Ecological attributes and trade-offs of living shorelines

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Continuum of shoreline protection approaches

Estuarine & coastal shorelines


Eastern Shore: The Virginia Coast Reserve

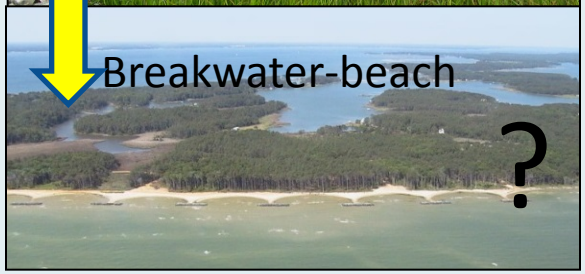

Tabbs Creek, VA

Minimally-Moderately altered


Created marsh


Oyster-sill ?


Marsh-sill ?

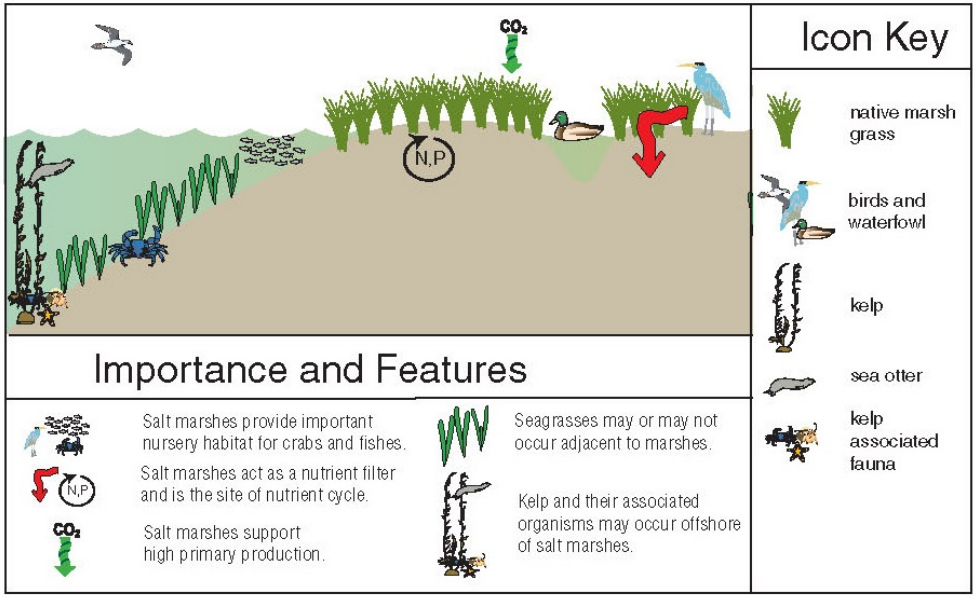

Breakwater-beach ?

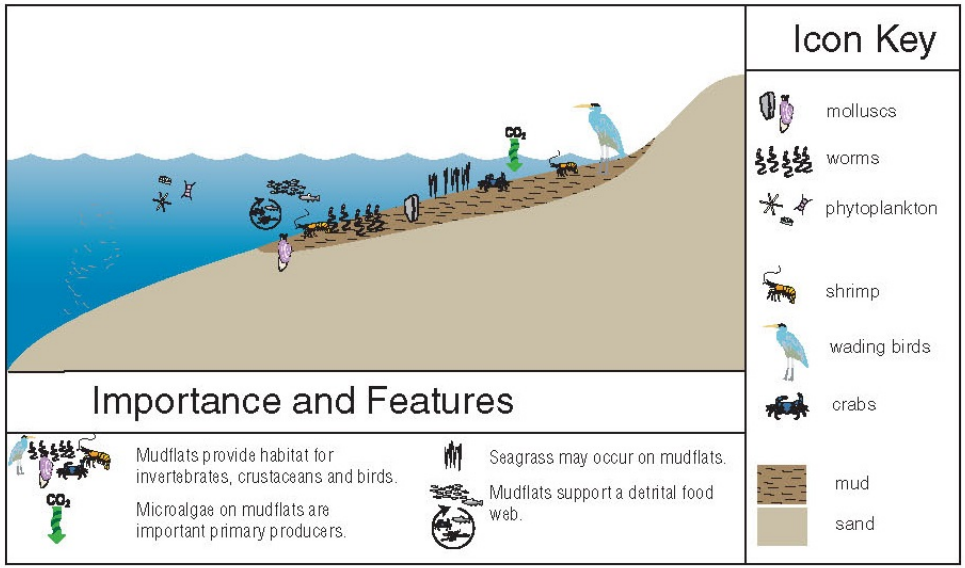
Highly altered


Bulkhead


Riprap Revetment

Ecosystem services of tidal marsh, flats, beaches, and shallows





- **Habitat provision** (feeding & refuge) – shore, wading, and marsh birds, reptiles, fish, & benthic invertebrates
- **Nesting habitat** for turtles (*beaches*)
- **SAV habitat** (*shallows*)
- **High primary production** by benthic algae, marsh, seagrass
- **Nutrient Processing** (uptake/cycling)
- **Decomposition of organic matter**
- **Secondary productivity transferred**
- **Wave attenuation** (*marsh, beach*)
- **Sediment stabilization** (*marsh, beach*)
- **Biodiversity**

Source: National Academy of Sciences

Shoreline hardening & riparian development impacts on ecosystem services

- Habitat loss & fragmentation – Forest, wetlands (Peterson and Lowe 2009; Dugan et al 2011)
- Connections btw upland & wetland severed
- Sediment supply & transport altered, increased scouring, turbidity (Bozek and Burdick 2005, NRC 2007)
- Static homogeneous shoreline, less biodiversity
- Increase in invasive spp (Chambers et al 1999)
- Decrease fish & benthos diversity (Peterson et al 2000, Chapman 2003, King et al 2005, Bilkovic et al 2006, Seitz et al 2006, Bilkovic & Roggero 2008, Morley et al 2012)
- Prevents the natural migration of habitats as sea level rises

Living shorelines: effects on ecosystem services

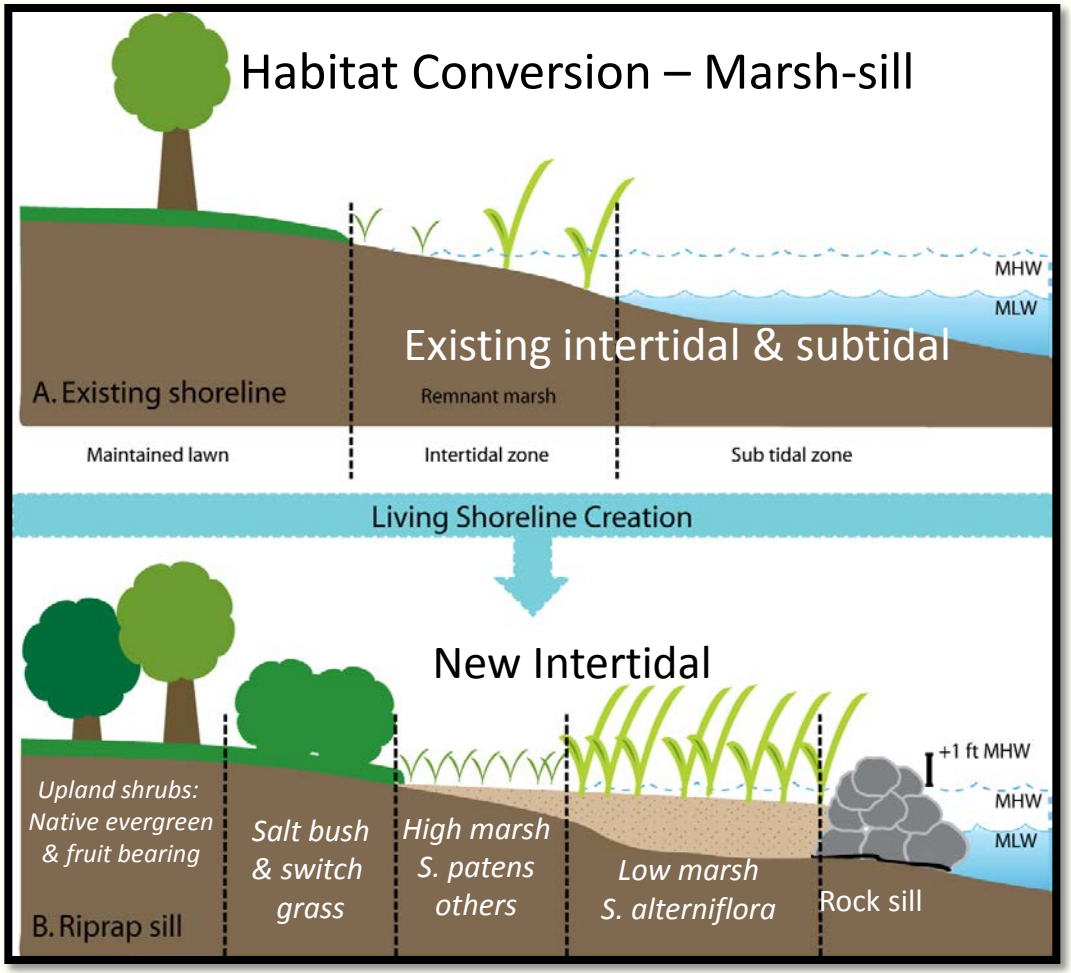
<u>Research Question</u>: What are the implications for converting existing habitat to a LS?

-Are Living Shls enhancing habitat AND does this habitat persist?

•Multiple living shoreline types & designs

-Hard to find replicates to conduct rigorous research

BUT, There have been advances in our knowledge since the last LS Summit…



<u>Ecological tradeoff:</u> conversion of *nonvegetated wetlands* and *shallow subtidal bottom* to marsh-sill

Evidence that well-designed marsh-sills are better than armoring

- Immediate terrestrial-aquatic connection not disrupted if rock is properly sized and placed offshore
- Intertidal is maintained –fish, crabs & their prey present
- Established planted marsh often provides equivalent production as natural marsh in time

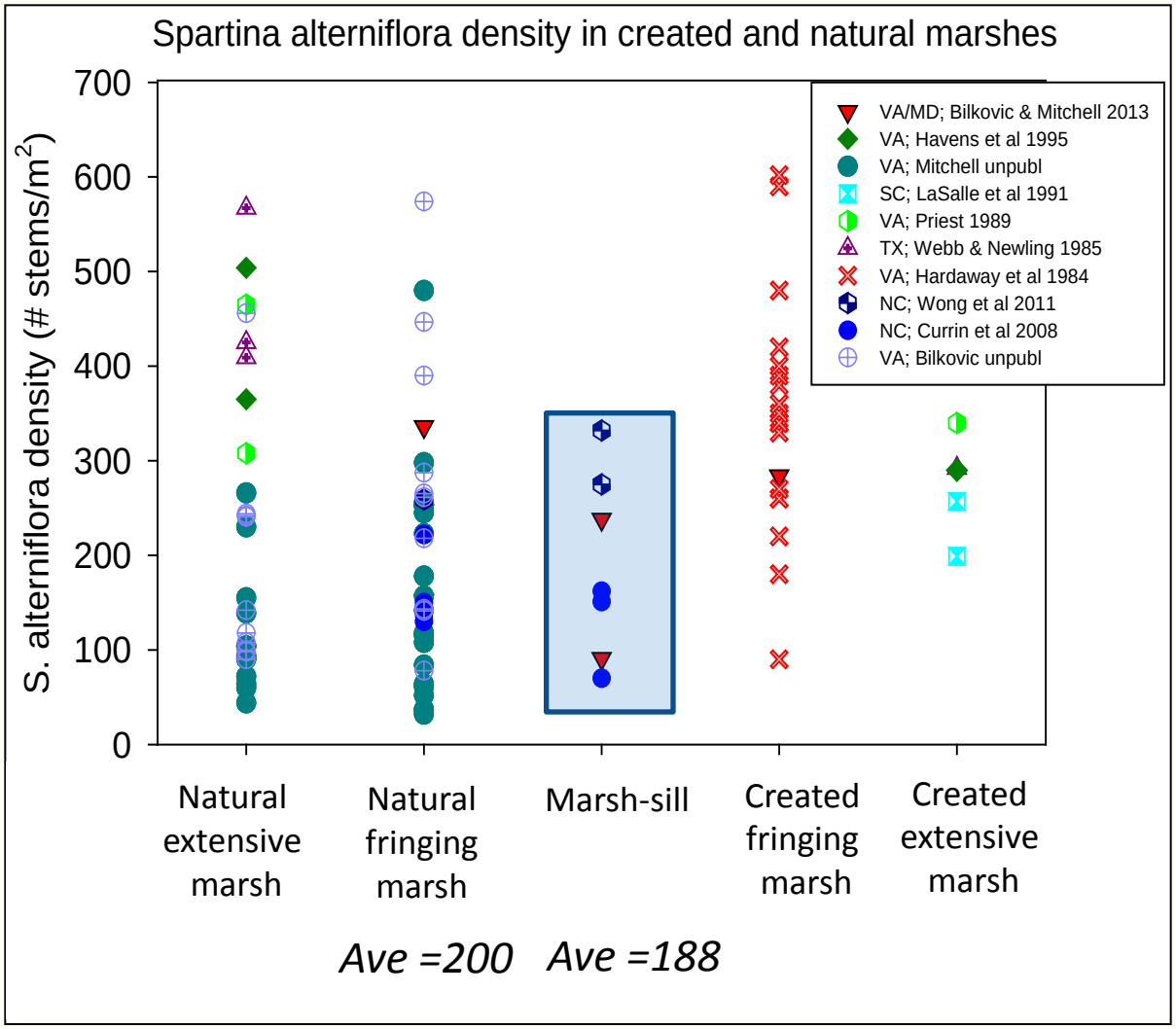
Marsh-sills may be following created wetland trajectories of ecosystem development

Vegetation: Evidence that plants develop faster (within 2-3 yrs) than biogeochemical processes (OM, nutrient accumulation) & benthic infauna (> 10 yrs)

Stems/m²

Marsh-sills: 70 - 332

Fringe marsh: 32 - 574

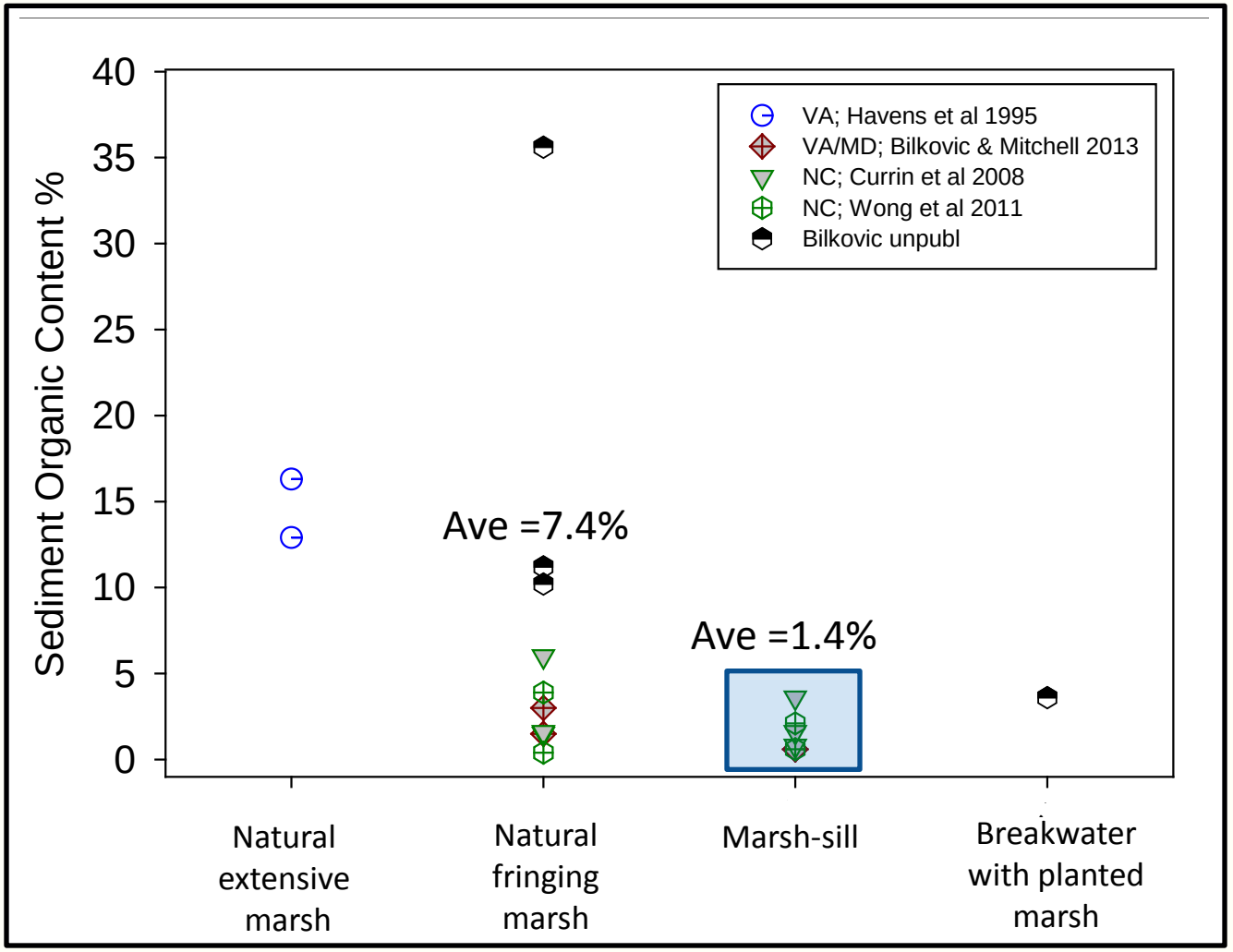


Sediment characteristics – Organic matter lagging

OM %

Marsh-sills: 0.6 - 3.6

Fringe marsh: 0.4 - 35.6



Generally, marsh-sill sediments coarser, and TOC & TN lower than in natural marshes

Benthic assemblages differ in marsh-sills from natural marsh

Important changes in benthic invertebrate communities (fish prey) in marsh-sills

Ecosystem Service providers

Clymenella torquata
bamboo worm

Infaunal Deposit feeders - ingest sediment & digest associated bacteria, microalgae & organic matter
-Bioturbation of sediment – increase oxygenation & nutrient cycling

Tagelus plebeius
Stout Razor Clam

Suspension/filter feeders: feed on algae & detrital particles suspended in the water
-Filter water, improve clarity

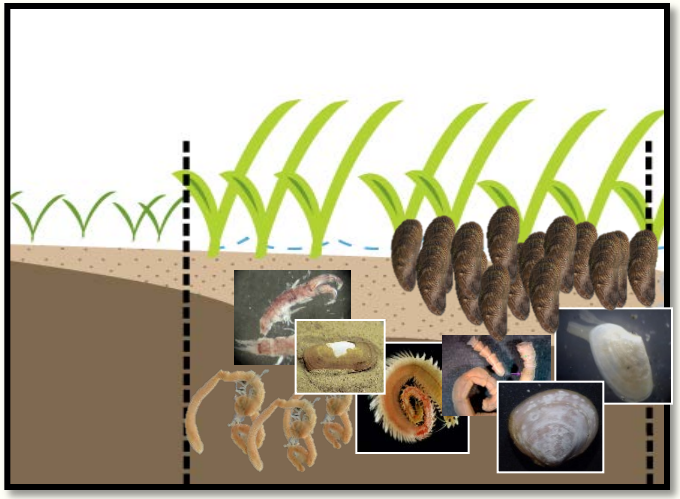
Oysters & mussels-sill | mussels – marsh

Marsh-sill benthic assemblages

- High abundance of filter-feeding epibiota at some but not all sites
- Less diverse in intertidal, but most ecological roles were filled
- Evidence of a relatively short recovery time for benthos following marsh-sill construction
- Offshore similar among shorelines

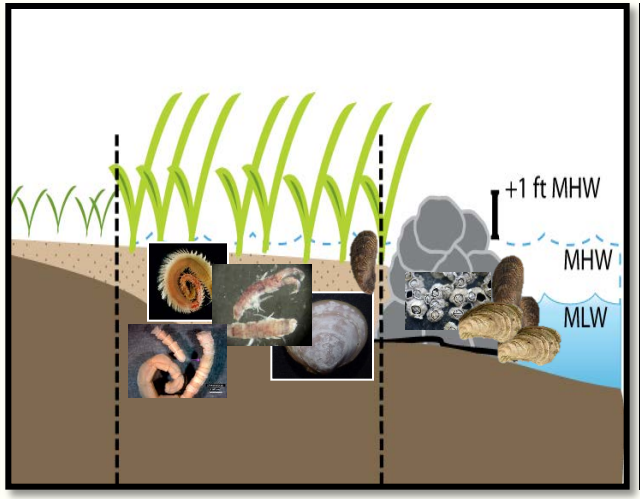
Benthic assemblages differ in marsh-sills from natural marsh

Natural marsh



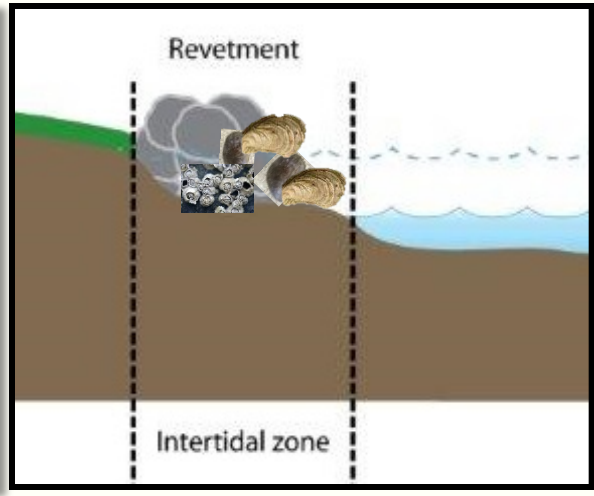
- **High** infauna diversity in intertidal
- Filter and deposit feeders, carnivores, omnivores
- High ribbed mussel density

Marsh-sill



- **Moderate** infauna diversity in intertidal
- Reduction of benthic algae behind sills

Riprap revetment



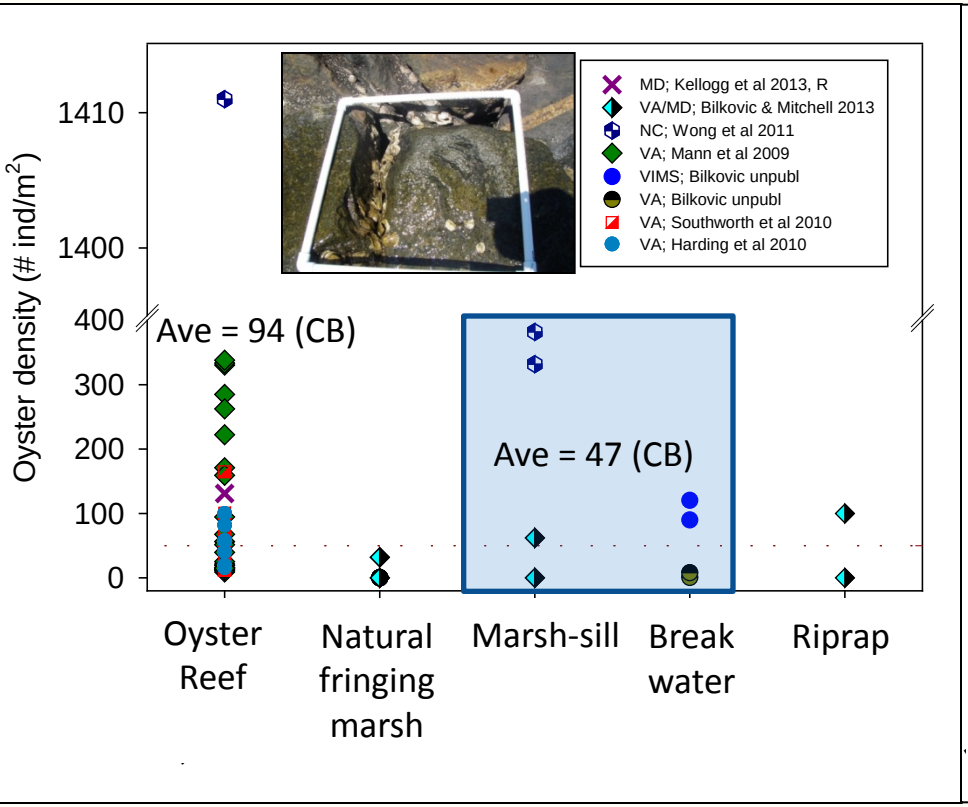
- **No/Low** infauna Intertidal covered

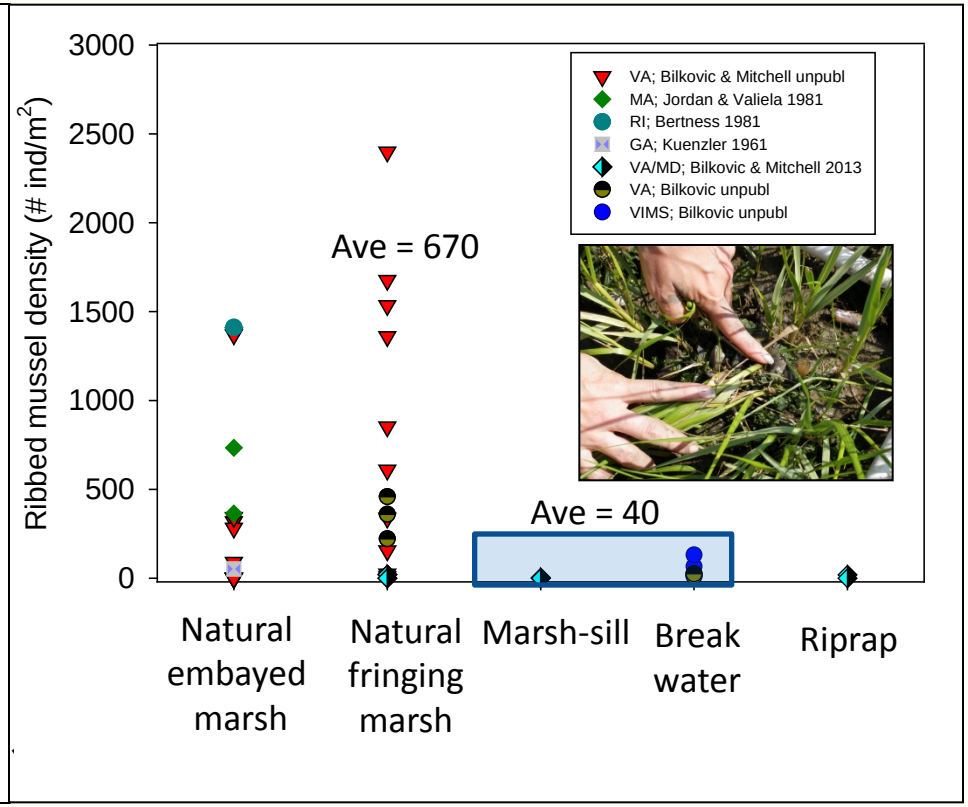
- Colonization of macroalgae and epibiota on rock -filter-feeders: *barnacles, mussel spp, oysters*

O'Connor et al 2011; Wong et al. 2011; Bilkovic & Mitchell 2013

Filter-feeding oysters and mussels typically observed in lower densities in hybrid living shorelines than natural marshes or reefs





~50-100 oysters/m^2 = productive reef
Some sills & breakwaters productive, some are not

Marsh-sills and breakwaters support much lower densities of ribbed mussels than natural marshes

Implications of introducing artificial rock structure to soft-bottom vs hard-bottom systems





Artificial rock structures not equivalent to rocky shores or natural reefs

- Colonizing epifauna and fish assemblages different from natural rocky shoreline assemblages (*Chapman 2003, Moschella et al 2005, Bulleri & Chapman 2010*)
- Less diverse and abundant possibly due to less structural complexity and higher disturbance than natural shorelines
- Other functions provided by natural reefs may not be provided by rock substrate (habitat for reef resident finfish, nutrient cycling, benthic-pelagic coupling)

Anthropogenic dispersal mechanism?: The introduction of artificial rocky shorelines may enhance recruitment & dispersal of species that are normally limited by availability of suitable substrate including native, non-native, & invasive species (*Davis et al 2002, Airoldi & Bulleri 2011, Mineur et al 2012*)

Many Research Questions remain unanswered….

Nekton assemblages & productivity depend on availability of suitable habitat

Compelling evidence that nekton assemblages are less diverse at armored shorelines compared to natural marshes & nekton utilization increases when armored shorelines are converted to living shorelines (diversity & density)

Assumed energy transfer to higher trophic levels has not been verified

- The role that living shorelines may play as fish and shellfish nursery habitat has not yet been measured. We need to demonstrate enhanced growth and protection from predation compared to other habitats *(work in progress)*

Persistent aquatic environment seaward from marsh edge may be essential

- *Sediment accretion landward of living shoreline structures may limit suitable habitat over time*

Davis et al 2008; Hardaway et al 2007, Seitz et al. 2006, Bilkovic & Roggero 2008…

A few take homes

Recent research suggests that a marsh-sill may be viewed as providing a net positive ecological benefit when

1) the only alternative is traditional hardening (bulkhead, riprap)
2) the sill is likely to be colonized by filter-feeding epibiota, and/or
3) the sill footprint can be minimized & shallow water habitat maintained

Alternatively, a marsh-sill should be viewed more negatively in situations where the sill unnecessarily or extensively replaces existing habitat

RESEARCH NEEDS

- Improved understanding of implications of introducing artificial rock structure to soft-bottom systems
- Better characterization of the existing habitat converted to LS to more accurately predict ecological benefits that may be gained
- Broader landscape level considerations --preserve shoreline diversity

THANK YOU!