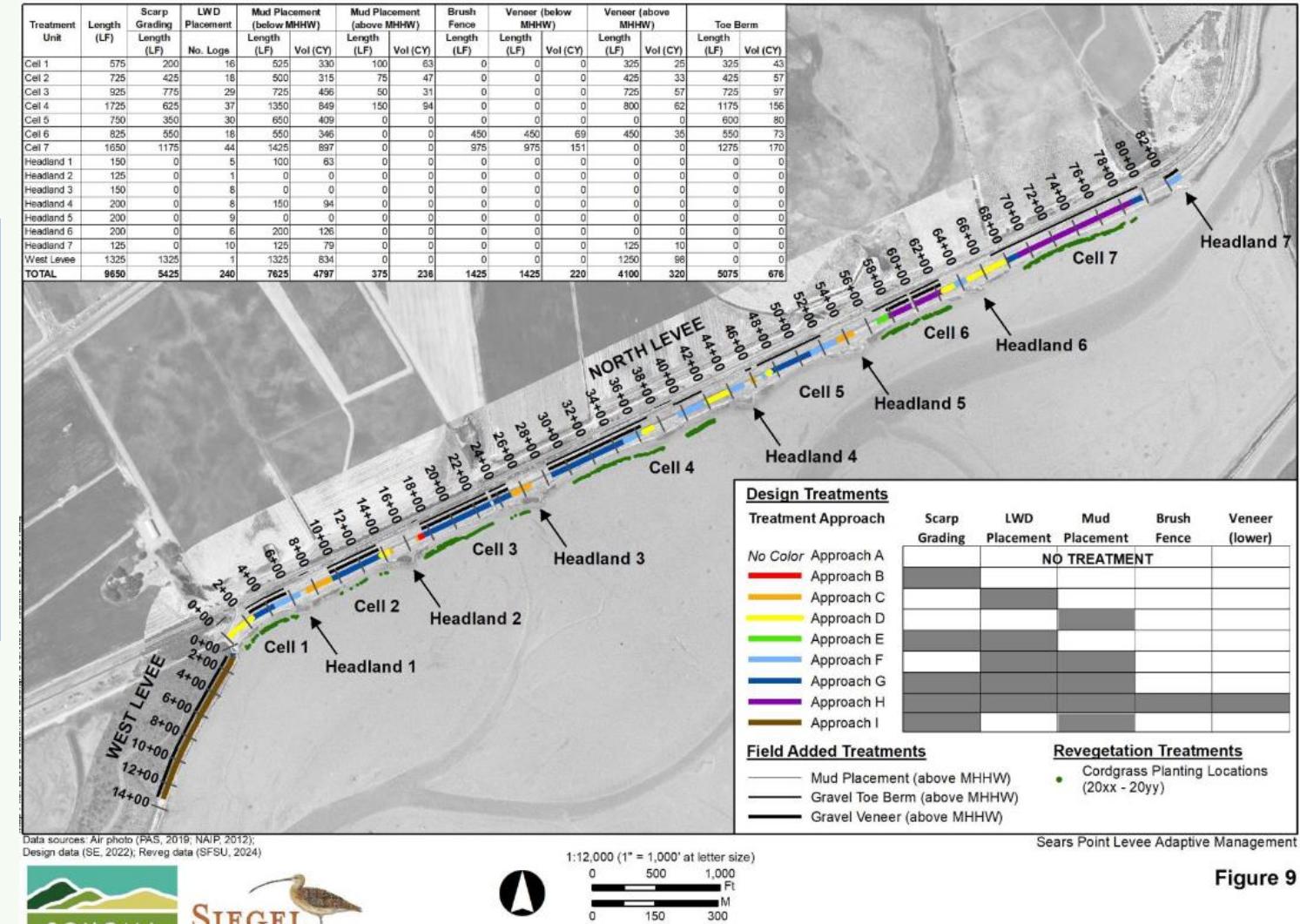
Project Site:

Sears Point Levee Adaptive Management Project

Shoreline Repair 2021:

Goal:

- Stop lateral erosion
- Restore habitat levee slopes
- Encourage:
 - emergent marsh vegetation
 - vertical accretion



Project Site: Sears Point Levee Adaptive Management Project

Shoreline Repair 2021:

- Salt marsh vegetation added (2019-2021)



Image: Stuart Siegel



Image: SP Restoration Project Monitoring Report 2015-2020

Project Site: Sears Point Levee Adaptive Management Project

Shoreline Repair 2021:

- Shoreline regraded
into a low angle slope

Before Construction
(photos August 2021)



After Construction
(photos February 2022)



Image: SPLAMP Report 2022

Project Site: Sears Point Levee Adaptive Management Project

Shoreline Repair 2021:

- Shoreline regraded into a low angle slope
- **Large-woody debris installation (logs)**

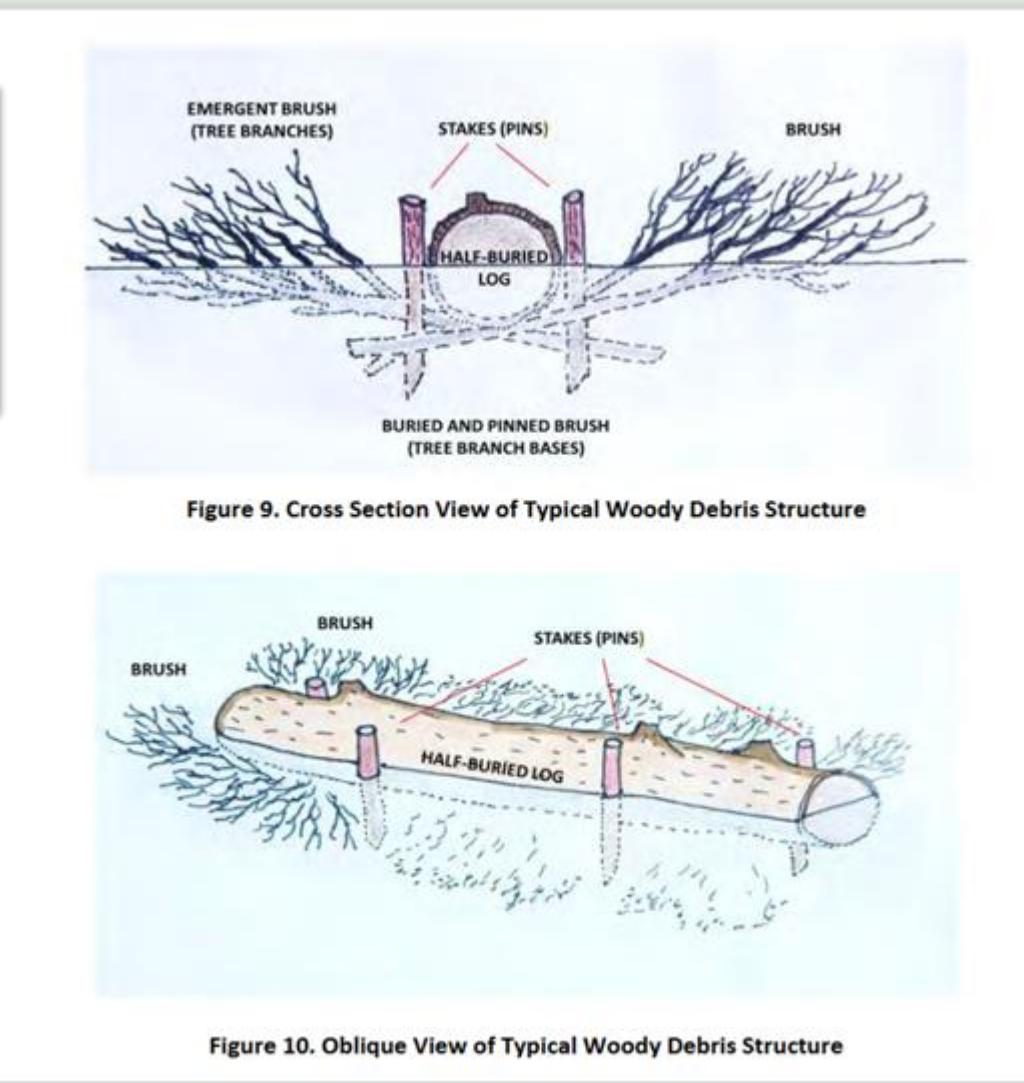


Figure 9. Cross Section View of Typical Woody Debris Structure

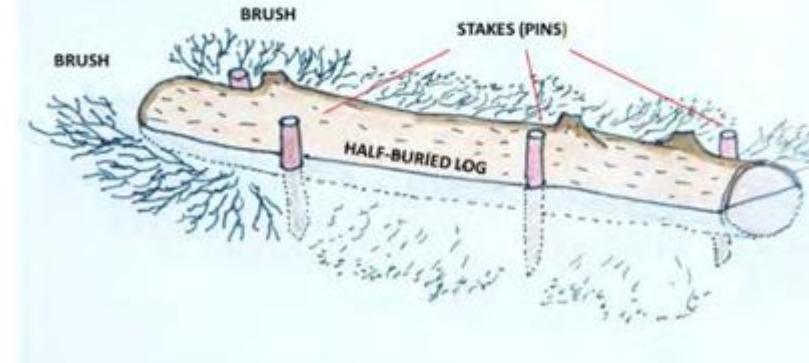


Figure 10. Oblique View of Typical Woody Debris Structure



Images: SPLAMP Report 2022

Project Site: Sears Point Levee Adaptive Management Project



Images: SPLAMP Report 2022

Project Site: Sears Point Levee Adaptive Management Project

Shoreline Repair 2021:

- Shoreline regraded into a low angle slope
- Large-woody debris installation
- Bay side of Logs:
 - Loose crushed dried bay mud



Project Site: Sears Point Levee Adaptive Management Project

Shoreline Repair 2021:

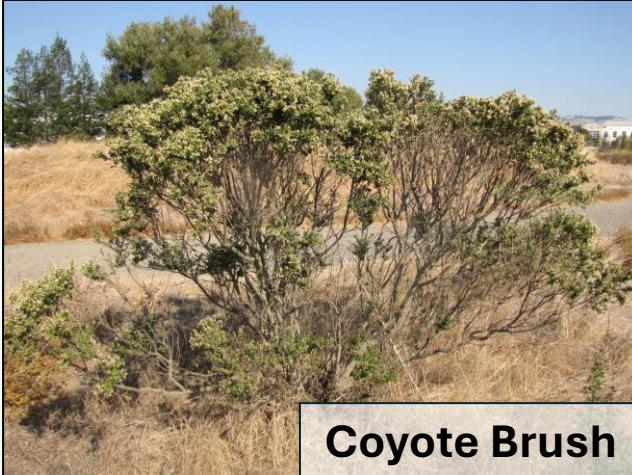
- Shoreline regraded into a low angle slope
- Large-woody debris installation
- Bay side of Logs:
 - Crushed dried bay mud
- Land side of logs:
 - Thin layer small angular gravel
 - Small rounded gravel



Project Site: Sears Point Levee Adaptive Management Project

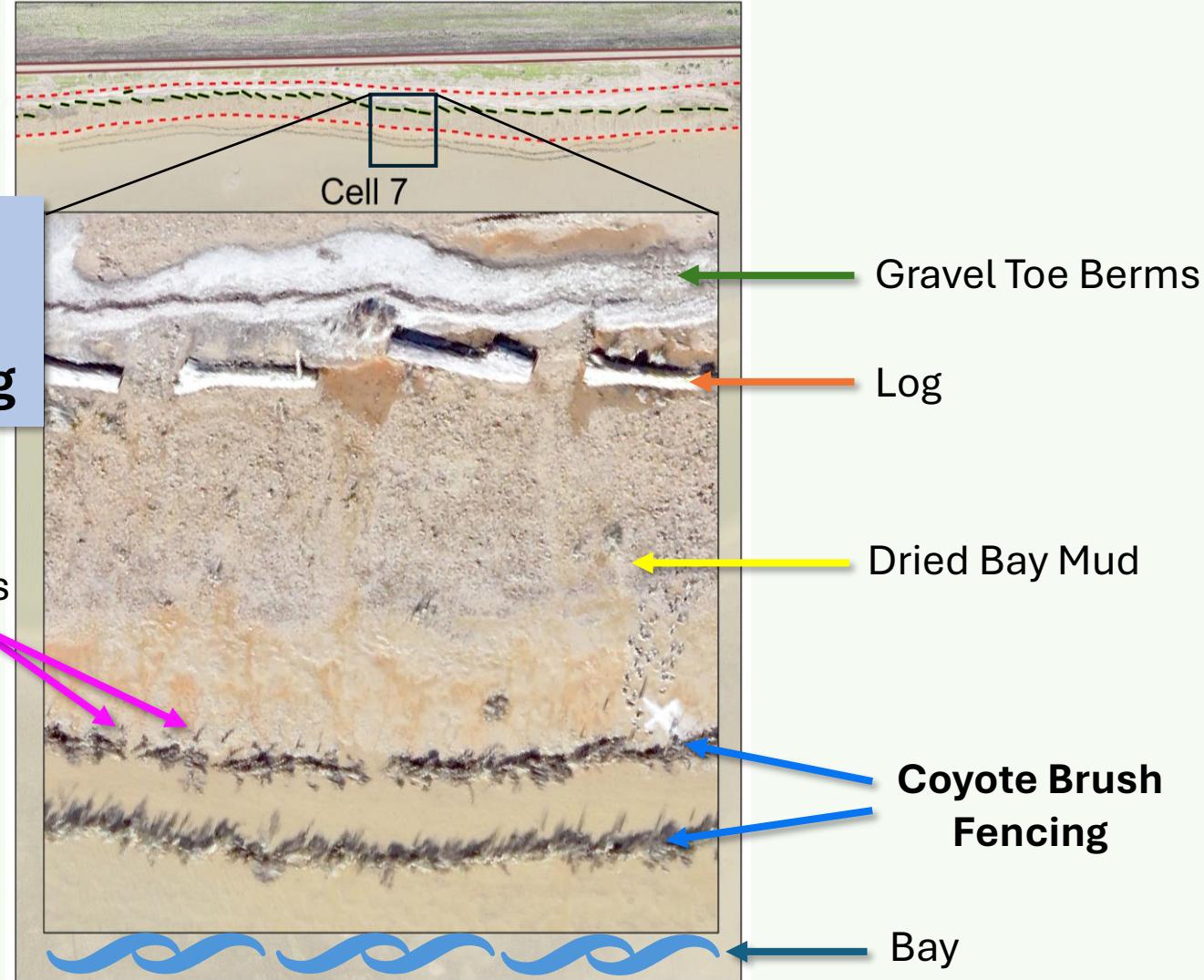
Shoreline Repair 2021:

- Supplementary treatments
 - East end ONLY:
 - Sacrificial coyote brush fencing



Coyote Brush

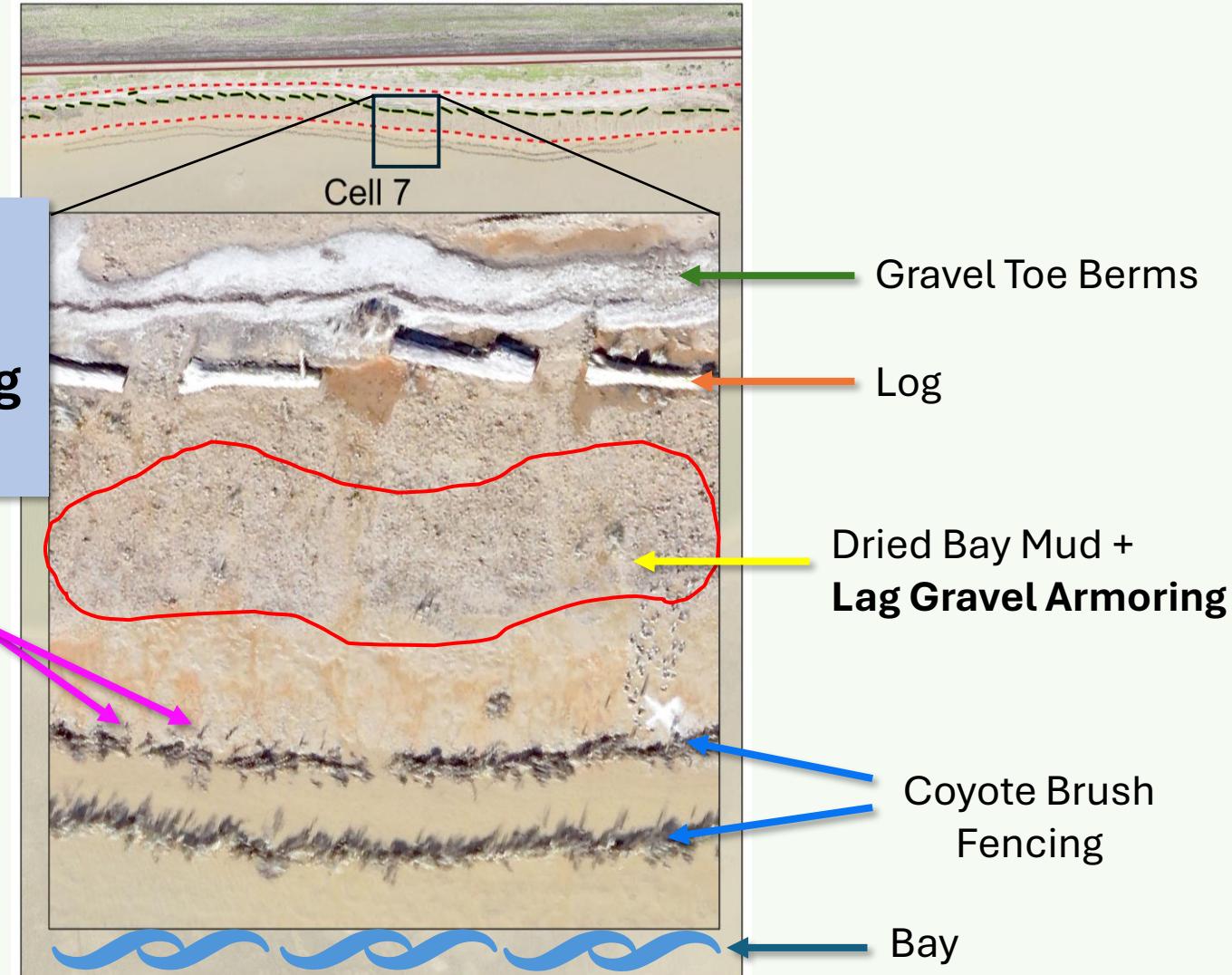
Background



Project Site: Sears Point Levee Adaptive Management Project

Shoreline Repair 2021:

- Supplementary treatments
 - East end ONLY:
 - Sacrificial coyote brush fencing
 - Lag gravel armoring



Background

Nature-Based Treatments by Shoreline End

West and Central Shoreline

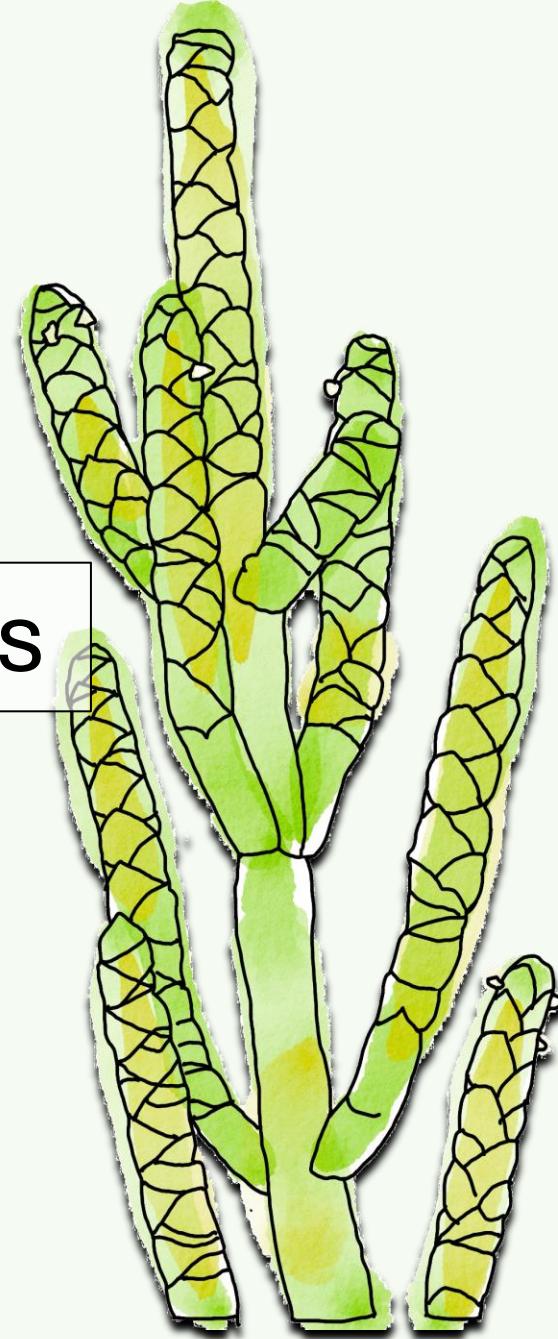
- Gravel toe berms
 - 1. Small angular gravel
 - 2. Pea-sized round gravel
- Logs
- Loose crushed dried bay mud
- Salt marsh plantings

East End

- Gravel toe berm
 - 1. Small angular gravel
 - 2. Pea-sized round gravel
- Logs
- Loose crushed dried bay mud
- Salt marsh plantings

- + Coyote brush fencing
- + Lag gravel armoring

Research Questions



**How does the intertidal marsh
zone change over time?**

More specifically...

How effective are the NBS treatments at minimizing erosion, and encouraging emergent marsh establishment along the habitat levee?

How does vegetation-sedimentation compare...

- 1. West vs. east**
- 2. Logs vs. between logs**
- 3. Between marsh zones**

How does vegetation-sedimentation compare...

1. West vs. east?



Research Questions

How does vegetation-sedimentation compare...

1. West vs. east?

A. West End – sheltered from southern storm winds, broad muflat

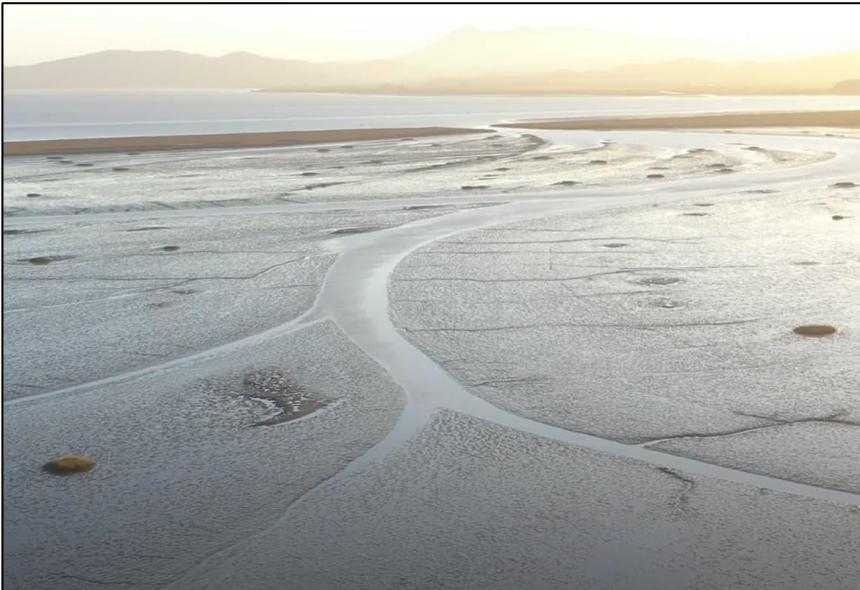
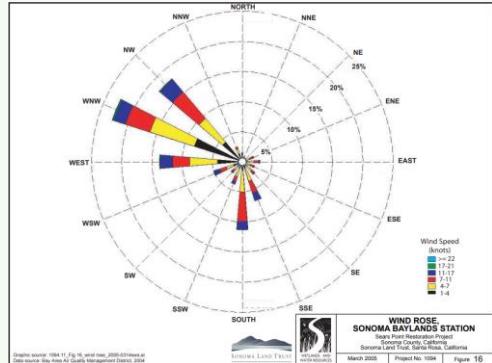
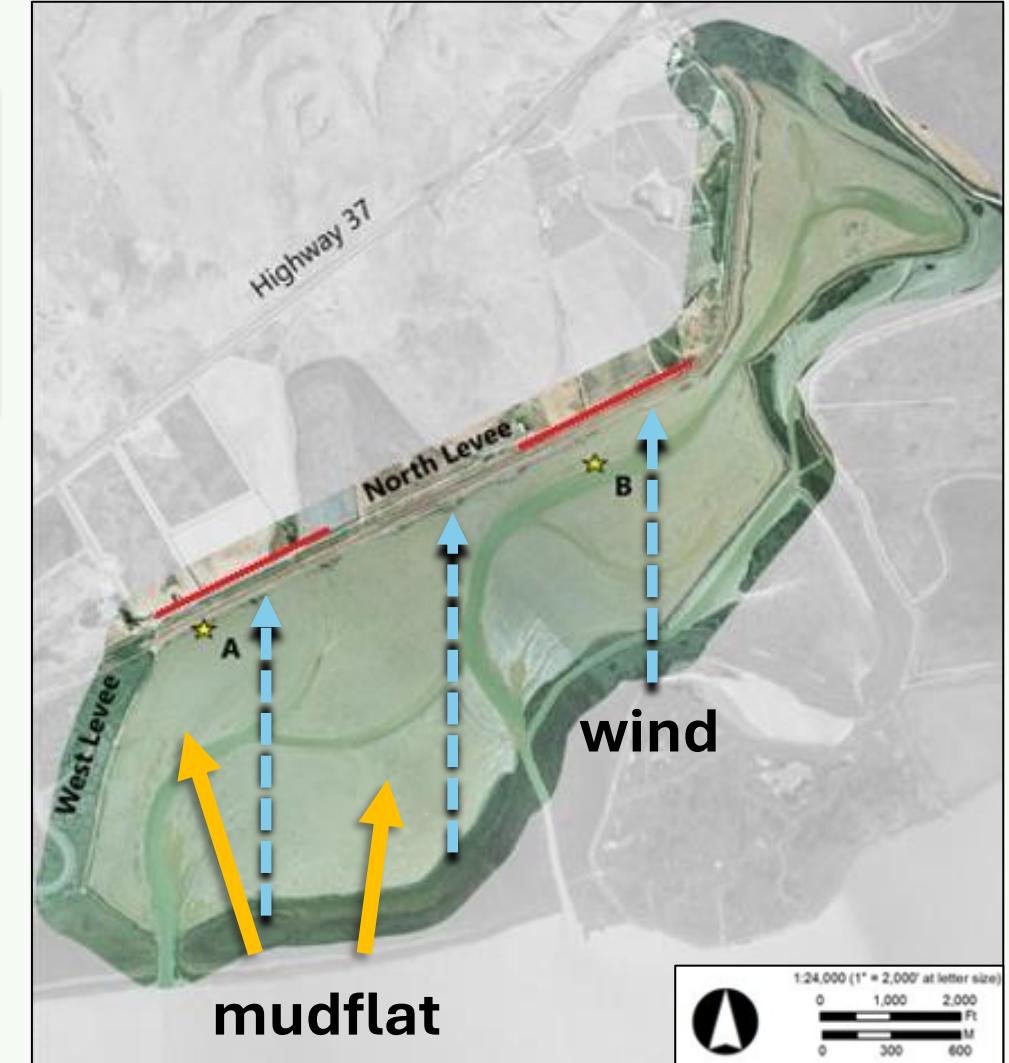


Image: SFB Joint Venture, 2022

Research Questions



How does vegetation-sedimentation compare...

1. West vs. east?

- A. West End – more sheltered from southern storm winds, broad mudflat
- B. East End – less shelter from southern storm winds and close proximity to large deep tidal channel



How does vegetation-sedimentation compare...

1. West vs. east?

Hypothesis:

- More sheltered west end experiences less wind wave energy, and therefore, more vegetation establishment and accretion.

Research Questions



How does vegetation-sedimentation compare...

2. At logs with mud vs.
between logs without mud?



At Log



Between Log

Research Questions

How does vegetation-sedimentation compare...

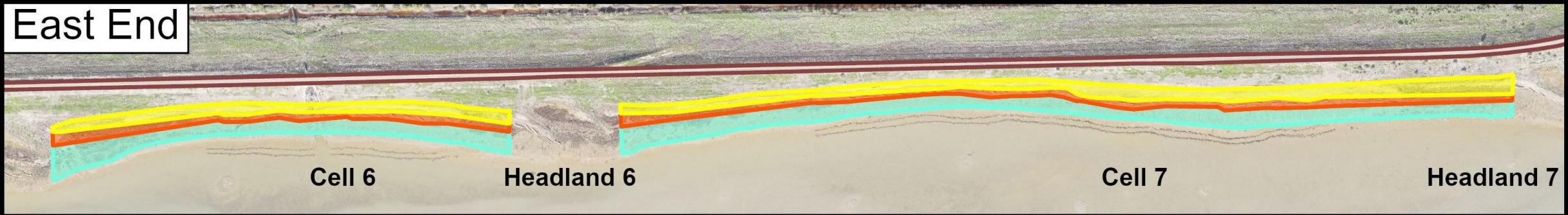
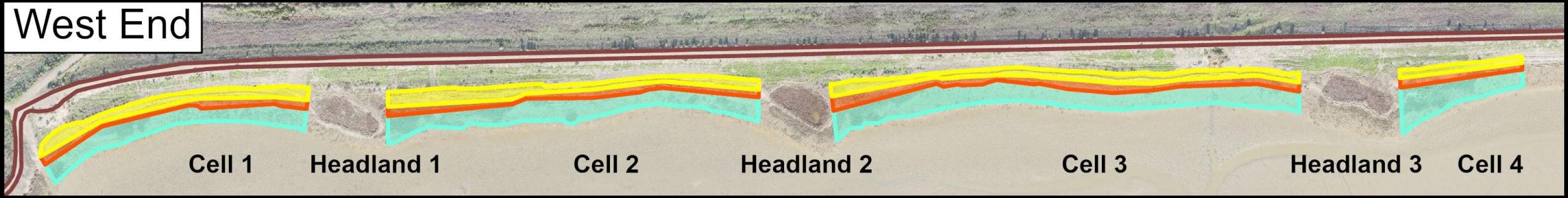
2. At logs with mud vs. between logs without mud?

Hypothesis:

Logs will create sheltered, sediment-rich areas on the bay side, promoting vegetation growth, while shallow drainage troughs with no or sparse vegetation, primarily *Spartina foliosa*, will form between the logs.

How does vegetation-sedimentation compare...

3. Between the upper, middle, and lower marsh zones?



Research Questions

How does vegetation-sedimentation compare...

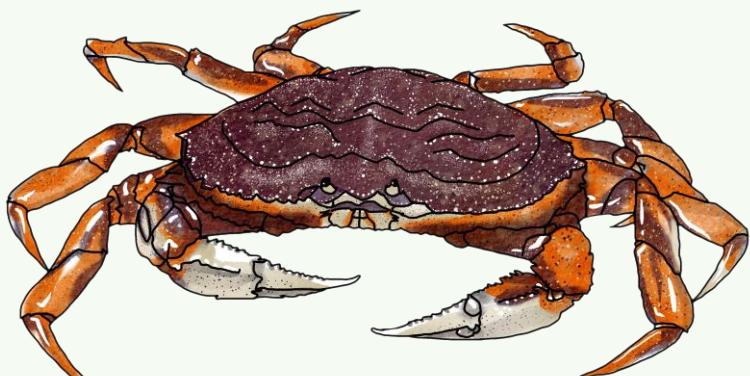
3. Between the upper, middle, and lower marsh zones?

Hypothesis:

In tandem with the other treatments, the logs would shelter the existing vegetation above them and trap sediment, resulting in two primary outcomes.

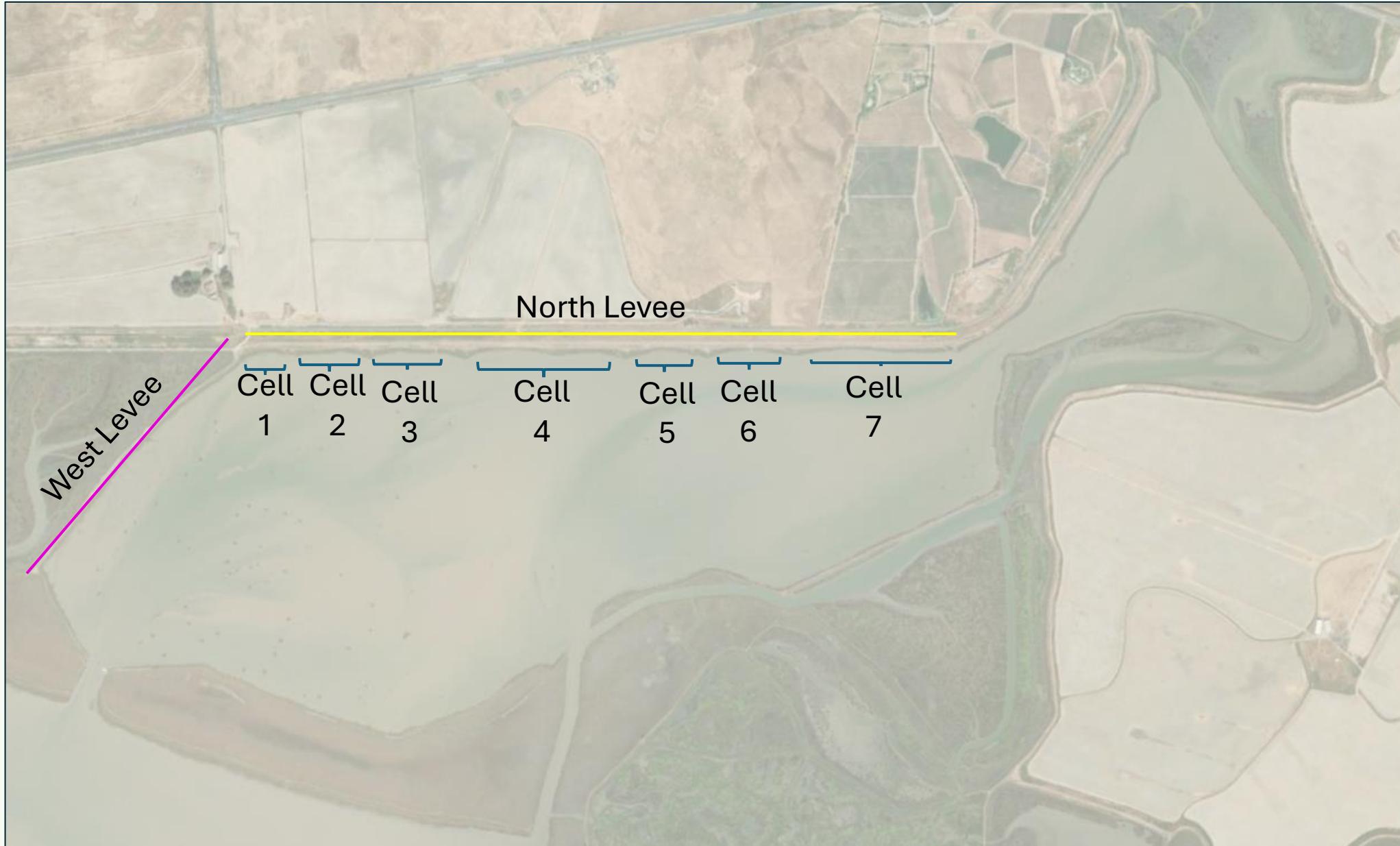
- First, a reduction in lateral wave erosion in the upper zone.
- Second, an increase in vegetation and elevation, greatest in the upper marsh, followed by the middle, and finally the lower marsh.

Methods





Methods



Methods



Methods

West End



East End



Thesis Research Extent

Methods

Biological Approach

Method 1: Vegetation Transects

Monthly Transect Surveys

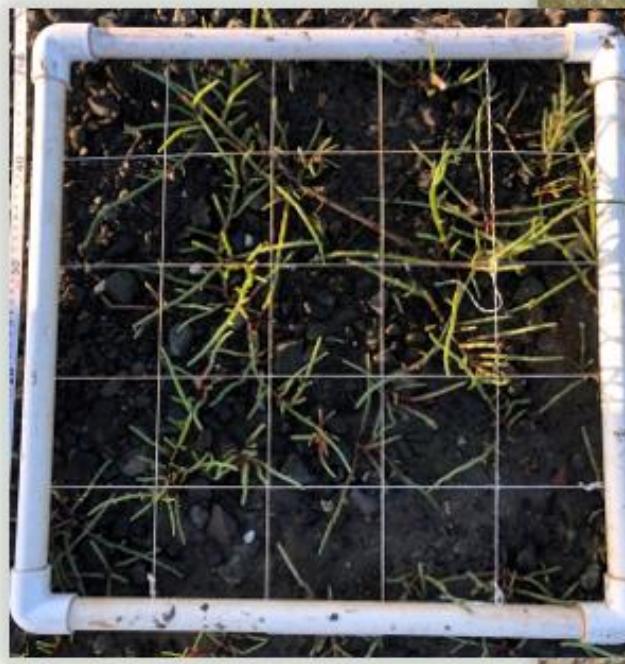
- Two active plant growing seasons
(June 2022 to August 2023)

Biological Approach

Method 1: Vegetation Transects

Monthly Transect Surveys

- Two active plant growing seasons (June 2022 to August 2023)
- 60 transects



Methods

Lower Zone

Middle Zone

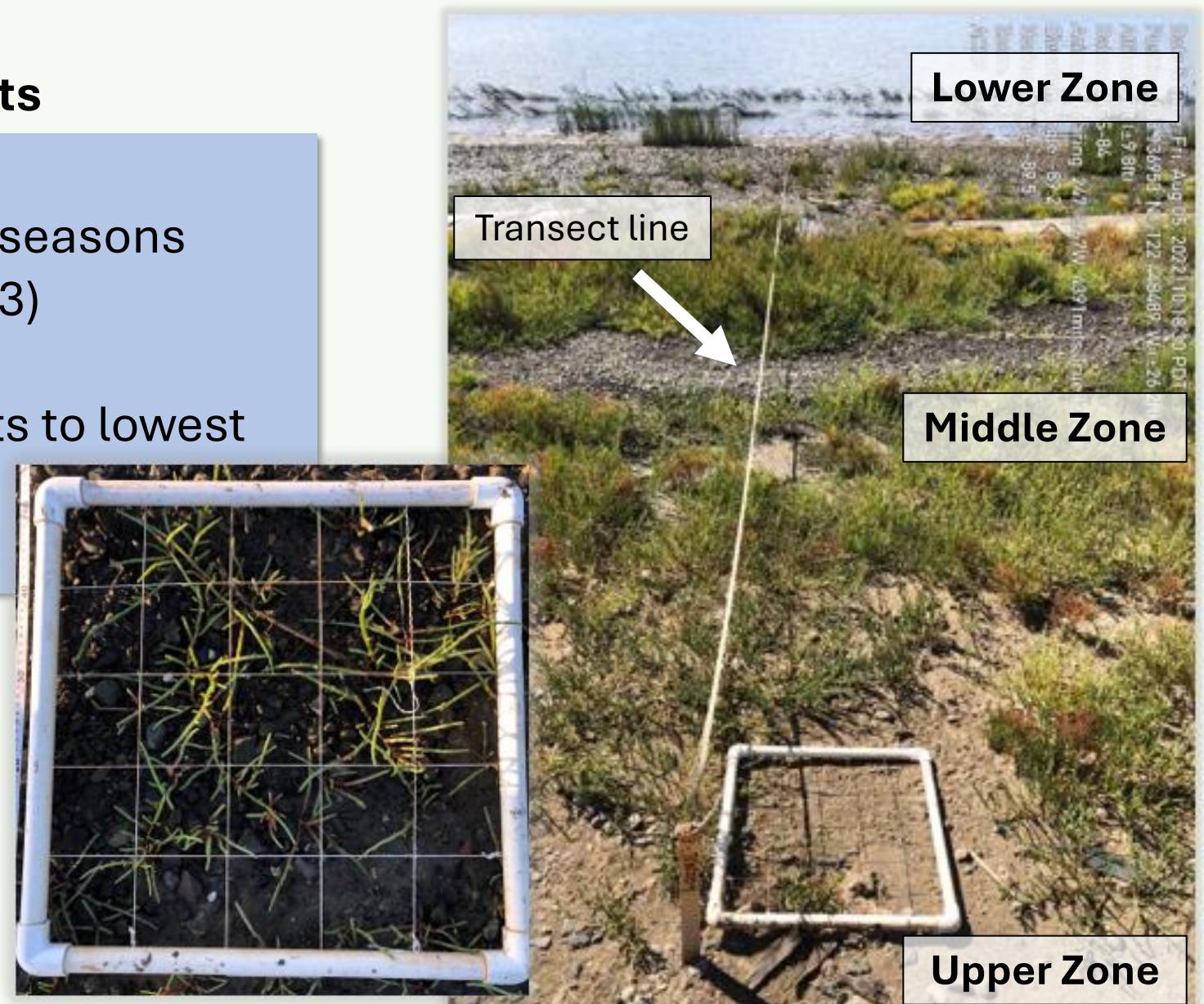
Upper Zone

Biological Approach

Method 1: Vegetation Transects

Monthly Transect Surveys

- Two active plant growing seasons (June 2022 to August 2023)
- 60 transects
 - Documented all plants to lowest taxonomic level
 - Percent canopy cover



Methods

Lower Zone

Middle Zone

Upper Zone

Biological Approach

 Research Project Extent

Method 2:

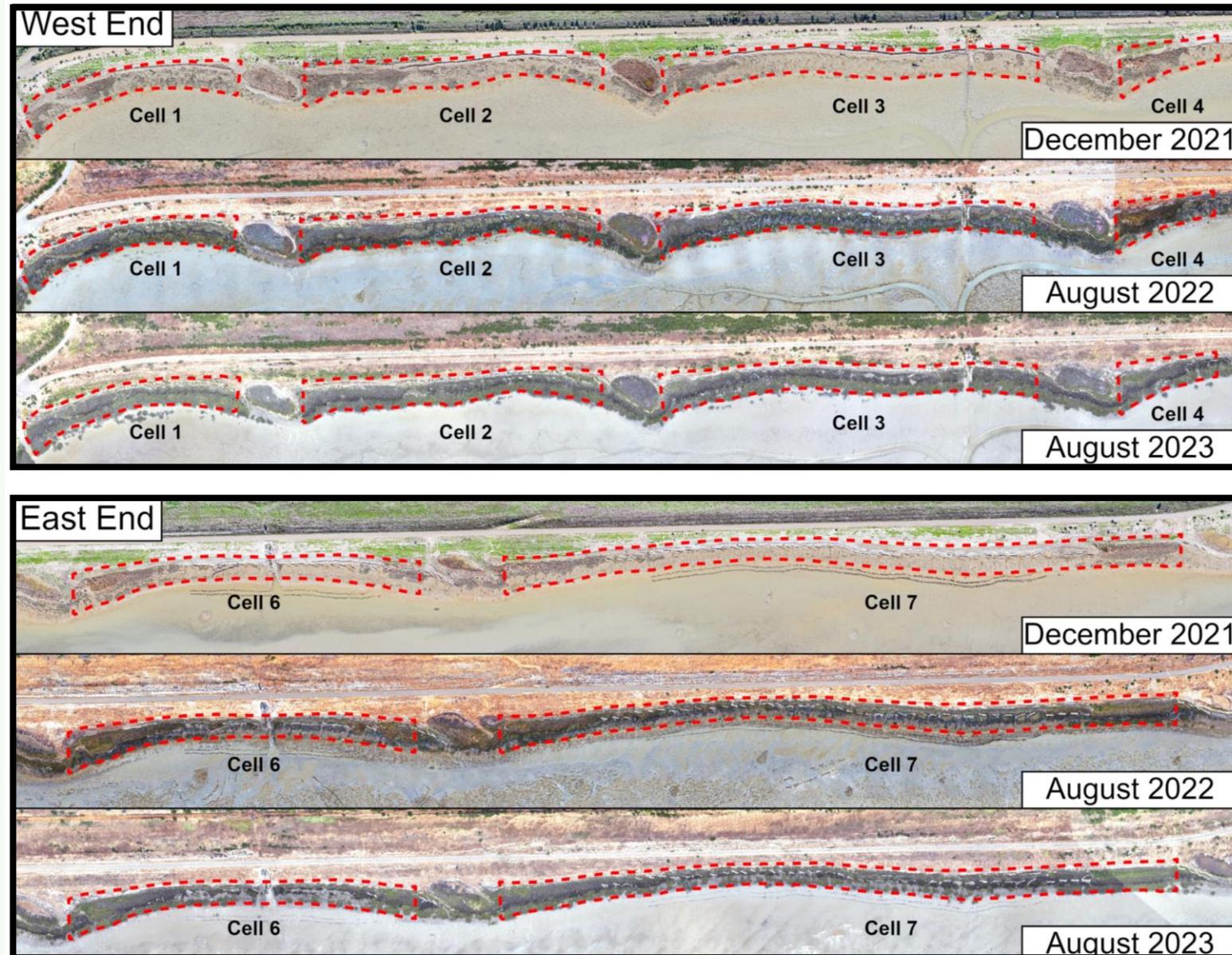
GIS Vegetation Mapping

- UAS aerial imagery - RTK GPS (SFEI and SFSU IGIS)
 - December 2021 (RGB)
 - August 2022 (RGB)
 - August 2023 (NIR & RGB)

*Data held to two control survey points



Methods

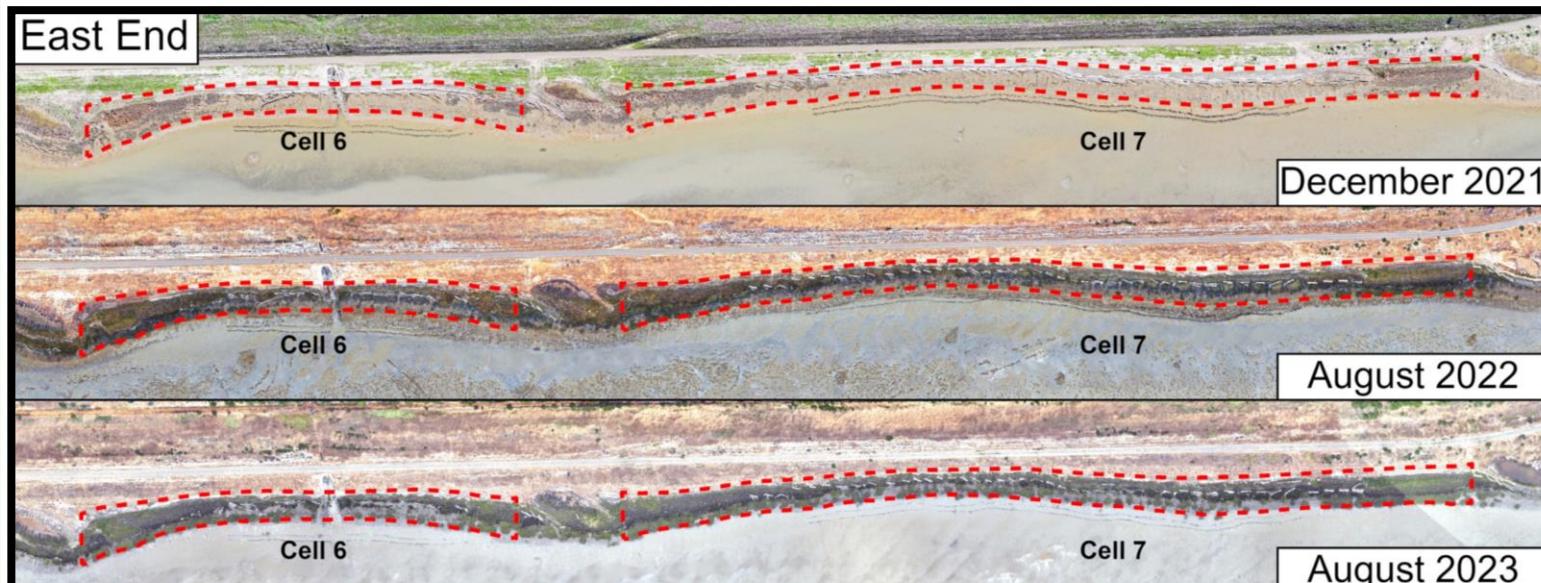
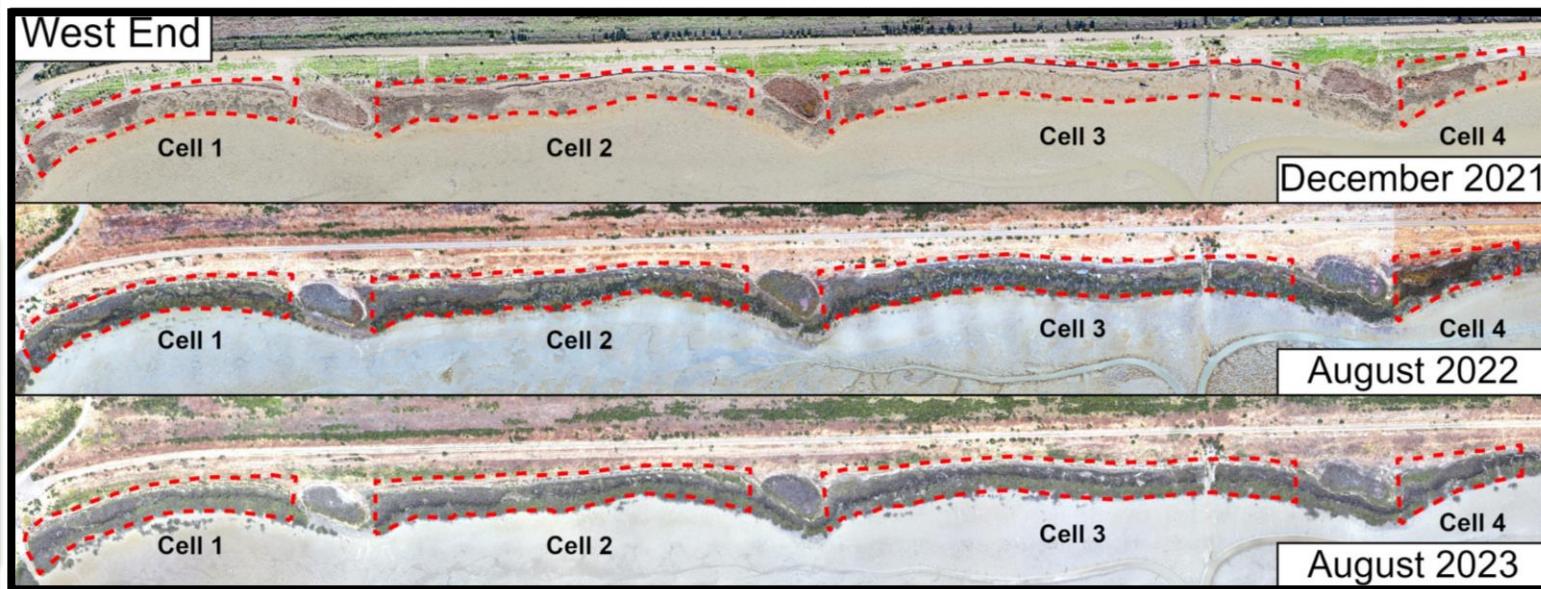


Biological Approach

 Research Project Extent

Method 2: GIS Vegetation Mapping

- Mapped:
 - Vegetation cover
 - Plant Communities
 - Derived change

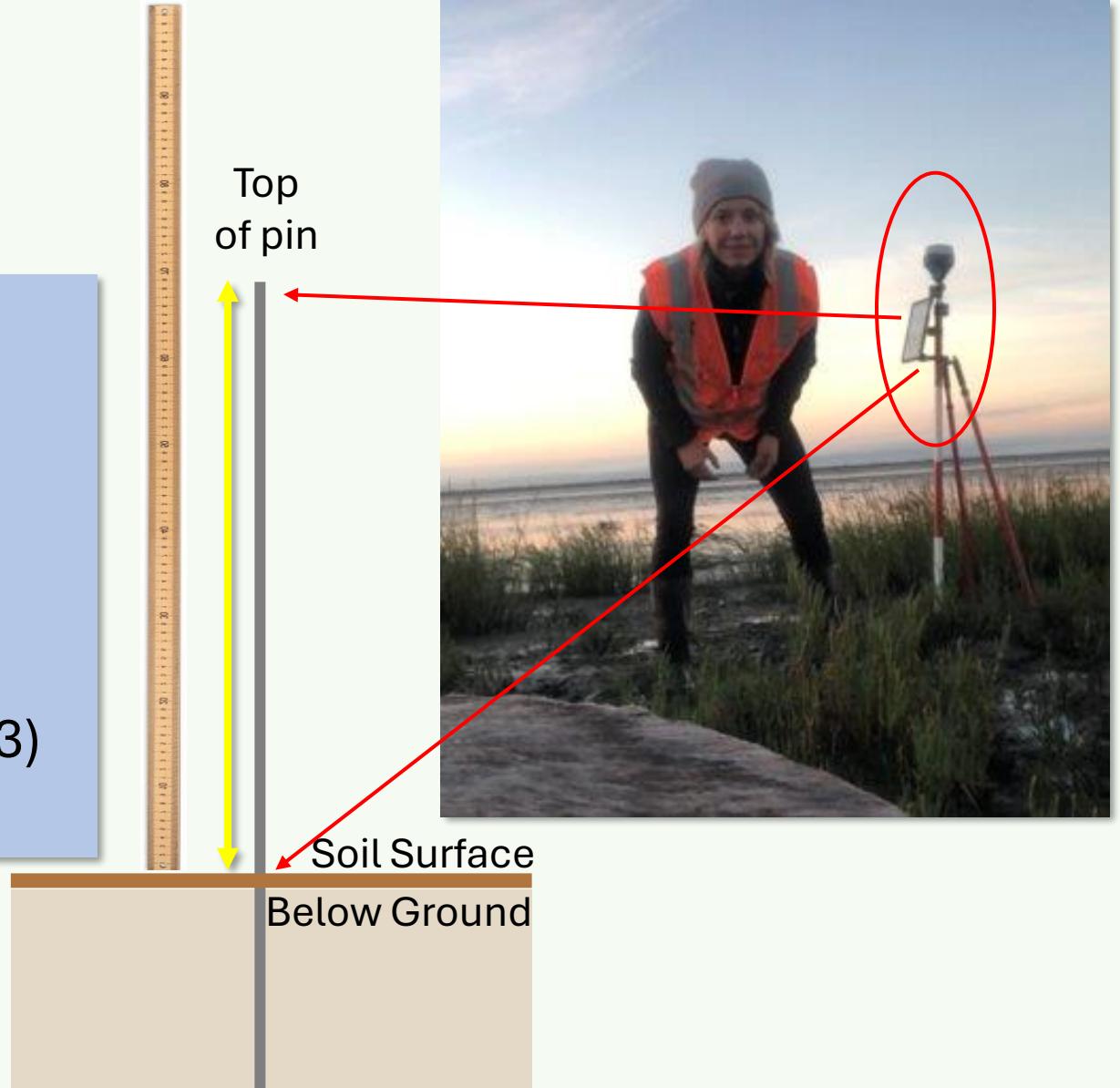


Methods

Physical Approach

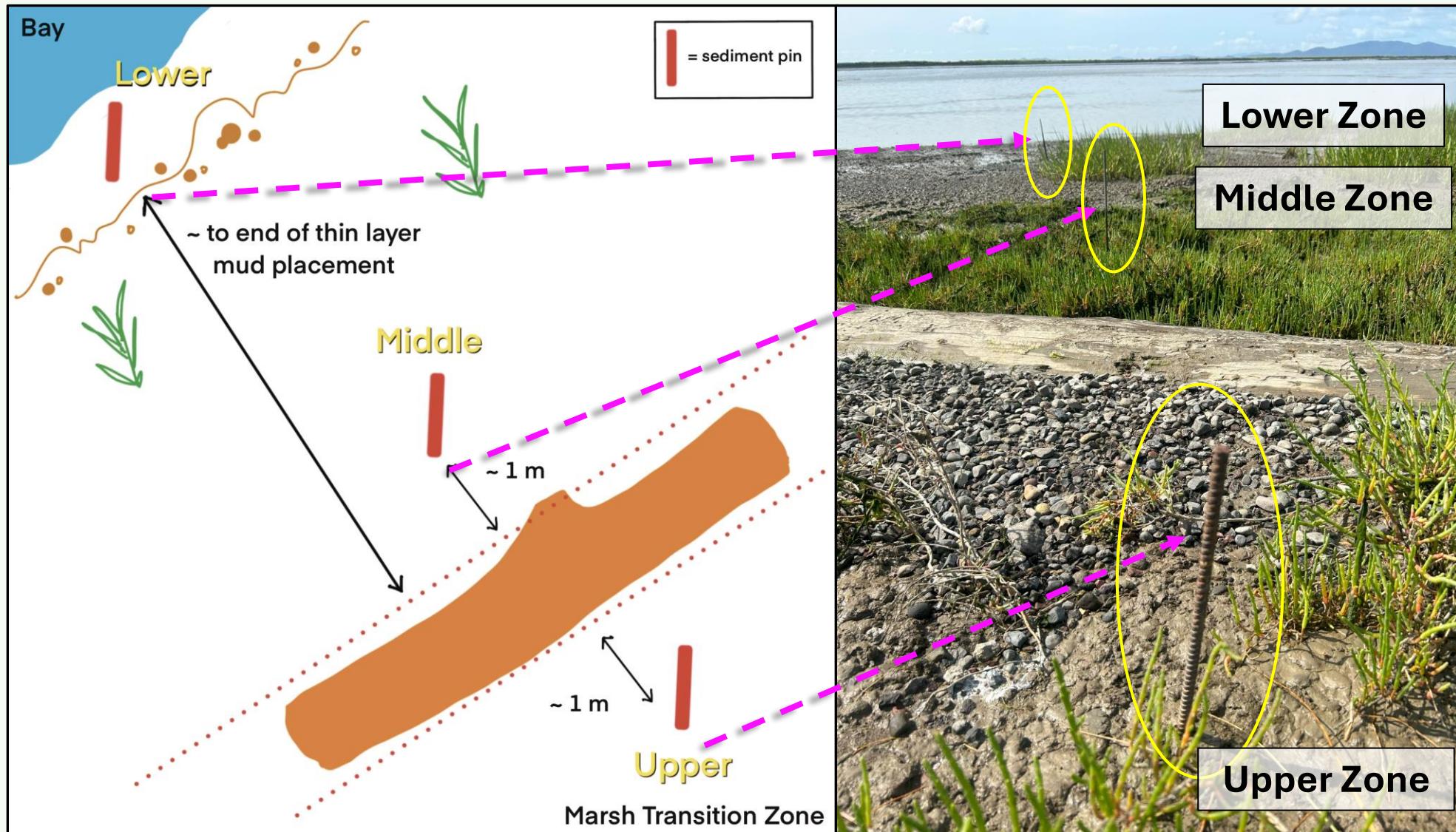
Method 3: Sediment Pins

- 117 rebar pins
- Surveys:
 - **RTK GPS**
 - Jun 2022 (after installation)
 - Sep 2023 (end of project)
 - **Meter stick**
 - Bimonthly (Jun 2022 – Sep 2023)
- Change in elevation



Physical Approach

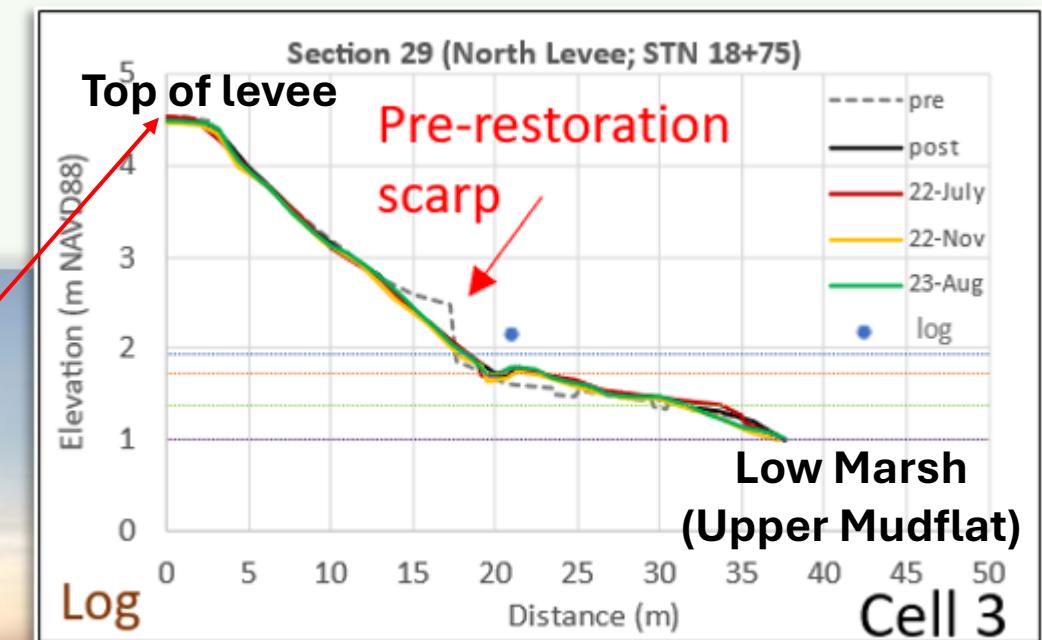
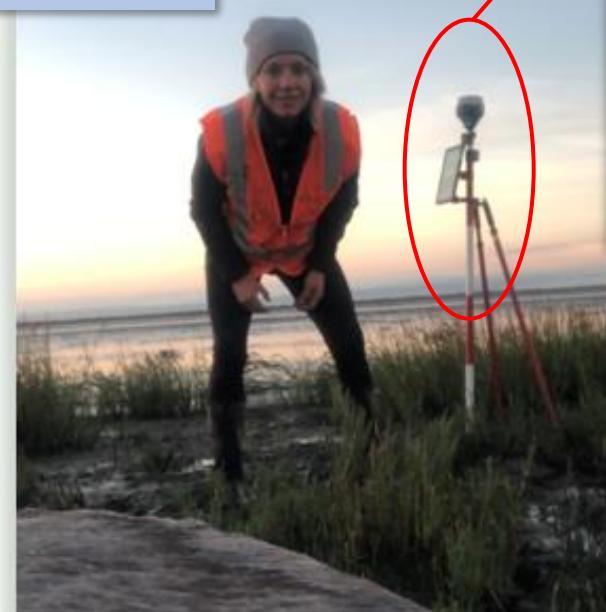
Method 3: Sediment Pins



Physical Approach

Method 4: Topographic Surveys

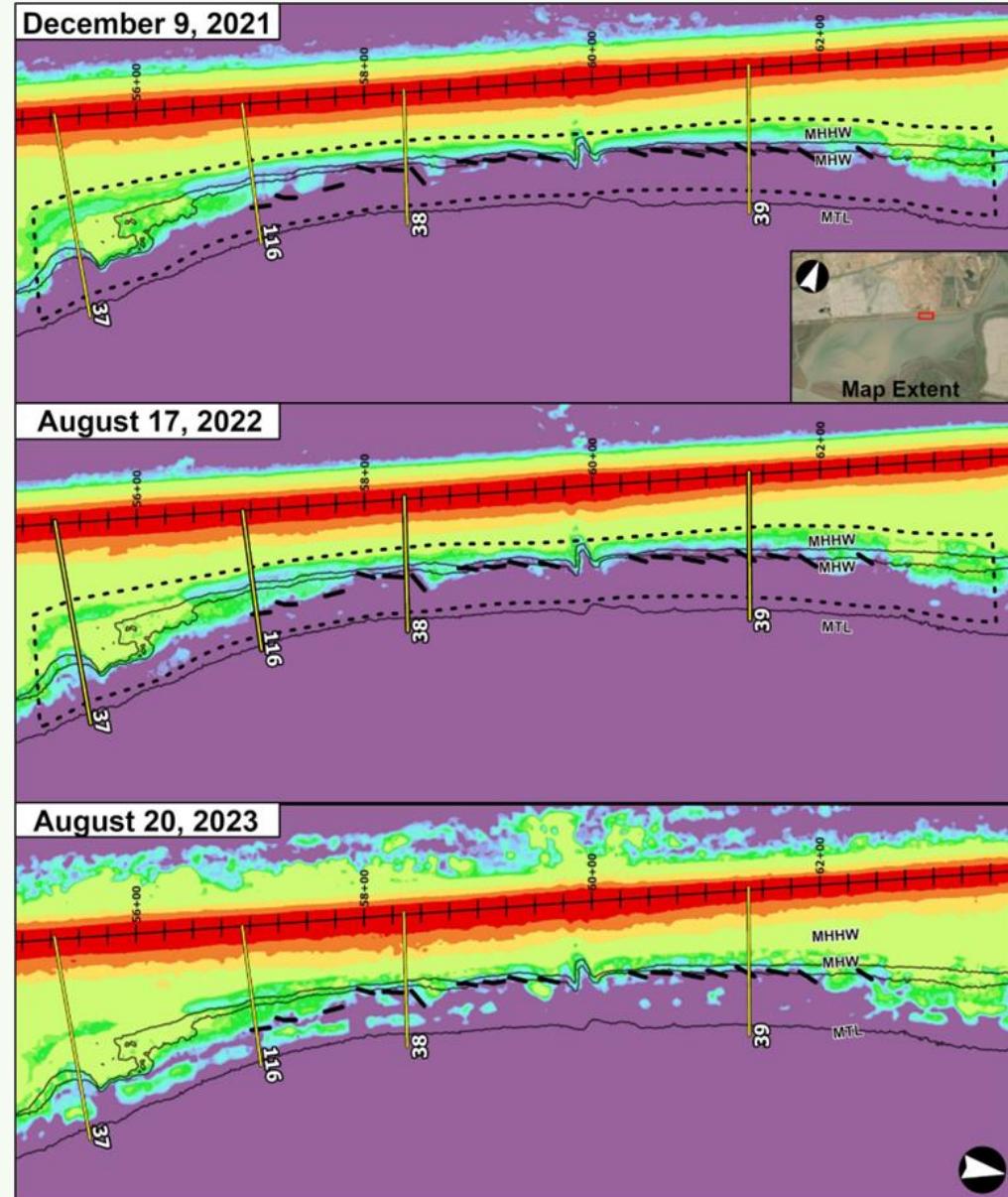
- 48 transects (22 thesis)
- RTK GPS - collect elevation data
 - July 2022
 - Nov 2022
 - Aug 2023
- Compare to pre/post restoration



Physical Approach

Method 4: Digital Terrain Modeling (DTM)

- Converted UAS aerial imagery
 - Represents surface elevation
 - Identify subtle surface changes



Results/Discussion



NBS Methods by Shoreline

West End

- Gravel toe berms
 - 1. Small angular gravel
 - 2. Pea-sized round gravel
- Logs
- Loose crushed dried bay mud
- Salt marsh planting

East End

- Gravel toe berm
 - 1. Small angular gravel
 - 2. Pea-sized round gravel
- Logs
- Loose crushed dried bay mud
- Salt marsh planting

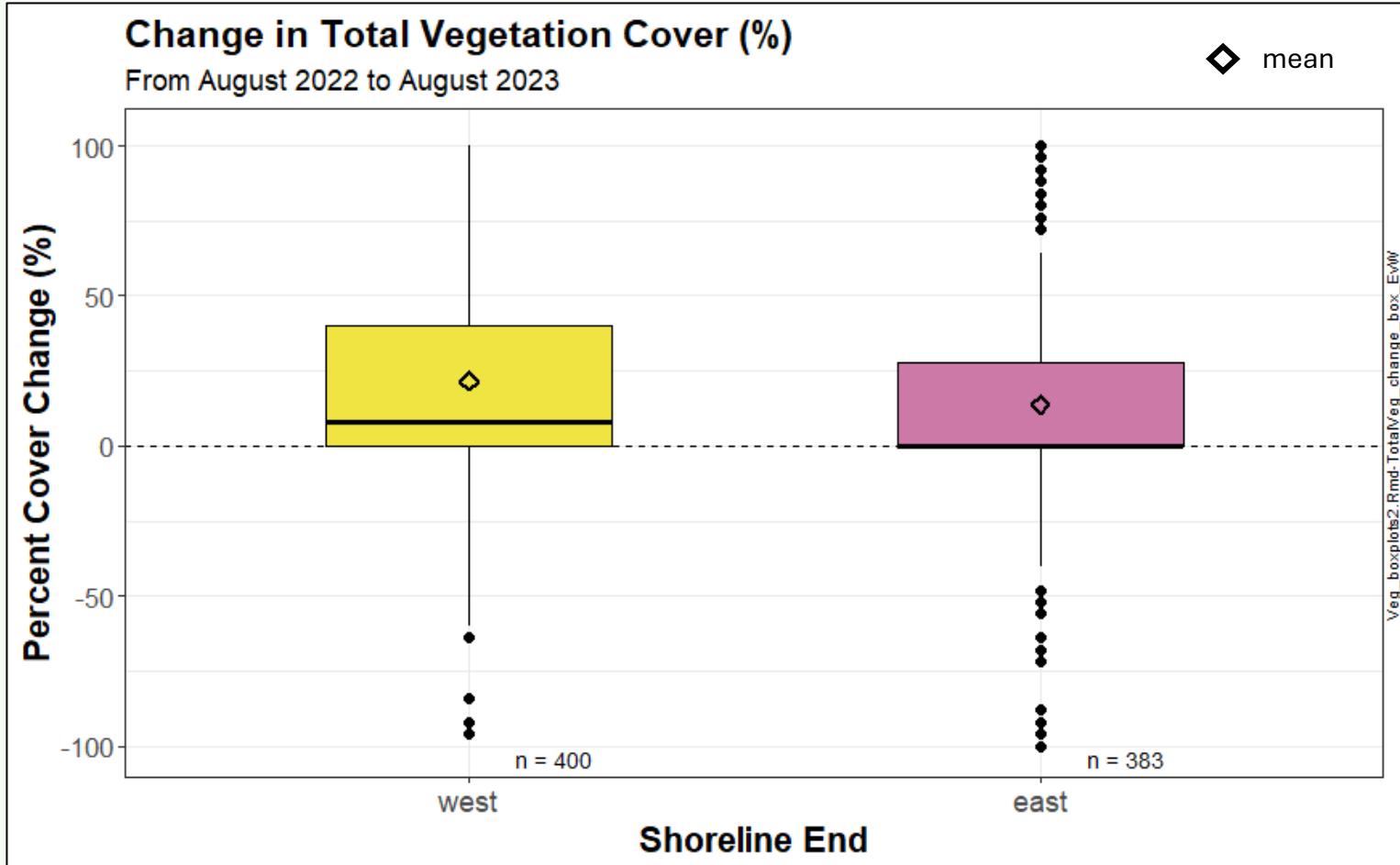
- + Coyote brush fencing
- + Lag gravel armoring

Research Questions:

How does vegetation-sedimentation compare...

1. West vs. east
2. Log vs. no-log
3. Between marsh zones: upper, middle, lower

Vegetation Transects

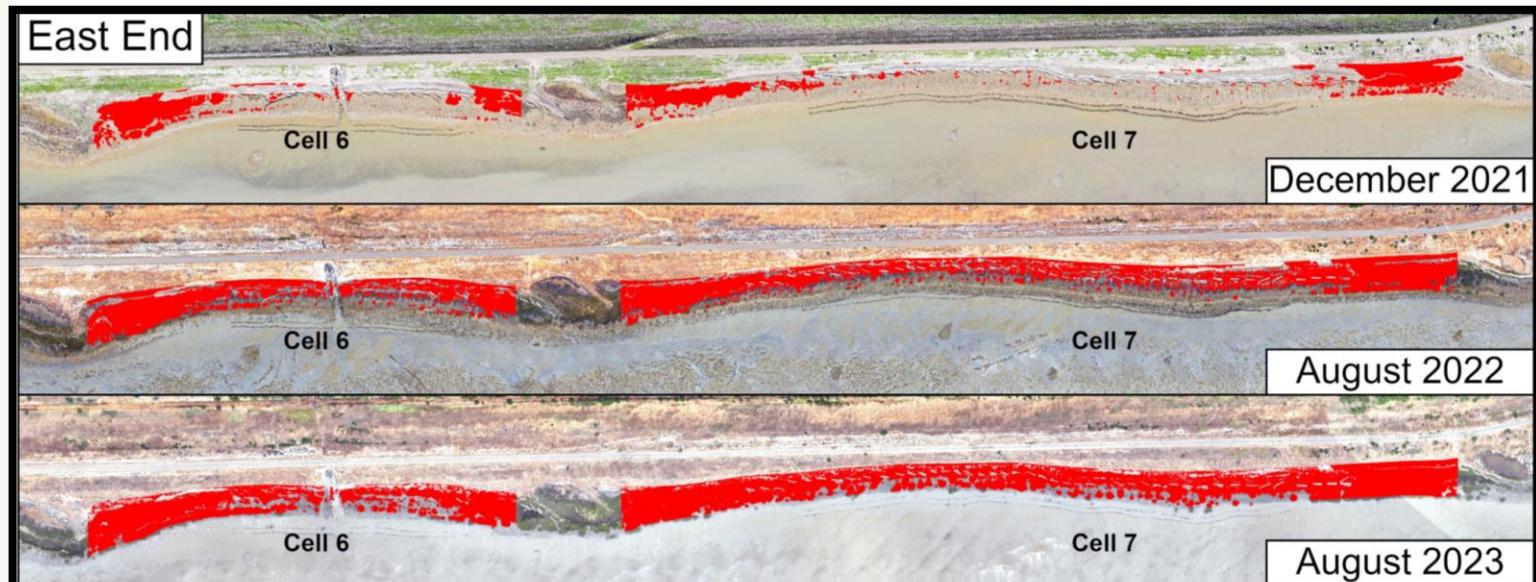
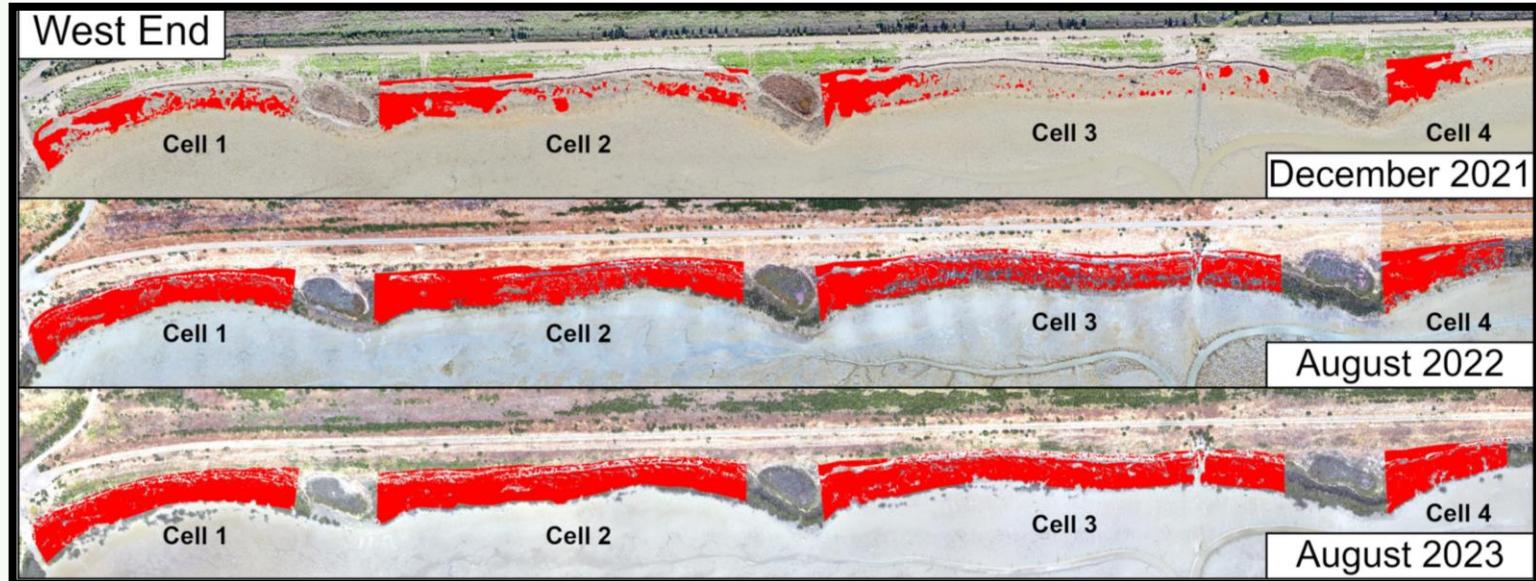
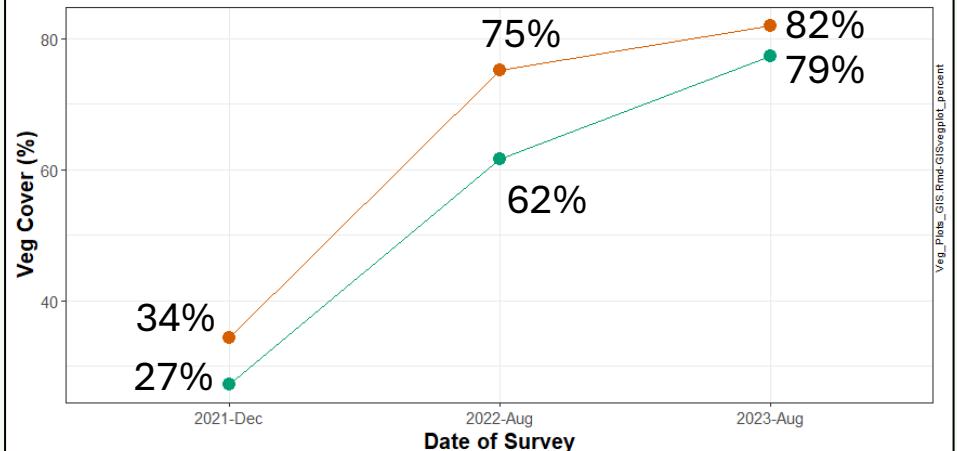


Results/Discussion

GIS Vegetation Mapping

Sears Point Vegetation Cover Over 3 Years via GIS & Aerial Imagery
Based on UAV imagery taken in Dec 2021, Aug 2022, and Aug 2023

Shoreline End • west • east



Marsh Vegetation

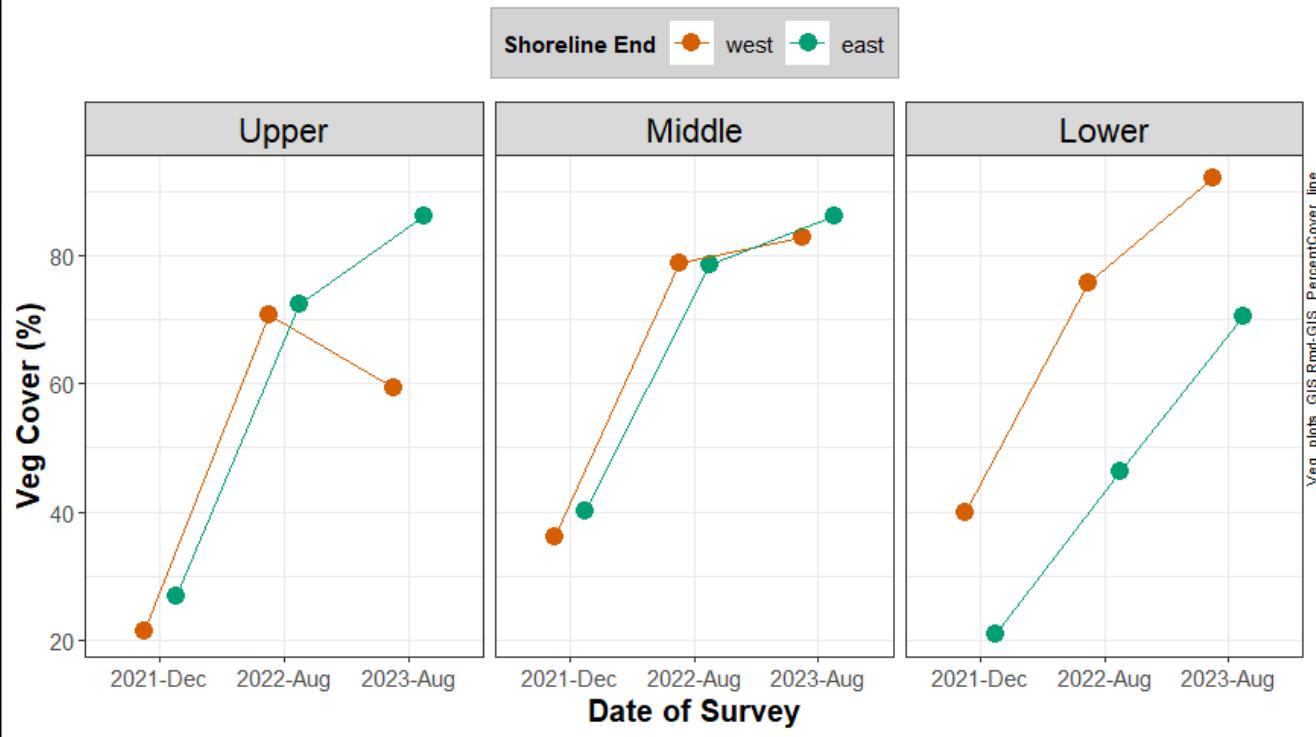
		Vegetated Area (hectares)		
Shoreline End	Total Area (hectares)	Date		
		Dec-21	Aug-22	Aug-23
West	1.592	0.548	1.197	1.310
East	1.463	0.397	0.902	1.154

Results/Discussion

GIS Vegetation Mapping

Sears Point Vegetation Cover Over 3 Years By Zone via GIS & Aerial Imagery

Based on UAV imagery taken in Dec 2021, Aug 2022, and Aug 2023



Shoreline End	Marsh Zone	Total Area of Marsh Zone (hectares)	Vegetated Area (hectares)			Percent Veg Cover			Percent Veg Cover		
			Date			Date			Change		
			Dec-21	Aug-22	Aug-23	Dec-21	Aug-22	Aug-23	Yr 1-2	Yr 2-3	Yr 1-3:
West	Upper	0.396	0.084	0.280	0.235	21.3%	70.8%	59.4%	49.4%	-11.4%	38.0%
	Middle	0.340	0.123	0.268	0.282	36.1%	78.8%	82.9%	42.7%	4.1%	46.8%
	Lower	0.856	0.341	0.649	0.789	39.8%	75.8%	92.2%	36.0%	16.4%	52.4%
East	Upper	0.440	0.118	0.319	0.380	26.8%	72.5%	86.3%	45.7%	13.8%	59.5%
	Middle	0.338	0.135	0.266	0.291	40.1%	78.7%	86.1%	38.6%	7.4%	46.0%
	Lower	0.685	0.144	0.317	0.483	21.0%	46.2%	70.6%	25.2%	24.3%	49.5%

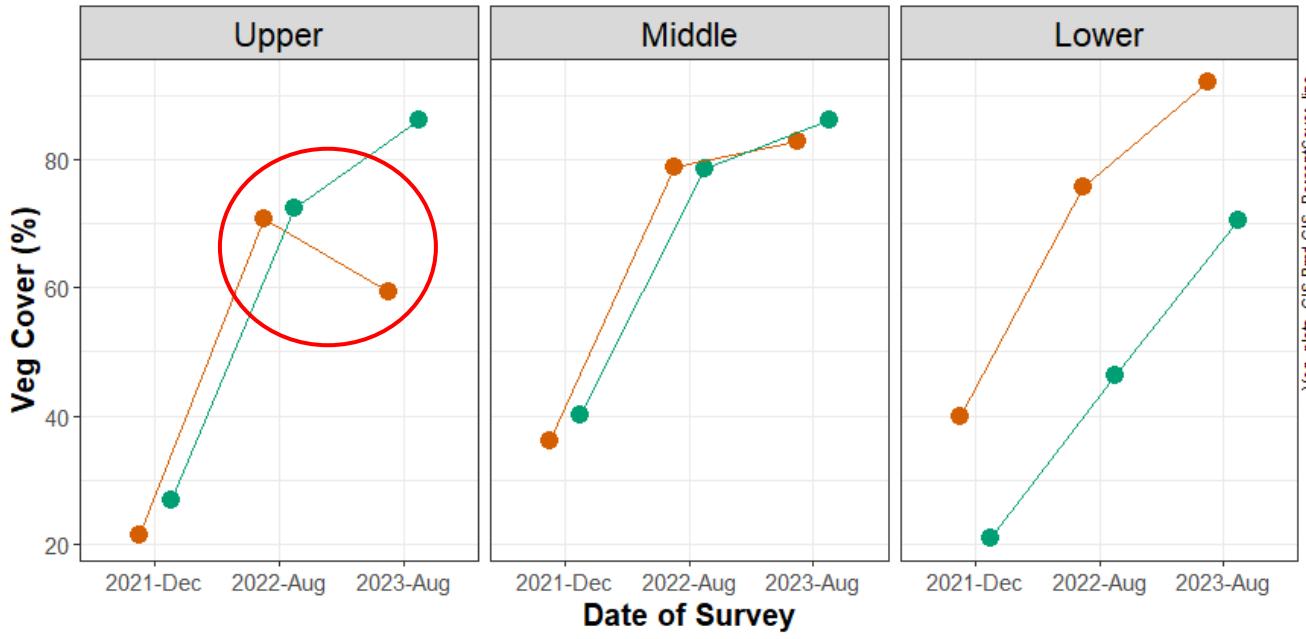
Results/Discussion

GIS Vegetation Mapping

Sears Point Vegetation Cover Over 3 Years By Zone via GIS & Aerial Imagery

Based on UAV imagery taken in Dec 2021, Aug 2022, and Aug 2023

Shoreline End west east



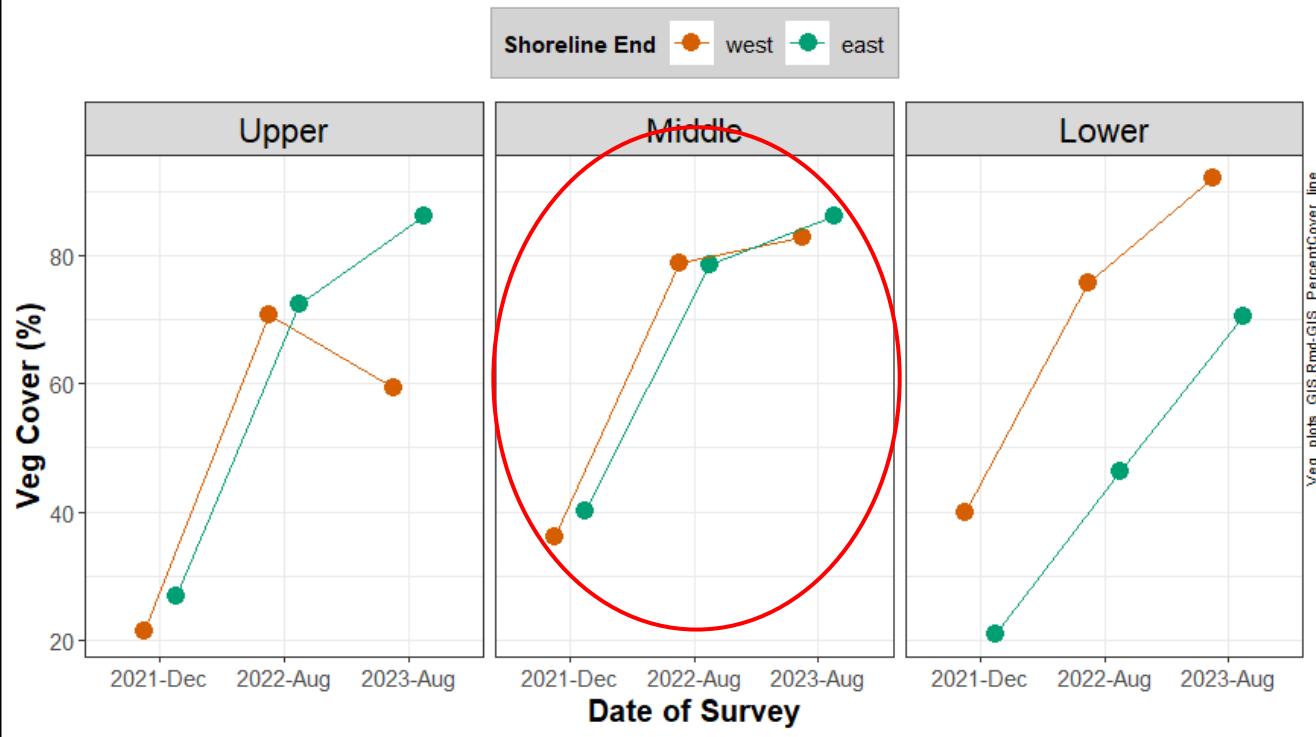
Shoreline End	Marsh Zone	Total Area of Marsh Zone (hectares)	Vegetated Area (hectares)			Percent Veg Cover			Percent Veg Cover		
			Date			Date			Change		
			Dec-21	Aug-22	Aug-23	Dec-21	Aug-22	Aug-23	Yr 1-2	Yr 2-3	Yr 1-3:
West	Upper	0.396	0.084	0.280	0.235	21.3%	70.8%	59.4%	49.4%	-11.4%	38.0%
	Middle	0.340	0.123	0.268	0.282	36.1%	78.8%	82.9%	42.7%	4.1%	46.8%
	Lower	0.856	0.341	0.649	0.789	39.8%	75.8%	92.2%	36.0%	16.4%	52.4%
East	Upper	0.440	0.118	0.319	0.380	26.8%	72.5%	86.3%	45.7%	13.8%	59.5%
	Middle	0.338	0.135	0.266	0.291	40.1%	78.7%	86.1%	38.6%	7.4%	46.0%
	Lower	0.685	0.144	0.317	0.483	21.0%	46.2%	70.6%	25.2%	24.3%	49.5%

Results/Discussion

GIS Vegetation Mapping

Sears Point Vegetation Cover Over 3 Years By Zone via GIS & Aerial Imagery

Based on UAV imagery taken in Dec 2021, Aug 2022, and Aug 2023



Results/Discussion

GIS Vegetation Mapping

Sears Point Vegetation Cover Over 3 Years By Zone via GIS & Aerial Imagery

Based on UAV imagery taken in Dec 2021, Aug 2022, and Aug 2023

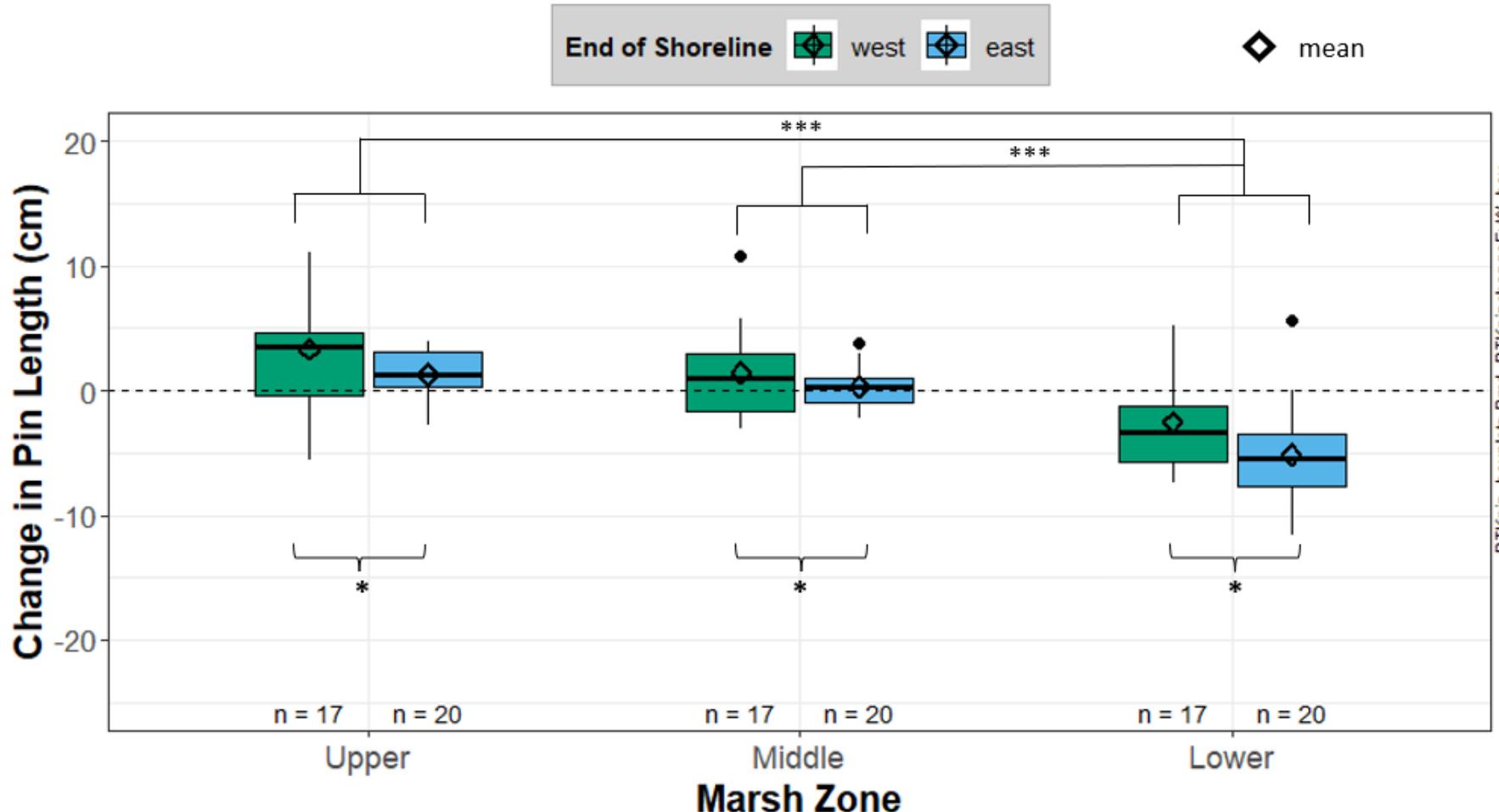


Results/Discussion

Sediment Pins

RTK Measurement: Change in Sediment Pin Length

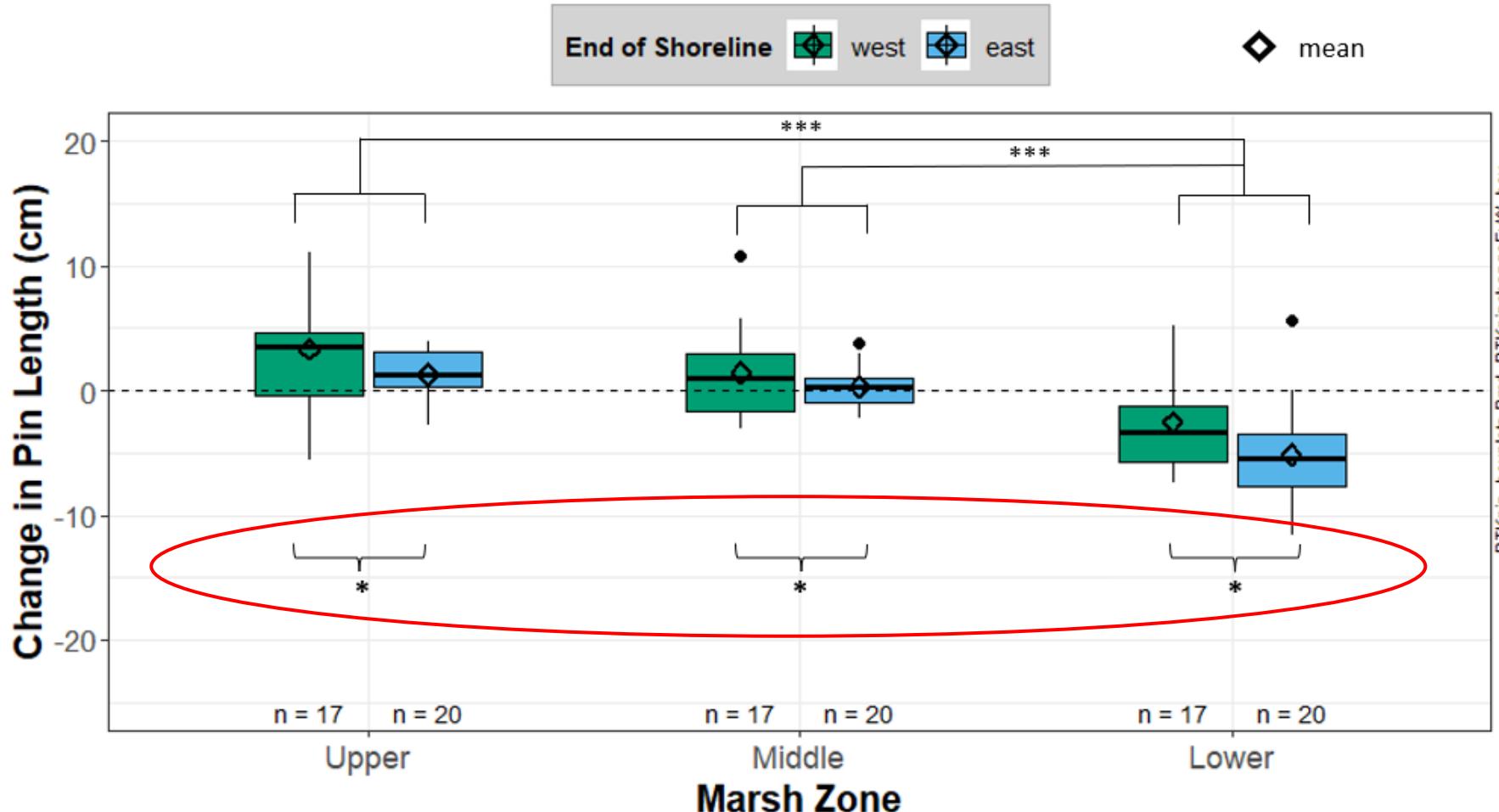
From Jun 2022 to Sep 2023 (Positive value = accretion Negative value = erosion)



Sediment Pins

RTK Measurement: Change in Sediment Pin Length

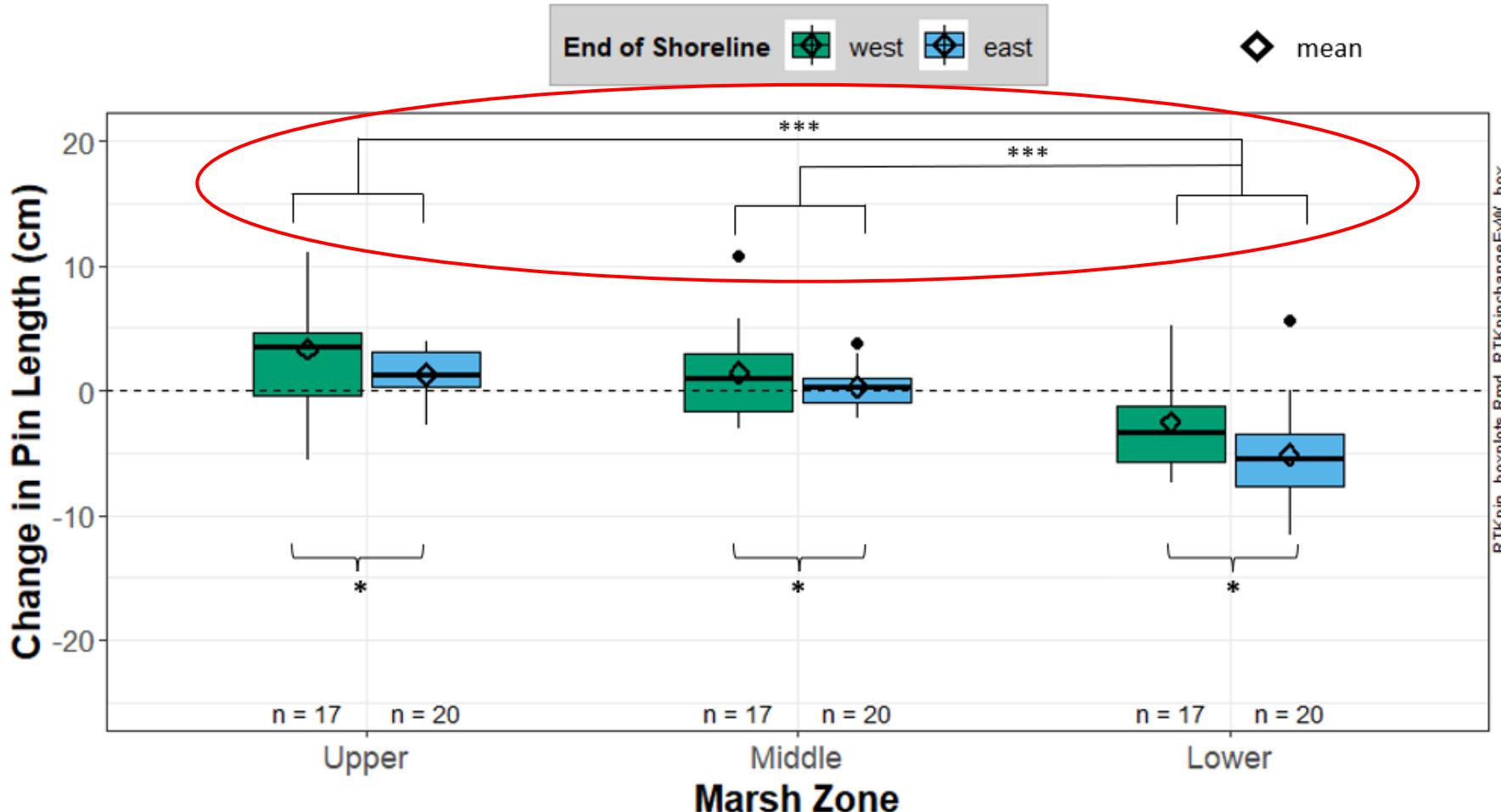
From Jun 2022 to Sep 2023 (Positive value = accretion Negative value = erosion)



Sediment Pins

RTK Measurement: Change in Sediment Pin Length

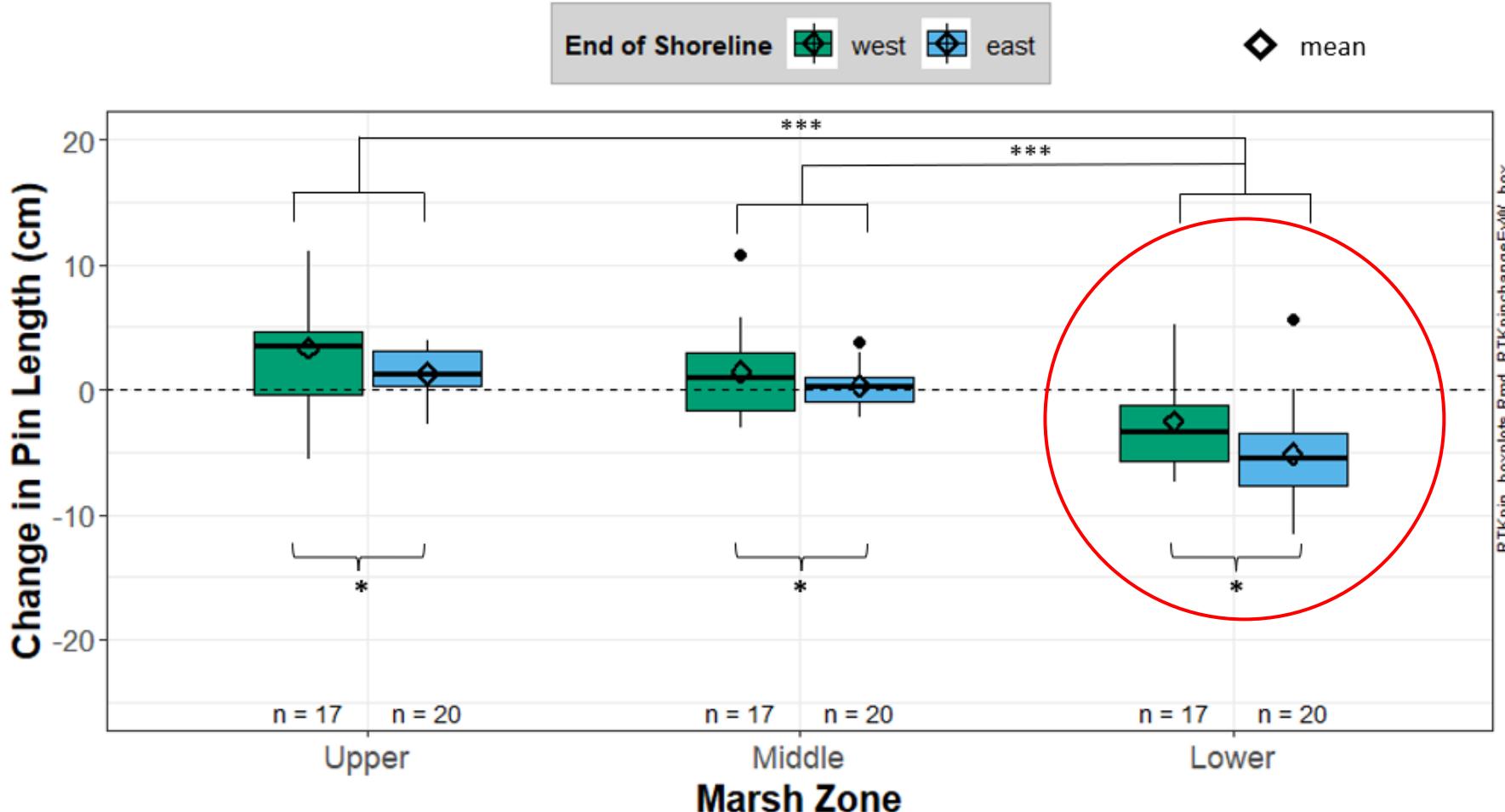
From Jun 2022 to Sep 2023 (Positive value = accretion Negative value = erosion)



Sediment Pins

RTK Measurement: Change in Sediment Pin Length

From Jun 2022 to Sep 2023 (Positive value = accretion Negative value = erosion)



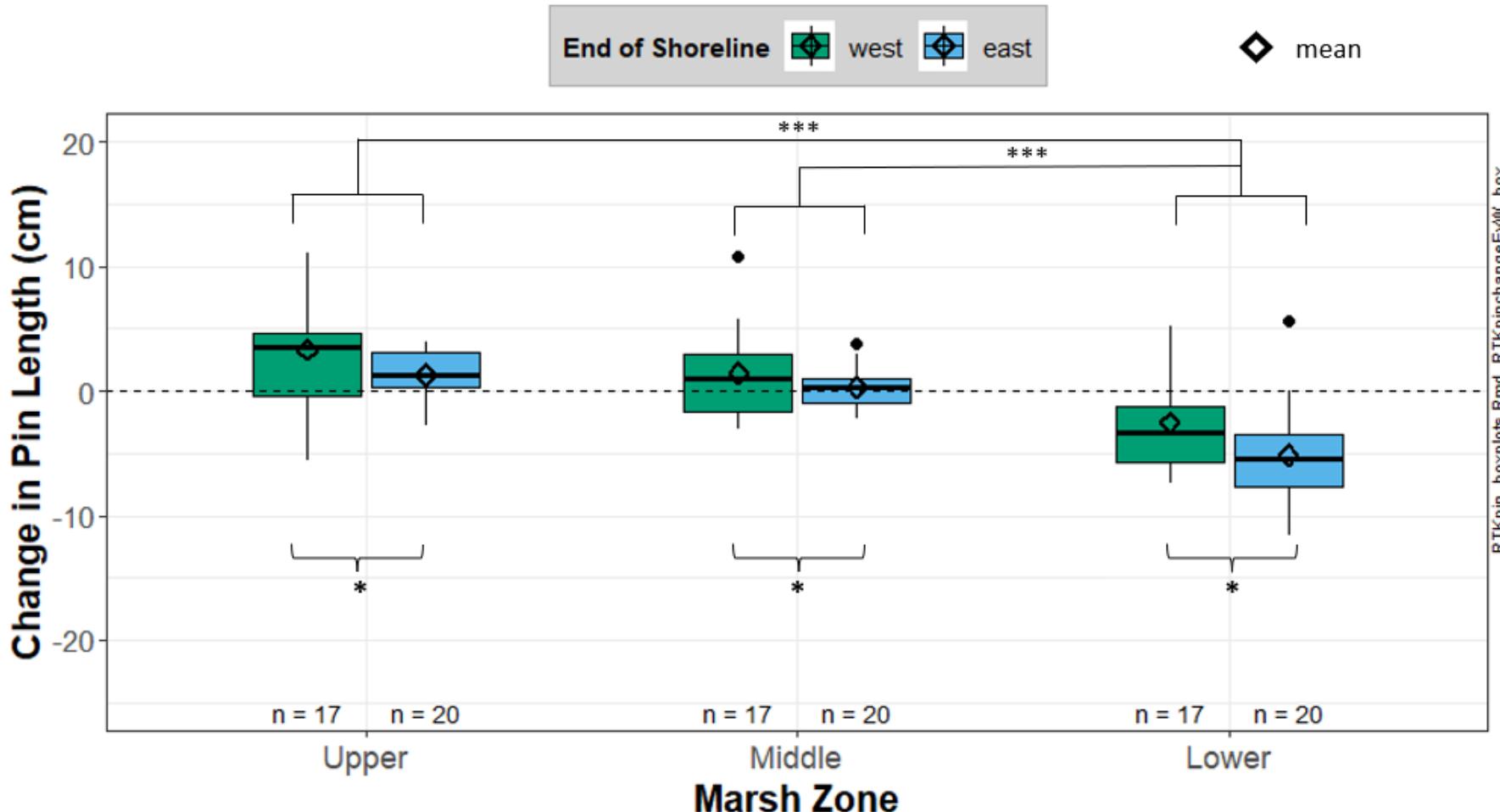
Results/ Discussion

Main Effects: Marsh zone: $X^2 = 72.639, p < 0.0001$

Sediment Pins

RTK Measurement: Change in Sediment Pin Length

From Jun 2022 to Sep 2023 (Positive value = accretion Negative value = erosion)



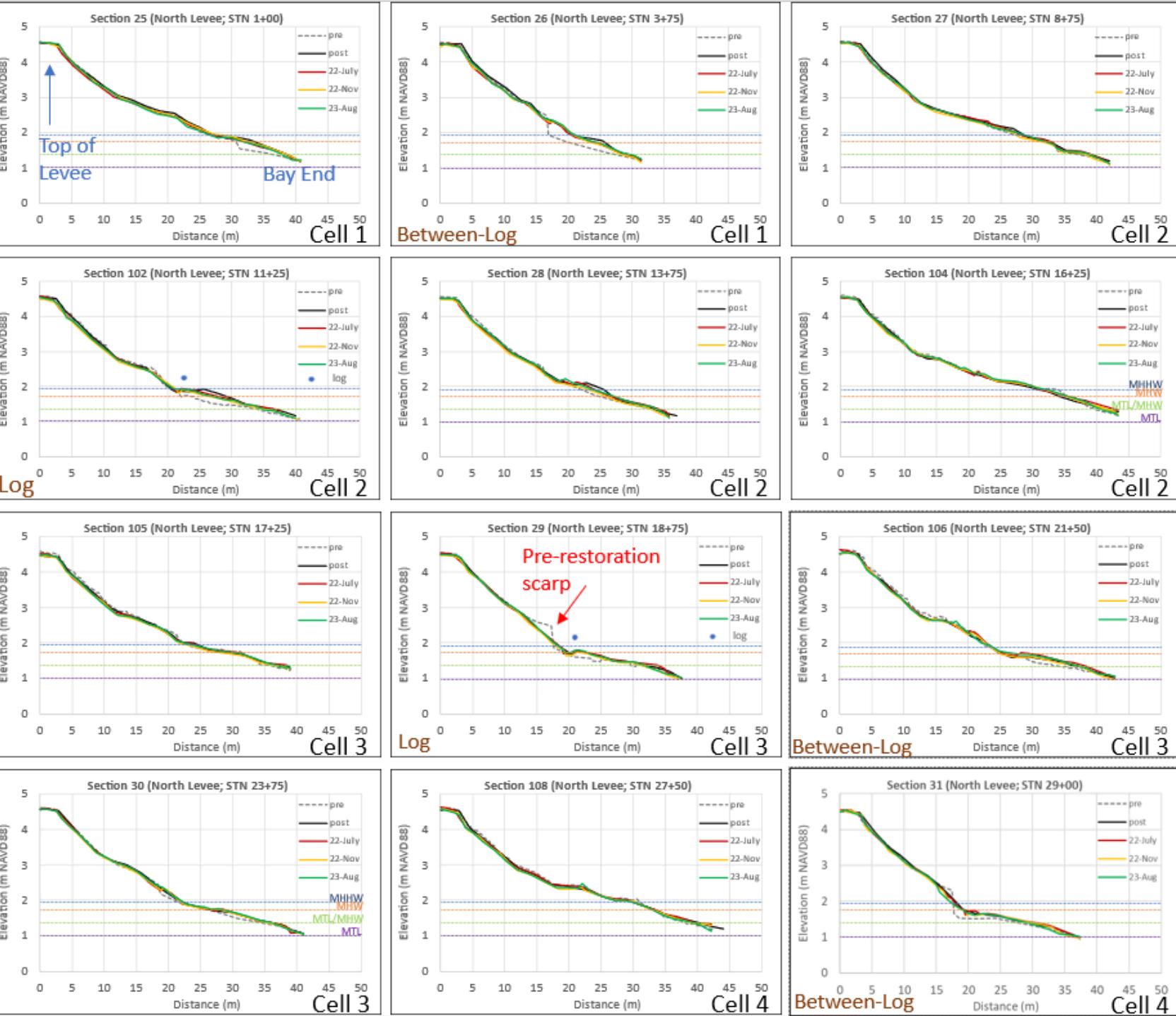
Topographic Transects

West End

Results/ Discussion

Tidal Datum

- MHHW (1.95 m)
- MHW (1.77 m)
- MTL/MHW (1.40 m)
- MTL (1.01 m)



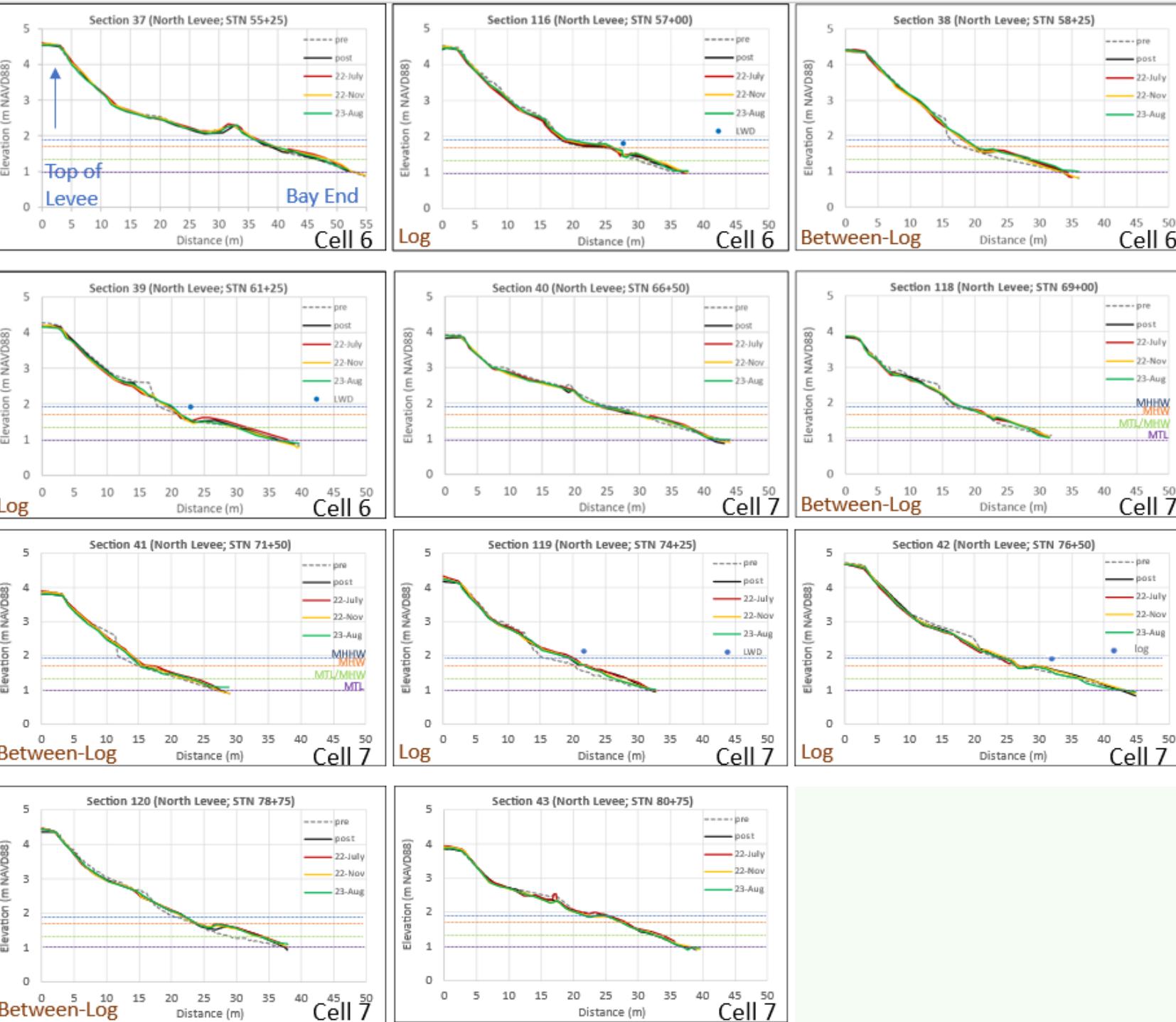
Topographic Transects

East End

Results/ Discussion

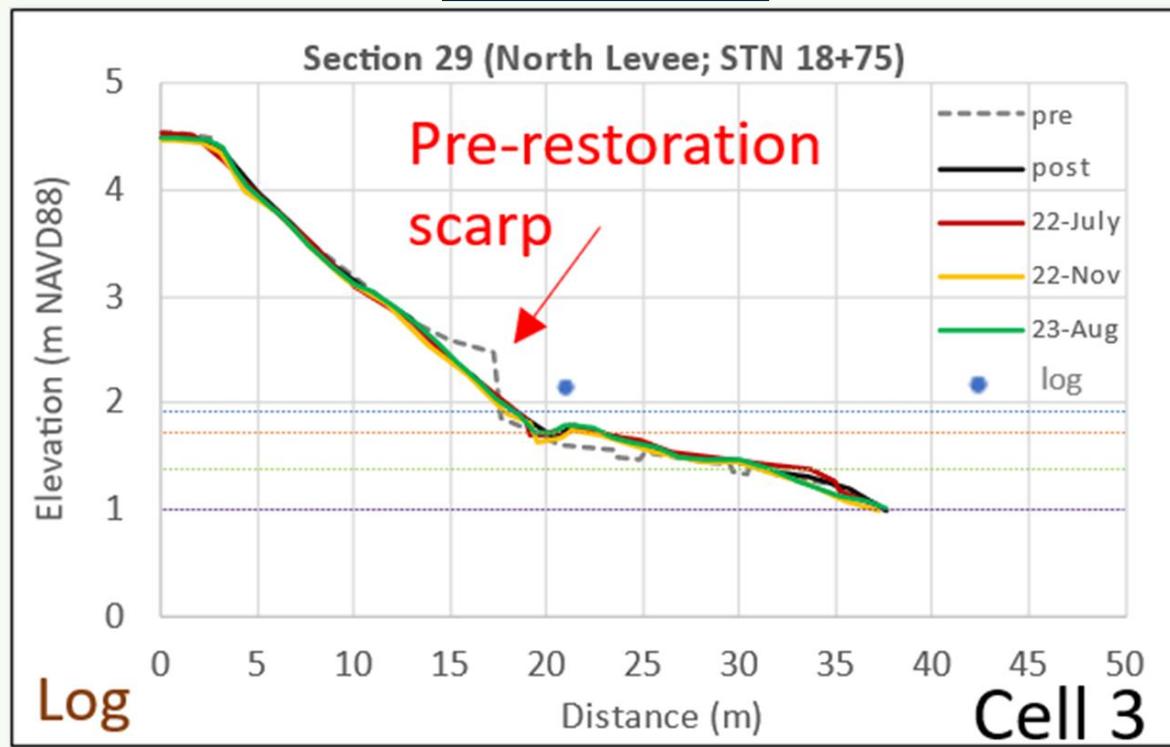
Tidal Datum

- MHHW (1.95 m)
- MHW (1.77 m)
- MTL/MHW (1.40 m)
- MTL (1.01 m)

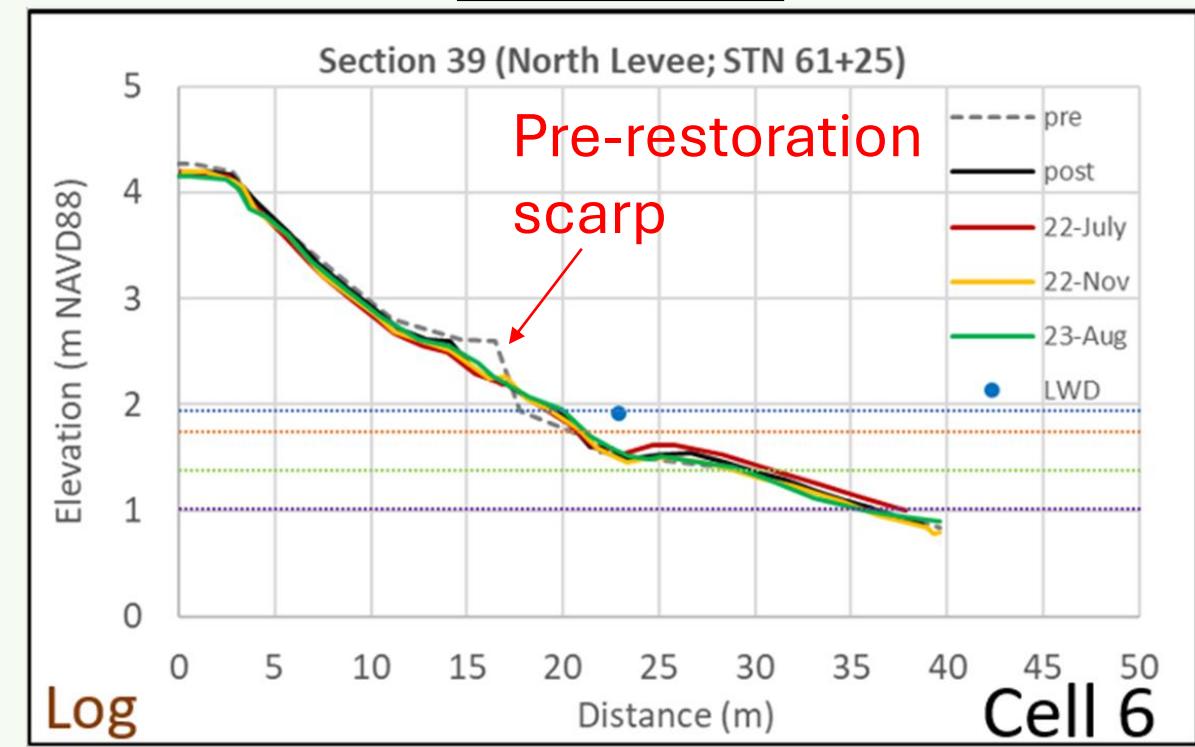


Topographic Transects

West End

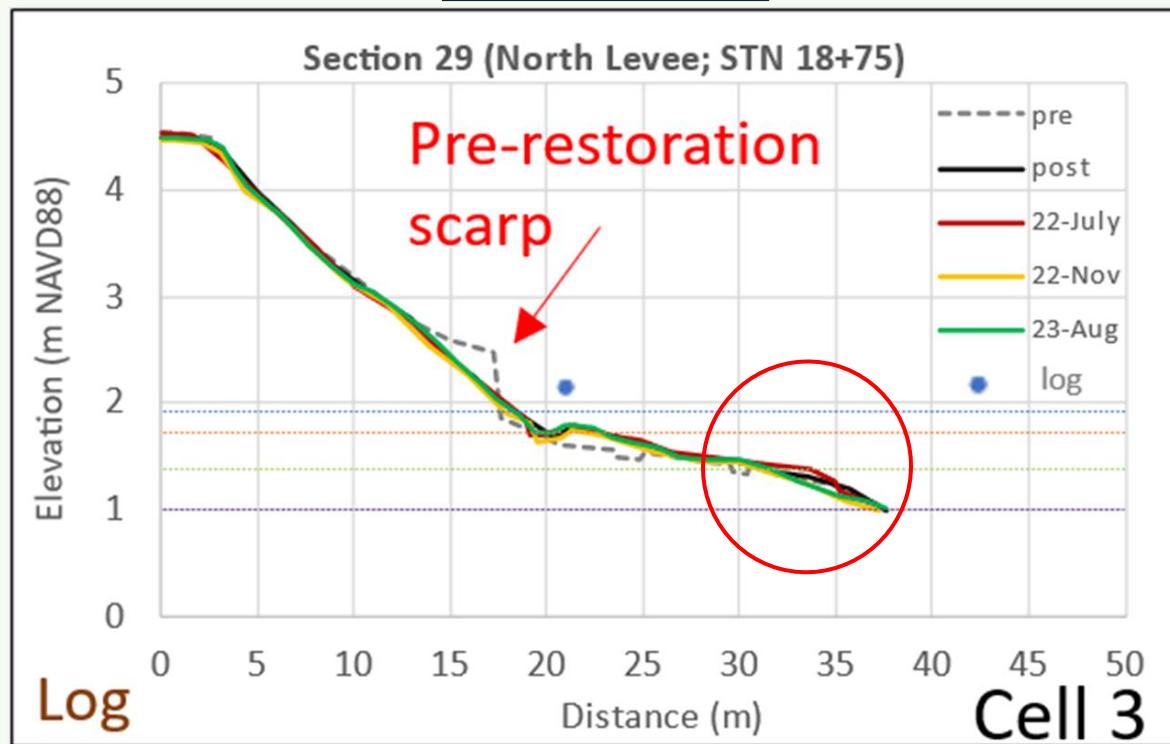


East End

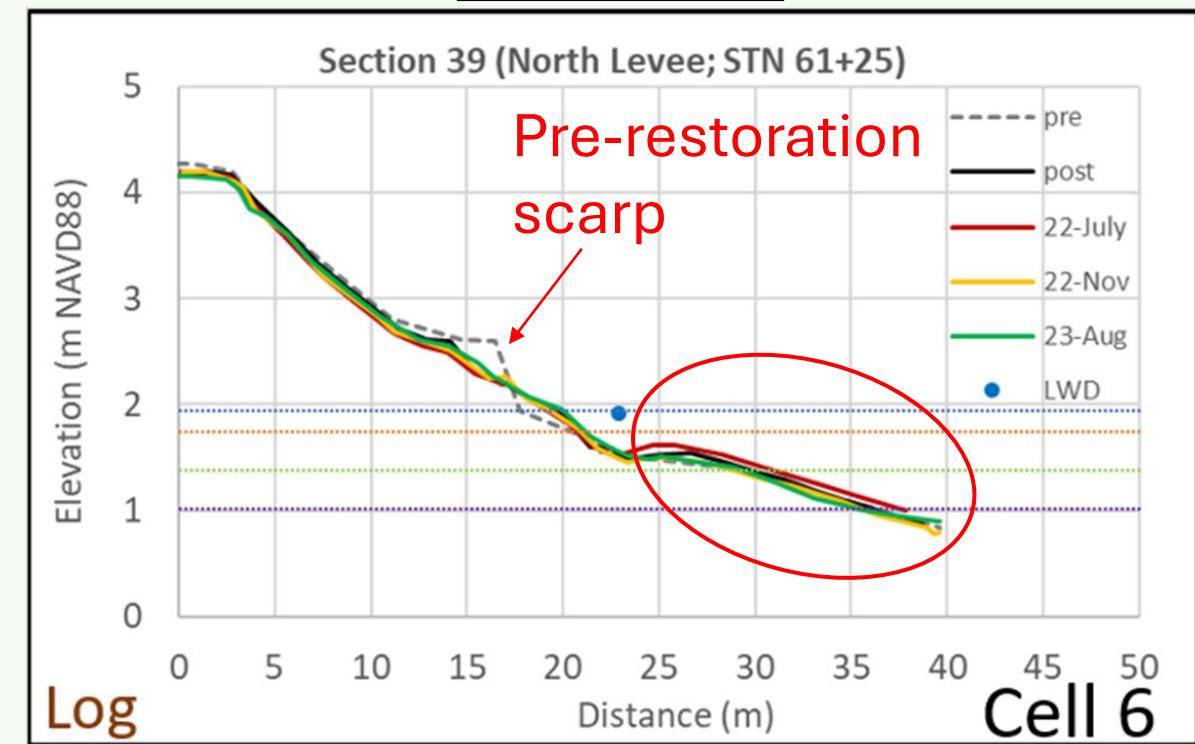


Topographic Transects

West End

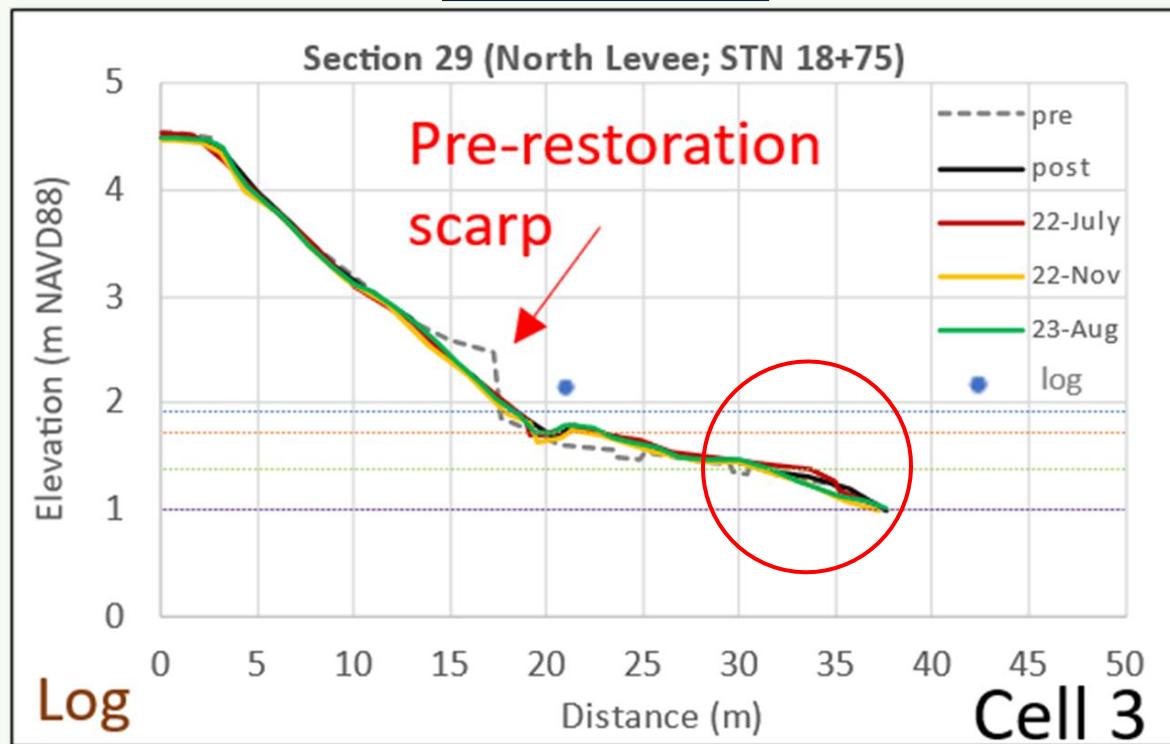


East End

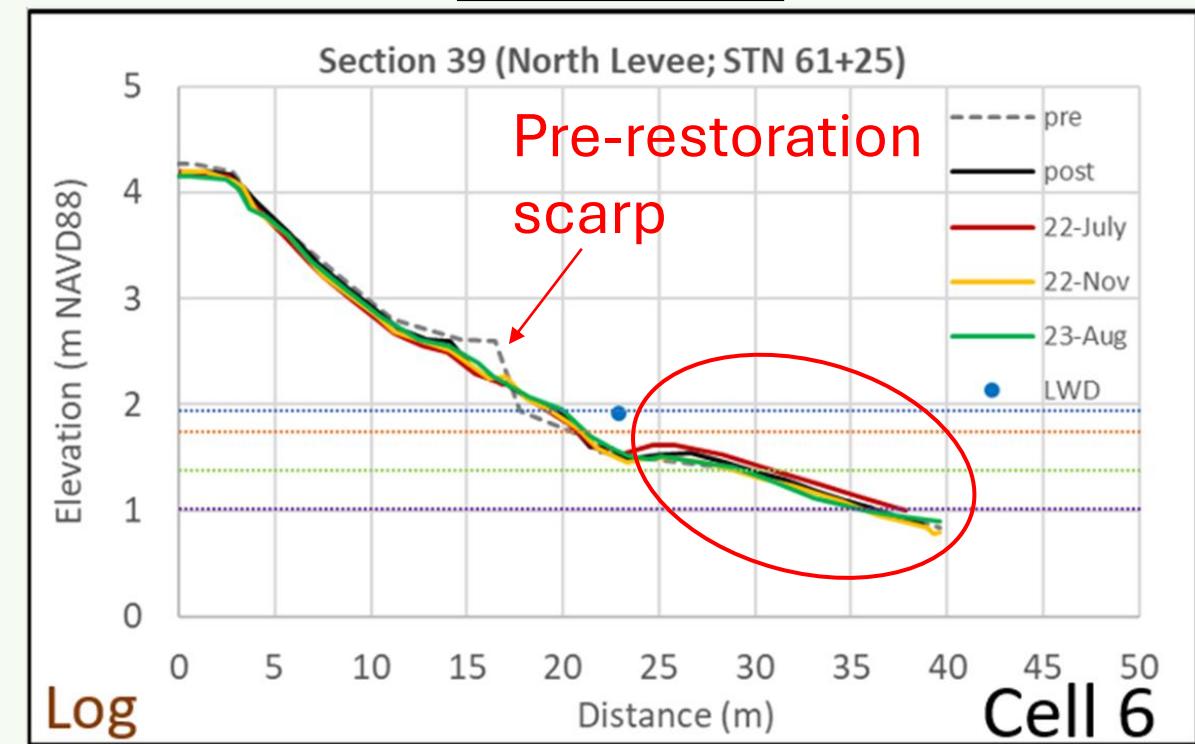


Topographic Transects

West End



East End



September 2022



June 2023



Image: Sears Point Year 2 Monitoring Report, 2023

Results/Discussion

September 2022



June 2023



Image: Sears Point Year 2 Monitoring Report, 2023

Results/Discussion

September 2022



June 2023



Image: Sears Point Year 2 Monitoring Report, 2023

Results/Discussion

September 2022



June 2023



Image: Sears Point Year 2 Monitoring Report, 2023

Results/Discussion

July 2022

Date & Time: Thu, Jul 07, 2022, 13:26:05 PDT
Position: 038°13'71.77"N / 122°44'77.69"W ($\pm 13.1\text{ft}$)
Altitude: 8ft ($\pm 9.8\text{ft}$)
Datum: WGS-84
Azimuth/Bearing: 170° S10E 3022mils True ($\pm 12^\circ$)
Elevation Angle: -26.3°
Horizon Angle: +01.2°
Zoom: 1.0X
ACRP



Coyote brush fencing

Bay mud still in place

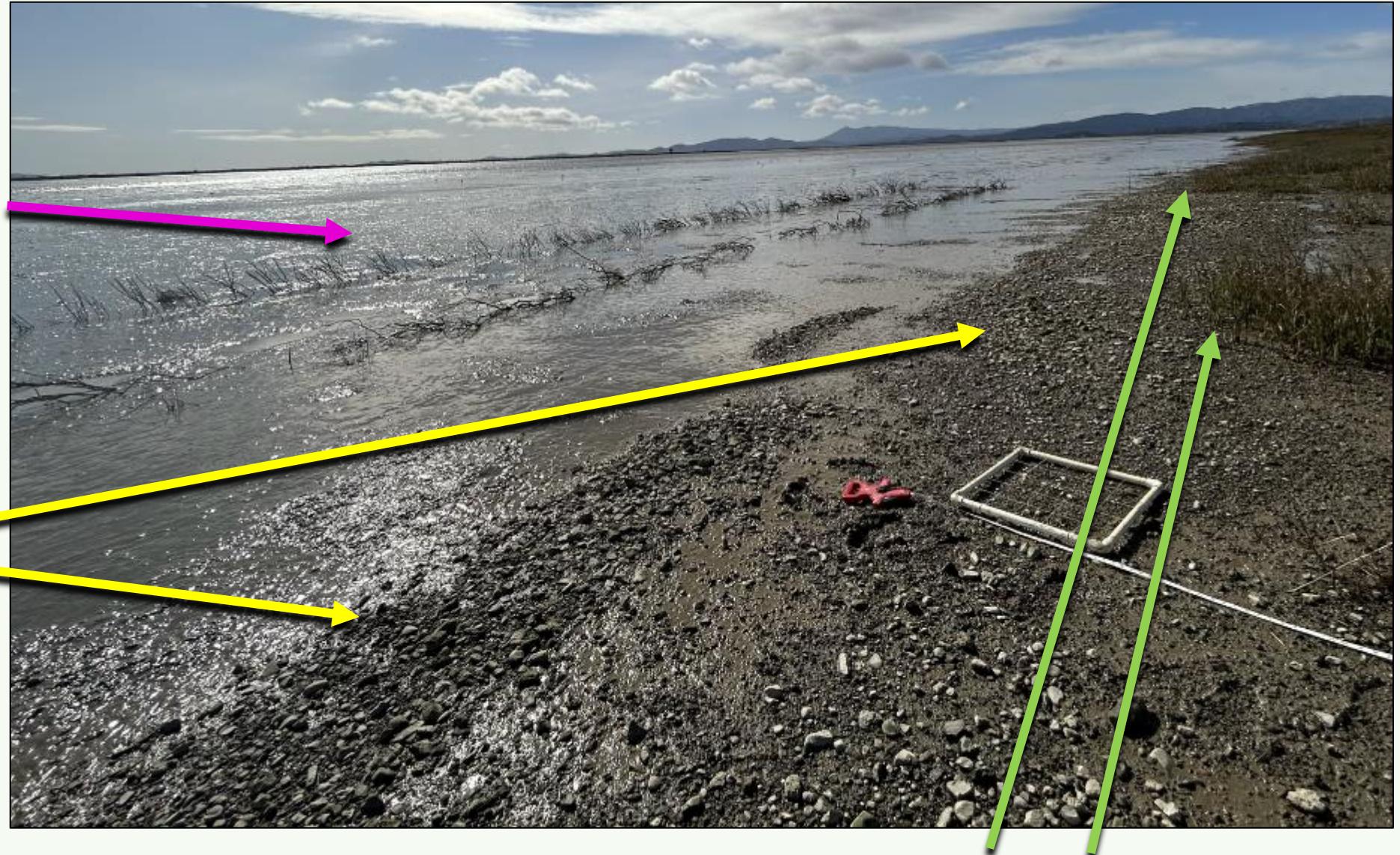
Results/Discussion

February 2023

Coyote brush fencing

Exposed gravel
lag armoring

Locked in *Spartina* colonies



Results/Discussion

February 2023

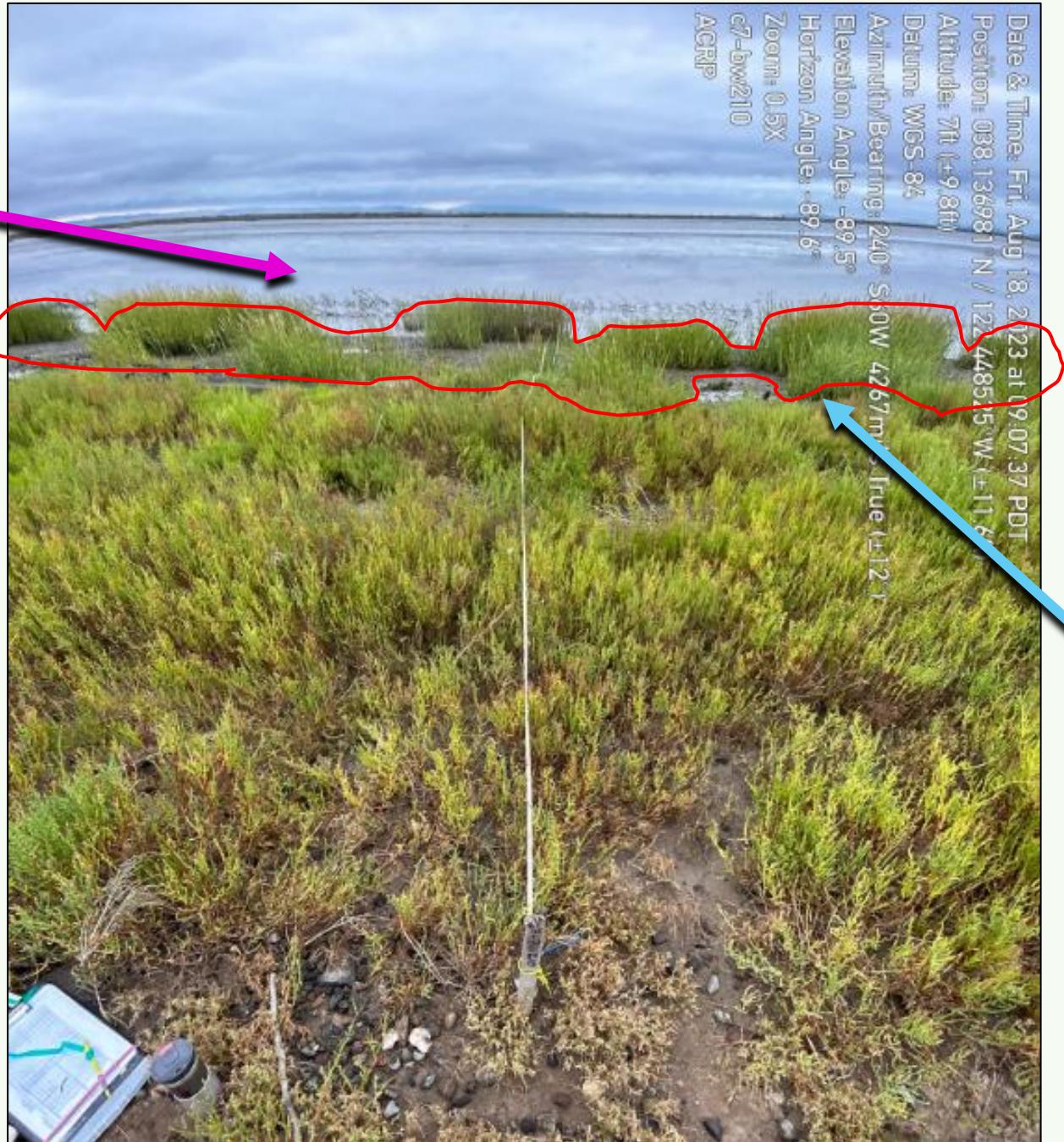
Coyote brush fencing



Results/Discussion

February 2023

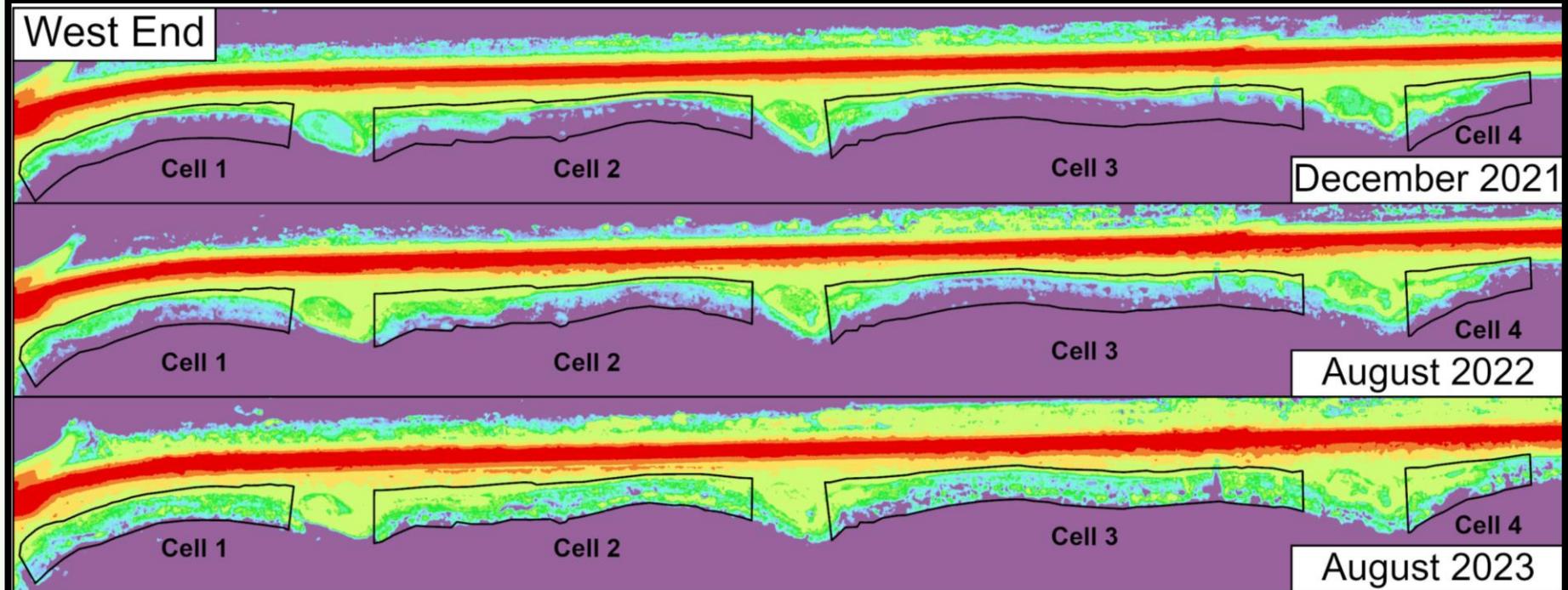
Coyote brush fencing



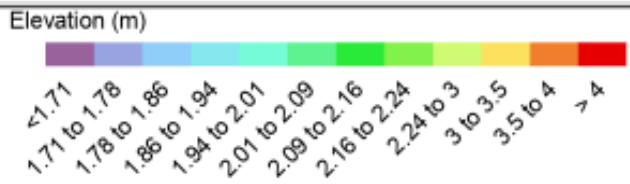
Locked in
Spartina
colonies

Results/Discussion

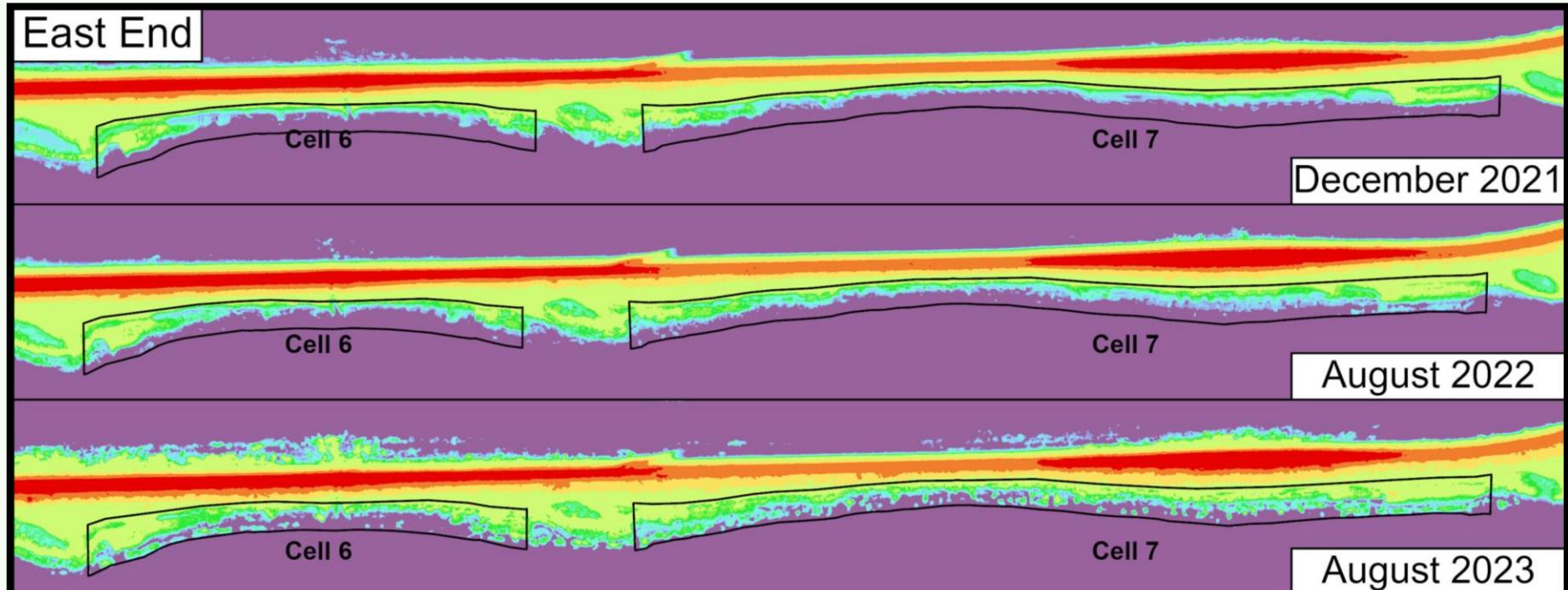
Digital Terrain Modeling



Research Project Extent



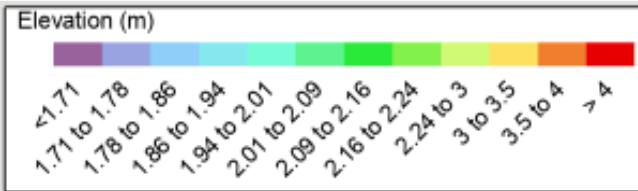
Increase in elevation



Results/Discussion

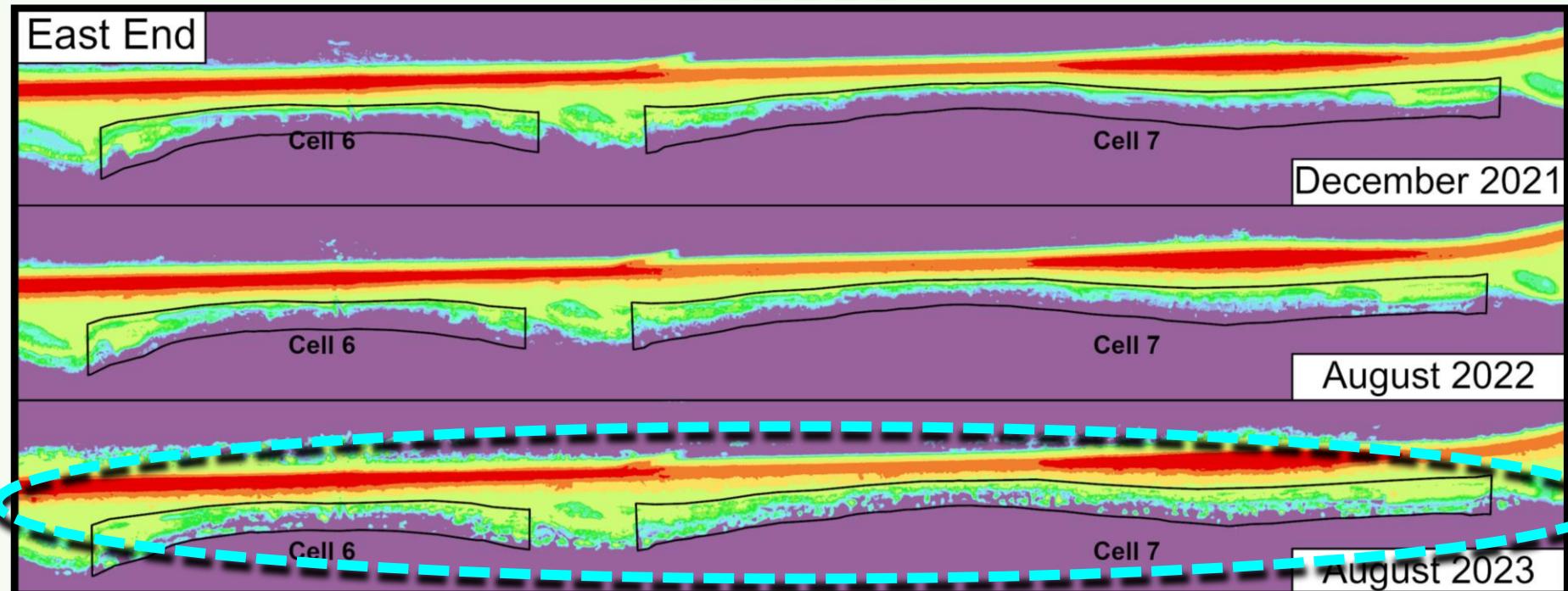
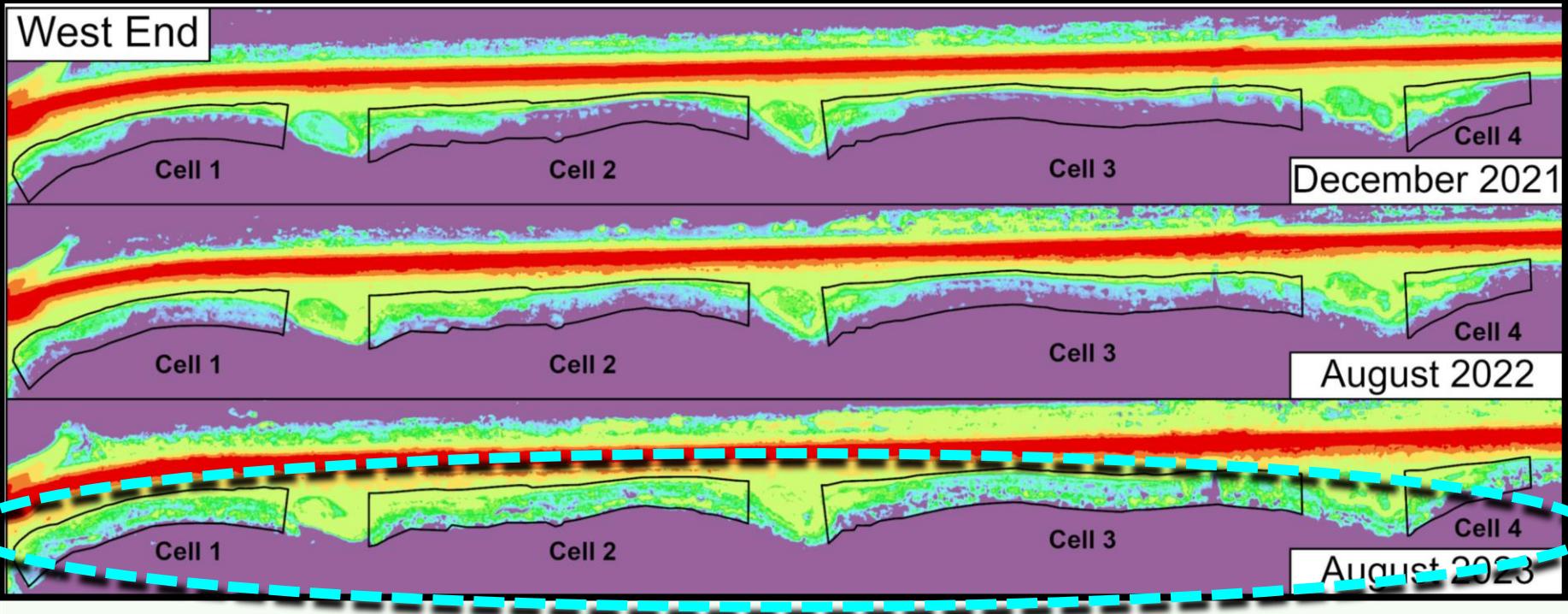
Digital Terrain Modeling

Research Project Extent



Increase in elevation

Results/Discussion



Digital Terrain Modeling

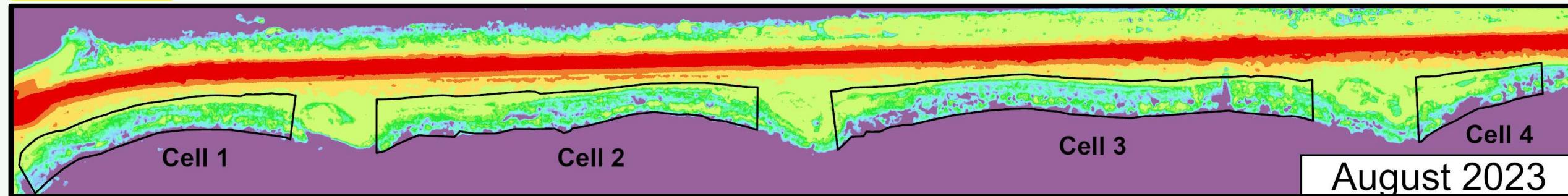
Research Project Extent

Elevation (m)



Increase in elevation

West End

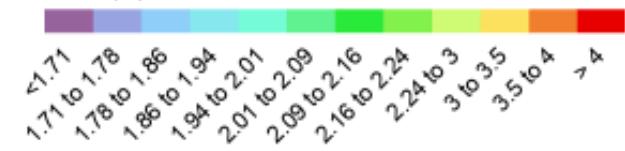


Results/Discussion

Digital Terrain Modeling

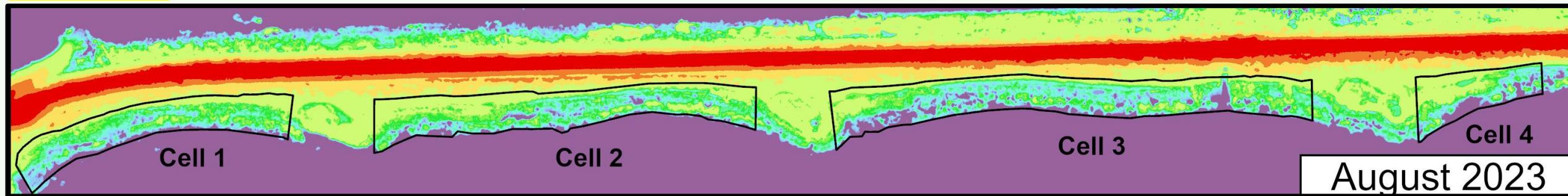
Research Project Extent

Elevation (m)

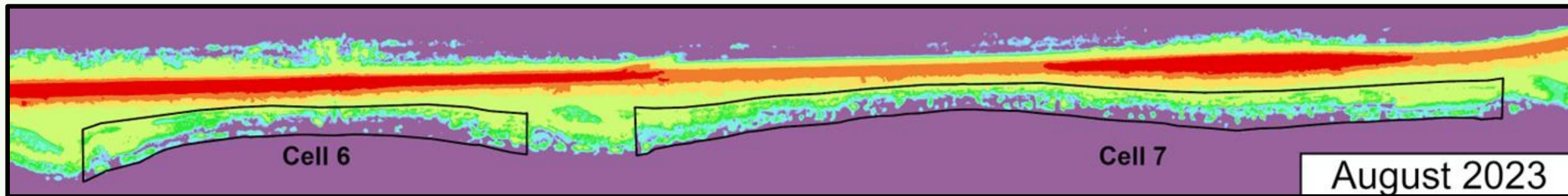


Increase in elevation

West End



August 2023

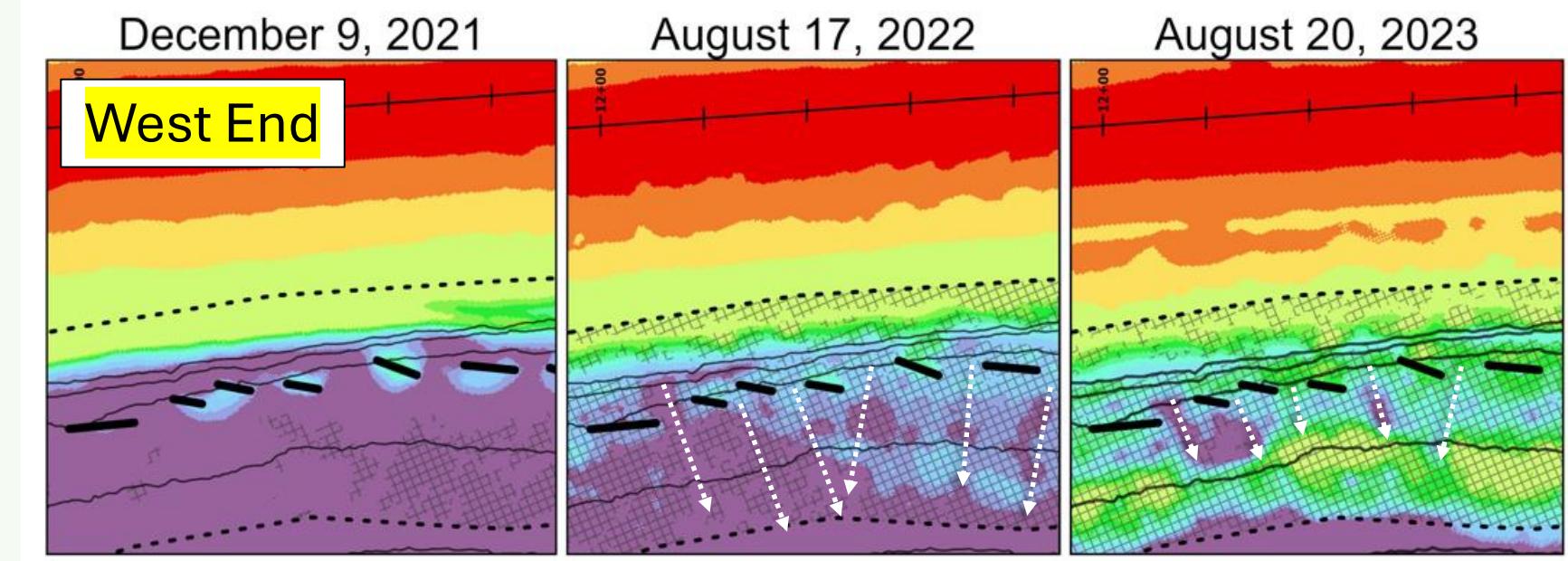
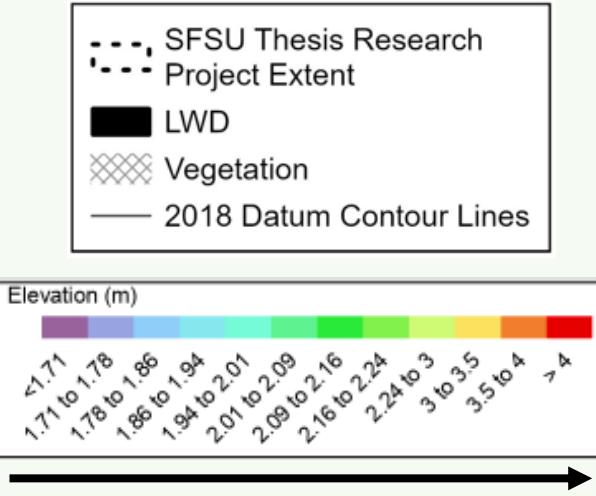


August 2023

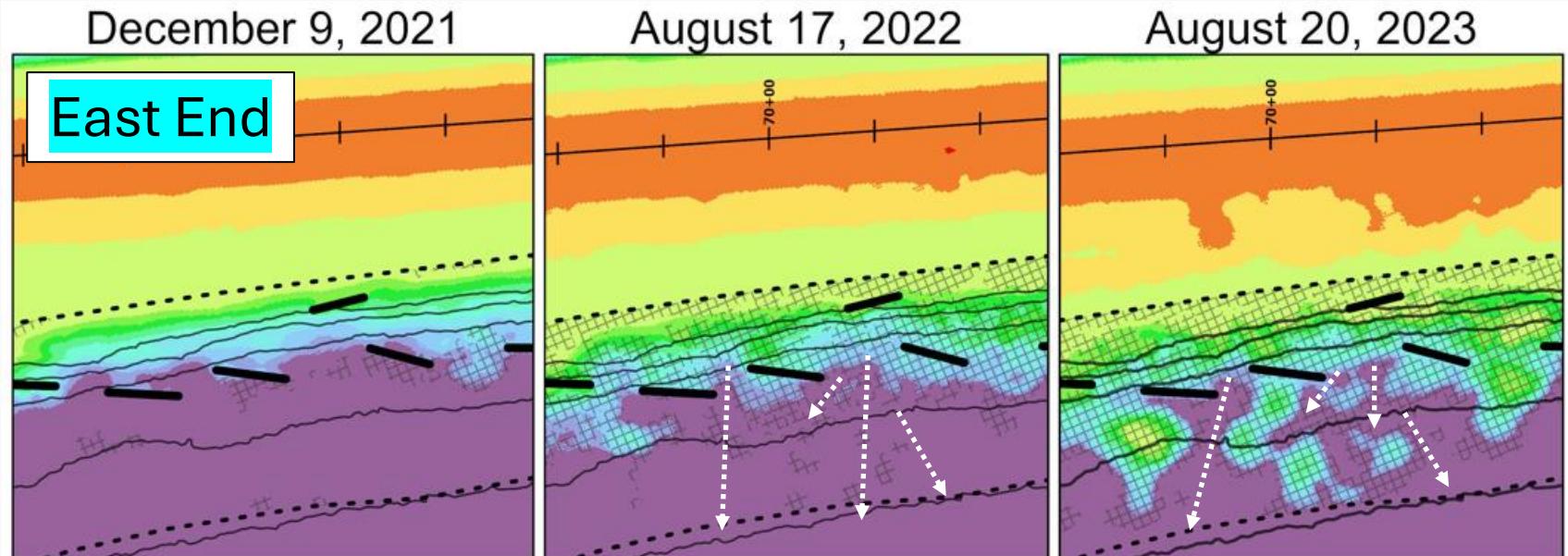
East End

Results/Discussion

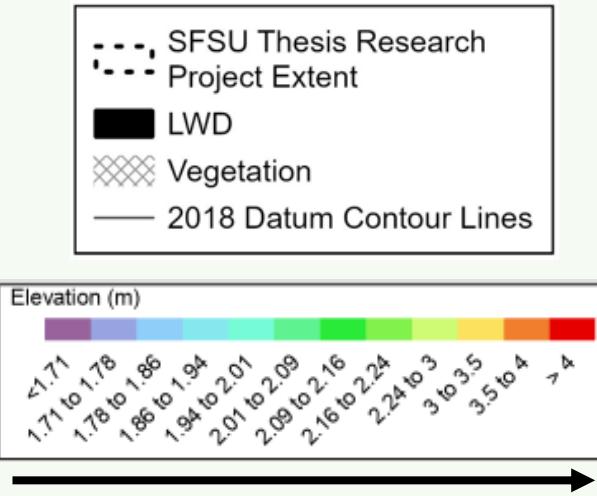
Digital Terrain Modeling



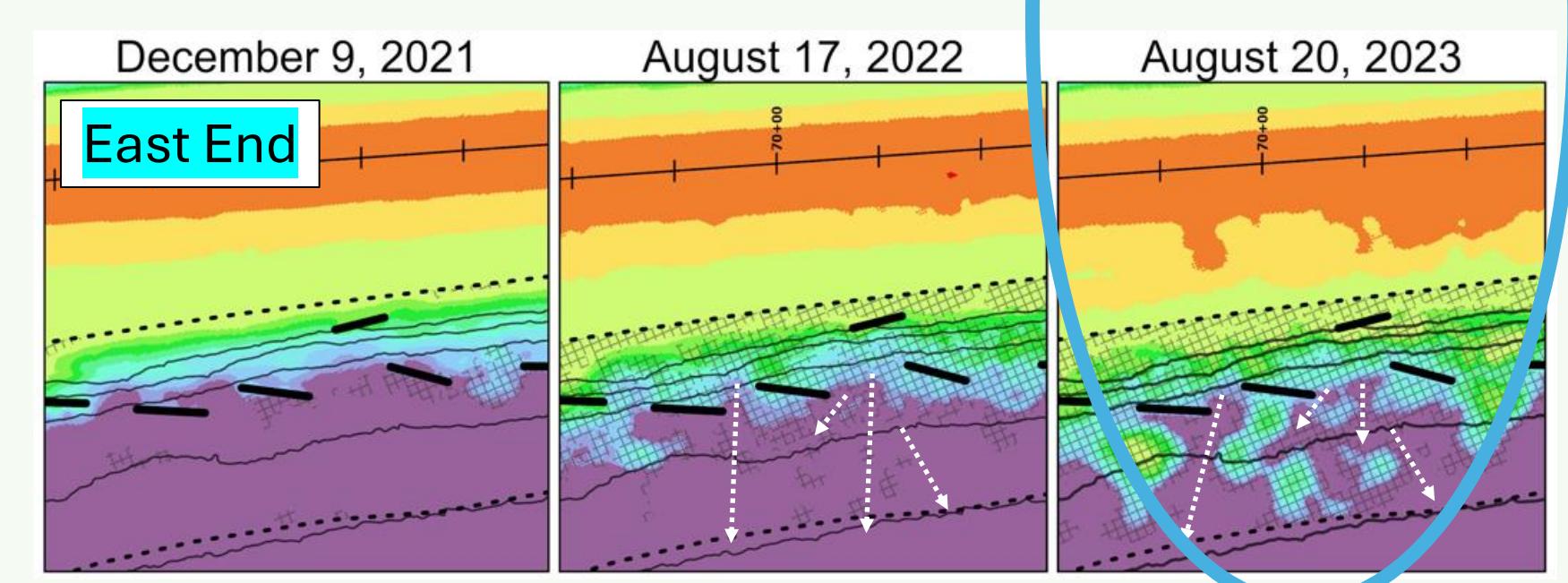
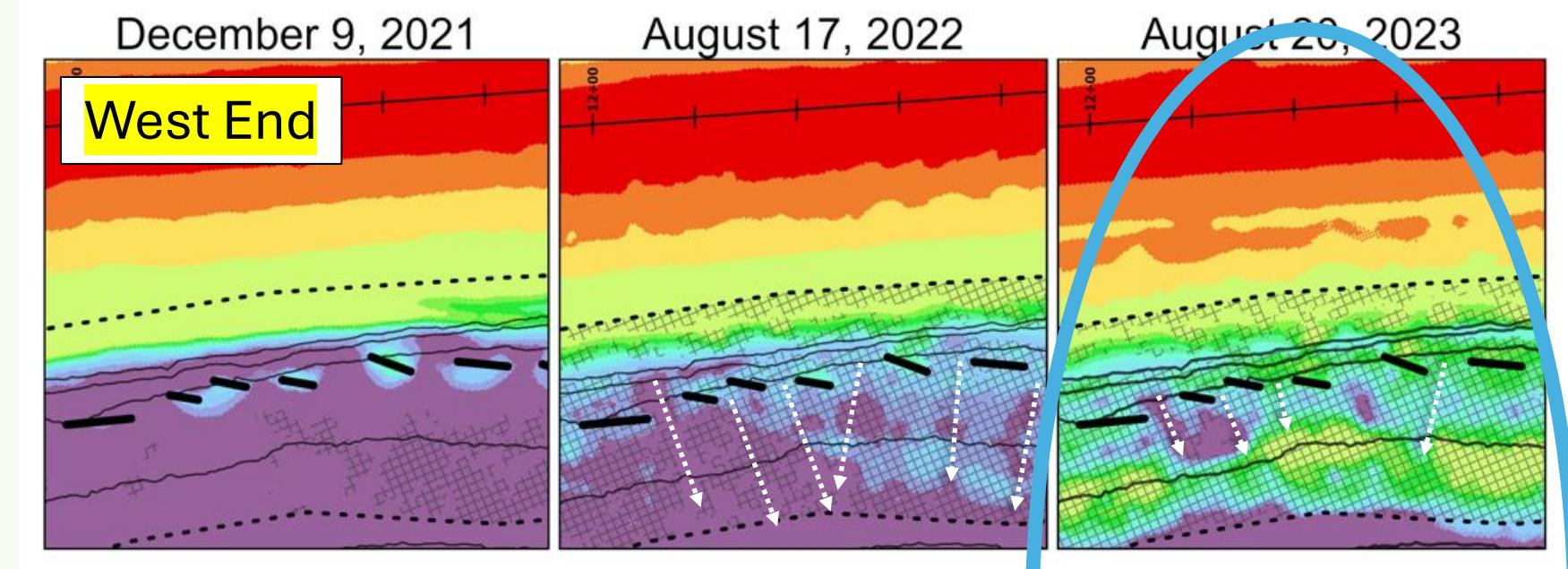
Results/Discussion



Digital Terrain Modeling

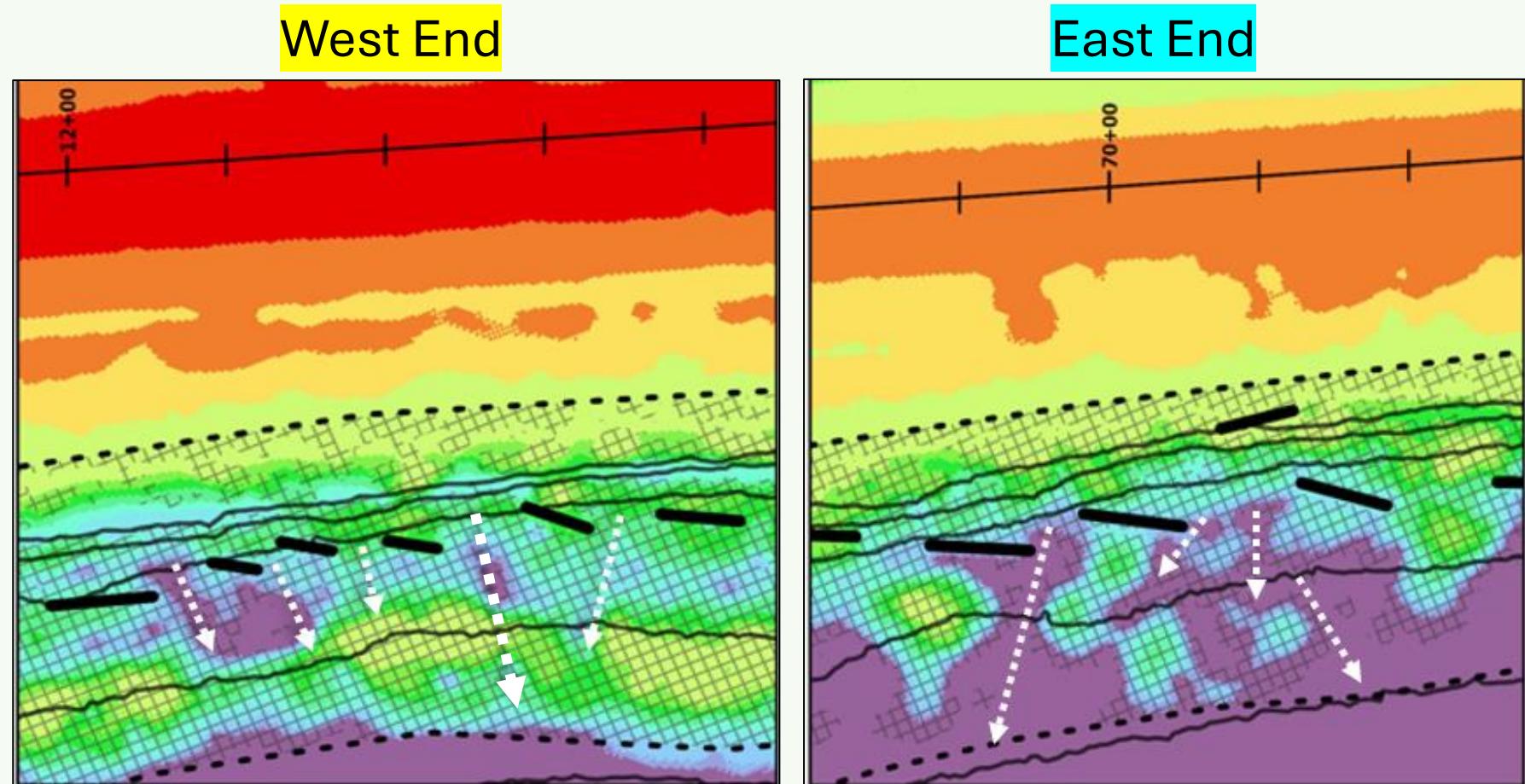
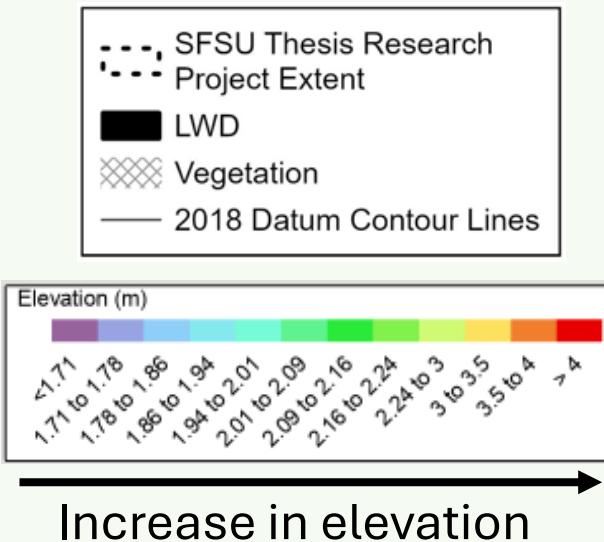


Results/Discussion



Digital Terrain Modeling

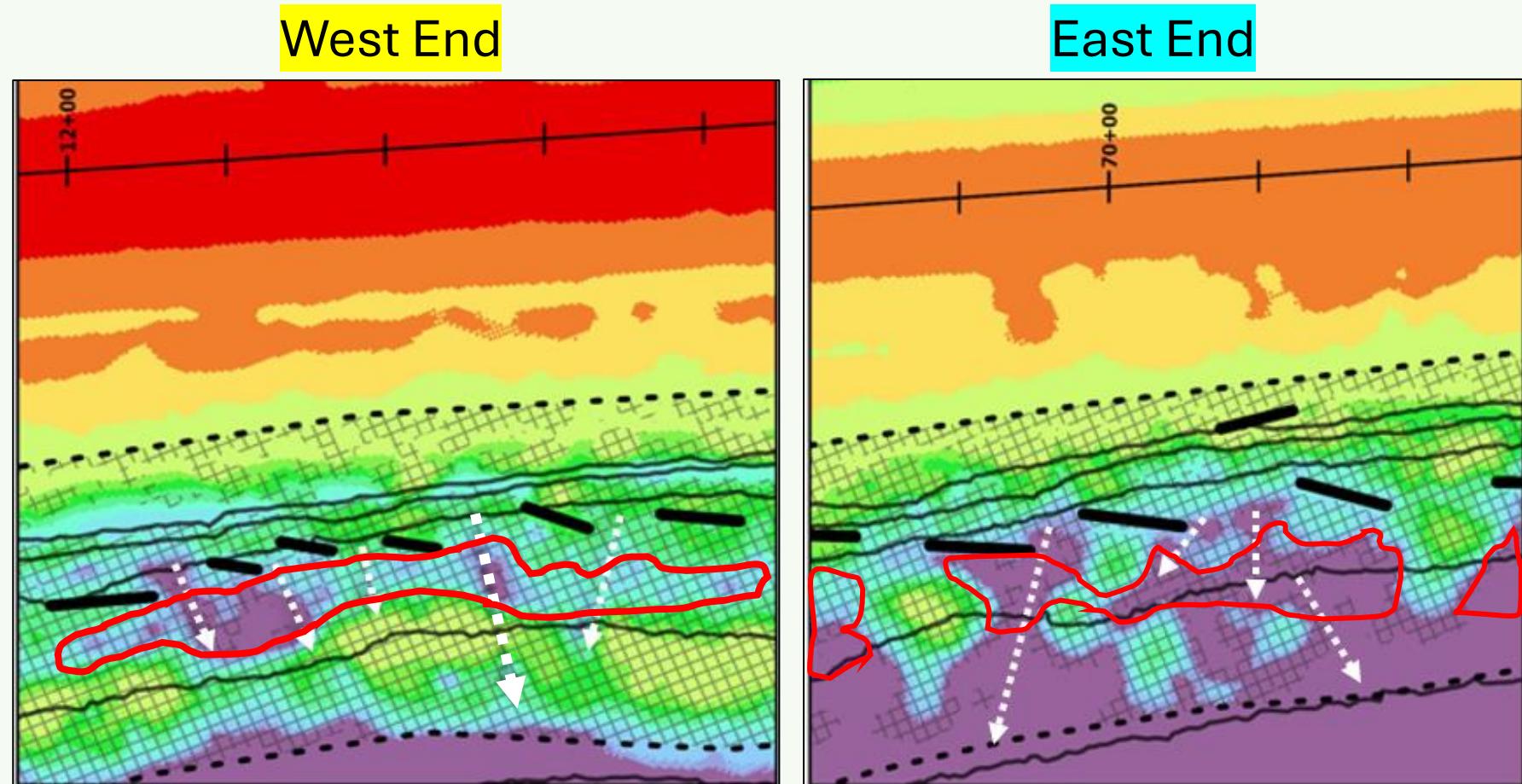
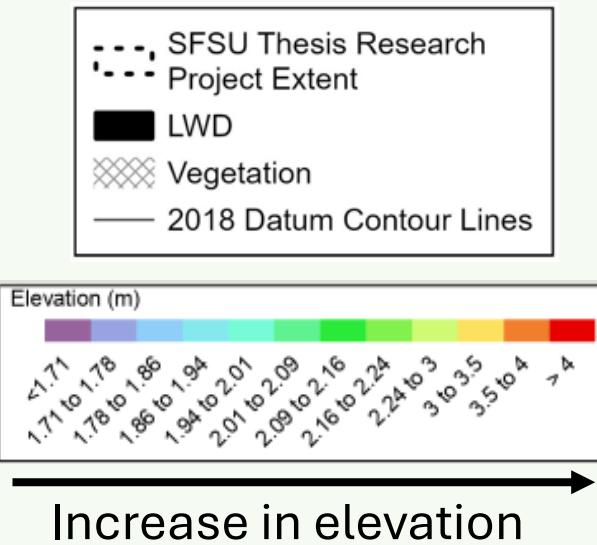
August 20, 2023



Results/Discussion

Digital Terrain Modeling

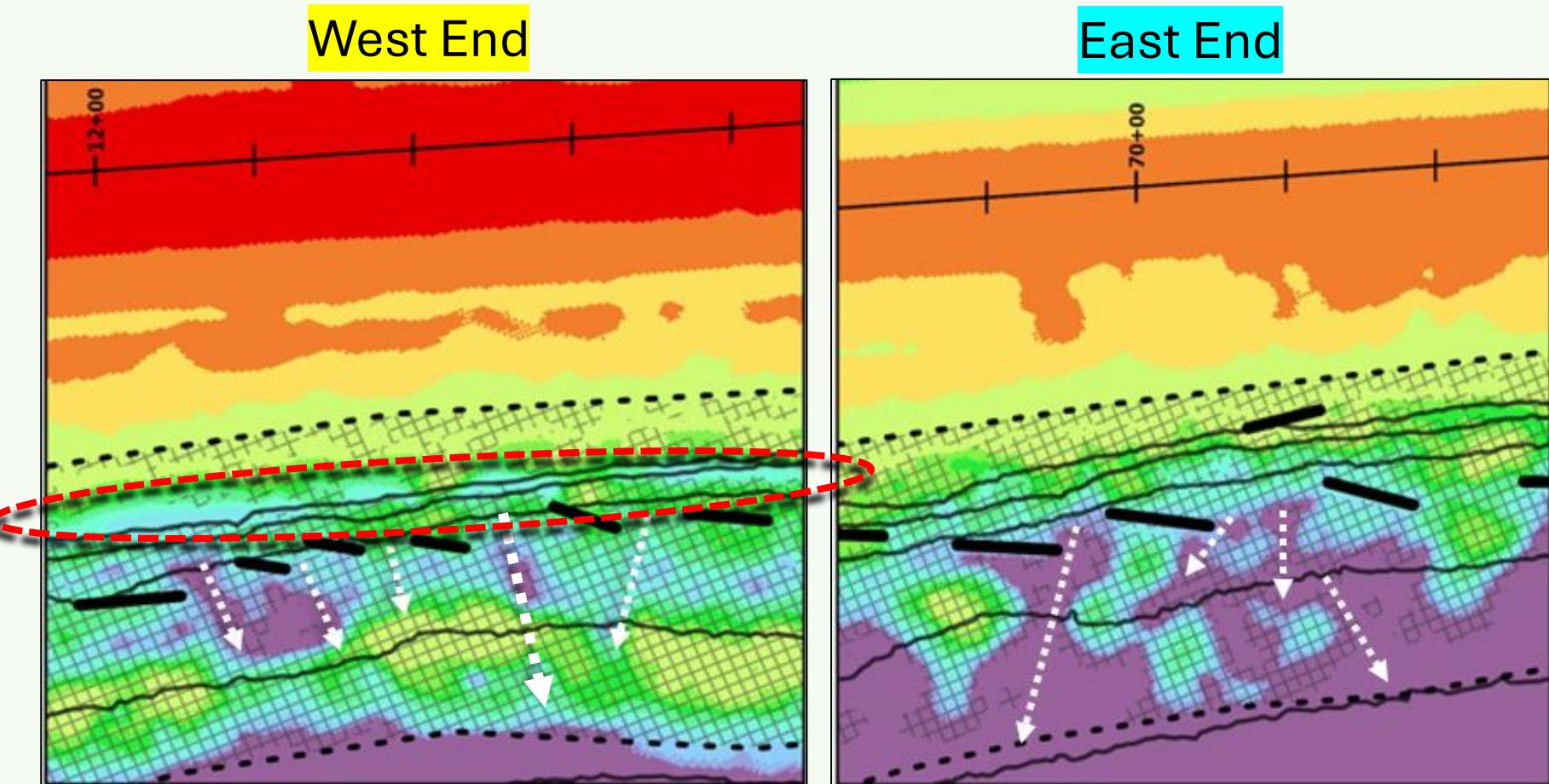
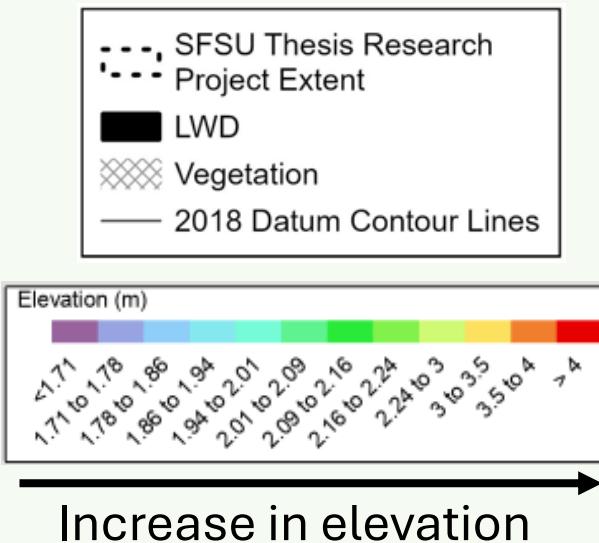
August 20, 2023



Results/Discussion

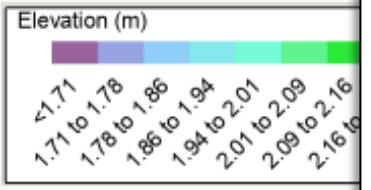
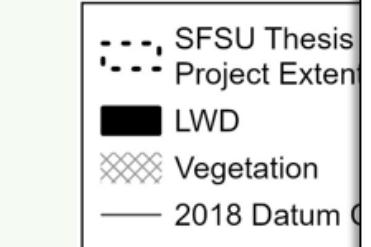
Digital Terrain Modeling

August 20, 2023

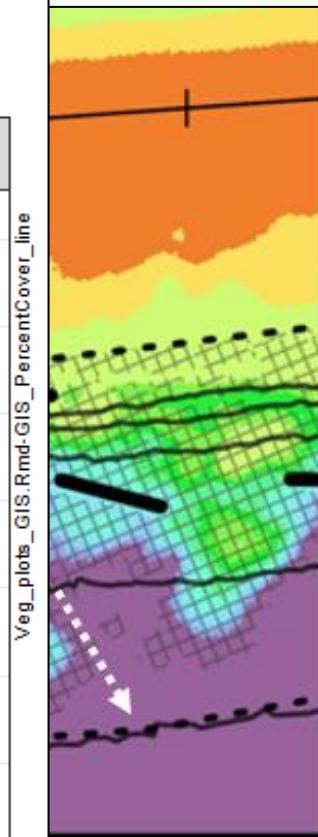
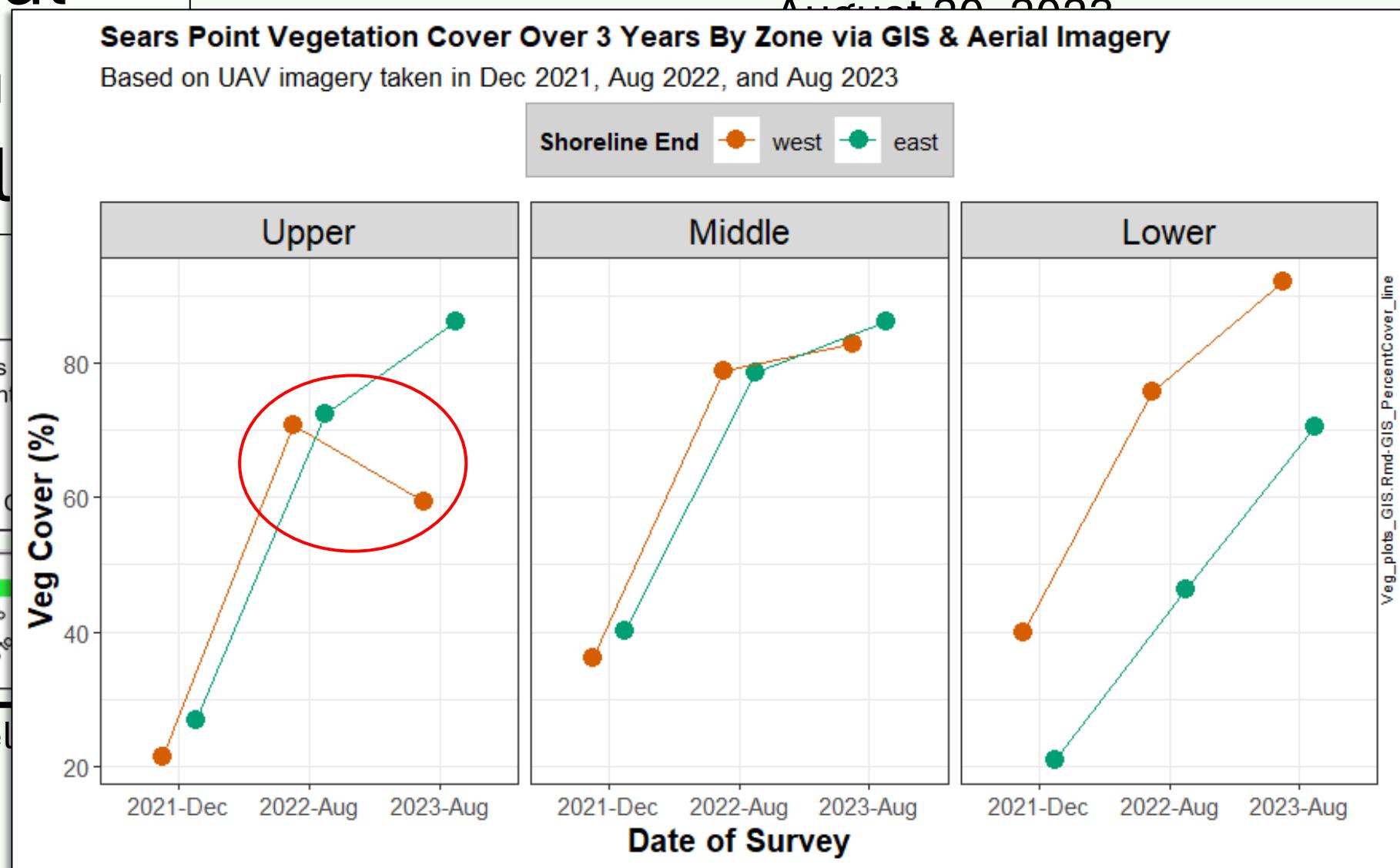


Results/Discussion

Digital Terra Model



Increase in elevation

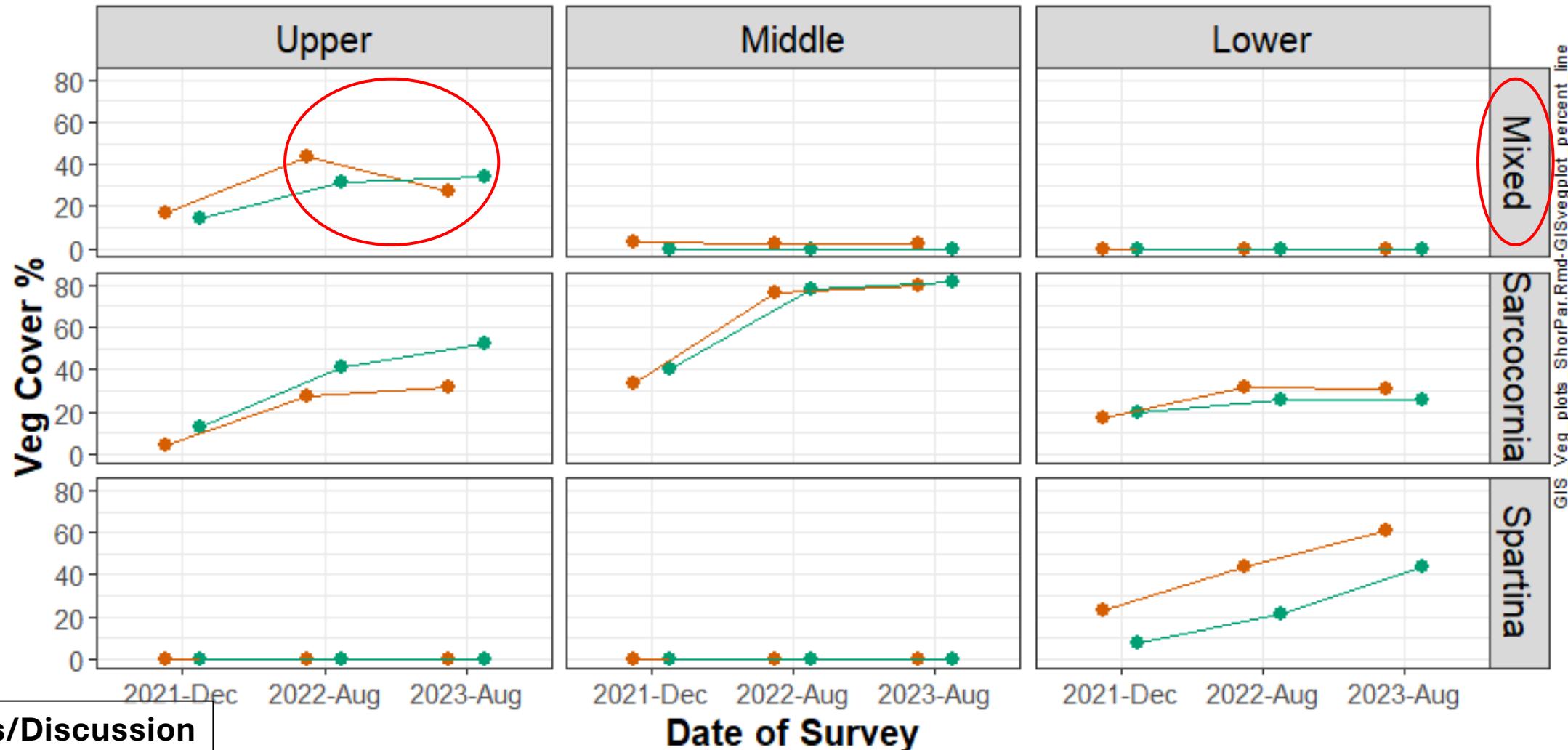


Results/Discussion

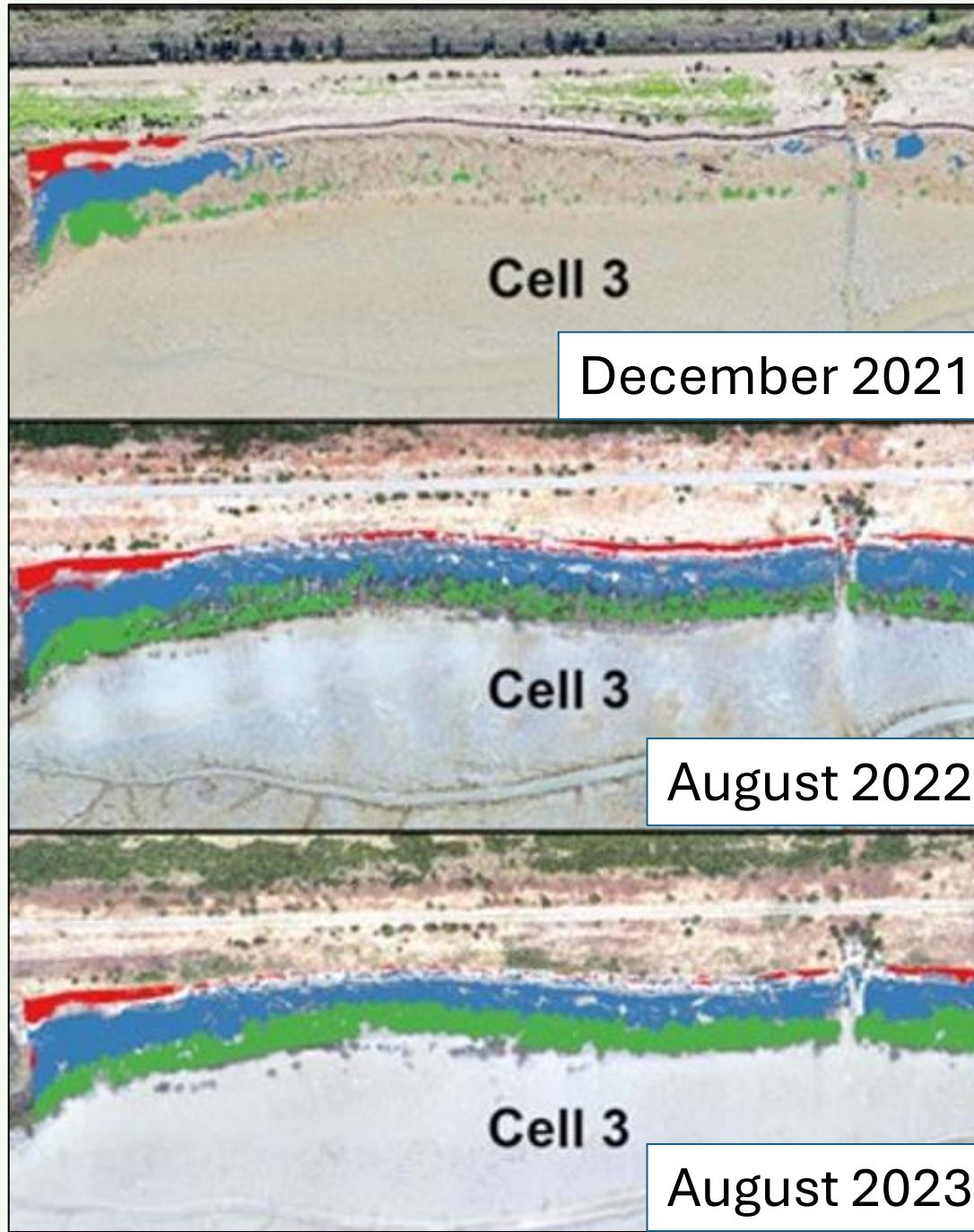
Sears Point Vegetation Cover Over 3 Years By Zone via GIS & Aerial Imagery

Based on UAV imagery taken in Dec 2021, Aug 2022, and Aug 2023

Shoreline End west east



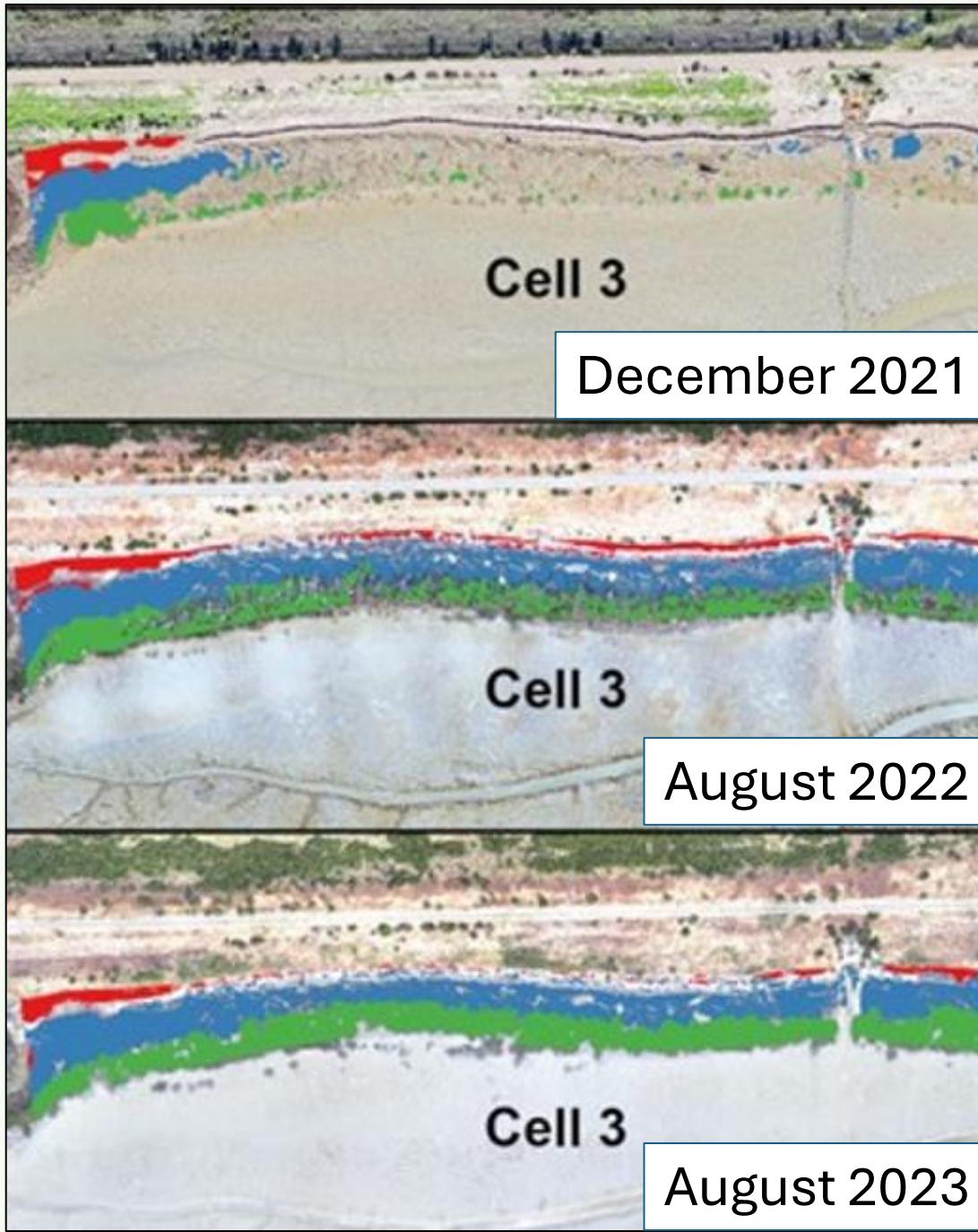
Results/Discussion



Spartina foliosa
“California cordgrass”



Results/Discussion

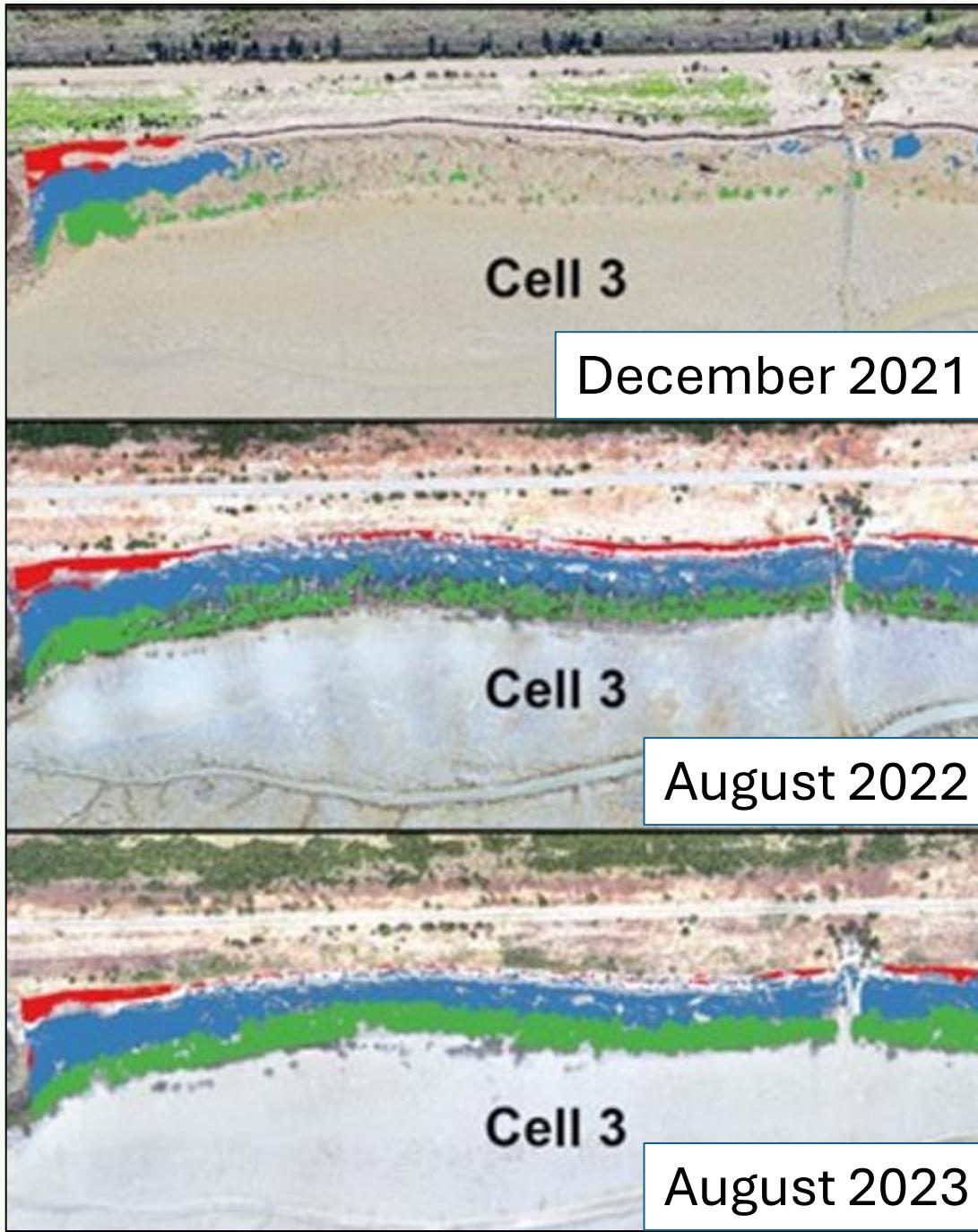


Results/Discussion

Sarcocornia pacifica
“Perennial pickleweed”



Results/Discussion



Results/Discussion

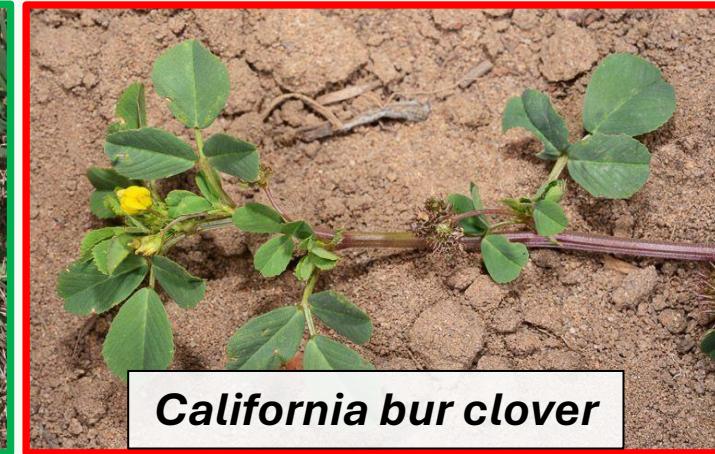
Mixed Transitional Vegetation Community



Brass buttons



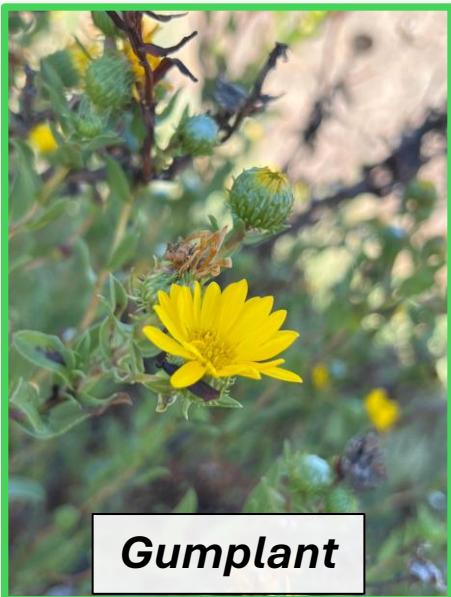
False dandelion



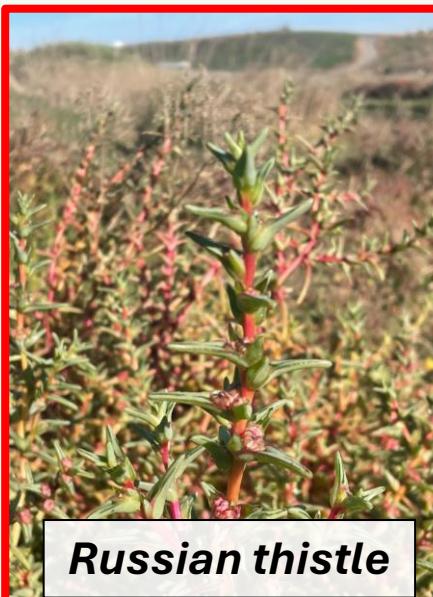
California bur clover



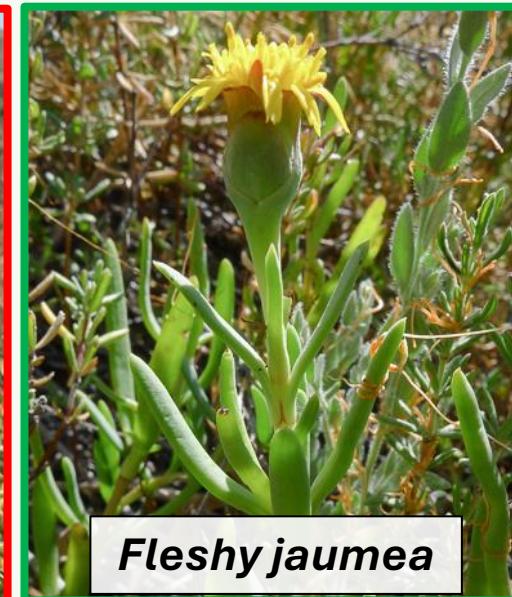
Wild radish



Gumplant



Russian thistle



Fleshy jaumea

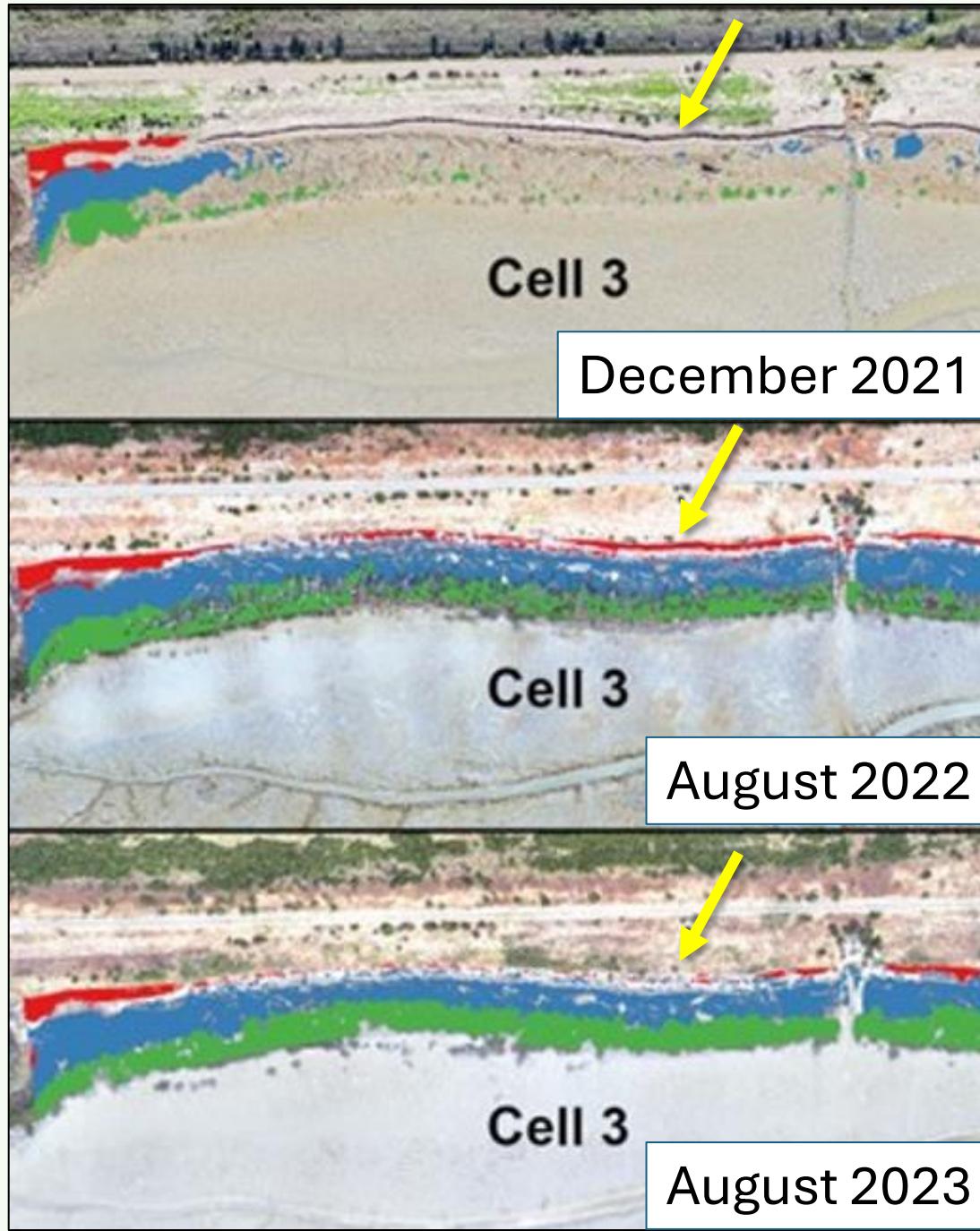


Creeping wild rye

Images: CalFlora, 2024

Results/Discussion

= native = invasive non-native

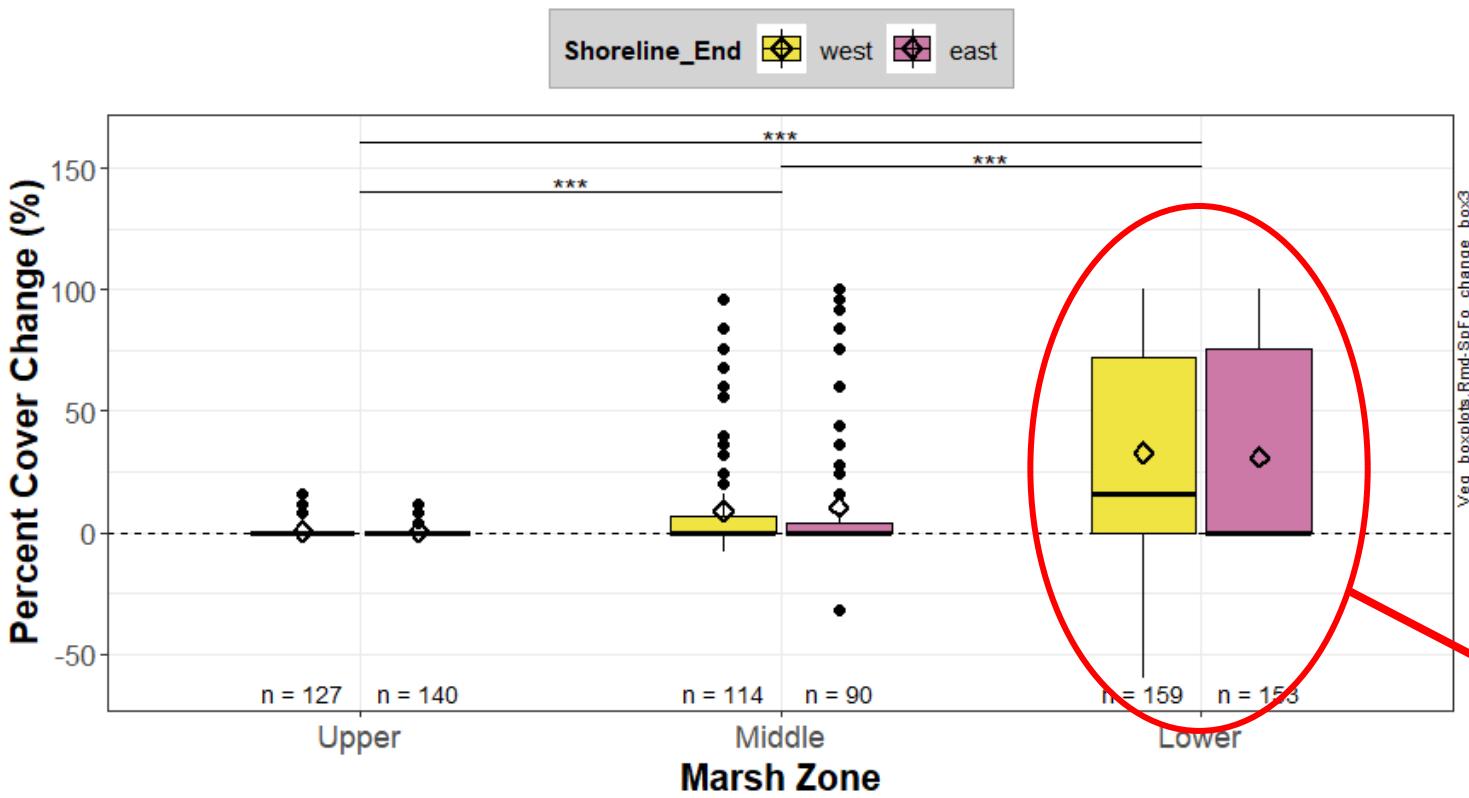


Mixed Transitional
Sarcocornia
Spartina

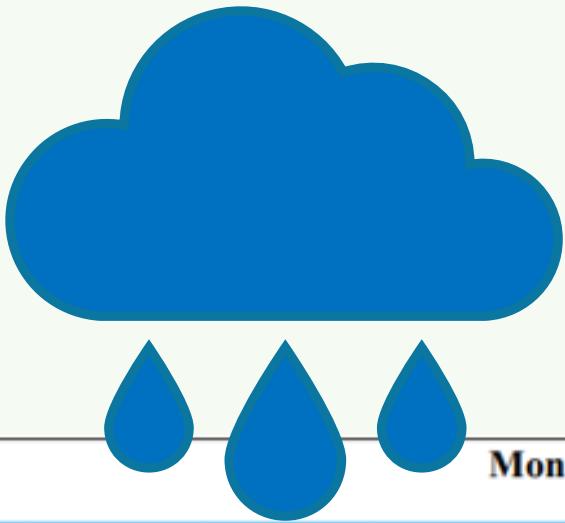
Results/Discussion

Change in *Spartina foliosa* Cover (%)

From August 2022 to August 2023



Results/Discussion



Monthly Total Precipitation for SANTA ROSA SONOMA CO AP, CA

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
2021	3.89	1.77	2.65	0.09	0.00	T	0.00	T	0.15	10.77	2.93	7.75	30.00
2022	0.61	T	1.30	2.06	0.09	0.66	T	T	0.96	0.01	1.23	9.71	16.63
2023	13.50	3.78	12.84	0.47	0.86	0.03	T	T	0.17	0.65	2.66	8.74	43.70
2024	9.57	9.55	4.57	0.90	0.82	T	M	M	M	M	M	M	M
Mean	6.89	3.78	5.34	0.88	0.44	0.17	T	T	0.43	3.81	2.27	8.73	30.11
Max	13.50 2023	9.55 2024	12.84 2023	2.06 2022	0.86 2023	0.66 2022	T 2023	T 2023	0.96 2022	10.77 2021	2.93 2021	9.71 2022	43.70 2023
Min	0.61 2022	T 2022	1.30 2022	0.09 2021	0.00 2021	T 2024	0.00 2021	T 2023	0.15 2021	0.01 2022	1.23 2022	7.75 2021	16.63 2022

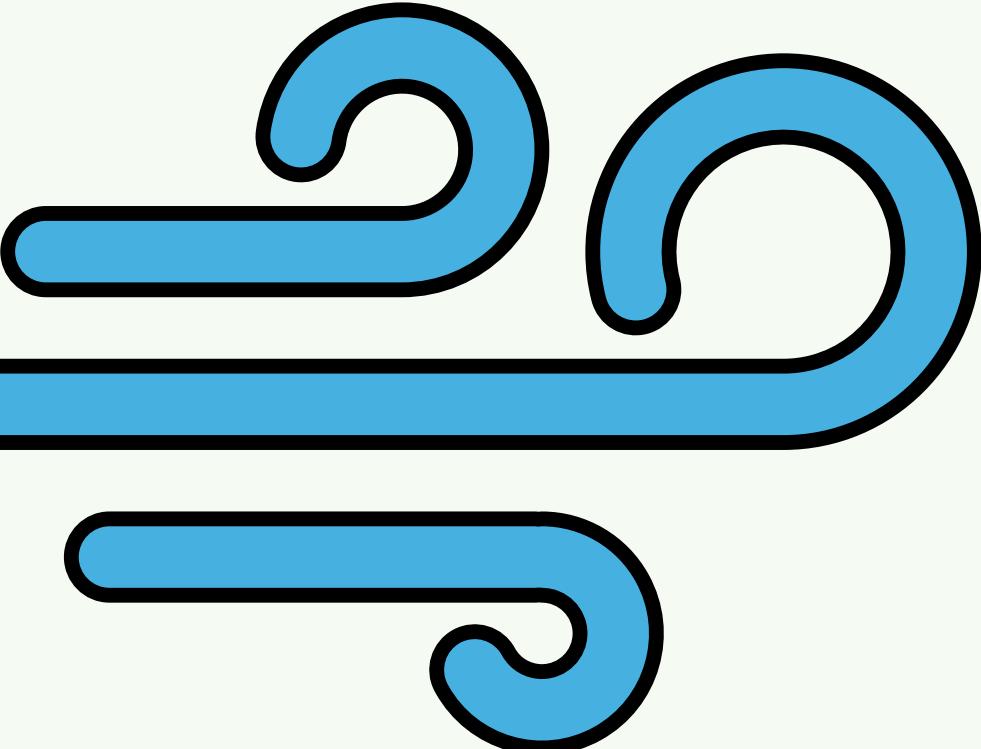
T stands for "Trace," indicating precipitation levels less than 0.01.

M stands for "Missing."

National Weather Service. (2024). Full Weather Glossary.

https://www.weather.gov/otx/Full_Weather_Glossary

Results/Discussion



National Centers for Environmental Information. (2023). Storm Events Database: Event data for Sonoma County, CA, December 2021 - August 2023 [Data set]. National Oceanic and Atmospheric Administration.

Results/Discussion

Begin Date	Begin Time	Event Type	Magnitude (kts)	End Date	End Time
12/13/2021	857	Flood		12/13/2021	957
12/13/2021	1300	Strong Wind	29	12/13/2021	1330
12/13/2021	2111	Flood		12/13/2021	2211
1/22/2022	100	High Wind	65	1/22/2022	700
3/4/2022	1200	Strong Wind	37	3/4/2022	1600
4/11/2022	1500	Strong Wind	35	4/11/2022	1600
5/2/2022	1500	Strong Wind	45	5/2/2022	1600
6/10/2022	1500	Heat		6/10/2022	1600
6/21/2022	1500	Heat		6/21/2022	1600
7/11/2022	2000	Coastal Flood		7/11/2022	2300
7/12/2022	2115	Coastal Flood		7/13/2022	15
7/13/2022	2340	Coastal Flood		7/14/2022	300
9/4/2022	1200	Heat		9/8/2022	1800
9/5/2022	1400	Heat		9/5/2022	1600
9/6/2022	1400	Heat		9/6/2022	1600
9/18/2022	1000	Strong Wind	38	9/18/2022	1100
9/18/2022	1100	Strong Wind	40	9/18/2022	1200
9/18/2022	1300	Strong Wind	41	9/18/2022	1400
12/27/2022	30	High Wind	61	12/27/2022	30
12/27/2022	310	High Wind	61	12/27/2022	310
1/4/2023	1715	Strong Wind	22	1/4/2023	1730
1/9/2023	740	Flood		1/9/2023	1000
1/14/2023	1715	Strong Wind	19	1/14/2023	2012
1/21/2023	800	Frost/Freeze		1/21/2023	900
2/21/2023	1330	Strong Wind	26	2/21/2023	1330
2/21/2023	1450	High Wind	57	2/21/2023	1450
2/21/2023	1734	Strong Wind	17	2/21/2023	1734
3/9/2023	2127	High Wind	56	3/9/2023	2127
3/9/2023	2229	Heavy Rain		3/9/2023	2229
3/14/2023	1110	High Wind	64	3/14/2023	1110
3/21/2023	1000	High Wind	51	3/21/2023	1000
3/28/2023	1030	High Wind	54	3/28/2023	1030
7/1/2023	0	Excessive Heat		7/1/2023	2359
7/16/2023	0	Heat		7/16/2023	2359

“Sand-spurrey” - *Spergularia* spp.

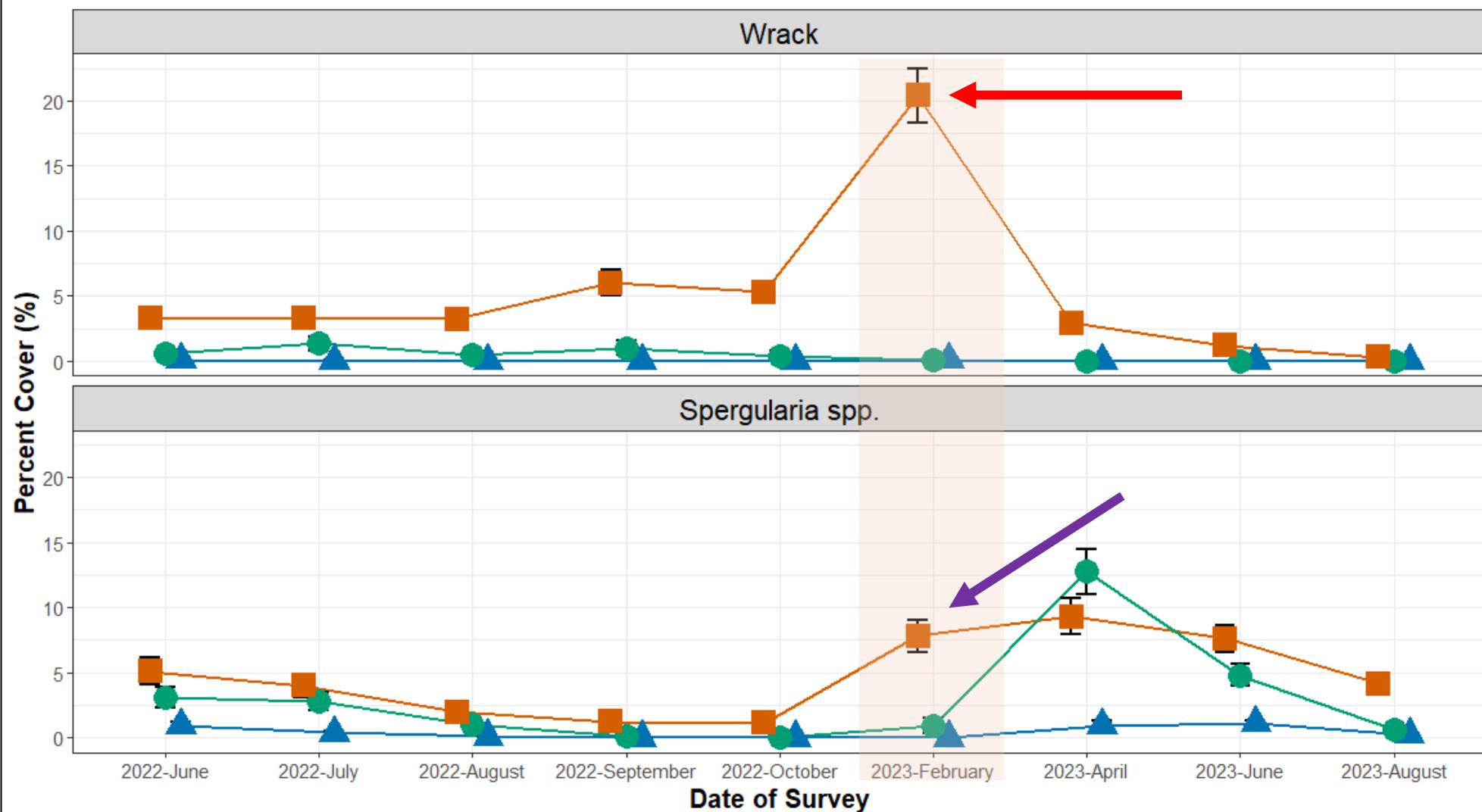


Results/Discussion

(Hartman et al., 1983; Tolley and Christian, 1999)

Cover of Wrack and *Spergularia* spp. over Time(%)

Marsh Zone █ Upper ● Middle ▲ Lower



Results/Discussion

Synthesis of Results

How effective are the NBS treatments at minimizing erosion, and encouraging emergent marsh establishment along the habitat levee?

The problem:

Cyclical erosion along shoreline, preventing vegetation establishment.

How effective are the NBS treatments at minimizing erosion, and encouraging emergent marsh establishment along the habitat levee?

Shoreline Stability:
No new scarp formation was observed along the shoreline*, indicating overall stability.

*Within my research project extent. Some slight scarping observed in a few areas outside (~0.15 – 0.3 m (1/2 -1 ft))

How effective are the NBS treatments at minimizing erosion, and encouraging emergent marsh establishment along the habitat levee?

West vs. East Performance:
As hypothesized, the west end showed greater vegetation establishment and sediment accretion compared to the east.

How effective are the NBS treatments at minimizing erosion, and encouraging emergent marsh establishment along the habitat levee?

Role of Treatments:

Despite greater accretion on the west, the east end also showed positive results, highlighting the effectiveness of additional treatments in reducing wind wave energy.

How effective are the NBS treatments at minimizing erosion, and encouraging emergent marsh establishment along the habitat levee?

Vegetation Loss:

The west end's upper middle zone experienced an 11% vegetation loss from 2022 to 2023, likely due to wrack line formation from *Spartina foliosa* expansion and strong winter storms.

How effective are the NBS treatments at minimizing erosion, and encouraging emergent marsh establishment along the habitat levee?

Sediment Dynamics:

Slight sediment loss occurred in middle and lower zones on both ends, but this sediment was designed to move and redistribute, supporting continued accretion and vegetation establishment in the upper areas of the marsh.

Limitations

- Not set up as an **experimental design**.
- Must rely on trends.

Limitations

- Not set up as an experimental design.
- Must rely on **trends**.

Limitations

- Not set up as an experimental design.
 - Must rely on trends.
- !
- **Continued monitoring** and data collection **important**
 - Holistic Approach: Vegetation establishment success due to combination of methods, rather than one single approach.

Limitations

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- **Holistic Approach:** Vegetation establishment success due to **combination of methods**, rather than one single approach.

Broader Implications

Nature-based strategies work to prevent erosion and increase habitat at a landscape scale – especially adding treatment in high energy areas, in this project lag gravel armoring.

Broader Implications

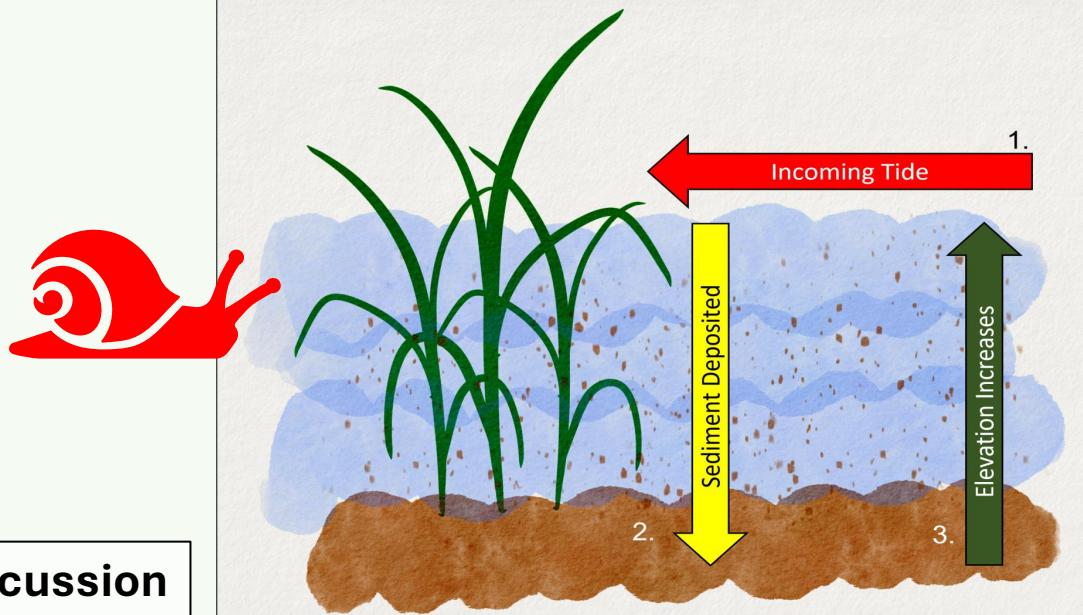
Using **natural elements** saves money and time, simultaneously providing habitat, recreational opportunities, and aesthetic beauty.

Narayan *et al.*, 2016

Broader Implications

**Vertical accretion alone is slow –
Transport and redistribution of bay mud/gravel is fast.**

Vertical
Accretion



Discussion

Wave
Deposition



Broader Implications

No tidal action until all restoration elements are in place!



Prospects for Future Progress

This analysis is a model for future projects:

- **Incorporates physical and biological data from:**
 - Vegetation and topographic surveys
 - Sediment pin measurements
 - And high resolution DTM's

Prospects for Future Progress

**Continued monitoring at Sears Point very necessary –
future storms and drought conditions**

Prospects for Future Progress

Critical need for similar research in other locations with:

- Different sediment supply
- Wind-wave energy gradients
- Tidal inundation
- Freshwater inputs

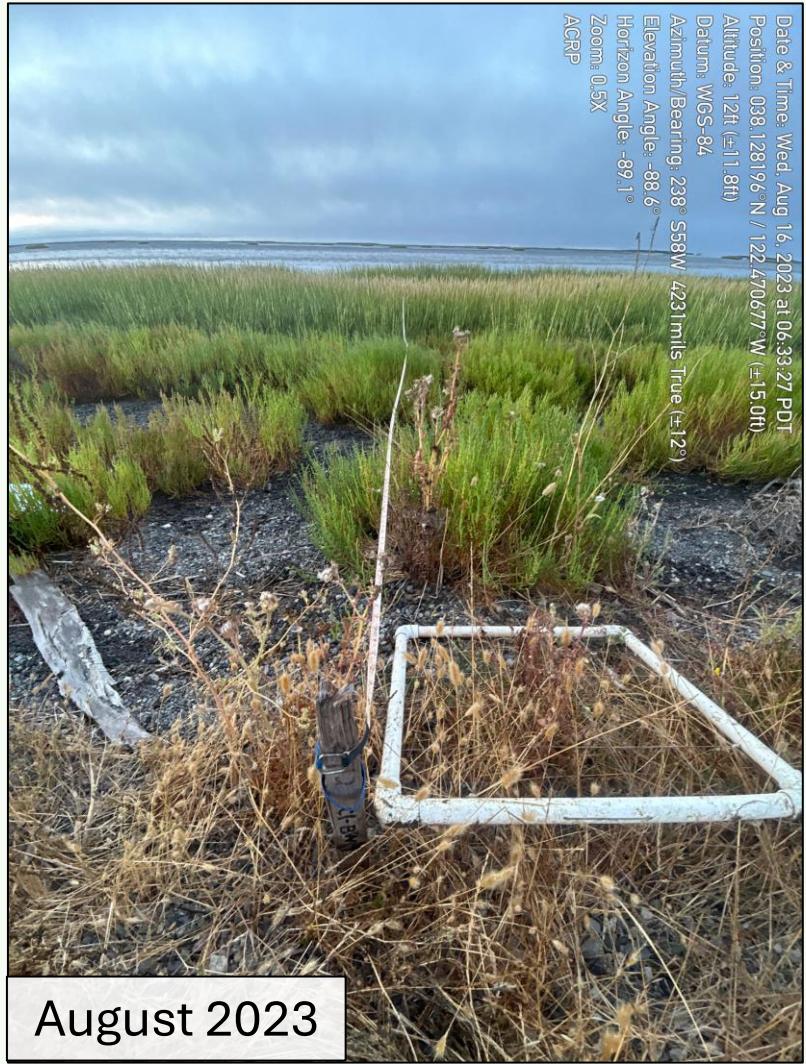
West End, Cell 1



June 2022



August 2022



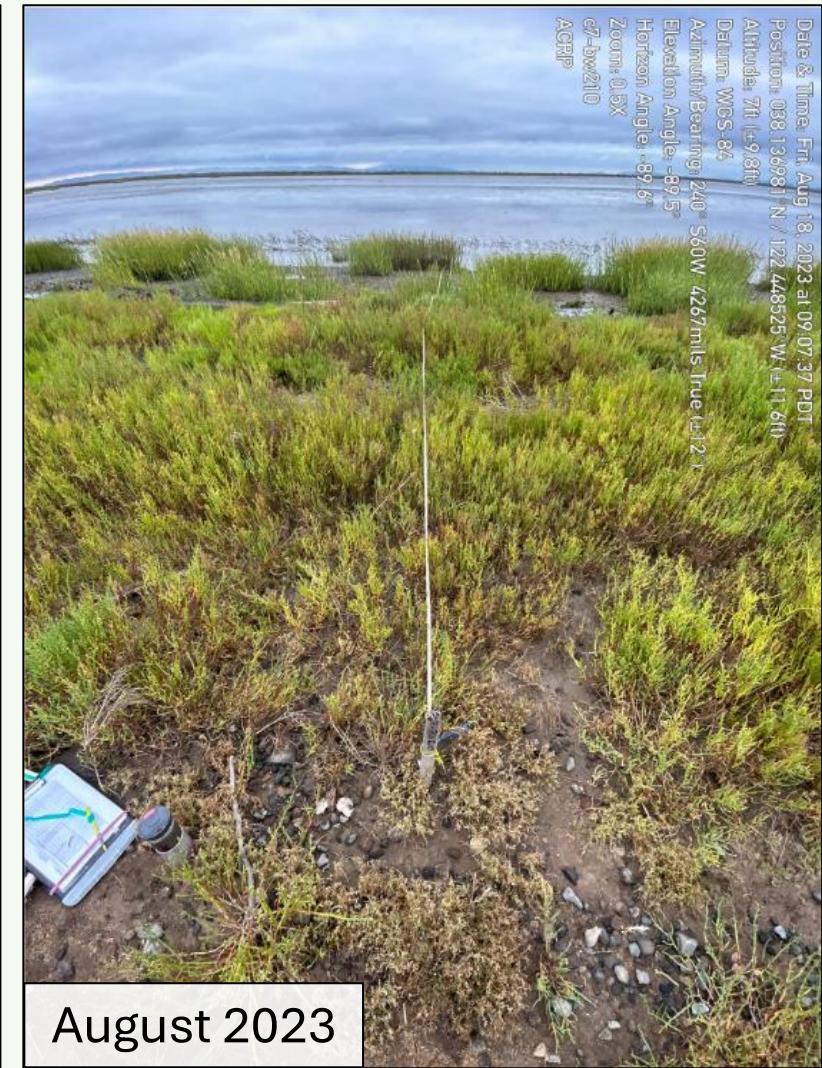
August 2023

Time

Transect C1-BW6

Date & Time: Wed, Aug 16, 2023 at 06:33:27 PDT
Position: 038°12'8.96"N / 122°47'06.77"W ($\pm 15.0\text{m}$)
Altitude: 12ft ($\pm 11.8\text{ft}$)
Datum: WGS-84
Azimuth/Bearing: 238° 558W / 4231mils True ($\pm 12^{\circ}$)
Elevation Angle: -88.6°
Horizon Angle: -89.1°
Zoom: 0.5X
ACRP

East End, Cell 7



June 2022

August 2022

August 2023

Time

Transect C7-BW209



October 2023



August 2024

Acknowledgements

Committee:

- Dr. Stuart Siegel, Dr. Katharyn Boyer, and Dr. Peter Baye

Lab Managers/Techs:

- Margot, Jessie, Kate, Sebastian, Christian, Jeremiah, and Anna

Boyer Lab Buddies:

- Tessa, Natalie, Jivan, Amy, Angelo, Emily, Josie, and Neil

Statistical Wizards:

- Julie Gonzalez, Margot Buchbinder, Wim Kimmerer, Michelle and Sean Jungbluth

GIS Wizard: Dan Gillenwater

Everyone else at EOS – Brita, Facilities Crew

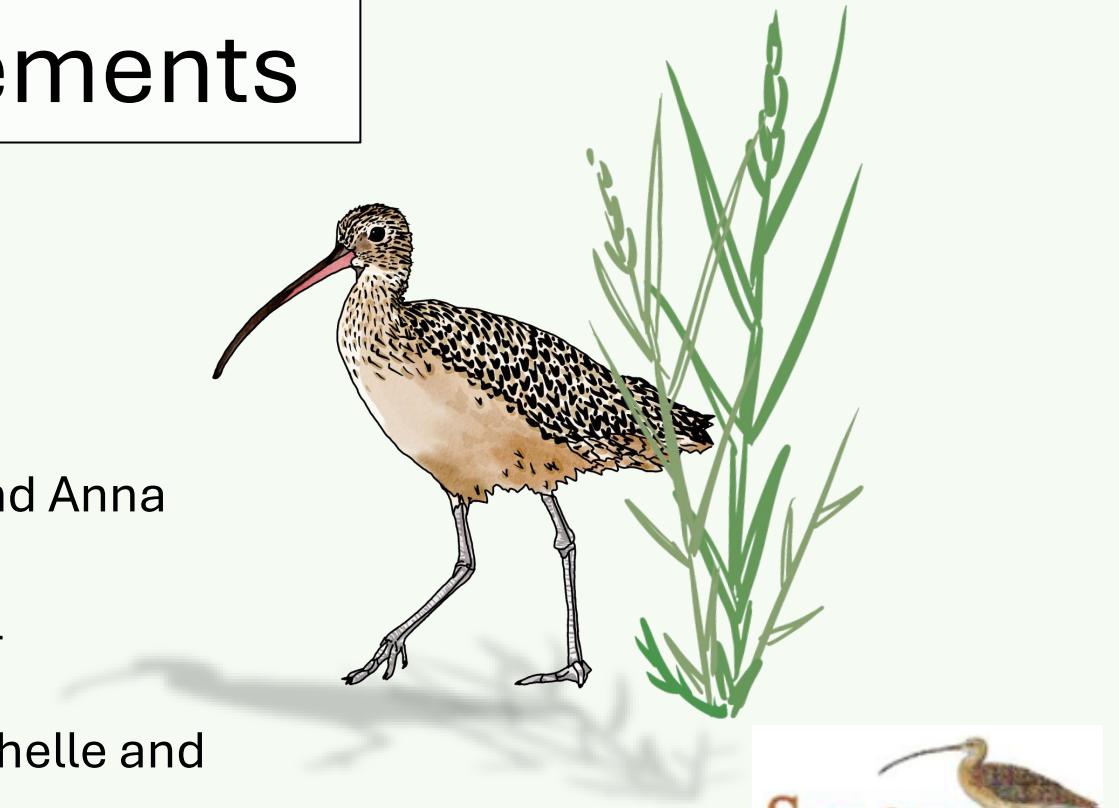
Cohort 5 Buddies:

- Danielle, Erick, and Dagny

Mike Vasey

Friends and Family Near and Far

Jeremyn Horsley



Funding:



National Estuarine
Research Reserve System
Science Collaborative

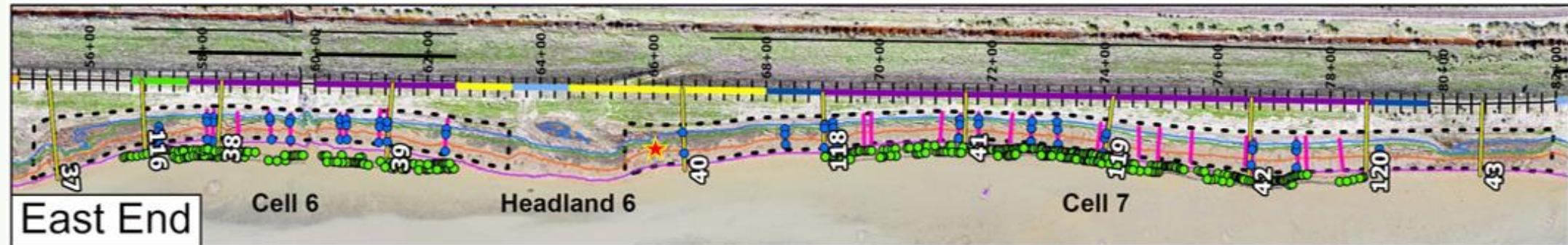
Maxwell | Hanrahan
FOUNDATION

Questions

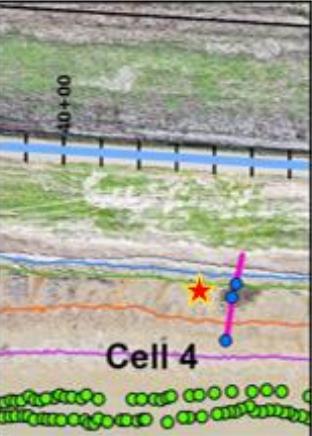
West End



East End



- SFSU Thesis Project Extent
- Vegetation Transect
- Topographic Transect and ID
- Sediment Pin
- Cordgrass Plug
- ★ Reference Transects
(Not included in stats)



Design Treatments

	Scarp Grading	LWD Placement	Mud Placement	Brush Fence	Veneer (lower)
No Color	Approach A	NO	TREATMENT		
—	Approach B				
—	Approach C				
—	Approach D				
—	Approach E				
—	Approach F				
—	Approach G				
—	Approach H				
—	Approach I				

Field Added Treatments

- Mud Placement (above MHHW)
- Gravel Toe Berm (above MHHW)
- Gravel Veneer (above MHHW)

datum

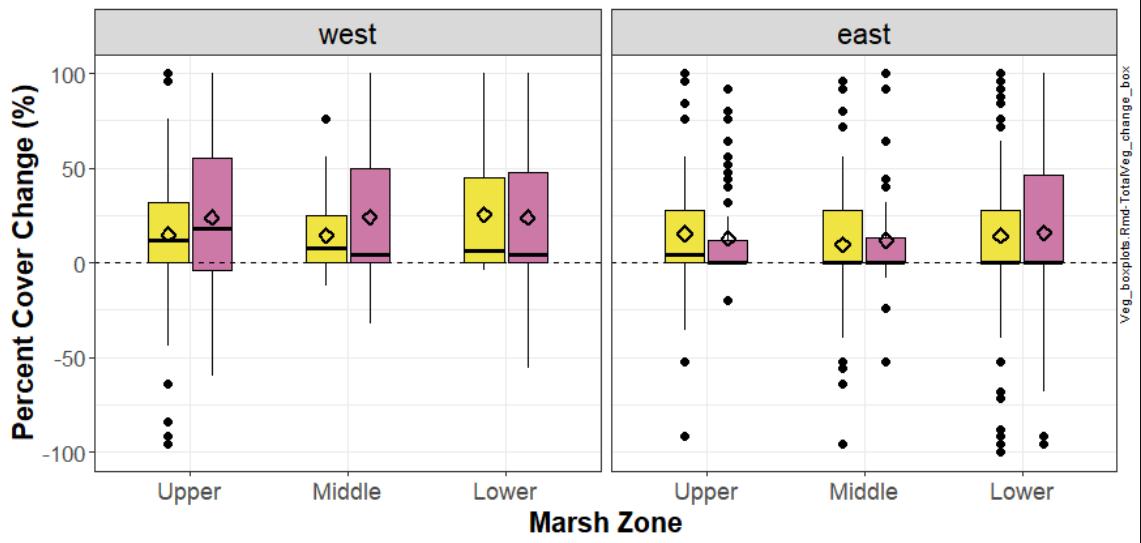
- MHHW
- MHW
- MTL
- MTL/MHW

Nature Based Treatment Map with Transects

Change in Total Vegetation Cover (%)

From August 2022 to August 2023

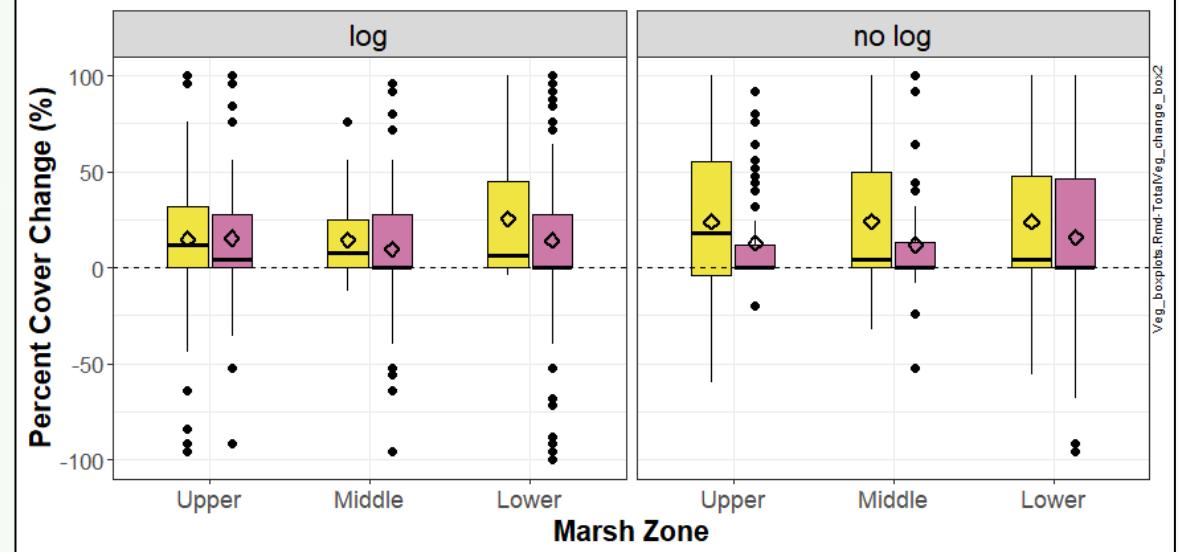
Log Presence log no log



Change in Total Vegetation Cover (%)

From August 2022 to August 2023

End of Shoreline west east

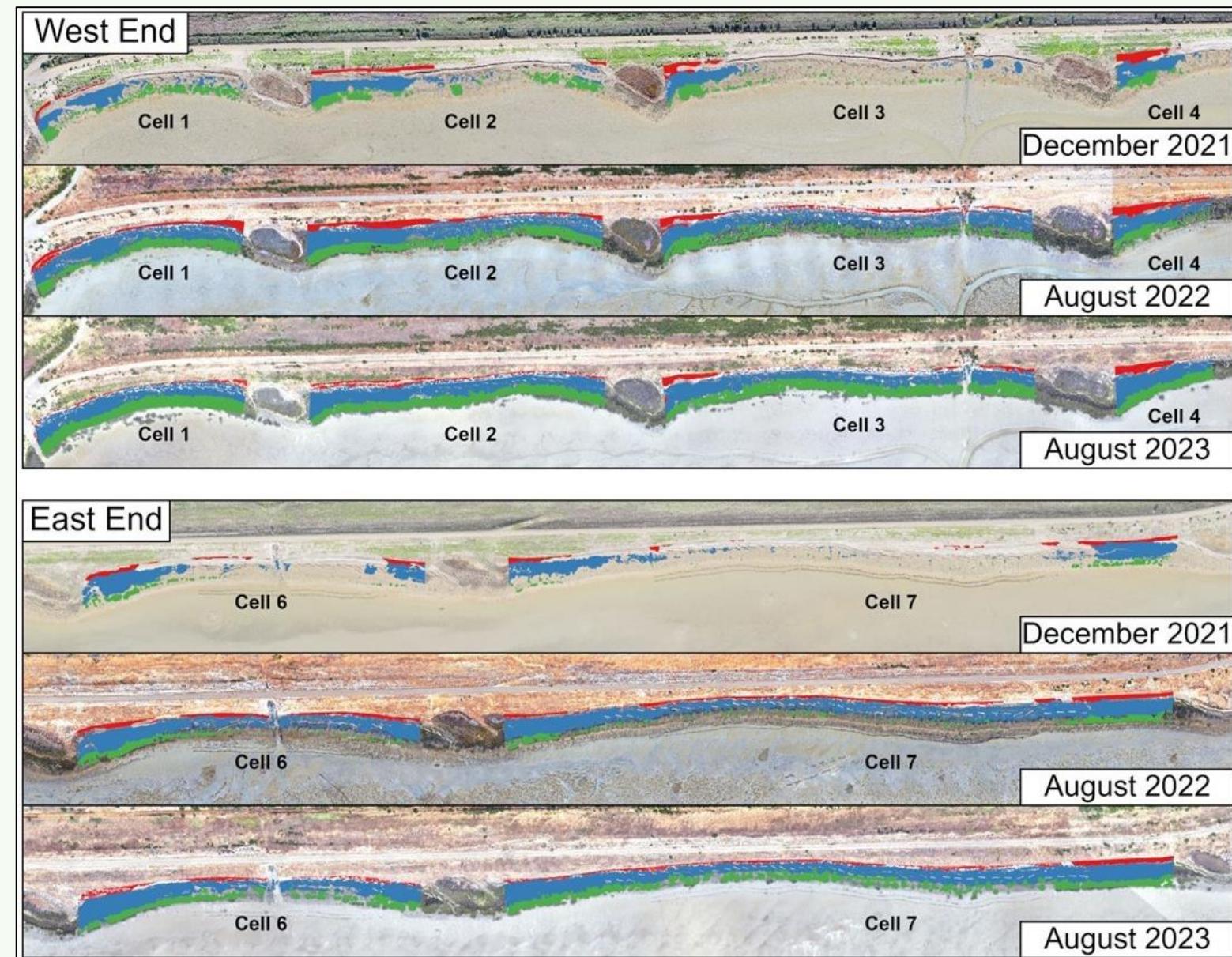


Results: GIS Vegetation Mapping

Dominant Veg Community Zones

- Mixed Transitional
- Sarcocornia
- Spartina

Shoreline End	Veg Zone	Vegetated Area (hectares)		
		Date	Dec-21	Aug-22
West	Mixed	0.076	0.181	0.112
	Salicornia	0.278	0.620	0.666
	Spartina	0.194	0.376	0.525
East	Mixed	0.061	0.141	0.316
	Salicornia	0.283	0.640	0.687
	Spartina	0.053	0.141	0.316

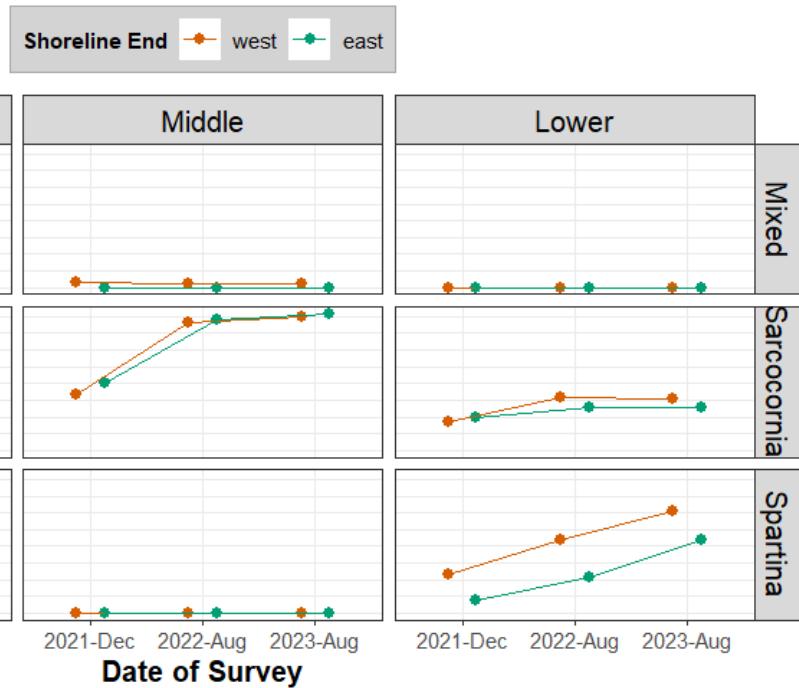


Results

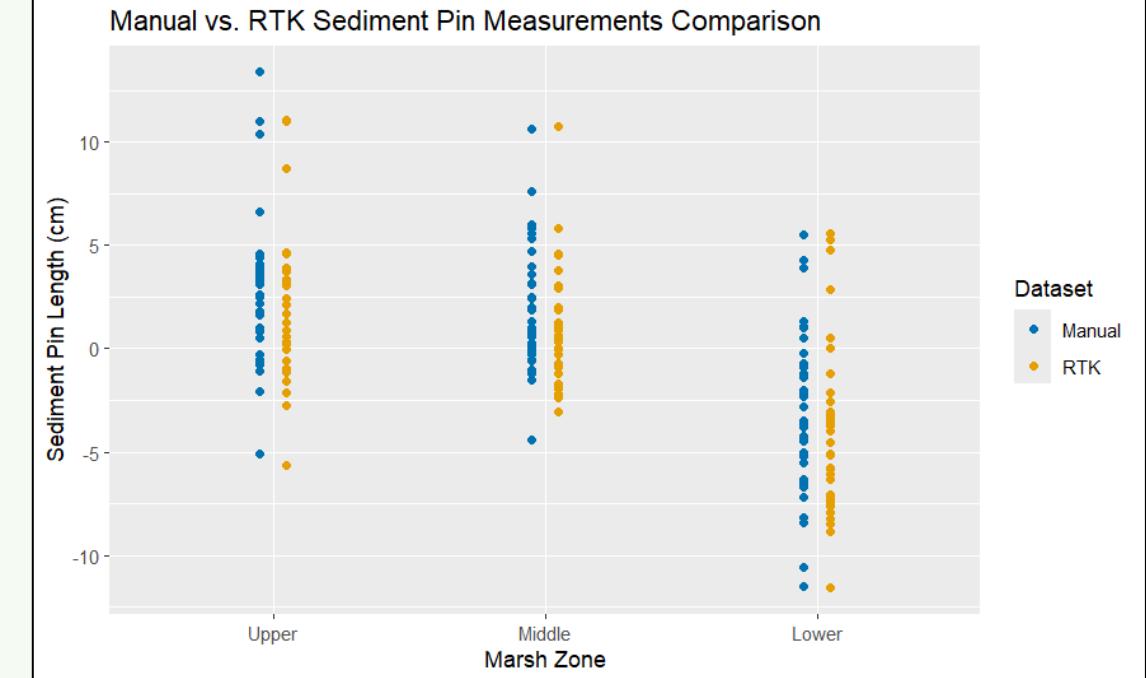
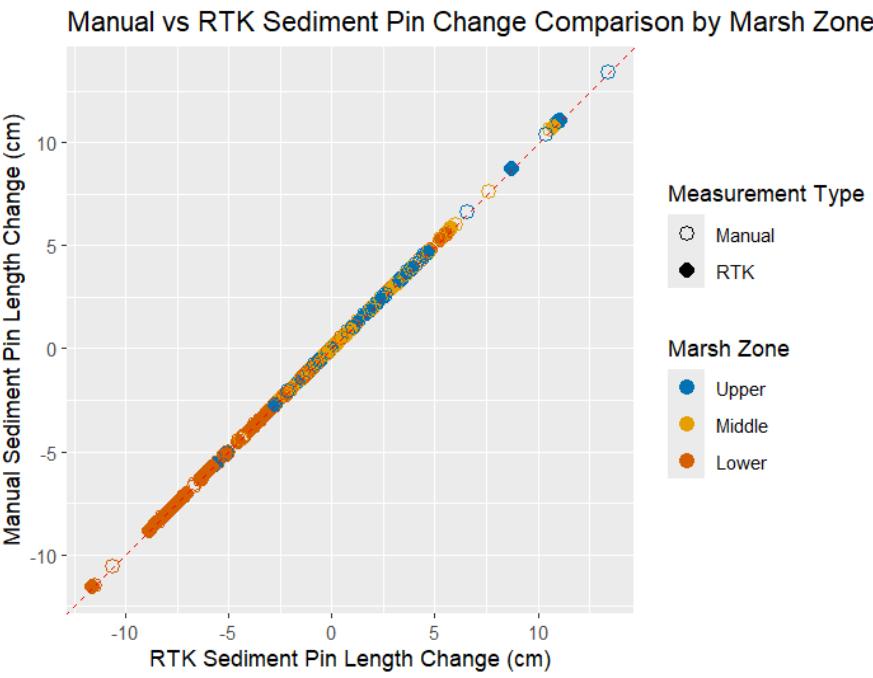
Results: GIS Vegetation Mapping

Sears Point Vegetation Cover Over 3 Years By Zone via GIS & Aerial Imagery

Based on UAV imagery taken in Dec 2021, Aug 2022, and Aug 2023



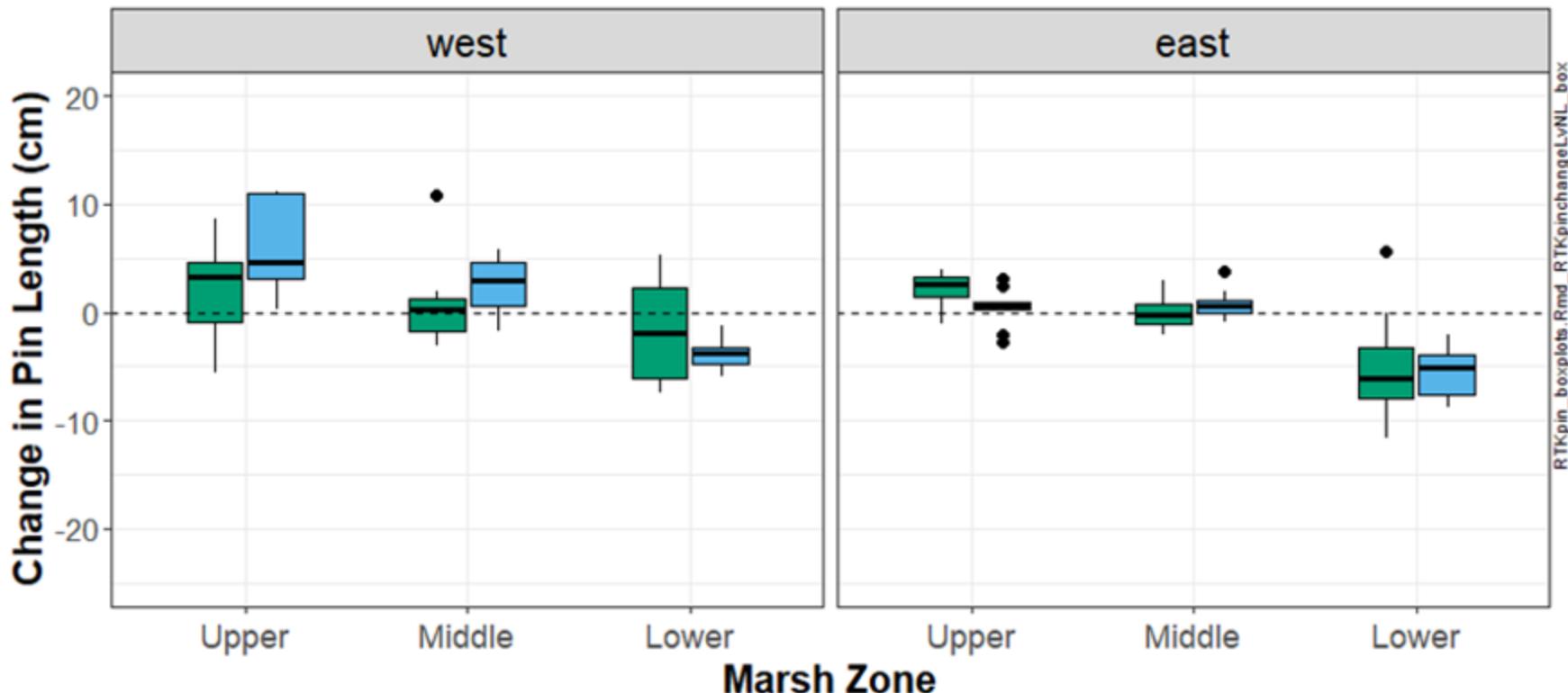
Results



RTK Measurement: Change in Sediment Pin Length

From Jun 2022 to Sep 2023 (Positive value = accretion Negative value = erosion)

Log Presence  log  no log



*n=10 west/log, n=7 west/no log, n=12 east/log, n=9 east/no log