NSF CSEES project update

Project activity: Tidal marsh frame movement under sea level rise

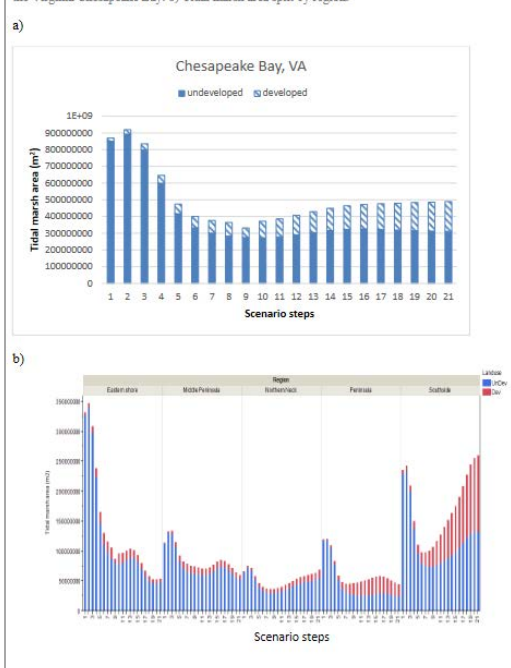
Objective: Tidal marshes are important ecological components of the coastal system that are currently responding to sea level rise-driven changes in tidal regimes. These changes will affect future tidal marsh distribution, connectivity and role in estuarine systems. Concurrently, human development along the coastline is creating barriers to marsh migration that will also be an important moderator of future tidal marsh distributions. Sea level rise is creating pressures for coastal areas to defend their infrastructure, leading to conflict between human and natural landscapes as tidal marshes attempt to migrate inland.

The goal of this project was to examine the movement of the tidal marsh frame across the landscape under projected sea level rise for the Chesapeake Bay, VA. This allows examination of changes in marsh extent by location, the conflict with developed lands, and targeting of critical areas for preservation and retreat management action.

Methods: Modeling of the tidal marsh extent was based on elevation in a high-resolution lidar data set of the Chesapeake Bay, VA localities using ArcGIS software. The vegetated tidal marsh frame in the Chesapeake Bay falls in an approximately 0.61m elevation range between Mean Sea Level (MSL) and the Highest Astronomical Tide (HAT). In this vulnerability matrix, the vegetated tidal marsh frame (as described above) was moved across a lidar-based digital elevation model (DEM) land surface in overlapping 0.15 m (the vertical resolution of the lidar data) elevational increments. To set a timeframe for shifts in elevation in the tidal frame, a sea level rise projection curve based on data from Sewell's Point, VA tide gauge was used. To examine the importance of developed areas on future marsh persistence, current impervious surfaces that are in the migration pathway were identified at each time step. This gives a "best case scenario", assuming no future development into coastal areas. Impervious surface projections for 2050 and 2100 within the migration pathway were also identified for the

appropriate time steps. This gives a "projected scenario" which assumes continued patterns of development into the coastal zone.

Figure 5-2. Changes in area (m2) within the tidal marsh elevation range over time. Scenario steps are 0.61m in range and move up 0.15m in elevation with each step. a) Total tidal marsh area in the Virginia Chesapeake Bay. b) Tidal marsh area split by region.



Results: This study shows that in the Chesapeake Bay, an estuarine system with a range of shoreline elevations and development characteristics, overall estuarine tidal marshes are projected to decline by approximately half over the next century. Not only is the area of tidal marsh projected to decline over time due to rising sea level, but the way in which the remaining area of marsh is distributed will change. In the current time frame, 38% of total tidal marsh area is in the Eastern Shore region and only 27% of tidal marshes are found in the Southside region. By the final time step, this has shifted so that the Southside region has 53% of all tidal marshes, while the Eastern Shore region has only 11% of the remaining tidal marshes. In the

Southside region, most of the marshes will be in Chesapeake and Virginia Beach. This means that lands in the Southside region, particularly in those two localities, are the most critical for preservation to ensure marsh migration while Eastern Shore and Peninsula regions have limited opportunity for marsh migration based on elevation.

Tidal freshwater habitats, which are found in the upper reaches of the estuary, typically backed by high elevation shorelines are particularly vulnerable. Due to their geological setting, losses of large extents of tidal freshwater habitat seem inevitable under sea level rise. However, in high salinity, low elevation, Bay-front localities, tidal marshes are capable of undergoing significant expansion. These areas should be prime management targets to maximize future tidal marsh extent. Redirecting new development to areas above 3m in elevation and actively removing impervious surfaces as they become tidally inundated results in a best possible future. Under rising sea levels and increased flooding, the future of tidal marshes will rely heavily on the policy decisions made and the balance of human and natural landscapes in the consideration of future development.

Publications:

Mitchell, M., Herman, J. & Hershner, C. Evolution of Tidal Marsh Distribution under Accelerating Sea Level Rise. Wetlands 40, 1789–1800 (2020). https://doi.org/10.1007/s13157-020-01387-1

And included in: Mitchell, Molly, "Impacts of Sea Level Rise on Tidal Wetland Extent and Distribution" (2018). Dissertations, Theses, and Masters Projects. Paper 1530192833. http://dx.doi.org/10.25773/v5-5s6z-v827

NSF CSEES project update

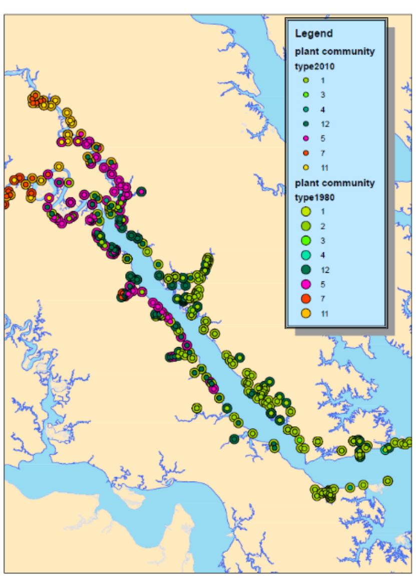
Project activity: Changes in marsh vegetation in response to sea level rise

Objective: Tidal marshes are important ecological components of the coastal system that are currently responding to sea level rise-driven changes in tidal regimes and their long term sustainability is a critical variable to understand. Sea level is rising at an unusually high rate in the Chesapeake Bay relative to most of the Atlantic coastline, putting Bay marshes at high risk from drowning and erosion. Understanding the patterns of change and the importance of different drivers of change is critical to planning for coastal resilience. Tidal marshes plant communities are highly reflective of their environment and can be an indicator of marsh resilience or response to sea level rise and may help improve predictions about future conditions. Specifically, marsh vegetation can help identify marshes which are not keeping pace with sea level rise (therefore likely to drown and disappear) and marshes which are undergoing salinization, resulting in ecosystem shifts. Changing marsh vegetation is a flexible measure of ecosystem alternation; understanding the patterns of vegetative change should enhance our understanding of future marsh changes and the ecosystem consequences of those shifts.

Methods: We used tidal marsh vegetation surveys from approximately 40 years apart to examine changes in plant communities indicative of stress from salinity and inundation. The Tidal Marsh Inventory is a geospatial survey of all tidal marshes in Virginia, including their location, extent and plant community which has been done twice, approximately 30-40 years apart. The surveys involved digitization of marsh extents and locations from maps and aerial imagery. Marshes were geospatially linked between the two time periods through superposition and cross-walking identification numbers. Field surveys of tidal marsh vegetation (henceforth referred to a TMIs or Tidal Marsh Inventories) were conducted in the Chesapeake Bay, Virginia, with a particular emphasis on the York River sub-estuary. Species matrices (York River) and community types (Chesapeake Bay, VA) were georeferenced for analysis and examined for inundation or salinization signals.

Results: Marsh plant community change was seen in 51% of marshes surveyed in both time periods. The most common of these changes was increased inundation, which accounted for about 12% of the marshes with altered community types. Signals of increased salinity were rarer, although freshwater marshes at the tops of shallow creeks were under-represented due to the difficulty of accessing them for the surveys. Patterns of community change suggested salinity increases near the freshwater-brackish water interfaces on the tributary rivers and some creek systems. In addition, examination of changes in both the extent of low marsh and the change in community type suggested areas of increased inundation and erosion that were fairly consistent between analyses, with erosion dominating on higher energy river shorelines and inundation dominating in creek systems. Indications of increased marsh inundation can be seen in the York River where areas that historically had significant high marsh community (40-50%) have converted to almost entirely low marsh. The change in low marsh extent was spatially variable, ranging from a large loss of low marsh vegetation (declined by 75%) to a large gain in the percent marsh covered by low marsh vegetation (increased by 100%). Another change between surveys was an expansion of *Phragmites australis*. The highest concentrations of *P. australis* dominated communities are found on the northern peninsula although it is currently found throughout the estuary including on high salinity Bayfront shorelines and lower salinity riverfront and creek shorelines. Changing marsh vegetation is a flexible measure of ecosystem alternation; understanding the patterns of vegetative change should

Figure 3-7. Mapped Community types identified from CAP analysis. Large dots are Historic, small dots are 2010.



enhance our understanding of future marsh changes and the ecosystem consequences of those shifts.

Shifts in vegetation patterns are an early signal of sea level rise-driven impacts to marshes. They can highlight marshes at high risk of drowning and disappearance and show where salinity intrusion is beginning to affect the community. The change in sea level over the period of examination was relatively small, approximately 15-20 cm, but shifts in communities were still evident. The expected rise over the next 30 years is nearly three times that (Boon and Mitchell 2015). The ability of the vegetation to reflect a small shift in sea level suggests that monitoring of vegetation is a useful sentinel of change, allowing for enhanced projections of sea level rise-drive ecosystem shifts.

Progress to date: This project has been completed. A draft paper “Marsh vegetation as an indicator of ecosystem response to sea level rise” is being prepared for publication. Results have been included in: Mitchell, Molly, "Impacts of Sea Level Rise on Tidal Wetland Extent and Distribution" (2018). Dissertations, Theses, and Masters Projects. Paper 1530192833. http://dx.doi.org/10.25773/v5-5s6z-v827

NSF CSEES project update

Project activity: Changes in marsh extent in response to sea level rise

Objective: Tidal marshes are important ecological components of the coastal system that are currently responding to sea level rise-driven changes in tidal regimes and their long term sustainability is a critical variable to understand. Sea level is rising at an unusually high rate in the Chesapeake Bay relative to most of the Atlantic coastline, putting Bay marshes at high risk from drowning and erosion. Understanding the patterns of change and the importance of different drivers of change is critical to planning for coastal resilience. Concurrent with sea-level rise, marshes are eroding and appear to be disappearing through ponding in their interior; in addition, in many places they are being replaced with shoreline stabilization structures. We examined the changes in marsh extent and community over the past 40 years within a Chesapeake Bay subestuary, to better understand the effects of sea-level rise and human pressure on marsh extent.

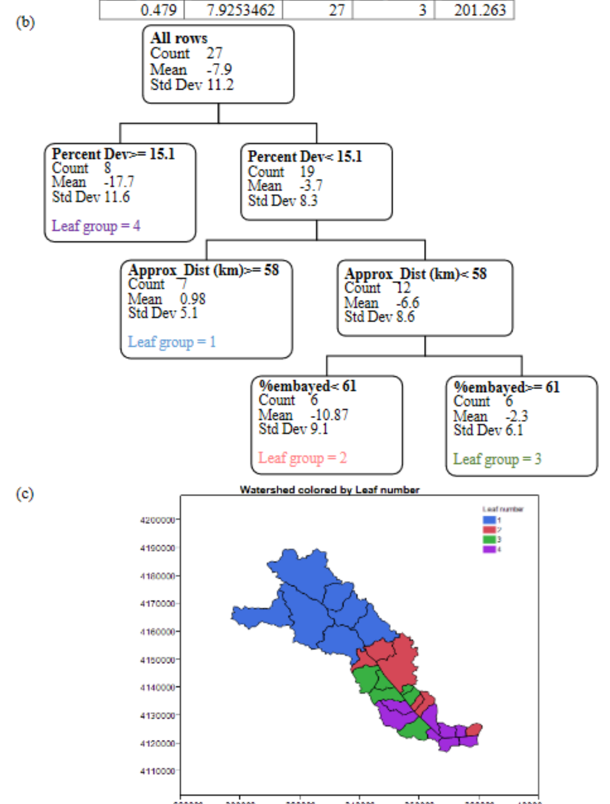
Methods: We used digital tidal marsh extents from approximately 40 years apart to examine shifts in marsh distribution. The Tidal Marsh Inventory is a geospatial survey of all tidal marshes in Virginia, including their location, extent and plant community which has been done twice, approximately 30-40 years apart. The surveys involved digitization of marsh extents and locations from maps and aerial imagery. Marshes were geospatially linked between the two time periods through superposition and cross-walking identification numbers. Marsh change was calculated on a subwatershed scale for the entire York River. Development, shoreline stabilization, wave energy, and migration potential were used in a recursive partition analysis to classify percent marsh change according to sub-watershed characteristics.

Results: Marsh change along the York River estuary is highly variable and that variability is not primarily explained by differences in erosion rates and migration potential, as would be expected under rising sea levels. Development and marsh form interact with location in the estuary, a surrogate for erosion potential, to modify the marsh response to sea-level rise. Although the marsh change analysis groups into four categories, there is variability in response even within those categories. This calls into question the current practices of evaluating regional marsh change with studies of only one or a few marshes and/or studies limited to only extensive marshes.

Figure 2-5. Partition analysis results: (a) AIC table, (b) tree diagram and (c) map of leaf group position in the watershed.

(a)

RSquare	RMSE	N	# of Splits	AICc
0.479	7.9253462	27	3	201.263



Developed landuse was the most important predictor of marsh loss. Sub-watersheds with high development (Leaf group 4) tend to have extensive creeks edged with fringe marshes. Percent marsh losses were heaviest in fringing marsh systems, which are ecologically important due to their high edge:area ratio. Developed areas also tend to have stabilized shorelines, heavy boat traffic and lawns that extend to the water. Land elevation is the dominant factor controlling marsh migration potential although it is moderated by development (which is the most important factor controlling marsh change in the partitioning analysis). Areas with low elevation lands immediately adjacent to wetlands show signs of marsh gain through migration, with marsh gain in the lower estuary primarily seen in extensive marshes as migration into interior forested hummocks (Figure 6), and along the river shoreline as migration into low-lying riparian uplands.

Within a single estuary, marsh change over time shows high spatial heterogeneity related to the variability in the importance of and interactions between multiple drivers. Erosion rates, migration opportunities, and the rate of sea-level rise all affect marsh persistence. Importantly, human actions are also critical, and frequently less predictable, determinants of how marshes respond through time. Understanding past changes in marsh extent are critical for improved prediction of future change under accelerating sea-level rise. Knowing which marshes are most vulnerable allows us to protect them, minimizing future impacts to estuarine systems.

Progress to date: This project has been completed. Results have been published in:

Mitchell, M., Herman, J., Bilkovic, D.M. and Hershner, C., 2017. Marsh persistence under sea-level rise is controlled by multiple, geologically variable stressors. Ecosystem Health and Sustainability, 3(10), DOI: 10.1080/20964129.2017.1396009.

And included in: Mitchell, Molly, "Impacts of Sea Level Rise on Tidal Wetland Extent and Distribution" (2018). Dissertations, Theses, and Masters Projects. Paper 1530192833. http://dx.doi.org/10.25773/v5-5s6z-v827