Evaluation of Ecosystem Response to Thin Layer Placement on a Jekyll Island, Georgia Salt Marsh

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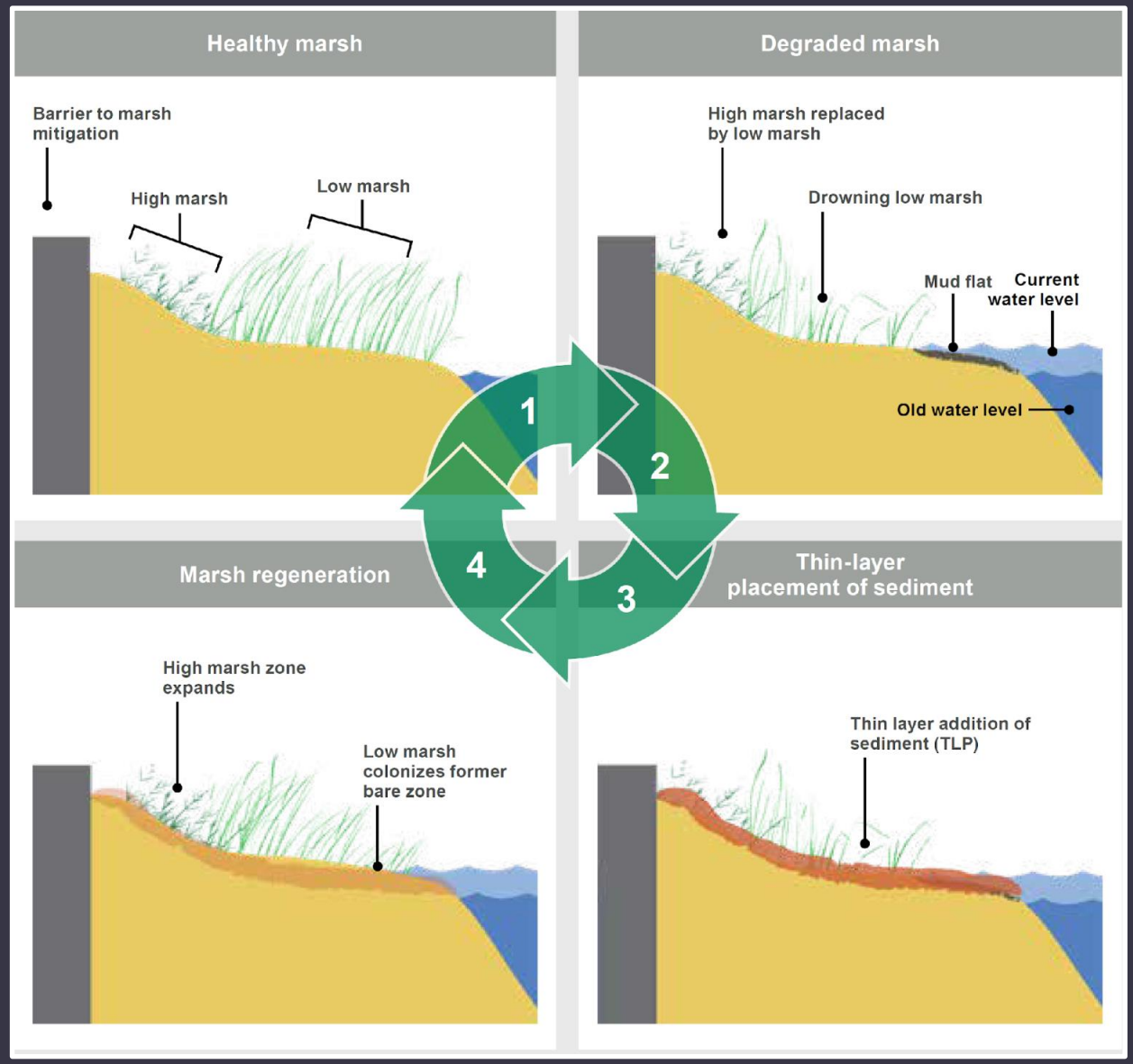
Thin Layer Placement (TLP)

- Marsh Ecosystem Services
  - Wastewater treatment
  - Blue carbon storage
  - Shoreline protection
  - Habitat
- Increased Flooding
  - Sea level rise (SLR)
  - Land subsidence
- TLP restores elevation by adding a layer of sediment
  - Increase nutrients, aeration
  - Increase productivity

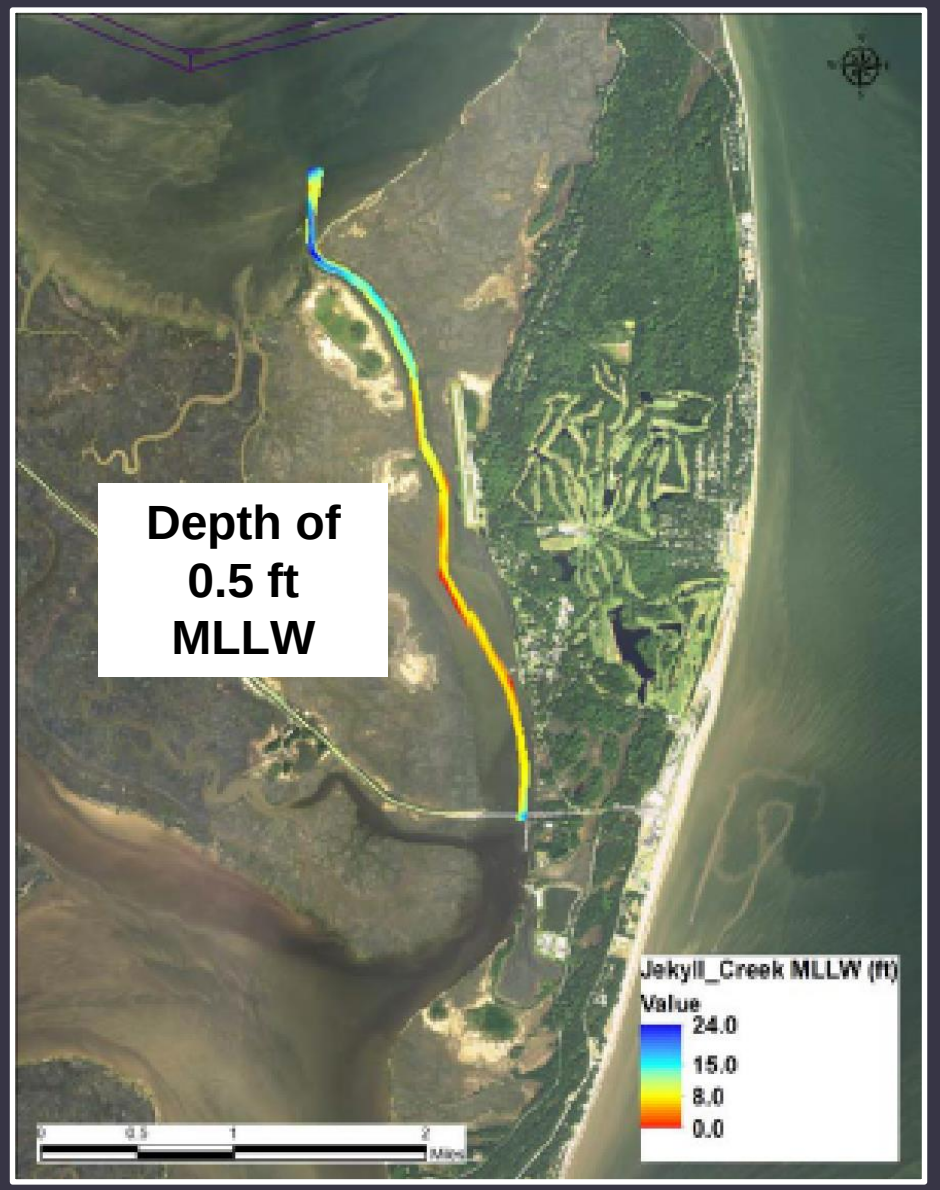


Source: NERRA, Raposa et al. 2023. Original graphic by Caravan Lab and LandSea Science

Jekyll Island Creek, GA

- Pilot project to explore beneficial use in salt marshes
  - Dredged material placement
- Jekyll Creek navigation hazard

- Partners
  - US Army Corps of Engineers
  - GA DNR Coastal Resources Div.
  - Jekyll Island Authority
  - The Nature Conservancy
  - NOAA, FWS, EPA



Materials provided by Jan MacKinnon (GA DNR CRD) and Clay McCoy (USACE)

Thin Layer Placement: Monitoring Objectives

Can TLP be used to support coastal resilience and maintenance of ecosystem services in Georgia tidal marshes?

- Monitor **physical parameters** of the application and control sites **pre- and post-TLP** application
- Monitor **biological parameters** of the impacted and control sites **pre- and post-TLP** application

TLP Monitoring Parameters

Physical Parameters

- Elevation
- Tide range
- Suspended sediment/turbidity
- Accretion
- Soil OM, bulk density

Biological Parameters

- Plant height, density
- Invertebrate density
- Microphytobenthos Chl *a*
- Above/belowground biomass

Remote Sensing

- Habitat: Aerial, UAV imagery
- Elevation: LIDAR

TLP Monitoring Dates

- Pre-TLP application: November 15, 2018
- Post-TLP application
  - TLP application (April 22, 2019)
  - Six-months post (October 5, 2019)
  - ~~12-months post (COVID CANCELLED)~~
  - ~~18-months post (COVID CANCELLED)~~
  - 24-months post (April 2021)
  - 30-months post (September/October 2021)
  - 60-months post (April 2024)
  - 72-months post (March/April 2025)

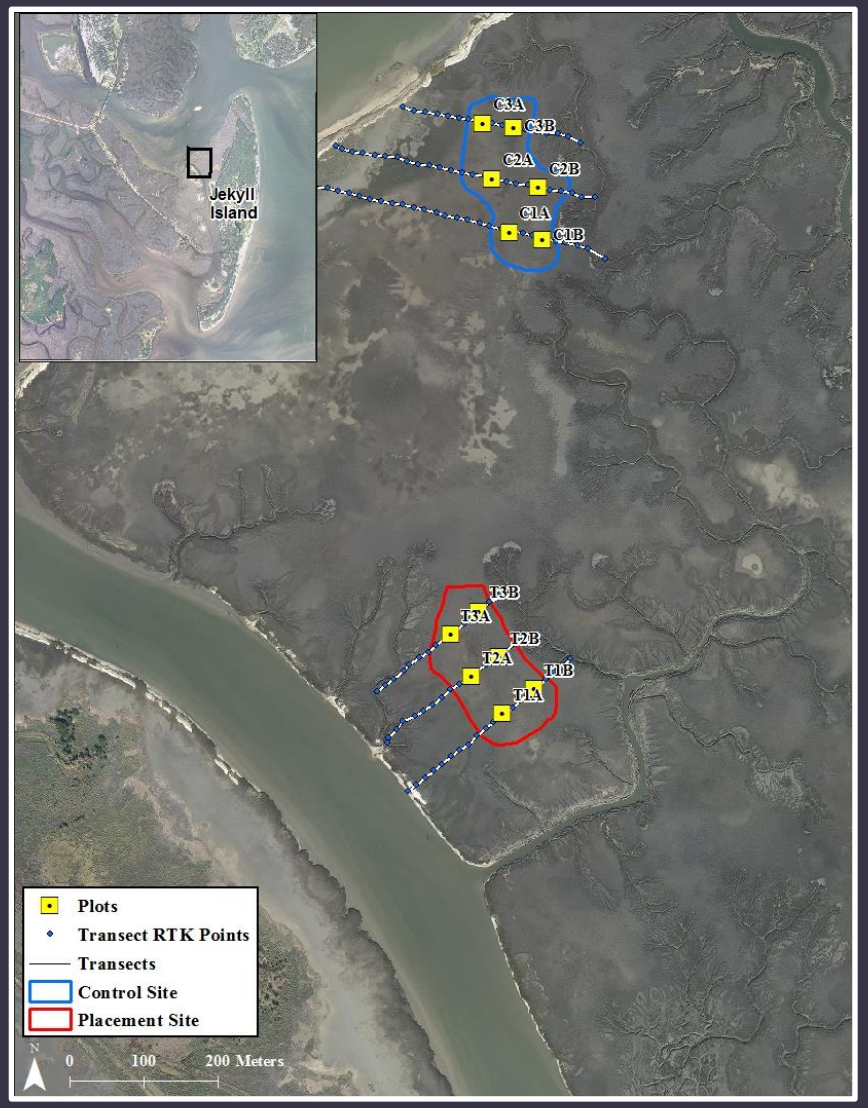
TLP Site Construction

- 5-acre TLP site
  - *Spartina alterniflora*
- April 2019 piped
  - 5,000 CY (3823 m^3) of hydraulic dredge
  - MHW ~ 0.84 – 0.91 m
  - 15 – 25 cm of dredge
- Pluff mud – Fine-grained silt and clay, with low sand content
- Coconut coir containment logs

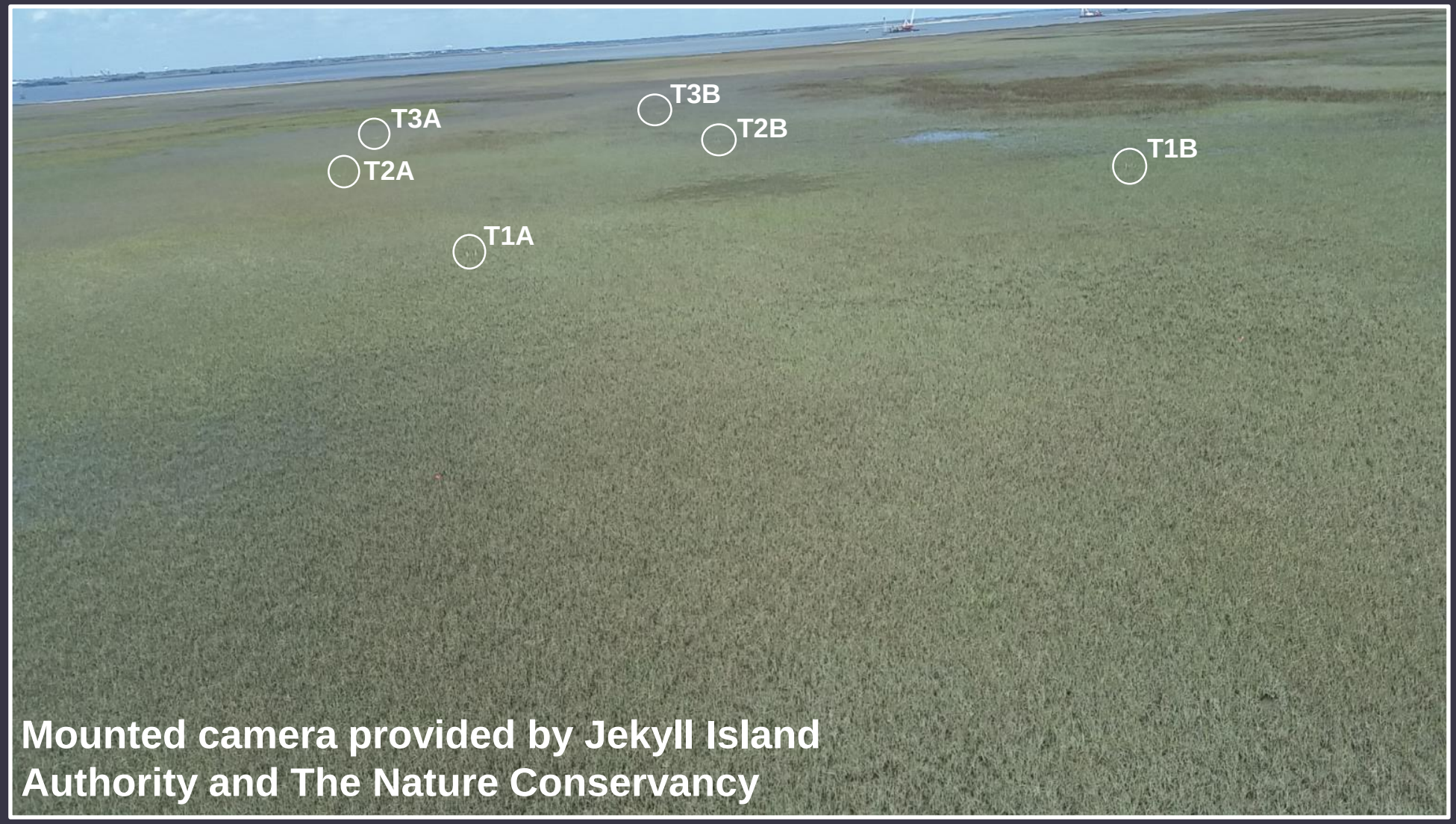
Photos by Clay McCoy, USACE Jacksonville District

Jekyll Island Study Site and Plot Layout

- Two Study Sites (5-acres)
  - Control Site
  - TLP Placement Site
- Plot Layout
  - 6 plots/site (1 x 1 m)
  - 3 elevation transects/site



Pre-TLP: March 24, 2019



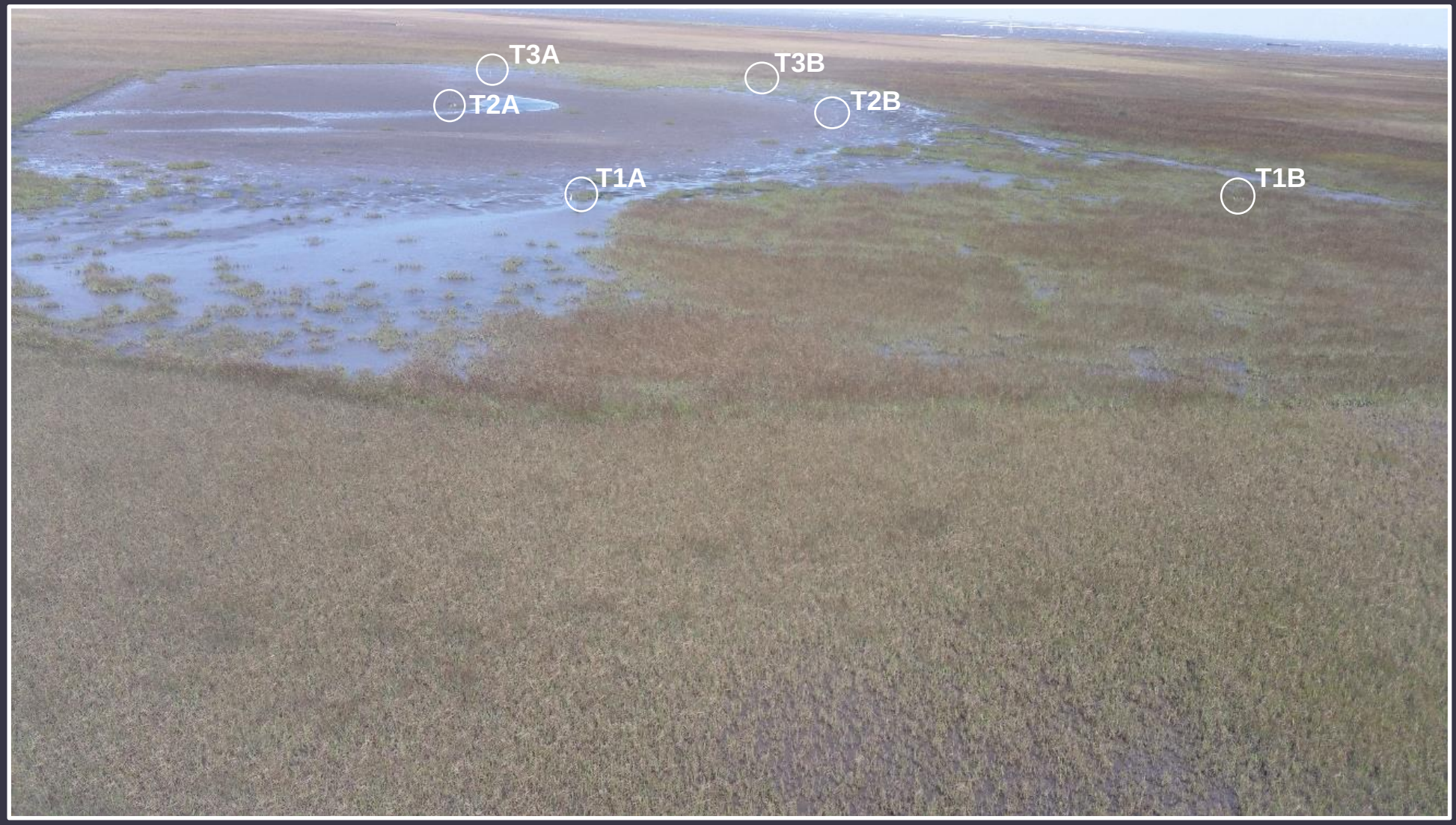
Note: Approximate plot locations shown

April 14, 2019 – Construction

Note: Approximate plot locations shown

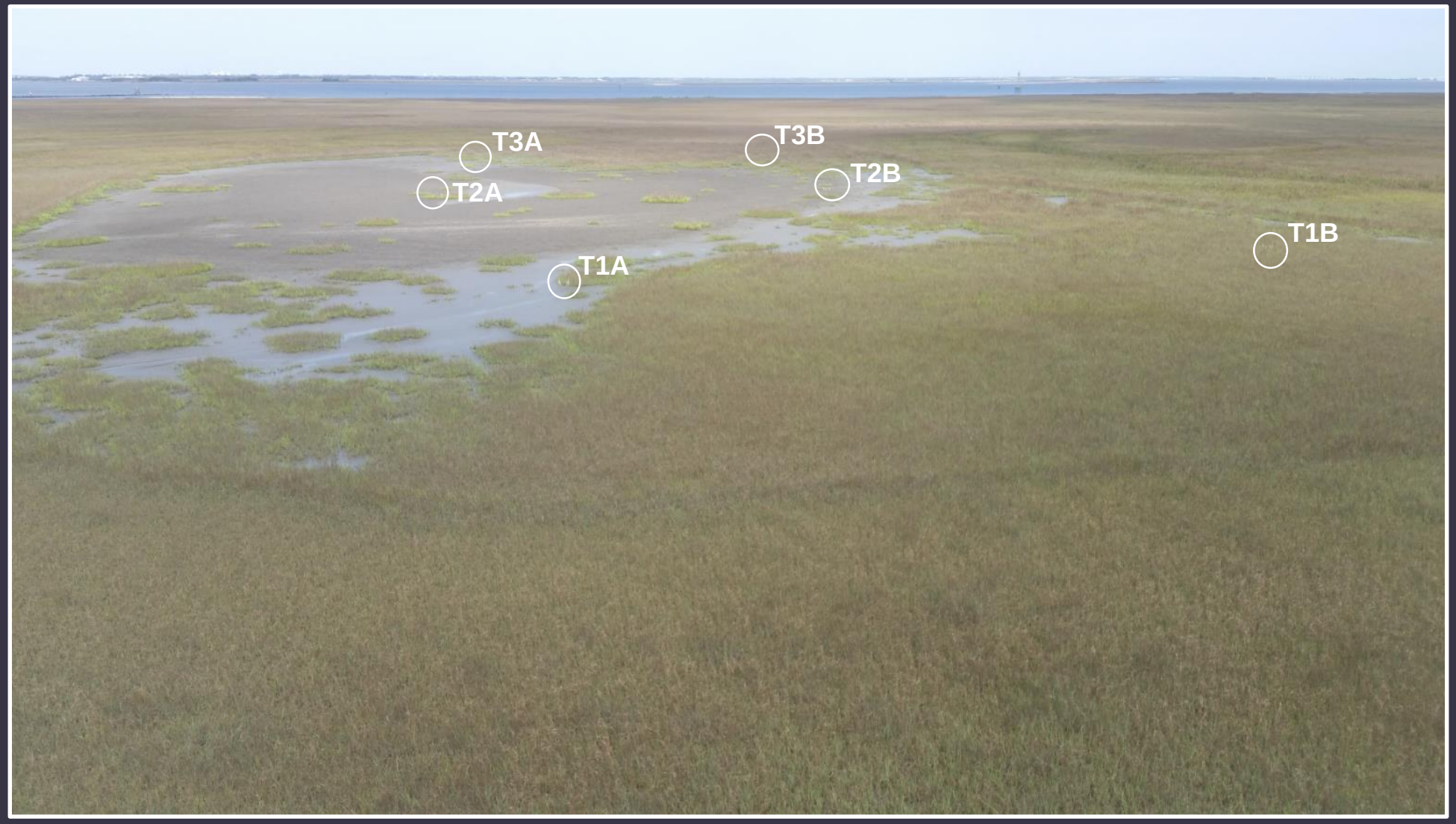
April 26, 2019 – Post-TLP

March 22, 2021 – 12-mo Post



Note: Approximate plot locations shown

March 15, 2022 – 24-mo Post

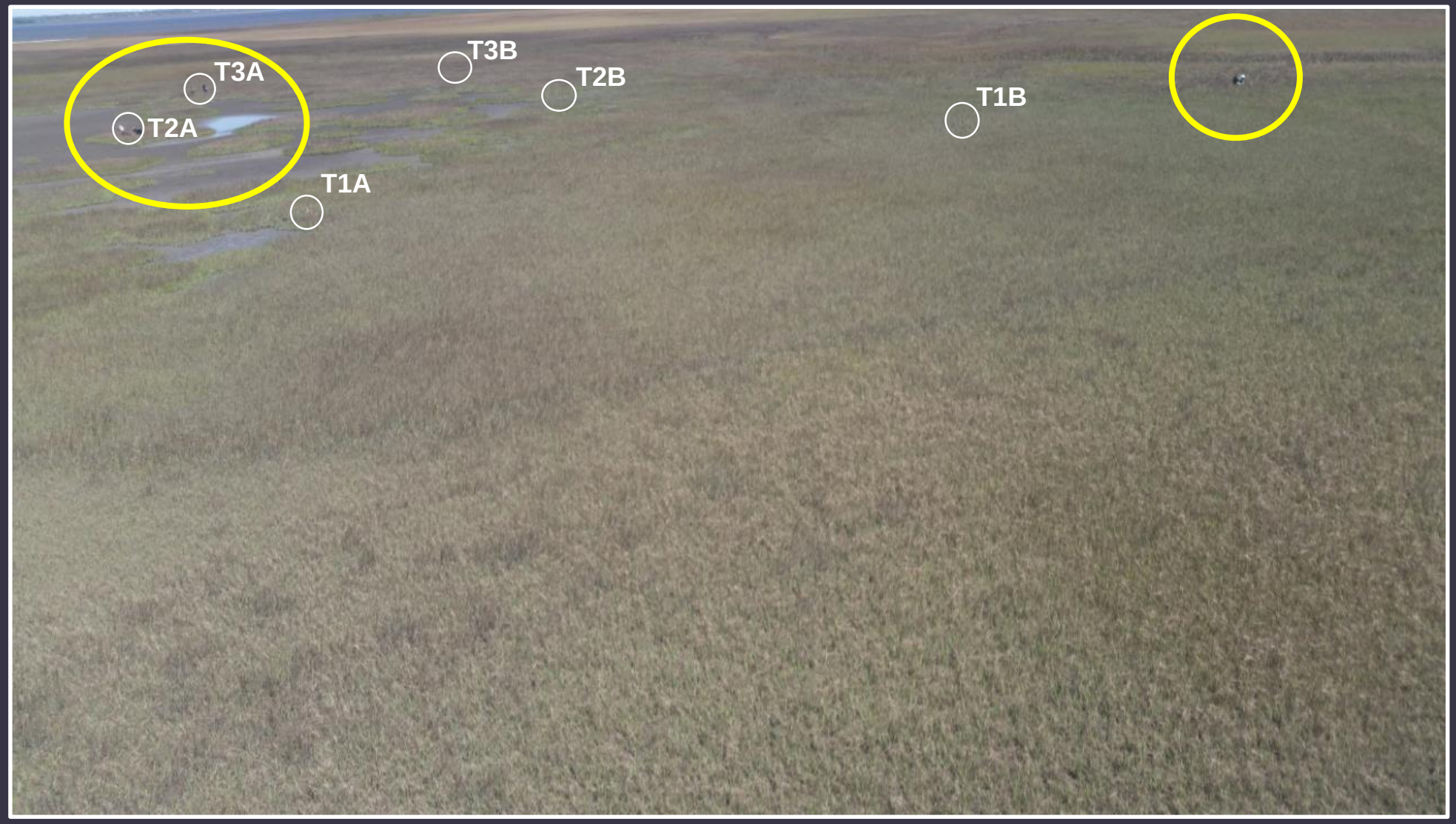


Note: Approximate plot locations shown

March 14, 2023 – 48-mo Post

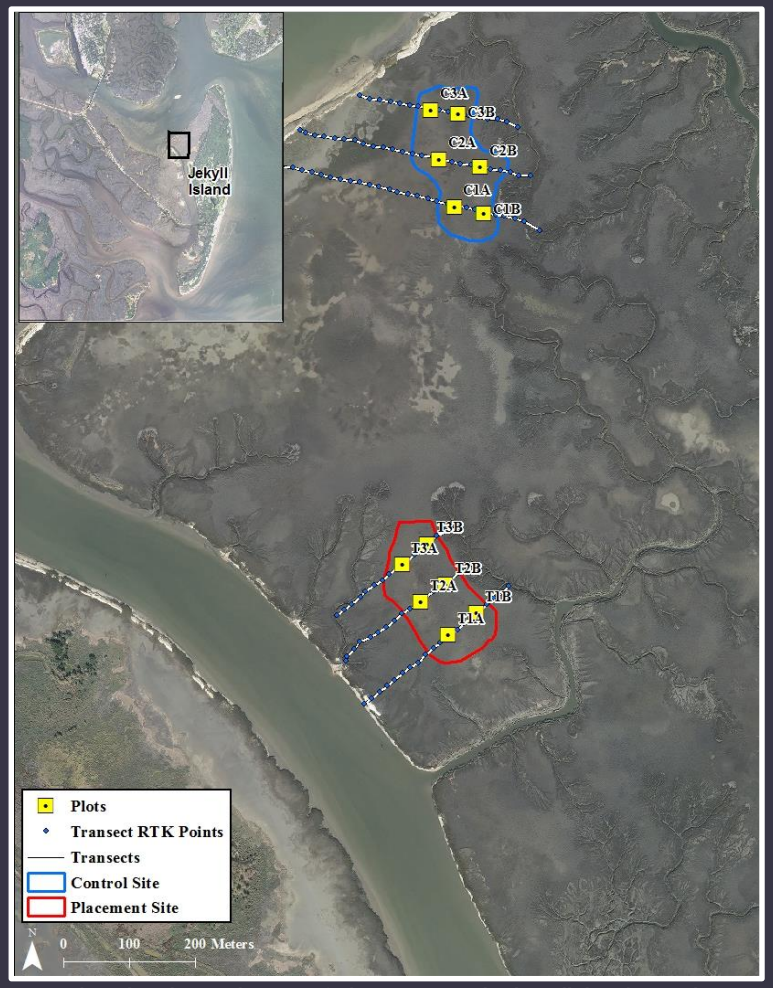
Note: Approximate plot locations shown

April 5, 2024 – 60-mo Post



Note: Approximate plot locations shown

Physical Parameters: Marsh Elevation



Study site locations of the control site (blue) and TLP (red), monitoring plots (yellow squares; C = Control, T = TLP), and RTK survey transects (lines).

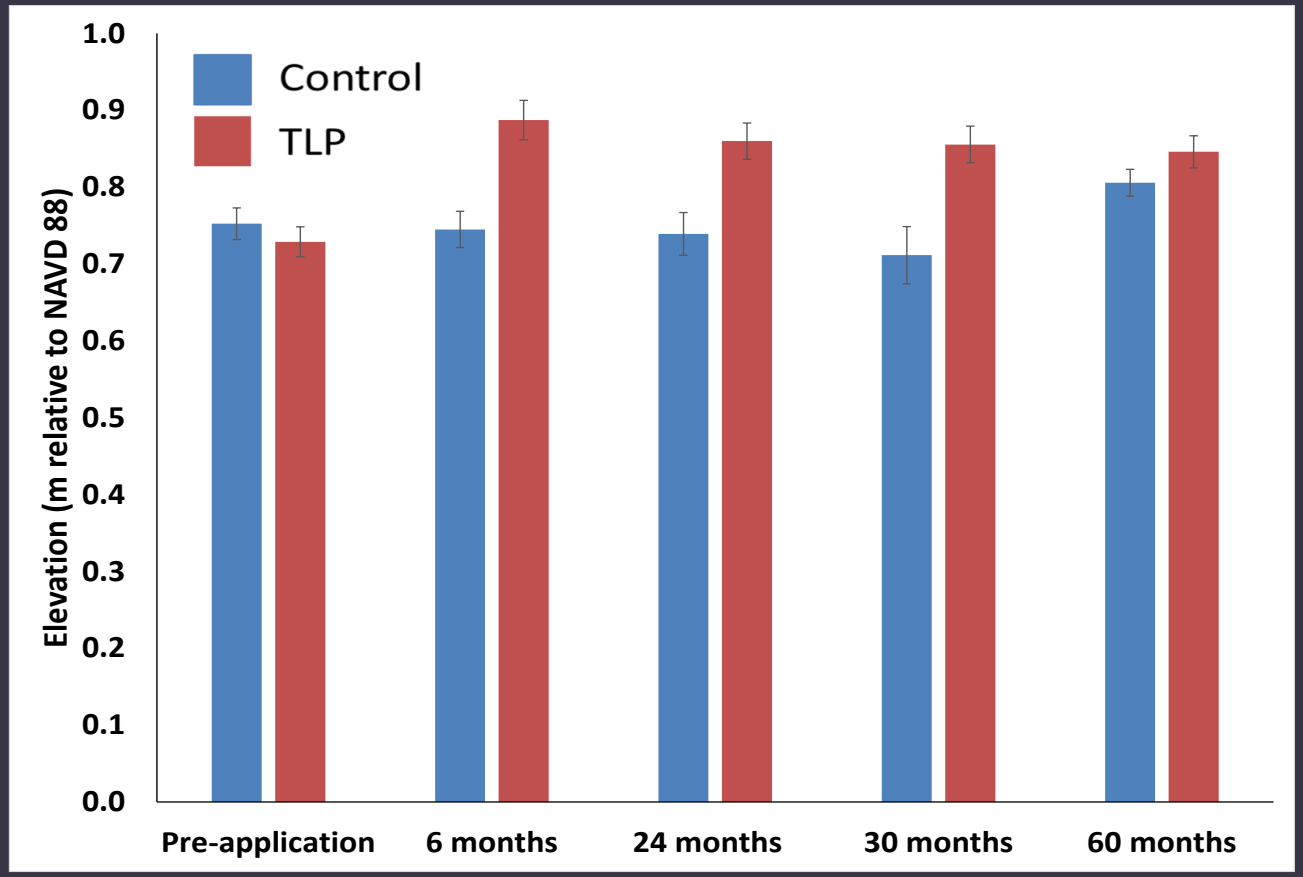
- Trimble RTK GPS
  - Surveyed plots
  - Surveyed every 15 m along transects
  - All sampling periods

RTK-GPS Survey of Transects

Physical Parameters: Marsh Elevation

- **Pre-TLP**
  - No difference between sites
- **60-Months Post-TLP**
  - TLP increased elevation
  - Site differences
  - RM ANOVA, $F_{1,9} = 14.88$, $p = 0.004$

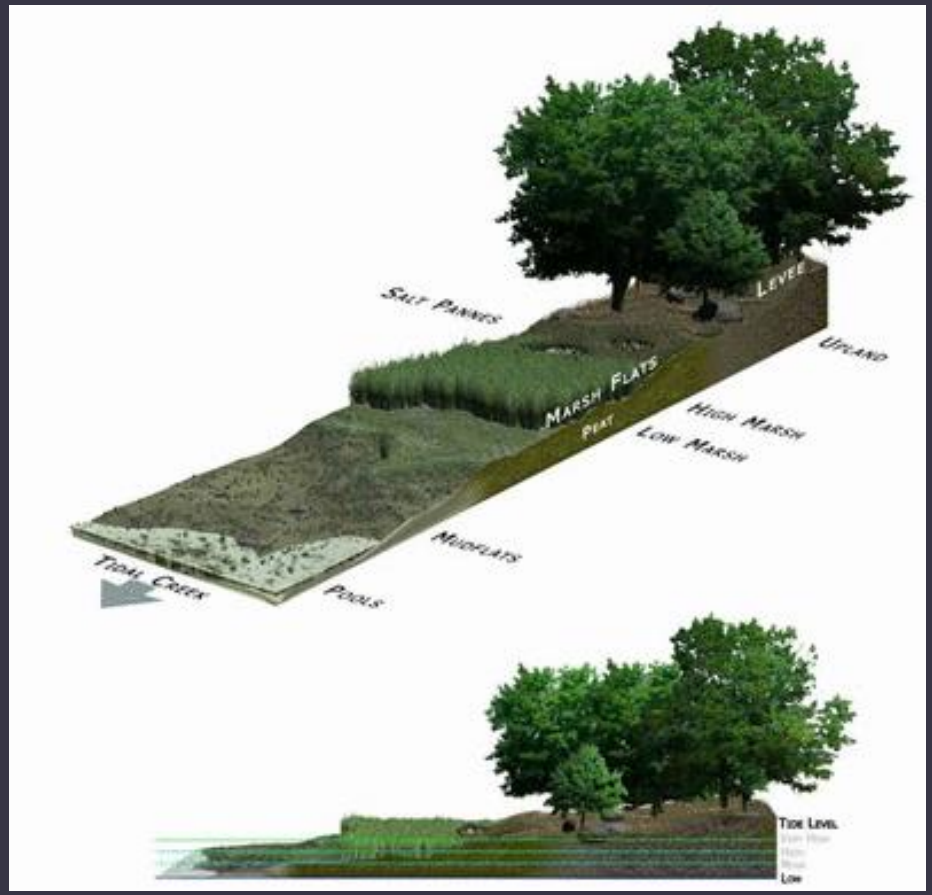
*Control plot was lost to creek head erosion



NAVD 88 (~ 0.80 m below MHW and ~ 0.20 m above MSL)

Physical Parameters: Tide Range

- Hobo loggers
  - Autonomous pressure transducers
  - Deployed post-TLP
  - Surveyed with RTK
- MSL relative to NAVD 88 and rate of SLR
  - Correlate with NOAA tide gages at Ft. Pulaski, GA and Fernandina Beach, FL

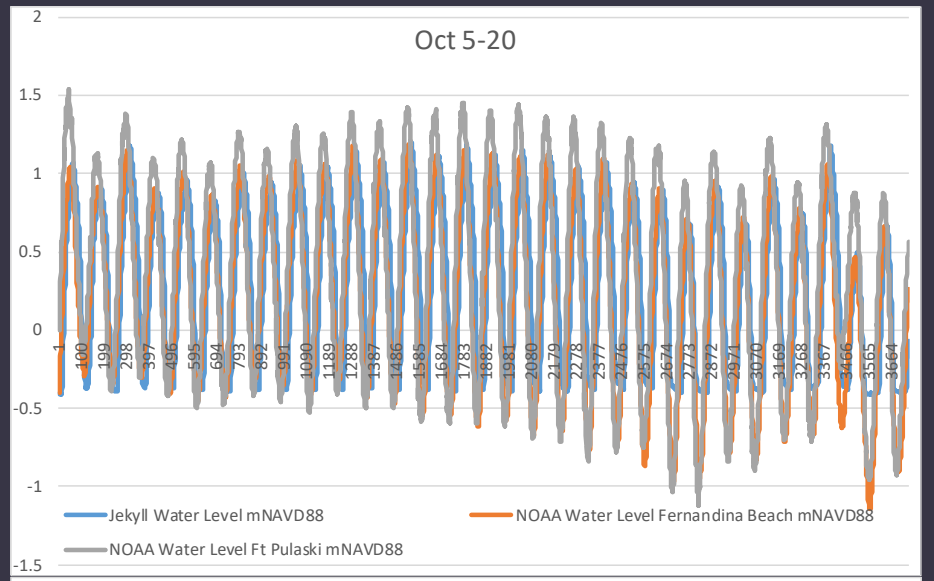


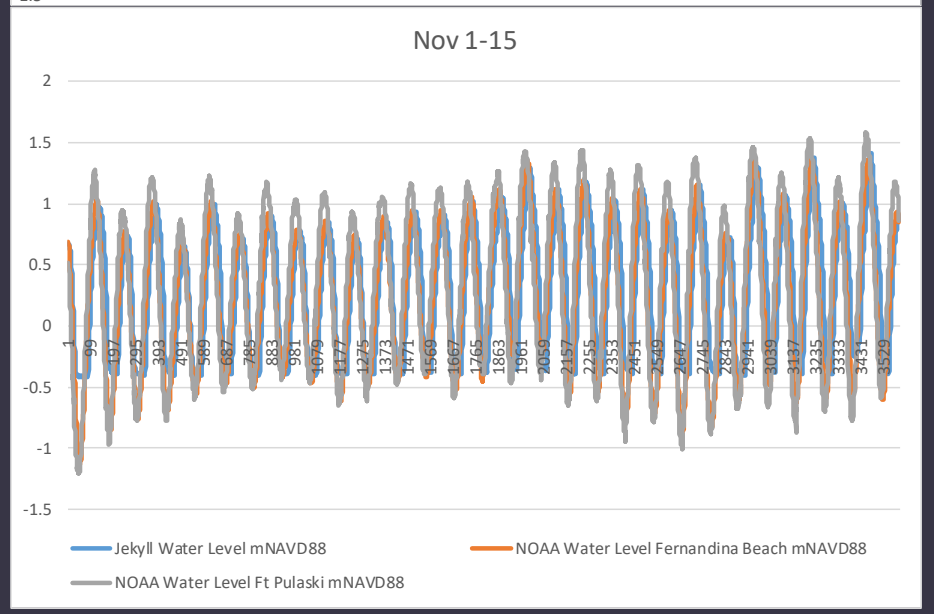
Source: NOAA National Ocean Service

Physical Parameters: Tide Range

- Hobo data match Fernandina Beach
- For the last 20 years:
  - MSL = 0.06 m NAVD
  - MHW = 1.07 m NAVD
  - SLR = 2.23 ±0.17 mm/yr
- Mean elevation pre-TLP of 0.7m and 0.85m NAVD 60-mo post-TLP
- Optimum elevation mid-way between the upper and lower limits
  - TLP site is near optimum

*NAVD 88 (~ 0.80 m below MHW and ~ 0.20 m above MSL)



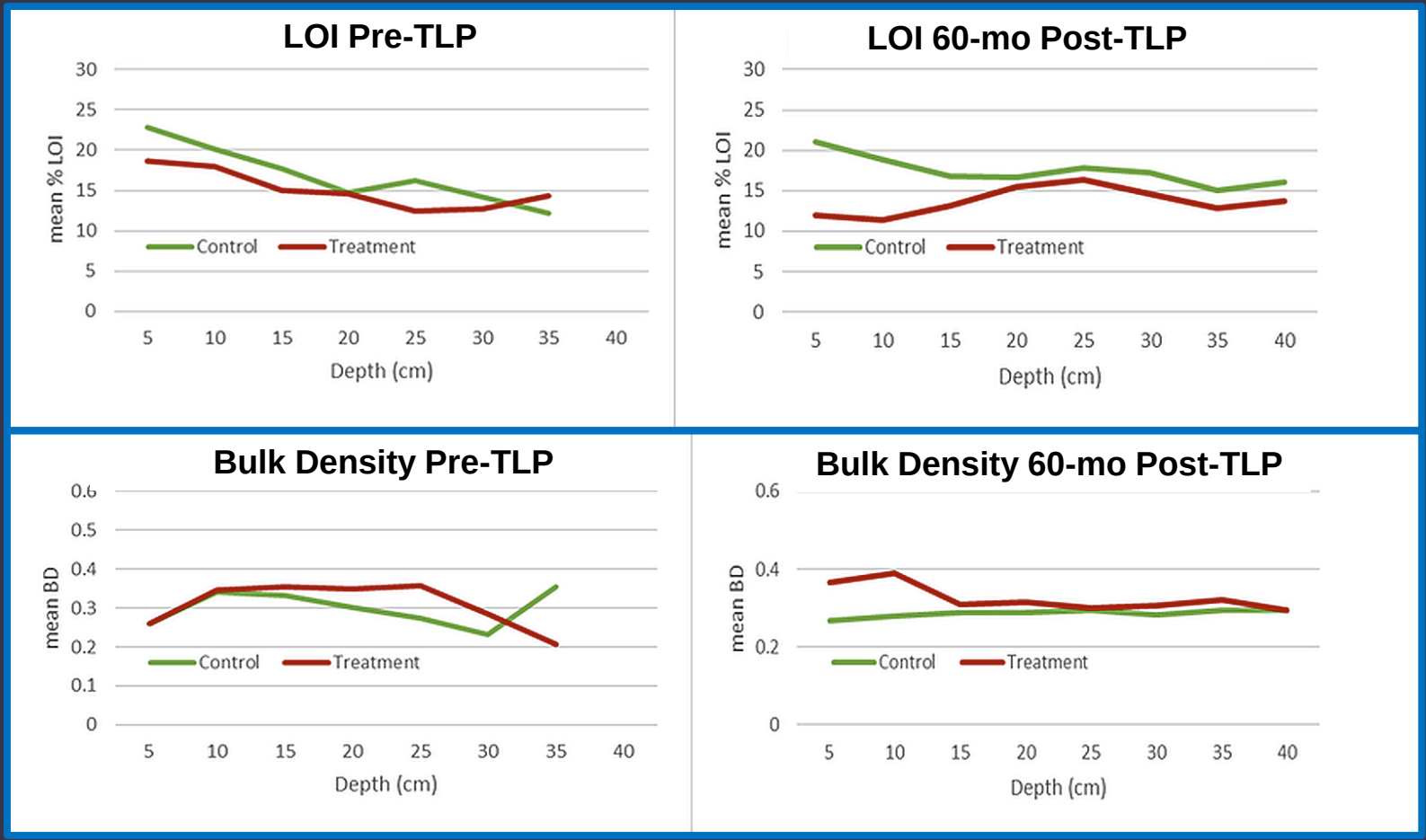


Hobo water level data for Jekyll (blue) correspond with Fernandina Beach (Station ID: 8720030) (orange) and Ft. Pulaski (grey) tide stations. All elevations are in m relative to NAVD 88.

Physical Parameters: Soil Cores

- Soil Cores
  - 12 cores (6 per site)
    - 30 cm long
    - 4-in pipes, 5-cm sections
  - Pre-TLP, annually
- Sediment bulk density (BD)
  - Volumes of dried samples
- Organic matter (OM) concentration and below-ground biomass
  - Loss on ignition (LOI): Dry, weigh, combust, reweigh

Physical Parameters: Soil Cores



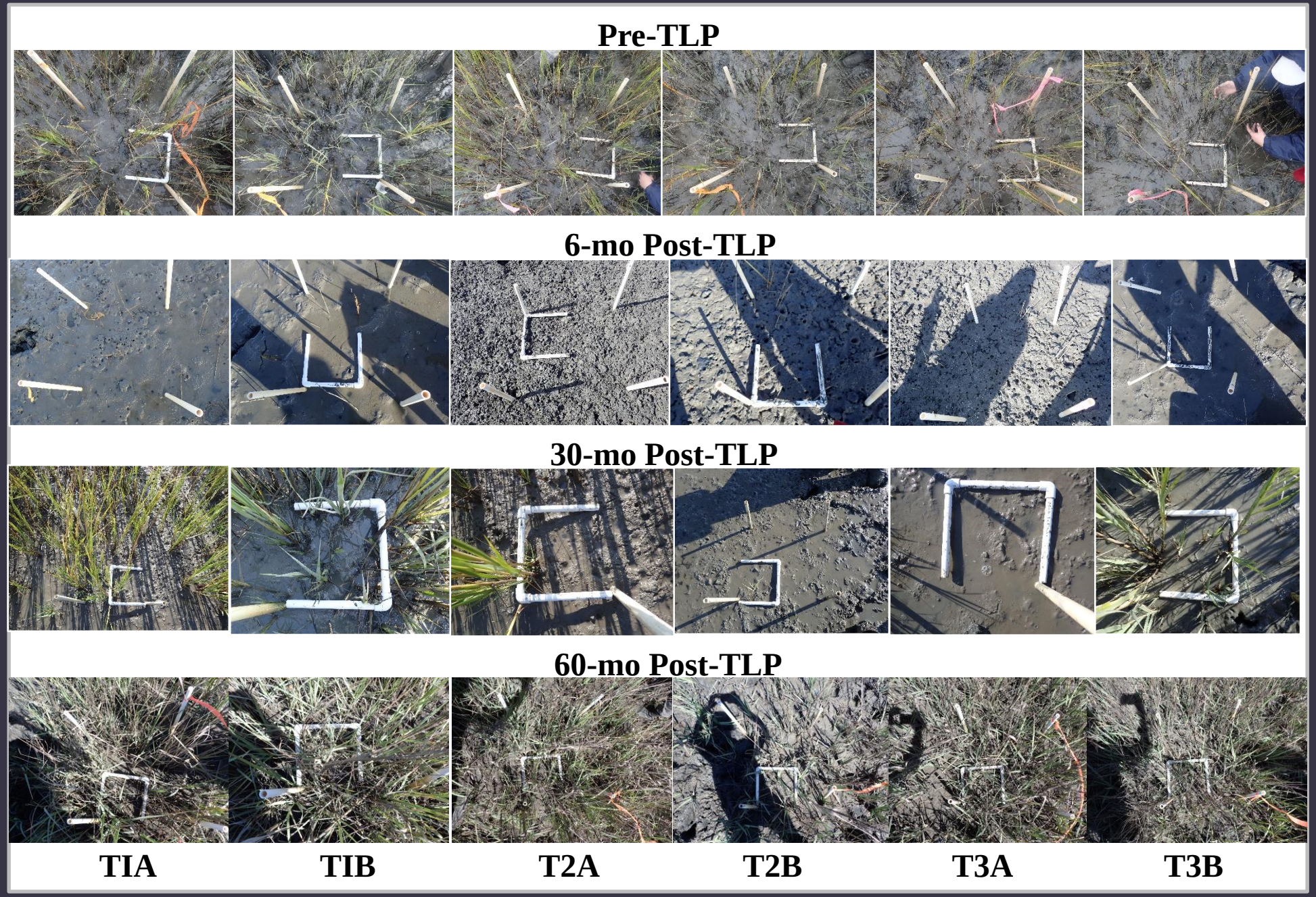
Control and TLP site soil core data pre-TLP application (November 2018, left) and 60-months post-TLP (April 2024,right) for loss on ignition (%) (LOI, top) and bulk density (g/cm3) (BD, bottom).

- **Pre-TLP**
  - LOI significant difference (p=0.01)
  - BD not different
- **60-Months Post-TLP**
  - TLP significantly lower LOI (p<0.0001)
  - LOI and BD varied over depth with significant treatment effect (p<0.0001)
    - Lower LOI and higher BD of the added thin layer
  - Belowground organic matter (OM) has not recovered at TLP site
    - Persistence of dead, macro-organic matter

Biological Parameters: Plant Characteristics

- 12 Plots (6 per site)
  - 0.25 m x 0.25 m plot
  - All sampling periods
- Plants
  - *Spartina alterniflora*
    - Tall (> 1 m)
    - Medium (0.5 – 1 m)
    - Short (< 0.5 m)
  - Percent cover
  - Stem height
  - Stem density

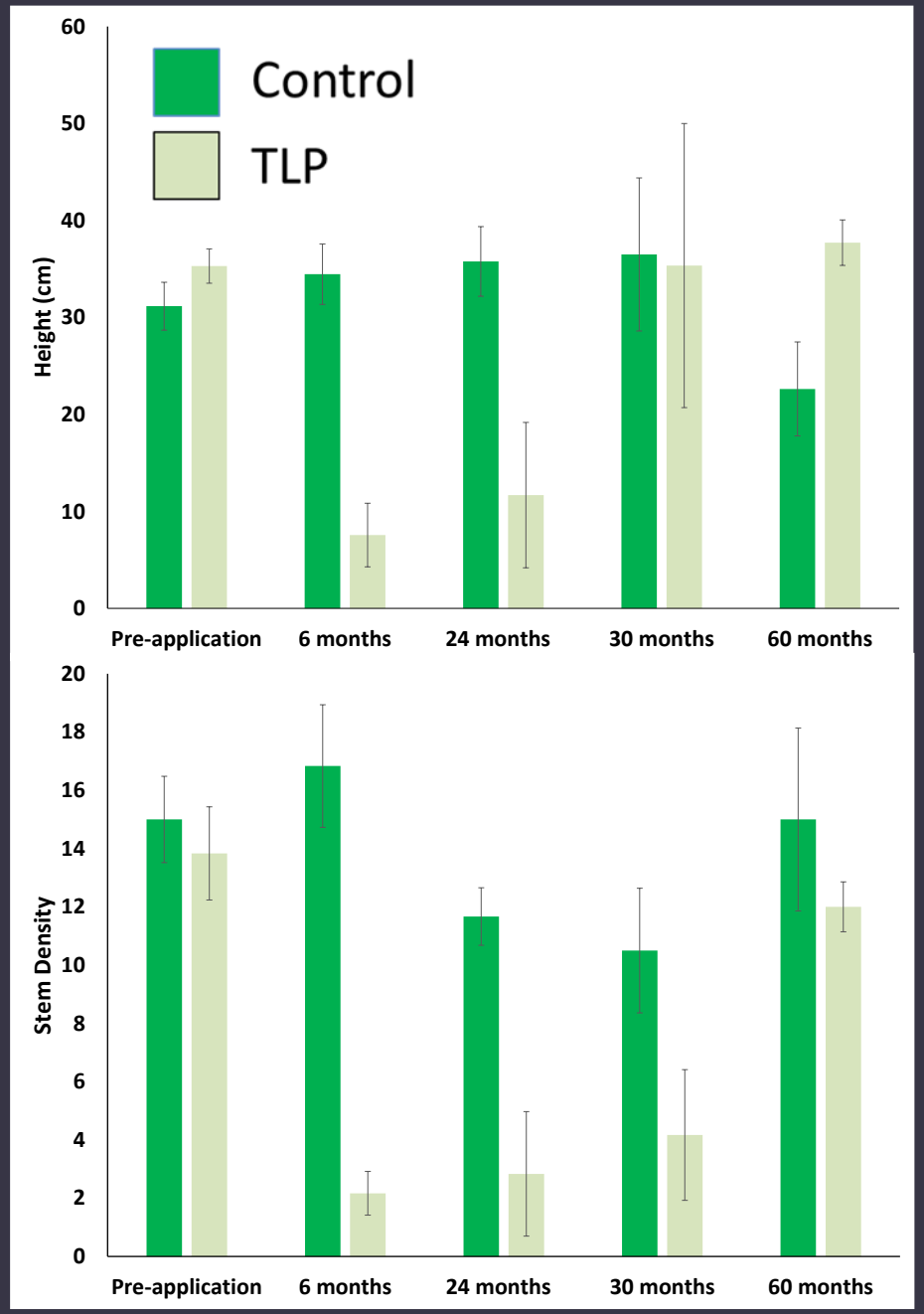
Examples of Control and TLP plant plots. Plots are 1 x 1 m. All plant data was collected within the smaller 0.25 x 0.25 m quadrat.



Plot recovery at the TLP site pre-TLP, 6-months post-TLP, 30-months post-TLP, and 60-months post-TLP.

Biological Parameters: Plant Height and Stem Count

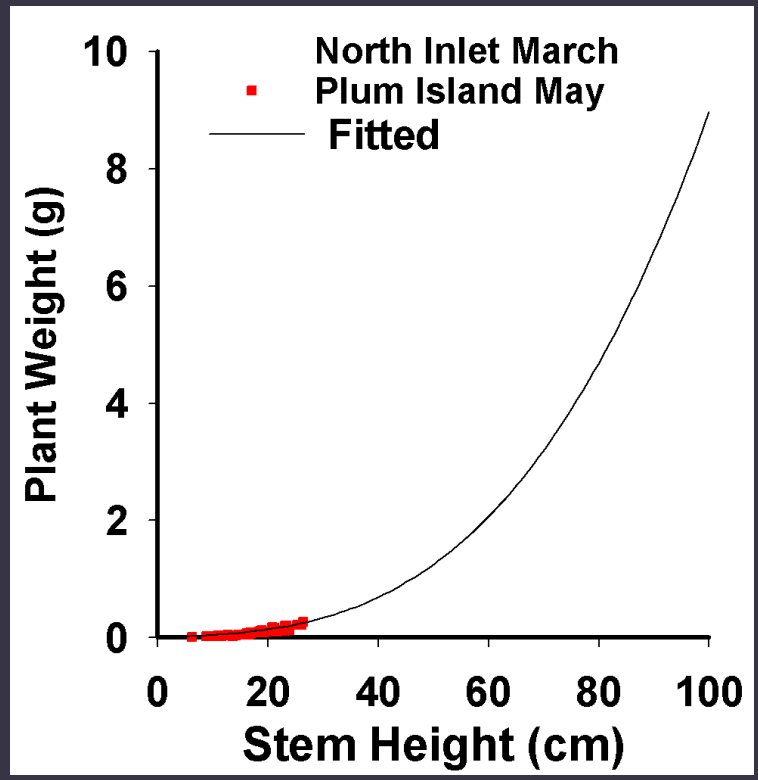
- **Pre-TLP**: No difference between sites
- **60-Months Post-TLP**
  - **Height:** Treatment*Time interaction
    - RM ANOVA, $F_{3,8} = 17.67$, $p = 0.0007$
    - TLP plots shorter until 30-mo post
    - Some plots had tall stems, some none
  - **Stem Density:** Treatment*Time interaction
    - RM ANOVA, $F_{3,8} = 8.57$, $p = 0.007$
    - Control site plots were denser
    - TLP stem densities increased slowly with time



*Control plot was lost to creek head erosion

Biological Parameters: Aboveground Biomass

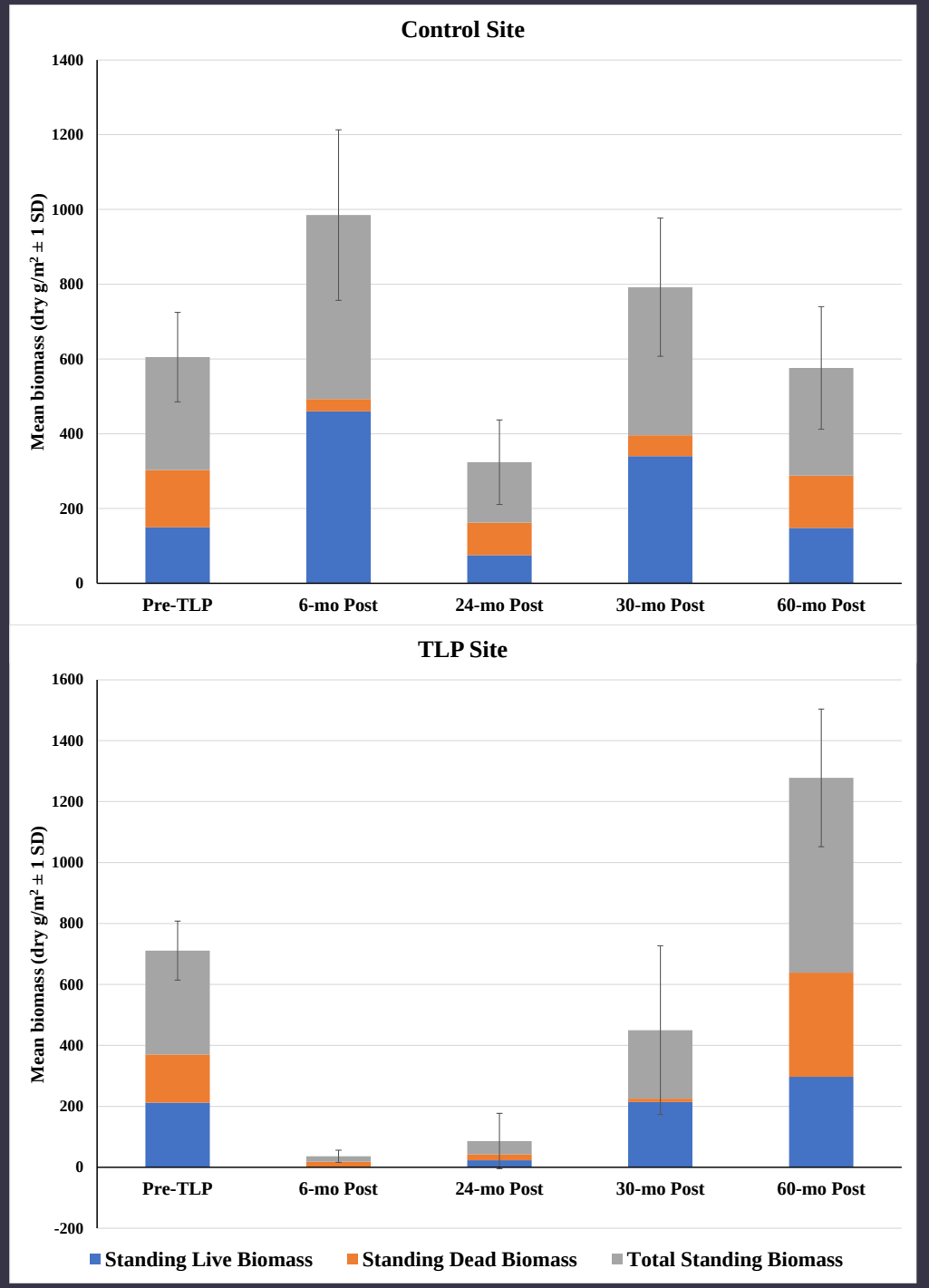
- 12 Plots (6 per site)
  - 0.25 m x 0.25 m plot
  - Nondestructive (all sampling periods)
  - Destructive (pre-TLP, 24 months post-TLP)
- Nondestructive
  - Stem heights to dry weight using allometry
- Destructive
  - Clipped all stems
  - Dried and weighed
  - Validate nondestructive



Morris and Haskin 1990

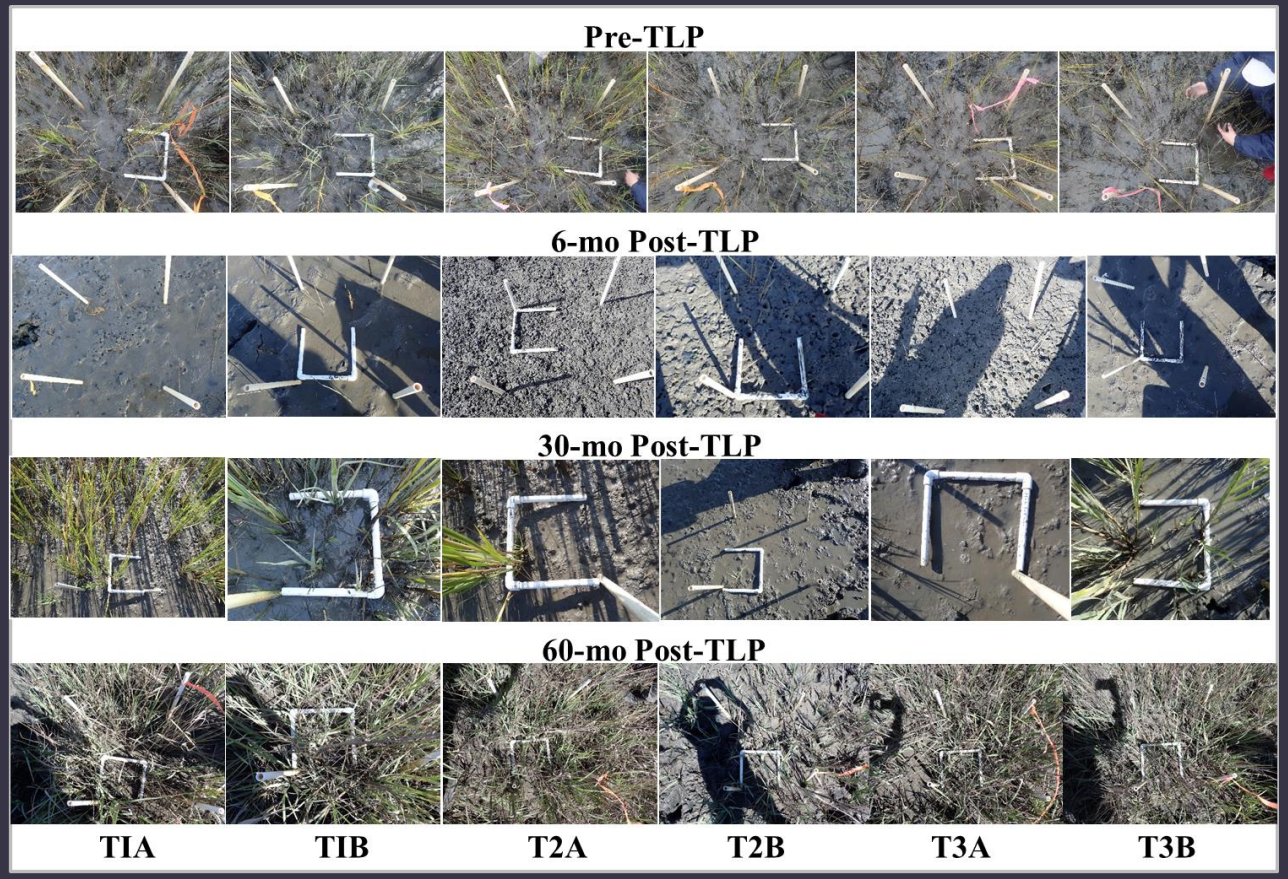
Biological Parameters: Aboveground Biomass

- Pre-TLP
  - No site differences
- 6-months Post
  - Zero live biomass at TLP
- 30-months Post
  - Patchy TLP recovery
    - SD was 50% of mean
    - Plots with zero biomass and plots with high biomass
- 60-months Post
  - TLP significantly greater than control (p = 0.01)
  - Patchy areas of higher biomass



Thin Layer Placement: Summary

- Physical Parameters
  - ★ Elevation
  - Tidal range
  - ★ Turbidity
  - ★ Soil cores (bulk density, OM)
- Biological Parameters
  - Plant characteristics
  - Above-ground biomass
  - ★ Invertebrates
  - ★ Microphytobenthos



Thin Layer Placement: Summary

- Monitored TLP and Control plots for 60-mo
- TLP site still recovering
  - Pattern is not uniform
  - Timing of recovery differs for parameters
  - Duration longer than anticipated
- Recovery patterns suggest recovery due to:
  - Wind event uncovering vegetation
  - Vegetive growth inward

Thin Layer Placement: Summary

- Recommendations:
  - TLP method
    - Timing of sediment delivery
    - Apply to smaller study area
    - Reduce application depth
    - Increase proportion of sand in sediment
    - Coir containment logs prevented tidal flooding
  - Monitoring
    - Use of boardwalks
    - Sediment elevation table (SET)

Photos by Clay McCoy, USACE Jacksonville District

Next Steps

- Continued monitoring using remote sensing data
  - Image analysis
  - UAV, LIDAR
- Back in the field!
  - March/April 2025

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Collaborators

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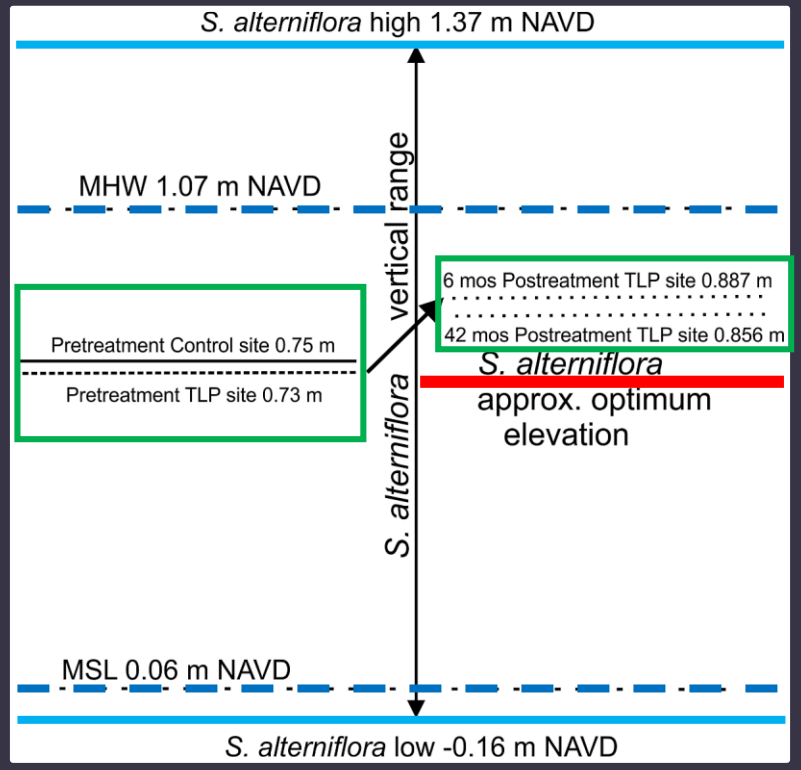
Thanks!

Spartina alterniflora Vertical Distribution



Relationship of TLP and Control site elevations pre- and post-TLP treatment to tidal datums and *S. alterniflora's* vertical range.

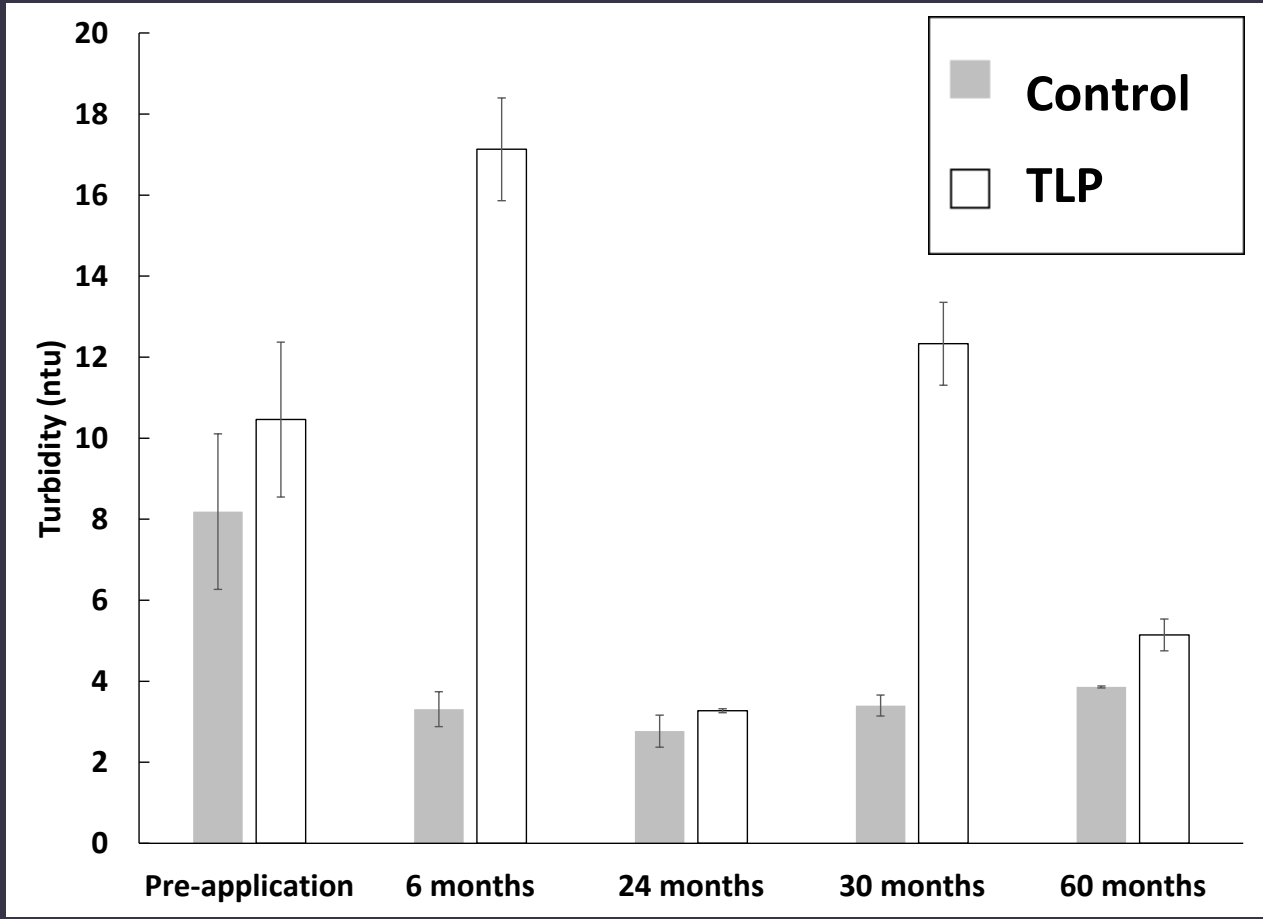
- *S. alterniflora* within tidal zone
  - 30 cm above MHW
  - 10 cm below MSL
- Growth limits
  - Lower: -0.16 m NAVD
  - Upper: 1.37 m NAVD
- Optimum elevation mid-way between the upper and lower limits
  - TLP and control sites were close to optimum

Physical Parameters: Turbidity

- Suspended Sediment Concentration
  - Turbidity
  - LaMotte 2020 turbidity meter
  - All sampling periods
  - Collected water samples in creek/river
  - Near Control and TLP sites
    - 3 samples each

Physical Parameters: Turbidity

- **Pre-TLP:** No difference
  - t-test, t_4=8.52=0.84, *p*=0.45
- **60-months Post-TLP:** Treatment*Time interaction
  - RM ANOVA, $F_{1,4}$ = 44.27, *p* = 0.002
- Response not predictable
  - At times significantly higher
  - At times no significant difference



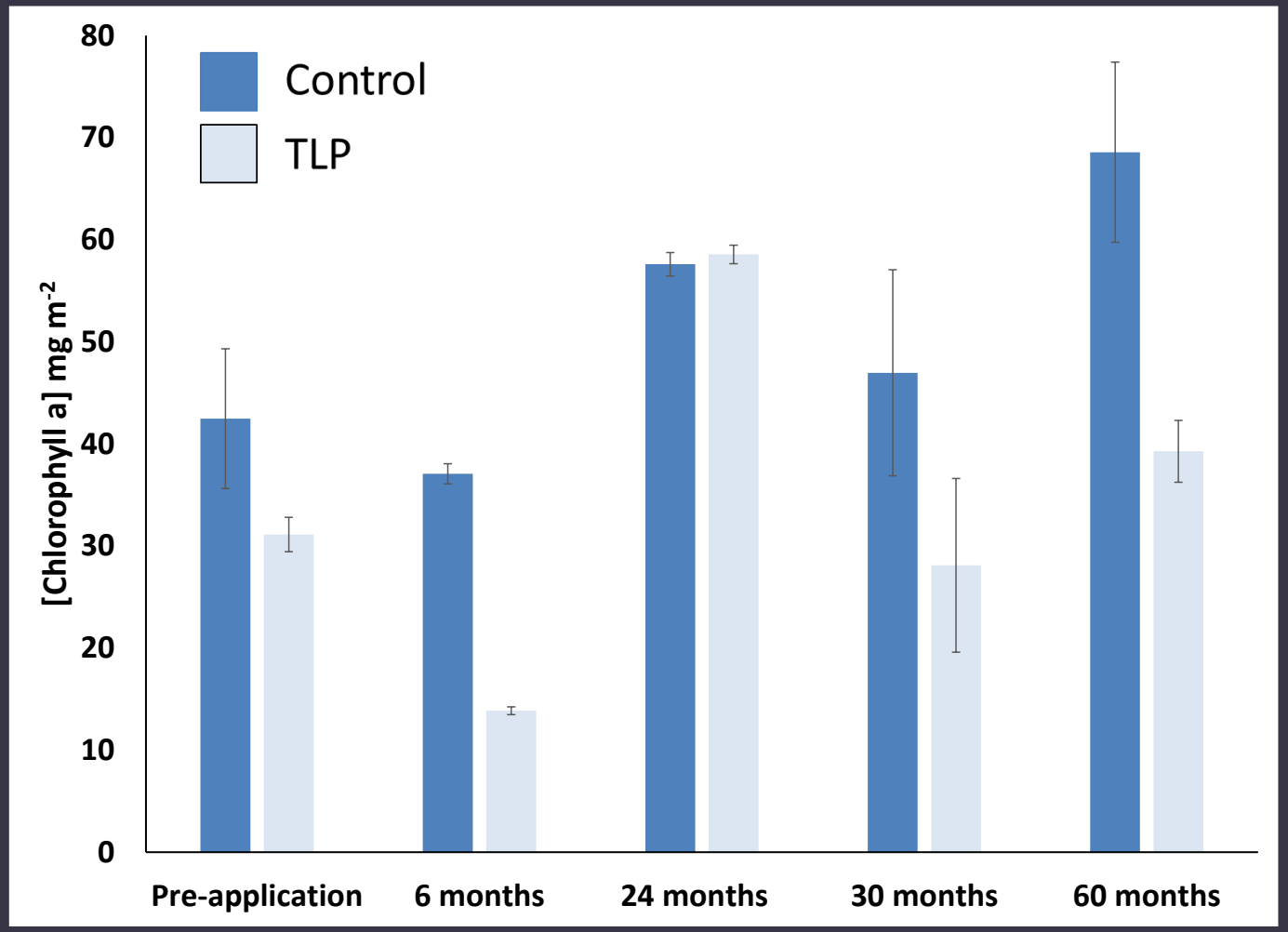
Mean water column turbidity adjacent to the TLP and control sites pre-TLP application, 6-, 24-, 30-, 60-months post-application. Error bars are ± one standard error of the mean.

Biological Parameters: Microphytobenthos

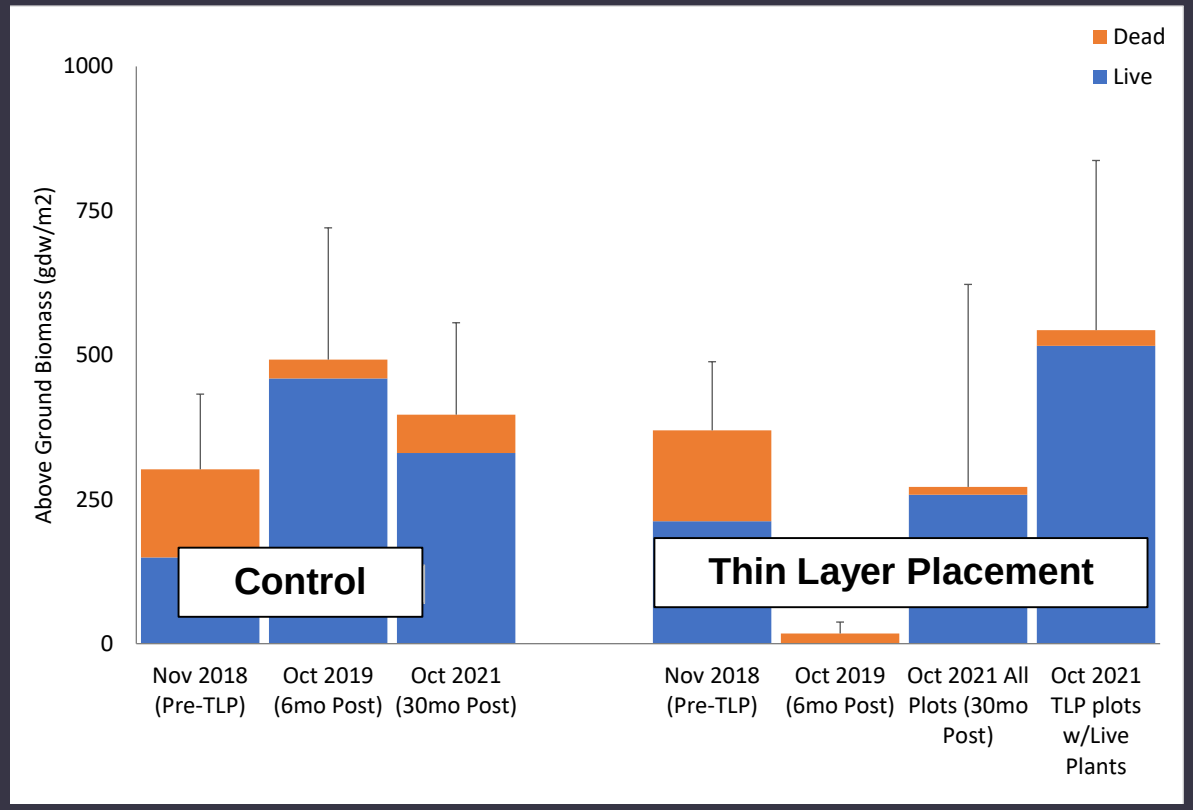
- 6 plots per site
- All sampling dates
- Collected three sediment cores (1 cm deep) per plot
- Extracted green pigments
- Measured chlorophyll a concentration using fluorometry

Biological Parameters: Microphytobenthos

- **Pre-TLP**: No difference between sites
- **60-Months Post-TLP**
  - TLP significantly lower
  - Differences over time
    - RM ANOVA, $F_{3,8} = 23.34$, $p = 0.0003$
  - Trend toward treatment effect
    - RM ANOVA, $F_{1,10} = 4.02$, $p = 0.07$



Biological Parameters: Aboveground Biomass



Live and dead biomass of control, pre-TLP treatment, and post-TLP treatment Jekyll Island sites.

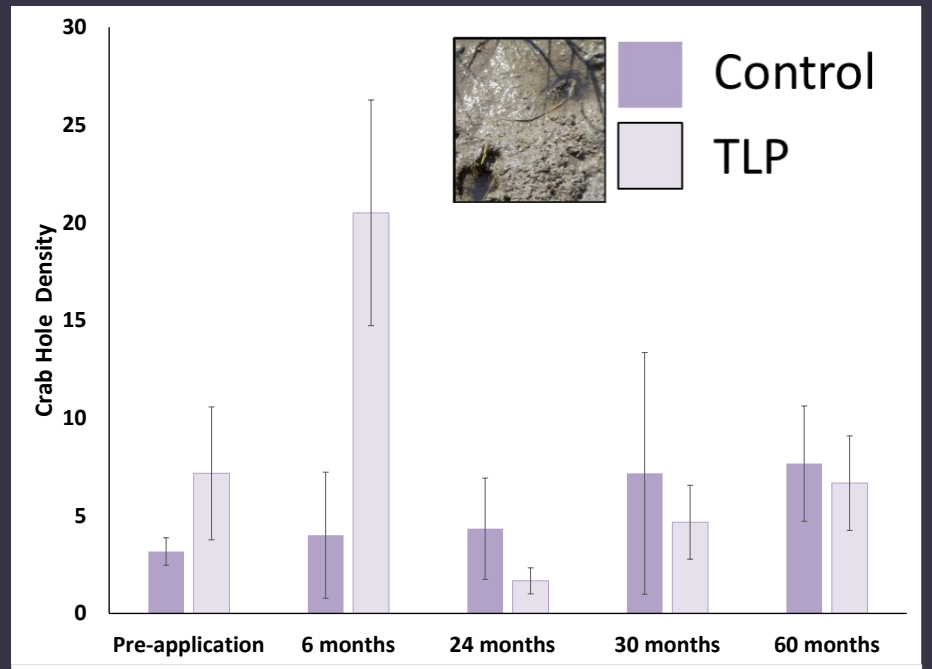
- Pre-TLP
  - No site differences
- 6-months Post
  - Zero live biomass at TLP
- 30-months Post
  - Patchy TLP recovery
  - Increase in live biomass
    - SD was 50% of mean
    - Plots with zero biomass and plots with high biomass
- 60-months Post
  - TLP significantly greater than control (p = 0.01)
  - Patchy areas of higher biomass

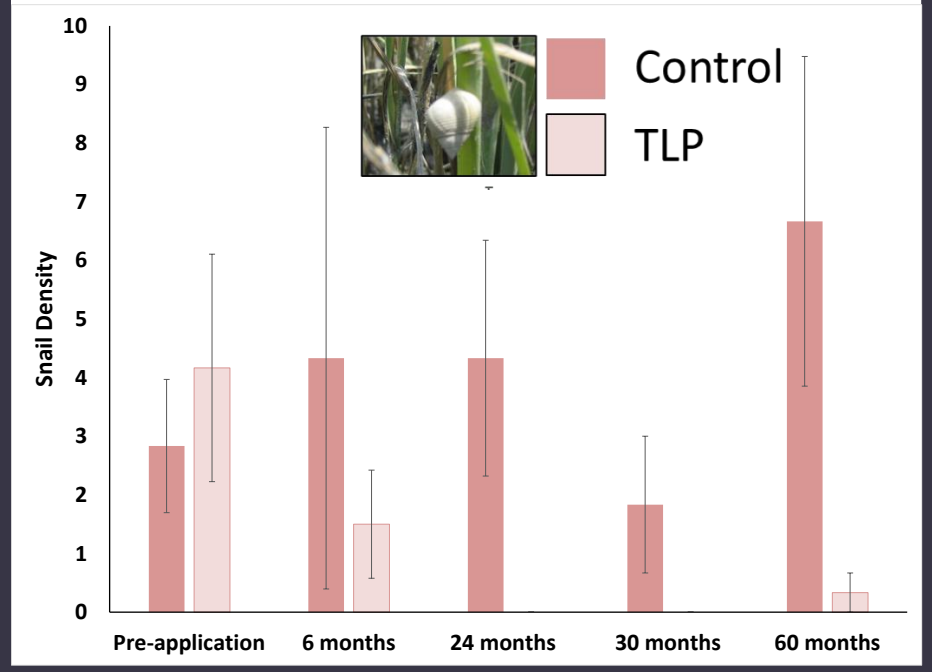
Biological Parameters: Invertebrates and Redox

- 6 plots per site
  - 0.25 m x 0.25 m plot
  - All sampling periods
- Invertebrates
  - Snails
    - *Littoraria irrorata*
    - *Melampus bidentatus*
  - Crab holes
    - *Uca spp.*
  - Mussels (1 x 1 m)
    - *Geukensia demissa*
- Soil redox

Biological Parameters: Crab Holes & Snail Count

- **Pre-TLP**: No difference between sites
- **60-Months Post-TLP**
  - **Crabs:** Treatment*Time interaction
    - RM ANOVA, $F_{3,8} = 8.03$, $p = 0.02$
  - **Snails:** Trend toward treatment effect on snails
    - RM ANOVA, $F_{1,10} = 3.17$, $p = 0.10$
  - **Mollusks:** Not enough data to analyze statistically





Biological Parameters: Redox

- **Pre-TLP**: No difference between sites
- **60-Months Post-TLP**: Treatment*time interaction
  - RM ANOVA, $F_{2,35}$ = 19.36, p <0.0001
- Mirrors plant response