Chapter 6
Charlotte Harbor and Estero Bay

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Description of the region

Charlotte Harbor is a large, complex estuary bordered by barrier islands that receives freshwater input from the Myakka, Peace, and Caloosahatchee rivers along with many other minor tributaries (Figure 6.1). Farther south, Estero Bay is also lined by barrier islands and receives freshwater flow from many small rivers and creeks. The substrate of the region is composed of deltaic accumulations deposited on the limestone bedrock 5,000 years ago when the rising sea flooded the Peace and Myakka rivers (FDEP 2007). The sediments in the region are predominantly poorly drained sandy and mucky soils. Coastal topography is low and gradually sloped, although numerous 15- to 20-foot (4.5–6 m) tall mounds and middens built by Native Americans contribute to local variability in elevation.

Mangrove forests dominate the remaining natural shorelines of Charlotte Harbor. These mangrove forests generally follow the classic species zonation, with *Rhizophora mangle* (red mangrove) present along the shoreline, followed by *Avicennia germinans* (black mangrove) and *Laguncularia racemosa* (white mangrove) farther inland. Salt marshes are not easily seen from the water as they are found on the landward side of the mangrove forests or on the interior of islands. Salt marshes in this region can be subdivided into 12 types based upon the predominant vegetation. *Juncus roemerianus (*black needlerush) and mixed-vegetation high marsh are the most common types (Beever et al. 2012). Additional common salt marsh vegetation includes *Spartina alterniflora* (smooth cordgrass), *Acrostichum* spp. (leather ferns), *Schoenoplectus robustus* (saltmarsh bulrush), *Distichlis spicata* (salt grass), and *Salicornia* spp. (glassworts). Salt marshes are diverse and may include intermittent algal mats, salt barrens, shrub mangroves, and *Conocarpus erectus* (buttonwood) trees (Beever et al. 2012).

Many of the region's original coastal wetlands were removed from the 1950s through the 1970s, a time in which the area was undergoing drastic population growth and was developed for agriculture, suburbs, and boat navigation. Large areas of salt marsh habitat were destroyed when 400 mi (640 km) of canals were constructed to provide entire subdivisions with waterfront property (SFWMD 2008). Twenty-five percent of the original mangrove swamps were lost to dredge-and-fill developments, and 41% of the natural shoreline has been significantly altered or lost (Beever et al. 2009, CHNEP 2013a). Changes to topography and hydrology included construction of navigation channels, mosquito ditches, spoil piles, seawalls, dams, and residential canals (FDEP 2007).

The population of the region has grown enormously in the past 50 years and continues to grow. From 2000 to 2007, the population of counties adjacent to Charlotte Harbor increased an average of 17% per county (Beever et al. 2009). According to projections from the U.S. Census, the estimated 2015 population was 701,982 for Lee County and 173,115 for Charlotte County (U.S. Census 2015). Human population is concentrated along the coastline, with the majority of residents living within 10 mi (16 km) of the Gulf of Mexico or an estuary's coastline (Beever et al. 2009). The estuarine and coastal waters are valuable to the local economy for tourism, sport and commercial fishing, and many forms of aquatic recreation (CHNEP 2008, CHNEP 2013a).

Management of the seasonally-alternating excess and shortage of freshwater has been an ongoing struggle for human development of South Florida at the expense of natural ecosystems. Flood-prevention structures alter natural hydrologic systems, concentrating freshwater run-

Figure 6.1. Mangrove and salt marsh coverage in the Charlotte Harbor region. Data source: SWFWMD 2011 and SFWMD 2009 land use/land cover data, based on FLUCCS classifications (FDOT 1999, SFWMD 2009a, SWFWMD 2011).

off in outflows and often deflecting flow away from salt marshes. This management has led to ecosystem shifts toward plant species that are more tolerant of high salinities (Beever et al. 2011). In the dry season, commercial, agricultural, and residential demand for water restricts freshwater input into natural ecosystems (Beever et al. 2012). Freshwater flow has decreased in the Peace River due to upstream urban, agricultural, and mining demands and depletion of the Floridan Aquifer (CHNEP 2013a). The upstream regions of the Caloosahatchee River have been channelized, and freshwater releases from Lake Okeechobee are regulated via the Franklin lock and dam. High-nutrient freshwater releases during the summer rainy season and limited freshwater flow during the dry season have led to widely variable estuarine conditions in the Caloosahatchee (CHNEP 2008, Beever et al. 2009).

The majority of the remaining natural shoreline is protected by state parks and other preserves. Charlotte Harbor includes five aquatic preserves: Pine Island Sound, Matlacha Pass, Cape Haze, Lemon Bay, and Gasparilla Sound Charlotte Harbor. State parks in the region include Charlotte Harbor Preserve, Cayo Costa, Myakka, Stump Pass Beach, Gasparilla Beach, and Don Pedro Island. While some barrier islands along Estero Bay are highly developed, the mainland shoreline of the bay remains natural, and much of it is preserved within Estero Bay Preserve State Park. Other state parks around Estero Bay include Lovers Key and Mound Key Archaeological State Park.

Threats to coastal wetlands

- **Altered hydrology and development:** The two greatest anthropogenic threats facing coastal wetlands in the Charlotte Harbor area are continued urban development and alteration of the natural hydrology (Beever et al. 2011). Unnatural hydrologic patterns due to flood-control structures and increasing demand for freshwater often starve or inundate coastal wetlands with freshwater. Continued population growth not only results in direct habitat loss in coastal regions and adjacent buffer zones, but also has indirect effects through pollution and continually growing demands for freshwater.
- **Climate change and sea-level rise:** Climate change is likely to increase seasonality and weather extremes in southwest Florida, causing more extreme temperatures and increasing precipitation during the wet season and less during the dry season (Peterson et al. 2008, Beever et al. 2012). Sea-level rise will result in increased inundation and coastal erosion. In 2009, Lee County had 22,241 acres (9,000 ha) of mangroves and 1,517 acres (613 ha) of salt marsh located at or below 1.5 ft (0.46 m) of elevation; these low elevations are vulnerable to seawater inundation at even modest estimates of future sea-level rise in the region (Beever et al. 2009). Mangrove habitat is projected to continue to expand inland in response to climate change, often at the expense of salt marsh habitats (NWF 2006). But if urban development is present landward of existing coastal wetland habitat, these coastal wetlands will be squeezed out by rising sea level (CHNEP 2009). Increases in hurricane severity, erosion, temperature extremes, anthropogenic disturbances, and invasive species will also likely lead to further ecological destabilization and shifts in species abundances (Beever et al. 2012, FDEP 2014a).
- **Invasive vegetation:** As of 2007, Charlotte Harbor Preserve State Park documented 38 invasive plants and 22 invasive animals (FDEP 2007). *Schinus terebinthifolius* (Brazilian pepper), *Melaleuca quinquenervia* (melaleuca), and *Casuarina* spp. (Australian pines) are very common in the region and encroach on the edges of mangrove and salt marsh habitat (CHNEP 2011).
- **Storm events:** Large numbers of mangroves were killed in 2004 when Hurricane Charlie made landfall in the Charlotte Harbor region as a Category 4 storm. The trees were killed and stripped of their leaves by the initial force of the storm, but they also suffered afterward from increased desiccation, disease, and insect herbivory (FDEP 2007). Coastal wetlands in the region can recover relatively quickly from natural disturbances such as hurricanes, fires, and drought, but they are more vulnerable to invasive vegetation afterward (Beever et al. 2009).
- **Mangrove trimming:** While much of Charlotte Harbor's coastlines are within preserves and state parks, urbanized development is present along a significant part of the estuarine shoreline, and mangroves are often trimmed along these waterfront properties (CHNEP 2011). Proper mangrove trimming, according to regulations established by the Florida Department of Environmental Protection (FDEP), has minimal impact on mangrove productivity, but improper hedging can result in the loss of more than 80% of productivity and kill the trees. Only 20% of mangroves are trimmed according to permitting regulations, and enforcement is difficult because FDEP field personnel are stretched extremely thin (Beever et al. 2011).
- **Erosion:** Coastal erosion has increased in recent decades, partly due to coastal development and boating inlets interrupting natural sediment flow (Beever et al. 2012). Several regions of critical erosion already occur on the outer edges of barrier islands in the region (Beever et al. 2009, FDEP 2014b).

Table 6.1. Historical acreages of mangrove swamps (FLUCCS 6120) and salt marshes (FLUCCS 6420) in Charlotte Harbor (Figure 6.1), by water management district. Data sources: SFWMD 2009a, SWFWMD 2011.

Year	SWFWMD Mangrove	SWFWMD Salt marsh
1990	18,810	8,171
1994	18,428	8,507
1999	18,403	8,533
2004	18,740	8,665
2005	18,737	8,679
2006	18,720	9,544
2007	18,719	9,543
2008	20,507	7,426
2009	20,490	7,732
2010	20,457	7,546
2011	20,461	7,571
Year	**SFWMD Mangrove**	**SFWMD Salt marsh**
1995	42,462	3,891
1999	41,093	3,732
2004–2005	41,057	4,160
2008–2009	41,482	4,612

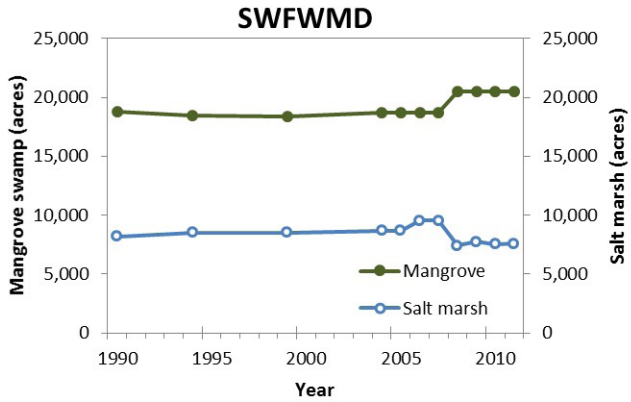

Figure 6.2. Acreages of mangrove swamps and salt marshes in the SWFWMD's portion of Charlotte Harbor (Figure 6.1 and Table 6.1). Data source: SWFWMD 2011.

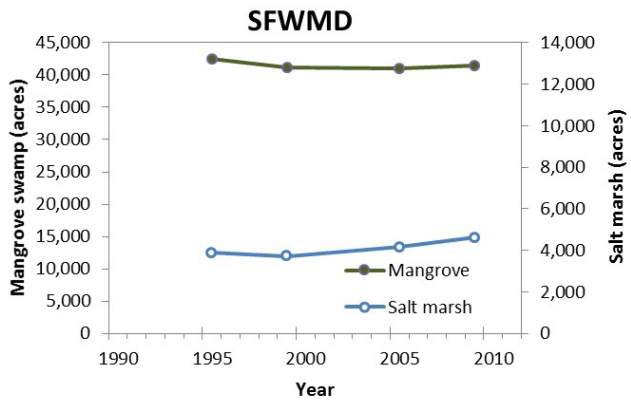

Figure 6.3. Acreages of mangrove swamps and salt marshes in the SFWMD's portion of the Charlotte Harbor region (Figure 6.1 and Table 6.1). Data source: SFWMD 2009a.

Mapping and monitoring efforts

Water management district mapping

The Charlotte Harbor and Estero Bay region is divided between the Southwest Florida Water Management District (SWFWMD) and the South Florida Water Management District (SFWMD) (Figure 6.1). SWFWMD conducted land use and land cover (LULC) surveys from 1990 through 2011 (Table 6.1, Figure 6.2). Features in 1-ft color infrared imagery were photointerpreted at a scale of 1:8,000. After the review of new imagery, updates and changes to map line work are digitized at a scale of 1:6,000. The features delineated in LULC maps are categorized according to Florida Land Use and Cover Classification System (FLUCCS) categories (FDOT 1999). SWFWMD's LULC mapping standards require that wetland features be at least 0.5 acre (0.2 ha) in area to be classified in maps.

SFWMD also conducts fairly regular LULC surveys within its boundaries (Table 6.1, Figure 6.3). The 2008–2009 land cover classifications were based on an SFWMD modified FLUCCS classification system (FDOT 1999, SFWMD 2009b). Minimum mapping units were 5 acres (2 ha) for uplands and 2 acres (0.8 ha) for wetlands. The 2008–2009 maps were made by interpreting aerial photography and updating 2004–2005 vector data (SFWMD 2009).

Some of the year-to-year variability seen in water management district salt marsh and mangrove acreage (Figures 6.2 and 6.3) is likely due to refinement of mapping methods and spatial resolution rather than actual annual variation (Beever et al. 2012, CHNEP 2014). Small annual changes in salt marsh and mangrove extent continue to occur as a result of restoration projects, mangrove encroachment into salt marshes, and small amounts of permitted development (CHNEP 2009, CHNEP 2011, CHNEP 2014). A salt marsh mapping study conducted during 2010–2012 (see below) offers a high-resolution map of salt marsh that identifies these small changes (Beever et al. 2012).

Charlotte Harbor National Estuary Program and Southwest Florida Regional Planning Council mapping

Beever et al. (2012) mapped 14,853 acres (6,010 ha) of salt marsh of all types in 2010–2012 within the Charlotte Harbor National Estuary Program (CHNEP) study area. Local acreages of salt marshes among the regional watersheds are shown in Table 6.2. Total salt marsh extent was greater in the 2010–2012 CHNEP study than in earlier mapping by the Florida Fish and Wildlife Conservation Commission, SFWMD, and SWFWMD (Beever et al. 2012). These differences are not thought to be the result of an actual increase in salt marsh extent, but rather the product of refined mapping methods in the CHNEP study. Significant areas of salt marsh were incorrectly mapped as mangrove forest in earlier mapping efforts and other areas of mangrove were designated as salt marsh. In some watersheds, some freshwater marsh and bare sand upland areas were previously mapped as salt marsh (Beever et al. 2012). An example of these adjustments (labelled as working base modifications) is shown in Figure 6.4, while Figure 6.5 shows the total extent of salt marshes and mangroves in the Charlotte Harbor region as determined by CHNEP and Southwest Florida Regional Planning Council (SWFRPC) mapping.

Predevelopment maps were created by SFWMD, CHNEP, and consultants using historical aerial photographs (Beever et al. 2012). Calculations based on these maps reveal that more than half of the salt marsh in the Charlotte Harbor area has been lost to development (salt marsh loss in each watershed is shown in Table 6.3). However, 74% of the remaining salt marsh extent is located on conserved land (Table 6.3).

In 2014, CHNEP initiated a new two-year mapping effort for mangroves in the Charlotte Harbor region. Mangroves were mapped by geomorphic type and species (example shown in Figure 6.6). Geomorphic types include overwash island, fringe, riverine, basin, hammock, scrub, and altered mangrove hedge. In addition, areas with die-offs, stress, and potential future loss were identified. Areas with blocked tidal flow can lead to stagnant water, which is a stressful condition for mangroves that may lead to die-offs, a phenomenon also referred to as a mangrove heart attack (Lewis et al. 2015). Further CHNEP efforts have focused on the identifying characteristics of stressed mangroves, including spectral signatures, which enable early identification and strategy development to prevent mangrove die-offs (Beever et al. 2016).

Table 6.2. Salt marsh acreage in Charlotte Harbor watersheds, as mapped by CHNEP in 2010–2012. Data source: Beever et al. 2012.

Watershed	Cordgrass	Black needlerush	Leather fern	Saltmarsh bulrush	Scrub mangrove	Algal	Saltern	Succulents	Mixed	Grasses	Shrub buttonwood	Total
Caloosahatchee	0.00	138.51	76.54	0.00	45.72	6.58	11.16	4.32	66.33	40.16	0.00	389.32
Charlotte Harbor	0.00	190.48	8.28	0.00	315.34	248.40	327.44	307.19	2,622.71	202.84	0.00	4,222.68
Dona and Roberts Bay	0.00	30.37	5.30	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	35.71
Estero Bay	0.00	726.26	38.58	0.00	246.95	532.74	198.45	167.15	779.50	65.57	18.71	2,773.91
Lemon Bay	0.04	10.62	37.82	0.00	1.37	12.28	11.01	21.59	25.10	42.35	0.00	162.18
Matlacha Pass	0.00	14.04	0.28	0.00	449.45	78.38	46.85	123.34	1,466.90	149.23	0.90	2,329.37
Myakka River	0.00	1,028.95	52.40	0.00	4.95	16.75	8.18	6.67	129.43	44.40	0.00	1,291.73
Peace River	0.04	1,446.11	238.27	337.37	51.35	7.90	1.42	32.97	180.98	5.25	0.00	2,301.66
Pine Island Sound	2.72	8.33	7.23	0.00	90.97	340.70	51.58	280.51	512.85	51.27	0.00	1,346.16
Total	2.81	3,455.16	388.15	337.37	1,160.39	1,237.14	644.97	939.42	5,717.47	560.92	19.62	14,463.42

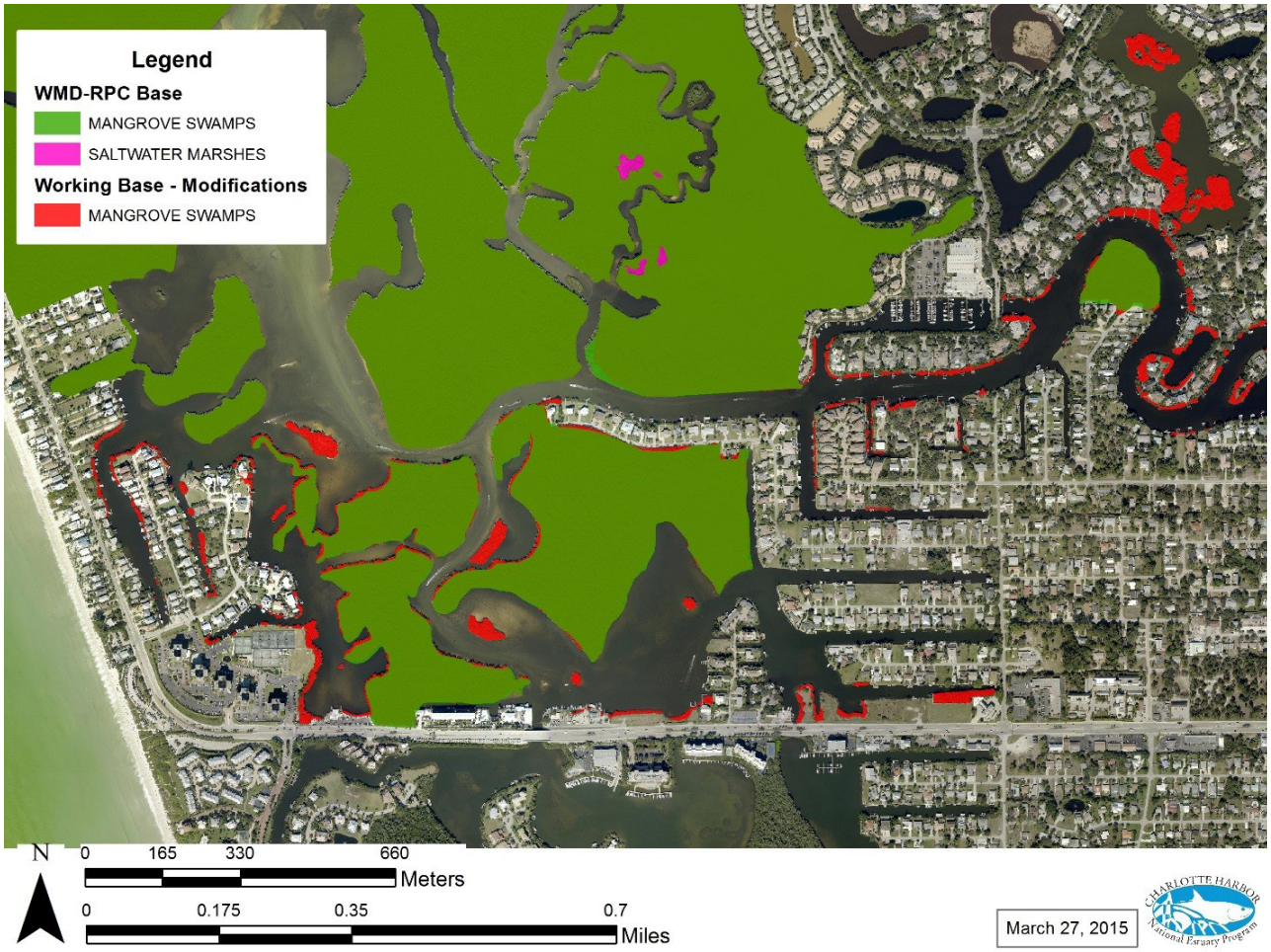

Figure 6.4. Example of mapping adjustments (working base modifications) made by CHNEP and SWFRPC to water management district and regional planning council base maps (WMD-RPC Base) near the Imperial River, south of Estero Bay.

Local assessments and reports

Many recent assessments of the Charlotte Harbor estuary and watershed are available from the Conservancy of Southwest Florida (CSF 2005, CSF 2011), CHNEP, and SWFRPC (Beever et al. 2009, 2011, and 2012, CHNEP 2008, 2009, 2011, 2013a, 2013b, and 2014). These documents include vulnerability assessments, estuary report cards, monitoring reports, and conservation and management plans for the region. The tidal stream assessment project mentioned in Chapters 4 and 5 also includes Charlotte Harbor and Estero Bay (SBEP 2016). The multicounty collaborative effort includes monitoring data on vegetation, bathymetry, and habitat in tidal creeks on the central west coast of Florida. The data from this project are publically available at www.sarasota.wateratlas.usf.edu/tidal-stream-assessments and are summarized in SBEP 2016.

Estuary report cards

The Conservancy for Southwest Florida used water quality and mapping data to create the 2005 and 2011 estuary report cards (CSF 2005, CSF 2011). The regional grades in these report cards were based on factors such as water nutrient concentrations, dissolved oxygen concentrations, presence of pathogens and heavy metals, hydrology, extent of all wetlands and mangroves compared with historical data, and area of conservation lands. Common problems identified included low concentrations of dissolved oxygen and high concentrations of nutrients, pathogens, or mercury. Some regions also received low scores due to altered hydrology, few remaining mangroves, and small amounts of conserved land. A summary of the scores given to the relevant regions is provided in Table 6.4; full evaluations and detailed maps of modern and historical mangrove extent may be found in the technical report (CSF 2011).

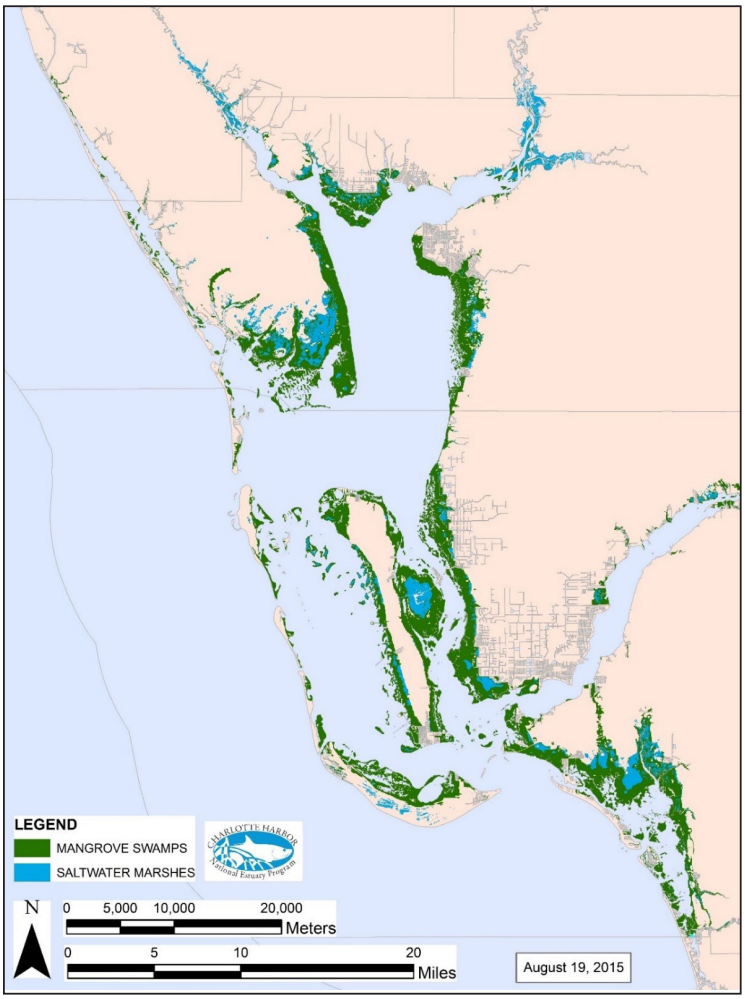

Figure 6.5. Mangrove swamp and salt marsh in Charlotte Harbor/Estero Bay, determined by the Charlotte Harbor National Estuary Program and the Southwest Florida Regional Planning Council.

Volunteer shoreline surveys

CHNEP used volunteers to conduct shoreline surveys in 2007, 2010, and 2013. The surveys identified the percentage of mangroves present on the shoreline, mangrove height and trimming style (if trimmed), the presence of nonnative vegetation, shoreline hardening, and type of construction. While the entire Charlotte Harbor estuary coastline was not surveyed, the same regions were covered in 2010 and 2013 (CHNEP 2013b). These surveys found an increased presence of mangroves and Brazilian pepper in several of the surveyed regions.

Sea Level Affecting Marshes Model

The Sea Level Affecting Marshes Model (SLAMM) Version 4.1 (NWF 2006) predicts coastal vegetation changes using the Intergovernmental Panel on Climate Change A1B climate scenario, which foresees a mean sea-level rise of 15.2 in. (38.6 cm) by 2100 (IPCC 2001). SLAMM predicts that 89% of salt marshes in the Charlotte Harbor area will disappear by 2100, but mangrove extent will increase by 75% (NWF 2006). Mangroves are expected to overtake large amounts of salt marsh habitat, but their success also depends upon their ability to accumulate sediment at a pace that keeps up with sea-level rise.

Table 6.3. A comparison of predevelopment and modern salt marsh extent in Charlotte Harbor watersheds, as mapped by CHNEP in 2010–2012. Conserved land was identified using SWFWMD and SFWMD 2009 LULC maps and 2011 Southwest Florida Regional Planning Council maps. Data sources: Beever et al. 2011, Beever et al. 2012, SFWMD 2009a, and SWFWMD 2011.

Watershed	Predevelopment acreage	2010–2012 acreage	Acreage change	% change	Current salt marsh acreage on conserved land	% of current salt marshes on conserved land
Caloosahatchee	2,659	389	−2,269	−85%	305	78%
Charlotte Harbor	11,548	4,223	−7,325	−63%	3,808	90%
Dona and Roberts Bay	6	36	30	488%	1	3%
Estero Bay	2,055	2,774	719	35%	2,508	90%
Lemon Bay	1,023	162	−861	−84%	111	69%
Myakka River	935	1,292	357	38%	511	40%
Peace River	5,540	2,302	−3,239	−58%	710	31%
Pine Island Sound and Matlacha Pass	10,577	3,679	−6,898	−65%	3,109	85%
Total	34,343	14,857	−19,486	−57%	11,063	74%

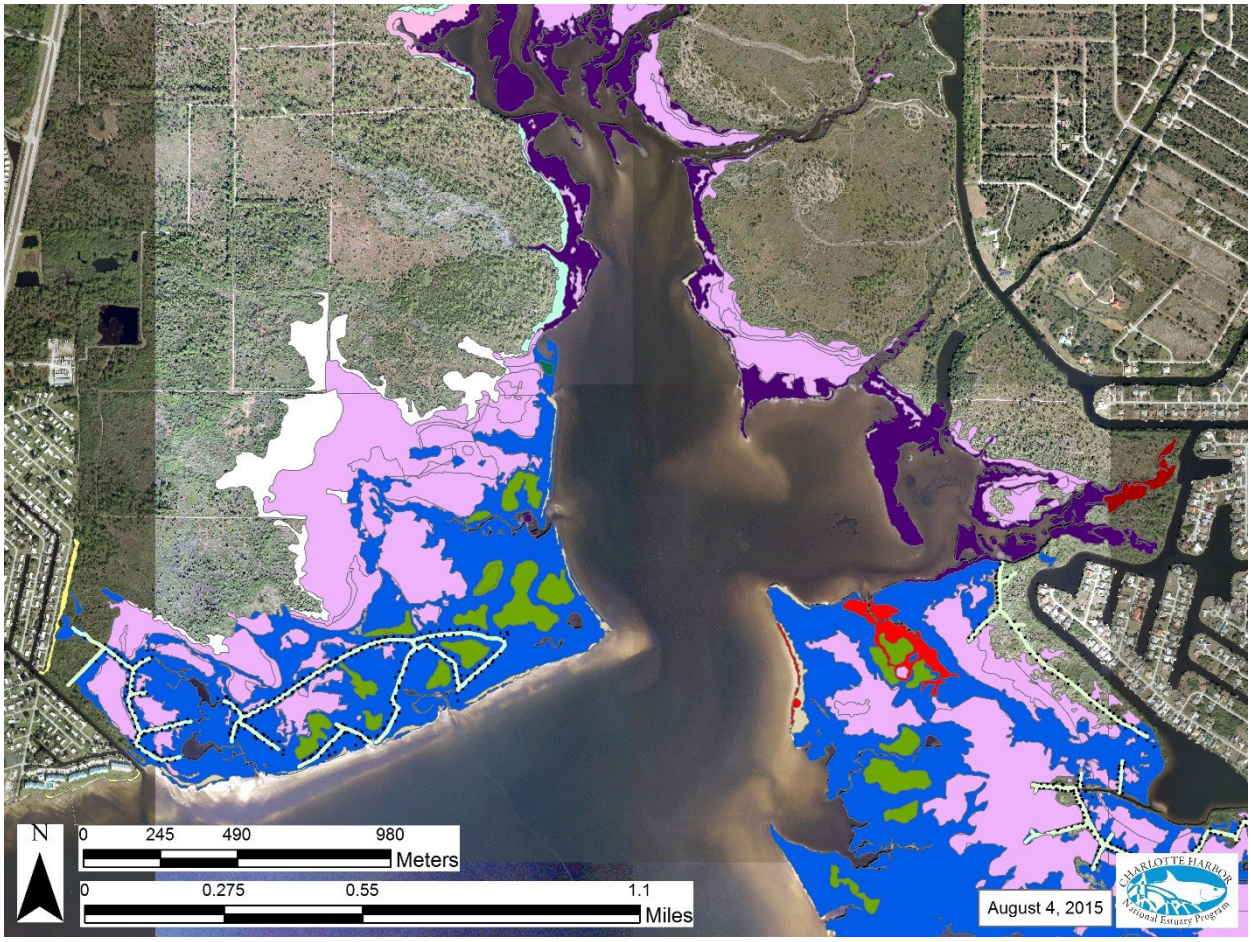

Figure 6.6. Example of detailed CHNEP mapping along Tippecanoe Bay in northern Charlotte Harbor. Pink = salt marsh, blue = mixed mangrove fringe, olive green = basin black mangrove, red = red mangrove fringe, white = white mangrove fringe, beige = tropical hardwood hammock (coastal berm), black dots = spoil along mosquito ditches.

Recommendations for protection, management, and monitoring

- Elevation-appropriate buffer zones that are protected from human development are needed on the landward edge of coastal wetlands. These will allow coastal wetlands to move inland as habitat is lost due to sea-level rise and erosion (CHNEP 2013a).
- Hydrologic flow following natural seasonal patterns needs to be re-established in the estuary. This includes minimizing large pulses of freshwater, establishing a reliable aquifer flow, restoring water conveyances, and planning for future water demands in the area (CHNEP 2013a).
- Additional public education and enforcement regarding appropriate mangrove trimming are needed. More FDEP personnel are needed to enforce mangrove trimming regulations, or mangrove trimming should be banned (Beever et al. 2011).
- Monitoring to document the effects of climate change and identify early signs of ecosystem-wide shifts is needed to best implement management and mitigation strategies (Beever et al. 2009). Invasive species and locally altered hydrology can also drive ecosystem shifts, but pre-emptive rehabilitation of stressed and degraded coastal wetland habitats could aid particularly vulnerable regions (Lewis et al. 2015, Beever et al. 2016). Recommendations regarding wetland mitigation practices in southwest Florida may be found in Beever et al. (2011).
- Management concerns in the Charlotte Harbor Preserve State Park management plan (FDEP 2007) include the need for mapping and inventory of plant and animal communities, increased effort to control the extent of invasive species, and hydrologic modeling. The plan also reinforced the need for consistent monitoring of natural resources and restoration projects. FDEP seeks to find a balance between land preservation efforts and making specific regions accessible for recreation. Continued population growth in the region necessitates conservation of freshwater resources and increases the importance of conserved land.

Table 6.4. Wildlife habitat grades of regions in and around the Charlotte Harbor Estuary. Data source: CSF 2011.

Estuary	Wetlands percent remaining	Mangroves percent remaining	Averaged percentage	Conservation lands percentage	Overall wildlife-habitat grade
Coastal Venice	48%	47%	48%	12%	C−
Lemon Bay	70%	55%	63%	25%	B
Greater Charlotte Harbor	64%	57%	61%	18%	B−
Pine Island Sound	70%	100%	85%	56%	A+
Caloosahatchee	39%	38%	39%	16%	D−
Estero Bay	62%	85%	74%	21%	B−

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Southwest Florida Regional Planning Council: www.swfrpc.org/

South Florida Water Management District: www.sfwmd.gov/

Southwest Florida Water Management District: www.swfwmd.state.fl.us/

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