**Project 1. The impacts of sea level rise on the marsh bird population in the Gulf of Mexico**

Recent model projections of sea level rise over the next century and beyond may move northern Gulf coastal environments into a new equilibrium regime, more similar to that experienced during the deglaciation than that which has existed during historic time.(Donoghue, 2011)

The EESLR-NGOM project is an integrated field observation and modeling project that provides resource managers in the northern Gulf of Mexico with the knowledge and tools to prepare for the impacts of astronomic tides and hurricane storm surge from sea level rise.

The potential effects of climate change are related to anthropogenic factors (Bradshaw and Holzapfel 2006), such as sea level rise and land subsidence (Daniels et al. 1993; Bayard and Elphick 2011). Increased sea level rise results in increased flooding of nests, eggs, and chicks, as well as rendering habitat on islands, beaches, or salt marshes no longer usable by nesting or foraging birds, such as Brown Pelicans, Piping Plovers, and most terns and skimmers (Daniels et al. 1993). Habitat for salt marsh species, such as Clapper Rails (Rallus longirostris) and Salt marsh Sparrows (Sharp-tailed Sparrow, Ammodramus caudacutus) (Bayard and Elphick 2011), will also be severely affected by sea level rise.

Development of wind energy is ongoing, both nearshore and offshore, and has the potential to disrupt bird migration across the Gulf (Morrison 2006).

Studies suggest that habitats and species assemblages will shift considerably over the coming decades (Forbes and Dunton 2006; Greenberg et al. 2006; Day et al. 2008). Some of these changes are due to human population increases and management, and others to sea level rise or subsidence. Management of water levels in marshes can shift the salinity gradient and marsh vegetation, with consequences for marsh-nesting species. Sea level rise, storms, and hurricanes can also influence forested habitats, which in turn affects avian use by both migrants and breeding birds (Gabrey and Afton 2000; Barrow et al. 2005, 2007).

Perhaps the most important features of the Gulf of Mexico for avian populations are related to the complex interaction between natural and anthropogenic factors that result in changes in land available (losses or gains), changes in the relative amount of different habitat types (sandy beaches, marshes, mudflats), and changes in salinity. The northern Gulf coast, especially Louisiana, is losing land at a rapid rate due to complex interactions among subsidence, sea level rise, tropical and other storms, inadequate water supply, and human disturbance (Visser et al. 2005; Valiela et al. 2009). The habitats along the Gulf coast are a shifting mosaic of changing elevation and salinity gradients that result in changes in vegetation species and patterns that affect nesting. Examples of changes are given throughout this chapter, but a few examples are mentioned in Table 12.3. Some habitat shifts result in changes in populations, while others result in changes in the species of birds that are able to use that habitat.

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This number may increase with time because of new information and potential range changes due to global warming. Some neotropical species may move northward into the Gulf coastal habitats (lagoons, marshes, mangroves). Semiaquatic birds (land birds feeding on aquatic species), and all land birds have been reported on islands of the Gulf or crossing its waters (Gallardo et al. 2009). Gallardo et al. (2009) drew the following conclusions: (1) approximately a third of the species occurring in the Gulf of Mexico are breeding residents with no apparent population movements; (2) about 65 % depend upon the Gulf shores for a migratory stopover, or overwintering; (3) 44 % are aquatic species and 27 % are marine; and (4) most feed on invertebrates (55 %) or vertebrates (28 %), while the others eat plants.

Spatial constraints often have to do with habitat suitability, whether for foraging, courting, breeding, migrating, or overwintering. With few exceptions (such as grebes and others that build floating nests), birds need dry land to breed because they lay eggs and are constrained to their nests during incubation, and often during the chick-rearing phase. Habitat suitability depends on the type and qualities required for each activity, and the stability of the habitats involved.

The habitat types available on barrier islands and mainlands include sandy beaches, salt marshes, brackish marshes, freshwater marshes, shrub/scrub, and forests.

This transition zone is a moving target in upper estuaries, and is influenced by seasonal or episodic river flows and fluctuations in daily tidal cycles. With the anticipated rise in sea level associated with global climate change, many salt and brackish marshes may become permanently inundated, and their landward edges will advance into what are currently freshwater marshes, shrub swamps, and uplands. The estuarine-freshwater transition zone will also migrate upriver with rising sea level.

Provide for Monitoring, Adaptive Management,

and Administrative Oversight to Support Restoration Implementation” to ensure that the portfolio of restoration projects provides long-term benefits to natural resources and services injured by the spill

The ecosystems in microtidal regions, such as the Mediterranean Sea and the northern Gulf of Mexico (NGOM), are more susceptible to marsh productivity and coverage losses due to sea level rise (SLR) [[4](https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0205176#pone.0205176.ref004)–[9](https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0205176#pone.0205176.ref009)].

Studies have shown that under moderate and high rates of SLR, marshes are likely to be entirely inundated, lose productivity, and ultimately transition to open water [[26](https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0205176#pone.0205176.ref026),[40](https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0205176#pone.0205176.ref040)]. These changes to the biogeomorphology of the system result in variable hydrodynamic changes [[24](https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0205176#pone.0205176.ref024),[25](https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0205176#pone.0205176.ref025),[28](https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0205176#pone.0205176.ref028),[41](https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0205176#pone.0205176.ref041)]. In response to these new local hydrodynamics, the marsh landscape adapts to changes in sediment supply and salinity, the creation of ponds, and new wave propagation patterns which often combine to widen back bays and create new or widen existing tidal creeks [[42](https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0205176#pone.0205176.ref042)–[45](https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0205176#pone.0205176.ref045)]. In addition, marsh systems often respond to SLR by migrating to higher lands if they are not obstructed by development or urban infrastructure [[28](https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0205176#pone.0205176.ref028),[46](https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0205176#pone.0205176.ref046),[47](https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0205176#pone.0205176.ref047)]. These potential regions for marsh migration in urban, agricultural, or forested areas must be assessed and mapped using marsh evolution models and preserved for restoration purposes [[48](https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0205176#pone.0205176.ref048),[49](https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0205176#pone.0205176.ref049)]. Previous studies have shown that if marshes are allowed to freely migrate upland, the net loss of marsh coverage could be minimal or in some cases even increase[[49](https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0205176#pone.0205176.ref049),[50](https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0205176#pone.0205176.ref050)].

In some cases, long-term stability is enhanced by habitat modification, as happened on Queen Bess Island for pelicans (Visser et al. 2005). In other cases, stability is reduced by erosion and loss of space.

Very high tides, usually associated with hurricanes, other storms, or winds, reduce reproductive success by flooding out nests,

eggs, and chicks in ground-nesting species. Tidal effects decrease hatching and fledging rates, and synchronize breeding behavior with lunar cycles (Shriver et al. 2007).

Changes in the timing, frequency, and intensity of storms and hurricanes can alter coastal hydrology, geomorphology, and nutrient structure, leading to changes in vegetative structure (Michener et al. 1997), which in turn will markedly affect bird use of coastal areas. Birds can adapt to slow changes more easily than to extreme events (van de Pol et al. 2010). Rush et al. (2009a) conducted censuses of birds nesting in coastal marshes of Alabama and Mississippi and found that Seaside Sparrows and Clapper Rails nested in habitats with higher salinity than did Least Bitterns (Ixobrychus exilis). Their models indicated that coastal altera- tions, sea level rise, and landward changes in habitat and salinity will lead to population increases in the former two species and declines in Least Bittern.

In the Gulf, gulls, terns, and skimmers forage in pelagic waters, shallow tidal creeks, and behind boats or near other human activities, as well as at landfills (garbage dumps), inland lakes, and impoundments (Burger 1987a, 1988a; Burger and Gochfeld 1983a; Patton 1988). Ducks breed mainly in marshes or in distant uplands, but spend the winter in coastal areas or in nearshore environments. Some ducks form large flocks on the water and forage on the open sea (diving ducks), while others feed at the marine-land interface in bays, estuaries, marshes, fields, and other terrestrial habitats (dabbling ducks). Herons, egrets, and ibises breed on islands and along coastal areas, and feed in intercoastal habitats; they do not feed in open water as most forage while standing. Shorebirds feed along the shoreline on the mainland, along barrier islands, or around offshore islands. Their feeding method of picking up items from the sand, from shallow water, or along wrack lines, ties them to the narrow band along the shoreline.

**Data**

This dataset is the bathymetry Digital Elevation Model for the northern Gulf of Mexico coast including most or portions of the southeastern parishes of Louisiana, the coastal counties of Mississippi and Alabama, and the western counties of the Florida panhandle.