Understanding the Fate of the Jug Bay Freshwater Tidal Wetlands in Light of Sea Level Rise: A Conceptual Model

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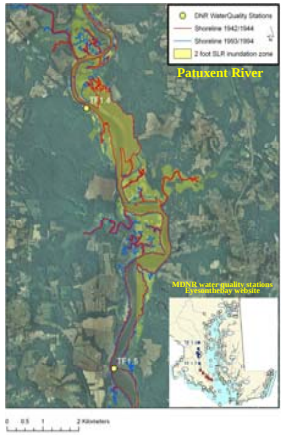
The wetlands of Jug Bay on the Patuxent River estuary represent one of the largest freshwater tidal systems on the U.S. East Coast. This unique ecosystem is characterized by a diverse community of plants including wild rice (Zizania aquatica), spatterdock (Nuphar advena), arrow arum (Peltandra virginica), broad-leaved arrowhead (Sagittaria latifolia), cattail (Typha spp.), and common reed (Phragmites australis). As a result of current climate change projections, an estimated sea level rise of 2.7 - 4.5 mm yr-1 within the Chesapeake Bay area may result in salinity and hydrological changes to the upstream portion of the estuary. These could trigger significant impacts to freshwater tidal wetlands, particularly to plant species sensitive to small-scale changes in salinity and inundation patterns. In an initial effort to evaluate the potential impacts of sea level rise to the Jug Bay freshwater tidal wetlands, a series of long-term monitoring data from Jug Bay and the Patuxent River were used to develop a conceptual model to support projections of the response of this system to different management and climate change scenarios. Information that was analyzed included a long-term record of plant community species composition, water quality data, surface elevation change data derived from studies measuring surface elevation tables, and habitat classification information. Projected impacts to the vegetation community varied depending on the degree of change in salinity and water levels, the range of the species' tolerance to these changes, and their position along the intertidal gradient.

Main Objectives

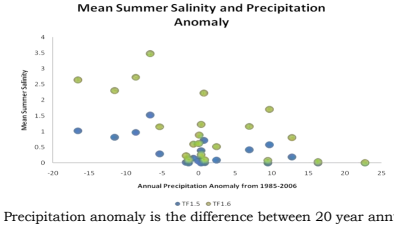
- Develop a conceptual model that identifies the main potential impacts of sea level rise on tidal freshwater marshes, particularly water level and salinity changes.
- Identify the relationships among the different factors affecting the ability of the wetland to keep pace with sea level rise.
- Derive initial predictions of potential impacts of SLR to marsh vegetation based on the analysis of longterm datasets.

Jug Bay Study Site

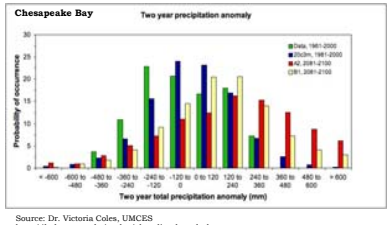


Two-foot sea level rise data from Anne Arundel County, Maryland DNR. 2007 imagery from the National Agriculture Inventory Program. Historical river shorelines from the Maryland Geological Survey.

Salinity Trends in the Patuxent River

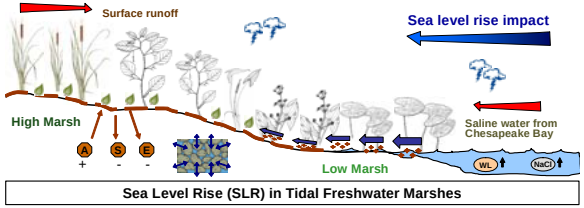


Precipitation anomaly is the difference between 20 year annual precipitation average and each annual value – more negative values indicate dry years. Salinity during summer months is higher during dry years. TF 1.6 is located downstream of TF1.5.



Source: Dr. Victoria Coles, UMCES
http://hpl.umces.edu/vcoles/cbayclim-drought.htm

Conceptual Model



Sea Level Rise (SLR) in Tidal Freshwater Marshes

Factors that Mitigate SLR Impacts

- Elevation change determines if marsh can keep up with sea level rise or not.
- \+ A: Accretion: inorganic and/or organic matter deposition on the marsh surface – positive impact on marsh elevation.
- \- S: Subsidence: loss in marsh elevation due to processes such as compaction, de-watering, and decomposition of organic matter.
- \- E: Erosion has a negative impact on marsh elevation.
- Storm events trigger the delivery of important sediments to the marsh system.
- Suspended sediments carried by the river can be deposited in the marsh.
- Organic matter: deposition (+) and decomposition (-) affects marsh vertical accretion.

Negative Impacts of SLR

- NaCl: Sea level rise results in salinity intrusion, which may affect marsh vegetation dynamics and marsh processes.
- WL: Sea level rise results in increased water levels, which leads to higher frequency and duration of flooding on the marsh. Increased water depth may change river velocity changing deposition and erosion rates.
- Groundwater salinity may increase due to salt water intrusion.

Tolerance of Tidal Freshwater Wetland Plants to Salinity and Flooding

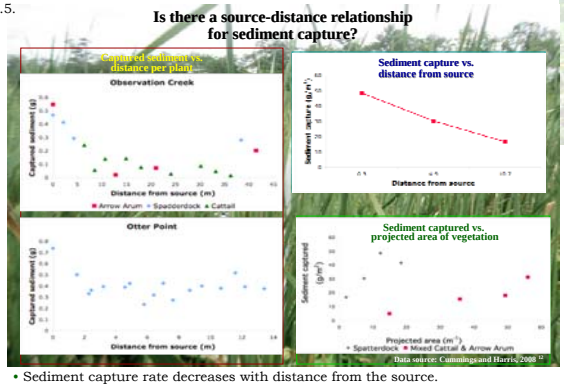
Salinity Range: ≤ 0.2 ppt | ≤ 0.4 ppt | ≤ 7.5 ppt | ≤ 18 ppt | Flood-tolerant plants

Species	A/P*	Salinity Tolerance[1]	Flooding Tolerance
Low Marsh			
Nuphar advena	P		
Zizania aquatica	A	0.37 ppt [2]	Reduced size & seed production with 30 – 50 cm flooding [3]
Pontederia cordata	P		
Middle Marsh			
Acorus calamus	P		
Sagittaria latifolia	P		
Leersia oryzoides	P		10 cm flooding reduced abundance [4]
Impatiens capensis	A		Flooding reduced germination rate [5]
Polygonum arifolium	A		10 cm flooding reduced abundance [4]
Peltandra virginica	P		Not affected by 10 cm flooding [4]
Typha angustifolia	P	Reduced biomass at > 10 ppt [2]	Grows in 1m water, tolerant to flooding [6]
High Marsh			
Acorus calamus	P		
Aster puniceus	P		
Bidens laevis	A/P		Flooding reduced germination rate [7]
Iris versicolor	P		
Lythrum salicaria (non native)	P		
Pilea pumilla	A		10 cm flooding reduced abundance [4]
Typha latifolia	P		
Polygonum punctatum	A		Flooding reduced germination rate [7]
Polygonum sagittatum	A		
Hibiscus palustris	P		
Phragmites australis	P	Growth decreased with > salinity[4]	Flooding prevented bud emergence [4]
Rosa palustris	P		
Swamp/High Marsh			
Acer rubrum	P		
Alnus serrulata	P		

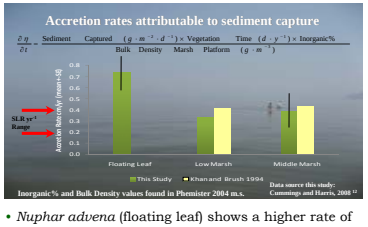
* A = Annual; P = Perennial

[1] Unless noted otherwise, salinity data from Anderson, Richard R., Russell G. Brown, and Robert D. Rappleye. 1968. Water quality and plant Distribution along the Upper Patuxent River, Maryland. Chesapeake Science 9(3) 145-156.

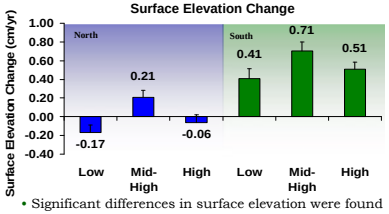
Marsh Sedimentation and Surface Elevation



- Sediment capture rate decreases with distance from the source.
- Plant sediment capture is related to distance from the sediment source, species, plant position and distance from the sediment surface, and plant leaf area, density, and orientation.

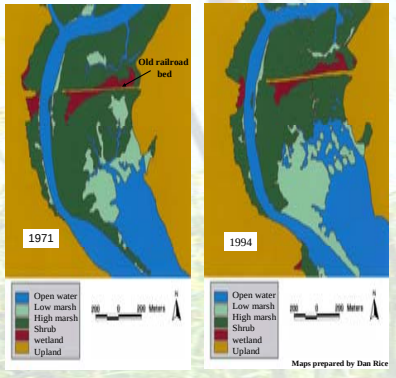


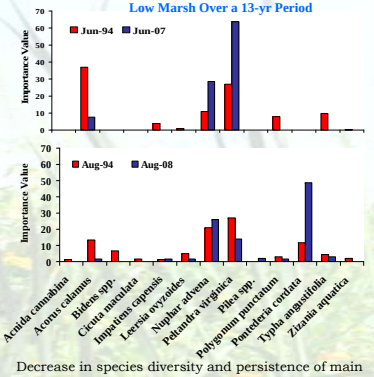
- *Nuphar advena* (floating leaf) shows a higher rate of accretion than the low and middle marsh.
- The N. advena zone is likely to keep pace with higher projected SLR rates if sediment loads remain constant.



- Significant differences in surface elevation were found between the marshes of the north and south side of the railroad at Jug Bay's Glebe Marsh.
- Surface elevation change did not differ significantly among marsh intertidal zones.

Longterm Record of Marsh Species Distribution along the Intertidal Gradient





Decrease in species diversity and persistence of main low marsh plants such as N. advena, P. virginica, and P. cordata.
Species changes could be associated with observed flooding increase in this low marsh.

1994 Vegetation data from D'Avanzo, 1995[10] and Perry, 1994 [11]

Tidal Freshwater Marsh Community Change Projections and Considerations in Response to Sea Level Rise

Sea level Rise

Salinity Increases

- Decreased abundance of intolerant species (i.e., wild rice).
- Tolerant species expand and survive.
- Plant diversity decreases.
- Plant productivity decreases.
- Soil porewater salinity increases.
- Biogeochemical and microbial processes may be altered.
- Organic matter decomposition rates will increase, affecting marsh surface elevation.
- Landuse effects on surface runoff and seasonal patterns of Patuxent River discharge may further affect interannual salinity variability, with dry years leading to higher summer salinity values in Jug Bay.

Inundation Increases

- Marsh transgression may occur: low marsh changes to open water; middle marsh to low marsh, and high marsh to mid marsh.
- Marsh landward progression would occur where suitable space is available.
- Increased water depth may change river velocity, thus changing deposition and erosion rates.
- Decrease in plant diversity.
- Increased dominance of flood tolerant species in the low marsh.
- Higher water levels might result in less exposure of mudflats during low tide.
- Low marsh species (e.g., wild rice) with a narrow flooding tolerance range could become restricted to smaller areas.

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