Description of the region

The coast of northeast Florida is a mosaic of interconnected estuarine habitats that include salt marshes, salt barrens, tidal creeks, and open water (Figure 13.1). Barrier islands, sand ridges, and dunes are found off the coast, protecting the extensive salt marshes by buffering energy from Atlantic waves, tides, and winds. Major river systems include the Nassau, St. Johns, Guana, Tolomato, and Matanzas rivers. The St. Johns River has the largest watershed in Florida and is often described as a series of interconnected lakes with a slow northern flow (NPS 1996). The eastern coast of Florida achieved its current shoreline 5,000 years ago after sea-level rise stabilized following the last ice age. The coast consists of multiple parallel terraces; these paleoshorelines were formed by variable sea levels during the Pleistocene (Frazel 2009). Sandy marine sediments are the largest component of the soils, although Native American populations that lived in the area left behind shell middens and burial mounds (Frazel 2009). Average annual rainfall is 55 in. (1.4 m); half of this precipitation falls between June and mid-October. Passing northeasters, tropical storms, and hurricanes bring strong waves to the region and cause extensive erosion along the coast.

The hydrology of the northeast coast of Florida has been altered by the Intracoastal Waterway, dikes, drainage ditches, and inland wells (Frazel 2009). The hydrology of the St. Johns River has been changed by dredging and deepening at its mouth in Jacksonville and by the construction of the Fulton Cut, which reduced tidal flow in the area. The Guana Dam was constructed in 1957 across the Guana River to improve hunting and fishing grounds. Originally located 394 ft (120 m) south of its current position, the St. Augustine inlet was modified in 1940 to improve navigation. Jetties were constructed on either side to stabilize the inlet. The Matanzas inlet has not been improved, although the construction of the Intracoastal Waterway has reduced current velocity and increased sediment deposition, such that the channel must be dredged (Frazel 2009). The Nassau River lacks channels or stabilization structures, although the location of tidal channels and the shape of Nassau Sound have changed significantly in the past century in response to a decrease in sediment supply and the shoreline stabilization of the St. Marys and St. Johns rivers (NPS 1996, Browder and Hobensack 2003).

Ground water is extracted from multiple depths including the Floridan Aquifer, deep artesian wells, and a shallow layer of freshwater (Frazel 2009, GTMNERR 2009). The Floridan Aquifer is about 2,000 ft (610 m) thick and is located approximately 100 ft (30 m) below the soil surface in Volusia County and is more than 500 ft (152 m) deep near the Georgia border (Scott and Hajishafie 1980). Average water levels of the Floridan Aquifer have dropped due to increasing urban and agricultural use (NPS 1996). Saltwater intrusion is a concern for freshwater supplies, particularly on the barrier islands (NPS 1996, Frazel 2009).
St. Johns, Flagler, and Volusia counties

Several reserves, state parks, and preserves are found along the northeast coast, including the Guana Tolomato Matanzas National Estuarine Research Reserve (GTMNERR). The reserve comprises approximately 75,000 acres (30,350 ha) of relatively undeveloped coastal and estuarine habitat and encloses a narrow (east–west) barrier-ed estuarine ecosystem that spans approximately 35 mi (56 km) north to south (Figure 13.2). The city of St. Augustine separates GTMNERR into northern and southern components; the northern component is associated with the Tolomato and Guana river estuaries, while the southern component incorporates the Matanzas River estuary. The GTMNERR is biogeographically positioned at the edge of two emergent vegetation habitats: salt marsh in the north (dominated by Spartina alterniflora, smooth cordgrass) and mangroves in the south (dominated by Avicennia germinans, black mangroves) (Zomlefer et al. 2006, Leitholf 2008, Frazel 2009). The Spartina-dominated low marsh is intermixed with and followed by the high-marsh species Juncus roemerianus (black needlerush), Salicornia spp. (glassworts), and Battis maritima (saltwort). About 20% of the land in the GTMNERR watershed is salt marsh; the remainder is pinelands, shrub and brushlands, hardwood hammocks, and barren lands. Oyster beds are common in the intertidal zones, while muddy and sandy tidal flats, barren of vegetation, can be found along channels and creeks (Frazel 2009).

St. Johns County contains the northernmost mangrove swamps and recorded examples of A. germinans, Rhizophora mangle (red mangrove), and Laguncularia racemosa (white mangrove) on the Atlantic coast of Florida (Zomlefer et al. 2006, Frazel 2009, Williams et al. 2014). Mangroves are not visible in St. Johns County in Figure 13.2 because land-cover mapping classifies predominant vegetation cover and does not show the extent of individual trees or clusters of mangroves. The primary factor limiting the northern extent of mangroves is temperature. In South Florida, mangrove forests thrive and replace salt marsh vegetation primarily due to shading (Lugo and Snedaker 1974, Odum et al. 1982). The northernmost occurrence of mangrove trees varies depending on the frequency of severe freezes in winter. Cold events in 1962, the late 1970s, and the 1980s led to uneven mangrove mortality along the east coast of Florida as far down as West Palm Beach (Odum and McIvor 1990). As evident in land use/land cover maps created by the St. Johns River Water Management District (SJR WMD), mangrove acreage has increased in recent decades (Table 13.1). This increase in mangrove habitat is likely a response to the reduced occurrence of cold events with air temperature less than −4°C in recent decades (Cavanaugh et al. 2014). The mangrove expansion seen in recent decades (Table 13.1) is in part recovery from the cold-event mortalities of the 1960s through the 1980s (Giri and Long 2014). Much of the current extent of mangrove swamps, particularly the cluster north of the Ponce de Leon Inlet (Figure 13.1), can be seen in 1943 land cover maps created by the SJRWMD. Although parts of the current expansion involves previously occupied mangrove habitats, a comparison between historical records and the current mangrove extent on the east coast have found that their northernmost occurrence is expanding (Williams et al. 2014).

The overlapping distribution of salt marsh and mangrove habitats in the GTMNERR provides a unique opportunity to examine the potential effects of climate change and sea-level rise on the distribution and diversity of emergent intertidal vegetation in this transitional zone. Numerous fish, invertebrate, bird, and reptile species rely upon these diverse estuarine habitats as a refuge from predators and habitat for foraging and reproduction (Odum and McIvor 1990, Kneib 1997, Sheaves 2005). Changes in the habitat ranges for these emergent intertidal marsh vegetation species may significantly impact numerous organisms throughout the estuary, since dominant vegetation is one of the most important factors determining the ecological function of coastal wetlands (Weinstein et al. 1997).

Nassau and Duval counties

Nassau and Duval counties include the largest estuarine marsh system on the east coast of Florida (NPS 1996). The St. Johns River, Fort George River, and Nassau River flow directly into the Atlantic Ocean after collecting water flowing from many meandering tributaries in this extensive salt marsh (Figure 13.3). In 2009, 29% of the area bordering a lake or waterway in the St. Johns River Basin was residential, while 45% was salt marsh or freshwater wetlands (LSJRBR 2014). Although parts of the area are highly populated, the overall proportions of residential land and other land-use categories remained fairly stable from 2000 to 2009. The close association between urban and industrial areas and estuarine wetlands in the St. Johns River Basin results in wetlands receiving freshwater that is low in dissolved oxygen and high in nutrients and other pollutants (LSJRBR 2014).

There are multiple state parks in Nassau and Duval counties (Big and Little Talbot Island, Fort George Island, Kathryn Abbey, and Amelia Island). Preserves include the Nassau River–St. Johns River Marshes Aquatic Preserve and the Fort Clinch State Park Aquatic Preserve. The Timucuan Ecological and Historic Preserve covers
46,000 acres (18,600 ha) and contains extensive *S. alterni-flora* and *J. roemerianus* salt marshes (Figure 13.3). The preserve lies in the southeastern reaches of the Atlantic Coastal Plain and includes the outflows of the Nassau and St. Johns rivers (NPS 1996).

**Figure 13.2.** Salt marsh and mangrove extent in St. Johns, Flagler, and Volusia counties. Data source: SJRWMD 2009a land use/land cover data, based upon FLCCS classifications (FDOT 1999, SJRWMD 2009a).

**Figure 13.3.** Salt marsh and mangrove extent in St. Johns, Flagler, and Volusia counties. Data source: SJRWMD 2009a land use/land cover data, based upon FLCCS classifications (FDOT 1999, SJRWMD 2009a).

**Threats to coastal wetlands**

- **Coastal development:** Rates of population growth vary widely along the northeastern coast of Florida. Although population growth in Nassau, Duval, and Volu-
Climate change and sea-level rise: Projected sea-level rise is expected to exacerbate shoreline erosion and necessitate landward migration of coastal wetlands. When the Sea Level Affecting Marches Model (SLAMM) was applied to the GTMNERR area with scenarios of 0.7–5.2 ft (0.2–1.6 m) of sea-level rise, it predicted that changes to vegetation land cover would extend 1.2–3.1 mi (2–5 km) inland of the shoreline (Linhoss et al. 2015). Coastal wetland acreage will be lost if sediment accretion does not keep pace with sea-level rise or if topography or coastal development hinders landward migration (Scavia et al. 2002, Linhoss et al. 2015). The St. Johns River has relatively low suspended sediment delivery, making it difficult for sediment accretion to keep pace with the rate of sea-level rise (LSJRBR 2014). Sediment delivery to the marshes lining the Intracoastal Waterway in Northeast Florida is also low, because there are no major tributaries. The altered hydrology brought on by sea-level rise and changes to freshwater availability can decrease overall ecosystem services of wetlands, such as primary productivity and nutrient removal (Scavia et al. 2002, Craft et al. 2009). Additionally, a continued decline in the frequency of cold temperatures is facilitating the northern expansion of mangroves (Cavanaugh et al. 2014). If temperature does not limit mangrove growth, the trees can shade out and eventually replace salt marsh, altering the balance between salt marsh and mangrove swamp in coastal habitats (Lugo and Snedaker 1974, Odum et al. 1982).

Altered hydrology: Hydrology has been altered locally by the construction of mosquito ditches, dikes, dams, and other water-control structures (Frazel 2009). Dredged ditches and channels result in saltwater intrusion into the freshwater zone. Roads and trails (particularly highway A1A) function as impoundments along the shore, preventing natural sheet flow, concentrating runoff, and frequently diverting freshwater runoff from wetlands (FDEP 2008a, FDEP 2008b). As the population in the region grows, the increasing demand for freshwater will likely result in salinity changes for coastal and inland wetlands (SJR WMD 2012, LSJRBR 2014). The predicted increases in salinity may be outside the tolerances of the current vegetation, particularly in freshwater and transitional wetlands.

Erosion: The sandy beaches and barrier islands of Northeast Florida are dynamic and active shorelines. Wave energy, passing storms, boat traffic, and vehicle traffic on the beach all contribute to erosion and modification of the shoreline (Frazel 2009). Coastal erosion is a significant problem along the Intracoastal Waterway due to high wave energy from boat wakes, converting salt marshes and oyster beds into tidal flats and mounds of dead shell. While wave energy, storms, and the migration of barrier islands are natural processes, shoreline migration and erosion threaten development and navigation along the coast, prompting shoreline stabilization and restoration projects. Inlet stabilization and shoreline hardening change the foci of erosional forces, destabilizing other locations and threatening coastal wetlands (Browder and Hobensack 2003).

Water quality: Water quality in the St. Johns River becomes considerably degraded, particularly adjacent to highly industrialized districts including paper mills and landfills. Nonpoint sources of pollution include stormwater runoff and poorly functioning septic systems (NPS 1996, Wicklein 2004). Tidal creeks are characterized by poor flushing, resulting in long pollutant resi-
Figure 13.3. Salt marsh extent in Nassau and Duval counties. Data source: SJRWMD 2009a land use/land cover data, based upon FLUCCS classifications (FDOT 1999, SJRWMD 2009a).
Radabaugh, Powell, and Moyer, editors

**Figure 13.4.** Acreages of mangrove swamps and salt marshes in northeast Florida. Source: SJRWMD 2009a.

...nidence times. Poor water quality ratings due to elevated levels of phosphorus and nitrogen were observed in the upstream reaches of the Nassau River, St. Johns River, and Clapboard Creek (Gregory et al. 2011). High concentrations of heavy metals were found in sediments along the St. Johns River in Duval County. Other water-quality concerns include excess nutrients, organic priority pollutants, bacterial growth, and high turbidity due to increased suspended solids (NPS 1996, Wicklein 2004, LSJRBR 2014). Improvements have been made to water quality in some areas, and there have been overall declines in fecal coliform bacteria and nutrient levels in the St. Johns River, although algal blooms remain frequent (LSJRBR 2014).

Other regions with concern for water quality include Pellicer Creek, located between Flagler and St. Johns counties, and the dredged canals along the Palm Coast (SJRWM 2003, FDEP 2008c). High densities of sewage-treatment systems along the Palm Coast contribute to water-quality concerns. The concentrations of heavy metals, nutrients, coliform bacteria, and dissolved oxygen fall outside of recommended limits. Sedimentation, a growing number of septic systems, and the quality of urban stormwater runoff are also concerns along the Guana, Tolomato and Matanzas rivers (SJRWM 2003, FDEP 2008c).

**Mapping and monitoring efforts**

**Water management district mapping**

SJRWM has conducted regular land use/land cover sampling since 1990 using aerial orthophotography (Table 13.1, Figure 13.4). These efforts have also used wetland assessments from the late 1980s with the assumption that regions identified as wetlands were still wetlands if they had not been developed. Exceptions occurred in areas in which wetlands had been drained or experienced prolonged dry conditions (SJRWM 2009a). In 2004, imagery had a 2-ft (0.62 m) ground sample distance resolution, captured from a height of 20,000 ft (6,096 m). The minimum mapping unit for wetlands was 0.5 acre (0.2 ha). Land features were categorized according to the Florida Land Use and Cover Classification System (FDOT 1999) and outlined in the SJRWMD photointerpretation key (SJRWM 2009b).

**Guana Tolomato Matanzas National Estuarine Research Reserve monitoring**

Salt marsh and mangrove sites are monitored in the GTMNERR as part of the national System-Wide Monitoring Program, which is designed to study ecological characteristics and dynamic responses to local and global changes (NOAA 2011). The GTMNERR’s emergent intertidal vegetation monitoring protocol is a combination of protocols from National Estuarine Research Reserve System Biological Monitoring (Moore 2013), National Park Service Southeast Coastal Network Salt Marsh Monitoring (Curtis and Asper 2012) and the Louisiana Department of Natural Resources Coastal Resource Division (Folse and West 2004). Components of monitoring include permanent emergent intertidal vegetation plots, which are used to determine canopy height and species percent cover (see full description in Chapter 1). Rod Surface Elevation Tables (RSETs) and marker horizons are also used to monitor marsh elevation and accretion (Cahoon et al. 2002a, 2002b). Initial results indicate that most sites are dominated by S. alterniflora, with J. roemerianus becoming more prevalent in the high marsh. Transects have shown that from shore to upland, S. alterniflora becomes shorter, and J. roemerianus increases in height.

Mangroves are monitored following Moore (2013). Trunk diameter and formation, vegetative ground cover, canopy height, and canopy characteristics are recorded in mangrove plots. Additional monitoring evaluates spatial and temporal patterns in vegetation and soil pore-water chemistry. Initial results found that when mangroves were present, A. germinans was predominant.

Weather (e.g., temperature, wind speed and direction, light, and precipitation) and water quality parameters (temperature, salinity, dissolved oxygen, pH, Secchi depth, total suspended solids, turbidity, chlorophyll a, nitrate, nitrite, ammonium, total Kjeldahl nitrogen, orthophosphate, total phosphorus, and fecal coliform) are also monitored throughout the reserve using standard NERRS protocols. Data and metadata are available at [www.nerrsdata.org](http://www.nerrsdata.org) and may also be obtained by contacting the research coordinator at GTMNERR.
The National Park Service’s Southeast Coast Network monitors soil salinity and rates of sediment accretion or subsidence in several salt marshes across the southeastern United States. Monitoring includes the deployment of RSETs following a version of the Louisiana Department of Natural Resources Coastal Resource Division protocol (Folse and West 2004). Monitoring occurs at eight locations including the Timucuan Ecological and Historic Preserve and Fort Matanzas National Monument in Northeast Florida. A full description of the program can be found at science.nature.nps.gov/im/units/secn/monitor/saltmarsh.cfm.

The Ocean and Coastal Resources Branch of the National Park Service recently completed a geospatial mapping project to classify and quantify the extent of *J. roemerianus* and *Spartina* spp. in the preserve. These data can be used to quantify changes in the community from year to year and to predict future change. Other classes such as water, trees, other upland vegetative communities, and salt flats were also quantified. Color infrared orthoimagery (2012), LiDAR data (2007), and Trimble eCognition software were used to accomplish this object-based image analysis. This technique groups neighboring homogeneous pixels and then uses contextual properties to enable the analyst to accurately classify a landscape (Cantor 2014). The data set can be downloaded at data.doio.gov/dataset/timucuan-ecological-and-historic-preserve-salt-marsh-classification.

**Figure 13.5.** Example of detailed land cover and emergent vegetation mapping performed by the SJRWMD in the GTMNERR (Kinser et al. 2007).

**SJRWMD and GTMNERR detailed emergent vegetation mapping**

Salt marsh and other tidal communities were mapped by the St. Johns River Water Management District within the GTMNERR using 2006 orthophotography and 2004 digital orthophoto quarter quads (DOQQs). Classifications of land cover were species-specific for mangroves and herbaceous plants (Kinser et al. 2007). Figure 13.5 shows an example of the detail and high resolution of this mapping effort.
Recommendations for protection, management, and monitoring

The numerous parks and preserves in this region list specific recommendations for their area of concern. Selected examples are listed below. Most common recommendations include restoring the natural hydrology, controlling sediment, converting armored shorelines into living shorelines, and restoring or protecting wetlands.

- Prevent unauthorized traffic by off-road vehicles in salt marshes by educating the public and erecting signs and fences. When damage occurs, restoration efforts may help the salt marsh recover more rapidly (GTMNERR 2009).
- Coastal Northeast Florida differs from many other regions of the state in that invasive vegetation such as *Schinus terebinthifolius* (Brazilian pepper) and *Casuarina* spp. (Australian pines) are not well established. Active vigilance is required to ensure that these and other nonnatives do not proliferate (FDEP 2008a, GTMNERR 2009).
- The Lower St. Johns River Basin Report recommends intensive monitoring of impacts to wetlands to determine the cumulative effect of incremental wetland loss to overall function and ecosystem services (LSJRBR 2014). The remaining wetlands need to be preserved, enhanced, or restored as needed.
- Goals of the 2008 Surface Water Improvement and Management Plan (SWIM) for the Lower St. Johns River Basin include improving water quality, restoration/protection of natural systems, preserving the floodplain, maintaining natural hydrology, and erosion control (SJRWMD 2008).
- Water quality and hydrology are critical components to maintaining the estuary in the Timucuan Ecological and Historic Preserve. Needs identified by the National Park Service include hydrologic modeling and monitoring of the three rivers, continuous water quality monitoring, and the restoration and protection of living shorelines (Gregory et al. 2011, NPS 2012).
- Goals listed within the management plans of Fort George Island Cultural State Park and Amelia Island State Park include monitoring and protection of natural resources that have altered hydrology due to the construction of ditches and roads. Specific goals include salt marsh restoration and continued monitoring and removal of invasive vegetation (FDEP 2008a, FDEP 2008b).

Works cited


Florida Department of Environmental Protection. 2008b. Amelia Island State Park, Big Talbot Island State Park, Little Talbot Island State Park, and George Crady Bridge Fishing Pier State Park unit management plan. Tallahassee. www.dep.state.fl.us/
Coastal Habitat Integrated Mapping and Monitoring Program Report: Florida 153


Florida Department of Environmental Protection. 2008c. Water quality assessment report: Upper East Coast. FDEP Division of Environmental Assessment and Restoration. Tallahassee.


General references and additional regional information

National Park Service salt marsh elevation monitoring: science.nature.nps.gov/im/units/secn/monitor/saltmarsh.cfm

National Park Service geomorphology and geology projects: irma.nps.gov/App/Reference/Profile/2209252
www.nature.nps.gov/geology/inventory/ige_publications.cfm

Planning for sea-level rise in the Matanzas Basin: planningmatanzas.org

Regional contacts

Nikki Dix, Guana Tolomato Matanzas National Estuarine Research Reserve, Nikki.Dix@dep.state.fl.us

Andrea Noel, Northeast Florida Aquatic Preserves, FDEP, Andrea.Noel@dep.state.fl.us