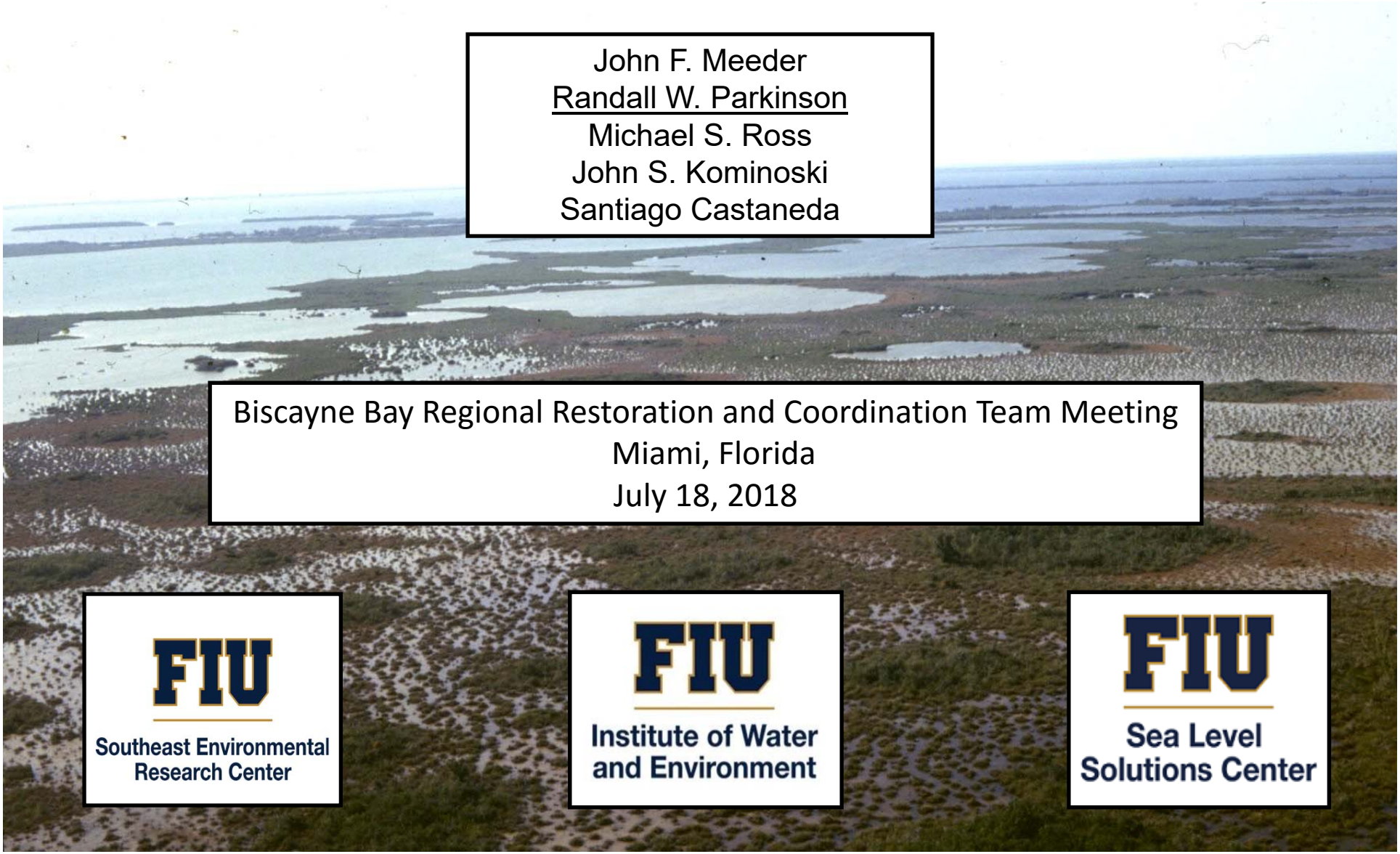
Effect of Anthropocene Sea-Level Rise on the Plant Communities, Soils, and Carbon Dynamics: Northern Reach of the Southeast Saline Everglades, Florida, USA



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Project synopsis

This investigation was designed to answer the following question:

How is accelerating rate of Anthropocene sea-level rise (SLR) changing the northern reach of the Southeast Saline Everglades (NRSESE)?

The study area consists of an oligotrophic micro-tidal wetland located on a stable carbonate platform with extremely low topographic relief and which receives only trace allochthonous sediment input.

Therefore, many of the variables which hamper analogous investigations are absent and the interpretation of our results are more likely to be accurate.

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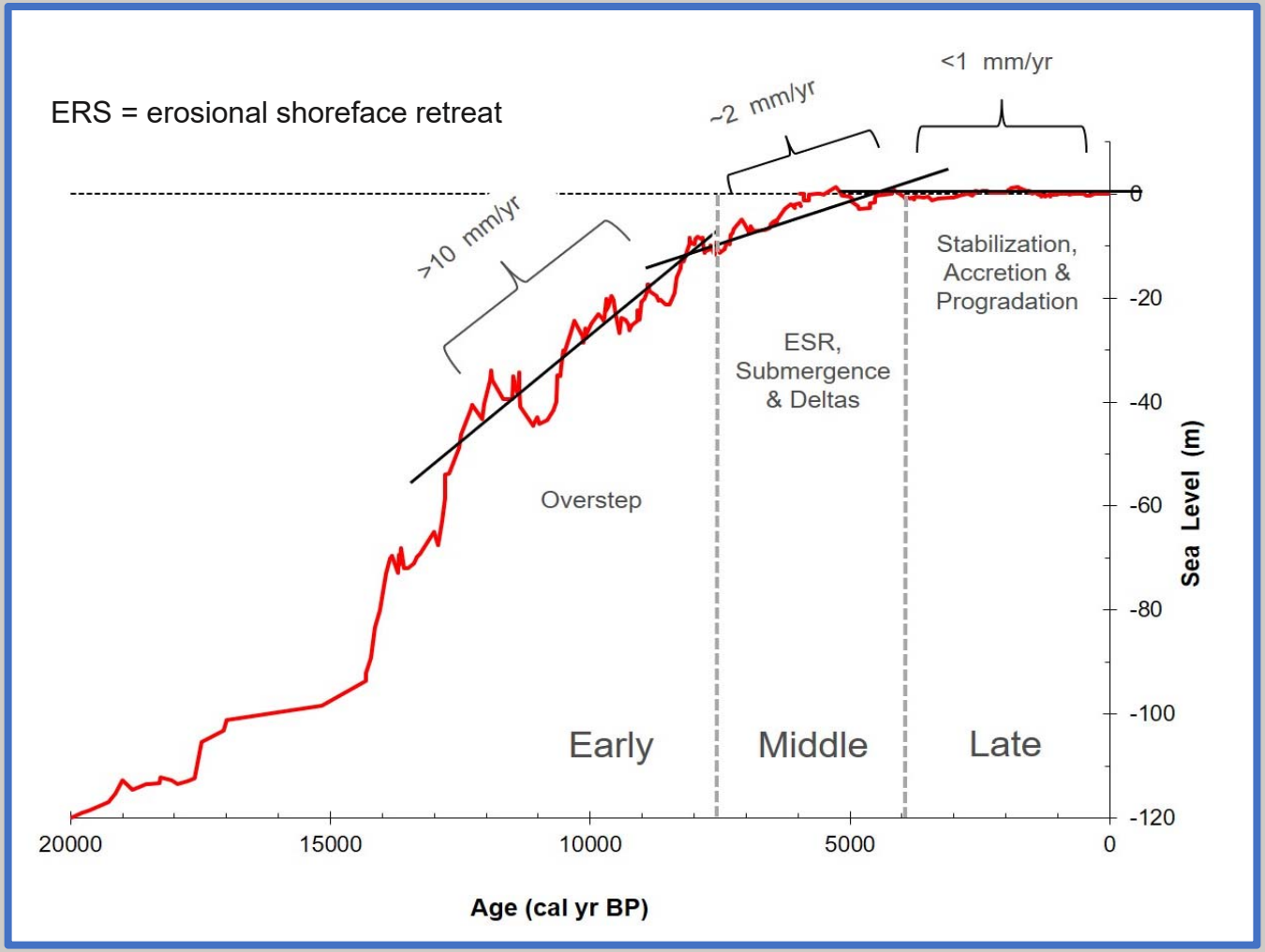
Regional trends in SLR during the late Quaternary period



Sea level history from Balsillie and Donoghue (2004)

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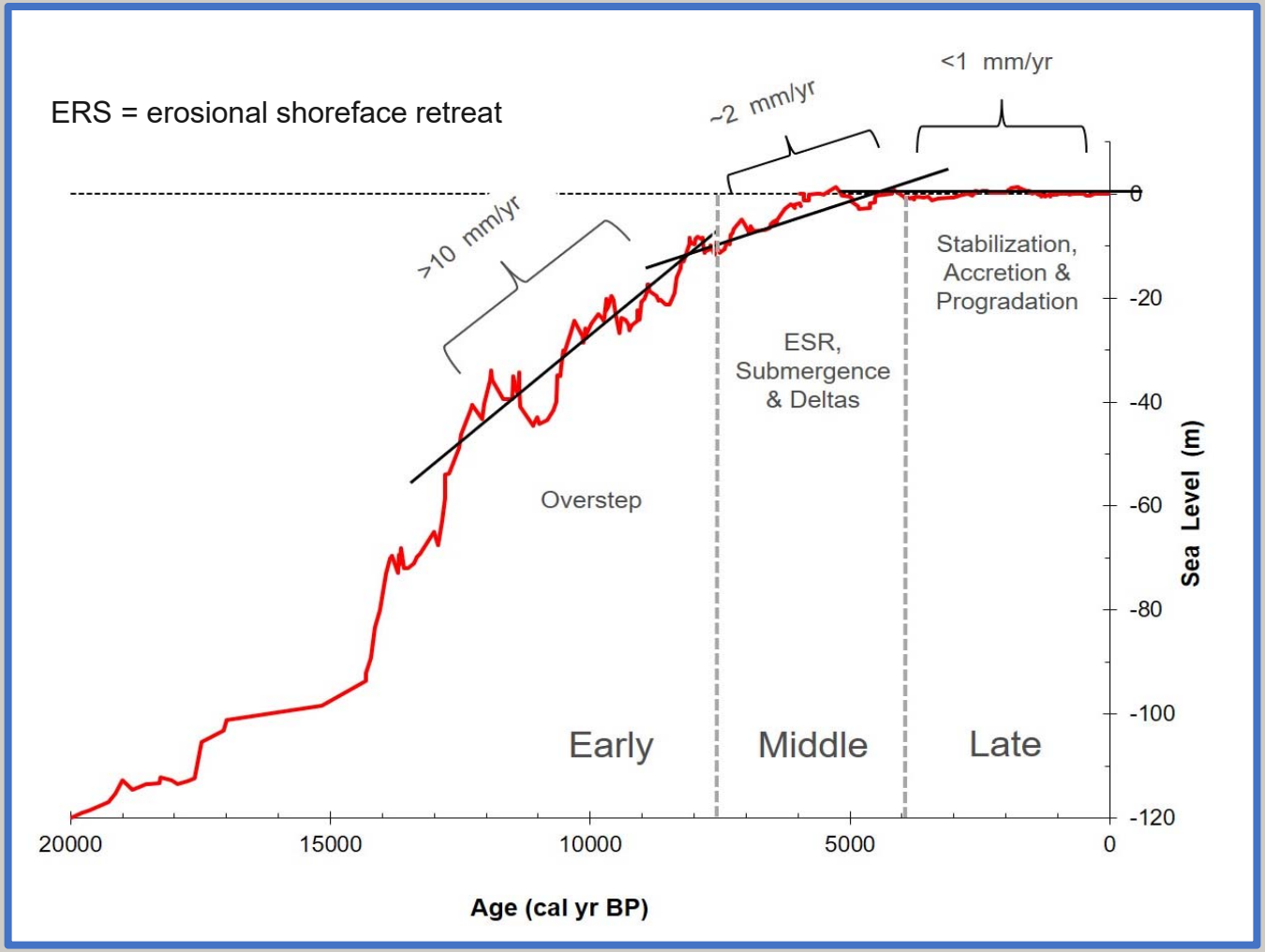

Sea level history from Balsillie and Donoghue (2004)

The rate of global eustatic SLR has steadily accelerated since the onset of Anthropocene epoch (~1900) and will very likely exceed 10 mm/yr by 2100 (Sweet et al., 2017).

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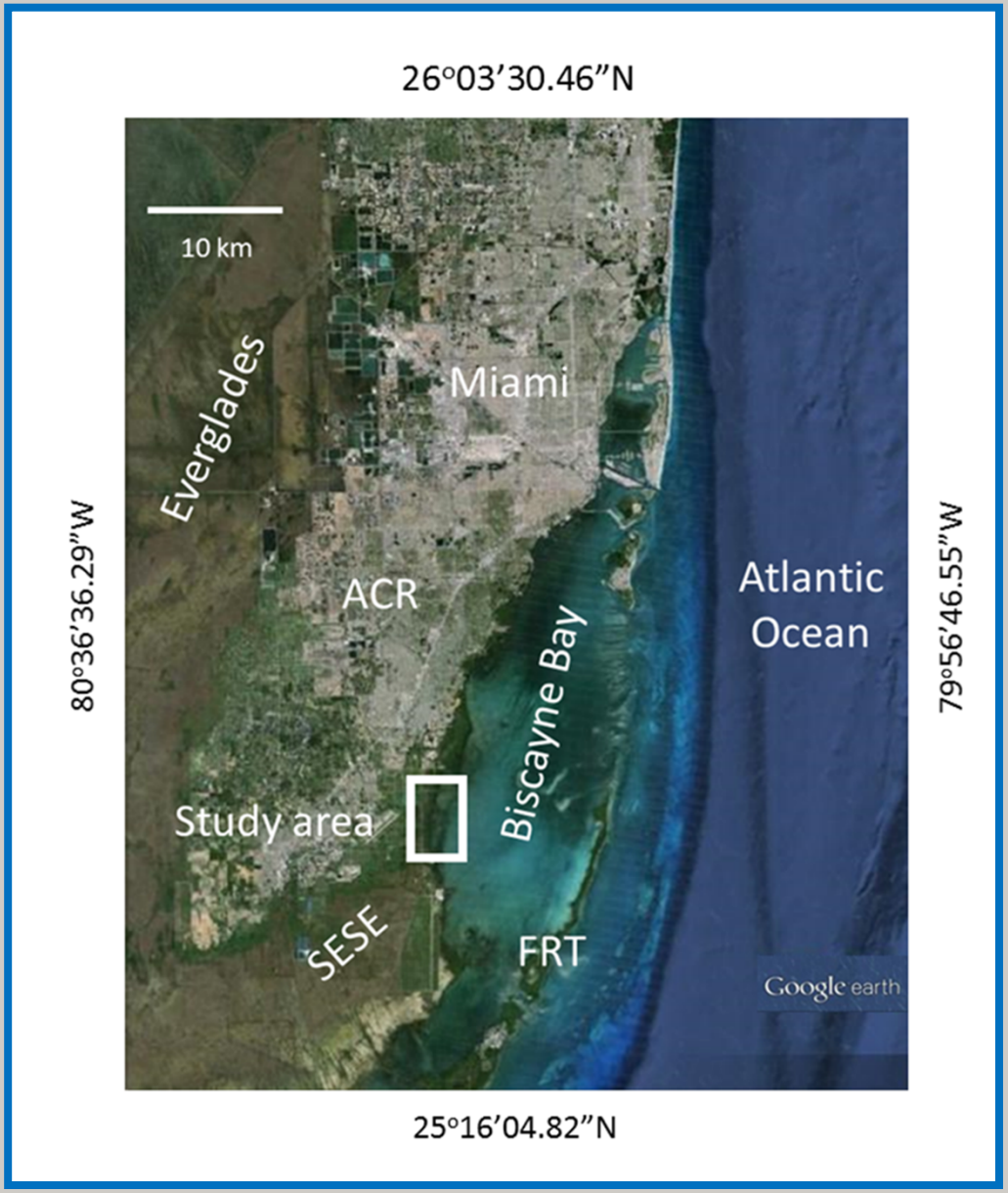
Project location: NRSESE



ACR = Atlantic Coastal Ridge
SESE = Southeast Saline Everglades
RFT = Florida Reef Tract

Study area is 2 km wide and 800 m deep

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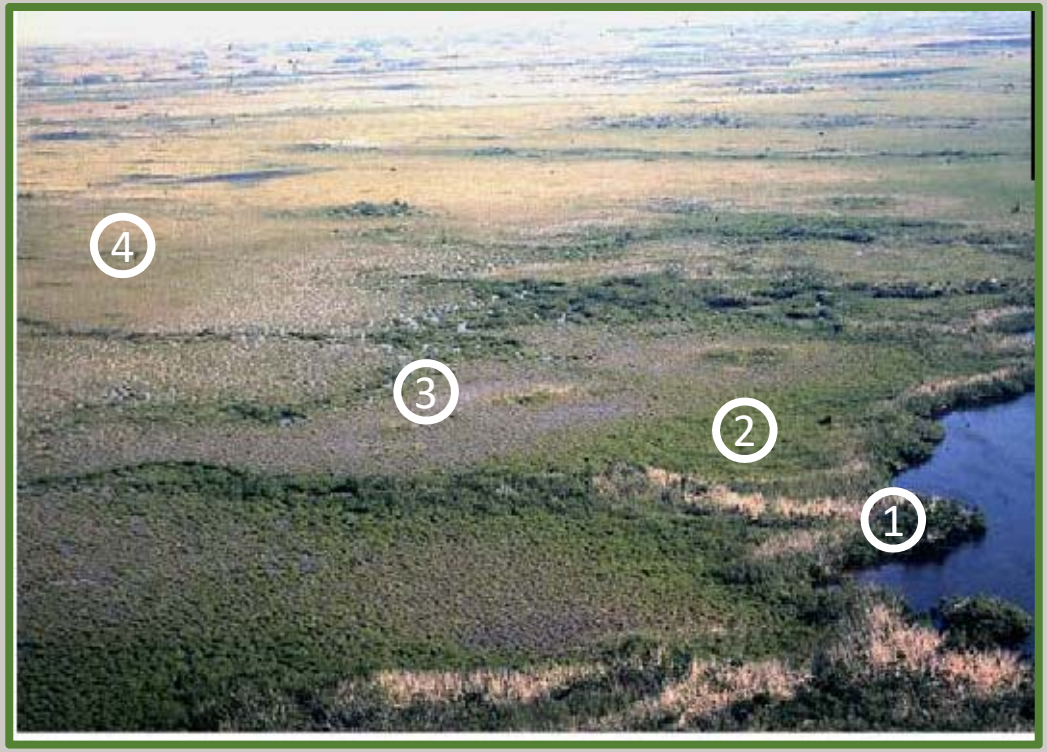
Project location (con't)

Photo Key	Landscape Feature	Plant Community	Sediment Type
1	Fringe mangrove	Red mangrove	Peat
2	Scrub mangrove	Red mangrove, periphyton	Peat-marl
3	Wet prairie	Periphyton	Marl
4	Marsh	Sawgrass, periphyton	Peat-marl



Note: photograph from northern Florida Bay to provide visual context of the historical landscape likely present in the NRSESE.

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Freshwater marl prairie soils

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Typical plant and soil types in the fringing- and scrub-red mangrove community

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Approach

- Historical landscape analysis was undertaken to document changes in NRSESE plant communities and other significant landscape features using aerial photography (1938, 1952, 1968, and 2009)
- 7 deep (2 – 3 meters) and 320 shallow (30 cm) cores were collected in the NRSESE to document sedimentology and stratigraphy of geological and historical landscape features
- Sedimentologic data (texture, composition, color), Salinity Index (SI), stratigraphic correlations, and Pb^{210} accumulation rates were generated using standard methods to quantify the soil characteristics associated with each NRSESE plant community or landscape feature
- These data, in tandem with knowledge of regional SLR, were used to quantify the historical evolution of NRSESE plant communities, soils, and carbon dynamics

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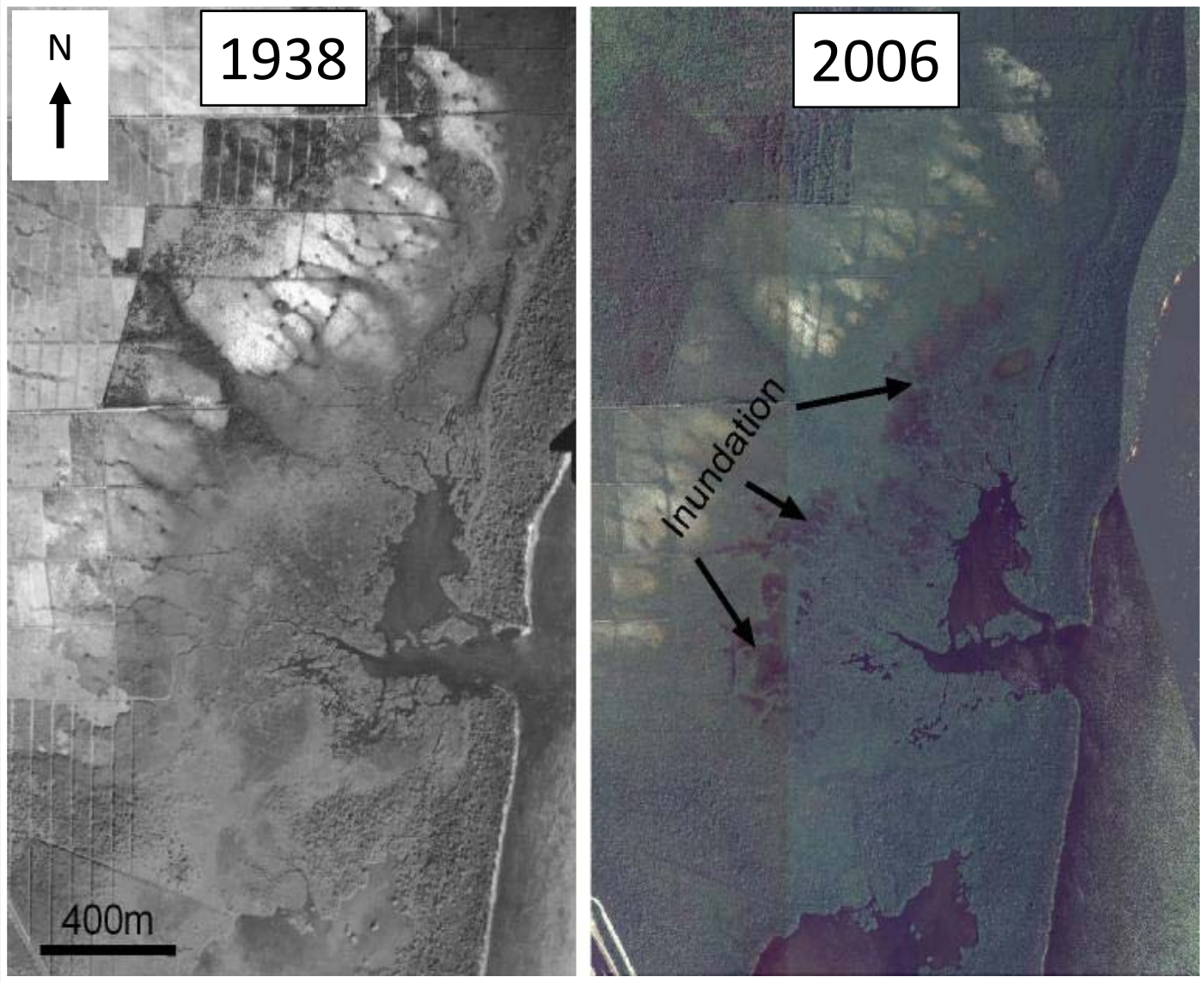
Historical changes in NRSESE landscape features were quantified using aerial photography obtained in 1938, 1952, 1968, 2006



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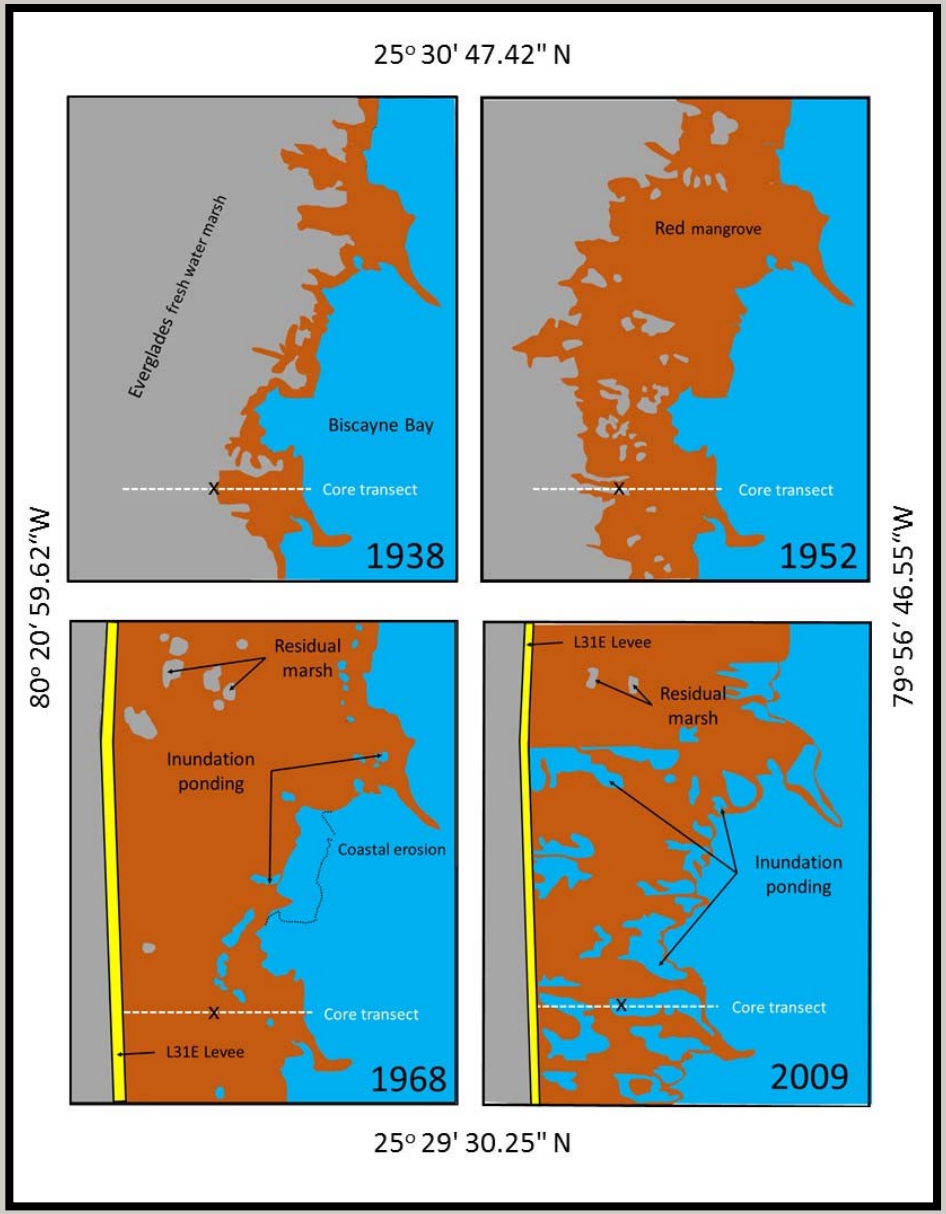
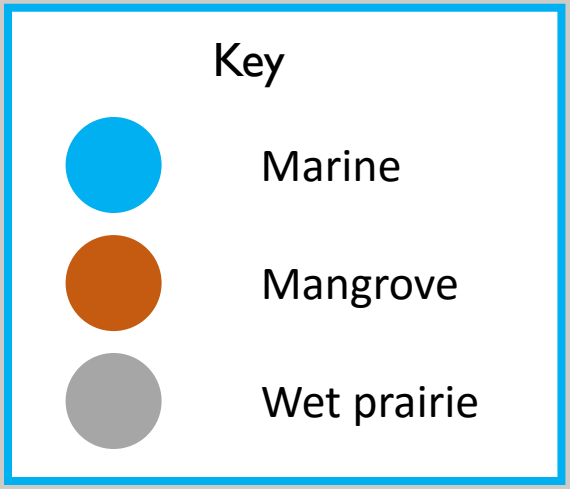
NRSESE historical landward drift of fringing- and dwarf-red mangrove





25 myr $^{-1}$ = average pace of landward mangrove community migration in the NRSESE before encountering L31E levee

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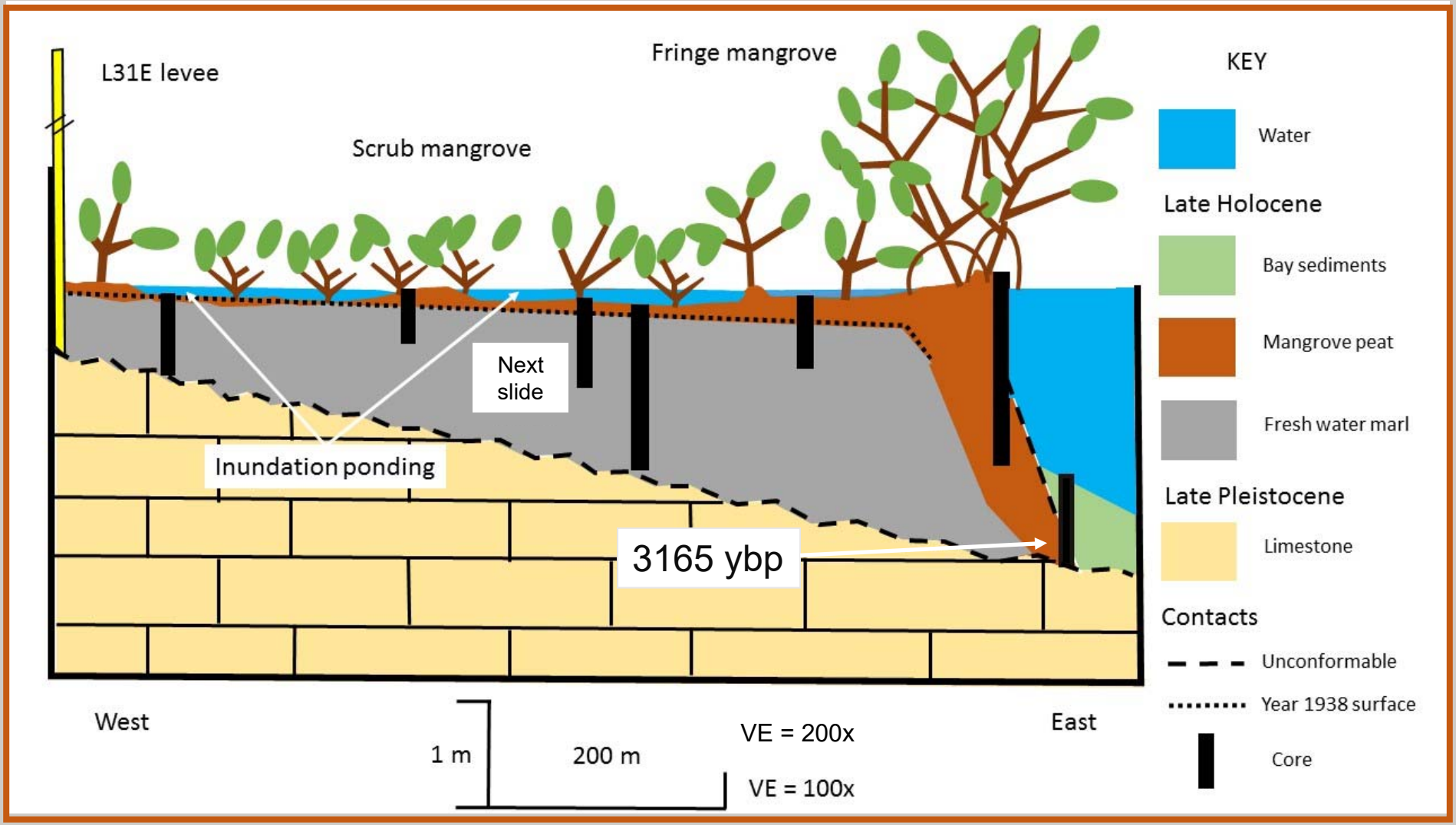
NRSESE sedimentology and stratigraphy was reconstructed using sediment cores along a 800 m long transect



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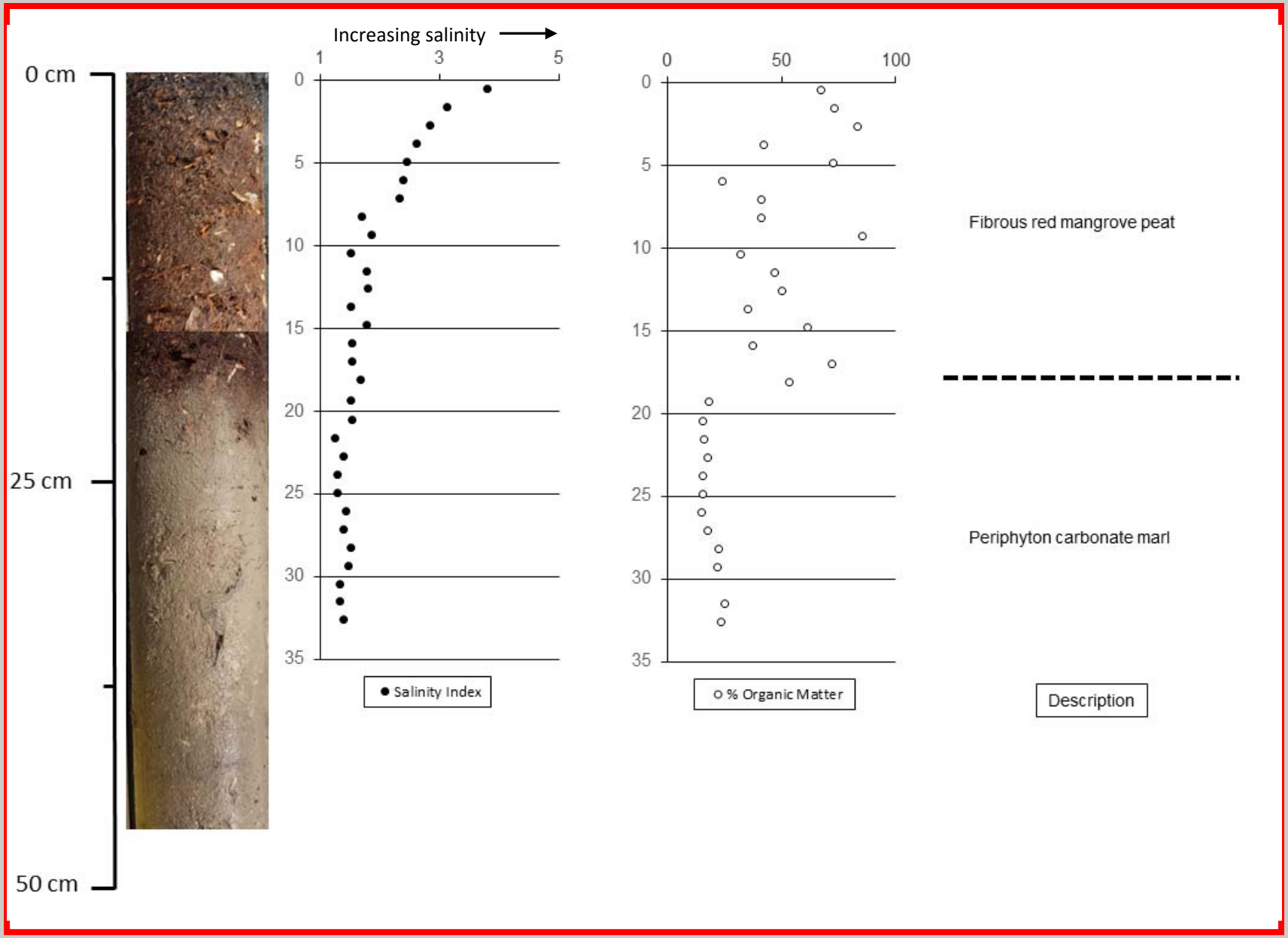
Transect core data collected in NRSESE mangrove scrub habitat



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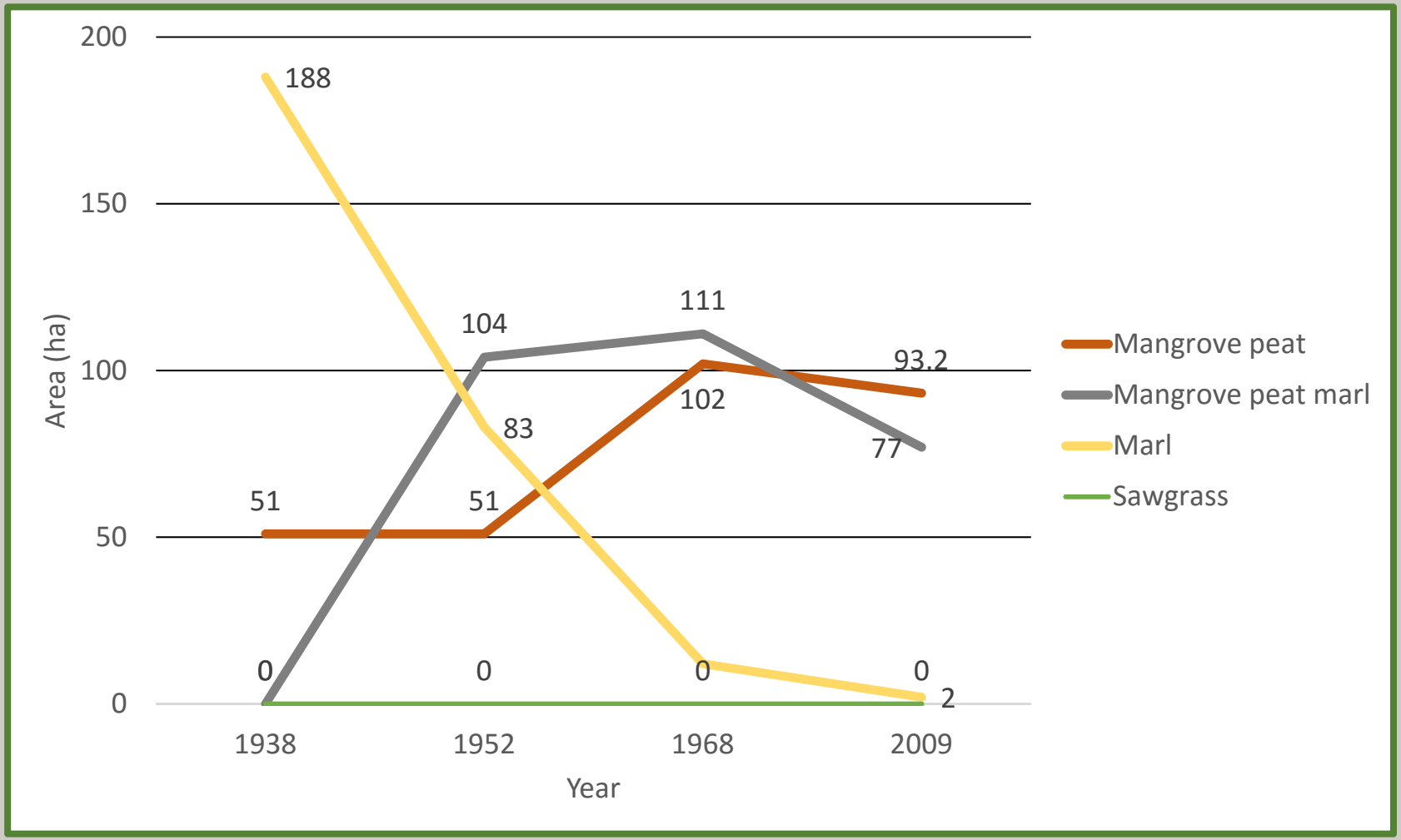
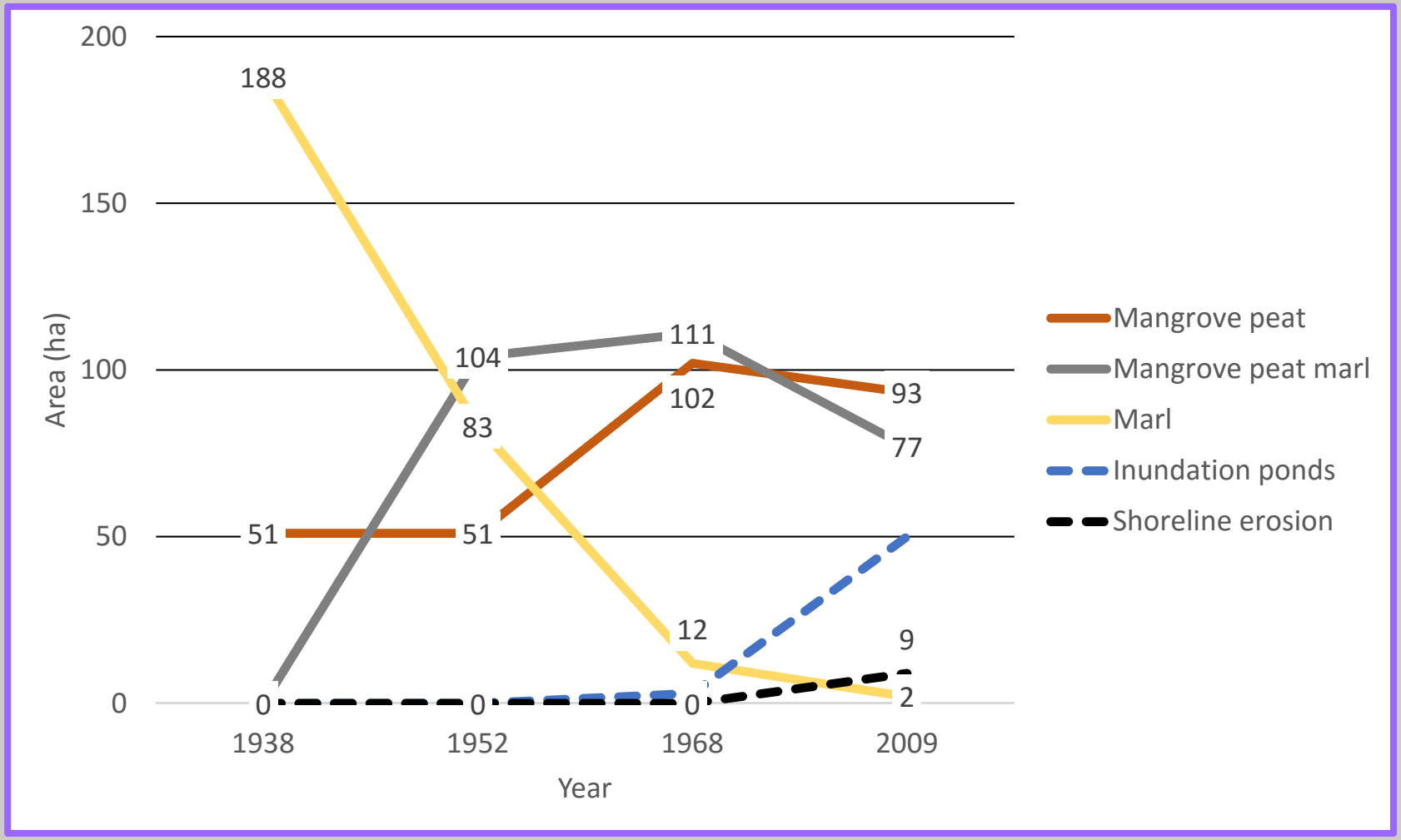
Area of NRSESE extant plant community sediments in 1938, 1952,1968, and 2009



Area of NRSESE extant plant community sediments and other significant landscape features in 1938, 1952,1968, and 2009



Pb^{210} based sediment accumulation rates using samples collected in NRSESE

Sediment type	N	Accumulation rate ($mm\ yr^{-1}$)
Mangrove peat	2	4.1
Mangrove peat marl	2	3.25
Marl	4	1.35
Sawgrass peat marl	2	2.1

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OM conversion of a 1 cm thick core sample to the annual rate of OC storage in each of the NRSESE plant communities

1. Conversion of 1 cm^3 soil sample to g OM per 1 cm^3
2. Conversion of g OM per 1 cm^3 to g OC per 1 cm^3 (g OM*0.58)
3. Conversion of g OC per 1 cm^3 to g OC per m^2 (area) x 1 cm (thickness)
4. Conversion of g OC per m^2 (area) x 1 cm (thickness) to g OC per m^2 per year based upon Pb^{210} accumulation rates

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Duration of time represented by a 1 cm thick soil sample recovered from each of the NRSESE plant communities

Sediment type	N	Accumulation rate (mm yr^{-1})	Time represented by 1 cm interval
Mangrove peat	2	4.1	2.4
Mangrove peat marl	2	3.25	3.1
Marl	4	1.35	7.4
Sawgrass peat marl	2	2.1	4.8

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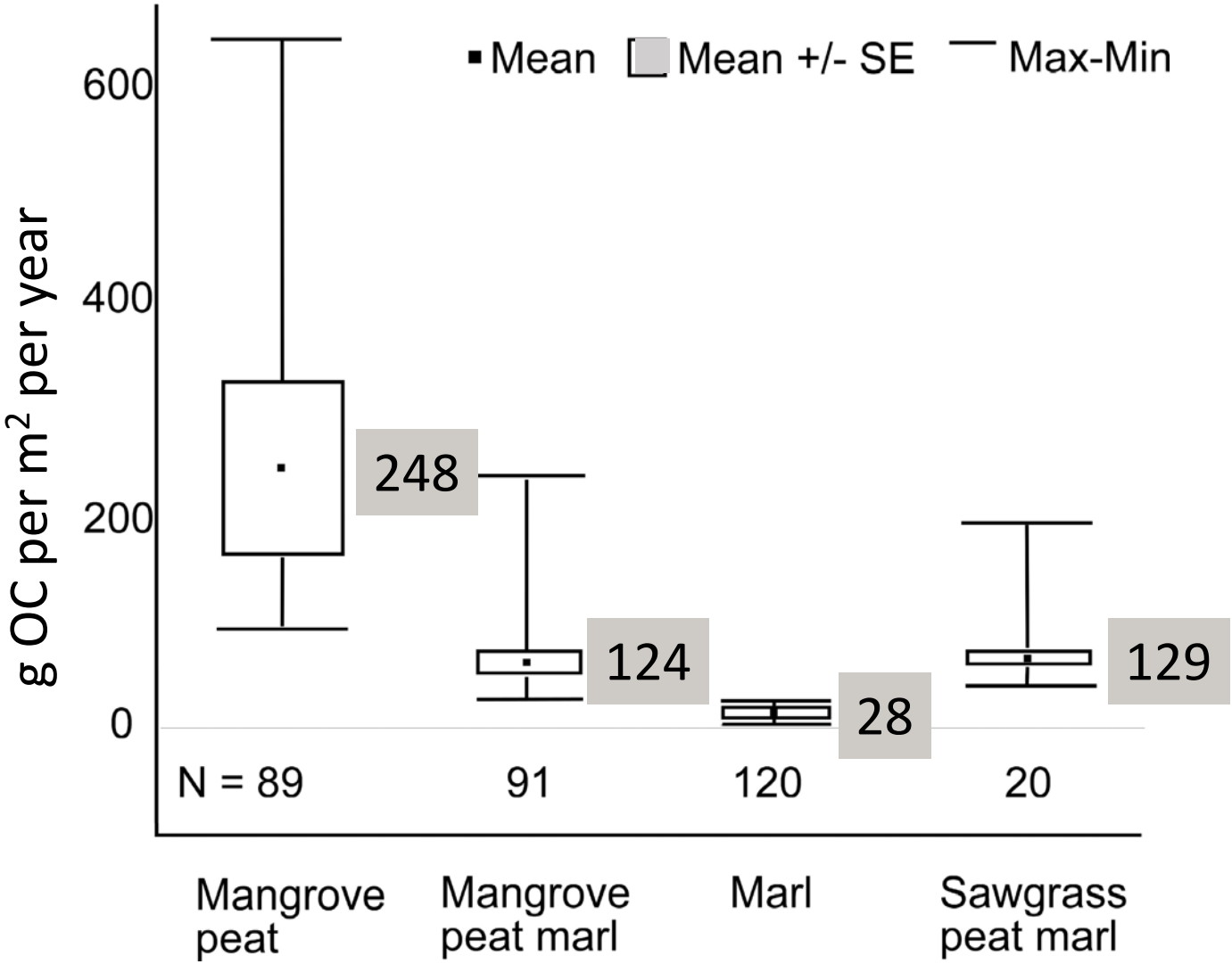
Annual rates of OC storage in each of the NRSESE plant communities



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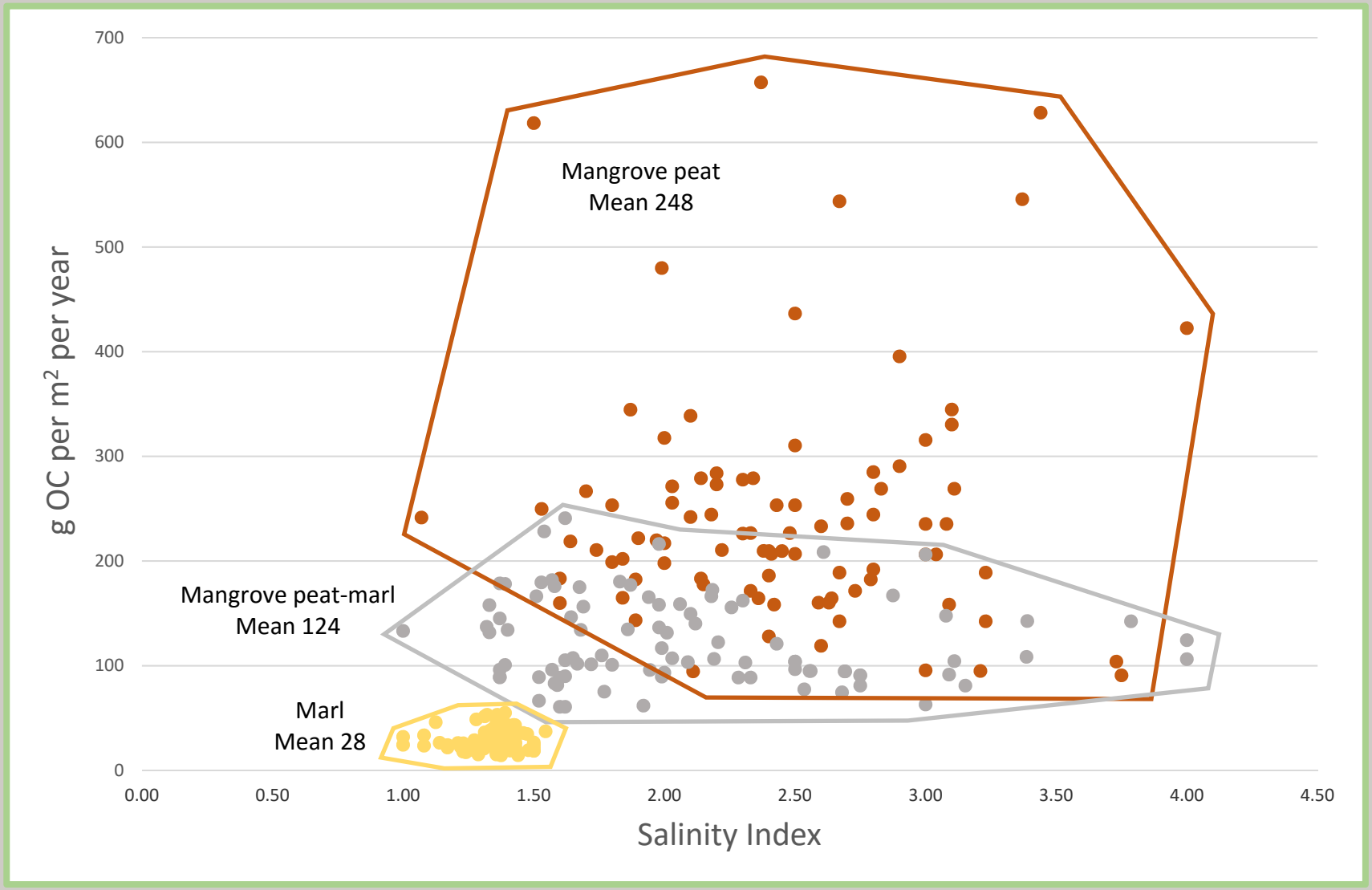
Rates of OC storage in NRSESE extant plant community soils increase with increasing salinity



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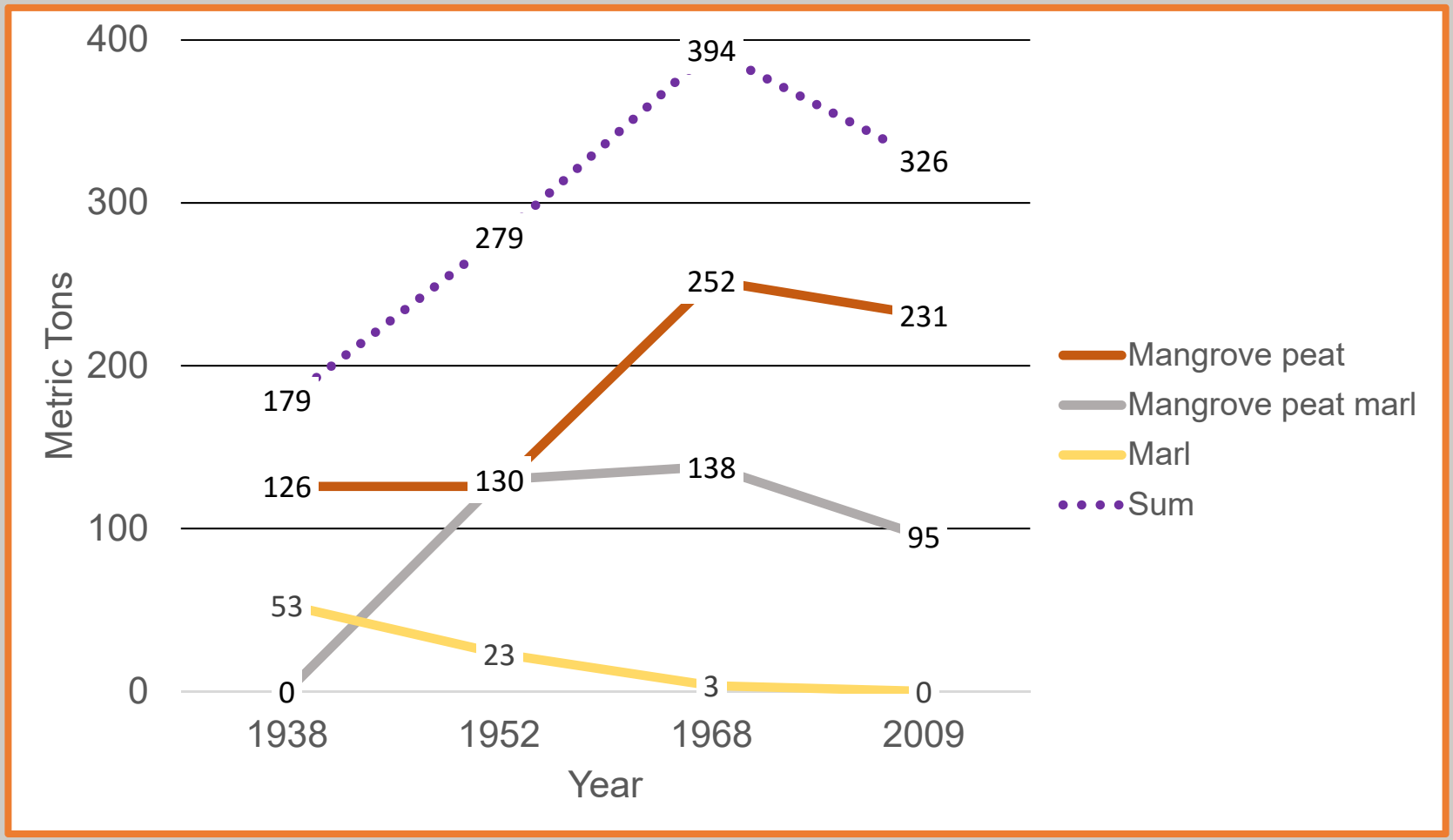
OC storage in soils in NRSESE extant plant communities in 1938, 1952, 1968, and 2009



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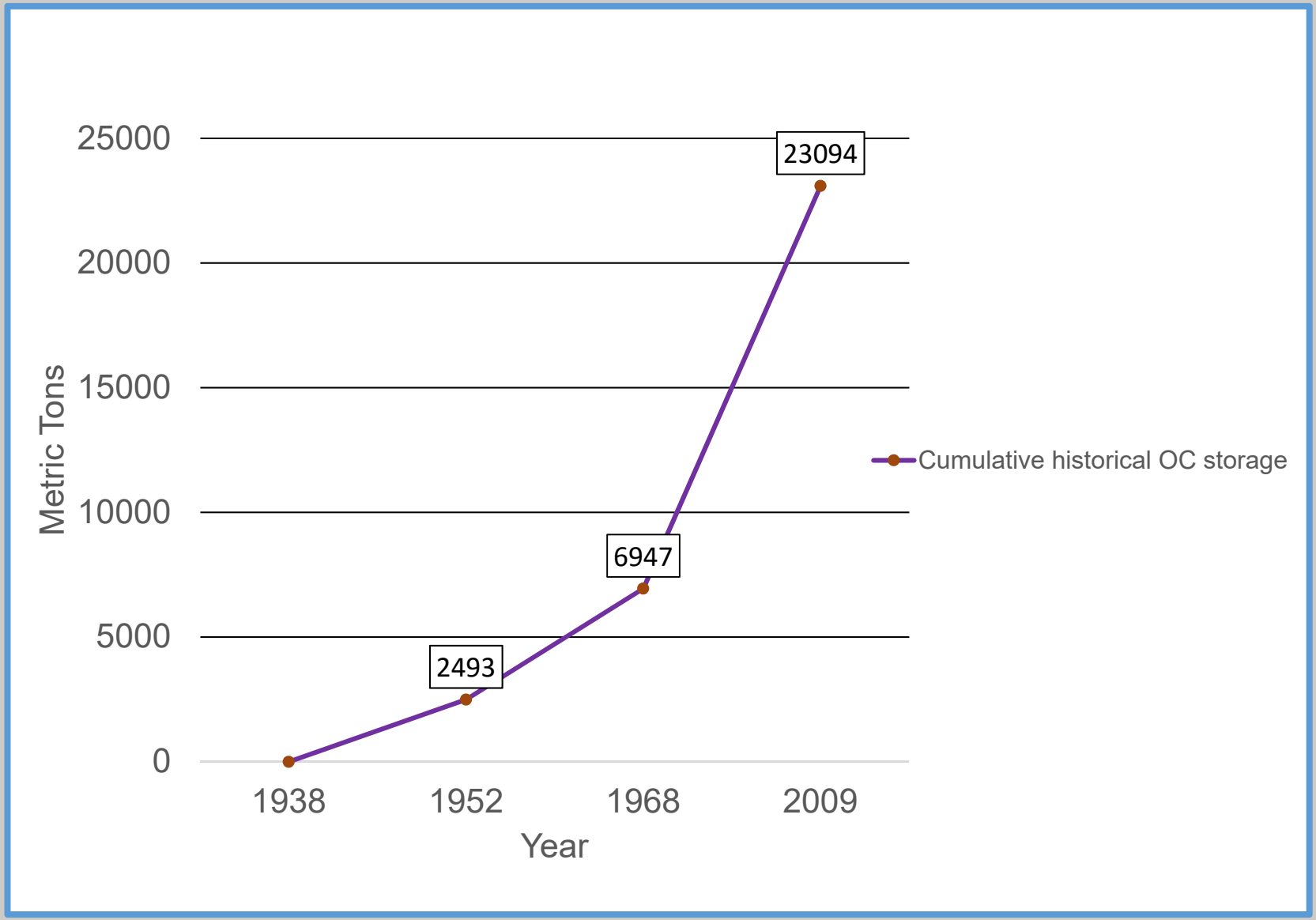
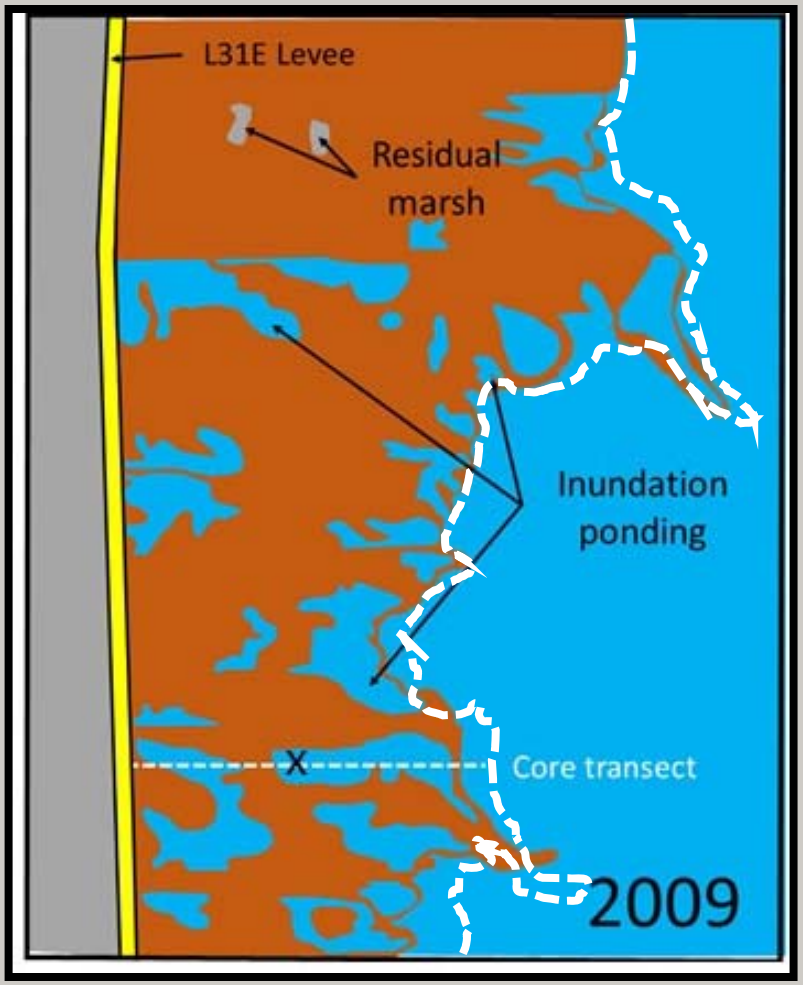
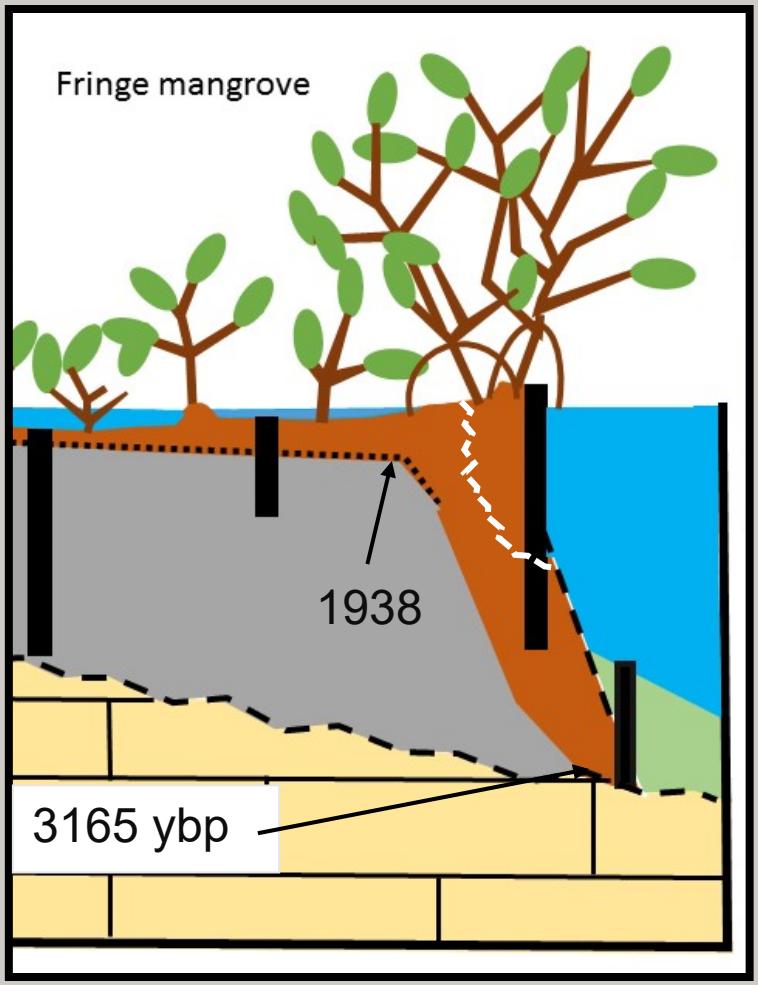
Cumulative OC storage in NRSESE extant plant communities in 1952, 1968, and 2009



NRSESE OC flux is influenced by long-term effects of SLR (rate, magnitude) and event landfall (erosion)





---------- 1968 shoreline

---------- Ravinement surface

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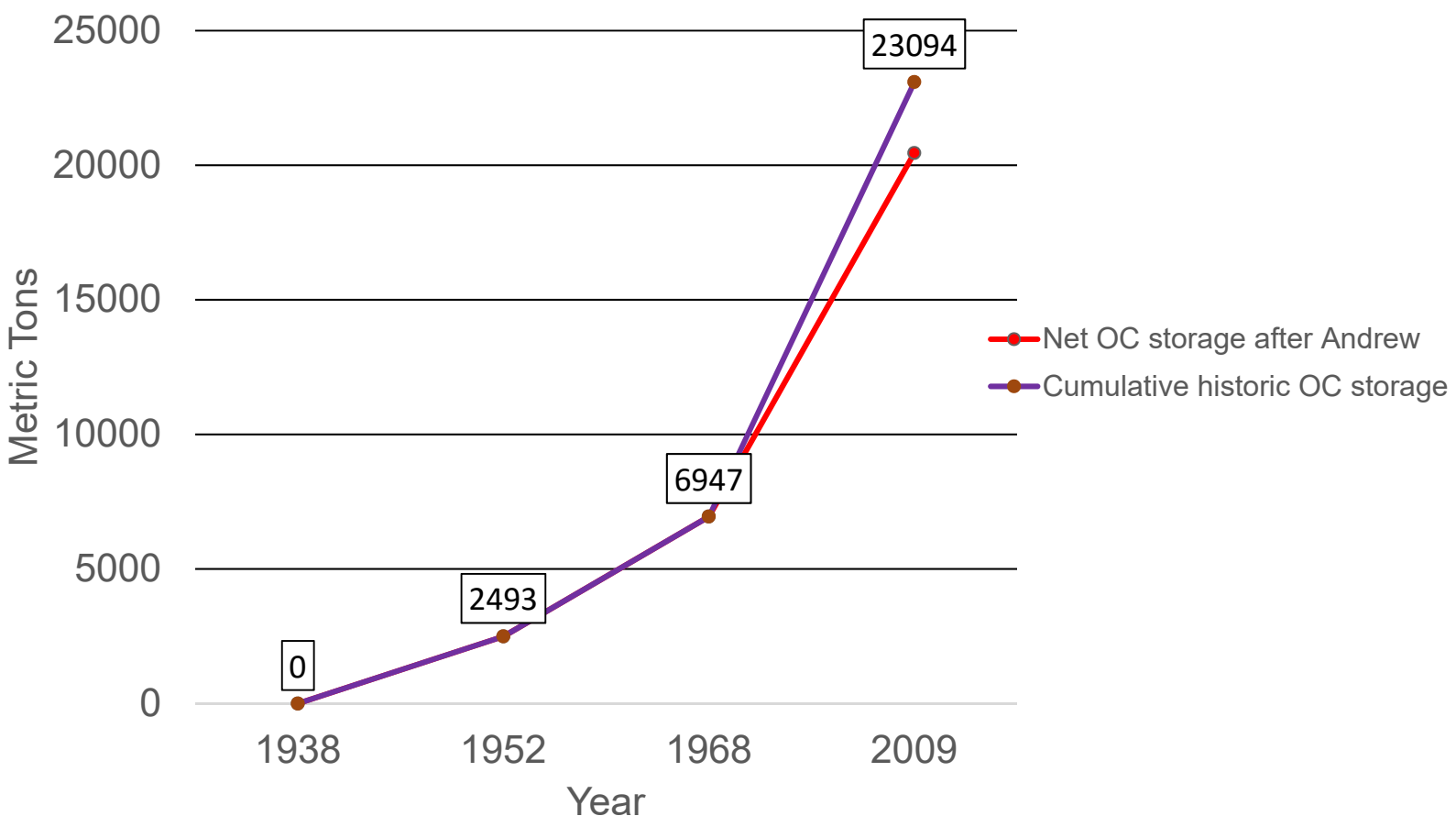
OC stocks in NRSESE were reduced by erosion of fringing red-mangrove soils during landfall of Hurricane Andrew (1992)



Event released an estimated 2600 MT or 10% of OC stored in NRSESE soils since 1938

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Concluding Remarks

- The historical sediment succession of NRSESE is transgressive and generated in response to Anthropocene SLR
- This initially resulted in a net increase in OC storage as the organic-rich fringe- and dwarf-red mangrove plant communities migrated landward into less carbon-rich environs
- By 1968, the entire study area had converted to red mangrove. Additional landward migration was blocked by the L31E levee
- Thereafter, OC storage was reduced by inundation ponding (prevailing) and event-driven coastal erosion (Hurricane Andrew 1992)

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Concluding Remarks (cont)

- Accelerating SLR and more frequent landfall of larger storm events are forecast to accompany climate change. Therefore, OC storage in NRSESE is forecast to diminish over time

- More frequent landfall of event-driven erosional events into the NRSESE will likely be accompanied by pulses of OC-rich shoreline soils into proximal marine waters (Florida Bay, Florida Reef Tract). The environmental and economic consequences of these pulses are poorly constrained at present, but will likely be substantial

- Based upon this study and others in the region, accelerating SLR will initially generate a transgressive soil sequence until a tipping point is reach. Thereafter, the replacement of south Florida natural environs by open water is most probable.

- This will be accompanied by decreased OC storage until the entire region is converted to a shallow, subtropical estuary

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Acknowledgements

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