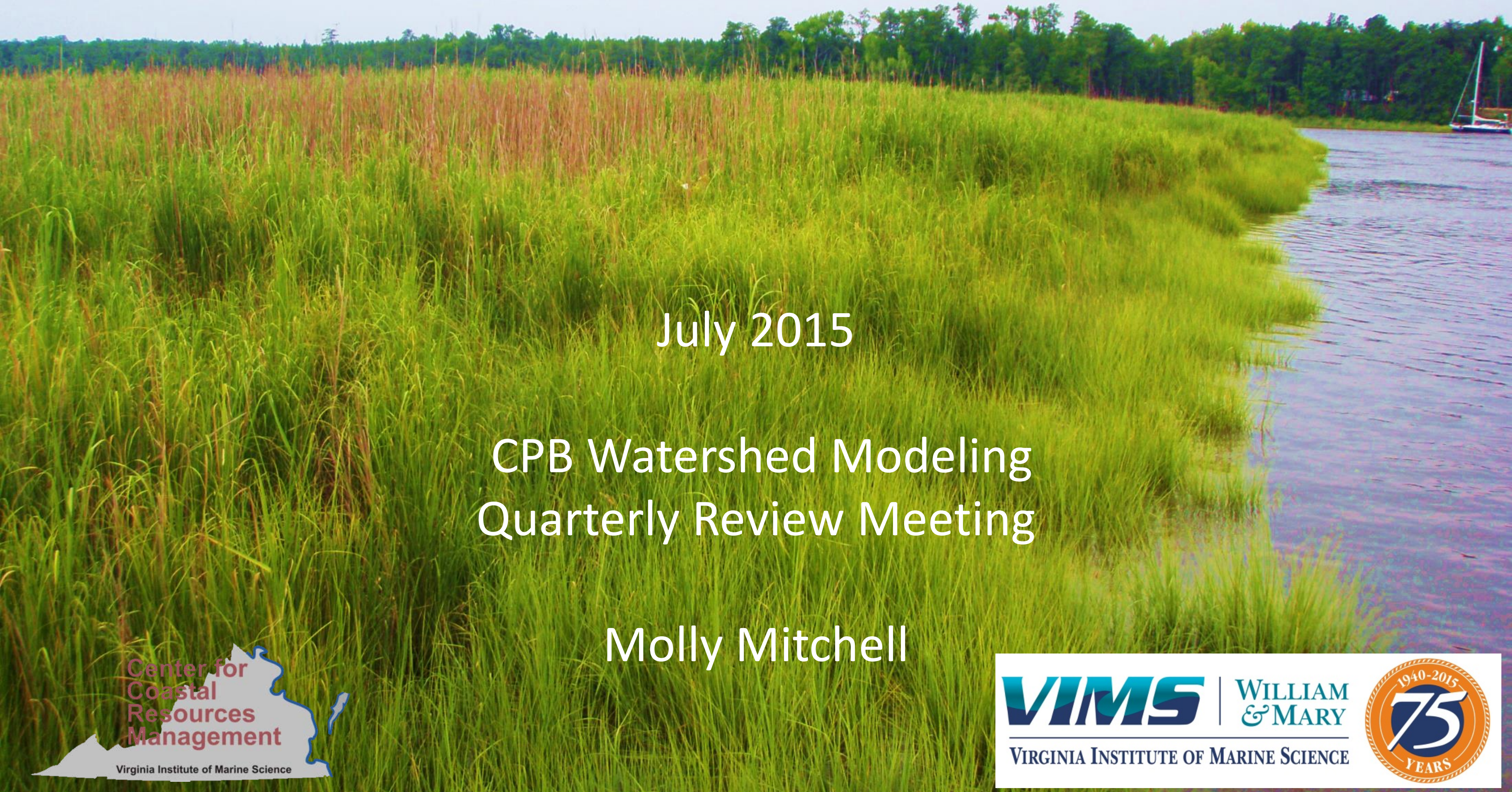
Loss of Coastal Marshes to Sea Level Rise



July 2015

CPB Watershed Modeling
Quarterly Review Meeting

Molly Mitchell

Center for Coastal Resources Management
Virginia Institute of Marine Science

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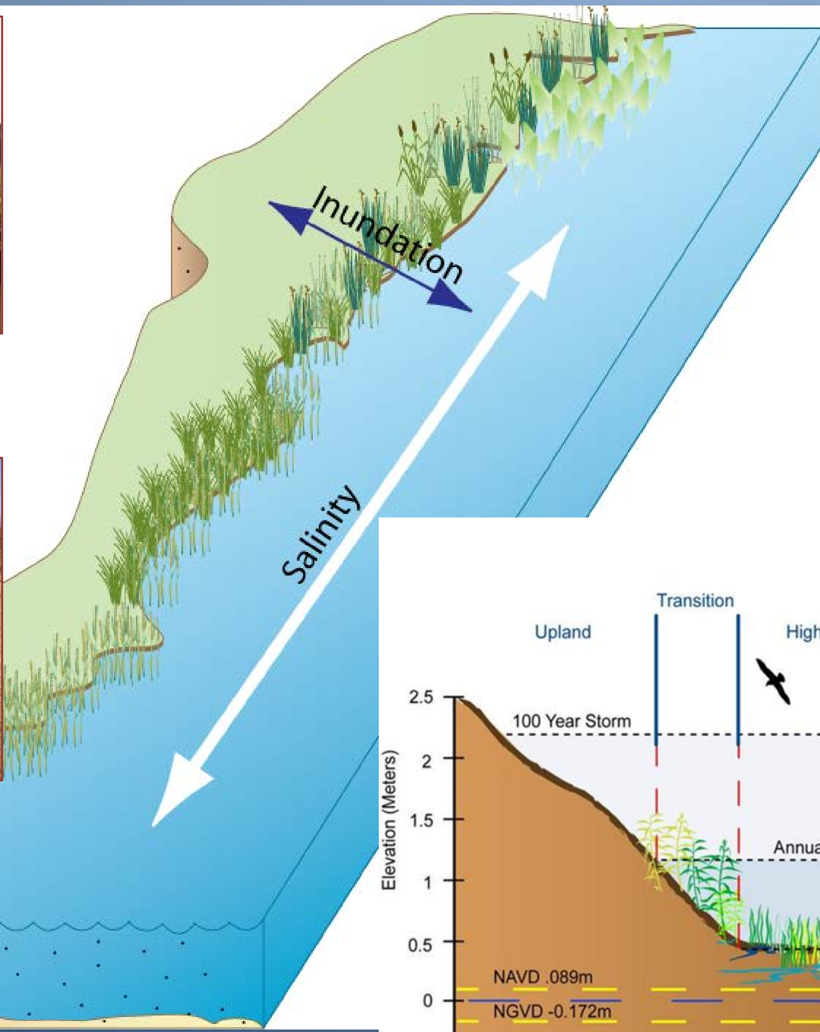
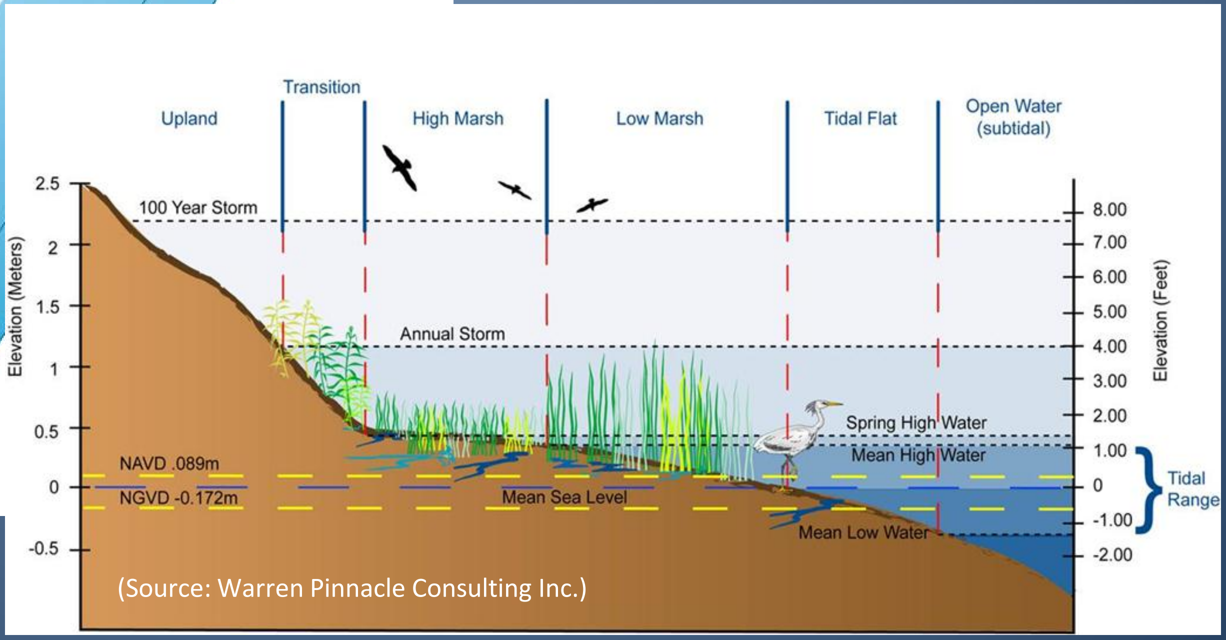
The tidal marsh community continuum





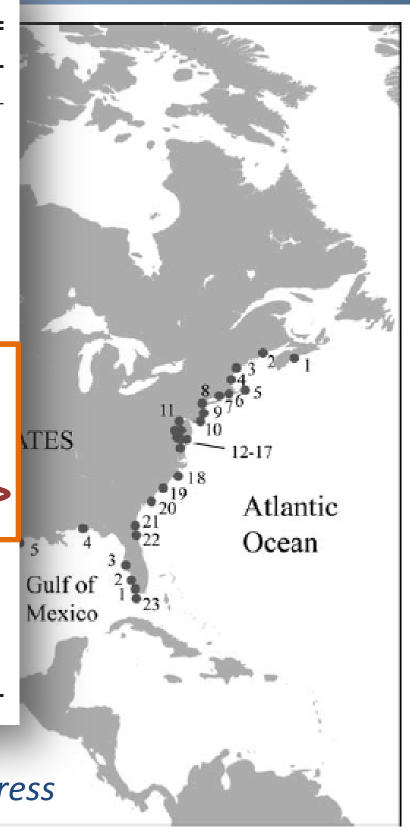
(Source: Warren Pinnacle Consulting Inc.)

Sea Level Rise in the CB

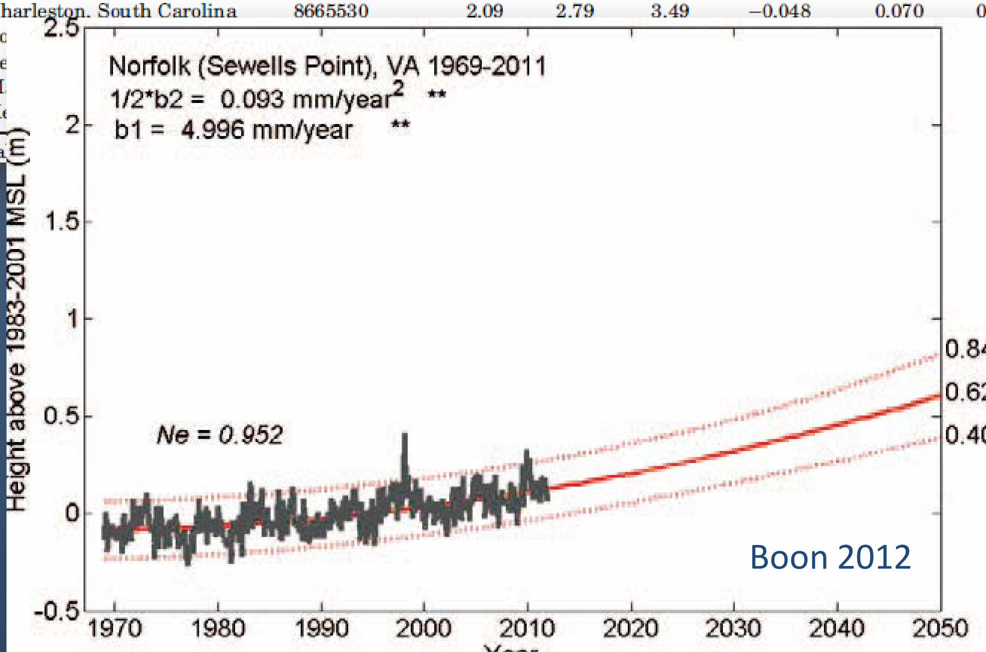
Table 1. *East Coast rise (β₁*), acceleration (β₂*), and projected year 2050 height percentiles given 1969–2014 monthly RMSL.*

Station	ID Number	β_1* (mm/y) 2.5%	β_1* (mm/y) 50%	β_1* (mm/y) 97.5%	β_2* (mm/y^2) 2.5%	β_2* (mm/y^2) 50%	β_2* (mm/y^2) 97.5%	2050 Projection (cm) 2.5%	2050 Projection (cm) 50%	2050 Projection (cm) 97.5%
1. Halifax, Nova Scotia	00490/491[a]	1.99	2.62	3.29	0.112	0.174	0.243	33	44	56
2. Eastport, Maine	8410140	0.73	1.73	2.72	0.183	0.271	0.357	41	56	71
3. Portland, Maine	8418150	0.15	1.23	2.41	0.153	0.256	0.359	33	51	69
4. Boston, Massachusetts	8443970	2.08	3.07	4.08	0.164	0.257	0.357	46	62	80
5. Nantucket, Massachusetts	8449130	2.97	3.64	4.37	0.071	0.157	0.242	33	48	62
6. Newport, Rhode Island	8452660	2.29	3.04	3.82	0.074	0.165	0.257	30	46	62
7. New London, Connecticut	8461490	2.59	3.52	4.45	0.098	0.209	0.316	37	55	75
8. The Battery, New York	8518750	2.63	3.49	4.37	0.047	0.158	0.266	29	47	66
9. Sandy Hook, New Jersey	8531680	3.25	4.26	5.23	0.104	0.212	0.319	43	61	79
10. Atlantic City, New Jersey	8534720	3.71	4.56	5.48	−0.055	0.105	0.251	19	45	68
11. Baltimore, Maryland	8574680	2.57	3.38	4.18	0.049	0.151	0.247	29	45	61
12. Annapolis, Maryland	8575512	2.66	3.53	4.41	0.080	0.181	0.280	34	51	67
13. Washington, DC	8594900	2.15	3.24	4.27	0.011	0.163	0.308	23	46	70
14. Solomons Island, Maryland	8577330	3.71	4.76	5.70	0.113	0.221	0.330	48	64	81
15. Yorktown, Virginia	8637624/689[a]	3.75	4.82	5.86	0.059	0.197	0.318	40	61	81
16. Norfolk, Virginia	8638610	4.15	5.11	6.04	0.034	0.160	0.289	37	57	78
17. Kiptopeke, Virginia	8632200	2.96	3.68	4.46	−0.037	0.077	0.181	16	34	52
18. Wilmington, North Carolina	8658120	0.84	1.70	2.58	−0.054	0.079	0.214	−1	23	45
19. Charleston, South Carolina	8665530	2.09	2.79	3.49	−0.048	0.070	0.184	7	28	46
20. Fo							177	5	27	47
21. Fe							130	−13	11	33
22. M							207	4	28	50
23. Ke							146	7	24	38

[a] Dua

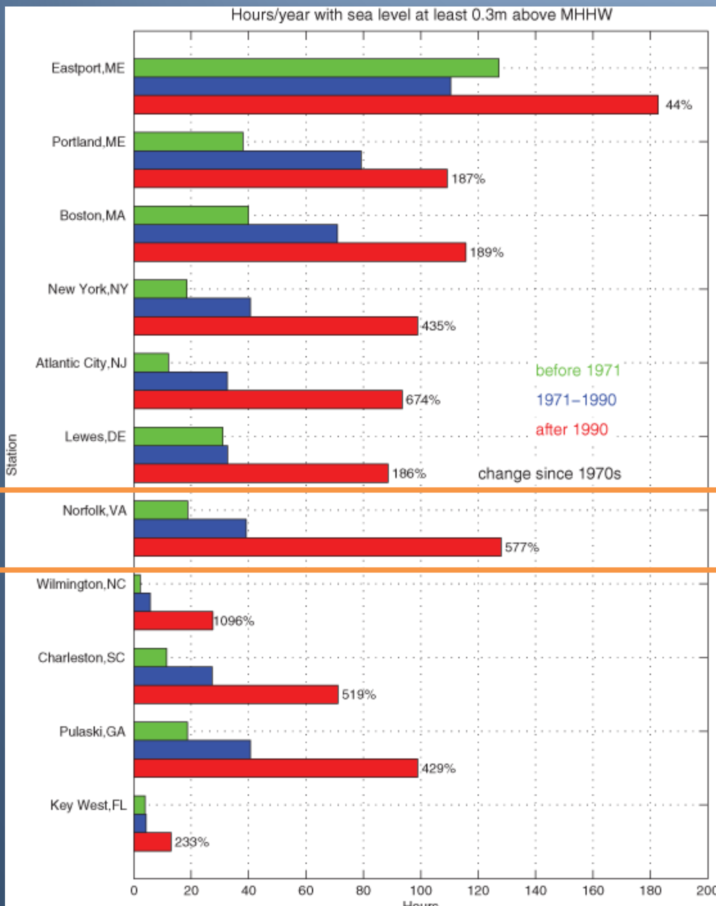


Boon and Mitchell *In press*



…stations 5 (Galveston) and 6 (Rockport), which have the highest median rise rates of any station in this study at 5.46 mm/y and 6.11 mm/y, respectively (Table 2), **followed by station 16 (Norfolk) at 5.11 mm/y …**

Increasing inundation



Ezer and Atkinson 2014

Photo by Marvin Nauman/FEMA

- Birds that nest in tall grasses lose habitat (king rails, least bitterns, etc.)
- Projections indicate that a 3-foot loss sea level rise could reduce populations by 48% (Wilson and Watts 2010)

Increasing salinity

- Salinity has increased ~ 0.5 ppt since 1949 (Hilton et al 2008), water levels have increased by ~ .22m (8.6 in)

- Chesapeake Bay estimates for salinity in 2100: 4-12 ppt increase over current levels

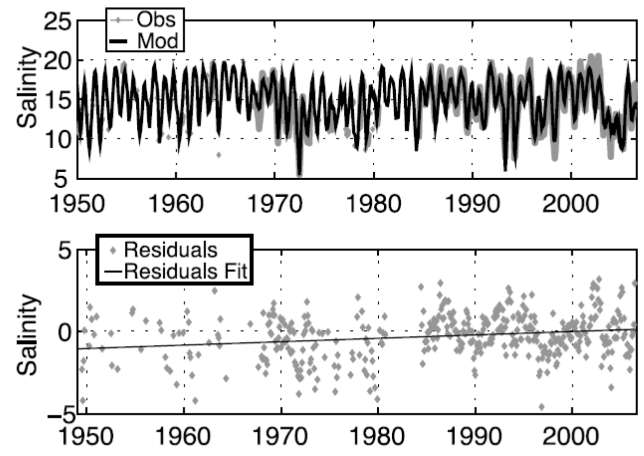


Figure 5. Salinity and residual time series for cell (4, 1). Model $r^2 = 0.78$.

Table 3. Number of days that salinity is predicted to exceed 0.1 parts per thousand at the head of the York estuary from June 1 to December 31 (total 214 days) of the year indicated for the no-rise scenario and the three sea-level rise scenarios.

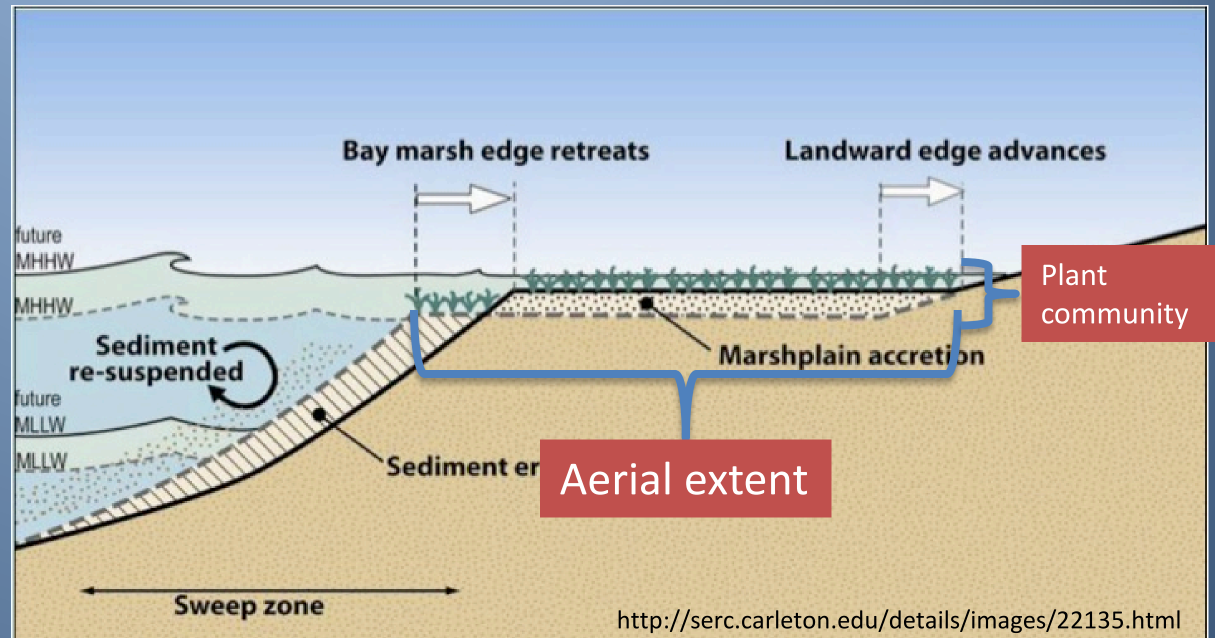
[cm, centimeter]

Model scenario	Dry year 2002	Wet year 2003	Typical year 2005
No rise	214	183	214
30-cm rise	214	201	214
50-cm rise	214	211	214
100-cm rise	214	214	214

"…a large increase in mean salinity is predicted for each sea-level rise scenario. This will greatly alter the existing water-quality gradients between the brackish water and freshwater. (Rice et al. 2011)

To keep pace with sea level

- Marshes migrate
- Marshes accrete (grow upwards)



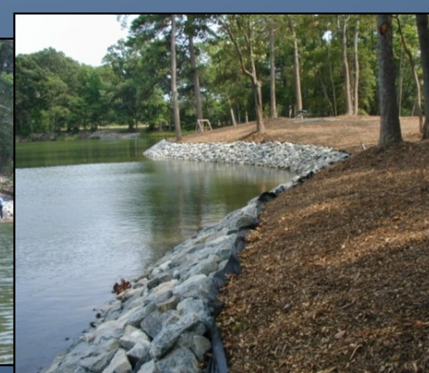
Chesapeake Bay

18% of tidal shoreline hardened

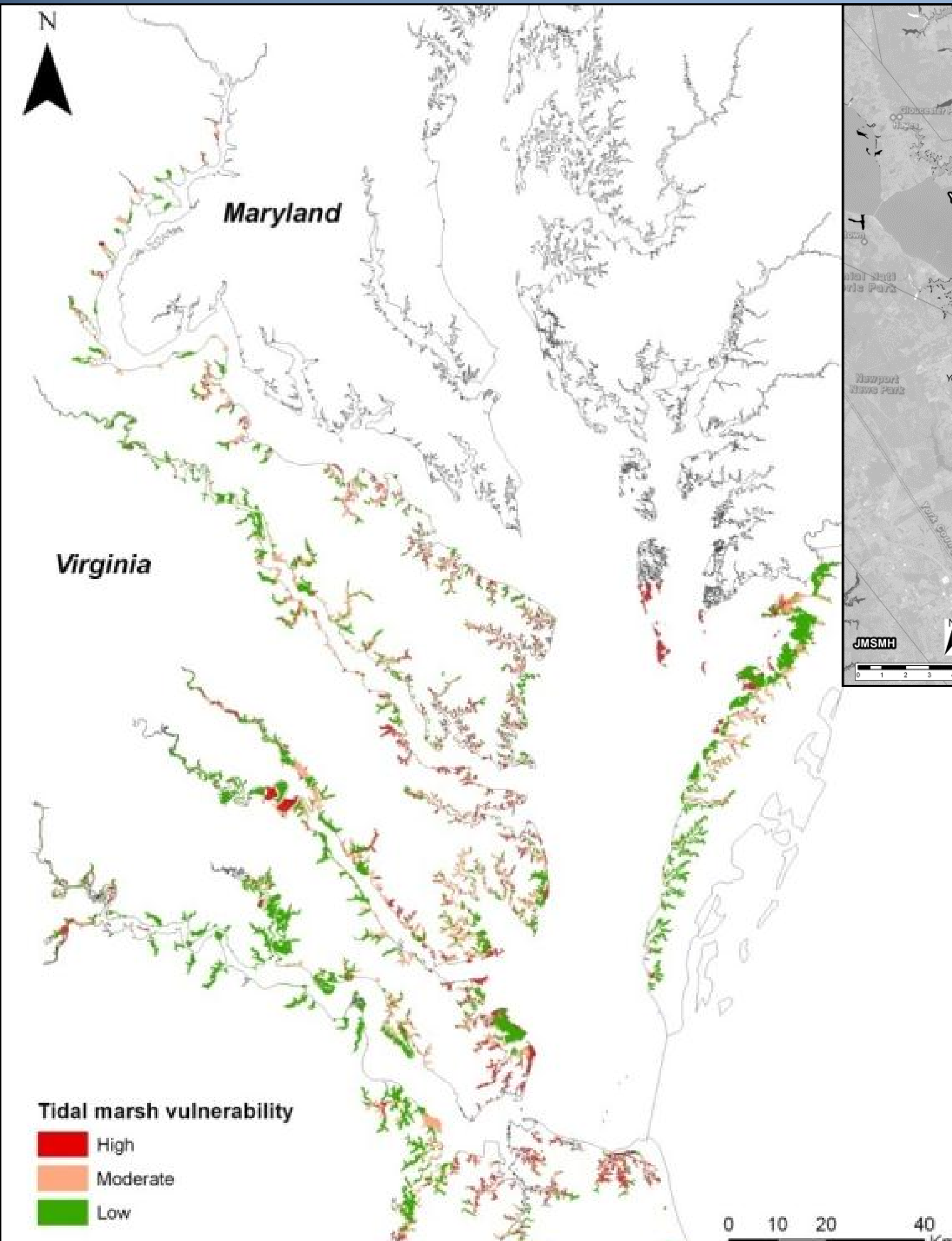
***VA**: 11%* ***MD**: 28%*

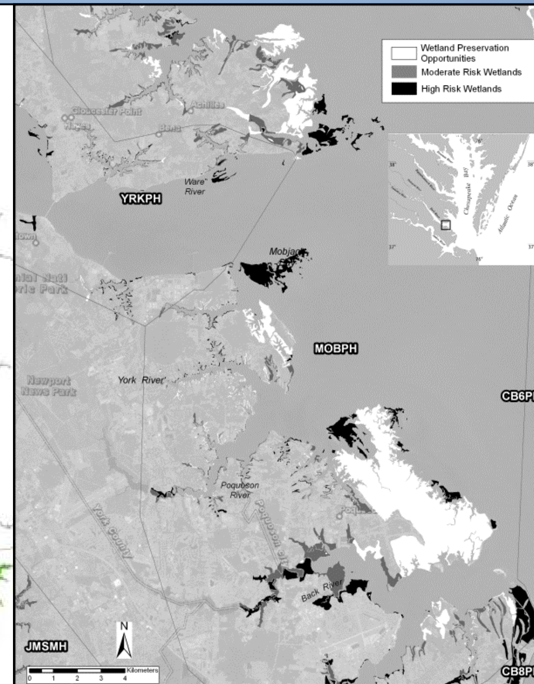
32% riparian land developed

~5 km² of artificial substrate introduced (*intertidal impacted*)

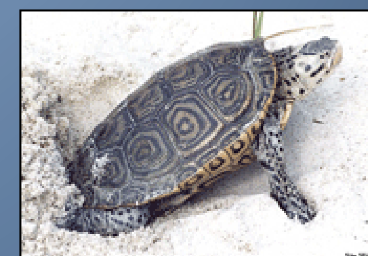


Tidal Marshes – SLR & barriers to migration

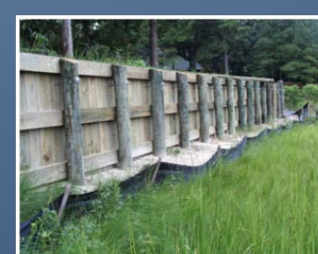




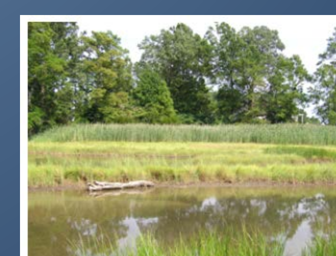
Tidal marshes in the meso-polyhaline reaches at highest risk due to land development & SLR



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



High Risk Marsh

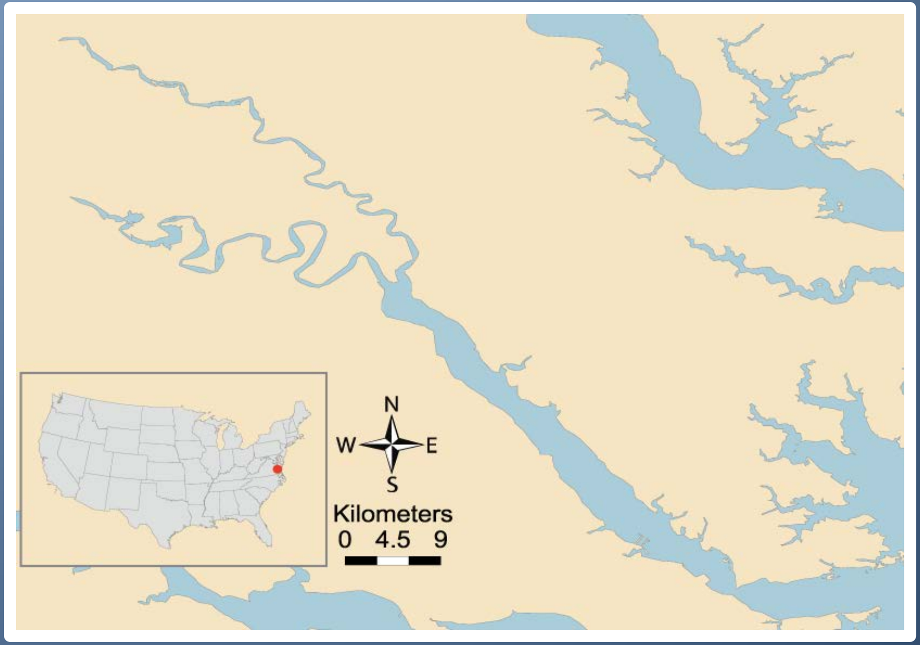


Low Risk Marsh

Bilkovic et al. 2009 Vulnerability of shallow tidal water habitats in Virginia to climate change. http://ccrm.vims.edu/research/climate_change/index.html

How are marshes responding to sea level rise?

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



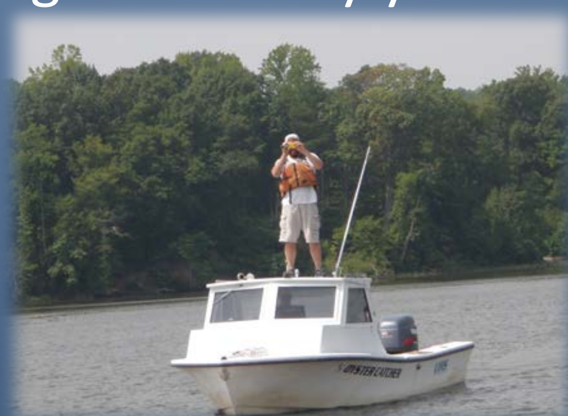
Original Tidal Marsh Inventory

- 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

- <u>Will</u> 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%).

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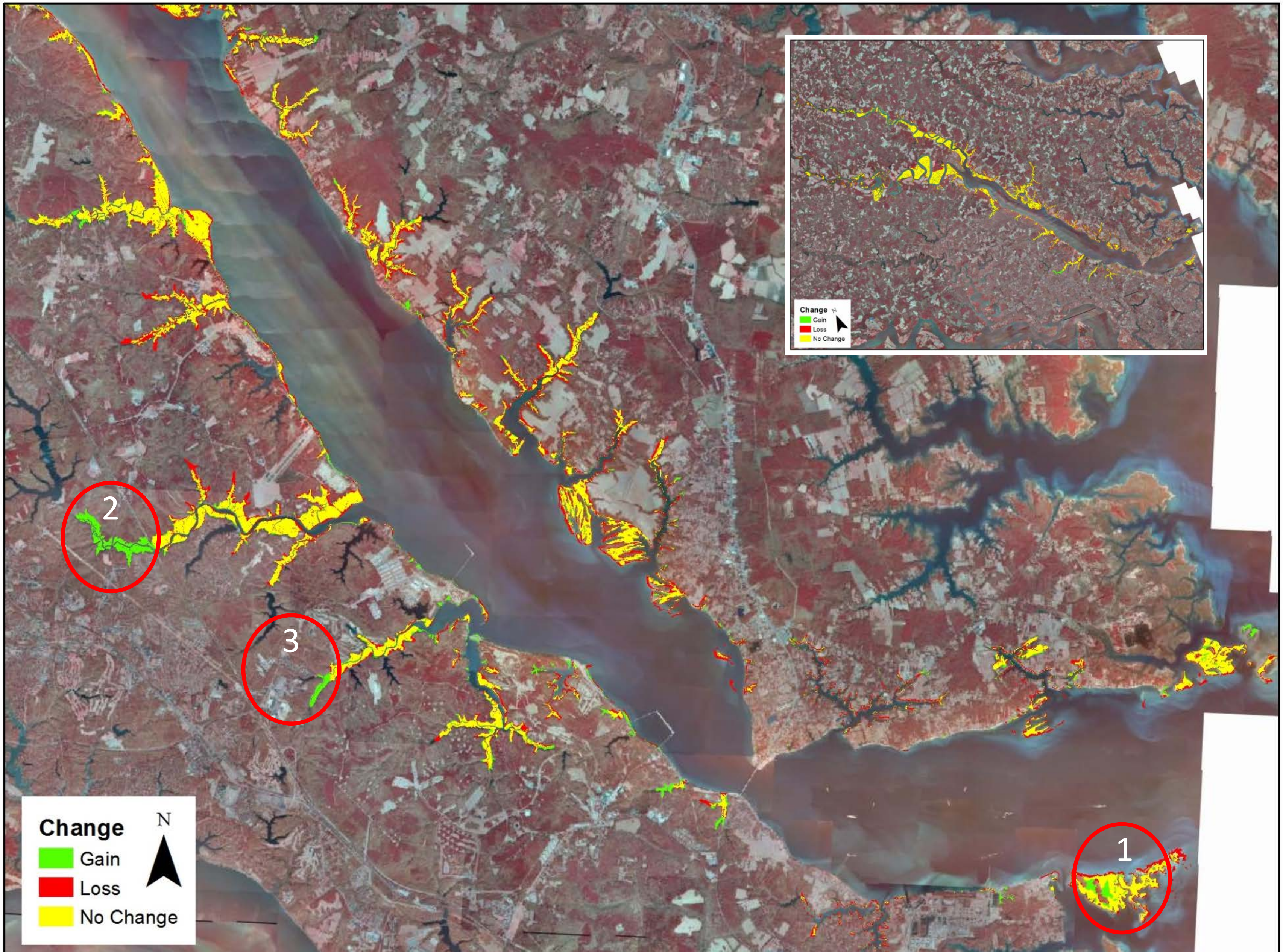
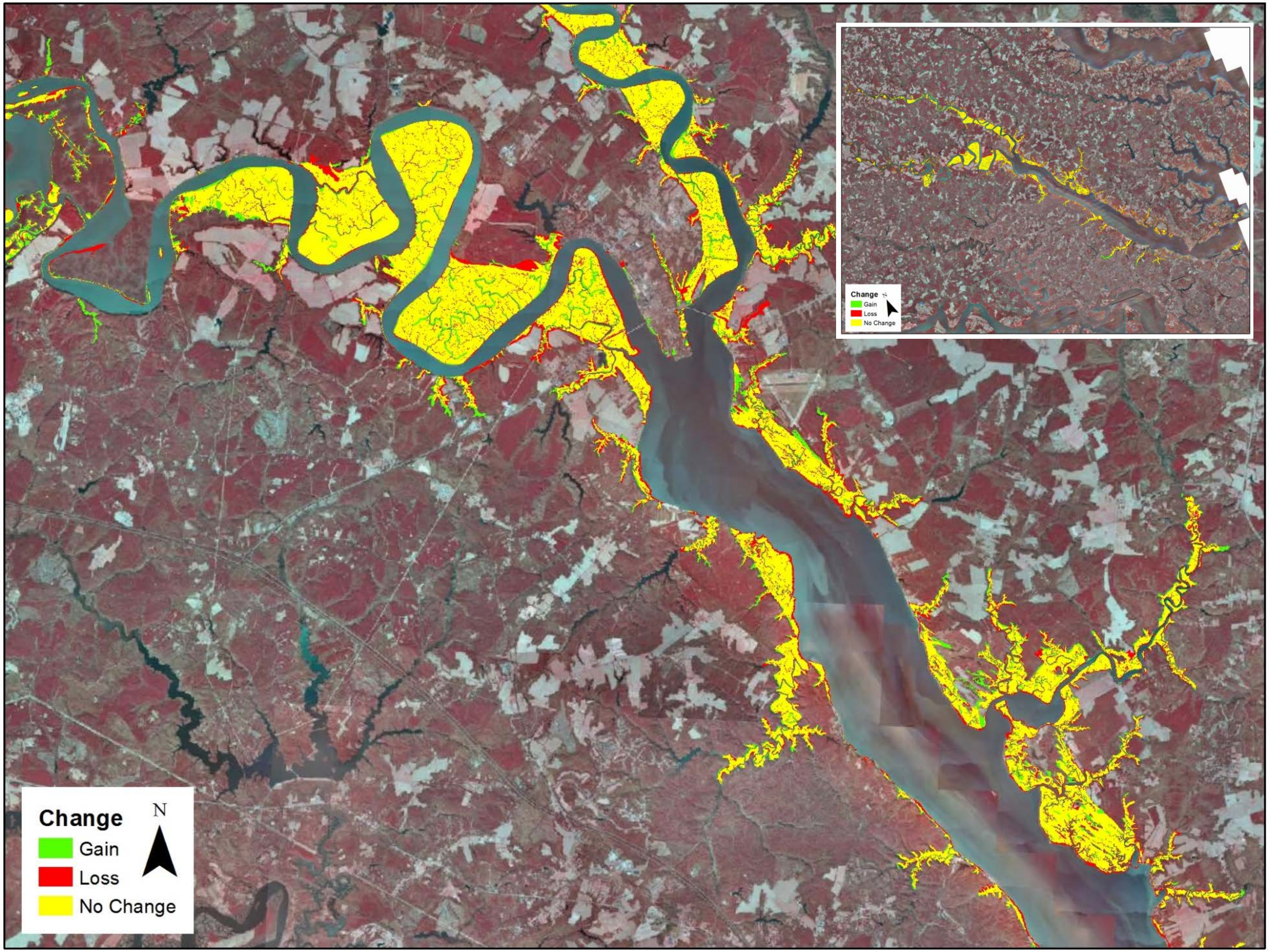




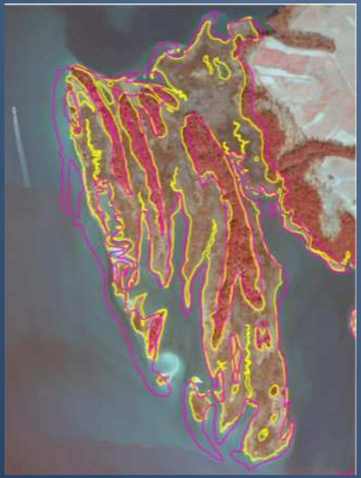
Change
Gain
Loss
No Change
N
Change
Gain
Loss
No Change

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

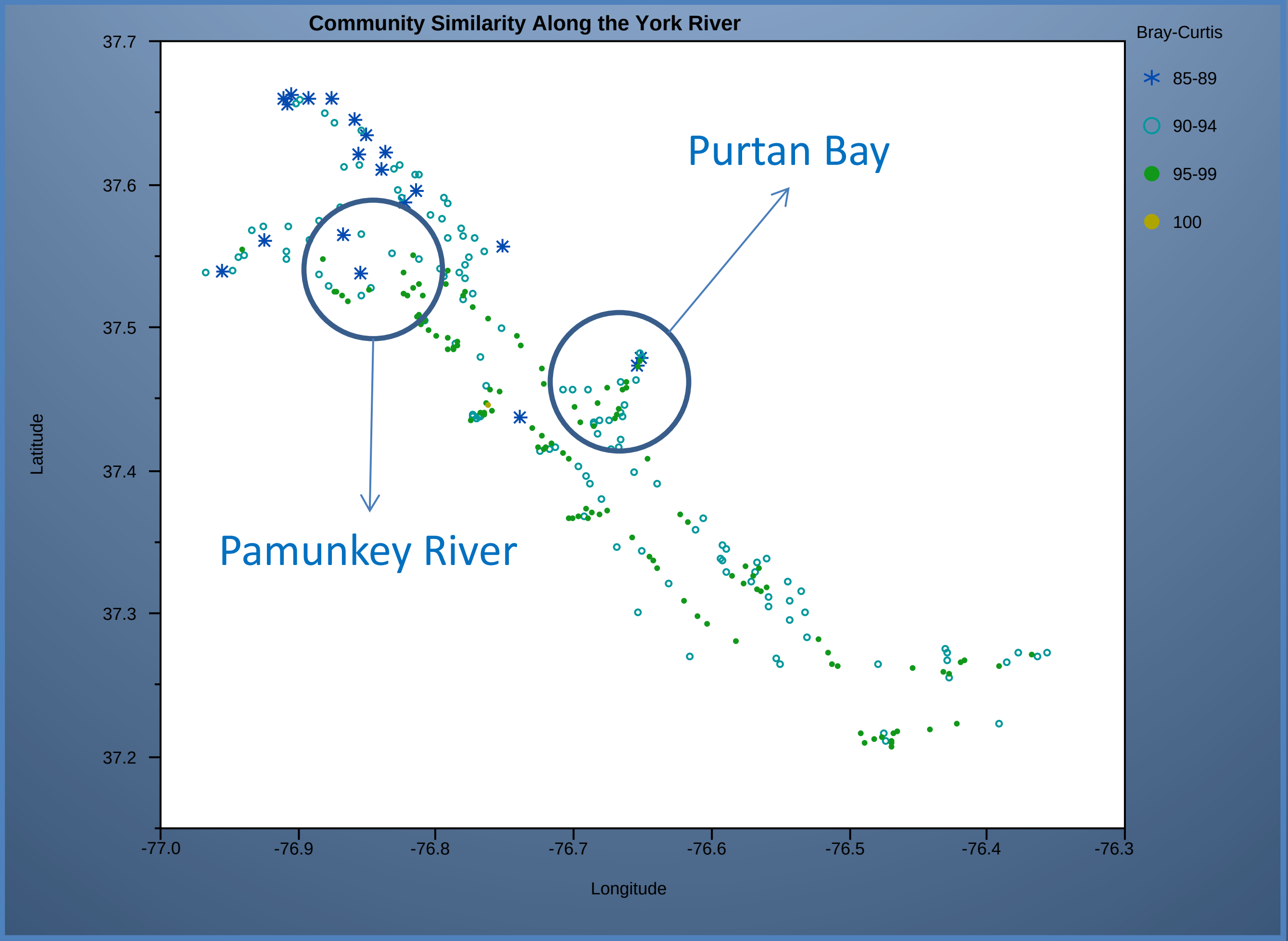
We have verified apparent erosion against other work.



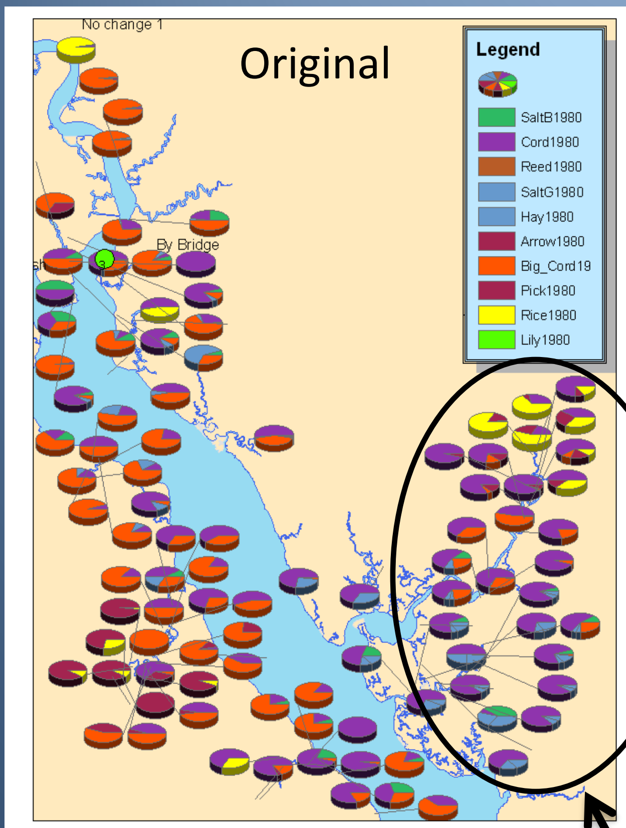
- Marsh lost ~ 44 acres between 1979 and 2009
- Predominantly due to shoreline erosion
- Milligan *et al*. (2010) found up to1.5 meters of erosion/year here

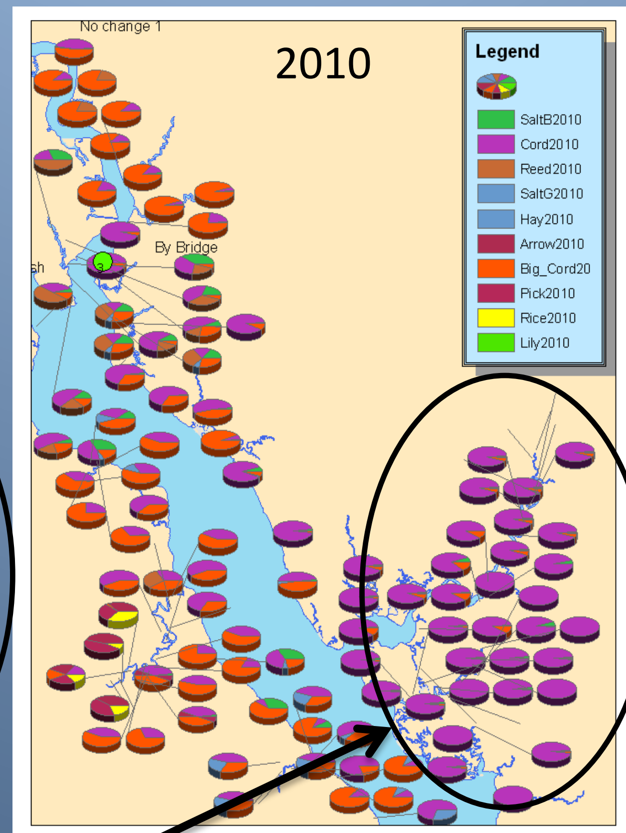
- Marsh lost ~ 134 acres between 1979 and 2009
- Predominantly due to shoreline erosion
- Milligan *et al*. (2010) found continuous recession here
- Some inland migration

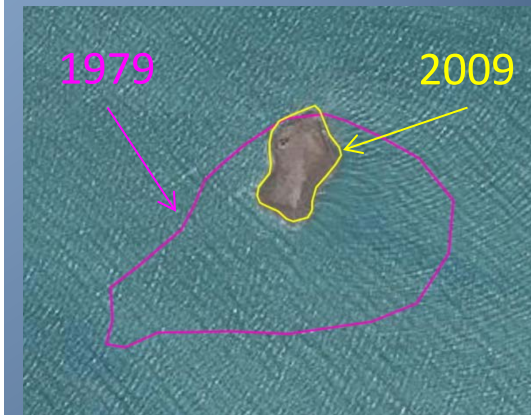
Community shifts between the 2 surveys



Purtan Bay



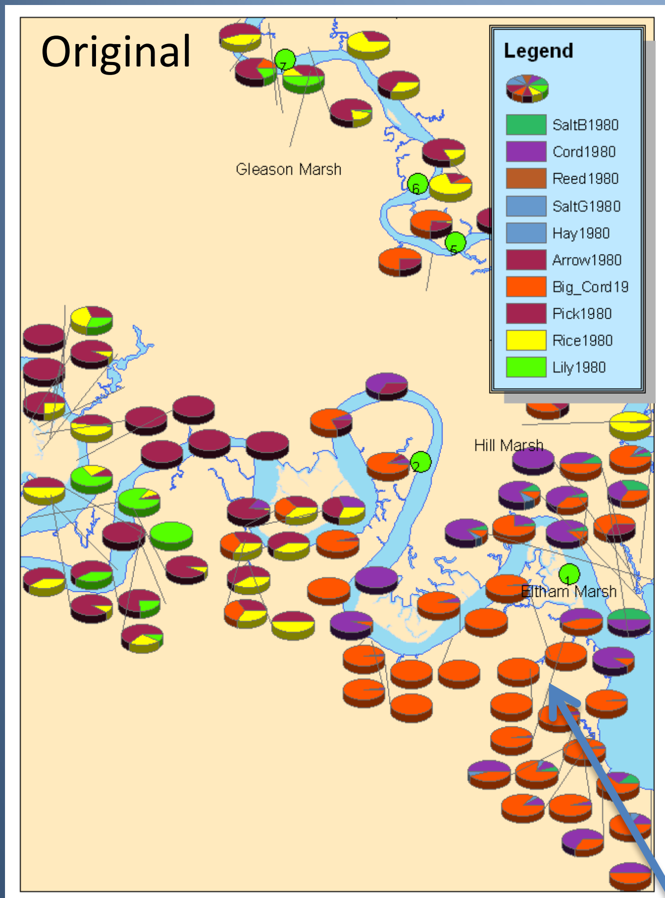


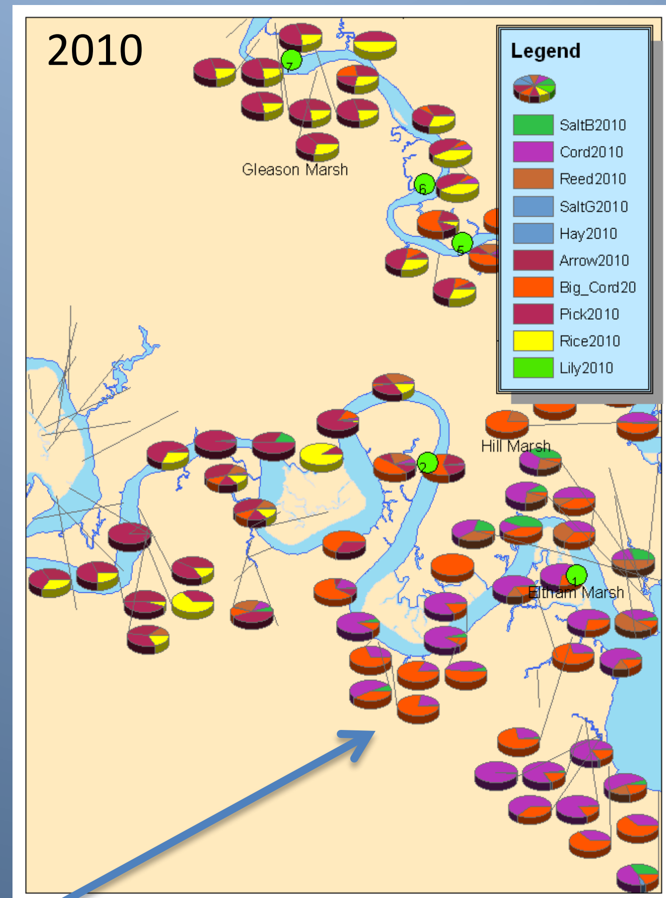


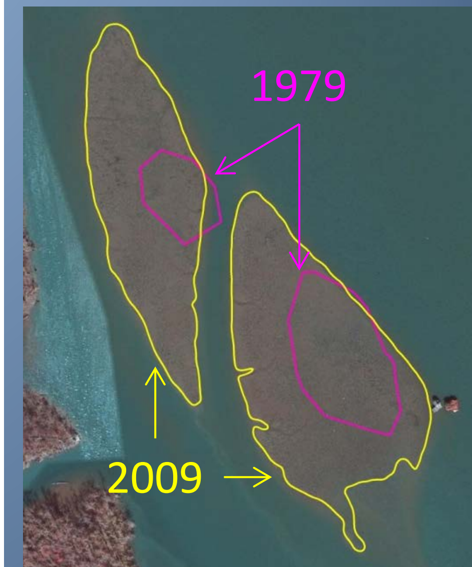
Purtan Creek Marsh Island

- 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

- Highest risk:
    - Fringe marshes (throughout)
    - High salinity/high energy marsh islands
    - Freshwater-headwater wetlands
    - Marshes in front of shoreline structures

- Lowest risk:
    - Extensive riverine marshes

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On-going work…

- What changes in function may have occurred with changes in communities?

- Have land use and shoreline alterations been a driver of changing communities?

- How do community change patterns shift across the Chesapeake Bay?

- How can this inform models of future marsh distribution?