

LOSS OF COASTAL MARSHES TO SEA LEVEL RISE

March 2016

A STAC Workshop:
The Development of Climate Projections for Use in
Chesapeake Bay Program Assessments

Molly Mitchell

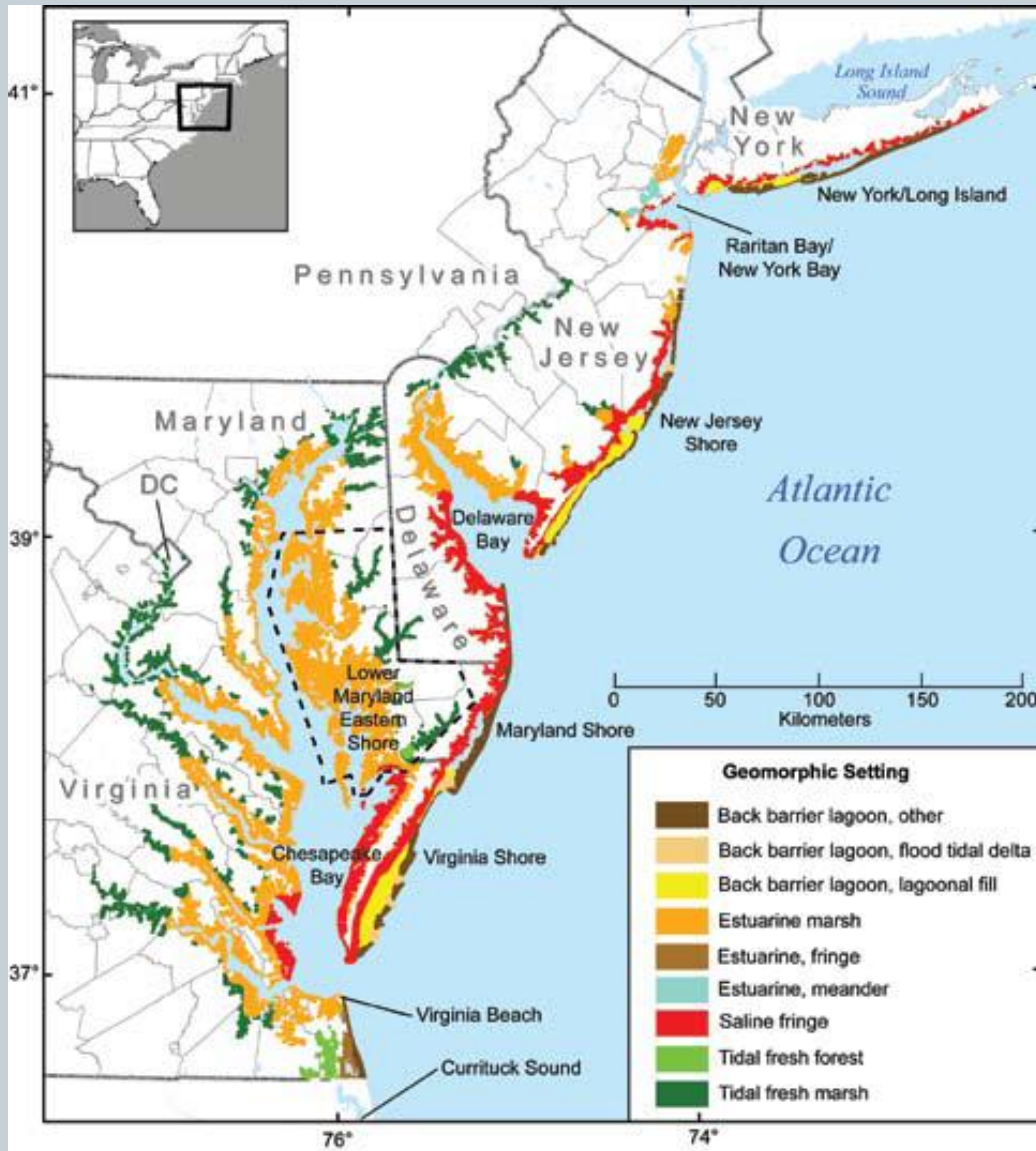
Center for
Coastal
Resources
Management

Virginia Institute of Marine Science

VIMS | WILLIAM
& MARY
VIRGINIA INSTITUTE OF MARINE SCIENCE

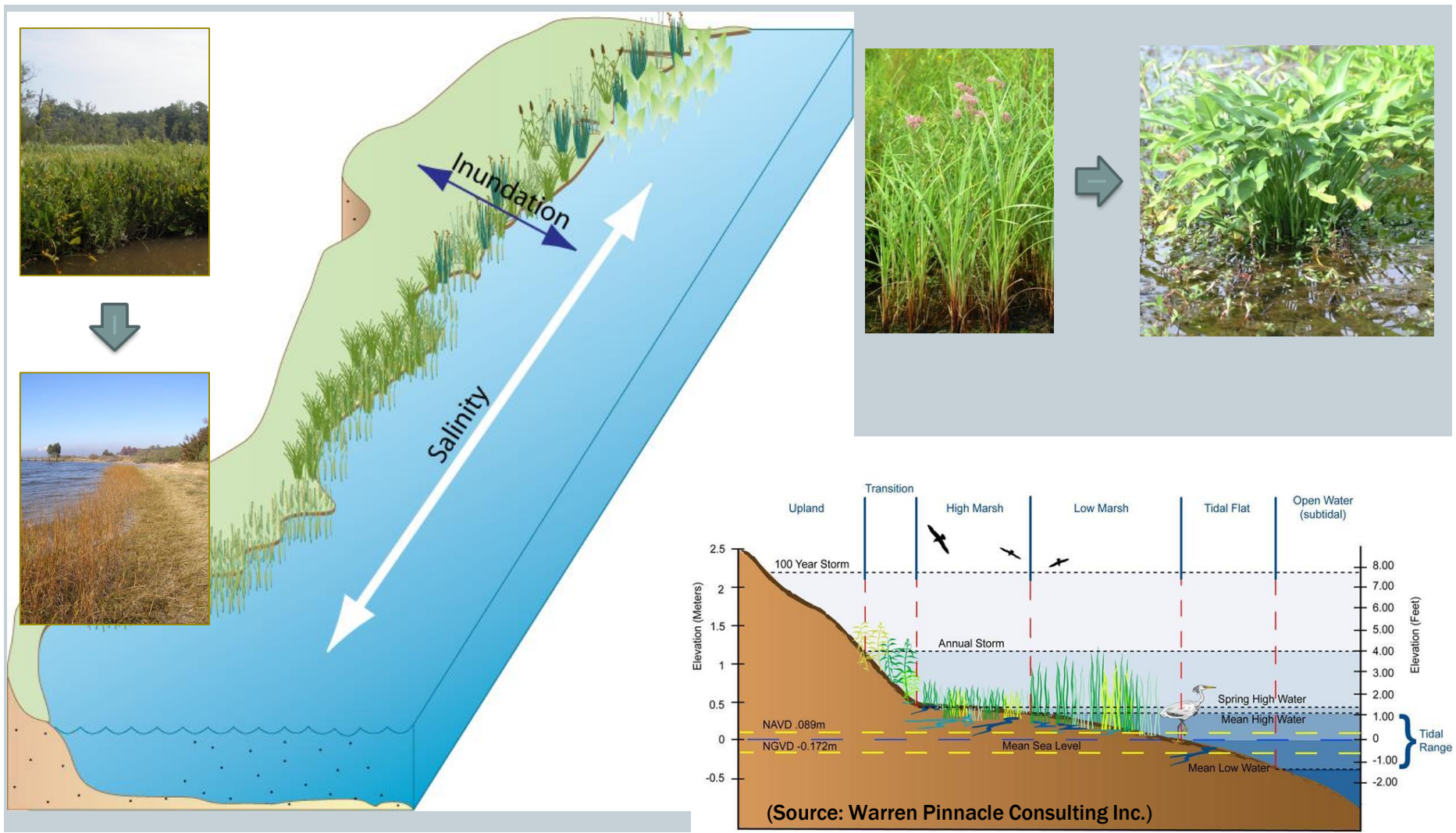


Geomorphic settings of mid-Atlantic tidal wetlands



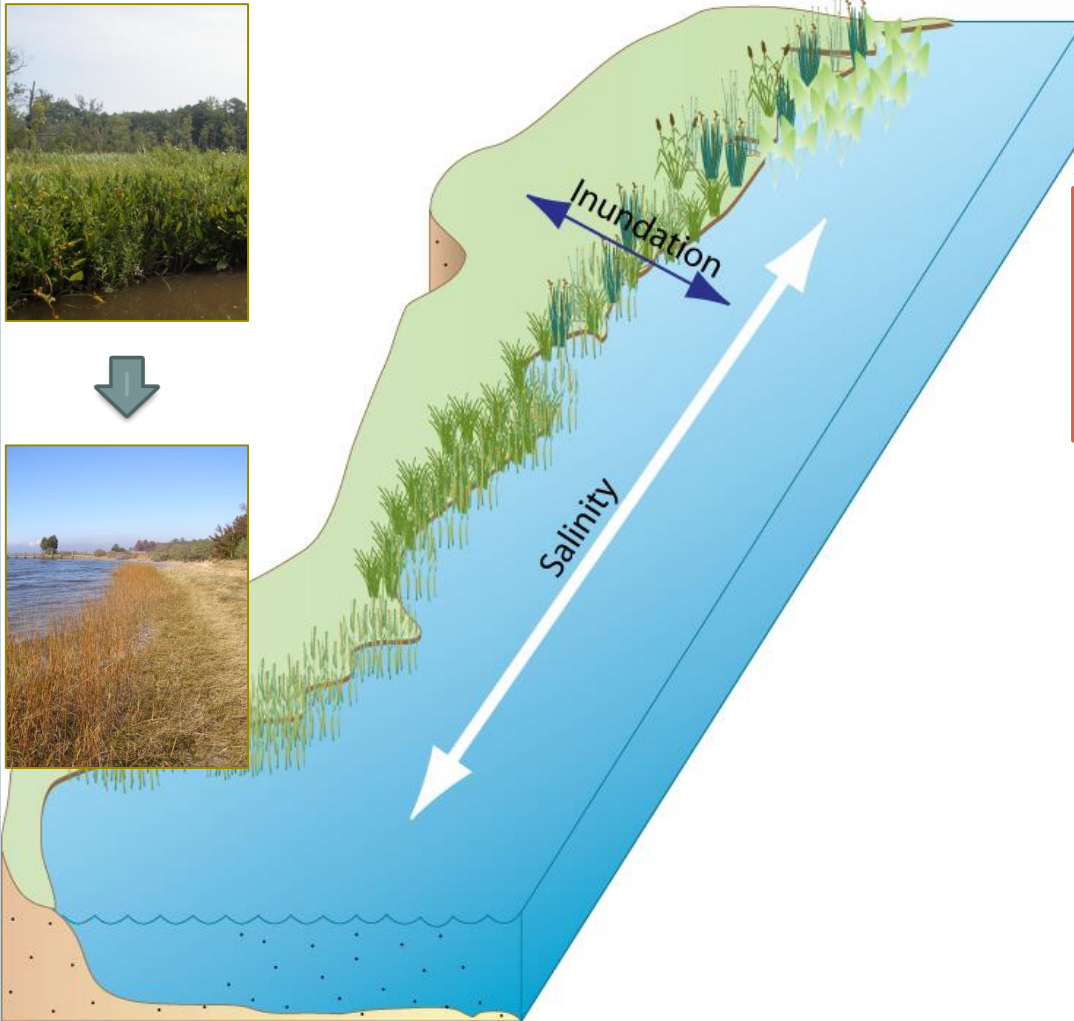
- Geomorphic settings have differing hydrodynamics, sediment sources, & vegetative communities
- Wetland response to climate change is expected to vary with geomorphic setting
- Different climate drivers are important in different settings
 - Precipitation more important for non-tidal, stream and headwater wetlands
 - Sea level rise more important for tidal wetlands

THE TIDAL MARSH COMMUNITY CONTINUUM



MARSH CHANGE THEORY

SALINITY CHANGE



Δ Water Levels

Controlled by:
SLR
Channel Slope
Freshwater flow

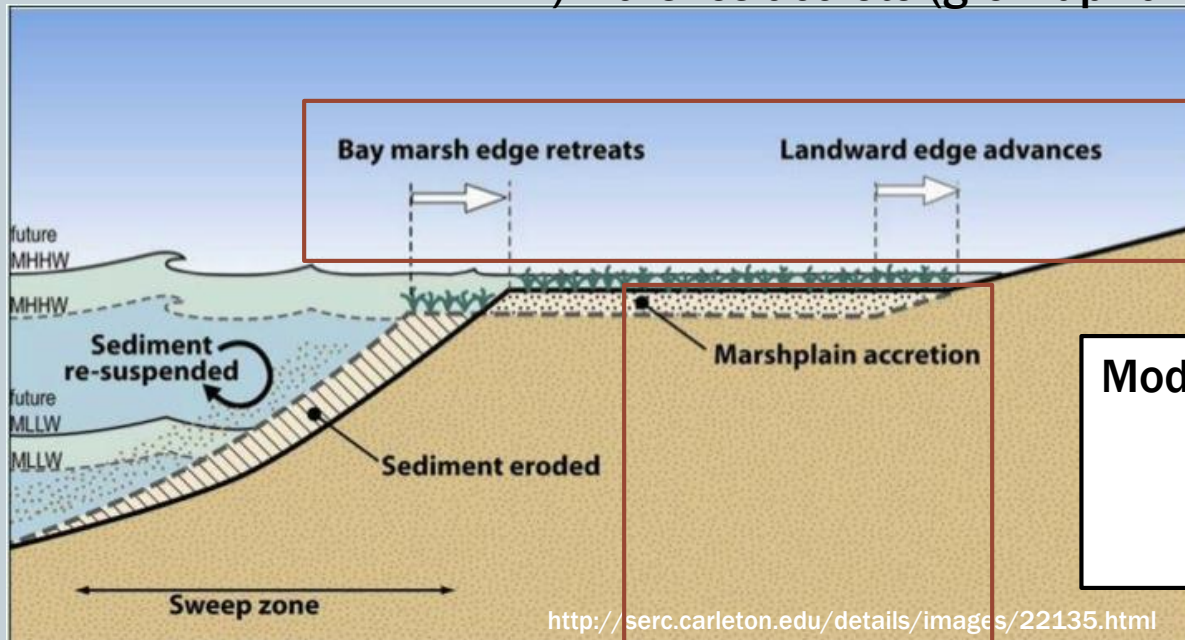
Δ Precipitation

Modified by:
Human Activity
(groundwater withdrawal,
development, etc)

MARSH CHANGE THEORY

LATERAL CHANGE

To keep pace with sea level: 1) Marshes migrate
2) Marshes accrete (grow upwards)



Δ Water Levels

Controlled by:
SLR
Land elevation

Modified by:
Shoreline alterations
Erosion rates
Human Activity

Δ CO₂

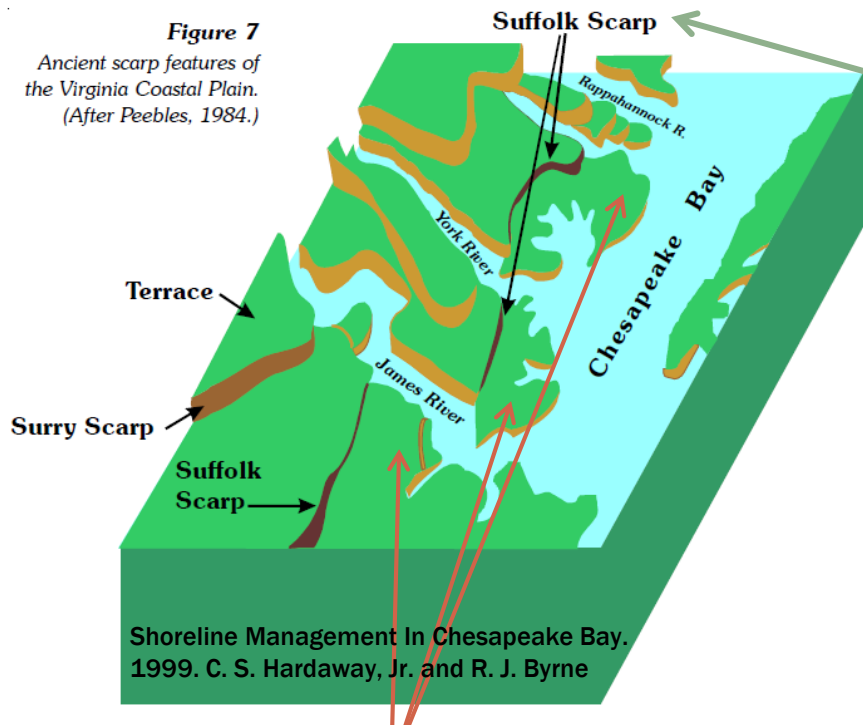
Δ Water Levels

Δ Temperature

Controlled by:
→ Plant production
→ Sediment availability
→ Sediment respiration

THE SHAPE OF THE COASTAL PLAIN

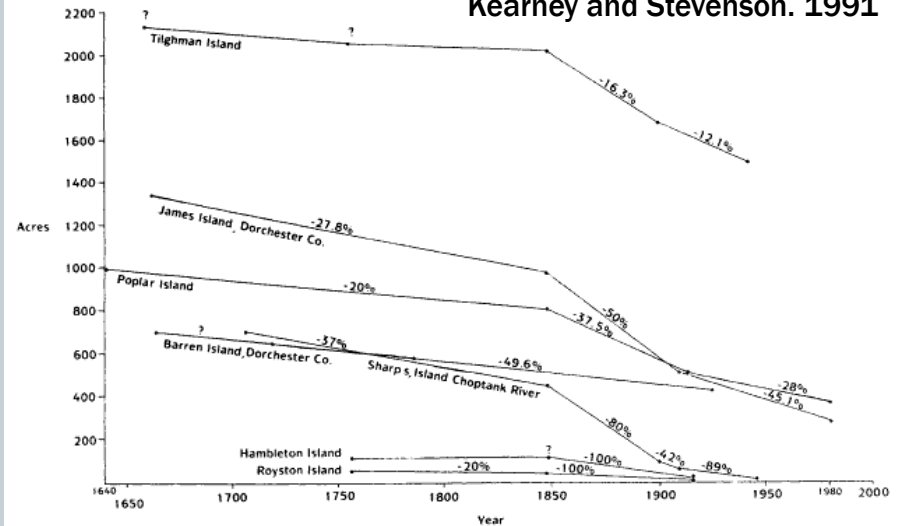
Figure 7
Ancient scarp features of
the Virginia Coastal Plain.
(After Peebles, 1984.)



The Suffolk Scarp is an ancient beach feature formed during a previous high stand in sea level

Here are extensive marshes & flat, easily flooded lands

Kearney and Stevenson. 1991



Changes in land area of bay islands over 300 years

SEA LEVEL AFFECTING MARSH MODEL (SLAMM)

Primary processes :

- **Inundation:** The rise of water levels and the salt boundary is tracked by reducing elevations of each cell as sea levels rise, thus keeping mean tide level constant at zero.
- **Accretion:** Sea-level rise is offset by sedimentation and vertical accretion using average or site-specific values for each wetland category.
- **Erosion:** Erosion is triggered based on a threshold of maximum fetch and the proximity of the wetland to estuarine water or open ocean.
- **Saturation:** Coastal swamps and fresh marshes can migrate onto adjacent uplands as a response to a rise in the water table
- **Salinity:** Salinity affects habitat switching in areas with significant freshwater flows
- **Overwash:** Beach migration and transport of sediments are calculated based on storm frequency.

SLAMM integrates localized conditions of sea-level rise, wetland elevation changes (accretion and submergence), and wave-action erosion to simulate wetland conversions. Therefore, relative sea-level rise is estimated based on site-specific conditions.

www.warrenpinnacle.com/prof/SLAMM

MARSH EQUALIBRIUM MODEL

Physical Inputs

Start	1991	year
Century Sea Level Rise	24	cm
Mean High Water	70	cm NAVD
Mean Sea Level	-2	cm NAVD
Lunar Nodal Amp	3.1	cm
Initial Rate SLR	0.24	cm/yr
Suspended Sed. Conc.	20	mg/liter
Marsh Elevation	43	cm NAVD

Biological Inputs

Max Veg Elev	90	cm
Min Veg Elev	-22	cm
Max Peak Biomass	1017	g/m ²
OM Decay rate	-0.8	1/time
Root&Rhizome:Shoot Ratio	3	g/g
BG turnover rate	3	year ⁻¹
Refractory Fraction (kr)	0.02	g/g
Max (95%) Root Depth	10	cm

Trapping Coef & Settling Velocity

k _s	3.22E-02	cm ⁻¹ yr ⁻¹
q	1.5E-03	g cm ⁻² yr ⁻¹

Model calibration requires measurement of:

- response of vegetation to relative elevation
- Δ elevation of the marsh surface as a consequence of changes in the biomass density of the vegetation
- sea level

Key focus is on vegetative characteristics and how they interact with the physical environment.

One of the outputs is “Carbon Accretion vs Time”, which is relevant to carbon storage concerns

Morris et al. 2002

jellyfish.geol.sc.edu/model/marsh/mem.asp

Comparison Mode: **Dual Maps** | Multi Maps

Dual-Map Comparison Mode

Change scenario-date combinations for either map by selecting from the drop-down menus below

Left Map:

1m Sea Level Rise - Base

Right Map:

1m Sea Level Rise - 2050

Reset Options

View Map Help

Edit Map Layers

View Layer Legend

Locate point across maps

Layer Legend

NATIONAL WILDLIFE REFUGE SYSTEM

Refuge Boundaries

COASTAL BARRIER RESOURCES ACT

CBRA Unit Boundaries

SLAMM COVER TYPES

Developed Dry Land

Undeveloped Dry Land

Swamp

Cypress Swamp

Inland Fresh Marsh

Tidal Fresh Marsh

Transitional Salt Marsh

Regularly Flooded Marsh (usually Salt Marsh)

Mangrove

Estuarine Beach

Tidal Flat

Ocean Beach

Inland Open Water

Riverine Tidal

Estuarine Open Water

Tidal Creek

Open Ocean

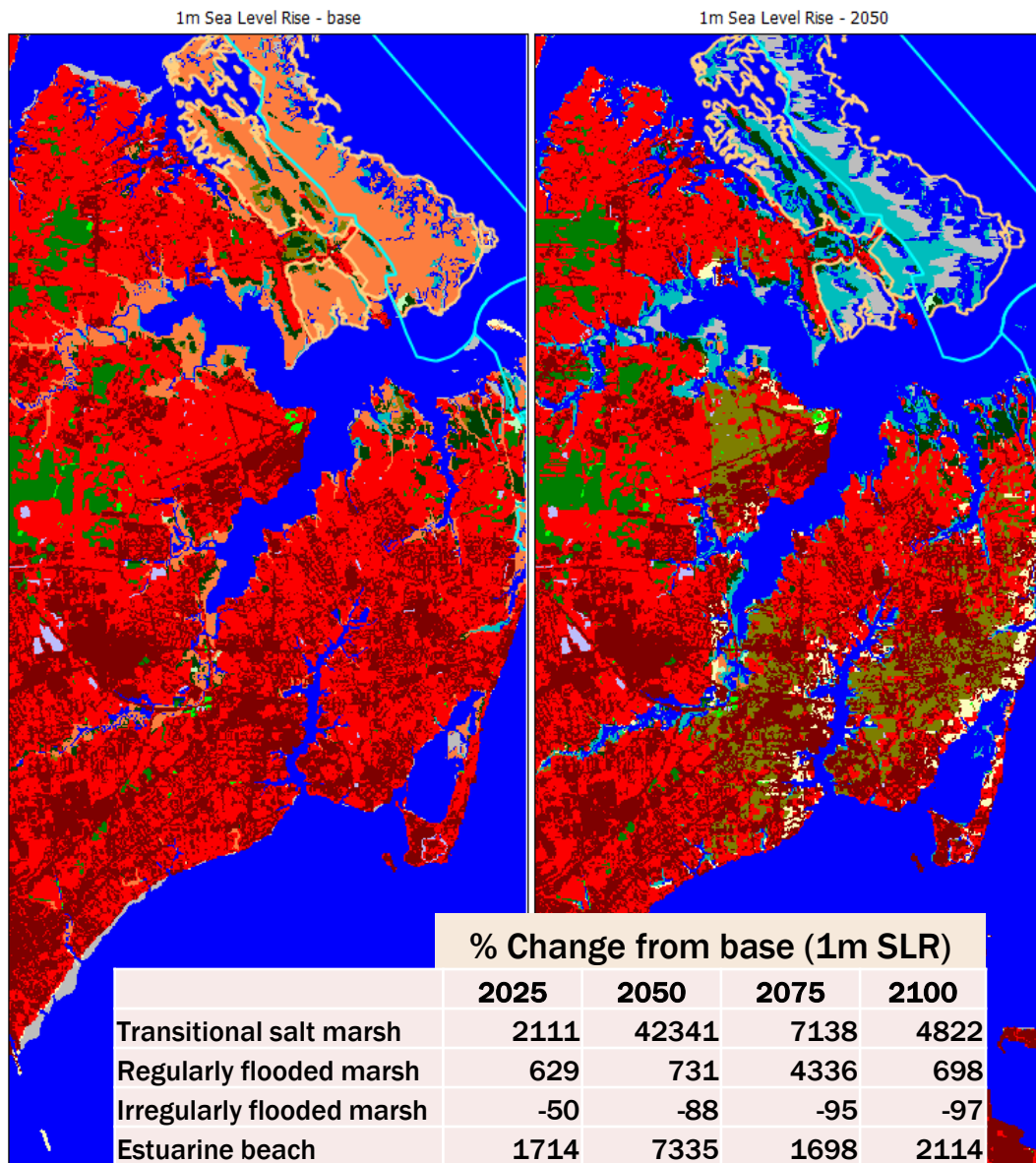
Irregularly Flooded Marsh (often Brackish)

Inland Shore

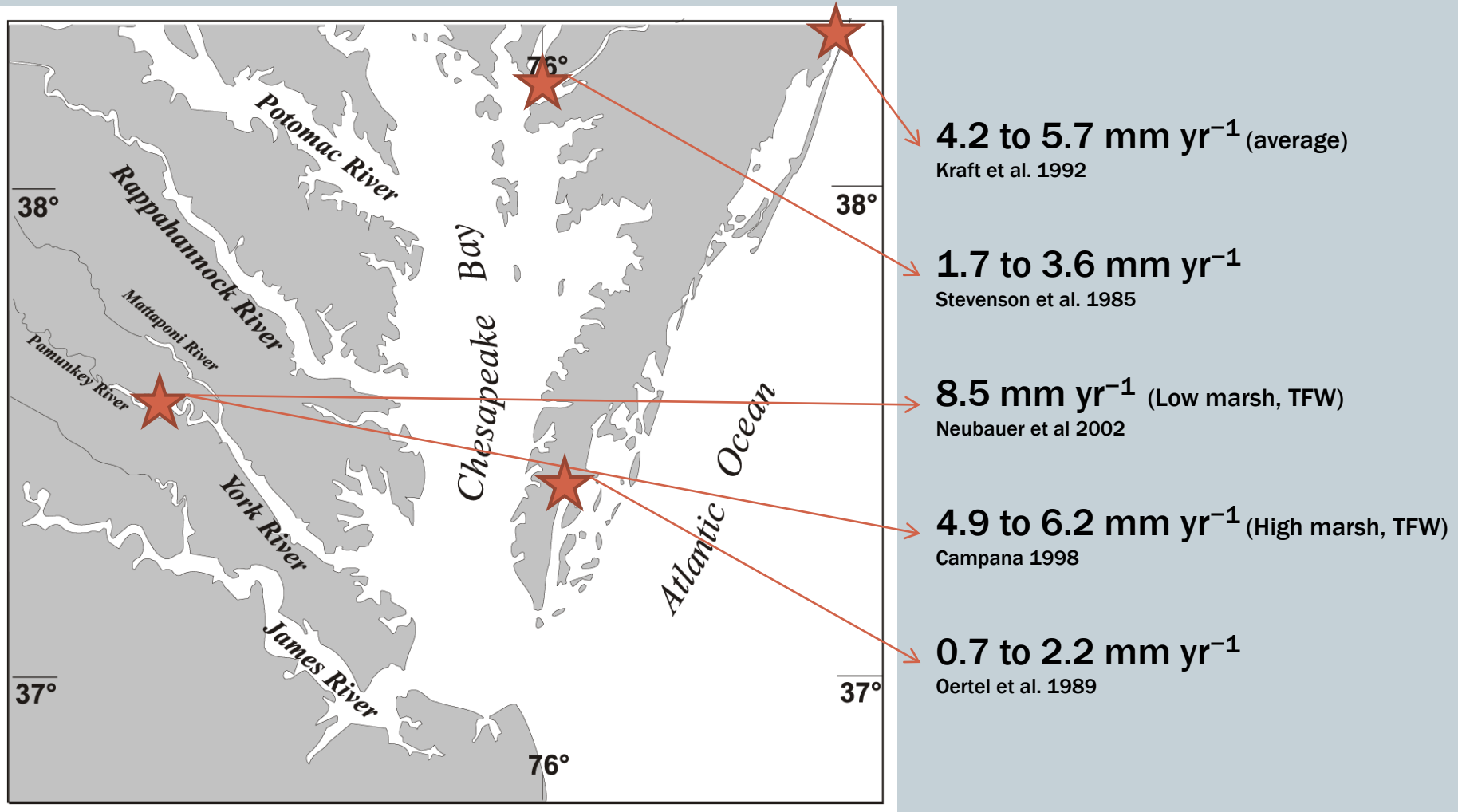
Tidal Swamp

OK

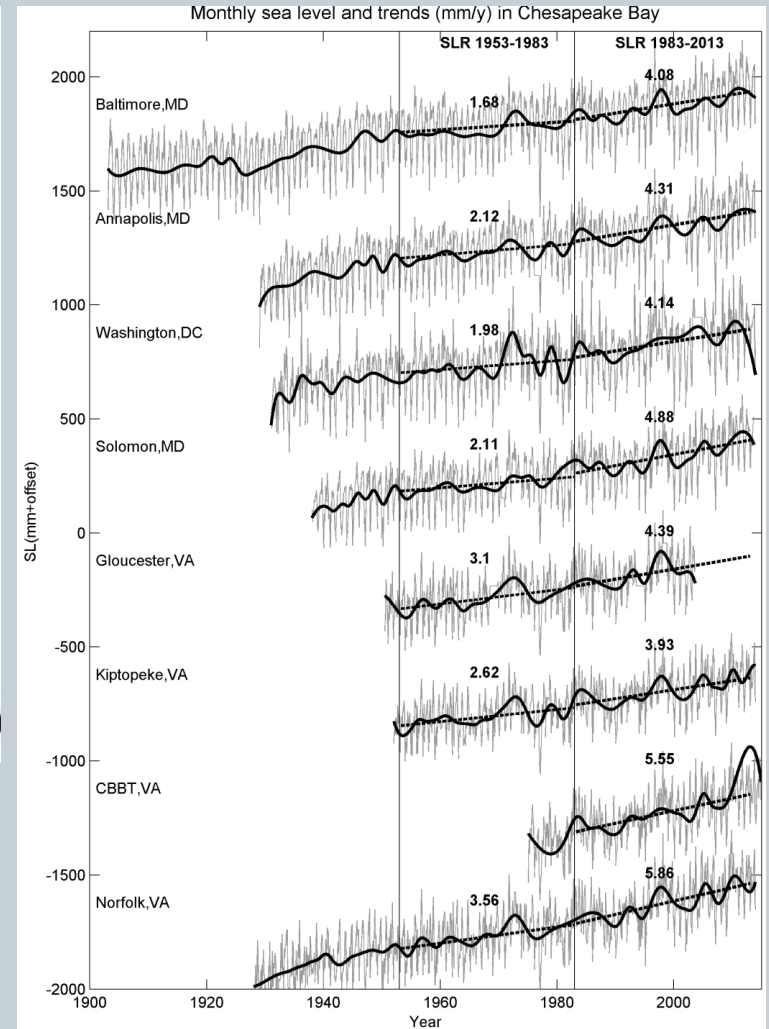
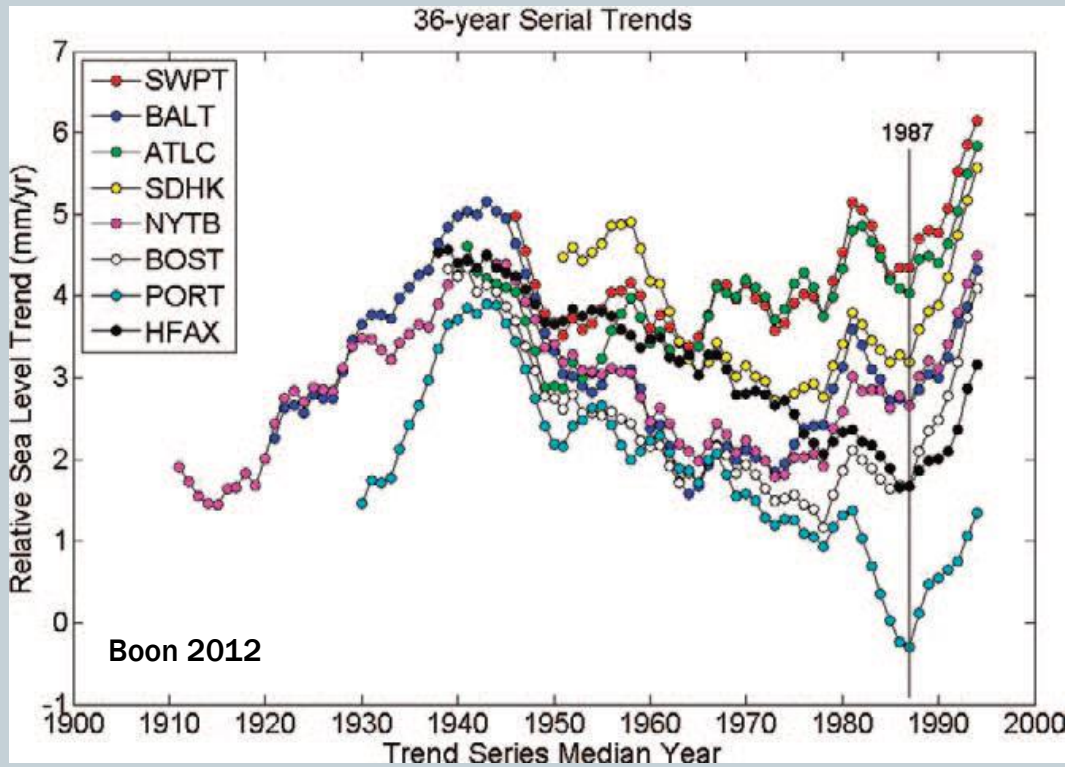
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A SAMPLING OF ACCRETION RATES



RECENT SEA LEVEL RISE



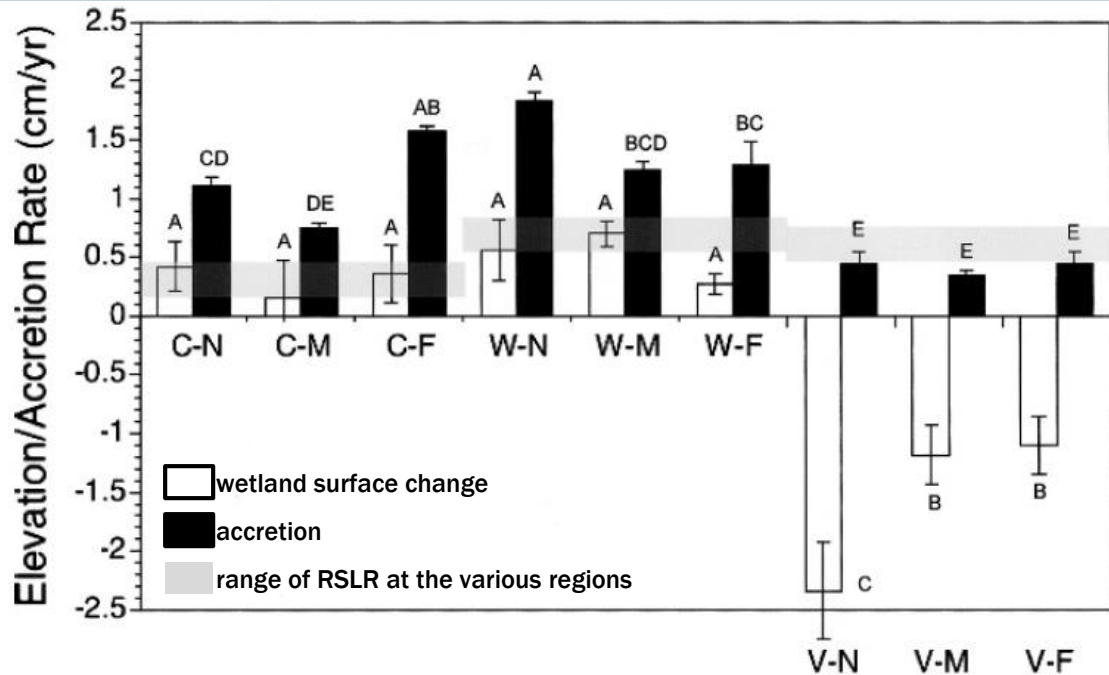
The average SLR for the Bay :

- 2.45 mm/y for 1953-1983
- 4.73 mm/y for 1983-2013
- 5.4 mm/y for 1996-2014

Ezer and Atkinson 2015

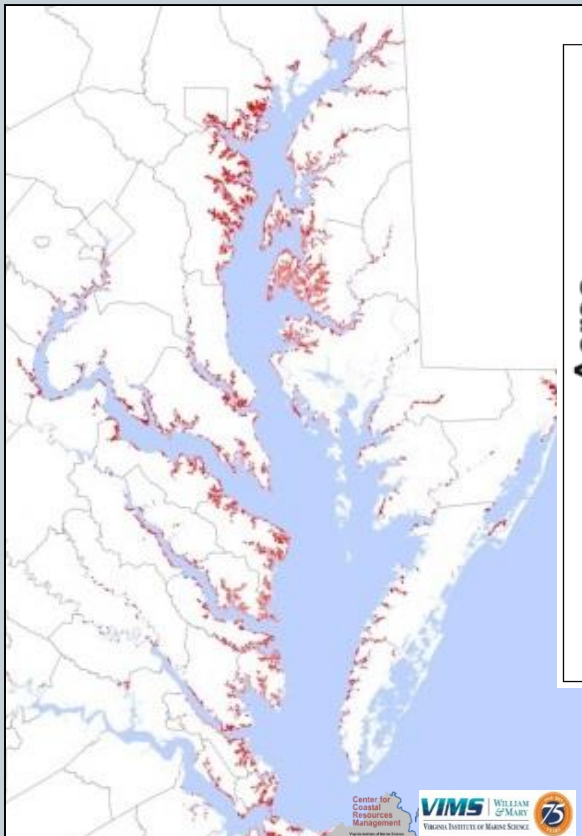
RSLR

ACCRETION \neq ELEVATION CHANGE

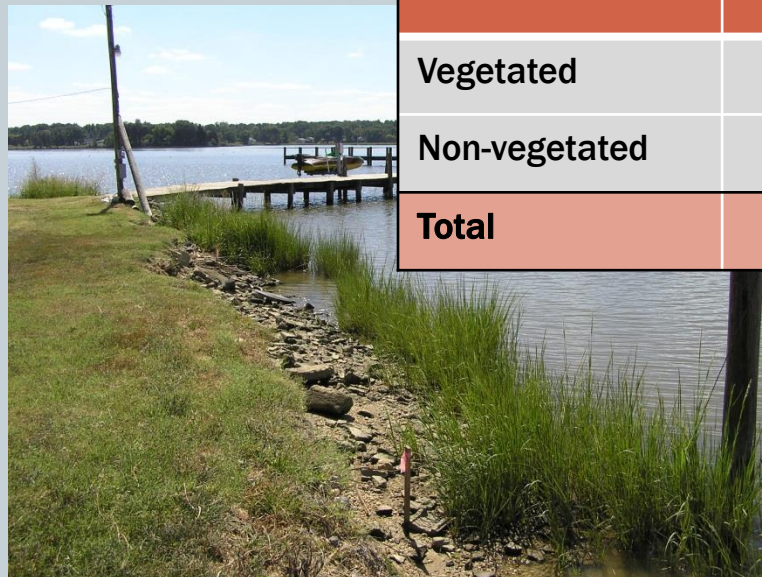
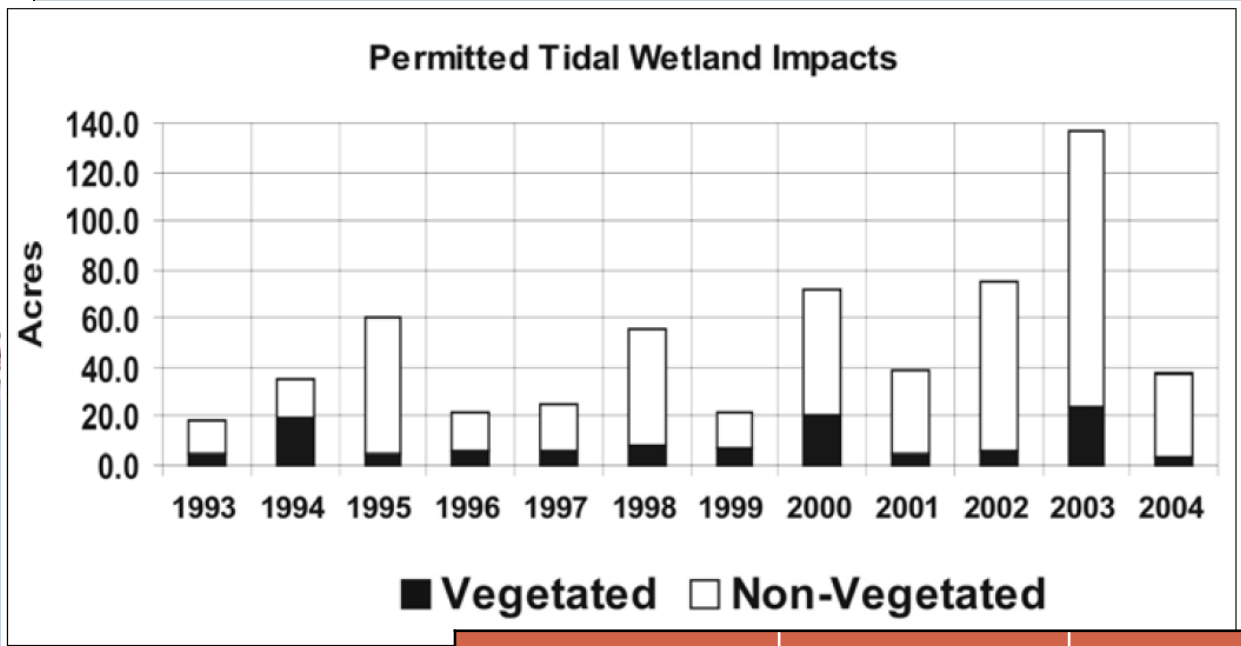


“Wetland elevation is directly influenced by a complex relationship between subsidence and accretion. Subsidence is defined as all local factors that contribute to the lowering of wetland elevation, including compaction and consolidation of sediments (both shallow and deep), tectonic activity, and human impacts...”

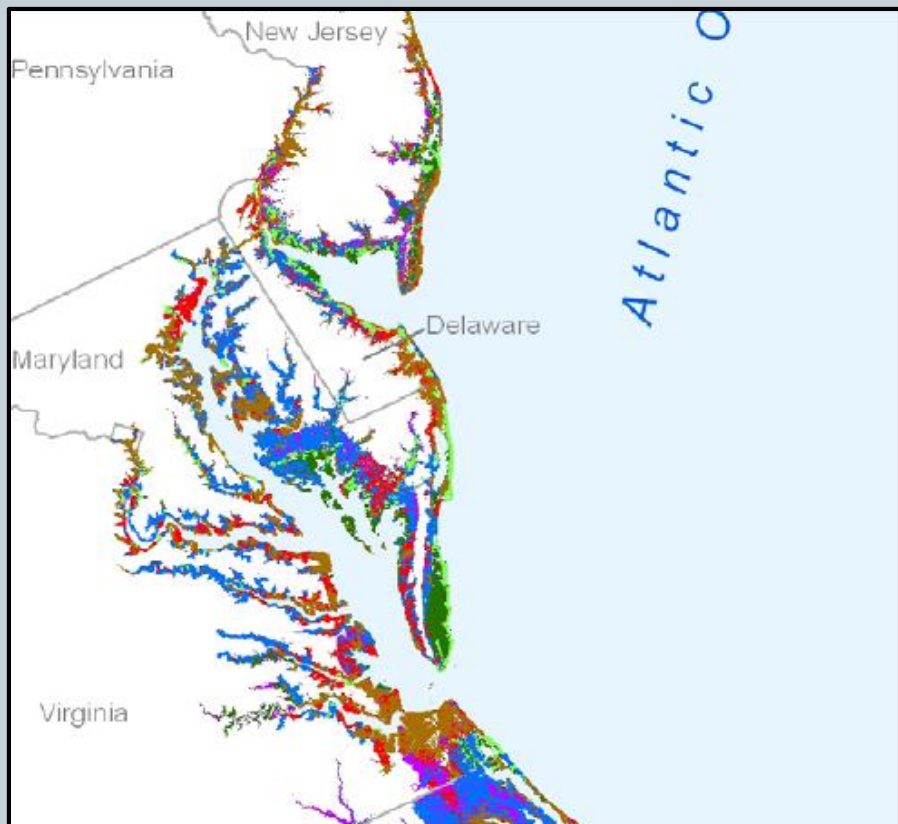
“Vertical accretion was always greater than surface elevation gain...with the difference due to shallow subsidence caused by compaction and consolidation of the substrate between the wetland surface and the end of the SET pipe”



Chesapeake Bay
18% of tidal shoreline hardened
VA: 11% MD: 28%
32% riparian land developed
 ~**5 km²** of artificial substrate introduced (*intertidal impacted*)



	Total impacted (acres)	Impacted acres/year
Vegetated	186	11
Non-vegetated	545	32
Total	731	43

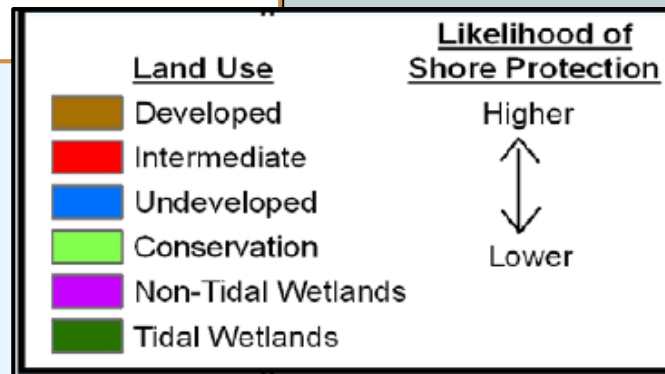


US Atlantic Coast: Only ~10% of lands have been set aside for conservation. Almost 60% of the land is expected to be developed thus unavailable for the inland migration of coastal habitats (*Titus et al 2009*)

Shoreline development results in:

- Habitat loss & fragmentation
- Sediment supply & transport alteration
- Increased scouring & turbidity
- Prevents natural migration of habitats with SLR

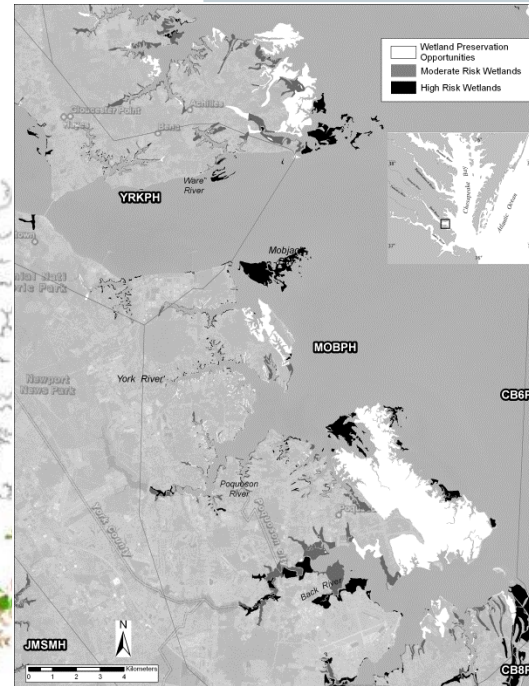
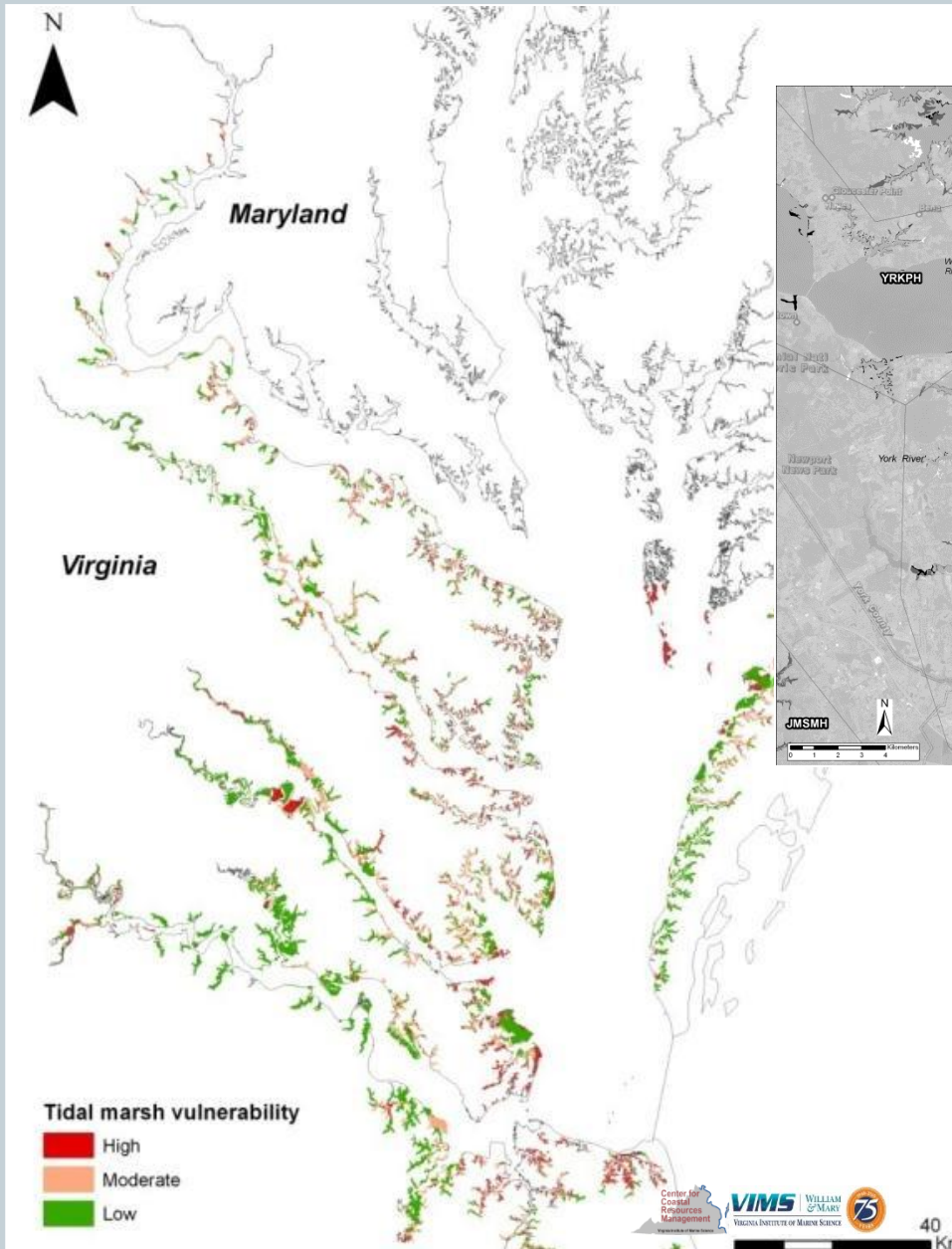
The future persistence of wetlands relies on human policies and decisions!



Tidal Marshes & barriers to migration

Tidal marshes in the meso-polyhaline reaches at highest risk due to land development & SLR

Tidal Marshes - vulnerability to fragmentation or loss from sea level rise on the basis of landscape setting (*bank height, land use & shoreline structures*). Marshes classified at low risk represent potential wetland preservation opportunities



Nearly 40% of Virginia marshes are vulnerable to SLR due to adjacent development



High Risk Marsh



Low Risk Marsh

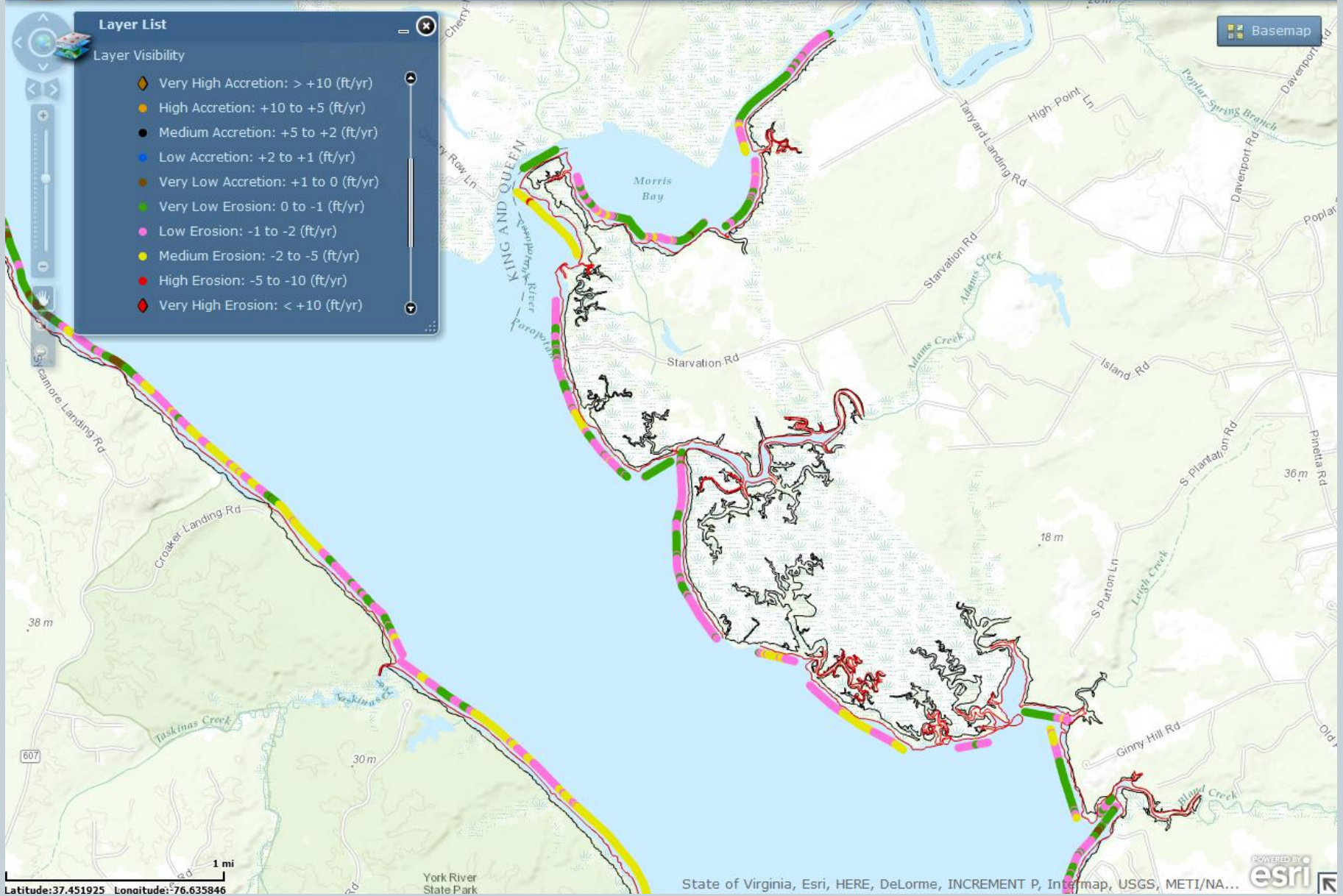


Enter address

Layer List

Layer Visibility

- ◆ Very High Accretion: > +10 (ft/yr)
- ◆ High Accretion: +10 to +5 (ft/yr)
- ◆ Medium Accretion: +5 to +2 (ft/yr)
- ◆ Low Accretion: +2 to +1 (ft/yr)
- ◆ Very Low Accretion: +1 to 0 (ft/yr)
- ◆ Very Low Erosion: 0 to -1 (ft/yr)
- ◆ Low Erosion: -1 to -2 (ft/yr)
- ◆ Medium Erosion: -2 to -5 (ft/yr)
- ◆ High Erosion: -5 to -10 (ft/yr)
- ◆ Very High Erosion: < -10 (ft/yr)



Latitude: 37.451925 Longitude: -76.635846

York River State Park

State of Virginia, Esri, HERE, DeLorme, INCREMENT P, Intermap, USGS, METI/NA...



HOW ARE MARSHES RESPONDING TO SEA LEVEL RISE?

- Compare the extent and composition of communities from the previous surveys with the existing marshes
 - Begin to establish trends of either marsh loss or gain
 - No net loss of wetlands is a management goal
 - Changes in community composition (indicative of estuarine processes)
 - Each community supports unique food webs and chemical processes



ORIGINAL TIDAL MARSH INVENTORY

- Covers all marshes in Virginia
- Every marsh location and extent was mapped
 - Marshes were digitized off topographic maps in the 1970s at 1:24,000
 - Marshes were verified during plant community survey
- Field sampling for vegetation data -- species %cover was collected for every marsh
 - Conducted between 1973 - 1991 for Virginia
 - The York River was done in several segments, between 1974 - 1987



NEW TIDAL MARSH INVENTORY

- Will cover all marshes in Virginia (maybe ½ done)
- Every marsh location and extent mapped
 - Marshes were digitized off 2009 aerial photography at 1:1,000
 - Marshes were verified during plant community survey
- Field sampling for vegetation data -- species %cover was collected for every marsh
 - Conducted in 2010 for the York River
 - 4-5 localities being done every year



Tidal wetland area changes between the 2 surveys

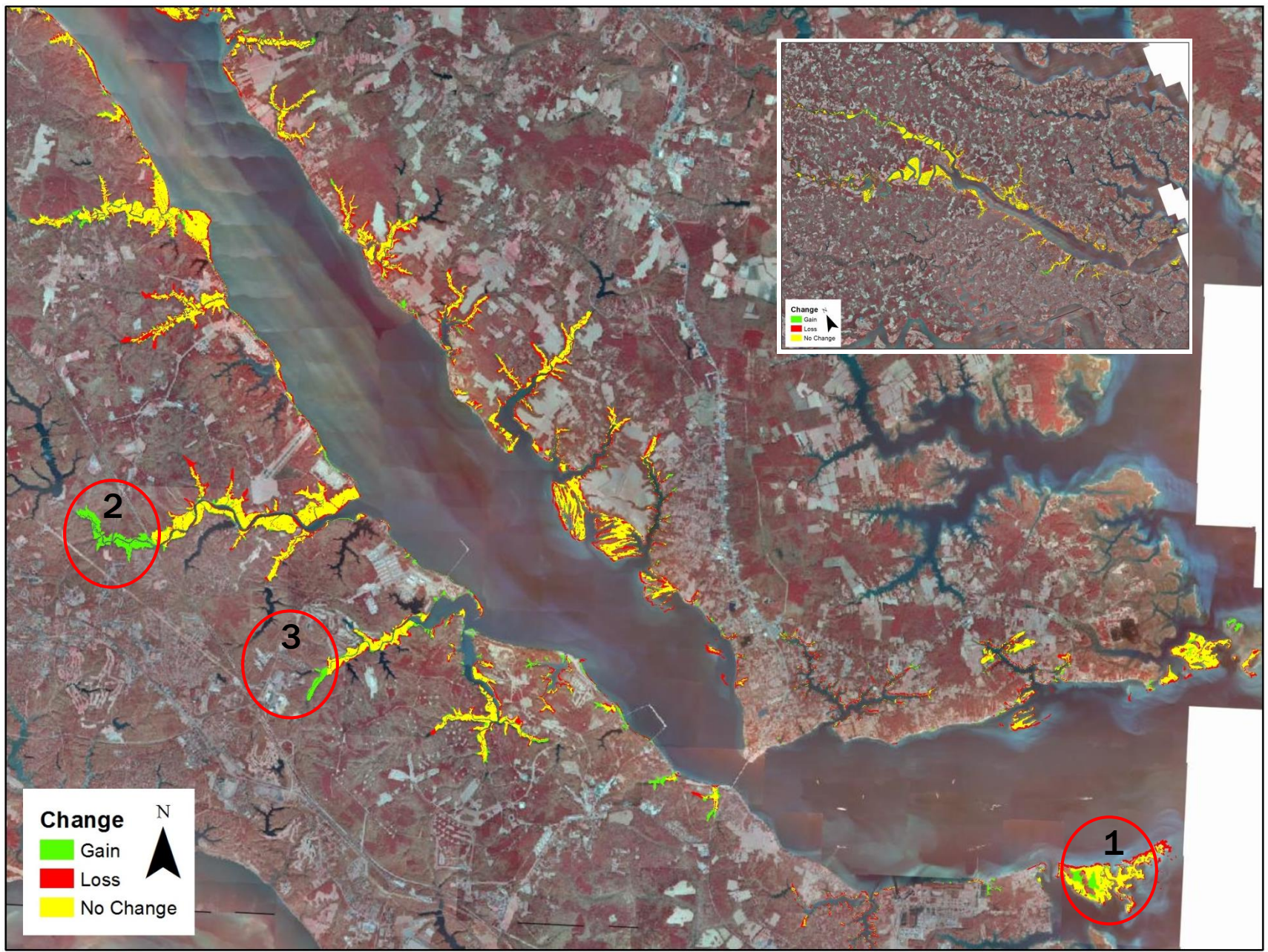
Used coverages of mapped wetlands for two time periods

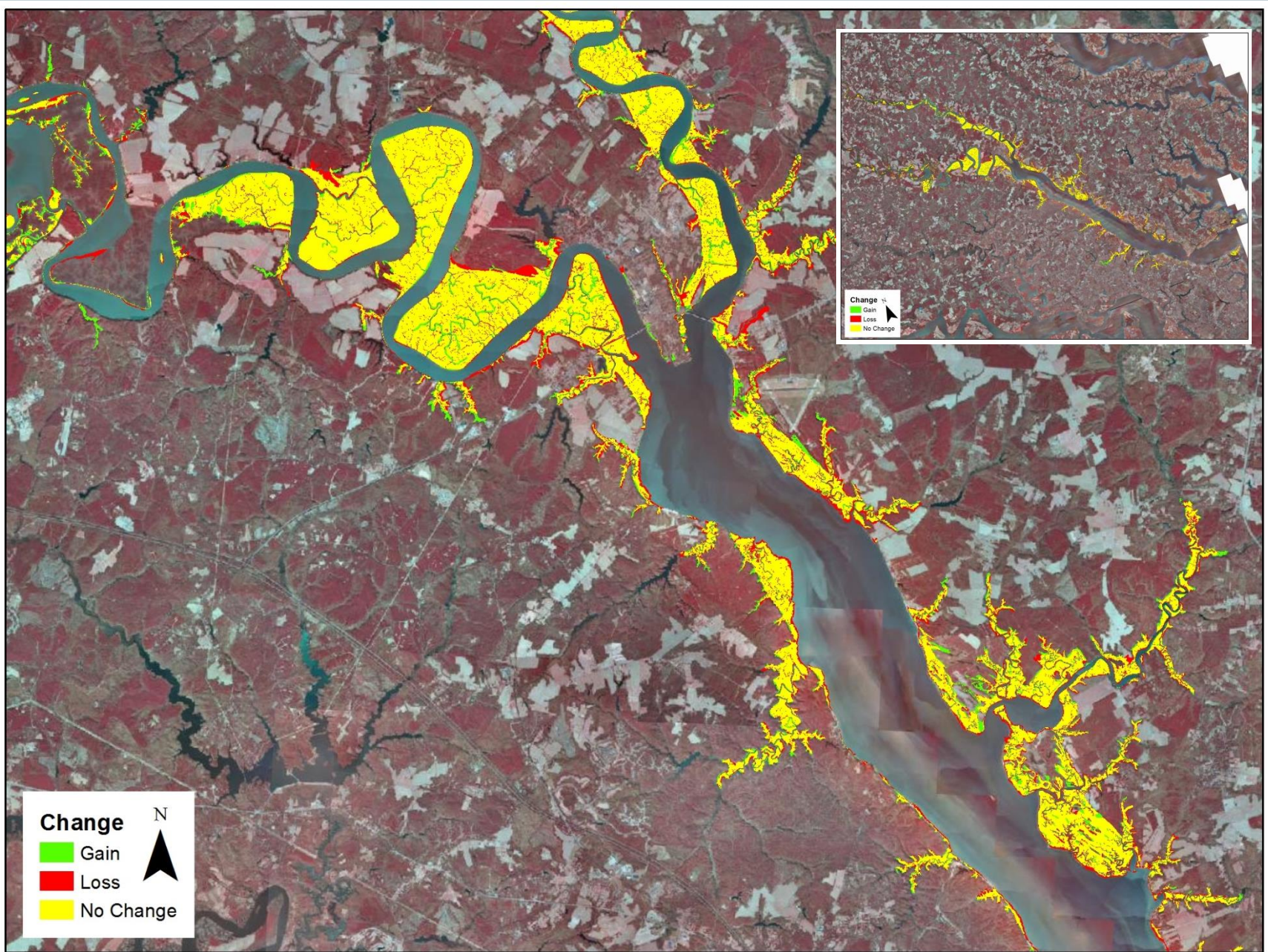
- Both coverages were clipped to the same study boundaries to insure a direct comparison
- Used superposition techniques in ArcMap to analysis of change in coverage

Marsh Class	1973 TMI	2009 TMI	Change
Embayed	5,462.279	4,872.708	-589.571
Extensive	13,934.873	13,077.216	-857.657
Fringe	999.927	714.400	-285.527
Marsh Island	798.140	736.492	-61.648
Total	21,195.219	19,400.816	-1,794.403

Marsh Class	Unchanged (ac)	Loss (ac)	Gain (ac)
Embayed	3,570.313	1,892.015	1,312.850
Extensive	11,872.249	2,062.629	1,222.298
Fringe	310.659	689.270	384.962
Marsh Island	566.777	231.363	160.708

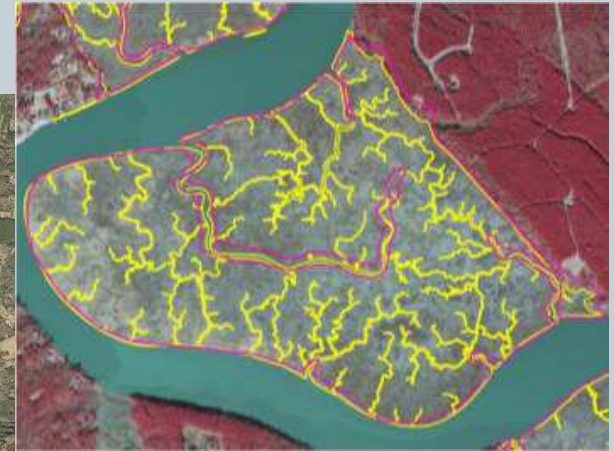
Fringe marshes = 69% of the original marshes lost Embayed marshes (34%); extensive marshes (15%), and marsh islands (29%).



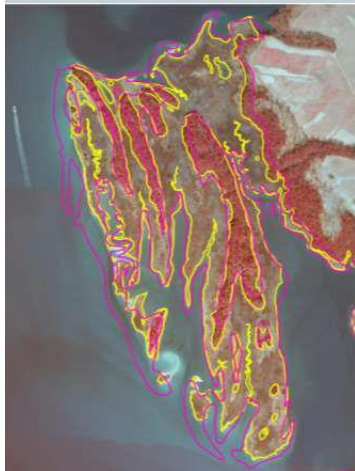


What is our confidence in these results?

- We know there are some overestimations of marsh loss
 - Mostly due to differences in scale and increased precision in digitizing
- We are working on techniques to minimize known errors



We have verified apparent erosion against other work.

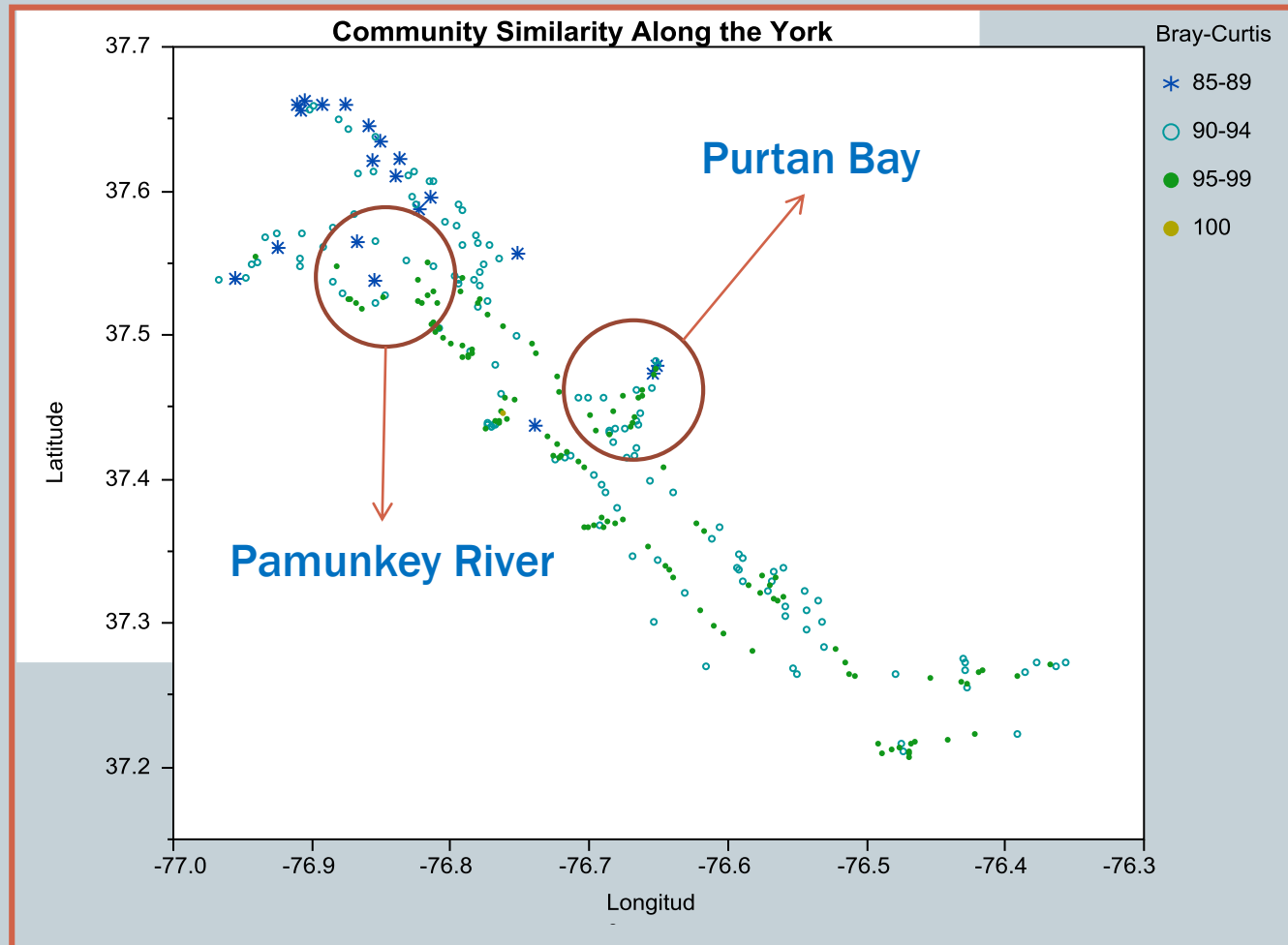


- Marsh lost ~ 44 acres between 1979 and 2009
- Predominantly due to shoreline erosion
- Milligan *et al.* (2010) found up to 1.5 meters of erosion/year here

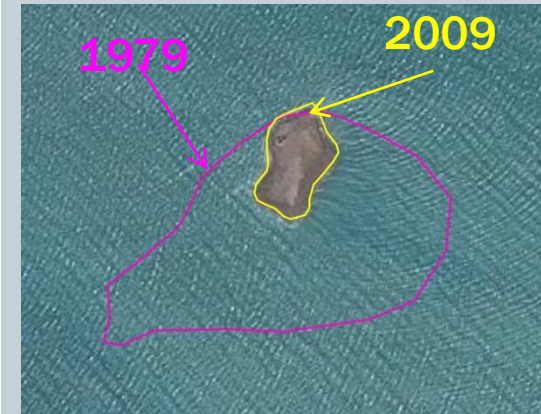
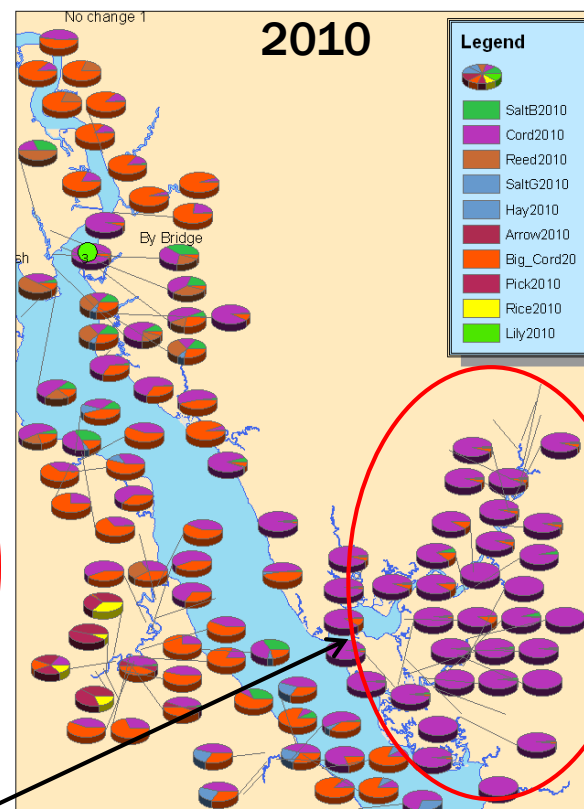
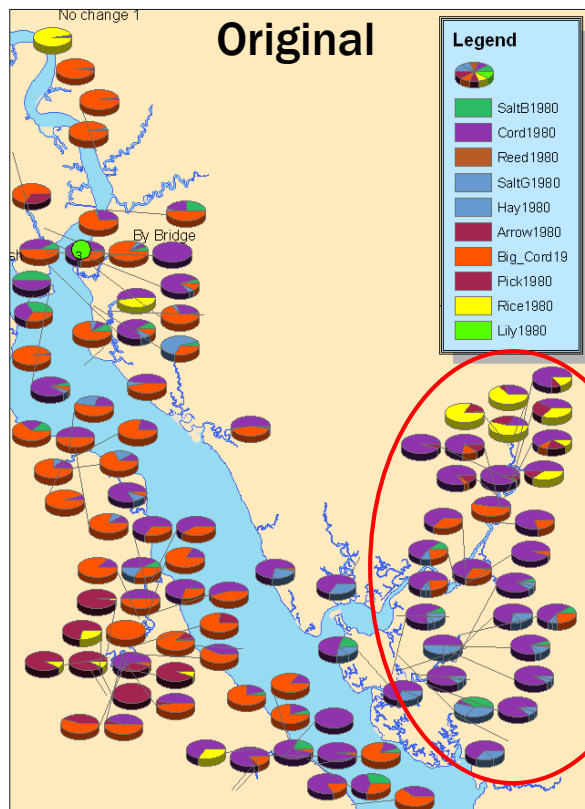


- Marsh lost ~ 134 acres between 1979 and 2009
- Predominantly due to shoreline erosion
- Milligan *et al.* (2010) found continuous recession here
- Some inland migration

COMMUNITY SHIFTS BETWEEN THE 2 SURVEYS



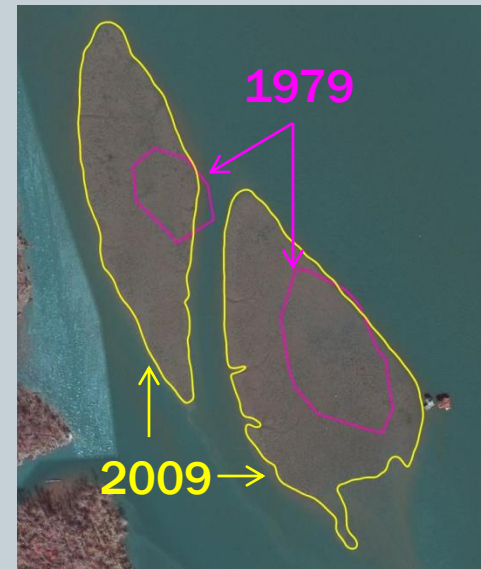
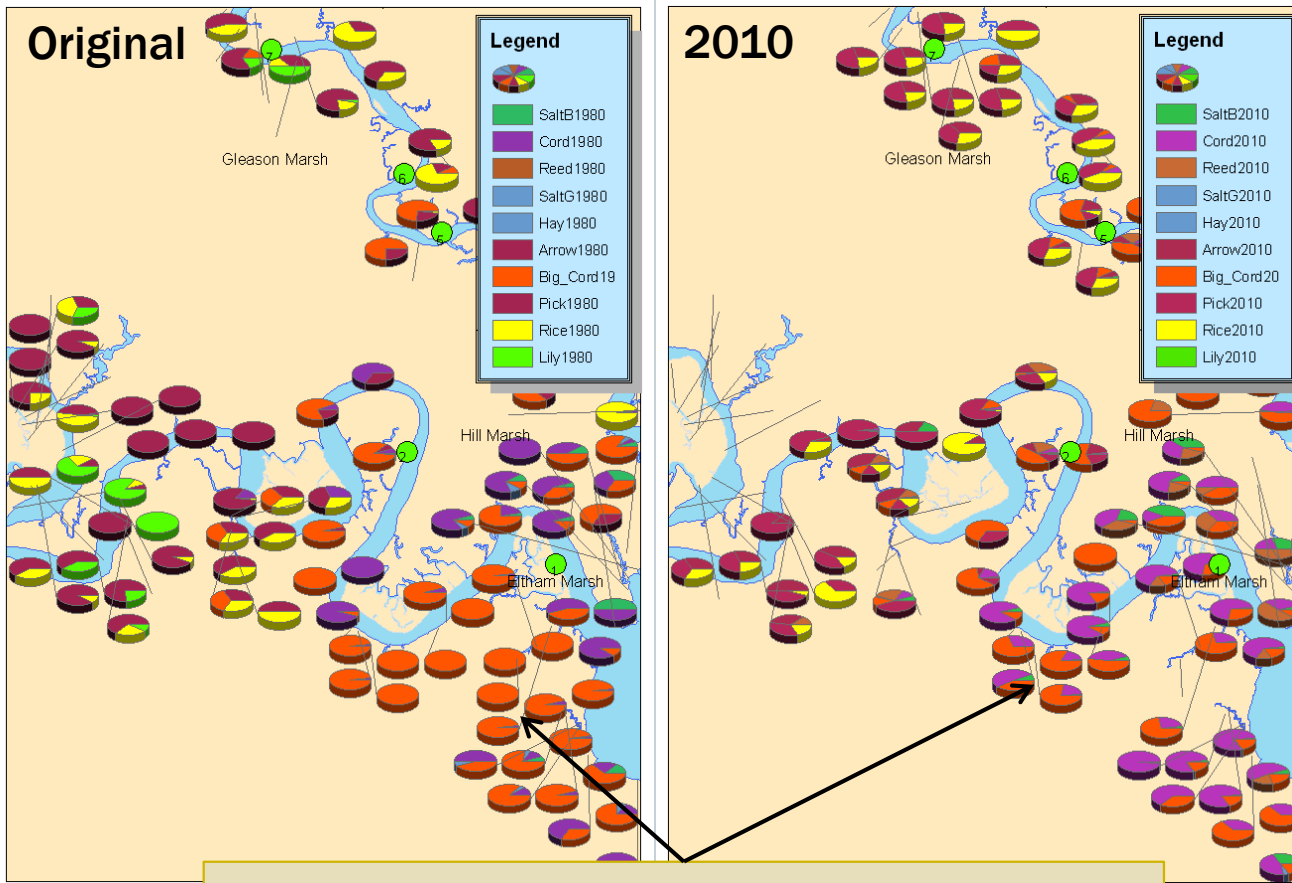
PURTAN BAY



Purtan Creek Marsh Island

- Shift from fairly diverse marshes to almost monotypic *Spartina alterniflora*.
- Lost fresh water community at top of creek

PAMUNKEY RIVER



Accretion of Pamunkey marsh islands

- Increased *S. alterniflora* presence
- Shift in dominant species
- = shift in salinity, innundation, or both?

CONCLUSIONS

- Marsh extent and plant composition have changed over the past 30 years, concurrent with sea level rise
- Loss of extent:
 - Fringe marshes (throughout)
 - High salinity/high energy marsh islands
 - Marshes in front of shoreline structures
- Change in community:
 - Freshwater-headwater wetlands
 - Extensive riverine marshes

CONCLUSIONS

- Large scale modeling may be compromised by spatial variability of marsh processes and driving factors
- Must determine the best way to accurately measure changes in marsh elevation if we want to incorporate into the models
- Human interactions are dynamic, and currently not effectively incorporated into models