Climate Effects on Salt Marsh Ecosystems

Salt marshes are incredibly productive and valuable coastal ecosystems that protect our coastlines and their species. However, due to their position in the coastal transition zone, salt marshes are particularly vulnerable to the impacts of climate change. When combined with anthropogenic changes, effects on the salt marsh ecosystem can be detrimental. The following discussion explores the salt marsh ecosystem and the climate impacts that pose the most significant risk to the future of this critical system.

Salt marshes are delicate ecosystems found along low-energy coastlines, predominantly in the intertidal zone of temperate estuaries. They occur in the northern and southern hemispheres but are replaced by mangrove ecosystems in the tropics (Thorne et al., 2012). Harsh conditions, such as high salinity levels, tidal movement, and minimal vegetation, have led to low species diversity (Thorne et al., 2012). The predominant species in these marshes are halophytic plants, commonly *Spartina* and *Salicornia,* which have adapted to survive in these extreme environments. Flooding, soil salinity, and competition have created specific zonation of different vegetation from low to high-elevation areas (Pennings & Callaway, 1992). Few animals in the salt marsh eat the vegetation, but the decomposition of the plants met with bacteria and fungi results in nutrient-rich detritus. The ebbing of the tides washes detritus and sediment in and out of the marshes resulting in high primary productivity, making them an essential part of the base of the estuarine food web (Morrissey et al., 2018).

These marshes are critical for the species that inhabit them and are also essential to humans, providing services that directly and indirectly impact our well-being. Salt marshes are formidable buffers against storms and flooding, reducing property damage and coastal erosion by reduction of wave energy through marsh plants. The plants reduce the intensity of the water as it flows through and around them. Even when vegetation is flattened or broken during weather events, the root system helps to keep the soil in place, preventing erosion (Pennings & Callaway, 1992). Salt marshes act as coastal sponges and carbon sinks, soaking up and filtering sediments of pollutants and excess nutrients from the water and sequestering carbon from the atmosphere for chemical functions such as photosynthesis (Pontee, 2013). Additionally, the sediments and detritus that support the base of the salt marsh food web ultimately feed commercially favored species, including flounder, striped bass, bluefish, and shellfish (Morrissey et al., 2018). The food web relay from the base level detritus to the top helps to sustain these commercial and recreational fisheries (H. Taylor, 2005).

The intricate system of tidal movement balances sediment supply and salinity, keeping the salt marsh balanced. If not offset by compensating changes, disruption in any of these processes can alter the entire system's stability (Hartig et al., 2002). The subtly of these communities makes them highly vulnerable to climate change impacts. They are susceptible to projected sea-level rise, increased storm frequency, and temperature. When communities face environmental challenges, they often respond through shifts in geographic distribution (migration), changes in phenology, adaptation through evolution, or extinction. However, these range shifts are only achievable with adequate habitat, good colonization ability, availability of food resources, and the absence of physical barriers that may inhibit movement. The man-made development of saltwater marshes, including but not limited to settlement, damming, dredging, diking, and draining, poses a considerable threat, as salt marshes are geographically limited (Thorne et al., 2012). Climate events synergistically met with anthropogenic land-use patterns make salt marsh ecosystems high-risk zones.

Sea levels have risen 8-9 inches since 1880, with a third occurring in the past two decades. The rising water level is primarily the result of melting ice sheets and glaciers and the thermal expansion of seawater as it warms (Lindsey, 2020). These rising sea levels have short-term and long-term impacts on salt marshes. Short-term impacts (less than 25 years) include increased predation, flooding of habitat, drowning of biota (particularly nests and young), population decline, and migration of vegetation and wildlife (Thorne et al., 2012). Long-term impacts (greater than 25 years) include extirpation, reorganization of communities, species adaptation, and range shifts in vegetation and wildlife (Thorne et al., 2012). When sea level rise is combined with human-induced land use, climate effects on salt marshes are exacerbated.

In Jamaica Bay (New York City), upland areas have been dredged and developed for the JFK airport and highways. Urbanizing these areas has caused diminished upland sediment, mortality of vegetation, and minimal upland migration, where displaced species are met with increased predation and competition (Hartig et al., 2002). When met with human-derived barriers, like this urbanization, saltmarsh species are inhibited in their upward migration. This constrained migration is often referred to as *coastal squeeze* (Pontee, 2013). Under coastal squeeze, we not only lose total marsh area, but the marsh will also cycle less nitrogen per unit resulting in higher rates of primary producers (Hughes, 2004). This upward migration and coastal squeeze have begun to alter this community permanently (Thorne et al., 2012). It is the alteration of this community that leads not only to the decreasing biodiversity in the world but also to the lack of effectiveness of the ecosystem in protecting humans from flooding.

In the San Francisco Bay, sea-level rise and weather incidents such as storm surges, high tides, and El Niño events are projected to raise sea levels by seven feet by 2100 (Bonafont, 2020). We already see these effects on the local salt marsh ecosystems with increasing flooding, edge erosion, and plant drowning (Thorne et al., 2012).

Increased weather events, in addition to sea-level rise, also affect sediment inputs and tidal dynamics. When the sea level exceeds the mineral sedimentation or accretion, there is an imbalance, and the marsh may begin to drown in place. Alternately, we may see changing tide dynamics and resulting erosion (Hartig et al., 2002). Even with sea-level rise and weather events, salt marshes can sustain themselves if they have enough sediment input and time to respond (Thorne et al., 2012). Human-induced disruptions such as watershed dams and underground extractions inhibit these natural processes that maintain marsh elevation in relation to sea level. Manufactured sea walls, often built to protect urban environments against storms and sea-level rise, reflect wave energy onto the marsh, increasing erosion and vegetative stress (Hughes, 2004). Other short-term impacts of increased weather events include impacts on vegetation structure, temporary habitat loss, and population decline. Long-term impacts include extirpation, scouring of salt marsh areas, range shift, vegetation death, and permanent habitat constriction (Thorne et al., 2012).

Averaged across ocean and land, the 2020 surface temperature of Earth was 1.76° F warmer than the twentieth-century average of 57°F, and the ten warmest years on record have occurred since 2005. This warming is attributed to climate change (Lindsey & Dahlman, 2021). Temperature affects biological and chemical processes, including photosynthesis, respiration, transpiration, decomposition, and nutrient cycling (Hughes, 2004). Greater temperatures also increase the rate of evaporation, thus increasing salinity. The shifting of biological and chemical processes combined with the direct effects of temperature increase may affect primary productivity, plant distributions and cause biodiversity loss (Gallagher & Daiber, 1974). Other short-term impacts of warming include vegetation and wildlife heat stress, increased vegetation mortality, a decrease in reproduction, and animal metabolic rate increase. Long-term impacts include extirpation, phenology changes within the community, and range shifts of vegetation and wildlife (Thorne et al., 2012).

With the effects of global climate change becoming apparent, it is clear that the salt marsh ecosystem is threatened. The most vulnerable habitats are the ones where species are already fragmented due to anthropogenic changes, such as urbanization, sea walls, levees, or roads, limiting upland areas for transgression and animal redistribution. Coastal scientists must determine which climatic variable will put populations at risk over the short-term and long-term and plan processes to improve the resilience of salt marsh wildlife. Conservation planning joined with targeted research to conserve biodiversity and ecosystem function, is critical for preserving these marshes.

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