Integrating biogeomorphic feedbacks in the coastal zone to bolster coastal resiliency

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Overview

The Challenge: protecting shorelines with ecologically friendly and sustainable infrastructure

A Possible Solution: living shorelines (cons
or without additional structures; LS)

But Potential Complication: interactions with submersed aquatic vegetation (SAV) beds

Main research questions – do living shorelines:

- Reduce shoreline erosion (**performance**)?
- Impact submersed aquatic vegetation (SAV) benthic habitat and/or distributions in adjacent shallow waters (subtidal) (**impacts**)?
- Increase net sediment/nutrient burial in the coastal zone (subtidal to intertidal) (**co-benefits**)?

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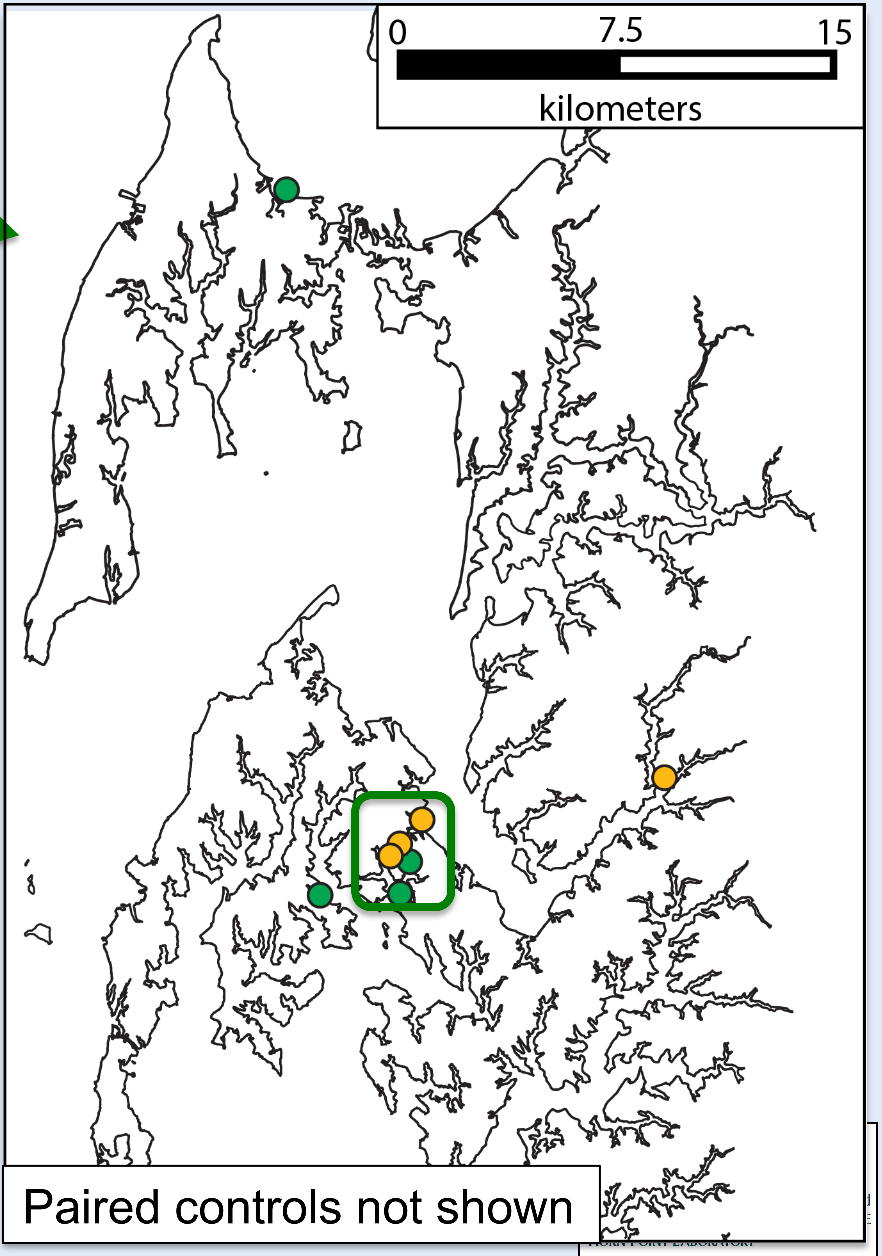
Shoreline Erosion

1. Chesapeake Bay (CB) focus but ubiquitous problem
   - 33% of CB's shoreline is eroding; 70% of the Maryland portion
   - 85% of CB's shoreline is privately owned

2. Past efforts focused on "hard" approaches like breakwaters and rip rap
   - ~25% of CB shoreline already hardened, up to >50% in some areas

3. Recent push (including Maryland laws in 2003) for living shorelines as alternative – but, how do they impact adjacent ecosystems, especially SAV? And, what are the trade-offs in ecosystem services?

Study Sites



8 sites with paired “controls” (nearby natural shorelines) in mesohaline CB:

- Weighted-bed density of SAV from 1978-2005 (GIS analysis of VIMS aerial data)
- 4 sites with persistent, dense SAV (green)
- 4 sites without SAV (yellow)

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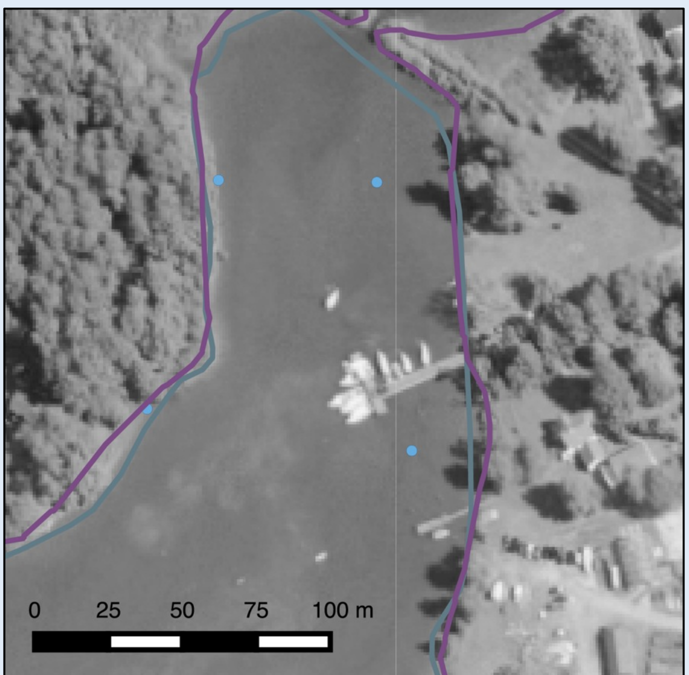
Performance: erosion rates before and after LS installation

GIS analysis:

- Historical: difference of 1942-1994 MGS shoreline surveys perpendicular to site
- Current: georeferenced aerial photos from VIMS; digitized shorelines in 2003 (before any LS installed) and 2017 (first field survey)

Feb 2007 Google Earth

LS
natural



Jul 2003 VIMS
Purple = 1994 shoreline
Blue = 1942 shoreline

MGS = Maryland Geological Survey
VIMS = Virginia Institute of Marine Science
Thank you Dave Wilcox and JJ Orth (VIMS)!

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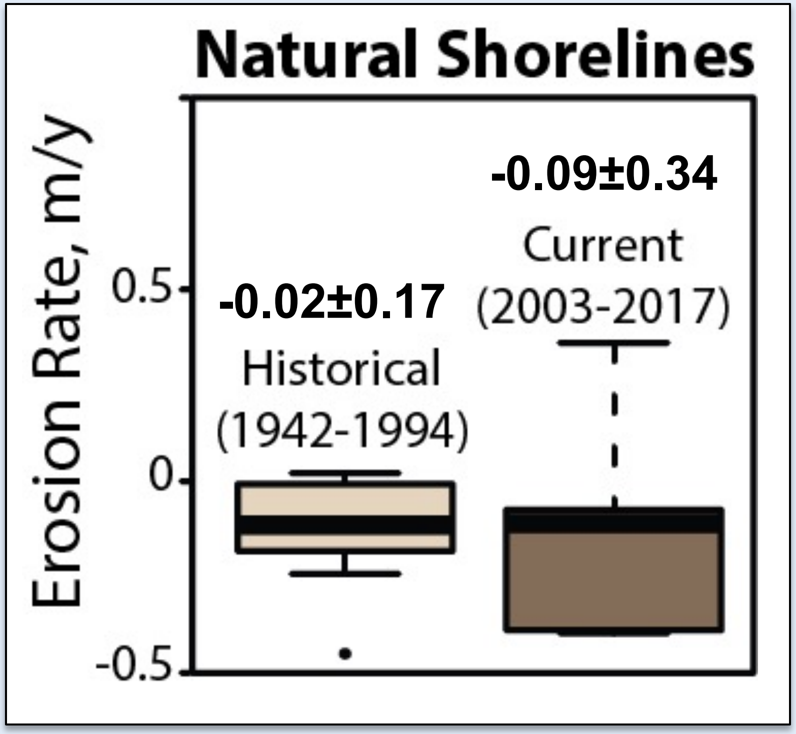
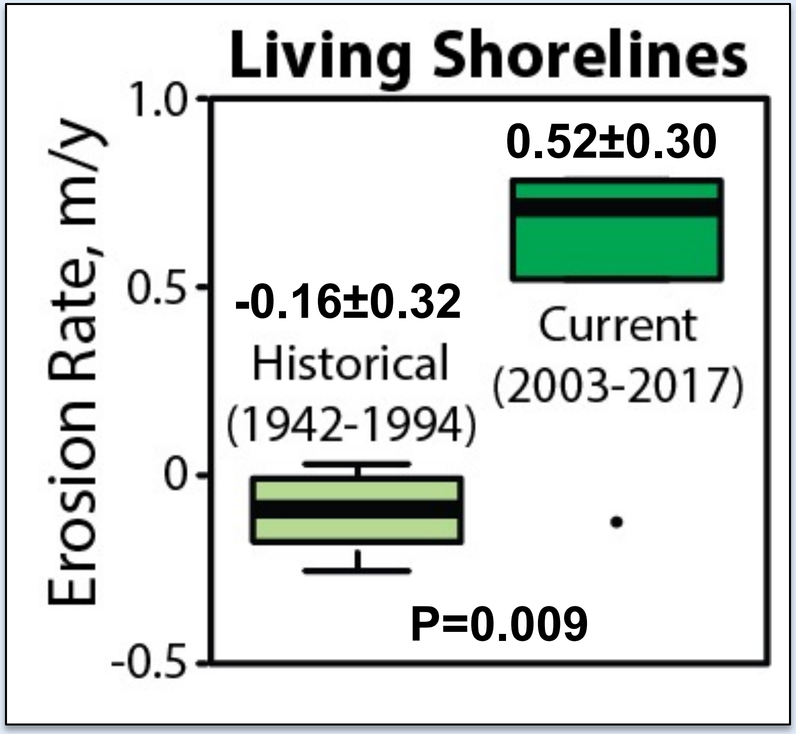
Erosion rates before and after LS installation



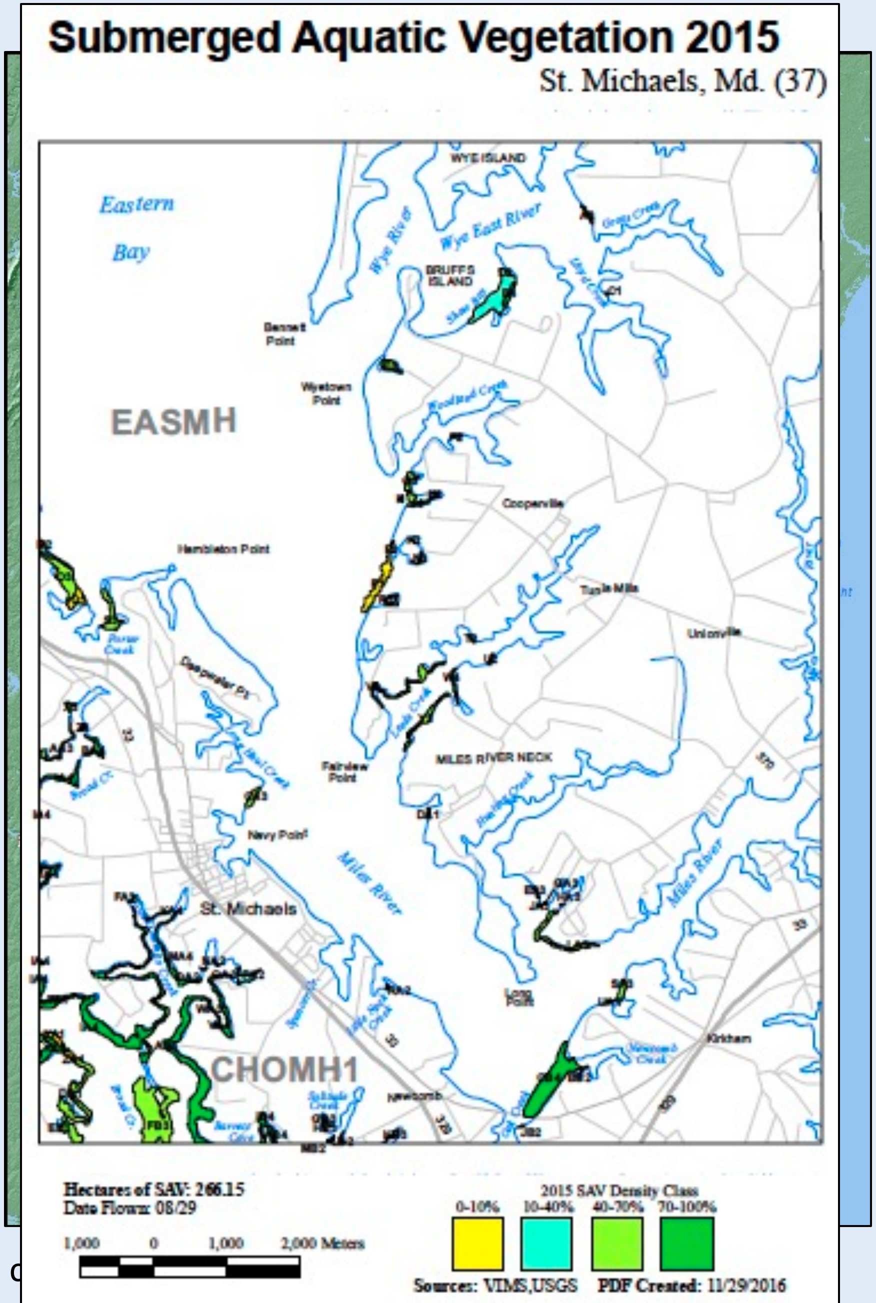


Trend of increasing erosion at natural shorelines but not statistically significant (p>0.10)

Significant accretion at living shorelines from installation (~instantaneous change rather than rate)

Net accretion occurs at living shorelines due to installation, while **erosion continues at or above historical rates at natural** sites

Impacts: Does living shoreline installation impact SAV?



Aerial photography from VIMS 1978, 1984-present w/ground surveys

Segments (large areas) and quads (smaller areas)

Delineate density classes: 0-10%, 10-40%, 40-70%, 70-100%

Photographs, GIS data on VIMS SAV website (http://web.vims.edu/bio/sav)

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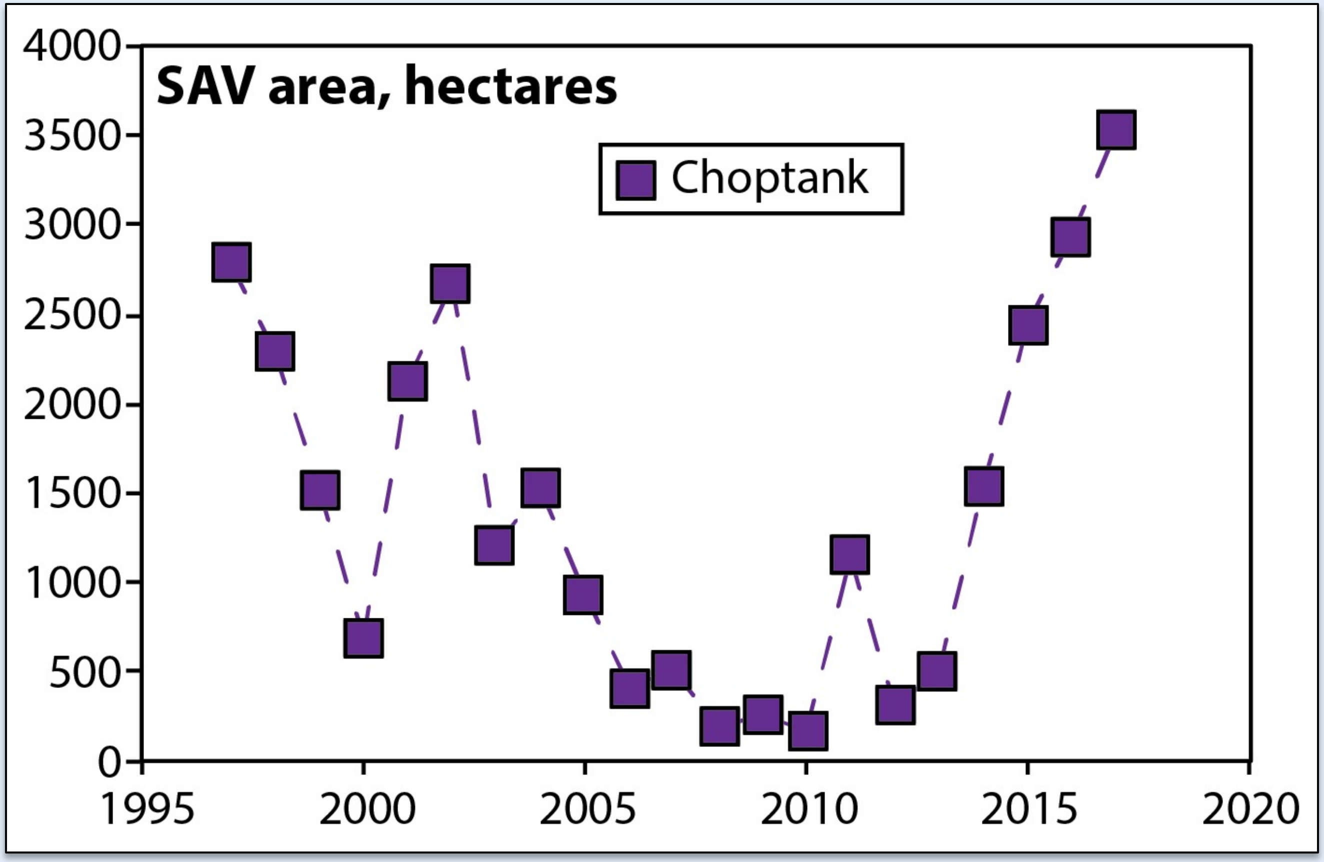
SAV area within segment – lots of variability!



- Area high at start of window (1997), decreases to 2000, recovery to 2002
- Decline after 2002, sustained low areas from 2005-2012, except for 2011
- Resurgence from 2012 to 2017

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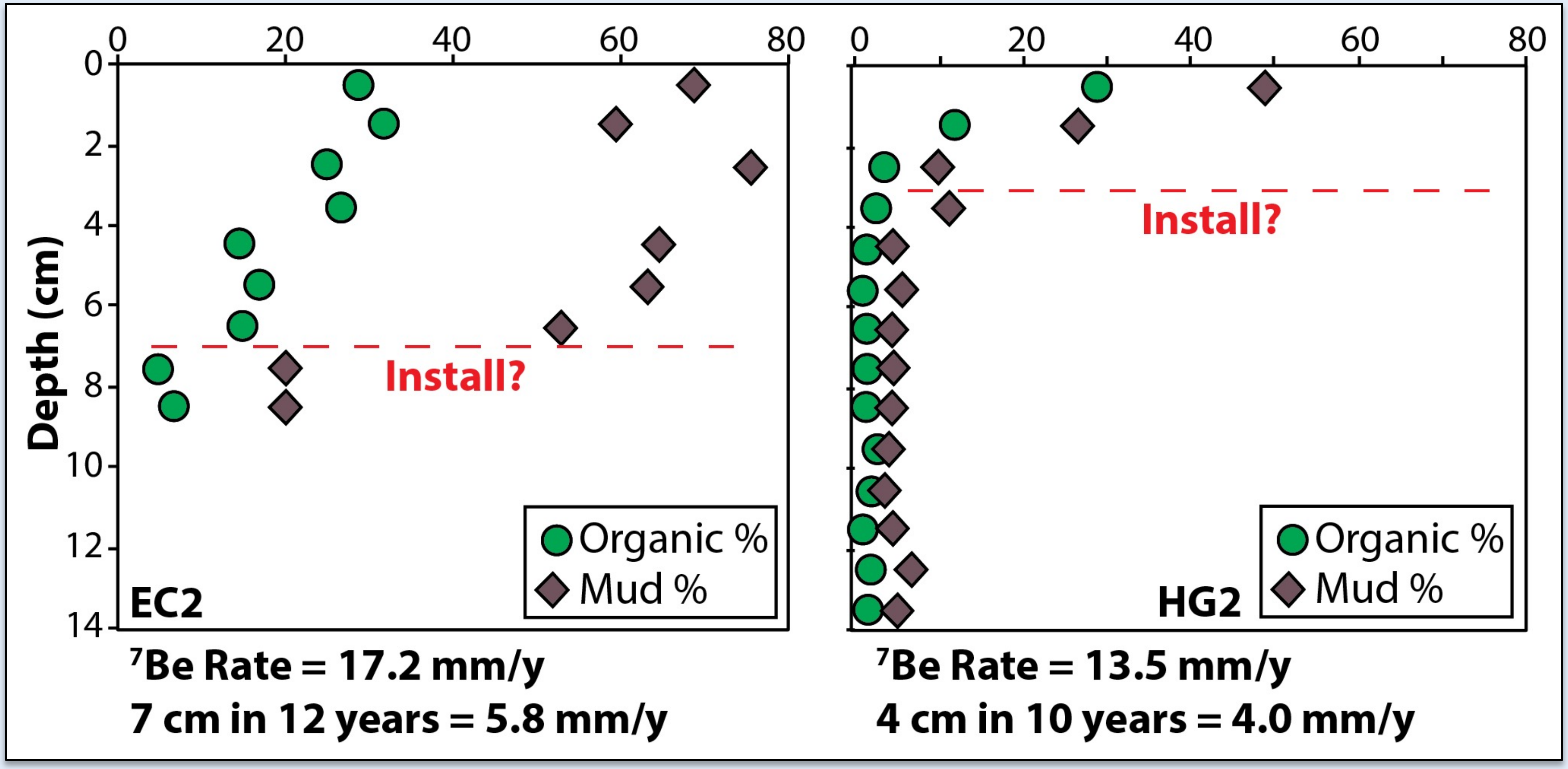
Year	Quad area (ha)	SAV – site	SAV – reference
1997	15.03	4	0
1998	35.60	3	3
1999	17.42	0	0
2000	0	0	0
2001	0	0	0
2002	0	0	0
2003	0	0	0
2004	25.42	4	4
2005	18.14	4	4
2006	16.65	3	3
2007	0	0	0
2008	0.52	0	0
2009	0	0	0
2010	0	0	0
2011	2.31	0	0
2012	3	0	0
2013	1.43	0	0
2014	1.26	0	0
2015	1.53	0	0
2016	8.30	0	0
2017	3.62	0	0

Quad area categories (ha):
0 = Absent
0-9 = Low
9-18 = Medium
18-27 = High
27-36 = Very high

Density categories (VIMS):
0 = Absent
1 = Low
2 = Medium
3 = High
4 = Very high

- 2005 install
- SAV disappears from site and nearby reference at same time
- SAV persists in quad at lower levels
- No obvious relationship to LS installation

Co-benefits of burial – example rates in the marsh of LS



- Change in sediment character (mud/organic content) likely from sand layer during installation (below line) overlain by marsh accretion (above line)

- ^{7}Be (half-life 53.3 days) rates are ~2-3 times higher than estimate from install horizon – recent acceleration, delay in first few years?

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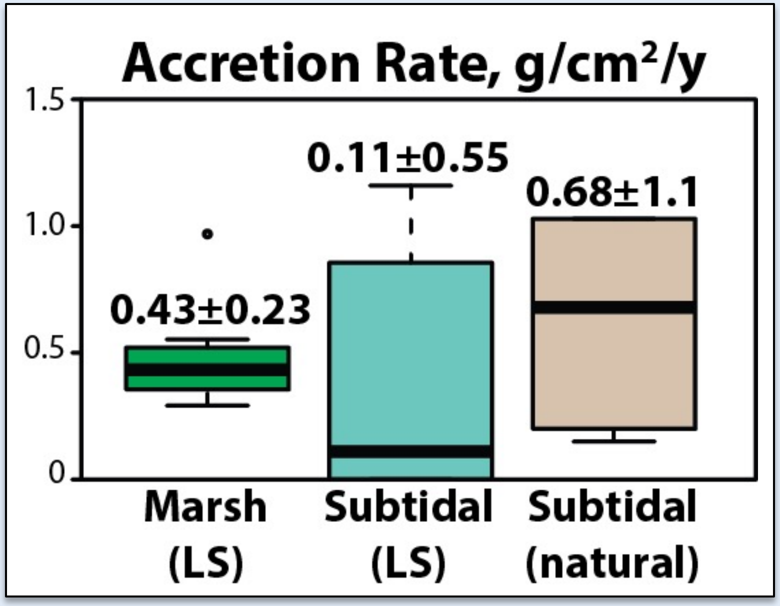
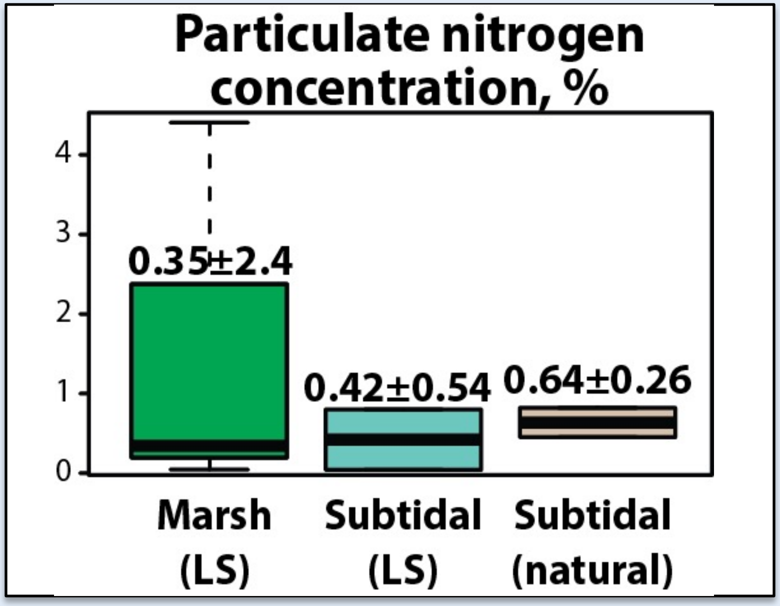
Nutrient burial rates





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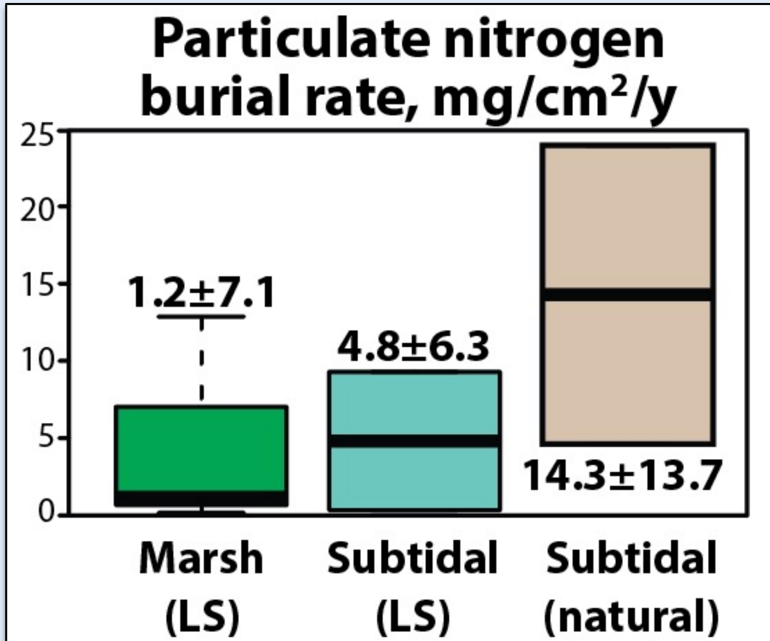
- Median accretion rate for marsh + subtidal LS ~ rate at natural shorelines; coincidence?
- **Very** limited PN concentration data; marsh value esp. variable
- PN burial rates calculated for sites, not using average values



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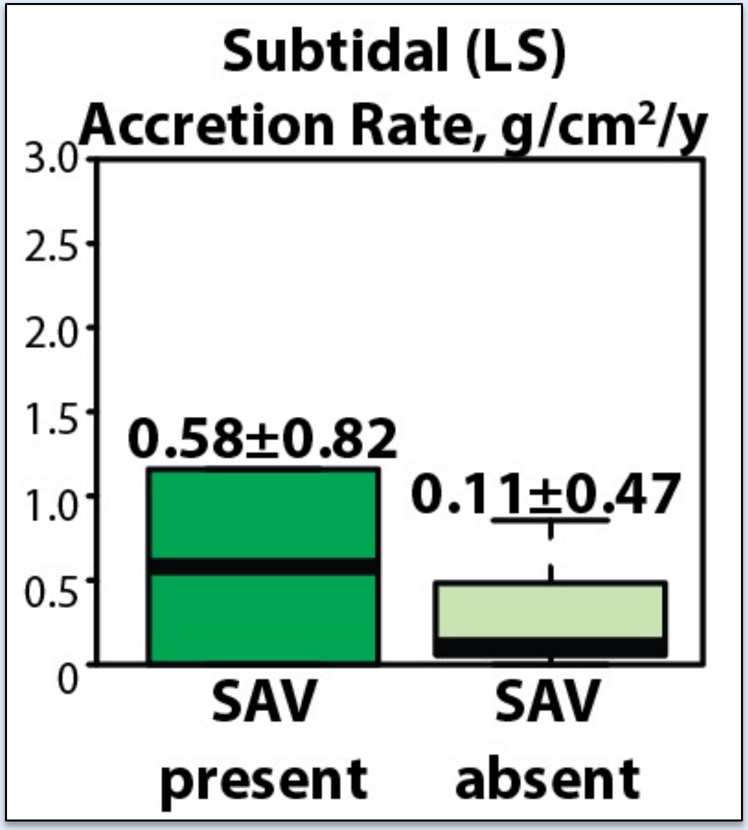
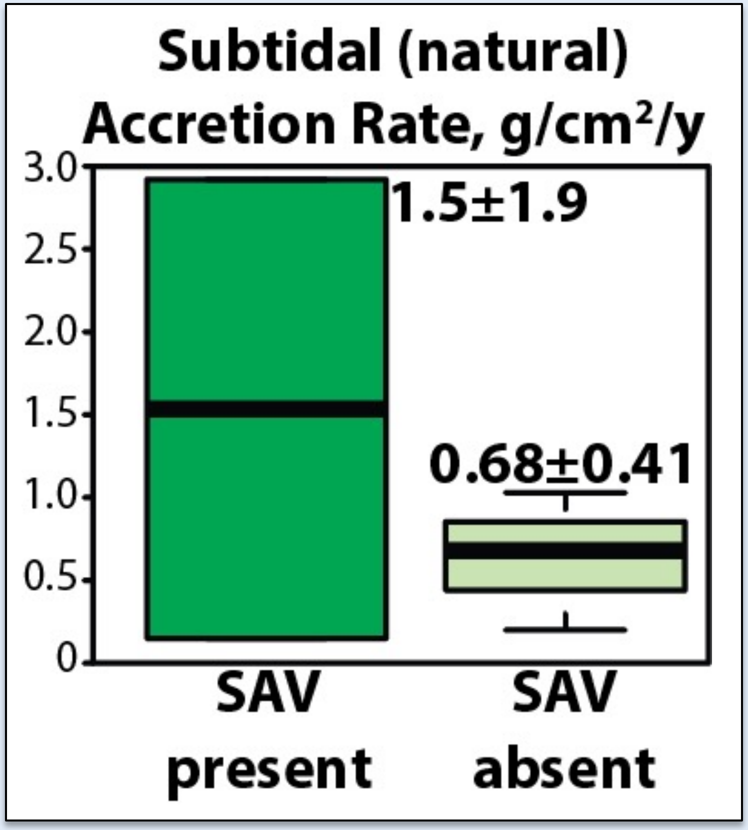
Burial rates – role of SAV





- Accretion rates are higher when SAV is present for both shoreline types
- Indicates SAV is effective at trapping sediments, though differences are not significant (variability, number of sites)

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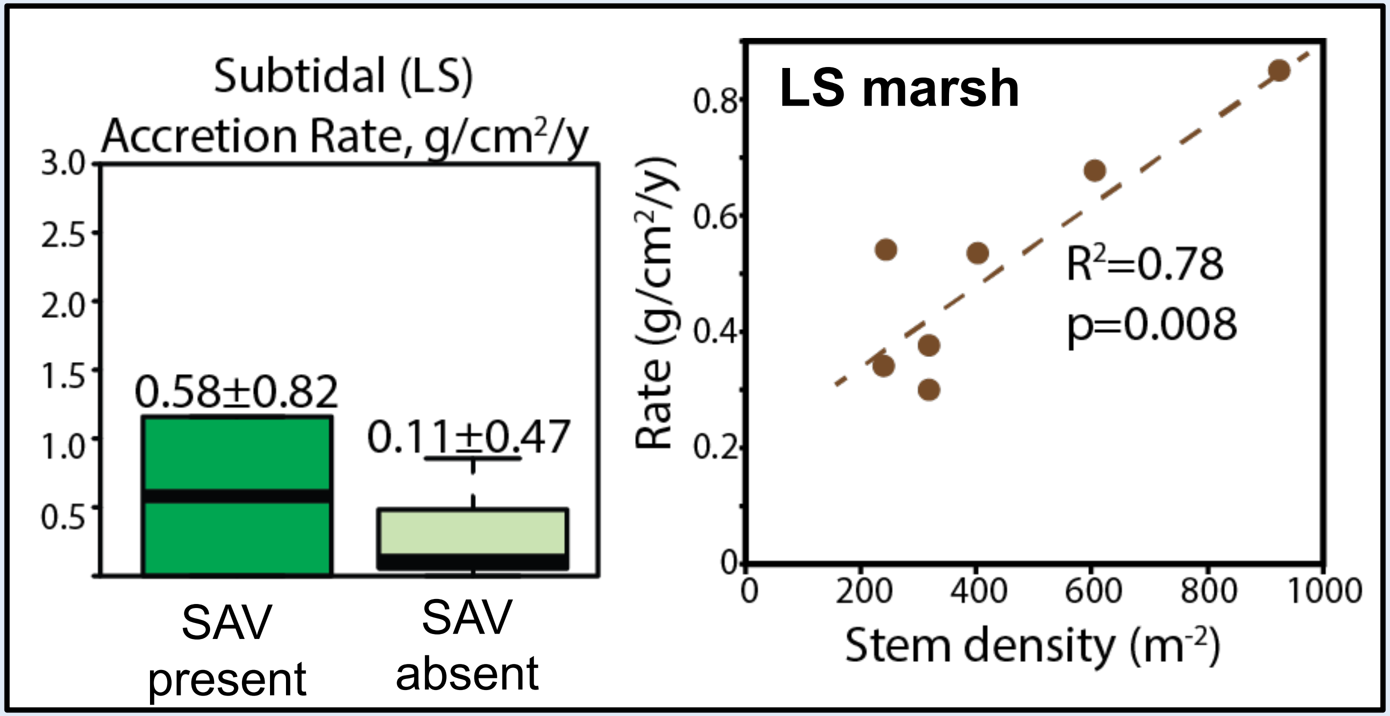
Role of plants in sediment burial



Accretion rates in shallow waters are higher when SAV is present

Accretion rates in the created marshes living shorelines are higher when stem density is higher

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Average burial rate, g/cm²/y	SAV present	SAV absent
Natural subtidal	1.5±1.9	0.64±0.42
LS subtidal	0.58±0.82	0.32±0.46
LS marsh	0.60±0.33	0.41±0.11

Average PN concentration*, %	
Natural subtidal	0.64±0.26
LS subtidal	0.42±0.54
LS marsh	1.6±2.4

*Very limited data so far

PN burial rate, mg/cm²/y	SAV present	SAV absent
Natural subtidal	9.8	4.2
LS subtidal	2.4	1.3
LS marsh	9.6	6.6

WINNER! LS with SAV = 12.0 mg/cm²/y

Second Place: natural with SAV

Third Place: LS without SAV = 7.9 mg/cm²/y

Loser: natural without SAV

Net burial is **highest when SAV is present adjacent to living shorelines** and **lowest when SAV is absent adjacent to natural shorelines.**

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Summary

Performance: shoreline erosion rates

- Net accretion at living shorelines due to construction
- Continuing erosion at or above historical rates at natural shorelines

Impacts of living shorelines to SAV?

- SAV distributions at all shorelines appear to follow trends in larger area, with no obvious qualitative impact of living shoreline installation

Co-benefits: sediment/nutrient burial rates

- Highest accretion rates occur in the subtidal adjacent to natural shorelines; much lower in subtidal adjacent to living shorelines
- Subtidal accretion rates are generally higher at sites with SAV than without
- Net nitrogen burial rates appear to be highest for sites with both living shorelines and SAV, and lowest for sites adjacent to natural shorelines without SAV

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