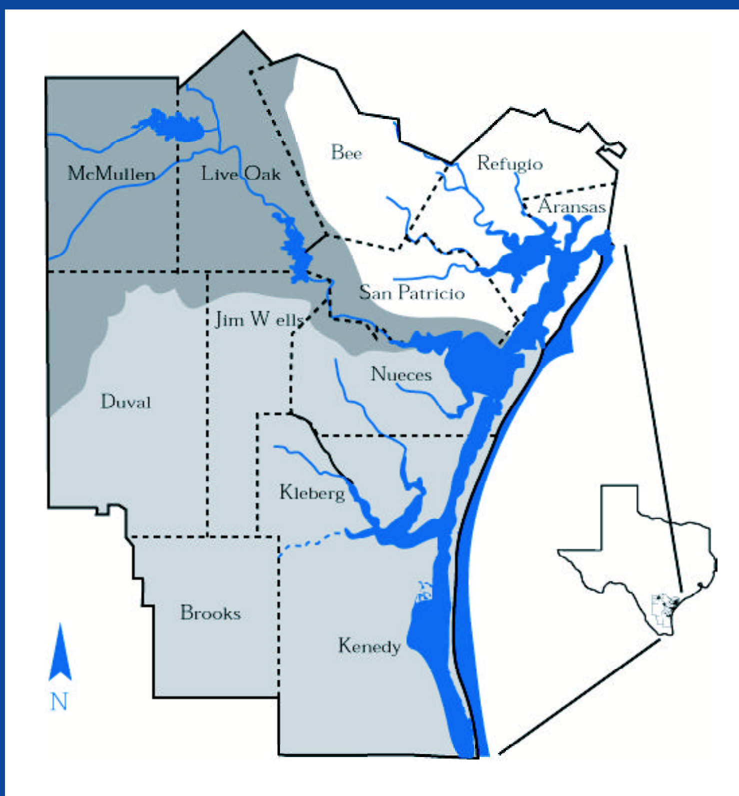
Current Status and Historical Trends of Selected Estuarine and Coastal Habitats in the Corpus Christi Bay National Estuary Program Study Area



Corpus Christi Bay National Estuary Program
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CURRENT STATUS AND HISTORICAL TRENDS OF SELECTED ESTUARINE AND COASTAL HABITATS IN THE CORPUS CHRISTI BAY NATIONAL ESTUARY PROGRAM STUDY AREA

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CORPUS CHRISTI BAY NATIONAL ESTUARY PROGRAM

The Corpus Christi Bay National Estuary Program (CCBNEP) is a four-year, community based effort to identify the problems facing the bays and estuaries of the Coastal Bend, and to develop a long-range, Comprehensive Conservation and Management Plan. The Program's fundamental purpose is to protect, restore, or enhance the quality of water, sediments, and living resources found within the 600 square mile estuarine portion of the study area.

The Coastal Bend bay system is one of 28 estuaries that have been designated as an **Estuary of National Significance** under a program established by the United States Congress through the Water Quality Act of 1987. This bay system was so designated in 1992 because of its benefits to Texas and the nation. For example:

- Corpus Christi Bay is the gateway to the nation's sixth largest port, and home to the third largest refinery and petrochemical complex. The Port generates over $1 billion of revenue for related businesses, more than $60 million in state and local taxes, and more than 31,000 jobs for Coastal Bend residents.
- The bays and estuaries are famous for their recreational and commercial fisheries production. A study by Texas Agricultural Experiment Station in 1987 found that these industries, along with other recreational activities, contributed nearly $760 million to the local economy, with a statewide impact of $1.3 billion, that year.
- Of the approximately 100 estuaries around the nation, the Coastal Bend ranks fourth in agricultural acreage. Row crops -- cotton, sorghum, and corn -- and livestock generated $480 million in 1994 with a statewide economic impact of $1.6 billion.
- There are over 2600 documented species of plants and animals in the Coastal Bend, including several species that are classified as endangered or threatened. Over 400 bird species live in or pass through the region every year, making the Coastal Bend one of the premier bird watching spots in the world.

The CCBNEP is gathering new and historical data to understand environmental status and trends in the bay ecosystem, determine sources of pollution, causes of habitat declines and risks to human health, and to identify specific management actions to be implemented over the course of several years. The 'priority issues' under investigation include:

- altered freshwater inflow
- declines in living resources
- loss of wetlands and other habitats
- bay debris
- degradation of water quality
- altered estuarine circulation
- selected public health issues

The **COASTAL BEND BAYS PLAN** that will result from these efforts will be the beginning of a well-coordinated and goal-directed future for this regional resource.

STUDY AREA DESCRIPTION

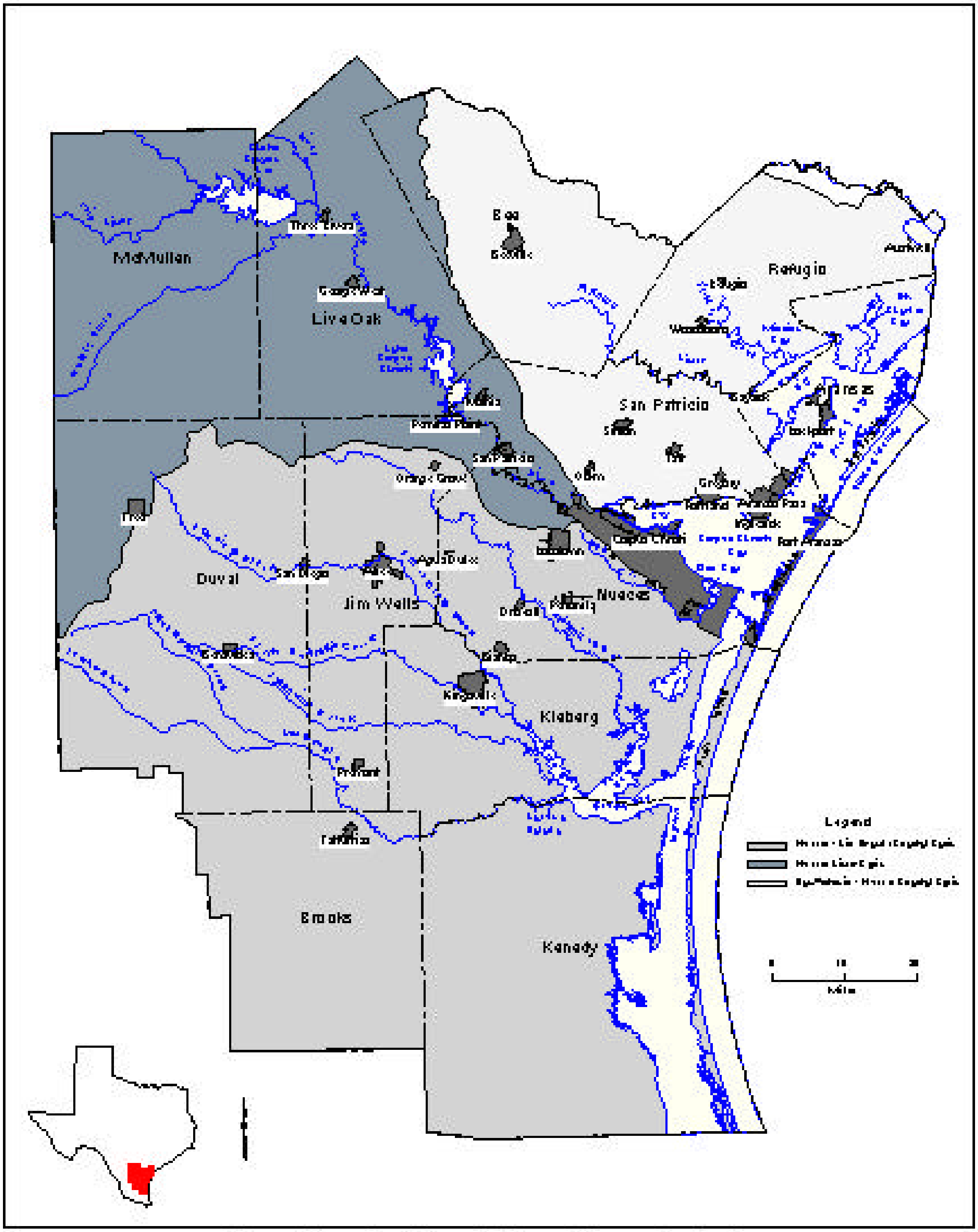
The CCBNEP study area includes three of the seven major estuary systems of the Texas Gulf Coast. These estuaries, the Aransas, Corpus Christi, and Upper Laguna Madre are shallow and biologically productive. Although connected, the estuaries are biogeographically distinct and increase in salinity from north to south. The Laguna Madre is unusual in being only one of three hypersaline lagoon systems in the world. The study area is bounded on its eastern edge by a series of barrier islands, including the world's longest -- Padre Island.

Recognizing that successful management of coastal waters requires an ecosystems approach and careful consideration of all sources of pollutants, the CCBNEP study area includes the 12 counties of the Coastal Bend: Refugio, Aransas, Nueces, San Patricio, Kleberg, Kenedy, Bee, Live Oak, McMullen, Duval, Jim Wells, and Brooks.

This region is part of the Gulf Coast and South Texas Plain, which are characterized by gently sloping plains. Soils are generally clay to sandy loams. There are three major rivers (Aransas, Mission, and Nueces), few natural lakes, and two reservoirs (Lake Corpus Christi and Choke Canyon Reservoir) in the region. The natural vegetation is a mixture of coastal prairie and mesquite chaparral savanna. Land use is largely devoted to rangeland (61%), with cropland and pastureland (27%) and other mixed uses (12%).

The region is semi-arid with a subtropical climate (average annual rainfall varies from 25 to 38 inches, and is highly variable from year to year). Summers are hot and humid, while winters are generally mild with occasional freezes. Hurricanes and tropical storms periodically affect the region.

On the following page is a regional map showing the three bay systems that comprise the CCBNEP study area.



Corpus Christi Bay National Estuary Program Study Area

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LIST OF ACRONYMS

CCBNEP	Corpus Christi Bay National Estuary Program
CCMP	Comprehensive Conservation and Management Plan
EPA	U.S. Environmental Protection Agency
GIS	Geographic Information System
GIWW	Gulf Intracoastal Waterway
GLO	Texas General Land Office
LSU	Louisiana State University
MOSS	Map Overlay and Statistical Subsystem
NRCS	Natural Resources Conservation Service
NWI	National Wetlands Inventory
PINS	Padre Island National Seashore
SCS	Soil Conservation Service
TCWS	Texas Colonial Waterbird Society
TNRCC	Texas Natural Resource Conservation Commission
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey

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EXECUTIVE SUMMARY

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Introduction

Wetland and associated aquatic habitats are essential biological components of the Corpus Christi-Aransas Bays estuarine systems. Understanding the spatial and temporal distribution of these habitats is critical for effective protection and management. This report presents results of an investigation to determine status and trends of wetlands, intertidal flats, riparian woodlands, shorelines, and dredged-material rookery islands in the CCBNEP area. The investigation, sponsored by the CCBNEP and funded by EPA and TNRCC, was a cooperative effort between the Bureau of Economic Geology, TPWD, and Texas A&M University–Corpus Christi.

Methods

The study area for this investigation encompasses primarily the Corpus Christi-Aransas Bay System, extending from the Mesquite Bay Quandrangle southward to upper Laguna Madre (Fig. I.). Counties include Refugio, Aransas, San Patricio, and Nueces, and parts of Calhoun and Kleberg. Status and trends of wetlands in the study area were determined by using a GIS to analyze the distribution of wetlands mapped on aerial photographs taken in the 1950's, 1979, and 1992. Maps and digital files were provided by the USFWS. Wetlands were mapped in accordance with the classification by Cowardin et al. (1979), in which wetlands were classified by system (marine, estuarine, riverine, palustrine, lacustrine), subsystem (reflective of hydrologic conditions), and class (descriptive of vegetation and substrate). Maps for 1979 and 1992 were additionally classified by subclass (subdivisions of vegetated classes only), water-regime, and special modifiers. Upland habitats were delineated on 1979 maps using a modified Anderson et al. (1976) land-use classification system.

Field sites were examined as part of the effort to characterize wetland plant communities and define wetland map units in the study area. Topographic surveys were conducted along several transects. Rookery islands composed of dredged material were also investigated.

Shorelines were classified, mapped, and digitized in order to differentiate shores that have been artificially hardened by riprap, seawalls, and other human structures from natural and other nonhardened shores. Shorelines were mapped using low altitude aerial videotape surveys and recent aerial photographs.

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Figure I. Study area defined by 30 USGS 7.5-minute quads

Current Status: 1992

Based on the 1992 NWI data, wetlands and aquatic habitats are dominated by an estuarine system that encompasses about 161,000 ha (398,000 acres) (Table I) in the 29 7.5-minute quadrangles that make up the study area (excluding South Bird Island quadrangle) (Fig. I).

Major estuarine and palustrine habitats include salt, brackish, and fresh marshes, riparian woodlands (including forested and scrub-shrub wetlands), intertidal flats, and estuarine open water/subtidal aquatic beds. Vegetated wetlands (marshes, scrub-shrub, and forested wetlands) have a total area of about 48,400 ha (119,595 acres), or about 11 percent of all habitats (Fig. II). Marshes, or estuarine and palustrine emergent wetlands, cover about 47,100 ha (116,385 acres), representing almost 97 percent of vegetated wetlands. Riparian woodlands, which include forested and scrub/shrub wetlands (1,270 ha) within the major fuvial-deltaic systems (Nueces, Aransas-Chiltipin, and Mission Rivers), have a total area of about 1,820 ha (4,500 acres), with the largest area (828 ha, or 2,045 acres) occurring in the Nueces River valley.

Table I. Areal extent of wetland systems and uplands in study area

System	Area (ha)	Area (acres)	Percent of Study Area
Estuarine	161,069	398,000	37
Palustine	26,580	65,678	6
Lacustrine	4,740	11,712	1
Riverine	255	630	<1
Marine (excludes marine open water)	716	1,768	<1
Total	193,358	477,788	44
Uplands	245,162	605,795	56

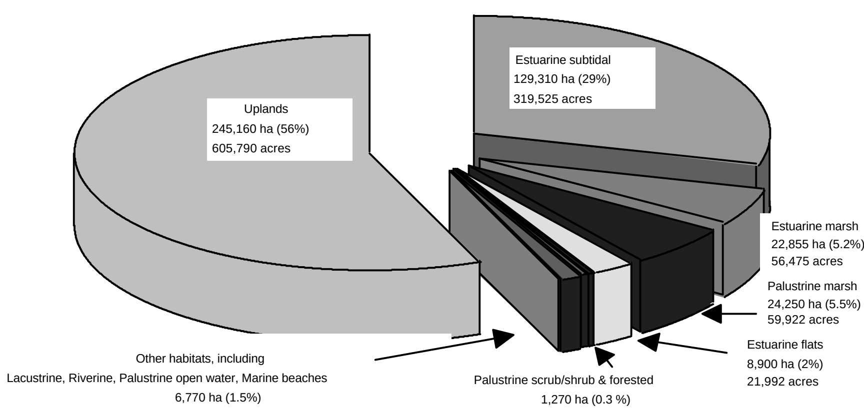

Figure II. Areal distribution, or status, of CCBNEP habitats in 1992. From NWI maps and unadjusted digital files.

Wetland Trends and Probable Causes

In analyzing trends, emphasis was placed on wetland classes and not on water regimes and special modifiers. This approach was taken because habitats were mapped only down to class on 1950's photographs. It should be noted that there are a number of possible photointerpretation shortcomings—not the least of which is involvement of different photointerpreters at different times. Because of photointerpretation and registration problems for the various vintages of maps, adjustments in wetland areas were made to more accurately reflect trends. There is more confidence in direction of trends than magnitudes.

From the 1950's and 1970's to the 1990's, some wetland classes underwent large-scale changes. In general, there were losses in tidal flats and gains in both estuarine (salt and brackish) and palustrine (fresh) marshes (Figs. III and IV). Forested and scrub-shrub wetland classes constitute a small part of the wetland system in the CCBNEP area. Relatively small changes (gains) occurred in both of these classes between the 1950's and 1992. Riparian woodlands in the Nueces, Aransas-Chiltipin, and Mission River valleys increased in area from 1979 to 1992.

Extensive changes in tidal flats occurred between the 1950's and 1979 when almost 10,000 ha (27,410 acres) was converted to other habitat classes. Approximately 55 percent of change in tidal flats was due to permanent inundation of flats and their replacement by either open water or seagrass beds. About 20% of the loss was due to conversion to marshes, and 20% to uplands. The most extensive losses in tidal flats occurred on the barrier islands, especially Mustang and San José Islands, and the flood-tidal delta, Harbor Island, where losses exceeded 2,000 ha (5,480 acres) from the 1950's to 1992 at each site. The other location where losses in tidal flats exceeded 2,000 ha (5,480 acres) was in the Corpus Christi/Nueces Bay – Laguna Madre system. The conversion of tidal flats to sub-tidal habitats (open water and seagrass beds) coincides with an accelerated rise in sea level from the mid-1960's to mid-1970's (Fig. V). In association with this sea-level rise and spread of seagrasses in newly submerged areas was a spread of emergent vegetation along the upper reaches of tidal flats. As topographically lower flats became permanently submerged and colonized by seagrass, higher, tidal flats became more frequently flooded, favoring growth of *Spartina alterniflora* (smooth cordgrass). This spread of *S. alterniflora* is apparent in sequential aerial photographs taken in 1952, 1979, 1992, and 1994. Loss of intertidal flat habitats in some areas was the result of dredge and fill activities related to navigation channel developments.

Analysis of adjusted digital data defining habitat class abundance and distribution from the 1950's to 1992 shows relatively large net gains in both estuarine (>4,600 ha) (11,365 acres) and palustrine marshes (>4,700 ha) (11,615 acres). Gains occurred during both periods, with the largest gain in estuarine marshes occurring during the 1950's to 1979, and the largest gain in palustine wetlands during 1979 to 1992 (Fig. IV). Whereas some gains in palustrine marsh were the result of photo-interpretative changes in class such as estuarine marsh to palustrine marsh, much of the gain was due to expansion of palustrine marsh in former upland areas on barrier islands and on the Pleistocene barrier strandplain ridge, Blackjack Peninsula. Although this increase in marsh may in many areas reflect differences in interpretation of historical and recent aerial photographs, there is evidence that island soils have become wetter since the 1950's and 1960's. Wetter conditions are in part a response to increasing amounts of precipitation since the mid-1950's drought, and rising sea level. We suspect that as sea level rises, the fresh-water lens, recharged by precipitation, also rises, creating wetter surface conditions and leading to more abundant and widespread hydrophytic vegetation. This scenario is supported by observations of environments on the Padre Island National Seashore where active back island dunes became stabilized by vegetation, and deflation areas and vegetated barrier flats became wetter and marshes more extensive. Furthermore, recent baseline studies of plant species on Mustang Island State Park indicate the presence of hydrophytic species not reported in previous plant surveys of Mustang and North Padre Islands.

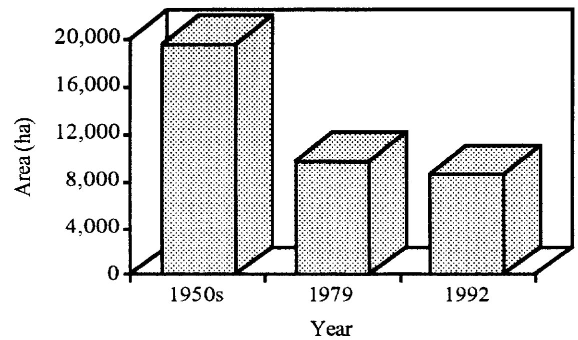

Figure III. Total area of estuarine intertidal flats in the CCBNEP study area for the 1950's, 1979, and 1992.

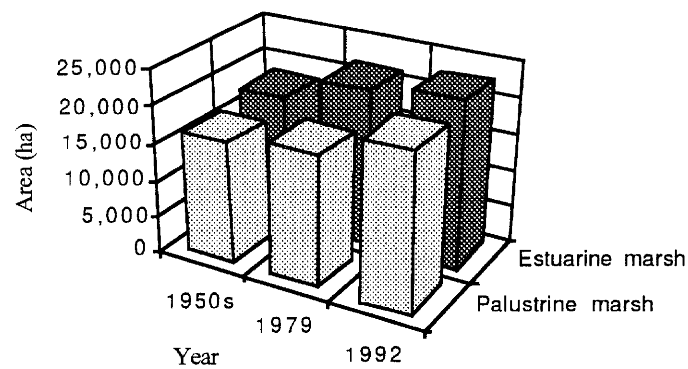

Figure IV. Total area of estuarine and palustine marshes in the CCBNEP study area for the 1950's, 1979, and 1992.

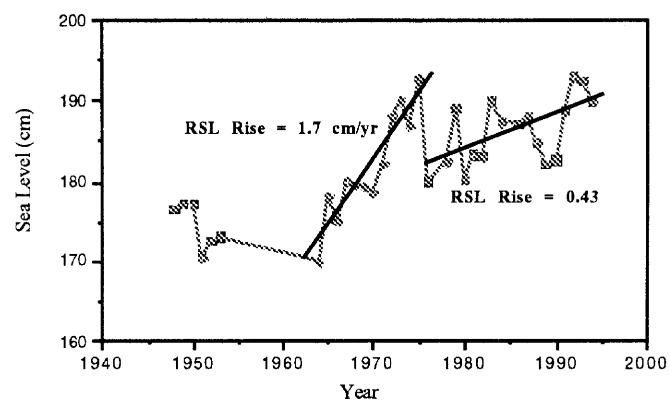

Figure V. Relative rise in sea level as recorded at the Rockport tide gauge. Data from NOAA.

Losses in marshes in the CCBNEP area, although limited in extent and offset by large gains, nevertheless have occurred. Types of marsh loss include conversion of marsh to agricultural and urban land and loss of marsh as a result of dredging, excavating, filling, draining, and leveeing. Among the significant losses are pothole wetlands on the coastal plain and Live Oak Peninsula/Ridge. Recent regional (White et al. 1993) and coast-wide studies (Moulton et al. 1997) have shown net loss of both vegetated wetlands and intertidal flats for areas of the Texas coast outside the CCBNEP area.

Shorelines

Maps prepared and digitized of hardened versus nonhardened shorelines indicate about 330 km (205 mi), or 16 percent, of shorelines are hardened or protected, and 1,684 km (1,047 mi) (84 percent) are natural or unprotected. Hardened shorelines include those that are protected by seawalls and other solid structures made of concrete, wood, or metal, and by riprap. Piers were also mapped, and the total linear kilometers of hardened shorelines includes piers. Unprotected shorelines include all nonhardened shorelines including those along dredged material. The most common shorelines are marshes, accounting for almost 900 km (559 mi) or 45 percent of the total shoreline length in the study area.

Rookery Islands

Rookery islands in the CCBNEP area are critical to the long-term survival of colonial waterbirds (gulls, terns, herons, egrets, pelicans, spoonbills, and ibises). Changes in island size, configuration, and available habitat types variously affected the success of certain species. Decreases in nesting pairs of bare-ground, nesting species (e.g., terns and skimmers) may be due primarily from loss of unvegetated beaches and flats to vegetated grasses, forbs, and shrubs. Some rookery islands were abandoned from extensive erosion.

American White Pelicans nested on three different islands in upper Laguna Madre since 1973. This population is the only coastal nesting population in the United States. Several explanations were postulated to understand this species' migration among these islands: elevated ectoparasite levels in established rookeries, storms, predators, disturbance, and brood reduction. Brown Pelicans made a dramatic recovery in the CCBNEP area since the mid-1970s, with consistently increasing nesting populations on Pelican Island Spoil rookery in Corpus Christi Bay. However, pelicans also nested briefly in other rookeries during the survey. No definitive data exists explaining if these pairs were expanding their nesting range from Pelican Island, or if they were migrating into the area from the north (upper Texas coast) or south (Mexican coast). Several potential factors were identified that may determine where pelican rookeries may be established: proximity to passes for increased water clarity and prey availability, vegetated areas that would support a nest on or near the ground, and limited human disturbance.

Factors that may negatively effect nesting trends of colonial waterbirds include: habitat loss and/or habitat degradation, predation, and human disturbance. Monitoring of colonial waterbird nesting success should be continued, as the Colonial Waterbird Census is the only long-term dataset available to assess status and trends. Continued partnerships among agencies, research and academic institutions, nonprofit conservation groups, and interest groups should be encouraged and supported financially. No quantitative data are presently available to evaluate successional changes in vegetation or spatial changes of island configuration and areal extent. Detailed studies of key rookeries (e.g., Pelican Island Spoil, Shamrock Island, 2nd Chain of Islands, Deadman Island, etc.) should be conducted, particularly those essential to species of concern.

CURRENT STATUS AND HISTORICAL TRENDS OF SELECTED ESTUARINE AND COASTAL HABITATS IN THE CORPUS CHRISTI BAY NATIONAL ESTUARY PROGRAM STUDY AREA

I. INTRODUCTION

Wetland and associated aquatic habitats are essential biological components of the Corpus Christi-Aransas Bay estuarine system. Understanding the spatial and temporal distribution of these habitats is critical for effective protection and management. This report presents results of an investigation to determine status and trends of wetlands, wind-tidal flats, riparian woodlands, shorelines, and dredged-material rookery islands in the Corpus Christi Bay-Aransas Bay system. The investigation, sponsored by the CCBNEP and funded by the EPA and TNRCC, was a cooperative effort between the Bureau of Economic Geology, TPWD, and Texas A&M University–Corpus Christi.

A. Objectives

The primary objective of this investigation was to determine the current status and historical trends of wetlands and wind-tidal flats in the Corpus Christi–Aransas Bay system (Fig. 1) based on maps prepared by the USFWS as part of the NWI. Associated objectives included (1) determining probable causes for documented wetland trends, (2) delineating trends in riparian woodlands, (3) characterizing wetland plant communities through field surveys, (4) mapping hardened and unprotected shorelines, and (5) analyzing changes in vegetation cover on rookery islands composed of dredged material.

B. Report Organization

The report is organized by chapters to allow more specific discussions of methods and results of the various topics presented. In Chapter I is the introduction, which treats the objectives, organization, wetland classification and definitions, setting of the study area, and general methods on status and trends. Presented in Chapter II is the classification of wetland and deepwater habitats (Cowardin et al. 1979) with examples of general vegetation types in the CCBNEP study area. A more detailed characterization of wetland plant communities by geographical areas is presented in Chapter III. Chapter IV is a discussion of the current status (1992) of the major estuarine and palustrine wetland classes and their areal distribution within the study area. Because of the complexity of analyzing historical wetland trends and the desire to define trends geographically, Chapter V emphasizes trends of marshes and tidal flats with respect to major geographic areas such as modern barrier islands, the Pleistocene barrier strandplain, fluvial-deltaic systems, and the coastal plain. Wetland distribution in 1992 is presented as part of the trend analysis, thereby documenting the current status of wetlands by major geographical area. Shorelines along the estuarine and marine systems are characterized by type in Chapter VI. Chapter VII presents a summary of the status and trends of rookery islands, a topic that is discussed more fully in a separate report (Smith and Cox, 1998). The conclusions are presented in Chapter VIII.

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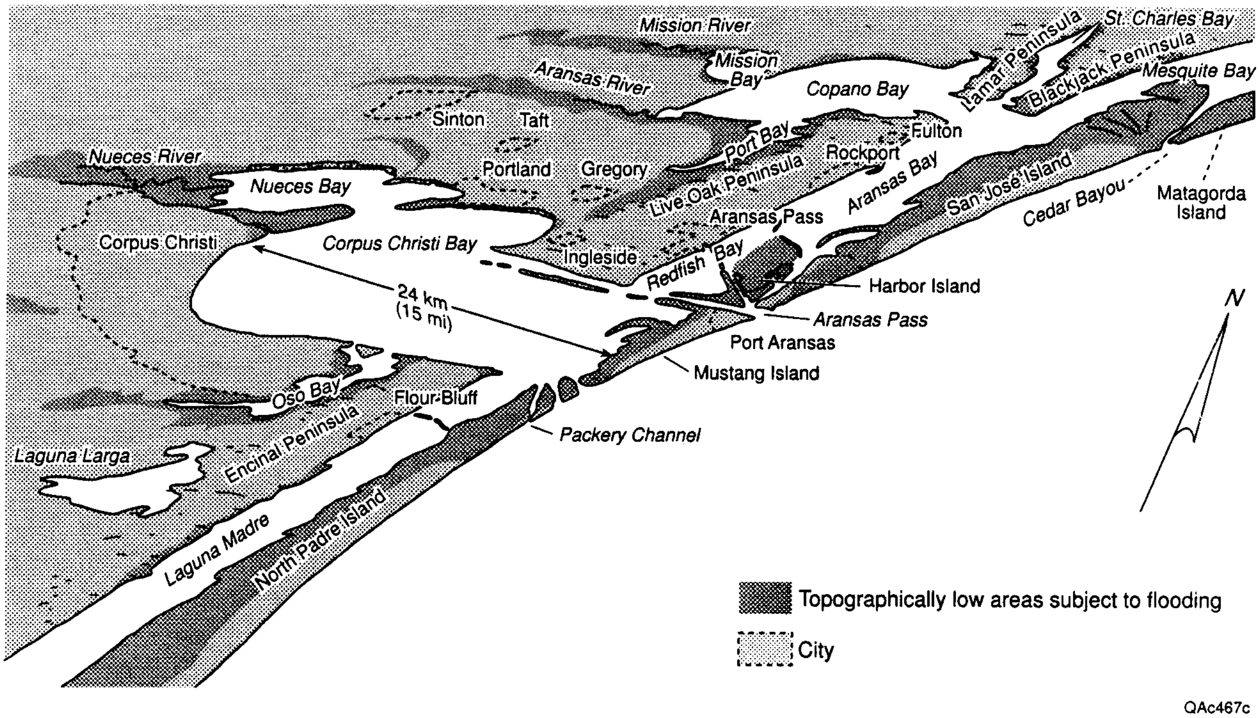


Figure 1. Index map of a selected portion of the CCBNEP study area.

C. 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 the CCBNEP project was to determine status and trends of wetlands in the Corpus Christi-Aransas Bay system using aerial photographs, classification and definition of wetlands were integrally connected to the photographs and the interpretation of wetland signatures. Wetlands were not defined nor mapped in accordance with the *Federal Manual for Identifying and Delineating Jurisdictional Wetlands* (Federal Interagency Committee for Wetland Delineation, 1989).

D. Study Area

The area for this study is defined by 30 USGS 7.5-minute quadrangles (quads) (Fig. 2) located in the northern half of CCBNEP project area shown on the cover of this report. For the South Bird Island quadrangle (Fig. 2), however, neither digital data nor maps were available for 1992 NRI delineations at the time of the study. Although the 1950's and 1979 wetlands data were analyzed for this quad, serious cartographic problems in the 1950's data prevented a meaningful quantitative comparison with 1979 data. Accordingly, the focus of the digital analysis was on the remaining 29 quads.

The study area covers the estuarine systems of Corpus Christi Bay and Aransas Bay, and secondary bay systems including Copano, Nueces, Mission, St. Charles, Redfish, and Mesquite Bays, and north Laguna Madre. Barrier islands include south Matagorda, San José, Mustang, and North Padre. Counties include Refugio, Aransas, San Patricio, and Nueces, and parts of Calhoun and Kleberg.

[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.

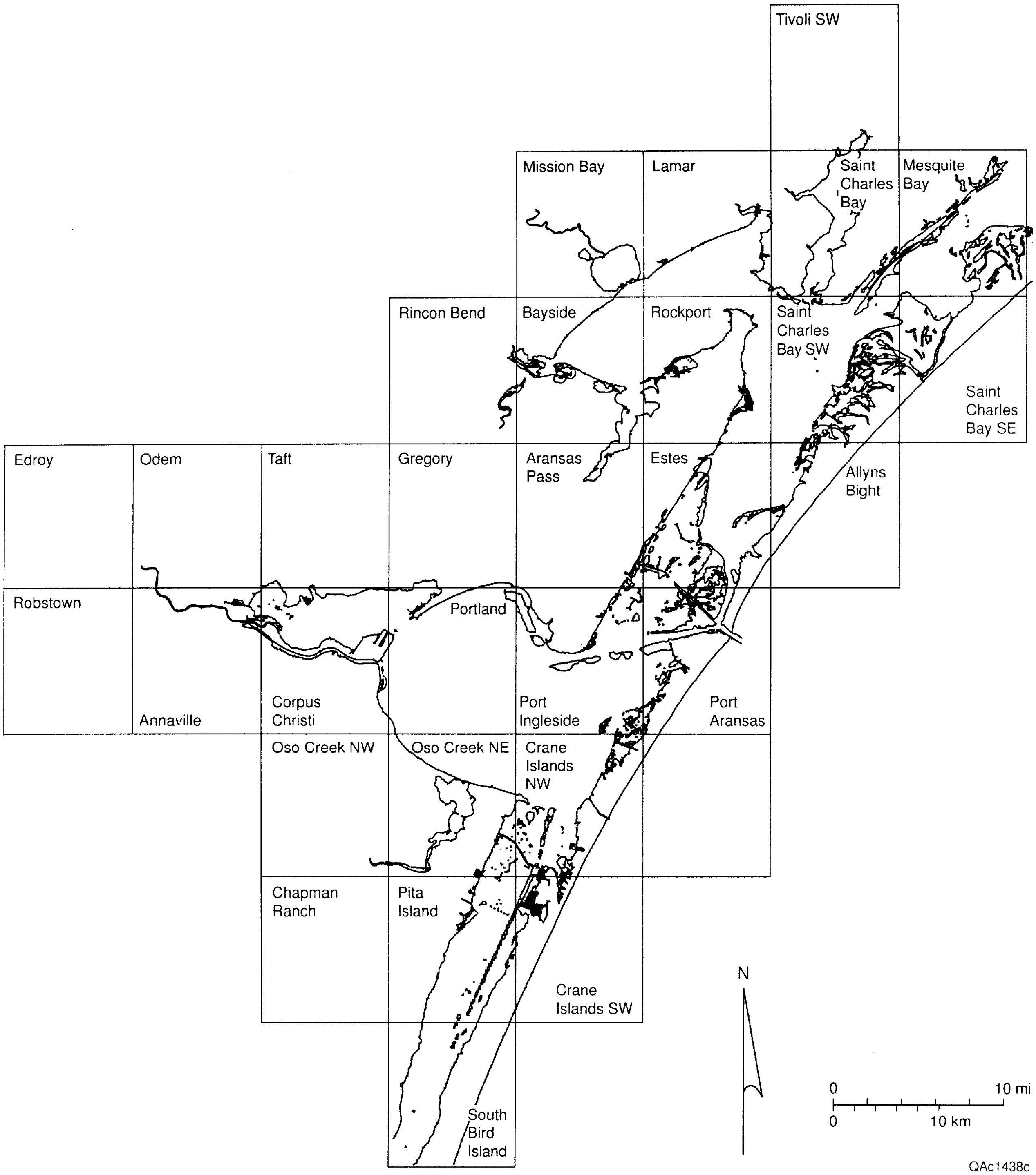


Figure 2. Study area defined by 30 USGS 7.5-minute quads

E. General Setting of the Corpus Christi–Aransas Bay System

The geologic framework of the Corpus Christi-Aransas Bay area consists of Modern-Holocene and Pleistocene systems including the modern wetland system (Fig. 3). Geomorphic features on which various types of coastal wetlands have developed are the result of numerous interacting processes. Physical processes that influence wetlands include rainfall, runoff, water table fluctuations, streamflow, evapotranspiration, waves and longshore currents, astronomical and wind tides, storms and hurricanes, deposition and erosion, subsidence, faulting, and sea-level rise. 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 wetlands that grade upward from the astronomical-tidal zone through the wind-tidal zone to the storm-tidal zone.

Bay-Estuary-Lagoon Setting

Exchange of marine waters with bay-estuary-lagoon waters in the Corpus Christi Bay-Aransas Bay system occurs primarily through a major tidal inlet, Aransas Pass, at the north end of Mustang Island (Fig. 1). Additional exchange occurs at Cedar Bayou, a narrow channel that connects the Gulf with Mesquite Bay. Predominant sources of freshwater inflow are the Nueces, Aransas, and Mission Rivers (Fig. 3), and the Guadalupe River, which although northeast of the study area is an important source of freshwater for Aransas Bay (Longley, 1994). Salinities in the estuarine system are generally highest in Laguna Madre, followed in order of decreasing average salinity, by Corpus Christi, Redfish, Aransas, Nueces, and Copano Bays (Holland et al. 1975, Brown et al. 1976, Hildebrand and King, 1978). Average salinities in Laguna Madre are generally above 30 parts per thousand (ppt), in marked contrast to Copano Bay where average salinities range from about 10 to 15 ppt, increasing toward the mouth of the bay. These numerous interacting processes in Corpus Christi Bay and adjacent bay systems have a major bearing on location and composition of wetland plant communities.

Relative Sea-level Rise

Relative sea-level rise is another important process affecting wetland and aquatic habitats. Relative sea-level rise 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 relative sea-level rise equation. Subsidence, especially associated with withdrawal of ground water 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 sea level rise recorded at Port Aransas (1959-1969) exceeded 1.2 cm/yr (Swanson and Thurlow, 1973). 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.

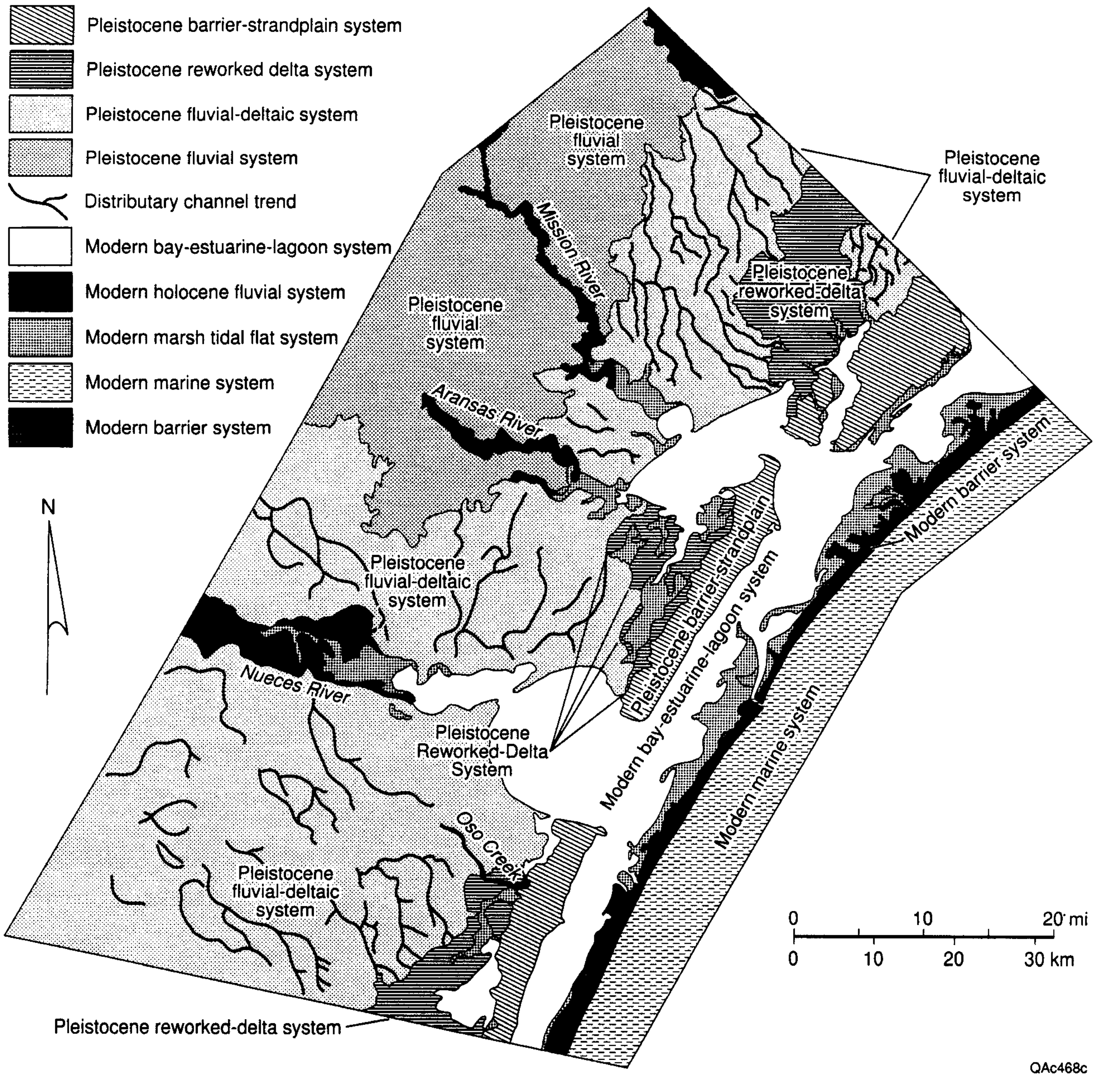


Figure 3. Natural systems in the Corpus Christi-Aransas Bay area. From Brown et al. (1976) and McGowen et al. (1976).

The tide gauge at Rockport provides the longest continuous record of sea-level variations in the CCBNEP study area. The average rate of sea-level rise from the 1950's to 1993 (with missing data in the late 1950's and early 1960's) is about 0.40 cm/yr. Rates of sea-level rise recorded by the tide gauge reached a high of 1.7 cm/yr from the mid 1960's to mid 1970's; this is time coincident with a maximum change in some habitats such as wind-tidal flats. These relationships are presented in detail in the discussion of wetland trends.

F. General Methods Used in Mapping and Analyzing Status and Trends

Status and trends of wetlands in the study area were determined by analyzing the distribution of wetlands mapped on aerial photographs taken in the 1950's, 1979, and 1992. 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). The 1992 maps of the CCBNEP area are part of a series of updated NWI maps of the Texas coastal zone.

Interpretation of Wetlands

Wetlands for all maps (1950's, 1979, and 1992) were delineated on aerial photographs through stereoscopic interpretation using procedures developed for the USFWS-NWI program. Field reconnaissance was an integral part of interpretation. Photographic signatures were compared to the appearance of wetlands in the field by observing vegetation, soil, hydrology, and topography. This information was weighted for seasonality and conditions existing at the time of photography and ground-truthing. Extensive field surveys of wetlands were conducted as part of this study in support of 1990's delineations (see discussions on field investigations and wetland plant communities). Still, field-surveyed sites represent only a small percentage of the thousands of areas (polygons) delineated. Most areas were delineated on the basis of photointerpretation alone, and mis-classifications may have occurred.

The following explanation is printed on all wetland maps that were used in this project to determine trends and status of wetlands in the CCBNEP area:

> 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. . .

Photographs

The 1950’s photographs are black-and-white stereo-pair, scale 1:24,000, taken in the mid 1950’s, mostly in 1956 but also in 1954 and 1958 (Larry Handley, NBS, Personal Communication, 1997). The 1979 and 1992 aerial photograhs are NASA color-infrared stereo-pair, scale 1:65,000, that were taken in November and December, respectively.

Photographs used are generally of high quality. Abnormally high precipitation in 1979, however, raised water levels in many interior fresh-water wetlands producing more standing water than in the 1950's and 1992. 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 severe drought that characterized the mid-1950’s in Texas (Riggio et al. 1987) may have influenced wetland signatures on photographs taken in 1956, at the height of the drought. These differences affected certain habitats and their interpreted, or mapped, water regimes.

Maps

As part of the USFWS NWI program, draft maps were prepared from interpreted aerial photographs, distributed for review, and checked in the field. Draft and final maps were prepared by transferring lines delineated on aerial photographs to USGS 7.5-minute quadrangle base maps, scale 1:24,000, using Zoom-Transfer Scopes. As in the photointerpretation process (discussed more thoroughly in a following section of photointerpretation errors), there is a margin of error involved in the transfer process. Transfers to maps were completed by a different contractor for the 1950’s photographs than for the 1979 and 1992 photographs. Accordingly, higher degrees of standardization and consistency were achieved in the 1979 and 1992 map series.

On 1979 and 1992 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 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 1992 maps (Fig. 6).

Thirty 7.5-minute quadrangles make up the study area for this investigation (Fig. 2). As part of the USFWS NWI program, delineations for the 1992 maps were digitized and entered into the GIS ARC/INFO for analysis on a quadrangle by quadrangle basis. GIS data files previously digitized and maintained by the USFWS for the 1950’s and 1979 photographs were obtained and translated to digital line graph (DLG) format in a form readable by ARC/INFO. Twelve historical NWI maps (four 1979 maps and eight 1956 maps) were not in digital form and had to be digitized (Table 1).

The digitizing process is a means of data capture of the lines, points, and polygons displayed on hard-copy maps. General procedures used by the UFWS are as follows. Data are captured with a digitizing tablet using a software package called the Analytical Mapping System (AMS). The AMS is a menu-driven geographically referenced digitizing system that contains predefined, sequential data-entry procedures, including: map preparation and georeferencing; digitizing and editing; polygon verification/formation; and data base construction and transfer. The base map to be digitized is registered to a geographic referencing system with AMS by establishing longitude and latitude registration marks (maximum 16, minimum 8) of the map as points within the

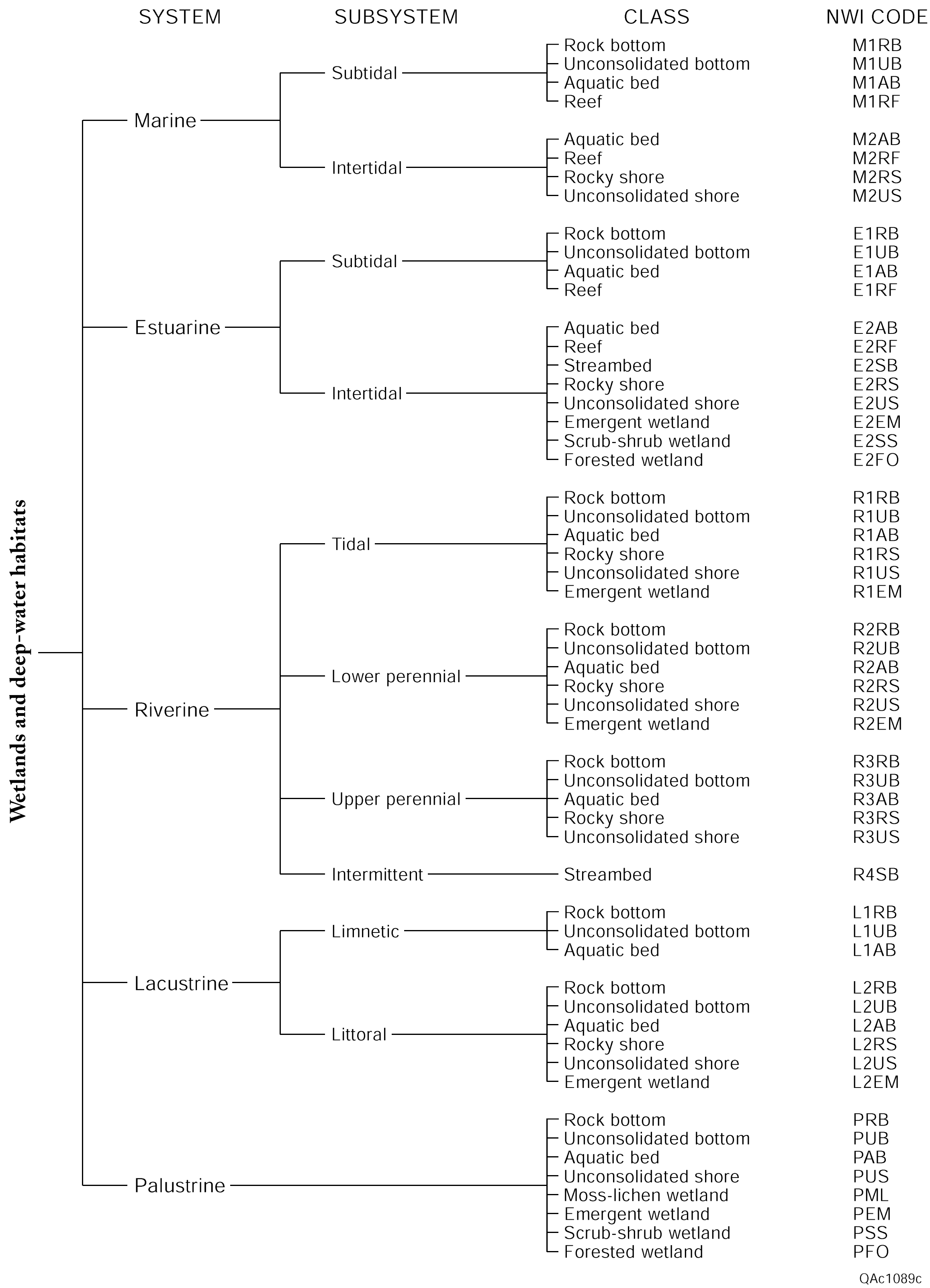


Figure 4. Classification hierarchy of wetlands and deepwater habitats showing systems, subsystems, and classes. From Cowardin et al. (1979).

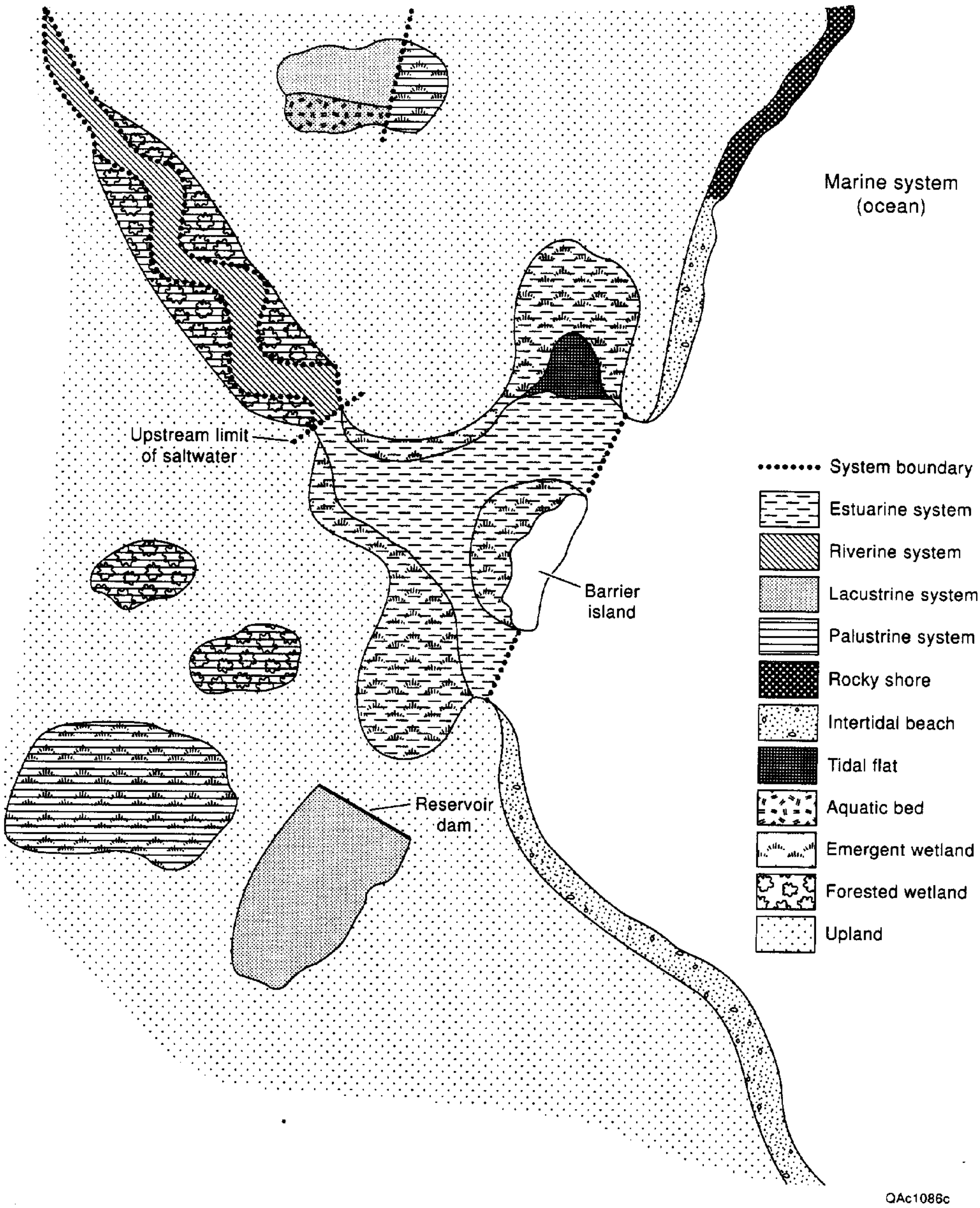
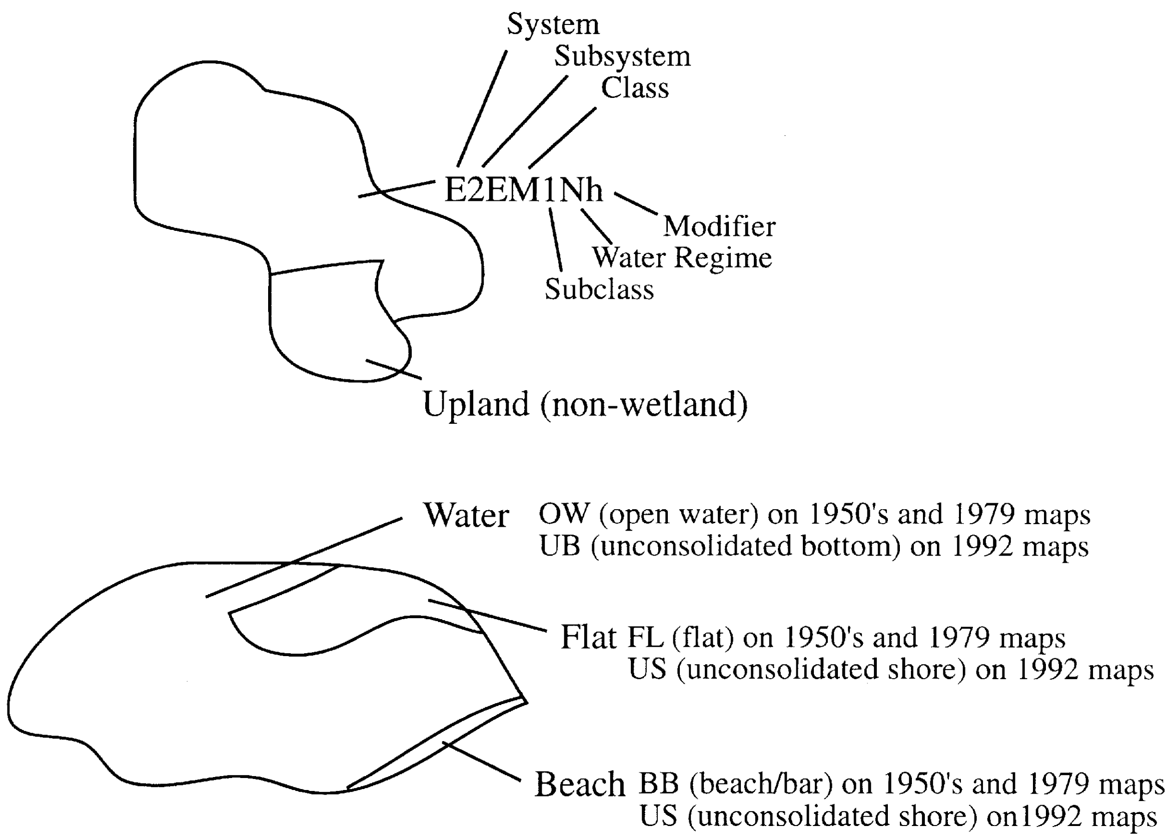


Figure 5. Schematic diagram showing major wetland and deepwater habitat systems. From Tiner (1984).



Upland Legend for 1979 maps only

Upland Classes
- U-Urban or Developed
- A-Agricultural
- F- Forest
- SS-Scrub/shrub
- R-Range
- B-Barren

Modifying Terms
- o-oil and gas
- r-rice field
- 6-deciduous
- 7-evergreen
- 8-mixed
- s-spoil

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

Table 1. Status of wetland digital data available from USFWS for quadrangles in the CCBNEP study area. D=digital data available; **x**=no existing digital data -- wetlands digitized from USFWS maps as part of this project; NA=neither digital data nor map available.

Quad Name	**1950's**	**1979**	**1992**
Allyns Bight	D	D	D
Annaville	**x**	D	D
Aransas Pass	D	D	D
Bayside	**x**	D	D
Chapman Ranch	**x**	D	D
Corpus Christi	D	D	D
Crane Islands NW	D	D	D
Crane Islands SW	D	D	D
Edroy	**x**	**x**	D
Estes	D	D	D
Gregory	D	D	D
Lamar	D	D	D
Mesquite Bay	D	D	D
Mission Bay	**x**	D	D
Odem	**x**	**x**	D
Oso Creek NE	D	D	D
Oso Creek NW	D	D	D
Pita Island	D	D	D
Port Aransas	D	D	D
Port Ingleside	D	D	D
Portland	D	D	D
Rincon Bend	**x**	**x**	D
Robstown	**x**	**x**	D
Rockport	D	D	D
South Bird Island	D	D	NA
St Charles Bay	D	D	D
St Charles Bay SE	D	D	D
St Charles Bay SW	D	D	D
Taft	D	D	D
Tivoli SW	D	D	D

digitizing tablet grid and the latitude/longitude registration points of the map. These values are either accepted or declined by the digitizer in compliance with national map-accuracy standards. The data are digitized and stored in an arc-mode format. AMS provides internal verification of polygon closure, island formation, and edge matching. Quality control is performed within AMS to identify errors in attribute assignment, open polygons, crossing line segments, unattached edge modes, or misassigned islands. Additional quality control is done by the digitizer who produces a plot of the digitized data and compares it to the original map. This provides a check for errant lines, missed polygons, missing lines, or lines that diverge from the original in location, direction, or directness. Following editing and verification, digital map data are transferred to a permanent AMS data base and can be exported to the MOSS or to ARC/INFO for analysis.

Results include GIS data sets consisting of electronic-information overlays corresponding to mapped habitat features for the 1950’s, 1979, and 1992. Data can be manipulated as information overlays, whereby scaling and selection features allow portions of the estuary to be electronically selected for specific analysis.

Among the objectives of GIS are to: (1) allow direct historical comparisons of habitat types to gauge historical trends and status of estuarine habitat, (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 (4) allow overlays to be combined from both this and future studies on other topics in a single system that integrates disparate environmental features for purposes of creating a CCMP. The GIS will become a flexible and valuable management tool for use by resource managers.

Field Investigations

Field investigations were conducted for two purposes: (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 used 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.

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II. CLASSIFICATION OF WETLAND AND DEEPWATER HABITATS IN THE CCBNEP AREA

Cowardin et al. (1979) defined five major systems in their classification of wetlands and deepwater habitats: Marine, Estuarine, Riverine, Lacustrine, and Palustrine (Fig. 4). All include wetlands and deepwater habitats except for the palustrine system, which includes only wetland habitats. 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 1992. In addition, water-regime modifiers (Table 2) and special modifiers were used for these years.

The USFWS-NWI program established criteria for mapping wetlands using the Cowardin et al. (1979) classification. Alphanumeric abbreviations are used to denote systems, subsystems, classes, subclasses, water regimes, and special modifiers (Table 3, 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 1992 maps. Much of the following discussion of wetland systems as defined by Cowardin et al. (1979) is modified from White et al. (1993). Nomenclature and symbols (Appendix) in this discussion are based primarily on the 1992 NWI maps.

A. Marine System

Marine areas include unconsolidated bottom (open water), unconsolidated shore (beaches), and rocky shore (jetties). Mean range of Gulf tides is about 0.6 m. 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). Composition of these areas is primarily sand and shell. Granite jetties along the coast in the marine system are classified as rocky shore intertidal, irregularly flooded, artificial substrate (M2RS2Pr).

B. 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 primarily from regularly flooded (E2USN) to irregularly flooded (E2USP).

Aquatic beds observed in this system are predominantly submerged rooted vascular plants (E1AB3L) that include, in the CCBNEP area (Fig. 1), *Halodule wrightii* (shoalgrass), *Thalassia testudinum* (turtlegrass), *Ruppia maritima* (widgeongrass), *Syringodium filiforme* (manateegrass), and *Halophila engelmannii* (clover grass) (Pulich et al. 1997).

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* (smooth cordgrass), *Batis maritima* (saltwort), *Distichlis spicata* (seashore saltgrass), *Salicornia* spp. (glasswort), *Monanthochloe littoralis* (shoregrass), *Suaeda linearis* (annual seepweed), and *Sesuvium portulacastrum* (sea- purslane) in more saline areas. In brackish areas,

Table 2. 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.
©	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
®*	Seasonally flooded—Tidal
(T)*	Semipermanently flooded—Tidal
(V)*	Permanently flooded—Tidal

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

Table 3. Wetland codes and descriptions from Cowardin et al. (1979). Codes listed below were used on 1992 NWI maps, 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* *Thalassia testudinum* *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	*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	Unconsloidated 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	*Scirpus 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.*

Species composition changes to a salt to brackish-water assemblage including *Scirpus maritimus* (saltmarsh bulrush). At slightly higher elevations irregularly flooded estuarine emergent wetlands (E2EM1P) (high salt and brackish marshes) include *Borrichia frutescens* (sea oxeye), *Distichlis spicata, Spartina spartinae* (gulf cordgrass), *Spartina patens* (saltmeadow cordgrass), *Fimbrystylis castanea* (marsh fimbry), *Scirpus maritimus*, *Aster* spp.(aster), and many others.

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) 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 class E2EM/FL was only used on 1956 and 1979 maps. In such combinations, each class must compose at least 30 percent of the mapped area (polygon); the dominant classes were listed first on 1992 maps, for example PEM/U or U/PEM, but on the 1950's and 1979 maps the wetland class was always listed first (PEM/U) whether or not it was most abundant. The wetland and upland combinations (PEM/U, POW/U) were used almost exclusively on the Pleistocene barrier-strandplain where complex topography produced complex configurations of wetlands and uplands that could not be adequately separated at the mapping scale.

The estuarine system extends upstream or 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 (freshwater) systems.

C. Lacustrine System

Water bodies greater than 8 ha are included in this system with both limnetic and littoral subsystems represented. Several lakes and reservoirs exist within the CCBNEP study area.

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 levees or artificial means. The artificially flooded modifier (K) is used in situations where water is controlled by pumps and siphons.

D. Riverine System

Three riverine subsystems occur in the project area: tidal (R1), lower perennial (R2), and intermittent (R4). The major rivers discharging directly into the bay sytems are the Nueces, Aransas, and Mission Rivers (Fig. 3). Ditches large enough to be delineated were identified with the excavated (x) modifier (for example, R2UBHx or R4SBAx).

E. 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), and artificially flooded areas by PUBK.

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 seasonally (PEM1R) and temporarily (PEM1S) flooded areas. Artificially flooded areas are designated PEM1K.

Vegetation communities typically characterizing areas mapped as low emergent wetlands (PEM1F) include *Scirpus californicus* (California bulrush), *Typha domingensis* (southern cattail), *Scirpus pungens* (three-square bulrush), *Eleocharis* spp. (spikerush), and others. 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), *Aster spinosus* (spiny aster), *Paspalum* spp. (paspalum), *Panicum* spp. (panic), and *Andropogon glomeratus* (bushy bluestem) 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 was better achieved through field transects, some of which included elevation measurements.

Palustrine scrub-shrub wetlands that were mapped are typically seasonally flooded (PSS1C) and dominated by *Salix nigra* (black willow), *Parkinsonia aculeata* (retama), *Acacia smallii* (huisache), 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* spp. Is labeled PSS2A or PSS2C depending on the water conditions present (Table 2).

Palustrine forested areas, consisting of temporarily (PFO1A) and seasonally (PFO1C) flooded forested areas, incorporate a large mixture of tree species including *Parkinsonia aculeata*, *Acacia smallii*, *Salix nigra*, *Fraxinus spp*. (ash), *Ulmus crassifolia* (cedar elm), *Celtis spp.* (hackberry), *Carya illinoensis* (pecan hickory), and others.

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III. CHARACTERIZATION OF WETLAND PLANT COMMUNITIES IN THE CCBNEP AREA

A. Introduction

The area encompasses an extensive, biologically productive estuarine and lagoonal system composed of numerous diverse and essential habitats and vast array of associated organisms. Understanding status and trends of these habitats is critical for comprehensive management plans. Characterization of wetland communities within the CCBNEP study area is necessary in evaluating changes in emergent wetland types. Therefore, the objectives of this portion of the project were to characterize the vegetation of typical wetland communities within the CCBNEP area.

B. Background

Extensive coastal marshes, predominantly brackish and saline, occur in the northern part of the CCBNEP study area where freshwater inflow and precipitation are higher than in the southern portion. Coastal marshes are replaced by extensive wind-tidal flats from Mustang Island southward, due to lower precipitation and high evaporation rates. Freshwater marshes located within the interior of Mustang and Padre Islands and along watercourses on the mainland are less extensive within the CCBNEP study area. Most freshwater marshes and riparian woodlands are located within the Nueces, Aransas, and Mission River floodplains. Decreases in freshwater wetland coverage have been attributed to diminished discharge resulting from upstream dams, clearing for urban and agricultural development, and hydrologic changes from brine discharge within creek systems (Brown et al. 1976).

C. Methods

Wetland Vegetation Characterization

Prevalent plant species characterizing NWI emergent, shrub-scrub, and forested wetland habitats were determined from limited field surveys and transects, and existing data from vegetation analysis of Chiltipin Creek (Tunnell et al. 1997), Aransas National Wildlife Refuge (Darnell et al. 1997), Copano Bay marsh (Wood et al. 1995), Mustang Island (Jenkins and Smith, 1997 and this study), Fennessey Flats (this study), Welder Wildlife Foundation oxbow lakes (Drawe et al. 1978, Haigh, 1984), and general literature. Site selection and number of transects for some field surveys were coordinated as part of the verification of photointerpretation work, and for use in characterization of wetland vegetation communities in the CCBNEP study area. Particular emphasis was placed on barrier island wetlands to evaluate changes in palustrine marshes over time; in general, a minimum of three transects was completed for each wetland community. Transects were aligned perpendicular to the elevation gradient that encompassed maximum number of vegetation associations.

A minimum of three transects within each wetland community were assessed for changes in vegetation association in relation to changes in elevation using a hand level and staff for transects of less than 100 m in length. A metric tape was used by field workers to locate appropriate points as delineated by wetland vegetation type along the transect. A Sokkia Set 3B electronic total station was used for transects > 100 m long at Mustang Island and Fennessey Flats. The total station was positioned at the highest elevation point within the transect or most appropriate site to ensure safety of equipment and operator. All vegetation along a vertical plane was recorded at each point and data from the total station recorded to evaluate changes in horizontal distance and change in elevation from the instrument to each point sampled (1 cm accuracy). Time of day was recorded for reading at the water line for later comparison to water-level data from appropriate tide gauges (Conrad Blucher Institute data). Existing artificial structures (i.e., roads, paths, channels, buildings, etc.) were also recorded. The total station was moved along the transect as necessary when visibility to the prism pole as blocked. A location was recorded for all transects at each endpoint and incorporated into a GIS.

Data were recorded on Excel spreadsheets for comparison between wetland sites and wetland communities, and for future status and trends evaluation in the CCBNEP study area. Graphical representations of wetland vegetation/elevation relationships were constructed for visual assessment and interpretation. Descriptions of previous vegetation characterization in the CCBNEP study area were used to provide a comprehensive synthesis of available information. Wetland community assemblages were determined by grouping species with similar ecological requirements (i.e., Correll and Johnston, 1970, Jones, 1982, Tiner, 1993) as well as wetland indicator status (Reed, 1988).

D. Results

Wetland Vegetation Dynamics Overview

Coastal Marshes

Coastal marshes comprise an extensive part of shorelines along the East Coast of the United States, northern Gulf of Mexico, and, to a lesser extent, West Coast and western Gulf of Mexico. They are primarily associated with areas of low relief on the continental slope and coastal plains. Coastal marshes exhibit unique structural and functional characteristics primarily controlled by environmental factors. Individual species' responses to stresses of inundation and salinity generally determine location across an elevational and salinity gradient.

Marshes that are situated along gently-sloping coastlines typically exhibit species zonation parallel to the shoreline. Coastal marsh zones have been delineated according to their elevation and tidal inundation. The lower or intertidal marsh is generally flooded daily, the upper or high marsh is infrequently flooded (Mitsch and Gosselink, 1993). Chabreck (1972) divided Gulf coastal plain communities into four zones: saline, brackish, intermediate, and fresh. The saline zone is typified by daily tidal inundation and salinities of 20-35 ppt. The brackish zone has a salinity range of 5-19 ppt and is affected by seasonality of tides, especially in spring and fall, and by storm surges due to tropical storms. The intermediate zone is tidally affected only by extreme storm surge events, which may not change salinity (0.5-5 ppt) but may increase water depth by impeded normal runoff. Salinity ranges greater than 40 ppt are designated as hyperhaline (Cowardin et al. 1979).

Tidal cycles are a primary component of hydrologic dynamics in coastal marsh systems. Varying degrees of inundation in relation to marsh elevation differentially affect vegetation dynamics. Effects of tides can be stressful to plants (e.g., submergence, anaerobic-soil conditions, deposition of salts in the soil), but also have beneficial effects by periodic flushing of salts out of the marsh and nutrients into the marsh (Mitsch and Gosselink, 1986). Seasonal cycles are superimposed on diurnal tide patterns, and have an additional impact (Bleakney, 1972, Armstrong et al. 1985, Wood, 1986). Additional aperiodic events, such as hurricanes and tropical storms, influence vegetation dynamics in coastal marshes by either increasing freshwater or saline inflow into the marshes (Miller and Egler, 1950, Shiflet, 1963, Chabreck and Palmisano, 1973, Hopkinson et al. 1978).

Tidal amplitude is much less in Gulf marshes than East coast marshes, usually less than 0.5 m (Turner, 1991, Ward et al. 1980). Prevailing south to southeasterly winds occur throughout much of the year producing wind tides that usually override astronomical cycles. These wind tides push water to the north-northwest from the Gulf through passes into shallow estuaries and marshes. Strong northerly winds during winter can reverse wind tides resulting in rapid removal of large amounts of water from the shallow coastal marshes and bays.

Although tidal regimes are similar to those in Louisiana, salinity levels are higher in South and Central Texas coastal marshes due to decreased annual rainfall and increased temperatures and evaporation rates (Texas Dept. Water Resources, 1984). Therefore, Texas coastal marshes may experience more severe environmental conditions than other regional coastal marshes and these conditions may affect marsh vegetation dynamics. However, limited information is available for determining effects of variable environmental conditions (e.g., water depth, salinity) on species distribution and composition in Texas coastal marshes.

Typical species zonation in Gulf coastal marshes include *Spartina alterniflora* in the lower saline zone, *S. patens* in the middle brackish zone, and, *Paspalum vaginatum* (seashore paspalum) in the higher intermediate zone. *Distichlis spicata* generally occurs between brackish and saline zones, but *D. spicata* is present in varying amounts throughout the marsh community. Other species occur in Gulf coastal marshes and are variously affected by environmental influences in response to their physiological requirements (Chabreck, 1972; Gosselink, 1984).

Barrier Islands

Barrier islands are located along most portions of the Texas coast originating as offshore shoals about 4500 years before present (YBP) (LeBlanc and Hodgson, 1959, Otvos, 1970a, 1970b, Brown et al. 1976, 1977) (Fig. 3). When sea level reached its present level (about 2800 to 2500 YBP), these offshore shoals formed a chain of barrier islands fronting the mainland estuaries that now occupy drowned Pleistocene river valleys (Morton and McGowen, 1980). Development of islands continued through a process of spit accretion resulting from both longshore littoral sediment transport and eolian (or wind) deposition (Weise and White, 1980; Britton and Morton, 1989). Passes that allow flow of Gulf waters into estuarine systems and outflow of waters from associated rivers into the Gulf also delineate individual islands within the CCBNEP Study Area (Matagorda, San Jose, Mustang, and Padre Islands).

Barrier islands typically develop vegetation zones corresponding to an associated topographical zone. Gulf beach habitat is located along the easternmost barrier island beach environment in Texas consisting of a marine, intertidal unconsolidated shoreline (foreshore and backshore zones). This high-energy zone generally does not support long-term vegetation (Kaplan, 1988). Coppice or embryo dunes are small, vegetated mounds of sand located at the landward edge of the backshore and beginning of the foredune ridge complex. Vegetation zonation is prominent on the primary dunes, with distinctive windward and leeward plant communities. Along Mustang and Padre Islands, dune topography is dynamic and may change appearance through eolian forces.

The vegetated flats lying between foredune fields and back-island dunes have greatest vegetation coverage and diversity of all barrier island communities (Britton and Morton, 1989). White et al. (1983) described wetland locations and vegetation characteristics associated with Mustang

Island. Proximal (low) and distal (high) salt-water marshes occur to a limited extent along bay margins. The most extensive salt-water marshes occur along margins of Mustang Island southwest of the Water Exchange Pass and northeast of Wilson's Cut. Both brackish and freshwater wetlands associated with the freshwater ground lens may form in association with ephemeral ponds in depressional areas in central parts of the island. Marshes supported by fresher water occur near the island center of the occupying deflation troughs and depressions and, in some localities, relict washover channels separated from Gulf and bay waters.

Tidal flats are present along the bay margin of Mustang and Padre islands where they replace salt marshes located at similar elevations on northern barrier islands. This north-south geographic shift in habitats has been explained as a result of lower rainfall/higher evaporation rates and an increase of wind-driven erosion in the southern area which has resulted in a decrease in barrier island vegetation (Brown et al. 1976). The irregular tidal regime and extremely high temperatures of sheetwater on flats often raises soil salinities above salt marsh vegetation tolerance limits. Therefore, biologic activity is often restricted to mats of blue-green algae formed on and within the tidal flat surface (Pulich et al. 1982).

Extensive vegetation studies of North Padre Island have been conducted over the past three decades. The SCS (NRCS) conducted an ecological survey of vegetation of Padre Island National Seashore (Rechenthin and Passey, 1967). Five vegetative types were recognized: coastal dunes, low coastal sands, salt marsh, salty sands and shoregrass flats. Britton and Morton (1989) described the following habitats for Mustang Island: backshore pioneer habitats, backshore near dunes or dune ridges, windward slopes of dunes or dune ridges, leeward slopes of dunes or dune ridges, and vegetation-stabilized sands and flats.

Vegetation classification systems have been used to designate vegetation to ecoregions, and Texas barrier islands are defined as the dunes/barrier zone of the Gulf Coast Prairies and Marshes ecoregion (LBJ School of Public Affairs, 1978). Seral stages of plant communities on Mustang Island were further defined as both tall grassland, forb-dominated vegetation and marshes at the series-level classification. A summarization of representative plant communities of Mustang Island State Park along an east-west transect included: Cenicilla (Beach Purslane)-Beach Morning Glory Series, Midgrass grassland of Seacoast Bluestem-Gulfdune Paspalum Series, and Glasswort-Saltwort Series (TPWD, 1990).

1975 Classification of Emergent Wetlands in the CCBNEP Area

Diener (1975) characterized coastal prairie and marshes along the Texas coast and mapped emergent vegetation in each of the estuarine areas (Table 4). Coastal marsh included the beach vegetation consisting of plants variously influenced by degrees of tidal inundation. Plant dominance changes from north to south, where *S. alterniflora* and *Batis maritima* are replaced by more salt-tolerant species.

1976 Classification of Emergent Wetlands in the CCBNEP Area

Marshes were described for the CCBNEP area using definitions for amount of salinity in the wetland and position along an elevational gradient (Table 5) (Brown et al. 1976). These definitions took into account variability of climatic regimes in the area and corresponding position of wetlands in the Coastal Bend. Each wetland unit was mapped in association with soil and biotic descriptions.

Table 4. Some wetland plant species associated with each bay system in the CCBNEP area for coastal marshes (including beach vegetation) (modified from Diener, 1975).

Bay	Scientific Name	
Copano-Aransas Bays		
	Batis maritima	*Spartina alterniflora*
	Monanthochloe littoralis	*Spartina patens*
	Salicornia bigelovii	*Sporobolus virginicus*
Corpus Christi Bay		
	B. maritima	*S. alterniflora*
	M. littoralis	*S. virginicus*
	S. bigelovii	*Suaeda linearis*
	Scirpus maritimus	*Uniola paniculata*
	Schizachyrium scoparium	
Laguna Madre		
	M. littoralis	*S. scoparium*
	Paspalum monostachyum	*S. linearis*
	S. bigelovii	*U. paniculata*

Table 5. Definitions of emergent wetland units used to characterize wetlands (Brown et al. 1976).

Unit/Subunit	Definition
Salt-water Marshes	"kept perennially wet by salt water [which] varies from less [35 ppt] to greater than normal marine salinity (35 ppt)… on flood-tidal deltas, along bay margins, and along the back sides of barrier islands and peninsulas"
Low	"characterized by pure stands of smooth cordgrass (*Spartina alterniflora*) that grow at the margin of salt-water bodies in water a few inches deep"
High	"inundated almost daily by either astronomical or wind tides and is characterized by numerous salt-tolerant, largely succulent plants that show an orderly succession in types from the water margin toward the higher and more saline substrates"
Fresh- to Brackish-water Marshes	"present at slightly higher elevations than salt marsh… salinity varies… with climatological conditions.. during prolonged dry periods, both surface and soil water have salinity in excess of 35 ppt … whereas during periods of excessive rainfall may be virtually fresh… present on Nueces delta and along some active and inactive tidal creeks and tributaries associated with Port Bay"
Fresh-water Marshes	"pure stands of fresh-water vegetation in the Corpus Christi area are best developed on the Nueces and Mission deltas and along the Nueces, Chiltipin-Aransas, and Mission Rivers… during wet climatic cycles, an ephemeral, poorly developed fresh-water marsh occupies low areas adjacent to Port Bay and McCampbell Slough"

1983 Classification of Emergent Wetlands in the CCBNEP Area

Emergent wetland units utilized in characterization and mapping of wetlands for Aransas, Mission, Copano, Port, Redfish, Corpus Christi, Nueces, Oso bays, and upper Laguna Madre were generally similar to those used in the Environmental Geologic Atlas series (Brown et al. 1976). Modifications included subdividing salt-water marshes into Proximal, Distal, and Mangrove; and, brackish-water and fresh-water marshes into Low and High. In addition, the undifferentiated marsh unit was included in this wetland characterization. Specific definitions of each unit and subunit are summarized in Table 6).

Table 6. Definitions of emergent wetland units and subunits used to characterize wetlands (White et al. 1983).

Unit/ Subunit	Definition
Salt-water Marshes	areas frequently flooded by tidal exchange via tidal channels and open waters of the bay-estuary-lagoon
Proximal	"more frequently flooded because of lower elevations and proximity to open water"
Distal	"less frequently flooded because of higher elevations and distal locations with respect to bay-estuary water"
Mangrove	"tend to grow along levees and higher zones of marshy islands but also occurs in lower areas"
Brackish-water Marshes	"transitional between the salt-water and fresh-water-influenced environments"
Fresh-water Marshes	receive freshwater flow from rivers, precipitation, runoff, and/or ground water; generally beyond the limits of salt-water flooding except during hurricanes
Low	"areas characterized by relatively frequent inundation as denoted by vegetation types and soil moisture or standing surface water"
High	"areas that appear to be less frequently flooded, having a drier wetland-plant assemblage and lower soil and surface moisture"
Undifferentiated Marshes	"sand or mud flats that have become colonized with marsh vegetation covering about 30 to 60 percent of their area"
Transitional	"those areas that, in terms of flooding and plant communities, are intermediate between wetland and upland areas…occasionally inundated but with less frequency and duration than are marshes"

This approach allowed for more detailed mapping of the wetlands within the study area than had previously been achieved. Each Unit/subunit was characterized by representative plant assemblages from emergent wetlands mapped during this study (Table 7). Several species are listed under different types of marshes, which is indicative of the variable tolerance levels of these species to flooding and salinity ranges. However, broad assemblages of plant species could be differentiated in relation to location and probability of flooding frequency.

Table 7. Emergent wetland units/subunits characterized by vegetation assemblages in the Corpus Christi area (modified from White et al. 1983).

Unit	Scientific Name	
Salt-water Marsh		
Proximal	*Spartina alterniflora*	*Borrichia frutescens*
	Batis maritima	*Suaeda* spp.
	Salicornia virginica	*Monanthochloe littoralis*
	S. bigelovii	*Avicennia germinans*
	Distichlis spicata	*Iva frutescens*
Distal	*Borrichia frutescens*	*Suaeda* spp.
	Monanthochloe littoralis	*Iva frutescens*
	D. spicata	*A. germinans*
Mangrove	*A. germinans*	
locally abundant	*Spartina spartinae*	*Spartina patens*
other species	*Lycium carolinianum*	*Sesuvium portulacastrum*
	Limonium nashii	*Heliotropium curassavicum*
	Sporobolus spp.	
Brackish-water Marsh		
Low marsh	*S. maritimus*	*Typha* spp.
	Scirpus americanus	*M. littoralis*
	Juncus spp.	*Salicornia* spp.
	Eleocharis spp.	*D. spicata*
High marsh	*S. spartina*	*Iva* spp.
	S. patens	*Iva frutescens*
	B. frutescens	*Sporobolus* spp.
	Phragmites australis	*D. spicata*
	Baccharis halimifolia	*L. nashii*
other species	*Cyperus* spp.	*Fimbristylis castanea*
	Sesuvium portulacastrum	*Hydrocotyle* spp.
	L. carolinianum	
Fresh-water Marsh		
Low marsh	*Typha. latifolia*	*Cyperus* spp.
	T. domingensis	*Bacopa monnieri*
	S. americanus	*Juncus* spp.
	Scirpus californicus	*Ludwigia* spp.
	P. australis	*Sagittaria* spp.
	Eleocharis spp.	*Paspalum lividum*
High marsh	*S. spartinae*	*Rhynchospora macrostachya*
	Paspalum spp.	*Fimbrystylis* spp.
	Polygonum spp.	*Aster spinosus*
	Panicum spp.	*S. patens*
	B. frutescens	
other species	*Leersia hexandra*	*Pontedaria* spp.
	Echinodorus spp.	*Sesbania drummondii*
	Eichhornia crassipes	*B. halimifolia*
	Rhynchospora spp.	*Cephalanthus occidentalis*
	Lemna spp.	*Salix nigra*
	Hydrocotyle spp.	*Parkinsonia aculeata*

Table 7 (continued).

Undifferentiated Marshes		
	Salicornia spp.	*L. nashii*
	B. maritima	*L. carolinanum*
	M. littoralis	*S. spartinae*
	Borrichia frutescens	*Spartina patens*
	Distichlis spicata	
Transitional Areas		
	Spartina spartinae	*Helianthus spp.*
	Cynodon dactylon	*Sorghum halepense*
	Borrichia frutescens	*Cassia fasciculata*
	Aster spinosus	*Cyperus spp.*
	Paspalum monostachyum	*Eleocharis spp.*
	Paspalum lividum	*Scirpus spp.*
	Panicum spp.	*Leersia hexandra*
	Rhynchospora spp.	*Croton spp.*
	Dichromena colorata	*Spartina patens*
	Andropogon virginicus	*Arundo donax*
	Iva annua	*Bluetaparon (=Philoxerus) vermicularis*
	Aristida spp.	*Baccharis halimifolia*
	Setaria spp.	*Sesbanis drummondii*
Fluvial and Flood-prone Woodlands		
	Parkinsonia aculeata	*Cephalanthus occidentalis*
	Acacia smallii (A. farnesiana)	*Carya illinoensis*
	Salix nigra	*Ilex vomitoria*
	Fraxinus spp.	*Quercus spp.*
	Ulmus crassifolia	*Sesbania spp.*
	Celtis spp.	*Tamarix spp.*
	Populus deltoides	

National Wetlands Inventory Classifications Descriptions

Most comparative studies of wetlands utilize the classification within *The Classification of Wetlands and Deepwater Habitats of the United States* (Cowardin et al. 1979) including those status and trends investigations of coastal and inland areas. This portion of the report follows both the Cowardin System definitions (Table 2), classification codes (Table 8), and subdivisions of salinity listed in White et al. (1983).

Table 8. Wetland codes and descriptions for wetlands with emergent vegetation (Cowardin et al. 1979).

NWI Code (Water Regime)	**NWI Description**	**Common Description**	**Characteristic Vegetation**
E2EM (P,N,)	Estuarine, intertidal emergent	Estuarine bay marshes, salt and brackish water	*Spartina alterniflora* *Spartina patens* *Distichlis spicata*
E2SS (N,P)	Estuarine, intertidal scrub/shrub	Estuarine shrubs	*Avicennia germinans* *Iva frutescens* *Baccharis halimifolia*
PEM (A,C,F,H)	Palustrine, emergent	Fresh-water marshes, meadows, depressions, or drainage areas	*Scirpus californicus* *Typha* spp.
PSS (A,C,F)	Palustrine, scrub/shrub	Willow thicket, river banks	*Salix nigra* *Sesbania drummondii*
PFO (A,C,F)	Palustrine, forested	Swamps, woodlands in floodplains, depressions, meadow rims	*Taxodium distichum* *Quercus* spp. *Fraxinus* spp.

Predominant Emergent Vegetation Communities in the Estuarine System

Chiltipin Creek High Marsh (E2EM1P)

Chiltipin Creek is located in the Aransas River watershed in San Patricio County. Extensive high marsh communities are associated with the floodplain of the creek prior to its confluence with the Aransas River. The wetland is a typical example of South Texas middle and high marsh plant communities, with unvegetated salt pans and several ephemeral brackish-water ponds located in the vegetated marsh matrix.

In this Estuarine, Intertidal, Emergent, Irregularly Flooded marsh: thirteen coastal marsh species have been documented: *D. spicata, M. littoralis, Salicornia virginica* (perennial glasswort), *S. bigelovii* (Annual glasswort), *Borrichia frutescens*, *Suaeda linearis*, *Limonium nashi* (sea lavender), *Scirpus maritimus*, *Batis maritima*, *Lycium carolinianum* (wolfberry), *Spartina spartinae*, and *Sporobolus virginicus* (coastal dropseed). Five dominance plant species (*D. spicata*, *B. frutescens*, *M littoralis*, *S. virginica*, and *B. maritima*) accounted for 98% of plants most frequently encountered (Tunnell et al. 1997).

Distichlis spicata, a native, disturbance-dependent perennial species, has the ability to tolerate and recover from various forms of disturbance (i.e., high salinities, temporary high water levels, uprooting from grazing) (Pethick, 1974, Bertness, 1991). Colonization typically occurs through vegetative expansion of adventitious runners from adjacent colonies, although establishment through seed germination may occur under the right conditions (Bertness et al. 1992).

Borrichia frutescens, a perennial shrub, or subshrub that can achieve heights of about 75 cm, is common on brackish, saline soils, mainly along bay beaches and in salt marshes (Jones, 1982). There is virtually no ecological information available about this species, although this clonally-propagating species appears to be affected by disturbance and high water levels (Tunnell et al. 1997).

Salicornia virginica, a low-growing, succulent perennial that can form dense mats or clumps, is common in salt marshes, tidal flats, and along bay and island beaches (Jones, 1982). *S. virginica* does not appear to be as affected by disturbance, although this species can expand quickly under good conditions but does appear to be negatively impacted by extended periods of high water (Tunnell et al. 1997).

Monanthochloe littoralis a native, warm-season perennial locally abundant on saline sites, is found both on sandy and muddy soils (Gould and Box, 1965). Relatively little is known about ecological requirements of this species, although it does not appear to tolerate extensive inundation or disturbance.

Batis maritima a semi-deciduous, succulent-leaved perennial exhibits considerable seasonal changes (Jones, 1982). Common along bay shores and in salt marshes or tidalflats, it expands into bare areas of the marsh by means of spreading or creeping stems.

This marsh is characteristic of high marsh vegetation assemblages where tidal water only reaches the marsh during spring tides or storm surges. Most species are perennials and tolerant of saline soil conditions. In most cases, they are able to maintain low standing crop biomass during inclement periods, and expand during optimum conditions. Zonation is not as obvious at a given time and the vegetation assemblage appears to be more of a mosaic of robust, perennial climax species, with the exception of *D. spicata*. This species rapidly colonizes areas of disturbance, therefore, its dominance is related to degree of disturbance (Tunnell et al. 1997).

Aransas National Wildlife Refuge Estuarine High Marsh (E2EMIP)

This refuge encompasses a diversity of wetland types utilized by a number of estuarine-dependent species, including the endangered Whooping Crane (*Grus americana*). In a larger evaluation of vegetation among natural sites and created sites, representative plant communities were determined for a high, brackish marsh on the mainland of the refuge (Darnell et al. 1997). The natural marsh was characterized by a series of semi-isolated tidal ponds typically dry during drought and low tide periods. Water retained in the ponds often evaporates over time resulting in increased salinities in the soils; therefore, little vegetation is present during most years in the pond. *Batis maritima, M. littoralis*, and *Salicornia* spp. were predominant in the marsh, comprising 77% of the plants recorded by the point-intercept method (Fig. 7). Several transects were located in each of three natural marshes, and high similarity values among the marshes reflected the low relief of the marsh surface. These species were locally abundant in patches reflecting microtopographic differences within the marsh (Fig. 8).

Black Point Estuarine Marsh at Copano Bay (E2EMIN, E2EMIP)

Extensive open water tidal ponds and associated vegetated estuarine marshes are located at the Aransas River Delta and its confluence with Copano Bay at Hwy 136 south of the town of Bayside. Eleven plant species were recorded in fall 1995, with five species representing 90% of the vegetated cover: *D. spicata, S. virginica, B. frutescens, B. maritima,* and *S. maritimus* (Wood et al. 1995). *Spartina alterniflora* was present near tidal openings and along the southern

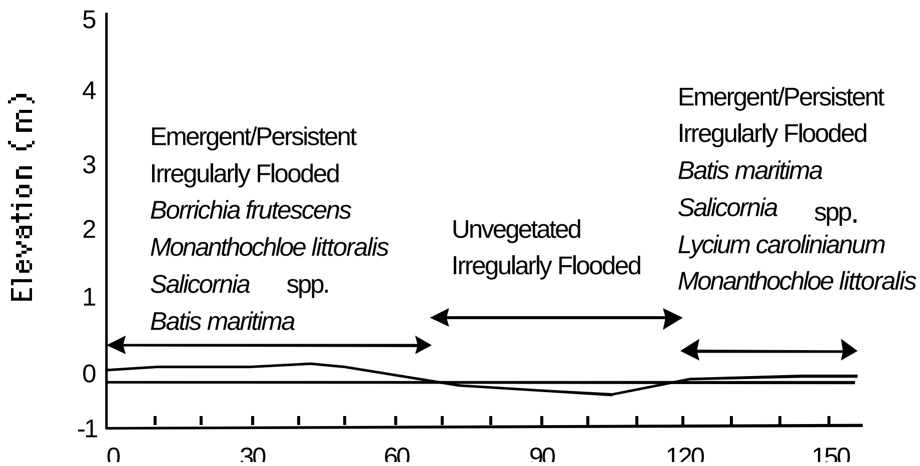

Figure 7. Profile of brackish, irregularly flooded marsh in Aransas National Wildlife Refuge showing relative elevations of plant communities through a marsh/ephemeral pond mosaic.

Figure 8. High brackish-marsh community on mainland of Aransas National Wildlife Refuge. Many salt-tolerant species share dominance including *Borrichia frutescens*, *Monanthochloe littoralis*,and *Lycium carolinianum*.

shorelines. Vegetation zonation was indicative of south Texas coastal salt marsh receiving adequate freshwater mixing with estuarine bay waters. *Spartina alterniflora* was present in intertidal, regularly flooded marsh zones (Fig. 9), while *D. spicata*, *S. maritimus*, and *S. virginica* were positioned in zones receiving irregular, estuarine flooding. Other species, such as *L. nashii, B. frutescens, Haplopappus phyllocephalus* (camphor daisy), and *Helianthus angustifolius* (Swamp Sunflower) were located at slightly higher elevations just below the road shoulder and higher shell berms on the Copano Bay shoreline.

Figure 9. Low salt-marsh community of *Spartina alterniflora* and open water at Black Point wetland near Bayside along Copano Bay, Refugio County, Texas.

Mustang Island Back Bay Marsh (E2EM1P)

This Estuarine Intertidal Emergent Irregularly Flooded marsh is located along the bay shorelines of Mustang Island. Results of three transects (Figs. 10-12) completed for this area illustrated the variability of dominant vegetation within this wetland type (Table 9).

Predominant plant species in Transect 1 (closest to a washover pass) included *M. littoralis* and *B. maritima*. Both *S. bigelovii* and *S. virginica* occurred in locally abundant patches, although not present in large, contiguous areas (Fig. 13). Plant dominance on Transect 2, was located in a densely vegetated area and included high frequencies of occurrence of *M. littoralis* and low frequencies of *S. spartinae, L. carolinianum,* and *S. virginica*. By comparison, Transect 3, the northernmost transect, had low frequencies of *S. virginicus, M. littoralis,* and *B. maritima* and even lower occurrence of *B. frutescens, L. carolinianum, S. patens,* and *S. spartinae*.

Spartina spartinae, a perennial grass species that grows in dense clumps (Gould, 1978), can form extensive meadows along coastal salt flats, coastal brackish marshlands and other lowland areas. *Lycium carolinianum* a spiny, semi-evergreen shrub with upright to spreading stems that produce red fruits during winter. This species is common along coastal marshes or in salt flats (Jones, 1982).

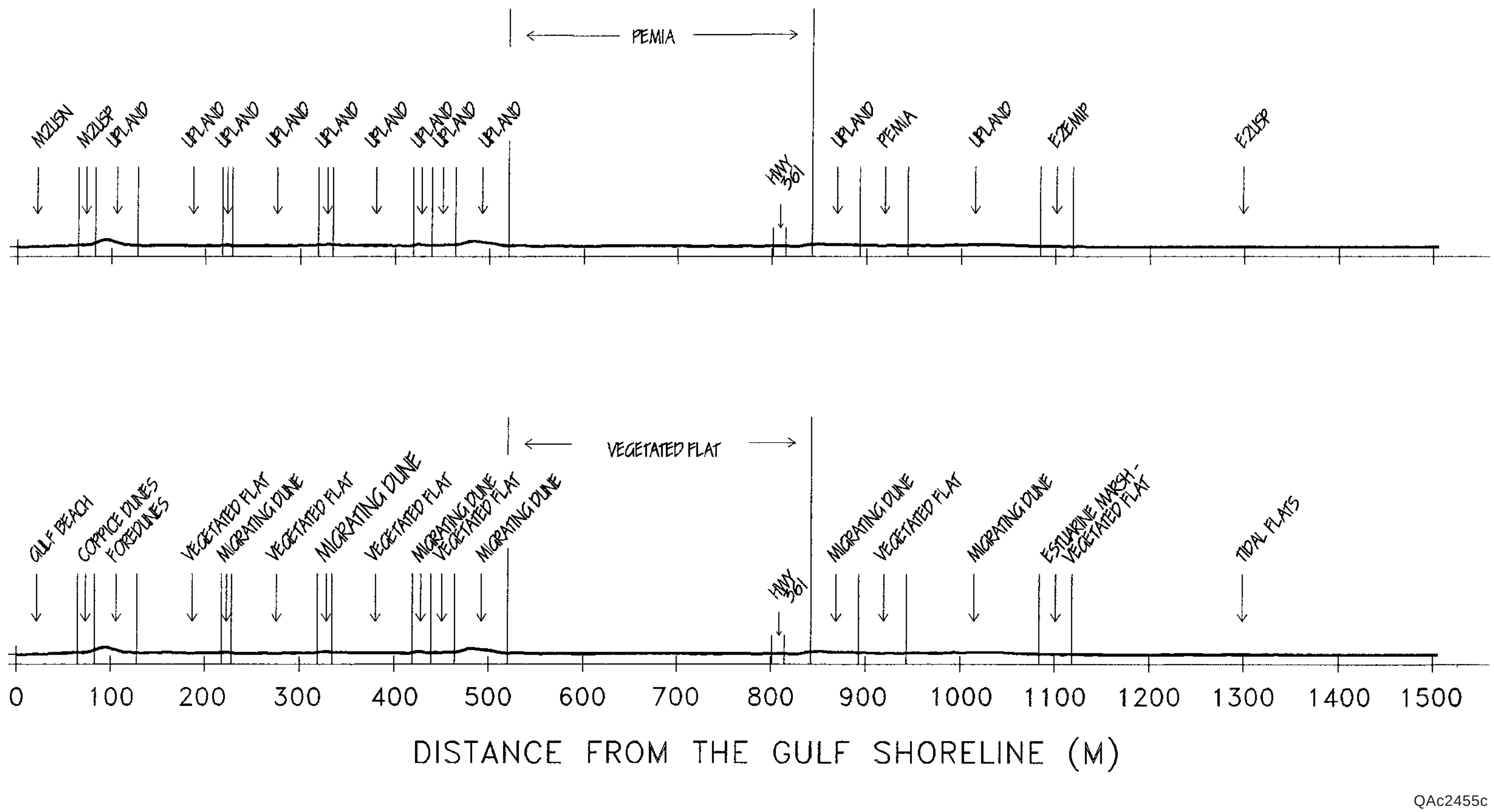

Figure 10. Elevation profile and wetland/upland communities along a cross-section of Mustang Island Transect 1, located north of Access Road 3.

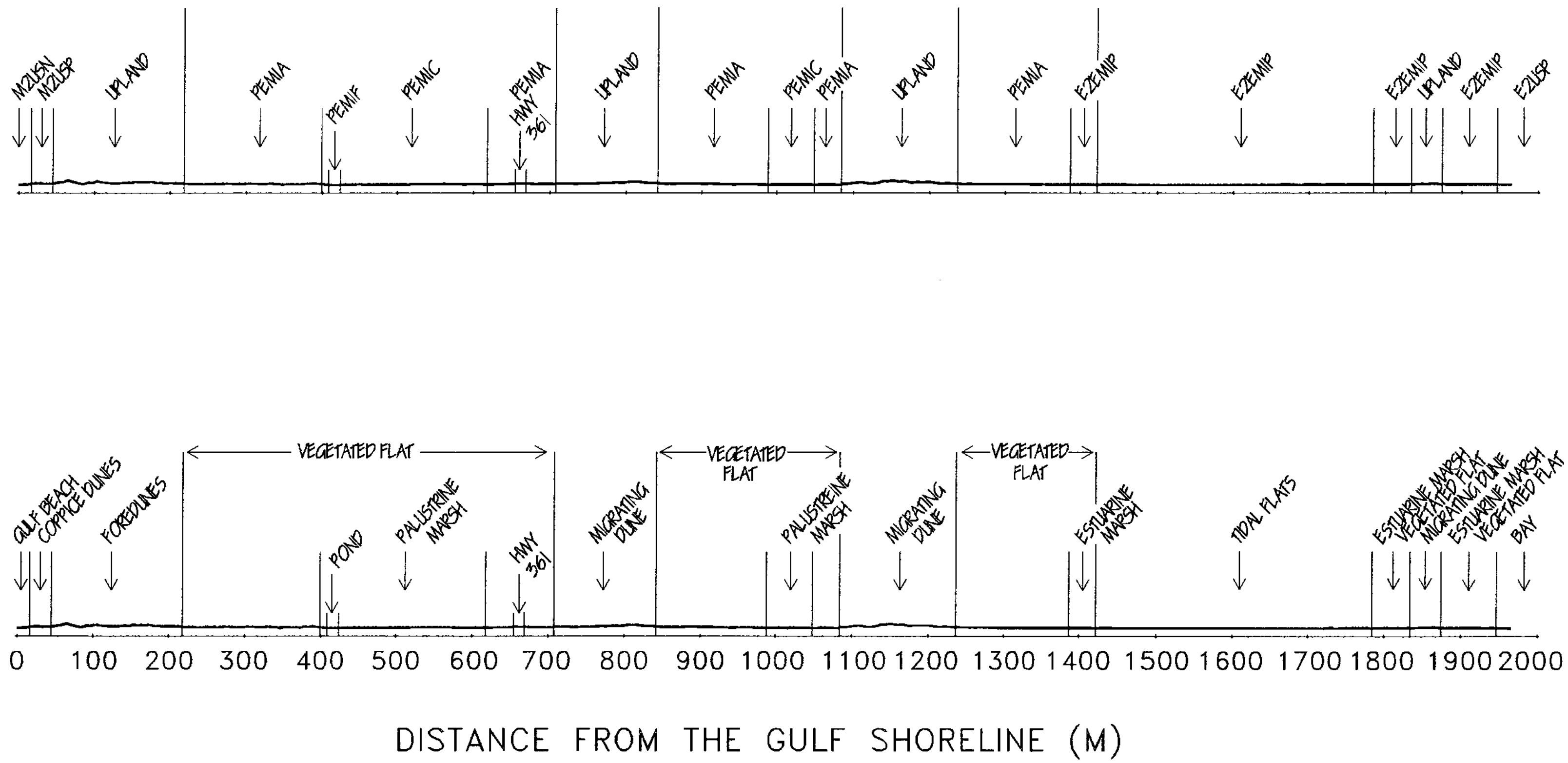

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Figure 11. Elevation profile and wetland/upland communities along a cross-section of Mustang Island Transect 2, located one mile south of Mustang Island State Park headquarters.

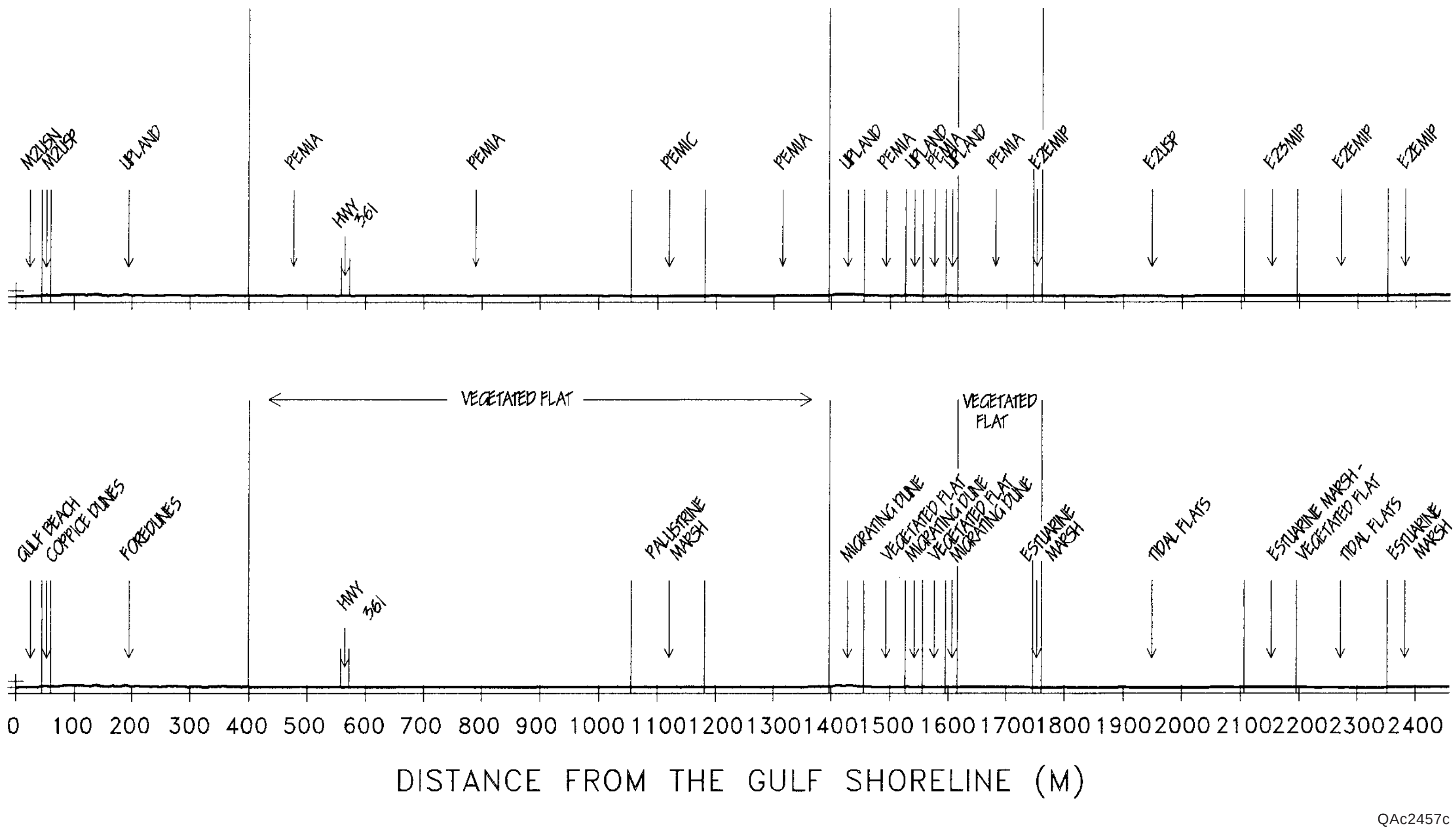

Figure 12. Elevation profile and wetland/upland communities along a cross-section of Mustang Island Transect 3, located north of Water Exchange Pass.

Table 9. Predominant plant species based on point-intercept sampling in Fall 1996 of the tidal flats zone on Mustang Island, Texas (modified from Jenkins et al. 1997).

Taxon	**#Points**	**#Live Readings**	**#Dead Readings**	**% Frequency**
Transect 1	78			
Batis maritima		15	0	19
Salicornia bigelovii		0	7	10
Monanthochloe littoralis		2	0	3
Transect 2	72			
M. littoralis		43	4	65
Spartina spartinae		2	0	3
Lycium carolinianum		4	1	7
Salicornia virginica		2	0	3
Transect 3	100			
Sporobolus virginicus		7	0	7
M. littoralis		8	2	10
B. maritima		17	0	17
Borrichia frutescens		3	0	3
L. carolinianum		2	0	2
Spartina patens		4	1	5
S. spartinae		3	1	4

Figure 13. High brackish marsh dominated by *Salicornia* spp. along the Corpus Christi Bay shoreline on Mustang Island.

A slightly different, more diverse plant assemblage occurred along the back shoreline of Mustang Island. This area was variably affected by extreme high storm tides that affected soil salinities and, thus, plant species dominance (Table 10). *Spartina patens* predominated in this high marsh, followed by *Fimbrystylis castanea*, *B. frutescens*, *Scirpus pungens*, *Paspalum monostachyum* (gulfdune paspalum), *Sporobolus virginicus*, and *Bluetaparon vermicularis* (silverhead).

Spartina patens is an erect or sometimes spreading perennial grass that can form monotypic stands, or it can be found in combination with other brackish marsh plants. This species is often documented in irregularly flooded brackish marshes, and tidal marshes, wet beaches, sand dunes and transitional borders of salt marshes. *Fimbrystylis castanea* was second in dominance on two of the transects and is a perennial sedge frequent in brackish or saline marshes, most often associated with barrier island flats (Jones, 1982). Generally, *F. castanea* and *S. pungens* are found in fresher soils than *B. frutescens*. *Paspalum monostachyum* is located within this area on slightly higher elevations, decreasing in frequency in lower swales. *Sporobolus virginicus* is a perennial grass species forming small clusters when well established. This species is most common on sandy soils in irregularly flooded estuarine marshes. *Bluetaparon vermicularis*, a perennial herb, expands by creeping stems and forms mats in moist, brackish or salty soils along beaches or in flats and marshes.

Table 10. Predominant plant species based on point-intercept sampling in Fall 1996 of the estuarine irregularly flooded, emergent marshes on Mustang Island, Texas (modified from Jenkins et al. 1997).

Taxon	**#Points**	**#Live Readings**	**#Dead Readings**	**% Frequency**
Transect 1	7			
Spartina patens		3	0	43
Borrichia frutescens		2	0	29
Scirpus pungens		0	0	0
Spartina spartinae		3	0	43
Transect 2	32			
S. patens		18	1	59
Fimbrystylis castanea		2	0	6
B. frutescens		4	0	13
Paspalum monostachyum		4	0	13
Sporobolus virginicus		6	0	19
S. pungens		3	0	9
Transect 3	21			
S. patens		12	2	67
F. castanea		1	2	14
Bluetaparon vermicularis		6	0	29
S. virginicus		5	0	24
B. frutescens		3	0	14

Predominant Emergent Vegetation in the Palustrine System

Mustang Island Fresh-Water Swales (PEM1A and PEMIC)

Vegetation communities located within vegetated flats on barrier islands respond to the amount of flooding they receive over several -year periods. Microtopography within this zone produces a series of undulating marshes locally affected by the moisture regime. Predominant species associated with areas temporarily flooded and seasonally flooded include *T. domingensis*, *S. pungens*, *Ipomoea sagittata* (saltmarsh morningglory), *Flaveria brownii* (longleaf flaveria), *Hydrocotyle bonariensis*, *B. frutescens*, and *Digitaria texana* (Texas crabgrass) (Table 11). Variability in frequency of occurrence was a result of the length of the transect that bisected palustrine marshes.

Table 11. Predominant plant species based on point-intercept sampling in Fall 1996 of palustrine, emergent, temporarily and seasonally flooded marshes on Mustang Island, Texas (modified from Jenkins et al. 1997).

Taxon	#Points	#Live Readings	#Dead Readings	% Frequency
Transect 2	56			
Typha domingensis		29	10	70
Scirpus pungens		15	1	29
Ipomoea sagittata		0	0	0
Flaveria brownii		9	0	16
Borrichia frutescens		7	0	13
Transect 3	25			
T. domingensis		10	3	52
S. pungens		7	0	28
Hydrocotyle bonariensis		0	0	0
Digitaria texana		13	0	52
F. brownii		6	0	12

Typha domingensis, a perennial species forms dense colonies in wet, fresh or brackish soils typical of ditches, swales, and marshes. This species has formed dense inpenetrable, monotypic stands within portions of the island interior (Fig. 14). *Scirpus pungens*, a perennial sedge forming colonies of triangular stems arising from hard and elongate rhizomes (Jones, 1982, Tiner, 1993). This species is frequent in low, fresh or brackish sands in depressions, swales and ditches.

Seasonally flooded and semipermanently flooded (PEMIF) marshes are also located within the island’s interior. Those wetlands that hold water most years are typically unvegetated and surrounded by emergent vegetation at the shallow edges (Fig. 14). These wetlands have been continuously inundated (~1 m) since 1995.

Figure 14. Fresh-marsh and open-water community on Mustang Island exhibiting both seasonally flooded and semipermanently flooded wetlands.

Fennessey Flats (PEMIA, PEMIC, PEMIF)

This palustrine wetland is located within one of the meanders of the Mission River in Refugio County and has some areas which are temporarily flooded, seasonally flooded, and semipermanently flooded (Fig. 15). This area encompasses about 500 acres of various wetland types, and depressional topography results in plant zonation ranging from transitional areas of *Leucosyris spinosa* (Mexican devil-weed) (previously *Aster spinosus*) and *Buchloë dactyloides* (buffalograss) downsloping to *S. spartinae*, then into *B. frutescens* and *L. carolinianum*. Water levels during this survey were located slightly below the monotypic zone of *S. californicus*. This species continued into the semipermanently flooded marsh to a water depth of about 15 cm, although it is presumed the wetland is typically at lower levels. No emergent, floating vegetation, or submergent vegetation was located at the lower end of the transect (Fig. 16).

Rob and Bessie Welder Wildlife Foundation Oxbow Lakes (PEMIC, PEMIF)

Two oxbow lakes are situated adjacent to the Aransas River within Welder Wildlife Refuge San Patricio County. They are typically flooded during most years, but dry out during droughts (Drawe et al. 1978). The vegetation responds to the wet/dry cycles and is characterized by persistent emergent vegetation capable of withstanding variable water regimes. Big Lake is about 52 ha in size, 1260 m long and 874 m wide and is bisected by a broken dike at the widest point with a 325 m X 152 m sand island in the center. Pollita Lake is 345 m northwest of Big Lake and is about 32 ha, and measures 893 m long and 305 m wide. Maximum sustained depths are

Figure 15. Saturated and temporarily flooded fresh-marsh community at Fennessey Flats adjacent to the Mission River in Refugio County. Predominant vegetation in foreground is *Spartina spartinae* with *Scirpus californicus* in background before riparian woodlands.

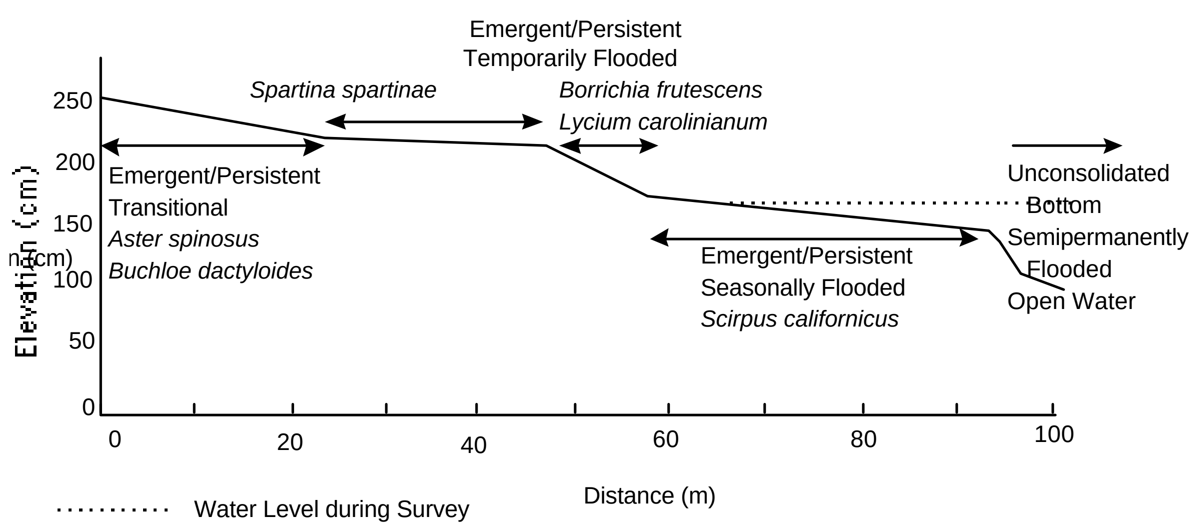

Figure 16. Profile of palustrine marsh in Fennessey Flats adjacent to Mission River, Refugio County showing elevations of plant communities in relation to degree of flooding.

typically 2 m, although these water levels are directly dependent upon direct precipitation and upland sheetflow runoff (Haigh, 1984). Water levels have been very high during this project and only visual observations could be undertaken. Many edge species characteristic of temporarily flooded marshes were barely emergent.

Predominant vegetation along lake margins is either dense stands of *T. domingensis* or *S. californicus* or open shoreline. Low swales associated with shallow shorelines included *S. drummondii*, *L. spinosa*, *Zizaniopsis miliacea* (Southern wildrice), *Echinodorus cordifolius* (burhead), and a few sedge species. Higher portions of the shoreline are dominated by *Paspalum* spp., *Panicum* spp., and *Leersia hexandra* (clubhead cutgrass). When water levels maintain deeper, open water areas, both lakes support dense stands of *Nelumbo lutea* (yellow lotus) and occasional patches of *Nymphea mexicana* (yellow water-lily) (Haigh, 1984). The islands in Big Lake have several tree species, *Acacia smallii* (Texas huisache), *Prosopis glandulosa* (mesquite), *Celtis pallida* (granjeno), *Celtis laevigata* (Texas sugarberry), and *Baccharis neglecta* (Roosevelt weed). Submergent and floating species documented during wet periods included *Ceratophyllum demersum* (coontail), *Zosterella dubia* (grassleaf mud-plantain) (previously *Heteranthera dubia*) and *Lemna minor* (duckweed) (Haigh, 1984). Other species documented during a wet year included *Ruppia maritima*, *Potamogeton pectinatus* (sago pondweed), and *Chara* spp. (muskgrass). During drought periods when even the deepest areas of the lakes are dry, vegetation is dominated by *Paspalum lividum* (longtom), *Neeragrostis reptans* (creeping lovegrass), and *Buchloe dactyloides* (Drawe et al. 1978).

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IV. STATUS OF WETLANDS AND AQUATIC HABITATS (1992)

Based on unadjusted NWI data for 1992, wetland and aquatic habitats covered an area of about 193,357 ha (excluding the marine open-water class) within 29 7.5-minute quadrangles that define the study area (Figs. 2 and 17). This constitutes 44 percent of the map area. Of the five wetland systems mapped (Fig. 4; Table 12), the estuarine system encompasses about 161,069 ha and represents approximately 37 percent of the total map area (Fig. 18). The palustrine system is second at 6 percent (26,580 ha), followed by the lacustrine, marine (excluding marine open water), and riverine (Table 12). Upland areas (245,162 ha) represent the remaining 56 percent of the total mapped area.

Vegetated wetlands (E2EM, E2SS, PEM, PEM/U, PFO, and PSS areas; excluding AB areas) cover about 48,350 ha, or 25 percent of the wetland and aquatic habitat system (excluding the marine open water or M1UB class). The marsh system (E2EM, PEM and PEM/U) (Fig. 19) is approximately 46,980 ha in size, or about 97 percent of the total vegetated wetland area. Estuarine subtidal environments and intertidal flats constitute 71 percent (138,210 ha) of the total area of wetland and deep-water habitats (193,360 ha). The extent of all mapped wetlands, deep-water habitats, and uplands for each year are presented in the Appendix.

A. Estuarine System

Estuarine Intertidal Emergent Wetlands

The estuarine intertidal emergent wetland habitat (E2EM) (marsh) consists of about 22,760 ha of salt and brackish marshes (Figs. 17 and 18; Table 12), which make up almost 47 percent of vegetated wetland habitats (emergent, scrub-shrub, and forested wetlands), and 49 percent of marsh habitats (emergent wetlands) in the Corpus Christi-Aransas Bay system.

The most extensive estuarine emergent wetlands occur (1) on the bayward side of barrier islands including Harbor Island, (2) in fluvial-deltaic areas of the Nueces, Mission and Aransas Rivers, and (3) along bayward shores of Blackjack Peninsula (Fig. 17). Four 7.5 minute quadrangles (St. Charles Bay, St. Charles Bay SE, St. Charles Bay SW, and Mesquite Bay) located in the northeast corner of the map area (Fig. 2) have an area of E2EM (salt marsh) that makes up 40 percent of all E2EM in the CCBNEP study area. The two most extensive occurrences of salt marsh occur on the broad washover fan complex on San José Island and on the Nueces River fluvial-deltaic system (Figs. 1 and 17).

Estuarine Intertidal Unconsolidated Shores and Aquatic Beds

Estuarine intertidal unconsolidated shores and intertidal aquatic beds (E2US, E2AB) include wind-tidal flats (designated as E2FL on 1950's and 1979 maps), beaches, and algal flats. Approximately 8,900 ha of E2US and E2AB were mapped in the CCBNEP area (Table 12). 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. 1976). These tidal habitats represent about 14 percent of the wetland system (excluding subtidal habitats, 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 considerably from that determined from aerial photographs.

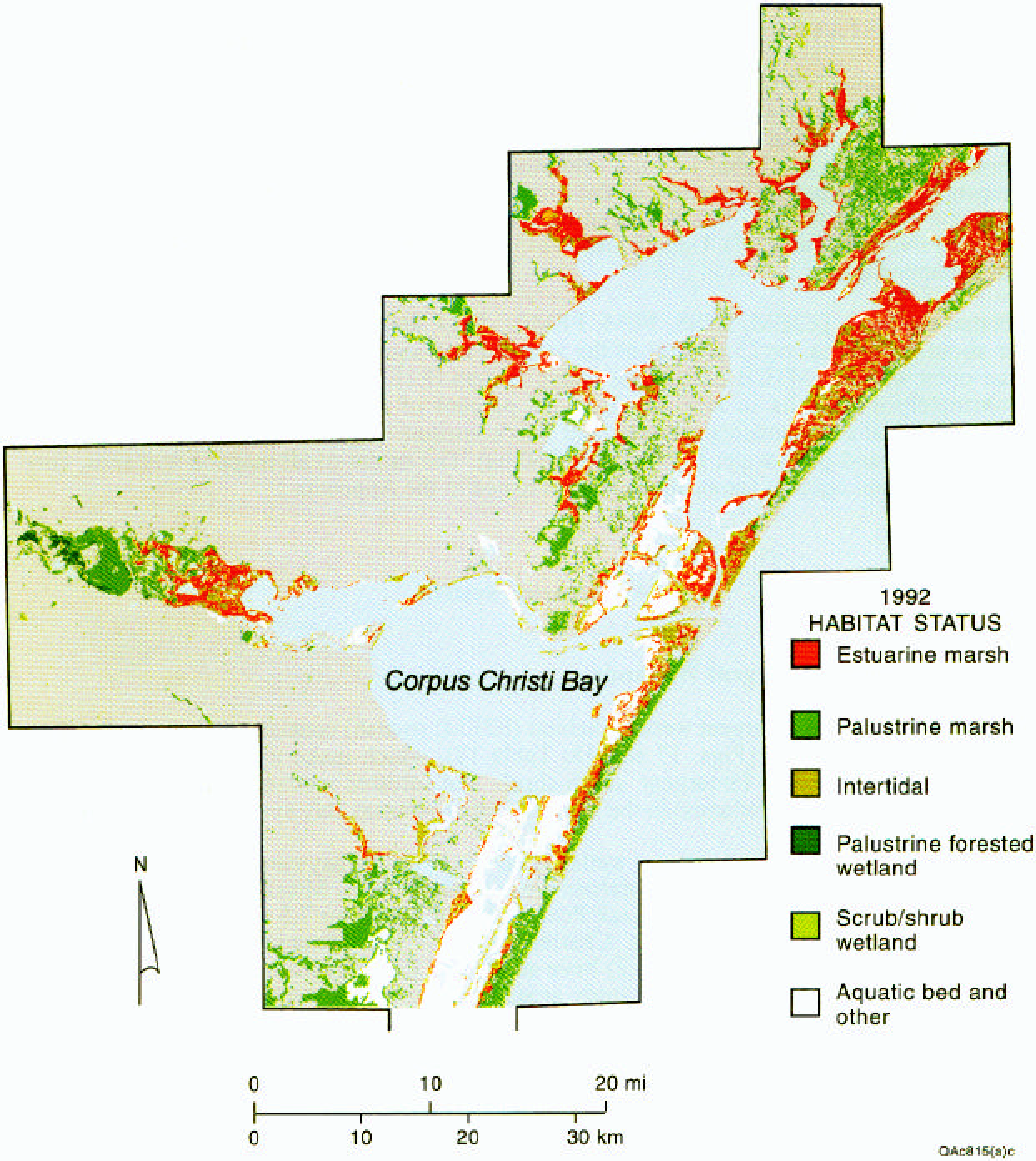

Figure 17. Distribution (1992) of wetland and aquatic habitats in the CCBNEP study area.

Table 12. Areal extent of mapped wetland and upland habitats in 1992. Based on compilation of habitat totals from NWI unadjusted digital data.

NWI CODE	**National Wetlands Inventory Description**	**Hectares**	**Acres**	**Percent**
E2EM	Estuarine Intertidal Emergent Vegetation	22,758	56,235	
E2SS	Estuarine Intertidal Scrub/Shrub Wetland	98	242	
E2FO	Estuarine Intertidal Forested Wetland	2	5	
E1AB	Estuarine Subtidal Aquatic Bed	18,727	46,274	
E1RF	Estuarine Subtidal Reef	31	77	
E2AB	Estuarine Intertidal Aquatic Bed	161	398	
E1UB	Estuarine Subtidal Unconsolidated Bottom	110,552	273,174	
E2US	Estuarine Intertidal Unconsolidated Shore	8,740	21,597	
	Total Estuarine System	161,069	398,001	37
PEM	Palustine Emergent Vegetation	23,292	57,555	
PEM/U	Palustrine Emergent Vegetation/Upland	537	1,327	
U/PEM	Upland/Palustrine Emergent Vegetation	392	969	
PSS	Palustrine Scrub/Shrub Wetland	527	1,302	
PFO	Palustrine Forested Wetland	743	1,836	
PAB	Palustrine Aquatic Bed	31	77	
PUB	Palustrine Unconsolidated Bottom	795	1,964	
PUS	Palustrine Unconsolidated Shore	263	650	
	Total Palustrine System	26,580	65,679	6
L1AB	Lacustrine Limnetic Aquatic Bed	22	54	
L2AB	Lacustrine Littoral Aquatic Bed	1,794	4,433	
L1UB	Lacustrine Limnetic Unconsolidated Bottom	1,557	3,847	
L2UB	Lacustrine Littoral Unconsolidated Bottom	8	20	
L2US	Lacustrine Limnetic Unconsolidated Shore	1,359	3,358	
	Total Lacustrine System	4,740	11,713	1
R1UB	Riverine Tidal Unconsolidated Bottom	4	10	
R2UB	Riverine Lower Perennial Unconsolidated Bottom	235	581	
R4SB	Riverine Intermittently Flooded Streambed	17	42	
	Total Riverine System	256	633	0.1
M2US	Marine Intertidal Unconsolidated Shore	716	1,769	0.2
U	Uplands	245,162	605,795	56
Total (Excluding Marine Unconsolidated Bottom-M1UB)		438,523	1,083,590	100

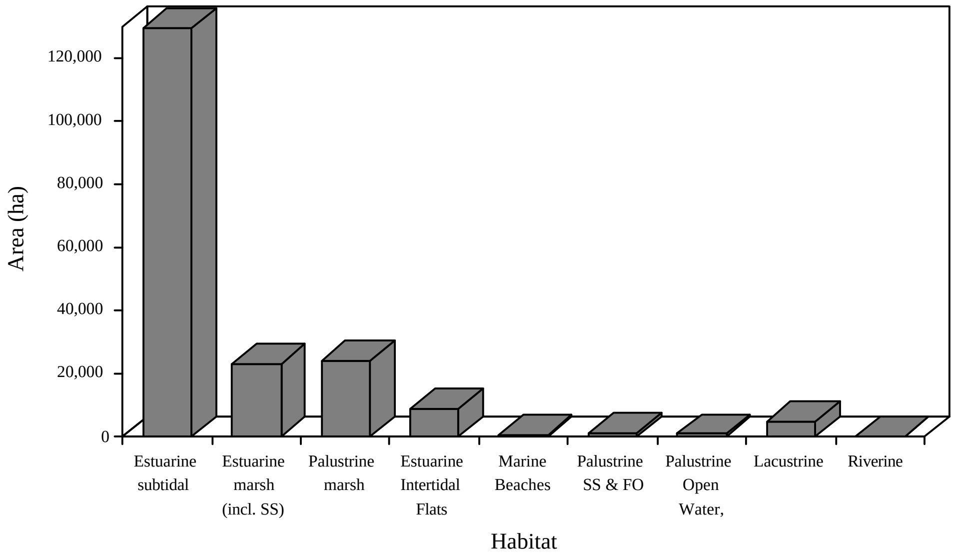

Figure 18. Graph showing areal extent of selected habitat classes and systems in the CCBNEP study area.

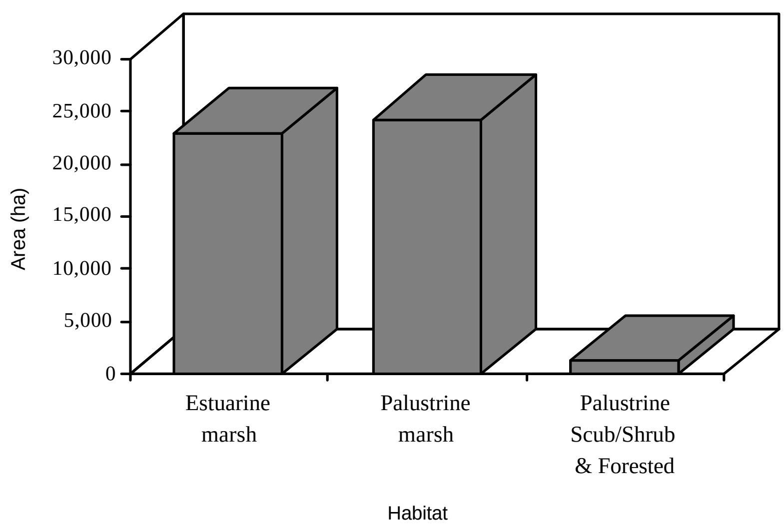

Figure 19. Graph showing areal extent of marshes and scrub/shrub–forested areas in the CCBNEP area.

Estuarine Intertidal Scrub/Shrub and Forested

The total area of mapped estuarine scrub-shrub wetlands (E2SS) in 1992 is approximately 100 ha. About 2 ha of estuarine forested habitat was mapped. Estuarine scrub-shrub habitat has broadest distribution on Harbor Island, where *Avicennia germinans* is abundant.

Estuarine Subtidal Aquatic Beds

Estuarine subtidal rooted vascular aquatic beds (E1AB3L) represent areas of submerged vascular vegetation, or seagrasses. Although this class was mapped as part of the NWI program using high-altitude aerial photographs, results are not presented here because of a more up-to-date and comprehensive analysis of seagrass beds by Pulich et al. (1997).

Estuarine Subtidal Unconsolidated Bottom

Estuarine subtidal unconsolidated bottom (open-water) habitat (E1UBL or E1OWL on 1950's and 1979 maps) is the heart of the estuarine system and consists principally of Corpus Christi, Nueces, Copano, and Aransas Bays, the northern tip of upper Laguna Madre, and associated smaller satellite bays and tidal lakes (Fig. 1). This habitat covers about 110,550 ha (Table 12). If other subtidal classes, such as subtidal aquatic beds and oyster reefs, are included with this class, the total area of subtidal estuarine habitats is 129,310 ha, about 67 percent of the wetland and deep-water habitat system (excluding M1UBL).

B. Palustrine System

Palustrine Emergent Wetlands

Palustrine emergent wetlands (PEM), or inland "freshwater marshes", cover approximately 24,220 ha (Figs. 18 and 19), and represent about 50 percent of the vegetated wetland system, and 51 percent of the marsh (emergent wetland) system. The broadest distribution of palustrine emergent wetlands is on the Pleistocene Barrier-Strandplain system (Blackjack Peninsula, Live Oak Peninsula/Ridge, and Encinal Peninsula), in inland areas of the Nueces River valley, and on Mustang and North Padre Islands (Figs. 1 and 17). In some areas, NWI maps include habitats designated as PEM/U (537 ha) and U/PEM (392 ha), which include palustrine emergent wetlands and uplands undifferentiated. This unit was mapped on the Pleistocene Barrier-Strandplain sands (Fig. 3) where complex, hummocky topography includes relict beach ridges and intervening swales, and eolian features characterized by blowouts, or deflation areas, and stabilized dunes. Within these areas is a complex network of wetlands juxtaposed with uplands that could not be adequately separated at the mapping scale of 1:24,000.

Palustrine Scrub-Shrub Wetlands

Palustrine scrub-shrub wetlands (PSS) total 527 ha (1 percent of vegetated wetlands). Most areas of scrub-shrub occur along rivers, bayous, and creeks, on the margins of reservoirs, and in relatively small depressions. The largest occurrence is in the Nueces River valley in the Edroy and Odem quadrangles.

Palustrine Forested Wetlands

The total area of forested wetland habitat (PFO) amounts to 743 ha, or about 1.5 percent of the vegetated wetland system . Forested wetlands are most extensive in the Nueces River valley in the Edroy quadrangle, where they make up more than 80 percent of the total PFO class in the CCBNEP study area.

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