Chapter 4
Tampa Bay

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Description of the Region

The Tampa Bay region is located on the west-central coast of Florida. It includes Tampa Bay proper, Florida's largest open-water estuary, which has a surface area of approximately 400 mi^2 (1,036 km^2) at high tide (Figure 4.1). The bay is fed by a watershed of roughly 2,600 mi^2 (6,730 km^2) with four major rivers (Hillsborough, Alafia, Manatee, and Little Manatee) and more than 100 small tributaries. The watershed includes large portions of Hillsborough, Pinellas, and Manatee counties, as well as smaller portions of Pasco and Polk counties. The area is highly urbanized, and the population around Tampa Bay has quintupled since the 1950s. Hillsborough, Pinellas, and Manatee counties were estimated to be home to more than 2.6 million people in 2015, and the population continues to grow (U.S. Census 2015). Although the area is highly developed, it also includes many city, county, and state parks and preserves, aquatic preserves, and national wildlife refuges.

The demands of a growing population have altered local hydrology due to freshwater withdrawal from tributaries and the construction of water reservoirs (Yates and Greening 2011). The concomitant increase in the extent of impervious surfaces in the watershed has resulted in increased runoff, transporting more nutrients and other pollutants into the bay. After Tampa Bay's deteriorating health became evident in the 1970s, upgraded sewage-treatment requirements in St. Petersburg and Tampa reduced nutrient outflow into the bay and reversed trends in eutrophication (Greening and Janicki 2006, Holland et al. 2006). Improvements in water quality, coupled with habitat restoration and protection plans, have increased the overall health of Tampa Bay ecosystems, but the growing population requires that management plans be adaptive (Holland et al. 2006, Yates and Greening 2011).

Tampa Bay and its shoreline contain a diverse array of habitats, flora, and fauna due to the bay's large size and wide salinity gradient. Coastal or estuarine wetlands include mangroves, salt barrens, and polyhaline, mesohaline, and oligohaline salt marshes. The system is dominated by mangroves, which has made up 67–75% of its total estuarine wetland coverage since the 1950s (Figures 4.2 and 4.3). Salt marshes made up 22–28% of coastal wetlands, and salt barrens making up the remaining 2–6%. In recent decades the proportion of mangroves has steadily increased as the proportion of salt marsh and salt barren coverage have decreased (Robison 2010).

Coastal wetlands generally declined in coverage from the 1950s to the early 1990s (Table 4.1, Figure 4.2). Since then, land acquisition and habitat restoration, undertaken primarily by public agencies but also by nongovernmental entities, have led to modest gains in habitat acreage (Figure 4.2). The largest increases in terms of both acreage and proportion have been seen in mangrove coverage; increases in salt marsh acreage and proportion have been

Figure 4.1. Mangrove and salt marsh coverage in the Tampa Bay region. Data source: SWFWMD 2011 land use/land cover data, based on FLUCCS classifications (FDOT 1999, SWFWMD 2011).

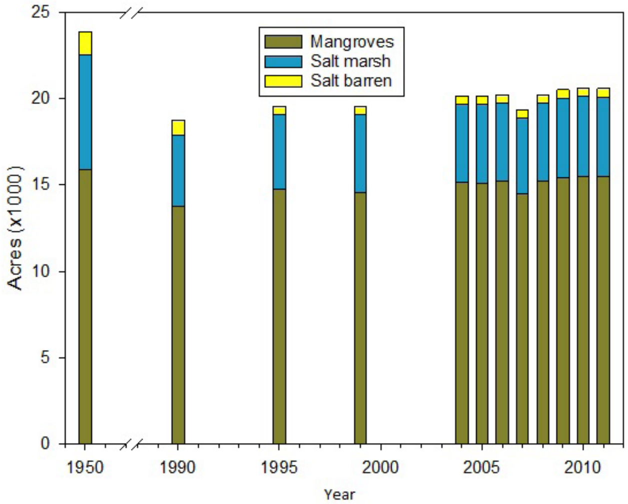

Figure 4.2. Baywide acreages of emergent saltwater vegetation, 1950–2011. See Table 4.1 for data sources.

moderate. Salt barren acreage remained relatively steady from 1995 to 2011, but it remains roughly one-third that estimated for the 1950s. Status and trends for coastal wetlands are explored by habitat type and bay segment in Tables 4.2–4.4 and Figure 4.3. Land cover classifications used for the 1950s data vary somewhat from Florida Land Use and Cover Classification System (FLUCCS) categories (FDOT 1999). See Lewis and Robison (1995) for a full explanation of land cover classifications and methods for estimating coastal wetland extent in 1950 and 1990.

Land use was first mapped by the Southwest Florida Water Management District (SWFWMD) in 1990, but mapping methodologies have varied over time (see Robison 2010). SWFWMD did not systematically map salt barren habitat types until 2004, but Robison (2010) estimated extent of salt barren habitat for 1995 and 1999 from color photography. Table 4.5 presents acreage and proportional changes in acreage of emergent saltwater vegetation over various time periods in each bay segment of Tampa Bay.

Table 4.1. Historical acreage estimates for Tampa Bay coastal wetlands.

Year	Data source	Mangroves	Salt marsh	Salt barren	Total
1900*	Lewis and Robison 1995	16,538	16,200	1,012	33,750
1950	Lewis and Robison 1995	15,894	6,621	1,371	23,886
1990	Lewis and Robison 1995	13,764	4,117	877	18,758
1995	Robison 2010	14,760	4,343	445	19,548
1999	Robison 2010	14,595	4,478	469	19,542
2004	SWFWMD	15,149	4,513	492	20,154
2005	SWFWMD	15,127	4,527	492	20,146
2006	SWFWMD	15,246	4,478	482	20,206
2007	SWFWMD	14,511	4,390	446	19,347
2008	SWFWMD	15,242	4,477	490	20,209
2009	SWFWMD	15,462	4,543	515	20,520
2010	SWFWMD	15,495	4,640	501	20,636
2011	SWFWMD	15,500	4,603	501	20,604

*1900 values based on estimated 1950s proportions, as described in Lewis and Robison (1995). Raabe et al. (2012) showed that proportions may have been quite different before 1900.

Clearwater Harbor and St. Joseph Sound

The northwestern portion of Pinellas County lies outside the Tampa Bay watershed (Figure 4.1). This region includes both salt marshes and mangroves in Clearwater Harbor to the south and St. Joseph Sound to the north (Table 4.6). Aerial photography from 1942 was used to establish land cover from that year; about 65% of the watershed had still not been developed (Janicki and Atkins 2011b). The largest loss of coastal wetlands in this area has been around the city of Clearwater, a result of extensive coastal development. In St. Joseph Sound, Clearwater Harbor North, and Clearwater Harbor South, 57, 67, and 98%, respectively, of mangrove habitats have now been lost (Janicki and Atkins 2011a, 2011b). Much of the remaining salt marsh and mangrove habitats in this area are found on several undeveloped barrier islands (Caladesi, Honeymoon, Three Rooker, and Anclote). Because the region is so highly developed, management efforts focus on preserving the wetland habitats that remain.

Ecosystem services provided by Tampa Bay wetlands

Coastal wetlands are extremely valuable to the Tampa Bay region. A project team from the U.S. Environmental Protection Agency Gulf Breeze Laboratory has performed extensive monitoring and modeling to determine the value of ecological services provided by the suite of habitats in Tampa Bay and its watershed (Russel et al. 2011, Russel and Greening 2015). Notable valuable services of wetlands include improvement of water quality, flood protection, and improvement of air quality and aesthetics. In addition to providing essential habitat and food sources for many estuarine species, wetlands also provide such ecosystem services as sequestering atmospheric carbon (Moyer et al. 2016) and reducing nitrogen in wastewater and stormwater discharges.

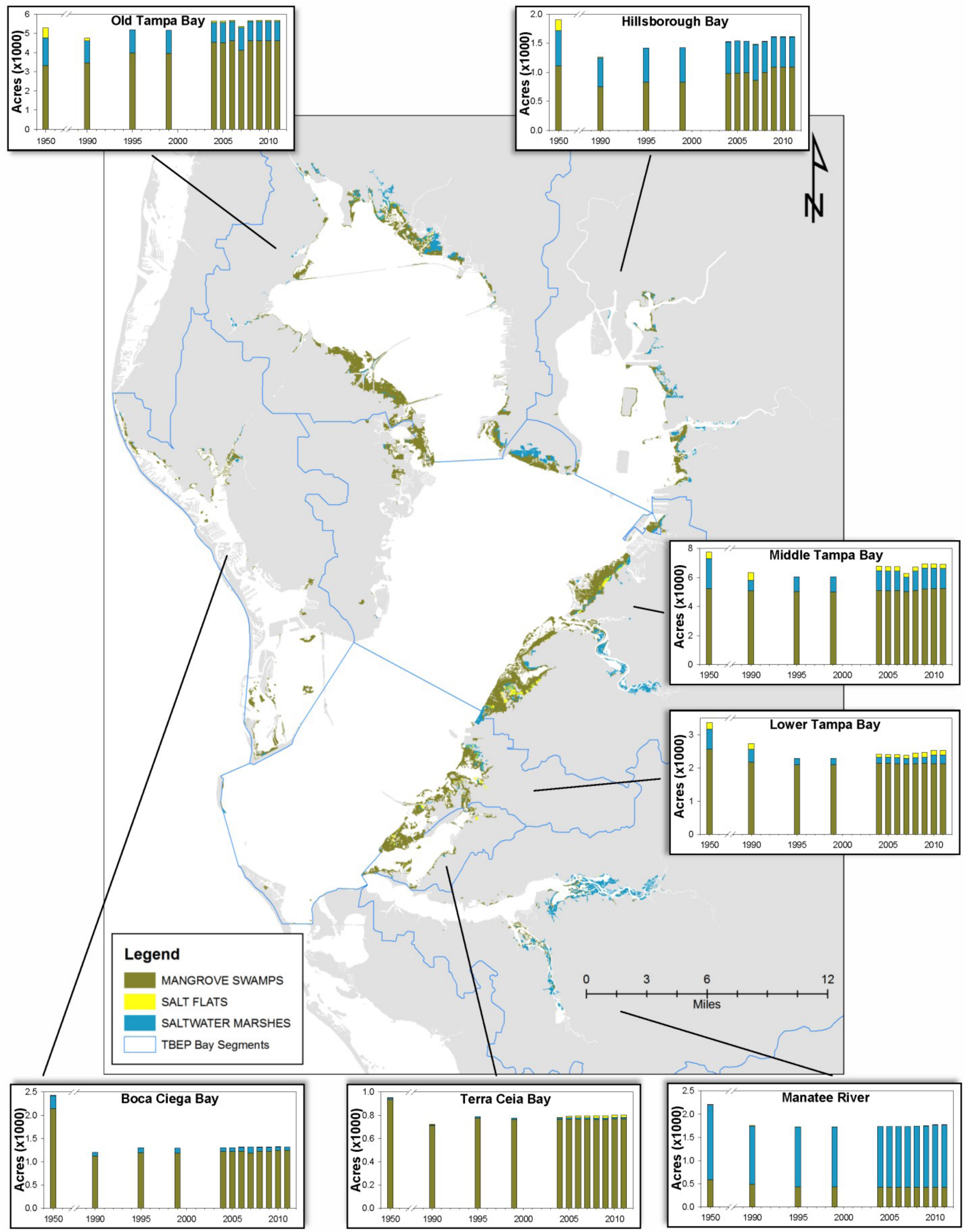

Figure 4.3. 2011 extent of coastal wetlands in the Tampa Bay region and acreage changes, 1950–2011, by bay segment. See Table 4.1 for data sources.

Table 4.2. Mangrove acreages in Tampa Bay from 1950–2011, by bay segment.

Year	Data source	Old Tampa Bay	Hillsborough Bay	Middle Tampa Bay	Lower Tampa Bay	Boca Ciega Bay	Terra Ceia Bay	Manatee River	Total
1950	Lewis and Robison 1995	3,321	1,112	5,225	2,563	2,143	937	592	15,893
1990	Lewis and Robison 1995	3,452	751	5,061	2,174	1,121	711	494	13,764
1995	SWFWMD	3,971	830	5,009	2,095	1,193	775	432	14,305
1999	SWFWMD	3,956	828	5,004	2,096	1,191	762	432	14,269
2004	SWFWMD	4,522	979	5,107	2,135	1,217	763	426	15,149
2005	SWFWMD	4,514	986	5,081	2,136	1,218	766	426	15,127
2006	SWFWMD	4,614	995	5,089	2,127	1,229	765	427	15,246
2007	SWFWMD	4,119	862	5,034	2,116	1,190	765	425	14,511
2008	SWFWMD	4,605	996	5,089	2,132	1,230	764	426	15,242
2009	SWFWMD	4,608	1088	5,210	2,139	1,231	762	424	15,462
2010	SWFWMD	4,610	1093	5,222	2,130	1,243	770	427	15,495
2011	SWFWMD	4,613	1093	5,224	2,131	1,242	770	427	15,500

Table 4.3. Salt marsh acreages in Tampa Bay, 1950–2011, by bay segment.

Year	Data source	Old Tampa Bay	Hillsborough Bay	Middle Tampa Bay	Lower Tampa Bay	Boca Ciega Bay	Terra Ceia Bay	Manatee River	Total
1950	Lewis and Robison 1995	1,446	603	2,075	606	274	13	1,604	6,621
1990	Lewis and Robison 1995	1,150	499	737	389	84	6	1,252	4,117
1995	SWFWMD	1,206	590	1,041	187	106	13	1,292	4,435
1999	SWFWMD	1,207	596	1,040	187	106	13	1,292	4,441
2004	SWFWMD	1,033	545	1,345	185	84	13	1,308	4,513
2005	SWFWMD	1,035	553	1,354	181	83	13	1,308	4,527
2006	SWFWMD	1,009	537	1,352	178	82	13	1,307	4,478
2007	SWFWMD	1,178	617	981	168	125	13	1,308	4,390
2008	SWFWMD	1,002	535	1,352	183	80	13	1,312	4,477
2009	SWFWMD	1,003	520	1,423	183	80	13	1,321	4,543
2010	SWFWMD	1,005	515	1,427	263	75	13	1,342	4,640
2011	SWFWMD	999	515	1,395	264	75	13	1,342	4,603

"Restore the Balance" Management Plan

Scientists and resource managers in the Tampa Bay region have developed and adopted habitat restoration targets and paradigms as part of the Tampa Bay Habitat Master Plan (Lewis and Robison 1995) and Tampa Bay Habitat Master Plan Update (Robison 2010). Production of these documents was coordinated by the Tampa Bay Estuary Program (TBEP). The documents were adopted by the TBEP's Policy Board, which includes elected officials and agency representatives at local, regional, state, and national levels. Because the master plans were vetted by technical and citizen advisory committees, they are often integrated into the habitat management plans for other local government partners, such as the SWFWMD, which has incorporated the restoration goals and projects into the Surface Water Improvement and Management (SWIM) Plan for Tampa Bay (SWFWMD 1999).

Table 4.4. Salt barren acreages in Tampa Bay, 1950–2011, by bay segment. Data not available for 1990–2004 because the SWFWMD did not systematically map salt barren habitat types before 2004.

Year	Data Source	Old Tampa Bay	Hillsborough Bay	Middle Tampa Bay	Lower Tampa Bay	Boca Ciega Bay	Terra Ceia Bay	Manatee River	Total
1950	Lewis and Robison 1995	516	195	436	194	14	1	15	1,371
1990	Lewis and Robison 1995	147	13	533	168	0	6	10	877
2004	SWFWMD	80	2	309	89	4	5	3	492
2005	SWFWMD	78	2	306	86	4	13	3	492
2006	SWFWMD	58	2	306	93	4	16	3	482
2007	SWFWMD	58	2	271	93	4	16	2	446
2008	SWFWMD	58	2	271	136	4	17	2	490
2009	SWFWMD	58	2	286	144	4	19	2	515
2010	SWFWMD	58	2	282	134	4	19	2	501
2011	SWFWMD	58	2	282	134	4	19	2	501

Quantitative protection and restoration targets have been established for coastal wetlands as part of the Tampa Bay management plan under an approach called Restore the Balance. Due to the extensive coastal development in the watershed, it is not realistic to expect to regain habitat acreage that was present in the 1950s. But because many fish and wildlife species rely on various estuarine habitats throughout their life cycles, Restore the Balance attempts to restore historical proportions of estuarine habitats in an attempt to ensure that there are no bottlenecks to the life history of any species that uses Tampa Bay (Morrison et al. 2011). This approach may prove challenging with current trends of mangrove expansion, as mangroves frequently overtake salt marsh habitat. The impacts of sea-level rise and climate change will also likely influence the relative proportions of habitats in the Tampa Bay area. These impacts, as well as Restore the Balance and other management strategies, will be evaluated in the 2017 Habitat Master Plan Update for Tampa Bay.

The Restore the Balance concept establishes targets using the 1950s ratio of estuarine habitats. The 1950s were selected as a starting point because they preceded much of the extensive development in the watershed (although Tampa and St. Petersburg were well established). Also, the first high-quality aerial photographs are available for the entire watershed in the 1950s, enabling photo-interpretation of land cover. Analyses of wetland extent for more recent periods (1990s, 2000s, 2010s) allowed determination of areal coverage and proportion by wetland type. Over the past 25 years, mangrove and salt marsh acreage have increased (Figure 4.2). The proportion of mangroves exceeds their 1950s proportion, while the proportions of both salt marsh and salt barrens are less than in the 1950s.

Quantitative Restore the Balance targets are established by basing desired habitat ratios on the wetland habitat that has been least impacted. In the Tampa Bay region, mangroves have actually increased in overall proportion and so are deemed the least impacted habitat. Restoration targets can be set for the remaining habitat types by utilizing the 1950s proportion in the equation $c/a = b/x$, where x = acreage restoration target for habitat of interest, a = current acreage of least-impacted habitat, b = 1950s proportion of target habitat, c = 1950s proportion of least-impacted habitat (Robison 2010). The acreage target becomes the change required to restore the historical proportion. The critical coastal habitat targets, as adopted in the Tampa Bay Habitat Master Plan Update, are shown in Table 4.7. Opportunistic restoration of mangrove habitat is still encouraged, but there is not a numeric restoration target for this habitat.

Mangrove dominance increasing

Mangrove coverage is increasing in Tampa Bay, likely as a result of climatic changes and hydrologic alterations. In previous decades, winter freezes led to mangrove die-offs. Freezes have been much rarer in recent decades and mangroves have encroached into areas previously inhabited by salt marshes. Tampa Bay coastal wetlands have shifted from a salt marsh-dominated system in the 1870s to a mangrove-dominated system (Raabe et al. 2012). By comparing present-day land cover to historical topographic maps and surveys from the 1870s, Raabe et al.

Table 4.5. Change in emergent saltwater vegetation in Tampa Bay during different periods, by bay segment. Data compiled from Lewis and Robison (1995) and Southwest Florida Water Management District land use/land cover data (SWFWMD 2011). Bay segments: OTB, Old Tampa Bay; HB, Hillsborough; MTB, Middle Tampa Bay; LTB, Little Tampa Bay; BCB, Boca Ciega Bay; TCB, Terra Ceia Bay; MR, Manatee River. SWFWMD did not systematically map salt barren habitat types until 2004.

MANGROVES

Bay segment/ year	1950	1990	% Change 1950–1990	1995	% Change 1990–1995	1999	% Change 1995–1999	2005	% Change 1999–2005	2010	% Change 2005–2010	2011	% Change 2010–2011
OTB	3,321	3,452	3.94	3,971	15.03	3,956	−0.38	4,514	14.11	4,610	2.13	4,613	0.07
HB	1,112	751	−32.46	830	10.52	828	−0.24	986	19.08	1,093	10.85	1,093	0.00
MTB	5,225	5,061	−3.14	5,009	−1.03	5,004	−0.10	5,081	1.54	5,222	2.78	5,224	0.04
LTB	2,563	2,174	−15.18	2,095	−3.63	2,096	0.05	2,136	1.91	2,130	−0.28	2,131	0.05
BCB	2,143	1,121	−47.69	1,193	6.42	1,191	−0.17	1,218	2.27	1,243	2.05	1,242	−0.08
TCB	937	711	−24.12	775	9.00	762	−1.68	766	0.52	770	0.52	770	0.00
MR	592	494	−16.55	432	−12.55	432	0.00	426	−1.39	427	0.23	427	0.00
TOTAL	15,893	13,764	−13.40	14,305	3.93	1,4269	−0.25	15,127	6.01	15,495	2.43	15,500	0.03

SALT MARSH

Bay segment/ year	1950	1990	% Change 1950–1990	1995	% Change 1990–1995	1999	% Change 1995–1999	2005	% Change 1999–2005	2010	% Change 2005–2010	2011	% Change 2010–2011
OTB	1,446	1,150	−20.47	1,206	4.87	1,207	0.08	1,035	−14.25	1,005	−2.90	999	−0.60
HB	603	499	−17.25	590	18.24	596	1.02	553	−7.21	515	−6.87	515	0.00
MTB	2,075	737	−64.48	1,041	41.25	1,040	−0.10	1,354	30.19	1,427	5.39	1,395	−2.24
LTB	606	389	−35.81	187	−51.93	187	0.00	181	−3.21	263	45.30	264	0.38
BCB	274	84	−69.34	106	26.19	106	0.00	83	−21.70	75	−9.64	75	0.00
TCB	13	6	−53.85	13	116.67	13	0.00	13	0.00	13	0.00	13	0.00
MR	1604	1252	−21.95	1,292	3.19	1292	0.00	1,308	1.24	1,342	2.60	1,342	0.00
TOTAL	6,621	4,117	−37.82	4,435	7.72	4,441	0.14	4,527	1.94	4640	2.50	4,603	−0.80

Table 4.5 (continued). Change in emergent saltwater vegetation in Tampa Bay during different periods, by bay segment. NA: data not available.

SALT BARREN													
Bay segment/ year	1950	1990	% Change 1950–1990	1995	% Change 1990–1995	1999	% Change 1995–1999	2005	% Change 1990–2005	2010	% Change 2005–2010	2011	% Change 2010–2011
OTB	516	147	−71.51	NA	NA	NA	NA	78	−46.94	58	−25.64	58	0.00
HB	195	13	−93.33	NA	NA	NA	NA	2	−84.62	2	0.00	2	0.00
MTB	436	533	22.25	NA	NA	NA	NA	306	−42.59	282	−7.84	282	0.00
LTB	194	168	−13.40	NA	NA	NA	NA	86	−48.81	134	55.81	134	0.00
BCB	14	0	−100.00	NA	NA	NA	NA	4	400.00	4	0.00	4	0.00
TCB	1	6	500.00	NA	NA	NA	NA	13	116.67	19	46.15	19	0.00
MR	15	10	−33.33	NA	NA	NA	NA	3	−70.00	2	−33.33	2	0.00
TOTAL	1371	877	−36.03	NA	NA	NA	NA	492	−43.90	501	1.83	501	0.00

(2012) determined that the ratio of salt marshes to mangroves has shifted from 86:14 to 25:75. Other estimates place the ratio of marshes to mangroves in Tampa Bay closer to 50:50 around 1900 (Lewis and Robison 1995). In either case, the Tampa Bay area is increasingly dominated by mangroves, as has been seen in parts of south Florida (Morrison et al. 2011). This trend is expected to continue due to climate change and sea-level rise, which favor mangrove expansion at the expense of other estuarine habitats (Sherwood and Greening 2012, 2014).

Mangroves provide many of the same ecosystem services as salt marshes, so mangrove expansion is not necessarily detrimental except for its effects on obligate salt marsh species. However this trend does suggest that resource managers must carefully evaluate restoration goals and paradigms such as Restore the Balance to determine if they are still realistic, attainable, and ecologically appropriate (Raabe et al. 2012, Sherwood and Greening 2012, 2014). If marshes and salt barrens are increasingly squeezed out of existing habitat, managers must also determine at what cost their long-term survival should be protected and how to ensure that there is adequate coverage and diversity of coastal habitats to support myriad estuary-dependent species.

Threats to coastal wetlands

While coastal wetlands enjoy greater protection due to regulations and management priorities adopted in the late 20th century, threats to their short- and long-term survival remain. The dominant threats to coastal wetlands in Tampa Bay include:

- **Coastal development:** Human population growth and urban sprawl continue in the Tampa Bay area, resulting in direct and indirect impacts on natural shoreline. Local, state, and federal permitting agencies require mitigation for impacts to these wetlands, which may differ with project location or conditions.
- **Hydrologic modifications:** Development in the watershed may also indirectly impact coastal wetlands through changes to natural hydrologic regimes. Freshwater flow may be reduced by impoundments or increased due to concentrated runoff from impervious surfaces. Reduced freshwater retention in the watershed leads to lower freshwater flows during the dry season (Robison 2010). Additionally, in the 1950s and 1960s many coastal wetlands in the Tampa Bay region were ditched in an effort to reduce mosquitoes (Morrison et al. 2011). The mosquito ditches altered tidal flow and sediment elevation, increasing salinity and removing uninterrupted habitat gradients in much of the bay.

Table 4.6. 2010 coastal wetland acreages surrounding Clearwater Harbor and St. Joseph Sound. Data from Janicki and Atkins (2011b).

	St. Joseph Sound	Clearwater Harbor North	Clearwater Harbor South	Total
Mainland mangrove	209	3	24	236
Island mangrove	153	390	24	567
Mainland salt marsh	448	3	2	454
Island salt marsh	77	13	0	90

Table 4.7. Protection and restoration targets of coastal wetlands in Tampa Bay under the Restore the Balance initiative (Robison 2010).

	Protection target (2007/2008 acres)	Restoration target (additional acres required)	Total target acreage for protection and restoration
Mangroves	15,139	opportunistically restore	15,139 (aim to protect existing acreage)
Salt marsh	4,395	1,918	6,313
Salt barren	447	840	1,287

- **Invasive vegetation:** Exotic plants, particularly *Schinus terebinthifolius* (Brazilian pepper) and *Casuarina* spp. (Australian pines), crowd the upland edges of coastal wetland habitat. Despite attempts to remove them, it is unlikely that these abundant species will be eradicated from the Tampa Bay area (Holland et al. 2006). It is illegal to sell or plant *Casuarina* spp. and *S. terebinthifolius* without a permit, and property owners are encouraged to remove plants of either species when encountered.
- **Climate change and sea-level rise:** Climate change impacts, including sea-level rise and warmer temperatures, are expected to influence long-term wetland extent and condition. In Florida, long-term stations recording sea level have measured a rise of about 8 in. (20 cm) in the past 100 years (Mitchum 2011). Rates of sea-level rise are accelerating; South Florida is expected to see sea levels rise by 32–40 in. (81–102 cm) by 2100 (Mitchum 2011); some estimates of global sea-level rise exceed 6 ft (1.8 m) by 2100 (NOAA 2012).

  Coastal vegetation is expected to migrate landward in response to sea-level rise, but this is only possible if refugia, undeveloped conserved land, are present adjacent to coastal wetland habitats. But extensive urban development in much of the Tampa Bay area inhibits landward migration. The rate of sea-level rise, rate of sediment accretion, and availability of adjacent natural land will all determine whether coastal wetlands are able to successfully retain their current position, migrate, or be squeezed out of existing habitat zones.

Mapping and monitoring efforts

Water management district mapping

To assist in resource management decision-making, SWFWMD conducts regional land use and land cover (LULC) mapping at regular intervals within its jurisdiction (SWFWMD 2011). Features in 1-ft color infrared imagery are 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 FLUCCS categories (FDOT 1999). The coastal wetland features of interest here are mangrove swamp (FLUCCS 6120), saltwater marsh (FLUCCS 6420), and salt flat (FLUCCS 6600). 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.

Critical Coastal Habitat Assessment

The Critical Coastal Habitat Assessment is a new long-term monitoring program for Tampa Bay that will assess the status, trends, and ecological function of a mosaic of critical coastal habitats. Its purpose is to detect habitat changes due to natural and indirect anthropogenic impacts, including those resulting from sea-level rise and climate change, and to improve habitat management (Janicki 2013, Sherwood and Greening 2012, 2014). To accomplish this, long-term fixed-transects were established in 2015–2016 to characterize baseline habitat structure (see full description in Chapter 1). Monitoring will be completed every 3–5 years to detect trends and assess changes in extent and ecological function of those habitats over time. Transects were established at nine sites around the Tampa Bay watershed in areas that have a full complement of emergent tidal wetland communities including mangroves, salt marshes, salt barrens, and coastal uplands. A multimedia training video will also be produced to aid other programs and communities in implementing similar long-term monitoring programs. Updates and documents will be posted at www.tbeptech.org/committees/habitat-partnership.

Tidal tributaries project

The remaining natural shorelines of tidal tributaries in Tampa Bay generally include a mix of emergent saltwater vegetation. These systems have been identified as prime nursery habitat for a variety of estuarine-dependent fauna. The TBEP first initiated a comprehensive monitoring program in selected Tampa Bay tidal tributaries in 2006 (Sherwood 2008). A large-scale assessment of tidal creeks in Tampa Bay, Sarasota Bay, and Charlotte Harbor was completed in 2013–2014 (SBEP 2016). The monitoring program included a general characterization of shoreline vegetation and later expanded surveys and habitat assessments throughout the tidal extent of small tidal tributaries in the bay (e.g., www.sarasota.wateratlas.usf.edu/tidal-stream-assessments). This work will be extended to other tidal tributaries and major rivers entering the bay as funds become available.

MangroveWatch

MangroveWatch is a citizen-science initiative established in Australia by Norm Duke and Jock Mackenzie, of James Cook University (Mackenzie et al. 2016, www.mangrovewatch.org.au/). Its purpose is to foster citizen awareness and involvement in the management of mangroves by enabling nonscientists to easily gather important forest monitoring data. In 2012, students and faculty in the biology department at Saint Leo University began using MangroveWatch's monitoring and mapping techniques in parts of Tampa Bay. The monitoring is accomplished by recording a video of the mangroves from a small boat running parallel to the shoreline. Geotagged images are extracted from the video (1 image per second of video) and visually evaluated at Saint Leo for forest characteristics such as canopy completeness, relative density of seedlings, evidence of anthropogenic canopy alteration, and signs of stress (e.g., dead trees, bare branches, obvious discoloration of leaves). The data from the evaluation of the images are used to generate GIS maps of shoreline forest condition, represented as 33-ft (10-m) color-coded linear shoreline segments. The Pinellas County Tampa Bay shoreline from the Skyway Bridge approach to Safety Harbor was recorded and evaluated biannually in 2012 and 2013. In 2014 and beyond, an annual (March-May) recording schedule was adopted. Citizens' groups have contacted MangroveWatch with requests to expand monitoring and mapping in other parts of Tampa Bay including Upper Tampa Bay Park, Cockroach Bay, and Terra Ceia Bay.

Minimum flows and levels

The SWFWMD has been characterizing riverbank vegetation since 1990 to support development of minimum flows and levels for the tidal portions of the Alafia, Hillsborough, Little Manatee, and Manatee rivers. Data collection methods include shoreline surveys and vegetation quadrats for identification of species composition and abundance. A full list of the reports from this project may be found at www.swfwmd.state.fl.us/projects/mfl/mfl_reports.php.

Tampa Bay restoration projects

The TBEP tracks success in restoring critical habitats, including salt marshes and mangroves, in the Tampa Bay area and reports the data annually to the U.S. Environmental Protection Agency. These data are also available in a downloadable geospatial format on the Tampa Bay Estuary Atlas (www.tampabay.wateratlas.usf.edu/restoration/).

Recommendations for protection, management, and monitoring

- Future wetland mapping and monitoring efforts should continue current programs, ensuring methodologically consistent, long-term data sets, as well as new initiatives meant to supplement coverage data with more rigorous monitoring of wetland quality. SWFWMD-led LULC analyses are critical tools for identifying regional trends in wetlands coverage. It would be advantageous to develop a supplemental monitoring program using photointerpretation of the LULC or other aerial imagery to assess wetland health, stress, hydrology, and disturbances. Smaller-scale changes in health and the extent of mangroves should be assessed using rigorous ground-truthing and monitoring. The fixed-location monitoring carried out in the Critical Coastal Habitat

Assessment is a powerful tool for detecting even subtle changes in habitat condition, but it is limited to selected sites. This program should be expanded to additional locations, and stable, long-term funding is needed. Citizen-science projects, such as MangroveWatch, should also be considered as possible sources of long-term, on-the-ground data on habitat quality.

- The previously mentioned Tampa Bay Habitat Master Plans have established several habitat restoration and management priorities for Tampa Bay (Lewis and Robison 1995, Robison 2010):
    - The concept of developing habitat mosaics that incorporate numerous habitat types, salinities and elevations has been embraced by the management and restoration community and has resulted in 1) more sophisticated restoration projects that are more similar to natural landscapes, 2) additional habitat for numerous wildlife species, and 3) habitats that are more resilient to disturbances and climate change.
    - The Restore the Balance approach to habitat protection and restoration seeks to restore and create habitats that have been disproportionately lost, such as salt marsh and salt barren habitats. The 2010 master plan update (Robison 2010) also advocates for larger restoration projects that incorporate major hydrological modifications such as re-establishing historical hydrological conditions or using treated wastewater to hydrate wetlands for the creation or restoration of salinity gradients and enhancing nutrient removal. Future master plans should focus on the validity of the Restore the Balance approach and existing habitat restoration paradigms.
    - Efforts to systematically map and monitor wetlands, establish measurable restoration targets, develop management recommendations, identify appropriate locations for habitat restoration, and track progress toward goals have been key components of regional planning. An evaluation of watershed-wide land use/land cover changes should be made every 3 years and an evaluation of habitat restoration and protection targets made every 10 years.
    - Tampa Bay scientific and resource management agencies have demonstrated that setting habitat priorities and targets can lead to measurable gains in habitat coverage, despite extensive and continuing development within the watershed. But ensuring the existence of abundant, high-quality emergent saltwater vegetation in Tampa Bay will require efforts by the Tampa Bay community at large including public entities, nongovernmental organizations, companies, academic institutions, citizens, and visitors.
- Public-private partnerships should be formed to protect or establish habitat on privately owned parcels of land. Such partnerships are especially important, because public entities' ability to acquire new lands is limited. Wetland restoration should continue to represent a mix of habitats, elevations, and salinities to ensure better long-term viability in the face of sea-level rise. When possible, upland areas adjacent to natural or created wetlands should also be protected, enabling landward migration of coastal wetlands. Restoration persistence in the face of sea-level rise should be tracked using long-term, on-the-ground monitoring as well as remote sensing to better inform future restoration projects. A comprehensive monitoring program that takes into account wetland ecosystem function would better position resource managers to modify management regimes when impacts to coverage or condition are detected. Finally, results, successes and challenges should be periodically shared within and beyond the Tampa Bay region via workshops, conferences, peer-reviewed literature, and site visits.

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