STATUS AND TRENDS OF WETLAND AND AQUATIC HABITATS ON BARRIER ISLANDS, FREEPORT TO EAST MATAGORDA BAY, AND SOUTH PADRE ISLAND

by

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EXECUTIVE SUMMARY

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Introduction

Wetland and aquatic habitats are essential components of barrier islands along the Texas coast. These valuable resources are highly productive biologically and chemically and are part of an ecosystem in which a variety of flora and fauna depend. Scientific investigations of wetland distribution and abundance through time are prerequisites to effective habitat management, thereby ensuring their protection and preservation and directly promoting long-term biological productivity and public use. This report presents results of two investigations designed to determine current status and historical trends of wetlands and associated aquatic habitats along (1) the Texas Gulf coast from Christmas Bay southwestward to East Matagorda Bay, an area that includes the Brazos River delta near Freeport, and (2) South Padre Island and Brazos Island, the barrier island system that extends to the Rio Grande south of Padre Island National Seashore. The northern study area is within Brazoria and Matagorda Counties and the southern study area is within Cameron and Willacy Counties (Fig. I).

The two study areas are very different. The area near Freeport is part of a delta plain without natural barrier islands. Islands that front this part of the coast were created by the Gulf Intracoastal Waterway (GIWW) that was dredged across this mainland area to connect the Galveston Bay system with the Matagorda Bay system. Included in this area is the San Bernard National Wildlife Refuge (SBNWR). Along this stretch of coast, the Brazos and San Bernard Rivers discharge into the Gulf of Mexico.

South Padre and Brazos Islands, in the South Texas study area, are barrier islands that separate the Gulf of Mexico from Laguna Madre and South Bay, respectively. These barriers are characterized by broad beaches, vegetation stabilized dunes, active dune fields, expansive wind-tidal flats, hurricane wash-over channels, brackish- and salt-water ponds and marshes, and black mangrove communities. Included in this study area are South Bay and the surrounding area that is located between the lower end of the Brownsville Ship Channel and the Rio Grande.

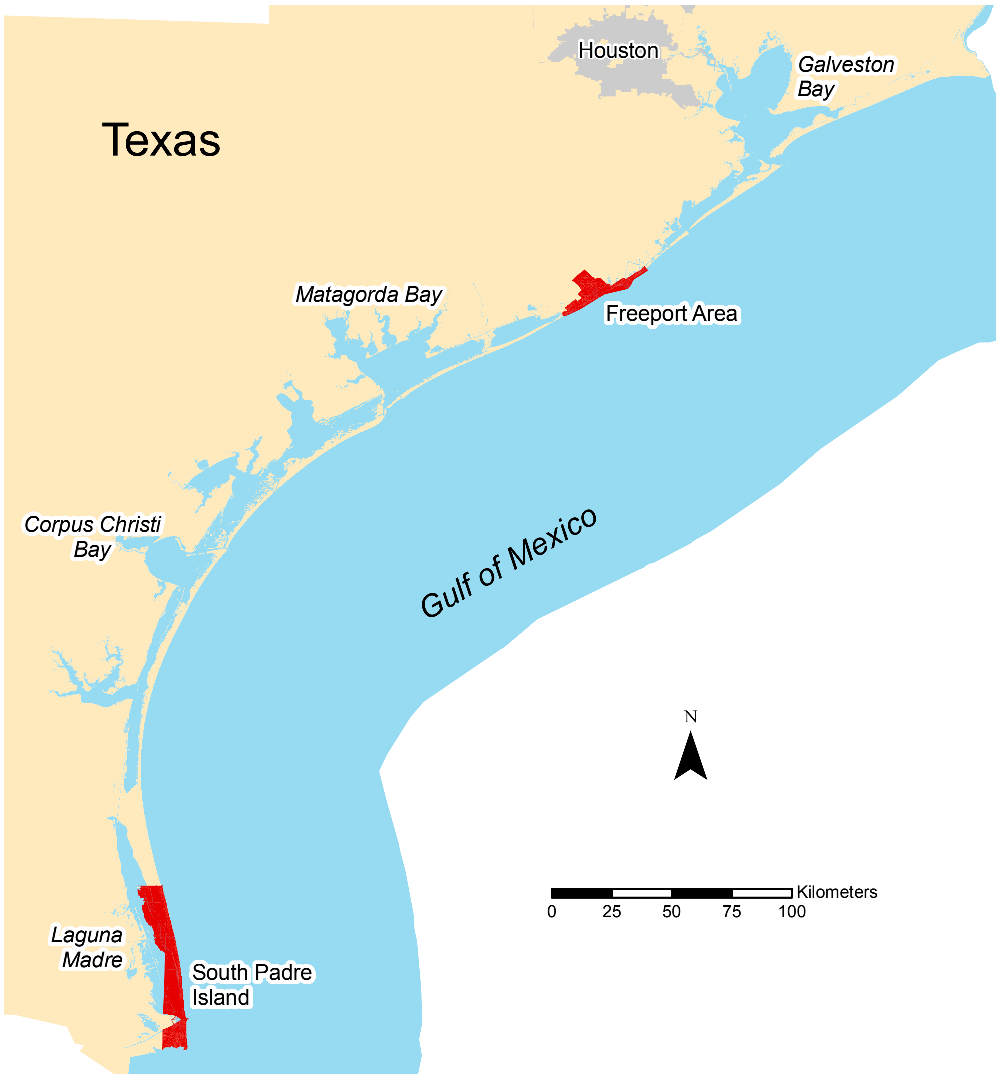

Figure I. Index map of wetland status and trends study areas.

Methods

This study of status and trends is based on wetlands interpreted and mapped on recent and historical aerial photographs. Current distribution (status) of wetlands was determined using color infrared (CIR) photographs taken in 2002. Historical distribution is based on 1950's black-and-white and 1979 CIR photographs. Mapped wetlands for each period were digitized and entered into a GIS for analysis. The historical GIS maps were obtained from the U.S. Fish and Wildlife Service (USFWS), who mapped the wetlands using methods established as part of the National Wetlands Inventory program. Methods included interpreting and delineating habitats on aerial photographs, field checking delineations, and transferring delineations to 1:24,000-scale base maps using a zoom transfer scope. The resulting maps were digitized and entered into a GIS, producing GIS maps for the two time periods. Both the 1950's and 1979 series USFWS maps, which are in digital format, were partially revised in this project to be more consistent with wetlands interpreted and delineated on the 2002 photographs.

Methods used to delineate 2002 habitats differed from the earlier methods. The 2002 photographs were scanned to create digital images with a pixel resolution of 0.5 m, and registered to USGS Digital Orthophoto Quadrangles (DOQ's). Mapping of wetlands and aquatic habitats was accomplished through interpretation and delineation of habitats on screen in a GIS at a scale of 1:4,000. The resulting current-status GIS maps were used to make direct comparisons with the historical GIS maps to determine habitat trends and probable causes of trends.

Wetlands were mapped in accordance with the classification by Cowardin et al. (1979), in which wetlands are classified by system (marine, estuarine, riverine, palustrine, lacustrine), subsystem (reflective of hydrologic conditions), and class (descriptive of vegetation and substrate). Maps for 1979 and 2002 were additionally classified by subclass (subdivisions of vegetated classes only), water-regime, and special modifiers. Field sites were examined to characterize wetland plant communities, define wetland map units, and ground-truth delineations. Topographic surveys conducted at several field sites provided data on relative elevation that helped define habitat boundaries and potential frequency of flooding, or water regimes.

In analyzing trends, wetland classes were emphasized over water regimes and special modifiers because habitats were mapped only down to class on 1950's photographs. We would also like to note that there is a margin of error in interpreting and delineating wetlands on aerial photographs, transferring delineations to base maps, and georeferencing the different vintages of maps to a common base for comparison. Accordingly, we have more confidence in the direction of trends than absolute magnitudes. Probable causes of historical changes are presented in discussions of geographic subareas.

Freeport to East Matagorda Bay

The Brazos and San Bernard Rivers cross the Freeport to East Matagorda Bay study area and discharge southwest of Freeport into the Gulf of Mexico. In 1929, the lower reach of the Brazos River was diverted so that the mouth of the river now discharges about 10 km down the coast (southwest) from its original location near Surfside (McGowen et. al. 1976). The "abandoned" part of the channel has been jettied and dredged to create the Freeport Ship Channel. At the diverted mouth of the Brazos River, a new delta has formed consisting of numerous beach ridges and interlying swales that are the sites of marshes and ponds. Except for progradation of this delta, historically high rates of erosion have characterized this part of the Texas coast, which is part of the relict deltaic headland of the Colorado and Brazos Rivers (McGowen et al. 1976). Erosion rates have locally exceeded 12 m/yr (Morton and Pieper, 1975; Paine and Morton, 1989; Gibeaut, et. al., 2000). The high rates of erosion have threatened to intersect the GIWW in one area, requiring construction of a seawall to protect the waterway. Most of the study area extends from the Gulf shoreline to the GIWW except in the vicinity of the San Bernard National Wildlife Refuge (SBNWR) where the area of study extends inland encompassing most of the Refuge and an area to the southwest near Caney Creek.

Current Status, 2002

Major habitats in the estuarine and palustrine system include salt, brackish, and fresh marshes, tidal flats, oyster reefs, aquatic beds, and Gulf beaches. Estuarine open water is also an important component of the salt and brackish marsh complex. The primary habitats mapped in the marine system are (1) the Gulf beach, which consists of the topographically lower fore beach and a higher, less frequently flooded backbeach, and (2) a belt of marine water that fringes the shoreline and extends out into the Gulf about 1 km marking the seaward boundary of the study area.

In 2002, wetland and aquatic habitats (excluding open water) were dominated by estuarine marshes(Fig. II), with a total area of about 8,320 ha (20,542 acres), followed by palustrine marshes totaling 1,330 ha (3,284 acres) These marshes make up 45% of the Freeport–East Matagorda Bay study area. Other major components of the study area are oyster reefs, open water, and uplands. The study area was subdivided into geographic areas – Brazos River delta, SBNWR, and Caney Creek area to allow a more site-specific analysis of status and trends (Fig. III). Included in the Brazos River delta subarea, is the stretch of shore from the Freeport Ship Channel to the San Bernard River, and in the Caney Creek subarea, the stretch of coast from the SBNWR boundary at Cedar Lakes southeastward to the area around Caney Creek.

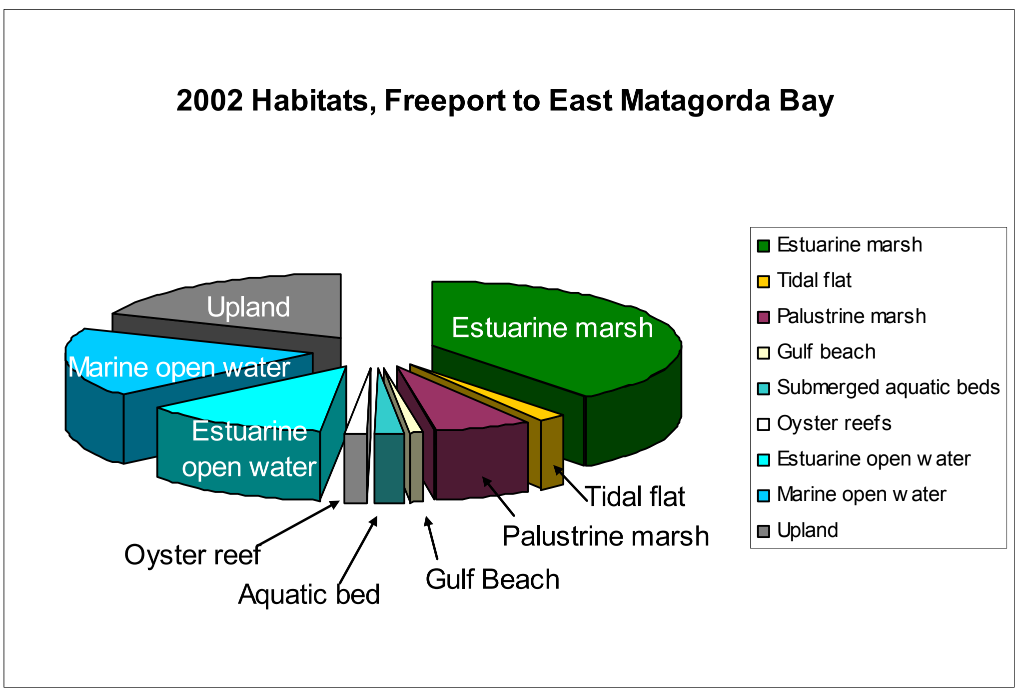

Figure II. Areal distribution of selected habitats in the Freeport–East Matagorda Bay study area in 2002.

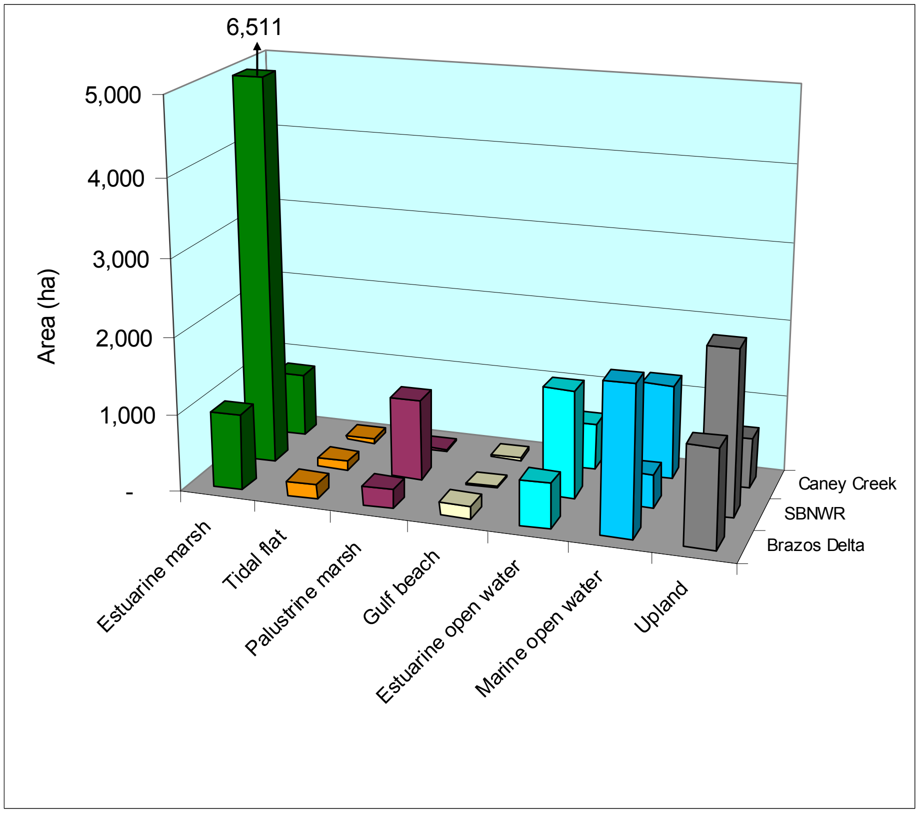

Figure III. Distribution of selected habitats by geographic areas (Brazos Delta, SBNWR, and Caney Creek) in 2002. The most extensive estuarine and palustrine marshes are in the SBNWR.

The most extensive estuarine emergent wetlands (salt and brackish water marshes) occur in the SBNWR where more than 6,500 ha (16,055 acres) of estuarine marsh was mapped on 2002 photos (Fig. III). The Refuge also contains the most palustrine marsh (1,052 ha; 2,598 acres), estuarine open water (1,400 ha; 3,458 acres), and oyster reefs (>200 ha; 494 acres) (reefs not shown in figure). Tidal flats are not widely distributed in this coastal area. Of the three subareas, the Brazos Delta has the most extensive tidal flats (185 ha; 457 acres) and Gulf beaches (166 ha; 410 acres) (Fig. III).

Wetland Trends and Probable Causes, 1950's–2002

From the 1950's to 2002 within the Freeport to East Matagorda Bay study area, there were losses and gains in most habitats. Analyses of spatial and temporal changes show that there was a net gain in estuarine marshes from the 1950's to 2002 (Fig. IV). The total area of marshes increased from 7,727 ha (19,086 acres) in the 1950's to

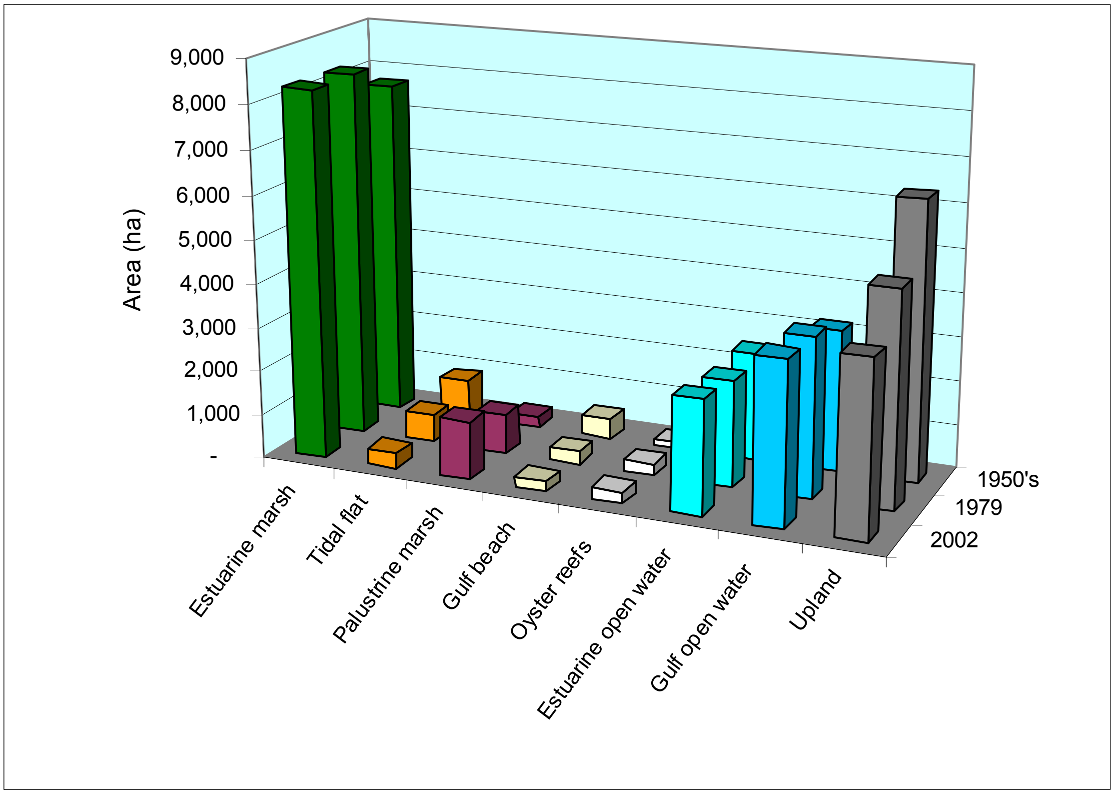

Figure IV. Area (ha) of selected habitats in the Freeport–East Matagorda Bay study area from the 1950's to 2002. Gulf open water that was included in the study area is composed of a fringe of water approximately 700 m wide (in 2002) and parallel to the Gulf beach. As the Gulf beach eroded through time, Gulf open water increased in area, but most of the increase in area was caused by a large misregistration in the 1950's data set.

Table I. Total area of major habitats in the Freeport–East Matagorda Bay study area in the1950's, 1979, and 2002.

Habitat	***1950's***		***1979***		***2002***	
	(ha)	(acres)	(ha)	(acres)	(ha)	(acres)
Estuarine marsh	7,727	19,086	8,319	20,548	8,319	20,548
Tidal flat	899	2,220	653	1,613	363	897
Palustrine marsh	264	651	887	2,190	1,330	3,285
Gulf beach	460	1,135	310	766	227	561
Oyster reefs	121	299	265	655	267	659
Estuarine open water	2,472	6,106	2,408	5,948	2,591	6,400
Gulf open water	3,224	7,962	3,629	8,964	3,701	9,141
Upland	6,336	15,650	4,881	12,056	3,954	9,766

8,319 ha (20,548 acres) in 1979, where it remained in 2002 (Table I; Fig. IV). This increase amounted to 592 ha (1,462 acres) from the 1950's through 2002. During the same time, there was a systematic decrease in tidal flats (E2FL or E2US). The area of flats declined from 899 ha (2,221 acres) in the 1950's to 653 ha (1,613 acres) in 1979 to 363 ha (897 acres) in 2002 (Table I). These changes reflect losses of 246 ha (608 acres) and 290 ha (716 acres) for each period, respectively. Palustrine marshes (PEM) increased in area by 623 ha (1,540 acres) from the 1950's through 1979 and by 443 ha (1,094 acres) from 1979 through 2002. Estuarine reefs (E1 and E2RF2) are oyster reefs. The mapped area of reefs increased from the 1950's to 1979/2002 by approximately 145 ha (358 acres). Reefs can be obscured by turbid water, however, and total distribution as interpreted on aerial photographs is approximate. The area of estuarine open water increased slightly from the earlier years to 2002 (Fig. IV). Gulf open water in the study area also increased from the 1950's to 1979 and 2002. The amount of mapped uplands in the study area decreased from the 1950's to later years. Probable causes of changes in habitats are presented in the following sections organized by geographic area.

The most significant trend, or change, on the **Brazos River Delta** and surrounding area was the loss of estuarine marsh from the 1950's to 1979 and 2002. Although there were losses and gains in marshes at different locations through time, the total area of marsh habitat, which was about 1,430 ha (3,532 acres) in the 1950's, decreased in size by 683 ha (1,687 acres) through 1979, but increased by 231 ha (571 acres) from 1979 to 2002. The net loss from the 1950's to 2002 was 452 ha (1,116 acres). This decrease in marsh represents a loss of about 30% of this habitat in the Brazos Delta subarea since the 1950's. Also, there was a systematic decrease in the area of tidal flats and Gulf beach from the 1950's to 2002. Palustrine marshes increased in area during this period, although the total area of this habitat was relatively small. The 30% decline in estuarine marsh from the 1950's to 2002 occurred as marshes that had developed at the mouth of the diverted Brazos River (see introduction) were eroded along the Gulf shoreline. Part of the loss was offset by delta progradation down drift of the mouth of the river where development of new marshes occurred. In addition, construction of the GIWW impacted wetlands as disposal of dredged material converted many to uplands. GIS overlay analysis of habitat distribution indicates that approximately 50% of the marsh loss in the Brazos delta subarea was the result of conversion to upland habitat.

San Bernard National Wildlife Refuge (SBNWR) experienced a systematic gain in estuarine and palustrine marshes between the mid-1950's and 2002. Palustrine marsh increased from a mid-1950's total of 241 ha (596 acres) to 801 ha (1,979 acres) in 1979 representing an increase of 232%. The subsequent increase to 1,052 ha (2,600 acres) in 2002 represents an additional 31%. As much as 75% of the gross palustrine marsh gain in the earlier time period occurred where mid-1950's uplands were mapped in 1979 as palustrine marsh. The later, much smaller, increase in palustrine marsh can be attributed to artificial modifications to the refuge landscape. Levees constructed to raise road beds above the surrounding marsh created a barrier to water movement. Surface hydrologic changes increased the amount and decreased the salinity of impounded water. A similar process occurred in disposal pits along the GIWW. While advancing the refuge goal of increasing fresh water habitat, these practices drowned marshes in some areas. High rates of palustrine marsh increase were experienced throughout the study time period but at a significantly reduced rate in the later time period. The largest wetland habitat by area in the SBNWR, estuarine marsh, increased from 5,054 ha (12,489 acres) in the mid-1950's to 6,414 ha (15,849 acres) in 1979, representing a 27% increase. By 2002 that area had increased to 6,511 ha (16,089 acres), an additional 2%. As with the palustrine marsh gain, most of the gross estuarine marsh gain (~78%) occurred where marsh migrated into uplands. Marsh area also increased as estuarine marsh moved into flat and open water areas along the periphery of the Cedar Lakes. Estuarine marsh habitat area increased in both study time periods but at much lower overall rates than palustrine marsh. Loss of estuarine marsh in the SBNWR can be attributed to several factors. Excavation and impoundment in habitat management areas and along the GIWW have reduced estuarine marshes through conversion to other habitats. The Cedar Lakes region of the Texas coast experienced one of the highest rates of shoreline erosion, replacing estuarine marsh with marine open water and shifting upland and flat habitats into previous marsh areas. The area surrounding the Cow Trap Lakes has experienced a systematic loss of estuarine marsh throughout the study time period. In this location excessive water fowl herbivory, in conjunction with relative sea-level rise, has converted large areas of estuarine marsh to aquatic beds and open water. Tidal flat habitat experienced a systematic decline during the study time period, primarily in the Cedar Lakes region. The mid-1950's total of 355 ha (877 acres) of tidal flat decreased to 286 ha (707 acres) by 1979 representing a 19% decrease. Roughly 50% of the tidal flat habitat became estuarine marsh during this time period. Tidal flat numbers continued to decline at a significantly higher rate between 1979 and 2002 when numbers decreased to 114 ha (282 acres; 60% decrease). Approximately 42% of the 1979 tidal flat habitat converted to estuarine marsh by 2002.

The most significant trend, or change, in the **Caney Creek** subarea was a loss of about 31% of the estuarine marsh habitat from the 1950's to 2002. The total area of salt and brackish marshes, which covered 1,210 ha (2,989 acres) in the 1950's, declined by 380 ha (939 acres) to a total of 830 ha (2,050 acres) by 2002. Coincident with the loss of marsh in this subarea was an increase in marine open water of 503 ha (1,242 acres). Other changes included a decline in tidal flats and Gulf beaches, and a systematic increase in estuarine open water through time. Palustrine marsh had a relatively small area of 14 ha in the 1950's, and increased slightly to 33 ha (82 acres) in 2001. The 31% decline in estuarine marsh habitat in the Caney Creek subarea can be attributed principally to (1) retreat of the Gulf shoreline and erosion of marshes, and (2) conversion of marshes to uplands through (a) residential development along Caney Creek, (b) dredged material disposal along the GIWW, and (c) seawall construction to protect the GIWW. Approximately 45% of the gross loss in marsh occurred from erosion and conversion of marsh to marine open water as the Gulf shoreline retreated, and about 30% of the loss occurred from conversion of marsh to uplands.

South Padre Island

The study area includes South Padre Island from Mansfield Channel southward to the Brownsville Ship Channel (Brazos Santiago Pass), and Brazos Island from Brazos Santiago Pass to the Rio Grande. Also included is the South Bay area, which is bound by Brazos Island to the east, the Rio Grande to the south, and the Brownsville Ship Channel and Laguna Madre to the north. The study area encompasses parts of 8 USGS 7.5' quadrangles, and is located within Cameron and Willacy Counties.

Unlike estuaries of the central and upper Texas coast where rivers discharge into bays forming typical estuaries diluted by fresh water inflows, the Rio Grande in South Texas discharges into the Gulf of Mexico. Laguna Madre has no major rivers discharging into it. That fact, coupled with the fact that this area receives the least amount of precipitation of all areas along the Texas coast (average annual precipitation in Willacy County is about 70 cm and in Cameron County 68 cm) (Texas Almanac, 2000-2001) contribute to high salinities in Laguna Madre. In addition to high salinity regimes, climate strongly dictates the relative importance of many significant geological processes. Among them, the direction and intensity of persistent winds that control the movement of wave trains approaching shore and the resulting direction of long shore currents and sediment transport. Geologically, South Padre Island developed initially as a spit extending from the eroding, relict Rio Grande Holocene-Modern deltaic system that has been retreating for hundreds of years (Brown et al., 1980). Most of South Padre Island's Gulf shoreline has been eroding except at the southern end near the jetties, which were constructed in 1935 (Morton and Pieper, 1975).

Current Status, 2002

In 2002, wetland, aquatic, and upland habitats covered 46,289 ha (114,382 acres) within the South Padre Island study area. This area includes buffer zones of open water roughly 1 km wide that parallels the shoreline in Laguna Madre and the shoreline in the Gulf. Approximately 6,885 ha (17,013 acres) within the study area was classified as uplands. Of the four wetland systems mapped, the estuarine system is the largest. The largest habitats are the wind-tidal and algal-flat classes (Fig. V and VI), together covering 21,666 ha (53,538 acres). Emergent vegetated wetlands (E2EM, E2SS, PEM) cover 768 ha (1,898 acres), about 80% of which is estuarine marsh. Another important habitat class is seagrass (E1AB3), which in the study area has an area of almost 4,000 ha (9,884 acres). Seagrass beds extend beyond the study area into Laguna Madre. The extent of all mapped wetlands, deepwater habitats, and uplands for each year is presented in the Appendix 2.

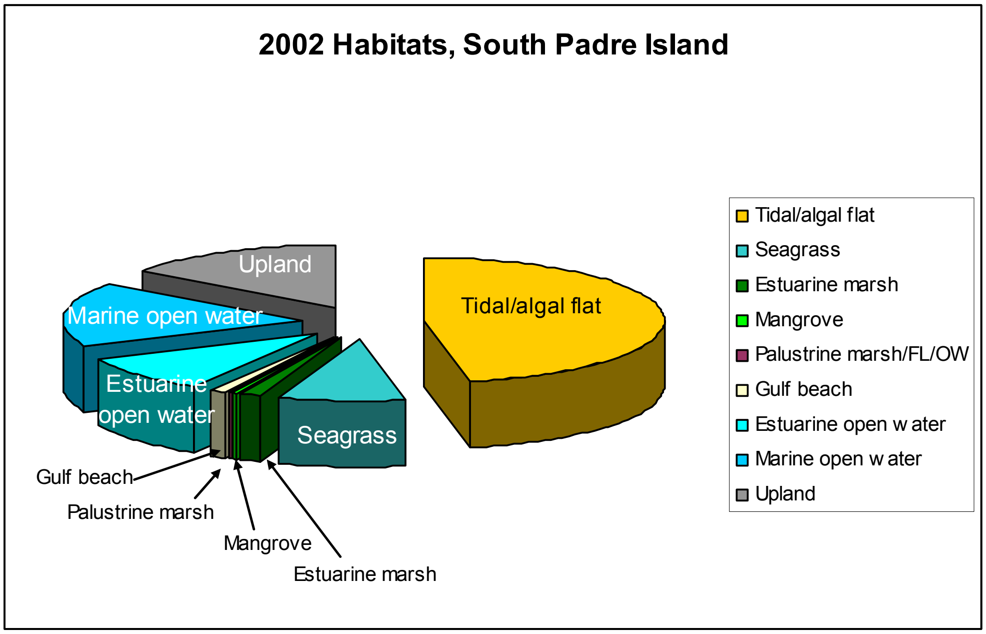

Figure V. Areal distribution of selected habitats in the South Padre Island study area in 2002.

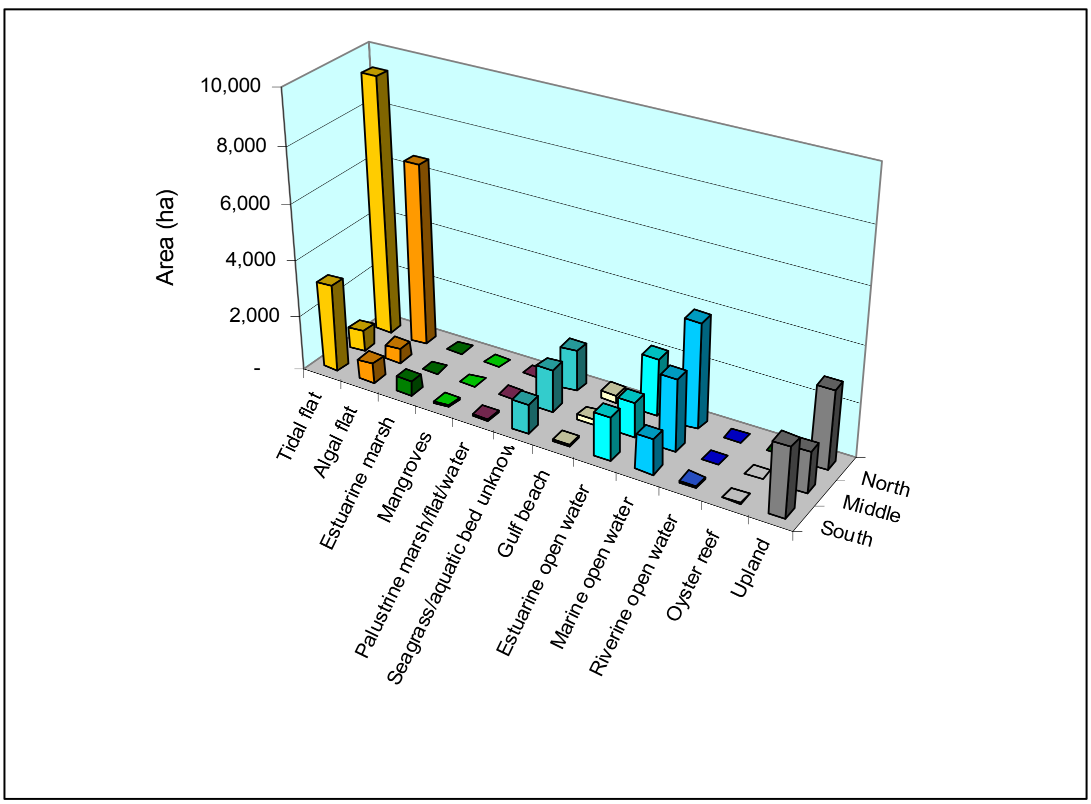

Figure VI. Distribution of selected habitats by geographic area in 2002, South Padre Island study area.

Wetland Trends and Probable Causes, 1950's–2002.

Analysis of trends in wetlands and aquatic habitats from the 1950's through 2002 shows that wind-tidal/algal flats decreased from the 1950's to 1979, and increased slightly from 1979 to 2002 (Table II; Fig. VII). Wind-tidal flats are, by far, the most extensive habitat. The broader distribution in the 1950's may be in part related to the mid-1950's drought when estuarine open water was apparently at lower levels than in 1979 and 2002. Accordingly, more flats would be exposed at that time. Seagrasses appeared to decline from the 1950's to 1979 and then increase to a higher level by 2002. Much of the decline in 1979 may have been an apparent and not real decline, as a result of high water levels and turbidities, which can obscure submerged seagrasses on aerial photographs. The total areas of estuarine marshes were relatively stable, not changing more than about 30 ha (74 acres) between periods. Their spatial distribution, however, was not necessarily the same. Estuarine scrub/shrub wetlands (primarily mangroves) showed an increase in time. Mangroves, however, could not be adequately mapped separately on the black-and-white 1950's photographs and were included with marshes in most areas. There was a real increase in mangrove distribution from 1979 to 2002, which is explained in the later discussion of subarea trends. Palustrine habitats had their largest distribution of 99 ha (245 acres) in 1979. Still, the difference in total area was relatively small in the 1950's (71 ha; 175 acres) and 2002 (87 ha; 215 acres). The large difference in area of estuarine open water, which covered an area almost twice as large in 1979 as in the 1950's and 2002 (Table II), appears to be due to higher water levels "captured" in the 1979 aerial photographs that flooded the tidal flats. This was a coast wide phenomenon. More detailed probable causes of changes are presented in the following sections organized by geographic area.

Table II. Areal distribution of selected habitats, 1950's to 2002, in the South Padre Island study area. Palustrine flat (US) and water (UB) are combined with Palustrine marsh in the table.

Habitats	1950's		1979		2002	
	(ha)	(acres)	(ha)	(acres)	(ha)	(acres)
Tidal/algal flat	23,800	58,786	20,698	51,124	21,666	53,515
Seagrass	3,343	8,257	1,998	4,935	4,033	9,962
Estuarine marsh	584	1,442	612	1,512	604	1,492
Mangrove	12	30	70	173	93	230
Palustrine marsh/US/UB	71	175	99	245	87	215
Gulf beach	393	971	503	1,242	600	1,482
Estuarine open water	4,812	11,886	8,133	20,089	4,487	11,083
Marine open water	6,656	16,440	7,603	18,779	7,709	19,041
Upland	6,475	15,993	6,468	15,976	6,884	17,003

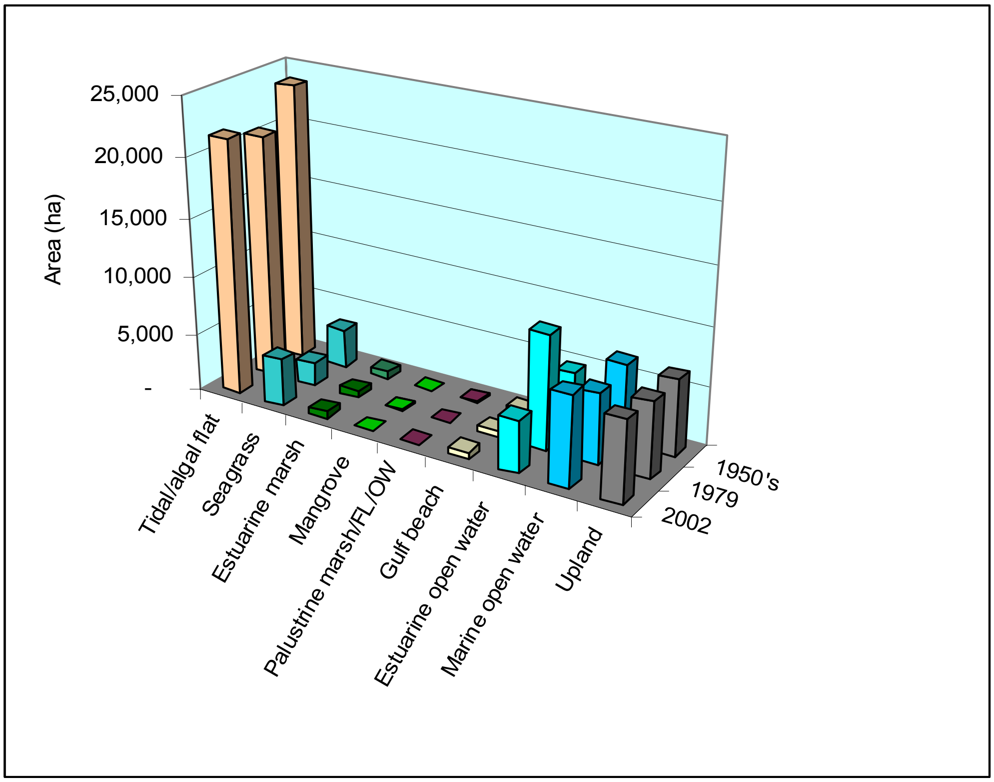

Figure VII. Areal extent of selected habitats from the 1950's to 2002 in the South Padre Island study area.

The most significant habitat trends in the **north area** (see Fig. 38 in main report) occurred at the interface between the wind-tidal flats (tidal flats and aquatic beds) and the uplands of the barrier island. Uplands increased from a total of 2,310 ha (5,708 acres) in the mid-1950's to 2,450 ha (6,054 acres) in 1979 (6% gain). The mid-1950's to 1979 net increase in uplands was due to a high gross increase of uplands where dunes shifted into previous tidal flat habitat (90% of gross upland gain). At the same time upland gain was offset by a large amount of encroachment of tidal flats into uplands (40% of gross upland loss). The trend continued in 2002 with a total of 2,860 ha (7,067 acres) of upland in the north area (17% gain). In the later time period, most of the upland gain was from deposition of dredged material along Mansfield Channel and the subsequent spread of sediment into nearby flats (86% of gain was from high flats). Although there was a continued net gain in uplands, the gross loss (~50%) of uplands was largely due to encroachment of high flats. Island morphology in this area appears to have been affected by changing laguna hydrology associated with the opening of the channel. Away from the channel, conversion of uplands into flats occurred at roughly the same rate as the conversion of flats into uplands. Wind-tidal flats lost about 7% of their area between the mid-1950's (17,198 ha; 42,497 acres) and 1979 (15,931 ha; 39,366 acres). A large part of the tidal flat loss (~50%) in the mid-1950's to 1979 time period was due to migration of dunes (mostly back island dunes migrating towards Laguna Madre) and expansion of uplands into flats. Elimination of cartographic error from the mid-1950's dataset would reduce the net gain of uplands and also reduce the net loss of flats in the earlier time period. As of 2002, the amount of wind-tidal flats hadn't changed significantly (15,976 ha; 39,477 acres) from 1979. Large fluctuations in the area of seagrass occurred within the study time period. In the mid-1950's seagrasses are found a short distance offshore in the southern half of the north area (817 ha; 2,018 acres). A small amount (88 ha; 218 acres) is mapped near Mansfield Channel in 1979 but most seagrass exists outside the study area boundary during this time period. By 2002 seagrasses had been reestablished near the island (1,484 ha; 3,667 acres) along the upper Laguna Madre. Marsh habitats in the north area of SPI occupy only a fraction of the total area. Estuarine marsh and palustrine marsh areas combined increase by 150% from the mid-1950's (36 ha; 89 acres) to 1979 (91 ha; 225 acres) followed by a small decrease in area of 8% in 2002 (84 ha; 208 acres). Much of the gain (~66%) of estuarine marsh between the mid-1950's and 1979 occurred on small islands in the Laguna Madre. Marshes may have been more plentiful in 1979 due to wetter conditions. Marine flats experienced a systematic gain throughout the study time period. In the mid-1950's gulf beach covered 190 ha (470 acres), by 1979 the area increased by 15% to 219 ha (541 acres), and in 2002 gulf beaches totaled 298 ha (736 acres), an additional increase of 36%. Gulf beaches increased in the north where the shoreline is accreting, thus, displacing marine open water. Beaches also increased further south in areas previously mapped as uplands and high flats in active washover channels.

In the **middle area** of South Padre Island, there was a systematic decline in tidal/algal flats with a loss of 623 ha (1,539 acres) from the 1950's to 2002, or about 33% of this resource with an area of 1,894 ha (4,678 acres) in the 1950's. Seagrasses also declined in area by 343 ha (847 acres) from 1,842 ha (4,550 acres) in the 1950's to 1,499 ha (3,703 acres) in 2002. Although estuarine marshes and mangroves represent a small area overall, marshes decreased in area from the 1950's to 1979, but increased from 1979 to 2002. Mangroves also increased in area from 1979 to 2002 (mangroves were not mapped in the 1950's). Estuarine and marine open water both increased from the 1950's to 2002 by approximately 35% and 20%, respectively. The area of Gulf beach increased from the 1950's to 1979, and remained relatively stable to 2002, although there was a small loss in area. The systematic decline in tidal flats can be attributed, in part, to replacement of the flats by uplands, primarily vegetated barrier flats and dunes, and to a lesser extent to urban development. As much as 75 % of the loss was due to upland conversion during the earlier period (1950's to 1979). The continued decline in tidal flats from 1979 to 2002 was in part the result of development. At the north edge of the city of South Padre Island, a marina was under development in 2002 in which multiple channels were dredged across the flats with a main trunk channel connected to Laguna Madre. In association with this development, dredged material was disposed on tidal flats converting them to upland areas. The convention center, which was constructed after 1979, also affected an area of tidal flats. The decline in seagrasses from the 1950's to 2002 was, in large part, the result of navigation channels that cut through seagrass beds along the lagoon margin of South Padre Island. The increase in marshes and mangroves from 1979 to 2002 primarily occurred along the shores of the city of South Padre Island. Marsh and mangrove vegetation spread along the lagoon margin, along channels, on tidal flats, at the South Padre Island Convention Center, and near the Queen Isabella Causeway. Boardwalks constructed across the marsh at the Convention Center provide easy access to visitors and help protect the marsh. The extensive brackish marsh at this site is in large part the result of outflow from a sewage treatment plant. The increase in marine open water within the middle study area is in part due to erosion and the landward retreat of the Gulf shoreline. South of Mansfield Channel to the Rio Grande, rates of shoreline retreat between 1974 and 1982 ranged from 1.5 to 6.5 m/yr (5 to about 20 ft/yr) at 14 measured sites, and was stable at 5 sites (Paine and Morton, 1989). Shorelines at half of the retreating sites moved faster than 3 m/yr (10 ft/yr). Similar retreat rates were observed between 1937 and 1974 (Morton and Pieper, 1975). It must be noted, however, that the increase in marine open water from the 1950's to 2002 is also due to misregistration of the 1950's map of this area. The entire island was shifted lagoonward thus increasing the area of marine water on the Gulf side. It was a problem that could not be corrected without remapping much of the USFWS 1950's data. The increase in estuarine water through time is in part due to dredging of navigation channels through seagrass beds, tidal flats, and other habitats. Higher tidal levels at the time the photos were taken also may have contributed to the more extensive water areas during later periods.

The **south area**, which encompasses South Bay, has experienced change in several habitat types over time. Tidal flats decreased in area by 18%, from 4,708 ha (11,629 acres) in 1950's to 3,883 ha (9,591 acres) in 2002. Seagrasses increased by 53%, from 684 ha (1,689 acres) in 1950's, to 1,049 ha (2,591 acres) in 2002. Mangroves increased by 29%, from 60 ha (148 acres) in 1979 (1950's figures are not available), to 77 ha (190 acres) in 2002. Palustrine marshes decreased by 19%, from 64 ha (158 acres) in 1950's to 52 ha (128 acres) in 2002. Gulf beaches increased by 51%, from 74 ha (183 acres) in 1950's to 112 ha (227 acres) in 2002. The estuarine marsh habitat has remained stable, from 506 ha (1,250 acres) in 1950's to 506 ha (1,250 acres) in 2002. The low areal extent of tidal flats in 1979 can be attributed to the wetter ground conditions at that time. Both the 1950's and 2002 ground conditions were drier in comparison, resulting in more tidal flats and less open water being mapped in those years. The overall decrease in flats from the 1950's to 2002 has several causes. Relative sea level rise, caused by both subsidence and eustatic sea-level change, led to some tidal flats being flooded by open water. Tidal flats were also lost as dredged material was piled up along excavated channels, replacing them with uplands. In some places, marshes replaced tidal flats. Mangroves, which were mapped in 1979 and 2002 only, have encroached on flats, open water, and uplands, and to a lesser extent, marshes.

STATUS AND TRENDS OF WETLAND AND AQUATIC HABITATS ON TEXAS BARRIER ISLANDS, FREEPORT TO EAST MATAGORDA BAY, AND SOUTH PADRE ISLAND

INTRODUCTION

Coastal wetlands on barrier islands are essential natural resources that are highly productive biologically and chemically and are part of an ecosystem in which a variety of flora and fauna depend (Fig. 1). Scientific investigations to determine status and trends of wetlands assist in their protection and preservation, directly benefiting long-term biological productivity and public use. This report is one in a series of wetland status and trends investigations of barrier islands along the Texas Coast; the first two investigations were of the central and upper Texas Gulf coast (White et al. 2002 and 2004).

Presented here are the results of two studies along the Texas Gulf coast, (1) Freeport southwestward to East Matagorda Bay, an area that includes the Brazos River delta near Freeport, and (2) South Padre Island and Brazos Island, the barrier island system that extends to the Rio Grande south of Padre Island National Seashore. The northern study area is within Brazoria and Matagorda Counties and the southern study area is within Cameron and Willacy Counties (Fig. 2).

Figure 1. Palustrine marsh and open water in the San Bernard National Wildlife Refuge. Plant species include *Echinodorus* sp., *Typha* sp., *Polygonum* sp., *Sesbania* sp., and *Salix* sp., among others.

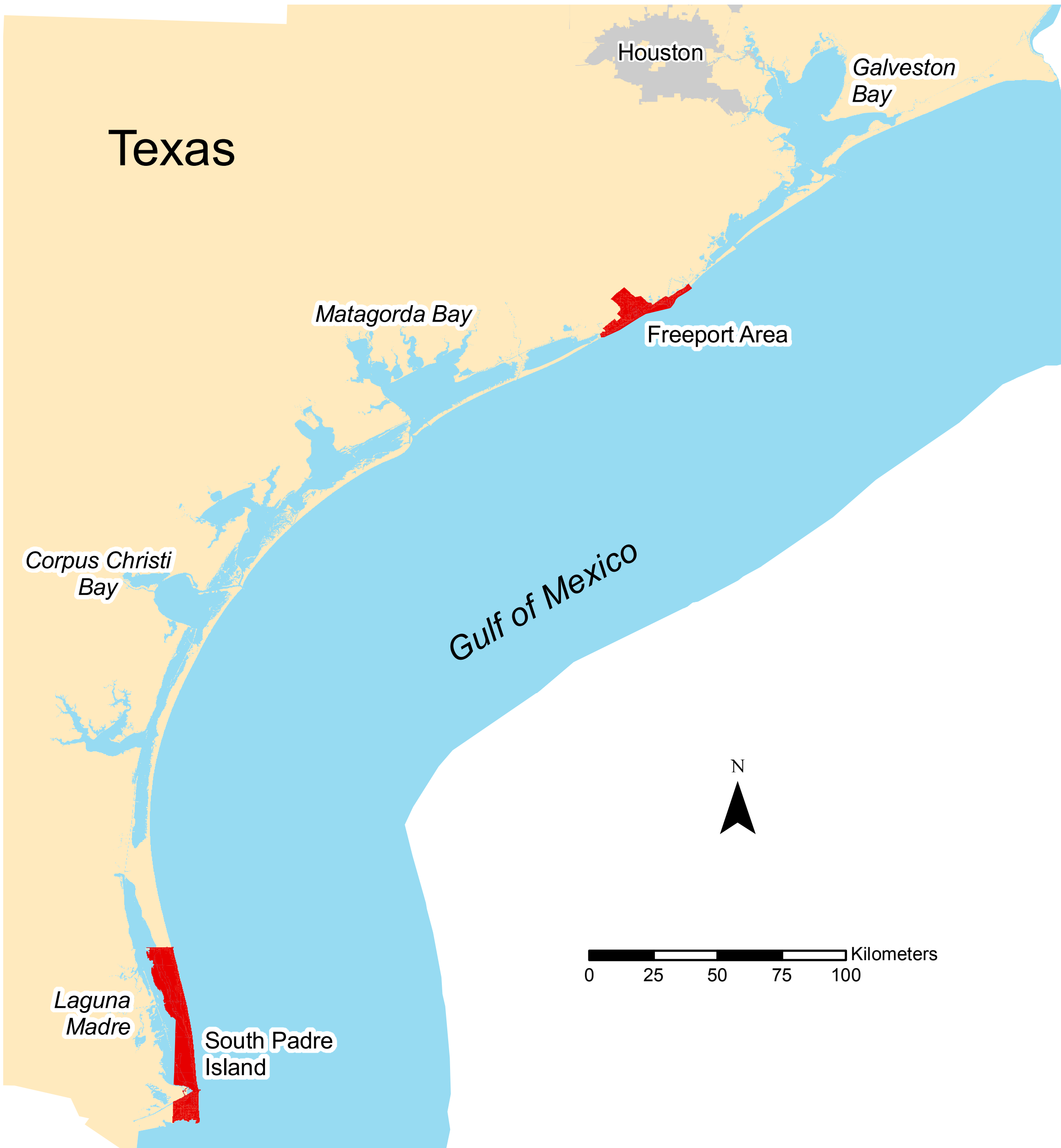

Figure 2. Index map showing the two study areas.

Previous studies of wetland status and trends along the Texas coast by the Bureau of Economic Geology (BEG), for example in the Galveston Bay system (White et al., 1993 and 2004), show that substantial losses in wetlands have occurred due to subsidence and associated relative sea-level rise. Some of the losses on Galveston Bay barriers have occurred along surface faults that appear to have become active as a result of underground fluid production. In contrast to those of the Galveston Bay system, studies of wetlands on barrier islands in the Matagorda Bay system (White et al. 2002) show that marshes have expanded as a result of relative sea-level rise. Between these two bay systems is the relict Colorado-Brazos River delta complex (McGowen et al. 1976), where extensive wetlands have not been recently studied to determine status and trends, nor have wetlands recently been studied on South Texas barrier islands. Wetland status and trends and probable causes of trends presented here focus on these two areas, including South Padre Island on the lower coast and the Brazos River delta and San Bernard National Wildlife Refuge on the central coast. Results help in our understanding of marsh changes on Texas barriers and coastlines, and pinpoint wetlands threatened from development, erosion, faulting, subsidence, and other processes. These data provide site-specific information for implementing management programs for protecting and possibly restoring these valuable natural resources.

METHODS

Mapping and Analyzing Status and Trends

Status and trends of wetlands in the study areas were determined by analyzing the distribution of wetlands mapped on aerial photographs taken in the 1950's, 1979, and 2002. Maps of the 1950's and 1979 were prepared as part of the USFWS-sponsored Texas Barrier Island Ecological Characterization study (Shew et al. 1981) by Texas A&M University and the National Coastal Ecosystems Team of the USFWS. Final maps of the 1979 series were prepared under the NWI program. Maps of the 1950's and 1979 series were digitized and initially analyzed in 1983 (USFWS, 1983). Current USFWS NWI maps and digital data for the Texas coast were prepared using 1992 aerial photographs. The current status of wetlands in this study is based on photographs contracted by GLO in 2002, and supplemented by photographic coverage from other sources where necessary. The 1992 NWI maps were used as collateral information for interpreting and mapping current wetland distribution.

Wetland Classification and Definition

For purposes of this investigation, wetlands were classified in accordance with *The Classification of Wetlands and Deepwater Habitats of the United States* by Cowardin et al. (1979). This is the classification used by the USFWS in delineating wetlands as part of the NWI.

Definitions of wetlands and deepwater habitats according to Cowardin et al. (1979) are:

> Wetlands are lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water. For purposes of this classification wetlands must have one or more of the following three attributes: (1) at least periodically, the land supports predominantly hydrophytes[1]; (2) the substrate is predominantly undrained hydric soil[2]; and (3) the substrate is nonsoil and is saturated with water or covered by shallow water at some time during the growing season of each year.
>
> Deepwater habitats are permanently flooded lands lying below the deepwater boundary of wetlands. Deepwater habitats include environments where surface water is permanent and often deep, so that water, rather than air, is the principal medium within which the dominant organisms live, whether or not they are attached to the substrate. As in wetlands, the dominant plants are hydrophytes; however, the substrates are considered nonsoil because the water is too deep to support emergent vegetation (U.S. Soil Conservation Service, Soil Survey Staff, 1975).

Because the fundamental objective of this project was to determine status and trends of wetlands using aerial photographs, classification and definition of wetlands are integrally connected to the photographs and the interpretation of wetland signatures. Wetlands were neither defined nor mapped in accordance with the *U.S. Army Corps of Engineers Wetland Delineation Manual, 1987*, which applies to jurisdictional wetlands.

Interpretation of Wetlands

Historical Wetland Distribution

Historical distribution of wetlands is based on the 1950's and 1979 USFWS wetland maps. Methods used by the USFWS include interpretation and delineation of wetlands and aquatic habitats on aerial photographs through stereoscopic interpretation. Field reconnaissance is an integral part of interpretation. Photographic signatures are compared with the appearance of wetlands in the field by observing vegetation, soil, hydrology, and topography. This information is weighted for seasonality and conditions existing at the time of photography and ground-truthing. Still, field-surveyed sites represent only a small percentage of the thousands of areas (polygons) delineated. Most areas are delineated on the basis of photointerpretation alone, and misclassifications may occur. The 1950's photographs are black-and-white stereo-pair, scale 1:24,000, most of the ones along the Texas coast having been taken in the mid 1950's (Larry Handley, USGS, Personal Communication, 1997). We think that the photographs covering the Freeport to East Matagorda Bay study area, however, were taken in the early 1950's based on a comparison of the 1950's wetland delineations with a photograph taken of the Brazos River delta in 1948. The 1979 aerial photographs are NASA color-infrared stereo-pair, scale 1:65,000, that were taken in November.

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[1]The USFWS has prepared a list of hydrophytes and other plants occurring in wetlands of the United States.
[2]The NRCS has prepared a list of hydric soils for use in this classification system.

Methods used by the USFWS NWI program involved transferring wetlands mapped on aerial photographs to USGS 7.5-minute-quadrangle base maps, scale 1:24,000, using a zoom-transfer scope. Wetlands on the completed maps were then digitized and the data entered into a GIS. As in the photointerpretation process, there is a margin of error involved in the transfer and digitization process.

Photographs used are generally of high quality. Abnormally high precipitation in 1979, however, raised water levels on tidal flats and in many island fresh to brackish wetlands. Thus, more standing water and wetter conditions were apparent on the 1979 photographs than on the 2002 photographs, which were taken during much drier conditions. Although the 1950's photographs are black-and-white, they are large scale (1:24,000), which aids in the photointerpretation and delineation process. The 1950's photographs were apparently taken before the severe drought that peaked in 1956 in Texas (Riggio et al. 1987). These differences in wet and dry conditions during the various years affected habitats, especially palustrine, and their interpreted, or mapped, water regimes.

The following explanation is printed on all USFWS wetland maps that were used in this project to determine trends of wetlands:

> This document (map) was prepared primarily by stereoscopic analysis of high-altitude aerial photographs. Wetlands were identified on the photographs based on vegetation, visible hydrology, and geography in accordance with "Classification of Wetlands and Deepwater Habitats of the United States" (FWS/OBS–79/31 December 1979). The aerial photographs typically reflect conditions during the specific year and season when they were taken. In addition, there is a margin of error inherent in the use of the aerial photographs. Thus, a detailed on-the-ground and historical analysis of a single site may result in a revision of the wetland boundaries established through photographic interpretation. In addition, some small wetlands and those obscured by dense forest cover may not be included on this document.
>
> Federal, State, and local regulatory agencies with jurisdiction over wetlands may define and describe wetlands in a different manner than that used in this inventory. There is no attempt in either the design or products of this inventory to define the limits of proprietary jurisdiction of any Federal, State or local government or to establish the geographical scope of the regulatory programs of government agencies…..

Revision of Historical Wetland Maps

As part of this study, researchers at BEG revised USFWS historical wetland maps (1950's and 1979) so that there would be closer agreement between the historical map units and the current (2002) wetland map units. Revisions of the USFWS data were restricted primarily to the estuarine marshes, tidal flats, and areas of open water. The principal reason for the revisions was that in many areas on the historical maps, estuarine intertidal emergent wetlands (E2EM) were combined with intertidal flats (E2FL) as a single map unit (E2EM/E2FL). In our revisions, many of these areas were subdivided into E2EM and E2FL where possible at the mapping scale. In addition, because of the larger scale of the 1950's aerial photographs (1:24,000) as compared with the 1979 photographs (~1:65,000), smaller wetlands, particularly water features, were mapped on the 1950's photographs. As part of the revisions, many of these smaller water bodies were mapped and added to the 1979 wetland maps.

To accomplish the revisions, aerial photographs taken in the mid-1950's and 1979 were scanned where necessary, rectified with respect to the existing historical maps, and the digital USFWS maps revised where necessary. Wetlands on the aerial photographs were interpreted and changes mapped directly on screen. The revised data were entered into the GIS.

Current Wetland Distribution (Status)

The current distribution of wetlands and aquatic habitats is based on color infrared (CIR) aerial photographs taken in 2002 under contract with the GLO, and supplemented with other recent photographs. Photographs were digital images with a pixel resolution of 0.5 to 1 meter and registered to USGS Digital Orthophoto Quads (DOQ's). Interpretation and mapping of wetlands and aquatic habitats were completed by BEG researchers through on-screen delineation of habitats. Delineations were digitized directly into the GIS (ArcGIS) at a scale of 1:4,000. An attempt was made to show about the same amount of detail as that in the historical maps in order to make accurate comparisons of wetland changes through time. Still, because of the method used, the current wetland maps show more detail than do the historical maps.

Field Investigations

Field investigations were conducted (1) to characterize wetland plant communities through representative field surveys and (2) to compare various wetland plant communities in the field with corresponding "signatures" on aerial photographs to define wetland classes, including water regimes, for mapping purposes. Characterization of prevalent plant associations provided vital plant community information for defining mapped wetland classes in terms of typical vegetation associations. In addition, mapping of wetlands near the Gulf shoreline was supported by Light Detection and Ranging (LIDAR) data acquired by BEG in 2000 (Fig. 3). LIDAR images provide detailed elevations that help differentiate between high and low marshes and flats and areas that are transitional between uplands and wetlands.

Variations in Classification

Classification of wetlands varied somewhat for the different years. On 1979 and 2002 maps, wetlands were classified by system, subsystem, class, subclass (for vegetated classes), water regime, and special modifier in accordance with Cowardin et al.(1979) (Figs. 4-6). For the 1950's maps, wetlands were classified by system, subsystem, and class. On 1979 maps, upland areas were also mapped and classified by upland

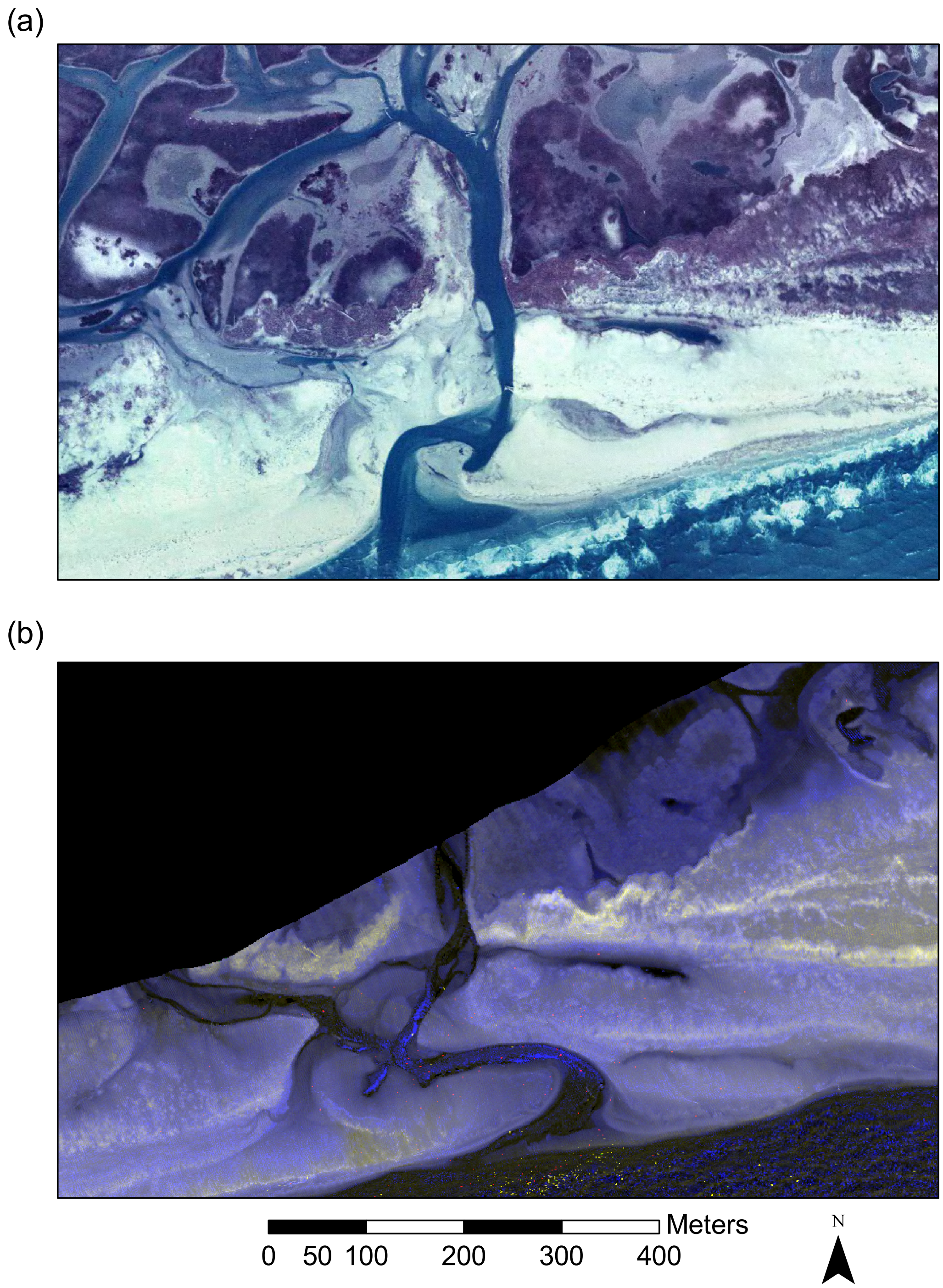


Figure 3. Example of LIDAR used to help delineate wetlands in selected areas where the LIDAR coverage was available. (a) 2002 aerial photograph of southeastern margin of Brazos River Delta, (b) LIDAR image of part of the area shown in photograph.

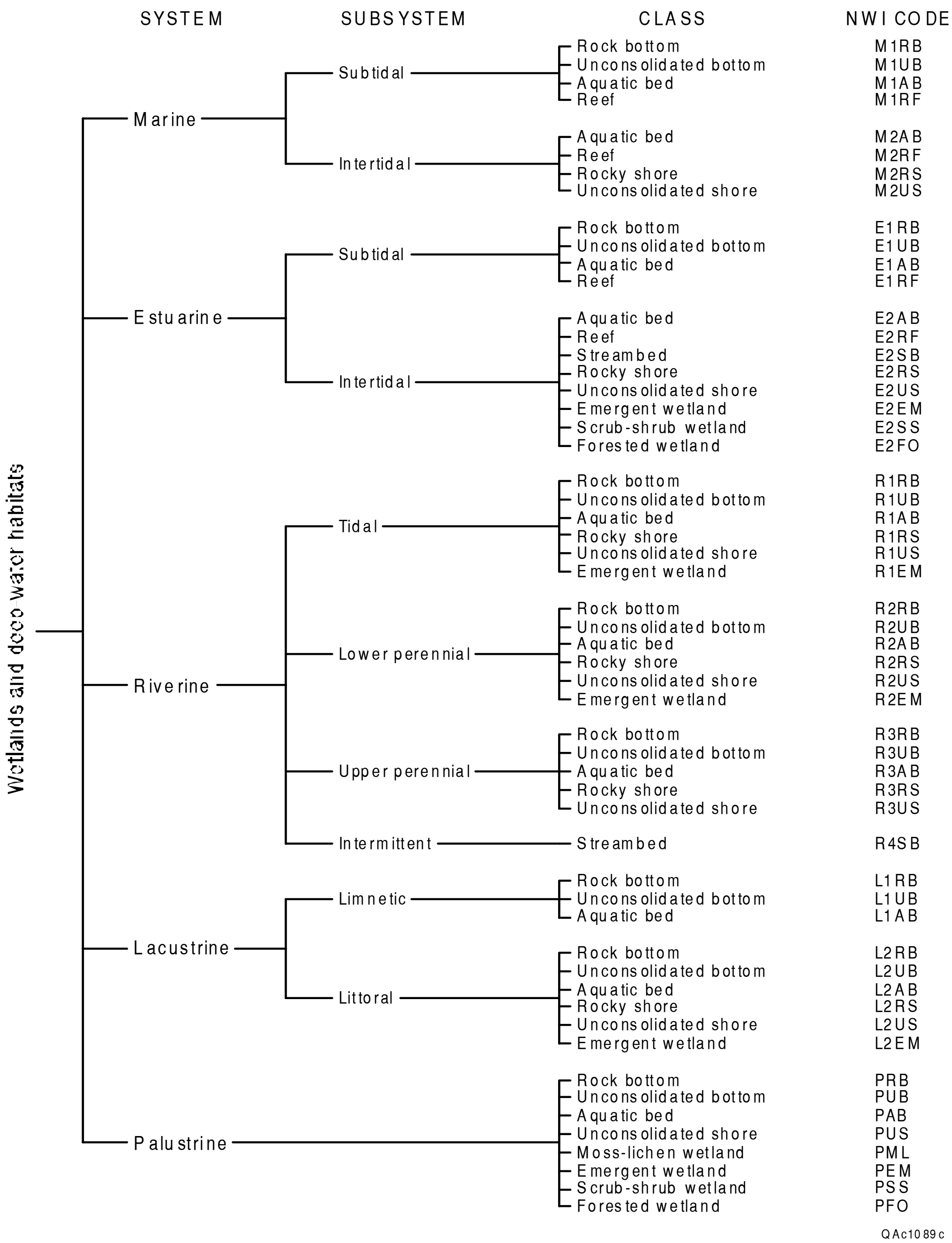


Figure 4. Classification hierarchy of wetlands and deepwater habitats showing systems, subsystems, and classes. From Cowardin et al. (1979).

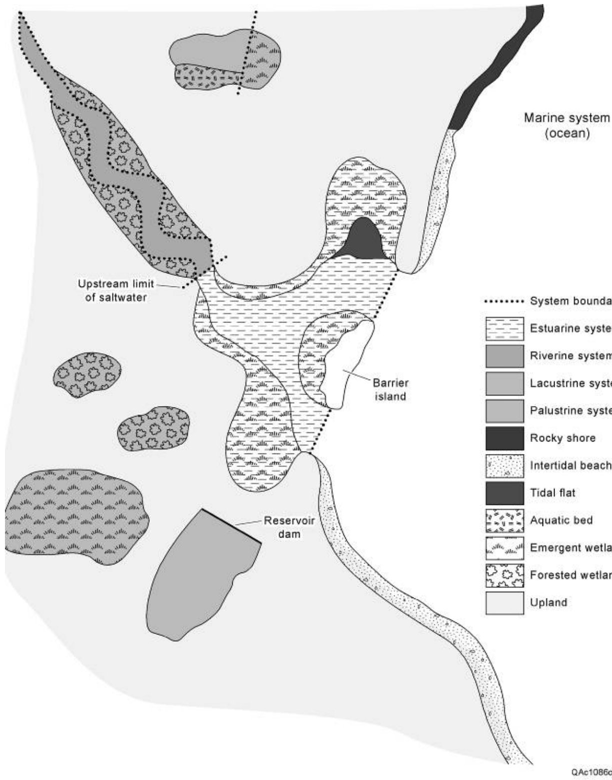


Figure 5. Schematic diagram showing major wetland and deepwater habitat systems. From Tiner (1984).

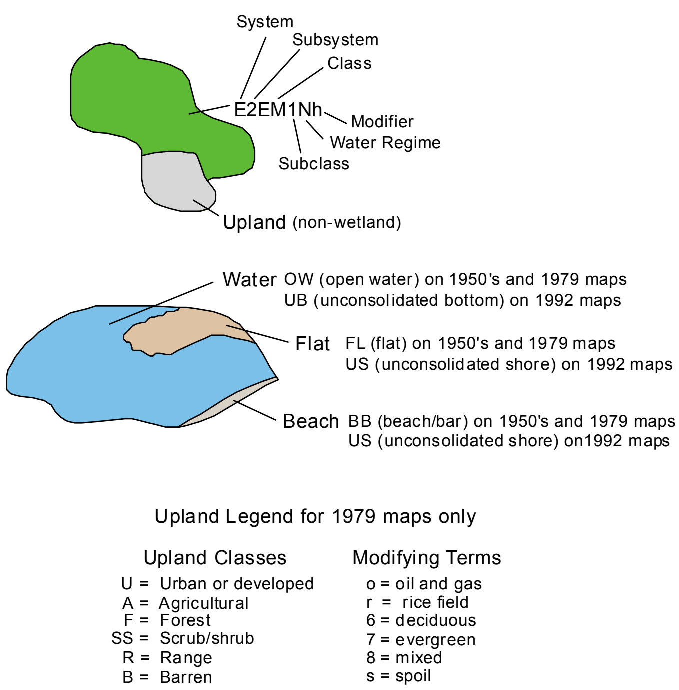


Figure 6. Example of symbology used to define wetland and upland habitats on NWI maps.

habitats using a modified Anderson et al. (1976) land-use classification system (Fig. 6). Flats and beach/bar classes designated separately on 1950's and 1979 maps were combined into a single class, unconsolidated shore, on 2002 maps, in accordance with updated NWI procedures as exemplified on 1992 NWI wetland maps (Fig. 6). USFWS data for the study area were selected from 7.5-minute quadrangles (Figs. 7 and 8) from files previously digitized and maintained by the USFWS for the 1950's and 1979 wetland maps.

Results include GIS data sets consisting of electronic-information layers corresponding to mapped habitat features for the 1950's, 1979, and 2002. Data can be manipulated as information overlays, whereby scaling and selection features allow portions of the estuary to be selected electronically for specific analysis.

Among the objectives of the GIS are to (1) allow direct historical comparisons of wetland types to gauge historical trends and status of habitats, (2) allow novel comparisons of feature overlays to suggest probable causes of wetland changes, (3) make information on wetlands directly available to managers in a convenient and readily assimilated form, and about the same amount of accuracy as that in the historical maps in order to make accurate comparisons of wetland changes through time (however, because of the method used, the current wetland maps show more detail than do the historical maps), and (4) allow overlays to be combined from wetland studies and other topical studies in a single system that integrates disparate environmental features for planning and management purposes. The GIS is a flexible and valuable management tool for use by resource managers. Still, users must be aware of potential errors, for example from registration differences, which can arise from direct analysis of GIS overlays.

Map-Registration Differences

There are map-registration differences between the historical and recent digital data. These cause errors when the data sets are overlain and analyzed in a GIS. The 2002 aerial photographs are georeferenced to USGS DOQ's. There is good agreement in registration with these base photographs. However, the historical data sets are not as well registered, and there is an offset in wetland boundaries between the historical and the 2002 data. When the two data sets are superimposed in a GIS, the offset creates apparent wetland changes that are in reality cartographic errors resulting from a lack of precision in registration. Re-registration of the USFWS digital data sets was beyond the scope of this project. Thus, caution must be used in interpreting changes from direct overlay of the different data sets as layers in a GIS. We tabulated wetland totals separately for each year to determine wetland changes within the given study area. Overlay of the data sets was done primarily to identify significant wetland changes that could be verified by analyzing and comparing aerial photographs.

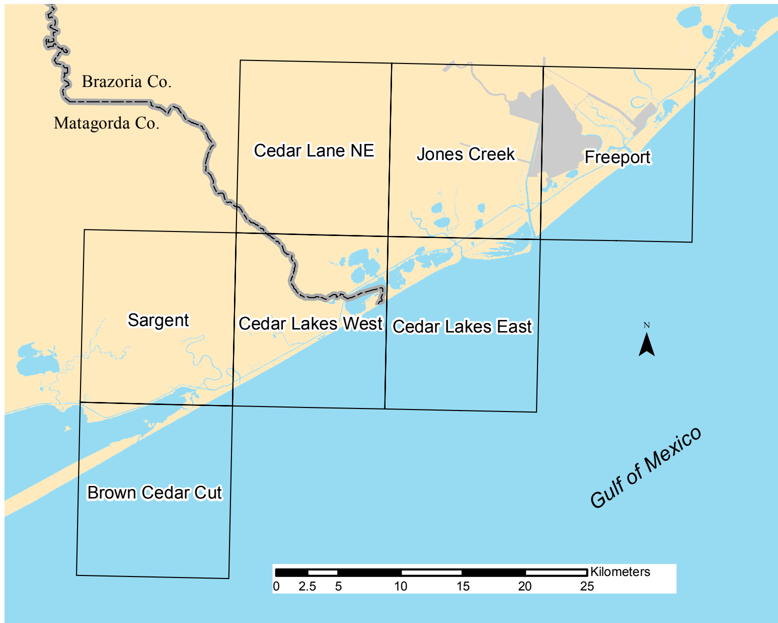


Figure 7. Index map of USGS 7.5'quadrangles covering Freeport–East Matagorda Bay study area.

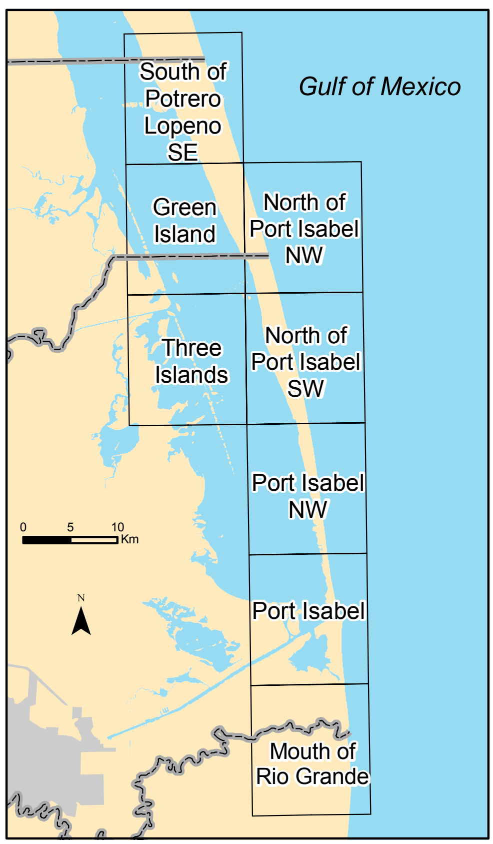


Figure 8. Index map of USGS 7.5' quadrangles covering the South Padre Island study area.

Methods used to Analyze Historical Trends in Wetland Habitats

Trends in wetland habitats were determined by analyzing habitat distribution as mapped on 2002, 1979, and 1950's aerial photographs. In analyzing trends, emphasis was placed on wetland classes (for example, E2EM and PEM), with less emphasis on water regimes and special modifiers. This approach was taken because habitats were mapped only down to class level on 1950's photographs and because water regimes can be influenced by local and short-term events such as tidal cycles and precipitation.

ArcGIS was used to analyze trends. This software allowed for direct comparison not only between years, but also by geographic areas such as the barrier island, peninsula, and delta. Analyses included tabulation of losses and gains in wetland classes for each area for selected periods. The GIS allowed cross classification of habitats in a given area as a means of determining changes and probable cause of such changes. Maps used in this report showing wetland distribution and changes were prepared from digital data using ArcGIS.

Possible Photointerpretation Errors

As mentioned previously, existing maps prepared from photointerpretation as part of the USFWS-NWI program and associated special projects were used to determine trends. Among the shortcomings of the photointerpretation process is that different photointerpreters were involved for different time periods, and interpretation of wetland areas can vary somewhat among interpreters. As a result, some changes in the distribution of wetlands from one period to the next may not be real but, rather, relicts of the interpretation process. Inconsistencies in interpretation seem to have occurred most frequently in high marsh to transitional areas where uplands and wetlands intergrade.

Some apparent wetland changes were due to different scales of aerial photographs. The 1950's aerial photographs were at a scale larger (1:24,000) than those taken in 1979 (1:65,000), which affected the minimum mapping unit delineated on photographs. Accordingly, a larger number of small wetland areas were mapped on earlier, larger-scale photographs, accounting for some wetland losses between earlier and later periods.

In general, wetland changes that seem to have been influenced the most by photointerpretation problems are interior (palustrine), temporarily flooded wetlands bordering on being transitional areas. Some apparent losses in palustrine wetlands were documented on barrier islands, but appear to be due to drier conditions when the 2002 photographs were taken.

In the analysis of trends, wetland areas for different time periods are compared without an attempt to factor out all misinterpretations or photo-to-map transfer errors except for major, obvious problems. However, maps and aerial photographs representing each period were visually compared as part of the trend-analysis process and as part of the effort to identify potential problems in interpretation. Still, users of the data should keep in mind that there is a margin of error inherent in photo interpretation and map preparation.

Wetland Codes

As mentioned in the introduction, some wetland codes used on 2002 maps are different from those used on the 1950's and 1979 maps (Fig. 6). In the following discussion of trends, E2US rather than E2FL (used on the 1950's and 1979 maps) is generally used to denote tidal flats, and UB (rather than OW) is used to represent open water.

CLASSIFICATION OF WETLAND AND DEEPWATER HABITATS IN THE STUDY AREAS

Cowardin et al. (1979) defined five major systems of wetlands and deepwater habitats: marine, estuarine, riverine, lacustrine, and palustrine (Fig. 4). Systems are divided into subsystems, which reflect hydrologic conditions, such as intertidal and subtidal for marine and estuarine systems. Subsystems are further divided into class, which describes the appearance of the wetland in terms of vegetation or substrate. Classes are divided into subclasses. Only vegetated classes were divided into subclasses for this project, and only for 1979 and 2002. In addition, water-regime modifiers (Table 1) and special modifiers were used only for these years.

The USFWS-NWI program established criteria for mapping wetlands on aerial photographs using the Cowardin et al. (1979) classification. Alphanumeric abbreviations are used to denote systems, subsystems, classes, subclasses, water regimes, and special modifiers (Table 2, Fig. 6). Symbols for certain habitats changed after 1979; these changes are shown in Figure 6 and are noted in the section on trends in wetland and aquatic habitats. Examples of alphanumeric abbreviations used in the section on status of wetlands apply only to 2002 maps. Much of the following discussion of wetland systems as defined by Cowardin et al. (1979) is modified from White et al. (1993, 1998). Nomenclature and symbols (Appendix) in this discussion are based primarily on 1992 NWI maps.

Marine System

Marine areas include unconsolidated bottom (open water), unconsolidated shore (beaches), and rocky shore (jetties). Mean range of Gulf tides is about 0.51 m (U.S. Department of Commerce, 1978). Nonvegetated open water overlying the Texas Continental Shelf is classified as marine subtidal unconsolidated bottom (M1UBL) (Table 2). Unconsolidated shore is mostly irregularly flooded shore or beach (M2USP), with a narrow zone of regularly flooded shore (M2USN) (Fig. 9 and 10). Composition of these areas is primarily sand and shell. Granite jetties along the coast in the marine system are classified as marine intertidal, rocky shore, irregularly flooded, rubble, and artificial (M2RS2Pr).

Figure 9. Gulf Beach in the Freeport area.

Figure 10. Gulf beach at Brazos Island. Turbidity plume in Gulf is from the Rio Grande during flood stage. The Rio Grande is just up drift to the right out of the photo.

Table 1. Water-regime descriptions for wetlands used in the Cowardin et al. (1979) classification system.

Nontidal	
(A)	Temporarily flooded—Surface water present for brief periods during growing season, but water table usually lies well below soil surface. Plants that grow both in uplands and wetlands are characteristic of this water regime.
(C)	Seasonally flooded—Surface water is present for extended periods, especially early in the growing season, but is absent by the end of the growing season in most years. The water table is extremely variable after flooding ceases, extending from saturated to well below the ground surface.
(F)	Semipermanently flooded—Surface water persists throughout the growing season in most years. When surface water is absent, the water table is usually at or very near the land's surface.
(H)	Permanently flooded—Water covers land surface throughout the year in all years.
(K)	Artificially flooded
Tidal	
(K)	Artificially flooded
(L)	Subtidal—Substrate is permanently flooded with tidal water.
(M)	Irregularly exposed—Land surface is exposed by tides less often than daily.
(N)	Regularly flooded—Tidal water alternately floods and exposes the land surface at least once daily.
(P)	Irregularly flooded—Tidal water floods the land surface less often than daily.
(S)*	Temporarily flooded—Tidal
(R)*	Seasonally flooded—Tidal
(T)*	Semipermanently flooded—Tidal
(V)*	Permanently flooded—Tidal

*These water regimes are only used in tidally influenced, fresh-water systems.

Estuarine System

The estuarine system consists of many types of wetland habitats. Estuarine subtidal unconsolidated bottom (E1UBL), or open water, occurs in the numerous bays and in adjacent salt and brackish marshes. Unconsolidated shore (E2US) (Figs. 11 a, b, c, d) includes tidal flats and estuarine beaches and bars. Water regimes for this habitat range primarily from regularly flooded (E2USN) to irregularly flooded (E2USP). Aquatic beds observed in this system are predominantly submerged, rooted vascular plants (E1AB3L) (Fig. 12) that may include *Halodule wrightii* (shoalgrass), *Ruppia maritima* (widgeongrass), *Thalassia testudinum* (turtlegrass), *Syringodium filiforme* (manateegrass), and *Halophila engelmannii* (clovergrass). All species have been reported in lower Laguna Madre (Breuer, 1962). Apparently, the most abundant species in the southern end of Laguna Madre and South Bay are *Thalassia testudinum*, *Syringodium filiforme*, and *Halodule wrightii* (Breuer, 1962).

(a)

(b)

(c)

(d)

Figure 11. Examples of wind-tidal flats in (a) the South Bay area, and (b) South Padre Island, and examples of algal mat (c) and algal flat, dark area (d), in the South Bay area.

Figure 12. Seagrass (dark area beyond channel marker) in Laguna Madre offshore from South Padre Island. The navigation channel dredged through the seagrass beds is apparent at the channel marker.

Table 2. Wetland codes and descriptions from Cowardin et al. (1979). Codes listed below were used in mapping wetlands on the 2002 delineations, which varied in some cases from 1950's and 1979 maps (see Fig. 6).

NWI code (water regime)	**NWI description**	**Common description**	**Characteristic vegetation**
M1UB (L)	Marine, subtidal unconsolidated bottom	Gulf of Mexico	Unconsolidated bottom
M2US (P,N,M)	Marine, intertidal unconsolidated shore	Marine beaches, barrier islands	Unconsolidated shore
M2RS (P)	Marine, intertidal rocky shore	Marine breakwaters, beach stabilizers	Jetties
E1UBL (L)	Estuarine, subtidal unconsolidated bottom	Estuarine bays	Unconsolidated bottom
E1AB (L)	Estuarine, subtidal aquatic bed	Estuarine seagrass or algae bed	*Halodule wrightii* *Halophila engelmannii* *Ruppia maritima*
E2US (P,N,M)	Estuarine, intertidal unconsolidated shore	Estuarine bay, tidal flats, beaches	Unconsolidated shore
E2EM (P,N)	Estuarine, intertidal emergent	Estuarine bay marshes, salt and brackish water	*Spartina alterniflora* *Spartina patens* *Distichlis spicata*
E2SS (P)	Estuarine, intertidal scrub-shrub	Estuarine shrubs	*Avicennia germinans* *Iva frutescens* *Baccharis halimifolia*
R1UB (V)	Riverine, tidal, unconsolidated bottom	Rivers	Unconsolidated bottom
R1SB (T)	Riverine, tidal, streambed	Rivers	Streambed
R2UB (H)	Riverine, lower perennial, unconsolidated bottom	Rivers	Unconsolidated bottom
R4SB (A,C)	Riverine, intermittent streambed	Streams, creeks	Streambed
L1UB (H,V)	Lacustrine, limnetic, unconsolidated bottom	Lakes	Unconsolidated bottom
L2UB (H,V)	Lacustrine, littoral, unconsolidated bottom	Lakes	Unconsolidated bottom
L2AB (H,V)	Lacustrine, littoral, aquatic bed	Lake aquatic vegetation	*Nelumbo lutea* *Ruppia maritima*
PUB (F,H,K)	Palustrine, unconsolidated bottom	Pond	Unconsolidated bottom
PAB (F,H)	Palustrine, aquatic bed	Pond, aquatic beds	*Nelumbo lutea*
PEM (A,C,F,S,R,T)	Palustrine emergent	Fresh-water marshes, meadows, depressions, or drainage areas	*Schoenoplectus californicus* *Typha spp.*
PSS (A,C,F,S,R,T)	Palustrine scrub-shrub	Willow thicket, river banks	*Salix nigra* *Parkinsonia aculeata* *Sesbania drummondii*
PFO (A,C,F,S,R,T)	Palustrine forested	Swamps, woodlands in floodplains depressions, meadow rims	*Salix nigra* *Fraxinus spp.* *Ulmus crassifolia* *Celtis spp.*

Emergent areas closest to estuarine waters consist of regularly flooded, salt-tolerant grasses (low salt and brackish marshes) (E2EM1N) (Figs. 13, 14, and 15). These communities are mainly composed of *Spartina alterniflora* (smooth cordgrass), *Batis maritima* (saltwort), *Distichlis spicata* (seashore saltgrass), *Salicornia* spp. (glasswort), *Monanthochloe littoralis* (shoregrass), *Suaeda linearis* (annual seepweed), and *Sesuvium portulacastrum* (sea-purslane) and scattered *Avicennia germinans* (black mangrove) in more saline areas.

In brackish areas, species composition changes to a salt to brackish-water assemblage, including *Schoenoplectus* (formerly *Scirpus*) spp. (bulrush), *Paspalum vaginatum* (seashore paspalum), *Spartina patens* (saltmeadow cordgrass), and *Phyla* sp. (frog fruit), among others. At slightly higher elevations, irregularly flooded estuarine emergent wetlands (E2EM1P) (high salt and brackish marshes) include *Borrichia frutescens* (sea oxeye), *Spartina patens*, *Spartina spartinae* (gulf cordgrass), *Fimbrystylis castanea* (marsh fimbry), *Aster* spp. (aster), and many others (Fig. 15).

Estuarine scrub/shrub wetlands (E2SS) are much less extensive than estuarine emergent wetlands. Representative plant species, in regularly flooded zones (E2SS1N), include *Avicennia germinans* (black mangrove) (Fig.16), and in irregularly flooded zones (E2SS1P**)** between emergent wetland communities and upland habitats, include *Iva frutescens* (big-leaf sumpweed), *Baccharis halimifolia* (sea-myrtle, or eastern false-willow), *Sesbania drummondii* (drummond's rattle-bush), and *Tamarix* spp. (salt cedar).

Mapping criteria allow classes to be mixed in complex areas where individual classes could not be separated. Most commonly used combinations include the estuarine emergent class and estuarine intertidal flat (E2EM/FL) and wetlands and uplands (PEM/U and POW/U). The E2EM/FL class was used only on 1956 and 1979 maps. In such combinations, each class must compose at least 30 percent of the mapped area (polygon); on the 1950's and 1979 maps, the wetland class was always listed first (PEM/U) regardless of whether it was most abundant. Using historical photographs, we subdivided these classes in most areas on the 1950's and 1979 maps to improve the consistency with the 2002 classes, which were mapped individually.

The estuarine system extends landward to the point where ocean-derived salts are less than 0.5 ppt (during average annual low flow) (Cowardin et al. 1979). Mapping these boundaries is subjective in the absence of detailed long-term salinity data characterizing water and marsh features. Vegetation types, proximity and connection to estuarine water bodies, salinities of water bodies, and location of artificial levees and dikes are frequently used as evidence to determine the boundary between estuarine and adjacent palustrine systems. In general, a pond or emergent wetland was placed in the palustrine system if there was an upland break that separated it from the estuarine system.

Figure 13. Example of salt marsh in the Caney Creek area. Species include *Spartina alterniflora* and *Batis maritima*.

Figure 14. Salt marsh composed primarily of *Batis maritima* on Brazos Island south of Padre Island.

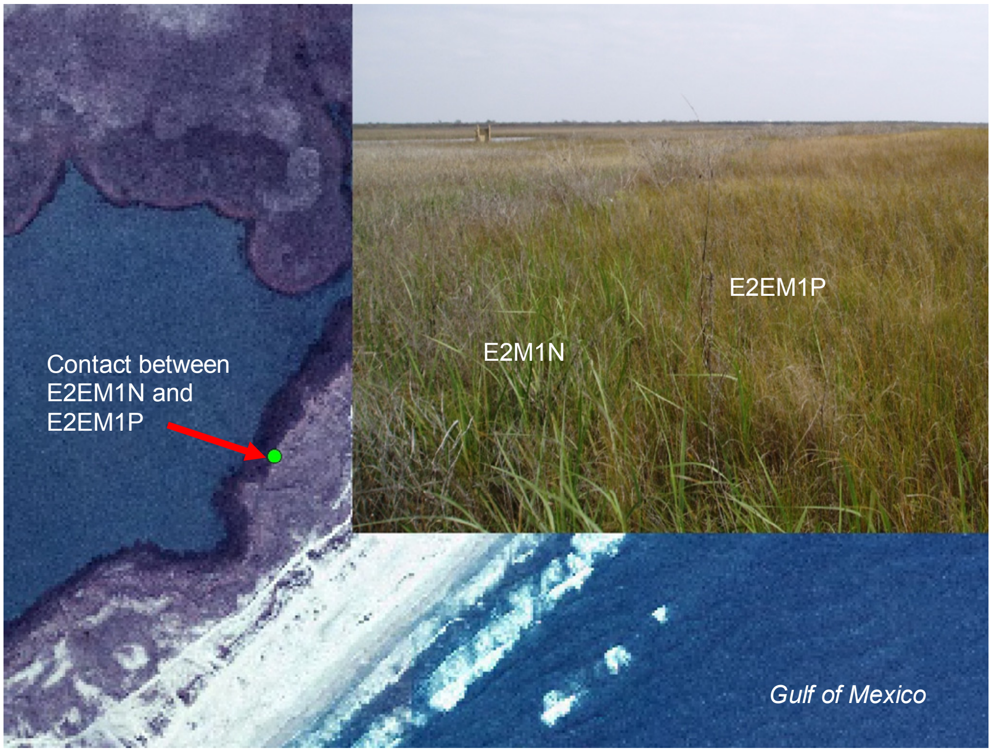


Figure 15. Example of low (E2EM1N) and high marsh (E2EM1P) contact in the Freeport area.

Figure 16. Example of *Avicennia germinans* (black mangroves) on Brazos Island near the Rio Grande.

Palustrine System

Palustrine areas include the following classes: unconsolidated bottom (open water), unconsolidated shore (including flats), aquatic bed, emergent (fresh or inland marsh), and scrub/shrub. Naturally occurring ponds are identified as unconsolidated bottom, permanently or semipermanently flooded (PUBH or PUBF). Excavated or impounded ponds and borrow pits are labeled (on 1979 maps) with their respective modifiers (PUBHx or PUBHh). Palustrine emergent wetlands are generally equivalent to fresh to brackish or inland marshes that are not inundated by estuarine tides. Semipermanently flooded emergent wetlands (PEM1F) are low, fresh marshes (Fig 17); seasonally flooded (PEM1C) (Fig. 18) and temporarily flooded (PEM1A) palustrine emergent wetlands are high, fresh marshes.

Vegetation communities typically characterizing areas mapped as low emergent wetlands (PEM1F) include *Paspalum vaginatum* (seashore paspalum), *Typha domingensis* (southern cattail), *Schoenoplectus pungens* (formerly *Scirpus americanus*) (three-square bulrush), *Eleocharis* spp. (spikerush), *Bacopa monnieri* (coastal water-hyssop), *Pluchea purpurascens* (saltmarsh camphor-weed), and others (Figs. 17 and 18). Other species reported include *Schoenoplectus californicus* and *Juncus* sp. Areas mapped as topographically higher and less frequently flooded emergent wetlands (PEM1A) include *S. spartinae, Borrichia frutescens, S. patens*, *Cyperus* spp. (flatsedge), *Hydrocotyle bonariensis* (coastal-plain penny-wort), *Phyla* sp. (frog fruit) *Aster spinosus* (spiny aster), *Paspalum* spp. (paspalum), *Panicum* spp. (panic), *Polygonum* sp. (smartweed), *Andropogon glomeratus* (bushy bluestem), and *Cynodon dactylon* (Bermuda grass) to mention a few.

It should be noted that in many areas, field observations revealed the existence of small depressions or mounds with plant communities and moisture regimes that varied from that which could be resolved on photographs. Thus, some plant species that may typify a low, regularly flooded marsh, for example, may be included in a high-marsh map unit. Differentiation of high- and low-marsh communities is better achieved through field transects that include elevation measurements.

Lacustrine System

Water bodies greater than 8 ha are included in this system, with both limnetic and littoral subsystems represented. Only one area was classified as lacustrine in1979 wetlands and none in the 2002 wetlands. Nonvegetated water bodies are labeled limnetic or littoral unconsolidated bottom (L1UB or L2UB) (L1OW or L2OW in 1950's and 1979 data sets), depending on water depth. The impounded modifier (h) is used on bodies of water impounded by levees or artificial means, and the modifier "s" to indicate spoil or dredged material.

Figure 17. Palustine marsh, primarily *Typha* (cattail), on South Padre Island.

Figure 18. Palustrine marsh in the Freeport area. Species include *Typha* sp.

Riverine System

Few areas were classified in the riverine system in the study area. The Rio Grande channel was mapped as estuarine along the lower marine influenced portion but was changed to riverine up river within the map area. The change from estuarine to palustrine marshes is at the point where ocean-derived salts along the channel are less than 0.5 ppt, which is upstream beyond the study area. (See explanation in last paragraph in preceding Estuarine System).

FREEPORT TO EAST MATAGORDA BAY

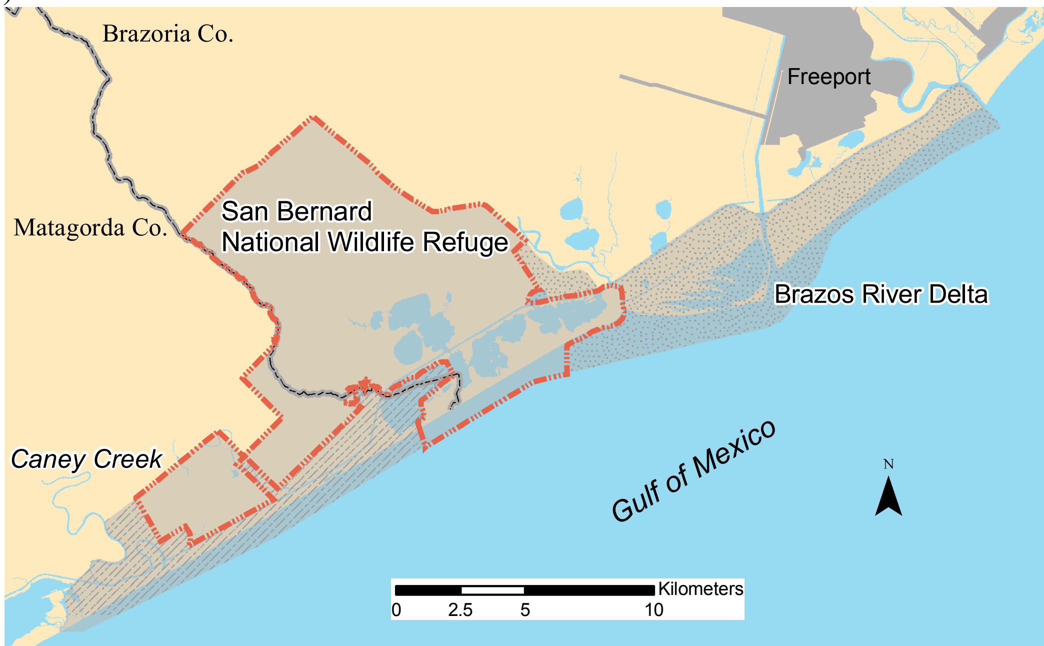
Study Area

The study area encompassing Freeport to East Matagorda Bay includes the shore and delta system between Freeport and East Matagorda Bay (which is southeast of Caney Creek in Fig. 19a). Included are the Brazos River delta, Cedar Lakes, Sargent Beach, and Caney Creek. The estuarine system in this area includes Cedar Lakes, the mouths of the Brazos and San Bernard Rivers, Caney Creek, the Gulf Intracoastal Waterway (GIWW), and connecting branch channels. The study area is located within Brazoria and Matagorda Counties. Numerous field sites in the study area were visited during this investigation (Fig. 19b).

General Setting of the Freeport to East Matagorda Area

Geologically, habitats in this area were deposited and formed by the Modern-Holocene Brazos–Colorado River deltaic system (Fig. 20a) (McGowen et. al. 1976). Today, the Brazos and San Bernard Rivers cross this area and discharge southwest of Freeport into the Gulf of Mexico. In 1929, the lower reach of the Brazos River was diverted so that the mouth of the river now discharges about 10 km down the coast (southwest) from its original location near Surfside (McGowen et. al. 1976). The "abandoned" part of the channel has been jettied and dredged to create the Freeport Ship Channel. At the diverted mouth of the Brazos River, a new delta has formed (Fig. 21) consisting of numerous beach ridges and interlying swales that are the sites of marshes and ponds. Except for progradation of this small delta, historically high rates of erosion have characterized this part of the Texas coast, which is part of the relict, retreating deltaic headland of the Colorado and Brazos Rivers. Erosion rates have locally exceeded 12 m/yr (Morton and Pieper, 1975; Paine and Morton, 1989; Gibeaut, et. al., 2000). The high rates of erosion have threatened to intersect the GIWW in one area, requiring construction of a seawall to protect the waterway (Fig. 22). Most of the study area extends from the Gulf shoreline to the GIWW except in the vicinity of the San Bernard National Wildlife Refuge where the area of study extends inland encompassing most of the Refuge and an area to the southwest near Caney Creek (Fig. 19).

(a)



(b)

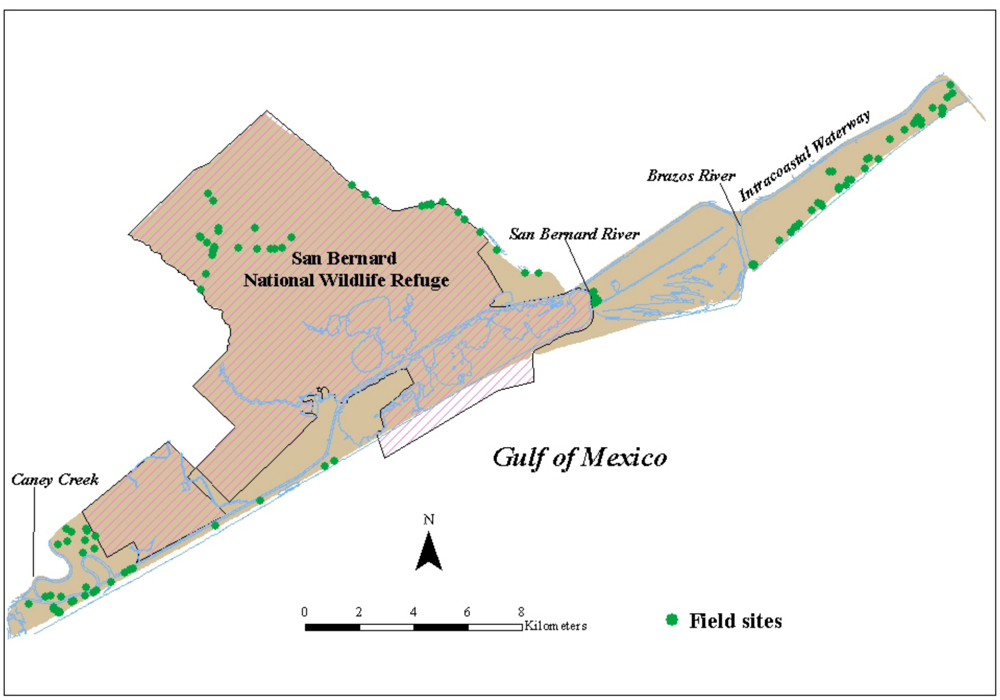


Figure 19. Index map of (a) study area subdivided into the following subareas: Brazos River delta (stippled pattern), San Bernard National Wildlife Refuge (outlined in red), and Caney Creek area (hachured pattern), and (b) field sites visited in the Freeport to East Matagorda Bay study area.

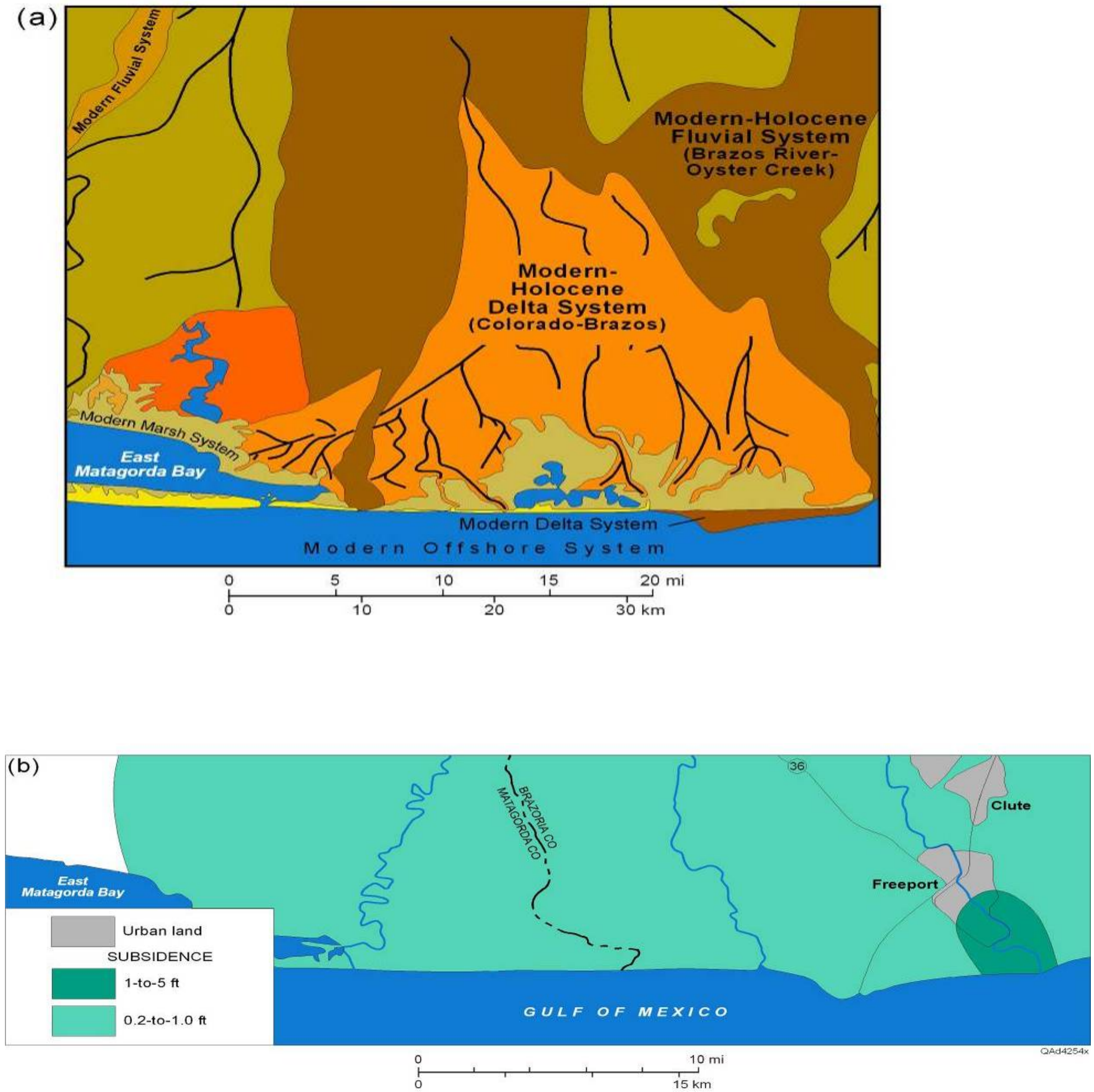


Figure 20. (a) Natural depositional systems in the Freeport area (from McGowen et al., 1976) and (b) subsidence from 1943-1973 (from Gabrysch and Bonnet, 1975). The relict Colorado-Brazos deltaic system filled any existing estuarine system and prograded into the Gulf. Today it is retreating through high rates of erosion except at the mouth of the diverted Brazos River where a small delta has formed.

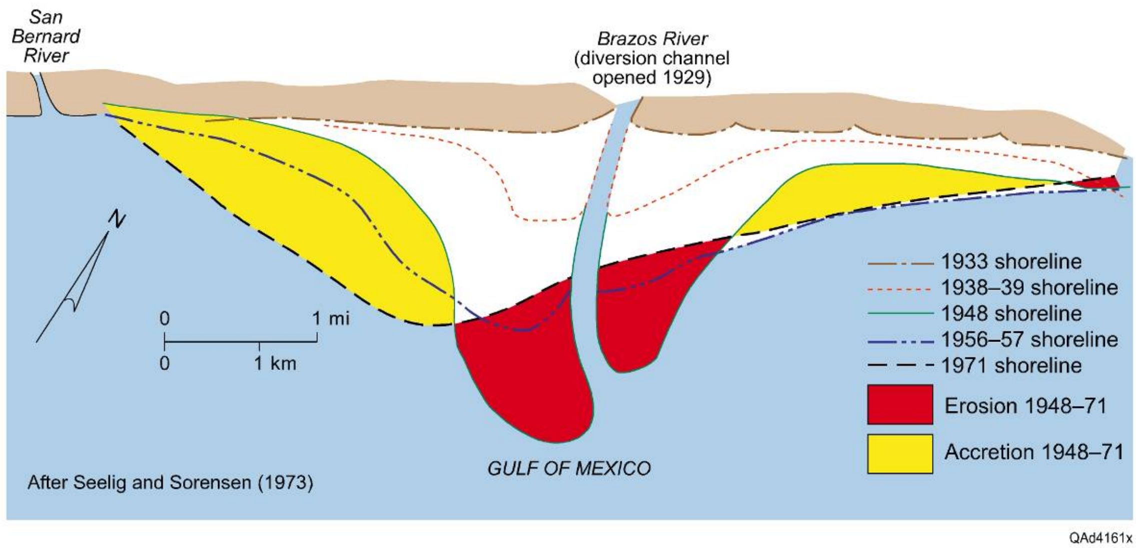


Figure 21. Historical position of the Brazos River diversion channel that was opened in 1929.

Figure 22. Top of shoreline protection feature constructed to protect the GIWW between Caney Creek and Cedar Lakes. View is gulfward.

Geomorphic features on which various types of wetlands have developed are the result of numerous interacting processes. Physical processes that influence wetlands include astronomical and wind tides, waves and longshore currents, storms and hurricanes, river flow, deposition and erosion, subsidence, faulting, sea-level rise, precipitation, water-table fluctuations, and evapotranspiration. These processes have contributed to development of a gradational array of permanently inundated to infrequently inundated environments ranging in elevation from estuarine subtidal areas to topographically higher intertidal wetlands that grade upward from the astronomical-tidal zone through the wind-tidal zone to the storm-tidal zone. Average tidal range is approximately 0.5 m in the Gulf in this area (Freeport Harbor) (U.S. Department of Commerce, 1978).

Relative Sea-Level Rise

Relative sea-level rise (RSLR) is another important process affecting wetland and aquatic habitats. RSLR, as used here, is the relative vertical rise in water level with respect to a datum at the land surface, whether it is caused by a rise in mean water level or subsidence of the land surface. Along the Texas coast, both processes, eustatic sea-level rise and subsidence, are part of the RSLR equation. Subsidence, especially associated with withdrawal of groundwater and oil and gas, is the overriding component.

Over the past century, sea level has risen on a worldwide (eustatic) basis at about 0.12 cm/yr, with a rate in the Gulf of Mexico and Caribbean region of 0.24 cm/yr (Gornitz et al. 1982; Gornitz and Lebedeff, 1987). Adding compactional subsidence to these rates yields a relative sea-level rise that locally exceeds 1.2 cm/yr (Swanson and Thurlow, 1973; Penland et al. 1988). Short-term rates of relative sea-level rise in the Freeport area exceeded 1.1 cm/yr from 1959 through 1971, (Swanson and Thurlow, 1973), and 1.4 cm/yr from 1954 through 1986 (records were incomplete for the years 1954, 1966, and 1984) (Lyles et al. 1988). These short-term rates can be affected by secular variations in sea level caused by climatic factors, such as droughts and periods of higher than normal precipitation and riverine discharge. Short-term sea-level variations produce temporary adjustments in the longer term trends related to eustatic sea-level rise and subsidence. Subsidence in the Freeport area resulting from ground water withdrawal and possibly hydrocarbon production is as much as 1.5 m (5 ft) (Fig. 20b). High rates of RSLR can cause changes in habitats such as estuarine marshes and wind-tidal flats (White et al. 1998). These types of changes are presented in the discussion of wetland trends.

Status of Wetlands and Aquatic Habitats, Freeport to East Matagorda Bay, 2002

Estuarine System

Marshes (Estuarine Intertidal Emergent Wetlands)

The estuarine intertidal emergent wetland habitat (E2EM) consists of 8,319 ha of salt and brackish marshes (Fig. 23 and 24). The irregularly flooded estuarine marsh, or high marsh, is most abundant at 5,358 ha (Table 3). The regularly flooded estuarine marsh, or low marsh, covers 2,961 ha. The most extensive estuarine emergent wetlands (salt and brackish marshes) occur in the SBNWR, which is the largest subarea mapped (Fig. 25 and 26; Table 4). Approximately 6,510 ha of estuarine marsh was mapped in the refuge, compared to 978 ha in the Brazos delta subarea, and 830 ha in the Caney Creek subarea. The estuarine intertidal marsh habitat makes up about 95% of the intertidal wetland habitats (e.g., excluding subtidal habitats – the E1 and M1 map units) in the study area.

Tidal Flats (Estuarine Intertidal Unconsolidated Shores)

Estuarine intertidal unconsolidated shores (E2US) include wind-tidal flats, beaches, and algal flats. Approximately 363 ha of E2US was mapped in the study area (Table 3). Tidal flats are most extensive in the Brazos delta subarea where 185 ha was mapped, followed by the SBNWR at 114 ha; 64 ha of tidal flat was mapped in the Caney Creek subarea Fig. 25; Table 4). Low, regularly flooded tidal flats are more extensive than high flats (Table 3). Because of the low astronomical tidal range, many flats are flooded only by wind-driven tides. These tidal habitats represent only 4% percent of the intertidal wetland system (excluding subtidal habitats and the E1 and M1 map units). The mapped extent of the tidal flats can be substantially affected by tidal levels at the time aerial photographs were taken. Accordingly, absolute areal extent of flats may vary from that determined using aerial photographs.

Aquatic Beds (Estuarine Subtidal Aquatic Beds)

Estuarine subtidal rooted vascular aquatic beds (E1AB3L) represent areas of submerged vascular vegetation, or seagrasses. Accurate delineation of seagrasses on aerial photographs is dependent on the season in which the photographs were taken and water turbidities, which can obscure seagrass areas. Only 6 ha of seagrasses were mapped in the study area. Most of the subtidal aquatic beds (381 ha) were mapped as unknown submergent (E1AB5) because the type of aquatic bed (algae or seagrass) could not be verified. We assumed most dark areas in estuarine waters, primarily in the refuge, were algal mats and organic material; locally, scattered oyster beds may have been included.

Table 3. Areal extent of mapped wetland and aquatic habitats in 2002, Freeport to East Matagorda Bay.

NWI Code	National Wetlands Inventory Description	Hectares	Acres	Percent
E1AB3	Estuarine Subtidal Aquatic Bed, Rooted Vascular	6	14	0.03
E1AB5	Estuarine Subtidal Aquatic Bed, Unknown Submergent	381	941	1.77
E1RF2L	Estuarine Subtidal Reef, Mollusk	200	494	0.93
E1UB	Estuarine Subtidal Unconsolidated Bottom	2,591	6,404	12.07
E2EM1N	Estuarine Intertidal Emergent Wetland, Regularly Flooded	2,961	7,317	13.79
E2EM1P	Estuarine Intertidal Emergent Wetland, Irregularly Flooded	5,358	13,239	24.95
E2RF2M	Estuarine Intertidal Reef, Mollusk	67	166	0.31
E2USM	Estuarine Intertidal Flat, Irregularly Exposed	44	109	0.20
E2USN	Estuarine Intertidal Flat, Regularly Flooded	178	440	0.83
E2USP	Estuarine Intertidal Flat, Irregularly Flooded	142	350	0.66
Subtotal		**11,928**	**29,475**	**55.56**
L2AB5	Lacustrine Littoral Aquatic Bed, Unknown Submergent	26	65	0.12
L2UBF	Lacustrine Littoral Unconsolidated Bottom, Semipermanently Flooded	13	33	0.06
L2UBK	Lacustrine Littoral Unconsolidated Bottom, Artificially Flooded	76	188	0.35
L2USK	Lacustrine Littoral Unconsolidated Shore, Artificially Flooded	67	166	0.31
Subtotal		**182**	**451**	**0.85**
M1UB	Marine Subtidal Unconsolidated Bottom	3,701	9,146	17.24
M2USN	Marine Intertidal Unconsolidated Shore, Regularly Flooded	39	95	0.18
M2USP	Marine Intertidal Unconsolidated Shore, Irregularly Flooded	189	466	0.88
Subtotal		**3,928**	**9,707**	**18.30**
PEM1A	Palustrine Emergent Wetland, Temporarily Flooded	636	1,571	2.96
PEM1C	Palustrine Emergent Wetland, Seasonally Flooded	260	644	1.21
PEM1F	Palustrine Emergent Wetland, Semi-Permanently Flooded	113	279	0.53
PEM1K	Palustrine Emergent Wetland, Artificially Flooded	321	792	1.49
PSS1A	Palustrine Scrub/Shrub Wetland	38	94	0.18
PUB	Palustrine Unconsolidated Bottom	5	11	0.02
PUBC	Palustrine Unconsolidated Bottom, Seasonally Flooded	3	8	0.02
PUBF	Palustrine Unconsolidated Bottom, Semi-Permanently Flooded	10	24	0.04
PUBH	Palustrine Unconsolidated Bottom, Permanently Flooded	4	9	0.02
PUBK	Palustrine Unconsolidated Bottom, Artificially Flooded	23	57	0.11
PUSK	Palustrine Unconsolidated Shore, Artificially Flooded	65	161	0.30
Subtotal		**1,478**	**3,651**	**6.88**
U	Upland	3,954	9,771	18.42
Total		**21,471**	**53,055**	**100.00**

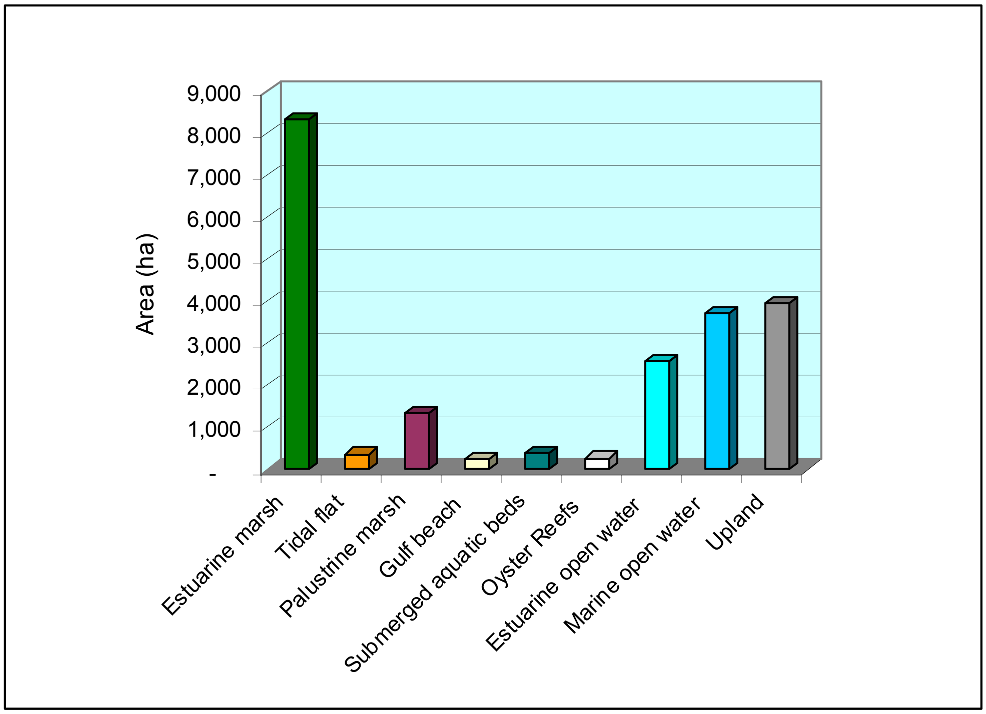


Figure 23. Areal distribution of selected habitats in the Freeport-East Matagorda Bay study area.

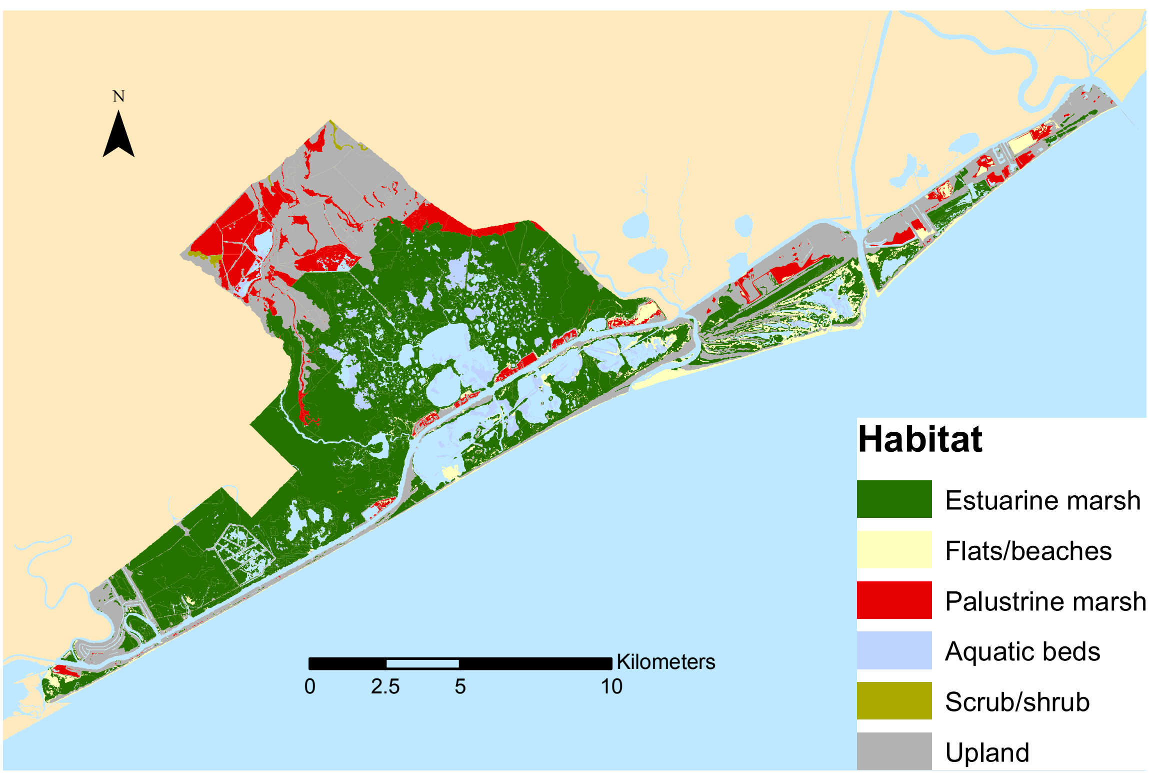


Figure 24. Distribution of major habitats in 2002 in the Freeport to East Matagorda Bay study area.

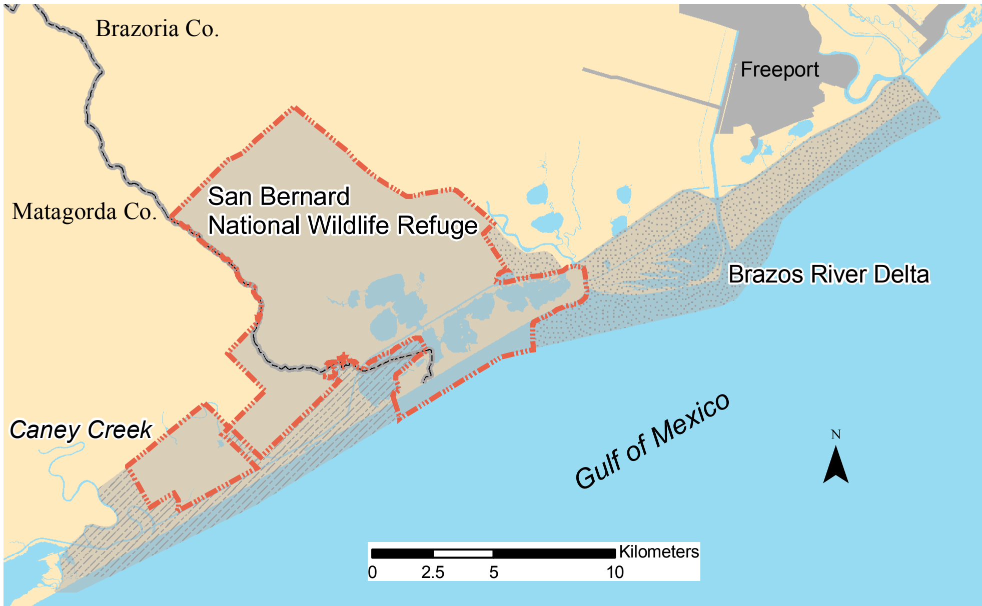


Figure 25. Index map of study area subdivided into the following subareas: Brazos River delta (stippled pattern), SBNWR (outlined in red), and Caney Creek area (hachured pattern).

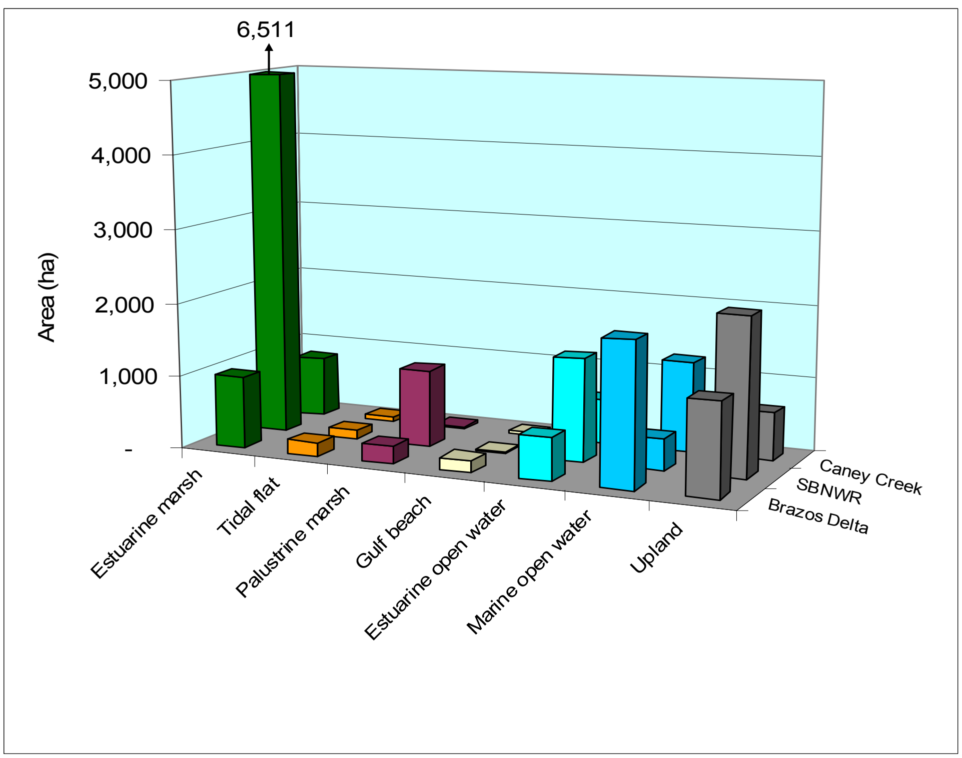


Figure 26. Distribution of selected habitats by geographic areas (Brazos Delta, SBNWR, and Caney Creek) in 2002. The most extensive estuarine and palustrine marshes are in the SBNWR.

Table 4. Areal extent (ha) of selected habitats for the three subareas in 2002.

	Brazos Delta	SBNWR	Caney Creek	Totals
Estuarine marsh	978	6,511	830	8,319
Tidal flat	185	114	64	363
Palustrine marsh	246	1,052	33	1,331
Gulf beach	166	22	39	227
Estuarine open water	580	1,400	610	2,590
Marine open water	1,941	434	1,327	3,701
Upland	1,271	2,149	648	4,068

Open Water (Estuarine Subtidal Unconsolidated Bottom)

Estuarine subtidal unconsolidated bottom (E1UBL), or open water, includes water features in the SBNWR such as Cedar Lakes and Cow Trap Lake (Fig. 27), the lower reaches of rivers, the GIWW, and other smaller water areas. The total area of estuarine open water is 2,590 ha, which is about 12% of all habitats in the study area including uplands.

Oyster Reefs (Estuarine Reefs)

Oyster reefs (E2RF2M) mapped on the 2002 photographs amounted to 200 ha and are mostly in Cedar Lakes and Cow Trap Lake in the SBNWR. Only those that were near the water's surface and were clearly visible were mapped.

Palustrine System

Marshes (Palustrine Emergent Wetlands)

Palustrine emergent wetlands (PEM), or inland "freshwater marshes," cover 1,331 ha (Fig. 23; Table 4) and represent 14% of emergent vegetated wetlands (EM + SS). The broadest distribution of palustrine emergent wetlands is in the SBNWR where more than 1,000 ha was mapped along the inland margins of the estuarine system (Figs. 1 and 28). Typically, palustrine marshes were classified into one of four water regimes: (1) temporarily flooded, (2) seasonally flooded, (3) semi-permanently flooded, and (4) artificially flooded. Most extensive in the map area were those that were temporarily flooded. Palustrine marshes in the SBNWR account for approximately 80 percent of this habitat mapped in the study area.

Open Water and Flat (Palustrine Unconsolidated Bottom and Shore)

Palustrine unconsolidated bottom (PUB), or open water, and palustrine unconsolidated shore (PUS), or flat, habitats are generally small-fresh to brackish water ponds and flats. The total mapped area of these habitats was only 110 ha, almost 60% of which were flats in artificially flooded dredged material disposal areas (Table 3).

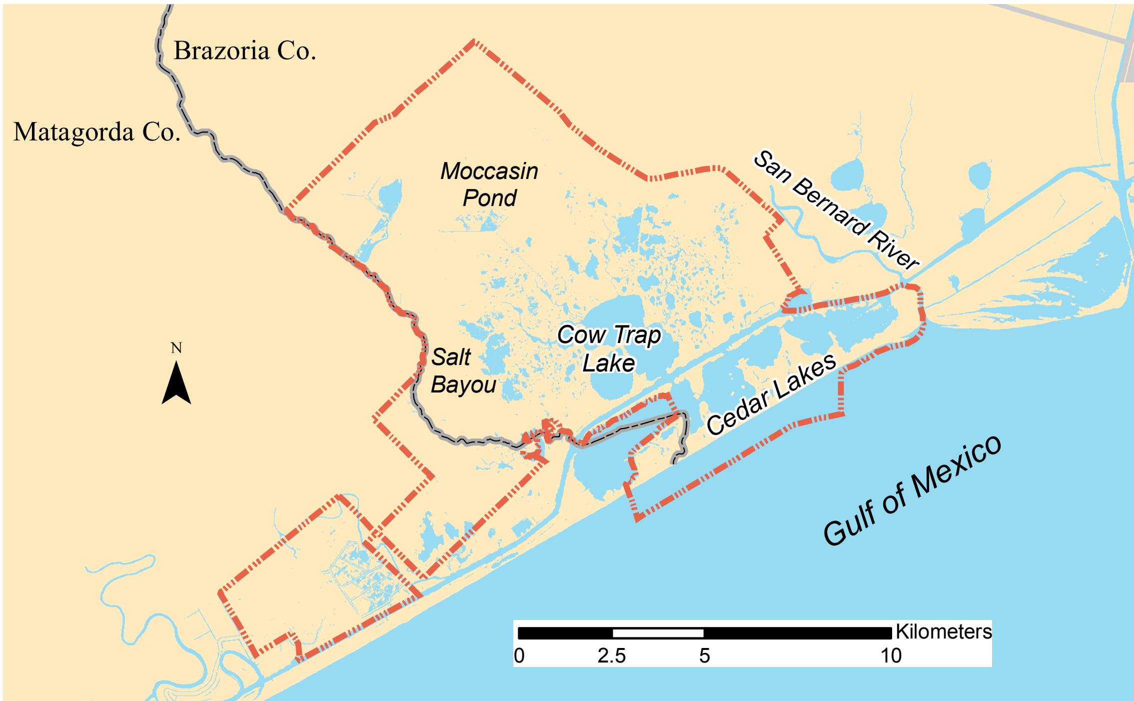


Figure 27. Major water features in the SBNWR.

Figure 28. Palustrine marsh dominated by *Aster spinosus* in the SBNWR.

Marine System

Gulf Beach and Open Water (Marine Intertidal Unconsolidated Shore and Subtidal Unconsolidated Bottom)

The Gulf beach represents the marine intertidal unconsolidated shore (M2US). Two components were mapped; the topographically lower, regularly flooded fore beach and irregularly flooded backbeach (Fig. 9). The total area of this habitat in the study area is 227 ha. This habitat is most extensive in the Brazos delta subarea, where almost 75% of this habitat was mapped (Fig. 26). A buffer zone approximately 1 km wide of marine subtidal unconsolidated bottom (M1UB), or marine open water was included along the Gulf shoreline, primarily to standardize the size of the map area for each time period analyzed.

Historical Trends in Wetland and Aquatic Habitats, Freeport to East Matagorda Bay

General Trends in Wetlands within the Study Area

Analysis of trends in wetlands and aquatic habitats in the Freeport to East Matagorda Bay study area shows that there was a net gain in estuarine marshes from the 1950's to 2002. The total area of marshes increased from 7,727 ha in the 1950's to 8,319 ha in 1979, where it remained in 2002 (Table 5; Figs. 29 and 30). This increase amounted to 592 ha from the 1950's through 2002. During the same time, there was a systematic decrease in tidal flats (E2FL or E2US). The area of flats declined from 899 ha in the 1950's to 653 ha in 1979 to 363 ha in 2002 (Table 5). These changes reflect losses of 246 ha and 290 ha for each period, respectively. Palustrine marshes (PEM) increased in area by 623 ha from the 1950's through 1979 and by 443 ha from 1979 through 2002. Estuarine reefs (E1 and E2RF2) are oyster reefs. The mapped area of reefs increased from the 1950's to 1979/2002 by approximately 145 ha. Reefs can be obscured by turbid water, however, and total distribution as interpreted on aerial photographs is approximate. The area of estuarine open water increased slightly from the earlier years to 2002 (Table 5). Gulf open water in the study area also increased

Table 5. Area (ha) of selected habitats in the Freeport-East Matagorda study area.

Habitat	1950's	1979	2002
Estuarine marsh	7,727	8,319	8,319
Tidal flat	899	653	363
Palustrine marsh	264	887	1,330
Gulf beach	460	310	227
Oyster reefs	121	265	267
Estuarine open water	2,472	2,408	2,591
Gulf open water	3,224	3,629	3,701
Upland	6,336	4,881	3,954

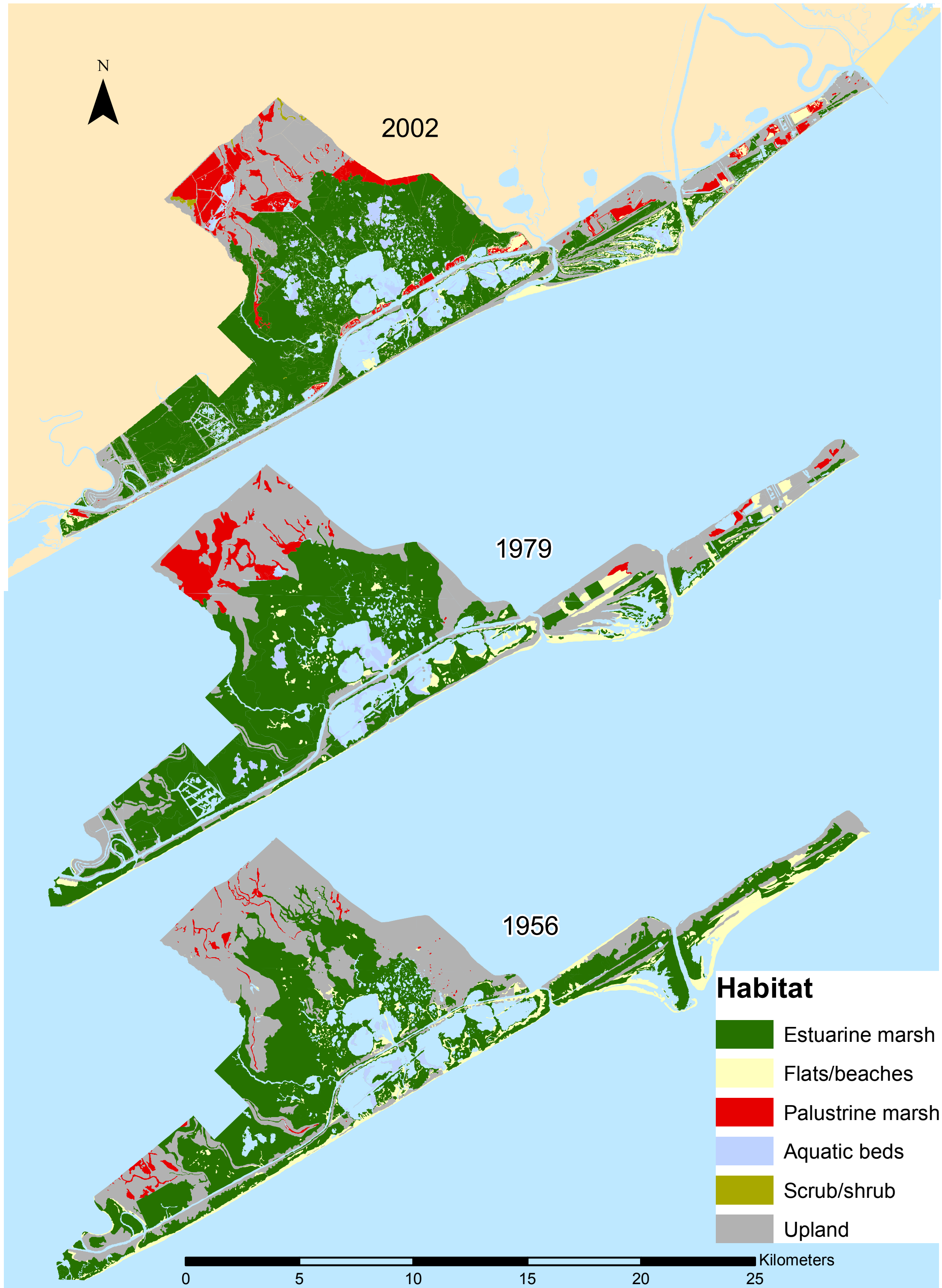


Figure 29. Map showing distribution of major wetland and aquatic habitats in 2002, 1979, and the 1950's in study area.

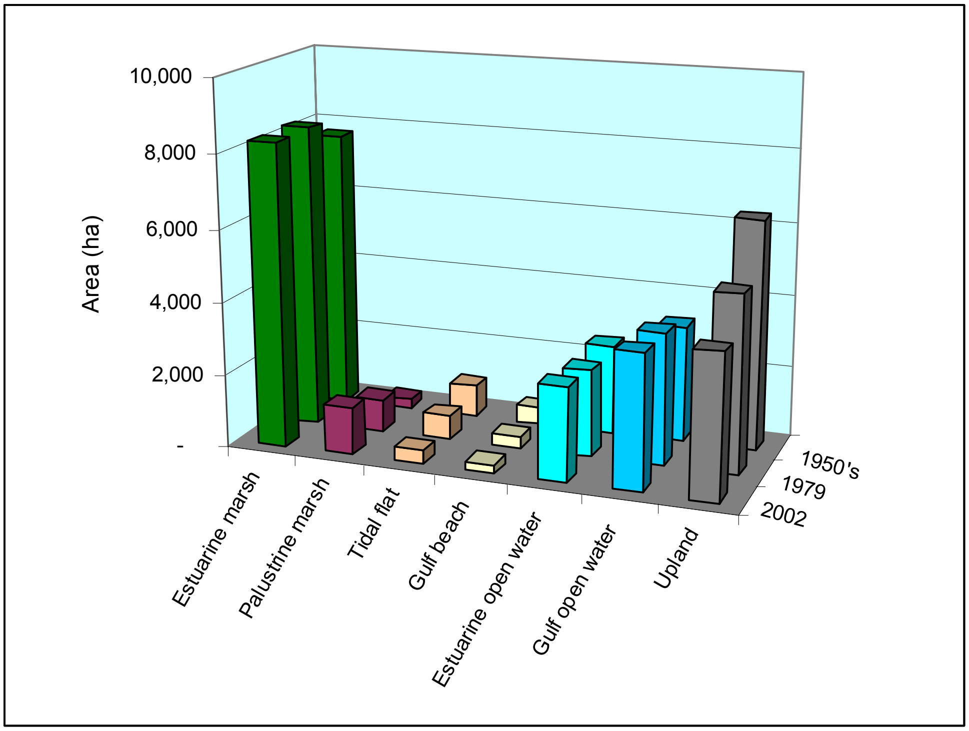


Figure 30. Areal extent of major habitats in the Freeport–East Matagorda study area in the 1950's, 1979, and 2002.

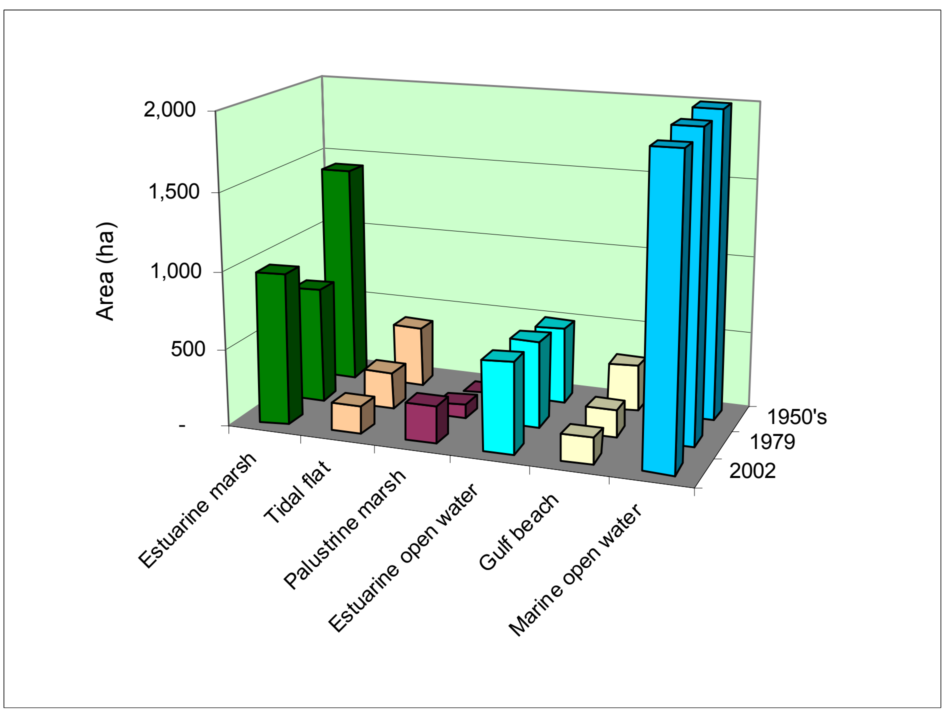


Figure 31. Areal extent of major habitats on the Brazos delta subarea in the 1950's, 1979, and 2002.

from the 1950's to 1979 and 2002.

The amount of mapped uplands in the study area decreased from the 1950's to later years. Probable causes of changes in habitats are presented in the following sections organized by geographic area.

Analysis of Habitat Trends by Geographic Area

As noted previously, the study area was subdivided into major natural areas and geographic components for analysis of the historical trends (Fig 25). The subareas are presented from northeast to southwest in the following order (1) Brazos delta, (2) San Bernard National Wildlife Refuge, and (3) Caney Creek. This subdivision allowed a more site-specific analysis of trends and their probable causes. Emphasis is placed on estuarine and palustrine marshes.

Brazos Delta

General Trends. The most significant trend, or change, on the Brazos delta and surrounding area was the loss of estuarine marsh from the 1950's to 1979 and 2002 (Fig. 31). Although there were losses and gains in marshes at different locations through time, the total area of marsh habitat, which was about 1,430 ha in the 1950's, decreased in size by 683 ha through 1979, but increased by 231 ha from 1979 to 2002. The net loss from the 1950's to 2002, however, was 452 ha. This decrease in marsh represents a loss of about 30% of this habitat in the Brazos delta subarea since the 1950's. Also, there was a systematic decrease in the area of tidal flats and Gulf beach from the 1950's to 2002 (Fig. 31). Palustrine marshes increased in area during this period, although the total area of this habitat was relatively small.

Probable Cause of Trends. The 30% decline in estuarine marsh from the 1950's to 2002 occurred as marshes that had developed at the mouth of the diverted Brazos river (see introduction) were eroded along the Gulf shoreline. Part of the loss was offset by delta progradation down drift of the mouth of the river where development of new marshes occurred (Fig. 32). In addition, construction of the GIWW impacted wetlands as disposal of dredged material converted many to uplands (Fig. 33). GIS overlay analysis of habitat distribution indicates that approximately 50% of the marsh loss in the Brazos delta subarea was the result of conversion to upland habitat.

San Bernard National Wildlife Refuge (SBNWR)

General Trends. The most significant trend in the refuge was the systematic gain in palustrine emergent marsh (PEM) between the mid-1950's and 2002 (Fig. 34). The original mid-1950s PEM area increased from 241 ha to 801 ha in 1979 representing an increase of 232%. The subsequent increase to 1,052 ha in 2002 represents an

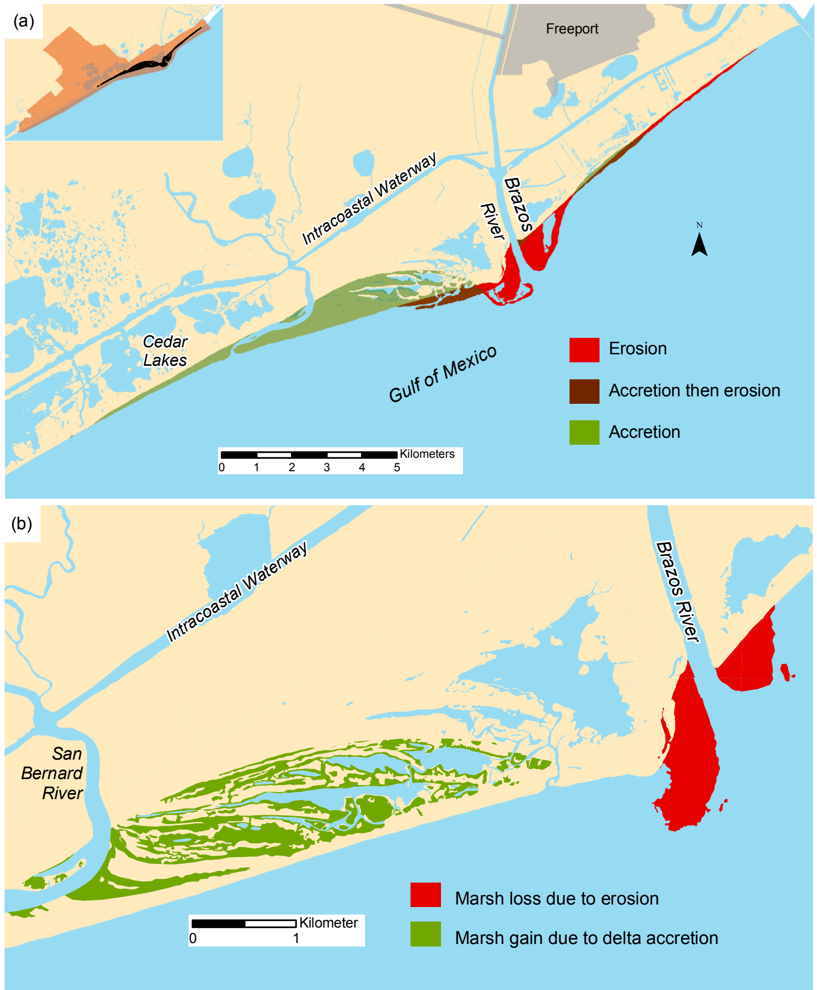


Figure 32. Changes in the Brazos River delta from the 1950's to 2002.

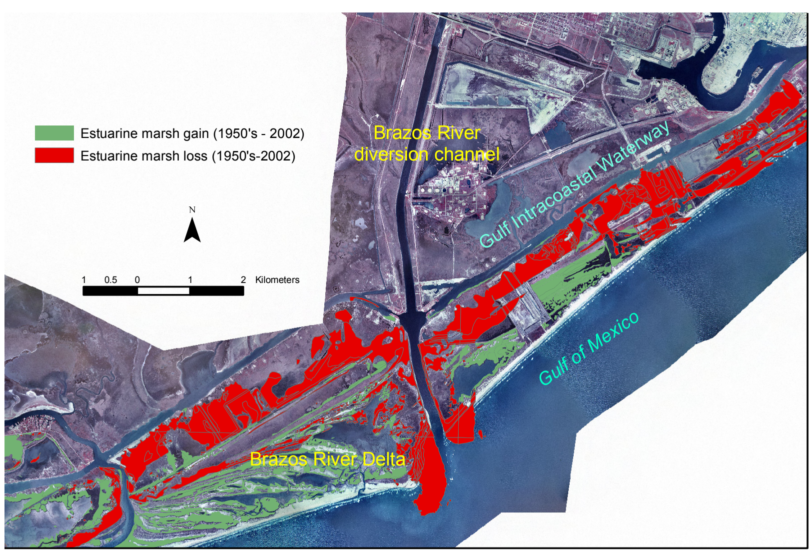


Figure 33. Illustration showing approximate locations of losses and gains in estuarine marsh on the Brazos River delta, and along the GIWW from the 1950's to 2002. Most of the loss along the GIWW was the result of dredged material disposal.

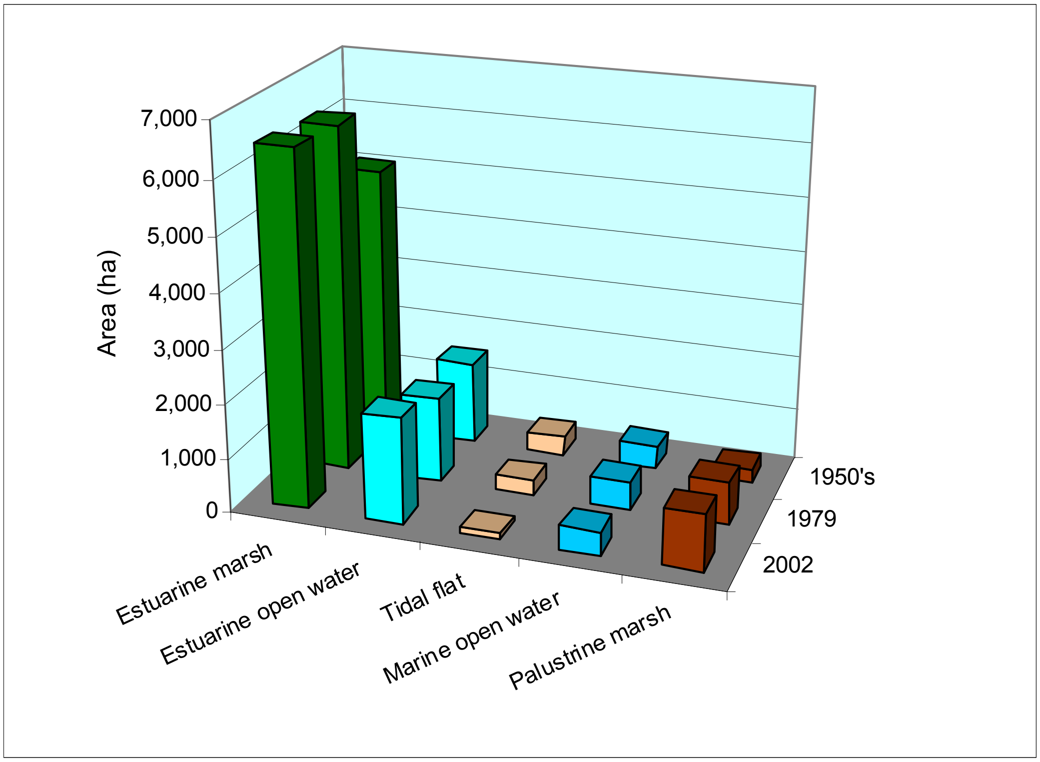


Figure 34. Areal extent of major habitats in the SBNWR in the mid-1950's, 1979, and 2002.

Figure 35. Lesser snow geese in an estuarine marsh in the SBNWR. Consumption of marsh vegetation by the geese contributes to vegetation loss and conversion of areas to open water (Miller et al., 1996).

additional 31%. While both time periods experienced high rates of PEM increase, the magnitude of the increase was reduced significantly in the later time period.

The largest wetland habitat by area in the SBNWR is estuarine intertidal emergent marsh (E2EM). Like PEM habitat, E2EM area increased in both time periods but at much lower rates. In the mid-1950's, E2EM covered 5,054 ha, increasing to 6,414 ha in 1979, representing a 27% increase. By 2002, that number had increased to 6,511 ha, an additional 2%.

Estuarine intertidal unconsolidated shore (E2US), or tidal flat habitat experienced a systematic decline in area through time. The mid-1950's total of 355 ha of E2US decreased to 286 ha by 1979, representing a 19% decrease. Tidal flat area continued to decline at a significantly higher rate between 1979 and 2002, when the area decreased to 114 ha (60% decrease).

Probable Cause of Trends. The large initial gain of palustrine marsh (PEM) in SBNWR is located in the northwest section of the refuge. PEM was mapped sparingly in this area in the mid-1950's, primarily confined to narrow riparian strips. By 1979, PEM occupied large areas that in the 1950's were mapped as upland. Approximately 75% of the gross PEM gain in the earlier time period was in areas previously mapped as uplands. Some of the PEM gain occurred where the mapped boundary between estuarine and palustrine marsh shifted. Later mapping placed this boundary further gulfward causing areas mapped as E2EM in the mid-1950's to be mapped as PEM in 1979 and 2002. Another area where PEM moved into upland areas is along the eastern edge of the refuge adjacent to the San Bernard River (Fig. 27 and 29). A large tract in this area accounts for ~160 ha of gross PEM gain.

Much of the 1979-2002 increase in PEM occurred in the Moccasin Pond area (Fig. 27). Construction of elevated road beds has altered the surface hydrology, pooling water and increasing marsh area. This increase appears to follow refuge management practices which encourage fresh water habitat. Newly constructed ponds produce a net increase of PEM, although some open water has inundated former PEM areas. An ~100 ha pond due west of Moccasin Pond, which formed between 1979-2002, inundated former PEM habitat. Another significant land use practice is the impoundment of dredged material along the GIWW. When left undisturbed for a period of time, disposal pits provide a favorable substrate for palustrine marsh development. Isolated from tidal influence palustrine species dominate. PEM was mapped in 2002 in several locations that were previously mapped as upland and E2EM.

Estuarine intertidal emergent marsh (E2EM) has shown a systematic increase through time. A net increase between the mid-1950s and 1979 of 27% is primarily located in transitional areas between high marsh (E2EM1P) and uplands. Areas mapped as uplands in the mid-1950's, which later became marsh, account for 78% of the gross E2EM gain. Marsh expansion occurred in several locations along the shores of the Cedar Lakes. Dredged material deposited between the GIWW and the lakes became vegetated and marsh expanded into the adjacent open waters of the lakes. On the land strip between the lakes and the Gulf of Mexico estuarine marsh migrated from the lake shore gulfward into flats and uplands. Marsh migration into uplands has been documented along other segments of the Texas coast where relative sea-level rise has caused a shift of wetland habitats towards environments previously occupied by upland species.

Loss of E2EM habitat in the mid-1950's to 1979 time period occurred where small ponds around Cow Trap Lake and large (50 ha) shallow wet areas in and around Salt Bayou formed. These areas, mapped as aquatic beds and E2EMFL, are incipient open water areas where marsh is experiencing flooding and erosion. Miller et al. (1996) suggest that high rates of lesser snow geese herbivory in these areas (Fig. 35) contributed to the conversion of emergent vegetation to open water. Further west, road construction around Moccasin Pond, prior to 1979, impounded estuarine marsh. Isolated from tidal influence the habitat experienced less saline conditions and converted from estuarine marsh to palustrine marsh. Moccasin Pond forms part of the boundary, as mapped in the later time periods, between estuarine-influenced marsh to the south and east and palustrine marsh to the north and west.

In the western part of the refuge, an interconnected grid of channels was excavated shortly after the mid-1950's NWI data capture. The purpose of the excavated features is uncertain but their construction required the destruction of E2EM habitat. Visual comparison between 1956-1957 Edgar Tobin aerial photo mosaic and 1979 CIR aerial photos identifies some areas of interpretational discrepancy between mid-1950's and 1979 E2EM mapping. An area mapped as marsh in the mid-1950's on the barrier island adjacent to the San Bernard River appears to be upland in all vintages of aerial photography. The upland signature extends to the strip of land between the Cedar Lakes and the Gulf of Mexico. However, E2EM habitat was lost along the Gulf margin of the land strip as a result of exceptionally high rates of shoreline erosion. On the landward side of the Cedar Lakes, additional E2EM loss resulted from dredged material deposited along the GIWW.

The trend towards increasing E2EM area continued into the later time period but at a lower rate (2%). As in the earlier time period, much of the gross gain (~58%) in E2EM between 1979 and 2002 is attributed to the migration of estuarine marsh into uplands. E2EM increase occurred along the Gulf edge of the Cedar Lakes where marsh migrated into former upland and beach areas. In the most eastern part of the Cedar Lakes, marsh moved into transitional areas previously mapped as flats.

Successful habitat management practices in the SBNWR between 1979 and 2002 further increased lacustrine open water in Moccasin Pond but at the cost of E2EM habitat. Large open water and aquatic bed areas formed north of Cow Trap Lake and to the west in Salt Bayou. Roughly 32% of the net E2EM loss between 1979 and 2002 was to estuarine subtidal aquatic bed (E1AB) habitat. Formation of these shallow water bodies suggests continued relative sea-level rise. Development of spoil pits along the GIWW has also lowered E2EM numbers. Impounded marsh was isolated from tidal influence and classified as PEM in the later time period.

Estuarine intertidal unconsolidated shore (E2US) is a relatively rare habitat in the SBNWR (Fig. 34). Within the study time frame E2US habitat numbers have consistently decreased. In the time period 1956-1979, roughly 50% of the E2US habitat became E2EM. Much of the conversion to E2EM took place on the periphery of the Cedar Lakes. Subsequent loss continued in this area, where ~42% of the 1979 E2US habitat converted to E2EM.

Caney Creek Area

General Trends. The most significant trend, or change, in the Caney Creek subarea (Fig. 25) was a loss of about 31% of the estuarine marsh habitat from the 1950's to 2002 (Fig. 36). The total area of salt and brackish marsh habitat, which covered 1,210 ha in the 1950's, declined by 380 ha to a total of 830 ha by 2002. Coincident with the loss of marsh in this subarea was an increase in marine open water of 503 ha (Fig. 36). Other changes included a decline in tidal flats and Gulf beaches, and a systematic increase in estuarine open water through time (Fig. 36). Palustrine marsh had a relatively small area of 14 ha in the 1950's, and increased slightly to 33 ha in 2001.

Probable Cause of Trends. The 31% decline in estuarine marsh habitat in the Caney Creek subarea can be attributed principally to (1) retreat of the Gulf shoreline and erosion of marshes (Fig. 37), and (2) conversion of marshes to uplands through (a) residential development along Caney Creek, (b) dredged material disposal along the GIWW, and (c) seawall construction to protect the GIWW (Fig. 22). Some of the excavation related to sea-wall construction, however, has produced marshes locally. Approximately 45% of the gross loss in marsh occurred from erosion and conversion of marsh to marine open water as the Gulf shoreline retreated, and about 30% of the loss occurred from conversion of marsh to uplands.

Summary and Conclusions, Freeport to East Matagorda Bay

The most significant trend or change on the **Brazos Delta** and surrounding area was the loss of estuarine marsh from the 1950's to 1979 and 2002. Although there were losses and gains in marshes at different locations through time, the total area of marsh habitat, which was about 1,430 ha in the 1950's, had a net loss of 452 ha from the 1950's to 2002. This decrease in marsh represents a loss of about 30% of this habitat in the Brazos Delta subarea since the 1950's. The 30% decline occurred as marshes that had developed at the mouth of the diverted Brazos River were eroded along the Gulf shoreline. Part of the loss was offset by delta progradation down drift of the mouth of the river where development of new marshes occurred. Additional marsh loss occurred along the GIWW as disposal of dredged material converted many of the 1950's marshes to uplands. GIS overlay analysis of habitat distribution indicates that approximately 50% of the marsh loss in the Brazos delta subarea was the result of conversion to upland habitat. Also, there was a systematic decrease in the area of tidal flats and Gulf beach from the 1950's to 2002. Palustrine marshes increased in area during this period, although the total area of this habitat was relatively small.

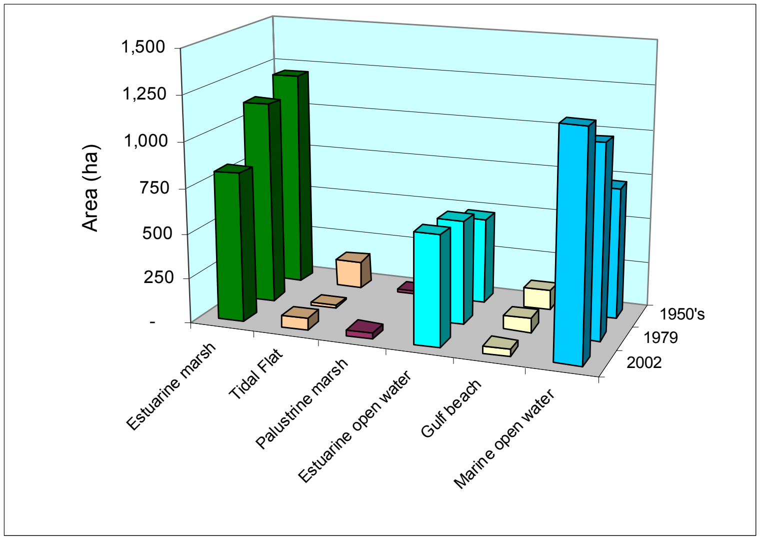


Figure 36. Areal distribution of major habitats in the Caney Creek subarea in the 1950's, 1979, and 2002.

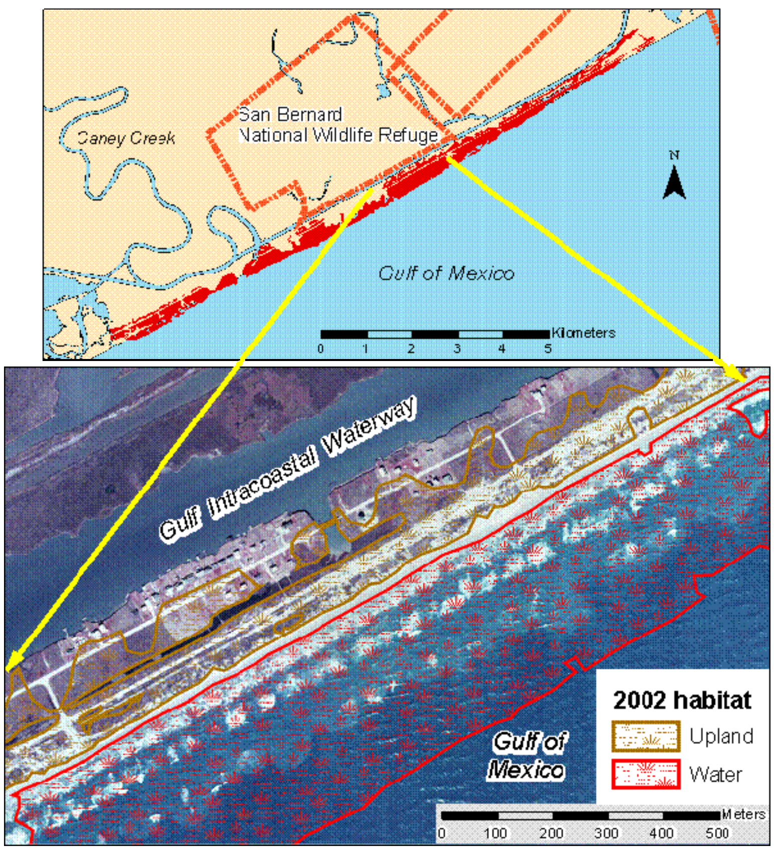


Figure 37. Loss of estuarine marsh due to Gulf shoreline erosion and development. The shoreline retreated approximately 300 m from the 1950's to 2002. The red pattern in the water represents the extent of estuarine marsh in the 1950's that was eroded and replaced by open water. The gold pattern on the land represents marsh that was displaced by development and construction of a seawall to protect the Gulf Intracoastal Waterway.

The most significant trend in the **San Bernard National Wildlife Refuge (SBNWR)** was the systematic gain in palustrine and estuarine marsh between the mid-1950's and 2002. The original mid-1950's palustrine marsh area increased from 241 ha to 801 ha in 1979, representing an increase of 232%. The subsequent increase to 1,052 ha in 2002 represents an additional 31%. Like palustrine marsh habitat, estuarine marsh area increased in both study time periods but at lower rates. In the mid-1950's, estuarine marsh covered 5,054 ha, increasing to 6,414 ha in 1979, representing a 27% increase. By 2002, that area had increased to 6,511 ha, an additional 2%. In both palustrine and estuarine marsh the earlier time period increase was primarily due to marsh encroachment into uplands. Movement of estuarine marsh into upland areas continued in the later time period. Dredged material deposition along the GIWW also increased both palustrine and estuarine marsh areas. When impounded, the lack of tidal influence in the disposal pit produces an environment more favorable for palustrine species. Fresh water impoundments, constructed as part of the refuge management plan, increased palustrine marsh area in the 1979-2002 time period. The effect of relative sea-level rise is most apparent in estuarine emergent marsh environments. Along the shores of the Cedar Lakes in both time periods, estuarine marsh increased in area as wetlands migrated in response to sea-level rise into areas previously occupied by flats and uplands. Other indications of relative sea-level rise are around the Cow Trap Lakes and Salt Bayou where open water ponds first appeared in former estuarine marsh habitat and expanded over time. Gulf shoreline erosion along the SBNWR stretch of the Texas coast was highest in the mid-1950's to 1979 time period. Large areas of estuarine marsh were eroded and replaced with marine open water. Estuarine marsh loss also occurred as a result of human intervention, where management practices and spoil deposition along the ICWW tend to favor palustrine habitat over estuarine habitat. Within the study time frame, tidal-flat habitat has consistently decreased. In the time period from1956-1979, roughly 50% of the tidal flat habitat became estuarine marsh. Much of the conversion to estuarine marsh took place on the periphery of the Cedar Lakes. Subsequent loss continued in this area where ~42% of the 1979 tidal flat habitat converted to estuarine marsh.

In the **Caney Creek** subarea, about 31% of the estuarine marsh habitat was lost from the 1950's to 2002. The total area of salt and brackish marshes, which covered 1,210 ha in the 1950's, declined in area to 830 ha by 2002, a loss of 380 ha. Coincident with the loss of marsh in this subarea was an increase in marine open water of 503 ha. Other changes included a decline in tidal flats and Gulf beaches, and a systematic increase in estuarine open water through time. Palustrine marsh had a relatively small area of 14 ha in the 1950's, and increased slightly to 33 ha in 2002. The 31% decline in estuarine marsh habitat in the Caney Creek subarea can be attributed principally to retreat of the Gulf shoreline and erosion of marshes, and conversion of marshes to uplands through residential development along Caney Creek, dredged material disposal along the GIWW, and seawall construction to protect the GIWW. Approximately 45% of the gross loss in marsh occurred from erosion and conversion of marsh to marine open water as the Gulf shoreline retreated, and about 30% of the loss occurred from conversion of marsh to uplands.

SOUTH PADRE ISLAND

Study Area

The study area includes South Padre Island from Mansfield Channel southward to the Brownsville Ship Channel (Brazos Santiago Pass), and Brazos Island from Brazos Santiago Pass to the Rio Grande. Also included is the South Bay area, which is bound by Brazos Island to the east, the Rio Grande to the South, and the Brownsville Ship Channel and Laguna Madre to the North (Fig. 38). The study area encompasses parts of 8 USGS 7.5' quadrangles (Fig. 8), and is located within Willacy and Cameron Counties.

General Setting of the South Padre Island Area

Unlike estuaries of the central and upper Texas coast, where rivers discharge into bays forming typical estuaries diluted by fresh water inflows, the Rio Grande in South Texas discharges into the Gulf of Mexico. Laguna Madre has no major rivers discharging into it. That fact, coupled with the fact that this area receives the least amount of precipitation of all areas along the Texas coast (average annual precipitation in Willacy County is about 70 cm and in Cameron County 68 cm) (Texas Almanac, 2000-2001) contribute to high salinities in Laguna Madre. Salinities at the southern end of Laguna Madre typically range from 23-36 parts per thousand (ppt) and are influenced by exchange of Gulf water through Brazos Santiago Pass (White et al., 1986). Salinities in South Bay average between 25 and 35 ppt. In the northern part of the study area near Mansfield Channel, salinities typically range from 20 to 40 ppt and average about 38 ppt.

In addition to high salinity regimes, climate strongly dictates the relative importance of many significant geological processes. Among them, the direction and intensity of persistent winds that control the movement of wave trains approaching shore and the resulting direction of long shore currents and sediment transport. Geologically, South Padre Island developed initially as a spit extending from the eroding, relict Rio Grande Holocene-Modern deltaic system that has been retreating for hundreds of years (Brown et al., 1980) (Fig. 39).

Most of South Padre Island's Gulf shoreline has been eroding except at the southern end near the jetties, which were constructed in 1935 (Morton and Pieper, 1975). From 1879-80 to 1974, overall net erosion was moderate, ranging from 2.4-4 m/yr (8-13 ft/yr). From 1974 to 1982, shorelines mostly continued to retreat (Paine and Morton, 1989). At 42 Gulf shoreline monitoring sites from Mansfield Channel to the Rio Grande, shorelines eroded at 25, advanced at 7, and showed no detectable change at 10. Rates ranged from 6.6 m/yr (21.6 ft/yr) of retreat to 17.6 m/yr (57.7 ft/yr) of advance (Paine and Morton, 1989).

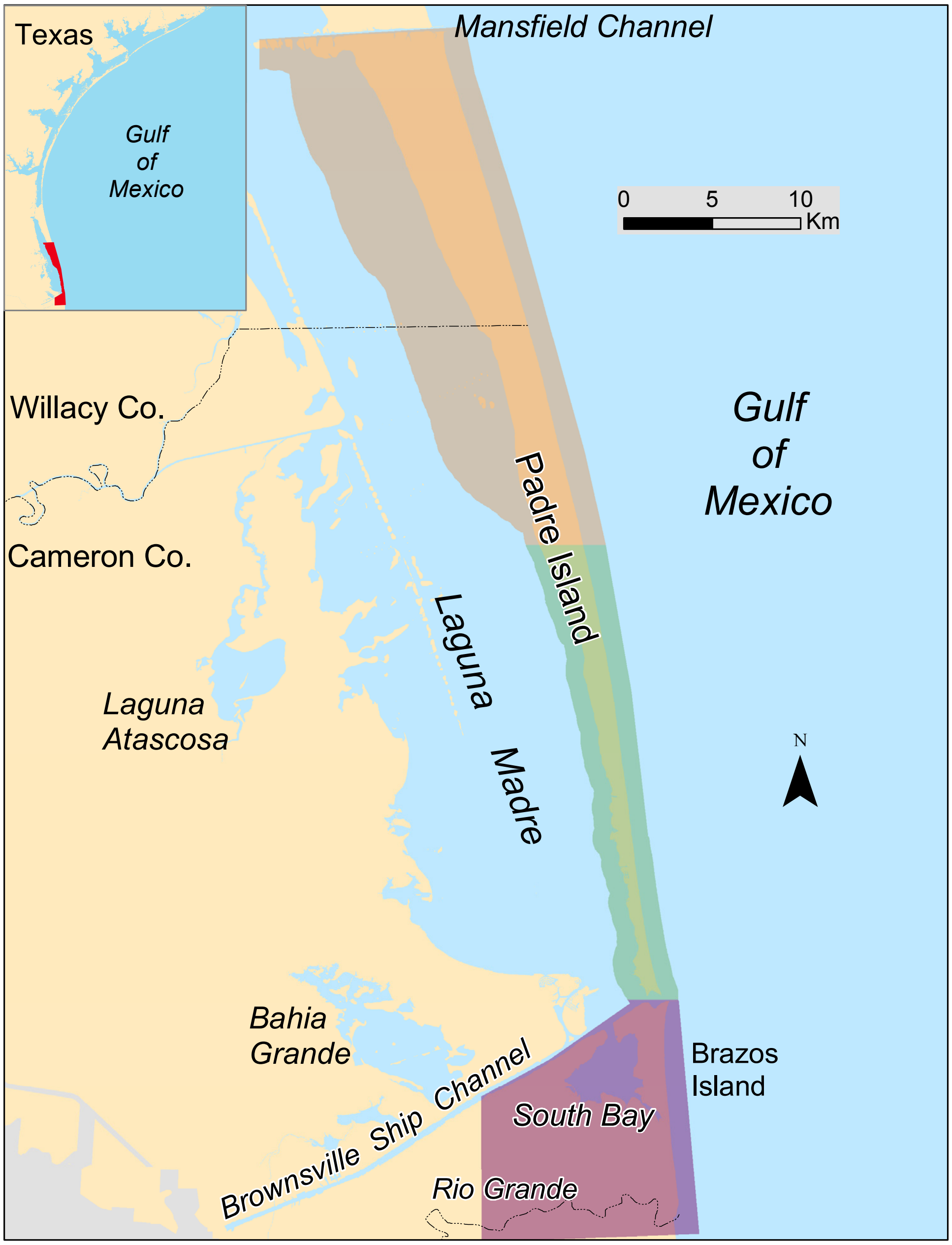


Figure 38. Index map of South Padre Island study area and north, middle, and south subareas. Subareas are color coded.

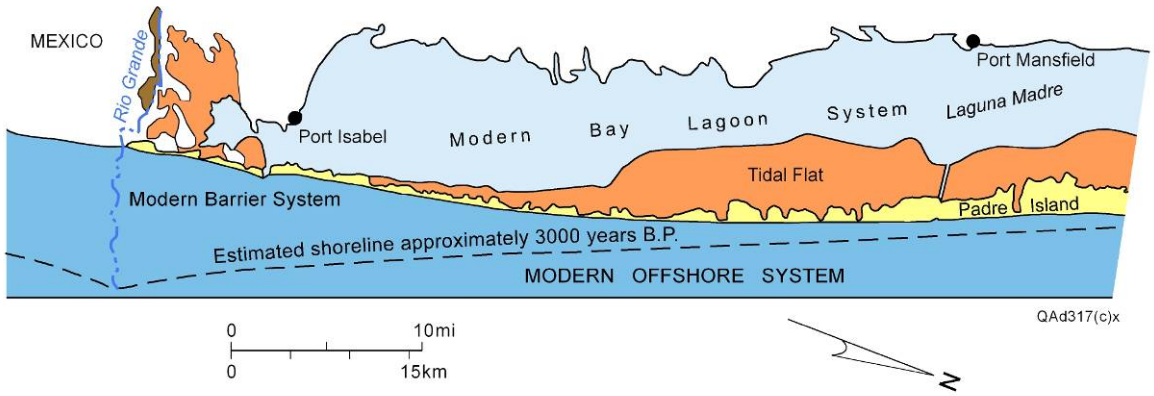


Figure 39. General illustration showing the modern bay-lagoon and offshore systems and estimated relict shoreline (3000 years before present) of the Rio Grande delta with respect to South Padre Island. From Brown et al. (1980).

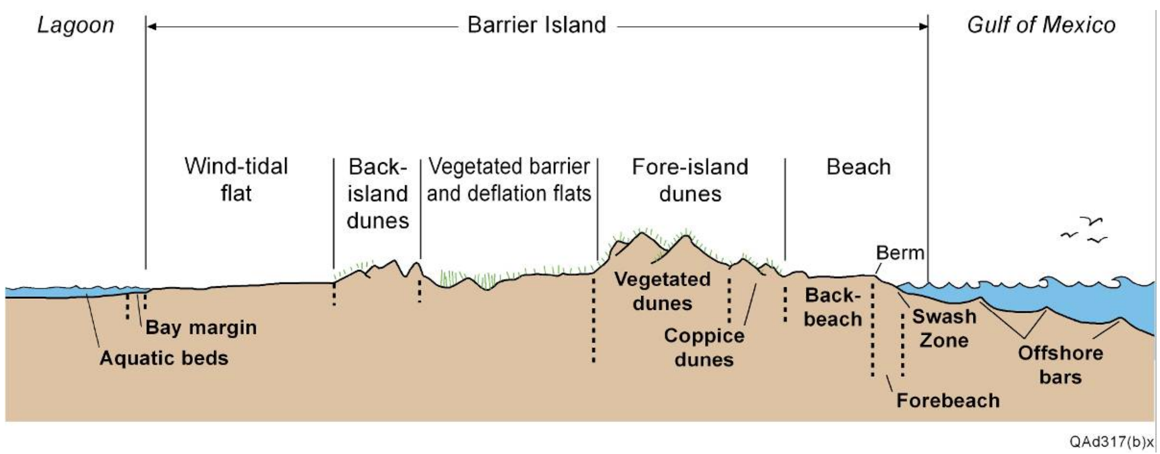


Figure 40. Generalized barrier island profile illustrating prominent features.

Prominent features on South Padre Island and Brazos Island are shown in the profile in Figure 40. Not shown, however, are the numerous hurricane washover channels (Fig. 41) through which hurricane surge waters flow, scouring channels and depositing sediments in washover fans on the lagoonward tidal flats. Much of South Padre Island is considered a low-profile barrier island (White et al. 1978), and hence does not have a continuous, vegetated, stabilized fore-island dune ridge. The dry climate and storm washovers lead to vegetation fragmentation and blowouts that are the sources of active dunes that migrate landward (Fig. 42). Left behind the migrating dunes are deflation flats and troughs that are topographic lows in which higher moisture levels support marsh vegetation such as *Schoenoplectus pungens* (Fig. 43a). In contrast to deflation that can create depressions for marsh development, migrating active dunes can fill the depressions and cover the vegetation (Fig. 43b and c). Low amounts of rainfall in this area produce higher lagoon salinities that inhibit the growth of some marshes, like broad stands of *Spartina alterniflora* that are typical in the central and upper Texas coast. On Padre Island, *Spartina alterniflora* has limited distribution. It grows along with *Avicennia germinans* (black mangrove) and other salt marsh plants (Fig. 44) at the south end of the Island where tidal flow through Brazos Santiago Pass (the tidal inlet/ship channel between Padre Island and Brazos Island) moderates salinities.

In this semi-arid climate, the most extensive habitats are broad wind-tidal flats (Fig. 11). Astronomical tides on the Gulf shore are about 0.4 m and in lower Laguna Madre about 0.3 m (Diener, 1975). The range in tides caused by persistent winds, however, can be much higher than the astronomical tides, flooding much broader flats. The numerous storm washover channels that become active during hurricanes and tropical storms, are closed between storms by sediments transported along shore. The scoured channels pond water and support marshes along their margins (Fig. 45).

Relative Sea-Level Rise

Relative sea-level rise (RSLR), as discussed more completely previously in the Freeport to East Matagorda Bay section, is another important process affecting wetland and aquatic habitats. Along the Texas coast, both processes, eustatic sea-level rise and subsidence, are part of the RSLR equation. Subsidence, especially associated with withdrawal of groundwater and oil and gas, is the overriding component (White and Morton, 1997). Over the past century, sea level has risen on a worldwide (eustatic) basis at about 0.12 cm/yr, with a rate in the Gulf of Mexico and Caribbean region of 0.24 cm/yr (Gornitz et al. 1982; Gornitz and Lebedeff, 1987). Adding compactional subsidence to these rates yields a relative sea-level rise that locally exceeds 1.2 cm/yr (Swanson and Thurlow, 1973; Penland et al. 1988). Relative sea-level rise in South Texas (Port Isabel) averaged 3.38 mm/yr from 1944 to 1999 (NOAA, NOS). High rates of RSLR can cause changes in habitats, such as estuarine marshes and wind-tidal flats (White et al. 1998). The Port Isabel tide gauge shows that RSLR rates are lower along the South Texas Gulf Coast than the middle or upper coast. Still, this lower RSLR rate can have an impact through time, as discussed in the sections on probable cause of habitat trends.

Figure 41. Storm washover channel on South Padre Island. Gulf is in distance.

(a)

(b)

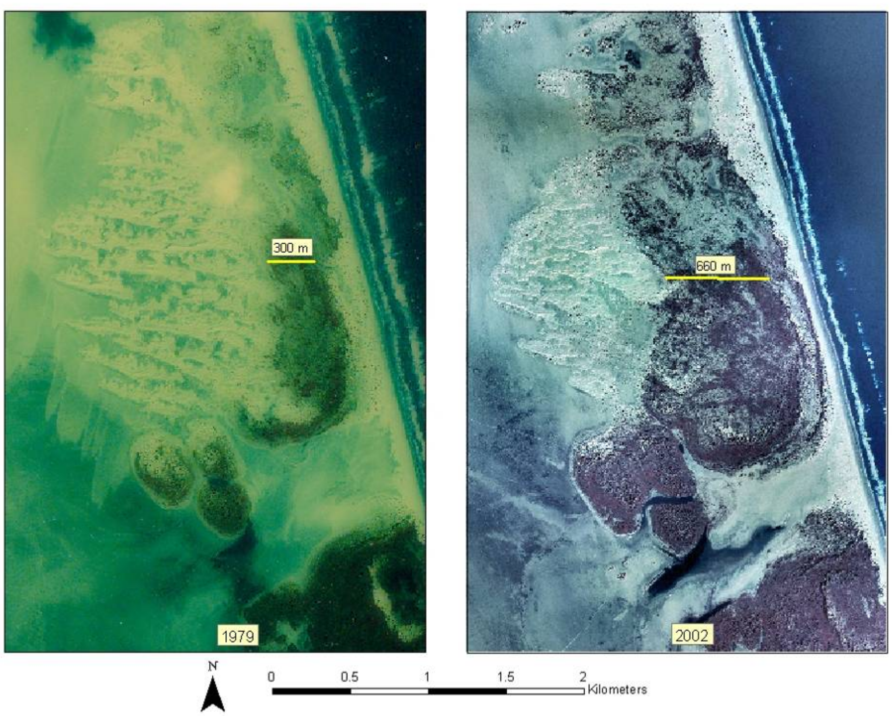


Figure 42. (a) Active dune and deflation area, (b) active dune field on South Padre Island showing the spread of vegetation (see meter bars) from 1979 to 2002 in deflation areas windward of the dune field.

(a)

(b)

(c)

Figure 43. (a) *Schoenoplectus pungens* in a depression lagoonward of the fore-island dune ridge in the distance, and (b) and (c) burial of *Schoenoplectus pungens* by an active dune migrating lagoonward.

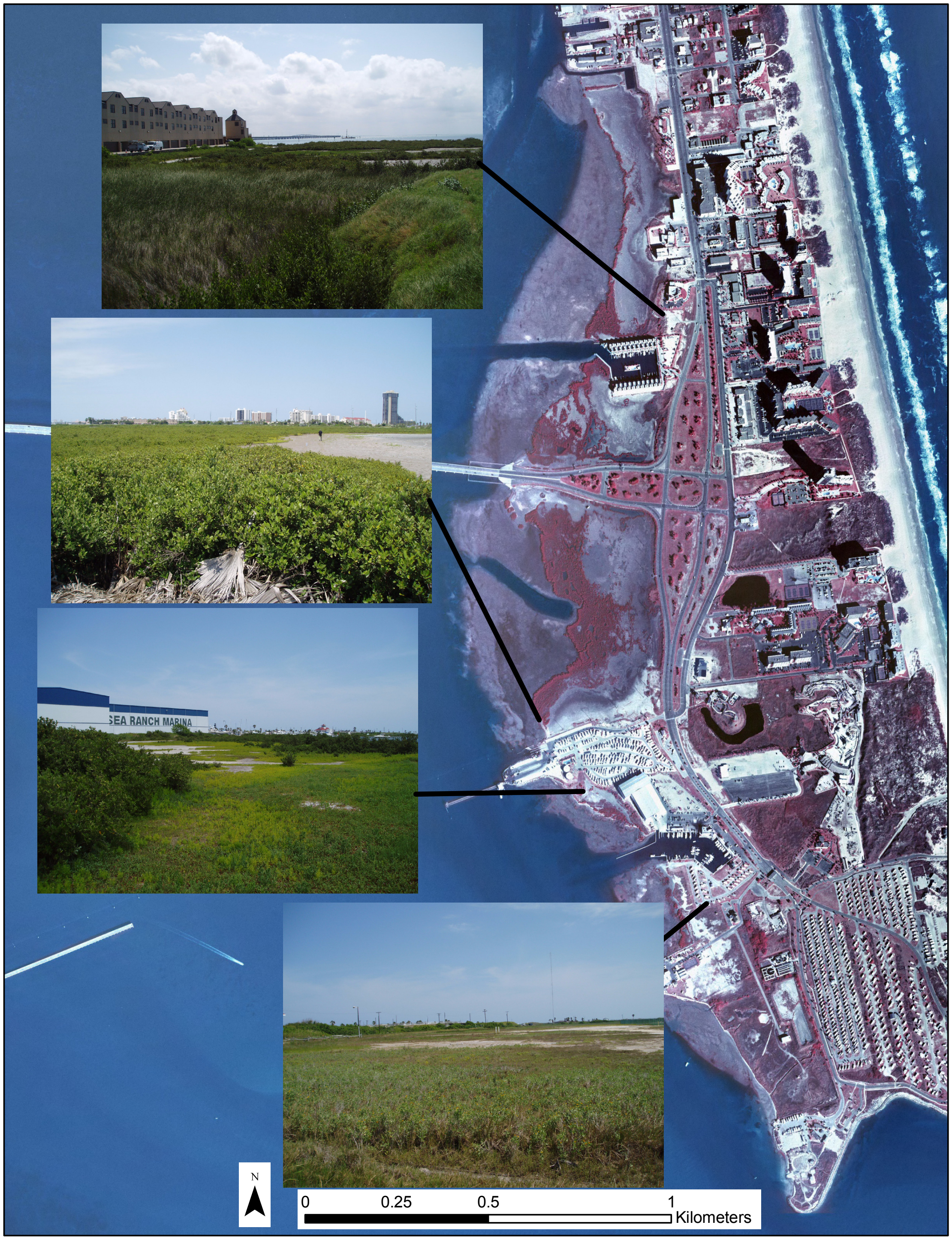


Figure 44. Examples of habitats at the south end of Padre Island. Vegetation includes *Avicennia germinans*, *Spartina patens*, *S. alterniflora*, *Batis maritima*, *Distichlis spicata*, *Monanthochloe littoralis*, *Suaeda* sp., *Salicornia* spp., *Borrichia frutescens*, among others.

Figure 45. Marsh vegetation along the margins of a storm washover channel on South Padre Island.

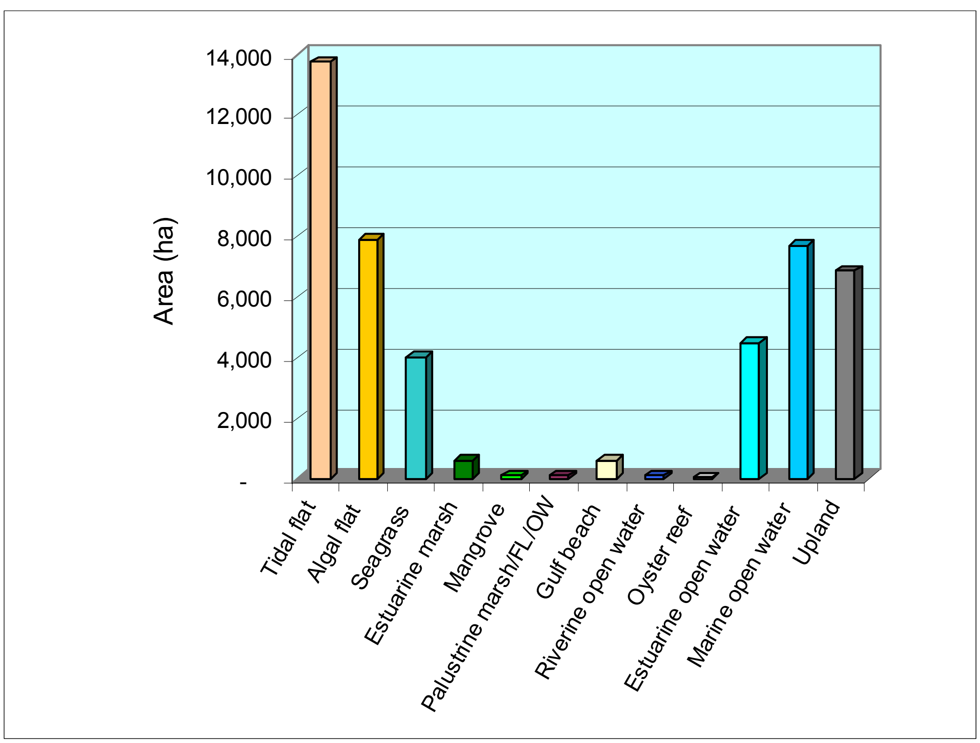


Figure 46. Areal distribution of selected habitats in 2002 on South Padre Island.

Status of wetlands and Aquatic Habitats, South Padre Island, 2002

In 2002, wetland, aquatic, and upland habitats covered 46,289 ha within the South Padre Island study area (Fig. 46 and 47; Table 6). This area includes buffer zones of open water roughly 1 km wide that parallel the shoreline in Laguna Madre and the shoreline in the Gulf. Approximately 6,885 ha within the study area was classified as uplands. Of the four wetland systems mapped, the estuarine system is the largest (Fig. 46; Table 6). The largest habitats are the wind-tidal and algal-flat classes, together covering 21,666 ha. Emergent vegetated wetlands (E2EM, E2SS, PEM) cover 768 ha, about 80% of which is estuarine marsh. Another important habitat is seagrass (E1AB3), which in the study area has an area of almost 4,000 ha. Seagrass beds extend beyond the study area into Laguna Madre. The extent of all mapped wetlands, deepwater habitats, and uplands for each year is presented in the appendix. Field site locations visited during this study are shown in Figure 48.

Estuarine System

Marshes (Estuarine Intertidal Emergent Wetlands)

The estuarine intertidal emergent wetland habitat (E2EM) consists of 605 ha of salt and brackish marshes. Unlike the central and upper coastal barriers, where the regularly flooded marshes are more abundant (White et al. 2002; 2004), irregularly flooded marshes are more abundant on these south Texas coastal barriers (Table 6). The irregularly flooded marshes cover 565 ha and the regularly flooded marshes only 39 ha. The most extensive estuarine emergent wetlands are in the south area, where 84% of this habitat occurs. Only 9% occurs in the north area and 7% in the middle area (areas are shown in Fig. 38). Locally, salt marsh assemblages fringe Laguna Madre in the north and middle areas (Fig. 49).

Tidal and Algal Flats (Estuarine Intertidal Unconsolidated Shores and Aquatic Beds)

Estuarine intertidal unconsolidated shores (E2US) include tidal flats and lagoon beaches (Figs. 11a and b). Estuarine intertidal aquatic beds (E2AB) are tidal flats in which blue-green algae have formed algal mats on the surface (Fig.11c). Approximately 13,277 ha of E2US and 7,853 ha of E2AB were mapped in the study area (Figure 46; Table 6). E2US and E2AB areas, mapped as irregularly exposed ("M" water regime) (Table 6), were included with open water (E1UB) in Table 7 and Figure 46. These areas are relatively small, totaling about 540 ha. Low, regularly flooded tidal flats are slightly more extensive than high, irregularly flooded flats (Table 6). Because of the low astronomical tidal range, many flats are flooded only by wind-driven tides and are, thus, designated as wind-tidal flats (Brown et al. 1980). A much larger area of low, regularly flooded aquatic beds (flats with algal mats) were mapped than high, irregularly flooded aquatic beds (Table 6). Together, tidal and algal flats,

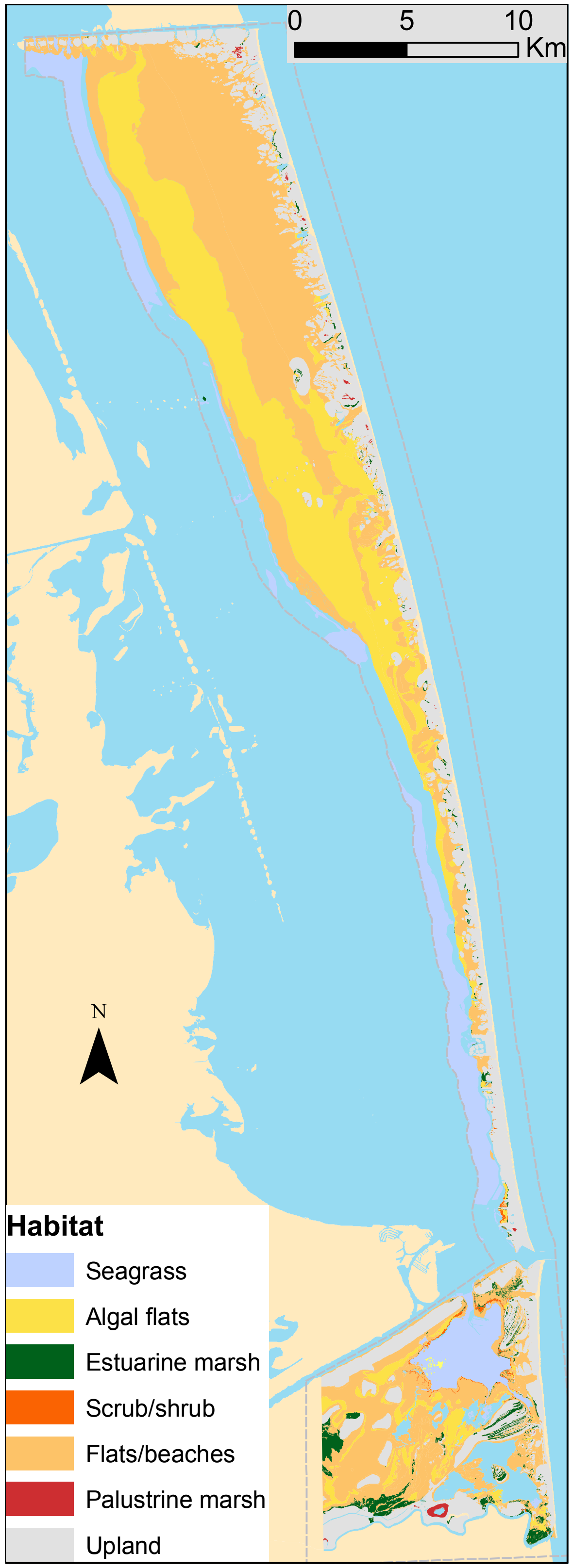


Figure 47. Map of habitats in 2002 for the South Padre Island study area.

Table 6. Areal extent of mapped wetland and aquatic habitats in the South Padre Island area in 2002, and percentage that each habitat represents in the study area.

NWI Code	*National Wetlands Inventory Description*	*Hectares*	*Acres*	*Percent*
E1AB3	Estuarine Subtidal Aquatic Bed, Rooted Vascular	3,998	9,879	8.64
E1AB5	Estuarine Subtidal Aquatic Bed, Unknown Submergent	35	86	0.08
E1RF2L	Estuarine Subtidal Reef, Mollusk	20	49	0.04
E1UB	Estuarine Subtidal Unconsolidated Bottom	4,487	11,087	9.69
E2AB1M	Estuarine Intertidal Aquatic Bed, Algal Irregularly Exposed	40	99	0.09
E2AB1N	Estuarine Intertidal Aquatic Bed, Algal Regularly Flooded	6,259	15,466	13.52
E2AB1P	Estuarine Intertidal Aquatic Bed, Algal Irregularly Flooded	1,594	3,939	3.44
E2EM1N	Estuarine Intertidal Emergent Wetland, Regularly Flooded	39	96	0.08
E2EM1P	Estuarine Intertidal Emergent Wetland, Irregularly Flooded	566	1,399	1.22
E2SS3	Estuarine Intertidal Scrub/Shrub Wetland	93	230	0.20
E2USM	Estuarine Intertidal Flat, Irregularly Exposed	496	1,226	1.07
E2USN	Estuarine Intertidal Flat, Regularly Flooded	6,938	17,144	14.99
E2USP	Estuarine Intertidal Flat, Irregularly Flooded	6,339	15,664	13.69
Subtotal		**30,904**	**76,364**	**66.76**
L1UBV	Lacustrine Limnetic Unconsolidated Bottom	12	28	0.02
M1UB	Marine Subtidal Unconsolidated Bottom	7,709	19,049	16.65
M2RS2P	Marine Intertidal Rocky Shore	2	4	0.00
M2USN	Marine Intertidal Unconsolidated Shore, Regularly Flooded	169	418	0.37
M2USP	Marine Intertidal Unconsolidated Shore, Irregularly Flooded	431	1,065	0.93
Subtotal		**8,311**	**20,535**	**17.95**
PEM1A	Palustrine Emergent Wetland, Temporarily Flooded	53	131	0.11
PEM1C	Palustrine Emergent Wetland, Seasonally Flooded	15	37	0.03
PEM1F	Palustrine Emergent Wetland, Semi-Permanently Flooded	2	4	0.00
PUB	Palustrine Unconsolidated Bottom	16	40	0.03
PUS	Palustrine Unconsolidated Shore	1	3	0.00
Subtotal		**87**	**215**	**0.19**
R1UBV	Riverine Tidal Unconsolidated Bottom	92	227	0.20
U	Upland	6,884	17,010	14.87
Total		**46,289**	**114,380**	**100.00**

Figure 48. Field site locations in the South Padre Island study area.

Figure 49. Example of salt marsh fringing Laguna Madre in the middle area. Species include *Sesuvium*, *Batis*, *Distichlis*, *Suaeda*, *Machaeranthera*, *Monanthocloe*, *Borrichia*, and *Spartina spartinae*.

Figure 50. Black mangrove shrubs along board walk over marsh near the SPI Convention Center. (Port Isabel High School students who accompanied us in this area.)

Table 7. Areal extent (ha) of selected habitats by geographic area in 2002, South Padre Island. See Figure 38 for location of different areas.

Habitat	North area (ha)	Middle area (ha)	South area (ha)
Tidal flat	9,360	754	3,164
Algal flat	6,617	517	719
Estuarine marsh	55	43	506
Mangroves	0	16	77
Palustrine marsh/flat/water	30	5	52
Seagrass/aquatic bed unknown	1,484	1,500	1,049
Gulf beach	298	190	112
Estuarine open water	2,110	1,305	1,568
Marine open water	3,841	2,617	1,250
Riverine open water	0	0	104
Oyster reef	0	0	20
Upland	2,860	1,500	2,524
Total	**26,655**	**8,486**	**11,153**

represent approximately 87% of the intertidal wetland system (excluding subtidal habitats and the E1 and M1 map units). The mapped extent of the tidal flats can be substantially affected by tidal levels at the time the aerial photographs were taken. Accordingly, absolute areal extent of flats may vary from that determined using aerial photographs.

Mangroves (Estuarine Intertidal Scrub/Shrub)

Estuarine scrub/shrub wetlands (E2SS) (mostly *Avicennia germinans* or black mangrove habitat) (Fig. 50) have a total area of 93 ha, or about 0.4% of the estuarine intertidal classes. With respect to the vegetated intertidal wetlands, it represents about 13% of the total. Scattered mangrove shrubs are a common component of many estuarine marshes (E2EM), particularly on the margins of South Bay and at the southern end of Padre Island. Only in areas where the mangrove shrubs were dominant and extensive enough were they mapped separately as E2SS habitat. This habitat has its broadest distribution on the margins of South Bay, near the Rio Grande, and in the vicinity of the Queen Isabella Causeway where it connects to South Padre Island (Fig. 44). Sherrod and McMillan (1981) noted that mangroves in this area are one of the three major concentrations along the Texas coast and are typically mixed with *Spartina*, *Batis*, and *Salicornia*.

Aquatic Beds (Estuarine Subtidal Aquatic Beds)

Estuarine subtidal, rooted, vascular aquatic beds (E1AB3L) represent areas of submerged, rooted, vascular vegetation, or seagrasses. Accurate delineation of seagrasses on aerial photographs is dependent on the season in which the photographs were taken and water turbidities, which can obscure seagrass areas. Seagrasses are visible in most of the 2002 photographs but are obscured by turbidities in some areas such as between the causeway and Brownsville Ship Channel and could not be mapped in total. Densities of the mapped seagrass ranged from very dense to patchy. Seagrass beds were mapped from the island to a distance of approximately 1km into Laguna Madre where the study area boundary is located. Within the study area, about 4,000 ha of seagrass beds was mapped. Seagrasses extend along most of South Padre Island and cover South Bay (Fig. 47). Distributions of seagrass in the mapped subareas are almost equal in the north and middle areas, covering 1,484 ha and 1,500 ha, respectively. The south subarea contains 1,049 ha of seagrass (Table 7).

Open Water (Estuarine Subtidal Unconsolidated Bottom)

In addition to the shallow lagoons and ponds within the marsh complexes, estuarine subtidal unconsolidated bottom (E1UBL), or open water, includes a strip of Laguna Madre water about 1 km wide, paralleling the lagoon shoreline. This area was included primarily for cartographic purposes to help standardize the study area for each time period. Including this zone, the total area of estuarine open water mapped in the study area is 4,487 ha. If the irregularly exposed tidal and algal flats (E2USM and E2ABM) are included, the total is 5,023 ha (Table 6).

Oyster Reefs (Estuarine Reefs)

Oyster reefs (E1RF2L) mapped on the 2002 photographs amounted to 20 ha in South Bay. Only those that were near the water's surface and that were clearly visible were mapped. Reefs in South Bay were present in the 1970's (White et al. 1986) and in the 1950's (Breuer, 1962) but were not mapped by USFWS on the 1979 and 1950's photographs. Without the historical data, we were unable to document the spatial and temporal trends in the reefs.

Palustrine System

Marshes (Palustrine Emergent Wetlands)

Palustrine emergent wetlands (PEM), or inland, non-tidal "freshwater" marshes, cover 70 ha (Fig 17; Table 6), and represent 9% of emergent vegetated wetlands. The broadest distribution is in the South Bay subarea where 38 ha occur, followed by the north subarea where 29 ha were mapped (Figs. 51 and Table 7. Only 3 ha were mapped in the middle South Padre Island subarea. More than 90% of the PEM in the South Bay area is the result of a single polygon that was mapped in a depression formed by past meanderings of the Rio Grande. Although brackish vegetation occurs in this area, it was mapped as palustrine because it is not connected to estuarine tidal flats or to the Rio Grande. Palustrine marshes on Padre Island often occur in isolated depressions deflated by the wind or scoured by past storm washover events. These marshes typically were classified into one of three water regimes: (1) temporarily flooded, (2) seasonally flooded, or (3) semi-permanently flooded. More than 75% of palustrine marshes were mapped as temporarily flooded, the driest water regime, in this dry South Texas area.

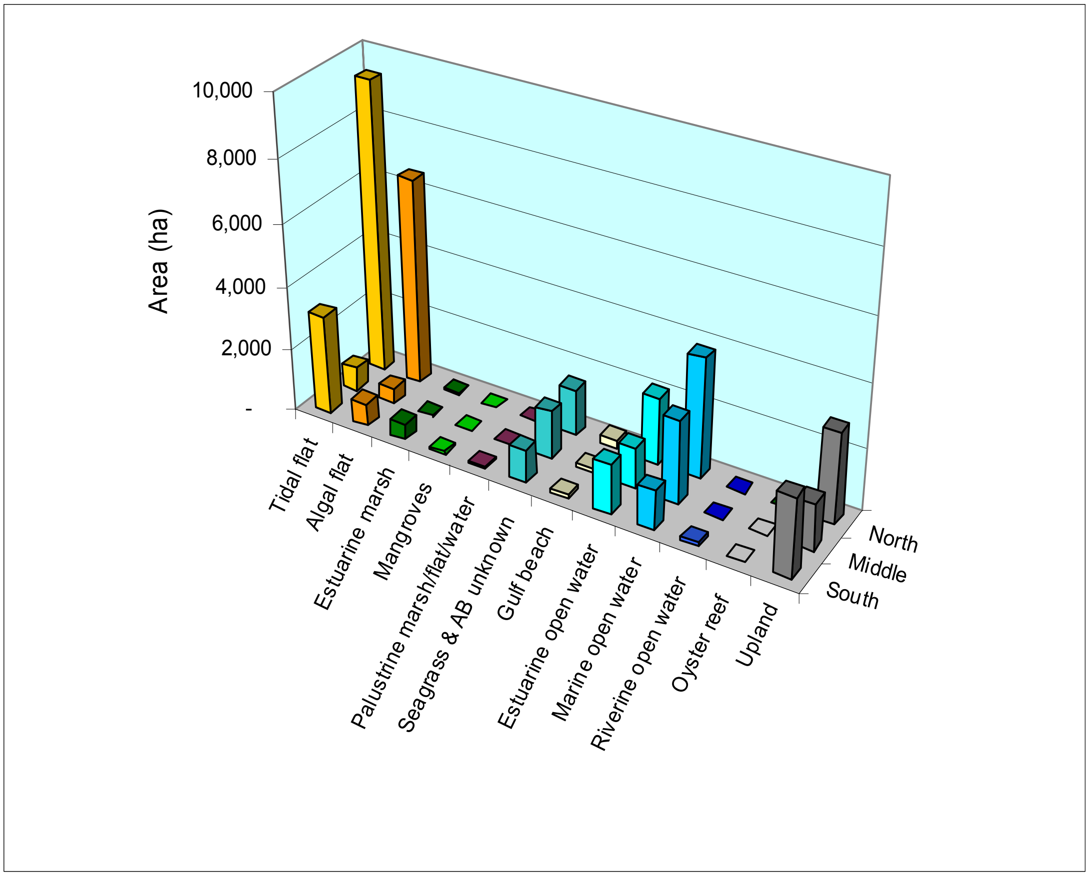


Figure 51. Areal distribution of habitats in the north, middle, and south areas of the South Padre Island study area.

Open water (Palustrine Unconsolidated Bottom)

Palustrine unconsolidated bottom (PUB), or open water, habitats are generally small fresh- to brackish-water ponds. The total mapped area of this habitat was only 16 ha, more than 85% occurring in one palustrine area near the Rio Grande.

Marine System

Gulf Beach (Marine Intertidal Unconsolidated Shore) and Other Marine Classes

The Gulf beach represents marine intertidal unconsolidated shore (M2US). Two components were mapped, the topographically lower regularly flooded fore beach and the irregularly flooded backbeach (Figs. 10 and 40). The total area of this habitat in the study area is 600 ha, almost half of which occurs in the north subarea (Table 7). A buffer zone of approximately 1 km wide of marine subtidal unconsolidated bottom (M1UB), or marine open water, was included along the Gulf shoreline primarily to standardize the size of the map area for each time period analyzed. Also, mapped in the marine system are the jetties at Brazos Santiago Pass (entrance to Brownsville Ship Channel). These features were mapped as marine intertidal rocky shore, rubble, irregularly flooded (M2RS2P), and have an area of about 2 ha.

Historical Trends in Wetlands and Aquatic Habitats, South Padre Island

General Trends in Wetlands within the Study Area

Analysis of trends in wetlands and aquatic habitats from the 1950's through 2002 shows that wind-tidal/algal flats decreased from the 1950's to the later dates (1979 and 2002) (Figs. 52 and 53; Table 8). Seagrasses declined from the 1950's to 1979 and then increase to a higher level by 2002. Much of the decline in 1979 may have been an apparent and not real decline, as a result of high-water levels and turbidities, which can obscure submerged seagrasses on aerial photographs. The total areas of estuarine marshes were relatively stable, not changing more than about 30 ha between periods. Their mapped, or spatial distribution, however, was not necessarily the same. Estuarine scrub/shrub wetlands (primarily mangroves) showed an increase in time. Mangroves, however, could not be adequately mapped separately on the black-and-white 1950's photographs and were included with marshes in most areas. There was a real increase in mangrove distribution from 1979 to 2002, which is explained in later discussion of subarea trends. Palustrine habitats had their largest distribution of 99 ha in 1979. Still, there is not a lot of difference in distribution from the 1950's (71 ha) and 2002 (87 ha). The large difference in area of estuarine open water, which covered an area almost twice as large in 1979 as in the 1950's and 2002 (Table 8), appears to be due to higher water levels in 1979 that flooded tidal flats and obscured seagrasses.

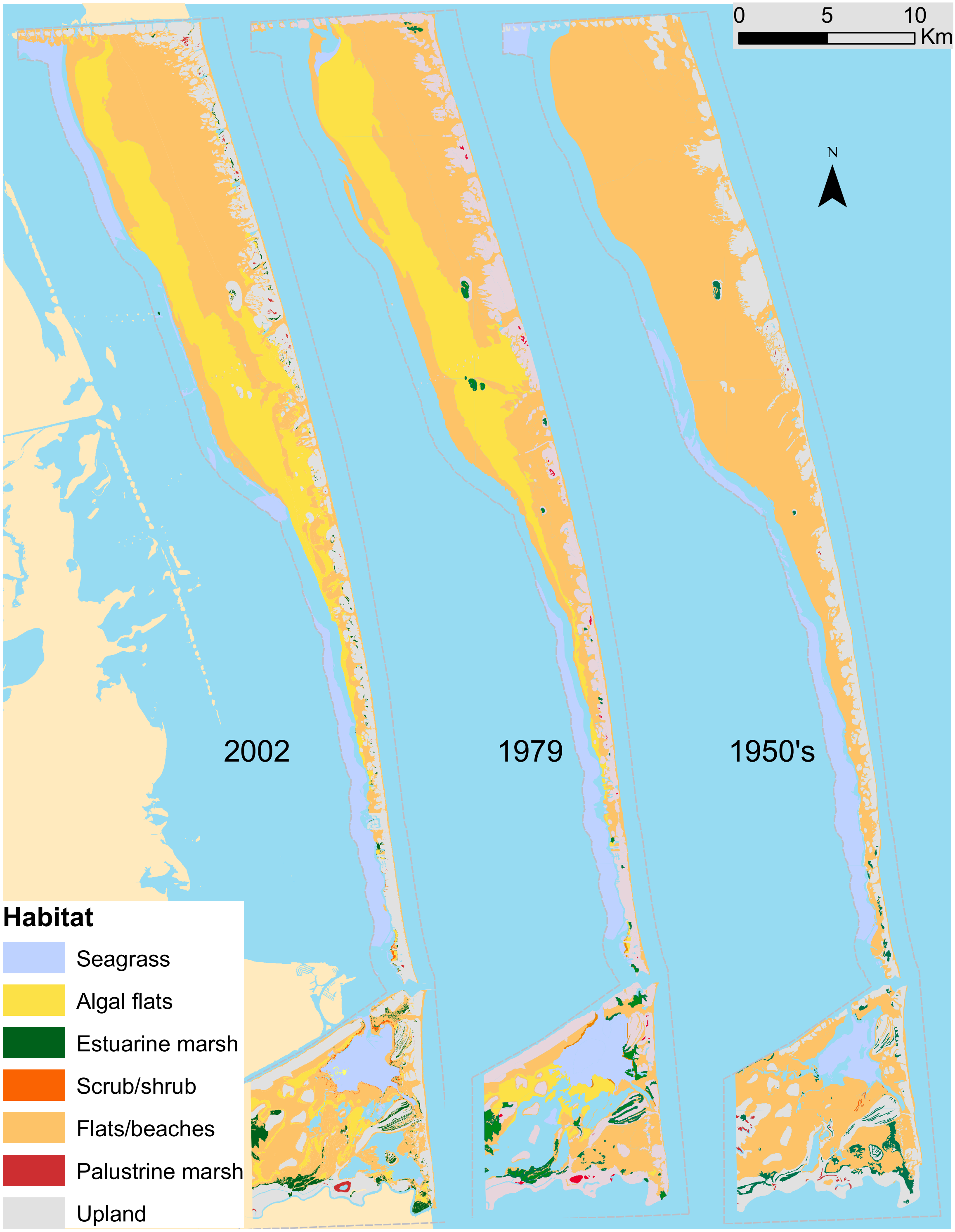


Figure 52. Maps showing distribution of major wetland and aquatic habitats in 2002, 1979, and the 1950’s in the South Padre Island study area. Algal flats shown only in 2002 and 1979. Seagrass shown only within map area in Laguna Madre.

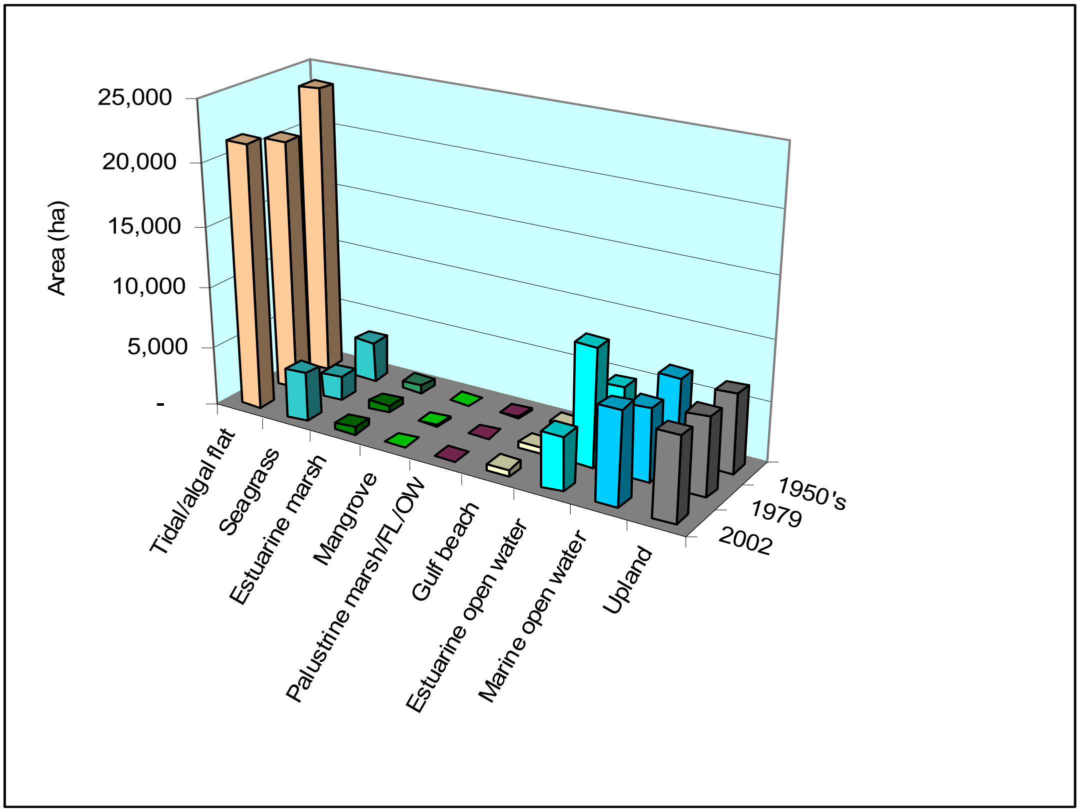


Figure 53. Areal extent of selected habitats from the 1950’s to 2002 in the South Padre Island study area. Wind-tidal flats are, by far, the most extensive habitat. The broader distribution in the 1950’s may be, in part, related to the mid-1950’s drought, when estuarine open water was apparently at lower levels than in 1979 and 2002.

Table 8. Areal distribution (ha) of selected habitats, 1950's to 2002, in the South Padre Island study area.

Habitats	1950's	1979	2002
Tidal/algal flat	23,800	20,698	21,666
Seagrass	3,343	1,998	4,033
Estuarine marsh	584	612	604
Mangrove	12	70	93
Palustrine marsh/FL/OW	71	99	87
Gulf beach	393	503	600
Estuarine open water	4,812	8,133	4,487
Marine open water	6,656	7,603	7,709
Upland	6,475	6,468	6,884

Analysis of Wetland Trends by Geographic Area

As in previous sections, the study area was subdivided into major natural areas and geographic components for analysis of historical trends (Fig. 38). The areas are presented in the following order (1) north area (2) middle area, and (3) south area. This subdivision allowed a more site-specific analysis of trends and their probable causes. Estuarine tidal flats, estuarine marshes, mangroves, seagrasses, and palustrine marshes are emphasized.

North Area

General Trends. The most significant habitat trends in the north area occurred at the interface between the wind-tidal flats, or estuarine intertidal unconsolidated shore (E2US), estuarine intertidal aquatic beds (E2AB), and uplands of the barrier island. Uplands increased from a total of 2,310 hectares in the mid-1950's to 2,450 hectares in 1979. The trend continued in 2002 with a total of 2,860 hectares of upland in the north area (Fig. 54 and 55).

Wind tidal flats, composed of estuarine intertidal unconsolidated shore (E2US) and aquatic beds (E2AB) lost about 7% of their area between the mid-1950's (17,198 ha) and 1979 (15,931 ha). As of 2002 the amount of wind-tidal flats hadn't changed significantly (15,976 ha).

Large fluctuations in the area of seagrass (estuarine subtidal aquatic beds, E1AB) occurred within the study time period. In the mid-1950's seagrasses were a short distance offshore in the southern half of the north area (817 ha). Only a small amount of seagrass (88 ha) is mapped near Mansfield Channel in 1979. By 2002 seagrasses had been reestablished near the island. The majority of the 1,484 ha of seagrass in the latest time period are along the upper Laguna Madre.

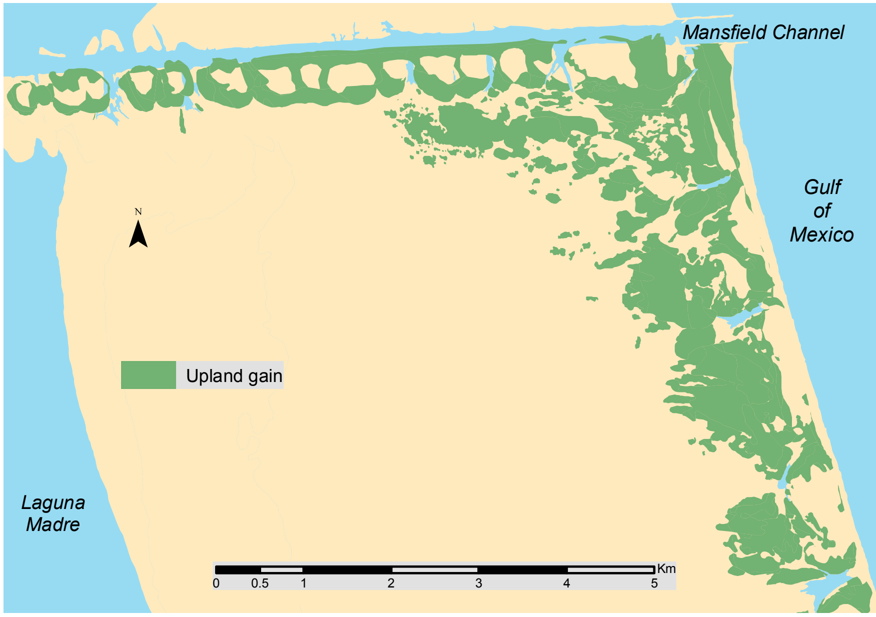


Figure 54. Gain in uplands 1950's to 2002 near Mansfield Channel.

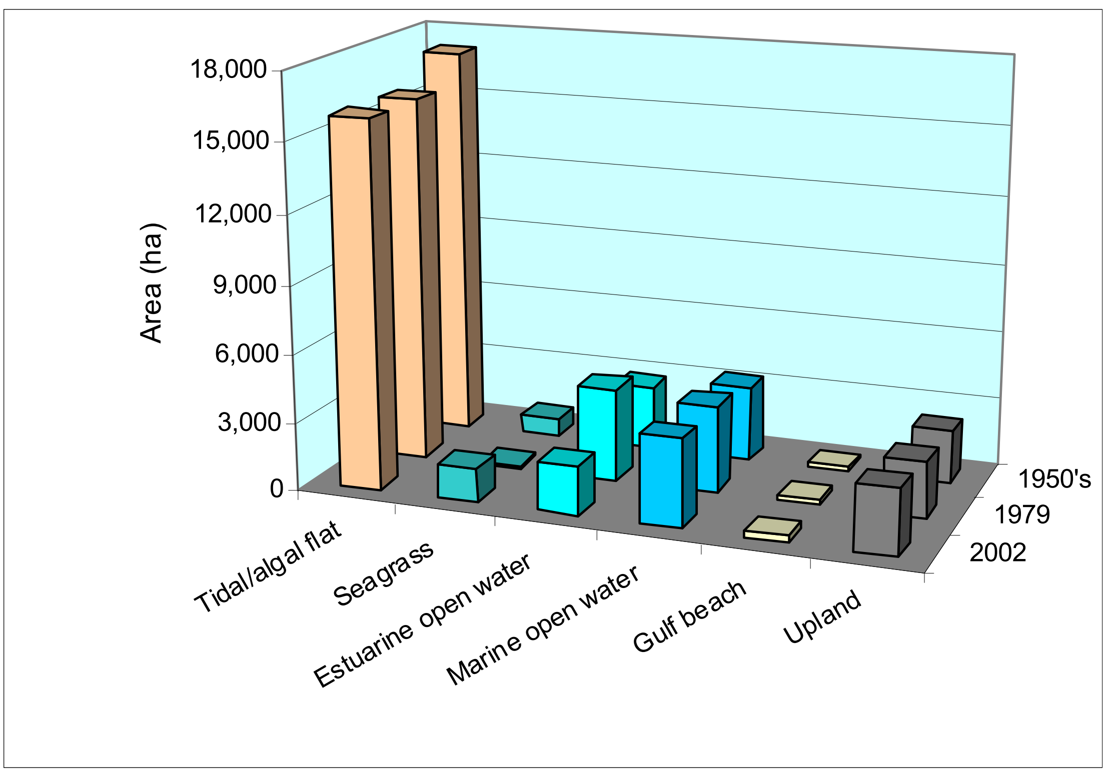


Figure 55. Areal extent of major habitats in north study area in the 1950's, 1979, and 2002.

Marsh habitats in the north area of SPI occupied only a fraction of the total area. Estuarine intertidal emergent marsh (E2EM) and palustrine emergent marsh (PEM) areas combined increased by 150% from the mid-1950's (36 ha) to 1979 (91 ha) followed by a small decrease in area of 8% in 2002 (84 ha).

Marine intertidal unconsolidated shore (M2US) experienced a systematic gain throughout the study time period. In the mid-1950's, the marine beach covered 190 ha, by 1979 the area increased by 15% to 219 ha, and in 2002 M2US totaled 298 ha an additional increase of 36%. An example of the Gulf beach and palustrine marshes located in the north area is shown in Figure 56.

Probable Cause of Trends. A large part of the E2US loss (~50%) in the mid-1950's to 1979 time period was due to migration and expansion of uplands into flats. Mostly back island dunes migrated towards the Laguna Madre. The 1950's NWI dataset displays a large flooded area extending 10 kilometers south of the channel. It's likely that the flooded area was caused by the construction of Mansfield Channel and that the 1950's photography captured the resulting inundation of the flats in the Laguna Madre. The flooded area was remapped by BEG staff as flat using the Environmental Geologic Atlas of Texas (EGAT) surficial deposits map boundary in order to provide a more consistent representation of conditions in the Laguna. Landscape modification caused by channel construction is apparent in the relocation of uplands and flats within the 1950's to 1979 time period (Fig. 54). The net increase in uplands was due to a high gross increase of uplands where dunes shifted into previous E2US habitat (90% of gross upland gain). At the same time, upland gain was offset by a large amount of encroachment of E2US into uplands (40% of gross upland loss). The mid-1950's map also contains a large registration error near the center of the north area. A misalignment of the shoreline position shifted much of the island gulfward. The apparent increase in uplands in this area in 1979 is an indication of the amount of offset caused by the cartographic shift of the island. Relocating the island to its actual position towards the laguna would greatly reduce the mid-1950's to 1979 increase in uplands in the shifted area. Elimination of cartographic error from the mid-1950's dataset would reduce the net gain of uplands and also reduce the net loss of flats in the earlier time period. The placement of the EGAT contact line between flats and open water in the 1950's dataset is approximate and may contribute to the large loss of E2US to E1UB. Approximately 33% of flat loss was to open water in the north area.

As in the earlier time period, we see a systematic gain of uplands in the north area between 1979 and 2002. In the later time period, most of the upland gain is from dredged material deposition along Mansfield Channel and spreading of the spoil into nearby flats (86% of gain was from E2USP). Although there was a continued net gain in uplands, the gross loss of uplands (~50%) was largely due to encroachment of high flats (E2USP). Island morphology in this area appears to have been affected by changing laguna hydrologic conditions associated with the opening of the channel. Away from the channel, upland movement into flats appears to occur at roughly the

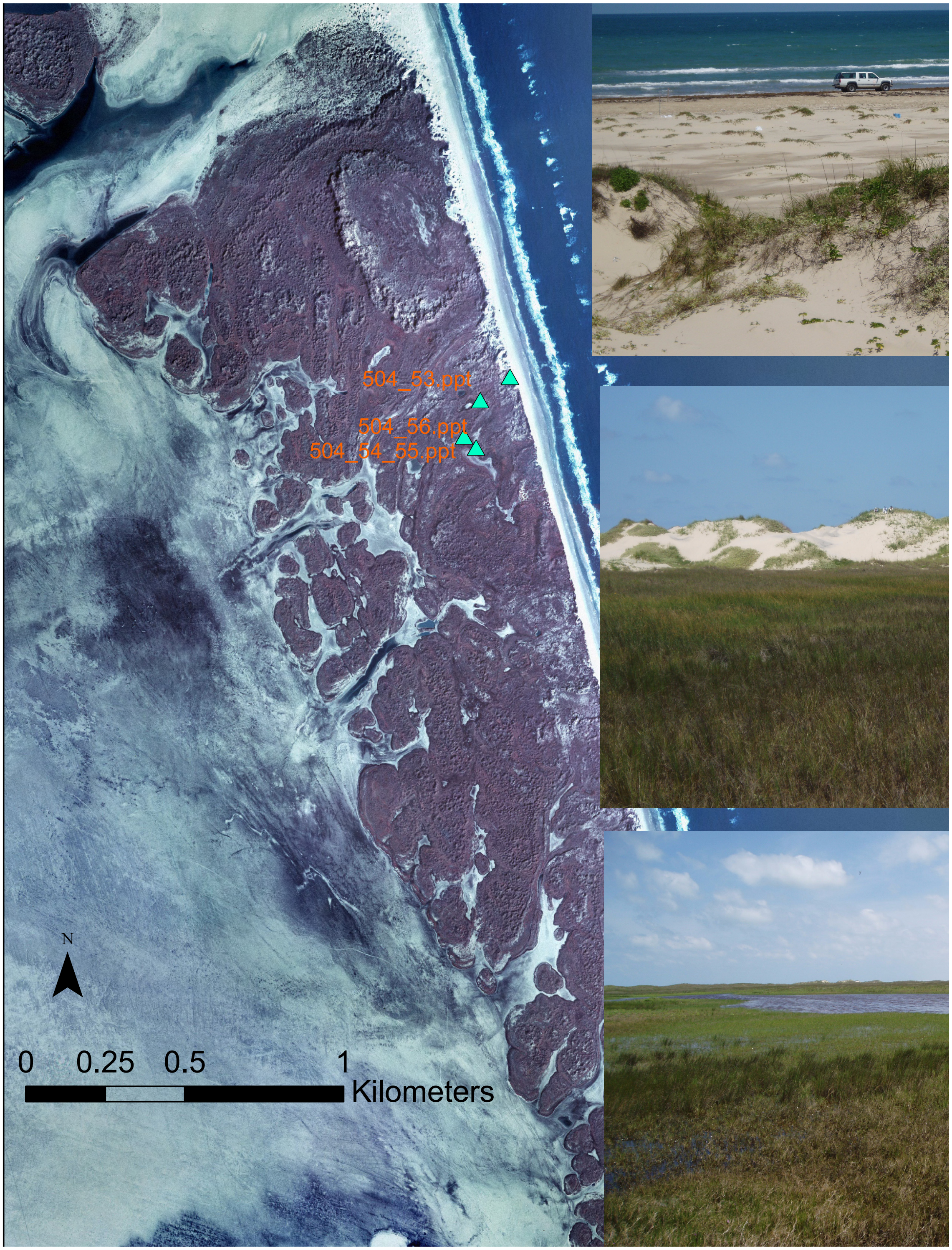


Figure 56. Field photos of (1) Gulf and beach, (2) palustrine marsh and fore-island dune, and (3) pond and palustrine marsh in the north area of SPI, south east of Deer Island (Fig. 57). Aerial photo showing locations where photos were taken was acquired in 2002.

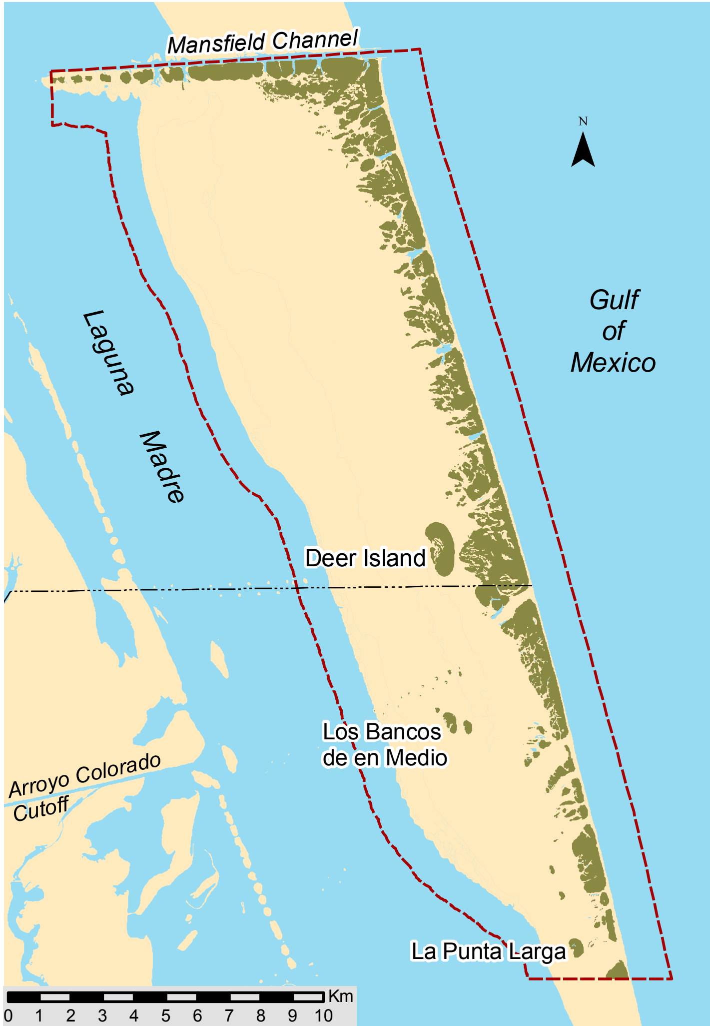


Figure 57. Index map showing features in the north area of SPI.

same rate as flat movement into uplands. Flats and uplands displaced each other as dunes migrated in a perpendicular orientation to the barrier island. Most of the change occurs on the relatively low gradient slope of the back island. Uplands also expand into washover channels during the later time period.

Seagrasses are apparent on 1979 photography in the same general area in the laguna as they are mapped in the mid-1950's but further away from the island. For the most part, seagrasses exist outside the study area boundary in 1979.

Much of the gain of E2EM (~66%) between the mid-1950's and 1979 occurred on the "Los Bancos de en Medio" islands (Fig. 57). In 1979, Deer Island (26.8 ha) and a group of smaller islands "Los Bancos de en Medio" to the south (27 ha) were mapped as E2EM1P but were mapped as upland in the other time periods. Marshes may have been more plentiful in 1979 due to wetter conditions. La Punta Larga, a small island at the southernmost end of the north region, lost ~3 ha of high marsh (E2EM1P) to upland between 1979 and 2002.

The increase in M2US in the north area generally follows the historical shoreline change regime encountered in this part of the island. Gulf beach is gained from marine open water in the north where the shoreline is accreting, and is gained further south from uplands and high flats (E2USP) in an area of active washover channels.

Middle Area

General Trends. The middle study area of South Padre Island (Fig. 38) underwent several habitat changes. There was a systematic decline in tidal flats (Fig. 58, Table 9) with a loss of 623 ha from the 1950's to 2002, or about 33% of this resource. Seagrasses in the middle area also declined in area by 343 ha by 2002 (Fig. 58). Although estuarine marshes and mangroves represent a small area overall, marshes decreased in area from the 1950's to 1979, but increased from 1979 to 2002. Mangroves also increased in area from 1979 to 2002 (Table 8) (mangroves were not mapped in the 1950's). Estuarine open water and marine open water both increased within the middle area from the 1950's to 2002 by approximately 35% and 20%, respectively (Fig. 58).The area of Gulf beach increased from the 1950's to 1979, and remained relatively stable to 2002, although there was a small loss in area.

Table 9. Area (ha) of selected habitats in the 1950's, 1979, and 2002, South Padre Island middle study area.

	1950's	*1979*	*2002*
Tidal and algal flats	1,894	1,584	1,270
Seagrass	1,842	1,545	1,499
Estuarine marsh	45	20	43
Mangrove	-	10	16
Palustrine marsh/water/flat	1	11	5
Gulf beach	129	219	190
Upland	1,386	1,403	1,500

Probable Cause of Trends. The systematic decline in tidal flats can be attributed to replacement of the flats by uplands, primarily vegetated barrier flats and dunes, and to urban development (Fig. 59). As much as 75 % of the loss was due to upland conversion during the earlier period (1950's to 1979). The continued decline in tidal flats from 1979 to 2002 was in part the result of development. At the north edge of the city of South Padre Island, a marina was under development in 2002 in which multiple channels were dredged across the flats with a main trunk channel connected to Laguna Madre. In association with this development, dredged material was disposed on tidal flats converting them to upland areas.

The decline in seagrasses from the 1950's to 2002 (Fig 58; Table 9) was in large part the result of navigation channels that cut through seagrass beds along the lagoon margin of South Padre Island (Fig. 12). In contrast to the decrease in area of seagrasses and tidal flats, marshes and mangroves together increased in area (Table 9)

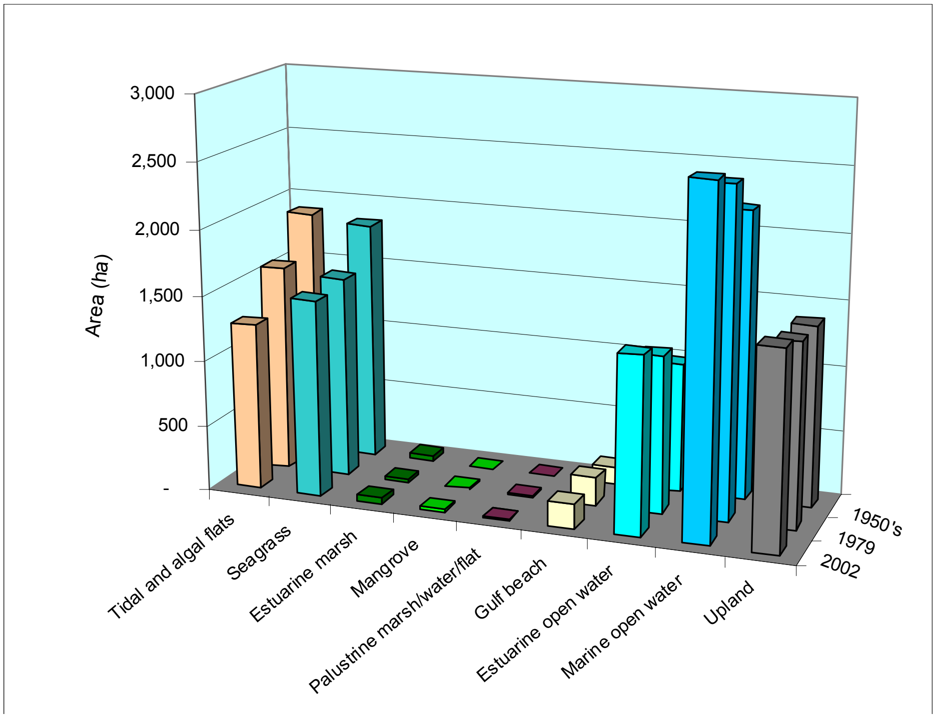


Figure 58. Areal extent of habitats in the 1950's, 1979, and 2002 in the middle area of SPI.

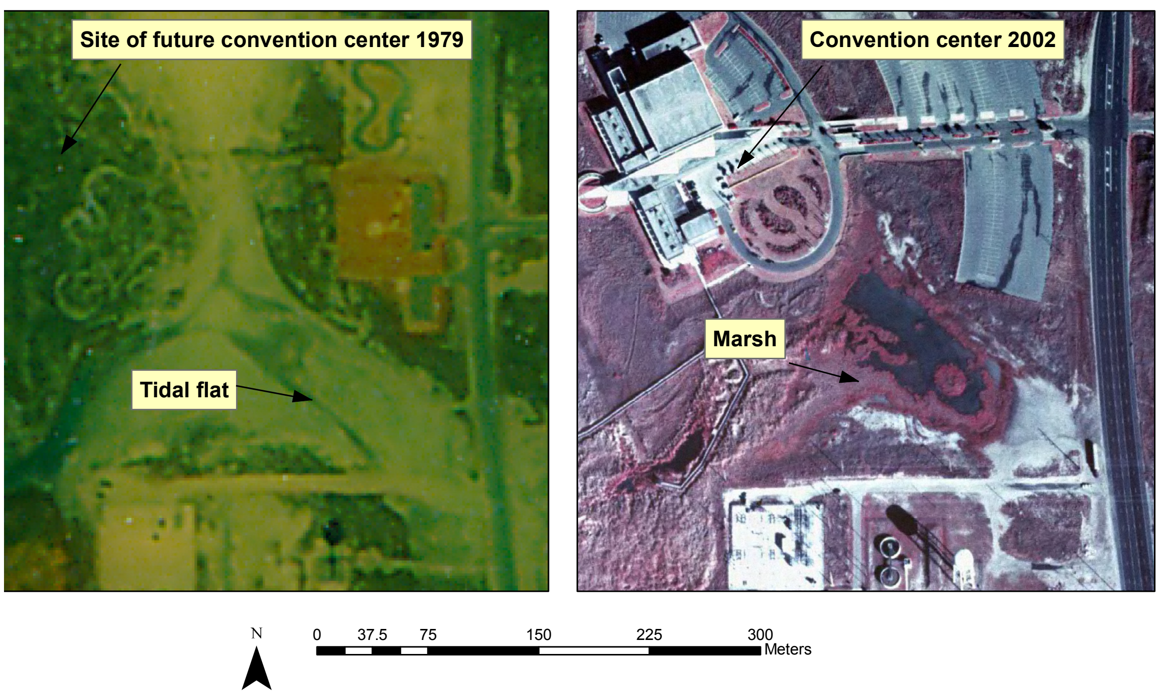


Figure 59. Habitat changes from construction of the SPI Convention Center included a loss in wind-tidal flats from 1979 to 2002, but a gain in marsh habitat. The importance of marshes in this area is recognized and promoted by boardwalks over the marshes, and educational displays about the flora and fauna.

primarily along the shores of the city of South Padre Island. Marsh and mangrove vegetation spread along the lagoon margin, along channels, on tidal flats, at the South Padre Island Convention Center, and near the Queen Isabella Causeway (Figs. 60 and 44). Boardwalks constructed across the marsh at the Convention Center provide easy access to visitors and help protect the marsh (Fig. 50). The extensive brackish marsh at this site is in large part the result of outflow from a sewage treatment plant. Abundant *Typha* (cattail) (Fig. 61) in this area is evidence of the freshwater discharges. Another location where extensive marsh and mangrove wetlands have developed is near the Queen Isabella Causeway (Fig. 44). Wetland vegetation has expanded across tidal flats in this area.

The increase in marine open water within the middle study area is principally due to erosion and the landward retreat of the Gulf shoreline. South of Mansfield Channel to the Rio Grande, rates of shoreline retreat between 1974 and 1982 ranged from 1.5 to 6.5 m/yr at 14 measured sites, and was stable at 5 sites (Paine and Morton, 1989). Shorelines at half of the retreating sites moved faster than 3 m/yr. Similar retreat rates were observed between 1937 and 1974 (Morton and Pieper, 1975). The increase in estuarine water through time (Fig. 58) is in part due to dredging of navigation channels through seagrass beds, tidal flats, and other habitats. Tidal levels at the time the photos were taken also may have contributed to the more extensive water areas during later periods.

South Area

General Trends. The south area, which encompasses South Bay, experienced change in several habitat types over time (Fig. 62). Tidal flats decreased in area by 18%, from 4,708 ha in 1950's to 3,883 ha in 2002. Seagrasses increased by 53%, from 684 ha in 1950's, to1049 ha in 2002. Mangroves increased by 29%, from 60 ha in 1979 (1950's figures are not available) to 77 ha in 2002 (Figs. 63 and 64). Palustrine marshes decreased by 19%, from 64 ha in 1950's to 52 ha in 2002. Gulf beaches increased by 51%, from 74 ha in 1950's to 112 ha in 2002. The estuarine marsh habitat remained stable in terms of total area, with 506 ha in both the 1950's 2002.

Probable Cause of Trends. The low areal extent of tidal flats in 1979 can be attributed to the wetter ground conditions at that time and more extensive flooding of tidal flats. Both the 1950's and 2002 ground conditions were drier in comparison, resulting in more tidal flats exposed and less open water being mapped in those years. The overall decrease in flats from 1950's to 2002 has several causes. Relative sea level rise, caused by both subsidence and eustatic sea-level change, led to some tidal flats being flooded by open water. Tidal flats were also lost as dredged material was piled up along excavated channels, replacing them with uplands. In some places marshes have replaced tidal flats. Mangroves, which were mapped in 1979 and 2002 only, have encroached on flats, open water, and uplands, and to a lesser extent, marshes (Figs. 63 and 64). The most extensive kind of tidal flats in 2002 were low, more frequently flooded flats (Fig. 65).

Figure 60. Examples of salt marsh, mangrove, and tidal flat habitats near the SPI Convention Center.

Figure 61. Example of widespread *Typha* near the SPI Convention Center and water treatment plant.

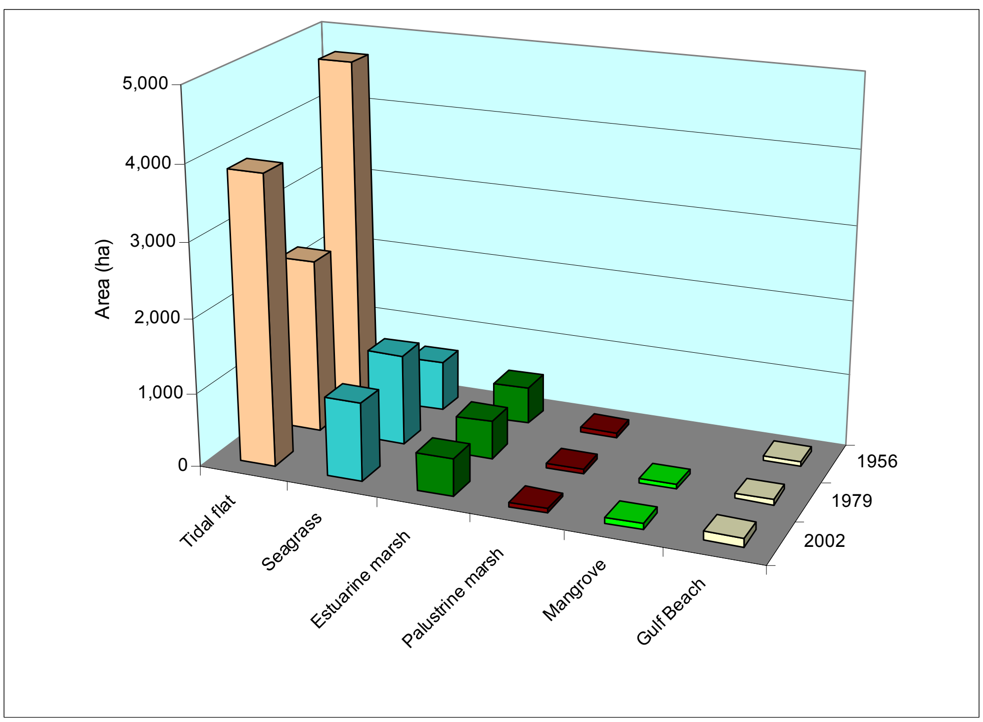


Figure 62. Areal distribution of selected habitats in the 1950's, 1979, and 2002, in the south area of South Padre Island.

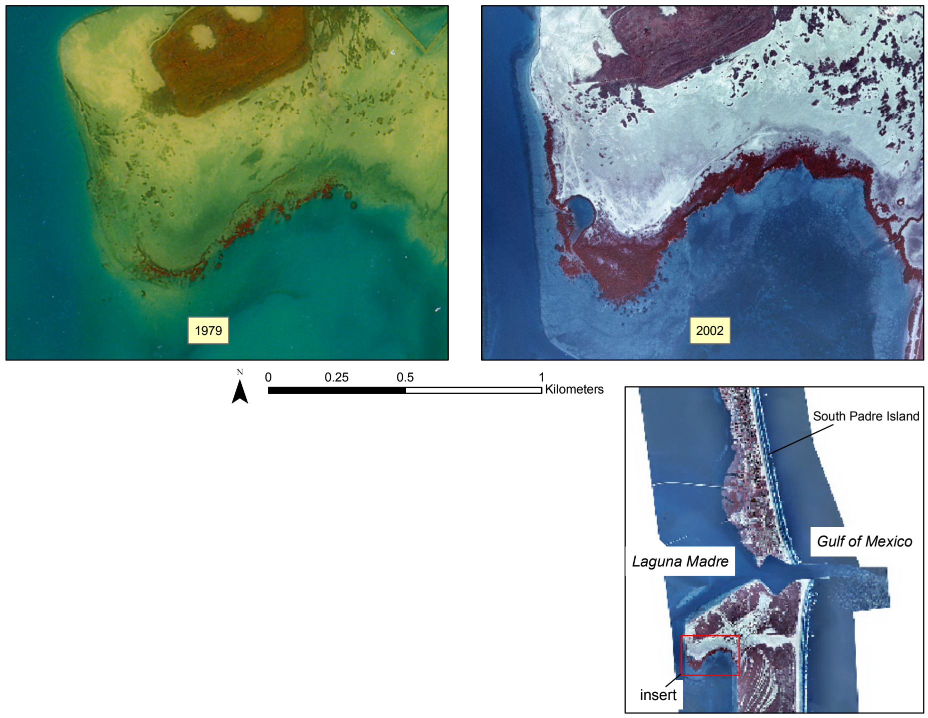


Figure 63. Spread of *Avicennia germinans* (Black Mangrove) from 1979 to 2002 on a wind-tidal flat on the margin of South Bay.

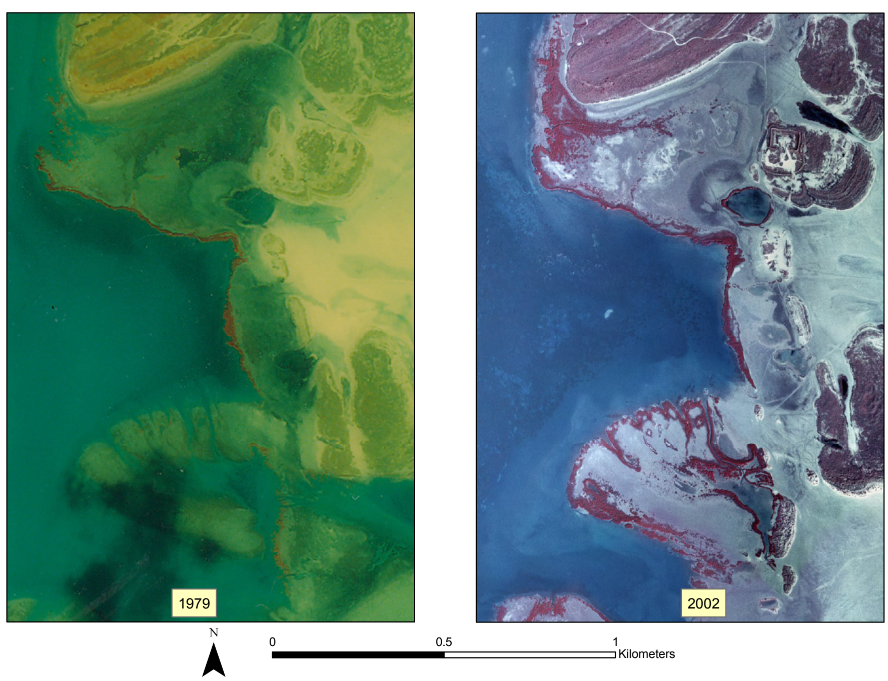


Figure 64. Expansion of mangroves onto tidal flats from 1979 to 2002.

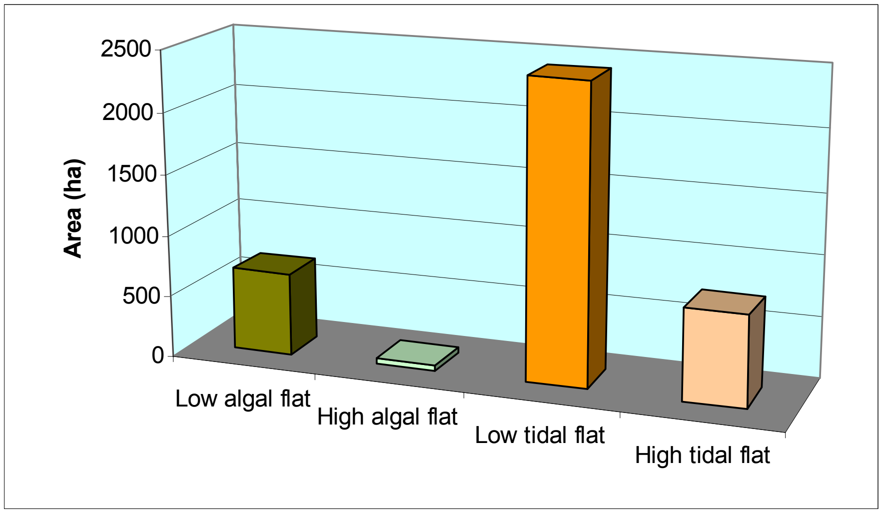


Figure 65. Types and areal extent of wind-tidal flats in 2002 in the south area of South Padre Island.

Summary and Conclusions, South Padre Island

Most changes in the **north area** occurred at the interface between the wind-tidal flats and the uplands of the barrier island. Uplands increased from a total of 2,310 ha in the mid-1950's to 2,450 ha in 1979 (6% gain). The mid-1950's to 1979 net increase in uplands was due to a high increase of uplands where dunes shifted into previous wind-tidal flat habitat. The trend continued in 2002 with a total of 2,860 ha of upland in the north area (17% gain). In the later time period, most of the upland gain was from dredged material deposition along Mansfield Channel and spreading of the material into nearby flats. Wind-tidal flats, composed of tidal and algal flats, lost about 7% of their area between the mid-1950's (17,198 ha) and 1979 (15,931 ha). A large part of the flat loss (~50%) in the mid-1950's to 1979 time period was due to migration and expansion of uplands into flats. As of 2002, the amount of wind-tidal flats hadn't changed significantly (15,976 ha). Large fluctuations in the area of seagrass occurred within the study time period. In the mid-1950's, seagrasses were found a short distance offshore in the southern half of the north area (817 ha). A small amount (88 ha) was mapped near Mansfield Channel in 1979 but most seagrass was located outside the study area boundary during this time period. By 2002, seagrasses had been reestablished near the island (1,484 ha) along the upper Laguna Madre. Marsh habitats in the north area of SPI occupied only a fraction of the total area. Estuarine and palustrine marsh areas combined, increased by 150% from the mid-1950's (36 ha) to 1979 (91 ha) followed by a small decrease in area of 8% in 2002 (84 ha). Much of the gain (~66%) of estuarine marsh between the mid-1950's and 1979 occurred on small islands in the Laguna Madre. Marshes may have been more plentiful in 1979 due to wetter conditions. Marine beaches experienced a systematic gain throughout the study time period. In the mid-1950's, marine beaches covered 190 hectares, by 1979 the area increased by 15% to 219 hectares, and in 2002 beaches totaled 298 hectares, an additional increase of 36%. Beach area was gained from marine open water in the north where the shoreline was accreting and was gained further south from uplands and high flats in areas of active washover channels.

The **middle study area** of South Padre Island underwent several habitat changes. There was a systematic decline in tidal flats with a loss of 623 ha from the 1950's to 2002, or about 33% of this resource. Seagrasses in the middle area also declined in area by 343 ha by 2002. Although estuarine marshes and mangroves represent a small area overall, marshes decreased in area from the 1950's to 1979, but increased from 1979 to 2002. Mangroves also increased in area from 1979 to 2002 (mangroves were not mapped in the 1950's). The area of Gulf beach increased from the 1950's to 1979, and remained relatively stable to 2002, although there was a small loss in area. The systematic decline in tidal flats can be attributed to replacement of the flats by uplands, primarily vegetated barrier flats and dunes, and to urban development. A large percentage of the loss was due to upland conversion during the earlier period (1950's to 1979). The continued decline in tidal flats from 1979 to 2002 was in part the result of development. At the north edge of the city of South Padre Island, a marina was under development in 2002 in which multiple channels were dredged across the flats with a main trunk channel connected to Laguna Madre. In association with this development, dredged material was disposed on tidal flats converting them to upland areas. The decline in seagrasses from the 1950's to 2002 was in large part the result of navigation channels that cut through seagrass beds along the lagoon margin of South Padre Island. In contrast to the decrease in area of seagrasses and tidal flats, marshes and mangroves together increased in area primarily along the shorelines of the city of South Padre Island. There was an apparent increase in marine open water within the middle study area. Part of the increase was due to misregistration on the 1950's map, which had a lagoonward shift in registration and thus caused an inaccurate loss in estuarine open water and an increase in open marine water. Some of the increase in marine open water, however, was real because of erosion and landward retreat of the Gulf shoreline. The increase in estuarine open water through time is in part due to dredging of navigation channels through seagrass beds, tidal flats, and other habitats. Tidal levels at the time the photos were taken also appear to have contributed to the more extensive water areas during later periods.

In the **south area**, or South Bay, changes in several habitat types have occurred over time. Tidal flats decreased in area by 18%, from 4,708 ha in 1950's to 3,883 ha in 2002. Seagrasses increased by 53%, from 684 ha in 1950's, to 1049 ha in 2002. Estuarine marsh habitat has remained stable, with 506 ha in both the 1950's and 2002. Mangroves increased by 29%, from 60 ha in 1979 (1950's figures are not available), to 77 ha in 2002. Palustrine marshes decreased by 19%, from 64 ha in 1950's to 52 ha in 2002. Gulf beaches increased by 51%, from 74 ha in 1950's to 112 ha in 2002. The low areal extent of tidal flats in 1979 can be attributed to the wetter ground conditions at that time. Both the 1950's and 2002 ground conditions were drier and tides were lower in comparison, resulting in more tidal flats and less open water being mapped in those years. The overall decrease in flats from 1950's to 2002 has several causes. Relative sea level rise, caused by both subsidence and eustatic change, led to some tidal flats being flooded by open water. Drought conditions in the mid 1950's lowered lagoon water levels exposing a broader area of tidal flats. Tidal flats were also lost as dredged material was piled up along excavated channels, replacing them with uplands. In some places marshes have replaced tidal flats. Mangroves, which were mapped in 1979 and 2002 only, have spread into flats, open water, and uplands, and to a lesser extent, marshes.

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APPENDIX 1

Total habitat areas for 2002, 1979, and 1950’s determined from GIS data sets of Freeport to East Matagorda Bay study area

2002		1979		1950's	
Habitat	**Hectares**	**Habitats**	**Hectares**	**Habitat**	**Hectares**
E1AB3	6	E1AB6L.	17	E1AB.	4
E1AB5	381				
		E1OWL.	2159	E1OW.	2472
E1RF2L	200	E1OWLH.	105		
		E1OWLX.	145	E1RF.	114
E1UB	2493				
E1UBx	98	E2AB2M.	3	E2BB.	1
		E2AB6M.	107		
E2EM1N	2954			E2EM.	7725
E2EM1Nd	5	E2EM1N.	3946		
E2EM1Ns	2	E2EM1P.	4236	E2FL.	929
E2EM1P	5323	E2EM1PH.	137		
E2EM1Pd	27			E2RF.	8
E2EM1Ps	8	E2FL2N.	18		
		E2FL2P.	13	M1OW.	3275
E2RF2M	67	E2FL3P.	14		
		E2FLM.	132	M2BB.	469
E2SS	1	E2FLN.	178		
		E2FLP.	186	PEM.	264
E2USM	44	E2FLPH.	1		
E2USN	176			PFL.	5
E2USNs	2	E2RF2M.	235		
E2USP	140	E2RF2N.	20	PFO.	0
E2USPs	2	E2RFLM.	10		
				POW.	7
L2AB5h	26	L1OWHH.	39		
				PSS.	10
L2UBFh	13	L2AB2FH.	10		
L2UBKh	64			R1OW.	3
L2UBKhs	12	L2FLCH.	17		
		L2FLYH.	53	R2AB.	1
L2USKhs	67	L2FLYHS.	21		
				R2OW.	2
M1UB	3701	L2OWFH.	23		
				U.	6336
M2USN	39	M1OWL.	3630		
M2USP	189				
		M2BBN.	11		
PEM1A	568	M2BBP.	298		
PEM1Ad	1				
PEM1Ah	67	PEM1A.	757		

PEM1C	102
PEM1Cd	1
PEM1Ch	157
PEM1F	16
PEM1Fh	96
PEM1Fx	0
PEM1Khs	321
PSS1A	38
PUB	5
PUBCh	3
PUBCx	0
PUBFh	10
PUBHx	4
PUBKh	0
PUBKhs	23
PUS	1
PUSKhs	65
R1UB	0
U	3954

PEM1C.	46
PEM1CH.	49
PEM1F.	4
PEM1FH.	15
PEM1Y.	15
PFLCR.	49
PFLYH.	14
POWF.	5
POWFH.	1
POWFHX.	0
POWFX.	0
POWH.	1
POWHH.	7
POWHX.	8
UA.	618
UBD.	35
UBS.	195
UR.	3689
UU.	339
UUO.	6

APPENDIX 2

Total habitat areas for 2002, 1979, and 1950’s determined from GIS data sets of South Padre Island study area

2002 Habitats	Hectares	1979 Habitats	Hectares	1950's Habitat	Hectares
E1AB3	3,998	E1AB2L.	88	E1AB.	3343
E1AB5	35	E1AB6L.	1910		
				E1OW.	4812
E1RF2L	20	E1OWL.	9758		
				E2EM.	584
E1UB	4,379	E2EM1N.	90		
E1UBx	108	E2EM1P.	516	E2FL.	23800
		E2EM5N.	5		
E2AB1M	40			E2SS.	12
E2AB1N	6,258	E2FL6N.	7638		
E2AB1P	1,551	E2FL6P.	22	L1OW.	7
E2AB1Ps	43	E2FLM.	28		
		E2FLN.	7206	M1OW.	6656
E2EM1N	36	E2FLNH.	13		
E2EM1Ns	3	E2FLP.	5722	M2BB.	394
E2EM1P	564	E2FLPH.	19		
E2EM1Ps	2			PEM.	47
		E2SS3N.	70		
E2SS3	93			PFL.	12
		L1OWHX.	12		
E2USM	496	L1OWV.	11	POW.	12
E2USN	6,811				
E2USNs	127	M1OWL.	5979	PSS.	1
E2USP	6,291				
E2USPs	48	M2BBP.	503	R1OW.	99
L1UBV	12	M2RS2PR.	2	U.	6475
M1UB	7,709	PEM1C.	7		
		PEM1F.	3		
M2RS2P	2	PEM1R.	3		
		PEM1Y.	59		
M2USN	168	PEM1YX.	1		
M2USP	431				
		PFLCHX.	5		
PEM1A	53	PFLCX.	5		
PEM1C	15				
PEM1F	2	POWFHX.	11		
		POWG.	4		
PUB	16	POWH.	2		
PUS	1	R1OWV.	110		

R1UBV	92	UA.	4897
		UB.	1
U	6,884	UBD.	695
		UBS.	465
		UU.	410