Sediment transport at the marsh-mudflat scale: Whale's Tail marsh in South San Francisco Bay

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RMP special study 2021/22

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Motivation

RMP SWG MQ4: How much sediment is passively reaching tidal marshes and restoration projects, and how could the amounts be increased by management actions?

We need to know more about how tidal and wave conditions in the shallows influence sediment delivery to marshes .

Sediment supply
- through tidal creeks
- across bay-marsh interface

Sediment loss due to wave-driven erosion at the marsh edge


China Camp marsh

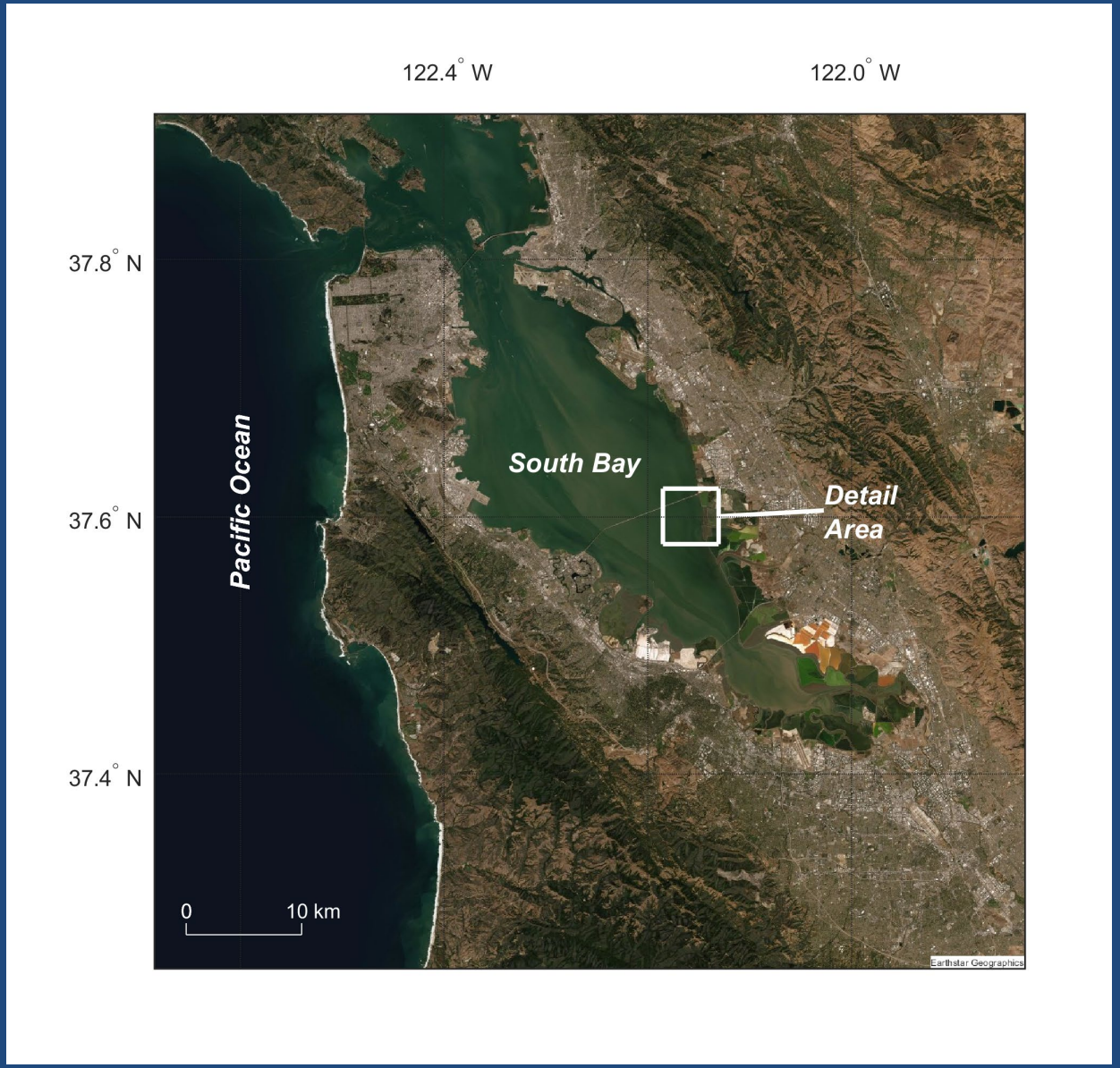

Whale's Tail marsh

Questions/goals

1. How do deposition and erosion in a salt marsh vary with tides, wave conditions, and season?
2. What information do we need to predict sediment deposition in a salt marsh?
   - suspended-sediment concentration (SSC) in the shallows ?
   - where and when?
   - other site attributes: wave climate, marsh edge morphology?
3. Collect data to support development of models of marsh resilience.

Whale’s Tail Marsh south in South San Francisco Bay

- Large wave fetch
- steep scarp/erosional edge
- Proximity to ongoing marsh restoration

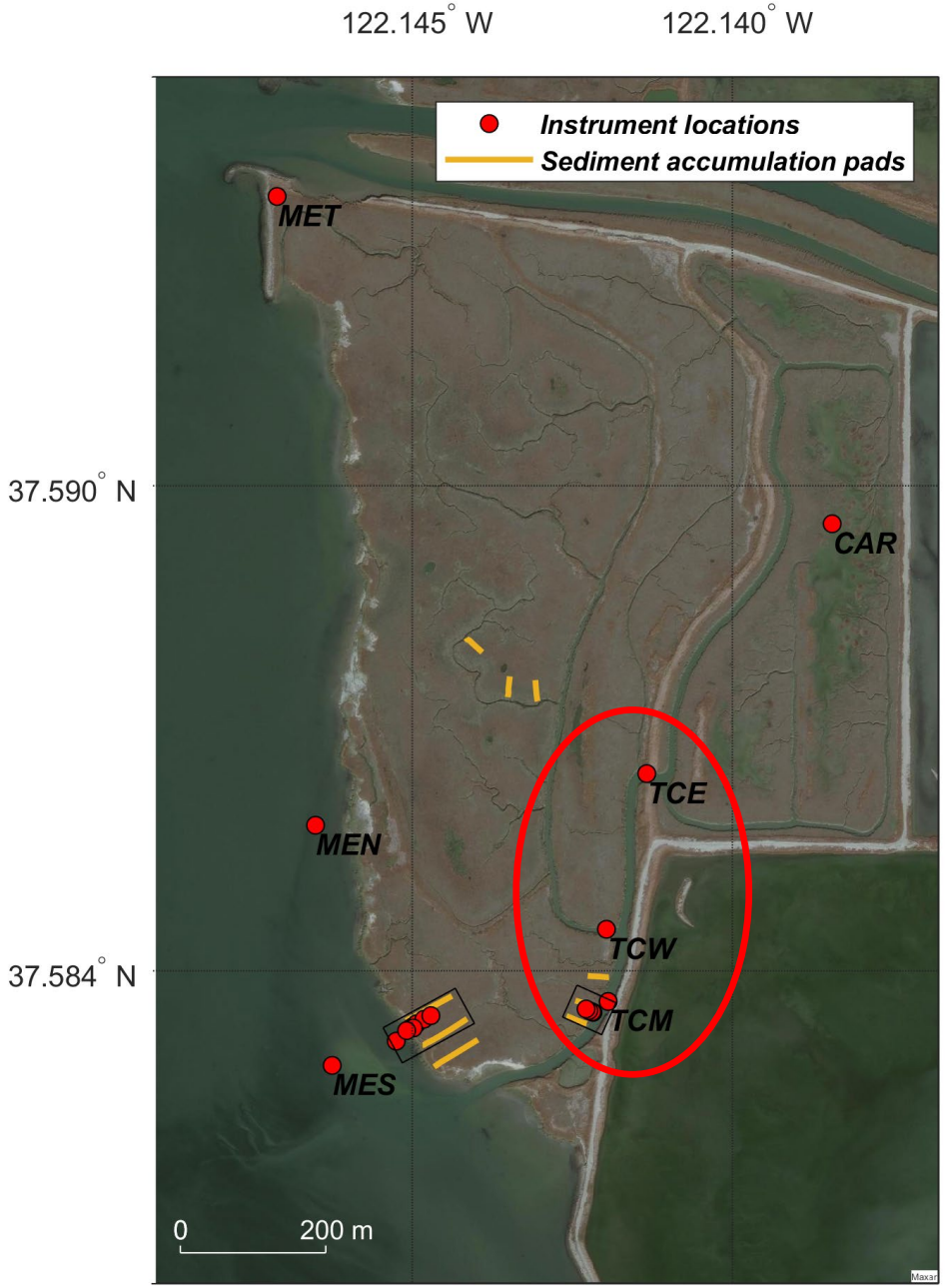


Data collection

Two study periods:

- May-June 2021 (summer)
- Dec 2021-Feb 2022 (winter)

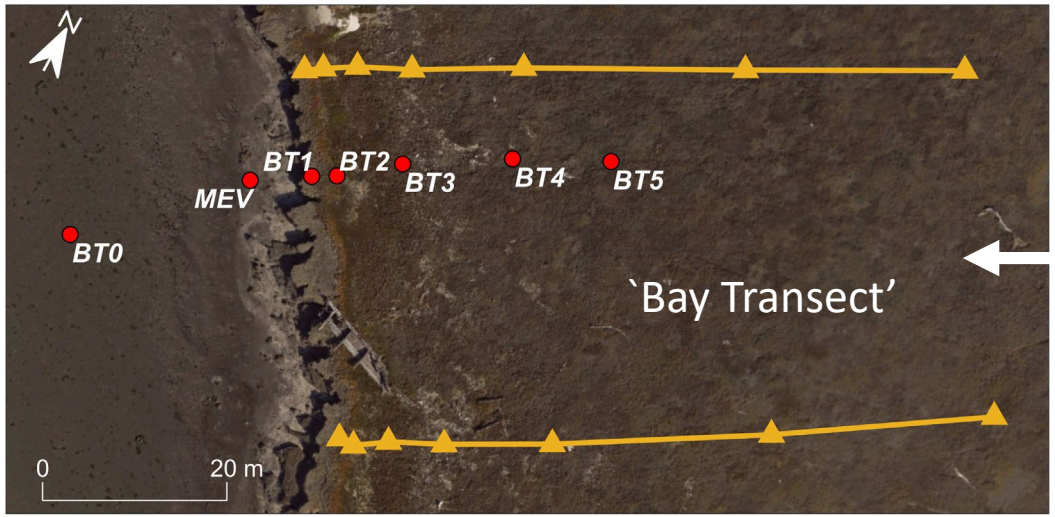
1. Marsh edge position, to track erosion
2. SSC, water level, waves, currents
   - Subtidal shallows,
   - intertidal shallows
3. Water and sediment flux in tidal creeks
4. Sediment grain size and bulk density
5. Marsh plain (next slide)

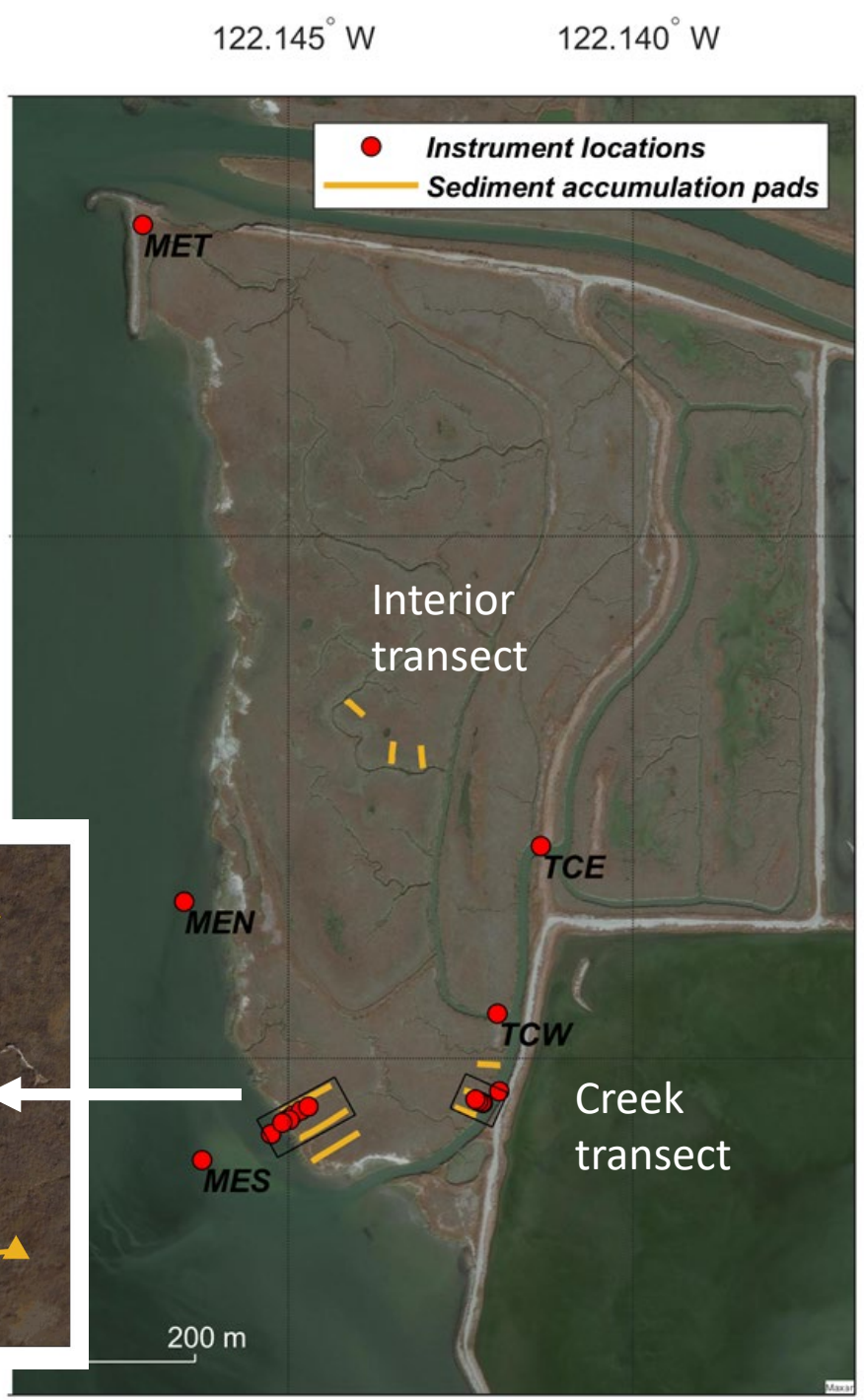


More Data collection

Marsh transects perpendicular to bay edge or channels

1. Deposition and accretion measurements (orange lines)
2. Vegetation characterization: % cover, height, density (orange)
3. SSC , waves, and water level at 10 min intervals (red)

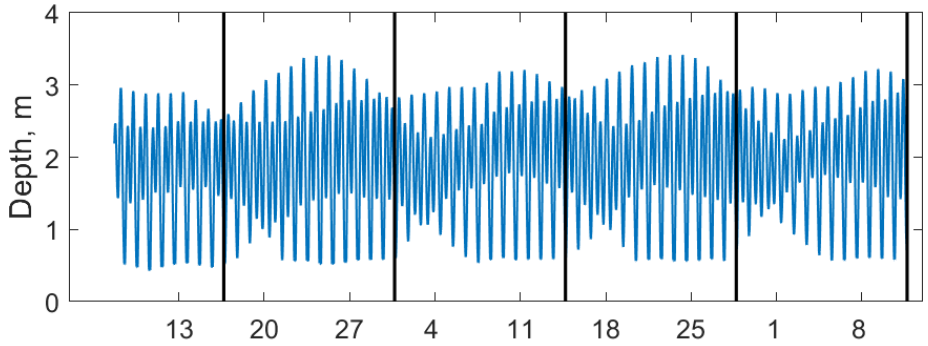


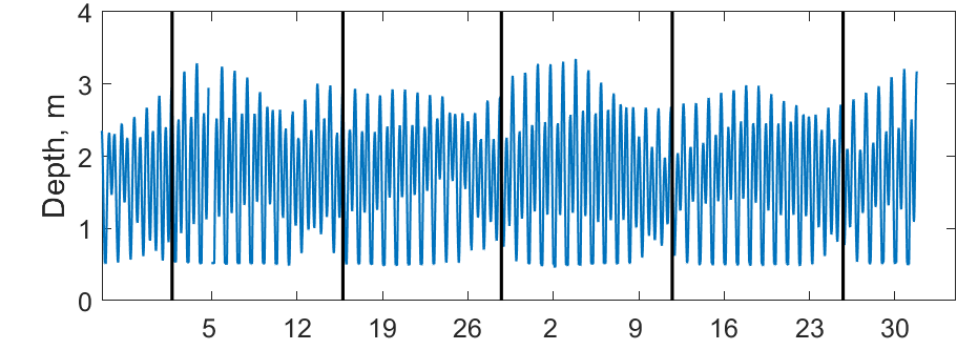


Bay shallows

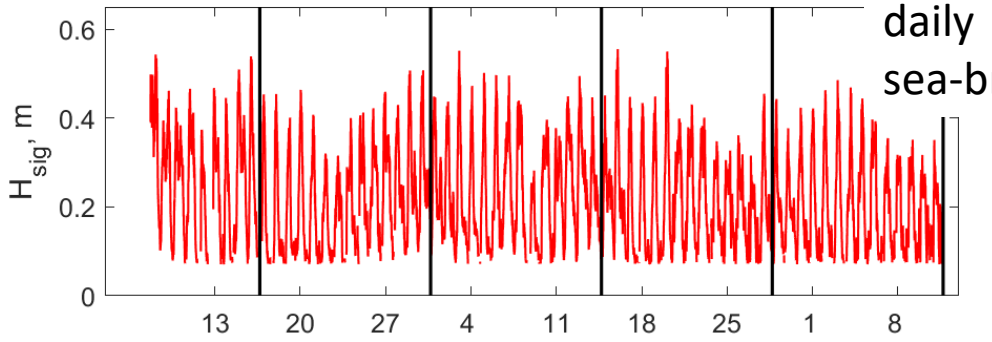
Summer

Winter

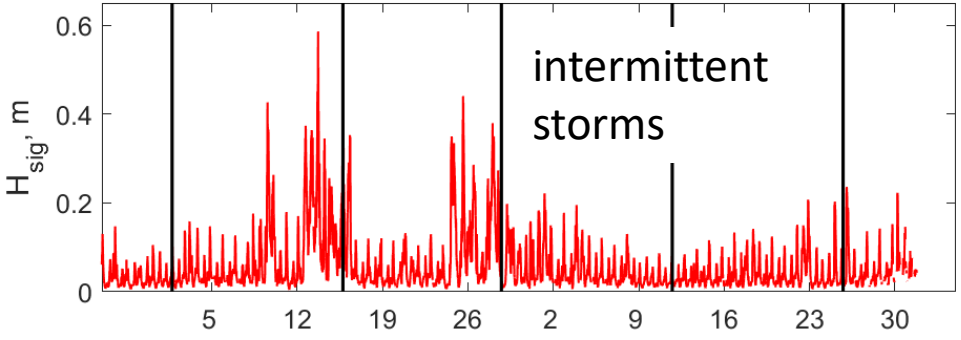




Significant wave height

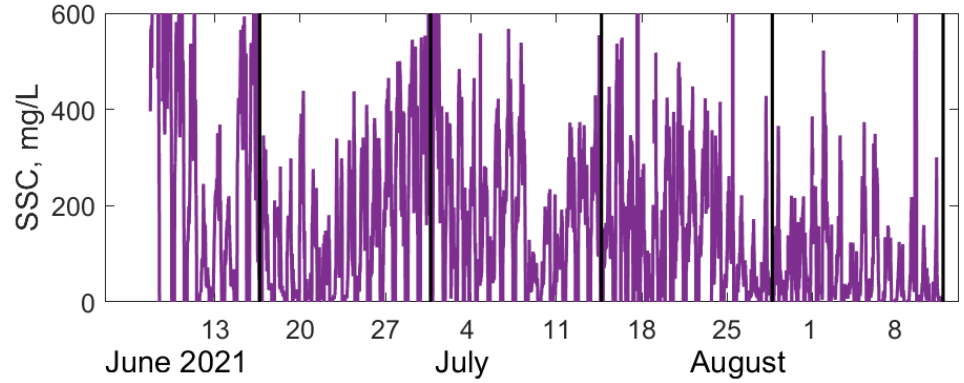


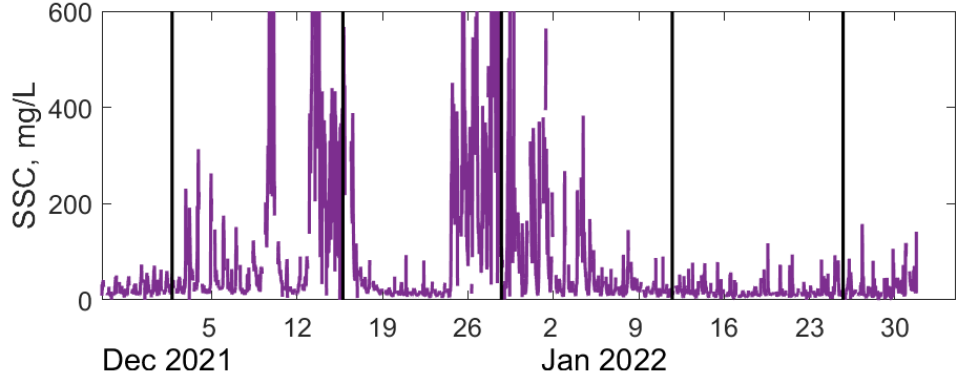
daily sea-breeze



intermittent storms

Suspended sediment concentration





Measuring lateral erosion

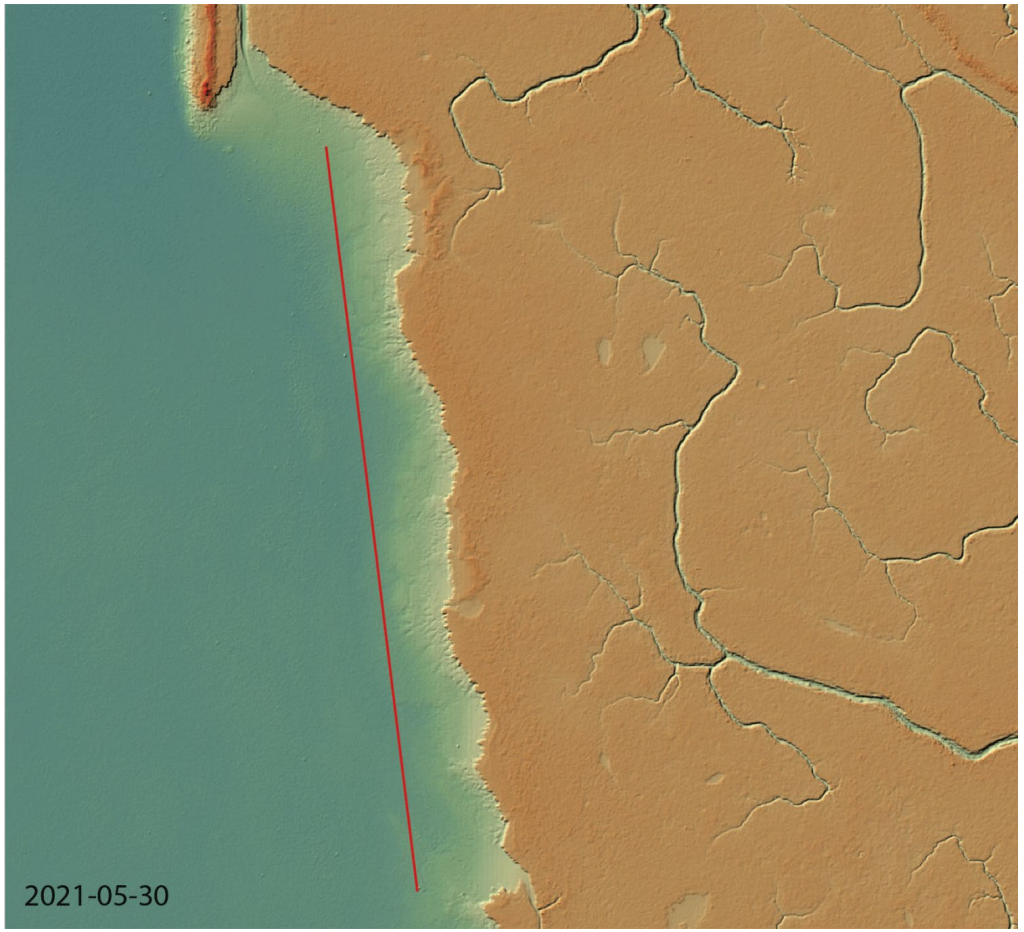
- Collected high-resolution imagery from an airplane at low tide
  - May 2021
  - Sept 2021
  - Nov 2021
  - Feb 2022
  - May 2022

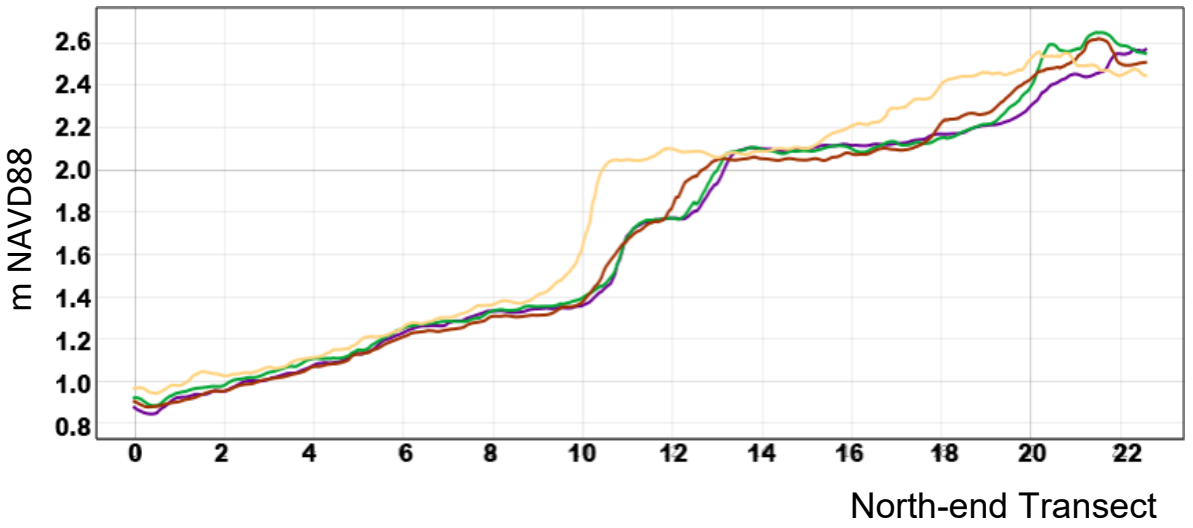
- Created high-resolution (5cm pixel) digital surface models of the marsh using Structure-from-Motion (SfM) Photogrammetry

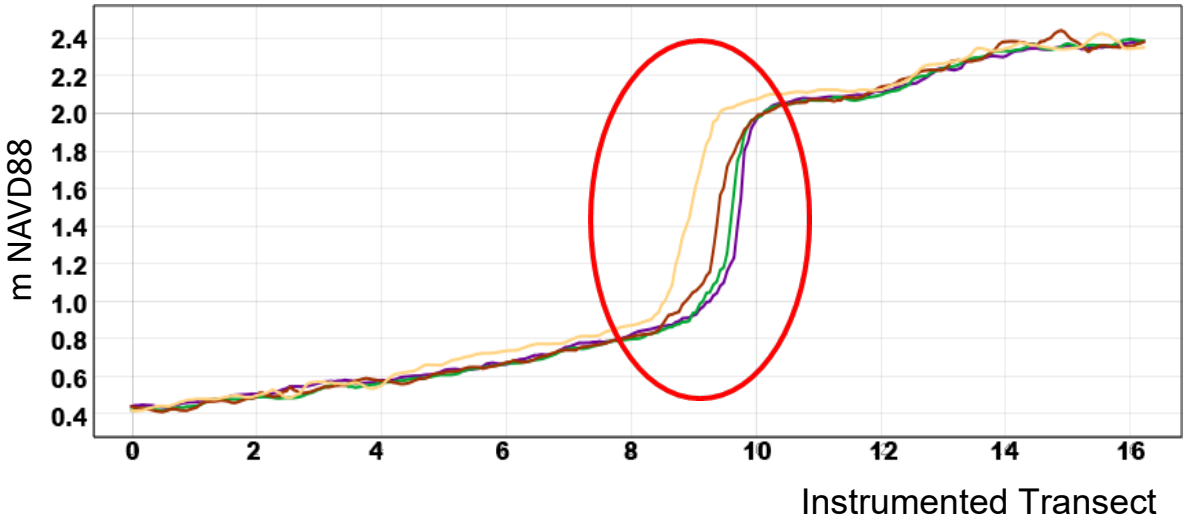
Ground control point

Orthographic image 02/10/2022

Clear erosion of the marsh edge

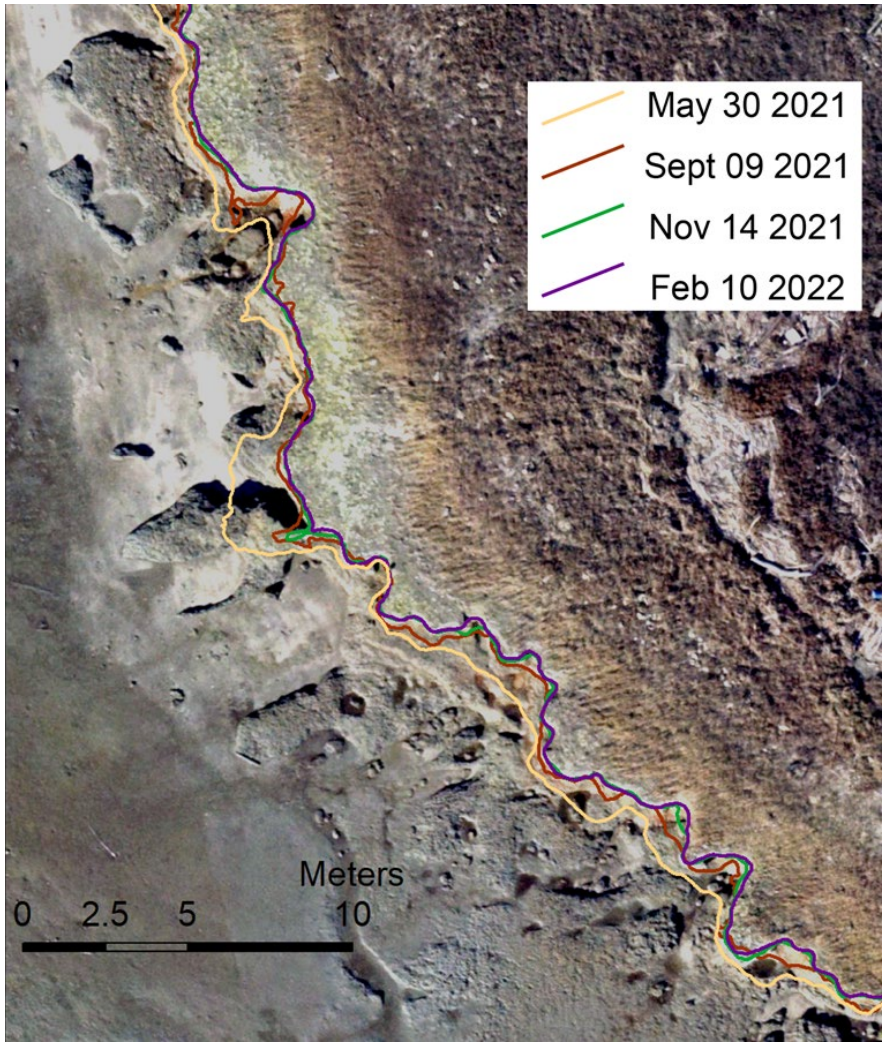






Marsh-edge lateral retreat rates

Time Period	Median Retreat Rate (m/yr)	% Marsh Erosional
May 2004 - May 2022 (~decadal)	-1.64	100
May 2021 - May 2022 (1 yr)	-1.46	95.2
May - Sep 2021 (summer)	-2.36	93.5
Sept - Nov 2021 (fall)	-0.35	60.4
Nov 2021 - Feb 2022 (winter)	-0.11	61.4
Feb - May 2022 (spring)	-1.81	94.0



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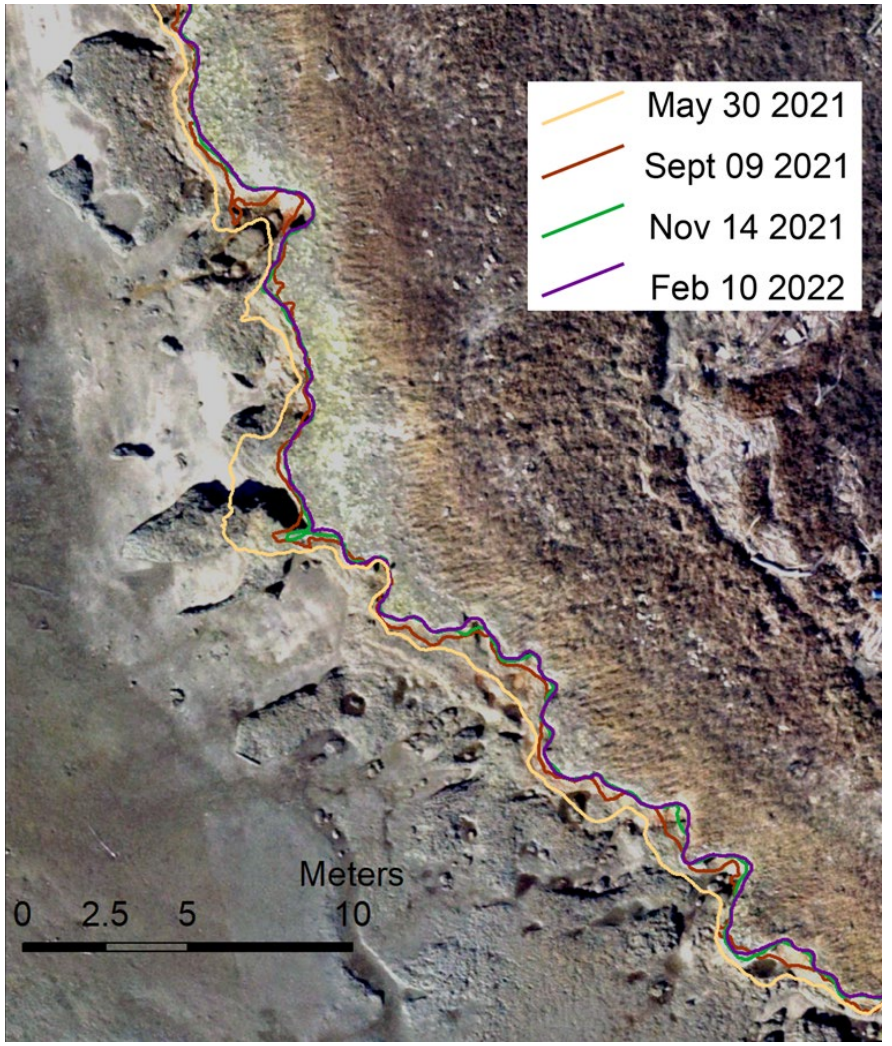


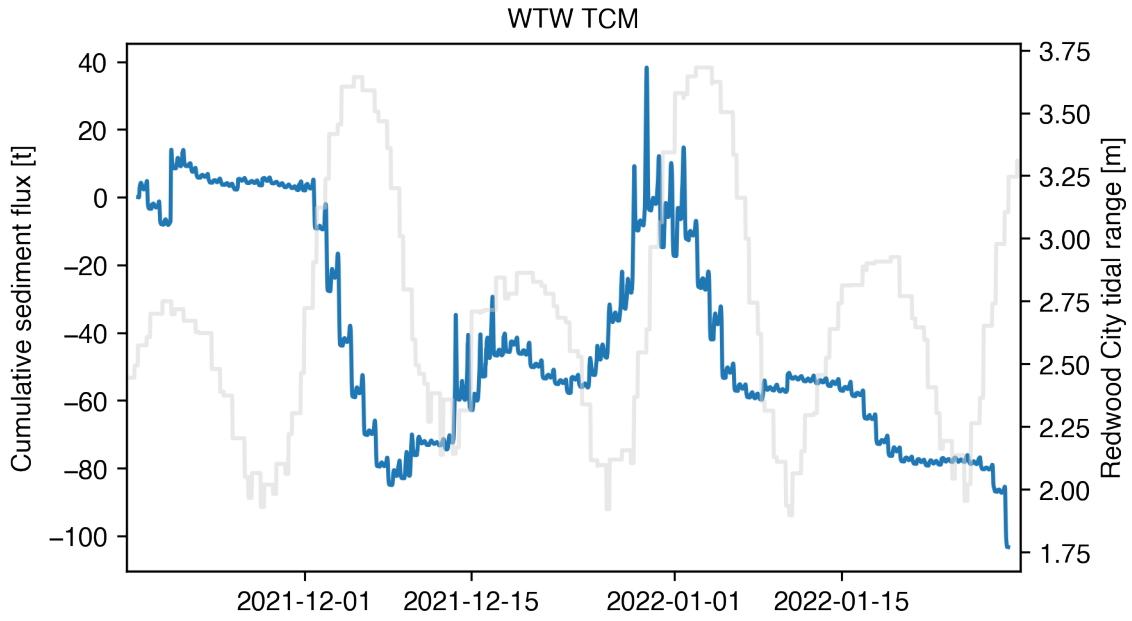
Most erosion in spring and summer: season of daily sea breeze

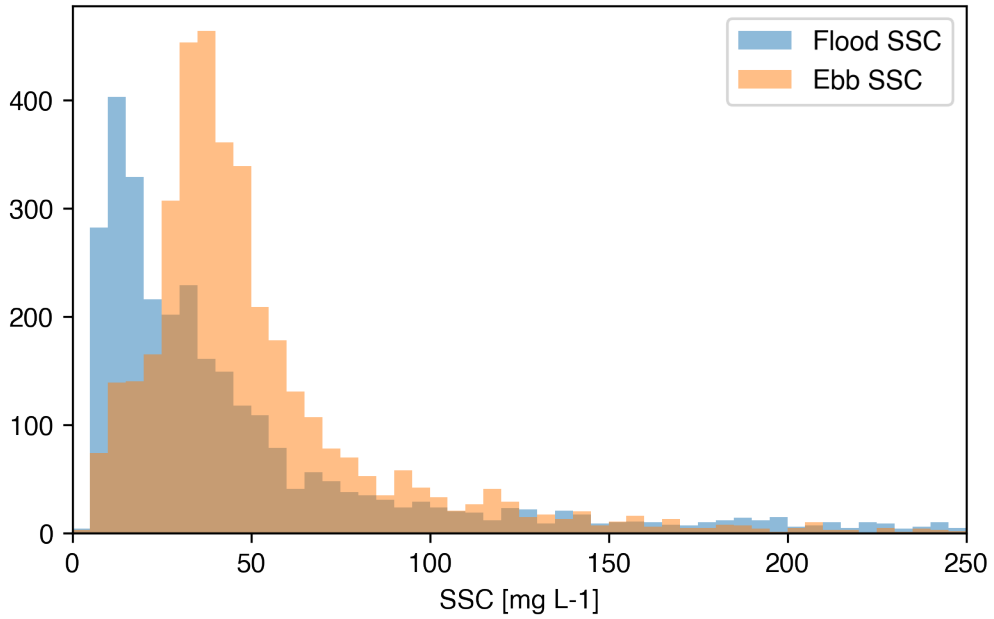
Tidal creek measurements

- 3 sites
- Water discharge (Q)
- SSC
- Water depth
- Suspended sediment flux (SSF)

Results: TCM winter

- Net export of sediment (~100 tons) through the main tidal creek
- Rate of export is greatest during large spring tides (`King tides')
- Import during weaker tides and storms
- Median SSC greater during ebb than flood tides (consistent with export).

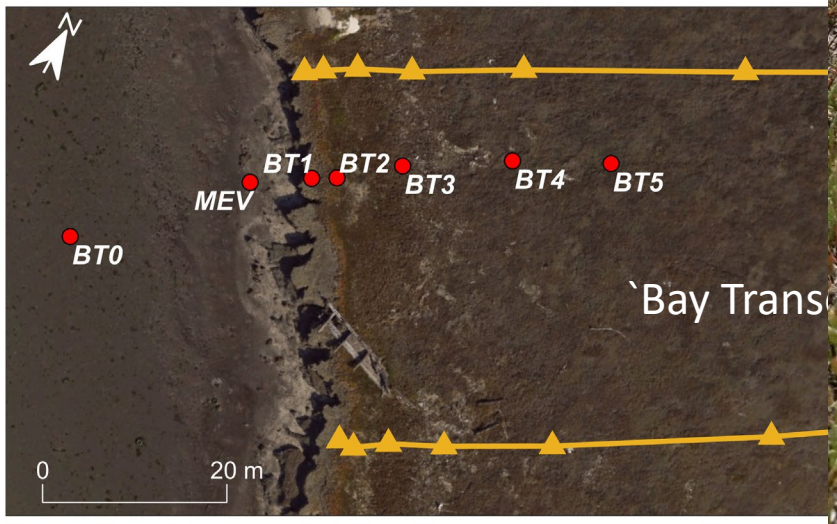




Measuring sediment deposition: sediment pads

Each region:

- 3 transects
- 6-7 distances per transect
- 3 replicates per distance
- collected every 14 days, dry mass measured

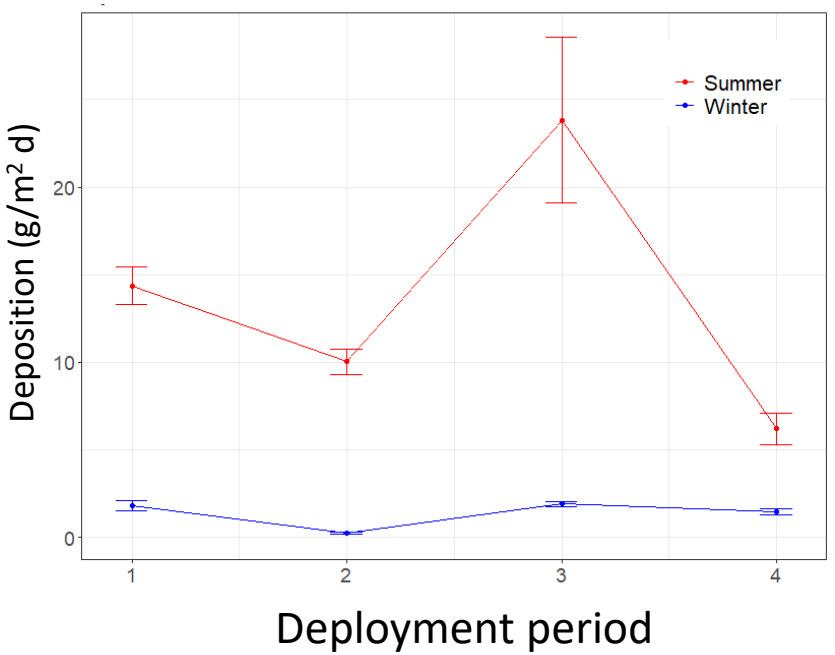


Deposition: temporal variation

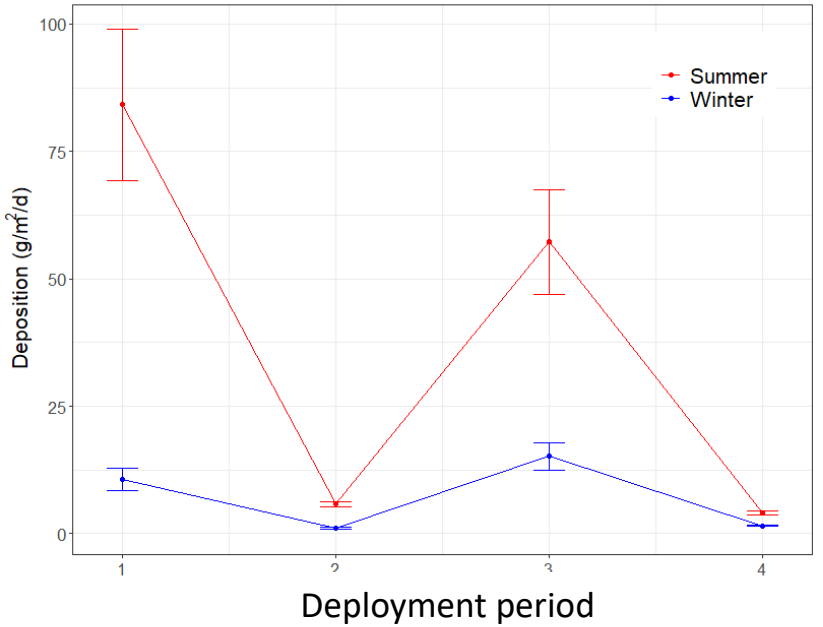
- Deposition much greater during summer than winter at all sites
- Deposition greater in periods with big spring than weaker spring tides
- Deposition greatest on channel transect, and lowest on bay transect

Averages across transects

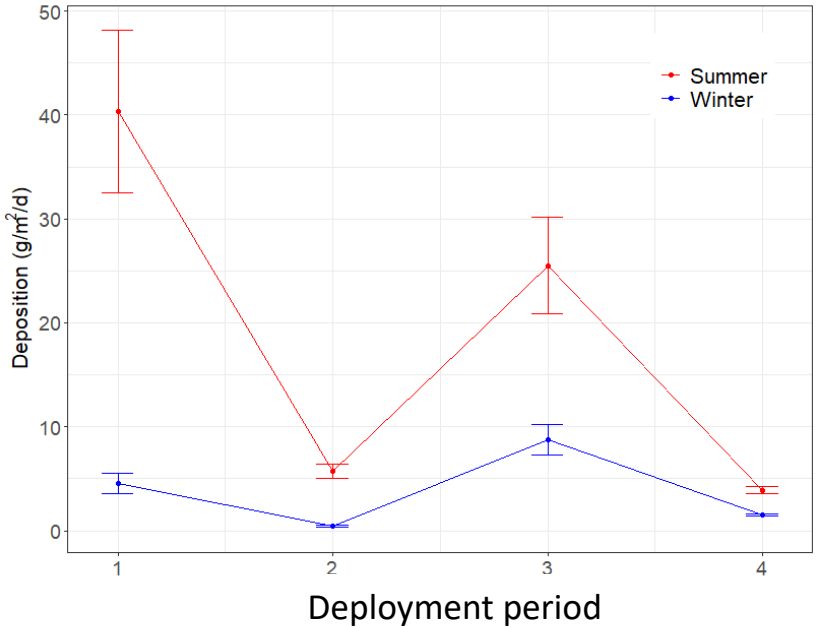
Bay transect



Channel transect



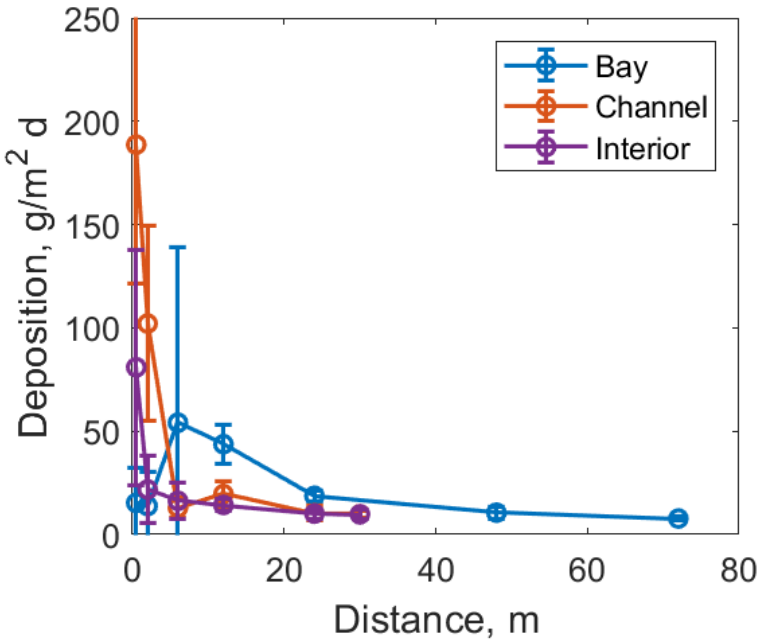
Interior transect



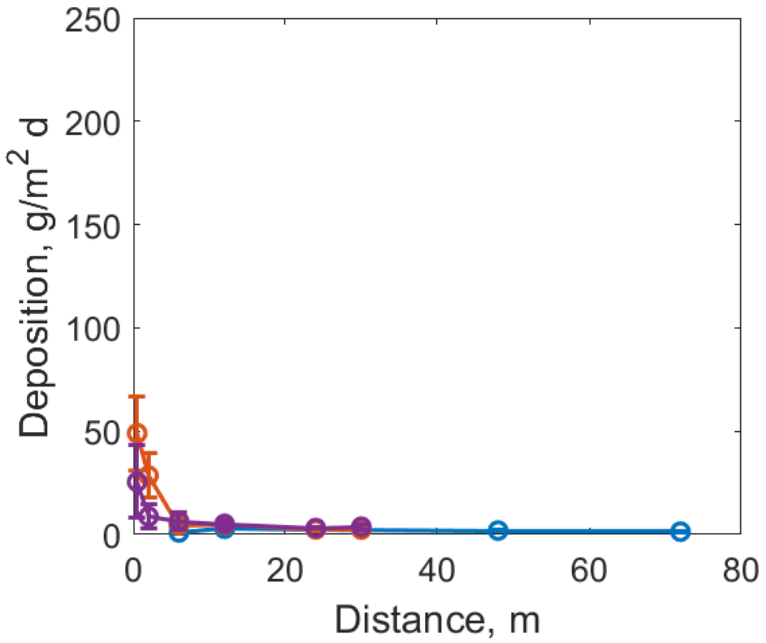
Deposition vs. distance from source

- Deposition greater in summer than winter
- Deposition decreases with distance from sediment source
- Maximum deposition further landward on Bay transect

Summer: period 3



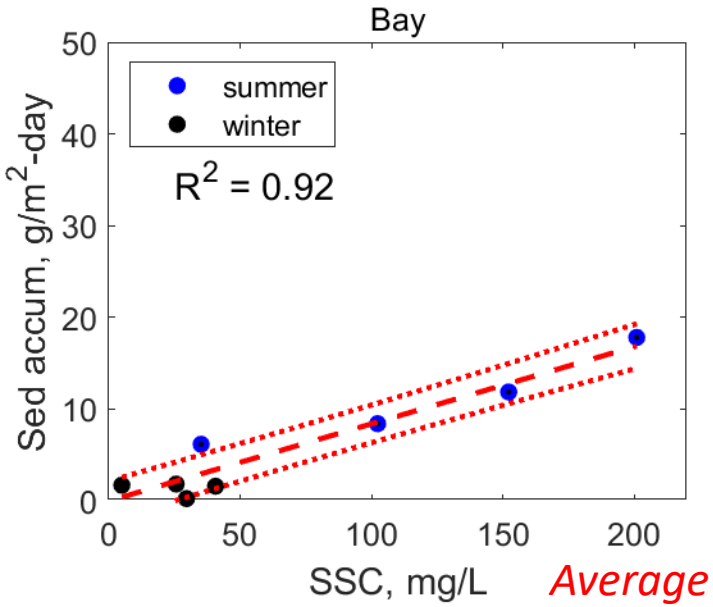
Winter: period 3

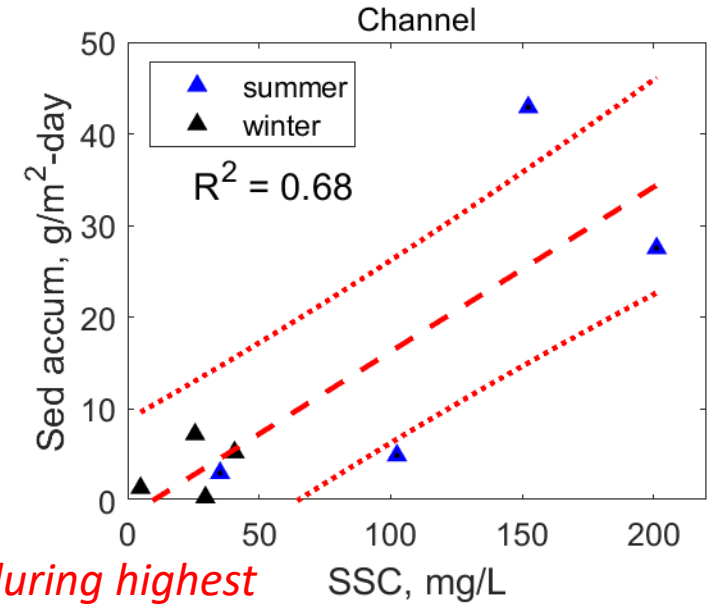


To investigate influence of conditions in the bay, we used the distance-weighted average deposition for each period and transect.

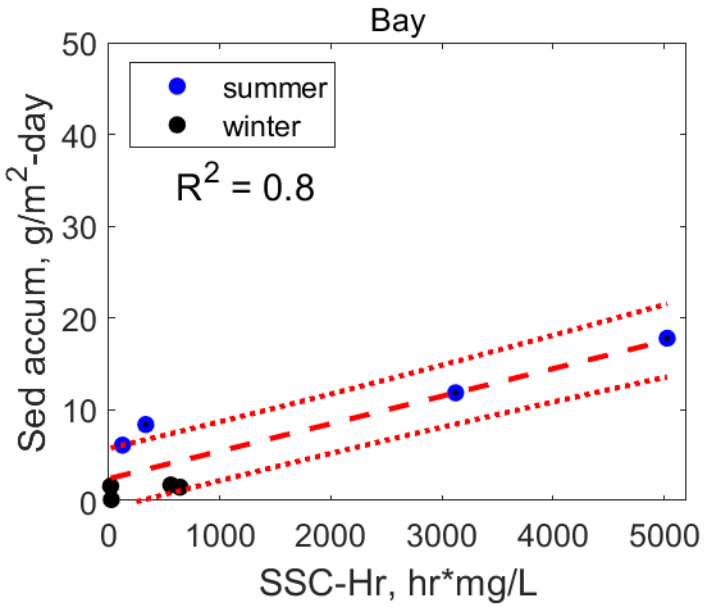
Deposition vs. SSC in bay shallows (station MES)

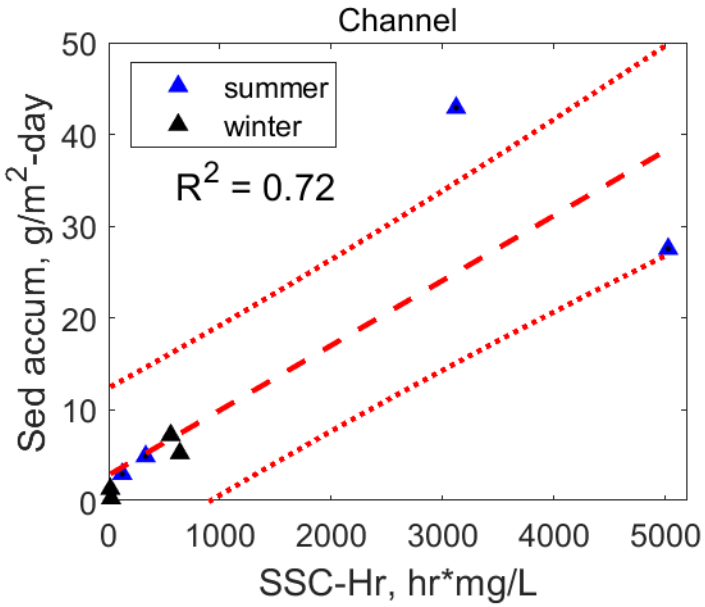
- Very strong relationship on Bay transect, weaker (but significant) on Channel transect
- Accounting for inundation time as well improves correlation slightly for Channel transect





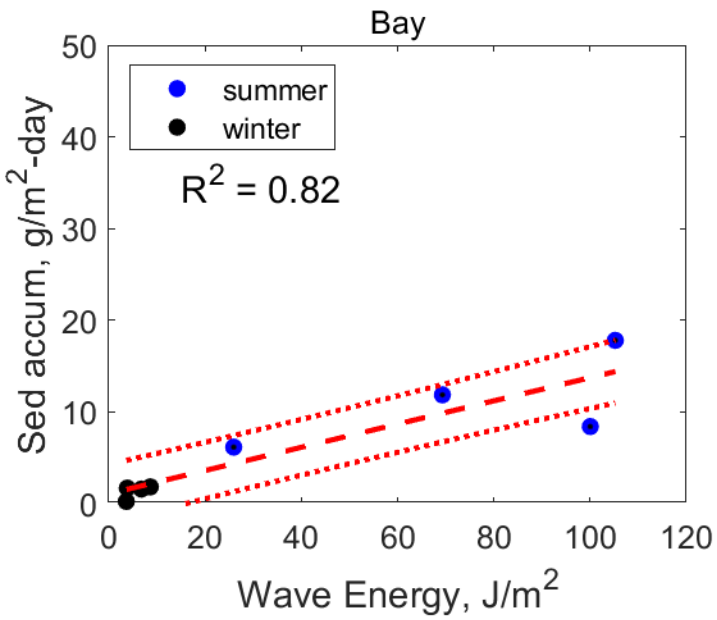
Average during highest tides of each 14-day period

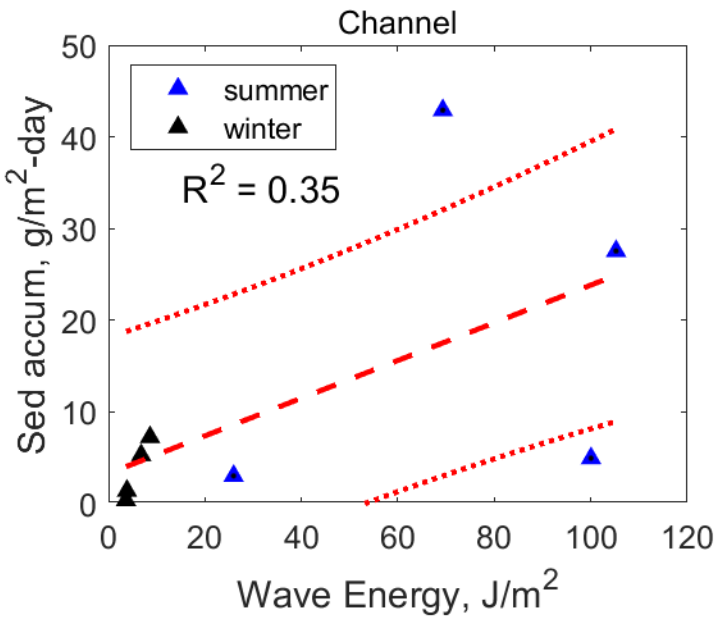




Deposition vs. wave energy in bay shallows (station BMV)

- Very strong relationship on Bay transect, weaker (but significant) on Channel transect





Marsh edge measurements show that 3,048 m^3 of sediment was eroded from the marsh edge between May 2021 and May 2022.

Approximately 2.28 tons

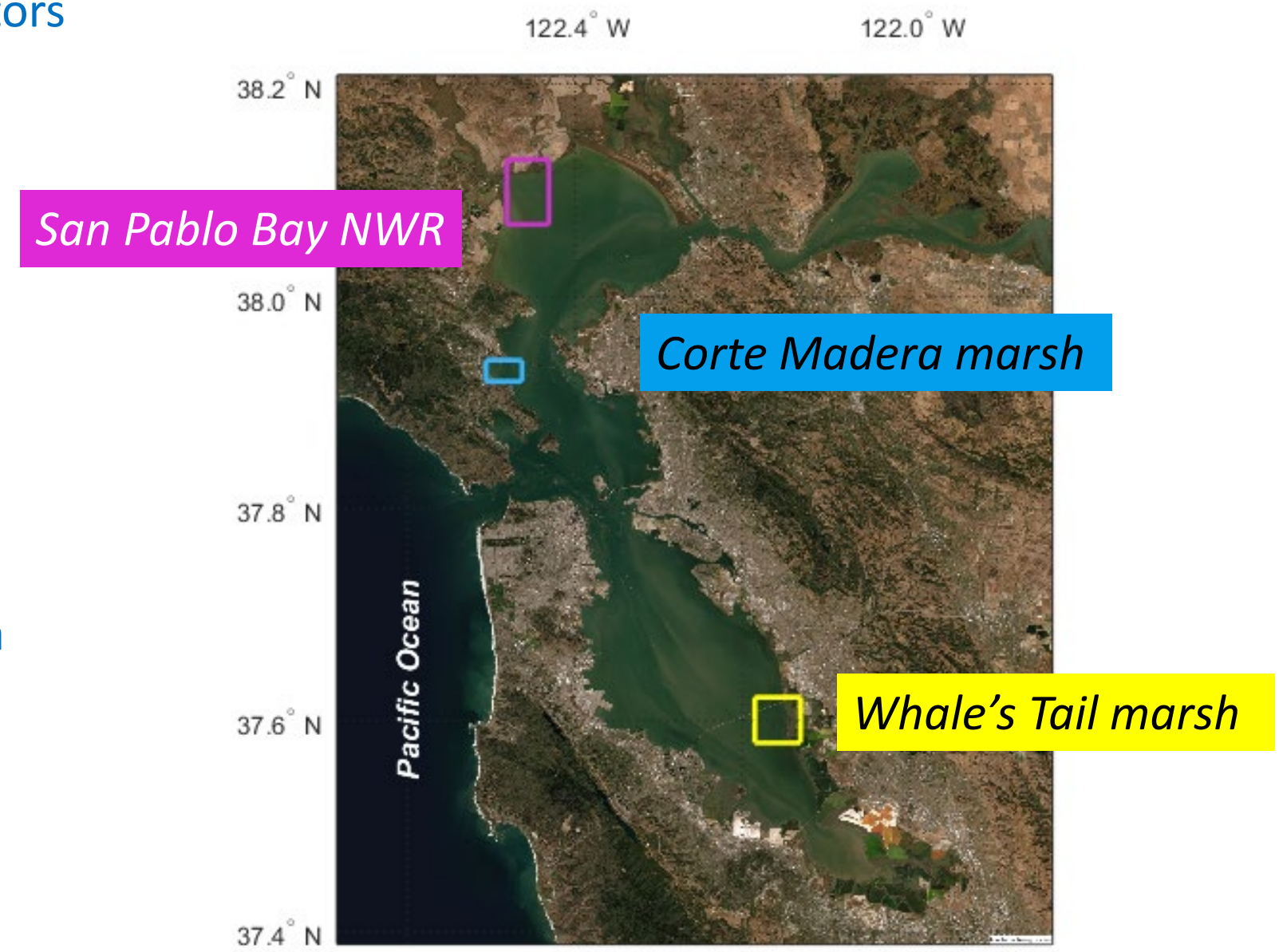
Corresponds to 8.7 $g/m^2/day$, evenly distributed across the marsh top over a year: same order of magnitude as observed deposition.

The relative importance of factors related to deposition in San Francisco Bay marshes varies depending on:

- Proximity to Delta and local sediment sources
- Wave exposure
- Marsh edge type
- Vegetation type

In spring 2022, we started data collection at two more sites (*2022/23 RMP special study*).

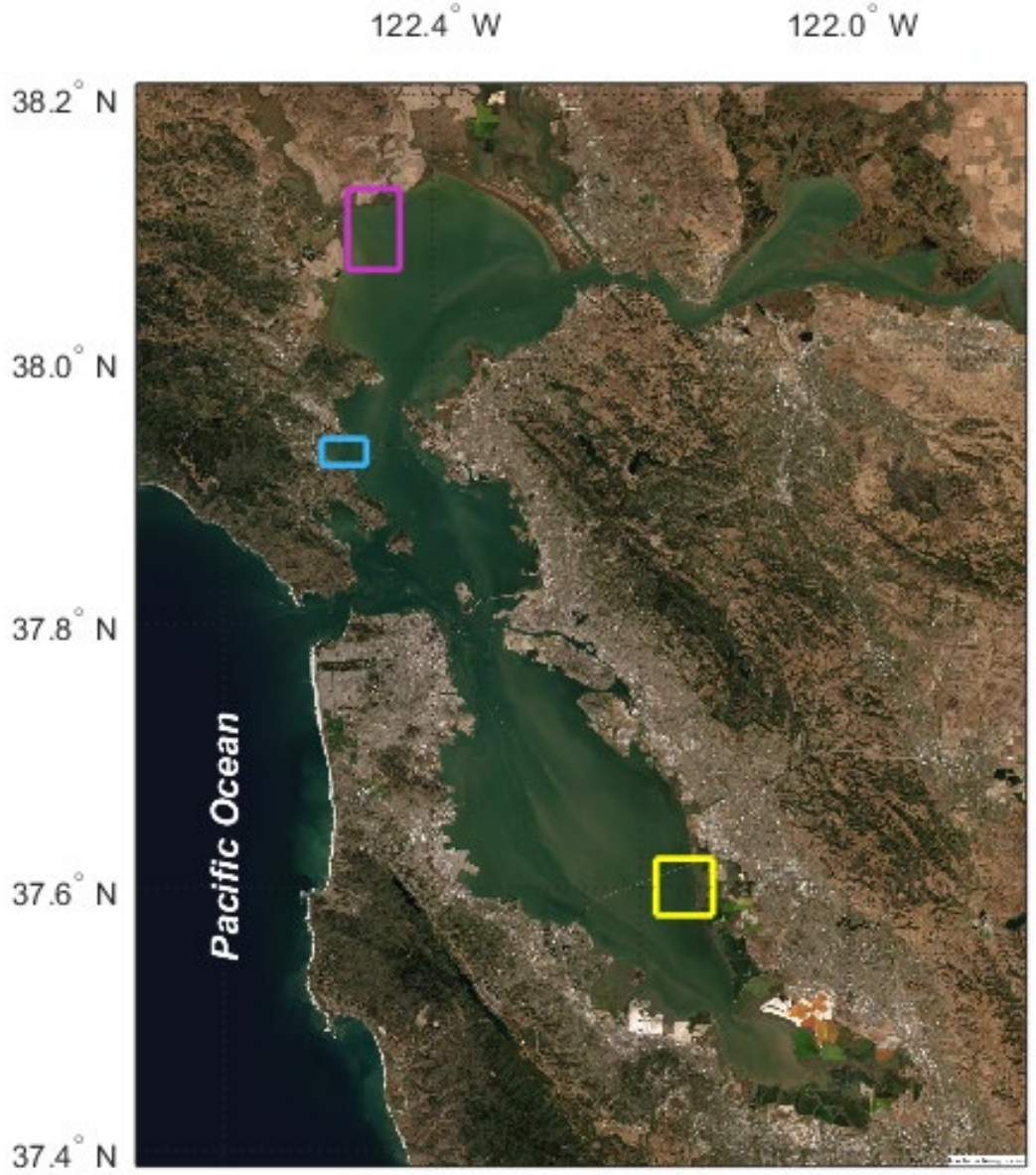
Less intensive data collection, longer duration



Ramped edge, fringing Spartina

Scarped edge ~0.5 m

Scarped edge 1-2 m



Conclusions: Whale's Tail marsh

The marsh edge is eroding laterally, and the rate of erosion is greater in summer than winter

Tidal creeks are exporting sediment, and the rate of export is greatest during large spring tides.

Deposition on the marsh plain

- much greater in summer than winter
- increases with inundation time (large spring tides)
- greater on the Creek and Interior transects than Bay

Greater wave energy in summer leads to

- Higher SSC in shallows
- Greater deposition on marsh plain
- Greater erosion of marsh edge