STATUS (DESCRIPTION AND DISTRIBUTION) OF WETLAND HABITATS

General Setting of the Galveston Bay System

The geologic framework of the Galveston Bay area consists of Modern-Holocene and Pleistocene systems including the modern wetland, or marsh and marsh-swamp systems (fig. 6). The geomorphic features on which the various types of coastal wetlands have developed are the result of numerous interacting processes. Physical processes that influence wetlands include rainfall, runoff, fluctuations in the water table, streamflow, evapotranspiration, waves and longshore currents, astronomical and wind tides, storms and hurricanes, deposition and erosion, subsidence, faulting, and sea-level rise (table 1). These processes have contributed to the development of a gradational array of permanently inundated to infrequently inundated environments ranging in elevation from the submerged lands of the estuarine system through the topographically higher wetland system, which grades upward from the astronomical-tidal zone through the wind-tidal zone to the storm-tidal zone.

Exchange of marine waters with bay-estuary-lagoon waters in the Galveston Bay system occurs primarily through two major tidal inlets, Bolivar Roads at the north end of Galveston Island, and San Luis Pass at its south end (fig. 6). Additional exchange occurs at Rollover Pass, a narrow dredged channel at the east end of Bolivar Peninsula. The predominant sources of fresh-water inflow are the Trinity and San Jacinto Rivers (fig. 6). Salinities in the Galveston Bay system are generally highest in West and Christmas Bays where mean salinities are typically above 20 ppt and may range into the 30's (Pulich and White, 1991; Orlando and others, 1991). These salinities are in marked contrast to Trinity Bay, where Trinity River fresh-water inflows have a moderating influence; mean monthly salinities in Trinity Bay are usually less than 15 ppt and occasionally are below 5 ppt (Pulich and White, 1991).

These numerous interacting processes in the Galveston Bay system have a major bearing on the location and composition of wetland plant communities.

Description of Mapped Wetlands in the Galveston Bay System

Wetland and Deepwater Habitats

Cowardin and others (1979) defined five major systems in their classification of wetlands and deepwater habitats: Marine, Estuarine, Riverine, Lacustrine, and Palustrine (fig. 3). All include wetlands and deepwater habitats except for the Palustrine System, which includes only wetland habitats. Systems are subdivided into subsystems, which reflect hydrologic conditions, such as intertidal and subtidal for the marine and estuarine systems. Subsystems are further subdivided into class, which describes the appearance of the wetland in terms of vegetation or substrate. Classes are subdivided into subclasses. Only vegetated classes were subdivided into subclasses for this project, and only for the years 1979 and 1989. In addition, water-regime modifiers (table 2) and special modifiers were used for these years.

The USFWS National Wetlands Inventory program established criteria for mapping wetlands using the Cowardin and others (1979) classification. Alphanumeric abbreviations are used to denote the systems, subsystems, classes, subclasses, water regimes, and special modifiers (table 3, fig. 5). Symbols for certain habitats changed after 1979; these changes are shown in figure 5 and are noted in the section on trends in wetland and aquatic habitats. Examples of alphanumeric abbreviations used in this section on status of wetlands apply only to the 1989 maps.

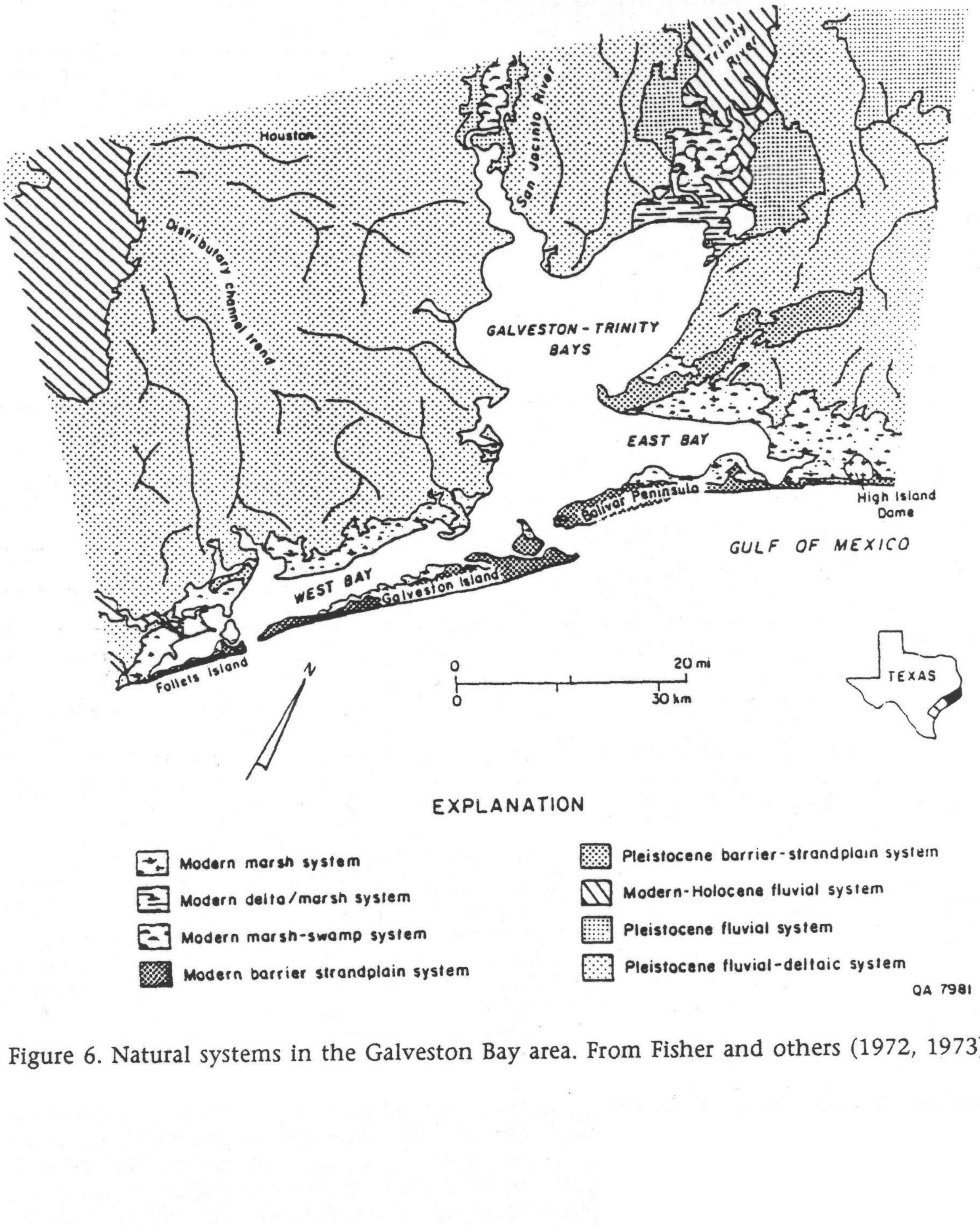


Figure 6. Natural systems in the Galveston Bay area. From Fisher and others (1972, 1973).

Table 1. Generalized characteristics of active coastal processes and conditions in the Galveston Bay area. From White and others (1985).

Climatic zone:	Humid *(Thornthwaite, 1948)*
Average annual precipitation:	41.8 to 51.5 inches/yr (106.2 to 130.8 cm/yr) *(Fisher and others, 1972)*
Dominant wind directions:	Southeasterly, northerly *(Fisher and others, 1972)*
Average wind speed (in 1978 at Texas City):	6.8 knots (12.6 km/hr) *(Shew and others, 1981)*
Astronomical tidal range: Gulf shoreline (Galveston Pleasure Pier) Mean diurnal: Bay shoreline (mean):	 2.1 ft (0.6 m) *(U.S. Department of Commerce, 1978)* 0.5 to 1.4 ft (0.2 to 0.4 m) *(Diener, 1975)*
Tidal current velocities: Bolivar Roads Average maximum flood: Average maximum ebb:	 3.3 knots (1.7 m/sec) *(Bernard and others, 1959)* 4.3 knots (2.2 m/sec) *(Bernard and others, 1959)*
Wave height (Gulf): (Caplan, Texas) Onshore wave height:	 Between 2.5 and 3.5 ft (0.8 and 1.1 m) about 65% of the time, *(U.S. Army Corps of Engineers, 1956)*
Direction of net longshore sediment transport:	Southwesterly *(Fisher and others, 1972)*
Maximum hurricane surge height on open coast:	12.7 ft (3.9 m) above MSL *(Bodine, 1969)*
Hurricane frequency:	12% in any one year *(Simpson and Lawrence, 1971)*
Gulf shoreline change, Bolivar Roads to San Luis Pass from 1850-52 to 1973-74:	Total gain from accretion of 1,074 acres and loss from erosion of 1,183 acres; net loss of 109 acres *(Morton, 1977)*
Subsidence: Pasadena - Houston Ship Channel area:	 8.5 to 9 ft (2.6 to 2.7 m) during 1906-1973 *(Ratzlaff, 1980)*
Faulting: Houston metropolitan area:	 Offset by at least 160 faults *(Verbeek and Clanton, 1981)*

Table 2. Water regime descriptions for wetlands used in the Cowardin and others (1979) classification system.

Nontidal

(A) Temporarily flooded—Surface water present for brief periods during the growing season, but water table usually lies 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 near the land's surface.

(H) Permanently flooded—Water covers land surface throughout the year in all years.

Tidal

(L) Subtidal—The substrate is permanently flooded with tidal water.

(M) Irregularly exposed—The 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, freshwater systems.

Table 3. Wetland codes and descriptions from Cowardin and others (1979).

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 bottom	Marine beaches, barrier islands	Unconsolidated shores
M2RS (P)	Marine, intertidal rocky shore	Marine breakers, beach stabilizers	Jetties
E1UBL (L)	Estuarine, subtidal unconsolidated bottom	Estuarine bays, Estuarine rivers	Unconsolidated bottom
E1AB (L)	Estuarine, subtidal aquatic bed	Estuarine bays	*Ruppia maritima* *Halodule wrightii*
E2US (P,N,M)	Estuarine, intertitdal 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	*Iva frutescens* *Baccharis halimifolia*
R1UB (V)	Riverine, tidal, unconsolidated bottom	Rivers	Unconsolidated bottom
R1SB (T)	Riverine, tidal, streambed	Rivers	Unconsolidated bottom
R2UB (H)	Riverine, lower perennial, unconsolidated bottom	Rivers	Unconsolidated bottom
R4SB (C,F)	Riverine, intermittent streambed	Streams, creeks	Unconsolidated bottom
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 and marshes	*Nelumbo lutea* *Ruppia maritima*
PUB (F,H)	Palustrine, aquatic bed	Pond, aquatic vegetation and marshes	*Nelumbo lutea*
PEM (A,C,F,S,R,T)	Palustrine emergent	Fresh-water marshes, meadows, depressions, or drainage areas	*Scirpus californicus* *Typha spp.* *Alternanthera philoxeriodes*
PSS (A,C,F,S,R,T)	Palustrine scrub/shrub	Willow thicket, river banks	*Salix nigra* *Sesbania drummondii*
PFO (A,C,F,S,R,T)	Palustrine forested	Swamps, woodlands in floodplains depressions, meadow rims	*Taxodium distichum* *Liquidambar styraciflua*

Marine System

Marine areas include unconsolidated bottom (open water), unconsolidated shore (beaches), and rocky shore (jetties). The mean range in Gulf tides is approximately 0.6 m (2.1 ft) (table 1). Nonvegetated open water overlying the Texas Continental Shelf is classified as marine subtidal unconsolidated bottom (M1UBL) (table 3). Unconsolidated shore is mostly irregularly flooded shore or beach (M2USP) with a narrow zone of regularly flooded shore (M2USN). The composition of these areas is primarily sand and shell. Granite jetties along the coast in the marine system are classified as rocky shore irregularly flooded artificial substrate (M2RSPr).

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) includes intertidal sand and mud flats and estuarine beaches and bars. Water regimes for this habitat range from irregularly exposed (E2USM), regularly flooded (E2USN), to irregularly flooded (E2USP).

Aquatic beds observed in this system are predominantly submerged rooted vascular plants (E1AB3L) that include, in the Christmas Bay area (fig. 1), *Halodule wrightii, Ruppia maritima, Halophila engelmanni,* and *Thalassia testudinum* (Pulich and White, 1991). Some areas that were delineated on 1989 photographs (which reflected extremely low tidal conditions) were classified as unknown aquatic bed (E1AB5L)—possibly algae and other organic material.

Emergent areas closest to estuarine waters consist of regularly flooded (E2EM1N) salt-tolerant grasses (low salt and brackish marshes). These communities are mainly composed of *Spartina alterniflora, Distichlis spicata, Salicornia* spp., *Batis maritima, Juncus roemerianus,* and *Scirpus maritimus* in more saline areas (fig. 7). In brackish areas such as in the Trinity River delta at the head of Trinity Bay, species composition changes toward a brackish to fresh-water assemblage. At slightly higher elevations the irregularly flooded estuarine emergent wetlands (E2EM1P) (high salt and brackish marshes) include *Spartina patens, Distichlis spicata, Spartina spartinae, Scirpus maritimus, Borrichia frutescens, Aster* spp., and many others (fig. 8).

Estuarine scrub-shrub wetlands (E2SS) are much less extensive than estuarine emergent wetlands. Representative plant species, which generally occur in irregularly flooded zones (E2SS1P) between emergent wetland communities and upland habitats, include *Iva frutescens, Baccharis halimifolia, Sesbania drummondii,* and *Tamarix gallica.*

Mapping criteria allow classes to be mixed in complex areas where individual classes cannot be separated. The most commonly used combinations include the estuarine emergent class (E2EM) and unconsolidated shore (E2US), for example, E2EM1P/USP. In such combinations, each class must compose at least 30 percent of the mapped area (polygon); the dominant classes were listed first on maps prepared from 1989 photographs. The estuarine emergent and unconsolidated shore combination was most frequently used on Galveston and Follets Islands where intertidal sand flats were juxtaposed with patches of salt-marsh vegetation. Vegetation commonly found in these areas includes *Monanthochloe littoralis, Salicornia* spp., *Batis maritima,* and *Suaeda linearis.*

The estuarine system extends upstream or landward to the point where ocean-derived salts are less than 0.5 parts per thousand (during average annual low flow) (Cowardin and others, 1979). Mapping of 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 fresh-water systems.

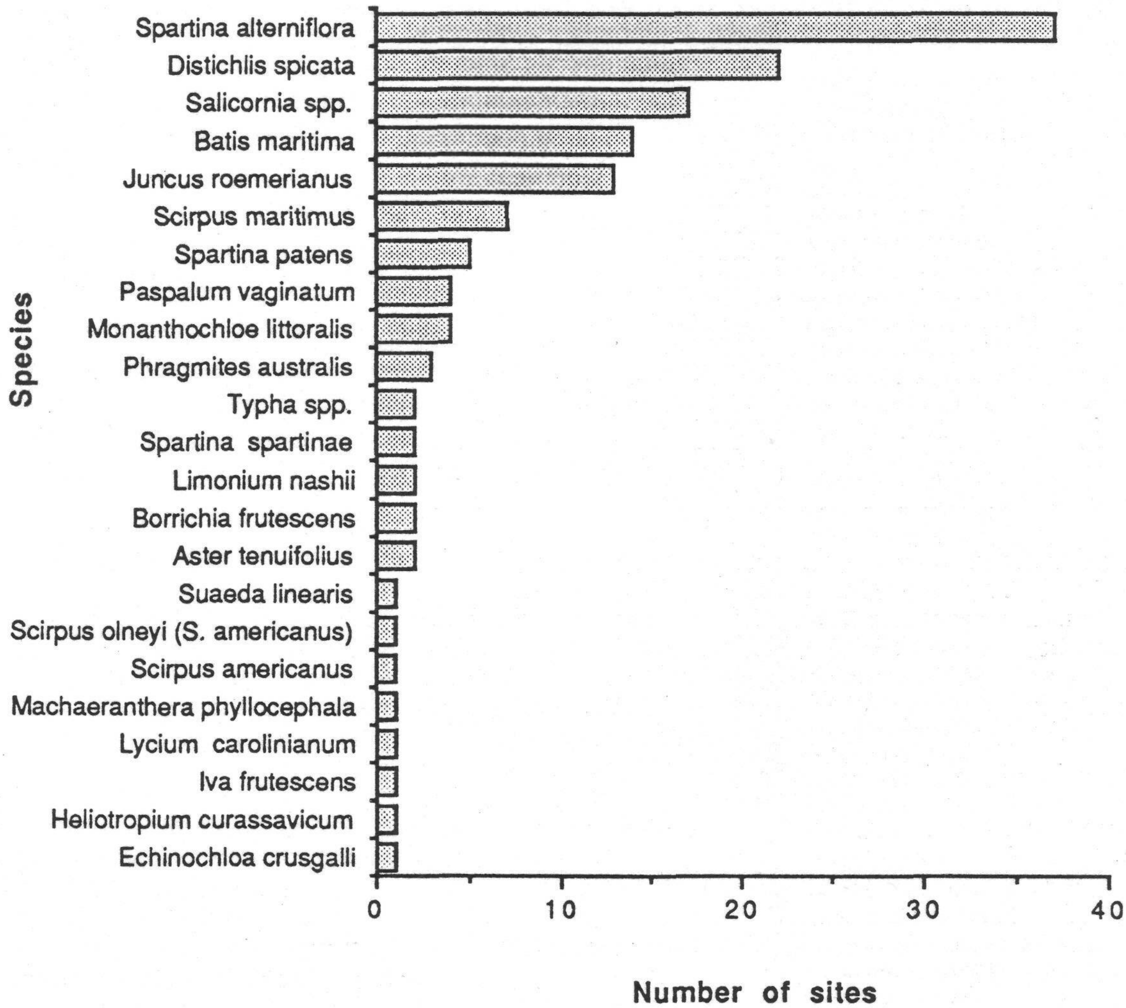


Figure 7. Plant species characterizing areas mapped as regularly flooded estuarine intertidal wetlands (E2EM1N), or low salt- and brackish-water marshes.

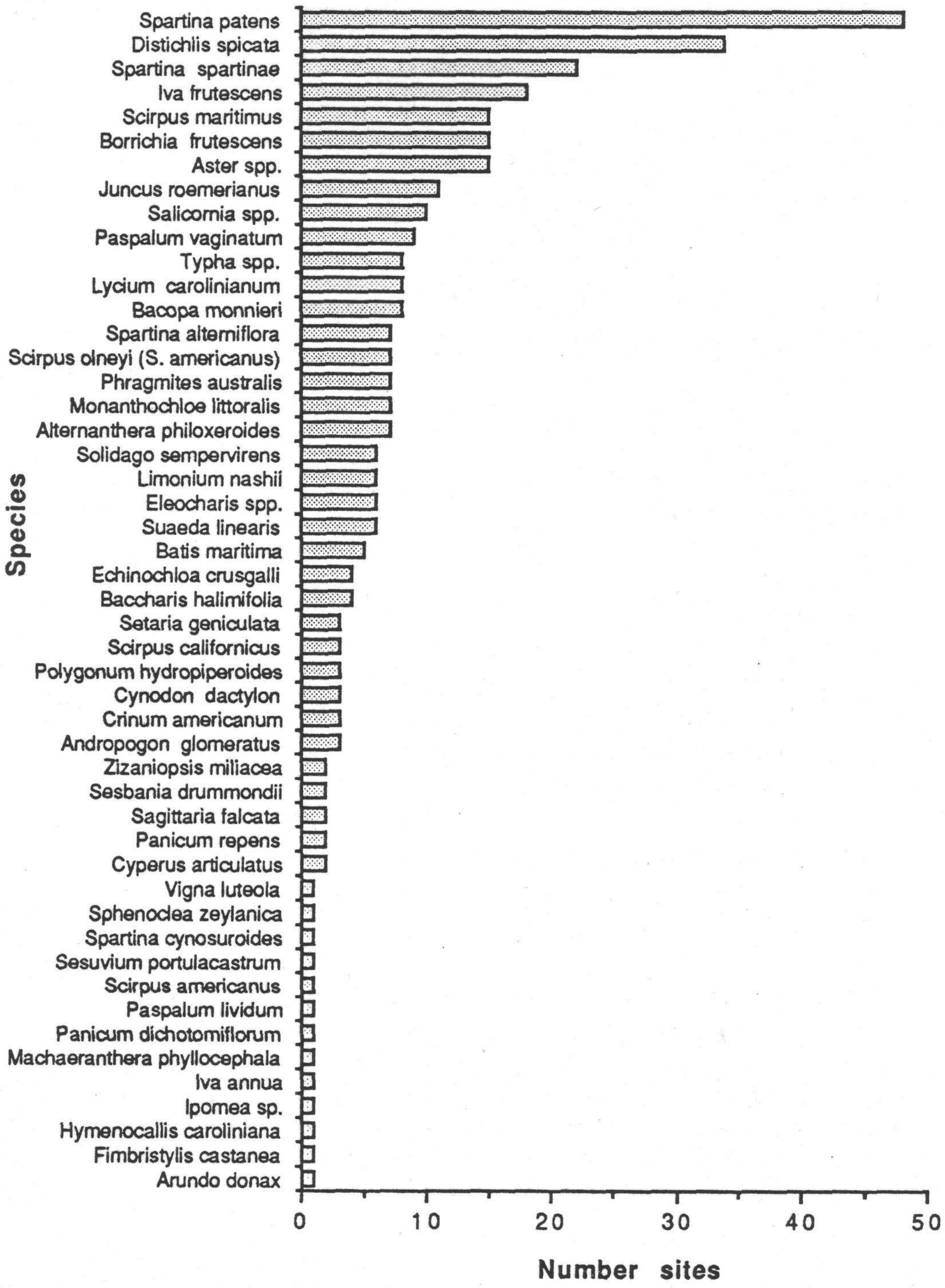


Figure 8. Plant species characterizing areas mapped as irregularly flooded estuarine intertidal wetlands (E2EM1P), or high salt- and brackish-water marshes.

Lacustrine System

Water bodies greater than 20 acres are included in this system with both limnetic and littoral subsystems represented. Numerous lakes and reservoirs exist within the study area. Major bodies of water include Lake Anahuac (Anahuac quad), Lake Charlotte (Cove quad), and Highlands Reservoir (Highlands quad).

Nonvegetated water bodies are labeled limnetic or littoral unconsolidated bottom (L1UB or L2UB) depending on water depth. Bodies of water with vegetation are classified with the subclass of rooted (L1AB3 and L2AB3) or floating (L1AB4 and L2AB4) aquatic bed. The impounded modifier (h) is used on bodies of water impounded by locks or artificial means. The artificially flooded modifier (k) is used in situations where water is controlled by pumps and siphons.

Riverine System

Three riverine subsystems occur in the project area: tidal (R1), lower perennial (R2), and intermittent (R4). The major rivers discharging into the bay are the Trinity and San Jacinto Rivers (fig. 6). Ditches large enough to be delineated were identified with the (x) modifier (for example, R2UBHx or R4SBFx).

Palustrine System

Palustrine areas include the following classes: unconsolidated bottom (open water), unconsolidated shore (including flats), aquatic bed, emergent (fresh or inland marsh), scrub-shrub, and forested. Naturally occurring ponds are identified as unconsolidated bottom permanently or semipermanently flooded (PUBH or PUBF). Excavated or impounded ponds and borrow pits are labeled with their respective modifiers (PUBHx or PUBHh).

Palustrine emergent wetlands are generally equivalent to fresh, or inland marshes. Semipermanently flooded emergent wetlands (PEM1F) are low fresh marshes; seasonally flooded (PEM1C) and temporarily flooded (PEM1A) palustrine emergent wetlands are high fresh marshes. Emergent areas bordering estuarine vegetation and estuarine-influenced rivers are typically affected by tides. For these tidally influenced fresh-water systems, special water-regime modifiers are applied for semipermanently (PEM1T), seasonally (PEM1R), and temporarily (PEM1S) flooded areas.

Vegetation communities typically characterizing areas mapped as low emergent wetlands (PEM1F and PEM1T) include *Scirpus californicus, Typha* spp., *Alternanthera philoxeroides, Cyperus articulatus, Spartina patens* (in higher areas), *Scirpus americanus, Polygonum hydropiperoides, Bacopa monnieri, Phragmites australis, Eleocharis* spp., *Zizaniopsis miliacea*, and others (fig. 9). Areas mapped as topographically higher and less frequently flooded emergent wetlands (PEM1C and PEM1A) include *Cyperus* spp., *Scirpus americanus, Eleocharis spp., Sesbania drummondii* (more typical in areas mapped as scrub-shrub), *Typha* spp., *Spartina patens*, and *Polygonum hydropiperoides*, to mention a few (fig. 10).

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 the photographs. Thus, some plant species that may typify a low regularly flooded marsh, for example, may be included in a high marsh map unit (see figs. 9 and 10, for instance). Differentiation of high and low marsh communities was better achieved through field transects, some of which include elevation measurements.

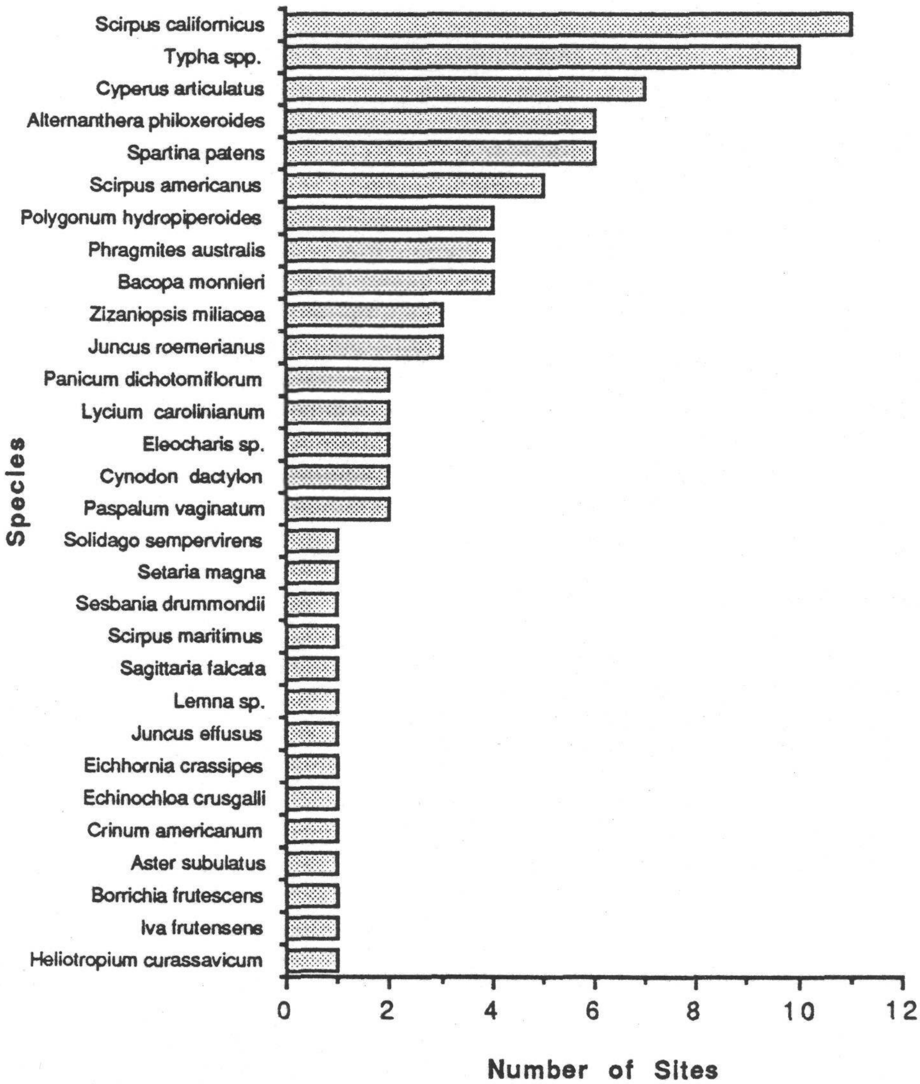


Figure 9. Plant species characterizing areas mapped as semipermanently flooded palustrine emergent wetlands (PEM1F and PEM1T), or low fresh-water marshes.

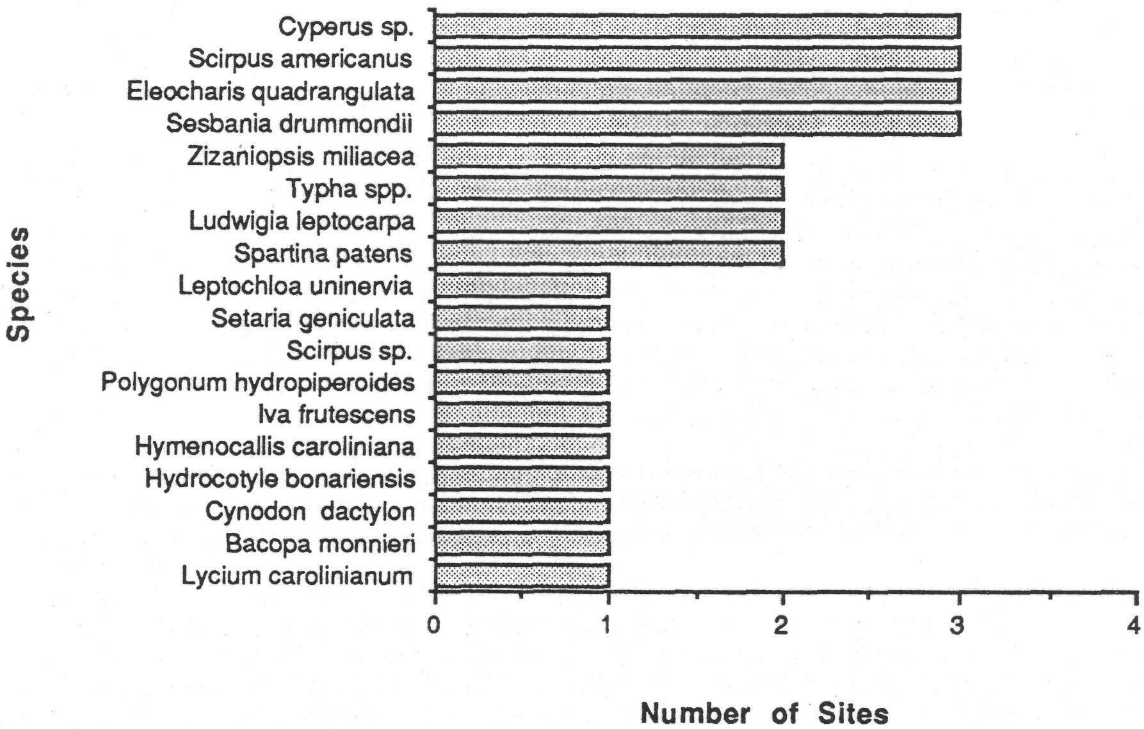


Figure 10. Plant species characterizing areas mapped as seasonally to temporarily flooded palustrine emergent wetlands (PEM1C AND PEM1A), or high fresh-water marshes.

Palustrine scrub-shrub wetlands that were mapped are typically seasonally flooded (PSS1C) and dominated by *Salix nigra, Sapium sebiferum,* and *Sesbania drummondii.* Temporarily and semipermanently flooded scrub-shrub habitat also occur with similar species. Water regimes include both tidally and nontidally influenced areas. *Tamarix gallica* is labeled PSS2A or PSS2C depending on the water conditions present (table 2).

Palustrine forested areas, semipermanently flooded (PFO2F), are represented by *Taxodium distichum.* Temporarily (PFO1A) and seasonally (PFO1C) flooded forested areas incorporate a large mixture of tree species including *Fraxinus pennsylvanica, Celtis laevigata, Salix nigra, Liquidambar styraciflua, Gleditsia aquatica, Planera aquatica, Sapium sebiferum, Cephalanthus occidentalis, Acer rubrum, Betula nigra,* and others. A split subclass was used when both needle-leaved and broad-leaved deciduous species are present (PFO2/1 or PFO1/2), with more than 30 percent coverage of each. The first subclass modifier is more abundant in canopy.

Species Composition of Wetland Plant Communities

To collect information on plant composition, wetland communities were surveyed at more than 180 sites around the Galveston Bay system; 135+ sites are shown in figure 11, and are listed in appendices A and B. The Galveston Bay project area is defined by 30 USGS 7.5-minute quadrangle maps, but one additional map (Freeport) was included for the field surveys. The maps were assigned numbers from 1 to 31 to simplify numerical designations of the surveyed sites (fig. 12). Species composition at the various sites along with very brief descriptive notes on the relationship of the identified plant communities to topography (e.g., high versus low zones) and local geographic features (such as roads or streams) are presented in appendix B. The relationships between plant species and relative elevations were determined along some transects (appendix C).

Wetland plant communities in the Galveston Bay system include high and low categories of salt, brackish, and fresh marshes, and forested wetlands. Other environments include mud and sand flats, beaches and bars, submerged vascular vegetation, disturbed areas, and open water.

The most widely distributed wetland habitats in the Galveston Bay system are marshes, the most extensive of which are brackish. Brackish marshes, as mapped by White and others (1985), compose roughly 65 to 70 percent of the marsh system in the Galveston Bay project area. Salt marshes are a distant second, composing roughly 25 to 30 percent. Fresh marshes make up the remaining 5 to 10 percent of the marsh system. Because many species can tolerate varying salinity regimes as well as water regimes, there is considerable overlap in the species composition of these marsh systems. The divergent plant communities in the project area are exemplified by the fresh marshes and swamps along the Trinity River, which contrast sharply with the salt marshes that fringe Christmas Bay.

Because of the predominance of brackish and salt marshes in the project area, more than 60 percent of the field surveys were located in these marshes. Surveys of other environments ranged from approximately 8 percent in forested wetlands to about 5 percent in transitional areas. With reference to all sites visited, the 15 most frequently encountered species were headed by *Spartina patens* and *Distichlis spicata* (fig. 13).

Each of the species in figure 13 was observed at more than 10 sites, *Spartina patens* and *Distichlis spicata* occurred at more than 55 sites, and *Spartina alterniflora* at more than 40 sites. Other species listed as among the top 25 reported include *Solidago* spp., *Limonium nashii, Phragmites australis, Lycium carolinianum, Paspalum vaginatum,* and *Suaeda linearis.* These species are typical of the brackish and salt marsh systems.

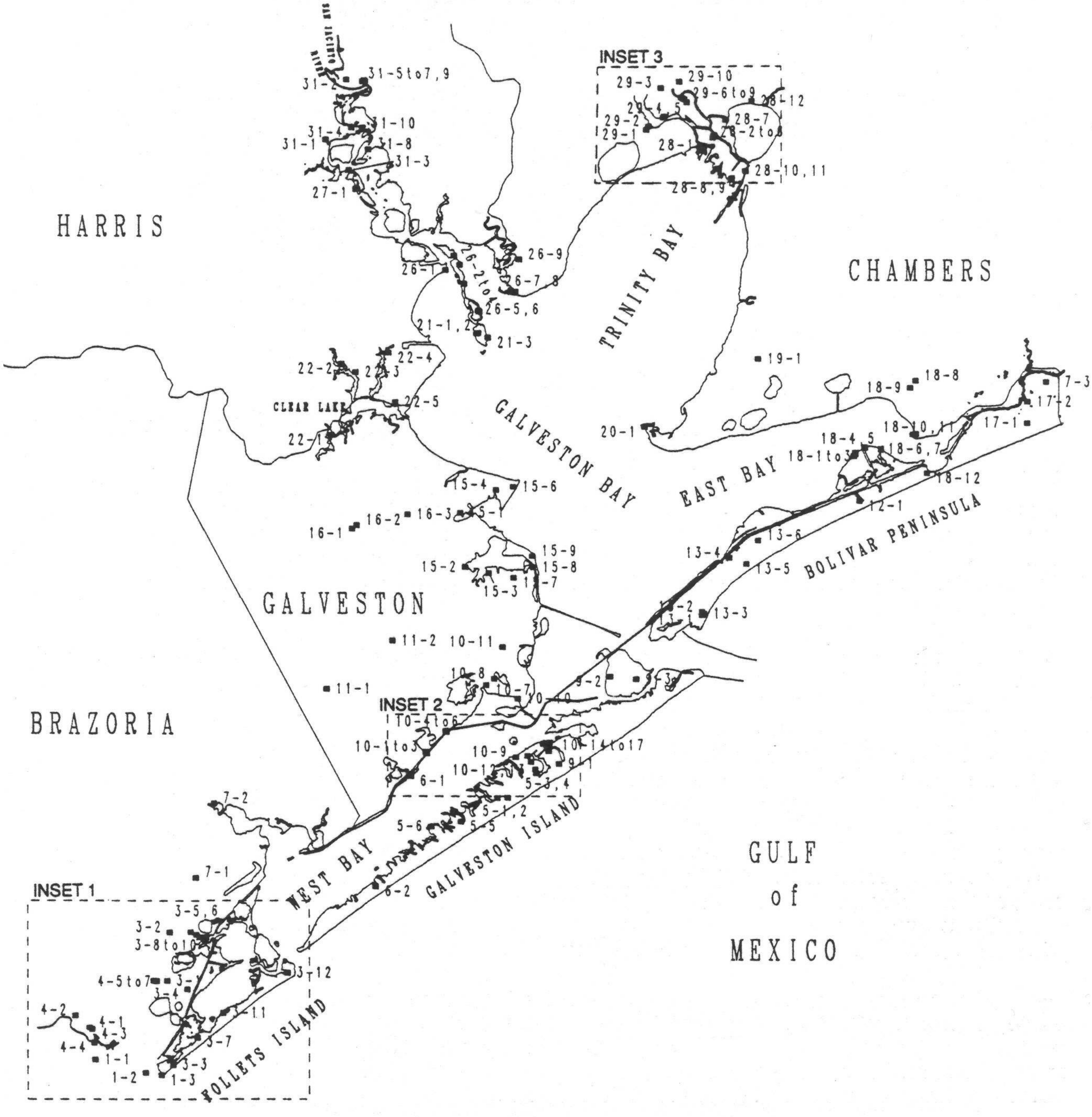


Figure 11. Location map of field survey sites. Inset maps are not shown. From White and Paine (1992).

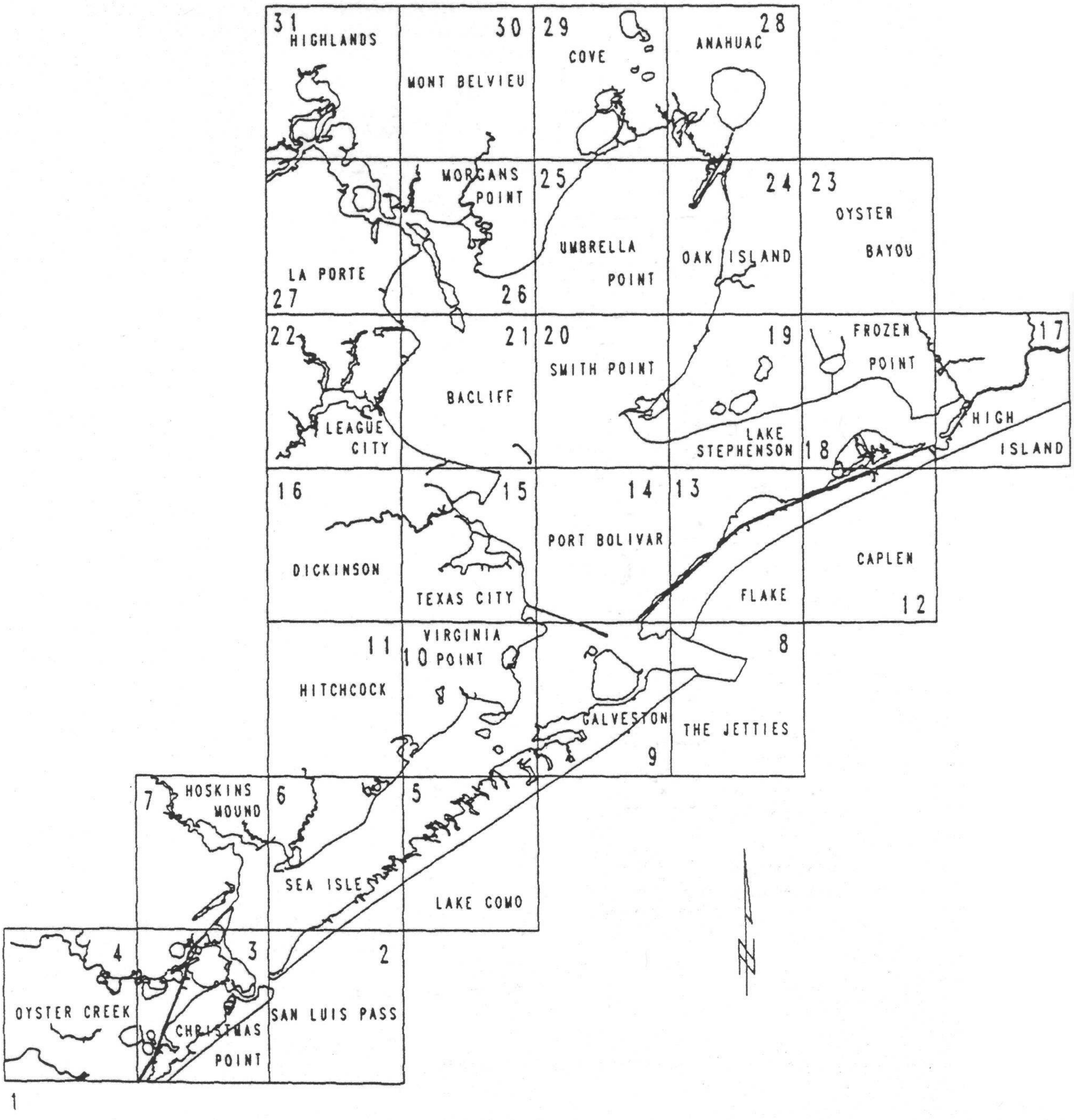


Figure 12. Index map of quadrangles and identifying numbers defining the Galveston Bay study area. The numbers are used in identifying field sites (see fig. 11).

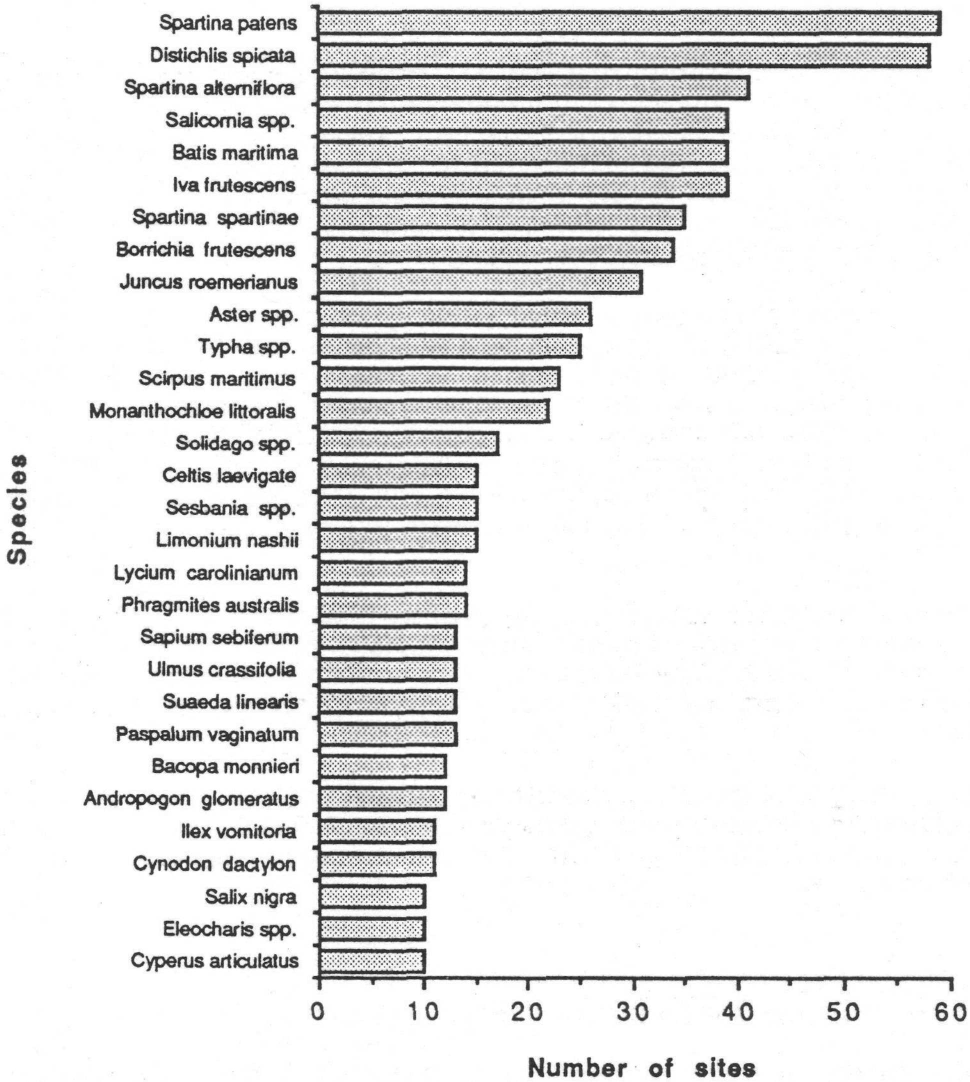


Figure 13. Dominant wetland species determined from field surveys in the Galveston Bay area.

Wetland Indicator Status of Prevalent Plants at Survey Sites

The scientific and common names of plant species identified at field survey sites are presented in table 4. Each species is classified in terms of its wetland indicator status for Region 6, which includes Texas, and for the Nation. The indicator status is based on the "National List of Plant Species That Occur in Wetlands: 1988, Texas" (Reed, 1988). In addition, the habit for each species as defined in the list (Reed, 1988) is presented in table 4.

Of the species identified at the survey sites (fig. 11), about 34 percent are classified as obligate (OBL) wetland plants, which means that under natural conditions these plants occur in wetlands with an estimated probability of 99 percent. Among the species are those typically found in wetter conditions, e.g., those characterizing topographically low salt, brackish, and fresh marshes (figs. 7 and 9). Such species include *Spartina alterniflora, Juncus roemerianus, Batis maritima, Scirpus californicus, Scirpus olneyi, Eleocharis* spp., *Bacopa monnieri, Typha* spp., *Alternanthera philoxeroides*, and *Sagittaria* spp., among others.

Approximately 37 percent of the species listed (table 4) are classified as Facultative Wetland plants (FACW, FACW+, FACW–). These species usually occur in wetlands, or have an estimated probability of 67 to 99 percent of occurring in wetlands; but occasionally they occur in nonwetland areas. Included species are those that typically define topographically higher marshes such as *Borrichia frutescens, Spartina patens, Distichlis spicata* (also common in topographically low marshes) *Spartina spartinae, Phragmites australis, Echinochloa crusgalli, Hydrocotyle bonariensis, Heliotropium curassuvicum*, and *Aster spinosus*, for example. Some Facultative Wetland plants may also occur in wetter, typically low marshes, for instance, *Paspalum vaginatum*.

About 19 percent of the listed species are classified as Facultative (FAC). These species are equally likely to occur in wetlands or nonwetlands (estimated probability 34–66 percent). Such species include grasses like *Setaria geniculata, Paspalum urvillei*, and *Panicum repens*. Many trees such as *Carya illinoensis, Celtis laevigata, Pinus taeda*, and *Ulmus crassifolia* also are listed as Facultative plants.

Only 7 percent of the plants listed are classified as Facultative Upland (FACU). These species are usually not found in wetlands; their estimated probability of occurring in wetlands is 1 to 33 percent. Such species include the grasses *Cynodon dactylon, Andropogon virginicus*, and *Eragrostis spectabilis*.

Wetland Plant Communities and Prevalent Species

In the following discussion of coastal wetland communities in the Galveston Bay system (extracted from White and Paine, 1992), marshes are subdivided into salt, brackish, and fresh communities to assist in the discussions of vegetation composition. A lack of long-term field data precludes the establishment of definite salinity values for these units. Because some plant species can tolerate a relatively large range in salinities (Penfound and Hathaway, 1938; Chabreck, 1972), species tend to overlap between the fresh-marsh and the brackish-marsh communities, and the brackish-marsh and the salt-marsh communities. In addition, wide variation can occur between surface water salinities and pore or ground water salinities, which can affect plant distribution (Webb, 1983). Overlap between communities also occurs between topographically high and low marshes. Some species can tolerate a range in water regimes, or frequencies of inundation, and therefore may occur in wet, low areas as well as in high, dryer areas.

Mapping of wetlands and aquatic habitats follows the classification by Cowardin and others, 1979. As mentioned previously, in general terms, emergent vegetation in the Estuarine system corresponds to salt and brackish marshes, and emergent vegetation in the Palustrine system

Table 4. Wetland indicator status and common names of plants identified in field surveys. Indicator status from Reed (1988). Abbreviations and symbols given at end of table. From White and Paine (1992)

Emergent spp. Scientific name	Emergent spp. Common name	Status, Reg. 6	Status, Nat.	Habit
Acer rubrum	Red maple	FAC	FAC	NT
Acacia angustissima	Fern acacia	not listed		
Alternanthera philoxeroides	Alligator weed	OBL	OBL	PIEF
Ambrosia psilostachya	Western ragweed	FAC-	FACU-, FAC	PNF
Ambosia trifida	Giant ragweed	FAC	FAC,FACW	ANF
Andropogon glomeratus	Bushy bluestem	FACW+	FACW,OBL	PNG
Andropogon virginicus	Broom-sedge	FACU+	FACU,FAC	PNG
Aristida sp.	Three-awn	FACW-to FACU		
Arundo donax	Giant reed	FAC+	FACU-,FACW	PIG
Aster spinosus	Spiny aster	FACW-	FAC, FACW	PNF
Aster subulatus	Annual saltmarsh aster	OBL	FACW,OBL	ANF
Aster tenuifolius	Perennial saltmarsh aster	OBL	OBL	PNF
Baccharis halimifolia	Eastern B., Sea-myrtle	FACW-	FAC,FACW	NS
Bacopa monnieri	Coastal waterhyssop	OBL	OBL	PNF
Batis maritima	Saltwort	OBL	OBL	N$S
Betula nigra	River birch	FACW	FACW,OBL	NT
Borrichia frutescens	Sea oxeye	FACW+	FACW+,OBL	NS
Cardiospermum halicacabum	Balloon vine	FAC	FACU,FAC	AIF
Carya aquatica	Water hickory	OBL	OBL	NT
Carya illinoensis	Pecan hickory	FAC+	FACU,FACW	NT
Celtis laevigata	Sugar-berry	FAC	UPL,FACW	NT
Celtis occidentalis	Common hacberry	FAC	FACU,FAC	NTS
Cephalanthus occidentalis	Common buttonbush	OBL	OBL	NT
Crinum americanum	Swamp lily	OBL	OBL	PNF
Cynodon dactylon	Bermuda grass	FACU+	FACU,FAC	PIG
Cyperus articulatus	Jointed flatsedge	OBL	OBL	PNGL
Cyperus elegans	Sticky flatsedge	FACW-	FACW-,FACW	PNGL
Cyperus oxylepis	Sharp-scale flatsedge	FACW	FACW	PNEGL
Cyperus virens	Green flatsedge	FACW	FACW	PNEGL
Dichromena colorata	Starrush whitetop	FACW	FACW	PNGL
Distichlis spicata	Seashore saltgrass	FACW+	FAC+,FACW+	PNG
Desmodium canadense	Tickclover	FAC	FACU, FAC	PNF
Echinochloa crusgalli	Barnyard grass, water millet	FACW-	FACU,FACW	AIG
Eichhornia crassipes	Common water-hyacinth	OBL	OBL	PNE/F (I-Ck.Lst.)
Eleocharis parvula	Dwarf spikesedge	OBL	OBL	PNGL
Eleocharis cellulosa	Gulf Coast spikesedge	OBL	OBL	PNGL
Eleocharis microcarpa	Small-fruit spikerush	OBL	OBL	ANEGL
Eleocharis quadrangulata	Squarestem spikesedge	OBL	OGL	PNEGL
Eleocharis lanceolata ?	Lanceleaf spikesedge	OBL	OBL	PNGL
Eleocharis sp.	Spikesedge	OBL?	OBL?	PIG?
Eragrostis spectabilis	Purple lovegrass	FACU-	UPL,FACU	PNG
Eustachys petraea	Pinewoods finger grass	FAC-	FACU-, FAC	NG
Fimbristylis castanea	Marsh fimbry	OBL	OBL	PNEGL
Forestiera acuminata	Swamp privet	OBL	OBL	NST
Fraxinus caroliniana	Carolina ash	OBL	OBL	NETS
Fraxinus pennsylvanica	Green ash	FACW-	FAC,FACW	NT
Gleditsia aquatica	Water locus	OBL	OBL	NET
Halodule wrightii	Shoalgrass	OBL	OBL	PNZF
Heliotropium curassavicum	Seaside heliotrope	FACW	FACW,OBL	API$F
Hydrocotyle bonariensis	Coastal plain penny-wort	FACW	FACW	PNF
Hymenocallis caroliniana	Carolina spider lily	FACW	FACW	PNF

Table 4 (cont.)

Emergent spp. Scientific name	Emergent spp. Common name	Status, Reg. 6	Status, Nat.	Habit
Ilex vomitoria	Yaupon	FAC-	FAC-,FAC	NST
Ipomea sp.	Morning glory	FAC?	FAC?	?
Iva annua	Annual sumpweed, marsh-elder	FAC	FAC	AIF
Iva angustifolia	Narrowleaf sumpweed	Not listed		
Iva frutescens	Big-leaf sumpweed	FACW	FACW,FACW+	PNH$F
Juncus effusus	Soft rush	OBL	FACW+,OBL	PNEGL
Juncus roemerianus	Needlegrass rush	OBL	OBL	PNGL
Lemna sp.	Duckweed	OBL	OBL	PN/F
Leptochloa uninervia	Mexican Spangle-Top	FACW	FACW-,FACW	ANG
Limonium nashii	Sea-lavender	NA*	OBL	PNF
Liquidambar styraciflua	Sweet gum	FAC	FAC,FACW	NT
Lolium perenne	Perennial ryegrass	FACU	FACU-, FAC	PIG
Ludwigia leptocarpa	River seedbox	OBL	OBL	PNEF
Lycium carolinianum	Carolina wolf-berry	FACW	VACW	NS
Machaeranthera phyllocephala	Camphor daisy	FACW	FACU,FACW	ANF
Medicago minima	Small medic	Not listed		
Monanthochloe littoralis	Shoregrass	OBL	OBL	PNEG
Nelumbo lutea	American lotus	OBL	OBL	PNZ/F
Nothoscordum bivalve	False garlic	FACU	FACU	PNF
Panicum dichotomiflorum	Fall panic grass	FACW	FAC,FACW	ANG
Panicum hians	Gaping panicum	FACW-	FACW-,OBL	PNG
Panicum virgatum	Switchgrass	FACW	FAC,FACW	PNG
Panicum repens	Torpedograss	FAC+	FAC+, FACW-	PIG
Parkinsonia aculeata	Retama	FACW-	FAC-,FACW	NT
Paspalum floridanum	Florida paspalum	FACW-	FACW-,FACW	PNG
Paspalum lividum	Longtom	OBL*	OBL	PNEG
Paspalum monostachyum	Gulfdune paspalum	FACW+	FACW,FACW+	PNG
Paspalum urvillei	Vasey grass	FAC	FAC	PIG
Paspalum vaginatum	Seashore paspalum	FACW+	FACW,OBL	PNG
Phragmites australis	Common reed	FACW	FACW,FACW+	PNEG
Phyla lanceolata	Lance leaf frog fruit	FACW	FACW,OBL	PNF
Physostegia intermedia	Intermediate Lionsheart	OBL	FACW-, OBL	PNF
Pinus taeda	Loblolly pine	FAC-	UPL,FAC	NT
Planera aquatica	Water elm	OBL	OBL	NET
Platanus occidentalis	American sycamore	FAC+	FAC,FACW	NT
Pluchea purpurascens	Saltmarsh camphor-weed	OBL	FACW+,OBL	AIEF
Pologonum hydropiperoides	Swamp smartweed	OBL	OBL	PNEF
Polygonum ramosissimum	Bushy knotweed	FACW	FACU-,FACW	ANF
Populus deltoides	Eastern cotton-wood	FAC	FAC,FACW	NT
Quercus phellos	Willow oak	FACW	FAC+,FACW	NT
Quercus falcata	Southern red oak	FACU	FACU-,FACU	NT
Quercus nigra	Water oak	FAC+	FAC,FACW	NT
Quercus virginiana	Live oak	FACU+	FACU,FACU+	NT
Ruppia maritima	Widgeon-grass	OBL	OBL	PNZF
Sabal minor	Dwarf palmetto	FACW	FACW	NST
Sabatia campestris	Prairie rose-gentian	FACU	FACU	ANF
Sagittaria falcata	Coastal arrow-head	OBL	OBL	PNEF
Sagittaria lancifolia	Bull-tongue arrow-head	OBL	OBL	PNEF
Salicornia bigelovii	Annual glasswort	0BL*	OBL	ANE$F
Salicornia virginica	Perennial glasswort	OBL*	OBL	PNE$F
Salix nigra	Black willow	FACW+	UPL, OBL	NT
Sapium sebiferum	Chinese tallow	FACU+	FACU+,FAC	IT
Scirpus americanus	Olney's (American) bulrush	OBL	OBL	PNEGL
Scirpus californicus	California bulbush	OBL	OBL	PNEGL
Scirpus maritimus	Saltmarsh bulrush	NI	OBL	PNEGL
Scirpus olneyi (S. americanus)	Olney's bulrush	OBL	OBL	PNEGL
Sesbania drummondii	Drummond's rattle-bush	FACW	FACW	NSH
Sesuvium portulacastrum	Sea-purslane	FACW	FACW	PN$F
Setaria geniculata	Knotroot bristlegrass	FAC	FAC	PNG
Setaria magna	Giant bristlegrass	FACW	FACW,FACW+	ANEG
Sisyrichium exile	Yellow blue-eyed grass	FACW	FAC, FACW-	AIF

Table 4 (cont.)

Emergent spp. Scientific name	Emergent spp. Common name	Status, Reg. 6	Status, Nat.	Habit
Solidago altissima	Tall goldenrod	FACU	FACU-, FACU+	PNF
Solidago sempervirens	Seaside golden-rod	FACW-	FACW-,FACW	PN$F
Spartina spartinae	Gulf cordgrass	FACW+	FACW+,OBL	PNG
Spartina alterniflora	Smooth cordgrass	OBL	OBL	PNEG
Spartina cynosuroides	Big cordgrass	OBL	OBL	PNEG
Spartina patens	Saltmeadow (marshhay) cordgrass	FACW	FACW,OBL	PNG
Spartina pectinata	Prairie cordgrass	FACW+	FACW,OBL	PNG
Spiranthes ovalis	October ladiestresses	FAC*	FAC	PNF
Sporobolus virginicus	Seashore dropseed	FACW+	FACW+	PNG
Sphenoclea zeylanica	Chicken-spike (piefruit)			
Suaeda linearis	Annual seepweed	OBL	OBL	ANEF
Tamarix gallica	Salt cedar	FACW	FAC, FACW	IT
Taxodium distichum	Bald cypress	OBL	OBL	NET
Thalassia testudinum	Turtle-grass	OBL	OBL	PNZF
Teucrium cubense	Small coast germander	FAC+	UPL, FACW	APNF
Typha spp.	Cattail	OBL	OBL	PNEF
Ulmus americana	American elm	FAC	FAC,FACW	NT
Ulmus crassifolia	Cedar elm	FAC	FAC	NT
Vigna luteola	Cowpea	FACW-	FACW-,FACW	PNVF
Zizaniopsis miliacea	Marsh millet, giant cutgrass	OBL	OBL	PNG

Habitat symbols	Characteristic or life form
A =	Annual
E =	Emergent
F =	Forb
/ =	Floating
G =	grass
GL =	Grass like
H =	Partly woody
HS =	Half shrub
I =	Introduced
N =	Native
P =	Perennial
S =	Shrub
Z =	Submerged
$ =	Succulent
T =	Tree
V =	Herbaceous vine
WV =	Woody vine
NA =	No agreement by regional panel
* =	Tentative assignment based on limited information
"+"=	More frequently found in wetland
"-"=	Less frequently found in wetland

ABBREVIATION	INDICATOR CATEGORY	DESCRIPTION
OBL	Obligate wetland	Occur almost always (est. prob. >99%) under natural conditions in wetlands.
FACW	Facultative wetland	Usually occur in wetlands (est. prob. 76-99%), but occasionally found in nonwetlands.
FAC	Facultative	Equally likely to occur in wetlands or nonwetlands (est. prob. 34-66%).
FACU	Facultative upland	Usually occur in nonwetlnads (est. prob. 67-99%), but occasionally found in wetlands (e.p. 1-33%).
UPL	Obligate upland	Occur in wetlands in another region, but occur almost always (e.p. >99%) under natural conditions in nonwetlands

corresponds to fresh marshes (table 3). Water regimes used as modifiers in classifying and mapping wetlands help define high and low wetlands (table 2).

Salt-Marsh Community (Estuarine Intertidal Emergent Wetlands)

Salt marshes were examined principally on Follets and Galveston Islands, and Bolivar Peninsula, along the inland margin of West Bay, near Texas City, and at Houston and Smith Points (White and Paine, 1992). Prevalent species in the salt-marsh community include *Spartina alterniflora* (smooth cordgrass), *Batis maritima* (saltwort), *Distichlis spicata* (saltgrass), *Salicornia virginica* and *S. bigelovii* (glasswort), *Borrichia frutescens* (sea-oxeye), *Monanthochloe littoralis* (shoregrass), *Juncus roemerianus* (needlegrass rush or blackrush), *Suaeda linearis* (seepweed), *Scirpus maritimus* (salt-marsh bulrush), *Limonium nashii* (sea-lavender), *Aster tenuifolius* (perennial saltmarsh aster) and *Lycium carolinianum* (Carolina wolfberry). Many of these species, such as smooth cordgrass, saltwort, saltgrass, and glasswort, are common in areas mapped as regularly-flooded estuarine intertidal areas (E2EM1N, fig. 7). At higher elevations, *Spartina patens* (marshhay cordgrass) and *Spartina spartinae* (Gulf cordgrass) occur, although these species are more common in brackish marshes. *Iva frutescens* (big-leaf sumpweed) is locally abundant at higher elevations such as along natural levees. These species—marshhay cordgrass, Gulf cordgrass, and big-leaf sumpweed—are among those that characterize irregularly flooded estuarine emergent wetlands (fig. 8).

The low salt-marsh community is dominated by *Spartina alterniflora*, which lives in the intertidal zone (fig. 14). Species intermixed most frequently with *Spartina alterniflora* along the upper part of the intertidal zone include *Batis maritima* (fig. 15), *Distichlis spicata, Scirpus maritimus, Juncus roemerianus*, and *Salicornia virginica*.

Wind-tidal sand flats are common features in some areas, especially on the barrier islands. Although algal mats are abundant in these areas, the flats are generally barren of emergent vegetation because of intermittent salt-water flooding and subsequent evaporation—a process that concentrates salts and inhibits the growth of most plants. Soil salinities on the flats can reach concentrations high enough to kill *Spartina alterniflora* and *Spartina patens* (Webb, 1983). The flats may locally have scattered salt-marsh vegetation. Common plant species are *Salicornia virginica, Salicornia bigelovii, Monanthochloe littoralis*, and *Batis maritima*. Zonation of some salt-marsh species is well defined by elevation transects at Smith Point, in the Brazoria National Wildlife Refuge, and other locations (see section on "Examples of Wetland Profiles Developed from Topographic Surveys" and appendix C).

The salt-marsh community corresponds in general terms to salt marshes (and locally, salt flats) defined by Shaw and Fredine (1956), Fisher and others (1972, 1973), Gosselink and others (1979), and White and others (1985), and to saline wetland species identified by Lazarine (n.d.). In accordance with the classification of wetlands by Cowardin and others (1979), this community is designated (down to class) as estuarine, intertidal, emergent wetland (E2EM). The water regime modifier, "regularly flooded" (N), is used most frequently to identify low-salt marshes; the modifier, "irregularly flooded" (P), is used to define higher marshes (table 2). (The classification by Cowardin and others has provisions for going beyond the class level and designating species dominance type, water chemistry, and human modifications; examples of the classification given here, however, will be only down to class and water regime.)

Brackish-Marsh Community (Estuarine Intertidal Emergent Wetlands)

The brackish-marsh community is transitional between salt marshes and fresh marshes. These areas are affected both by storm-tidal flooding from bay-estuary-lagoon and Gulf waters and by fresh-water inundation from rivers, precipitation and runoff, or ground water. Because the brackish-marsh community encompasses a range in salinities from near fresh to near saline, the

Figure 14. Low salt-marsh community (E2EM1N) of *Spartina alterniflora*, and open water on the inland margins of Jones Bay (east end of West Bay). Site No. 10-7 (fig. 11), Virginia Point quad. View is toward Galveston Island.

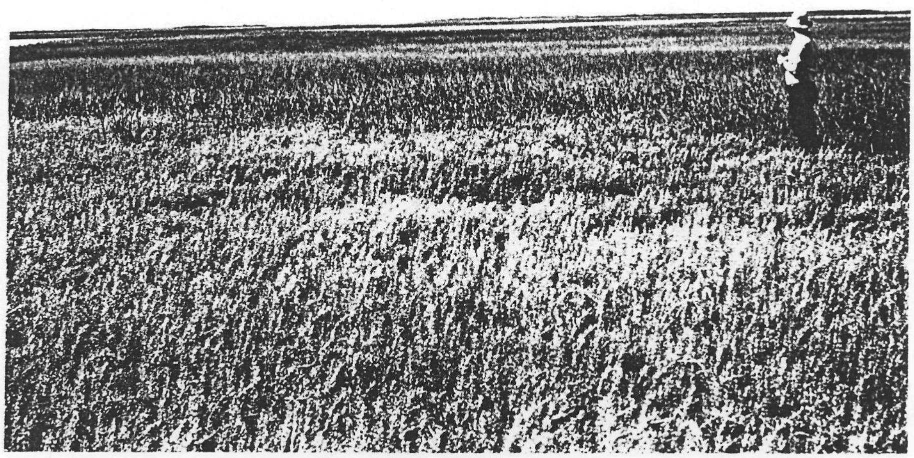


Figure 15. Salt-marsh community (E2EM) on Follets Island. *Batis maritima* in foreground, intergrades with *Spartina alterniflora* in background. Site No. 3-3 (fig. 11), Christmas Point quad. View is landward. See survey line at this site in appendix C.

vegetation types cover a broad spectrum. Species range from those typical of saline marshes to those that occur in fresh marshes.

Areas in which brackish-marsh surveys were conducted included the Brazoria National Wildlife Refuge (figs. 16 and 17), Anahuac National Wildlife Refuge and near High Island, Galveston, and Follets Islands, and Trinity River delta. Among the dominant species in topographically higher areas of this community are *Spartina patens* (salt meadow cordgrass), *Spartina spartinae* (gulf cordgrass), *Borrichia frutescens* (sea oxeye), *Phragmites australis* (common reed), *Solidago sempervirens* (seaside goldenrod), *Panicum virgatum* (switchgrass) and *Spartina cynosuroides* (big cordgrass). Other prevalent species, most of which occur in lower, wetter areas (relative to the cordgrasses) include *Scirpus maritimus* (salt marsh bullrush), *Scirpus olneyi* (*olney bulrush*), *Juncus roemerianus* (needlegrass rush), *Typha* spp. (cattail), *Paspalum vaginatum* (seashore paspalum), *Scirpus californicus* (California bulrush), *Scirpus americanus* (three-square bulrush), *Alternanthera philoxeroides* (alligatorweed), *Eleocharis* sp. (spikesedge), *Bacopa monnieri* (coastal waterhyssop), *Echinochloa crusgalli* (barnyard grass or water millet), and *Aster tenuifolius* and *A. subulatus* (saline and saltmarsh aster), among others. *Spartina alterniflora* (smooth cordgrass) also occurs locally in the brackish-marsh community (fig. 16). Zonation of various species with respect to elevation are illustrated by marsh profiles on the Trinity River delta and in the Brazoria and Anahuac National Wildlife Refuges (appendix C). There are considerable differences in brackish marsh composition in the Brazoria and Anahuac National Wildlife Refuges compared to brackish marshes in the Trinity River delta. In general, the Trinity River delta, which has extensive areas of *Alternanthera philoxeroides* and other species occurring in fresher areas, is toward the fresh end of the brackish salinity spectrum.

The brackish-marsh community corresponds, generally, with the coastal salt meadows (grading into fresh marshes) defined by Shaw and Fredine (1956), the brackish (closed) and brackish- to fresh-water marsh by Fisher and others (1972, 1973), the brackish and intermediate marsh by Gosselink and others (1979), and the brackish marsh by Harcombe and Neaville (1977) and White and others (1985). In the classification system of Cowardin and others (1979) this community is generally designated (down to class) as estuarine, intertidal, emergent wetland (E2EM). Water regimes are generally the same as for the salt marshes—regularly flooded (N) (low marshes) and irregularly flooded (P) (high marshes).

Spartina spartinae is a common species in brackish marshes (fig. 17). Because of its tendency to occur mostly in topographically higher areas, it has been placed in the marsh, transitional (occurring between wetlands and uplands), and prairie communities by various researchers. It occurs in many areas in conjunction with *Spartina patens*, becoming more predominant and extensive (relative to *Spartina patens*) south of the Galveston Bay area along the Texas coast. Tharp (1926) listed *Spartina spartinae* as a dominant species in the coastal marsh community, but also included it as part of a coastal prairie-marsh transition community. McAtee (1976) noted that *Spartina spartinae* flourishes at an elevation between lowland marshes and higher uplands, and apparently requires periodic inundation. The U.S. Army Corps of Engineers, which has jurisdictional responsibilities for wetlands, considers it to be a transitional species (Lazarine, n.d.). Many classifications place it in wetlands, transitional areas, and prairie grasslands (Fisher and others, 1972, 1973; Correll and Correll, 1975; White and others, 1985), presumably depending on associated plants and soil-moisture conditions reflecting inundation frequency. In the list of wetland plants of Texas (Reed, 1988), *Spartina spartinae* is categorized as usually found in wetlands, but occasionally found in nonwetlands. Harcombe and Neaville (1977) place it in their cordgrass prairie unit, but also list it in a checklist of marsh species and note that it probably once was more extensive (in Chambers County) as an intermediate type between upland prairie and brackish marsh. Fleetwood (n.d.) reported that *Spartina spartinae* was the predominant species in his salty prairie community.

Brackish marshes dominate the coastal marsh community between High Island and Trinity Bay (fig. 6). They are also widely distributed along the lower reaches of the Trinity bay-head delta below Interstate Highway 10, inland from parts of West Bay and the Intracoastal Waterway in the Christmas Bay area. They occur in swales and intergrade with salt marshes and sand flats on Galveston Island and Bolivar Peninsula.

Figure 16. Brackish-marsh community (E2EM1P and E2EM1N) in the Brazoria National Wildlife Refuge southwest of Hoskins Mound. Although dominant species are *Spartina patens* and *Distichlis spicata*, *Spartina alterniflora* occurs along the tidal channel. *Ruppia maritima* (widgeongrass) occurs in the channel. Site No. 3-2 (fig. 11), Christmas Point and Oyster Creek quads. View is landward. This site is on the Oyster Creek quad. at the west end of the survey line at this site. See survey line in appendix C.

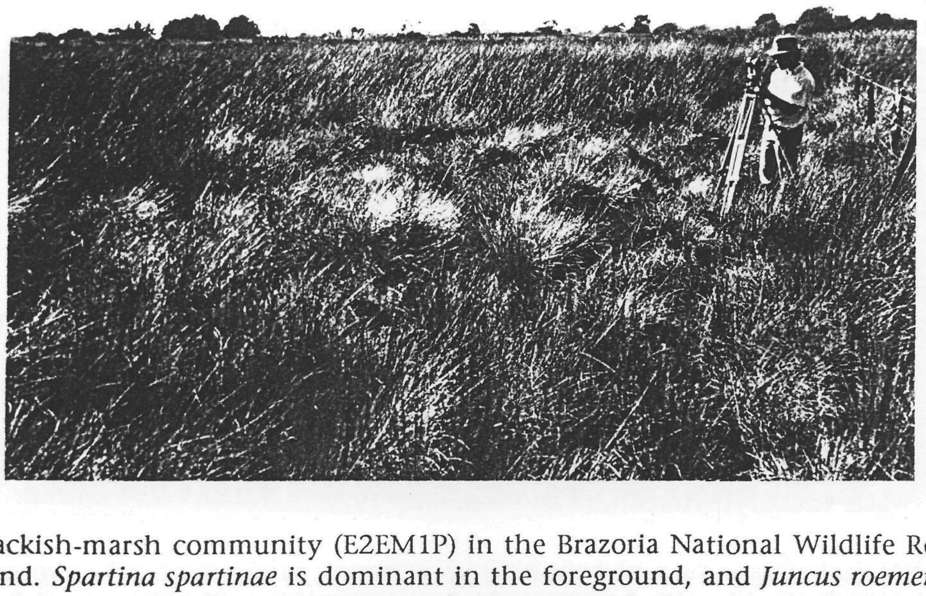


Figure 17. Brackish-marsh community (E2EM1P) in the Brazoria National Wildlife Refuge east of Hoskins Mound. *Spartina spartinae* is dominant in the foreground, and *Juncus roemerianus* in the background. Site No. 7-1 (fig. 11), Hoskins Mound quad. Several elevation surveys were conducted in this area (appendix C).

Fresh-Marsh Community (Palustrine Emergent Wetlands)

Surveys of fresh to intermediate marshes were conducted along the Trinity (figs. 18 and 19) and San Jacinto Rivers and at other inland sites. Environments in which fresh marshes occur are generally beyond the limits of salt-water flooding except perhaps locally during hurricanes. The fresh-water influence from rivers, precipitation, runoff, and ground water is sufficient to maintain a fresher water vegetation community (although many species also occur in brackish marshes) consisting of species such as *Typha* spp., *Phragmites australis, Zizaniopsis miliacea* (marsh millet or giant cutgrass), *Sagittaria falcata* (coastal arrow-head), *Scirpus californicus, Eleocharis quadrangulata* (squarestem spikesedge) and other species of *Eleocharis, Cyperus* spp. (flatsedge), *Bacopa monnieri, Alternanthera philoxeroides, Paspalum lividum* (longtom), and *Eichhornia crassipes* (water hyacinth) in lower, wetter areas. Topographically higher areas generally include such species as *Phragmites australis, Paspalum* spp., *Polygonum* sp. (smartweed), *Panicum* spp. (panic grass), *Rhynchospora* spp. (beakrush), and *Aster spinosus* (spiney aster). Riverine and tidally influenced fresh-water marshes, along the lower reaches of the Trinity and San Jacinto Rivers for example, are functionally different from interior nontidal-influenced fresh-water marsh areas. Tidally influenced fresh-water systems were designated on maps with special water-regime modifiers (table 2). Shrubs such as *Sesbania drummondii* (rattlebush) are scattered around the margins of some fresh marshes and are locally abundant. Some species that are more common in brackish marshes such as *Spartina spartinae* may also occur in fresh marshes. Harcombe and Neaville (1977) used *Spartina patens* as an indicator of brackish conditions in differentiating brackish from fresh marshes.

The fresh-marsh community corresponds to the deep fresh and shallow fresh marshes of Shaw and Fredine (1956), inland fresh-water marsh and, locally, brackish- to fresh-water marsh of Fisher and others (1972, 1973), and fresh marsh of Fleetwood (n.d.), Harcombe and Neaville (1977), Gosselink and others (1979), and White and others (1985). Following the classification by Cowardin and others (1979) this community could be designated (down to class) as palustrine, emergent wetland (PEM) in areas where persistent emergent vegetation such as *Typha* spp. is present, and palustrine aquatic bed (PAB), where floating vascular plants such as *Eichhornia crassipes* occur. A variety of water regimes can be applied under the Cowardin system. Low fresh marshes are usually characterized by the "semipermanently flooded" (F) or "seasonally flooded" (C) water regimes, and higher marshes by the "temporarily flooded" (A) regime, and occasionally the "seasonally flooded" regime. Fresh-water marshes in tidally influenced areas, have a different set of modifiers ranging from "semipermanently flooded—tidal" (T) to "temporarily flooded—tidal" (S) (table 2). These regimes are applicable along river systems, for example, and have been applied to some fresh marshes in the Trinity River delta.

Fresh marshes occur inland along river or fluvial systems and in upland basins and depressions on the mainland and locally on the barrier islands. Upstream along the river valleys of the Trinity and San Jacinto Rivers, salinities decrease and fresh marshes intergrade with and replace brackish marshes (fig. 18). Fresh marshes also occur locally in swales on the modern barrier islands, on the Pleistocene barrier strandplain, and in abandoned channels and courses of the Pleistocene fluvial-deltaic systems (fig. 6).

Forested Wetland Communities (Swamps) (Palustrine Forested Wetlands)

Forested wetlands as defined by Cowardin and others (1979) include swamps as well as forested areas less frequently inundated. Swamps, as defined most commonly, are woodlands or forested areas that contain saturated soils or are inundated by water during much of the year. This community is located almost entirely in the alluvial valley of the Trinity River. The swamp community is composed principally of *Taxodium distichum* (bald cypress) (fig. 20). Associated species may include *Cephalanthus occidentalis* (buttonbush), *Planera aquatica* (water elm), and *Carya aquatic* (water hickory) (Harcombe and Neaville, 1977).

Figure 18. Fresh-marsh community (PEM1T) in the Trinity River valley north of Interstate Highway 10. Species include *Cyperus articulatus, Sagittaria falcata, Scirpus californicus, Zizaniopsis miliacea*, and *Alternanthera philoxeroides*. Site No. 29-3 (fig. 11), Cove quad. View is westward.

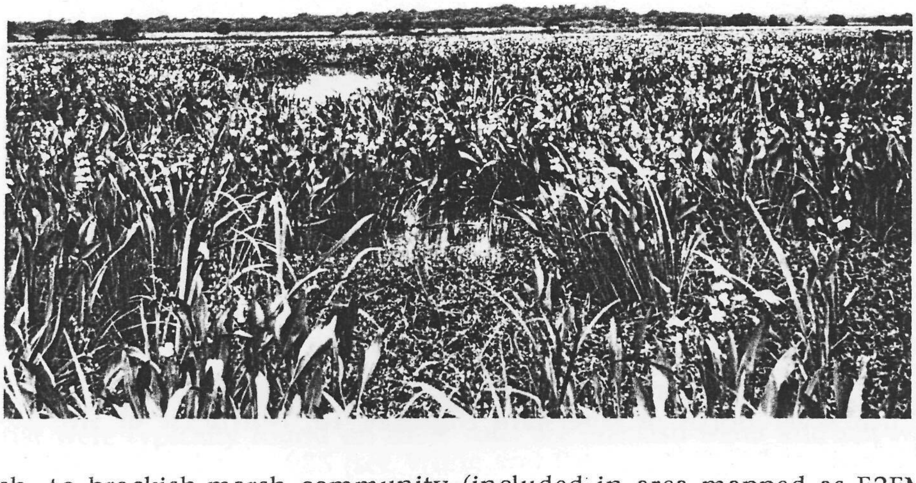


Figure 19. Fresh- to brackish-marsh community (included in area mapped as E2EM1P) on the Trinity River delta near Old River Lake. Species include *Zizaniopsis miliacea, Sagittaria falcata*, and *Alternanthera philoxeroides*. Site No. 29-2 (fig. 11), Cove. View is northwest.

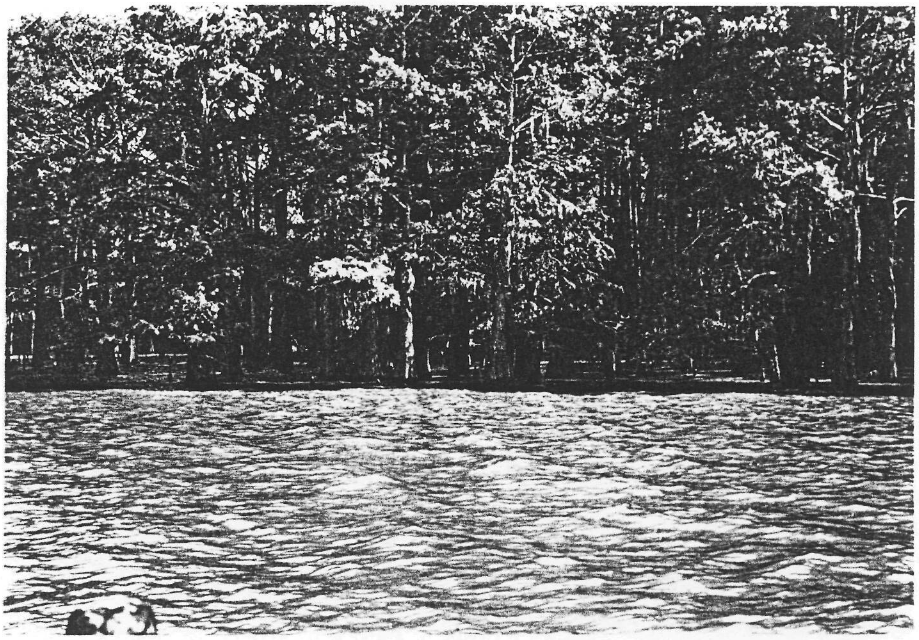


Figure 20. Swamp community, or forested wetlands (PFO2T), dominated by *Taxodium distichum* along the Trinity River north of Interstate Highway 10. Northeast of site 29-10 (fig. 11), Anahuac quad.

Areas along the floodplains of streams (excluding swamps) support assemblages of water-tolerant trees and shrubs that are inundated less frequently than swamps. Trees and shrubs occurring in these areas include *Planera aquatica* (water elm), *Quercus phellos* (willow oak), *Quercus nigra* (water oak), *Fraxinus pennsylvanica* (green ash), *Fraxinus caroliniana* (Carolina ash), *Salix nigra* (black willow), *Ulmus* spp. (elm), *Celtis laevigata* (sugar-berry), *Carya illinoensis* (pecan hickory), *Carya aquatica* (water hickory), *Cephalanthus occidentalis* (button bush), *Ilex vomitoria* (yaupon), *Liquidambar styraciflua* (sweet gum), *Sapium sebiferum* (Chinese tallow), *Parkinsonia aculeata* (retama), *Gleditsia aquatica* (water locus), and *Sabal minor* (dwarf palmetto). Occurring with hardwoods in some topographically higher areas is *Pinus taeda* (loblolly pine).

Submerged Vegetation Community (Estuarine Subtidal Aquatic Bed)

Submerged vegetation has a limited distribution in the Galveston Bay system. It occurs principally in patches along the margins of the Trinity River delta, upper Trinity Bay, and Christmas Bay (Pulich and White, 1991). Plant species occurring in the comparatively fresh area of the Trinity River delta include *Ruppia maritima* (widgeongrass), *Vallisneria americana* (wild celery), *Potamogeton pusillus* (pondweed), and *Najas quadalupensis* (water nymph) (Pulich and others, 1991). The dominant submerged vegetation along the north and eastern shores of upper Trinity Bay is *Ruppia maritima* (Pulich and White, 1991). In the Christmas Bay area, near Follets island, several true seagrasses occur including *Halodule wrightii* (shoalgrass), the dominant species, *Halophila engelmannii* (clovergrass), and *Thalassia testudinum* (turtlegrass) (Pulich and White, 1991). *Ruppia maritima* is abundant in many inland water bodies and tidal creeks (fig. 16).

The submerged-vegetation community is classified under sounds and bays by Shaw and Fredine (1956); as grassflats by Fisher and others (1972, 1973) and White and others (1985); and as submerged vegetation by Diener (1975). Submerged-vegetation communities are designated as estuarine, subtidal, aquatic bed (E1AB) in the classification by Cowardin and others (1979); the water-regime modifier is "subtidal" (L) (table 2).

Soils and Wetland Community Relationships

At 135+ sites surveyed around the Galveston Bay system, approximately 40 soil types were identified from county soil surveys (appendix A). Several soils were encountered more frequently than others, and can be considered the dominant soils corresponding to wetland communities. For example, the soil most frequently occurring at wetland survey sites was the Harris clay. This typically saline, poorly-drained soil is flooded by abnormally high tides, and supports a vegetation assemblage composed predominantly of *Spartina patens* and *Distichlis spicata*. These species were the most frequently encountered during field surveys.

To simplify the discussion of soil types and their relationships to wetland communities, Marsh Rangeland Sites defined by Crenwelge and others (1988) in the soil survey of Galveston County will be used for comparing soils with wetland communities described in this report. Marsh Rangeland Sites (Crenwelge and others, 1988) include the following 8 sites:

(1) The **Salt Marsh Range Site**, with elevations of 0.3 to 1.2 m (1 to 4 ft) above mean sea level, occurs in relatively level coastal marsh areas and in flood plains. It is composed of the Harris clay (Ha and 19), Placedo clay (Pd), and Veston loam, strongly saline (Vx). Almost 40 sites, or about 30 percent of all the sites surveyed, corresponded to the Salt Marsh Range Site complex as defined by Crenwelge and others (1988). Based on field survey locations, the wetland communities that were typically found on these soils are brackish-water and salt-water marshes (as mapped by White and others, 1985 [see White and Paine, 1992]). These communities make up 70 percent of the survey sites within the Salt Marsh Range. High brackish-water marshes

represent 30 percent of the sites. Among the dominant species in high brackish- and high salt-water marshes are *Spartina patens* and *Distichlis Spicata* (fig. 8).

(2) The **Tidal Flat Range Site** corresponds to broad coastal tidal marshes at elevations slightly below mean sea level to about 0.3 m (1 ft) above mean sea level. It consists of the Follet clay loam (Fo), Tatlum clay loam (Ta), and the Tracosa soil in the Caplen-Tracosa complex (Ct), the Tracosa mucky clay (Tm), and the Tracosa mucky clay-clay, low complex (Tx). Approximately 15 percent of the field survey sites are located within the Tidal Flat Range Site. The predominant wetland communities (as defined and mapped by White and others, 1985) are proximal salt-water marshes, which represent about 70 percent of the field survey sites located in the Tidal Flat Range Site. The predominant vegetation is *Spartina alterniflora;* other species may include *Batis maritima, Distichlis spicata, Salicornia* spp., *Scirpus maritimus,* and *Juncus roemerianus.*

(3) The **Salt Flat Range Site** occurs in nearly level coastal marshes with elevations slightly above to about 1 m (3 ft) above mean sea level. Soils of this range site are strongly saline Mustang fine sand (Ms) and very strongly saline Veston loam (Vx). Sixteen survey sites were located within these soils, or slightly more than 10 percent of all sites surveyed. Wetland communities represented on the Salt Flat Range site are predominantly salt-water marshes, but some include transitional areas and mixtures of marshes and sand flats. Vegetation includes *Batis maritima, Monanthochloe littoralis, Salicornia* spp., *Borrichia frutescens, Distichlis spicata, Limonium nashii, Lycium carolinianum* and others.

(4) The **Low Coastal Range Site** consists of level to gently sloping coastal sands that roughly parallel the Gulf shoreline; elevations are less than 3 m (10 ft) above mean sea level. Soils in this range site are the Galveston soil in the Galveston-Nass complex (Gc) and Nass-Galveston complex (Nx), and Mustang soils in Mustang fine sand (Mn), Mustang-Nass complex (Mt), and Mustang fine sand, slightly saline (Ms). The Galveston and Mustang soils are at elevations generally too high for marsh development, and therefore, correspond most frequently to uplands (U) and possibly transitional areas. Wetlands occur in the Nass soils of the Gc and Nx complexes (see Coastal Swale Range Site).

(5) The **Coastal Swale Range Site** occurs in swales between beach ridges and in shallow depressions on nearly level coastal flats. Soils in this range site are principally in the Nass soil of the Galveston-Nass complex (Gc), the Mustang-Nass complex (Mt), and the Nass-Galveston complex, shell substratum (Nx). Vegetation communities were surveyed at nine sites corresponding to soils in the Coastal Swale Range Site. The areas surveyed were mostly located on Galveston Island, much of which is characterized by relict beach ridge and swale topography. Vegetation communities are predominantly defined by brackish- and salt-water marshes, both low and high marshes (White and others, 1985). Vegetation includes *Spartina patens, Distichlis spicata, Paspalum vaginatum, Paspalum monostachyum, Monanthochloe littoralis, Spartina spartinae, Juncus roemerianus, Salicornia* spp., and *Borrichia frutescens.*

(6) The **Deep Marsh Range Site** commonly corresponds with marshes near bays and bayous where tidal-water salinities are lower because of saltwater and freshwater mixing. Elevations range from mean sea level to 0.3 m (1 ft) above. Soils include the Caplen mucky silty clay loam (Ca), and the Caplen soil in the Caplen-Tracosa complex (Ct). Dominant vegetation is *Spartina patens* and *Distichlis spicata. Spartina cynosuroides* has been a dominant species on this range site in the past, but has been replaced principally by *Spartina patens* (Crenwelge and others, 1988). Depending on water depth and salinities, *Sagittaria* and bulrushes may also occur in this marsh range site. Only two survey sites (high, or distal, salt-water marshes) occur within this range site.

(7) The **Salty Prairie Range Site** occurs on broad, relatively level coastal flats and marshes, where elevations range from 0.6 to 2.4 m (2 to 8 ft) above mean sea level. Among the soils characterizing this range site is the Ijam soil in the Ijam clay, 0- to 2-percent slopes (ImA), and 2- to 8-percent slopes (ImB), Narta fine sandy loam (Na), Sievers loam (SeB), and slightly saline Veston loam (Vx). Most of the survey sites in this range site correspond to the Ijam soils, which might be considered a disturbed soil complex. Ijam soils are formed in saline, clayey, marine,

and alluvial sediment deposits that were dredged to construct and maintain canals or waterways. Plant communities on these soils vary widely because of the variations in salinities and elevations that characterize this range site. Plant communities may include brackish- and salt-water marshes, flats, transitional areas, and uplands. The dominant vegetation in many topographically higher areas is *Spartina spartinae*. Other species may include *Borrichia frutescens*, *Panicum virgatum*, *Spartina patens*, *Phragmites australis*, and *Setaria geniculata*.

(8) The **Coastal Sand Range Site** is composed of nearly level to undulating coastal ridges that parallel the Gulf shoreline. Elevations, which are as much as 3.7 m (12 ft) above mean sea level, preclude marsh development on this range site.

Examples of Wetland Profiles Developed from Topographic Survey Transects

Topographic surveys of marsh communities were conducted at selected sites around the Galveston Bay system. These data are presented in appendix C. Descriptions of the zonation of plant species along two transects are presented here.

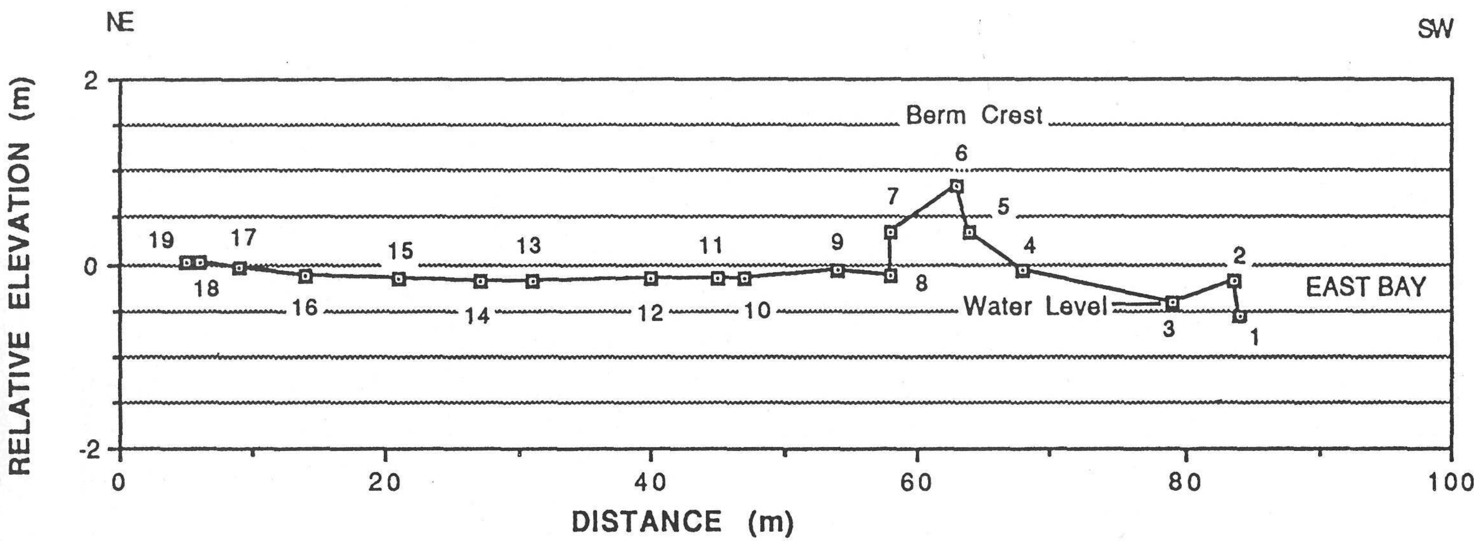
Smith Point Transect

The elevation survey of the Smith Point marsh is shown in figure 21. The transect has a bearing of south 45 degrees west (S45°W) and is approximately 85 m (~279 ft) long. The southwest end of the transect intersects the shoreline of East Galveston Bay. The total range in elevation of the transect is approximately 1.5 m (~5 ft), which is the vertical distance from station 1 (just below the water line) to station 6, the crest of the shell berm. Marsh plants, which are absent on the shell berm, have a much lower range in elevation, about 45 cm (~1.5 ft) (fig. 21). This salt marsh community, which is classified as an estuarine intertidal emergent community (E2EM) as defined by Cowardin, and others (1979), is made up of about eight different species. *Spartina alterniflora* (smooth cordgrass), as expected, occurs at the lowest elevation (water line), and a community composed of *Spartina spartinae* (gulf cordgrass or sacahuista), *Spartina patens* (marshhay cordgrass), *Iva frutescens* (big-leaf sumpweed or marshelder), and *Borrichia frutescens* (sea oxeye) occurs at the highest elevation (stations 18–19, fig. 21). The profile exemplifies how small changes in elevation along the microtidal Texas coast can affect plant distribution. Occurring at elevations between the water line and the highest marsh plants on the profile are several species (fig. 21) including, at lower elevations, *Scirpus maritimus* (saltmarsh bulrush) and *Juncus roemerianus* (needlegrass rush); at slightly higher elevations *Distichlis spicata* (seashore saltgrass) occurs. *Spartina patens* and *Borrichia* also occur at intermediate elevations, but are still higher than *Spartina alterniflora*, *Scirpus*, *Juncus*, and *Distichlis*. The range in elevation for *Spartina alterniflora* is about 25 cm (~0.8 ft) along this transect, so it occurs mixed with other species locally.

A close look at the profile (fig. 21) shows that very small changes in elevation can apparently increase the regularity of flooding and enable species like *Spartina alterniflora* to become established. Stations 10 and 14 have *Spartina alterniflora* mixed with *Distichlis*. At slightly higher elevations toward station 12, only *Distichlis* is present.

This particular survey shows that, in general, the species occurring at lowest (and therefore most frequently flooded) elevations are *Spartina alterniflora*, *Scirpus maritimus*, and *Juncus roemerianus*, with *Distichlis* mixing with these species locally. Occurring at higher elevations are *Spartina patens*, *Borrichia*, *Spartina spartinae*, and *Iva frutescens*.

Wetland indicator plant species designations in *The National List of Plant Species that Occur in Wetlands: 1988 Texas*, by P. B. Reed, U.S. Fish and Wildlife Service, were used as a guide to help delineate species associations in some areas. Species identified along the Smith Point profile are



1	Base of erosional scarp
2 to 3	*Spartina alterniflora*
3 to 4	Erosional clay ramp
4 to 8	Shell berm
8 to 9	*Juncus roemerianus*
9 to 10	*Spartina patens*
10 to 11	*Spartina alterniflora-Distichlis spicata*
11 to 13	*Distichlis spicata*
13 to 15	*Spartina alterniflora-Distichlis spicata*
15 to 16	*Scirpus maritimus-S. alterniflora-Distichlis*
16 to 17	*Distichlis-S. alterniflora-Scirpus-Borrichia frutescens*
17 to 18	*Spartina spartinae*
18 to 19	*S. spartinae-Spartina patens-Iva frutescens-Borrichia*

Figure 21. Profile of salt marsh at Smith Point showing relative elevations of plant communities. Site No. 20-1.

all wetland species, but *Spartina alterniflora*, *Scirpus maritimus*, and *Juncus roemerianus* are classified as obligate (OBL) wetland plants, which means that under natural conditions they have an estimated probability of occurring in wetlands more than 99 percent of the time. The other species listed above (i.e., those occurring at slightly higher and drier elevations) are facultative wetland (FACW) plants, which means that they usually occur in wetlands (estimated probability of 67 to 99 percent), but occasionally are found in nonwetlands. As expected, the elevation measurements properly defined the species that can tolerate wetter conditions, and are therefore more frequently found in wetlands.

Brazoria National Wildlife Refuge Transect

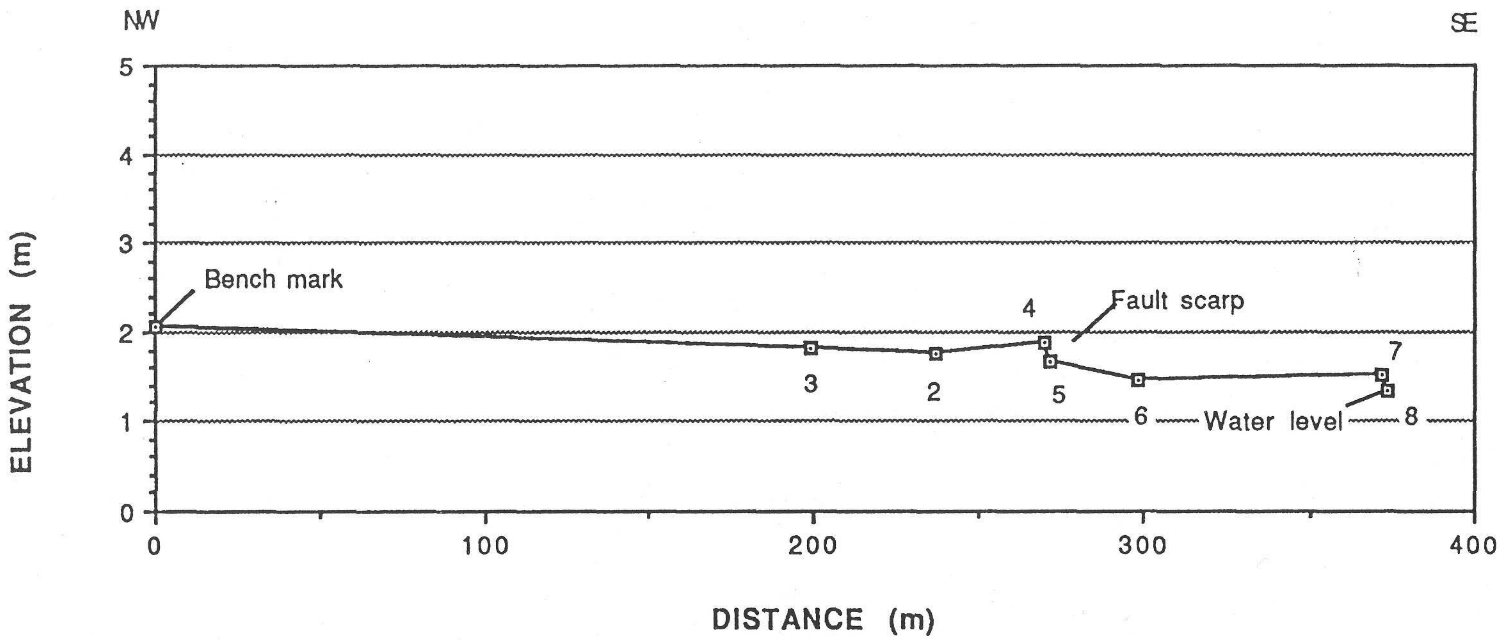
A second salt marsh transect along which elevations, distances, and bearings were measured was located in the Brazoria National Wildlife Refuge (fig. 22). The transect, which is approximately 375 m (1,230 ft) long, is oriented roughly perpendicular to the hydrologic gradient and was tied to a USGS bench mark with an elevation of 2.2 m (6.6 ft) at the northwest end of the transect. Lower elevations occur on the downthrown side of a fault (White and others, 1985; see following section on faulting and subsidence) located at stations 4 and 5 on the profile (fig. 22). The difference in elevations on each side of the fault line produces a dramatic effect in the vegetation communities. Between the bench mark and station 4 at the edge of the fault (this segment of the transect marks the upthrown side of the fault) the plant community is dominated by *Spartina spartinae*, with scattered species including *Setaria geniculata* (knotroot bristlegrass), *Iva annua* (seacoast sumpweed), and *Aster* sp. Additional species reported in this area in the Brazoria County Soil Survey include *Nothoscordum bivalve* (false garlic) and *Sabatia campestris* (prairie rose-gentian). The dominant species *Spartina spartinae* is classified as a faculative wetland (FACW), but other species, except for *Aster* (OBL), are found much less frequently in wetlands. *Iva annua* and *Setaria* are classified as facultative (FAC), and are, therefore, equally likely to occur in nonwetlands as wetlands. *Sabatia* and *Nothoscordum* are classified as facultative upland species (FACU), which means the probability of their occurring in a wetland is only 1 to 33 percent.

On the downthrown side of the fault a definite wetland community occurs. The drop in elevation from the top of the fault scarp to the wetland community is more than 30 cm (>1 ft). Plant species between stations 5 and 6 (fig. 22) on the profile are composed of patches of *Monanthochloe*, *Salicornia*, and *Batis*, occurring within a sand/mud flat that is capped by an algal mat. At lower elevations, between stations 6 and 7, *Distichlis* composes about 90 percent of the community, with scattered *Salicornia* making up the remaining 10 percent. All of the species on the downthrown side of the fault, where wetter conditions characterize the lower elevations, are obligate wetland plants.

Distribution of Wetland and Aquatic Habitats (1989)

In the late 1980's, wetland and aquatic habitats covered an area of about 570,000 acres (excluding the marine open-water class) within the 30 7.5-minute quadrangles that define the Galveston Bay project area (fig. 2). This constitutes 53 percent of the total map area. Of the five wetland systems mapped (fig. 3; table 5), the estuarine system encompasses about 507,500 acres and represents approximately 48 percent of the total map area. The palustrine system is second at 3 percent (34,100 acres), followed by the lacustrine (2 percent), riverine (0.2 percent), and marine (0.2 percent, excluding open water) (table 5). Upland areas (nearly 497,000 acres) represent the remaining 47 percent of the total mapped area.

Vegetated wetlands (E2EM, E2SS, PEM, PFO, and PSS areas; excluding AB areas) cover about 138,600 acres, or 25 percent of the wetland and deep-water habitat system (again excluding the marine open water or M1UB class). The marsh system (E2EM, E2EM/US, E2US/EM, and PEM) (fig. 23) covers approximately 130,400 acres, representing about 94 percent of the total



PLANT COMMUNITIES AND GEOMORPHIC FEATURES ALONG PROFILE

BM to 2	*Spartina spartinae (80%), Setaria geniculata, Aster sp., Iva annua, others (20%)*
2 to 4	*Spartina spartinae (90%)*
4 to 5	Fault Scarp
5 to 6	Mixed flat and emergent vegetation *Monanthochloe-Salicornia-Batis*
6 to 7	*Distichlis spicata (90%), Salicornia sp. (10%)*

Figure 22. Profile of brackish marsh in the Brazoria National Wildlife Refuge showing relative elevations of plant communities. Site No. 3-1.

Table 5. Areal extent of mapped wetland and upland habitats in 1989.

NWI CODE	National Wetlands Inventory Description	ACRES
E2EM	Estuarine Intertidal Emergent Vegetation	103,533
E2EM/US	Estuarine Intertidal Emergent Vegetation/Unconsolidated Shore	2,905
E2US/EM	Estuarine Intertidal Unconsolidated Shore/Emergent Vegetation	1,723
E2SS	Estuarine Intertidal Scrub/Shrub Wetland	551
E1AB	Estuarine Subtidal Aquatic Bed	1,688
E2AB	Estuarine Intertidal Aquatic Bed	1,084
E1UB	Estuarine Subtidal Unconsolidated Bottom	378,202
E2US	Estuarine Intertidal Unconsolidated Shore	17,773
PEM	Palustine Emergent Vegetation	22,211
PSS	Palustrine Scrub/Shrub Wetland	2,014
PFO	Palustrine Forested Wetland	5,648
PAB	Palustrine Aquatic Bed	85
PUB	Palustrine Unconsolidated Bottom	3,580
PUS	Palustrine Unconsolidated Shore	577
L1AB	Lacustrine Limnetic Aquatic Bed	309
L2AB	Lacustrine Littoral Aquatic Bed	1,403
L1UB	Lacustrine Limnetic Unconsolidated Bottom	8,899
L2UB	Lacustrine Littoral Unconsolidated Bottom	6,287
L2US	Lacustrine Limnetic Unconsolidated Shore	4,674
R1UB	Riverine Tidal Unconsolidated Bottom	2,754
R2UB	Riverine Lower Perennial Unconsolidated Bottom	241
R1US	Riverine Tidal Unconsolidated Shore	14
M1UB	Marine Subtidal Unconsolidated Bottom	219,522
M2US	Marine Intertidal Unconsolidated Shore	1,955
M2AB	Marine Intertidal Aquatic Bed	376
UA	Upland Agriculture	131,024
UB	Upland Barren	1,925
UF	Upland Forested	45,516
UR	Upland Range	146,990
USS	Upland Scrub/Shrub	48,525
UU	Upland Urban	124,895

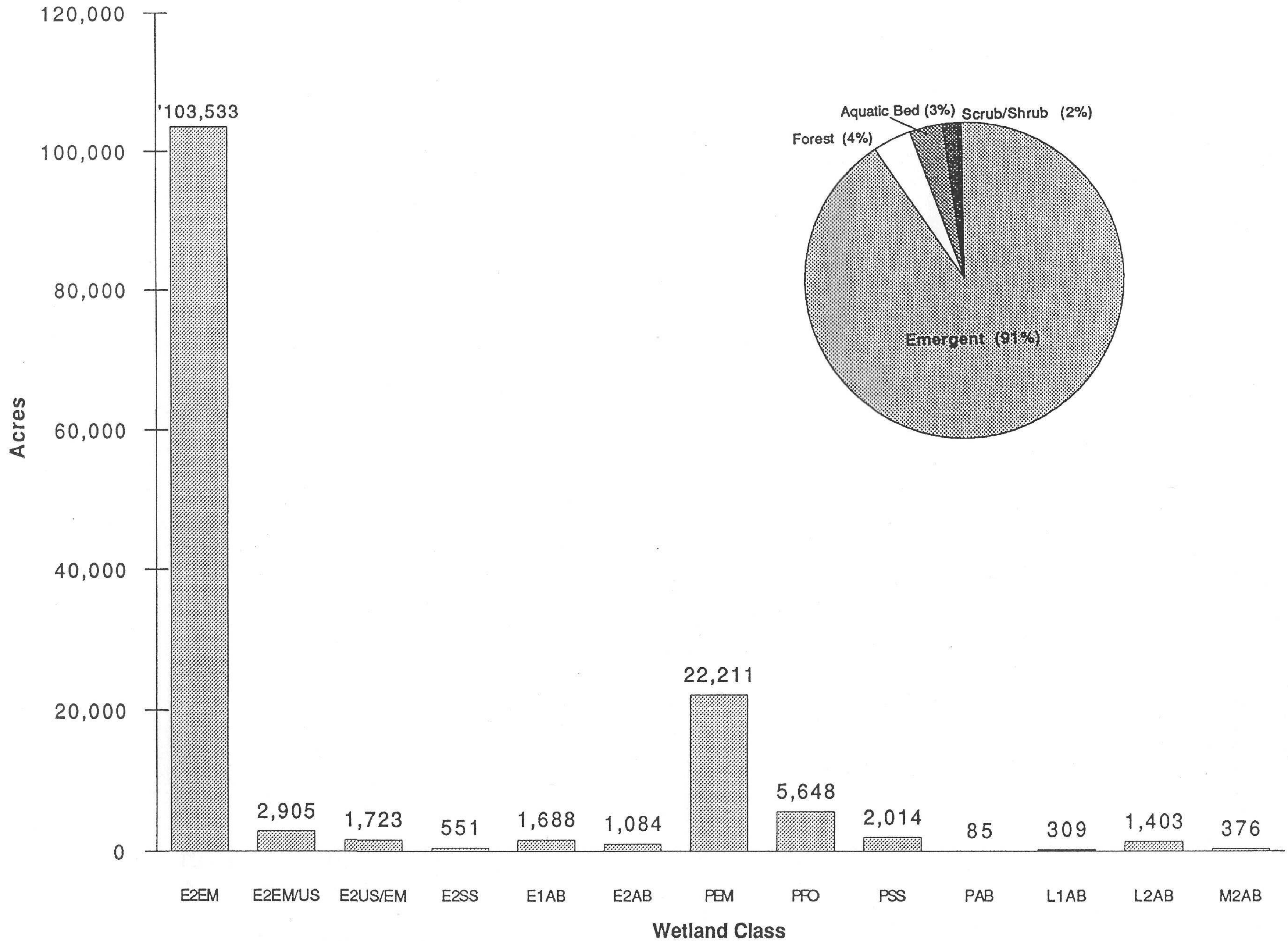


Figure 23. Bar graph showing total areal extent of vegetated wetland classes in 1989 in the Galveston Bay system. Refer to table 5 for wetland class descriptions.

vegetated wetlands. Estuarine open water and intertidal flats constitute almost 70 percent (~396,000 acres) of the total area of wetland and deep-water habitats (570,000). The extent (in acres) of all mapped wetlands, deep-water habitats, and uplands for each of the 30 quads are presented in appendix D.

Estuarine System

Estuarine Intertidal Emergent Wetlands

The estuarine intertidal emergent wetland habitat (E2EM, E2EM/US, and E2US/EM) (marsh) is the most extensive wetland habitat in the Galveston Bay system (fig. 23; table 5). It consists of about 108,200 acres of salt and brackish marshes, which make up approximately 75 percent of the vegetated wetland habitats (including aquatic beds), and 83 percent of the marsh habitats (emergent wetlands) in the Galveston Bay system. The general distribution of estuarine emergent wetlands can be determined by comparing figure 24, which shows estuarine and palustrine emergent wetlands with figure 25, which shows only the palustrine system.

Extensive estuarine emergent wetlands occur around East and West Bays and at the head of Trinity Bay in the Trinity River delta (fig. 24). These areas are prominently defined by 12 quads where salt and brackish marshes cover broad areas (fig. 26). The High Island quad is the site of the most extensive marsh system; it contains more than 20,000 acres of estuarine emergent wetlands, consisting almost totally of brackish marshes (fig. 27). These brackish marshes continue westward into the adjacent quads of Frozen Point and Lake Stephenson. Together, marshes in these three quads situated along East Bay represent the most extensive marsh habitat system in the Galveston Bay study area. More than 45,000 acres of estuarine emergent wetlands were mapped in these three quads on the 1989 photographs. The Anahuac National Wildlife Refuge encompasses a portion of this extensive emergent wetland system.

Other quads containing more than 5,000 acres of estuarine emergent wetlands are located at the southwest end of West Bay and include Christmas Point (11,400 acres), Sea Isle (7,900 acres), Oyster Creek (6,700), Hoskins Mound (7,000 acres), and Virginia Point (5,600 acres) (fig. 27). Six additional quads contain at least 1,000 acres of estuarine emergent wetlands. Estuarine emergent wetlands consisting primarily of salt marshes characterize the bayward sides of the barriers—Bolivar Peninsula, Galveston Island, and Follets Island (figs. 6 and 24). The Trinity River delta is the site of relatively extensive brackish marshes that grade into fresh marshes northward up the river valley.

Estuarine Intertidal Unconsolidated Shores

Estuarine intertidal unconsolidated shores (E2US) include intertidal flats and beaches. Approximately 17,800 acres of E2US were mapped in the Galveston Bay system (table 5). This habitat represents about 9 percent of the wetland system (excluding subtidal habitats, the E1 and M1 map units). Because of extremely low tides during the time the 1989 aerial photographs were taken, this habitat includes many areas that are normally submerged. Map units were not corrected for the low tides, and therefore the extent of the intertidal flats mapped on 1989 photographs is an overestimate. These exposed areas were mapped using an "M" water-regime modifier (E2USM), which is used to define areas that are irregularly exposed (table 2). This water regime was rarely used on the 1979 aerial photographs because of high tides.

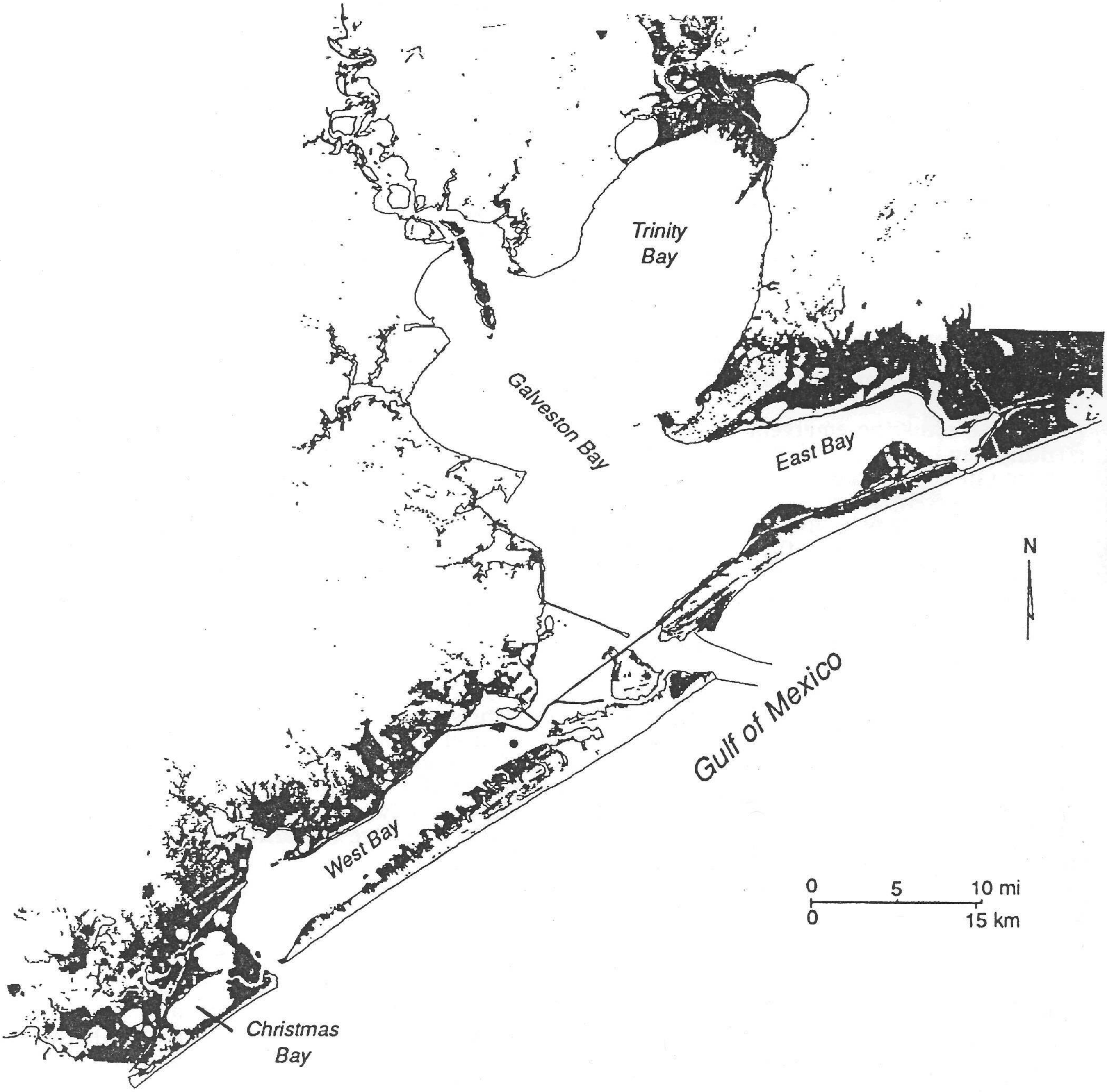


Figure 24. Distribution in 1989 of estuarine (E2EM, E2EM/US, and E2US/EM) and palustrine (PEM) emergent wetlands (marshes) in the Galveston Bay system. Compare with figure 25 to determine palustrine areas.

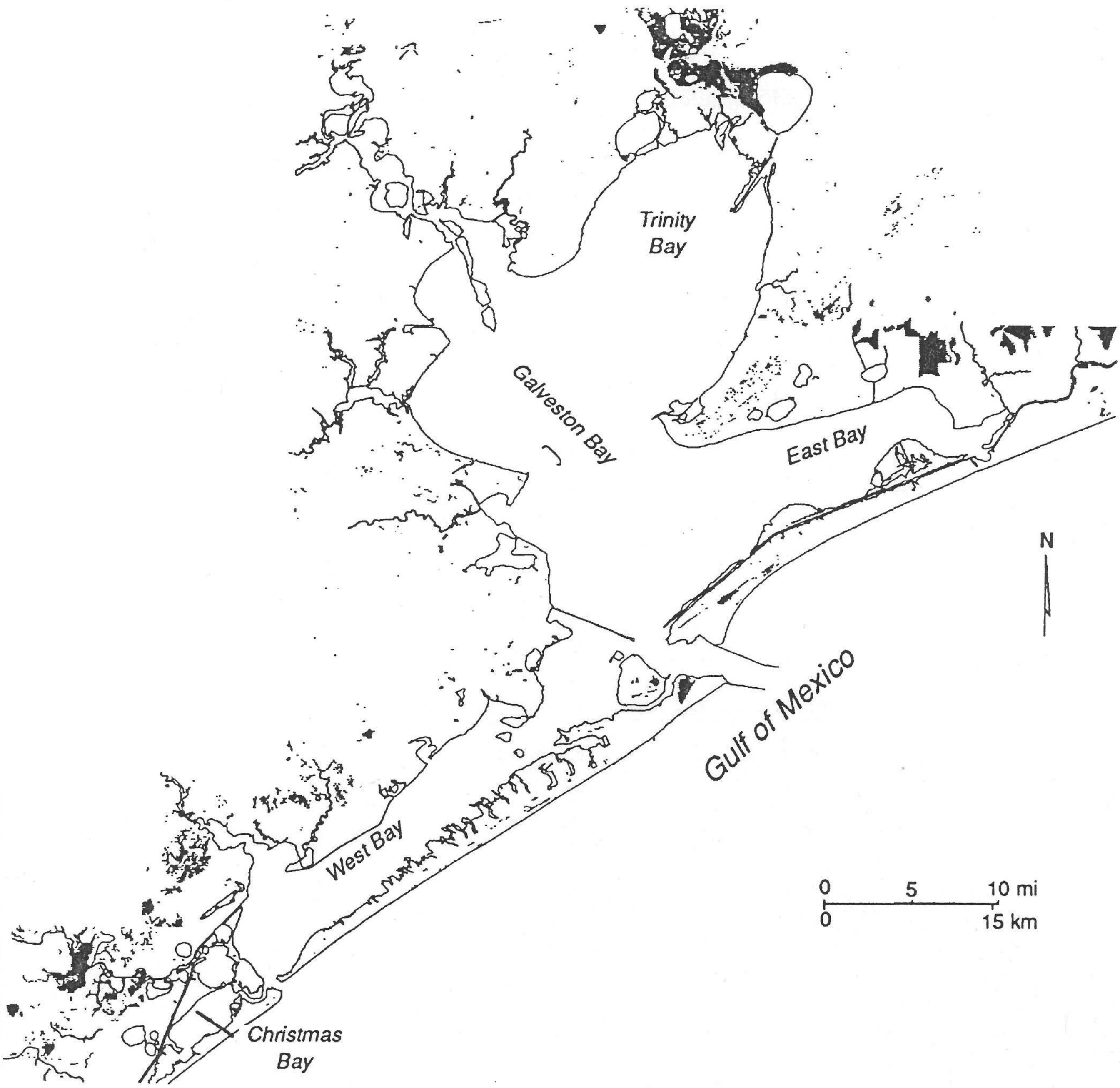


Figure 25. Distribution in 1989 of palustrine emergent wetlands (PEM) (fresh, or inland, marshes) in the Galveston Bay system.

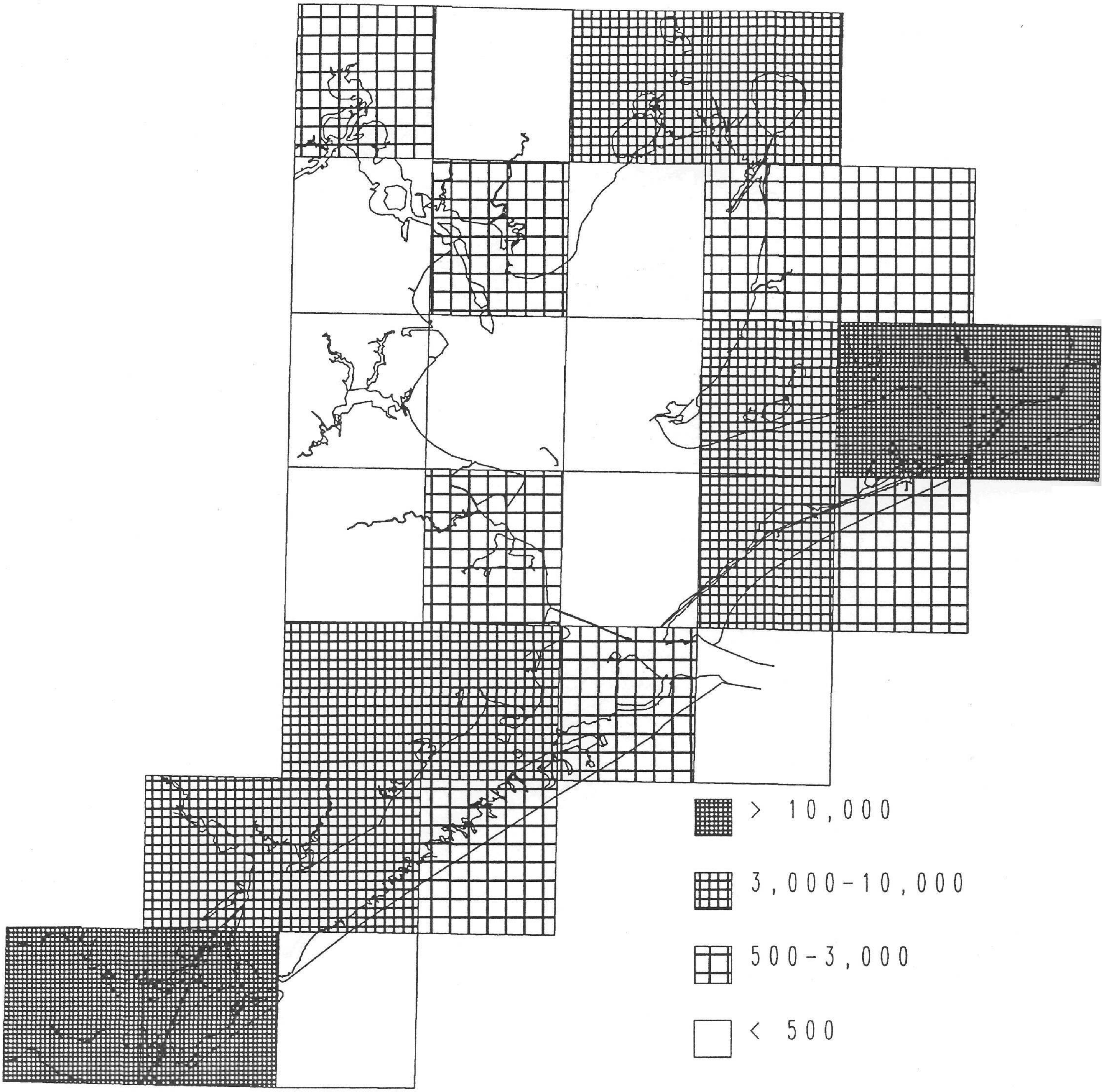


Figure 26. Map of 7.5-minute quads showing the distribution and extent (acres) of emergent wetlands (marshes) in 1989.

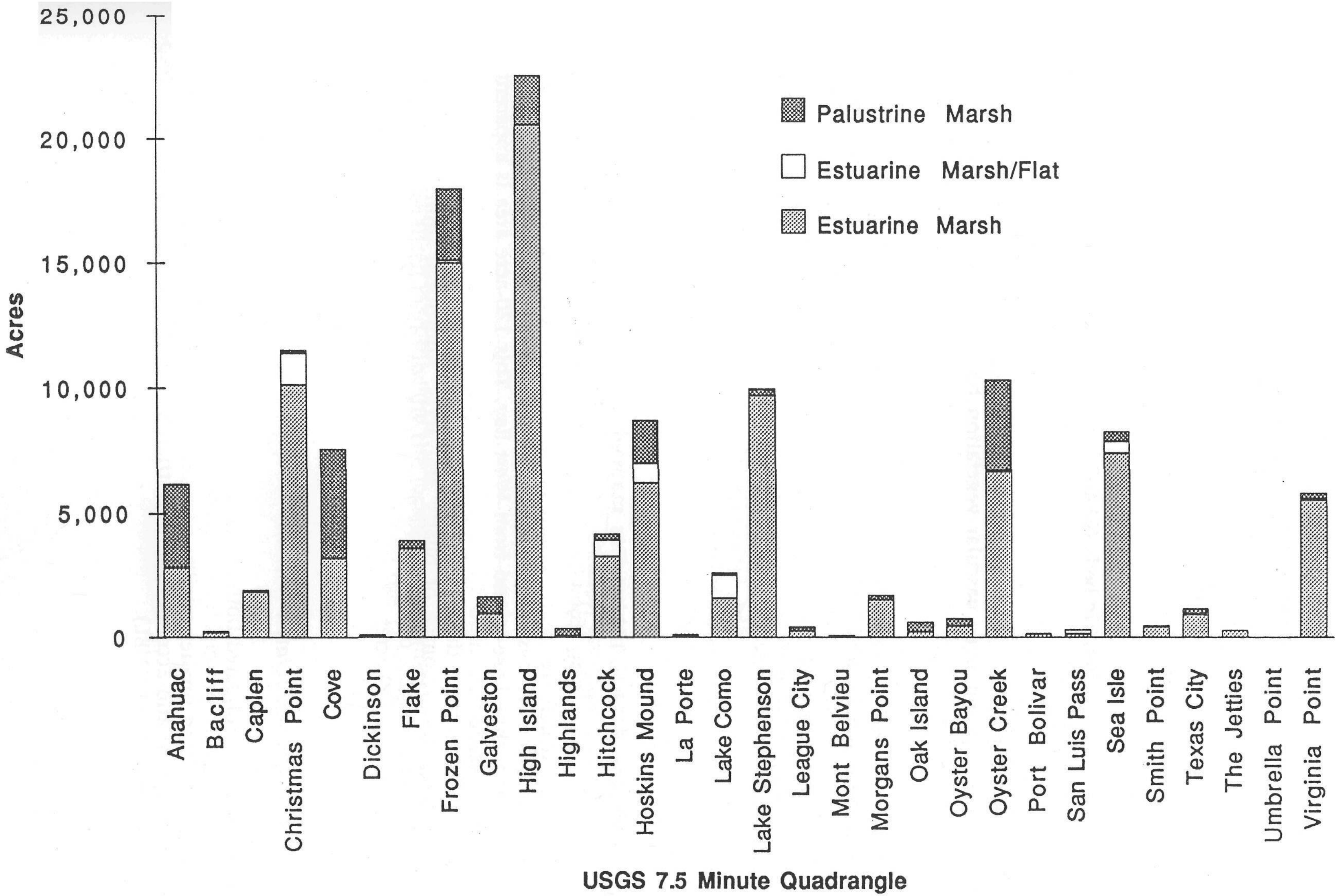


Figure 27. Bar graph of 7.5-minute quads showing the extent (acres) of emergent wetlands in 1989.

Estuarine Intertidal Scrub-Shrub Wetlands

The total area of mapped estuarine scrub-shrub wetlands (E2SS) on the 1989 data base is approximately 550 acres (fig. 23). This habitat was mapped in 21 of the 30 quads. The Virginia Point and Morgans Point quads have the largest amount of estuarine scrub-shrub, each with about 100 acres. Other quads, individually, contain fewer than 50 acres.

Estuarine Aquatic Beds

Estuarine subtidal rooted vascular aquatic beds (E1AB3L) represent areas of submerged vascular vegetation including marine grasses. Covering a total area of approximately 700 acres in the Galveston Bay project area in 1989, 386 acres were mapped in Christmas Bay, Christmas Point quad, where the largest distribution occurs. Other important areas include upper Trinity Bay along its eastern shore (Oak Island quad) and along the margins of the Trinity River delta (Anahuac and Cove quads). Submerged vascular vegetation has been previously reported and mapped in these areas (Benton and others, 1979; White and others, 1985; Pulich and others, 1991) (figs. 28 and 29).

In upper Trinity Bay along the margins of the Trinity River delta, submerged aquatics include such species as *Vallisneria* and *Ruppia* (Pulich and others, 1991). Because of the seasonal die-back in this area, coupled with the low tides occurring at the time of the November 1989 photo mission, the mapped aquatic beds do not reflect their true extent in the delta area. A general, simplified illustration showing areas in which aquatic beds have been known to occur along the margins of the delta is shown in figure 29.

Narrow bands (totaling 35 acres) mapped as unknown submerged aquatic beds (E1AB5L) along the eastern margins of Trinity Bay in the Lake Stephenson quad are also possibly rooted vascular plants (*Ruppia maritima*).

Other quads in which the E1AB3L habitat was mapped include Hoskins Mound, along the margins of Chocolate Bayou. Two areas (totaling 125 acres) on either side of the bayou show a dark, characteristic reflectance on the 1989 aerial photographs, but they were misidentified as aquatic beds. These areas, which are clearly visible on the aerial photographs as a result of the extremely low tides, are extensive oyster beds. Another area mapped as aquatic beds occurs in the Sea Isle quad in Carancahua Lake inland from West Bay. This 120-acre area is apparently a shallow subaqueous organic-rich mud flat that has a photographic signature similar to submerged vegetation. Subtracting these two areas from the mapped bay total of 950 acres yields a submerged vegetation resource of nearly 700 acres. Additional unmapped areas in upper Trinity Bay along the margins of the Tinity River delta (fig. 29) suggest that the resource could be somewhat larger than 700 acres.

Estuarine Subtidal Unconsolidated Bottom

The estuarine subtidal unconsolidated bottom (open-water) habitat (E1UBL) is the heart of the estuarine system and consists principally of Galveston, Trinity, East, West, Christmas, and Chocolate Bays, and associated smaller satellite bays and tidal lakes (fig. 1). This habitat covers about 378,200 acres (table 5) and accounts for more than 65 percent of the wetland and deep-water habitat system (excluding M1UBL).

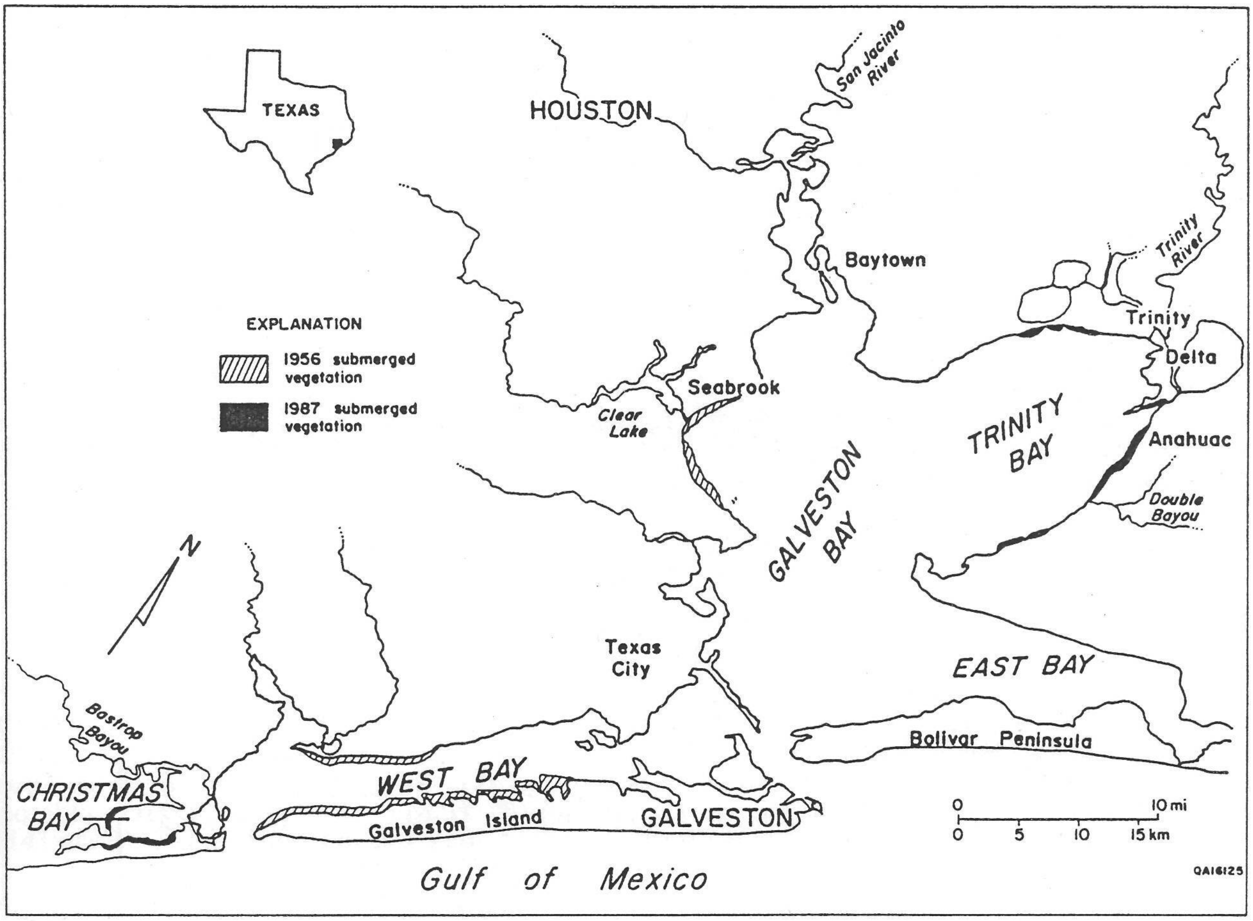


Figure 28. Generalized map showing the locations of submerged vegetation in 1956 and 1987 in the Galveston Bay system, excluding areas along the Trinity River delta. The 1956 distribution of submerged vegetation in Trinity and Christmas Bays is not shown. Modified from Pulich and White (1991).

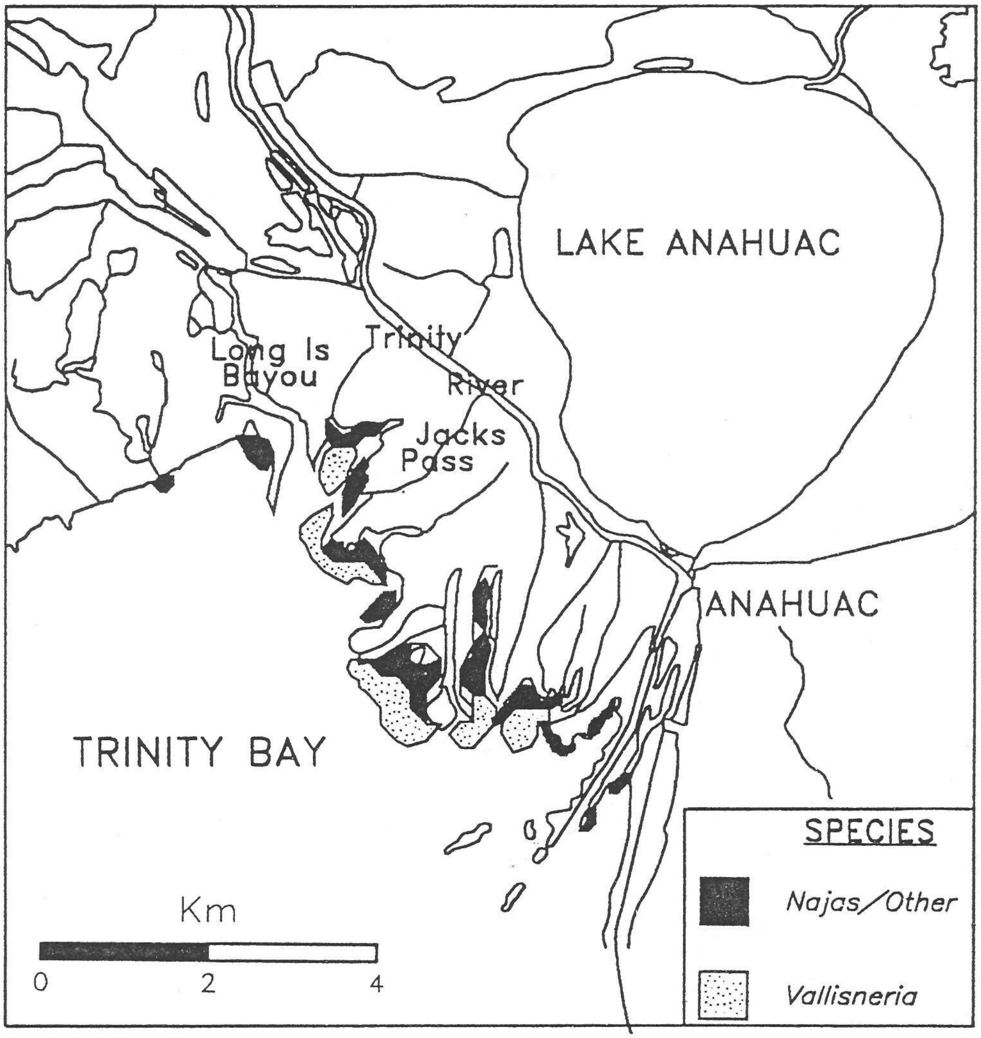


Figure 29. Generalized map showing the approximate locations of submerged vegetation along the margins of the Trinity River delta. From Pulich and others (1991).

Palustrine System

Palustrine Emergent Wetlands

Palustrine emergent wetlands (PEM), or "inland," "fresh-water" marshes, cover more than 22,000 acres (figs. 23 and 25), and represent approximately 16 percent of the vegetated wetland system (including aquatic beds), and 17 percent of the marsh (emergent wetland) system. The widest distribution of this habitat occurs in inland areas along the Trinity River alluvial valley in the Anahuac and Cove quads, inland of Christmas Bay and West Bay (Oyster Creek and Hoskins Mound quads), and inland of East Bay (Frozen Point and High Island quads) (figs. 2 and 25). Cove, Oyster Creek, and Anahuac have the largest areas of palustrine emergent wetlands, accounting for about 4,380, 3,600, and 3,360 acres, respectively (fig. 27). Frozen Point has almost 3,000 acres, and Hoskins Mound and High Island each contain more than 1,000 acres (fig. 27).

Palustrine Scrub-Shrub Wetlands

Palustrine scrub-shrub wetlands (PSS) total about 2,000 acres (fig. 23) (slightly >1 percent of vegetated wetlands); much of this acreage occurs in the Highlands (422 acres) and Dickinson quads (300 acres). All other quads each contain less than 140 acres of scrub-shrub wetlands. Most areas of scrub-shrub occur along rivers, bayous, and creeks, on the margins of reservoirs, and in relatively small depressions.

Palustrine Forested Wetlands

The total area of forested wetland habitat amounts to 5,648 acres (fig. 23), or about 4 percent of the vegetated wetland system (including aquatic beds). Forested wetlands (PFO) are most abundant in the Trinity River floodplain, defined by the Anahuac and Cove quads; these quads contain about 2,320 and 1,890 acres of forested wetlands, respectively. Other quads with notable acreages of PFO are Oyster Creek (675 acres), Highlands (441 acres), and Hitchcock (141 acres). The distribution of forested wetlands in other quads range from 55 to 0 acres.

TRENDS IN WETLAND HABITATS

Methods Used to Analyze Trends

Trends in wetland habitats were determined by analyzing habitat distribution as mapped on 1950's (fig. 30), 1979 (fig. 31), and 1987–1989 (fig. 24) aerial photographs. Most of the analyses focused on changes that occurred between the 1950's and late 1980's, the longest period of record. 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. The 1979 photographs were taken during a period of high tides and the 1989 photographs during a period of low tides.