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Sea-Level Rise & Virginia's Coastal Wetlands

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The importance of Virginia’s coastal wetlands is well established. Over the past 44 years, since the Tidal Wetlands Act was adopted in 1972, the wetlands management program has evolved in response to new scientific understanding in order to preserve the benefits of healthy coastal wetlands. For example, program revisions were made when cumulative impacts from multiple, incremental projects became obvious and also when wetland compensation policies and practices were found to not effectively replace natural wetlands.

The wetlands management program must continue to evolve as we learn more about sea-level rise. The effects of sea-level rise on tidal wetlands are numerous and already apparent in local wetlands (Figure 1).

Some of these effects include:

- more frequent inundation
- changes in tidal amplitude
- changes in tidal flow patterns
- changes in sediment transport and vertical accretion rates
- shoreline erosion
- migration of estuarine salinity gradients
- changes in plant and animal species composition
- landward migration of tidal waters and habitats
- habitat loss

Wetlands have a natural ability to adjust to some of these factors, yet scientists have discovered that their ability to do so depends on human decisions and responses to some of the same factors.

“Climate change is causing significant impacts on ocean and coastal habitats, with effects likely to increase in the future. While these impacts are varied... sea-level rise has one of the most direct effects on tidal wetlands.”
- NOAA Restoration Center, 2011

This issue is dedicated to helping coastal managers better understand how the gradual, long-term increase in the average sea level is already affecting different types of coastal wetlands in Virginia. This information will foster improved understanding and continued evolution of wetland decision making that considers both development and natural stresses on wetlands. Understanding sea-level rise effects on coastal wetlands is also important to effectively locate and design wetland restoration, wetland compensation, and living shoreline projects that are supposed to provide wetland benefits into the future.

Figure 1. Evidence of sea-level rise at the VIMS Teaching Marsh includes changes in plant species, landward wetland migration, and increased inundation.
How Sea-Level Rise is Measured

The National Water Level Observation Network has been operating on all U.S. coasts dating back to the early 1800’s. Older tidal measuring stations used mechanical instruments, while modern stations use advanced acoustics and electronics to measure the time it takes for an audio signal to travel down a sounding tube to the water surface and back. Highly accurate sea-surface heights have also been measured since 1992 using satellite radar altimetry. This method measures the time it takes a radar pulse to travel from the satellite antenna to the sea surface and back to the satellite receiver.

A minimum 30-year time span is used to estimate long-term sea-level trends to account for repeatable, predictable cycles, such as tidal, seasonal, and interannual variation between years. There are eight water level stations in Virginia where long-term sea-level trends have been calculated by the National Oceanic and Atmospheric Administration (NOAA). The Sewells Point tide station at the Norfolk Naval Base is one of these locations.

The monthly observed water levels at Sewells Point have been highly variable with extreme high and low tides. Yet the trend in mean monthly sea levels, shown by the red line, has increased by about 0.9 feet since the Commonwealth’s wetlands management program started (Figure 2). The present monthly mean sea level is also higher than the current benchmark elevation determined from the latest 19-year tidal epoch from 1983-2001.

Figure 2. Long-term sea-level trend measured at Sewells Point tide station, Norfolk, Virginia.
Relative Sea-Level Rise in Virginia

Global sea-level rise refers to the worldwide increase in the volume of the world’s oceans due to thermal expansion and from melting ice caps and glaciers. Relative sea-level rise refers to the combined effects of global sea-level rise with other localized processes that affect the long-term sea level at a particular location or region. Scientists are now estimating that Virginia’s relative sea-level rise is more than twice the global rate due to these regional processes (Table 2).

Ocean circulation changes are one of these other processes. New evidence is being reported of changes to the Atlantic Meridional Overturning Circulation pattern, which includes the Gulf Stream off of Virginia’s coast. The Gulf Stream current started to slow down in the mid-1990’s and its path has shifted. A slower ocean current means less pressure to move water away from the coast and the result is higher water levels along the mid-Atlantic coast.

Land subsidence or sinking relative to the Earth’s center is another primary factor causing about half of Virginia’s relative sea-level rise. One cause of land subsidence is ‘isostatic glacial rebound.’ This is the Earth’s crust readjusting to the pressure and then retreat of continental ice sheets over the past 10,000 years (Figure 3). Groundwater removal for industrial uses and drinking water is another contemporary, human process that contributes to land subsidence.

Table 2. Dominant drivers of Virginia’s relative sea-level rise.

<table>
<thead>
<tr>
<th>Primary Cause</th>
<th>Processes</th>
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</thead>
<tbody>
<tr>
<td>Global Sea-Level Rise</td>
<td>• Warming and expanding ocean water</td>
</tr>
<tr>
<td>increase in the volume of the world’s oceans</td>
<td>• Melting ice sheets</td>
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<tr>
<td>Ocean Circulation</td>
<td>• Atlantic Meridional Overturning</td>
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<td></td>
<td>• Circulation changes</td>
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<tr>
<td>Land Subsidence</td>
<td>• Isostatic glacial rebound</td>
</tr>
<tr>
<td></td>
<td>• Groundwater withdrawals</td>
</tr>
<tr>
<td>Relative Sea-Level Rise</td>
<td>All processes combined</td>
</tr>
<tr>
<td>the combined effects of global sea level rise</td>
<td></td>
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<tr>
<td>with other localized processes</td>
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</table>

“Sea-level rise in Virginia is a documented fact. Water levels in Hampton Roads have risen more than one foot over the past 80 years. The causes of this rise are well understood.”

– Carl Hershner & Molly Mitchell
Rising Tides, Sinking Coast
Coastal Wetland Responses to Sea-Level Rise

Coastal wetlands are dynamic habitats that change in response to surrounding environmental conditions, including sea-level rise. Some wetlands actively engineer their position vertically within the tide range to keep pace with sea-level rise. They may also shift positions horizontally over time by erosion along seaward edges and landward expansion into adjacent upland habitats (Figure 4).

Vertical Development

A coastal wetland will persist in the same location if it builds vertically at a rate at least equal to the rise in sea level. If the water level rises faster than the wetland elevation builds vertically, then the wetland will gradually become submerged. Tidal wetlands build vertically through the accumulation of mineral sediments and the buildup of plant organic matter. This process depends on local conditions, such as the available sediment supply.

Mineral sediments are deposited on the surface when the wetland is flooded. There is recent evidence that increased flooding due to sea-level rise actually increases the rate of sediment accretion on some wetland surfaces. Instead of being overwhelmed by sea-level rise, some wetlands are able to keep pace through vertical elevation adjustments. Sediments can also be removed from the wetland surface by storms, tides, heavy rainfall, and ice buildup.

In addition to mineral sediments, organic matter accumulates on the wetland surface and below the ground from plant production and decomposition, especially root and rhizome growth. The rate of vertical development from organic matter varies for different wetland types. The rate of organic matter accumulation in common reed grass (*Phragmites australis*) wetlands, for example, is greater than other wetland types because of traits that support higher below-ground productivity.

Figure 4. Illustration of vertical and horizontal wetland responses to sea-level rise.

**CCRM Sea-Level Rise Research**

- **Marsh migration model 2016** a model to simulate physical, biogeochemical, and human components to assess the evolution and persistence of tidal marshes under different sea-level rise scenarios
- **Tidal marsh change analysis 2016** comparisons between historic and current Tidal Marsh Inventories
- **Effects of sea-level rise on tidal wetlands in the Lynnhaven River Watershed 2009** a geospatial model to quantify potential wetland loss under various sea-level rise scenarios
- **Vulnerability of shallow tidal water habitats in Virginia to climate change 2009** models that forecast the distribution of key habitats within the next 50 to 100 years, including tidal wetlands
### Horizontal Migration

Wetlands also respond to sea-level rise by moving horizontally to higher elevations on land or into adjacent waters if they fill with sediment. The most common type of wetland migration in Virginia is erosion of the seaward edge and migration inland. There are many locations where marsh edge erosion is happening and also where formerly upland habitats are shifting to wetlands (Figure 5).

Marsh edge erosion increases with sea-level rise because there is less dissipation of incoming waves with a higher water level. Landward migration occurs for wetlands adjacent to low upland banks and beaches with gradual slopes and where the adjacent upland plants die back because they cannot tolerate rising water levels and increased salinity. Landward marsh migration is less likely to occur next to high, vertical banks and permanent impediments such as development or shoreline defense structures that prevent migration.

Even if wetlands can shift horizontally, wetland survival still depends on vertical accretion processes. Recent studies suggest that the highest possible rate of organic matter accumulation is 5 mm/year. This rate is actually less than the current rate of sea-level rise in some areas. That is why scientists now assume that wetlands need both mineral sediment accretion plus the ability to migrate inland to keep pace with sea-level rise.

### Community Shifts

The conversion of upland to wetland habitat is just one type of community shift. If a wetland cannot keep pace with sea-level rise vertically or horizontally, then increased flooding levels and inundation frequency can force vegetation changes to occur. Sea-level rise has also moved saline waters further upstream where tidal freshwater wetlands are located. It only takes a minimal salinity increase to alter freshwater wetland ecosystems.

#### Documented Community Shifts

Forced By Sea-Level Rise

- Low-lying farms, forests and residential yards converting to tidal marsh
- High marshes converting to low marshes
- Tidal freshwater forested wetlands converting to marshes without trees
- Freshwater marshes converting to brackish marshes
- Low vegetated marshes converting to mud flats and open water

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**Figure 5.** Horizontal wetland movement occurs through (a) marsh edge erosion (above left) and (b) landward migration into upland habitats that cannot tolerate rising water levels (above right).
Human Interference with Wetland Response to Sea-Level Rise

Wetlands are not responding to sea-level rise in a vacuum. Coastal communities are also responding to sea-level rise, increased erosion, more frequent tidal inundation, and coastal storms in ways that affect wetlands. New development pressures and the desire for economic growth are on-going. Coastal development, shore protection activities, and landscape management practices affect the surrounding environmental conditions that determine how or if wetlands can adjust to sea-level rise.

There are both inadvertent and deliberate actions and land use choices that prevent wetlands from adjusting (Figure 6). These interferences include:

- Physical obstacles to landward migration
- Reduced intertidal space available, deeper water in adjacent nearshore
- Reduced local sediment supply
- Interruption to onshore and alongshore sediment movement
- Filling in migrating wetlands to maintain upland elevation
- Plant stress caused by routine landscape practices, e.g. mowing, herbicides
- Nutrient enrichment that affects organic matter production and decomposition

Cumulative impacts to coastal wetlands have been documented over the past 44 years in spite of protection measures and compensation requirements put in place by the Tidal Wetlands Act. Sea-level rise is a contributing factor to these observed wetland changes and loss. Since coastal wetlands depend on both vertical accretion and landward migration, adequate sediment supplies and space are essential. Yet sediment processes are already highly altered and continue to be impacted, while the potential area for landward migration is small compared to the extent of wetlands at risk, especially in developed urban estuaries.
Sea-Level Rise Forecasts

Another growing concern for Virginia’s coastal wetlands are recent sea-level rise forecast scenarios. A number of different techniques and models are used to predict future trends in sea-level rise. Forecasts for Virginia’s relative sea-level rise are currently based on data from the 2014 National Climate Change Assessment (http://nca2014.globalchange.gov).

The original baseline assessment was for global sea-level rise only, so it was adjusted to incorporate land subsidence rates documented in southeast Virginia by the U.S. Geological Survey (USGS). There are four future sea-level rise scenarios for southeast Virginia displayed in the graph below (Figure 7). Each colored curve represents a possible scenario based on a range of estimates.

The current 2016 mean monthly sea level at Sewells Point falls on the yellow ‘high’ forecast curve. This indicates the rate of sea-level rise is already higher than the historic trend. The trend reflects an acceleration in sea-level rise due to rising global temperatures. If this relationship is sustained, Virginia’s sea-level rise over the next 50 years could be almost double what it was over the past 50 years.

**Highest** – worst case scenario from global warming and maximum possible contribution from ice sheet and glacial melting

**High** – upper end of recent model projections

**Low** – based on fourth assessment model of the Intergovernmental Panel on Climate Change using conservative assumptions about future greenhouse gas emissions

**Historic** – a projection of observed long-term rates of sea-level rise going back a century or more

Figure 7. Sea-level rise forecast scenario curves with +30 and +50 year projections from the current water level at Sewells Point.
Resource Management Strategies

If this future sea-level forecast is accurate, then continued wetland loss is expected if current management practices and policies are not adjusted to incorporate sea-level rise effects. It is not too late to adopt management strategies to reduce wetland vulnerability to sea-level rise. These strategies can be implemented at small and large scales by multiple parties in the public and private sectors.

- **Adjust jurisdictional wetland boundaries** – The legally defined area of jurisdictional tidal wetlands is based on the local tide range, so it shifts with a rising sea level.

- **Rigorous application of the Commonwealth’s preference for living shoreline alternatives** – Where shoreline stabilization is needed, the default decision for local wetlands boards should be designs that inherently preserve the opportunity for fringing tidal wetlands to maintain themselves both vertically through sediment accretion and landward migration.

- **Perform local tide studies for living shorelines and compensation wetland design** – Don’t rely on tidal datum based on 1983-2001 tidal epoch because it is lower than the current mean sea level.

- **Identify resilient wetlands** – Focus on wetlands with a demonstrated ability to keep pace with sea-level rise based on current scientific information.

- **Locate and plan for potential migration areas** – Target land conservation and acquisition next to wetlands with the greatest chance for long-term survival.

- **Assign public interest values** – Identify economic and other contributions from coastal wetlands & develop incentives to accommodate rather than prevent wetland migration on private property.

**Additional Information & Resources**

Understanding Sea-Level Observations – NASA Sea-Level Change Observations from Space
https://sealevel.nasa.gov/

http://ccrm.vims.edu/research/climate_change/index.html

http://ccrm.vims.edu/gis_data_maps/static_maps/lynnhaven_project/LynnhavenFinalReport.pdf