Modeling Future Changes in Barrier-Island Wetlands on Galveston Island, Texas

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Abstract

Distribution of barrier-island subenvironments is strongly related to elevation above or below mean sea level. The style of transition of estuarine habitats during rising sea level depends largely on the slope of the upland and sediment supply. Fringing wetlands on the barrier islands of Galveston Bay exist within a narrow elevation range, with shifts from barren tidal flat to marsh to upland vegetation occurring across areas with just a 50- to 60-cm rise in elevation. This amount of topographic change may occur gradually over an extensive coastal plain or, as is often the case on the bay sides of sandy barrier islands, on a small scale and in complicated patterns across relict geomorphic features, such as storm-surge channels, washover and flood-tidal delta deposits, and beach ridges and swales.

For this research, a wetland map derived from manual interpretation of color infrared photography and extensive field checks is combined with a high-resolution (1-m postings and .1- to .15-m vertical accuracy) lidar-derived digital elevation model to quantify topographic relationships of barrier-island subenvironments. The combined data set forms the basis of an inundation model to determine the likely transition of wetlands during expected future sea-level rise. In addition to changes caused by inundation, wetlands in the study area erode along the bayward fringes as a result of waves and tidal currents. Therefore, rates of shoreline change computed by comparing historical shorelines from the 1930s, 1950s, 1980s, and 1990s are incorporated into the wetland change model. Vertical sediment accretion occurs and partly offsets the inundating effects of relative sea-level rise. A sedimentation model that describes vertical accretion as a function of elevation is also contained in the wetland model. The sedimentation function is based on measured accretion rates in similar settings in the Gulf of Mexico that indicate slower rates at higher elevations. The highest vertical accretion rate occurs at the elevation of the lower low-marsh boundary and is set equal to the long-term relative sea-level rise rate, as measured from 1908 through 1999 (6.5 mm/yr). Below the low-marsh boundary the rate is zero. Above the boundary, the function decreases the accretion rate according to the expected duration of tidal inundation. In the supratidal zone, the vertical accretion rate is zero.

The digital elevation model is classified using elevation intervals assigned to open-water, low-flat, low-marsh, high-flat, high-marsh, and upland environments. Elevation is the primary factor in determining these environments, but not the only factor, thus causing misclassifications. Therefore, to arrive at an optimal classification, the lower boundary of the low flat is determined, and then the upper boundary of the high marsh, which is the wetland/upland boundary, is adjusted until the total area of wetland matches what was actually mapped on the photography and in the field. Elevation intervals for other wetland environments are then adjusted so that they have the same area as what was mapped.

The study area is a 7.5-km-long, undeveloped part of the bay side of Galveston Island. Relict storm-surge channels create a highly crenulated bay shoreline dominated in low-marsh environments by *Spartina alterniflora*, with high-marsh environments characterized by *Spartina patens* and other plants. The diurnal tide range is 0.3 m, but the elevation of the wetland/upland boundary is about 1 m above mean sea level. Episodic high wind tides, which are not well reflected in the long-term average of water-level data, cause a higher encroachment of wetlands than would

be expected from the tide range. Rate of relative sea-level rise as measured from 1908 through 1999 is 6.5 mm/yr; however, considerable interannual and decadal variation has occurred.

The wetlands model was run 46 years into the future. The record of mean annual water levels as measured at a bayside tide gauge from 1956 through 2002 was used to calculate sea-level input into the model. Because wetlands are not expected to respond to sea-level fluctuations within a year's time, the running average of the previous 5 years of sea level was used. The 5-year running average was differenced each year to provide the amount of sea-level change for each annual iteration of the model.

In 2002, 316 ha of marsh was mapped, with 58% of it being low marsh and 42% high marsh. At the end of the 47-year model run, 256 ha of marsh exists, with 32% being low marsh and 68% high marsh. The overall decline in marsh is 19%, with high marsh increasing by 35% and low marsh decreasing by 56%. Shoreline retreat caused the loss of about 30 ha of low marsh but did not affect high marsh.

The model shows marsh migrating up the gently sloping back barrier in a complicated pattern dictated by the relict geomorphology but disappearing on the bayward side owing to inundation and shoreline retreat. Similar patterns and amounts of change are observed when comparing 1956 and 2002 aerial photography. During that 46-year time period, there was about a 26% loss of marsh area. High- and low-marsh environments were not broken out on the 1956 photography, so comparing marsh types is not possible. However, observed marsh upland migration patterns and an overall similar decrease in marsh area indicate that assumptions in the model, particularly vertical accretion function, shoreline retreat, and marsh-elevation relationships, are reasonable.

A projected 20% loss of marsh over 46 years based on a historical sea-level-change record, without accounting for any increase in rate of sea-level rise due to climate change, is a concern. Furthermore, most of the loss is in low marsh, which is an important environment for fishery juveniles. The high rate of low-marsh decline is partly offset by upland migration in this undeveloped setting. However, development is now occurring, and more is proposed in areas where the model projects an upland transition to wetlands.