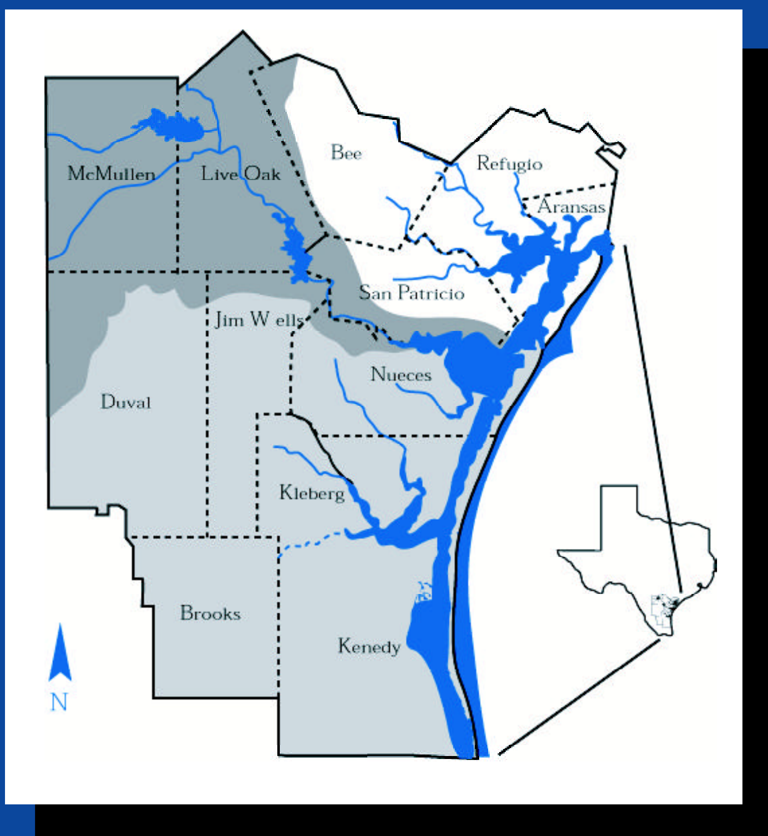
# Current Status and Historical Trends of the Estuarine Living Resources within the Corpus Christi Bay National Estuary Program Study Area

Volume 1 of 4




**Corpus Christi Bay National Estuary Program**

**CCBNEP-06A • January 1996**

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# Volume 1

# Current Status and Historical Trends of the Estuarine Living Resources within 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

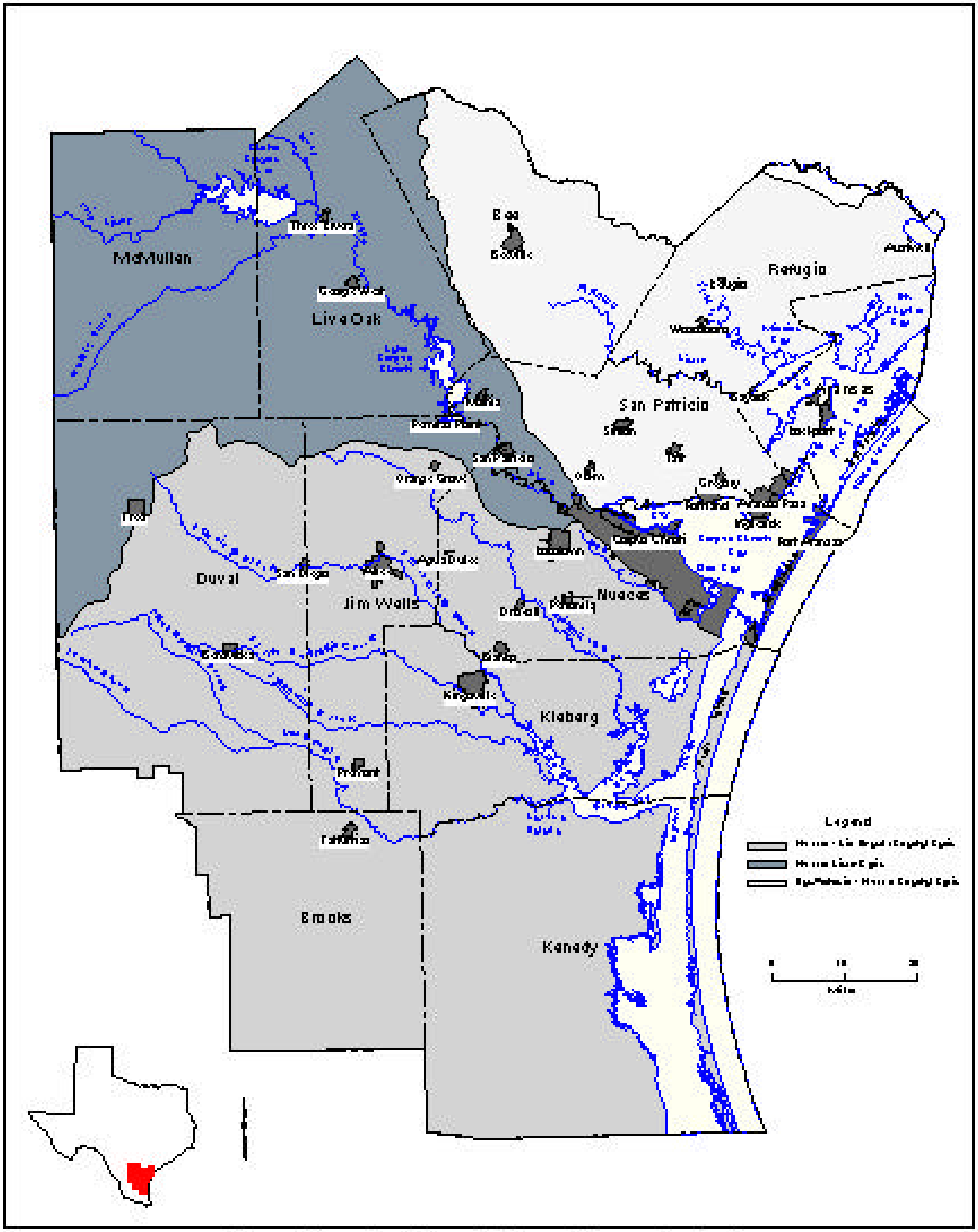
The CCBNEP study area includes three of the seven major estuary systems of the Texas Gulf Coast. These estuaries, the Aransas, Corpus Christi, and Upper Laguna Madre are shallow and biologically productive. Although connected, the estuaries are biogeographically distinct and increase in salinity from 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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# PREFACE

The summarization and analysis of the living resources of the Corpus Christi Bay National Estuary Program (CCBNEP) study area has been a rewarding, yet almost overwhelming task. However, now that a framework for the 3,178 species, eight major habitats, 49 protected species, and an introduced species is intact, it should become a standard resource tool for managers and scientists alike who deal with estuarine living resources within the Texas Coastal Bend. For resource managers, it should serve as a status reference of what is currently known, and to scientists, a challenge of what still needs to be done in areas of little or no information.

The overall organization and ecosystem approach of this review is presented as follows: the physical setting; the species; the habitats; the target organisms (i.e. species of concern, and trend-analyzed species); the probable causes of noted trends; and finally, the information gaps that have been identified.

Although the length of this report (1,442 pages in four volumes) is somewhat overwhelming, a complete review and presentation of current knowledge was necessary in order to address the many items requested in the original scope of work and to determine the probable causes and information gaps required in the contract. To make the document more "user friendly" to a broader audience, it is presented in four volumes, each of which can stand alone: Volume 1 (532 pages) - the main body and text; Volume 2 (496 pages) - the avian resources; Volume 3 (116 pages)- the project summary; and, Volume 4 (298 pages) - the species checklist, discussion, and conclusions. Each of these volumes have their own table of contents and literature cited. Likewise, within Volume 1, major sections can also be "pulled out" in chapter-type format (eg., habitat chapters, protected species, etc.) for use by the CCBNEP management conference members, or others.

Finally, there will undoubtedly be unintentional omissions discovered and refinements that will need to be made. Likewise, as new information becomes available, it should be incorporated, if this document is to remain as a working instrument for managers and researchers within the area. Consequently, it should be considered for review and update within five, but no longer than ten years.

John W. Tunnell, Jr.
January, 1996

# ACKNOWLEDGEMENTS

The *Current Status and Historical Trends of the Estuarine Living Resources within the Corpus Christi Bay National Estuary Program Study Area* represents a massive effort by several individuals and the collaborative effort of many. Foremost in the overall effort were Sandra Alvarado, Dr. Elizabeth Smith, and Dr. Kim Withers of the Center for Coastal Studies at Texas A&M University-Corpus Christi. Major contributions on larger sections of the report were contributed by Sharon Bartels, Gene Blacklock, and Dr. Allan Chaney (all of Ecoservices, Inc.), Susan Cox, Gene Douglas, Al Drumright, Bonnie Ponwith, and Dennis Rocha of the Center for Coastal Studies. Other contributors include Carl Beaver, Beau Hardegree, David Hicks, Gloria Krause, Dr. Roy and Robbie Lehman, Brien Nicolau, Ron Smith, Nicki Sohn, and Terri Wood.

Due to the amount of effort given by certain individuals, we would like to designate authorship within Volume 1 as follows for certain sections of the report:

Open Bay - Gene Douglas
Hard Substrate - Sandra Alvarado
Oyster Reefs - Al Drumright
Seagrass Meadows - Kim Withers
Coastal Marshes - Elizabeth Smith
Tidal Flats - Kim Withers
Barrier Islands - Elizabeth Smith
Gulf Beaches - Dennis Rocha
Species of Concern- Elizabeth Smith
Status of the Brown Mussel - David Hicks
Fishery Resources - Bonnie Ponwith and Quenton Dokken

Major compilers of Volume 3, the species checklist, include:

Algae - Roy Lehman and Terri Wood
Vascular Plants - Elizabeth Smith
Porifera, Cnidaria, and Ctenophora - Ron Smith
Annelida - Gene Douglas
Mollusca - Sandra Alvarado
Arthropoda - Dennis Rocha, Sandra Alvarado, and Kendall Kelley
Echinodermata - Sandra Alvarado and Dennis Rocha
Fish - Carl Beaver, Susan Cox, and Bonnie Ponwith
Amphibians, Reptiles and Mammals - Elizabeth Smith
Birds - Allan Chaney, Sharon Bartels, and Gene Blacklock

Part of the design and implementation, suggestions on content, and final review included Project Consultants and Technical Advisors, a team of local academic and agency experts on living resources within the Texas Coastal Bend, including:

University of Texas, Marine Science Institute
Dr. Ed Buskey
Dr. Ken Dunton
Dr. Paul Montagna
Mr. Scott Holt

Texas A&M University-Corpus Christi, Biology Department
Dr. David McKee

Texas A&M University, Wildlife and Fisheries Science Department
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Texas Parks and Wildlife Department, Resource Protection Division
Mr. Lee Elliott

National Biological Service, Southern Science Center
Dr. Chris Onuf
Ms. Donna Shaver

U.S. Fish and Wildlife Service, Ecological Services
Ms. Karen Meyers

The species checklist, Volume 3, benefited greatly by review and comment by over 20 taxonomic specialists from around the United States. These are individually listed with their affiliation in the checklist volume and are gratefully acknowledged.

The Corpus Christi Bay National Estuary Program office gave policy and management guidance via a designated team for this project, including Dr. Hudson DeYoe, Project Coordinator; Larry McEachron, Designated Reviewer; and Laura Radde, EPA Project Officer. Larry McEachron in turn chaired the Designated Review Team of Robyn Cobb, Dr. Bob Edwards, Bill Fuls, and Rick Medina. All of these people, along with Mr. Ray Allen, reviewed the May 1995 Draft Report.

We gratefully acknowledge and extend our appreciation to all of the authors, compilers, reviewers, consultants, and technical advisors for their time and commitment to making this project a success. We especially thank Larry McEachron for his detailed and constructive review and comments.

John W. Tunnell, Jr. and Quenton R. Dokken
Principal Investigators
CCBNEP Living Resources Project

Center for Coastal Studies
Texas A&M University-Corpus Christi

January 1996

# EXECUTIVE SUMMARY

Living resources within the Corpus Christi Bay National Estuary Program (CCBNEP) study area are recognized as "unique and valuable resources which require protection" (CCBNEP, 1994a). The 121 km (75 mi) coastline of the Coastal Bend extends across three different bay systems and demonstrates a gradient of north to south climatic and aquatic conditions. The northern Mission-Aransas Estuary is brackish and subhumid, with salt marshes, oyster reefs, and fringing grass beds, while the southern Laguna Madre is hypersaline and semiarid, with vast expanses of shallow water and dense seagrass beds. The Nueces Estuary lies between these sparsely populated areas and supports the second largest human population on Texas estuarine shorelines.

The Living Resources Project involved a "holistic" or ecosystem level characterization of the living resources of the CCBNEP study area. This approach required a compilation of all known species of the area, as well as an examination of their habitats and their ecological roles or functioning. Protected species, designated as threatened or endangered, as well as introduced or exotic species were also characterized. During and after this information gathering and status characterization phase of the project, which included extensive review of published and unpublished literature, a final determination was made on the probable causes of recognized trends in populations of species, as well as information gaps about the species or their habitats.

A total of 3,178 species of plants and animals are listed in the checklist (Volume 4) of species from the CCBNEP study area estuarine waters and islands. The list includes 836 species of plants from seven different divisions, and 2,342 species of animals from 23 phyla. The largest group of plants is the diatoms, a phytoplankton group, with 341 species. Of the animals there are 1,418 invertebrates and 924 vertebrates. Eighty-five percent of all the invertebrates are found within three major phyla: Arthropoda (insects, crabs, shrimp, etc., 633 species), Annelida (segmented worms, with 289), and Mollusca (seashells, 230). Vertebrates are dominated by birds (494 species) and fish (234), with smaller numbers of reptiles (87), mammals (79), and amphibians (30).

Nationally and internationally renowned taxonomists who reviewed the prepared checklist, as well as recent literature on marine biodiversity, indicate that the CCBNEP species list should be considerably larger, probably as high as 4,000-5,000 species, or more. There is an obvious lack of information on many of the lesser-known or smaller sized groups of marine invertebrates and phytoplankton.

Predominant estuarine and island habitats within the CCBNEP study area include: Open Bay, Hard Substrates (jetties, groins, etc.), Oyster Reefs, Seagrass Meadows, Coastal Marshes, Tidal Flats, Barrier Islands, and Gulf Beaches. The Open Bay and Seagrass Meadow habitats have the largest number of species and have been the most studied. Oyster Reefs have many associated species but have been little studied, except for the oyster itself as a commercial commodity. Hard Substrates, Coastal Marshes, and Tidal Flats within the CCBNEP study area have not been studied much.

The Open Bay and Seagrass habitats have been impacted or altered primarily by dredging, channelization, and anthropogenic inputs. Oyster Reefs have been virtually eliminated from Nueces Bay by mudshell dredging, but they appear to be doing well in the Mission-Aransas

Estuary. Barrier Islands and Gulf Beaches are mostly affected by commercial development related to recreation and tourism and by oil spills.

Target organisms requiring special attention include fishery and avian resources (the only groups amenable to trend analysis), "protected species", and exotic or introduced species. Fishery resources were characterized via fishery dependent data acquired and analyzed from Texas Parks and Wildlife annual reports between 1972 and 1993, which revealed trend shifts of dockside commercial landings in shrimp and fish, but fairly consistent crab harvests. Shrimp harvest more than tripled from 1.8 million pounds in 1972 to 6.0 million pounds in 1993, while finfish harvest diminished. Changes in consumer demand and fishery regulations make it difficult to determine if changes harvest trends reflect changes in population abundances. Other trends in the commercial fishery, as well as recreational fishery are evident, and can usually be correlated with regulatory changes. Impacts to the fishery have been caused by opening and closing barrier island inlets, freezes, algal blooms, hypersalinity in the Laguna Madre, rainfall and floods, and hurricanes. Current management and conservation issues include harvest regulations, water management, finfish stock enhancement, and coastal zone management.

Avian resources of the CCBNEP study area include 494 species of birds, which were characterized utilizing three datasets for historical trends, the Texas Colonial Waterbird Counts, and two National Audubon Society Christmas Bird Counts: Aransas National Wildlife Refuge (38 years) and Corpus Christi (31 years). Although no overall trends for all birds collectively were identified, positive, negative, and neutral trends were determined for individual species. Over 400 trend analyses were run on the various species, and 101 species or groups are discussed individually with reasons for trends suggested. Colonial nesting waterbirds generally have decreasing nesting populations and stable or increasing winter populations. Loss and degradation of nesting habitats, and disturbance by humans are cited as causes for negative trends. Positive trends seen in most wintering waterfowl are generally attributed to increased national populations and available habitat. Stable to positive trends are seen with most shorebirds. Neotropical migrants within the CCBNEP study area mostly show stable to positive trends, although these data must be used with caution since the US Fish and Wildlife Services has declared major downward trends in many species nationally due to loss of habitat throughout their range.

Forty-nine species within the 12-county CCBNEP study area are Federally Listed as Endangered, Threatened, or Candidate species. Nineteen of these live in estuarine areas, including one plant (roughseed purslane), five sea turtles (Kemp's ridley, loggerhead, green, hawksbill, leatherback), one marsh turtle (Texas diamondback terrapin), one marsh snake (Gulf Coast salt marsh snake), and 11 birds (Brown Pelican, Reddish Egret, White-faced Ibis, Whooping Crane, American Peregrine Falcon, Piping Plover, Western Snowy Plover, Eskimo Curlew, Interior Least Tern, Loggerhead Shrike). The Whooping Crane and Brown Pelican show increasing population trends due to intensive management, while others are decreasing for various reasons, usually habitat degradation or loss. The status and trends of endangered, estuarine-obligate birds (Whooping Crane, Brown Pelican, Piping Plover, Interior Least Tern, and Eskimo Curlew) and sea turtles are summarized. In most cases, there is insufficient information to establish the status or trends of other species.

Of the exotic or introduced species, only the edible brown mussel is found in coastal waters, but the fire ant is also established on dredge material islands, occasionally impacting nesting success of colonial waterbirds.

The most widely cited probable causes of declining trends in certain species or groups of the CCBNEP study area are degradation and loss of habitat. Within the estuary, dredging has probably been the single largest cause of negative impact. However, some beneficial uses of dredging activity include lower salinity due to better circulation in the Laguna Madre and creation of colonial nesting waterbird habitat on dredge material islands. Most recently, habitat creation, restoration, or enhancement is being attempted with some dredge material. On the land agricultural, industrial, and municipal activities have caused the most degradation and loss of habitat. Increasing trends in human population levels in the Coastal Bend will likewise increase environmental stresses to natural populations, such as freshwater demand, increased liquid and solid waste, and habitat stresses.

Summarization of knowledge gaps indicates that more appears to be known about the physical environment than the biological component of the CCBNEP study area. Least is known about the ecological processes and linkages between systems, as well as the biology and taxonomy of the smaller-sized, lesser-known invertebrates and plants. Especially lacking are long-term datasets which are necessary for scientists and managers alike to monitor and identify trends in natural populations, other than birds and fish.

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# LIST OF ACRONYMS

| | |
|---|---|
| ABA | American Birding Association |
| ACOE (USACOE) | Army Corp of Engineers |
| ADU | American Ornithological Union |
| ANWR | Aransas National Wildlife Refuge |
| AWP | Aransas Wood Buffalo Population (Whooping Crane) |
| BEG | Bureau of Economic Geology |
| CBC | Christmas Bird Counts |
| CCBNEP | Corpus Christi Bay National Estuary Program |
| CCS | Center for Coastal Studies |
| CCW | Corpus Christi (Audubon Christmas Bird Count area) |
| CL | Carapace Length (in turtles) |
| CWS | Canadian Wildlife Service |
| EPA (USEPA) | Environmental Protection Agency |
| GIS | Geographic Information System |
| GIWW | Gulf Intracoastal Waterway |
| GLO | Texas General Land Office |
| HEART | Help Endangered Animals - - Ridley Turtles |
| INP | Instituto Nacional de Pesca (of Mexico) |
| IGW | Inshore Gulf Waters |
| MARPOL | Marine Pollution Treaty |
| MMRP | Marine Mammal Research Program |
| MOU | Memorandum of Understanding |
| NMFS | National Marine Fisheries Service |
| NPS | National Park Service |
| NOAA | National Oceanic and Atmospheric Administration |
| PA/CC | Port Aransas and Corpus Christi (regions) |
| PI | Principal Investigator |
| PINS | Padre Island National Seashore |
| QA | Quality Assurance |
| TAMU-CC | Texas A&M University - Corpus Christi |
| TCWS | Texas Colonical Waterbird Surveys |
| TDWR | Texas Department of Water Resources |
| TEAS | Texas Agricultural Experiment Station |
| TED | Turtle Excluder Device |
| TGFC | Texas Game and Fish Commission |
| TGFOC | Texas Game, Fish and Oyster Commission |
| TMMSN | Texas Marine Mammal Stranding Network |
| TNRCC | Texas Natural Resource Conservation Commission |
| TPWD | Texas Parks and Wildlife Department |
| TWC | Texas Water Commission |
| TWDB | Texas Water Development Board |
| USGS | United States Geological Survey |
| USFWS | United States Fish and Wildlife Service |
| USVI | United States Virgin Islands |
| UTMSI | University of Texas Marine Science Institute |
| YBP | Years Before Present |

Table of Contents



# I. Introduction: The Living Resources Project

The "Status of Living Resources" was identified as a potential Priority Problem in the Governor's 1992 Nomination of Corpus Christi Bay as an "Estuary of National Significance" (TWC, 1992). Subsequently, the living resources within the Corpus Christi Bay National Estuary Program (CCBNEP) study area were recognized as "unique and valuable resources which required protection" (CCBNEP, 1994a). Within the 12-county area known locally as the Texas Coastal Bend, the 121 km (75 mi) coastline extends across three different bay systems. Like the entire Texas coast, this smaller segment demonstrates a gradient in climatic and aquatic conditions from north to south. The northern Mission-Aransas Estuary, winter territory for the endangered Whooping Crane, is a brackish water, subhumid area, compared to the hypersaline, semiarid conditions of the Laguna Madre in the southern portion of the study area with vast shallow-water seagrass beds. Between these sparsely populated areas lies the Nueces Estuary with the second largest human population on an estuarine shoreline in Texas (CCBNEP, 1994a).

The citizens of the Coastal Bend began expressing concerns about the declining environmental conditions that have appeared in recent years. The ability to catch a fish on a weekend trip, walk on a clean beach, or eat an oyster from the bay was no longer a certainty (CCBNEP, 1994a). Likewise, the appearance of a red tide and a persistent brown tide suggested that non-point source nutrients were of significant concern. Declines in commercial and recreational landings coinciding with increasing fishing pressure indicated conflicting trends. Finally, the impact on local biota and habitats caused by the occurrence of oil spills and accidental discharges has created some concern (CCBNEP, 1994a).

Knowledge of these issues "up-front" (before nomination) and significant commitment by state and local agencies is why the CCBNEP was chosen as one of the first National Estuary Programs (NEP) to use the "streamlined approach" for development of a Comprehensive Conservation and Management Plan (CCMP) (CCBNEP, 1994b). After the initial Planning Phase, including establishment of the five Management Conference committees, the Characterization Phase began with 11 characterization projects. The main focus of these initial studies was to identify and characterize the estuaries' problems and their probable causes. The Scientific and Technical Advisory Committee (STAC), composed of about 70 scientific and technical experts, drafted the Scopes of Work for all 11 projects via subcommittees. All projects were to adhere to the objectives or elements: 1) determination of trends; 2) identification of probable causes; and 3) identification of critical missing data. Each project would follow specific directives in the Scope of Work within the Request for Proposals to contractors.

Major tasks for the Living Resources Project included:

1) **Literature Survey** of estuarine living resources, both published and unpublished;

2) **Data Acquisition** for determining temporal and spatial variability and, where possible, statistically significant changes in abundance and distribution of populations of estuarine species, including key/selected species from the following groups:

a. decomposers;
b. marine algae, seagrasses, and marine plants;
c. phytoplankton and zooplankton;
d. benthos in marshes and open bays;
e. molluscs and other invertebrates;
f-1. larval fish in the plankton and nursery grounds (i.e., seagrass beds);
f-2. nekton including commercially, recreationally, and ecologically important fin fish and shellfish (i.e. shrimp, blue crab);
g. amphibians and reptiles;
h. migratory waterfowl and shorebirds;
i. colonial nesting birds;
j. neotropical songbirds;
k. marine mammals;
l. endangered, threatened, and candidate species of birds, amphibians, reptiles, and mammals;
m. exotic and introduced species.

Data sets amenable to trend analyses were to include those "collected at near regular intervals over a period of at least five years". Other datasets of shorter duration were to be identified;

3) **Data Analysis and Trend Determination** to determine current status and historical spatial and temporal trends of estuarine living resources. Datasets with sufficient data for statistical or trend analyses were to be used to identify potential problems as indicated by significant declines (in favorable species) or increases (for nuisance or exotic species) in abundance;

4) **Identification of Probable Causes** for changes or trends in living resources; and finally,

5) **Identification of Data and Information Gaps** as a result of those analyses.

The Principal Investigators at the Center for Coastal Studies, Texas A&M University-Corpus Christi determined that a team approach was the only feasible way to address the enormous number of species and issues to be dealt with in the Living Resources Project. Likewise, it was decided that a "holistic" or ecosystem level approach would be best for characterizing and ultimately determining probable causes and information gaps. These decisions were based on the philosophy that we should know and understand the whole system and how it functions in order to best manage its resources, rather than manage specific parts without knowing interrelationships within the system. Ultimately, this turned out to be almost overwhelming in magnitude, but we believe it produced a multifaceted product for all concerned with the “health” of the CCBNEP area.
If this ecosystem approach is compared to other NEPs, it is unique, since most focused on "selected" or "key" living resources (Galveston Bay NEP, Delaware Estuary Program), some focused on "resources at risk" (Long Island Sound Study), and others had no separate living resource project (Tampa Bay NEP). Another unique and complicating aspect of the CCBNEP is the fact that it covers

three estuarine systems rather than a single estuary. Only the Delaware Inland Bays NEP includes three separate systems, but they do not range from brackish to hypersaline (EPA, 1992). Finally, no other NEP has produced a comprehensive species checklist, including references, habitat distribution, and relative abundance.

Living resources are defined in this document as living plants and animals. However, in our ecosystem approach, we have also placed great importance on the habitats where these plants and animals live, and therefore, have described them also.

## II. Study Area: The Physical Environment and Overview

### A. Geographical Setting and Estuarine Classification

The CCBNEP study area closely aligns with what is identified as the Texas Coastal Bend (Fig. II.1). A testament to the unique and diverse biota of the area is the number of research centers dedicated mostly, or at least in-part, to studying the area: Caesar Kleberg Wildlife Research Institute at Texas A&M University-Kingsville, Center for Coastal Studies at Texas A&M University-Corpus Christi, Welder Wildlife Refuge near Sinton, and the University of Texas Marine Science Institute located in Port Aransas, in addition to the numerous state and federal offices concerned with conservation issues. Likewise, several books have been dedicated solely to particular taxonomic groups (although all terrestrial) of the Coastal Bend (Gould and Box, 1965; Jones, 1975; Rappole and Blacklock, 1985).

Geographically, the Coastal Bend has been variously defined. Generally, it refers to the curvature or bend in the central Texas coastline. Gould and Box (1965) used the term to describe the "trade territory" around the city of Corpus Christi, encompassing from north to south the coastal counties of Calhoun, Refugio, Aransas, San Patricio, Nueces, and the northeastern half of Kleberg. This definition included five major estuarine systems, including the Lavaca Estuary, Guadalupe Estuary, Mission-Aransas Estuary, Nueces Estuary, and the Baffin Bay-Upper Laguna Madre system. Alternatively, Jones (1975) set the limits of the Coastal Bend from the vicinity of San Antonio Bay (Guadalupe Estuary) curving southward along the coastline to Baffin Bay or somewhat beyond. Jones included all of Refugio, Aransas, San Patricio, Nueces, and Kleberg counties in his coverage, as well as portions of Jim Wells, Goliad, Bee, Live Oak, Brooks, Kenedy, Victoria, and Calhoun. Rappole and Blacklock (1985) define the Coastal Bend specifically as the county lines of Refugio, Goliad, Bee, Live Oak, Jim Wells, and Kleberg in the north, west, and south, respectively, and the Gulf of México shoreline in the east.

Politically, the Coastal Bend includes the twelve-county area encompassed by the Coastal Bend Council of Governments: Aransas, Bee, Brooks, Duval, Jim Wells, Kenedy, Kleberg, Live Oak, McMullen, Nueces, Refugio, and San Patricio. The CCBNEP study area similarly, encompasses all or part of these twelve counties, extending from the eastern edge of Mesquite Bay in the north to the southern limit of “The Hole” or northern edge of the Land-Cut in the Laguna Madre (Fig. II.1).

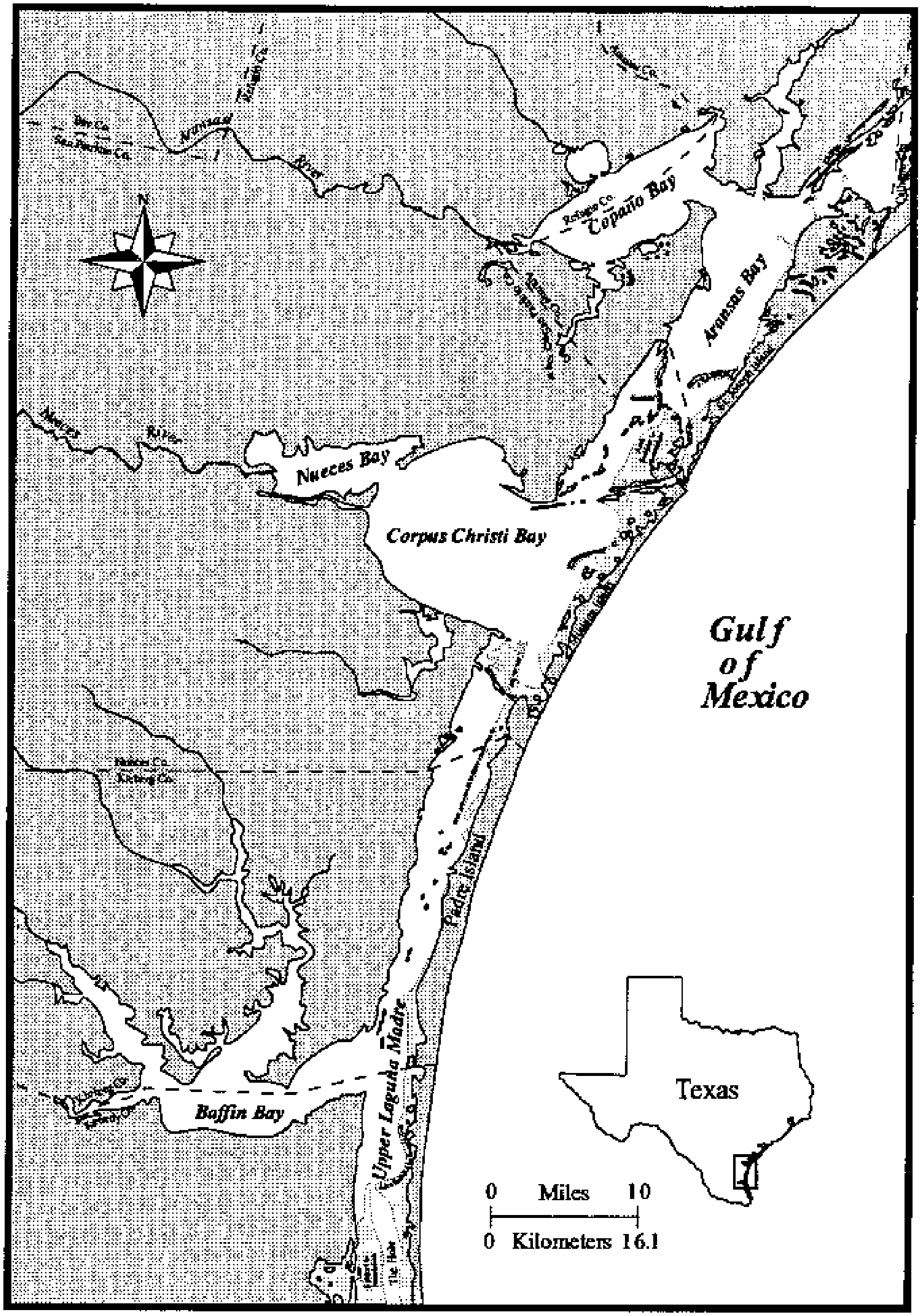



Fig. II.1. The estuarine portion of the Corpus Christi Bay National Estuary Program Study Area extending from Mesquite Bay and southern Matagorda Island in the north through the entire upper Laguna Madre to the Landcut in the south.

Living resources of the CCBNEP are the theme of this report; however, understanding the unique geographical location, geological history, and climatic conditions are paramount to grasping the biological diversity of the region. The study area is at the crossroads of species from east and west, as well as from north and south. Rappole and Blacklock (1985) note the Coastal Bend is the richest bird country in North America north of the tropics. The great diversity of species encountered in the area is also due to the wide array of land and aquatic habitat types: arid chaparral, lush riparian forests, oak savannas, oxbow lakes and swales, river deltas, coastal marshes and ponds, oyster reefs, open bay bottoms, barrier islands, jetties and other hard substrates, and sandy beaches.

Of the seven major open bay, estuarine systems on the Texas coast, three are located within the CCBNEP study area: Mission-Aransas Estuary (Aransas-Copano Bay System), Nueces Estuary (Nueces-Corpus Christi Bay System), and upper Laguna Madre Estuary (Upper Laguna Madre System, including Baffin Bay) (Diener, 1975; TWDB, 1981, 1983; Henley and Rauschuber 1981; Armstrong, 1987) (Fig. II.1). These three estuarine systems have three drainage basins: San Antonio-Nueces Coastal Basin in the north; Nueces River Basin centrally located; and Nueces-Rio Grande Coastal Basin to the south (TNRCC/TCRP, 1994; Alan Plummer and Assoc., 1994) (Fig. II.2). There is some contribution from all three drainage basins into the Nueces Estuary, but the most southerly part of the study area below Baffin Bay has no riverine drainage into Laguna Madre (Brown, et al. 1977). The San Antonio-Nueces Coastal Basin and northeastern portion (CCBNEP drainage area) of the Nueces-Rio Grande Coastal Basin are small in size and drain only Coastal Plain, Pleistocene Age sediments. The Nueces River Basin starts in the Cretaceous Age, Edwards Plateau limestone of Central Texas. Extensive information on all aspects of these three drainage basins is presented in the Texas Natural Resources Conservation Commission, Clean Rivers Program (TNRCC, 1994; Alan Plummer and Assoc., 1994).

The San Antonio-Nueces Coastal Basin has a drainage area of 6,868 $km^2$ (2,652 $mi^2$). Main tributaries include the Mission River, which discharges into Mission Bay, and the Aransas River, discharging into Copano Bay. Other minor streams empty into Copano, Aransas, and St. Charles bays (Henley and Rauschuber, 1981; TNRCC, 1994).

The Nueces River Basin, largest of the three within the study area, has a drainage area of 43,900 $km^2$ (16,950 $mi^2$). Principle streams include the Atascosa and Frio Rivers, which flow into Choke Canyon Reservoir, and the Nueces River which flows into Lake Corpus Christi. Choke Canyon Reservoir flows into the Nueces River above Lake Corpus Christi (Henley and Rauschuber, 1981; Alan Plummer and Assoc., 1994).

Having the most southerly influence on the CCBNEP study area, the Nueces-Rio Grande Coastal Basin has a large drainage area and encompasses most of South Texas south of the Nueces River Basin extending to the Rio Grande. However, only the very northeastern portion of this drainage, about 7752 $km^2$ (2993 $mi^2$), empties into Baffin Bay and upper Laguna Madre. Intermittent streams of Los Olmos, Santa Gertrudis, San Fernando, and Petronila Creeks drain into various branches of Baffin Bay. Oso Creek drains into Oso Bay (TNRCC, 1994).

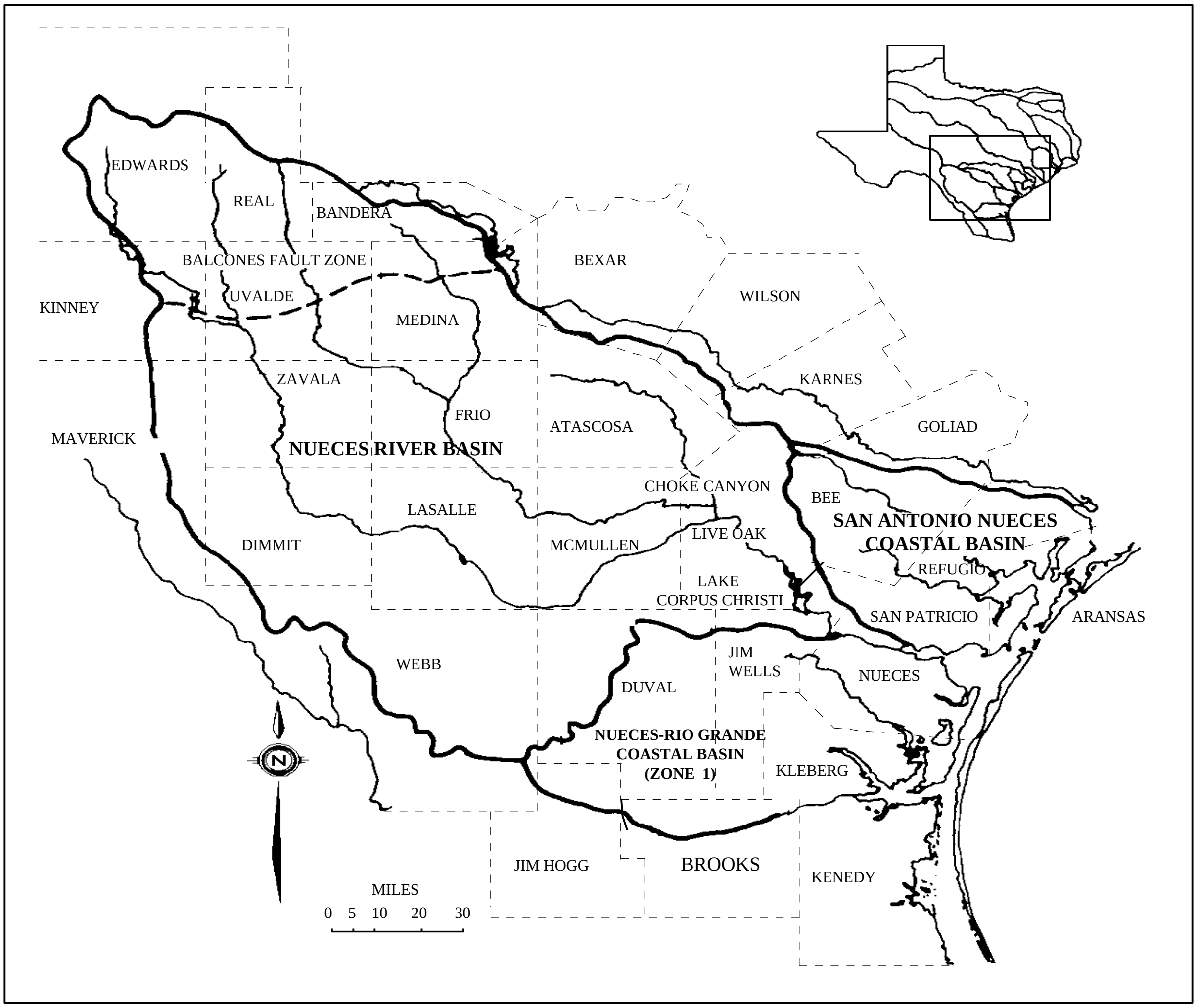



Fig. II.2. Three drainage basins that contribute to the CCBNEP study area (adapted from Henley and Rauschuber, 1981).

Major and minor bays of the CCBNEP study area are listed in Table II.1; areal coverage is presented in Table II.2. The entire estuarine area totals 132,867 hectares (328,320 acres) or 1330 $km^2$ (514 $mi^2$). The estuarine system is bounded on the east by four barrier islands from north to south: Matagorda, St. Joseph, Mustang, and Padre islands. Only one major pass (Aransas Pass) connects the bay systems to the Gulf of México. Aransas Pass is the major jettied entrance to the Corpus Christi Ship Channel. A second jettied inlet is called the Corpus Christi Water-Exchange Pass (locally known as Fish Pass), but it closed shortly after its opening in 1972 (Behrens et al., 1977). Corpus Christi Pass, a natural tidal inlet between Mustang Island and Padre Island, now known as Packery Channel, has been closed since 1929 (Brown et al., 1976a). It, along with Newport and Corpus Christi (new) Passes are ephemeral channels across the barrier islands and are open only after severe storms or hurricanes (Brown et al., 1976a).

Table II.1. Major and minor bays and coastal lakes within the CCBNEP study area.

| Aransas Estuary | Nueces Estuary | Baffin Bay-Laguna Madre |
|---|---|---|
| Aransas Bay | Corpus Christi Bay | Alazan Bay |
| Carlos Bay | Nueces Bay | Baffin Bay |
| Copano Bay | Oso Bay | Cayo del Grullo |
| Little Bay | Redfish Bay | Cayo del Infernillo |
| Mission Bay | Sunset Lake | Laguna Salada |
| Mission Lake | | Upper Laguna Madre |
| *Mesquite Bay | | |
| Port Bay | | |
| South Bay | | |
| Salt Lake | | |
| St. Charles Bay | | |
| Sundown Bay | | |
| Swan Lake | | |

* Mesquite Bay is normally considered part of the San Antonio Bay system, but it is included herein as part of the CCBNEP study area.

To the north, Cedar Bayou lies between Matagorda Island and St. Joseph Island and connects Mesquite Bay, the most northerly part of the study area, with the Gulf of México. Historical records reveal Cedar Bayou has alternately opened and closed (Brown et al., 1976b).

At the most northerly and southerly ends of the CCBNEP study area, Mesquite Bay connects with Ayres Bay and the San Antonio Estuary; upper Laguna Madre connects via the Intracoastal Waterway through the Land-Cut to Redfish Bay in the lower Laguna Madre system. Details of each of the three estuarine systems within the CCBNEP study area are presented in Figure II.3 (Aransas Estuary), Figure II.4 (Nueces Estuary), and Figure II.5 (Upper Laguna Madre).

In terms of Pritchard's (1967) geomorphic classification of estuaries Copano, Nueces-Corpus Christi, and Baffin Bay, which are all perpendicular to the coastline, are coastal plain estuaries, composed of drowned river valleys. Aransas and Redfish bays and upper Laguna Madre are all considered bar-built estuaries and are oriented parallel to the coast. Pritchard (1967) defines an estuary as "a semi-enclosed coastal body of water having a free connection to the open sea and within which sea-water is measurably diluted with fresh water derived from land drainage". This definition applies well with the Mission-Aransas Estuary and the Nueces Estuary, but is not always

Table II.2. Areal coverage of major water bodies within CCBNEP study area at mean low water (from Diener, 1975).

| System/Bay | $mi^2$ | $km^2$ | Acres | Hectares |
|---|---|---|---|---|
| **Aransas Estuary** | 188.2 | 486.4 | 119,960 | 48,547 |
| Aransas Bay | 88 | 228 | 56,220 | 22,752 |
| Copano Bay | 65 | 169 | 41,740 | 16,892 |
| Mesquite Bay | 13 | 33 | 8,080 | 3,270 |
| Mission Bay | 6 | 15 | 3,760 | 1,522 |
| Mission Lake | 0.2 | 0.4 | 100 | 40 |
| Port Bay | 3 | 7 | 1,650 | 668 |
| St. Charles Bay | 13 | 34 | 8,410 | 3,403 |
| **Nueces Estuary** | 167 | 434 | 106,990 | 43,298 |
| Corpus Christi Bay | 115 | 299 | 73,820 | 29,874 |
| Nueces Bay | 29 | 75 | 18,470 | 7,475 |
| Oso Bay | 8 | 21 | 5,070 | 2,052 |
| Redfish Bay | 15 | 39 | 9,630 | 3,897 |
| **Baffin Bay/Upper Laguna Madre** | 159 | 410 | 101,370 | 41,022 |
| Alazan Bay | 22 | 56 | 13,860 | 5,609 |
| Baffin Bay | 50 | 129 | 31,870 | 12,897 |
| Cayo del Grullo | 7 | 18 | 4,470 | 1,809 |
| Cayo del Infernillo | 1 | 3 | 700 | 283 |
| Laguna Salada | 5 | 13 | 3,230 | 1,307 |
| Upper Laguna Madre | 74 | 191 | 47,240 | 19,117 |
| **CCBNEP Study Area** | 514.2 | 1,330.4 | 328,320 | 132,867 |

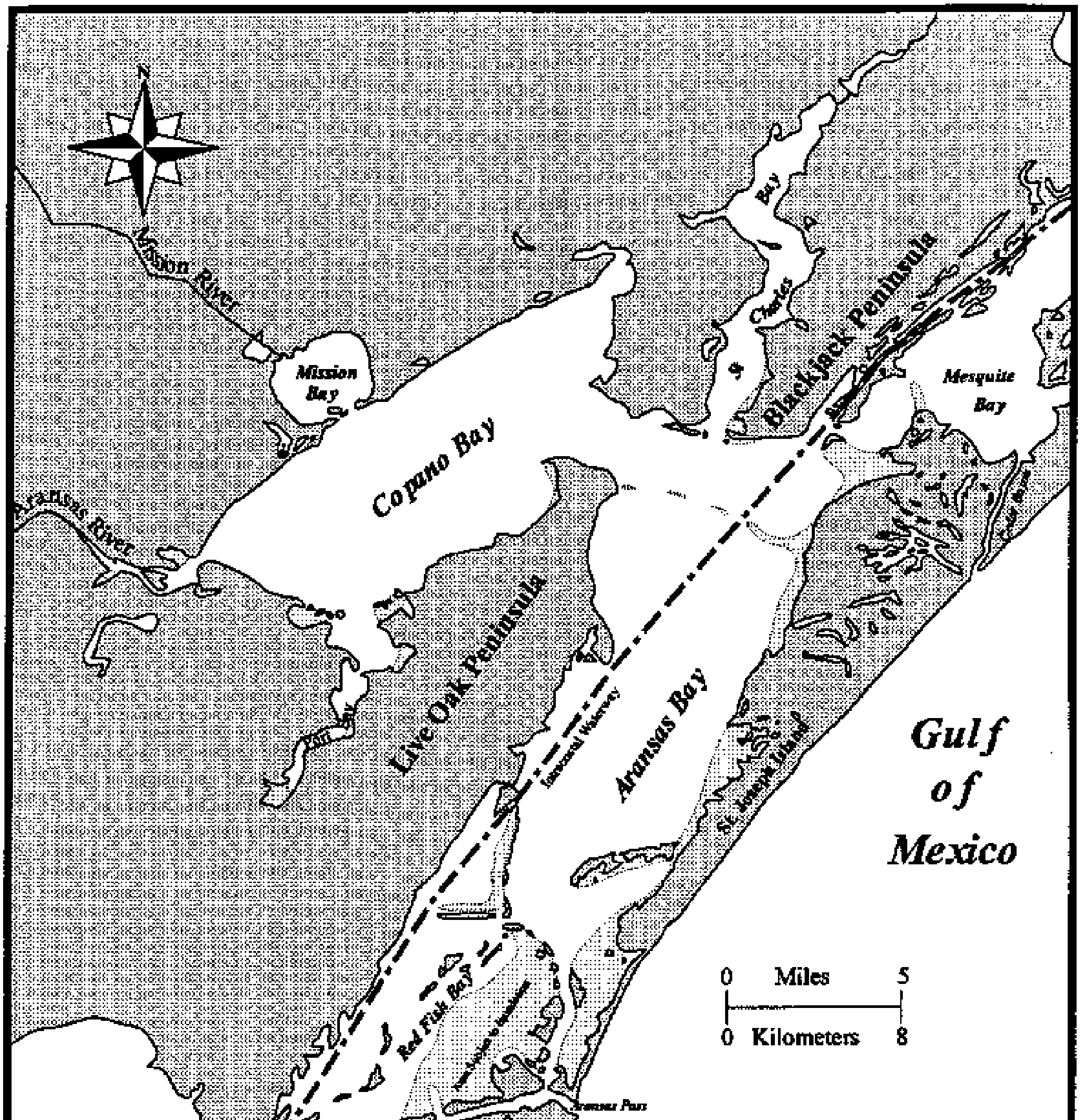



Fig. II.3. Mission-Aransas Estuary portion of CCBNEP study area.

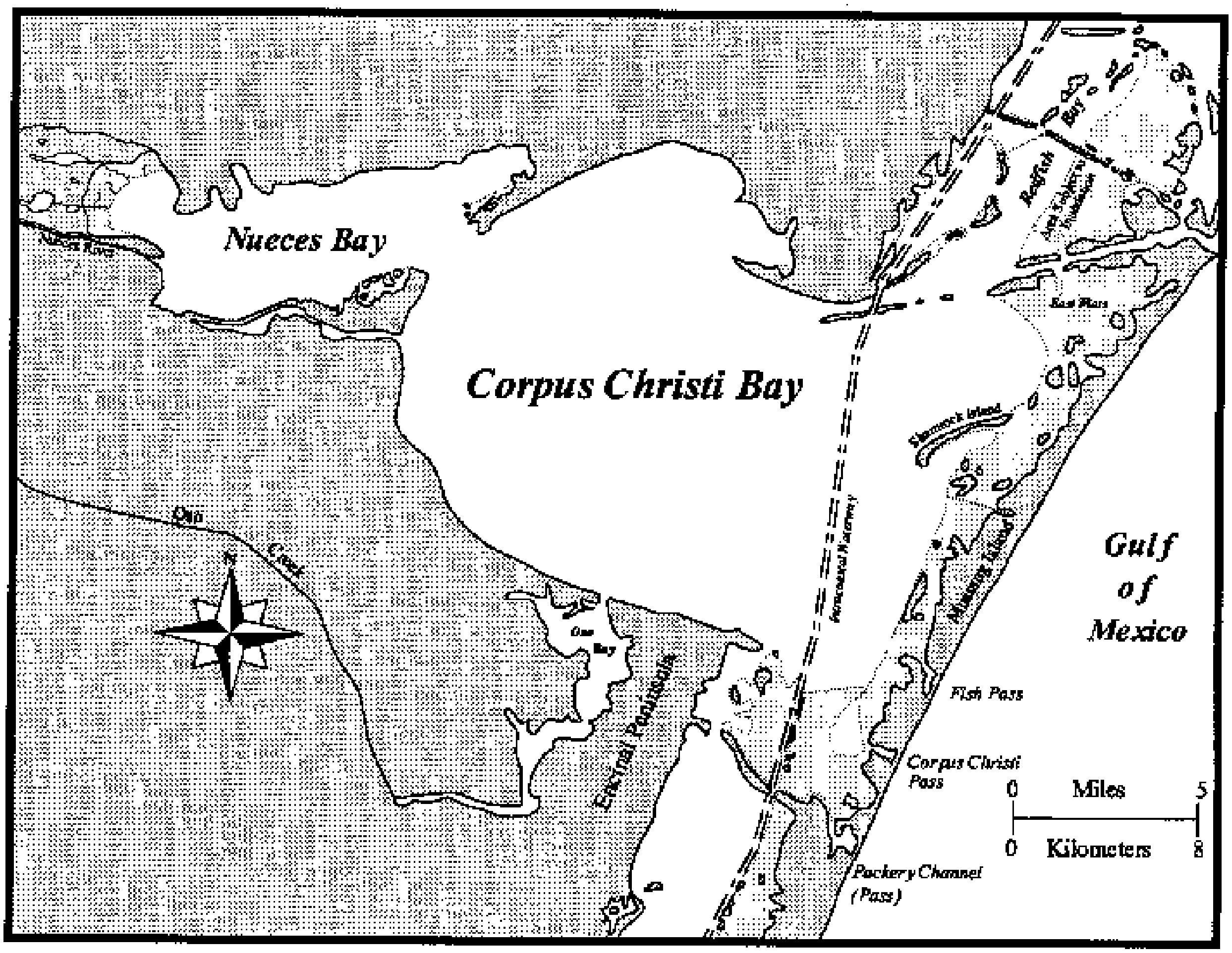



Fig. II.4. Nueces Estuary portion of CCBNEP study area.

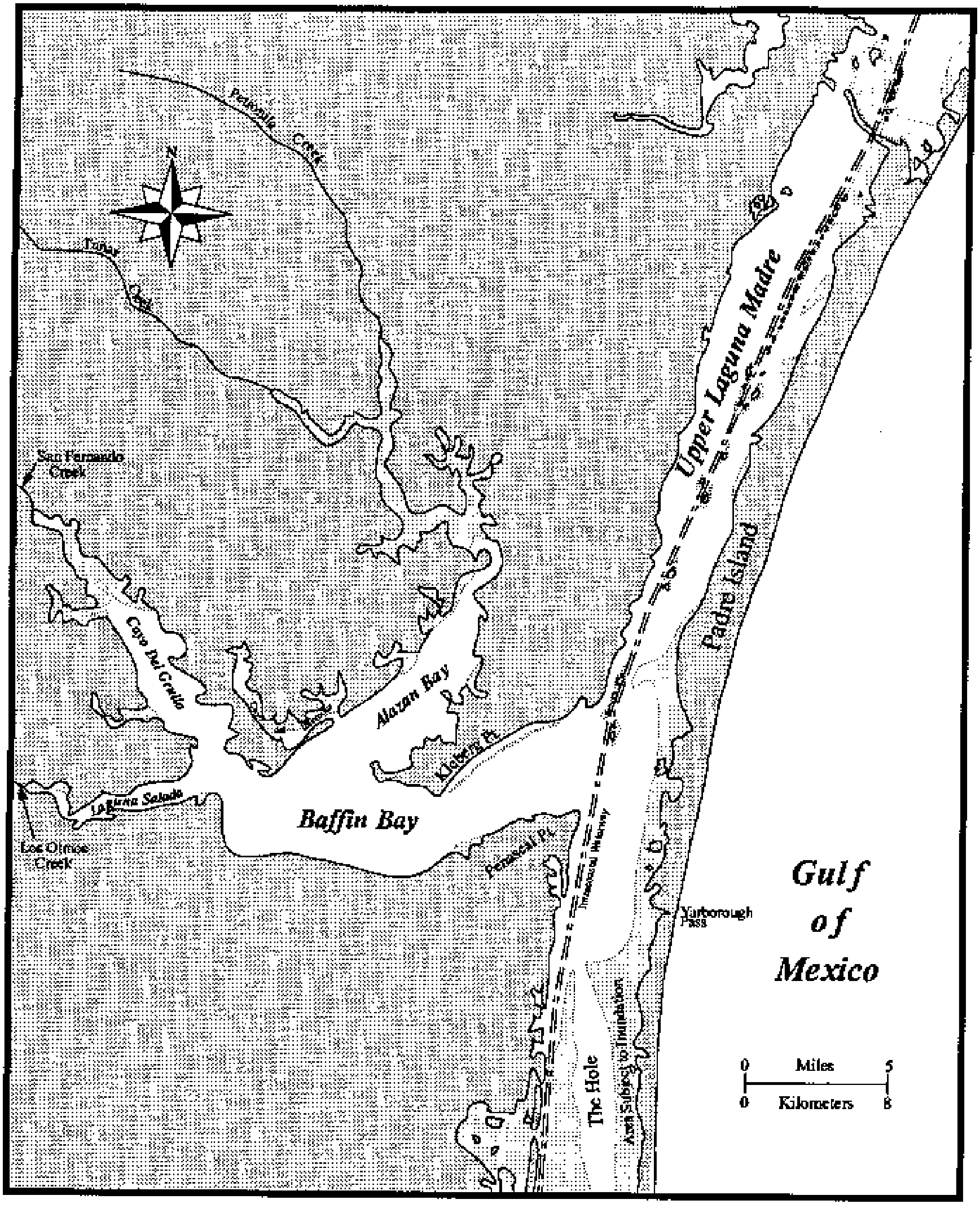



Fig. II.5. Upper Laguna Madre-Baffin Bay portion of CCBNEP study area.

true for the Baffin Bay-upper Laguna Madre system, because it usually is not measurably diluted with freshwater runoff and its connections to the open sea are remote (Aransas and Mansfield passes).

Alternatively, Emery and Stevenson (1957) define two types of estuaries based upon tidal and salinity features: (1) a normal or "positive" estuary and (2) an hypersaline or "negative" estuary. Characterized by upstream salinities lowered by adequate river inflow and mixing, the Mission-Aransas Estuary and Nueces Estuary are normal estuaries. The Baffin Bay-upper Laguna Madre system, however, is of the latter type, being characterized by arid climatic conditions, poor land runoff, limited tidal influence, and salinities routinely higher than those of the adjacent ocean.

## B. Driving Forces and Human Influence

The principal driving forces that determine the habitat and community structure, as well as biological processes, in the CCBNEP estuaries are: (1) freshwater inflow; (2) basin physiography; (3) seasonal changes in nutrient supply and availability; (4) short- and long-term salinity fluctuations; (5) wind-influenced currents, tides, and sedimentological processes; (6) astronomical and seasonal tidal influences; and (7) hurricanes (Hayes, 1965; Morton and McGowen, 1980; Flint and Younk, 1983; Livingston, 1984; Armstrong, 1987; Montagna and Kalke, 1992).

Morton and McGowen (1980) review processes operating in Texas bays, noting that "bays are a transition between continental and marine environments". At times they are dominated by their associated fluvial systems, but during droughts, they become dominated by marine elements. Physical processes operating within the bays can be divided into two categories, those that are active daily throughout the year, such as tides, winds, waves, etc., and those that are seasonal and are of short duration, but high intensity, such as large winter storms or hurricanes (Morton and McGowen, 1980).

Human influences within the CCBNEP study area are greatest around the moderately populated and industrialized shores of the Nueces Estuary and to a lesser extent around the other two estuarine systems. In general, the local economy is based upon agriculture, ranching, oil and gas, sport and commercial fishing, and tourism (Diener, 1975; Brown et al., 1976, 1977; McGowen et al., 1976).

Initial priority problems (CCBNEP 1994a) or previously identified human influences (Diener, 1975) affecting living natural resources include:

1. reduced freshwater inflow
2. degradation of water quality
3. destruction or loss of wetlands and other critical habitats
4. altered estuarine circulation from channelization and disposal of dredge material
5. point source and non-point source pollution
6. bay debris
7. persistent brown tide and periodic red tides

Most of these issues will be addressed by specific work-projects during the Year-1 characterization phase of the CCBNEP. Ever increasing human population levels and uses of the estuaries will also be addressed during this time frame. The specific impact of these issues on the living resources within the CCBNEP study area are dealt with in Section 5 of this report.

**C. Geologic History**

The geomorphologic structures of most estuaries are ephemeral in terms of geological time. Climatological forces or factors are continuously at work shaping and reshaping the basin features. Characteristics of the present CCBNEP study area are dependent upon current and past interactions and linkages between upland drainages, the offshore marine system, and the dynamic geologic history of the Texas coast.

The environmental geology of the Texas coast has been uniquely and thoroughly characterized by the Bureau of Economic Geology (BEG), University of Texas at Austin. During a multi-year effort in the 1970's, this agency produced seven volumes entitled the *Environmental Geologic Atlas of the Texas Coastal Zone*. Each of the volumes, covering seven different areas of the coast, consist of a book and nine detailed maps. The text covers the geology, geologic history, climate, coastal processes, human impact, and information about each map. Maps include a large 1:125,000 scale map on the environmental geology of each area, and eight smaller maps at 1:250,000 scale covering: physical properties; environmental and biologic assemblages; current land use; mineral and energy resources; active processes; man-made features and water systems; rainfall, stream discharge, and surface salinity; and topography and bathymetry. This set of volumes and the follow-up *Submerged Lands of Texas* produced during the 1980's covering the same areas with detailed field sampling data provide Texas with possibly the best documented/characterized coastal zone in the United States. Three of these BEG volumes in each set cover the CCBNEP study area either all or in part: all of the Corpus Christi Area books (Brown et al., 1976; White et al., 1983), the southern part of the Port Lavaca Area (McGowen et al., 1976; White et al., 1989a), and the northern part of the Kingsville Area (Brown et al., 1977; White et al., 1989b).

The present Texas coastline is primarily a product of Pleistocene and Recent (i.e., Holocene, Modern) geologic history. The Pleistocene ice age included over one million years of complex glacial and interglacial climatic and sea-level changes (Brown et al., 1977; Fig. II.6A). It consisted of at least four major glacial episodes separated by warmer interglacial periods. Sea levels during the Pleistocene ranged from 91 - 137 m (300-450 ft.) lower than present during glaciation when water was trapped in great, continental ice sheets to near present levels during interglacial, warm periods (Brown et al., 1977).

One dominant physiographic feature within the CCBNEP study area formed during the late Pleistocene is an upland expression of former marine periods extending further inland. Although its origin is questioned, a large sand body approximately 4.8 km (3 mi) in width parallels the present coast along Encinal and Live Oak Peninsulas and Live Oak Ridge. These distinctive, exposed sand bodies, which can be seen in Flour Bluff, Ingleside, Fulton, and Aransas National Wildlife Refuge (ANWR), are thought to be either a former barrier island (Price, 1933) or barrier strand plain (Wilkinson et al., 1975).

Chronologically, beginning about 50,000 to 60,000 YBP (years before present), sea level began dropping during the final episodes of Wisconsin glaciation. The Pleistocene Nueces and other rivers entered the Gulf of México some 93 km (50 nautical miles) east of the present shoreline (Fig. II.6B and II.7A) and cut deep river valleys into older deposited sediments. About 18,000 YBP, sea level began to rise gradually as the last glaciation period diminished (Fig. II.6C). The lower reaches of river valleys began filling with sediments, but sea level rise exceeded sedimentation and lower portions of the valleys were drowned (Fig. II.7B) (LeBlanc and Hodgson, 1959; Brown et al., 1976).

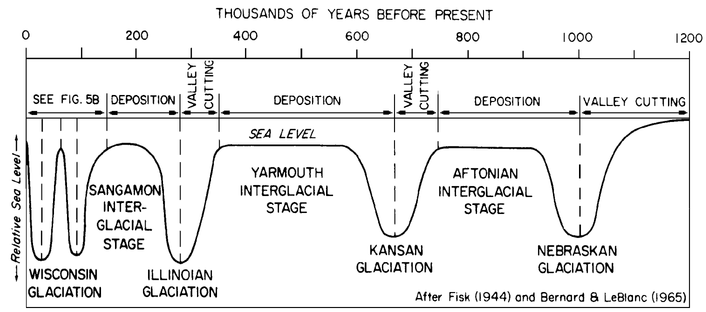
About 4,500 YBP (end of Holocene, beginning of Modern time) when sea level was about 4.6 m (15 ft) below present, modern geologic processes became active. When sea level reached its approximate present level, 2,800 to 2,500 YBP, several natural changes began to occur: (1) the estuaries began to fill with sediment from eroding drowned river valley walls and deltaic sediments from rivers and streams, with oyster reefs, and with Gulf of México sediments via tidal inlets; (2) streams continued to erode the coastal plain headward; (3) offshore shoals slowly coalesced into barrier islands, restricting bays and lagoons landward; (4) coastal marshes, seagrass beds, and wind-tidal flats developed; and, (5) eolian erosion and deposition continued to modify the Modern barrier islands and the relict Ingleside (Pleistocene) barrier-strandplain (Fig. II.7C) (Brown et al., 1976).

## D. Climate

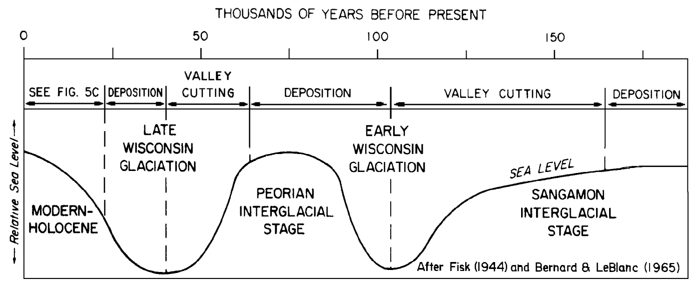
The importance of climate on the composition and distribution of estuarine organisms and habitats cannot be overstated. Geologists and biologists have long recognized the importance of understanding effects of climate on geologic processes and biota respectively.

Within the CCBNEP study area wide variability in climatic conditions is the norm. Local citizens often state "the only thing predictable about our weather here is that it is unpredictable". Carr (1967) discusses the use of "climatological normals" or averages based on day-to-day or month-to-month calculations, but he strongly implies the tremendous year-to-year variations in unpredictable cycles are not revealed in those "normals". Data used to compute climatic averages of precipitation and temperature ("normals") include the extremes on either side of the averages, but the sometimes impressive day-to-day, season-to-season, and even year-to-year variations lie completely obscured or embedded in these averages (Carr, 1967).

Typically, the study area can be characterized as "a subhumid-to-semiarid east coast subtropical climate, with extreme variability in precipitation" with generally high humidity and infrequent but significant killing frosts (Fulbright et al., 1990). The CCBNEP study area mirrors on a small scale the north-to-south moist-to-dry gradient characteristic of the entire Texas coast (Brown et al., 1976, 1977; McGowen et al., 1976; Morton and McGowen, 1980). Generally, the area experiences high temperatures along with deficiencies in moisture, especially to the south. Major climatic influences are temperature, precipitation and evaporation, wind, and tropical storms or hurricanes.




A

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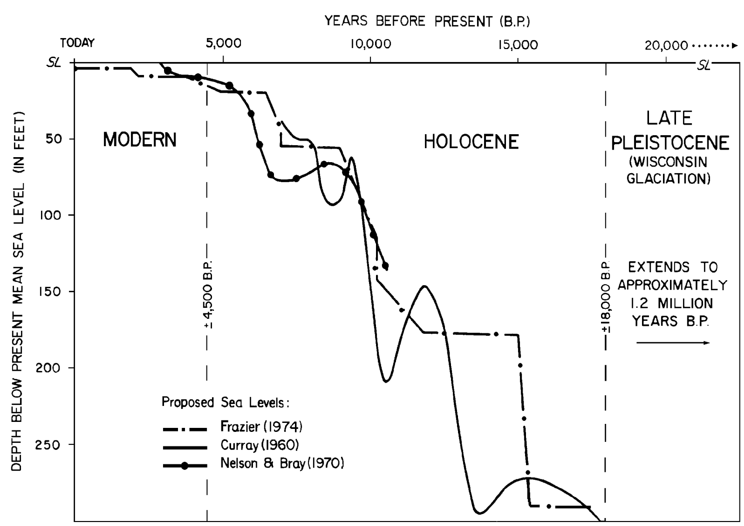


C

Fig. II.6. Sea-level changes related to glacial and interglacial stages. (A) Generalized Pleistocene sea-level variations and associated erosional and depositional episodes. (B) Generalized sea-level changes during Late Wisconsin glaciation. (C) Proposed sea-level changes during last 20,000 years (from Brown et al., 1977).

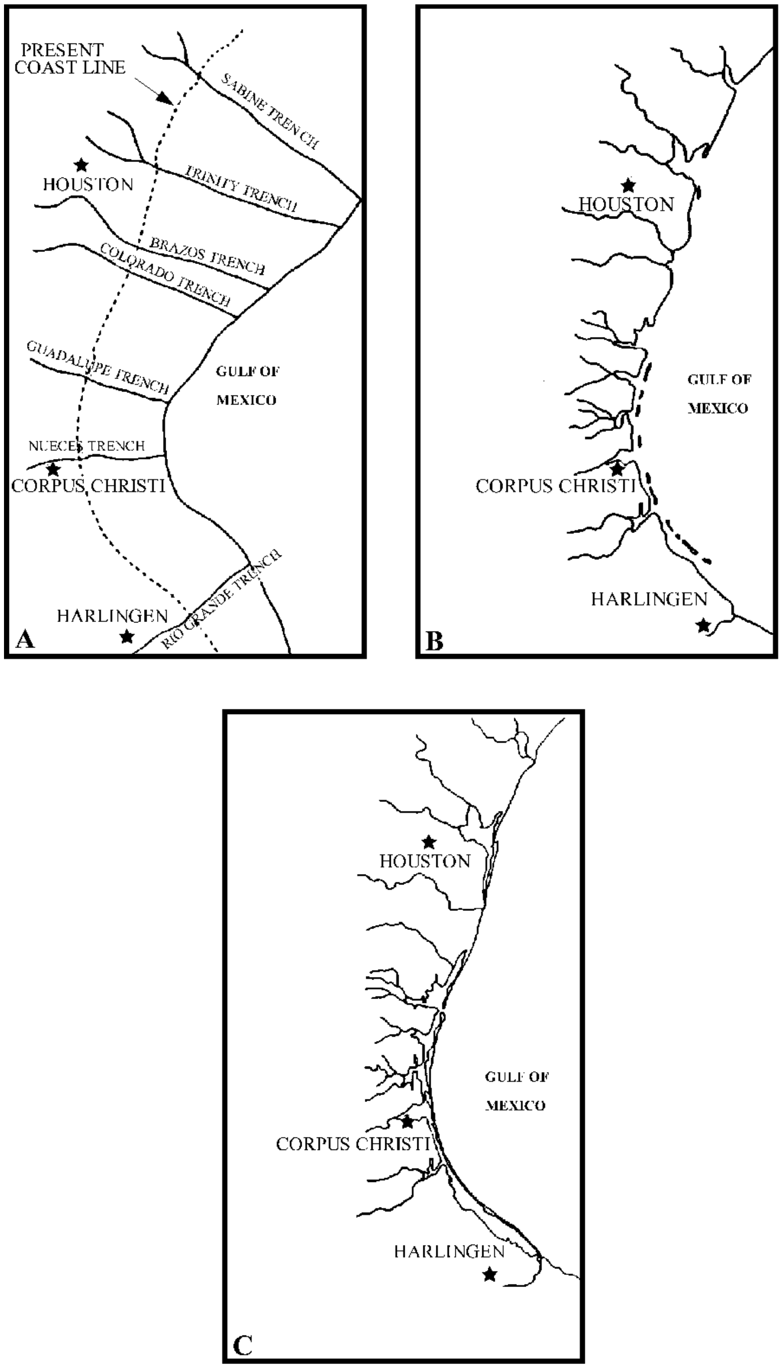


Fig. II.7. Origin and development of the Texas shoreline: (A) Late Pleistocene falling sea level stage; (B) Early Modern sea level stage with barrier islands forming; (C) Present standing sea level stage (from Le Blanc and Hodgson, 1959.

**1. Temperature**

Temperature within the study area varies only slightly (Table II.3). Minor gradients can be seen from both north to south and east to west. The slight 2.3$^o$ latitudinal change across the study area accounts for the normal 1.1-1.7$^o$ C (2-3$^o$ F) gradient seen from north to south. Similarly, the east-west gradient can be explained by the moderating marine influence of the Gulf of México on coastal county temperatures, slightly warmer in winter and slightly cooler in summer than inland areas.

Generally, average winter minima (January) range from 8.3-8.9$^o$ C (47$^o$-48$^o$ F) north to south in coastal counties, and average summer maxima (July) range from 33.3-35.6$^o$ C (92-96$^o$ F). Inland counties are warmer (summer) or cooler (winter) by 1.1-1.7$^o$ C (2-3$^o$ F). The yearly average in the north ranges from 21.1-21.7$^o$ C (70-71$^o$ F), whereas in the south it is 22.8$^o$ C (73$^o$ F) for both inland and coastal counties.

The major impact of temperature within the study area is the infrequent but significant killing frosts or freezes. Impacts on estuarine biota of these killing freezes have been documented in the literature over many decades (Gunter, 1941; Gunter and Hildebrand, 1951; Hicks, 1993; McEachron, et al., 1994; Martin and McEachron, in press).

**2. Precipitation**

Average annual rainfall along the coast within the CCBNEP study area ranges from 91.4 cm (36 in.) in the north to less than 73.7 cm (29 in.) in the south (Carr, 1967). Inland, the average annual values are slightly lower, ranging from 88.9 cm (35 in) to 68.6 cm (27 in.) north to south, respectively (Carr, 1967; Brown et al., 1976, 1977; McGowen et al., 1976). Corpus Christi, near the center of the study area averages 72.4 cm. (28.5 in.) annually. The average annual trend across the study area decreases from north to south along the coast, as well as from east to west going inland (Fig. II.8A).

Annual precipitation values alone are not necessarily significant unless compared with precipitation deficiency (Orton, 1969) caused by evapotranspiration (evaporation from soil surface) and transpiration from plants (Thornthwaite, 1948). To the north in the Port Lavaca area, deficit values range from 7.6 to 40.6 cm (3 to 16 in; McGowen et al., 1976) and in the Kingsville area to the south 48.3 to 71.1 cm (19 to 28 in; Brown et al., 1977) (Fig. II.8B). Between 1931 and 1960, the Corpus Christi area had a precipitation deficit of about 30.5 to 40.6 cm (12 to 16 in) (Carr, 1967; Brown et al., 1976). Coupled with this deficient rainfall budget is the seasonal bimodal distribution of precipitation within the central and northern part of the study area (Fig. II.9). To the south, however, the bimodal pattern begins to diminish in the spring in favor of a late summer and fall peak when tropical weather systems typically affect the coast. This latter pattern is typical along the US Gulf coast only in extreme South Texas and South Florida (Shew et al., 1981).

Table II.3. Air temperature within the CCBNEP study area (from Brown et al., 1976; Brown et al., 1977; McGowen et al., 1977). Temperatures are given in degrees Celsius with degrees Fahrenheit in parenthesis.

| Area | Average Winter Minima (January) | Average Summer Maxima (July) | Yearly Average (Inland - Coastal) |
|---|---|---|---|
| **North (Port Lavaca Area)** | | | 21.1-21.7 (70-71) |
| Inland Counties | 7.2 (45) | 35.0 (95) | |
| Coastal Counties | 8.3 (47) | 33.3 (92) | |
| **Central (Corpus Christi Area)** | | | 21.1-22.2 (70-72) |
| Inland Counties | 6.7 (44) | 36.1 (97) | |
| Coastal Counties | 8.3 (47) | 33.3 (92) | |
| **South (Kingsville Area)** | | | 22.8 (73) |
| Coastal Counties | 8.9 (48) | 35.6 (96) | |

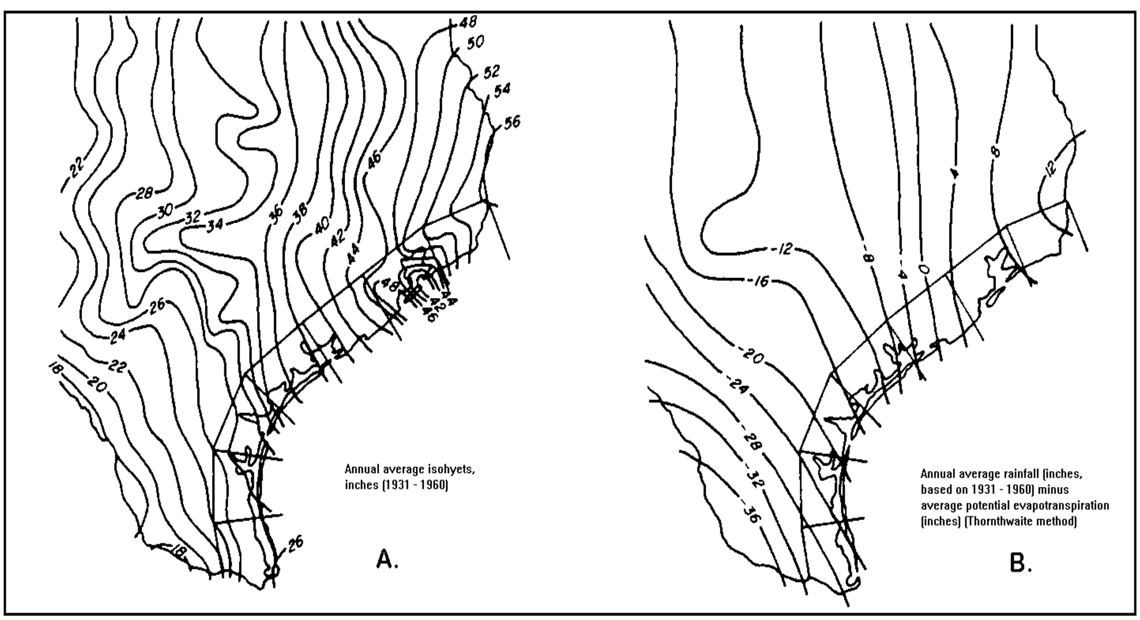


Fig. II.8. Regional precipitation (A) (after Carr, 1967) and deficiency (B) (after Orton, 1969) for the CCBNEP study area and the rest of the Texas coastal zone.

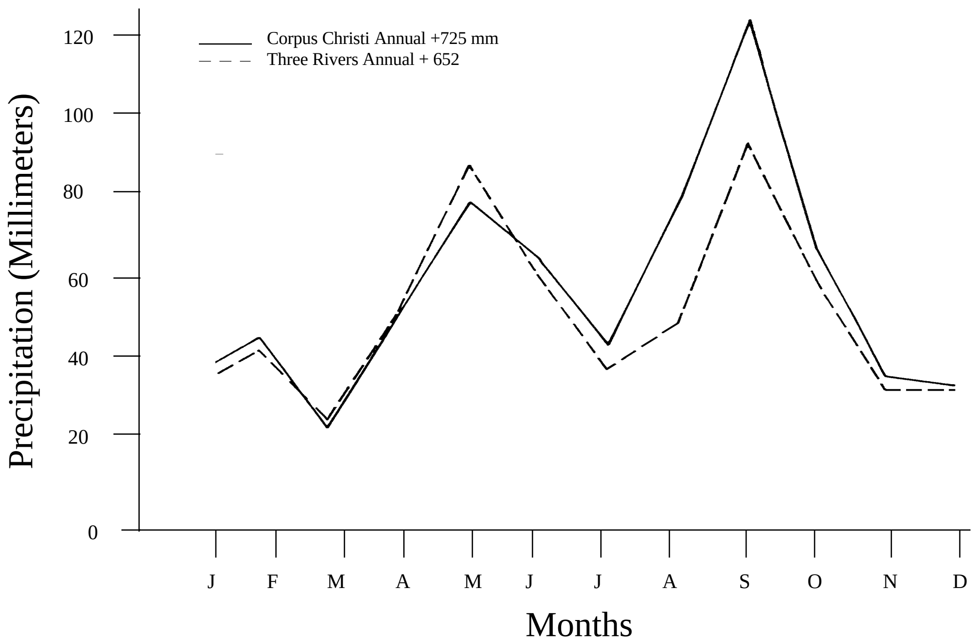


Fig. II.9. Mean seasonal precipitation for Corpus Christi showing distinctive bimodal distribution of rainfall, typical of the CCBNEP study area (from Shew et al., 1988).

Price (1968) uniquely demonstrated the long term variability of climatic conditions within the Corpus Christi area by analyzing rainfall patterns over 100 years (Table II.4). Noting that Corpus Christi lies on the boundary between Thornthwaite's (1948) semi-arid and sub-humid climatic zone, he revealed that 41 years were semi-arid and 41 years were dry sub-humid. However, he also reported that the range of variability extended from five years of fully arid (desert) conditions to two years of fully humid. Multi-year, severe to extreme droughts occurred within the CCBNEP study area during the 1930's, 1950's, and 1960's; mild to moderate droughts occurred in all other decades from 1930 to 1985 (Riggio, et al., 1987).

Table II.4. Climatic years per century at Corpus Christi.

| Fully Arid (Desert) | Semi-Arid | Dry Sub-Humid | Moist Sub-Humid | Fully Humid |
|---|---|---|---|---|
| 5 | 41 | 41 | 11 | 2 |

**3. Wind**

Two principal wind regimes dominate the CCBNEP study area: persistent, southeasterly winds from March through September and north-northeasterly winds from October through February (Behrens and Watson, 1973; Brown et al., 1976). Sedimentologists stressed the importance of winds affecting coastal processes along the Texas coast, noting that it "is perhaps the most important agent that influences coastal (geological) development" (Morton and McGowen, 1980; Price, 1933; Lohse, 1955; Copeland and Thompson, 1968; Watson, 1968; Brown et al., 1976, 1977; McGowen, 1976). Strongest winds occur during tropical storms and hurricanes generating high velocity currents which move vast quantities of sediment in relatively short periods of time (Hayes, 1967; Morton and McGowen, 1980).

Wind stress can cause the water level in bays to set-down (lower) and set-up (rise) on upwind and downwind sides of the bay as much as 2-3 feet (Fisk, 1959; Brown et al., 1976, 1977). The set-up can cause extensive flooding of many kilometers (square miles) of wind-tidal flats as well as low-lying vegetated marshes. Benthic recruitment to tidal flats can occur during these flood stages (Withers, 1994). Lohse (1955) presented wind roses for the South Texas coast of two different types - prevailing winds and predominant winds (Fig. II.10). Prevailing wind direction is the direction that winds blow most of the time during each month. Predominant wind direction is the direction in which surface winds expend the greatest amount of energy month to month (McGowen et al., 1977).

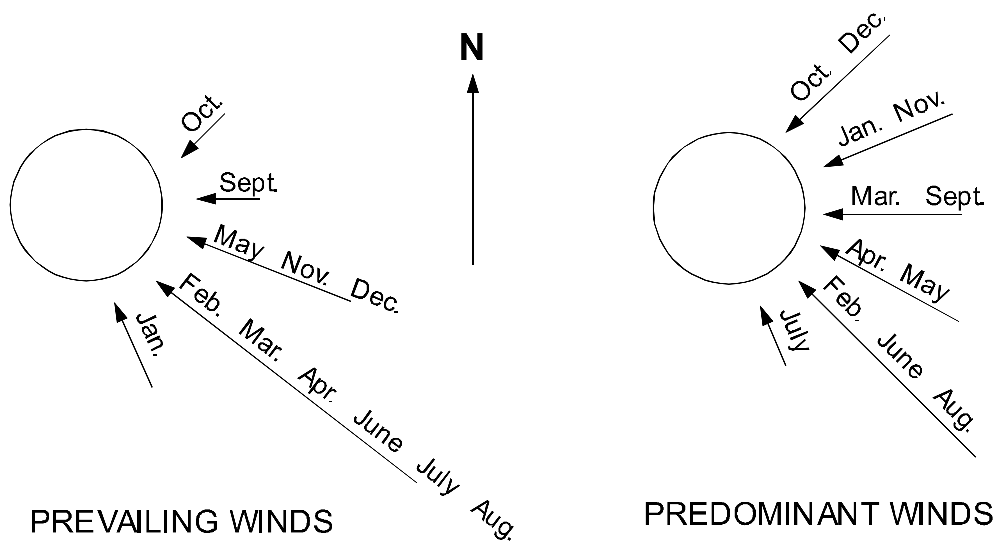


Fig. II.10. Prevailing and predominant winds of the South Texas coast (from Lohse, 1955; McGowen, 1971).

## 4. Tropical Storms and Hurricanes

Tropical storms with winds of 64.4 - 117.5 km/h (40 - 73 mph) and hurricanes with winds of greater than 119.1 km/h (74 mph) are tropical cyclones generated during June through November each year. The counterclockwise winds of these storm systems may be hundreds of miles in diameter and strike the Texas coast an average of once every 1.5 years (Hayes, 1965, 1967).

Characteristics of these storms that originate in the tropics include high-velocity winds along the periphery of the storm, a calm center (eye), low barometric pressure, torrential rainfall, and tornadoes (McGowen et al., 1970; McGowen et al., 1977; Morton and McGowen, 1980). August and September are the months of greatest frequency of hurricanes hitting the Texas coast (Fig. II.11). The human, environmental, and geologic impacts on the Texas coast caused by these storms are well documented (Hayes, 1965, 1967; McGowen et al., 1970; Henry et al., 1980; Broussard and Martin, 1986). Major natural resource impacts include extensive deposition and erosion; breaching cuts through barrier islands and peninsulas; flooding of low-lying areas by marine waters from the storm surge during the storm, then freshwater from torrential rainfall after the storm; and, finally flushing of bay systems with both marine (surge) waters and fresh (rainfall) waters.

Within the CCBNEP study area historical records indicate great variability in storm characteristics and impacts. For instance, Hurricane Carla (1961) generated a large storm surge, Hurricane Beulah (1967) torrential rainfall and flooding, and Hurricane Celia (1970) exceptionally high winds. Ecologically, flushing caused by the storm surge or torrential rainfall can flush pollutants (Brown et al., 1976) or cause ecological and fisheries changes (Hildebrand, 1969, 1980). Such an event could cause redistribution of many marine species, especially planktonic and larval forms. Likewise, some scientists and residents believe the only way to rid the Laguna Madre of the "Texas Brown Tide," an algal bloom, will be a major flushing event caused by a hurricane.

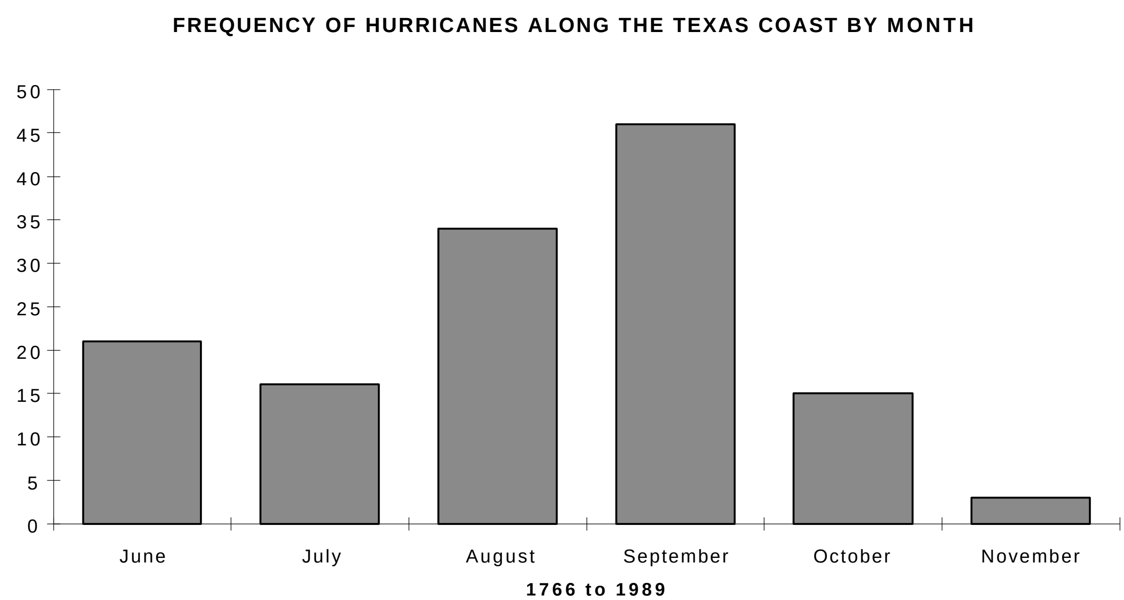


Fig. II.11. Frequency of hurricanes hitting the Texas coast 1766-1989.

## E. Hydrographic Conditions

Hydrographic conditions of the CCBNEP study area are influenced primarily by climatic conditions, freshwater inflow, and, to a lesser extent, tidal exchange.

### 1. Freshwater Inflow

The Mission, Aransas, and Nueces Rivers contribute the major freshwater inflows into the CCBNEP study area. However, all drainages within the study area share a single major or common Gulf of México connection at Port Aransas (Aransas Pass). Minimum and maximum annual inflows, median inflows, and mean inflows from surface runoff from the three drainage basins of the study area are presented in Table II.5 (TWC, 1992). Again, the great variability of this ecological system is demonstrated by the broad range of inflows (i.e. 0 $m^3$ [0 ac. ft.] inflow into upper Laguna Madre in 1963 to 3,383,672,580 $m^3$ [2,744,260 ac. ft.] into the Nueces Estuary in 1971).

Table II.5. Freshwater inflows in acre-feet per year into the three estuarine systems of the CCBNEP study area. Year in which maximum and minimum inflows occurred is in parentheses (TWC, 1992).

| Estuary | Minimum Annual Inflow | Maximum Annual Inflow | Median Inflow | Mean Inflow | Inflow-Volume Ratio |
|---|---|---|---|---|---|
| Aransas | 7,503 (1950) | 1,542,142 (1967) | 324,228 | 429,189 | 0.64 |
| Corpus Christi-Nueces | 42,551 (1962) | 2,744,260 (1971) | 414,337 | 633,597 | 0.71 |
| Upper Laguna Madre | 0 (1963) | 818,00 (1967) | 73,000 | 156,928 | 0.30 |

Other hydrologic parameters, such as evaporation and precipitation, along with inflows, provide a better understanding of the water balance and estuarine salinity levels within the area (Table II.6) (TWC, 1992). Differences among basins are evident; both the Aransas Estuary and the Baffin Bay - upper Laguna Madre system receive most of their inflow from adjacent ungauged areas, whereas most inflows into the Nueces system are from gauged areas further inland. Also, the Aransas and Nueces estuaries have a net positive input of freshwater, whereas the Baffin Bay - upper Laguna Madre system has a negative inflow balance on average (TWC, 1992). A salinity gradient is normally present in all three estuarine systems. However, the Aransas and Nueces estuarine gradient is of decreasing salinity from the Aransas inlet to the upper bays, whereas the Baffin Bay - upper Laguna Madre system gradient is often, but not always, the opposite, increasing salinity away from the inlet.

Table II.6. Estuarine hydrology in acre-feet per year of the CCBNEP study area (TWC, 1992).

| Estuary | Gauged Inflow | Ungauged Inflow | Evaporation | Precipitation | Inflow Balance |
|---|---|---|---|---|---|
| Aransas | 130,665 | 298,524 | 614,715 | 379,450 | 193,923 |
| Corpus Christi-Nueces | 584,303 | 49,294 | 608,969 | 301,927 | 326,555 |
| Upper Laguna Madre | 21,400 | 135,528 | 842,899 | 397,306 | -288,665 |

## 2. Tidal Exchange and Circulation

Tidal exchange in Texas estuaries is due to astronomical tides, meteorological conditions (winds, barometric pressure), and density stratification (Armstrong, 1987). Due to shallow bay depths and a relatively small tidal prism (Smith 1974, 1977, 1978), wind exerts a much greater influence on bay circulation than astronomical tides (Morton and McGowen, 1980). Substantial exchange of water between the Gulf of México and Texas estuaries occurs from wind-generated tides (Ward, et al., 1982).

Astronomical tides within the study area are predominantly diurnal, but also have a semidiurnal component. Mean tidal range along the Gulf beach is about 45 cm (1.5 ft) (Morton and McGowen, 1980), whereas astronomical tidal range within bays, especially in upper bays, is generally <15 cm (0.5 ft). The greatest influence on the bay system by astronomical tides is at the tidal inlet. Seasonal high tides occur during the spring (highest in late May) and fall (October) and seasonal lows occur during winter (February) and summer (July).

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## III. Methods

To complete the compilation of the *Current Status and Historical Trends of Estuarine Living Resources of the Corpus Christi Bay National Estuary Program Study Area*, the Texas A&M University-Corpus Christi Center for Coastal Studies team defined the following objectives (see proposal, Tunnell and Dokken, 1994):

*1) To summarize existing knowledge of key organisms and/ or communities;*

*2) To attempt to explain ecological and/or environmental probable causes of observed spatial or temporal population trends; and,*

*3) To identify organisms and communities for which data are lacking.*

### A. Outline of Approach

Because of the areal extent of the project area, the proposed study was approached from various hierarchical levels: single species, habitat, and ecosystem. This provided a framework that would aid in the identification of current state of knowledge, probable causes for changes in status or trends, and knowledge gaps. Current status and historical trends in abundance and distribution of populations of economically and ecologically important estuarine species, endangered, threatened, protected, or exotic species, and resident marine mammals were determined by reviewing and synthesizing available published and unpublished data and reports. In addition, the first comprehensive species list was compiled. The Center for Coastal Studies assembled a team of scientists who represented a consortium of local universities and state and federal wildlife and resource agencies as consultants and technical advisors. They were used in project planning, guidance, and review Best professional judgement identified probable causes of spatial or temporal trends observed in the data or referenced in the literature.

### B. General Literature Review, and Data Acquisition, Compilation, and Analysis

Current status and historical trends of important estuarine habitats and key estuarine organisms were determined primarily by comprehensive literature reviews. Published data resources were included from peer-reviewed scientific journal articles (international, national, and regional) and agency documents (federal, state, and local). Unpublished data resources included agency reports, dissertations, and theses. Each document was assessed according to: (1) QA/QC measures imposed on data collection; (2) information of specific and consistent methodological procedures; (3) evaluation of concurrent research objectives, methods, and results of independent data sets for comparative purposes; and, (4) best professional judgement. High priority was given to data sets where both water quality, environmental, and organism parameters were collected. Data sets from monitoring programs that contained data collected at regular intervals for at least five years and not funded under this contract were identified and assessed for further evaluation. Data amenable to trend (time series) analyses were noted within the report for future consideration by the CCBNEP Project Coordinator. Data sets collected at regular intervals over a reasonable length of time (but < five years), or collected over a broad area within the CCBNEP study area at one time, are documented.

### C. Comprehensive Species List

The comprehensive species list included habitat, distribution, and relative abundance of each species. The species list was organized phylogenetically, and encompassed the following groups: Algae, Vascular Plants, Invertebrates, Fishes, Amphibians, Reptiles, Birds, and Mammals. References were selected from published and unpublished data resources and critically assessed by criteria listed previously. Abundance rankings were categorized as Abundant, Common, Uncommon, and Rare specific to each habitat from which they were documented. Abundance determinations for each major reference were documented in the preface of each group for quality assurance within and between lists. Organisms known to occur, but for which there are few data resources, were listed for further evaluation of missing data and knowledge of the species.

### D. Selected Habitats and Organisms of Interest

#### 1. Habitats

The structure and trophic dynamics of important estuarine habitats (Open Bay, Oyster Reef, Hard Substrate, Seagrass Meadow, Coastal Marsh, Tidal Flat, Barrier Island, and Gulf Beach) were characterized as communities using the US Fish and Wildlife Service model of community profiles. In many cases, information was lacking; therefore, an extensive portion of habitat function was used from similar studies outside the study area. We believe by incorporating this related information, a framework was constructed examining both habitat structure and function from which further research, conservation, and management assessments could be based. Although data on individual species populations within these communities were often limited both spatially and temporally, general status of the community and changes in density and distribution of species were determined when possible. When data were available, areal extent of the communities was determined; however, habitat coverage was not mapped since CCBNEP Year-Two projects will engage in that activity. Data that could be useful for further spatial analysis (e.g., incorporation in GIS) were documented in the final report.

#### 2. Target Organisms

#### 2.1 Species of Concern

The project area contains habitats that are critical to survival of several specially listed species of birds, sea turtles and other reptiles, marine mammals, and plants. The status and trends for the following estuarine-dependent, selected species were determined based on literature and agency databases: Whooping Crane, Piping Plover, Brown Pelican, Least Tern, Eskimo Curlew, Kemp's ridley turtle, loggerhead turtle, green turtle, leatherback turtle, hawksbill turtle, and marine mammal species that either utilize the estuarine systems of the area, or have stranded along the Gulf and bay beaches. Databases generated by agencies and special interest groups were utilized, including: USFWS Ecological Services, Endangered Species (Angela Brooks - Plants; Karen Meyers - Animals; Corpus Christi Office); TPWD, Resource Protection Division (Lee Elliot; Corpus Christi Office); National Park Service - Padre Island National Seashore (Donna J. Shaver - Marine Turtles), and Marine Mammal Stranding Network (David McKee; Corpus Christi Area Co-Coordinator).

Exotic and introduced, estuarine-dependent species are important because these organisms often displace native populations. The status of the introduced edible brown mussel (*Perna perna)* will be discussed.

## 2.2 Fishery Resources

Assessment of living marine resources were limited to fisheries data from Texas Parks and Wildlife Department (TPWD), Coastal Fisheries Division Project Reports and Management Data Series from 1972 to present. Key personnel in the TPWD Coastal Division were consulted when clarification was needed. Each summary was annotated with information on the data source, the sampling program through which the data were collected, and a caveat listing any data limitations. Methodological approaches of different projects were assessed prior to comparative evaluations. Each data set was additionally evaluated to determine correspondence to status and trend analyses objectives of this report; i.e., data were used in a manner consistent for which they were intended. If data were pertinent but did not contain certain criteria, they were identified and discussed. These criteria included, but were not limited to: short-term studies or studies that addressed specific objectives; methodologies inconsistent with other research designs; and/or, lack of comprehensive environmental parameters for time-series data analyses.

To complete a more comprehensive characterization (i.e., beyond only species of economic importance) of the nektonic community of the CCBNEP study area we also: 1) reviewed other existing literature/data sets relating to commercially important species, and 2) reviewed, analyzed, and synthesized existing data/information on non-commercial species common to the area.

The final report represents a synthesis and discussion of long-term trends in selected fauna as described by existing reports from these multiple sources. The discussion includes activities and possible impacts of such occurrences as recreational and fishing activities and changes in management guidelines, habitat loss, climatic events, and stock enhancement. Possible impacts of future development and activities were also considered. TPWD will perform a time-series analysis on their coastal monitoring dataset during Year-Two of the CCBNEP.

## 2.3 Avian Resources

Long-term datasets from bird censuses within the project area were the only others (like TPWD coastal fisheries) that were amenable to detailed trend analysis. Due to the unique and vital importance of birds within the study area, the Center for Coastal Studies subcontracted this portion of the living resources project to Ecoservices, longtime avian experts in the Texas Coastal Bend. The objectives of this portion of the study were to: (1) assemble relevant literature on the CCBNEP study area, not only to assess status and trends, but also to assist with development of a comprehensive species list containing habitat requirements, distribution and abundance; (2) evaluate assembled information to assess the current and historical status of CCBNEP study area avian resources, especially concentrating on colonial-nesting waterbirds, shorebirds, and neotropical migrating passerines; (3) evaluate the collected data for its validity in assessing population trends, again concentrating on the groups mentioned above; (4) analyze appropriate data for statistically significant trends and probable causes in avian population of the CCBNEP study area; and, (5) identify gaps in existing monitoring program coverage. Existing data sets relevant to the area were identified and reviewed. These data were examined for possible inclusion in the comprehensive species list, current and historical status evaluation, and/or population trends analysis. For data sets that met the necessary criteria (i.e., longevity of coverage, geographical extent, adequate taxonomic coverage), trend analysis was conducted for most individual species as well as for guilds of species that share a winter feeding area. Appropriate analysis techniques was chosen based on the character of the data set.

Status and trends of the avian resources were evaluated through analyses of Colonial Waterbird and Christmas Bird Count data. Both data sets were collected over an extensive period and reflect two temporal dimensions (early summer, winter). These data sets were selected as per the acceptance criteria previously stated. In addition, quality control was imposed by collection of data over a short time period each year and extensive overlap of organizers, observers, and compilers among years. These data are collected by volunteer observers; however, these volunteers enforce stringent performance standards as to how data are collected and usually have excellent knowledge in bird identification. Weather conditions may have imposed a bias on data and were included in the analyses. Correction factors were determined for variance in observer hours, method of data collection (by foot or by car), and areal coverage. The Colonial Waterbird counts were made on nesting pairs; therefore, true estimates of the populations were not possible. However, these data were amenable to determine trends of nesting populations through time. These two data sets did not address population status of migrating birds in spring or fall, as there are no long-term, comprehensive data sets available for these periods. Temporal population trends of all selected species were examined using Simple Linear Regression as the mean of estimating the Trend component of the Time Series (composed of Trend, Seasonal, Cycle and Irregular components). The ratio of "Explained" to "Total" variation was measured and evaluated, as well as the significance of regression models and residuals of each model. If a rank transformation was used to minimize the effect of erratic data, an estimate of its correlation was made. In some cases, analysis was extended to Multivariate Linear or Non-Linear Regression to allow the best estimate of the Trend component of the Time Series, if a particular model appeared appropriate. A complete description of statistical approach, methodologies, analyses, and interpretation of results is addressed within Volume 2 of this report.

## E. Identification of Probable Causes

When temporal or spatial correlations in trends in abundance or distribution of organisms or communities were noted, Center for Coastal Studies scientists recorded and discussed them with consultants to determine, by their best professional judgement, probable causes. A matrix presenting the relative impact of CCBNEP priority problems and other local perturbations on living resources was compiled as a quick reference. Recommendations were made for future studies to address causes of observed trends.

### F. Identification of Data and Information Gaps

Part of the proposed work was to compile a comprehensive species list which included distribution in various habitat types and relative abundance. As this list was compiled, species and higher taxa for which there are little or no available data were identified. Determining the status of various communities in the study area also resulted in identifying both species and communities for which data are lacking. Specific data gaps are presented in tabular or graphic form as well as discussed in the final report with a focus on future characterization and monitoring needs. A second matrix was prepared to summarize knowledge gaps for each habitat.

## IV. Results

### A. Living Resources - Species Checklist

A comprehensive summary or review of all living resources within the CCBNEP study area has never been accomplished. An extensive review of literature concerning the study area reveals studies have generally focused on specific taxonomic groups, populations, habitats, communities, or processes, but none have given a synoptic picture of the entire estuarine system. The most comprehensive summaries to date within the study area have focused on influence of freshwater inflow on certain components of the estuarine system, namely commercial fishery harvests (TDWR, 1981, 1983; Henley and Rauschuber, 1981). Synthesis of selected information for the entire Texas coast is also available (Diener, 1975; Shew et. al., 1981; Armstrong, 1987), as well as regional reviews of the western and southern Gulf of México shorelines (Britton and Morton, 1989), and the entire Gulf of México (Galtsolf, 1954a).

Prehistoric inhabitants of the Texas coast were the earliest users of estuarine living resources (Hester, 1980; Cox, 1994). Shell debris and artifacts in coastal areas around bay margins indicate a high dependence on estuarine species as food resources, especially oysters (*Crassostrea virginica*) clams (*Rangia cuneata)*, whelks (*Busycon contrarium)* and fish (red drum, *Sciaenops ocellatus*).

The earliest scientific studies of living resources along the Texas coast were by scientists first from Europe and later from the museums of early colonial America. Typically, scientific field expeditions collected specimens for study by the early museums, such as the Philadelphia Academy of Sciences and the Museum of Comparative Zoology at Harvard. Most early work during the 19th century was concerned with discovery; i.e. description of new species and determination of their geographical distribution (Hubbs, 1964). The still-popular taxonomic groups of today like molluscs, fish, and birds were some of the first to be studied along the Texas coast. Andrews (1977) notes of the 325 species listed in her book on Texas coast seashells, 225 species were described by less than 20 scientists, most of whom lived in the 19th century.

After these taxonomic and geographic distribution studies, federal fishery biologists began reporting harvest information. The first studies on the biota within the Texas Coastal Bend were conducted from local institutions by local biologists beginning in the 1930's and 1940's at Corpus Christi Junior College (now Del Mar College), Texas College of Arts and Industries (now Texas A&M University-Kingsville), and the Texas Game, Fish, and Oyster Commission (now TPWD) in Rockport. Cross and Parks (1937) published the first account of the flora and fauna of the Nueces Estuary. Their checklist of species includes 296 marine and estuarine species, as well as 271 upland plants (Table IV.A.1). Of the 268 animals listed 140 were invertebrates, 124 fish, three reptiles, and one mammal. No birds or amphibians were listed. They also listed 28 maritime plants that included five species of algae and 23 species of salt-tolerant vegetation.

In 1941, Professor Clyde T. Reed of the Texas College of Arts and Industries, published the first account of marine life along the entire Texas coast. Although his book encompassed the coast from Galveston to Port Isabel, he focused on the Copano Bay to Baffin Bay area. He listed 46 species of game fish from Texas Gulf and bay waters and 23 species as the principal commercial species. He also included 69 species of algae, 176 species of molluscs, 24 sharks and rays, five reptiles (sea turtles), and one mammal; he listed no birds or amphibians. The prevailing view concerning marine resource utilization in the 1930’s and 1940’s is evident in the following quotations concerning Leatherback turtles: *"This huge turtle, like the next two listed* [Loggerhead and Kemp's Ridley]*, is of little value except for oil, fertilizer, and stock and pet feed*"; and porpoises: *"These animals are very numerous; yet, little use is made of them. Their hides and oil are first consideration, and other parts may or may not be of use. Porpoise are rarely taken for commercial purposes"*. The idea that a resource is valuable only if it has a commercial (economic) use is diametrically opposed to the view of many people today in which a resource’s intrinsic and/or aesthetic values are recognized.

Table IV.A.1. Taxonomic comparison of early species compilations to current CCBNEP Living Resources Project.

| Taxonomic Group | Cross & Parks, 1937 | Reed, 1941 | Trott, 1960 | CCBNEP, 1995 |
|---|---|---|---|---|
| **Plants** | **304** | **69** | **0** | **836** |
| Algae | 5 | 69 | 0 | 511 |
| Vasc. Plants | 299 | 0 | 0 | 325 |
| **Animals** | **268** | **245** | **609** | **2,342** |
| Invertebrates | 140 | 146 | 609 | 1,418 |
| Vertebrates | 128 | 99 | 0 | 924 |
| **Total Biota** | **672** | **314** | **609** | **3,178** |

The Texas Game, Fish and Oyster Commission Laboratory in Rockport was opened in 1949 (Galtsoff, 1954b). Emphasis at the lab was on shellfish and finfish management within the Texas Coastal Bend. However, Gordon Gunter, a fisheries biologist at the lab, published several papers on fish biology and ecology of the area (Gunter, 1940, 1945).

With the establishment of the Institute of Marine Science of the University of Texas (now University of Texas at Austin Marine Science Institute) in Port Aransas in 1948 and increased interest by other universities and agencies, studies on the living resources in Texas coastal bays proliferated in the 1950's (e.g., Breuer, 1957; Gunter, 1950; Hedgepeth, 1953; Hoese, 1958; Ladd, 1951, 1957; Parker, 1955, 1959; Post, 1951; Simmons, 1957; Whitten et. al. 1950). In 1960, Lamarr Trott, of the Marine Science Institute, prepared a preliminary (mimeographed) invertebrate checklist for the Port Aransas area (Trott, 1960). Although not published, it was at the time, the most complete list that included and summarized earlier studies as well as collections in the museum of the Institute. Trott listed a total of 609 invertebrate species, including 10 phyla (see Table IV.A.1). The current compilation of species reported within the CCBNEP study area consists of 3,178 species (Appendix I in Volume 4).

Zoogeographically, marine waters of Texas have a predominantly warm-temperate fauna and have been referred to as the Carolina Region or Carolinean Province, which extends across the northern Gulf of México, as well as along the southeastern United States Atlantic coastline (Briggs, 1974). Estuarine fauna of the CCBNEP study area is almost completely warm-temperate, whereas seasonal summer, warm waters may reveal tropical species occasionally along the Gulf beaches and jetties at Port Aransas.

Along the shoreline and inland, the vegetation has been classified within the Gulf Prairies and Marshes Vegetation Area (Fig. IV.1) (Gould, 1975; Hatch et al., 1990) and the terrestrial wildlife falls within the northeastern portion of the Tamaulipan Biotic Province (Fig. IV.2) (Blair, 1950).

**1. Plants**

Eight hundred thirty-six species of plants within seven different divisions have been recorded for the CCBNEP study area (Table IV.A.2).

**1.1 Algae**

The estuarine and marine algae are represented by six divisions and 511 species. Diatoms (Bacillariophyta) are the most diverse group with 341 species. Forty-three species of dinoflagellates (Pyrrophyta) have been recorded. Benthic algae include 118 species in three divisions: Rhodophyta - 68 species, Chlorophyta - 33 species; Phaeophyta, 17 species; and. Nine species of blue-green algae (Cyanophyta or Cyanobacteria) have been listed.

**1.2 Vascular Plants**

All vascular plants are in the division Spermatophyta and include submergent, emergent, and upland plants. Three hundred twenty-five species have been recorded. The most diverse families

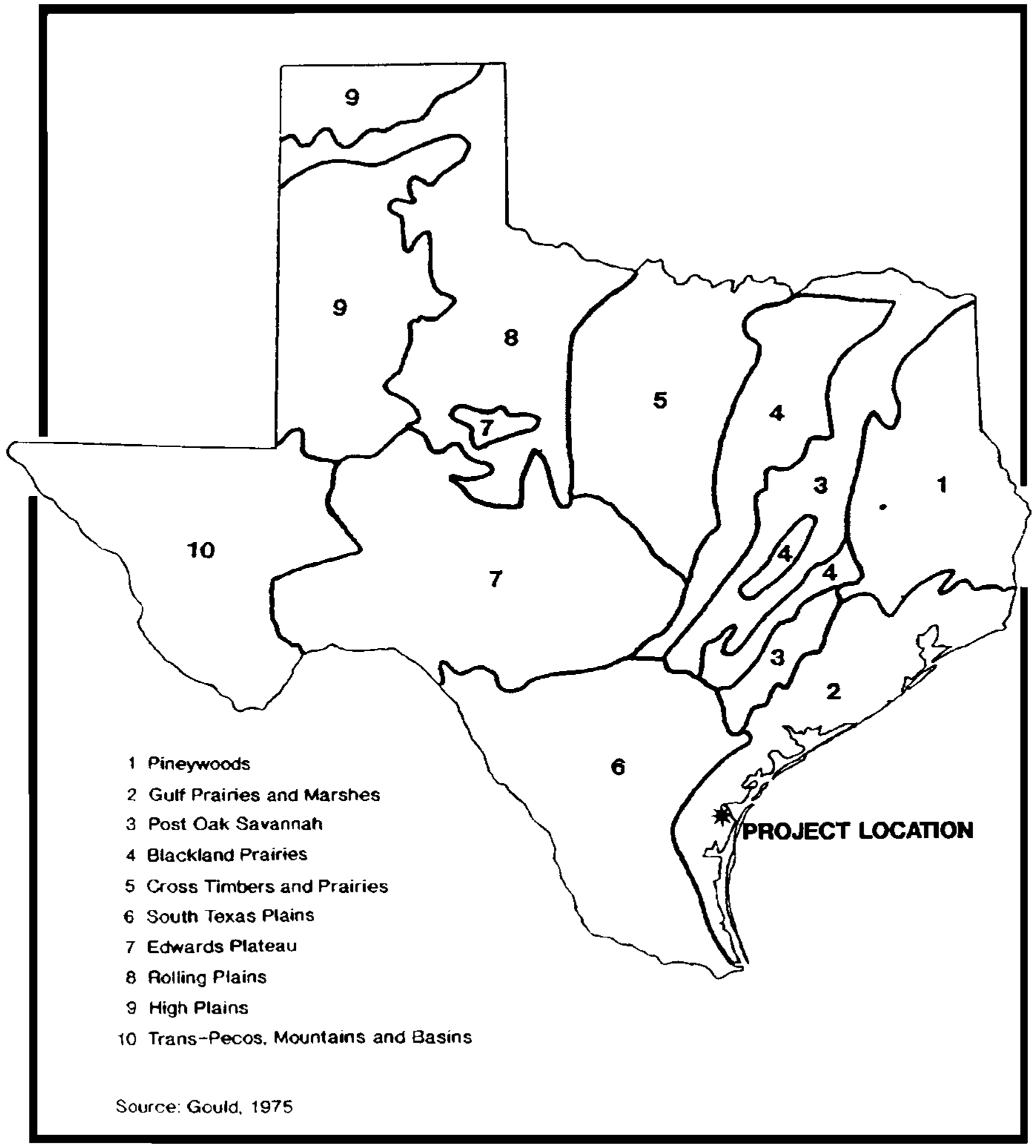


Figure IV.1. CCBNEP study area in relation to the Vegetation Areas of Texas (from Gould, 1975).

are the grasses (Poaceae, 51 species), composites (Asteraceae, 40 species), legumes (Fabaceae, 33 species), and sedges (Cyperaceae, 27 species).

## 2. Animals

There is a minimum 2,342 species of animals in 23 phyla (Table IV.A.2).

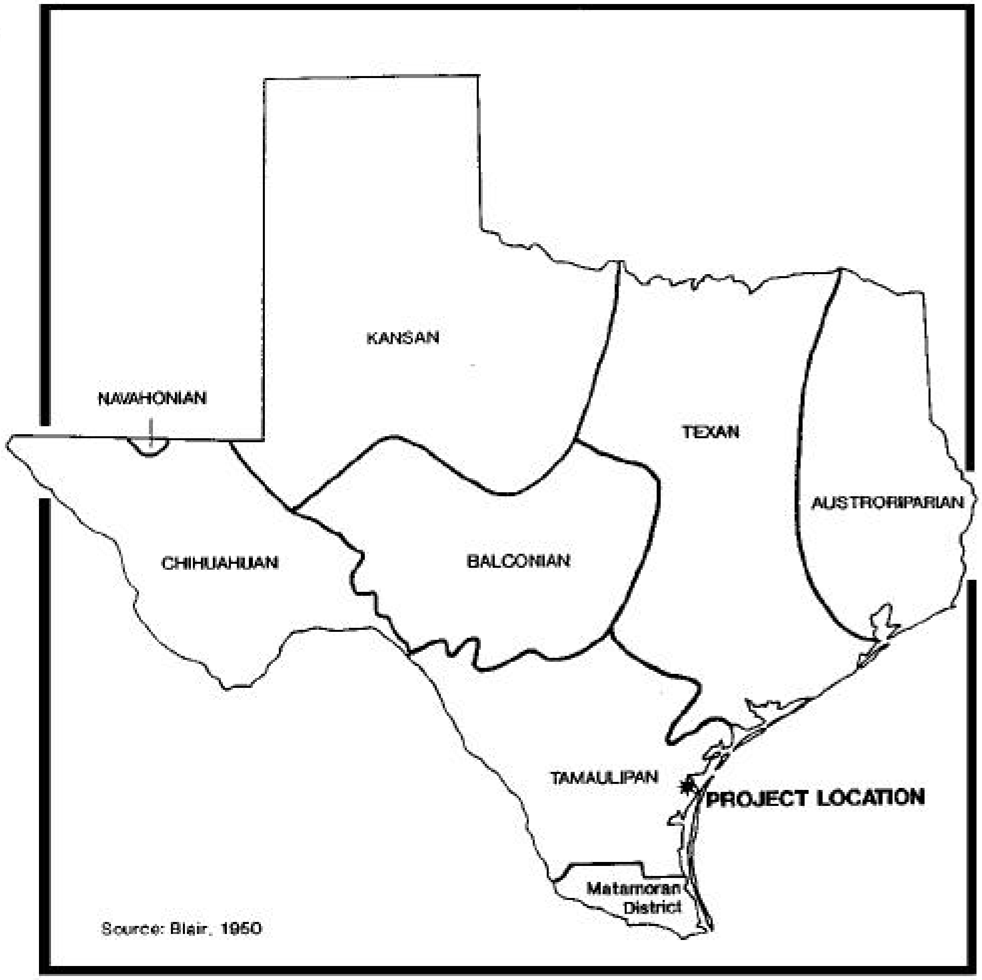


Figure IV.2. CCBNEP study area in relation to the Biotic Province of Texas (from Blair, 1950).

## 2.1 Invertebrates

This grouping includes single-celled protists (Phyla Sarcomastigophora and Ciliophora), the “true” invertebrates (Porifera through Chaetognatha) as well as “invertebrate chordates” (Subphyla Urochordata and Hemichordata). Most animals listed (1,418) are invertebrates. The 18 “true” invertebrate phyla can be grouped into three categories according to number of species per phylum. Three phyla include almost 85% (1,152) of all the invertebrate species (Arthropoda, 633; Annelida, 289; Mollusca, 230). Certain taxonomic groups within these three phyla dominate in most estuarine habitats, including polychaetes, gastropods, bivalves, and crustaceans. The second group of six phyla contains about 13% (178) of the total invertebrate species and much smaller numbers of species per phylum (Nematoda, 50; Cnidaria, 36; Nemertea, 33; Echinodermata, 29; Bryozoa, 19; Porifera, 11;). The final group of 10 phyla includes only about 2% (28) of the invertebrate

Table IV.A.2. Numbers of species found in each division or phylum within the CCBNEP study area. * Phylum present, but no published or unpublished species accounts.

| Taxon | Number of Species |
|---|---|
| Division Cyanophyta | 9 |
| Division Bacillariophyta | 341 |
| Division Pyrrhophyta | 43 |
| Division Chlorophyta | 33 |
| Division Phaeophyta | 17 |
| Division Rhodophyta | 68 |
| Division Spermatophyta | 325 |
| Phylum Sarcomastigophora | 31 |
| Phylum Ciliophora | 13 |
| Phylum Porifera | 11 |
| Phylum Cnidaria | 36 |
| Phylum Ctenophora | 2 |
| Phylum Platyhelminthes | 3 |
| Phylum Nemertea | 33 |
| Phylum Gastrotricha | 2 |
| Phylum Nematoda | 50 |
| Phylum Rotifera | 8 |
| Phylum Kinorhyncha | 1 |
| Phylum Gnathostomulida | 1 |
| Phylum Annelida | 289 |
| Phylum Mollusca | 230 |
| Phylum Arthropoda | 633 |
| Phylum Sipunculida | 3 |
| Phylum Echiurida | 1 |
| Phylum Tardigrada | * |
| Phylum Bryozoa | 19 |
| Phylum Phoronida | 2 |
| Phylum Brachiopoda | 1 |
| Phylum Echinodermata | 29 |
| Phylum Chaetognatha | 4 |
| Phylum Chordata | 940 |
| Subphylum Urochordata | 14 |
| Subphylum Hemichordata | 2 |
| Subphylum Vertebrata | 924 |
| Class Elasmobranchiomorphi | 23 |
| Class Osteichthys | 211 |
| Class Amphibia | 30 |
| Class Reptilia | 87 |
| Class Aves | 494 |
| Class Mammalia | 79 |

species and consists of the lesser known phyla (Rotifera, 8; Chaetognatha, 6; Platyhelminthes, 3; Sipunculida, 3; Ctenophora, 2; Phoronida, 2; Gastrotricha, 2; Kinorhyncha, 1; Gnathostomulida, 1, Echiurida, 1; Brachiopoda, 1). There are several other phyla not listed in the literature but have been found during estuarine studies in the area ( e.g., Tardigrada) (R. Kalke, pers. comm.).

The number of species of some invertebrate taxa within the CCBNEP checklist should be considered with caution, especially the smaller-sized and lesser known groups. Recent critical reviews of biological diversity in the sea indicate that there are far greater numbers than previously known or expected for some groups (Fenchel, 1993). Locally within the CCBNEP study area, recent studies of marine, benthic meiofauna and macrofauna reveal many new species and previously unrecorded but known species (P. Montagna, pers. comm.). Groups particularly in need of taxonomic attention include the platyhelminths, gastrotrichs, nematodes, rotifers, gnathostomulids, polychaetes, and the smallest molluscs and crustaceans.

### 2.2 Vertebrates

There are 924 species of vertebrates listed including 494 birds, 234 fish, 87 reptiles, 79 mammals, and 30 amphibians. The fish include 211 bony and 23 cartilaginous species. The amphibians, reptiles, and mammals are dominated by terrestrial species found on natural islands within the area; but they do include five species of sea turtles and 17 species of marine mammals. Birds are the largest vertebrate group and include 19 orders and 55 families. The dominant group is the passerines (Passeriformes), which includes the majority of the neotropical migrant landbirds, with 155 species. Significant numbers of species are also found in two waterbird groups, shorebirds (Charadriiformes) with 80 species and waterfowl (Anseriformes) with 38 species.

## 3. Biodiversity

Biological diversity, or biodiversity as it is more commonly termed today, refers to the number of species, either within a defined area or globally. In conservation contexts, biodiversity is increasingly being interpreted at the level of ecosystems or communities of interacting organisms (May, 1994). Marine biodiversity provides a wealth of essential goods and services to humankind. However, this diversity can be diminished on land and sea alike by five major threats: over-exploitation, physical alteration, pollution, introduction of alien species and global atmospheric change (Norse, 1995). These threats to marine biodiversity are driven by increasing human population and resource consumption, general lack of knowledge, weak institutions and failure to place sufficient economic value on products and services from the sea (Norse, 1995).

On a global scale threats to marine biodiversity are greatest in estuaries and coastal waters near large human population centers (Norse, 1995). As scientists and resource managers work closer together they both agree that public education is a key factor in all marine conservation and that informed people opt for sustainability. Emphasis and far greater support is needed in the traditional areas of taxonomy, biogeography, and ecology for inventory, and long-term monitoring of marine species and ecosystems (Norse, 1993, 1995).

Within the CCBNEP study area, it may appear that biodiversity is great upon looking at the species checklist (Appendix I in Volume 4). However, several critical concerns have surfaced with the literature search and compilation of the checklist. Nationally, as well as locally, for the last several decades, there has been a general trend away from systematics and taxonomy, which is now being recognized as a crisis at a time when species and ecosystem inventories are greatly needed for monitoring purposes (Feldman and Manning, 1992). Secondly, some major multi-year inventories of CCBNEP estuarine species were never published in peer-reviewed scientific journals, and therefore, species were not verified. Our nationally recognized, verification taxonomists for this Living Resources Project discovered numerous errors and discrepancies in the "gray literature" of the area. In defense of some of these major studies, it must be pointed out that they made great contributions to the knowledge of biodiversity in the area, and also, that most scientific journals of today will not accept such lengthy listings, therefore compounding the problem.

Lastly, our checklist is greatly lacking in demonstrating the total biodiversity of the area, especially in terms of the smaller-sized and lesser known invertebrates. Some of these groups are undoubtedly missing many species, even hundreds, from the checklist. The list should probably contain between 4,000-5,000 species, possibly more. However, with the current situation nationally of training fewer and fewer systematists, it is unlikely that the numbers will increase significantly in the near future.

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