Chapter 8. Habitat Protection and Restoration

By Gerold Morrison (AMEC–BCI); Doug Robison (PBS&J); and Kimberly K. Yates (U.S. Geological Survey–St. Petersburg, Florida)

IN THE CONTEXT OF TAMPA BAY resource management, "habitat" has been defined as the combination of substrates and structures — both physical and biological — that provide critical shelter and food for estuarine dependent species (Lewis and Robison, 1995; PBS&J, 2009; fig. 8–1). Within the estuary itself, seagrass beds and emergent tidal wetlands have been identified as key habitat types because of the primary productivity and physical structure they provide and the secondary productivity they support. Other important habitats for bay management include oyster bars, hard or "live" bottom, artificial habitats, coastal uplands, and freshwater wetlands located within the foraging ranges of coastal-nesting wading bird colonies.

With the exception of seagrasses, the efforts that have been undertaken to address resource-management issues affecting each of these habitat types are summarized below, using information excerpted from Lewis and Estevez (1988), Abrahamson and Hartnett (1990), Jaap and Hallock (1990), Kushlan (1990), Livingston (1990), Montague and Wiegert (1990), Odum and McIvor (1990), Lewis and Robison (1995), and PBS&J (2009). Seagrass management is discussed in detail in Chapter 4.

Figure 8–1. Coastal mangrove forest typical of the southeastern shoreline of Tampa Bay. Photo by Carole McIvor, U.S. Geological Survey.

Emergent Tidal Wetlands

Emergent tidal wetlands (fig. 8–2) occur primarily along the natural intertidal zone that rims much of the bay and its tidal tributaries, and to a lesser extent along filled intertidal areas created by urban and port development (Lewis and Robison, 1995; PBS&J, 2009). Three categories of emergent tidal wetlands have been recognized for management purposes: mangrove forests, salt marshes, and salt barrens. Based upon the salinity regime in which they occur and their species composition, salt marshes can be further subdivided into three categories. Polyhaline marshes coexist with mangroves along the shoreline of the bay, whereas mesohaline and oligohaline marshes occur in rivers and tidal tributaries to the bay. Hypersaline plant communities, or salt barrens, typically occur on infrequently flooded tidal flats, usually at or slightly above the spring high water line.

In the subtropical latitudes of Tampa Bay, where brief periods of freezing weather occur in some years, the assemblage of plant species that comprise tropical mangrove forests and temperate polyhaline marshes generally exist in a state of dynamic equilibrium, with the herbaceous marsh grasses serving a pioneer successional role and the woody mangrove trees forming a climax community. Given the proper elevation, substrate, and energy conditions, these species are also capable of colonizing newly created intertidal areas, as well as existing intertidal areas that have been impacted by freeze damage, erosion, or human activities. As a result, the overall coverage and relative composition of the various types of emergent tidal wetlands in the bay tend to fluctuate over time in response to both natural and anthropogenic factors.

Figure 8–2. Emergent tidal wetlands in Tampa Bay, characterized by mangrove forests, salt marshes, and salt barrens (not pictured). Photo by Carole McIvor, U.S. Geological Survey.

Emergent tidal wetlands collectively form an important habitat complex in Tampa Bay, providing foraging areas for much of the bay's wildlife, serving as sites of nutrient cycling, helping to stabilize submerged shoreline sediments and minimize shoreline erosion, and assimilating some of the contaminants carried in runoff from upland urban areas. They also provide attachment sites and substrates for algal and invertebrate communities, and aquatic habitat for numerous species of fish and invertebrates including mullet, red drum, tarpon and snook and a variety of shrimps and crabs. The marsh grasses and mangrove trees also provide critical feeding, nesting and sheltering habitat for a variety of birds, including pelicans, cormorants, herons, ibises, spoonbills and egrets.

Salinity is a critical factor in determining the spatial distribution and species composition of these wetlands. Although a number of salinity classification systems have been described in the technical literature, none has been universally adopted by the scientific community. A salinity classification scheme that generally corresponds with the distribution of emergent wetland types in the Tampa Bay area is shown in table 8–1.

Table 8–1. General salinity classification scheme for Tampa Bay.

[From PBS&J, 2009]

Classification	Salinity Range (ppt)
Freshwater	0–4
Oligohaline	2–15
Mesohaline	11–19
Polyhaline	15–28
Euhaline	23–35

Mangrove Forest

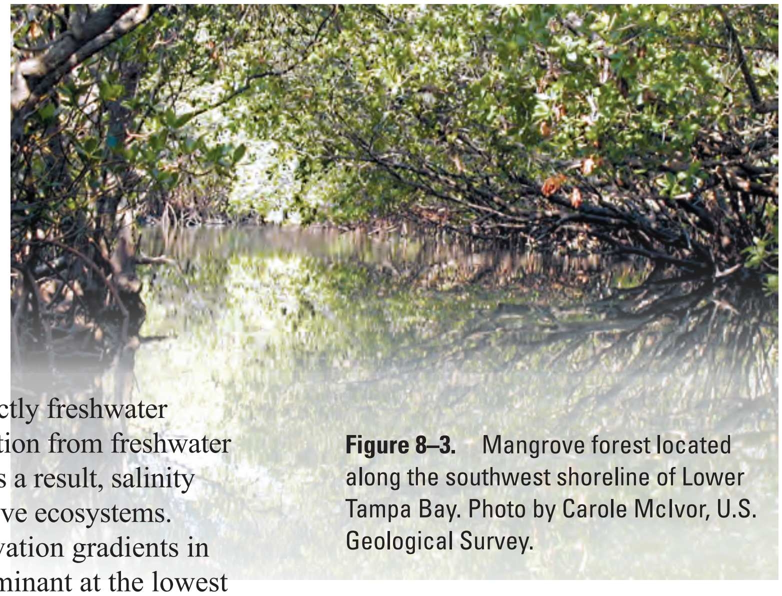


Figure 8–3. Mangrove forest located along the southwest shoreline of Lower Tampa Bay. Photo by Carole McIvor, U.S. Geological Survey.

Mangrove forests in Florida are composed of four species of trees: red mangrove (*Rhizophora mangle*), black mangrove (*Avicennia germinans*), white mangrove (*Laguncularia racemosa*), and buttonwood (*Conocarpus erecta*) (Odum and McIvor, 1990; figs. 8–3 and 8–4*A*–*D*). All are facultative halophytes — meaning that saltwater is not required for growth — and all can be grown in freshwater. However, mangrove ecosystems do not occur in strictly freshwater environments, apparently due to ecological competition from freshwater vascular plant species (Odum and McIvor, 1990). As a result, salinity plays a key role in the spatial distribution of mangrove ecosystems.

The four tree species are distributed along elevation gradients in the intertidal zone, with red mangroves usually dominant at the lowest elevations and buttonwoods at the highest. Lewis and Estevez (1988) noted that most mangrove stands in Tampa Bay can be characterized as fringing forests, where the trees grow on shorelines with gradual slopes, are exposed to tidal action but are not overwashed on a daily basis, have relatively sluggish internal water flow due to tides and waves, and experience only minor tidal scouring. Also, in response to factors such as local topography, time since the last freeze event, changes in freshwater discharge and other periodic disturbances, a given mangrove stand can include marsh species at elevations lower or higher than the stand itself, and within windfalls or lightning strike areas of the stand (PBS&J, 2009).

As noted, mangroves are cold-sensitive tropical and subtropical plants whose geographic distributions correspond to the frequency of freezing temperatures. The black mangrove is the most cold-tolerant species and extends northward along the Gulf Coast to Louisiana as scattered shrubs within the predominant tidal marsh vegetation (Odum and McIvor, 1990). Stress caused by freezing temperatures occurs periodically in Tampa Bay, producing a north-to-south gradient in mangrove maturity with more mature stands located toward the south. Lewis and Estevez (1988) noted that a mix of younger forests and tidal marsh communities occurred in the northern part of the bay in the mid-1980s, but observations since then (Raabe and Gauron, 2007) indicate that mangroves now dominate the intertidal zone throughout Tampa Bay. Raabe and Gauron attribute this conversion to a complex interplay of climate change, river discharge, and urbanization impacts (box 8–1).

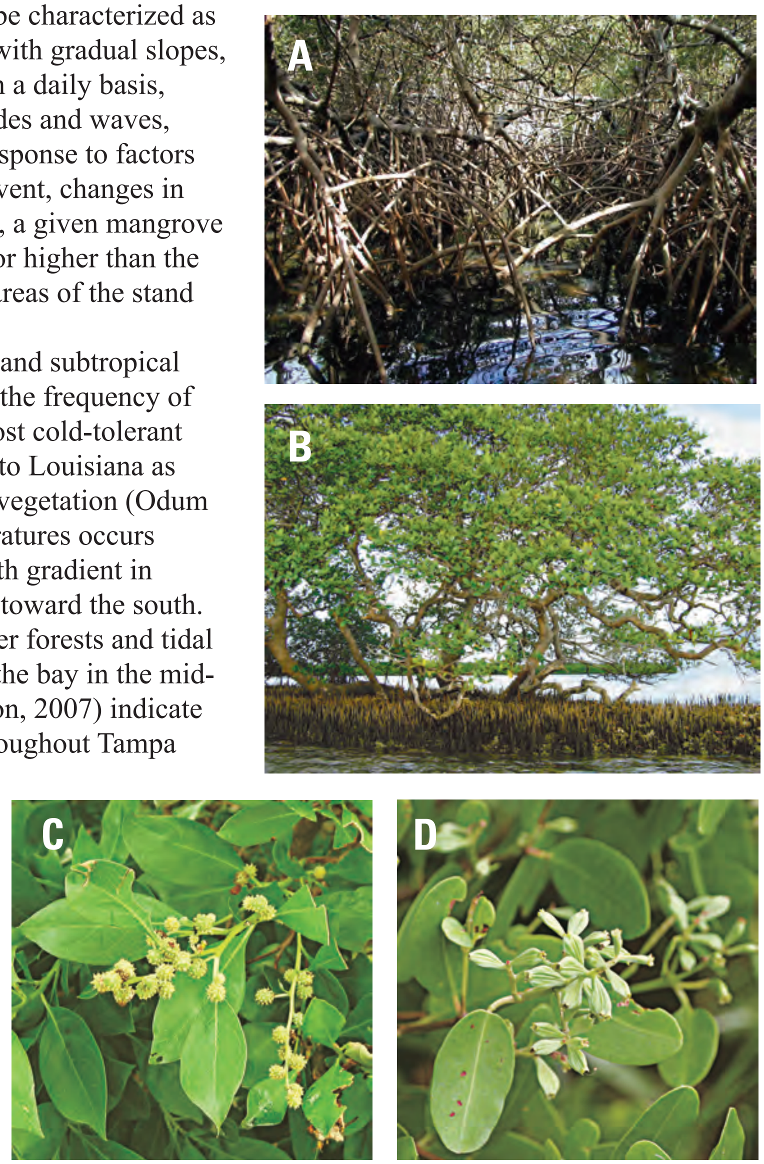


Figure 8–4. Four tree species that dominate the mangrove forests of Tampa Bay: *A*, red mangrove (*Rhizophora mangle*); *B*, black mangrove (*Avicennia germinans*); *C*, buttonwood (*Conocarpus erectus*); and *D*, white mangrove (*Laguncularia racemosa*). Photos by Holly Greening, Tampa Bay Estuary Program.

Box 8–1. Historic Records Shed Light on Marsh to Mangrove Conversion in Tidal Wetlands

By Kimberly K. Yates and Ellen A. Raabe (U.S. Geological Survey–St. Petersburg, Florida)

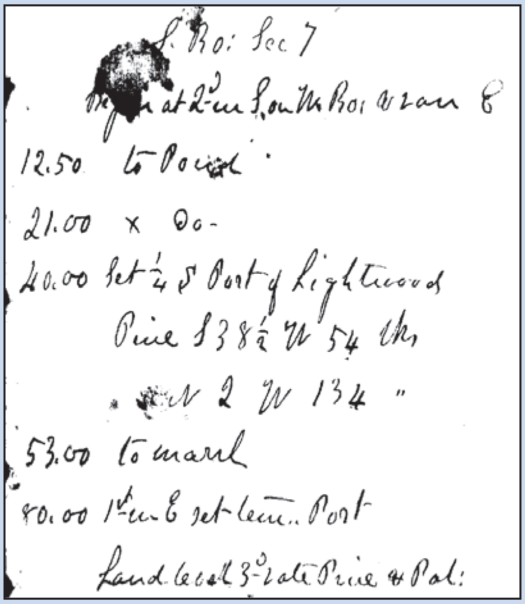
Tampa Bay is located at a climatic boundary characterized by cooler temperatures and temperate conditions to the north, and warmer temperatures and subtropical conditions to the south. This boundary is also the location of a transition zone, with salt marsh predominant to the north, and mangroves predominant to the south. Today, mangrove forests dominate the intertidal zones in Tampa Bay. However, historic surveys from 100 to 150 years ago indicate that emergent wetlands were characterized by a mixture of tidal marsh, mud flats, salt barrens, and fringing mangroves (Raabe and Gauron, 2007). USGS recently completed a quantitative habitat change analysis to compare presettlement and modern distribution of coastal habitats. Raabe and Gauron (2007) georectified, digitized, and analyzed Public Land Surveys and U.S. Coast and Geodetic Surveys from the 1840s to 1870s, and 1999 SWFWMD land cover classifications from four study sites including Upper Old Tampa Bay, Feather Sound, the Alafia River Area, and Terra Ceia (box 8–1, fig. 1). Results of their analysis indicate that 40 to 100 percent of the bay, along north/south and freshwater/saltwater gradients, has experienced conversion of emergent marsh to mangroves. This transition is most pronounced in the southern and western parts of the bay, and least pronounced in the northern bay and near freshwater sources. Changes in percent cover of terrestrial, open water, mangrove, and tidal marsh habitat in each of four areas from the 1870s to 1999 are shown in box 8–1, fig. 2. Percent change for the intertidal zone is summarized in box 8–1, table 1.

Box 8–1, Table 1. Acres of nonmangrove, mangrove, and intertidal area in the 1870s and 1999.

[Percent (%) change in acreage from the 1870s to 1999. From Raabe and Gauron, 2007]

Location	Year	Nonmangrove % (acres)	Mangrove % (acres)	Intertidal area (acres) % change
Terra Ceia	1874	59 (950)	41 (659)	(1,609)
	1999	7 (273)	93 (3,422)	(3,695)
				130% Gain
Feather Sound	1875	88 (2,556)	12 (358)	(2,914)
	1999	4 (113)	96 (2,764)	(2,877)
				2% Loss
Alafia River	1876	96 (890)	4 (37)	(927)
	1999	29 (199)	71 (496)	(695)
				25% Loss
Upper Old Tampa Bay	1875	99 (2,089)	1 (6)	(2,095)
	1999	48 (821)	52 (905)	(1,726)
				18% Loss
Total	1870s	86 (6,485)	14 (1,060)	(7,545)
	1999	25 (1,406)	75 (4,165)	(8,993)
Change		78% Loss	290% Gain	(1,448) 19% Gain

Public Land Survey Notes and Interpretation


S. Boi: Sec 7
Began at 2nd m South Boi & ran E
12.50 to Pond
21.00 x Do-
40.00 Set 1/2 S Post of Lightwood
Pine S 38 1/2 W 54 lks
N 2 W 134 "
53.00 to marsh
80.00 1st m E set tem. Post
Land level 3rd rate Pine & Pal:

South Boundary Section 7 (T 30 R 17)
Began at 2nd mile South on West
Boundary and ran East
Distance

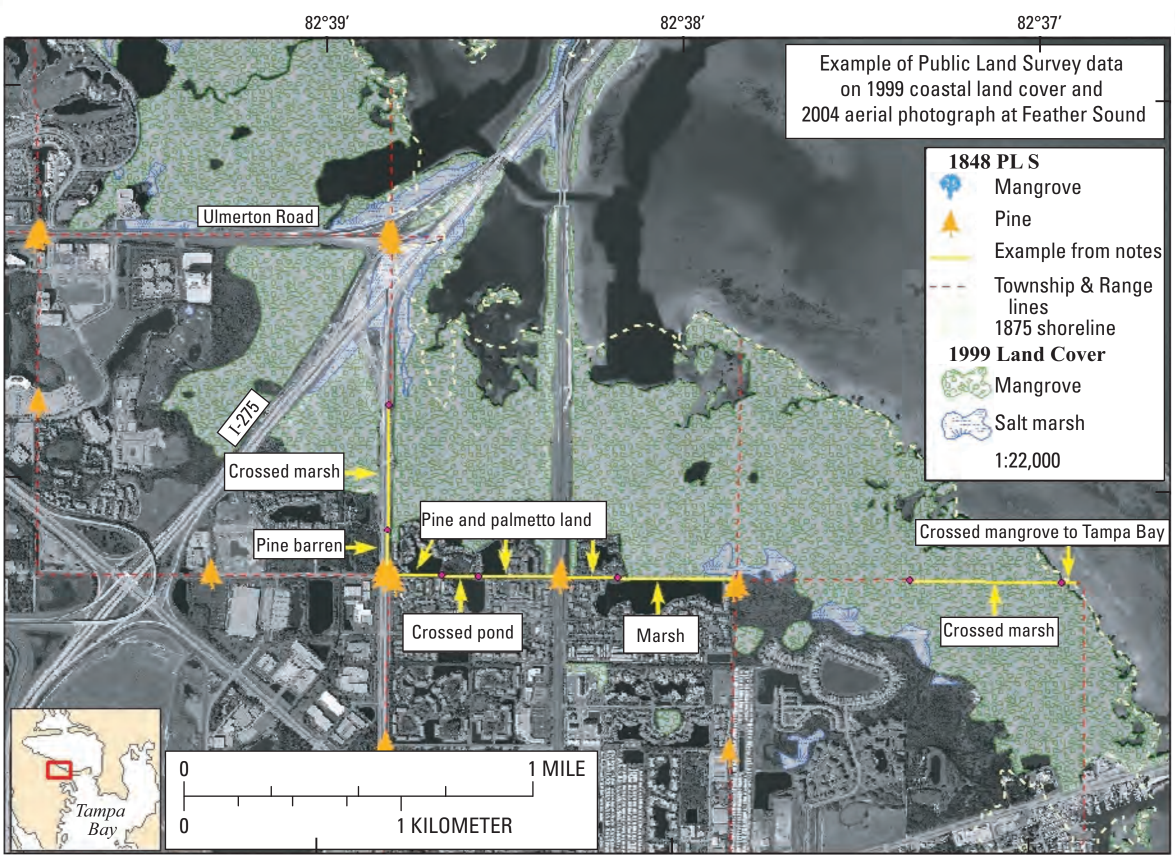
12.50 to pond
21.00 crossing pond
40.00 set 1/2 mile post of Lightwood

Pine South 38 1/2 West 54 links
Pine North 2 West 134 links

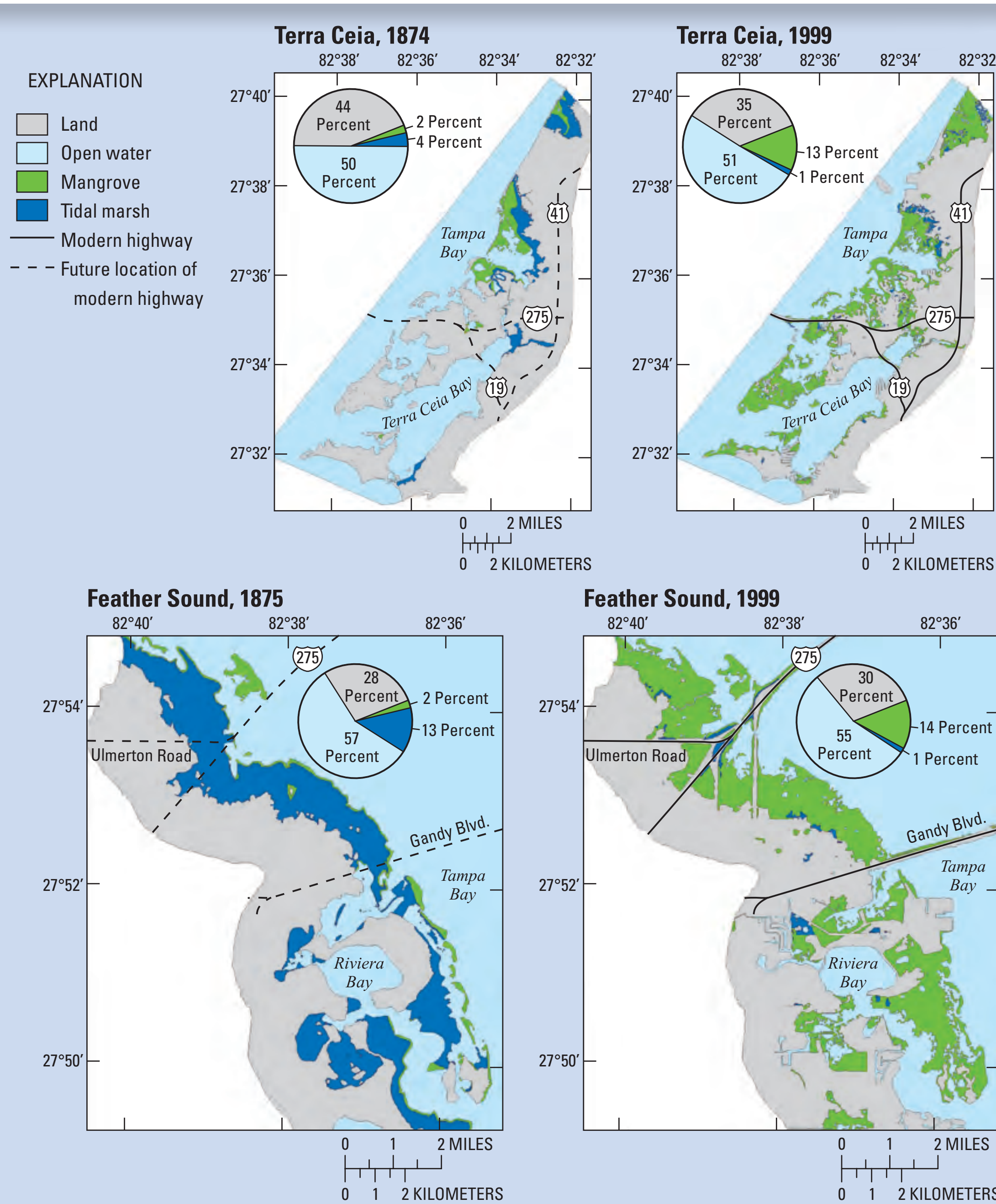
53.00 to marsh
80.00 1st mile East set temporary post

Land level 3rd rate pine and palmetto

Interpreted notes overlaid on 1999 Coastal Land Cover Map and 2004 aerial photograph of Feather Sound

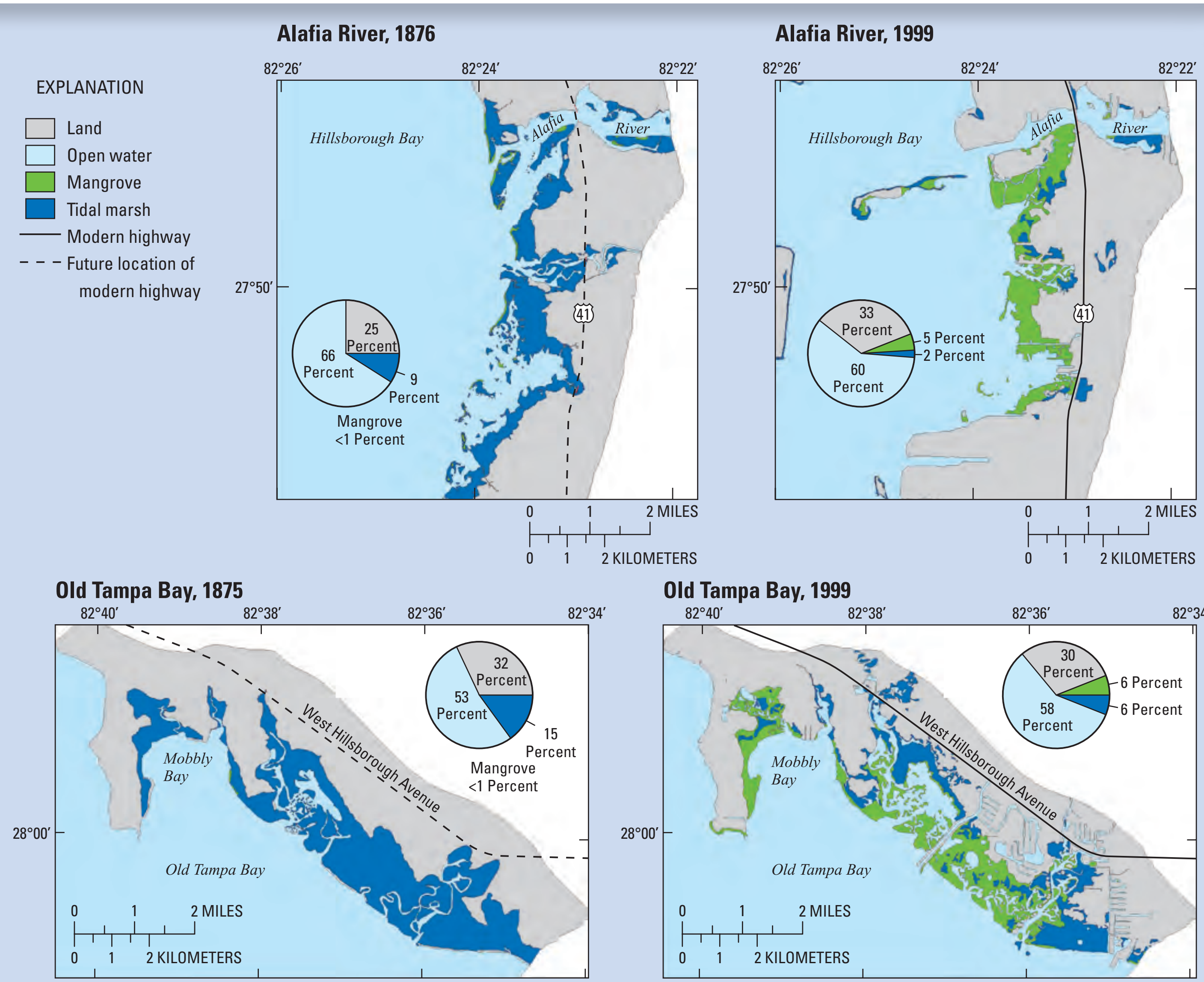


Box 8–1, Figure 1. Example of original Public Land Survey notes and interpretation and overlay of Public Land Survey data on 1999 aerial photography. Image by Ellen Raabe, U.S. Geological Survey.



Box 8–1, Figure 2. Changes in percent cover of terrestrial, open water, mangrove, and tidal marsh habitat from the 1870s to 1999 for Terra Ceia Bay, Feather Sound, Alafia River, and Old Tampa Bay. Data from Ellen Raabe, U.S. Geological Survey.

Raabe and Gauron (2007) attribute this conversion to a complex interplay of climate change, river discharge, and urbanization impacts. Sea-level records from St. Petersburg indicate a sea-level rise of about 2.36 to 2.67 mm/year (Zervas, 2001; *http://tidesandcurrents.noaa.gov/sltrends/sltrends_station.shtml?stnid=8726520*). Assuming a constant rate, sea-level rise from 1870 to 1999 was about 30 cm. Rising sea-level can result in loss of intertidal area as the shoreline boundary migrates inland, and the movement of the landward intertidal boundary is blocked by urban development (PBS&J, 2009). Temperature records from Tampa (GISS NASA *http://data.giss.nasa.gov/gistemp/graphs/*) indicate that annual mean temperatures and summer temperatures have increased from 1890 to 2007. As temperatures



become warmer, fewer winter freeze events occur, allowing mangroves to spread to more northern locations in Tampa Bay. Freshwater discharge records for the Hillsborough and Alafia Rivers (Stoker and others, 1996) indicate significant decreases in freshwater flow to the bay from 1939 to 1992. Additionally, mosquito ditching in the 1950s connected freshwater ponds to the bay, thereby increasing tidal flow into low-lying coastal landscape. The alteration of salinity and hydrological regimes in wetland areas of Tampa Bay may have promoted mangrove growth where marsh grasses were more dominant.

Results of this study support the qualitative observations of the SWFWMD emergent tidal wetland change analysis (PBS&J, 2009), indicating that about 31 percent of salt marsh and salt barren communities in Tampa Bay appear to be in transition to mangrove dominated communities. More detailed investigations of historical coastal ecology are required to better understand the magnitude of impact to wetland ecosystems resulting from multiple forcing factors.

Box 8–1, Figure 2. Changes in percent cover of terrestrial, open water, mangrove, and tidal marsh habitat from the 1870s to 1999 for Terra Ceia Bay, Feather Sound, Alafia River, and Old Tampa Bay. Data from Ellen Raabe, U.S. Geological Survey.—Continued

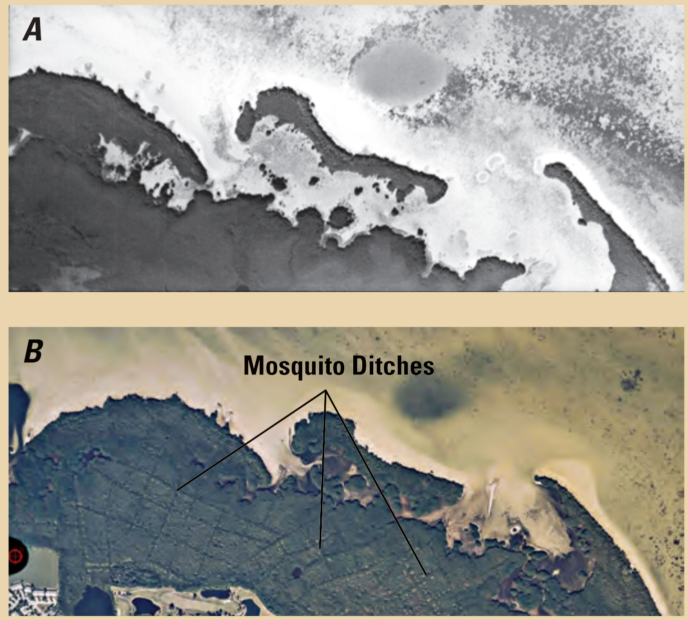
Box 8–2. Mosquito Ditching of Mangrove Forests

By Kimberly K. Yates, Thomas J. Smith, III, and Carole McIvor (U.S. Geological Survey–St. Petersburg, Florida)

During the 1950s and 1960s, many mangrove forests along the coast of Tampa Bay were dredged to create a network of intertidal ditches in a checkerboard pattern (box 8–2, fig. 1*A*, *B*). The intention of this "mosquito ditching" was to allow tidal waters (with fish) to penetrate the inland reaches of the intertidal zone to enhance tidal flooding and minimize the amount of infrequently flooded but continuously damp sediments suitable for mosquito breeding. Such reduction of mosquito-breeding habitat would reduce the numbers of nuisance mosquitoes in nearby residential communities.

The mosquito ditching process involved dredging a network of ditches through the wetland and side-casting the resulting spoil alongside the ditches in the mangrove forest (box 8–2, fig. 2). Mosquito ditching had unintended side effects, including: (1) conversion of high intertidal salt marshes and salterns to mangrove forests; (2) creation of "spoil mound" habitat well-suited to colonization by undesirable exotic plants (Brazilian pepper); and (3) creation of new but relatively short-lived channel habitat — the ditches themselves.

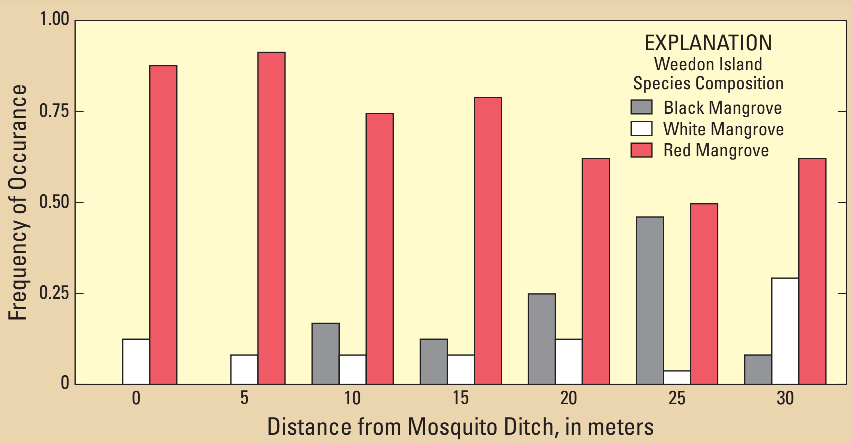
The ditches are reliant on tidal flushing to keep them free of accumulating fine sediments. After 50 to 60 years, many of the poorly flushed ditches farthest from major tidal creeks or bay shorelines are infilling and being converted to wet depressions. Today, many of the wetland restoration efforts in Tampa Bay focus on whether or not to level the spoil mounds and fill the ditches to restore natural hydrodynamic flow conditions to wetland areas. The impact of these ditches on wetland sediments, intertidal vegetation, and fish communities was largely unknown until recently, making it difficult for resource managers to predict how restoration efforts might affect plant and animal communities. USGS scientists performed a series of field investigations to: (1) determine how mosquito ditching affected the composition and distribution of wetland vegetation; (2) identify whether mosquito ditches provide small fishes habitat equivalent to that in natural tidal creeks; and (3) examine a new technique for restoration. Study sites for these investigations included Weedon Island Preserve, Terra Ceia Aquatic Preserve and Buffer, Mobbly Bayou Wilderness Preserve, and Gateway Restoration Tract.



Box 8–2, Figure 1. Photographs of mangrove forest habitat near Feather Sound in Old Tampa Bay *A*, in 1952, prior to mosquito ditching, and *B*, in 2002, showing the checkerboard pattern created by mosquito ditching. Digital photos courtesy of U.S. Geological Survey.

Box 8–2, Figure 2. Example of mosquito ditch adjacent to Tampa Bay. Photo by Carole McIvor, U.S. Geological Survey.

Smith (2004) used permanent vegetation plots and point center quarter transects to characterize vegetation along transects perpendicular to, and moving away from, mosquito ditches and spoil mounds. Results show a transition from primarily red mangroves with a smaller number of white mangroves nearest the mosquito ditches, to a mixture of red, white, and black mangroves further from mosquito ditches (box 8–2, fig. 3).



Box 8–2, Figure 3. Transition in mangrove tree species along a transect perpendicular to a mosquito ditch at Weedon Island in Old Tampa Bay. From Thomas J. Smith III, U.S. Geological Survey.

Krebs and others (2007) sampled nekton (fish, shrimp, and crabs) from natural tidal creeks and well-flushed mosquito ditches to quantify overall community composition and densities of forage and economically valuable species (box 8–2, fig. 4). Their results indicate that a rich community of 76 species, including economically valuable common snook, striped mullet, spot, red drum, and blue crab, occur in both kinds of tidal channels. Differences in distribution occurred between species; juvenile blue crabs were most abundant in some mosquito ditches (Yeager and others, 2007), whereas juvenile snook were found in similar abundance in natural tidal creeks and some mosquito ditches. Results further indicate that environmental conditions (salinity, current velocity, and shoreline vegetation) may provide a more useful indication of habitat "value" for nekton than simply whether or not the habitat has been altered.

Box 8–2, Figure 4. Sampling of fish in mangrove forest creeks in Tampa Bay. Photo by Carole McIvor, U.S. Geological Survey.

Restoration of mangrove wetlands to remove spoil mounds and ditches traditionally involves using heavy equipment, which could cause additional damage to some wetland areas. Smith and others (2007) assessed the efficacy of an alternative technique, hydroleveling, involving the use of a relatively small pump that directs a stream of high pressure water to blast sediments from spoil mounds into adjacent forests (box 8–2, fig. 5). Field testing indicated that this technique was problematic, because there was incomplete restoration of elevation grades on spoil mounds, resulting in poor colonization by native species. In addition, sediment burial of aerial roots of mangroves adjacent to mounds resulted in localized mangrove mortality. Resource managers are currently using results from these studies and other USGS research to assess how physical changes in wetland areas have affected vegetation and habitat use, and to better plan and implement restoration projects in wetlands altered by mosquito ditching and other forms of coastal development.

Box 8–2, Figure 5. Hydroleveling of spoil mounds created by mosquito ditching of mangrove forests in Tampa Bay. Photo by Thomas J. Smith III, U.S. Geological Survey.

Figure 8–5. Red mangrove propagules. Photo by Holly Greening, Tampa Bay Estuary Program.

An important characteristic of all mangroves is that their reproduction includes seedling dispersal by water and by vivipary. The term “vivipary” means that there is no true or independent “seed,” but continuous development from embryo to seedling occurs while the seedlings are attached to the parent tree (fig. 8–5). The reproductive units released from the parent tree, which are referred to as “propagules,” float and remain viable for extended periods of time, allowing them to disperse widely and become established quickly in areas where suitable substrate types and wave energy conditions are found. These are usually shallow depositional areas with low wave energy, factors that allow the establishment of propagules and provide the fine-grained (and frequently anaerobic) sediments to which mangroves are adapted (Odum and McIvor, 1990).

Ecologically, mangrove stands are important as habitat for fish, shellfish, birds, and other wildlife, as sources of detritus to support estuarine food webs, and as contributors to shoreline stability. Although there is general agreement that mangrove ecosystems export appreciable quantities of organic carbon, at least over short distances, there remains much uncertainty concerning the importance of this material in secondary production of invertebrates, fishes, birds, and other animals in the food web (Lewis and Estevez, 1988; Odum and McIvor, 1990).

Salt Marsh

Tidal marshes are unique in both their species composition and ecological role in the estuary system. They are recognized as important nursery habitat for a number of fish and shellfish species, and provide feeding habitat for migratory birds, waterfowl and shorebirds. The primary productivity of salt marshes is reportedly among the highest of any of the world’s ecosystems (Montague and Wiegert, 1990). Some species of native salt marsh vegetation, most notably smooth cordgrass (*Spartina alterniflora*), are pioneer colonizers that can rapidly expand into and throughout disturbed intertidal areas. Their presence helps to stabilize the sediments and reduce wave energy, allowing other species, such as mangroves to become established (Lewis and Estevez, 1988).

As summarized by Montague and Wiegert (1990), the salt marshes of Florida are intertidal ecosystems whose plant communities include a mixture of nonwoody rushes, sedges, and grasses that are inundated at least periodically by saltwater. They occur most commonly in areas where wave energy is sufficiently low to prevent physical scouring and where the density of mangrove trees is sufficiently low to prevent excessive shading. Smooth cordgrass (*Spartina alterniflora*) and black needlerush (*Juncus roemerianus*) are the two predominant plant species found in the salt marshes of Tampa Bay (Lewis and Estevez, 1988; fig. 8–6).

Oligohaline marshes are distinctive in both their species composition and their ecological role, and for management purposes are often treated as a distinct plant community (Lewis and Robison, 1995). Oligohaline marshes are herbaceous wetlands located in the tidally influenced reaches of rivers or streams, where the plant community exhibits a mixture of true marine plants and typical freshwater taxa, such as cattails (*Typha domingensis*) and sawgrass (*Cladium jamaicense*) that tolerate low salt concentrations (fig. 8–7). The predominant plant species of oligohaline marshes include black needlerush, leather fern (*Acrostichum danaeifolium*), cattails, sawgrass, bulrush (*Scirpus robustus*), and spider lily (*Hymenocallis palmeri*). For management purposes the "oligohaline" salinity regime has been operationally defined by local managers, based on the observed distributions of these plant species in Tampa Bay, as a range of 2 to 15 ppt (table 8–1) (Lewis and Robison, 1995).

Ecologically, oligohaline marshes and low salinity mangrove forests are recognized as important nursery habitats for such species as blue crab (*Callinectes sapidus*), snook (*Centropomus undecimalis*), tarpon (*Megalops atlanticus*), and ladyfish (*Elops saurus*). Because recognition of this key role in estuarine life cycles has come only in recent decades, much of this habitat has been lost or highly modified. As a result, the reduced amount of this habitat type may represent a limiting factor in total population sizes of some estuarine-dependent species (Lewis and Robison, 1995).

Figure 8–6. Salt marsh located along the eastern shoreline of Tampa Bay. Photo by Carole McIvor, U.S. Geological Survey.

Salt Barrens

Salt barrens (which are also referred to as salt flats or salterns; fig. 8–8) are typically located along the upland fringes of mangrove forests or salt marshes, in upper intertidal areas that are inundated by tides only once or twice per month and experience episodic hypersaline conditions due to evaporation and the accumulation of residual salt (Lewis and Estevez, 1988). Salinity varies seasonally, in response to variations in tidal inundation and rainfall. The vegetative cover, which is usually patchy and sparse, is provided by a unique flora that includes annual glasswort (*Salicornia bigelovii*), perennial glasswort (*Salicornia virginica*), key grass (*Monoanthochloe littoralis*), sea lavender (*Limonium caroliniarum*), samphire (*Blutaparon vermiculare*), and sea purslane (*Sesuvium portulacastrum*). Due to their low structural complexity and lack of obvious fauna, salt barrens have often been assumed to have limited ecological value. Although their importance to estuarine productivity remains poorly documented, they are now known to provide important seasonal and diurnal feeding habitats for wading birds and a number of estuarine fish species (Lewis and Estevez, 1988).

Figure 8–7. Oligohaline marsh with sawgrass and blackrush. Photo by Nanette O'Hara, Tampa Bay Estuary Program.

Figure 8–8. Typical salt barren in Tampa Bay fringed by mangrove forest. Photo by Carole McIvor, U.S. Geological Survey.

Oyster Bars

Oysters are filter-feeding, sedentary invertebrates that feed on unicellular algae, suspended particulate organic matter, and possibly, dissolved organic substances (Livingston, 1990). Spawning occurs in estuarine areas from late spring through early fall, and the planktonic larvae require a solid substrate for attachment and development (Livingston, 1990). *Crassostrea virginica* is the predominant species in Florida estuaries, although *Ostrea equestris* can also be abundant in high-salinity areas (Arnold and Berrigan, 2002). Oysters were historically abundant in Tampa Bay, particularly in northern Old Tampa Bay, an area that supported a commercial fishery during the late 1800s. The fishery declined during the first half of the 20th century, however, and commercial harvesting no longer occurs in the bay (Lewis and Estevez, 1988; Arnold and Berrigan, 2002). Presently, the known distribution of significant oyster bars is limited to fringe reefs in the upper reaches of the bay (northern Old Tampa Bay, McKay Bay) and areas adjacent to significant freshwater inputs (Cockroach Bay; fig. 8–9). However, oyster bars have proven to be difficult to map and assess because they are small submerged features, and their signature on aerial photography is difficult to distinguish (O’Keefe and others, 2006). Perhaps the most limiting factor to their abundance and distribution in Tampa Bay is suitable bottom type (hard bottom) for larval attachment and growth.

Oysters provide food and habitat for a variety of estuarine species, including boring sponges, gastropod mollusks, polychaete worms, and decapod crustaceans. Physiologically, adult oysters can inhabit a wide range of salinities (3 to 35 ppt) and adapt to relatively rapid salinity changes (Arnold and Berrigan, 2002). In Gulf Coast estuaries they are most abundant in areas where salinity ranges between 10 and 30 ppt. Several important sources of mortality, including the disease-causing parasites *Haplosporidium nelsoni* (“MSX”) and *Perkinsus marinus* (“Dermo”), and predators, such as stone crabs (*Menippe* spp.) and the oyster drill (*Thais haemastoma*), are also more abundant in areas where salinity exceeds 10 ppt. Variations in freshwater inflow and salinity, therefore, can have a substantial influence on the distribution, abundance, and productivity of estuarine oyster populations (Arnold and Berrigan, 2002).

Figure 8–9. Exposed oyster bar at low tide. Photo by Carole McIvor, U.S. Geological Survey.

The Florida Fish and Wildlife Research Institute (FWRI) mapped the distribution of oyster bars in Tampa Bay to establish a baseline map for the current extent of oysters, and compared it to a historic map produced by the USGS (O'Keefe and others, 2006). Estimates from these maps indicate that there are currently 44 acres of oyster bar habitat in Tampa Bay (PBS&J, 2009).

Hard Bottom

Hard bottom communities, also known as "live bottom," are among the most widely distributed marine habitats in Florida waters, occurring from shallow subtidal areas to the edge of the continental shelf (Jaap and Hollock, 1990). The primary requirement for the establishment of a live bottom biota is the availability of a solid substrate to which its inhabitants can attach.

Although quantitative information is sparse, the areal extent of hard bottom habitats in Tampa Bay appears to be small (hundreds of acres) relative to the aerial extent of other benthic-habitat types, such as seagrasses and unvegetated estuarine sediments (Ash and Runnels, 2003). The most extensive natural hard bottom substrate that has been identified occurs along the southeastern margin of the bay, as a line of limestone outcrops that roughly parallels the shoreline from the Little Manatee River southward offshore of Bishop Harbor and Rattlesnake Key (Ash and Runnels, 2003). Patches of hard bottom are also found in embayments within this area.

Like oyster bars, these features have proven difficult to map and assess because they are small submerged features, and their signature on aerial photography is difficult to distinguish. They support a diverse assemblage of animal and plant species, including sea whips (*Leptogorgia veigulata*), loggerhead sponges (*Spheciospongia vesparia*), boring sponges (*Clionia* spp.), hard corals (*Siderastrea radians*), and macroalgae (*Sargassum filipendulum* and *Caulerpa mexicana*) (Lewis and Estevez 1998; fig. 8–10). Although the substrates underlying these known hard bottom areas appear to be natural, distinctions between different substrate types (for example, limestone, beach rock, oyster reef, and other natural substrates) have not yet been made (Ash and Runnels, 2003).

Figure 8–10. Natural hard bottom occurs in the Terra Ceia Aquatic Preserve in Lower Tampa Bay. Photo by Randy Runnels, Florida Department of Environmental Protection.

Tidal Rivers and Tributaries

More than 300 named and unnamed creeks and other small tributaries have been identified in the Tampa Bay watershed, including more than 150 which are tidally influenced (fig. 8–11; TBTTRT, 2008). Tidal tributaries occur in all areas of the bay (box 8–3). Land use in their catchments includes urban, residential, agricultural and some relatively unaltered drainage areas. As a group, the larger tidal rivers — the Hillsborough, Alafia, Little Manatee, Manatee, and Braden Rivers — provide a significant percentage of the freshwater inflows and nutrient inputs that help drive the complex of physical, chemical, and biological processes that define Tampa Bay (Estevez and others, 1991; see also Chapter 6). Much of the oligohaline habitat in Tampa Bay occurs within and adjacent to the tidal reaches of these rivers. The tidal tributaries provide a different range of habitats than the open water, higher salinity areas of the bay, and represent an interface between the bay and its watershed.

Tidal tributaries in Tampa Bay are important to estuarine-dependent fish populations, providing both nursery habitat and foraging areas (Krebs and others, 2007; Yeager and others, 2007). They support populations of benthic microalgae and benthic macroinvertebrates that provide resources for higher trophic levels (box 8–3). Differences in the abiotic and biotic conditions governing fish utilization between the small, tidally influenced systems are more pronounced than in the larger waterbodies into which they generally drain (TBTTRT, 2008; box 8–3).

Figure 8–11. Oligohaline stretch of Frog Creek, a tidal tributary of Tampa Bay. Note mix of salt-tolerant leather fern and freshwater oak trees. Photo by Holly Greening, Tampa Bay Estuary Program.

Box 8–3. Tampa Bay Tidal Tributaries Initiative

By Edward Sherwood (Tampa Bay Estuary Program)

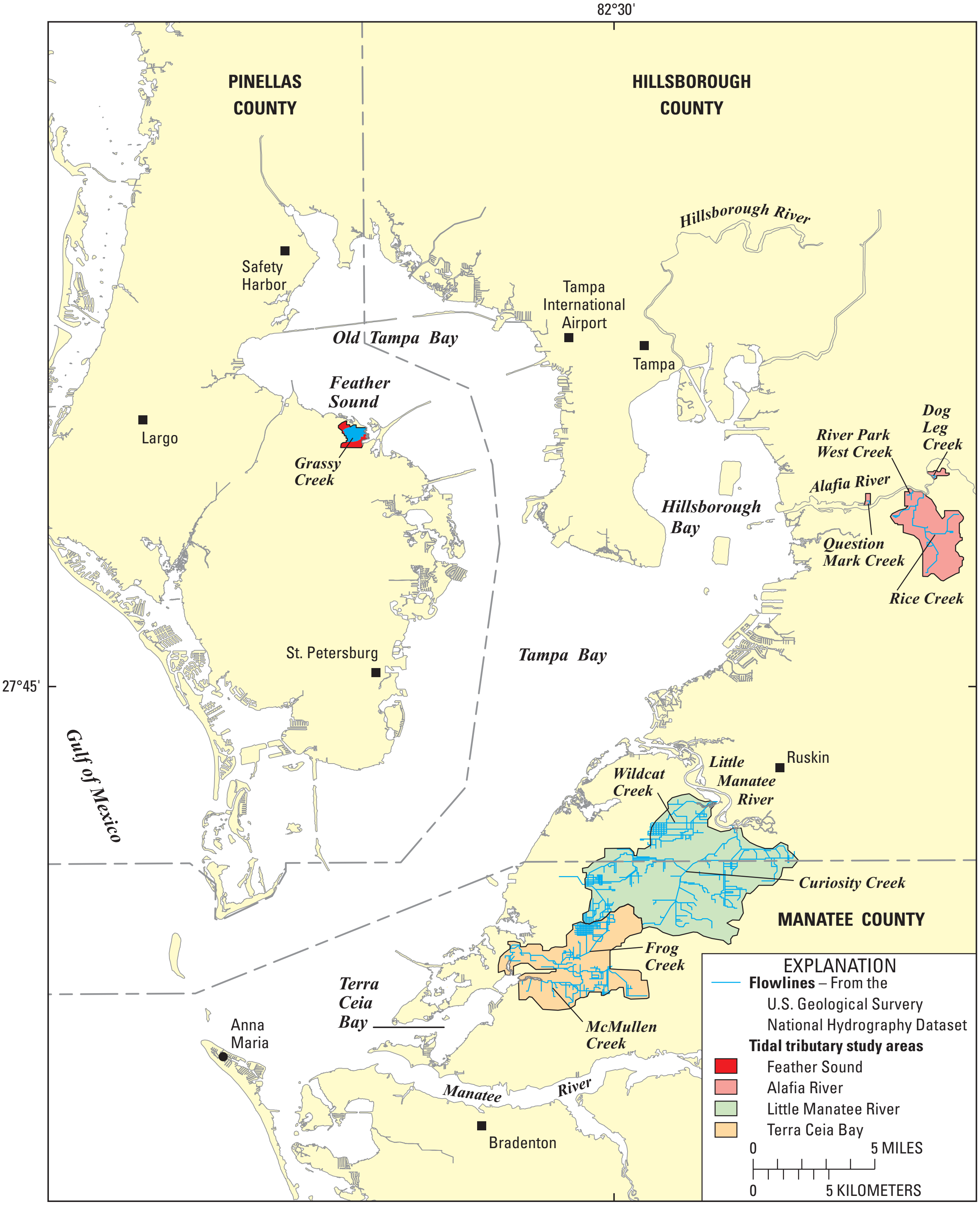
More than 300 named and unnamed creeks and other small tributaries have been identified in the Tampa Bay watershed, including more than 150 that are tidally influenced. Tidal tributaries occur in all areas of the bay (see Chapter 2, fig. 2–5). Land use in their catchments includes urban, residential, agricultural and some relatively unaltered drainage areas.

Tidal creeks have major influence on the productivity and diversity of natural resources in many estuarine systems (Holland and others, 2004). Relatively small, tidally influenced coastal and riverine creeks with and without direct freshwater input, dredged inlets, and other "backwater" areas are subject to a range of anthropogenic impacts (Clark, 1991; Morrison and Boler, 2005). Small tidal creeks are important nursery habitat for many species of fish (Krebs and others, 2007; Yeager and others, 2007; TBTTRT, 2008). A 1986 assessment of 30 representative tidal tributaries around Tampa Bay found that 60 percent were either natural or in restorable condition (Clark, 1991). Until recently, however, few formal studies of the ecology of these systems have occurred. In order to provide more information on these important habitat areas, a tidal tributary habitat initiative (TBTTRT, 2008) was initiated with the objectives of:

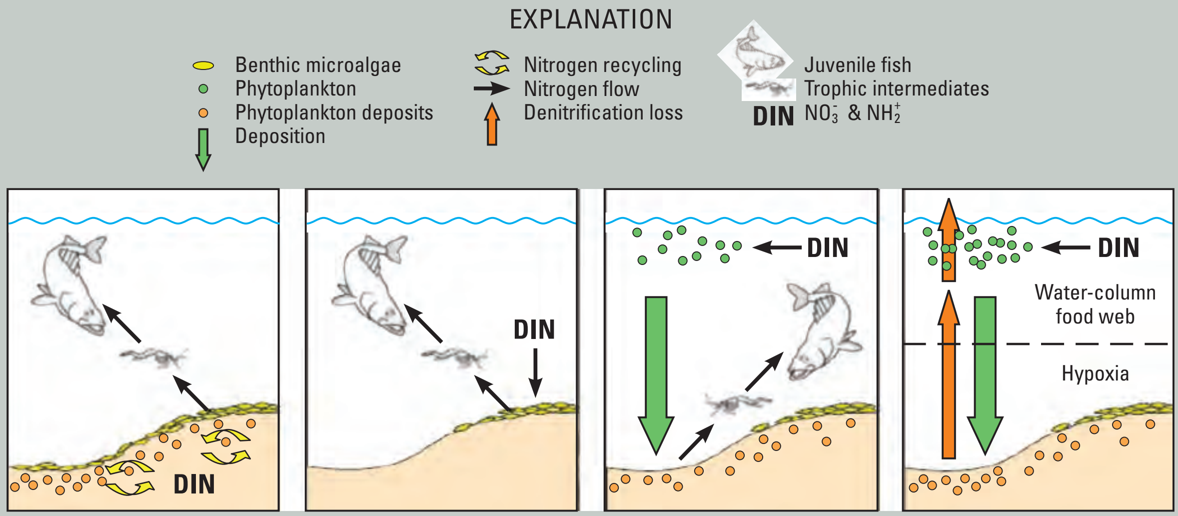
- Characterizing the fisheries resources of Tampa Bay tidal tributaries,
- Determining the effects of watershed condition, water quality, and structural habitat on their fisheries resources;
- Developing measurable goals, management recommendations, and a tidal tributary management strategy based on study results; and
- Communicating findings to resource managers and the public to support informed decisionmaking regarding the management of tidal tributary habitats.

Assessments of small, tidally influenced creek systems and their adjacent riverine and bay habitats were conducted in several parts of the estuary (box 8–3, fig.1). Study areas were chosen such that tidal tributary watersheds exhibiting relatively high and relatively low levels of anthropogenic alteration (based on the local knowledge of the project team) would be represented. The preliminary working hypotheses were that: (A) tidal tributaries are important habitats for fish and invertebrates within the Tampa Bay ecosystem; and (B) water and sediment quality, and biological resources in tidal tributaries with watersheds that have been more heavily modified by human activities, will be degraded relative to those with less altered watersheds.

The 2-year study demonstrated that tidal tributaries are important to estuarine-dependent fish populations, providing both habitat and food resources (TBTTRT, 2008). The study areas were found to provide a location for the production



Box 8–3, Figure 1. Locations of study sites used in tidal tributaries assessment project. From Tampa Bay Tidal Tributary Research Team (2008).



Scenario 1. Benthic microalgal community (BMAC). Scenatio is dependent on benthic normoxia and nitrogen from benthic recycling (e.g., middle estuary during dry season).

Scenario 2. Benthic microalgal community (BMAC). Scenatio is dependent on benthic normoxia and nitrogen from the water column. Assumes CDOM shading at depth (e.g., upper estuary during wet season).

Scenario 3. Phytoplankton based benthic community (PBBC). Requires water-column nutrients, a depositional environment and benthic normoxia (e.g., middle estuary during wet season).

Scenario 4. Phytoplankton based water-column community (PBWC). Requires water-column nutrients, causes benthic hypoxia (e.g., near river mouth during floods). Some nitrogen is removed via denitrification.

Box 8–3, Figure 2. Schematic illustrating four nitrogen (N) pathway scenarios for tidally influenced systems in Tampa Bay. From Tampa Bay Tidal Tributary Research Team (2008).

of benthic microalgae and trophic intermediates including benthic macroinvertebrates (for example amphipods and mysids) that ultimately reached higher trophic levels and influenced production of juvenile estuarine fish (summarized schematically in box 8–3, fig. 2).

Many fish species are known to use a continuum of habitat types at different life stages, including tidal creeks, their tributaries, adjacent larger tidal rivers, small embayments, open bays, and in some cases, open ocean or gulf waters. Differences in the abiotic and biotic conditions governing fish use were more pronounced between the small, tidally influenced systems than between these systems and the larger waterbodies to which they drained. For common snook, an economically important fisheries species, low-salinity tidal tributaries and backwater habitats were shown to provide a critically, unique nursery habitat along the "estuarine continuum" (TBTTRT, 2008).

A major driving force of higher trophic processes in these tidal tributaries appeared to be the delivery pattern of freshwater inflow they experienced. Inflow from the contributing watershed can regulate productivity in small tidal tributaries by governing the flux of watershed-derived nutrients and constituents that decrease water clarity. Benthic microalgae, major sources of primary production in the less-eutrophic study areas, require adequate light for photosynthesis. Due to their relative shallowness, tidal tributaries provide optimal areas for benthic microalgae growth when hydrologic and physico-chemical conditions are favorable. Sudden peak inflows or runoff can "flush out" juvenile nekton and sediments, scour channels, and introduce unsuitable water-quality conditions within the tributaries, thereby reducing or eliminating benthic microalgae production and altering biotic communities (TBTTRT, 2008).

Similarly, low or no freshwater flow can increase concentrations of water column algae and promote hypoxic conditions (low or no DO) due to increased water residence times. These factors can, in turn, reduce the production of benthic microalgae, causing a cascading effect to benthic trophic intermediates and ultimately fishery resources. In terms of sustained ecological production, study results indicated that Tampa Bay tidal tributaries with minimally altered, natural flow regimes exhibit the greatest estuarine value to fisheries resources through sustained benthic microalgae production and N cycling (TBTTRT, 2008).

Furthermore, undeveloped watersheds, and the natural riparian vegetation associated with them, provide a buffer that controls water flow rates to tidal tributaries, retaining rainfall in wetlands and watershed soils during the wet season (thus reducing “flashiness”) and gradually releasing water as sustained baseflow to these tidally influenced systems during the dry season. In developed watersheds with greater amounts of impervious surface, rainfall is not as effectively retained in the watershed but can run off quickly and at higher volumes, causing rapid, “flashy” increases in flow. The study found a statistical relationship between degraded water and benthic quality conditions in tidal tributaries with higher levels of landscape development along their banks. Results suggested that the degree of landscape alteration can have an impact on in-situ abiotic conditions (TBTTRT, 2008).

Recommended management actions from the tidal tributary habitat initiative include the following:

- Maintaining connectivity between open bay waters, tidal rivers and smaller, tidal tributaries to allow fish movement, water flow and nutrient flux. Fish require a mosaic of habitats throughout their life cycle, and the most effective management would be based on a system-wide scale. This concept is important in terms of the landscape’s connectivity to the surface waters, as well as instream processes that promote desirable conditions within the tributaries for nekton.
- Reducing the “flashiness” of water flow to tidal tributaries would promote more natural hydrologic regimes and foster productivity of benthic microalgae and trophic intermediates. Maintaining and restoring natural wetlands, marshes and riparian corridors in tidal tributary watersheds, as well as considering additional methods of enhancing water retention and gradual release as baseflow, would be of primary importance.
- Tracking physical parameters, water chemistry and quality of nursery habitats of Tampa Bay tidal tributaries by monitoring freshwater inflow, watershed development, water-quality indicators and nekton habitat use. This would improve managers’ understanding of the ecological roles of small tidal tributaries within the larger habitat mosaic.
- Improving public education and stewardship of tidal tributaries by promoting an Adopt-a-Creek Program. Tidal tributaries are often overlooked as environmental management priorities, and increased appreciation of their importance as nursery habitats could improve that situation.

Artificial Habitats

The term “artificial habitats” refers to manmade hard substrates placed in the estuarine and marine environment to provide habitat functions for fish and invertebrates (fig. 8–12; fig. 8–13). The three most common types of artificial habitats in Tampa Bay include:

- Artificial reefs — typically composed of concrete construction debris or sunken vessels;
- Oyster domes (also known as reef balls) — hollow modules with numerous holes, made from poured concrete, and typically deployed along vertical seawalls; and
- Rock rip-rap jetties and fill along vertical seawalls — jetty and seawall areas that have been reinforced with rocks of various sizes.

Oyster dome and rock rip-rap fill areas, although individually small in size, may cumulatively constitute an important habitat component in Tampa Bay. These features increase habitat structure and substrate diversity, especially in urban areas with extensive vertical seawall construction. These structures attract encrusting filter-feeding invertebrates including sponges and bivalve molluscs, an extensive epibenthic fauna, and benthic microalgae. Based mostly on anecdotal evidence, these structures are thought to contribute to localized improvements in water quality (due to the removal of suspended matter by filter feeding organisms) as well as increased fish abundance and diversity. There are currently 538 acres of documented artificial habitats in Tampa Bay (PBS&J, 2009).

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B

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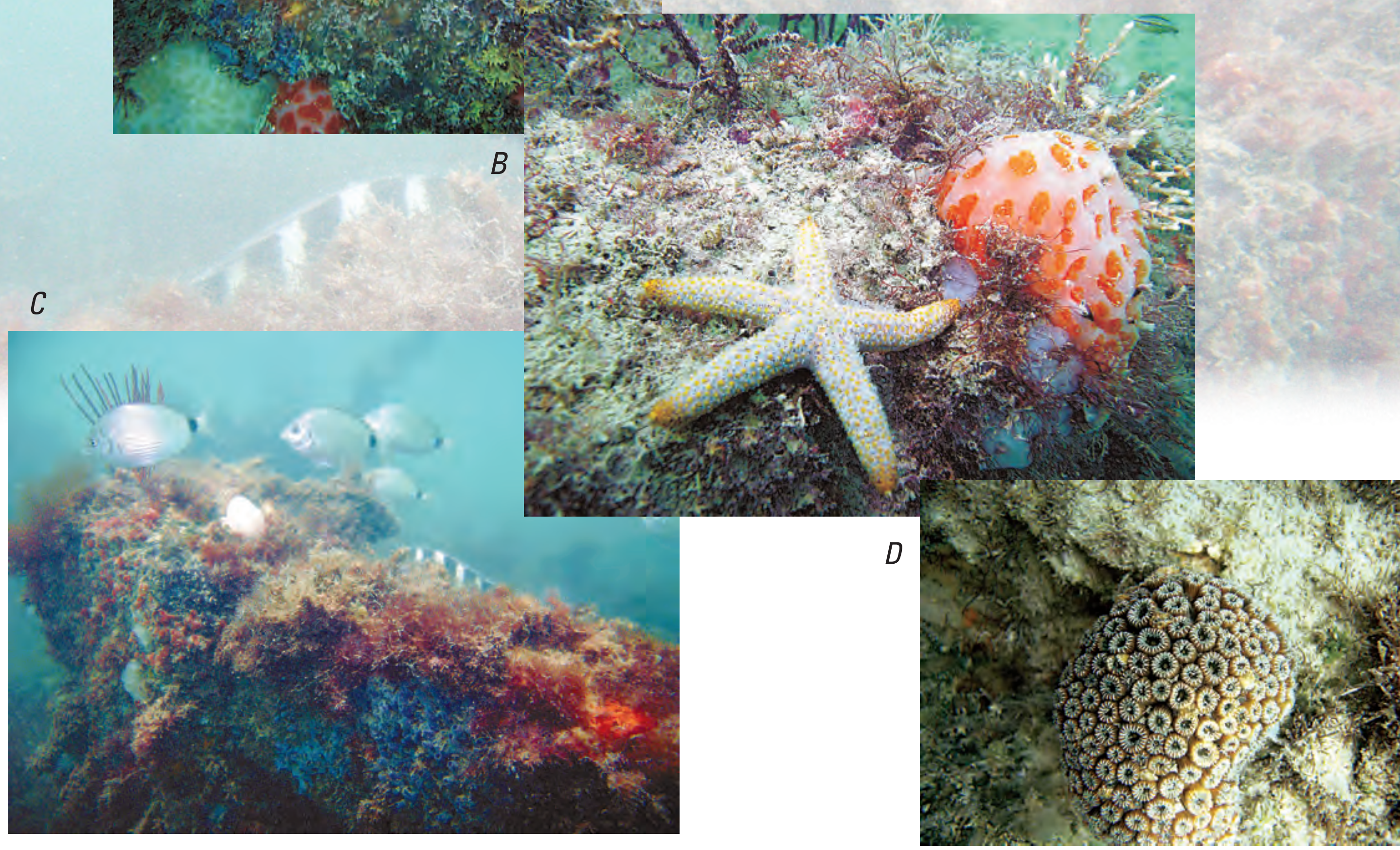
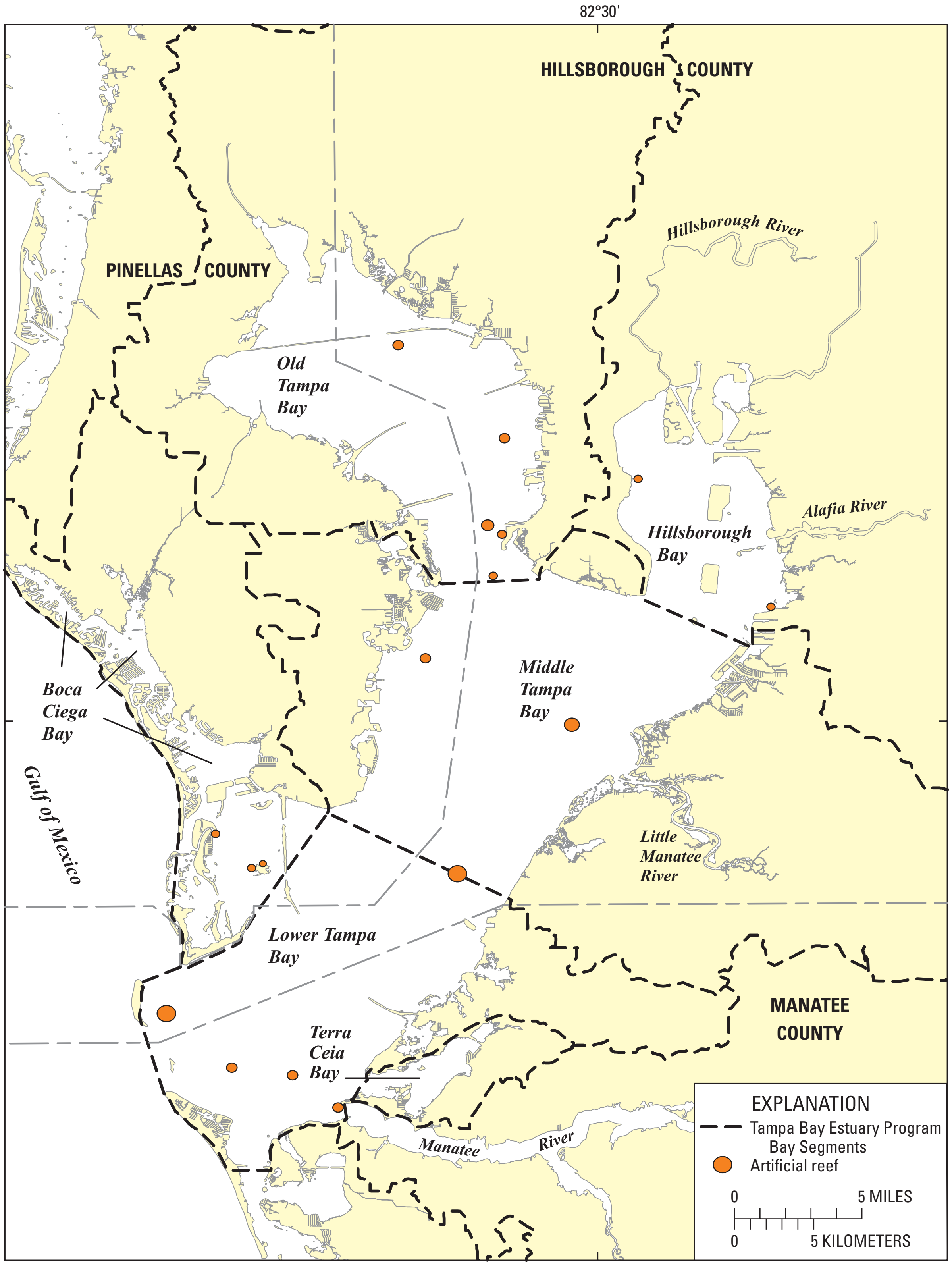


Figure 8–12. Inhabitants of the Egmont Key and Fort Dade artificial reefs located in Lower Tampa Bay include: *A*, encrusting sponges; *B*, sea star and encrusting sponges; *C*, encrusting sponges, bryozoans and spot-tail pinfish; *D*, hard coral. Photos by Tom Ash, Environmental Protection Commission of Hillsborough County.



Source: PBS&J, Inc.

Figure 8–13. Location of artificial reefs in Tampa Bay. From PBS&J, Inc. (2009).

Coastal Uplands

Coastal uplands buffer emergent tidal wetlands from urban and agricultural development, and provide important transitional habitats for estuarine reptiles, such as the diamondback terrapin and the mangrove water snake. The status and ecological function of coastal upland habitats in Tampa Bay, however, have generally been poorly studied (PBS&J, 2009).

Coastal uplands are not a distinct habitat type, such as mangrove forests or salt marshes. Rather, in the Tampa Bay region, the term refers generally to the complex of flatwoods (fig. 8–14) and associated hammocks that occur immediately landward of emergent tidal wetlands.

Figure 8–14. Coastal uplands can include slash pines and palmetto. Photo by Holly Greening, Tampa Bay Estuary Program.

As summarized by Abrahamson and Hartnett (1990), the term “flatwoods” includes a number of distinct plant communities found on a variety of soil types. In Florida, most are characterized by a relatively open overstory of pines, an extensive shrub stratum, and a variable and often sparse herbaceous layer. On a statewide basis the four dominant tree species are longleaf pine (*Pinus palustris*), typical slash pine (*P. elliottii*), South Florida slash pine (*P. elliotti* var. densa) and pond pine (*P. serotina*), occurring either in pure stands or admixtures dependent on geographical location, climate, fire history, and level of human alteration. Live oak (*Quercus virginiana*), water oak (*Q. nigra*), cabbage palm (*Sabal palmetto*), sweet gum (*Liquidambar styraciflua*), red maple (*Acer rubrum*), and ash

(*Fraxinus* spp.) occur in the flatwoods of central and northern coastal Florida, usually as interspersed hammocks on slightly higher ground. There are currently 9,000 acres of this coastal upland habitat in the Tampa Bay watershed (PBS&J, 2009).

Freshwater Wetlands

The Tampa Bay habitat management effort is primarily concerned with habitat types that are considered critical for sustaining populations of estuarine dependent fish, invertebrates, birds and other wildlife. As a result, its freshwater wetlands component focuses on flatwoods marshes and the shallow, sometimes ephemeral, ponds within them (fig. 8–15), which make up a small subset of the complex of freshwater wetlands that occur in the Tampa Bay watershed.

Although hardwood swamps and other types of freshwater marshes are vitally important to the hydrology of the bay, most do not provide significant habitat for estuarine-dependent species. However, freshwater wetlands located within the foraging areas of the bay's nesting wading bird populations do provide such habitat, and have been a key component of the bay management effort (Lewis and Robison, 1995; fig. 8–16). Studies have shown that during the nesting period, coastal-nesting white ibis (*Eudocimus albus*) are dependent on access to freshwater wetland foraging areas, because osmoregulatory limitations make it difficult for their nestlings to develop on a diet composed entirely of saltwater prey (Bildstein, 1993). Flatwoods marshes and shallow freshwater ponds are important foraging areas for nesting ibis and other wading birds. There is currently 26,800 acres of flatwoods marsh habitat within the foraging areas of coastal-nesting wading bird populations in the Tampa Bay watershed (PBS&J, 2009).

Figure 8–15. Shallow pond within a flatwoods marsh. Photo by Doug Robison, PBS&J, Inc.

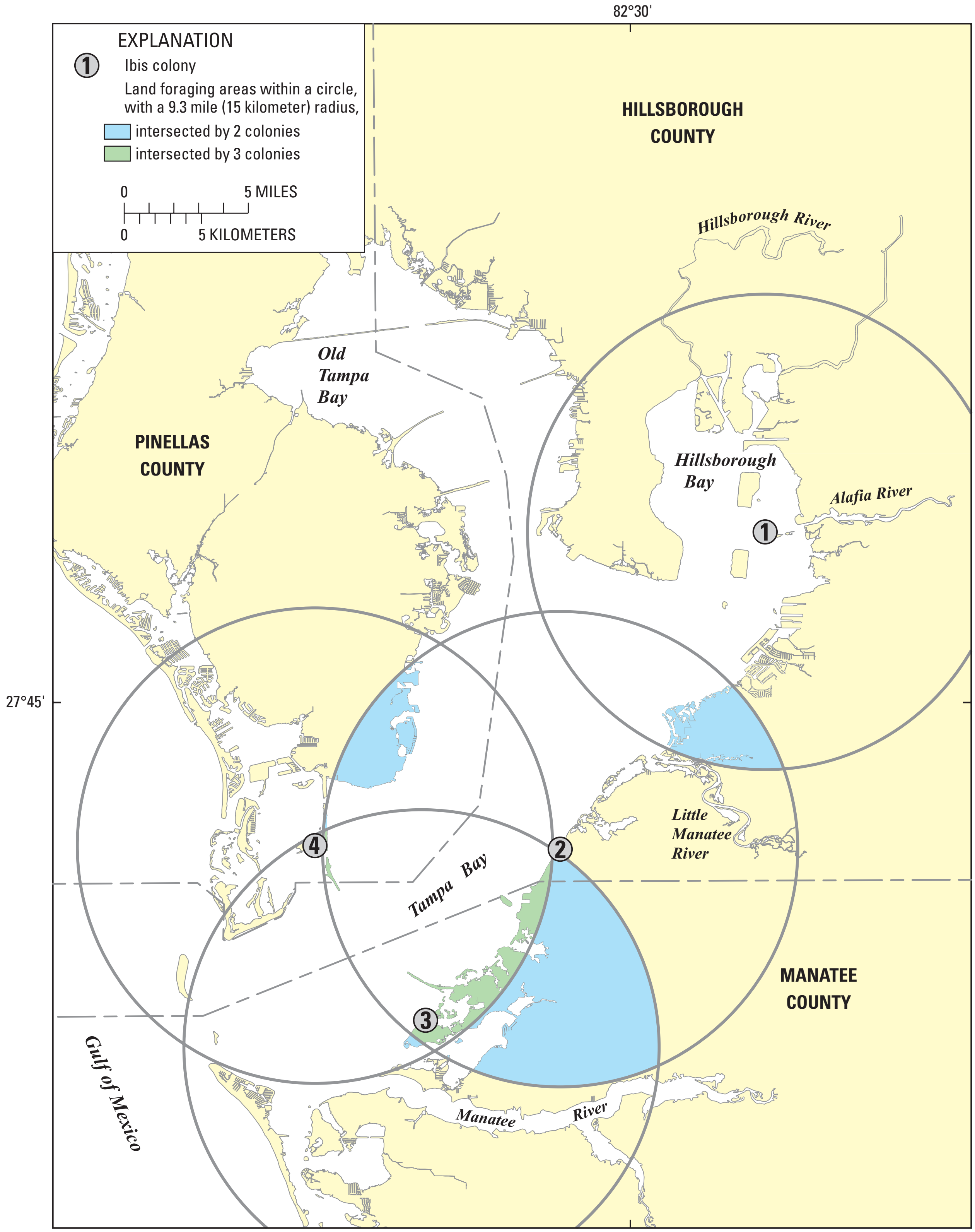


Figure 8–16. Areas within the estimated foraging ranges of four major coastal nesting colonies of white ibis and other wading birds in Tampa Bay: (1) Alafia Banks, (2) Piney Point, (3) Terra Ceia Bird Sanctuary/Washburn Sanctuary, and (4) Tarpon Key. From Tampa Audubon Society (1999).

Habitat Threats

The primary anthropogenic threats to Tampa Bay habitats are similar to those affecting other estuaries in the coastal United States and other industrialized nations around the world. These include dredge and fill activities, urbanization, water-quality degradation, consumptive water use (including freshwater withdrawals, diversions, and impoundments), and climate change and sea-level rise (PBS&J, 2009)

Dredge and Fill

Dredge and fill activities (fig. 8–17) associated with urbanization and the construction of shipping channels and port facilities have been responsible for much of the physical habitat loss that has occurred in Tampa Bay. These activities include the removal of substrate via dredging for development and deepening of ship channels and harbors, followed by placement of dredged materials in different locations. There was an estimated bay-wide loss of emergent tidal wetlands of 5,128 acres (about 21 percent) between 1950 and 1990, and the vast majority of these losses were attributed to dredge and fill (Lewis and Robison, 1995). Lewis and Estevez (1988) estimate that the total surface area of the bay has been reduced by 3.6 percent relative to predevelopment conditions due to dredging of navigation channels and filling of intertidal or deeper open-water areas. That surface area is similar to the size of the Interbay Peninsula, south of Ballast Point. Historically, the majority of the areas filled in Tampa Bay were low-lying emergent tidal wetlands and seagrass meadows (Lewis and Estevez, 1988). The majority of these impacts occurred before the enactment of the Clean Water Act and the implementation of Federal wetland regulatory programs in the 1970s. Since that time, dredge and fill impacts have been significantly reduced through Federal and State regulation. However, maintenance of shipping channels and port berths still generates about 1 million cubic yards of dredged material each year (PBS&J, 2009).

Figure 8–17. Dredging activity using a clamshell dredge. Photo by Nanette O'Hara, Tampa Bay Estuary Program.

Box 8–4. Avifaunal Populations in Tampa Bay

By A.B. Hodgson (Audubon of Florida, Florida Coastal Islands Sanctuaries)

The viability of coastal bird populations in Tampa Bay is dependent upon the preservation of coastal habitats. These populations depend upon freshwater and tidal wetlands and the estuary as feeding grounds, and on bay islands and other coastal areas as nesting locations. Many coastal species' populations have declined in the past 30 years, particularly those that forage primarily in freshwater wetlands. These declines are likely attributable to regional urbanization and loss of both breeding and foraging habitats. Populations of a few species (Roseate Spoonbill, American Oystercatcher, and Caspian, Royal and Sandwich Terns) appear to be increasing (Hodgson and others, 2006).

The Tampa Bay system supports 29 nesting species of water-associated birds, including beach-nesting birds and their allies. Of these, 14 species are State or federally listed due to population trends or rarity. Total numbers in recent years have ranged from about 30,000 to 52,000 breeding pairs and their young, or nearly 200,000 individuals, making this one of the largest and most diverse waterbird communities within Florida outside the Everglades. Among these species, pelicans, herons, egrets, ibis, gulls, terns, and skimmers are particularly useful as ecological indicators because their large size (box 8–4, fig. 1*A–I*) and colonial habits allow them to be fairly easily censused. Audubon of Florida's Coastal Islands Sanctuaries Program

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C

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B

Box 8–4, Figure 1. Waterbirds that nest in the Tampa Bay area include *A,* Reddish Egret (shown here is the rare white morph); *B,* White Ibis in breeding phase; *C,* Brown Pelican juveniles at the Coffeepot Bayou Island colony; *D,* Great Egret in courtship display; *E,* Sandwich Tern; *F,* American Oystercatcher; *G,* Black Skimmer; *H,* Snowy Egret; *I,* Roseate Spoonbill. Photos by Gerold Morrison, AMEC-BCI.


E


F

annually locates and censuses all known coastal and inland nesting colonies in Tampa Bay. Between 1994 and 2006, White Ibis and Laughing Gulls accounted for 60 to 70 percent of all individuals in most years (Hodgson and others, 2006).

Most of the nesting colonies within Tampa Bay are located on islands in the estuary or in lakes. The Richard T. Paul Alafia Bank Bird Sanctuary is among the most diverse bird colonies in the United States, with 16 to 20 species nesting here annually. Predation, primarily from raccoons, is an ongoing problem at many bird colony nesting sites. Proper management includes removal of mammalian predators to sustain the breeding bird populations. Posting and patrol of nesting sites to deter human disturbance, remove discarded fishing line, and provide public education and outreach (especially for boaters and fishermen) are also critical management activities. Direct human disturbance of the nesting birds, the continued loss of coastal wetland and estuarine foraging habitats, and entanglement in discarded fishing line contribute to management concerns in the protection of the bay's avifaunal species. The numerous land acquisition programs in the region have not kept pace with the rapid urban and suburban development and consequent loss of critically important habitats. Coastal freshwater wetlands and tidal marshes have been lost or negatively impacted by hydrologic alterations and pollution inputs, reducing wetland biomass productivity and affecting forage availability for birds. This fact has been recognized by the regional land management community, and the restoration of coastal freshwater and estuarine systems is a priority of restoration projects surrounding Tampa Bay. All effective strategies must be considered to protect and sustain the region's colonial waterbird populations (Hodgson and others, 2006).


H


G


I

Urbanization

As noted, urbanization increases the imperviousness of watersheds, through factors, such as soil compaction and the installation of roofs, sidewalks, parking lots and roadways (Schueler and Holland, 2000). Increasing imperviousness affects watershed hydrology by increasing the rates and volumes of stormwater runoff and reducing the amount of water that infiltrates the soil to recharge groundwater aquifers. The effects of imperviousness can be seen in stream hydrographs that show more rapid flow responses to rainfall events, and often show reduced dry-season flows due to reductions in base flow from the surficial aquifer (Schueler and Holland, 2000). These hydrologic changes also impact water quality. Increased rates of erosion from land clearing can cause increased turbidity and delivery of potentially contaminated sediments to natural waters. Contaminants that accumulate on impervious surfaces are washed off and rapidly delivered to receiving waters (Schueler and Holland, 2000; NRC 2005).

In Florida, stormwater management regulations that have been in place since the 1980s have helped to reduce these impacts. In the Tampa Bay area, however, parts of several of the largest urban centers were constructed on or near the bay shoreline prior to the implementation of modern stormwater regulations. These older urban, commercial and industrial areas have affected the hydrology and water quality of numerous tidal streams and the tidal reaches of the larger tributaries.

Water and Sediment Quality

As noted, management of contaminant loadings and other factors that impact water and sediment quality have been key elements in several of the resource-management strategies developed for Tampa Bay. Nutrient loadings affect water clarity, impacting the growth and extent of seagrass habitats. Additionally, sediment contaminants including metals, pesticides, PAHs and PCBs can affect the quality of benthic and wetland habitats. These issues are discussed in more detail in Chapters 4, 5 and 7.

Consumptive Water Use

Consumptive water use refers to the withdrawal or diversion of freshwater from groundwater aquifers and surface-waterbodies for use in supporting human population needs for agricultural and landscape irrigation, potable water supplies, and industrial uses. In Florida, consumptive uses are regulated by the State's five water management districts. Florida law also requires the districts to establish minimum flows and levels for surface waters and aquifers within their jurisdictions. As currently defined in State statute, the minimum flow for a given waterbody is the "limit at which further withdrawals would be significantly harmful to the water resources or ecology of the area." However, existing legislation does not define the term "significantly harmful." As a result, the criteria and impacts that will be used to identify a withdrawal level at which "significant harm" occurs must be determined by managers on a case-by-case basis. An analogous situation is occurring in the State of Texas, where studies indicate that similarly ambiguous policy language is hindering efforts by State agencies to manage water resources in a comprehensive and ecologically protective manner (NRC, 2005).

As noted in Chapter 6, excessive levels of consumptive water use have the potential to impact important estuarine habitats by altering natural hydrologic and water-quality conditions in tidal streams and rivers. The physical and chemical processes affected by changes in freshwater inflows are complex. The most direct impacts are related to changes in natural salinity patterns, when brackish water extends farther upstream in tidal tributaries in response to reduced freshwater inflows. Long-term changes in salinity distribution can in turn alter the distribution of plant communities along a salinity gradient, as plants have evolved to tolerate specific salinity conditions. Dislocation of areas of high primary and secondary productivity can also occur in response to changes in flows and nutrient discharges. Such dislocations can result in changes in organic sediment deposition, benthic community structure, and the recruitment success of larval and juvenile fishes. Concerns also exist regarding the cumulative effect of freshwater withdrawals that could potentially reduce the total volume of freshwater delivered to the bay (PBS&J, 2009).

An additional impact related to consumptive water use is the construction of impoundments in free-flowing tidal streams and rivers. Impoundments are constructed primarily to create freshwater storage reservoirs for consumptive water use, or to provide flood protection or barriers to saltwater intrusion. The following historically free-flowing waterbodies draining to Tampa Bay have been impounded:

- Hillsborough River (producing the Hillsborough River Reservoir)
- Sixmile Creek/Palm River (producing parts of the Tampa Bypass Canal)
- Manatee River (producing Lake Manatee)
- Braden River (producing the Evers Reservoir)
- Long Bayou (producing Lake Seminole)
- Salt Creek (producing Lake Maggiore)
- Alligator Creek (producing Alligator Lake)

The impoundments listed above have resulted in major habitat alteration and loss, barriers to migrating fish and wildlife, and disruptions to natural physical and chemical processes and gradients that occur in tidal streams and rivers. For these reasons, it is unlikely that new impoundments on other free-flowing waterbodies in the Tampa Bay watershed would be permitted under current environmental regulations (PBS&J, 2009).

Climate Change

Based on assessments of atmospheric and oceanic monitoring data, and information from a suite of global models, the IPCC (2007) summarized climate change issues as follows:

- The term “climate change” refers to a change in the state of the climate that can be identified by changes in the mean and/or the variability of its properties, persists for decades or longer, and is caused by natural variability or as a result of human activities;
- Evidence that global climate is warming is unequivocal, based on observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level;
- Since 1750, global atmospheric concentrations of greenhouse gases (such as CO_2, CH_4 and N_2O) have increased substantially as a result of fossil fuel use, deforestation, and other land use changes;
- Most of the observed increase in global average temperatures since the mid-20th century is very likely due to the observed increase in anthropogenic greenhouse gas concentrations;
- Observational evidence from all continents and most oceans shows that many natural systems are being affected by climate change;
- The resilience of many ecosystems is likely to be exceeded during the 21st century by a combination of climate change, associated disturbances (flooding, drought, wildfire, and ocean acidification), and other stressors (land use changes, pollution, fragmentation of natural systems, and over-exploitation of resources).

Using the magnitudes and rates of climate change projected by the IPCC (2007) as a starting point, the FOCC (2009) forecast a range of “probable” and “possible” impacts on Florida’s coastal areas that may occur in coming decades. In the Tampa Bay area, the potential habitat-related impacts evaluated by the FOCC (2009) can be grouped into three broad categories based on their underlying causes: those associated with sea-level rise, those associated with increasing air and water temperature, and those associated with increasing acidification of seawater.

Sea-Level Rise

Global sea-level rose by about 120 m during the several millennia that followed the end of the last ice age (about 21,000 years ago). Sea level then stabilized, between 3,000 and 2,000 years ago, at a level that did not change substantially until the mid-19th century (Bindoff and others, 2007). Sea level began rising once again during the 19th century, and during the 20th century it is estimated to have risen at a rate of about 1.7 millimeter per year (mm/yr). Since 1993 sea level has been rising at a faster rate — about 3 mm/yr — and is projected to rise at somewhat higher rates throughout the 21st century (Bindoff and others, 2007). Given a range of plausible greenhouse gas emission scenarios, global simulation models suggest that by 2100 average sea level may have risen to about 0.6 m above 1980–1990 levels. However, these simulations do not address a number of uncertainties (such as changes in the melting rates of the Greenland and Antarctic ice sheets) that could potentially produce greater increases, and “the upper values of the ranges given are not to be considered upper bounds for sea-level rise”

(Bindoff and others, 2007). In addition, sea-level rise is expected to continue for centuries, even if greenhouse gas emissions are stabilized, due to the time scales of climate processes.

The impacts of rising sea level on habitats in the Tampa Bay area will depend on both the rate and the magnitude of the rise. The current rate is about an inch a decade, based upon NOAA tide gage data (fig. 8–18). As summarized by the FOCC (2009) and references therein, it appears probable that water depths will continue to increase within the bay's current shoreline, and the shoreline itself will migrate landward in areas where manmade structures, such as seawalls and bulkheads, are not present to prevent such movement. Depending on the rate of sea-level rise, emergent tidal wetlands and other coastal habitats may be able to persist by accreting vertically, migrating landward, or both. If the sea level increases more rapidly than the biota can respond, however, these adaptive responses might not be possible. Coastal habitats may also be lost in areas where manmade structures prevent landward migration (Williams and others, 1997; FOCC, 2009).

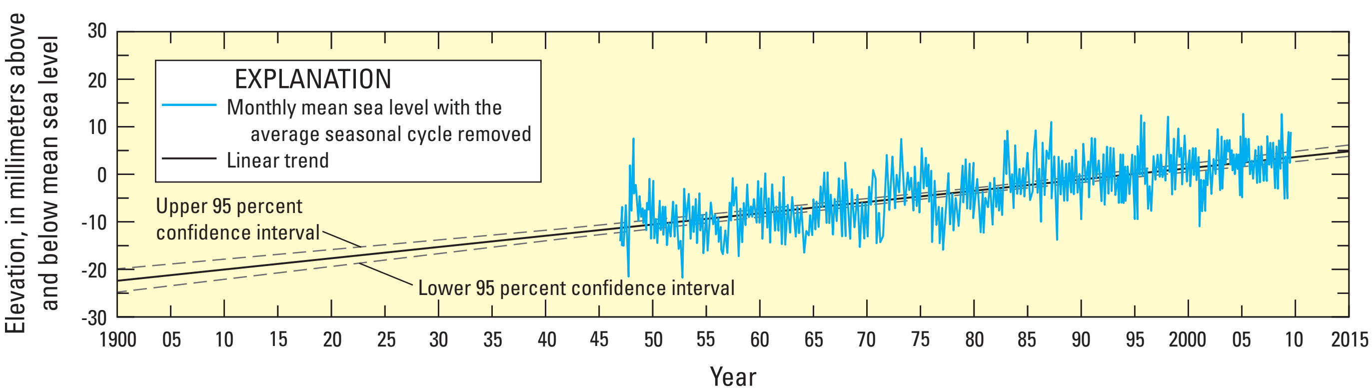

Figure 8–18. Mean sea-level trend for St. Petersburg, Florida, 1948–2009. The mean sea-level trend is 2.36 millimeter per year (mm/yr) with a 95 percent confidence interval of ± 0.29 mm/yr based on monthly mean sea-level data from 1947 to 2006, which is equivalent to a change of 0.77 feet in 100 years. Accessed at *http://tidesandcurrents.noaa.gov/sltrends/sltrends_station.shtml?stnid=8726520*.

Increasing Temperature

Over the next two decades, the IPCC (2007) has projected that global mean air temperature will warm at a rate of about 0.2 °C per decade, with the greatest warming occurring over land and at high northern latitudes, and the least occurring over the Southern Ocean and parts of the North Atlantic Ocean. Sea-surface temperatures have also been increasing in tropical and subtropical waters, rising by an average of 0.3 °C between the 1950s and 1990 (FOCC, 2009). Probable impacts of the ongoing temperature increase that are anticipated to occur during the 21st century include: increased eutrophication (due to enhanced physiological activity by bloom-forming phytoplankton and macroalgae); increased stress, disease, and mortality among corals, sponges, and fishes (due to factors such as temperature stress, more frequent disease outbreaks, more frequent harmful algal blooms, and more frequent hypoxic events); and changes in the geographic distributions of native and introduced species (due to net northward shifts of species in response to changing temperature regimes) (FOCC, 2009).

Increasing Acidification of Coastal Waters

Due to the uptake of additional carbon dioxide, the total inorganic carbon concentration of the world's oceans has increased, causing a decrease in the depth at which calcium carbonate dissolves and a decrease in surface ocean pH. On average, pH has fallen (ocean waters have become more acidic) by 0.1 units since 1750. Observations of pH at available monitoring stations for the last 20 years also show trends of decreasing pH at a rate of 0.02 pH units per decade (Bindoff and others, 2007). Because pH is expressed in a logarithmic scale, changes as small as 0.1 pH units can have large impacts on marine organisms, such as corals, echinoderms, crustaceans, mollusks, and certain plankton whose shells or cell coverings include calcium carbonate (FOCC, 2009). Potential habitat impacts in the Tampa Bay region during the 21st century include variations (upward and then downward) in the productivity of some marine plants as pH declines, reductions in populations of marine organisms that have difficulty tolerating the pH decreases, and increased dissolution of carbonate sediments (FOCC, 2009).

Management Responses

In addition to long-term reductions in anthropogenic emissions of greenhouse gases, the FOCC (2009) recommended a number of steps that can be taken to respond to climate change. Although some habitat-related impacts may have to be accepted as highly probable, such as loss of coral reefs in southern Florida, others could potentially be mitigated. For example, additional coastal lands may be protected from development, so that tidal wetlands will be able to migrate inland with ongoing sea-level rise. Given the difficult social, political, and environmental tradeoffs that will be necessary when formulating such responses, decision makers will require access to sound technical information and interpretive tools. The FOCC (2009), therefore, recommended the following as priority areas for future investigative work:

- Improving the tools available to predict the rate and magnitude of future sea-level rise in Florida, and potential impacts to natural resources, based on existing IPCC emissions scenarios;
- Estimating potential impacts to fisheries productivity due to changes in estuarine habitats caused by climate change; and
- Monitoring, modeling, and mapping the responses of natural systems, such as coral reef communities and other at-risk habitats, to improve managers' abilities to predict the future impacts of climate change on these systems.

Paradigms for Habitat Restoration and Protection

Two basic strategies have been implemented to restore and protect priority habitats in Tampa Bay. These are the "restoring the balance" approach and the "habitat mosaic" approach.

"Restoring the Balance"

To develop an overall strategy for habitat restoration and protection, Lewis and Robison (1995) identified 10 faunal guilds representing major categories of estuarine-dependent species (table 8–2). The species in these guilds were assumed to have developed successful life history strategies based on the optimal use of the various habitat types that existed prior to major anthropogenic impacts in Tampa Bay (circa 1900). Since that time, however, differential rates of habitat loss have produced a greater relative

Table 8–2. Faunal guilds for habitat restoration and land acquisition master plan for Tampa Bay.

[From Lewis and Robison, 1995]

Guild No.	Type	Life history	Common name	Scientific name
1	Open water filter feeder	Adult	Bay anchovy	*Anchoa mitchilli*
			Atlantic menhaden	*Brevoortia tyrannus*
			Atlantic thread herring	*Opisthonema oglinum*
2	Shallow water forage fish	Adult	Striped killifish	*Fundulus majalis*
			Sheepshead killifish	*Cyprinodon variegatus*
			Silver perch	*Bairdiella chrysoura*
			Spot	*Leiostomus xanthurus*
			Clown goby	*Microgobius gulosus*
			Lined sole	*Achirus lineatus*
			Hogchoker	*Trinectes maculatus*
3	Recreationally and commercially important fish and shellfish	Juvenile	Tarpon	*Megalops atlanticus*
			Red drum	*Sciaenops ocellatus*
			Common snook[1]	*Centropomus undecimalis*
			Spotted seatrout	*Cynoscion nebulosus*
			Striped mullet	*Mugil cephalus*
			Blue crab	*Callinectes sapidus*
			Pink shrimp	*Farfantepenaeus duorarum*
4	Subtidal invertebrates	Adult	Soft bottom deposit feeders	
			Caridean shrimp	
5	Intertidal invertebrates	Adult	Fiddler crabs	*Uca* spp.
			Horn shells	
6	Estuarine molluscs	Adult	Marsh snails	
			Marsh clam	*Rangia* spp.
			Crown conch	*Melongena corona*
7	Estuarine dependent birds	Adult	Brown pelican[1]	*Pelecanus occidentalis*
			Least tern[2]	*Sterna antillarum*
			Reddish egret[1]	*Egretta rufescens*
			American oystercatcher	*Haematopus palliatus*
			Roseate spoonbill[1]	*Platalea ajaja*
			Willet	*Catoptophorus semipalmatus*
			Laughing gull	*Leucophaeus atricilla*
8	Estuarine dependent birds requiring freshwater foraging habitat (during nesting season)	Adult	White ibis[1]	*Eudocimus albus*
			Snowy egret[1]	*Egretta thula*
			Little blue heron[1]	*Egretta caerulea*
9	Estuarine reptiles	Adult	Diamondback terrapin	*Malaclemys terrapin*
			Mangrove water snake	*Nerodia clarkii compressicauda*
10	Marine mammals	Adult	Manatee[3]	*Trichechus manatus*
			Bottlenose dolphin	*Tursiops truncatus*

[1]Listed by the Florida Game and Freshwater Fish Commission (FGFWFC) as species of "special concern."
[2]Listed by the FGFWFC as "threatened."
[3]Listed by the FGFWFC and U.S. Fish and Wildlife Service as "endangered."

abundance of some habitat types (for example, mangrove forest) and a lower relative abundance of others (for example, oligohaline marsh). If a more-impacted habitat type is essential to the life history requirements of a species, it is assumed that this differential habitat loss could create a choke point or limiting factor on the overall population size of that species. Lewis and Robison (1995) also assumed that it would not be possible to restore all lost or impacted habitats, and that human needs will continue to put pressure on remaining habitats in the Tampa Bay watershed.

Given those assumptions, Lewis and Robison (1995) proposed the use of a "restoring the balance" strategy, which seeks to restore the historic relative proportions rather than the total predevelopment acreage of the priority habitat types. Under this paradigm, restoration activities are focused on habitats whose spatial extent has been disproportionately reduced or degraded.

It is important to note that all species in the identified faunal guilds (table 8–2) have geographic ranges that extend far beyond the boundaries of Tampa Bay. Their life history strategies have presumably been shaped by the spatial distributions and magnitudes of key habitat types on these larger geographic scales. However, the "restoring the balance" paradigm has been generally accepted by bay managers as a useful conceptual model for local habitat restoration and land acquisition activities. It has been an attractive model, largely because its expectations are realistic, given that it is not economically feasible to restore the Tampa Bay ecosystem to predevelopment conditions. Also, the resulting restoration goals and targets are based on living resources, and are tied to the habitat needs of recognized ecologically and economically important species (PBS&J, 2009).

Since its adoption as a key element of the Tampa Bay Comprehensive Conservation and Management Plan (TBEP, 1996), the "restoring the balance" strategy has had a significant influence on habitat restoration project designs and, to a lesser extent, decisions on acquisition of public land. A clear priority was established for restoring low salinity tidal marshes, which were identified by Lewis and Robison (1995) as the emergent wetland habitat type that had been disproportionately impacted. In response, most publicly funded habitat restoration projects conducted since the mid-1990s have attempted to incorporate a "salinity gradient" component into their designs, using available freshwater sources, thus emphasizing oligohaline habitats in an effort to be consistent with the paradigm (PBS&J, 2009). However, as described in the following section, such attempts have been limited to specific sites on an opportunistic basis.

The "Habitat Mosaic" Approach

Most public restoration lands are acquired opportunistically as they become available on the real estate market. Thus, it has generally not been feasible to implement the "restoring the balance" paradigm on the watershed scale via strategic land acquisitions and restoration of large contiguous systems. Therefore, the paradigm has been implemented on a smaller scale through what is termed a "habitat mosaic" approach, pioneered by the SWFWMD Surface Water Improvement and Management Program (Henningsen, 2005).

In this approach, an attempt is made on each habitat restoration site to incorporate a diversity of habitat types and functions, as opposed to a single habitat type. As it has evolved, the approach has come to incorporate such habitats as undulating shorelines, coves and embayments, shallow subtidal flats, deep subtidal pools, artificial reefs, oyster bar substrates, and salinity gradients ranging from freshwater wetlands to semi-isolated brackish ponds to braided tidal channels (Henningsen, 2005). Where feasible, attempts are also made to provide for "polishing" of stormwater runoff (improving the water quality via natural hydrological and ecological processes) from adjacent urban and agriculture land uses. In addition, designs since the early 1990s have increasingly emphasized acquisition of high marsh and coastal upland components in anticipation of sea-level rise. Although a comprehensive summary of all the public and private sector projects has not yet been compiled, available data indicate that at least 5,065 acres of such habitat have been established, enhanced, or protected in the Tampa Bay area in recent years (PBS&J, 2009).

Habitat Restoration and Protection Targets

Quantitative restoration targets can be calculated for the emergent tidal wetland habitats. However, more mapping and data collection must be completed on other habitats (oyster bars, hard bottom, tidal tributaries, artificial habitats, coastal uplands, and coastal freshwater flatwoods and marshes) before similar restoration targets can be established for them.

Emergent Tidal Wetlands

Using the "restoring the balance" paradigm, quantitative restoration targets can be calculated for the three types of emergent tidal wetlands (mangroves, oligohaline marshes, and salt barrens) that were identified by Lewis and Robison (1995) as the initial focus of the Tampa Bay habitat management effort. An overall acreage target for emergent tidal wetlands is calculated by dividing the most recently computed (in this case, 2006) acreage of the least impacted habitat (mangrove/polyhaline marsh) by its proportional 1950 acreage (0.247 for mangrove/polyhaline marsh). This formula produces a bay-wide target acreage for all emergent tidal wetlands of 59,287 acres. From this total restoration target, the other habitat targets can be determined by multiplying their 1950 proportional acreage by the total bay-wide restoration target. Results of these calculations, which are updated periodically as new land cover maps become available, are shown in table 8–3.

As indicated in table 8–3, under current conditions the Tampa Bay mangrove forest target is being met, but additional work is needed to reach the salt marsh and salt barren targets. The policy implications of this analysis are that future habitat restoration and protection efforts in Tampa Bay should continue to focus strongly on low salinity salt marsh habitats, as well as hypersaline salt barren and high marsh habitats. These two habitat types have been lost in disproportionate amounts compared to mangrove forest habitat. Furthermore, these two habitat types appear to be more seriously threatened by the anticipated impacts of climate change, sea-level rise, and consumptive water use (PBS&J, 2009).

Table 8–3. Summary of recommended protection and restoration targets for Tampa Bay habitats.

[From PBS&J, Inc., 2009]

Habitat type	Estimated 2000 extent	Target	Comments
Mangrove/polyhaline marsh	14,644 acres	Protect existing	Target currently met
Oligohaline marsh	4,386 acres	6,107 acres	Restore 1,721 acres
Salt barren	493 acres	1,245 acres	Restore 752 acres
Oyster bars	Insufficient information	Protect existing	Need comprehensive inventory and mapping
Hard bottom	Insufficient information	Protect existing	Need comprehensive inventory and mapping
Tidal tributaries	Insufficient information	Protect existing	Need comprehensive inventory and mapping
Artificial habitats	538 currently in place	Protect existing and enhance as appropriate	
Coastal uplands	9,000 acres	Protect existing	Dependent on public acquisition
Coastal freshwater flatwoods marshes	26,800 acres	Protect existing	For bay management purposes, focus on freshwater marshes within 9.3 miles of the bay shoreline

Other Habitat Types

Comprehensive inventory and mapping of other key habitat types have not yet been completed, and it is not possible to establish quantitative restoration targets for them at this time. Nonetheless, the establishment of qualitative protection targets is appropriate. Oyster bars and hard bottom habitats, for example, are protected under Federal wetland regulations because they are submerged habitats and recognized as “essential fish habitat.” They are also protected under State wetland regulations and sovereign lands rules. Although permits can be issued for the dredging and/or filling of these habitats, such permits would require significant mitigation. Both are relatively rare and important habitat types in Tampa Bay and, therefore, have been identified as habitats of special concern that should be afforded a very high level of protection (PBS&J, 2009).

Tidal tributary habitats are important in maintaining hydrologic connectivity between open bay waters, tidal rivers, and smaller tidal creeks, and in facilitating fish movement, water flow, and nutrient fluxes between the watershed and the estuary. Fish require a mosaic of habitats throughout their life cycle; management of such habitats is most effective when it is based on a system-wide scale. This concept is important in terms of the landscape’s connectivity to the surface waters, as well as for biogeochemical processes that promote desirable conditions within the tributaries for biotic resources. Therefore, wherever it is technically and economically feasible, and not contrary to the public interest (for example, with respect to flood protection), the removal of existing salt barriers and impoundments in Tampa Bay tidal tributaries and the restoration of tributaries to a free-flowing condition should be considered.

In addition, measures to reduce the effects of imperviousness on stormwater runoff delivered to tidal tributaries should be considered wherever it is technically feasible. Although provisions to attenuate and treat stormwater discharges already exist in State rules, further attenuation may be needed to promote natural hydrologic regimes and foster productivity of benthic micro-algae and trophic intermediates in tidal tributaries. Maintaining and restoring natural wetlands and riparian corridors within the watersheds of tidal tributaries, and considering additional methods for increasing dynamic watershed storage and gradual release throughout their basins, have been put forth as primary recommendations (TBTTRT, 2008; PBS&J, 2009).

Artificial habitats are manmade features that perform numerous beneficial functions to offset past adverse impacts. For these reasons, existing and future artificial habitats in Tampa Bay have been recognized as important habitat types that should be protected and enhanced, as appropriate (PBS&J, 2009). Artificial habitats, including artificial reefs, oyster domes, and lime rock rip-rap shoreline fills, are essentially manmade enhancements to existing conditions. They are most effective in increasing habitat diversity and richness in areas lacking vertical structure and/or suitable substrates, such as bare sand bottom or vertical seawalls. Therefore, a true "restoration" goal based on historical habitat cover for artificial habitats is not appropriate. However, it is appropriate to propose a quantitative establishment target for artificial habitats. A minimum of 1 linear mile of vertical seawall could be fit with oyster domes each year. Although this is a subjective target, it is economically feasible because much of the labor for these projects is performed by volunteers.

It is also appropriate for existing local and State programs to continue to operate as they have in the past with respect to artificial reef construction in bay waters, as dictated by available material and funds. Submerged artificial habitats are likely to be protected under Federal wetland regulations and have been recognized as "essential fish habitat" in some instances. Similarly, artificial habitats may be protected under State wetland regulations and sovereign lands rules. Although permits can be issued for the dredging and/or filling of established artificial habitats, such permits would likely require significant mitigation.

Coastal uplands are not a single habitat type, but include a complex of mesic flatwoods and hydric hammocks that occur just landward of emergent tidal wetlands. For management purposes in the Tampa Bay region, they are defined as occurring within 3 mi of the bay shoreline (PBS&J, 2009). The upland regions are not protected by Federal or State wetland regulations and, therefore, are highly susceptible to urbanization and other forms of land development. Acquisition is likely to be the most effective way to protect them. They are habitats of special concern, and are considered a very high priority for acquisition, protection, and restoration (PBS&J, 2009).

With respect to freshwater wetlands, flatwoods marshes located within the foraging range of coastal-nesting white ibis rookeries are a key habitat type for the Tampa Bay management effort. There are currently an estimated 26,800 acres of flatwoods marshes located within 9.3 mi of the bay shoreline, the estimated foraging distance of nesting white ibis when seeking food for their young (Tampa Audubon Society, 1999). These freshwater wetlands are protected under Federal, State and local wetland regulations, and although permits can be issued for dredging and/or filling them, such permits typically require mitigation. Flatwoods marsh habitat is an important habitat type in the Tampa Bay watershed and, therefore, has been recognized as a habitat of special concern that would benefit from the highest level of protection that is possible under existing Federal and State law and local ordinances.

In addition to these issues, a number of other topics related to the Tampa Bay habitat management program have been addressed in recent years. These topics include the use of wetland functional assessments, the development of recommended wetland mitigation criteria, and the development of monitoring and assessment recommendations for habitat restoration projects. Detailed summaries of these issues are provided by Lewis and Robison (1995), the TBEP Mitigation Criteria Working Group (1999), and PBS&J (2009).

Finally, steps have also been taken to improve survival rates of the endangered Florida manatee (*Trichechus manatus latirostris*) in shallow-water habitats within the bay. Manatees are protected by the Florida Manatee Sanctuary Act (§370.12(2), Florida Statutes) and the Federal Marine Mammal Protection and Endangered Species Acts, and parts of Tampa Bay have been designated as critical habitat for the species. Collisions with boats account for about 25 percent of all documented manatee deaths in Florida (Calleson and Frohlich, 2007). To reduce this source of mortality in the Tampa Bay area, the Florida Fish and Wildlife Conservation Commission proposed a number of manatee protection zones whereby boat operation or operation speeds would be regulated (through the establishment of no entry, slow speed, or idle speed areas) on a year-round or seasonal basis. Pursuant to State law, a local rule review committee was convened to evaluate and provide local perspectives on the proposed zones. Following extensive input from the committee, and the adoption of additional regulated boating speed zones by city and county governments, a network of manatee protection areas (shown in fig. 8–19) was implemented in 2003. Regulation of boat speed limits in these areas are believed to reduce mortality risk for manatees by providing a greater reaction time for both the boat operator and the manatee, and by reducing the severity of injuries in the event that a collision occurs (Calleson and Frohlich, 2007).

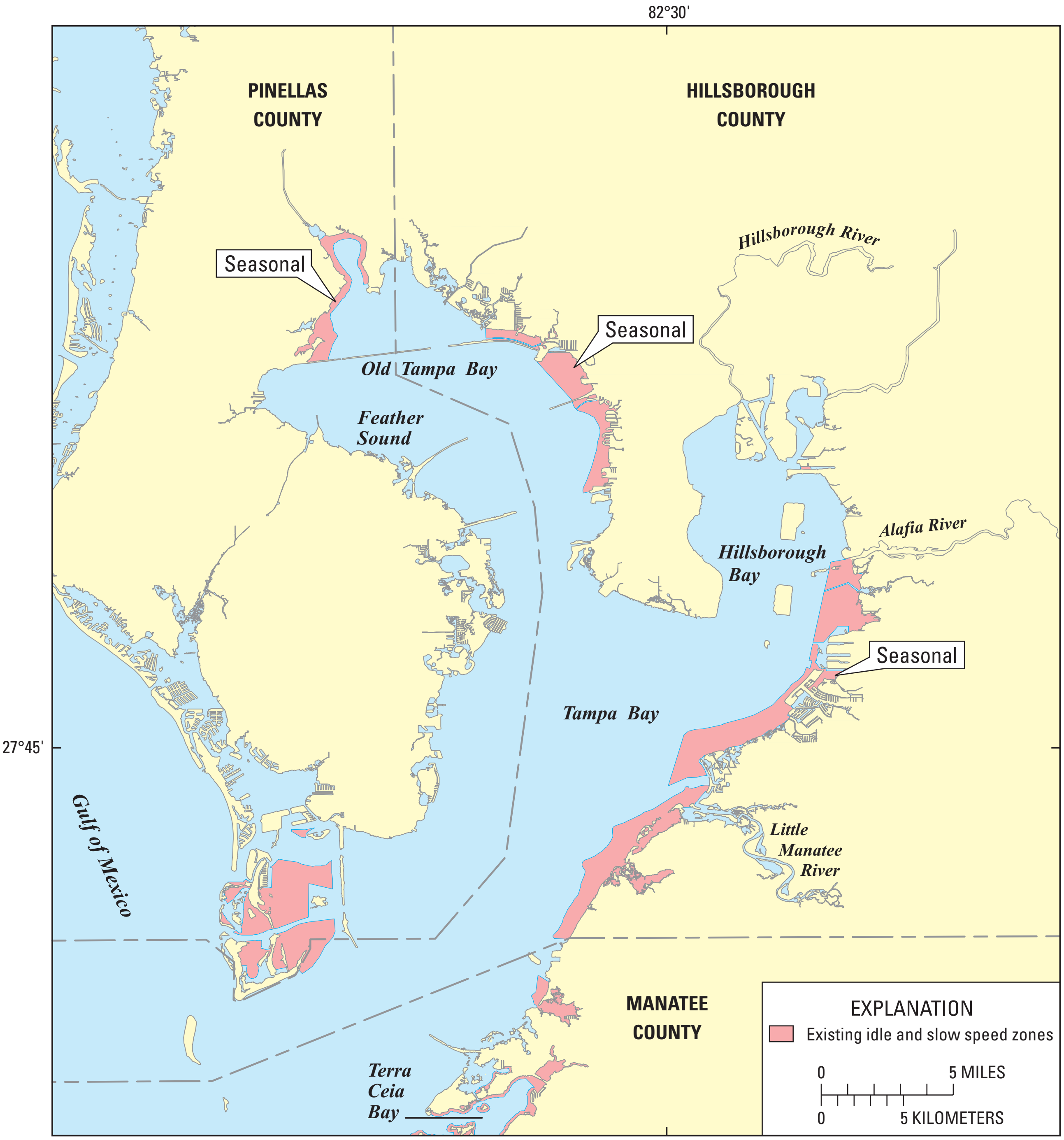

Figure 8–19. Manatee protection zones in Tampa Bay. From Environmental Protection Commission of Hillsborough County (2007).

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