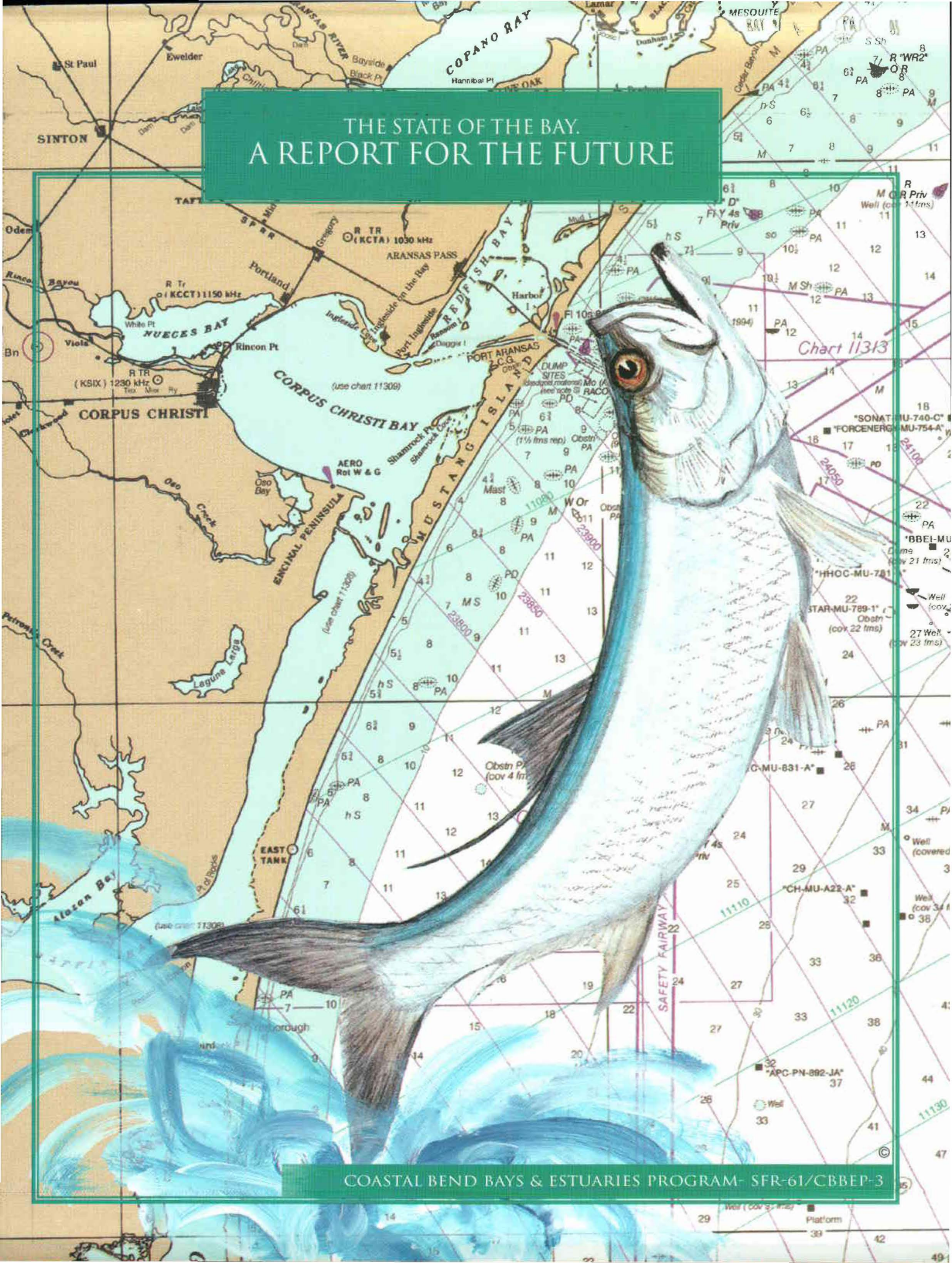
THE STATE OF THE BAY.
A REPORT FOR THE FUTURE



COASTAL BEND BAYS & ESTUARIES PROGRAM- SFR-61/CBBEP-3

The National Estuary Program was established by the Clean Water Act Amendments of 1987 to protect nationally significant estuaries threatened by pollution, development, and overuse. National Estuary Programs combine the knowledge and talents of citizen and technical advisors, senior governmental officials and staff, and elected officials (working through a Management Conference) to develop sound scientific information about the estuary and to promote effective management solutions to identified problems. The Coastal Bend estuaries were selected for inclusion in the elite ranks of this 28-member national program in October 1992.

During the first year of the program, the Management Conference identified a list of priority issues that affect not only the health of the estuaries, but also the regional economy and the region's high quality of life. Potential issues were discussed by more than 300 people in 13 public meetings held around the region. Six of the priority issues were confirmed through this process and one additional priority issue, public health, was added as a result of public comment. The seven priority issues are altered freshwater inflows, loss of wetlands and other estuarine habitats, condition of living resources, degradation of water and sediment quality, altered estuarine circulation, bay debris, and public health issues.

A draft Management Plan (the Coastal Bend Bays Plan) was released for public review in early 1998 and a revised plan is expected to be approved in late 1998. This plan identifies the recommended actions developed, through a consensus-based process, to address the priority issues and their contributing factors.

The Coastal Bend Bays Plan, along with more than 30 technical characterization reports which serve as the information base for this report, was prepared under the auspices of the Corpus Christi Bay National Estuary Program. The Program's name was changed to the Coastal Bend Bays & Estuaries Program in recognition of the wider geographic area described herein as the "project area".

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THE STATE OF THE BAY:
PREFACE

Estuaries, the transition zone between fresh and salt water, provide a vast array of services to the Coastal Bend human population, as well as a home and food for a huge percentage of our fish and shrimp during some stage of their lives. Many of our diverse plants and wildife use these waters for a home and food as well. Because of their great productivity, Coastal Bend estuaries support prime commercial and recreational fishing activities for both residents and visitors. They also provide many other valuable services like water purification, storm protection, and education. In addition to all these services, Coastal Bend estuaries are used for other recreational activities, such as swimming and boating, and for commercial activities, such as marine transportation, oil and gas production, business and residential development. These varied uses of our estuaries and their resources influence the way the estuaries function and their ability to sustain productivity.

Along the Texas coast there are seven major estuaries. Three of these estuaries -- the Aransas, Corpus Christi, and upper Laguna Madre -- are in the 12 county region known as the Coastal Bend. The Coastal Bend is home to over 540,000 people, representing about three percent of the population of Texas. Over time, human use of the Coastal Bend's land and water resources for economic and recreational activities has changed the natural environment, and even stressed the environment in some areas.

The dredging of the ship channel and inner coastal waterway and damming of the Nueces, Frio, and Atascosa Rivers have resulted in profound changes in water flows in the estuaries and associated habitats. Agricultural activities have sometimes led to erosion of the land and to increases in pesticides and nutrients in the estuaries. The installation and maintenance of oil and gas pipelines have disrupted aquatic habitats. Other uses of the land and water resources can cause problems as well. For example, boating and bay shrimping can disturb bay bottoms and the organisms that depend on this environment.

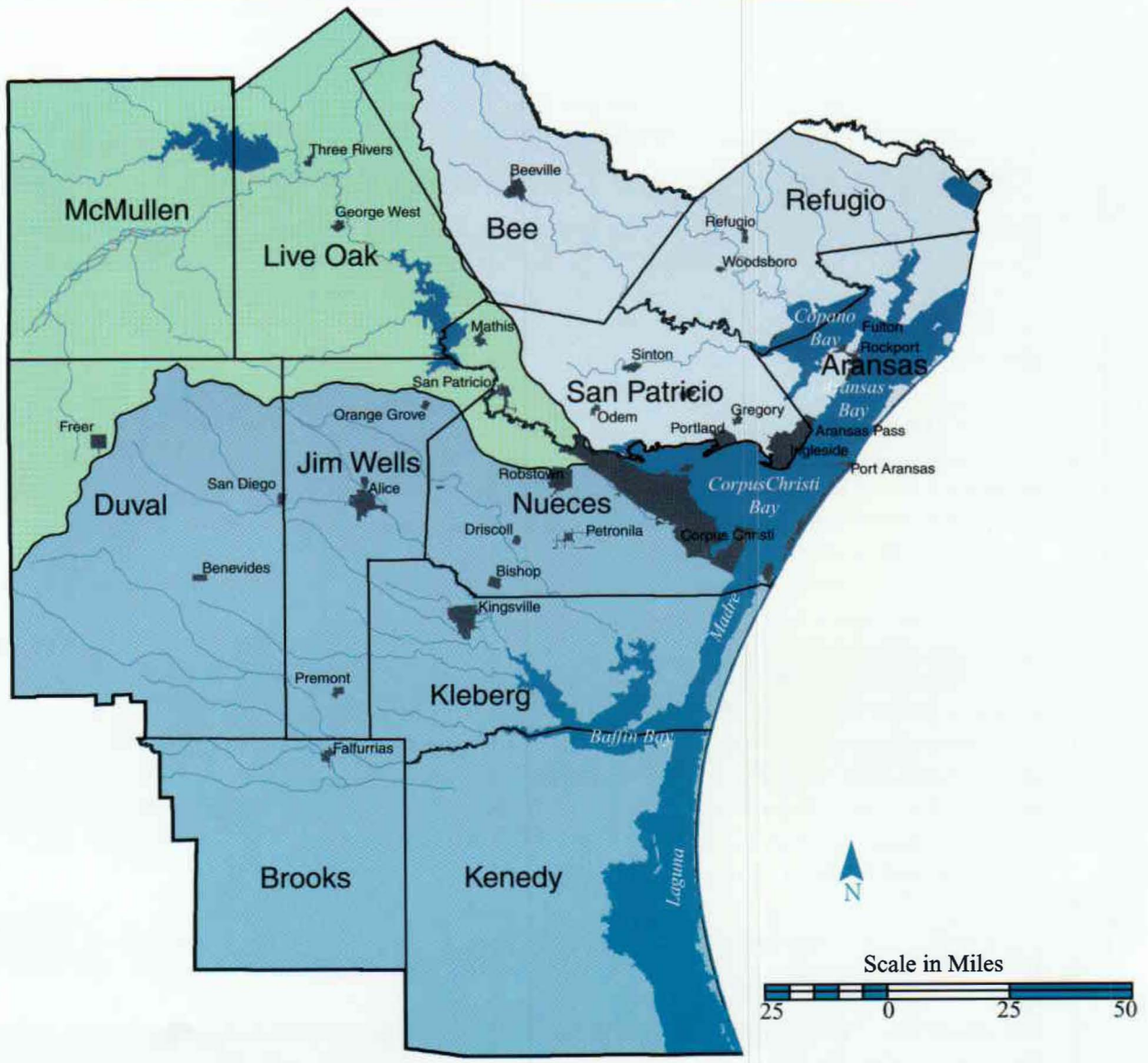
An increasing number of visitors results in an increased demand for more public access points so people can use the beaches and bays. However, increased bay usage threatens habitat integrity and imperils the natural resources that attract visitors to the area in the first place. The challenge for the Coastal Bend community is to continue to provide for the many important uses of the estuaries and their natural resources while protecting these resources for many generations to come. This is one reason that citizens of the Coastal Bend launched an initiative to designate the region as a National Estuary Program site.

The following chapters explore the rich history of the Coastal Bend region, from before the first settlers through today. The natural characteristics of the bays and estuaries of the Coastal Bend region are described, including their physical structure, diverse habitats, and luxuriant plant and animal life. The extent of historic and current human impacts are summarized. Additionally, the economic, public health, and ecological issues as researched and defined by the Coastal Bend Bays & Estuaries Program (CBBEP) are presented. Most of the information presented in this State of the Bay is taken from technical reports prepared for the CBBEP and are available from the CBBEP office.

THE COASTAL BEND BAYS & ESTUARIES: MAP

The Coastal Bend Bays & Estuaries Program (CBBEP) project area is made up of a network of bays and rivers in the 12 counties of the Coastal Bend area of South Texas. The CBBEP encompasses the area from the eastern edge of Mesquite Bay in the north to the southern limit of "The Hole", or the northern edge of the land cut in Laguna Madre. It is bounded on the east by four barrier islands: Matagorda, San Jose, Mustang, and Padre Islands. Only one major pass, the Aransas Pass, connects the estuary system to the Gulf of Mexico.





Legend

- San Antonio - Nueces Coastal Basin
- Nueces River Basin
- Nueces - Rio Grande Coastal Basin

CONTENTS

- A Summary of Findings — PAGE 4
- A Story of Change — PAGE 7
- What Makes an Estuary Work? — PAGE 19
- How Healthy are our Estuaries Today? — PAGE 27
- What Can You Do? — PAGE 61
- Glossary — PAGE 64

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THE STATE OF THE BAY: A SUMMARY OF FINDINGS

Habitat and Living Resources

The type and distribution of habitats in the Coastal Bend bays have significantly changed over the past century due to natural phenomena and human activities. Wind-tidal flats have declined the most, losing more than 24,710 acres during this time. Intertidal marsh losses in some areas have been offset by substantial gains in other areas. The total area of bay bottom covered by seagrass beds has increased substantially since the first surveys in the late 1950s. Seagrasses in Coastal Bend bays now represent about 40 percent of all seagrasses in Texas. Seagrass coverage in some areas has declined, however, due to motorboat propeller scarring and shading caused by plankton blooms and algal growth.

The most recent list of the living resources found in the Coastal Bend bays and marshes includes at least 835 species of plants and 2,340 species of animals. Since many small and inconspicuous animals have not been identified, the actual number of species may be as high as 5,000. There are 19 species of plants and animals in the Coastal Bend that are threatened or endangered.

The Coastal Bend is one of the richest sources of fisheries in Texas, providing over 28 percent of the state's commercial harvest of finfish, shrimp, crabs, and other aquatic species each year. There is evidence, however, of declines in populations of pink and brown shrimp, adult blue crabs, Atlantic croaker, and Gulf menhaden. Populations of other species, such as spotted seatrout and red drum, have increased over the past several decades, largely as a result of fisheries management practices.

Over 490 species of birds have been recorded in the Coastal Bend. This enormous diversity is attributed to the availability of numerous habitats, and to the geographical location of the Coastal Bend within a major migration route. Several species are in serious decline in the Coastal Bend, however, including the great egret, snowy egret, and Forester's tern.

Red tide and brown tide have caused biological and economic damage in recent years. The causes of these excessive growths of algae are not clear.

Freshwater Resources

Freshwater inflow to the estuaries comes from the Nueces River basin and from other streams and rivers that flow into the Coastal Bend bays. The region is drought-prone with infrequent occurrences of excess rainfall events, thus freshwater inflow into the system is of critical concern.

Annual flow from the Nueces River declined by 55 percent over the past 60 years. This change in flow is associated primarily with reduced inflows to the Nueces basin and construction of Lake Corpus Christi and Choke Canyon Reservoir. Overall, there has been a 19 percent reduction in freshwater inflow to all the Coastal Bend estuaries. At present, the Aransas Estuary receives about 53 percent of the total 1.2 million acre-feet of freshwater inflow to the region. The Corpus Christi Estuary currently receives 35 percent of the total inflow, while the upper Laguna Madre receives about 12 percent.

Low freshwater inflow rates and high evaporation rates combine to produce a 50 month freshwater replacement rate for the Corpus Christi Estuary, which is quite long relative to other estuaries throughout the nation. This means that the estuary is not well flushed and is potentially more sensitive to wasteloads, including pollutants. In addition, warm water temperatures and high salinities result in low oxygen levels that are only slightly above the state water quality standard (5 parts per million), established to avoid physiological stress to living resources. Thus, the estuary has little capacity to absorb additional pollutants without harm.

Human Uses

Tourism and bay-related activities clearly impact the Coastal Bend economy, providing nearly 25 percent of area jobs. Sport-fishing, bird watching, and windsurfing together contribute over $90 million a year to the local economy. Over the last 20 years, the Coastal Bend's recreational fishery contributed about 28 percent of the total catch from all Texas Bays.

The growing number of bay users, however, is putting increased pressure on the natural resources of the Coastal Bend and has resulted in losses of critical habitats and reductions in animal populations. Residential and industrial developments have led to the conversion of about 17 percent of natural beach and marsh shoreline into hardened shorelines with bulkheads, riprap, and other solid structures.

Public health threats from water contact or consumption of local seafoods are not significant at the present time. However, oysters from Nueces Bay and blue crabs from Redfish and Baffin Bays have elevated tissue levels of several heavy metals, suggesting the need for additional monitoring to ensure seafood safety.

Maritime Commerce and Dredging

Both vessel traffic and the volume of freight transported within the estuaries of the Coastal Bend have increased substantially over the past two decades. More than 90 percent of this cargo is oil and petrochemicals. Spills of these hazardous materials have been substantially reduced since enactment and enforcement of the Oil Pollution Act of 1990.

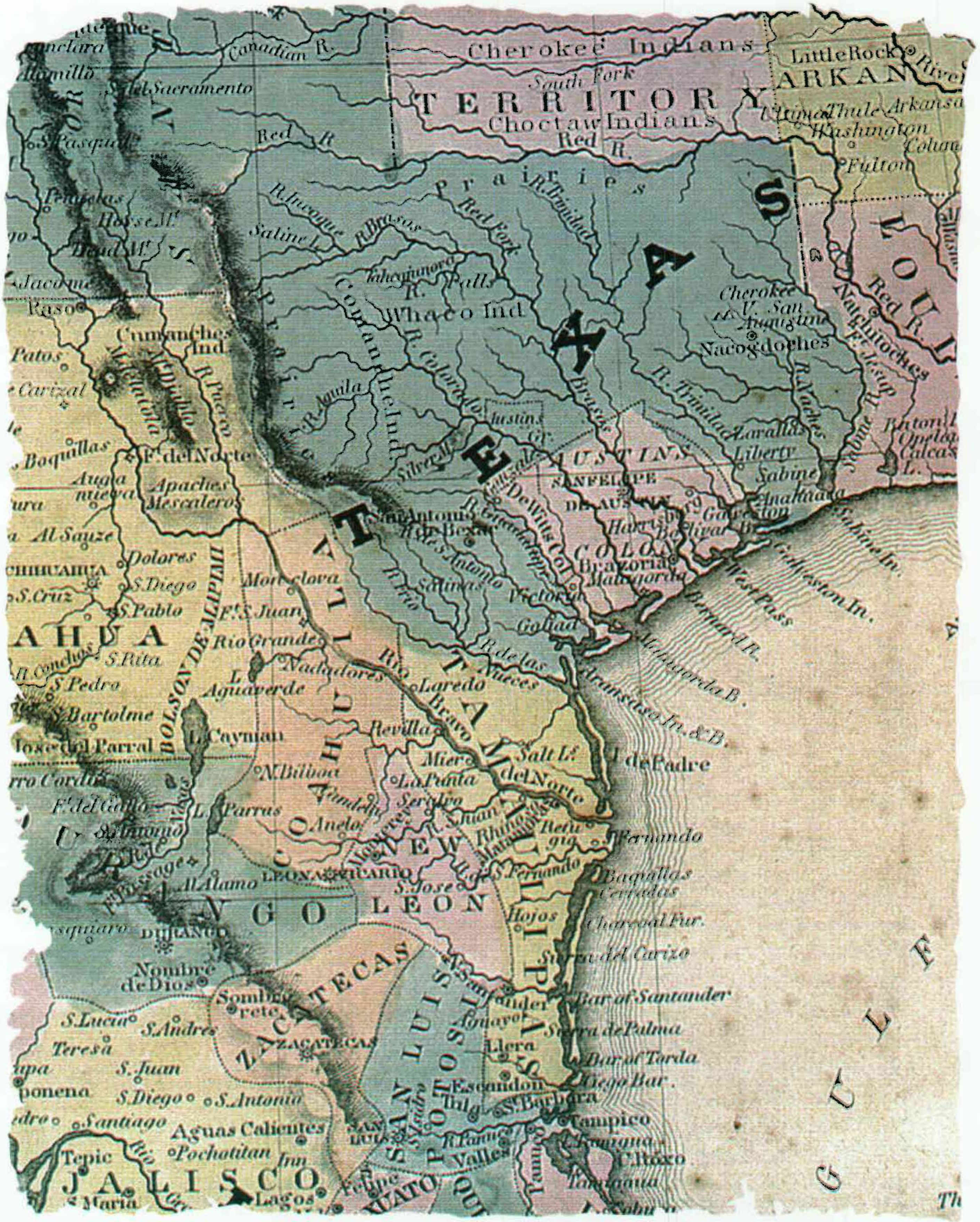
Dredging is a necessary and ongoing activity to maintain navigable waterways in the Coastal Bend estuaries. There is, however, a lack of consensus about the beneficial or adverse effects of dredging projects and the disposal of dredged material.

Water and Sediment Quality

Water and sediment quality within the Coastal Bend estuaries is generally good to moderate but some areas of fair to poor quality have been identified. The Inner Harbor has the highest levels of many pollutants including metals, PCBs, organic contaminants, and fecal coliforms. Nueces Bay has consistently high metal concentrations in both the sediment and water column. Zinc levels appear to be increasing in some regions of the bays and are 10 times higher in the Inner Harbor sediment than in portions of the Houston Ship Channel. Trends in concentrations of other metals cannot be determined from the available data. It is unlikely that metal contaminants in the bays pose a threat to aquatic life.

Most identifiable or "point source" loadings of pollutants are found in the central portion of the Coastal Bend bays, primarily in Nueces and Corpus Christi Bays, while the upper bays receive the least. However, pollutants from these sources have decreased over the past 25 years.

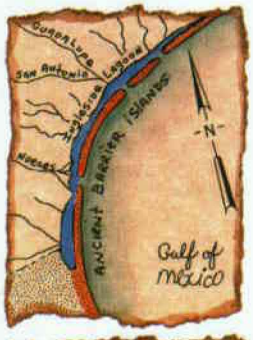
Urban and agricultural runoff and airborne pollutants, often from far away sources, all contribute to what is known as "nonpoint source" pollution. The central bays receive most of the urban runoff while the upper bays receive much of the agricultural runoff. Chemicals in the water from these sources are found at levels more-or-less typical of other Texas bays. The highest concentrations of the common pesticides are found in Baffin and Copano Bays, but concentrations do not exceed standards. Sediments from some urban storm drain outfall sites have elevated levels of contaminants, are toxic to sensitive life stages of test organisms, and have a low diversity of bottom dwelling organisms.

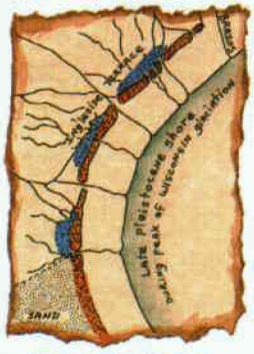

Cherokee Indians
TERRITORY
Choctaw Indians
Red R.
Canadian R.
Red R.
Prairies
TEXAS
Nacogdoches
Whaco Ind.
Comanche Ind.
R. Colorado
Brazos
R. Trinidad
AUSTINS
Liberty
Sabine
Galveston
Brazoria
Matagorda
Victoria
Goliad
San Antonio
R. Nueces
Laredo
Rio Bravo
Rio Grande
Revilla
Mier
Monclova
Parras
Saltillo
COAHUILA
TAMAULIPAS
NUEVO LEON
ZACATECAS
SAN LUIS POTOSI
Tampico
JALISCO
Aguas Calientes
Tepic
Lagos
Dolores
S. Diego
S. Pablo
BOLSON DE MAPIMI
L. Cayman
Nombre de Dios
Sombrerete
Cumanches Ind.
Apaches Mescaleros
F. del Norte
Natchitoches
LittleRock
ARKAN
Washington
Fulton
Galveston In.
Sabine In.
West Pass
Bernard R.
Matagorda B.
Aransaso In. & B.
I. de Padre
Fernando
Bar of Santander
Bar of Tarda
GULF
Patos
Carizal
Boquillas
Al Sauze
S. Rita
S. Pedro
S. Bartolme
Jose del Parral
Teresa
S. Juan
S. Diego
S. Antonio
S. Andres
S. Lucia
Santiago
Pochotitan
Escandon
Llera
S. Barbara
Valles

THE STATE OF THE BAY:
A STORY OF CHANGE

"The estuary is the point where man, the sea -- his immemorial ally and adversary -- and the land meet and challenge each other."

(U.S. Department of the Interior, National Estuarine Pollution study, November 1969)





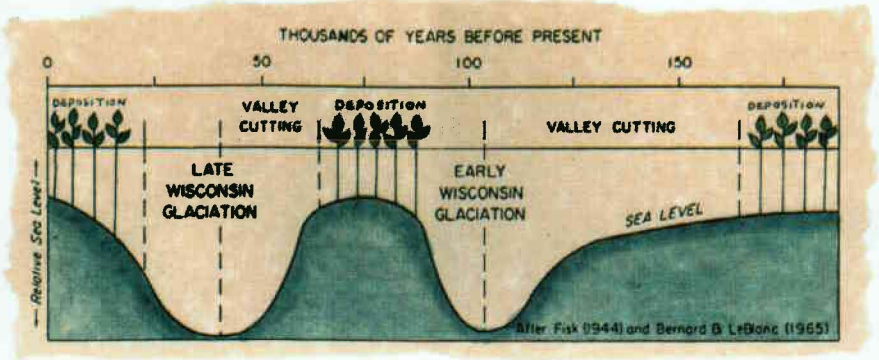


Within the 12 county Coastal Bend area of Texas, there are three estuarine systems (the Aransas, the Corpus Christi, and the upper Laguna Madre), which include 25 bays. These estuaries have evolved over the last several thousand years, and the natural environment as we know it today is the product of dynamic geological and ecological change. Because, historically, human settlements have thrived in areas which provided a suitable living place and abundant resources, the chronology of settlement in the Coastal Bend has been intimately linked to periods when natural changes in the environment favored colonization.

At the peak of the last Ice Age (called the "Pleistocene" by geologists), around 18,000 B.C., much of the world's water supply was captured within massive continental glaciers. Hence, the coastal estuaries as known today did not exist. Sea level was 300 feet or more below its present position, and the Gulf shoreline was far east of its modern location. As global temperatures warmed toward the end of the Pleistocene, around 16,000 B.C., glacial ice began to melt causing the sea level to rise. Geologic studies show that, by 7,000 B.C., the rising sea had begun to flood the river valleys along the Texas coastline, creating the early forms of the Coastal Bend estuaries as well as the other major estuaries and bays currently found along the Texas coast.

The modern estuarine system evolved over the next few thousand years as sea level continued to rise at a slower rate. Between 7,000 and 1,000 B.C., sea level rose unevenly. Periods of stable or slowly rising sea level alternated with times of rapid rise. Recent geologic studies suggest sea level was relatively stable between about 6,000 and 5,000 B.C., again between 4,000 and 2,500 B.C., and finally during the last 3,000 years or so, when the sea has been at about its present level.

The major time frames during which prehistoric people lived along the shores of the Coastal Bend are roughly the same as those periods when sea level was relatively stable. This is probably because stable sea level tends to favor an abundance of aquatic life. The gradual accumulation of clay, sand, and silt on bay bottoms formed broad areas of shallow-water vegetation and marshes. Decaying plant material in these areas contributed organic nutrients important for sustaining life in the estuaries. With abundant nutrients, the bays and lagoons could support large populations of crustaceans, mollusks, and fish, which would have pro-











vided a rich source of food for prehistoric peoples.

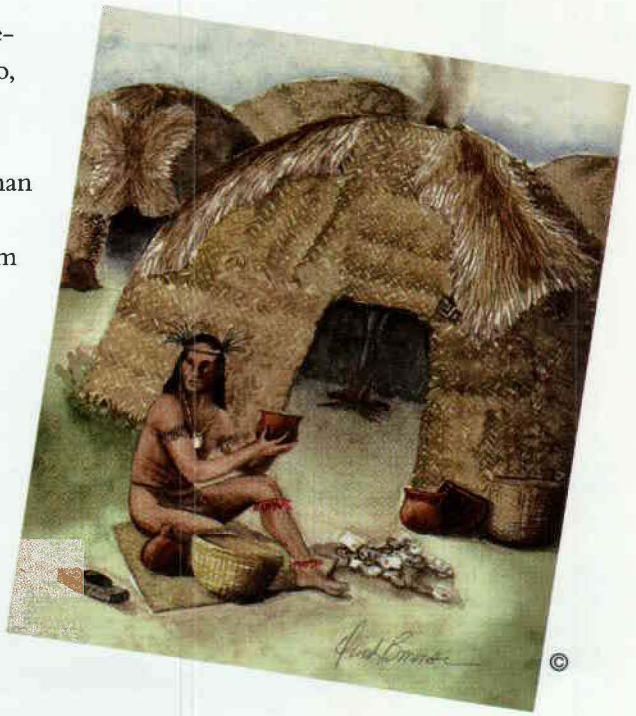
The Archaic Period

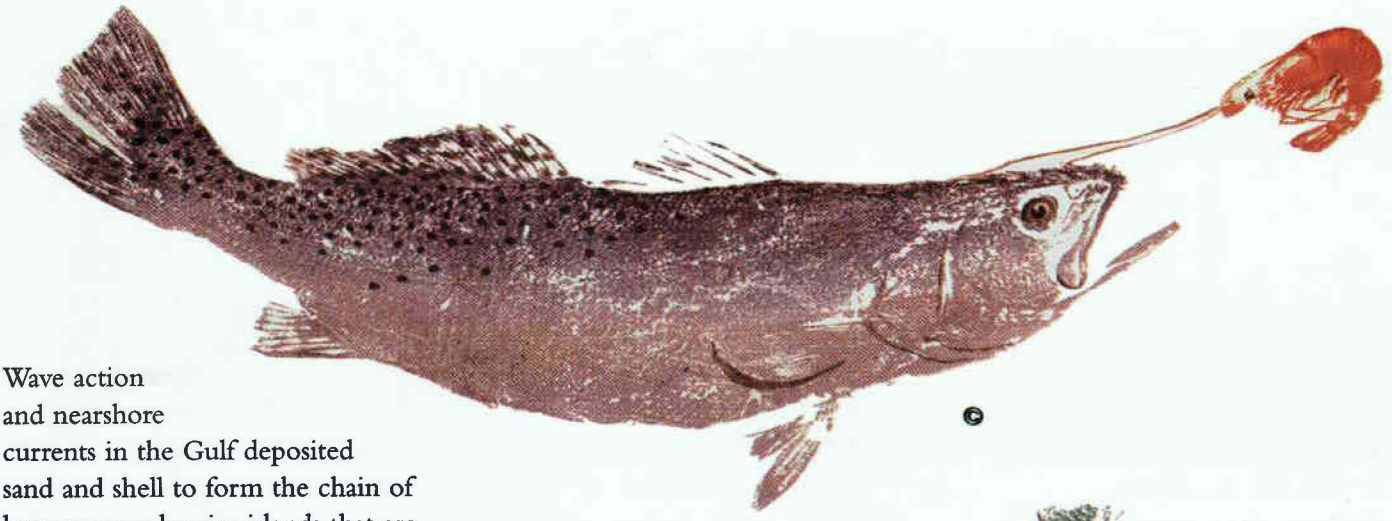
Archaeological studies at sites around Corpus Christi and Nueces Bays show that prehistoric Native Americans camped along the shorelines as early as 5,500 B.C. This period of occupation is known as the "Archaic" Period. In Texas, the Archaic Period lasted until the appearance of the bow and arrow and pottery between about 500 and 800 A.D.

Based on the lack of archaeological sites, there was little human presence in the Coastal Bend between 4,800 and 4,000 B.C. Geologic evidence suggests that sea level may have been rising rapidly at this time. The food-rich shoreline shallows would have been inundated and too small in area to offer an abundance of resources for prehistoric peoples. However, for the subsequent 1,400 years or so, until 2,500 B.C., the shorelines were once again attractive to human settlement. Archeological sites from this period typically contain dense deposits of discarded shells of oysters and Rangia flexuosa clams. There is also evidence of fishing, as indicated by the remains of black drum, red drum, spotted seatrout, Atlantic croaker, and saltwater catfish.

A gap in archeological evidence of shoreline settlement occurred again between about 2,500 and 1,000 B.C. There is geologic evidence for rapid sea level rise during this period. Once again, the vegetated shallows and marshes important for production of nutrients may have been greatly reduced in area. Consequently, the food resources necessary to favor the residence of sizeable numbers of people were absent.

By around 1,000 B.C., sea level had stabilized close to its modern position and the estuarine environment began to resemble its present form. In fact, without the sprawl of today's commercial and residential development, the Coastal Bend bay system would look much like it did during the days of the Karankawa Indians, the first settlers.





Wave action and nearshore currents in the Gulf deposited sand and shell to form the chain of long, narrow barrier islands that are a prominent feature of today's coastline. Behind the barrier islands, river-borne sand, silt, and clay sediments partially filled the bays and lagoons, creating broad shallow water areas and supporting marshes along bay shorelines and around the head of Nueces Bay and the Nueces River Delta. The plant communities in these areas provided a rich source of organic nutrients as a food source. The broad, vegetated shallows became ideal protective nursery areas for the young of many of the fish and shrimp species that have historically abounded in the bays and lagoons. A growing reliance on fish by prehistoric people is shown by dramatic increases in the numbers of fish remains found in archaeological sites dating about 2,000 years ago. As the estuaries became an increasingly rich source of food, the population of coastal Indian groups increased, as shown by larger campsites with thicker deposits of camp debris than in earlier times.

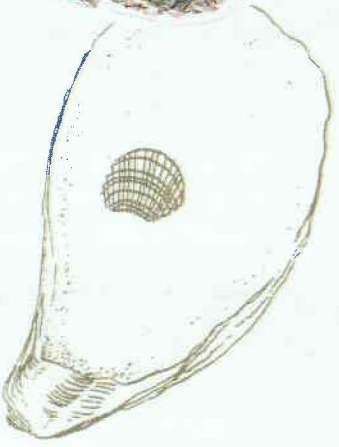
The Late Prehistoric Period

The Late Prehistoric Period began around 800 to 1,000 A.D. Native American people, notably the Karankawa Indians, began to acquire new technologies. The bow and arrow replaced the dart and spear as the main hunting weapon. Pottery, a technology introduced from the north, was commonly used.

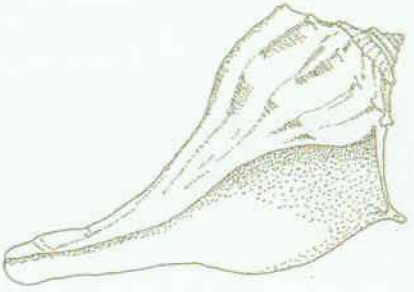
During the Late Prehistoric Period, the rich resources of the estuaries were of great importance to native peoples. Fish bones are found in tremendous quantities on archaeological sites, indicating that species such as black drum, red drum, spotted seatrout, and Atlantic croaker had become important dietary staples. Large numbers of perforated oyster shells, probably used as net weights, suggest that fish were commonly harvested in nets. Shellfish such as oyster, lightning whelk, and bay scallop were gathered. Bones of deer and bison indicate that hunting of game animals was also common.

Large shoreline fishing camps were occupied mainly from the fall through the winter and early spring. This seasonal presence of fishing camps may be related to the fall and winter early spring spawning cycles of red and black drum, large fish species which would have been abundant in the bays during their reproductive season. During the spring and summer, much of the population left the shorelines to set up hunting camps along the lower











The wreck of LaSalle's ship, the Belle, was discovered in Matagorda Bay's murky waters more than 300 years after LaSalle's ill fated mission to reach the Mississippi by sea. Another French ship L'Aimable, found just this year, was part of the colonization effort by La Salle. With 300 French colonists aboard, L'Aimable went aground off Matagorda Island in 1685. Fearing further French settlement, the Spanish authorities in New Spain (Mexico) built a series of missions and presidios. The earliest mission near the coast was Espiritu Santo, which unsuccessfully attempted to convert the Karankawas to Christianity.





reaches of the Nueces River and other streams flowing into coastal bays. Studies of animal bone refuse at these sites show that the main sources of meat at hunting camps were white-tailed deer and buffalo.



The Early Historic Period

The first European to leave a record of native life on the Texas coast was Cabeza de Vaca, who was shipwrecked and marooned on the upper part of the coast in 1528, possibly at Galveston Island. Cabeza de Vaca's account states that native people lived on this island during the fall and winter, subsisting mainly on fish and plant roots gathered from the lagoonal waters on the back side of the island. In the spring, the Indians moved to the mainland, where they gathered oysters from the shoreline, and probably hunted and gathered plants as well.

The Karankawa Indians were encountered by various European explorers and Spanish missionaries and soldiers beginning in the late 1600s. Early records indicate that these Indians had detailed knowledge of their environment and its resources. Dugout canoes were made for transportation on the rivers, bays, and lagoons behind the barrier islands, although they were unsuitable for travel in the open sea. The bow and arrow was used for hunting and even some fishing.

European Colonization

The French were the first Europeans to colonize the Texas central coast region, beginning with La Salle's Fort St. Louis settlement (near Matagorda Bay) in 1685.

After many years of conflict between the Karankawas and the Spanish colonists, a treaty of peace was concluded in 1790. Historical documents indicate that this was the beginning of some 40 years of peace and alliance between the two parties. In fact, the final Spanish mission of Nuestra SeÒora del Refugio, established in 1795 at the site of present-day Refugio, Texas, became a focal point for conversion of many Karankawas to Christianity. The peaceful interaction between the Karankawas and the Spanish colony ended abruptly when the revolution in Mexico expelled Spanish authority and the newly formed Mexican government grant-

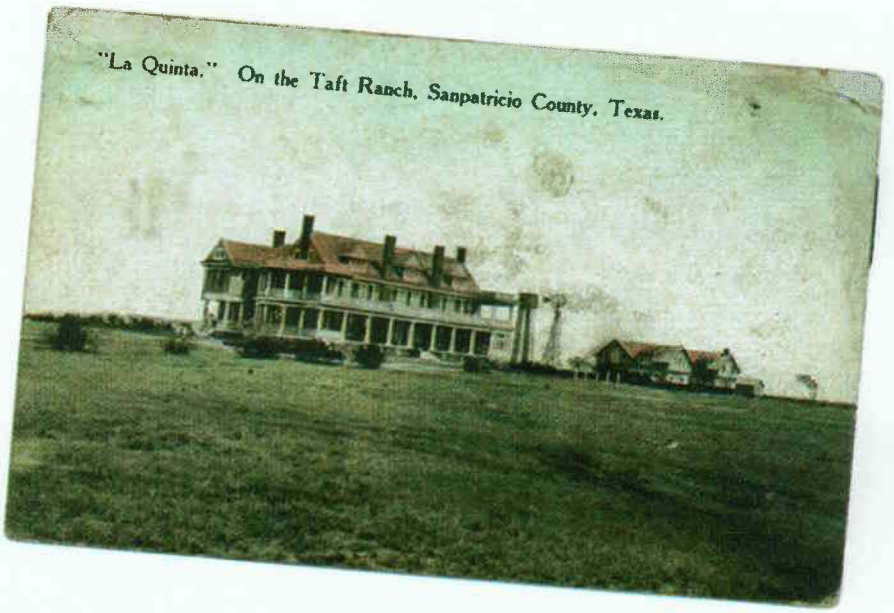
ed large tracts of land to cattle ranchers. By the 1850s, the Karankawas had been driven from their homeland, and many probably fled to northern Mexico. Over the next two decades, the Karankawas disappeared.

The Wartime Years

Between 1834 and 1835, as Texas struggled for independence from Mexico, there were skirmishes and battles throughout the Coastal Bend region. Although the revolution ended in 1836, the border between Texas and Mexico -- between the Nueces River and the Rio Grande -- was under dispute for many years. In 1839, a small lucrative trading post was founded on the site of present day Corpus Christi, considered the furthermost outpost of both Texas and Mexico.

During the 1840s and 1850s, the main concerns in the region were Indian attacks and commerce. An interest in improving commerce resulted in several unsuccessful attempts to deepen the pass into Corpus Christi Bay. The citizens of the region also failed in their attempt to petition the U.S. government to base troops in the area to provide protection from the Indians.

By the time of the Civil War, the region was firmly behind the southern cause, even though slavery was not very prevalent. This position seems to have been an outgrowth of the lack of federal government response to petitions for protection and support. During the Civil War, the Union successfully blockaded the Texas coast, including entry into Corpus Christi Bay. This resulted in the opening of a Confederate overland highway of trade between East Texas and Mexico.

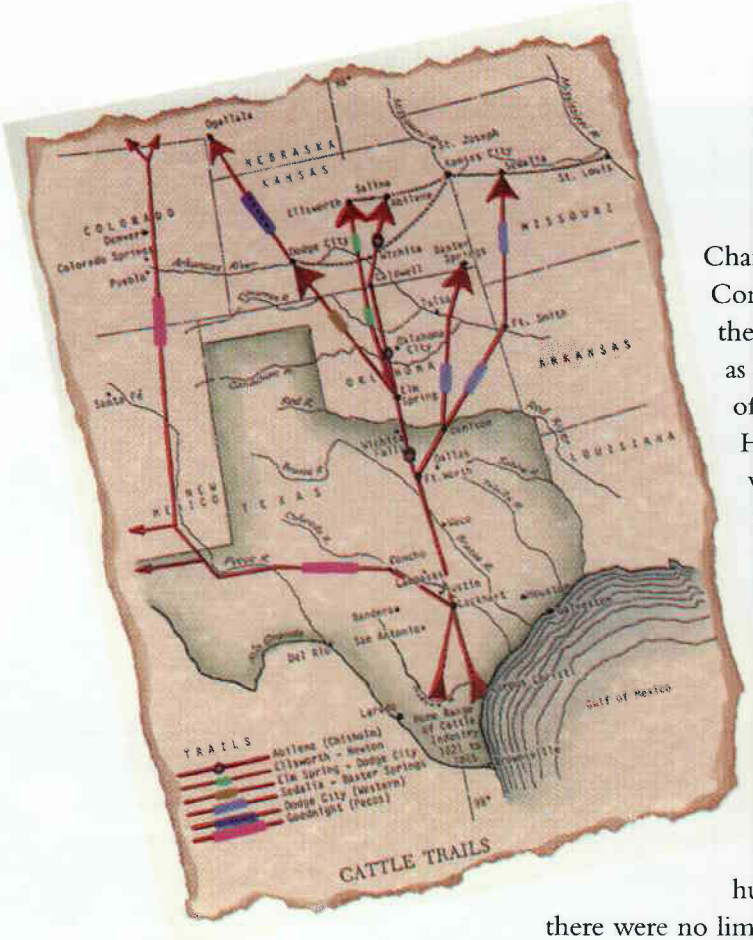


Early ranchers received vast tracts of land as grants from the Mexican or Spanish governments. Among these ranches were the King Ranch (headquartered in Kleberg County), the O'Connor Ranch (headquartered in Refugio County), the Welder Ranch (headquartered in Refugio County), and the Coleman-Fulton Pasture Company (later the Taft Ranch) (headquartered in San Patricio County).

The Late 1800s

The reconstruction period following the Civil War was a time of lawlessness in the region. It was also during this time that the cattle industry flourished, stimulated by the unregulated growth of herds during the War. Tanning and tallow factories sprang up along the coast between Corpus Christi and Galveston. Cattle were so numerous that many were slaughtered for their hides alone, leaving their carcasses to rot in city streets.

The city of Rockport was founded in 1866 and provided the first cattle pens and a wharf. The first hide and tallow factory in Rockport was built in 1867, and the city grew to become the center of commerce in the region. In 1888, Rockport was twice the size of Corpus Christi, and the



Chamber of Commerce advertised the future Rockport as the "Coming City of 200,000 people". Hides and tallow were shipped via schooner; over 300,000 hides were shipped from Rockport and Corpus Christi in 1872.

The sand flats were a hunter's paradise; there were no limits on ducks, geese, cranes, and other waterfowl. Egg-hunting expeditions brought in thousands of bird eggs. A news report said of one weekend foray: "crane, shear-water, pelican, snipe, duck, dove, mockingbird, etc." Boston and New York milliners advertised premium prices for heron plumes, egret plumes, and alligator skins, as well as for feathers and skins from sea birds of all species, blue jays, yellow hammers, silver grey herons, white pelicans, and swans.



In 1894, the total marine harvest for Aransas, Refugio, and Nueces Counties was approximately 3 million pounds, including fish, oysters, and sea turtles, valued at approximately $115,000.



A hurricane in September 1874 was a harbinger of things to come for those who would build their homes and businesses on a low lying sandspit. The 1874 storm wrecked the Corpus Christi bayfront, destroying structures and boats along the main street, Water Street.

The arrival of the railroad and the ice plant business enabled fresh fish and game to be shipped to far points and boosted fishing to a major industry. The Corpus Christi Caller reported in 1892: "Fishermen have been getting rich in quick order. On Saturday, the fish boats made one haul near the reef and captured 20,000 pounds, which netted them $750".

Between 1865 and 1900, local governments undertook several public works projects. Deepening the channel into Corpus Christi became a hot local political issue which was resolved in 1874 by increasing the channel depth to eight feet. In 1891, Corpus Christi had telephones, telegraph service, two railroads, two fine hotels, an electric system was pending, and the economy was booming. In the late 1890s, however, a financial panic gripped the country and the Eastern money that had fueled the boom dried up. Progress on public works projects was stymied. For example, the dredge broke down on Mustang Island and, for lack of spare parts, was swallowed up by the sands of the barrier island.



Crossing the oyster reef from Portland to Corpus Christi circa 1900.

The 20th Century: Human Development and Impacts

"We all like to congregate," he went on, "at boundary conditions. Where land meets water. Where earth meets air. Where body meets mind. Where space meets time. We like to be on one side and look at the other." (Mostly Harmless, Douglas Adams, Crown Publishers Inc.)

Corpus Christi in 1900 was an unusual combination of cowtown and coastal village. Rockport was still the center of commerce for the region and its population had grown from a few hundred settlers to over 35,000 people. The primary industries were cattle, cotton, and shipping. However, both natural and human related events would change the relationship between Rockport and Corpus Christi, starting with a hurricane in 1919 which virtually destroyed Rockport.

While courting the farmer, Corpus Christi promoters did not overlook the tourist. The city was billed as an all year seaside resort, "where the weary can come for rest, the invalid come for health, and the gay devotee come for pleasure". It was surely a paradise for sportsmen; no piece of promotional literature was complete without pictures of shotgunners festooned with dozens of ducks, a gigantic tarpon towering over a man with a rod, or long stringers of trout.









(1919)



Beulah (1967)



Celia (1970)

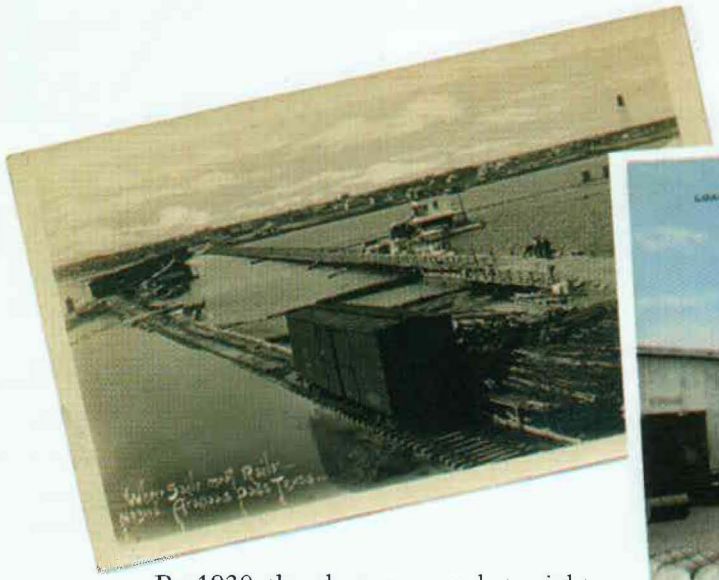
Today, Corpus Christi Beach is an island, connected to the city by Harbor Bridge, which was constructed over the ship channel. Once, however, it was El Rincon, a peninsula jutting out from the landmass of the city. In 1908, El Rincon was declared to have the best fishing waters along the Texas coast. The transportation system was so effective that fish caught in the morning were often at their destination by afternoon. Four companies were packing fish and oysters. In 1907 alone, one million pounds of fish and 10 million oysters were shipped.

A municipal administration elected in 1913 under Mayor Roy Miller began the transformation of Corpus Christi into a modern city. Within 3 years, the administration paved 12 miles of streets, laid 26 miles of storm and sanitary sewers, installed a modern water system, built a new city hall and municipal wharf, and installed a paid fire department.

In 1922, Corpus Christi was selected under the Federal Rivers and Harbor Act as the location for a "safe and adequate harbor" for this area of Texas.

The 1926 dredging of the ship channel and opening of the Port of Corpus Christi ushered in an era of rapid growth for the region -- wharves, oil docks, warehouses, storage tanks, manufacturing facilities, and other industrial plants were built.







By 1930, the changes in Corpus Christi were evident. The cowtown had fulfilled its promise to the farmer and home-seeker; for example, in 1930, Nueces County was the top cotton producing county in the United States. The coastal village had become a modern city as well as a seaport. The area's great natural gas supplies and oilfields had been tapped and the first large industrial plant would be built in three years. Seawall construction and dredging extended the shoreline from present-day Water Street to Ocean Drive. In the early 1940s, the Gulf Intracoastal Waterway was constructed from Galveston to Corpus Christi, enabling large volumes of bulk commodities to be shipped and received at relatively low cost. The link to Brownsville was constructed a decade later.

There was an increase in fishing and a decline in oystering. During the early and mid 1900s, tarpon drew tourists from around the world and Port Aransas, first known as Tarpon, was a fishing mecca for this fish. Today, tarpon are rarely caught in the area. There has been much speculation about what might have contributed to the loss of the tarpon and other species but, to date, scientists do not have a definitive answer. Decreasing freshwater inflows, increased use of pesticides, habitat loss, and overfishing have all been suspected as causes for the decline.

By the mid-1960s, the years of intense growth and change had been replaced with decidedly slower growth and little change. However, five economic sectors had risen to prominence in the region: agriculture, oil and gas production, manufacturing and port related transportation, government activities (largely national defense), and the visitor industry.

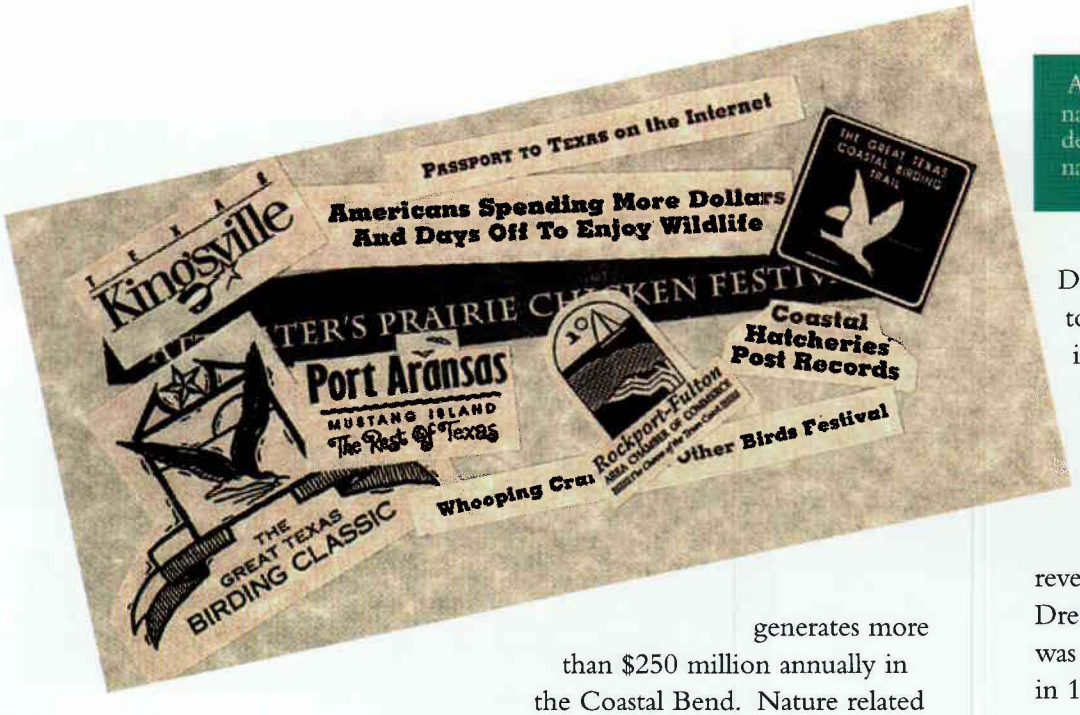
Today's Economy

Today, over 540,000 people live within the 12 county region of the Coastal Bend. By the year 2050 close to a million people will call the Coastal Bend home.

In Texas, tourism is a $23 billion a year business, the third largest industry in the state. Tourism



Corpus Christi's population increased from 10,522 in 1920 to 27,410 in 1930 and was destined to double again in each of the two following decades.



A profitable and sustainable nature tourism industry is dependent upon an enduring nature resource base.

generates more than $250 million annually in the Coastal Bend. Nature related tourism is the fastest growing component of the growing tourist industry.

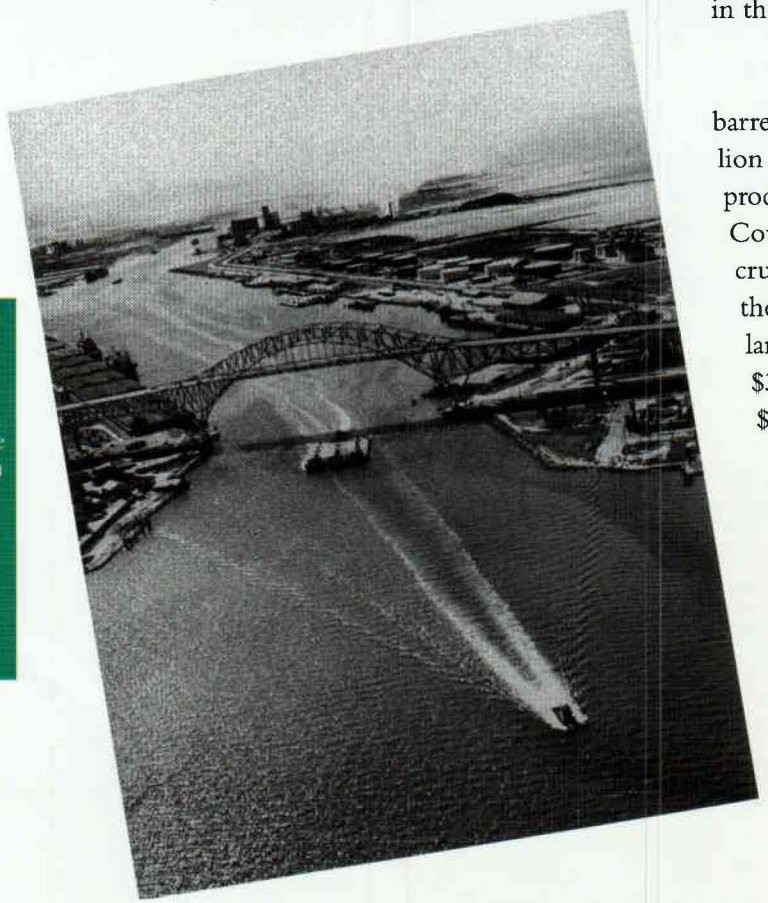
Nature tourists are travelers who spend their time and money enjoying and appreciating a broad range of outdoor activities that have a minimum impact on the environment.

For a combination of reasons, including regulatory controls, the total landings of commercial finfish have dropped from three million pounds in 1977 to less than one million pounds per year since 1984.

During this same period, the total pounds of shrimp landed in the region have increased 400 percent.

The Port of Corpus Christi, the nation's sixth largest, generates over $1 billion of revenue for related businesses. Dredging to a depth of 45 feet was completed in 1990.

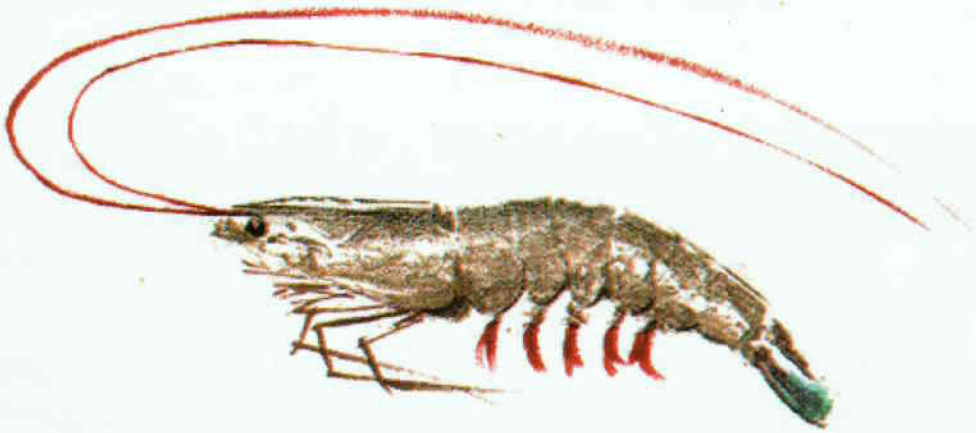
Of the approximately 100 estuaries around the nation, the Coastal Bend ranks fourth in agricultural acreage. Row crops (cotton, sorghum, and corn) and livestock generated $480 million in 1994, with a statewide economic impact of $1.6 billion. In 1993, there were 4,500 ranches supporting 280,000 head of cattle in the Coastal Bend.



In 1994, 15.3 million barrels of crude oil and 399 million cubic feet of natural gas were produced in the region. Refugio County led in the production of crude oil and Duval County in the production of gas. The dollar value at the wellhead was $324 million for oil (1993) and $685 million for gas (1992).

The Corpus Christi Port (the nation's 6th largest) 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. A total of 6,618 vessels traveled through the Port's channels in 1994. That same year, total tonnage exceeded 77 million.

There are four military facilities in the Coastal Bend region: Corpus Christi Army Depot, Naval Air Station Corpus Christi, Naval Station Ingleside, and Naval Air Station Kingsville. Employees at these facilities number



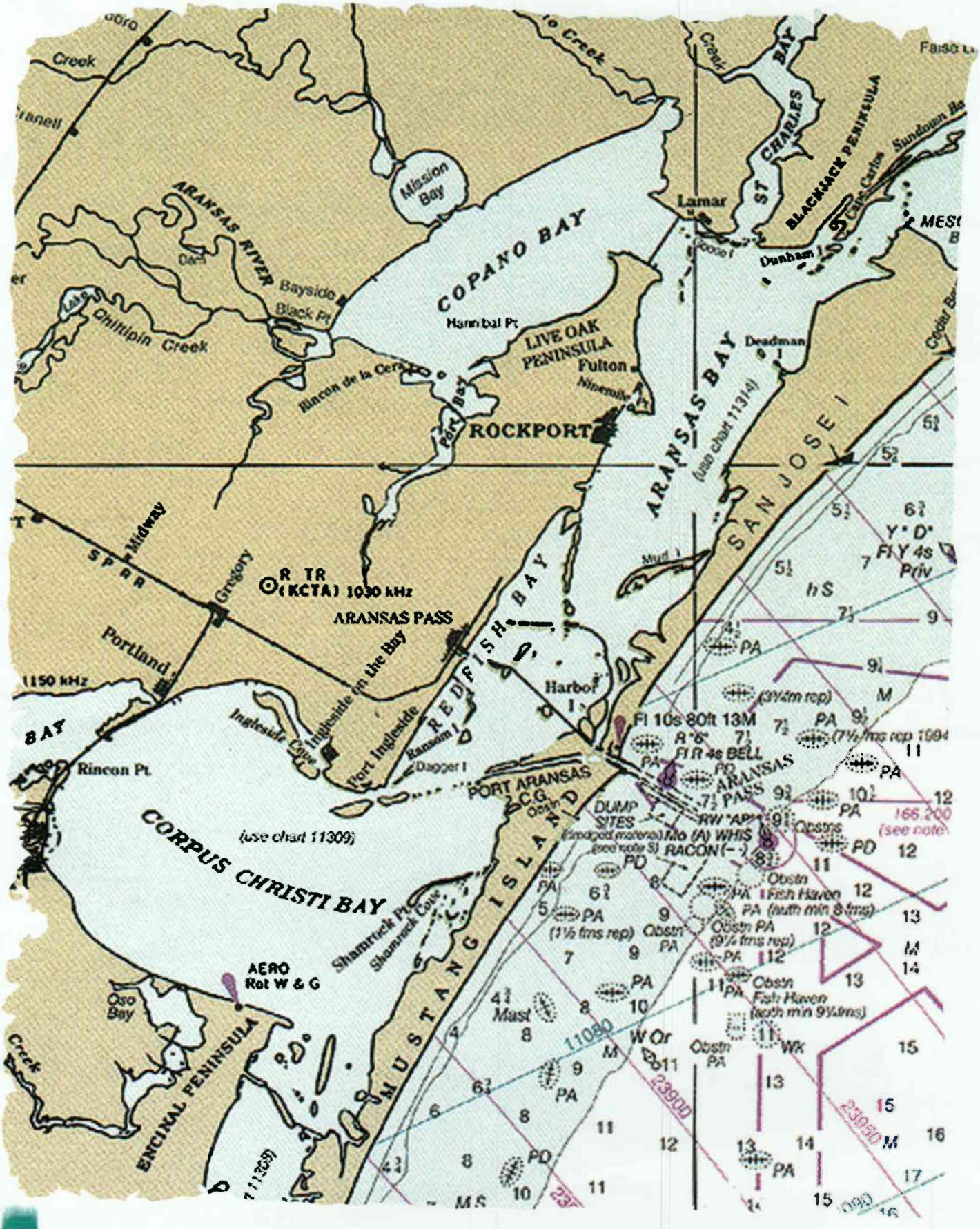
over 11,800 with an annual payroll of over $316 million.

The use of the land and water resources for these activities has changed the natural environment in some cases and created stress in others. The challenge is to continue to provide for the many important uses of the Coastal Bend bays and estuaries while protecting their natural resources for many generations to come.

Shrimp is the state's most valuable commercial food fishery with 1993 landings of 74 million pounds worth $131 million. The total market impact of the shrimp harvest on the state economy is estimated at half a billion dollars. The ex-vessel value of commercial landings of marine species within the Coastal Bend has increased from $2 million in 1972 to $5.8 million in 1982, and $13.2 million in 1992.



Five million people visited the Coastal Bend in 1996. Recreational fishing generates $37 million per year in state and local taxes, with a regional economic impact of $546 million. Non-fishing recreational activity adds another $23 million in state and local taxes, and $340 million in regional economic impact. A study by the Texas Agricultural Experiment Station in 1987 found that the recreational and commercial fisheries and related industries, along with other recreational activities, contributed nearly $760 million to the local economy, with a statewide impact of $1.3 billion that year.


Creek
Mission Bay
ARANSAS RIVER
Bayside
Black Pt
Chiltipin Creek
COPANO BAY
Harnbal Pt
LIVE OAK PENINSULA
Fulton
Rincon de la Cera
ROCKPORT
Port Bay
ARANSAS BAY
(use chart 11314)
Lamar
ST CHARLES BAY
BLACKJACK PENINSULA
Dunham I
Deadman I
SAN JOSE I
Midway
SP RR
Gregory
R TR
(KCTA) 1030 kHz
ARANSAS PASS
Portland
1150 kHz
REDFISH BAY
Harbor I
Ingleside on the Bay
Ingleside Cove
Port Ingleside
Ransom I
Dagger I
Rincon Pt
BAY
CORPUS CHRISTI BAY
(use chart 11309)
PORT ARANSAS
CG
Obstn
DUMP SITES
(dredged material)
(see note 5)
Mo (A) WHIS
RACON (–)
Fl 10s 80ft 13M
R "6"
Fl R 4s BELL
ARANSAS PASS
Fish Haven
(south min 8 fms)
(9¼ fms rep)
(1½ fms rep)
(3¼m rep)
Fl Y 4s
Priv
Shamrock Pt
Shamrock Cove
MUSTANG ISLAND
AERO
Rot W & G
Oso Bay
ENCINAL PENINSULA
Creek
Mast
W Or
Wk
11080
23900
23950
166.200
(see note)

THE STATE OF THE BAY:
WHAT MAKES AN ESTUARY WORK?

"An estuary is a partially enclosed coastal body of water which is either permanently or periodically open to the sea, and within which there is a measurable variation of salinity due to the mixture of sea water with fresh water derived from land." J.H. Day

Estuaries are unique and complex transitional zones between freshwater and saltwater that provide tremendous economic, ecological, and aesthetic values. They contain a variety of habitat types, which, in turn, support luxuriant vegetation and substantial numbers of animals. Throughout human history, the richness of estuarine waters and their surrounding habitats have led to colonization and the rise of civilizations. Today, estuarine areas are important economically for their commercial and sport fisheries, navigational waterways, and various types of recreation.

The most defining features of estuaries are best observed from the air. A curious observer on an aerial tour of a Texas estuary would first see a river at the head of the estuary, away from the ocean. The river mouth may be difficult to pinpoint due to the natural widening and meandering of the river and the presence of marsh vegetation. In this area of the estuary, freshwater carries large amounts of sediment and the water appears brown and murky.

In the direction of the ocean, the water becomes greenish and transparent as sediment settles to the bottom. Marshes, dunes, and mud flats border the shoreline of the estuary, while submerged seagrass beds appear as dark green smudges on a light brown mud bottom. A wide opening or narrow pass through a barrier island provides an opening to the sea.

Viewing an estuary from the air, however, does not do justice to its diverse assemblage of plants and animals and its life-sustaining functions. To appreciate this biodiversity, one would have to walk through salt marsh wetlands and dunes, swim in shallow areas to observe plants, young fish, and crustaceans, dig in the mud for small organisms, and tow nets of various shapes and sizes to reveal other hidden secrets. Even then, one would see only a fraction of the species that the estuary supports. Understanding this complexity is a key step in preserving the delicate balance between the living resources and the environment on which they depend.

Within the estuary and the marsh lives a fascinating diversity of creatures ranging in size and development from one-celled plants to migrant birds and shrimp; permanent residents such as clams, blue crabs, and fish; and even marine mammals like the bottlenosed dolphin. The ultimate benefits to us for preserving this biodiversity are a bountiful harvest, aesthetic pleasure, recreational opportunities, tourism, and other economic rewards.

Formation of Estuaries

Barrier island estuaries, such as those found along the Texas coast, are common on the Atlantic and Gulf Coasts of the United States. The barrier island, composed mainly of sand and shell, lies parallel to the coast and separates estuarine waters from ocean waters. An extensive network of these barrier islands runs from Maine to Texas, a distance of over 2,500 miles. While some are mere



Tropical storms and hurricanes strike the Coastal Bend on average every five to ten years. They often produce very heavy rainfall and, occasionally, significant storm-surge flooding as well. These powerful storms reshape the coastal landscape by moving massive amounts of sand and mud from one place to another, especially on the barrier islands and in the bays. They can temporally open new tidal passes and close others.

Estuaries such as the Laguna Madre experience limited exchange with the sea and little riverine inflow. The high water temperatures typical of subtropical climates lead to extensive evaporation. As a consequence, salinities tend to be even higher than seawater. Such estuaries are known as hypersaline lagoons. The Laguna Madre is one of only a few hypersaline lagoons in the world.

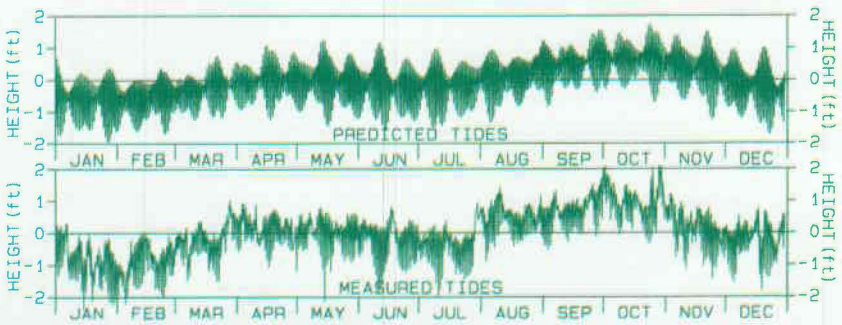
shoals, others extend continuously for hundreds of miles. Padre Island in Texas is one of the world's longest barrier islands.

These estuaries are formed by the interaction of the coastline with the rising ocean following a glaciation event. The complex of bars built by marine processes, and coastal dunes formed by wind-blown sand are slowly eroded by waves and storms. Eventually a pass is opened, allowing seawater to flood the area behind the dunes. The flooded area becomes a shallow estuary, and what was once a dune is now a barrier island.

Barrier islands offer protection to coastal areas and estuarine habitats from storms, hurricanes, and wave action. They also provide extensive habitat for animals and plants, ranging from clams, worms, and ghost shrimp buried among sand grains on the beach, to drought-resistant dune vegetation. Given the turbulent nature of their formation, sea level changes which may occur over time, and storm-caused erosion, barrier islands are not stable over long time periods. The ocean will eventually claim that which it owns.

Tides and Salinity

Tides are caused by the gravitational pull of the moon and sun on ocean waters. As the tide rises (flood tide), water is pushed into an estuary through one or more tidal passes and the estuary gets temporarily deeper. Likewise, receding water (ebb tide) results in a lowering of the water level within an estuary. The timing and height of low and high tides along the coast depend on the shape and size of the estuaries and the orientation



Predicted v/s actual tides at the UTMSI Pier Laboratory (27 50.3'N; 097 03.0'W) for 1995



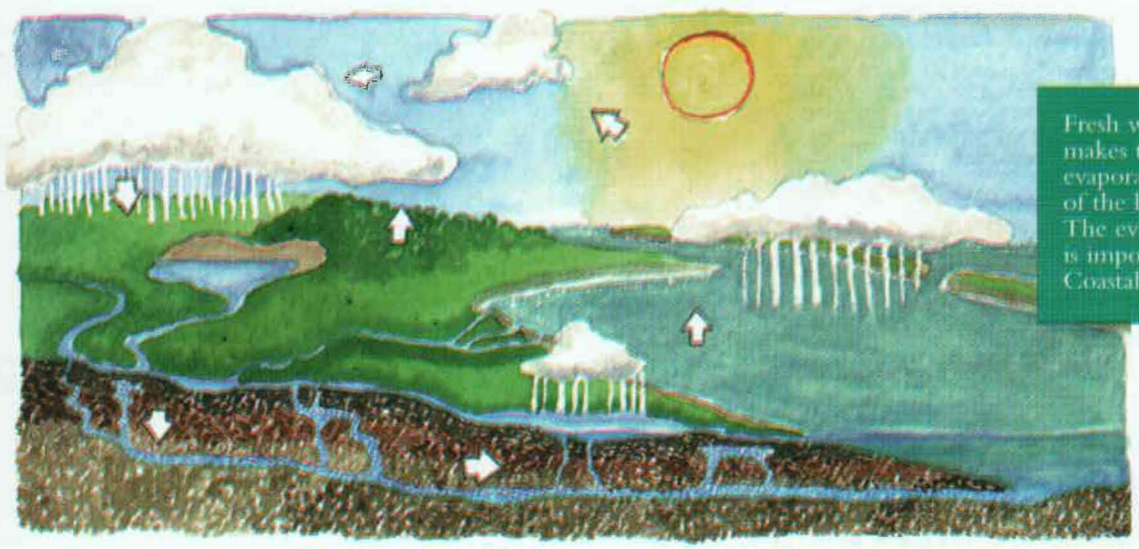
The climate of the Coastal Bend is sub-humid and sub-tropical, with short, mild winters and long, hot, humid summers. At any time of the year there can be one-day rainfall totals in excess of 5 inches, and much higher totals are possible during hurricanes. On the other hand, it is not uncommon for the region to go 30 to 40 days without measurable rainfall. Annual rainfall at Corpus Christi has ranged from about 19 inches to almost 50 inches with an annual average of about 30 inches. Extreme conditions are essentially the norm in the Coastal Bend, and this climate pattern has substantial impacts on physical and biological processes in the estuaries. Local climate patterns also play an important role in an area's ecology.

of the coastline. In the Coastal Bend, these factors combine to produce a relatively small daily tidal range of about 1.5 feet on Gulf beaches and only 0.5 feet in the upper bays like Nueces Bay.

The action of tides plays an important role in estuarine circulation, primarily by mixing seawater with the lighter freshwater. As freshwater enters an estuary from a river, it can form a "lens" which floats above seawater. In most shallow estuaries, the action of tides, storms, and wind leads to extensive mixing of both fresh and salt water. Such estuaries are considered well mixed.

Salinity varies widely within an estuary. It is lowest near the river mouth because of the influence of freshwater. Conversely, salinities are usually much higher closer to the tidal pass as a result of the influence of seawater.

In Texas, the salinity characteristics of estuaries follow a distinct latitudinal pattern. Low-salinity estuaries are found toward the northeast due to the significant influence of rivers and rainfall.



Fresh water flowing into the bays makes the bay water fresher, while evaporation of water from the surface of the bays increases the salinity. The evaporation/precipitation cycle is important in regulating salinity in Coastal Bend Bays.

Nutrients are necessary for plant growth and are delivered naturally to an estuary by rivers and local runoff from rainfall. Flourishing plants can, in turn, support large numbers of organisms higher in the food web. The productivity of a system is measured by the quantity and growth of its organisms. Estuaries are among the most productive ecosystems in the world .

Salinities tend to be higher in southern estuaries due to scant rainfall, low freshwater inflow, and high evaporation.

The salinity structure of an estuary plays an important role in defining the distribution of different kinds of animals and plants. Some living resources are tolerant of only freshwater or seawater. Other living resources are capable of surviving within a range of salinities to which they have adapted. Because of salinity differences, estuarine ecosystems encompass many different types of habitats and support diverse plant and animal life.



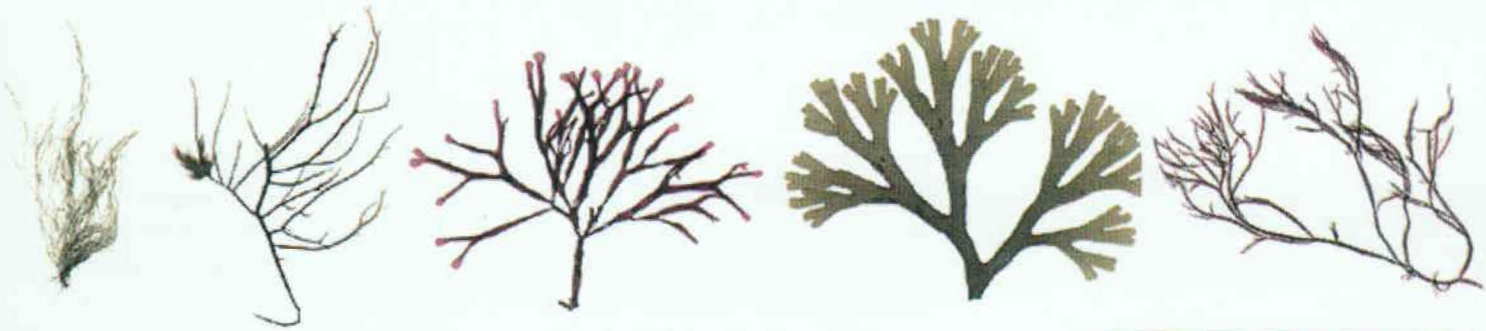
Occasional events, such as heavy rain or a hurricane, can completely change the salinity of an entire estuary in a very short time period. In an extreme case, an estuary could resemble a giant lake, or, alternatively, a lack of freshwater inflow could raise the salinity way above normal. Both of these conditions, when extended for long periods of time, can be harmful to many plants and animals.

Biota - The Plants and Animals

"What makes it so hard to organize the environment sensibly is that everything we touch is hooked up to everything else."
Isaac Asimov

Estuaries include a variety of habitats, such as marshes, seagrass beds, unvegetated bay bottoms, oyster reefs, and wind tidal flats. The species composition of a particular habitat results from the interaction of many factors, including salinity, nutrients, currents, light and oxygen availability, sediment distribution, and temperature. The land and waters of the Coastal Bend provide a home for over 2,000 kinds of animals. Nearly 500 species of resident and migratory birds make this area one of the richest birding regions in North America.

At the base of the estuarine food web are plants, the primary producers. Plants require both light and nutrients. Plants need sufficient light for photosynthesis and there-



fore are found in shallow areas or floating near the water surface.

There are a variety of primary producers. For example, phytoplankton are microscopic plants that abound in the water or are embedded in the top layer of bottom sediment where light is still available. Algae are much larger aquatic plants that exhibit a dazzling display of color and form. They lack roots and stems, and their fronds (leaves) soak up nutrients directly from the water. Algae usually thrive attached to rocks, other plants, or even while drifting freely.

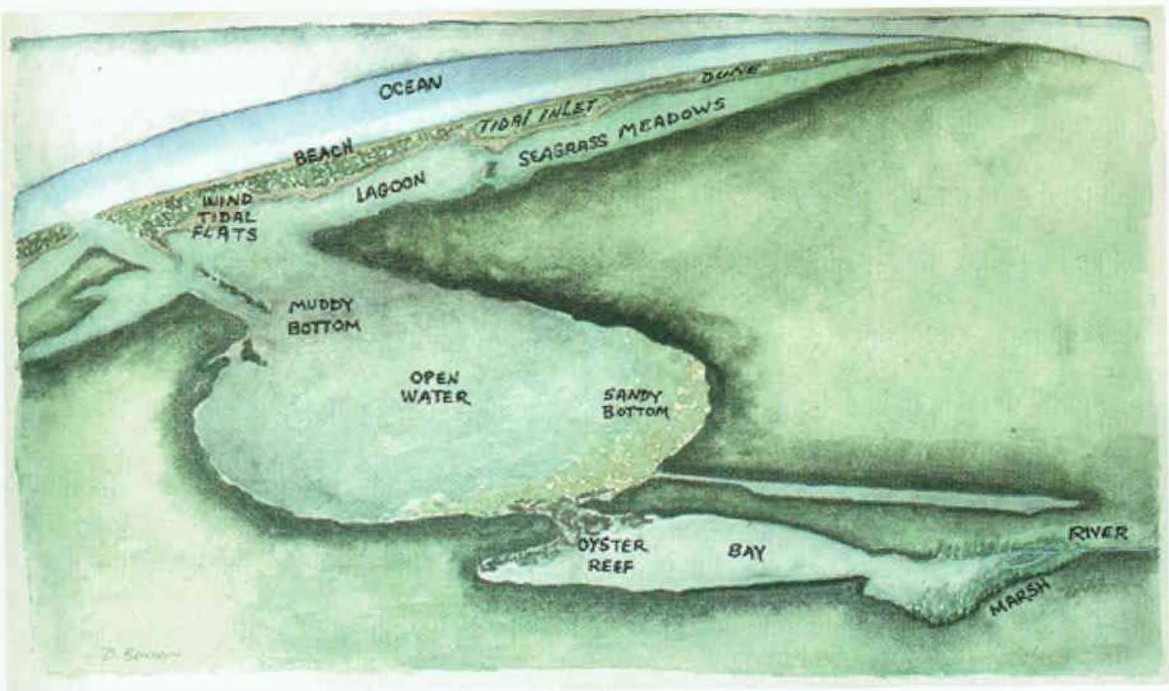
Seagrasses have roots and other structures commonly found in the terrestrial plants, from which they evolved. As the only group of true marine flowering plants, seagrasses have the capacity to remain permanently submerged in estuarine areas.

Seagrass habitats typically contain large numbers of animals. Often called "nursery areas", seagrass meadows provide both food and shelter for the young of numerous fish and shrimp, including red drum, spotted seatrout, and brown shrimp. Adult fish like to feed in this lush habitat too. Seagrass meadows also have numerous permanent residents, but these are mostly small and relatively inconspicuous species such as seahorses, gobies, and grass shrimp.

The distribution and coverage of seagrass meadows vary over time due to both human distur-

Seaweeds are found attatched to jetties, piers, oysters and other hard substrates.

All plant groups contribute to the productivity of an estuary. A relatively small fraction of plant material is directly consumed by animals, while a significant portion is consumed by bacteria. The bacteria are, in turn, consumed by larger organisms. Bacteria also aid in the regeneration of nutrients from decaying plant and animal material. Hence, they are in essence the "recyclers" of the estuarine environment and are largely responsible for sustaining the productivity of the system.





Shoal Grass



Manatee Grass

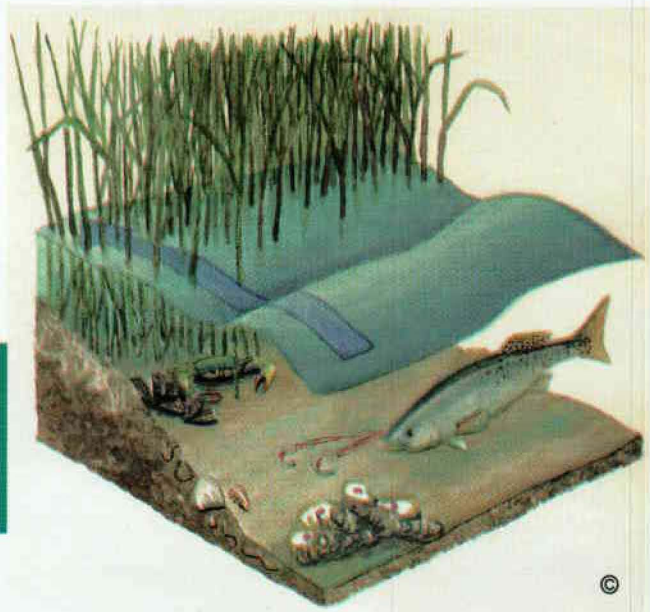


Turtle Grass



Clover Grass

Marshes and shallow vegetated bays slow the velocity of flood waters and buffer coastal lands against storm and wave damage.



bances and natural processes. Because seagrasses require large amounts of light for growth, disturbances that cause long-term reductions in available light are among the primary factors that impact seagrass health. These disturbances include changes in land use patterns, erosion, channel dredging, and placement of dredged material, all of which may increase turbidity.

Reduced light availability can also result from excessive nutrient loadings from fertilizers, sewage disposal, and other sources. This can lead to an increase in phytoplankton blooms which can reduce light penetration. In addition to reducing light availability, channel dredging can directly impact seagrasses if channels are dug through seagrass beds, or if dredged material is placed on the seagrasses. However, federal and state regulations enacted over the past two decades have substantially reduced dredging activity through seagrass meadows.

There are many potential fates for primary producers. Zooplankton, a community composed of tiny animals such as protozoans, crustaceans, and the larvae of crabs and shrimp, may graze on phytoplankton or on each other. Zooplankton serve as food for small fish and some birds, which are capable of filtering them from the water.

Bay bottoms teem with life and provide a rich food supply for other animals. The term "benthos" is used for the wide assortment of plants and animals associated with the bottom of an estuary, including clams that filter water for small particles of food and burrowing worms and shrimp that consume the remains of plant and animal material. These organisms are key components in the movement of energy from plants to higher level consumers in the estuaries. Birds and fish, as well as crabs, feed on these bottom dwelling animals.

Services Provided by Estuaries

Estuaries provide a vast array of services to Coastal Bend residents and visitors. In addition to providing a home and food for many diverse plants and animals and a bountiful harvest of seafood, these services include water purification, storm protection, recreation, education, and maritime commerce.

Estuaries provide natural flood control and function as pollution filtration systems. As water circulates through an estuary, plants use some of the potential pollutants,

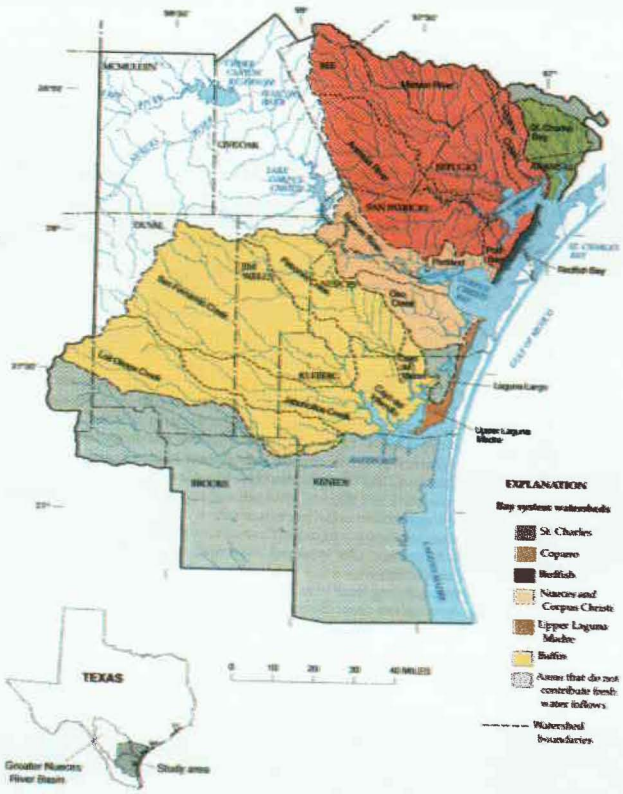
such as phosphorus and nitrogen, as nutrients. The natural capacity of plants to use pollutants for healthy growth is limited, however. If estuarine waters are excessively contaminated with toxins such as pesticides, heavy metals, or industrial chemicals, these pollutants can pass into the food web and potentially degrade the system.

Seagrasses and marsh plants prevent erosion because their underground root structure binds sediments in place. In addition, the submerged leaves of seagrasses promote sediment deposition. During heavy rainfall events water flows into marshes where it can be stored and slowly released.

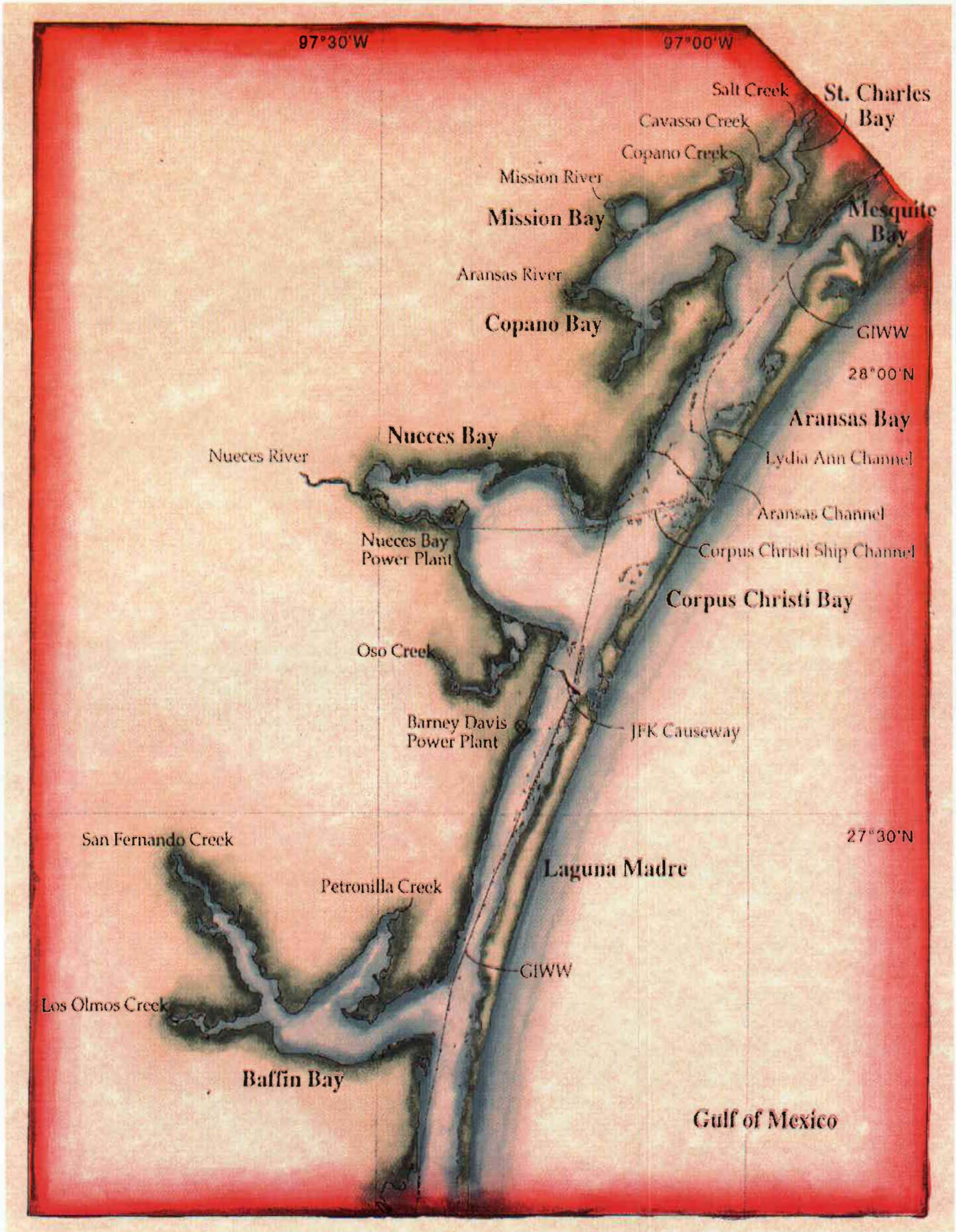
To properly function and maintain these many beneficial uses, an estuary relies on a blend of biology, chemistry, physics, and geology. A growing human population can unbalance and threaten these unique systems. For example, habitats can be lost (e.g., converting a seagrass bed to a dredged material island), or natural functions can be degraded (e.g., limiting the flow of fresh water, which, in turn, inhibits the natural function of estuaries to filter contaminants). Any of these changes could have direct negative impacts on human health and happiness.

The Human Connection

Over 540,000 people live in the Coastal Bend, a 10 percent increase in just seven years, and population growth is expected to continue rapidly. This growing population, while placing enormous pressure on our estuarine waters and surrounding habitats, also provides a unique opportunity to nurture and protect the beauty and bounty of these natural resources. The bays and estuaries of the Coastal Bend provide us with a wonderful quality of life -- abundant plant and animal life and recreational, educational, and job opportunities unlike anywhere else. We derive pleasure and economic value from tourism, sport and commercial fishing, shipping, sailing, bird watching, hunting, and beach-combing. Above all, our lives are enriched by seeing a sunset over the bay, a redfish in the flats turning to strike our lure, a dolphin leading the ferry, or hearing a laughing gull call.






97°30'W
97°00'W
Salt Creek
St. Charles Bay
Cavasso Creek
Copano Creek
Mission River
Mission Bay
Mesquite Bay
Aransas River
Copano Bay
GIWW
28°00'N
Aransas Bay
Nueces Bay
Nueces River
Lydia Ann Channel
Aransas Channel
Nueces Bay Power Plant
Corpus Christi Ship Channel
Corpus Christi Bay
Oso Creek
Barney Davis Power Plant
JFK Causeway
San Fernando Creek
27°30'N
Laguna Madre
Petronilla Creek
GIWW
Los Olmos Creek
Baffin Bay
Gulf of Mexico

HABITAT AND LIVING RESOURCES

Habitat Gains and Losses

Estuaries like those in the Coastal Bend are among the most productive environments in the world. The variety of habitats found in and surrounding the estuaries of the Coastal Bend offer bountiful food and shelter for a diversity of plants and animals. However, these estuarine plants and animals are threatened by loss of habitat, pollution, and over-harvesting.

Although all estuarine habitats are linked to each other in one way or another, each has its own set of characteristics and its own suite of perils. Typical habitats in Coastal Bend estuaries include the open bay mud bottom and water column, seagrass meadows, coastal wetlands, tidal flats, beaches and barrier islands, oyster reefs, and other hard substrates. It is not possible to understand or measure changes in the health or status of living resources without having a good understanding of the status and health of their habitats.



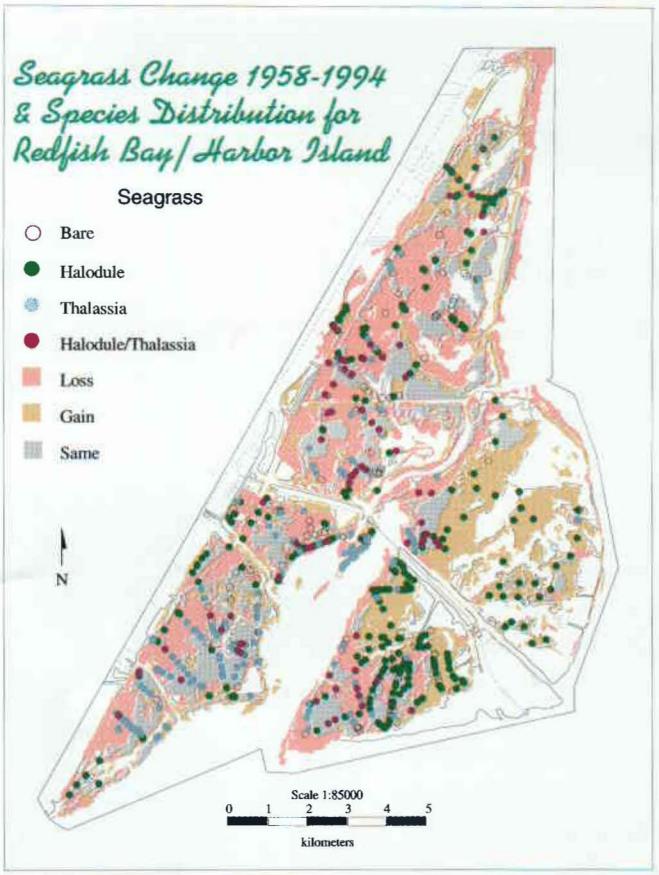
By far, the most extensive habitat in Coastal Bend estuaries is Open Water Habitat

Open Water Habitat

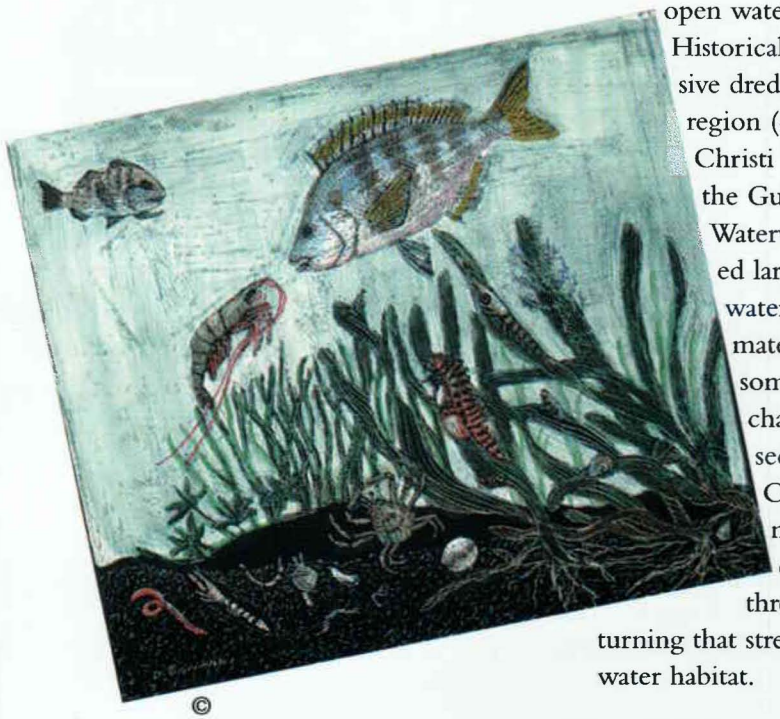
The unvegetated bay bottom and its overlying water column constitute the open water habitat. Covering over 275,000 acres, this is by far the most extensive habitat in Coastal Bend estuaries, especially in the Nueces and Aransas estuaries, where water depth, turbidity, and salinity limit the distribution of other habitats. Only in Redfish Bay and the Laguna Madre are other habitats, primarily seagrass meadows, more widespread than open water. The dominant plants in the open water environment are phytoplankton algae. Many small animals also live in this environment and provide food for larger animals.

Various natural processes and human modifications can alter the size of open water habitat. Over geological time scales, sediments brought into estuaries by river flow will ultimately fill the estuaries, changing open water habitat to extensive marsh and to upland habitat. On shorter, more relevant, time scales, there are three major disturbances that can change the relative amount of open water habitat: subsidence (a geologic process whereby the land sinks), shoreline modification, and dredging and dredged material placement.

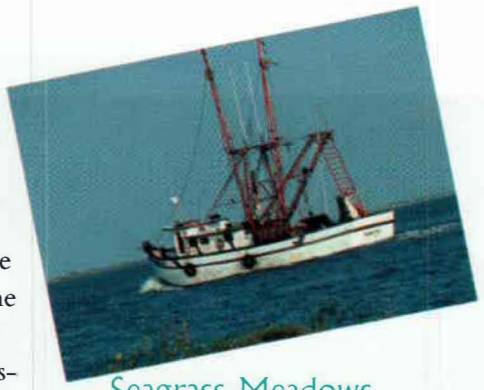
Subsidence could enlarge the area of open water at the expense of seagrass and marsh habitats. However, subsidence rates are very low in the Coastal Bend and do not currently pose a problem. Shoreline modification typically impacts shallow water marsh and seagrass habitats more than open water habitats. It has been estimated, however, that about 15 percent of the surface area of Nueces Bay



Halodule is shoal grass.
Thalassia is turtle grass.



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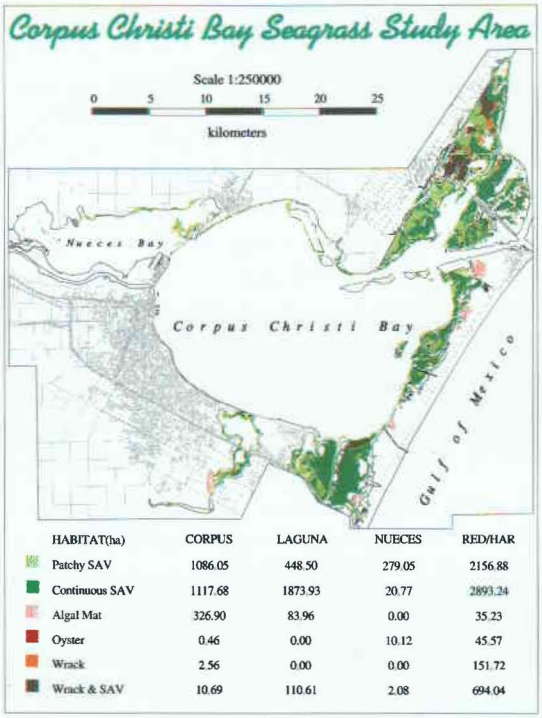
Seagrass Meadows

Seagrass meadows cover over 92,000 acres of bay bottom in the Coastal Bend, representing almost 40 percent of the seagrasses found in all Texas waters. Seagrasses do best in shallow, low energy areas where wave action is limited and gentle currents flow. They are found along the shallow bay margins of barrier and dredged material islands and on the shallow "flats" typical of estuaries like the Laguna Madre and Redfish Bay. Coastal Bend seagrasses cover a substantial portion of the upper Laguna Madre, Redfish Bay, and the shorelines of Mustang and San Jose Islands; the majority, over 61,000 acres, are found in the upper Laguna Madre and Baffin Bay. In fact, the upper Laguna Madre hosts the largest expanse of continuous seagrass habitat on the Texas coast. Coastal Bend seagrasses are actually composed of five different species, but shoal grass and turtle grass are the two most common.

Both natural phenomena and human disturbances can impact seagrass meadows in the Coastal Bend. Waves and currents associated with hurricanes can tear the plants from the ground or cover them with sediments. Small changes in sea level can produce large scale changes in seagrass coverage, as seagrasses in the Coastal Bend are generally limited to a narrow depth range of a few inches to no more than 4 to 5 feet.

was lost during the development of the Inner Harbor and its associated industrial complex during the period from 1924 to 1995. A substantial portion of that area was previously open water habitat.

Extensive dredging in shallow habitats like seagrasses, tidal flats, or marshes could potentially increase the amount of open water habitat. Conversely, the placement of dredged material in open water areas may decrease the depth of the bottom and form seagrass beds, marsh land, or even dry land, where open water once existed. Historically, the most extensive dredging projects in the region (e.g., the Corpus Christi Ship Channel and the Gulf Intracoastal Waterway) were conducted largely through open water, creating dredged material islands along some sections of the channels. A five mile section of the Corpus Christi Ship Channel near Port Aransas was originally dredged through shallow flats, turning that stretch into open water habitat.



HABITAT(ha)	CORPUS	LAGUNA	NUECES	RED/HAR
Patchy SAV	1086.05	448.50	279.05	2156.88
Continuous SAV	1117.68	1873.93	20.77	2893.24
Algal Mat	326.90	83.96	0.00	35.23
Oyster	0.46	0.00	10.12	45.57
Wrack	2.56	0.00	0.00	151.72
Wrack & SAV	10.69	110.61	2.08	694.04

Mapping the distribution of submerged aquatic vegetation (SAV) like seagrass and algae allow managers to track critical habitat.

Motorboat propeller scarring has a direct mechanical impact on seagrass meadows. A recent study of the extent of propeller scarring in the Coastal Bend indicated that a third of the 16,300 acres of seagrass meadows surveyed have moderate (5-20%) or heavy (greater than 20%) scarring. The East Flats and Shamrock Island regions of the Corpus Christi estuary are heavily scarred, as are some areas of Redfish Bay. The most highly impacted area is Estes Flats, in Redfish Bay, where over 97 percent of seagrasses are scarred.

The dynamic nature of seagrass beds means that some areas are gaining and some are losing coverage at any one time, and often for different reasons. The overall trend in the Coastal Bend has been a substantial increase in seagrass coverage from 1958 to 1974, followed by a continued but less rapid expansion between 1974 and 1994. Over the past 35 years, total seagrass coverage in Coastal Bend estuaries has increased by about 38,000 acres. There have been net gains of about 815 acres in the Redfish Bay/Harbor Island complex, about 5,722 acres along the Mustang Island shore, and about 32,123 acres in the upper Laguna Madre. The sustained increase in coverage along Mustang Island has been largely due to a rise in sea level over the period and also the pristine nature of the area.

Although seagrass coverage has generally increased in the Coastal Bend, some areas have lost large tracts of meadows. For example, there has been a decline in seagrass coverage in the northern portion of Redfish Bay adjacent to the mainland, especially between 1974 and 1994. It is believed that this decline is due to a combination of excessive nutrients in runoff from surrounding developments and physical damage from motorboat propeller scars.

The Laguna Madre has experienced a decline in seagrass coverage since 1990. This followed a dramatic increase in shoal grass coverage between 1967 and 1988 mainly resulting from reduced salinity extremes and improved water quality following construction of the Gulf Intracoastal Waterway. The more recent decline was caused by the presence of a brown tide algal bloom which has shaded the seagrasses and deprived them of their energy supply. It is estimated that 3.8 percent of the seagrass beds in the Laguna Madre were lost between 1990 and 1995.

Intentional selection by motorboat operators of "shortcuts" to traverse seagrass meadows contributes to seagrass damage. Propeller scarring can also occur accidentally if motorboat operators misjudge water depth or the location of navigation channels. There is a need for public information and awareness on the extent of seagrass damage caused by propellers, the length of time required for seagrass recovery, and the importance of seagrass habitats in the healthy functioning of estuaries.

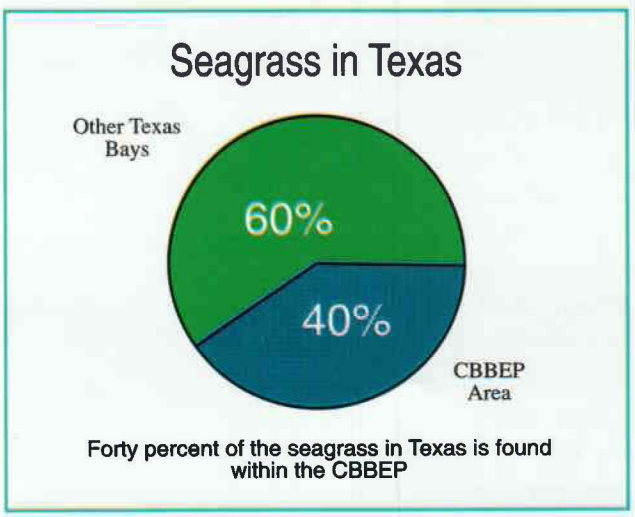
A potential conflict exists between tourism and habitat quality. An increasing number of visitors produces an increased demand for more public access points so people can use the beaches and bays. However, increased usage of beaches and bays threatens habitat integrity and imperils the natural resources that attract visitors to the area in the first place. For example, the relatively pristine nature of the bay shoreline of Mustang Island and its expanding seagrass meadows is due, at least in part, to limited public access to that area. On the other hand, the northern Redfish Bay area, characterized by extensive shoreline development and relatively abundant public access points, is showing signs of seagrass stress.

Coastal Marshes

Coastal Marshes cover about 113,000 acres or about 11 percent of all aquatic habitats in the Coastal Bend. These habitats occur along the intertidal area between the land and estuarine waters and at the mouths of rivers and streams where they discharge into the estuaries. Extensive coastal marshes occur in the northern portion of the Coastal Bend, where freshwater inflow and precipitation are higher. In the southern areas, extensive marshes are largely replaced by wind-tidal flats. Vegetation in Coastal Bend marshes is dominated by smooth cordgrass, especially in the lower portion of the marshes. Glasswort, sea-oxeye daisy, and other flowering plants occupy the higher reach of the marshes.

The primary threats to coastal marshes are dredge and fill operations, oil and chemical spills, coastal development, and changes in sea level. In the first part of the century, some Coastal Bend marshes were dredged, filled, and drained to convert them to agricultural and urban lands. The more prominent of these losses were associated with pothole wetlands on the coastal mainland. Overall, however, coastal marshes in the Coastal Bend have expanded in area since the first comprehensive survey in the 1950s. This increase is largely due to the permanent flooding of intertidal mudflats caused by persistent sea level rise over that period, allowing marsh plants to expand into the margins of those wetter areas.

Currently, regulations designed to protect aquatic resources often require mitigation projects, in which new marsh is created to replace habitat destroyed elsewhere. In the Coastal Bend, a number of potential sites have been identified for marsh creation, restoration, or enhancement. However, while it is often possible to create a new marsh that resembles a natural marsh, our ability to replace the ecological function of a natural marsh is controversial and will require more information. Until such information is available, avoiding disturbance of marshland is the preferred objective.



Wind-tidal Flats

Wind-tidal Flats are the seemingly barren, relatively featureless, sand and mud environments bordering lagoons and bays. The term "wind-tidal flat" is used because flooding is more often caused by wind driving water onto the flats than by tides. Primary production in these habitats is typically dominated by mats of tiny algae and bacteria rather than by the



phytoplankton, filamentous algae, or flowering plants typical of other estuarine habitats. Despite their barren appearance, wind-tidal flats can be very productive. In addition, these flats may contribute a significant amount of new nitrogen to the ecosystem. Bacteria in these flats are very efficient at transforming atmospheric nitrogen into forms that supply nutrition to other aquatic plants, similar to the way in which peas and beans supply nitrogen to soils in farms and gardens.

The variety of plant and animal life on tidal flats is rather limited compared to other habitats, but the numbers of residents can be quite high. Tidal flats are home to small crustaceans, worms, and insect larvae that are of critical importance to shorebirds. They are essential habitat for the Piping Plover, a threatened species, and are significant feeding and loafing areas for numerous other shorebirds as well.

Wind-tidal flats currently cover about 21,442 acres or about 14 percent of wetlands in the Coastal Bend area. Since the early 1950s, over 24,000 acres of wind-tidal flats have disappeared. About 95 percent of this loss is due to a rise in sea level which, between mid-1960 and the mid-1970s, averaged over 0.6 inches per year. The rising sea level permanently flooded about 55 percent of the lost flats and allowed seagrasses and marshes to colonize another 40 percent of the lost flats. Human disturbances led to the remaining 5 percent loss.



A new birding site on Mustang Island, the Port Aransas Wetlands Park (site 59), designated as part of the Great Texas Coastal Birding Trail, showcases the importance of these tidal flats for birds.



Shrimp life cycle

Buried reefs found as deep as 4 meters below the sediment surface in Corpus Christi Bay and up to 18 meters deep in Baffin Bay tell us that conditions for oysters, as well as other animals, have changed dramatically over the past 10,000 years as sea level rose and the climate changed to drier conditions.

The image of tidal flats as wastelands that do not contribute aesthetically, economically, or ecologically to an area is the underlying cause of most human disturbances and alterations. Channels have often been dredged through these flats, dramatically changing the water flow pattern. Dredged material is often placed on the flats, smothering the plant and animal communities and often blocking the normal water flow across the remainder of the flat. In addition, tracking by off-road vehicles can destroy this fragile habitat.

Beaches, Dunes, and Tidal Inlets

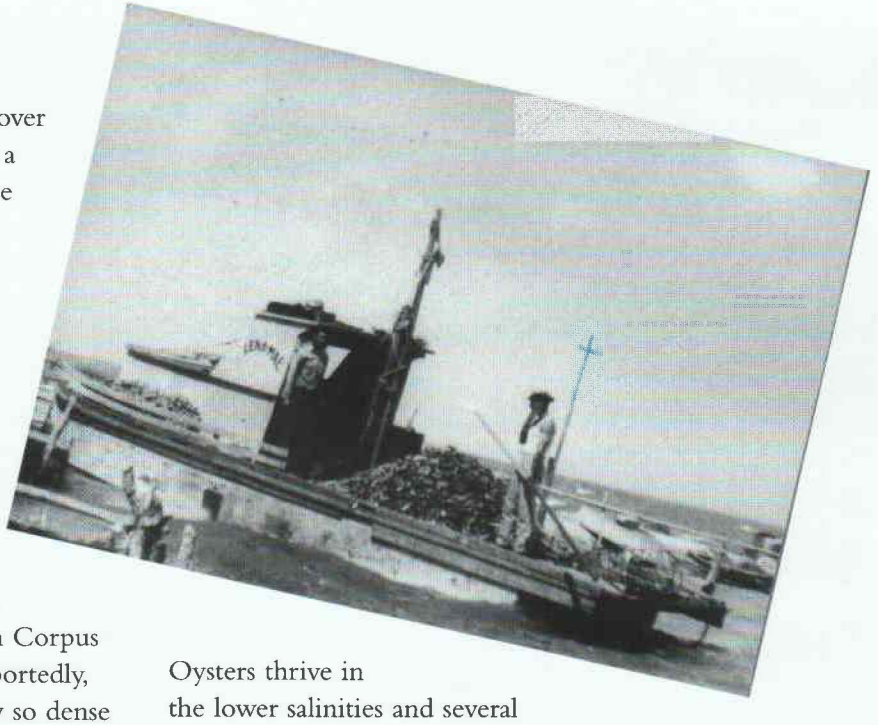
Longshore currents and wave energy on the ocean shore work together to form barrier islands, the elongated strips of sand that lie parallel to the mainland and separate the estuaries and lagoons from the oceans. Barrier islands play a vital role in protecting the relatively tranquil estuaries and lagoons from the often turbulent ocean. In fact, without the barrier islands, our form of estuaries and lagoons would not exist. These coastal land forms are very dynamic, constantly being reshaped by winds, waves, and currents. The dynamic processes are most apparent at the breaks between islands where tides flow between the oceans and the estuaries. Over time, these inlets have migrated up and down the coast. In recent times, however, most have been stabilized by jetty construction and channel dredging to provide for safe navigation.

Tidal inlets play a critical role in the life cycle of shrimp, croaker, redfish, mullet, and many other common species. Many adult species spawn offshore, and their offspring flow with the currents to the coast and through the tidal inlets into the estuaries. Within the estuaries, the larvae and juveniles of fish, shrimp, and other species use the seagrass beds, marshes, and bay bottoms for food and shelter. After a few months to a few years, maturing adults move into the deeper waters and find their way back through the tidal inlets to offshore spawning



©

grounds to start the cycle over again. Thus, tidal inlets are a critical link in the life cycle of most commercial and recreational fish and shellfish species.



Oyster Reefs and other Hard-Substrate Habitats

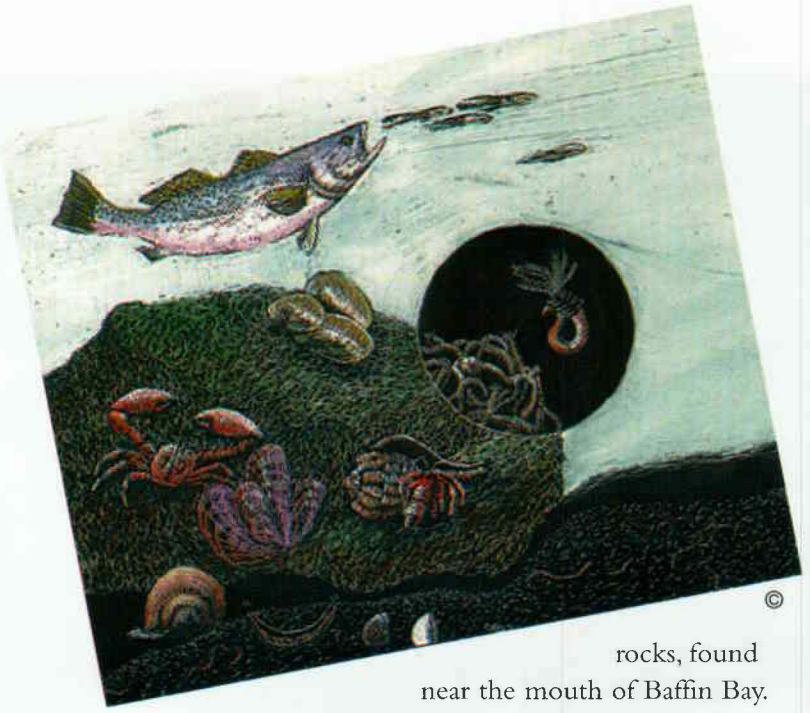
As recently as the mid-1800s, a large oyster reef spanned the mouth of Nueces Bay and served as a bridge between Corpus Christi and Portland. Reportedly, oyster reefs were originally so dense in northern Aransas Bay that the Indians could cross the 10 miles from Lamar Peninsula to San Jose Island on foot by simply following the reefs. Most of this material must have been removed by shell dredging. Removing the shell enhanced water exchange between Nueces and Corpus Christi Bays and between San Antonio and Aransas Bays. Shell removal may have increased the volume of water in Nueces Bay by as much as 50 percent.

Today, extensive live oyster reefs are found primarily in the northern portion of the Coastal Bend, especially in Mesquite, Copano, and northern Aransas Bays where higher freshwater inflow maintains moderate salinities. Salinities in these bays are typically 10 to 20 parts per thousand (ppt), whereas salinities in Corpus Christi and Nueces Bays are typically 20 to 30 ppt, and often over 40 ppt in upper Laguna Madre and Baffin Bay. Oysters thrive in the lower salinities and several oyster predators, especially the oyster drill snail, cannot tolerate this condition. Although scattered oysters and small reefs can still be found in Corpus Christi Bay, most of these reefs are currently dead or even buried.

Extensive shell dredging operations were conducted in the 1930s and 1940s throughout the Coastal Bend. Regulations imposed in the 1950s and 1960s to eliminate the damage to living reefs and adjacent bay bottoms finally brought the practice to an end by the mid 1970s. It is not precisely known how much shell was removed but records indicate that, in this century, 24 million cubic yards of shell were removed from Nueces Bay alone. More shell may have been taken from bays in the northern part of the Coastal Bend.

One type of fairly extensive natural hard bottom in the Coastal Bend is the serpulid reefs, or worm

Oyster shell, or mudshell as it was called in the industry, has been a common building and paving material since the beginning of European settlement. It was mixed as "shell-crete" for building material and crushed for use as paving material for streets and driveways. Historically, the shell was easily dug from live and buried reefs in shallow water and "ancient" reefs on land. Actually many of these "paleo-reefs" were not actual reefs but old Indian middens. It was reported that, in the 1920s, arrowheads could frequently be found on the streets of Rockport after they were repaved with shell.



rocks, found near the mouth of Baffin Bay. These reefs, covering about 4,000 acres, are formed from the hardened tubes of polychaete worms and are estimated to have been built around 3,000 years ago. Although some additional growth may have taken place during the past 300 years, there are few if any worms living on the reefs today.

Overall, about 18 percent of the Coastal Bend shoreline has been converted to hardened shoreline.

Aside from the widespread oyster reefs and scattered serpulid worm reefs in the upper Laguna Madre and Baffin Bay, hard bottom habitats are relatively rare in the Coastal Bend. Artificial, human-made structures such as jetties, groins, breakwaters, and bulkheads make up the majority of hard substrate habitat. These structures can replace seagrass, marsh, and tidal flat habitats as a result of shoreline development. Over one-half of the shorelines of Corpus Christi, Nueces, and Oso Bays has been altered in the past century, and much of this area has been converted to hardened shoreline.



Living Resources

The most recent and comprehensive list of the living resources found in the Coastal Bend includes at least 835 species of plants associated with bays and marshes and over 2,340 species of animals. Since many small and inconspicuous animals have not been identified and catalogued, the actual number of species may be as high as 5,000. In addition to the tremendous aesthetic, recreational, and commercial values associated with these living resources, they are also sources of current and future medicinal, industrial, and agricultural products.

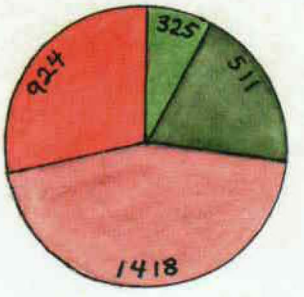
Scientists believe that the natural system of checks and balances is

dependent on maintaining biological diversity, or the number of species found within a defined geographical area. Biological diversity of the aquatic and adjacent terrestrial ecosystems is increasingly threatened by the impacts of large numbers of people living, working, and playing near coastal areas. Biological diversity can also be affected by human activities within the larger watershed region that drains into our bays and estuaries.

Fishes

Fishes are a very diverse group of animals. They can be found throughout the estuaries: some are water column dwellers, some live among seagrass blades in the shallow flats, and others prefer open water bottoms, oyster reefs, or the surf zone along the beach. The habitat occupied by a fish may change over its lifetime. For example, juvenile stages of many species are found in estuarine seagrass meadows while the adults live offshore.

Over 80 percent of all fish, crabs, and shrimp spend a portion of their life in estuaries. The abundance of fish within a particular estuary can be influenced by both natural and human factors. Natural factors include weather events such as freezes and hurricanes, access to tidal passes for migrating species, toxic algal blooms, and salinity. The amount of freshwater inflow into an estuary, which plays a crucial role in the health of the system, is determined by both natural rainfall patterns and human modifications within the watershed. Other human-related factors affecting fish populations include overfishing, pollution, and habitat loss and degradation.

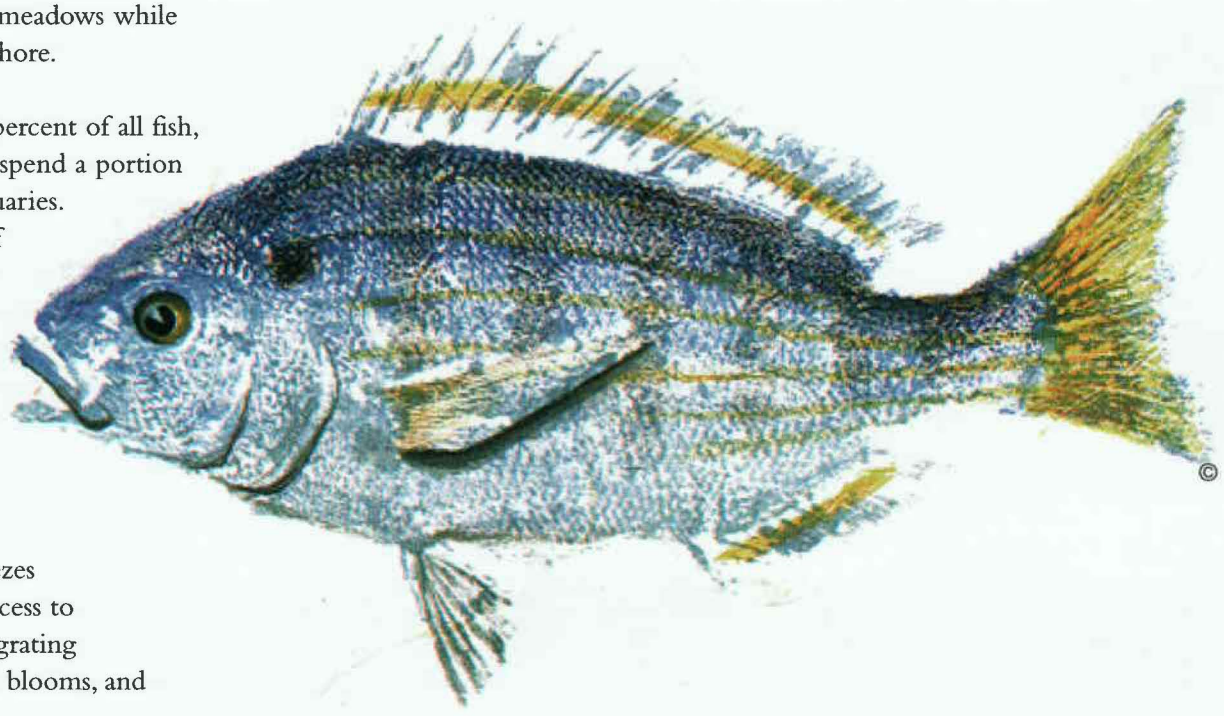


Species composition in Coastal Bend Region

- Algae
- Vascular plants
- Invertebrates
- Vertebrates

The Coastal Bend is one of the richest sources of fisheries in Texas. Between 1972 and 1992, an average of 8.4 million pounds per year of finfish, shrimp, crabs, and other aquatic species were reported as commercially harvested. Although the proportions of finfish, shrimp, and blue crab harvested in

Management and Conservation of Populations - Living resources are currently managed with the goal to use them in a renewable and sustainable fashion and to preserve species diversity. The target of most living resource management plans is human activity. Regulation may be required to avoid the over-harvesting of living resources, particularly in heavily populated areas.





The Texas commercial shrimping industry increased dramatically in the 1920s, when trawling gear towed by motorized vessels began to be used. Shrimping has since become the largest food fishery in the state. In 1993, 74 million pounds of shrimp were landed statewide with an estimated economic value of $500 million.

the early 1970s were roughly similar, today's fishing industry is dominated by shrimp harvesting.

Between 1988 and 1993, reported shrimp landings in the Coastal Bend ranged between 60 and 90 percent of the total commercial seafood harvest. Most inshore shrimp harvested in the Coastal Bend are from the Aransas and Corpus Christi estuaries; reported landings in the upper Laguna Madre are mostly finfish. Even though total shrimp landings in the Coastal Bend are known, it is difficult to evaluate the status of the population through time. On a statewide basis, however, there is evidence that, although the intensity of bay shrimping has increased dramatically, individual shrimping vessels must currently fish for more hours to obtain the same catch as 20 years ago. If this statewide trend applies to the Coastal Bend, shrimpers are fishing harder to catch fewer shrimp.



One impact of shrimping is the catch of unintended species, or bycatch. Bycatch from the shrimping industry includes finfish, crabs, starfish, and squid. One study indicates that finfish bycatch comprised between 1.5 and 7 times the weight of the shrimp caught in the Aransas and Corpus Christi estuaries. Although most bycatch is returned to the water, there is little scientific information as to what proportion of the bycatch actually survives. Casual observation suggests that, other than crabs, few animals probably survive shrimp boat handling and culling. A cooperative study between the CBBEP, the shrimping industry, and Texas Parks and Wildlife is testing several bycatch reduction devices (BRDs) on nets used in the Coastal Bend. Preliminary results indicate that these devices hold promise in reducing the unwanted catches from shrimp nets.

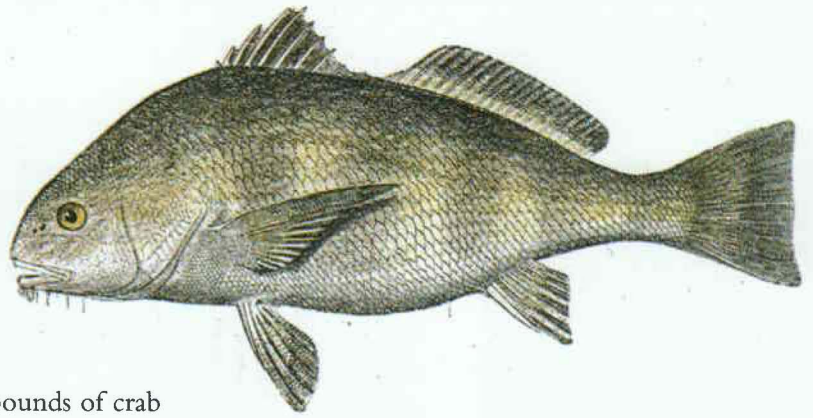
Other impacts of shrimp trawling include the alteration of species abundance and composition on the bay bottoms and the resuspension of large quantities of sediments. Suspended sediment can smother marine organisms and lead to excessive nutrients in the water. Unfortunately, there is lit-



tle information on the extent or long-term consequences of these environmental impacts, either at the local or national levels.

The commercial finfish catch within the Coastal Bend comprised about half the catch of all Texas bays between the 1970s and early 1990s. The finfish catch declined sharply after 1979 due to drops in population caused, in part, by overfishing. In response, a statewide ban on the commercial harvest of red drum and spotted seatrout was introduced in 1981. The commercial finfish catch was about 3 million pounds in 1996, made up primarily of black drum taken from the upper Laguna Madre.

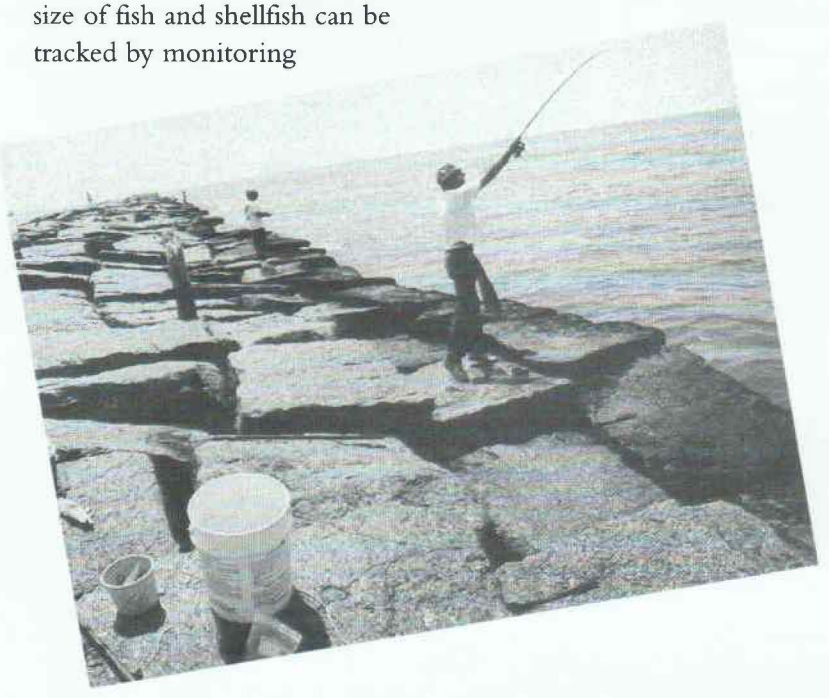
Although shrimp and finfish are the most sought-after species in the Coastal Bend, blue crabs and, to a lesser extent, oysters are also commercially important. Blue crab harvesting in the Coastal Bend region provided about a fourth of the state's total reported catch between 1972 and 1992; between 1.5 and 1.8 million pounds of crab were harvested each year. On the other hand, Coastal Bend oysters provide a fairly small fraction of the total harvest in Texas.



The recreational fishery in the Coastal Bend contributed about 28 percent of the total catch in all Texas bays between 1976 and 1991. Over this same time frame, the amount of sport-fishing activity has generally increased while the number of fish landed has decreased. This decline in landings is due mainly to more restrictive size and catch limits for desirable species such as red drum and spotted seatrout.

Trends in the population size of fish and shellfish can be tracked by monitoring

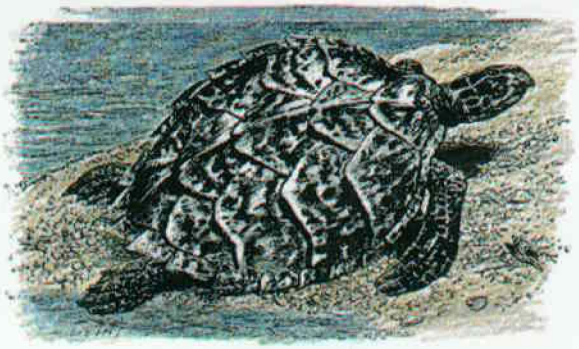
The economic impact of the commercial and recreational fisheries, both harvest and sales, along the Texas coast is in excess of $2 billion a year. Tens of thousands of jobs are associated with the industry. Historically, as the human population density has increased along the coast, demand for fisheries resources has expanded. Fishing efforts have increased to meet this demand and, in some fisheries, technological advances have yielded larger returns for less effort.



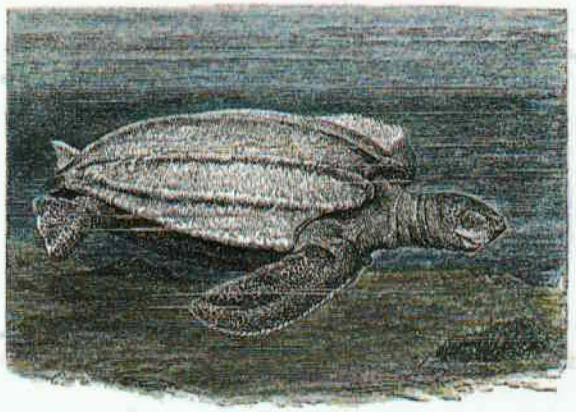
Sea turtles vary widely in size. An adult Kemp's ridley is relatively small at 26 inches, whereas the largest living turtle, the leatherback, can measure up to 6 feet in shell length and weigh about 1,400 pounds. Female turtles must be at least 20 years old before they are capable of egg-laying. Given this long maturation period, turtle populations are very susceptible to human disturbances.

Fish and shellfish are potentially renewable resources. They can respond to positive management actions fairly rapidly as long as sufficient quality habitat is available. Without suitable quality habitats, no management actions are likely to restore and maintain diminished populations.

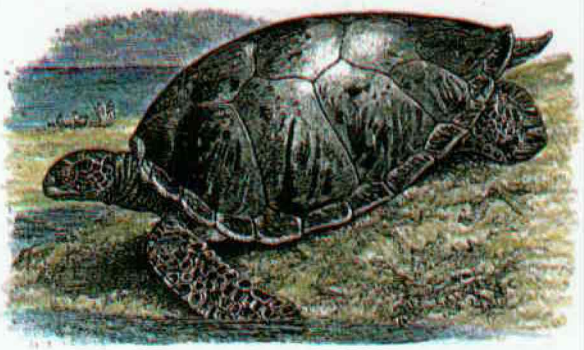
An endangered species is "any species which is in danger of extinction throughout all or a significant portion of its range other than a species of the Class Insecta determined by the Secretary to constitute a pest whose protection under the provisions of this Act would present an overwhelming and overriding risk to man."



Hawksbill Turtle



Leatherback Turtle



Green Turtle

catches in the commercial and recreational fishery and by direct sampling of these resources by scientists. The latter method provides so-called fisheries-independent data that is not influenced by changes in the activity or skill levels of commercial and recreational fishermen. Studies in the Coastal Bend over the past 20 years show that some species have prospered while others have declined. The numbers of adult black drum, spotted seatrout, and sub-adult red drum have generally increased over that time period as have the numbers of white shrimp. However, brown and pink shrimp, adult blue crabs, and Gulf menhaden have generally declined.

Sea Turtles

Although the Gulf of Mexico region once hosted significant populations of five species of marine turtles, today they are rare or absent in many areas. The hawksbill, loggerhead, leatherback, and Kemp's ridley sea turtles are currently considered endangered by the National Marine Fisheries Service (NMFS), U.S. Fish and Wildlife Service (FWS) and Texas Parks and Wildlife. The Green sea turtle is considered threatened by these agencies.

A threatened species is "any species which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range."
From the Endangered Species Act of 1973.

In the mid-1800s, turtles were intensely harvested for meat and oil; four canneries existed along the Texas coast. In 1881, a cannery was established at Fulton, on Aransas Bay, and probably the majority of captured turtles for this plant were from Aransas Bay. The Green turtle was the leading marine product (by weight) harvested from Laguna Madre waters, although it is very likely that other species were harvested from these waters as well. Matagorda Bay and lower Laguna

Madre were also sources of sea turtles. Due to over-harvesting, the industry collapsed by the early 1900s.

From the 1940s to the 1960s, eggs of Kemp's ridley sea turtles were heavily exploited at their primary nesting site in Rancho Nuevo, Tamaulipas, Mexico, about 200 miles south of Brownsville. During the same period, fishing for finfish and shrimp increased along the Texas coast, and many turtles perished as bycatch in these fisheries. Today, Kemp's ridley is the most endangered turtle species of the Gulf of Mexico. It is believed that, of the nearly 40,000 females known to nest in Rancho Nuevo in the 1940s, only 700 females remain.

Despite the low number of adults, the nesting population at Rancho Nuevo has increased during the last two decades. This is largely due to collaborative conservation efforts by the U.S. and Mexican governments to protect the nesting sites. In addition, the National Marine Fisheries Service in 1987 implemented the use of Turtle Exclusion Devices (TEDs) that allow turtles to escape from fishing nets. Despite the use of TEDs, turtle strandings have been at near record levels for the past four years.

Sea turtle populations face a variety of additional threats: human population growth and development of coastal areas, dredging, beach cleaning, beach motor traffic, pollution, ingestion of debris, impact with boat hulls or propellers, artificial lighting, recreational beach equipment, and power plant entrapment. The ecology of various sea turtle species must be studied in greater detail, so that adequate conservation measures can be implemented. The implementation of appropriate conservation measures is dependent on ongoing public education and support.

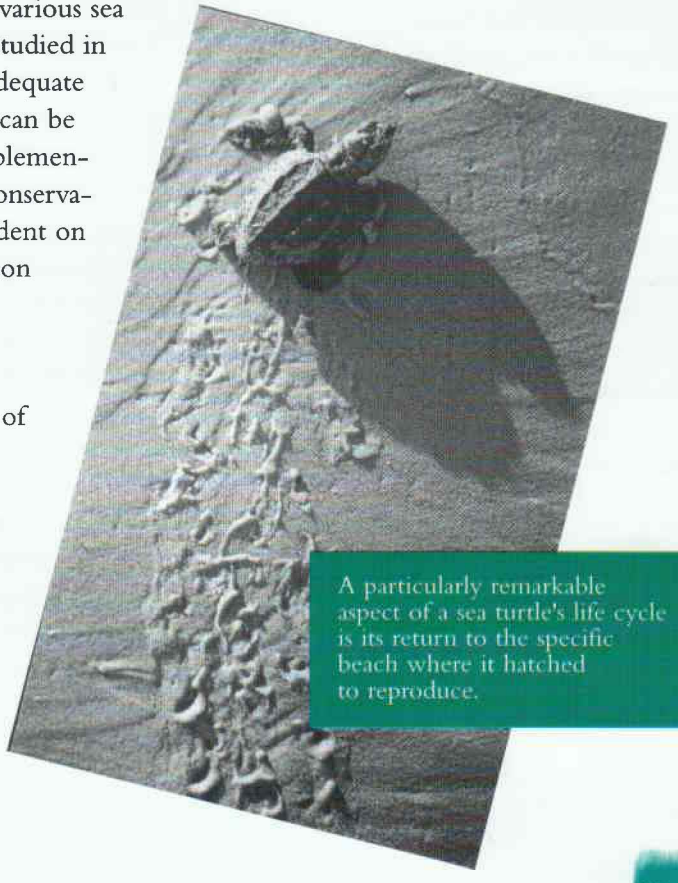


There are 19 species of plants and animals found in the Coastal Bend that are classified as threatened or endangered.

Turtle eggs are considered a delicacy and the congregation of large numbers of reproducing females at one site has led to the collection of thousands of eggs and the destruction of entire generations of sea turtles, particularly the Kemp's ridley.

Marine mammals

People generally think of marine mammals as a particularly fascinating group of aquatic animals. And, because of similarities to humans, marine mammals are potentially susceptible to the same contaminants as humans.



A particularly remarkable aspect of a sea turtle's life cycle is its return to the specific beach where it hatched to reproduce.



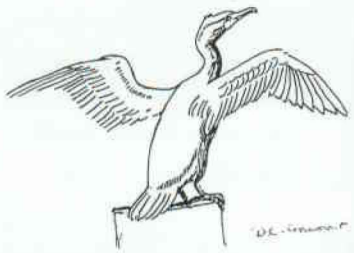
Rough-toothed



Atlantic spotted



Atlantic bottlenose



The first documented report of birds in the Coastal Bend is attributed to Alvar Nunez Cabeza de Vaca, the Spanish explorer who lived among Indian tribes in Central and South Texas between 1528 and 1536. By the late 19th century, explorers and historians such as George B. Sennett and Frank M. Chapman had documented the remarkable abundance of birds. The first reports of declining populations also correspond to that time period. In 1891, Chapman wrote about the negative consequences of hunting and collecting feathers for hat decoration.

The Atlantic bottlenose dolphin is the most common marine mammal in the Coastal Bend and is often observed feeding in the channels, bays, and even shallow areas. The population of this species appears stable, although counts are difficult because dolphin migrate between offshore areas and the bays. The Atlantic spotted dolphin and the rough-toothed dolphin are both listed as threatened species in Texas, although little is known about their abundance in the Coastal Bend.

A potential increase in the number of marine mammal strandings during the last few years has drawn considerable public attention. Animals are considered stranded when they are found either alive or dead on shore. Stranding incidents are reported to the Texas Marine Mammal Stranding Network which activates volunteers to investigate the stranding, provide aid to injured animals, and determine the cause of death if possible. The most commonly stranded species in the Coastal Bend is the bottlenose dolphin and usually only one animal is found at a time. Between January and April 1992, however, 83 bottlenose dolphins were stranded on Coastal Bend beaches, from unknown causes.

Stranded dolphins may suffer from diseases or wounds caused by boats, net entanglement, knives, or gunshots. Most dolphins, however, die of causes that cannot be readily determined. Both natural disturbances, such as freezes and diseases, and human-related disturbances, such as toxic contaminants in the environment, affect the health and status of marine mammals. There are no comprehensive studies of the extent of these effects in the Coastal Bend.

Birds

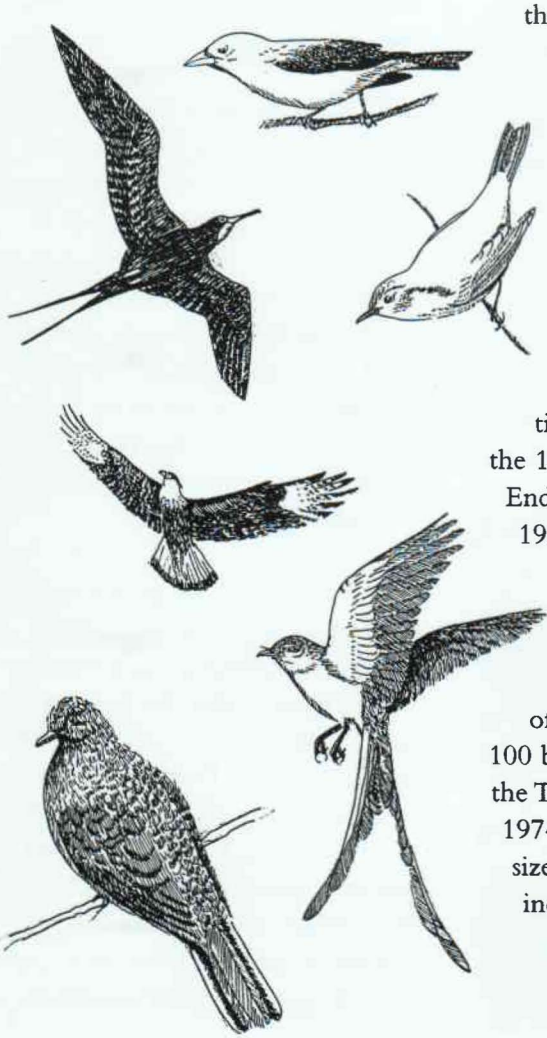
The Coastal Bend is a birder's paradise, providing a seasonal variety of colorful migrants, nesters, and local residents. In addition to their aesthetic value, birds provide recreational benefits as well as a natural check for insects and other pests.

There are an astonishing 494 verified bird species living in or migrating through the Coastal Bend. An additional 38 species have been reported but these sightings have not yet been verified. To put these counts in perspective, it is estimated that the entire state of Texas hosts about 600 species of birds. The enormous diversity of bird species in the Coastal Bend is attributed to its key geographical location as a

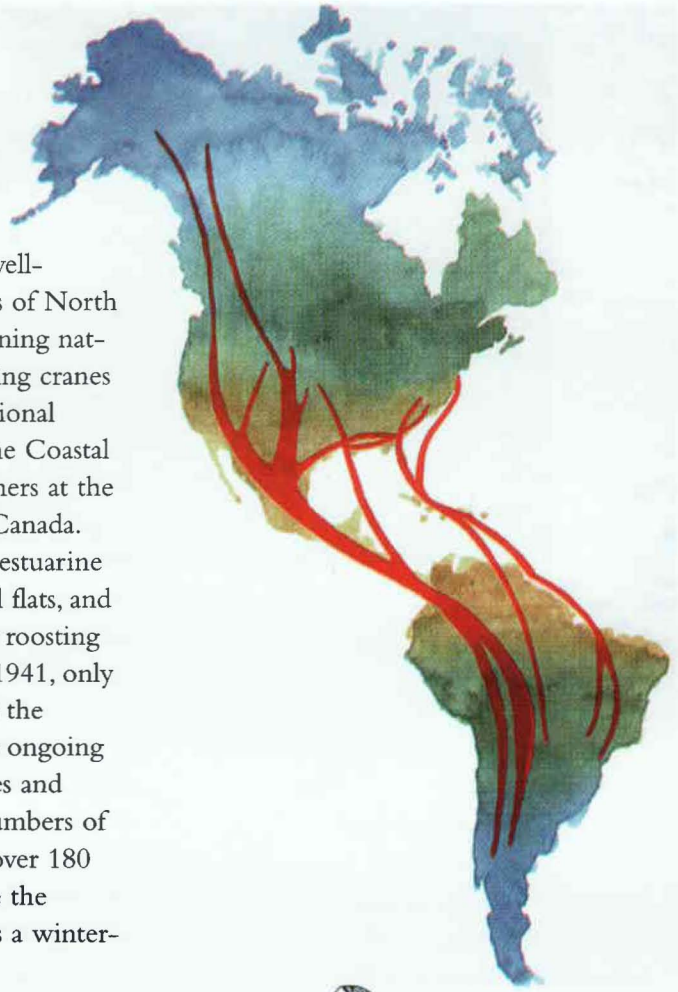
stopover point for migrants. Additionally, there are numerous types of food for resident and migrant birds and many available feeding and nesting habitats, including Gulf beaches, prairies, oak mottes, flats, freshwater marshes, and urban land.

There are eight federally-listed endangered or threatened bird species in the Coastal Bend, including the whooping crane, piping plover, and brown pelican. These species are threatened by habitat loss and degradation, water conservation practices which may limit freshwater inflow to coastal habitats, contamination, and human disturbances such as boating and oil and gas operations.

The whooping crane is one of the most well-known endangered species of North America. The single remaining natural population of whooping cranes winters at the Aransas National Wildlife Refuge, within the Coastal Bend, and spends its summers at the Buffalo National Park in Canada. Whooping cranes require estuarine marshes, shallow bays, tidal flats, and upland rangeland areas for roosting and feeding in winter. In 1941, only 15 or 16 birds wintered at the Refuge. Due to extensive ongoing efforts by the United States and Canada to restore the numbers of these majestic birds, over 180 birds currently use the Coastal Bend as a wintering ground.



Another well-known endangered species found in the Coastal Bend is the brown pelican. Hunters and fishermen caused declines in populations of these birds prior to the 1930s. Use of the pesticide Endrin (containing DDT), in the 1950s, further decimated the populations of these birds. DDT accumulated in adult birds and resulted in eggshell thinning and high offspring mortality. Less than 100 brown pelicans nested along the Texas coast between 1967 and 1974. Since then, the population size of brown pelicans has increased. Pelican Island in





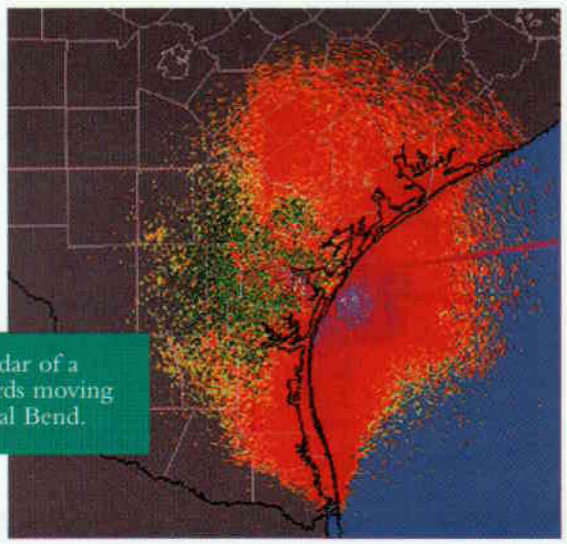
Bird surveys are conducted during certain times of the year to determine trends in the long-term abundance of selected species. One survey, the Christmas Bird Count (CBC) sponsored by the National Audubon Society, concentrates on species found in the Coastal Bend at the beginning of winter. Another, the Texas Colonial Waterbird Survey, focuses on 25 species of water birds that nest in the area.



Corpus Christi Bay now hosts about 50 percent of the nesting pairs in Texas.

Hunting led to a serious decline of piping plovers early in this century and further declines are associated with extensive loss of habitat. This species winters in coastal areas of the southern United States, especially Texas, and spends the summer months from Canada south to Nebraska and the Great Lakes. In the Coastal Bend, piping plovers depend on tidal flats and washover passes. The piping plover is listed as a threatened species and, it is believed that if the current declines continue, the species could go extinct within an 80 year period.

Some birds are highly valued as game species. Although there is little specific information regarding the economic impact of bird hunting in the Coastal Bend, hunting of all game species is a $1 billion a year industry in Texas. Among the 25 species hunted within the Coastal Bend are the greater white-fronted goose, snow goose, Canada goose, wood duck, mallard, mottled duck, northern pintail, redhead duck, ring-neck duck, blue-winged teal, wild turkey, bobwhite quail, and mourning dove.



Echoes on weather radar of a cloud of migrating birds moving on shore in the Coastal Bend.

The status of nesting populations of colonial water birds, including herons, egrets, gulls, and terns is currently unclear. Some decreasing trends recorded in nesting can be attributed to the degradation of nesting habitat and disturbance by humans or predators, while some increases in abundance, associated with seasonal counts such as the Christmas Bird Count, may be attributable to the range expansion of wintering species. Populations of some species of waterfowl and shorebirds are reportedly increasing while others, like the great egret, snowy egret, tricolored heron, redhead, gull-billed tern and Forster's tern are declining.

Neotropical migrant song birds in the Coastal Bend include various species of vireos, warblers, and sparrows. A positive trend in abundance of some of these species has been documented by the Christmas Bird Counts. However, the U.S. Fish and Wildlife Service has declared the study of neotropical migrants a priority due to the rapid loss of their habitat, particularly in Mexico.

Although progress has clearly been made in estimating the number of species and population sizes of birds within the Coastal Bend, it is evident that further work is still required. The number and species of birds migrating through the area during spring and fall are not well documented. Several Gulf-wide studies to understand and quantify migration across and around the Gulf of Mexico are in



progress.
Overall, there is insufficient information on the vast majority of species found in the Coastal Bend to determine population status and habitat needs.

Harmful Algal Blooms.

Algal blooms appear to be an increasingly common phenomena on a worldwide scale. Some blooms are considered harmful because of their potential threat to human health through the consumption of contaminated seafood, while others cause changes in the abundance and distribution of plants and animals. Two types of harmful algal blooms, red tides and brown tides, have affected the Coastal Bend in recent years. Although these particular names refer to the water discoloration that occurs during the bloom event, harmful algal blooms can be present without observable changes in water color.

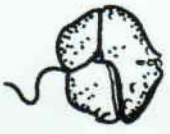
There have been less than a dozen documented red tide blooms over the entire Texas coast and only one documented brown tide bloom. This brown tide bloom has persisted in Laguna Madre from January of 1990 to the summer of 1998. The bloom began in Baffin Bay, a system that was already stressed by persistent high salinities and reduced populations of organisms that could potentially feed on the brown tide algae. It has been suggested that the occurrence of two severe freezes in December of 1989, resulting in massive fish and shellfish kills, caused the release of a large nutrient pulse from the decomposing organisms and, in turn, fueled the initial bloom of the brown tide.

The brown tide reduced water clarity, shaded out seagrass beds, and disrupted sport fishing activities. Although there has been no apparent effect on populations of adult fish and shellfish, the brown tide is toxic to newly hatched fish larvae, and the densities of fish larvae appear to have declined in areas severely impacted by the brown tide.



Perhaps the most important unanswered question is: why did the brown tide persist for so long?

Bird Watching - Due to high species diversity, Texas is considered the foremost bird watching destination in the country. The Aransas National Wildlife Refuge and the Rockport-Fulton area, wintering ground of the endangered whooping crane and other migratory waterfowl, host between 75,000 and 100,000 tourists every year. The Hummingbird Celebration, held in Rockport, and the Whooping Crane Celebration, held in Port Aransas, attract thousands of visitors each year. Although few detailed studies are available, it has been estimated that $600 million per year is spent on equipment used for observation of all non-game species, much of which is associated with bird watching.



In the early 1990s, the organism causing the brown tide was unknown to the scientific community. Scientists have since shown that this organism is present at very low densities in other Texas estuaries and in Florida, but only in Laguna Madre did it bloom so persistently. The proposed name for this new species is Aureoumbra lagunensis.

The dinoflagellates responsible for the so-called red tides have pigments that can tint the water red during a bloom. Beachcombers notice red tides in other ways -- airborne toxins sting the insides of their noses and throats.

In recent times, red tides have become more frequent and more noticeable but they have been around at least since biblical times. In Exodus, a plague turned the water blood red and destroyed fish. Science News, Sept 27, 1997.

Spanish conquistadors found discolored water and dead fish in the Gulf of Mexico as early as 1530, and a massive 1935 fish kill near Corpus Christi was mistakenly blamed on an undersea volcanic eruption.
From the Harmful Algae Page http://www.redtide.whoi.edu/hab/.

A variety of reasons have been suggested. The brown tide may suppress the growth of other phytoplankton and negatively affect organisms that would feed on it. Also, the lack of freshwater inflow to Laguna Madre and the restricted exchange of water with the Gulf of Mexico make it difficult to disperse an algal bloom once it becomes established.

Red tides are caused by a type of phytoplankton called dinoflagellates. Unlike brown tides, red tides produce toxins that can cause extensive mortality in fish. Only one species occurring in Texas, *Gymnodinium breve*, can cause human health problems. Although not lethal to humans, this organism can cause neurotoxic shellfish poisoning, with abdominal pain, vomiting, diarrhea, vertigo, malaise, and headaches.

Red tides are rare on the Texas coast compared to other areas of the Gulf of Mexico, such as the west coast of Florida. Of the 11 documented red tide blooms along the Texas coast through 1997, only two affected the estuarine waters of the Coastal Bend. The 1986-1987 red tide affected oysters in the bays, and the 1997 bloom affected both oysters and fish. The periodic closure of selected oyster beds by the Texas Department of Health due to detectable levels of red tide suggests that small blooms of red tide may be more common than is generally thought.

Although the ecological and economic impacts of red tides can sometimes be very severe, they appear to have no long term effects on the ecosystem. Fish populations and tourism rebound quickly following the infrequent blooms. Should toxic blooms in Texas increase in frequency and/or severity, however, monitoring activities should be considered



to provide warnings of bloom initiation and transport along the Texas coast.

Freshwater Resources

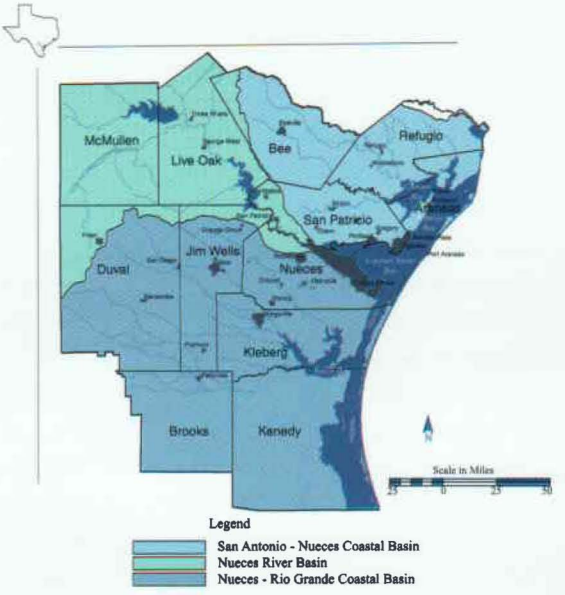
"... the water we drink today also cooled the thirsts of our most ancient ancestors, and even the creatures that came before them. That we can use the same water over and over again is testament to nature's recycling efficiency. The point is that water is a finite resource. For all intents and purposes, no one is making any more of it."

(Texas Shores, Vol. 30, number 4, 1998).

Freshwater was in short supply in South Texas even before people established ranches, towns, railroads, and industries in the semi-arid region. In the face of increasing population and more industry, the scarcity of locally available freshwater means there will always be competing demands on this limited resource.

Freshwater Inflows

Freshwater flowing into the estuaries of the Coastal Bend comes from three major watersheds that cover a total area of about 26,866 square miles. The Nueces River basin is by far the largest drainage area, covering about 16,700 square miles. It extends into the hill country northwest of San Antonio and drains into Nueces Bay, at the head of Corpus Christi Bay. The other two watersheds are essentially coastal, draining local rainfall into the estuaries. In the southern part of the Coastal Bend, the Nueces-Rio Grande basin covers about 7,211 square miles. Streams in this watershed drain into both upper Laguna Madre and into Corpus Christi Bay. In the northern portion of the region, the San Antonio-Nueces coastal basin covers approximately 2,629 square miles and drains primarily into Copano Bay through the Aransas and Mission Rivers.



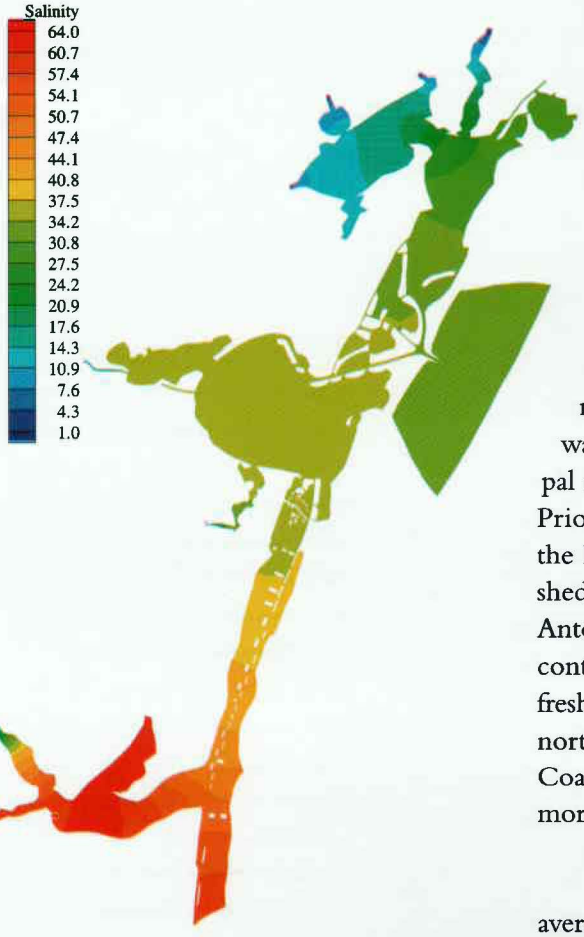
Due to local variation in rainfall patterns, the ability of local soils to absorb rainfall, and the presence of reservoirs, the three watersheds contribute freshwater to the estuaries in disproportion to their size. Although the smallest watershed, the San Antonio-Nueces basin contributes about 53 percent of the total 1.2 million cubic feet of freshwater that enters Coastal Bend estuaries annually. The much larger Nueces River basin currently contributes about 32 percent, and the mid-sized Nueces-Rio Grande watershed contributes only 15 percent.

The total amount of freshwater inflow to Coastal Bend estuaries is relatively low compared to many other coastal areas along the Gulf and Atlantic seaboards. For example, Matagorda Bay, just to the north, receives five times more inflow than is currently received by Corpus Christi Bay. Substantially more rain falls in the northern coastal watershed of the Coastal Bend than in the much larger, but

Freshwater inflows perform three major functions that are essential for sustaining productive estuaries. First, they blend with the Gulf's seawater to provide a range of salt concentrations needed by the living resources that use the estuaries. Second, freshwater inflows bring nutrients essential to the total productivity of estuarine ecosystems. Third, rivers and streams bring in sediments needed to maintain deltas and coastal marshes and avoid the erosion of coastal uplands.

Water that falls to the surface as rain is also returned to the atmosphere through evaporation. Although the high humidity of the Coastal Bend reduces its evaporation rate, evaporation still exceeds precipitation by more than two to one. The result is high salinities in the estuaries, especially toward the southern portion of the Coastal Bend.

Average Summer Salinity (ppt)



relatively arid, interior watershed. In addition, average annual freshwater inflow from the Nueces River has decreased by approximately 53 percent since about 1940. There are two major reservoirs (defined as having a capacity of more than 5,000 acre feet) in the Nueces River basin. Lake Corpus Christi was formed by the construction of Mathis Dam (near the town of Mathis) on the Nueces River in the early 1930s. It was later enlarged by construction of Wesley Seal Dam in 1959. Choke Canyon reservoir, on the Frio River near the town of Three Rivers, was built in 1982.

The retention of water by these two reservoirs in the Nueces basin has had a substantial impact on freshwater inflows to the Corpus Christi estuary. Historical records indicate that the reduction in freshwater inflow is primarily associated with the construction of Choke Canyon reservoir and the diversion of water for agricultural and municipal uses upstream of the reservoir. Prior to the alteration of flows in the Nueces River, the two watersheds (Nueces River basin and San Antonio-Nueces basin) would have contributed similar amounts of freshwater to the estuaries. The northern and central portions of the Coastal Bend would have been more alike than they now are.

In addition to reducing average annual inflows, reservoir construction has also changed the nature of freshwater delivery to the estuaries. Many rivers in the United States, including those in Texas located to the north of the Coastal Bend, have seasonal flows related to spring rains, thaws, and late summer dry periods. However, river flow in south Texas, particularly the Nueces River, is less predictable. Heavy rain may occur at any time during the year, resulting in short, but intense, freshets interspersed with relatively long periods of low river flow. A major tropical cyclone can be the most significant rain event for several years.

Historically, the Coastal Bend estuaries were periodically inundated with a large pulse of freshwater followed by relatively long periods of low inflow. These periodic floods flushed the estuaries, reducing salinities and adding sediments and nutrients from the land, and ultimately rejuvenated the estuarine ecosystem. A significant effect of the water retention capacity of reservoirs in the Nueces River basin has been to minimize the impact of periodic floods, reducing their magnitude and extending the time over which they occur. During times of drought, the reservoirs may virtually eliminate the occasional pulses of freshwater and sediments that would naturally occur and that are necessary for the health of the Coastal Bend estuaries. Reservoirs have reduced river inflow as well as the levels of sediments and nutrients carried by the inflow.

In the Laguna Madre, where freshwater inflow is low and

exchange with the Gulf is minimal, high evaporation rates increase salinities to values exceeding those of seawater. This condition, known as hypersalinity, has a profound effect on the ecology of the system. Prior to the construction of the Gulf Intracoastal Waterway through the Laguna Madre, salinities occasionally exceeded 100 ppt and major fish kills were reported. Waterway construction substantially increased water exchange between the upper Laguna Madre and adjacent bays, and decreased salinities. Fish kills due to hypersalinity are no longer reported from this area.

The combination of naturally low inflow rates and high evaporation rates creates relatively long freshwater flow-through times within Coastal Bend estuaries. In fact, it takes four years for water to move through the Aransas and Corpus Christi estuaries. Any unwanted substances, such as toxic pollutants or excess nutrients, that enter these estuaries will not be quickly washed out. Thus, the capacity of our estuaries to assimilate waste materials is relatively low compared to many other estuaries where water residence time is much shorter.

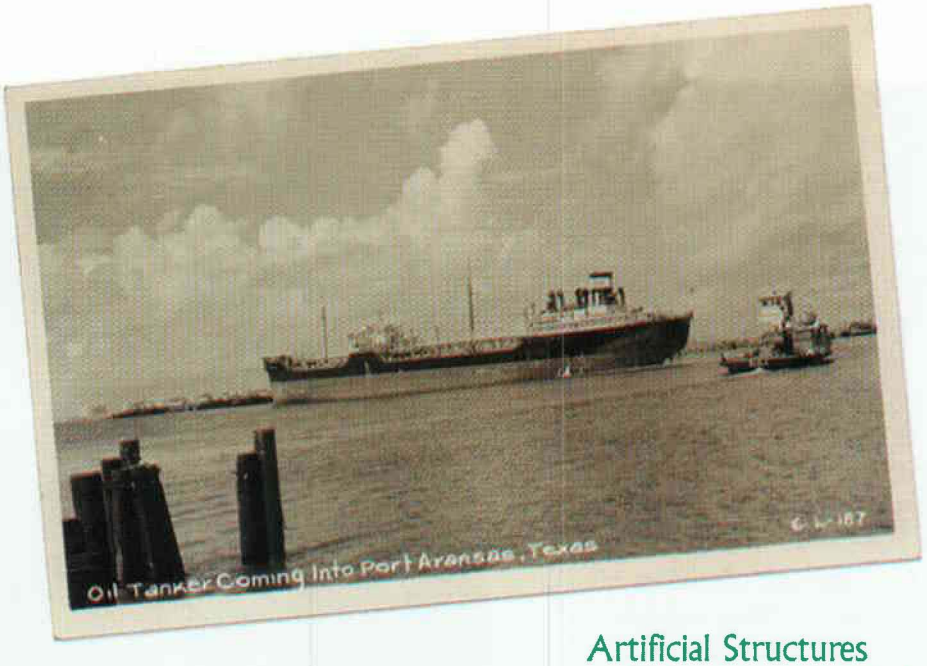


Circulation

Water movement, or circulation, within the estuaries is critically important in the distribution and transportation of waterborne substances, including pollutants, nutrients, or biological components such as plankton or even fish larvae. Certain circulation patterns can also moderate excessive salinities and temperatures. Circulation is driven by several factors including freshwater inflow that enters at a river mouth and pushes through the estuaries, tidal exchanges with the Gulf of Mexico that pulse water in and out of the lower bays, and winds.

Since the Coastal Bend is characterized by low freshwater inflow and a small daily tidal range, winds and other weather events are the major factors driving estuarine circulation. The daily sea breezes in summer and regular frontal passages in winter act to stir water within the estuaries. Water is piled up on the downwind side while the water

Corpus Christi is one of the windiest locations in the United States and this has a major impact on the ecology of the Coastal Bend estuaries. Unlike many other parts of the world, where strong tides or extensive freshwater inflow from rivers are the main forces that move water around, wind-generated currents are often more important in the Coastal Bend. The magnitude of wind driven currents and waves depends on the fetch, or the uninterrupted distance that the wind can blow over water. Both the Corpus Christi and Aransas estuaries offer a long fetch, allowing persistent and relatively strong winds to generate significant waves and currents. This is the main force for moving water, sediments, animals, and pollutants within Coastal Bend estuaries. During episodes of strong winds, waves and currents can change water levels in some areas of the estuaries by as much as 2 to 3 feet in less than a day, causing extensive flooding or drying of tidal flats and low-lying marshes.



level drops on the lee side. These relatively short-term events do not result in water exchange between the estuaries. On the other hand, the occasional strong polar cold fronts experienced by the Coastal Bend do have the strength and duration to produce significant water exchange between the estuaries and the Gulf of Mexico. Such meteorological events reduce some of the problems associated with the very long water residence time.

Another important source of water movement is the seasonal variation in water levels. The Coastal Bend usually experiences high water levels during the spring and fall and low water levels during the winter and summer. These variations in water level are on the order of 2 to 3 feet, almost twice the daily tidal range. More importantly, these water level changes last for weeks or months, and thus contribute to the exchange of water throughout the estuaries. Daily tides, on the other hand, contribute to the exchange of water only in the vicinity of the tidal inlets and act on a much shorter time scale.

Artificial Structures and Estuarine Circulation

Water circulation can be altered significantly by human activities. In the Coastal Bend, several engineering projects may have had substantial impacts on circulation and the mixing of fresh and salt waters in the estuaries. Four examples are the construction of the Corpus Christi Ship Channel, the John F. Kennedy Causeway connecting Padre Island with the mainland, the diversion of water from the Nueces River for municipal and industrial use, and the use of cooling water by two electric generating stations. Using mathematical models, the impacts of each of these projects were examined including the predicted effects of removing each of them.

The single, greatest impact on circulation in Coastal Bend estuaries was caused by construction of the Corpus Christi Ship Channel. Prior to 1907, the area between Port Aransas and Corpus Christi Bay, known as Turtle Cove, was composed of shallow mudflats. There was virtually no water exchange across the flats, and the only substantial connection between Corpus

Christi Bay and the Gulf of Mexico was through Corpus Christi Bayou, which connected the Corpus Christi and Aransas estuaries. The Corpus Christi estuary was largely isolated from daily tidal influences, although little is known about the water quality conditions at the time. The first "deep-draft" channel was dredged through the flats in 1925. By 1968, the 45 feet deep by 400 feet wide ship channel provided a major connection between the Corpus Christi estuary and the Gulf. Today, the major site of tidal exchange in the whole region is between the Corpus Christi estuary and the Gulf whereas, historically, it was between the Aransas estuary and the Gulf.

Models predict that this historic alteration in circulation increased water current speeds throughout the Corpus Christi estuary by as much as 50 to 60 percent and increased the mixing of water within the estuary. As a result, it is estimated that salinities in the Corpus Christi and Aransas estuaries were reduced by 1 to 3 ppt in dry periods and were increased by as much as 3 ppt during wet periods. Thus, the channel has acted to moderate extreme salinity conditions.

The JFK Causeway is a landbridge across the northern-most portion of the Laguna Madre. It has been suggested that the causeway restricts the exchange of water between the Laguna Madre and Corpus Christi Bay. Prior to the construction of the causeway, circulation between these two estuaries was relatively poor due to the natural shallowness of Bulkhead Flats, which separated the two. Today, two channels through the causeway, the Gulf Intracoastal Waterway and the Humble Channel, allow water exchange between the Laguna Madre and Corpus Christi Bay. Measurements of currents in these two channels show that, while short-term tidal exchanges are largely blocked by the presence of the causeway, long-term water exchange between the Corpus Christi and Laguna Madre estuaries is not substantially impeded. Removing the causeway would eliminate the blocking effect that results in accumulation of dead seagrass leaves and other debris along the shore. Mathematical models suggest that removing the causeway would also result in a moderate increase in circulation, but essentially no change in salinity, in the immediate vicinity of the causeway. It would not, however, have any substantial effect on circulation or mixing over most of the upper Laguna Madre or Baffin Bay.

Average freshwater inflows through the Aransas-Nueces basin into Copano Bay have not declined over time, remaining at historical levels. Circulation and salinities in this region have not been altered by human activities.



The potential effect of changes to freshwater inflow on circulation within the Coastal Bend estuaries has also been examined. Mathematical models indicate that the impacts of eliminating water withdrawal from the Nueces River for municipal and industrial uses, while leaving all other modifications in place, would be restricted to Nueces Bay. The predicted result is that, in dry years, salinities could be reduced by as much as 2 ppt in Nueces Bay and that a significant salinity gradient would be established across the bay. Alternatively, little effect is seen in wet years.



Operation of two water-cooled electrical generating stations has a significant effect on circulation as each station pumps substantial volumes of water into its plant from one bay and discharges the water into another bay. For example, the Barney Davis plant draws water from the upper Laguna Madre and discharges the water into Oso Bay, where it eventually flows into the Corpus Christi estuary. Virtually all the water drawn through the intake comes from the northern extent of the Laguna Madre and, ultimately, from the Corpus Christi estuary through the JFK Causeway. Essentially no water comes from the main body of the Laguna Madre. Modeling studies indicate that eliminating the intake of water by the Barney Davis power plant would have a localized effect on circulation. Water flow through the causeway would be significantly reduced as almost 50 percent of the flow through the causeway is due to the power plant. Although elimination of the power plant would alter salinity in the vicinity of the JFK Causeway by 1.5 to 2.0 ppt, there would be essentially no effect on the rest of the estuary.

A similar situation is documented with the CP&L Power Plant near Nueces Bay. This plant takes water from the Inner Harbor, which is fed by Corpus Christi Bay, and discharges the water into the central portion of Nueces Bay. Models predict that, without this plant, salinity in the immediate vicinity of the discharge could be reduced by as much as 6 ppt, but essentially no effect would be seen in the other portions of the bay.

If all four of the examined projects were removed, the combined effects would be strongest in Nueces Bay, where average salinities would be reduced by as much as 12 ppt during wet years. Corpus Christi Bay salinities could be as much as 6 ppt lower. At the JFK Causeway, salinities would be more variable than they are now, increasing by about 4 ppt in dry years, but decreasing by as much as 5 ppt in wet years.

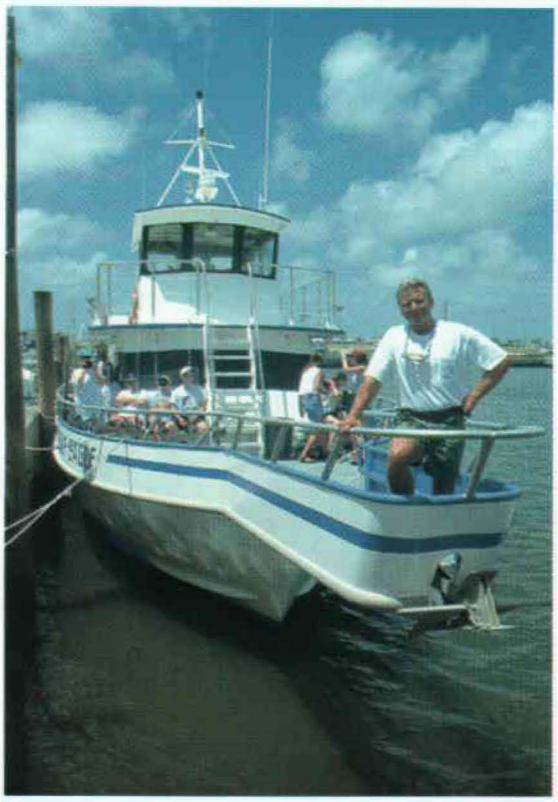
"Our bays and estuaries are the lifeblood of the Gulf Coast community, providing billions of dollars in economic activity and countless hours of recreational opportunity"
Former Governor Ann Richards

Human Concerns

The Coastal Bend is home to over 540,000 residents, or about 3 percent of the Texas population. Most people (58%) live in Nueces County and the City of Corpus Christi, along the shores of the Corpus Christi estuary.

A wide variety of economic activities are supported or influenced by the area's bays and estuaries. Many industries or activities, such as the petroleum refining and chemical industries, ship and boat building and repair, and water transport services are located on or near the water because of convenience or cost advantages. These activities may impact the quality of the water and aesthetic value of the estuaries. Other economic activities in the region, including commercial fishing, tourism, and related industries, are more directly connected to the aesthetic and environmental qualities of the estuaries. Together, these estuary-related activities have a total economic impact of $4.1 billion, providing about one-third of the jobs in the Coastal Bend, and generating $1.3 billion in personal income (1995 data). The petroleum and chemical industries have the greatest dollar impact, but tourism and military activities have the greatest job impact.

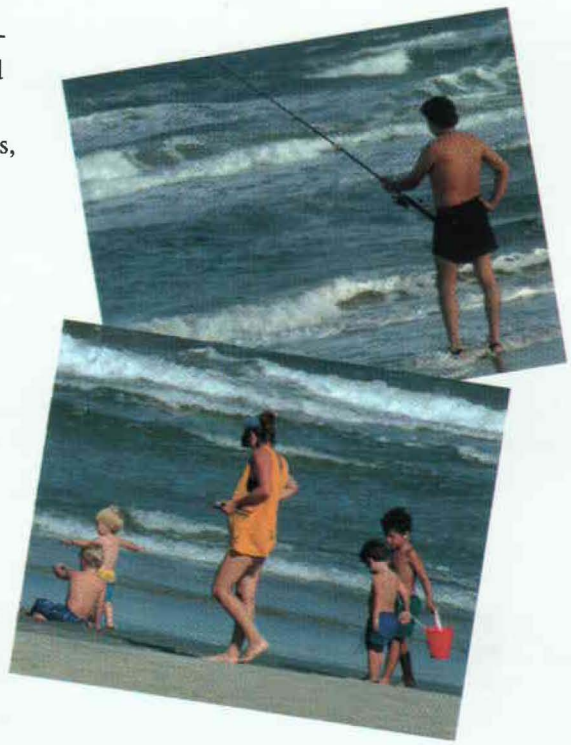
The recreational appeal of the Coastal Bend is quite obvious. The sparkling waters and sandy beaches provide opportunities for fishing, birdwatching, windsurfing, waterfowl hunting, camping, jet skiing, kayaking and canoeing, swimming, sailing, power boating, and numerous other outdoor, water-related activities. The economic value of each of these activities is not known but fishing, birdwatching, and windsurfing are estimated to contribute $90 million to the local economy. Many other values, such as aesthetic enjoyment and a sense of communication with nature, just can't be quantified.



Coliform bacteria come from sewage that enters the estuaries, from pastureland runoff, and from mammals and birds in the marshes. Vibrio are naturally occurring bacteria in marine and estuarine waters.

Public Health

There are three primary public health issues related to the estuarine environment: the possibility of contracting a disease or illness through eating contaminated foods, the possibility of contracting a disease or illness through physical contact with contaminated waters, and the possibility of injuries during water-related activities.





One of the major risks associated with eating seafood is the ingestion of pathogens, disease-producing organisms such as bacteria and viruses. Coliform bacteria are used as indicators of sewage contamination which could contain human pathogens. Many oyster beds in the Coastal Bend are closed to harvesting because of known or potential contamination.



The amount of reef area closed to harvesting has also increased substantially over the past 35 years. There does not, however, appear to be an increasing trend in coliform bacteria levels found in oysters throughout the Coastal Bend over that period, so the increase in closures is mainly due to changes in regulatory and monitoring procedures. With relatively little commercial harvesting of oysters in the Coastal Bend, most oysters consumed here come from outside the region.

While many types of diseases could be contracted from the consumption of raw oysters, the primary risk to humans is from Vibrio, especially for persons with immune system problems. Although oysters are a potential source of Vibrio infections, it is also possible for infection to result from direct contact with contaminated waters, particularly if an open wound is involved. Thus, all the reported cases of Vibrio infections are not necessarily from oyster consumption. Vibrio infections are very serious in the at-risk population and the death rate is high. Fortunately, the number of reported infections in the Coastal Bend population is quite low despite the opportunities residents and visitors have for both seafood consumption and water contact. An average of only one infection per year is reported in the Coastal Bend.

With the exception of Vibrio bacteria, most disease organisms that pose a potential threat through body contact do not survive in seawater. The Nueces County Health Department monitors local waters for the occurrence of coliform bacteria and has consistently found our estuaries are suitable for swimming and other water sports. Therefore, the threat of contracting an illness through contact with the water appears quite minimal.

Another risk from eating seafood is the ingestion of toxic substances. These substances include metals like zinc and copper, as well as organic compounds like PCB's (polychlorinated biphenyls), pesticides, and herbicides. The highest concentrations of these contaminants are found in some of the sites where runoff from rainfall drains into the estuaries and near wastewater discharge areas.These areas are in the Inner Harbor, in Nueces Bay, and other isolated sites around the Coastal Bend. Toxic concentrations are similar to what has been found in Galveston Bay, except that zinc levels in the Inner Harbor are 10 times the levels found in portions of the Houston Ship Channel. Although information on local contaminant levels has not been collected consistently enough to clearly determine trends, it appears that the concentration of metals is declining with a few exceptions. Several metals may be increasing in Copano Bay, and zinc seems to be increasing in large areas of Corpus Christi Bay and Baffin Bay.

In contrast to the well-publicized problems with toxic contamination of fish and shellfish in other areas of the U. S., there is little indication of a problem in the Coastal Bend.

Water-based recreational activities are popular in the Coastal Bend and these activities result in a substantial percentage of all recreational accidents. Most of the accidents are associated with swimming and fishing. Water-related fatalities number about 8 to 10 each year, about two-thirds from recreational activities and one-third from commercial activities. From a public health standpoint, water-related accidents pose a substantially higher risk than disease associated with either contaminated foods or waters.



A recent compilation of data from the Coastal Bend found that, out of 5,500 tissue samples of aquatic organisms analyzed for toxic substances, less than 100 were above levels considered high enough to be of concern. Only two potential problem areas were found: oysters from Nueces Bay had elevated zinc levels and fish from the Inner Harbor in Corpus Christi Bay had elevated PCB contents. These are not considered significant public health concerns since oyster harvesting is prohibited in Nueces Bay and the Inner Harbor is not an important fishing area.

Bay Debris

Urban and suburban areas throughout much of the U.S. are littered with the solid waste products of modern society. The Coastal Bend is no exception. Although it is not usual to see high concentrations of litter along the remote beach and bay shorelines of the Coastal Bend, bay debris in general is quite visible.

There is little definitive information on the amount or kinds of debris within the Coastal Bend, but it is common to find plastic items such as bags, ropes, six-pack rings, pellets, "peanut" packing material, pails, netting, sheeting, and occasionally medical waste, large appliances, and chemical containers -- some with and some without their contents. The sources, relative amounts, trends in amount or distribution, and impacts of the materials are essentially unknown.

It appears that public health risk from ingestion of toxic substances in seafood is quite small at the present time.





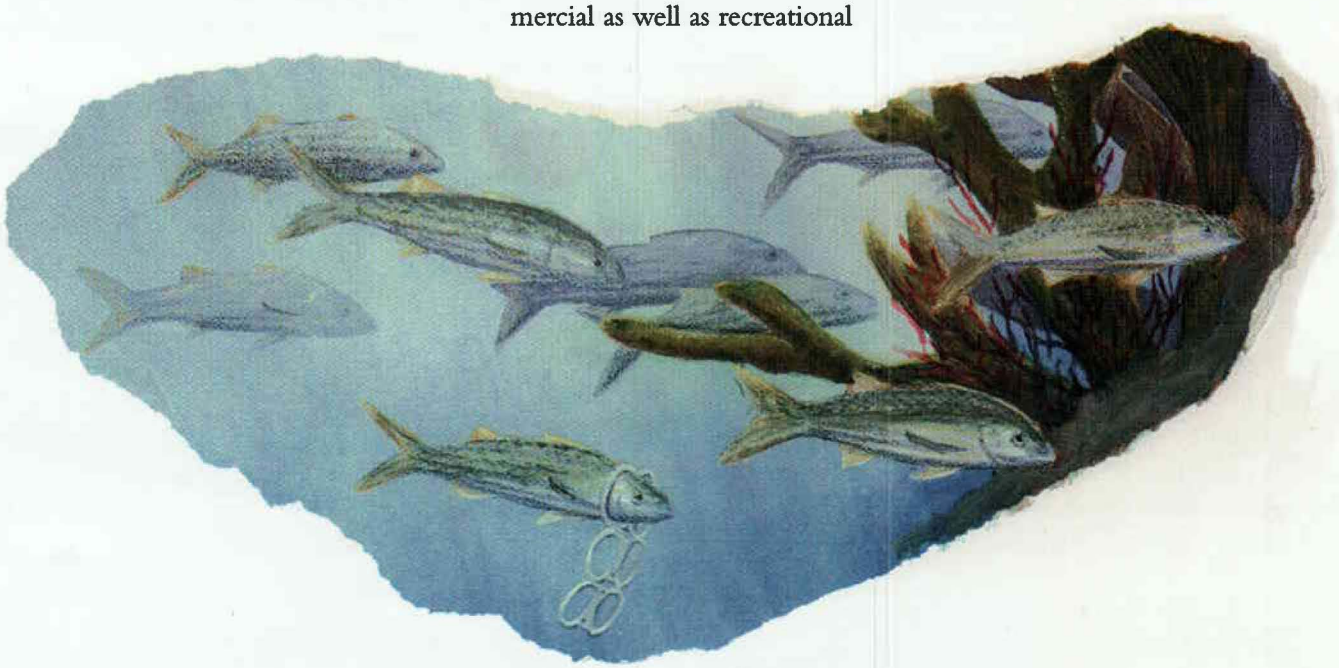
Debris clearly has an aesthetic impact on visitors to the bays and beaches. Numerous cleanup efforts, mostly by volunteers, are organized to remove material from sight.

Studies of debris in other areas of the Gulf of Mexico have shown that there are definite biological impacts. Among these are: ingestion of various items such as plastic bags and foam "peanut" materials by animals that mistake them for food, entanglement of marine mammals and birds in nets and lines, and the covering of bottom sediments and seagrasses with large accumulations of debris.

Maritime Commerce

We make extensive use of the Coastal Bend estuaries for commercial as well as recreational activities. The Port of Corpus Christi is the sixth largest port in the U.S., and its 45 foot draft makes it one of the deepest ports on the Gulf Coast. An increasing trend in vessel traffic (about 80,000 trips from all types of vessels in 1993) and the amount of freight transported (about 77 million tons in 1994) has been documented.

There have been relatively few vessel collisions or major spills in the estuaries. The soft bottoms onshore and offshore are relatively forgiving to ships or barges that run aground. Moreover, spills have generally been concentrated within the Corpus Christi Inner Harbor where it is relatively easy to contain a spill and minimize damage to wildlife and the marine environment. Nevertheless, accidents involving both ships and pipelines have occurred, and incidents in recent years have increased awareness that we must do everything practical to minimize the potential for additional accidents.





Water And Sediment Quality

Pollutants may enter an estuary from identifiable sources, called "point sources", or from scattered and diffuse sources, called "nonpoint sources". Point sources include municipal and industrial wastewater treatment plants where the amount and kinds of discharges are authorized and monitored by various state and federal agencies. The amounts and kinds of pollutants from these sources are known and their inputs to the estuaries can be estimated.

Nonpoint sources include the runoff from residential and industrial sites, agricultural land, marinas, stormwater outfalls, improperly installed or maintained septic tanks, airborne materials, and other natural and human activities. The kinds and amounts of pollutants from these sources are seldom measured directly and are often not known, but they typically contribute toxic substances, coliform bacteria, oil and grease, nutrients, sediments, or organic material to the estuaries.

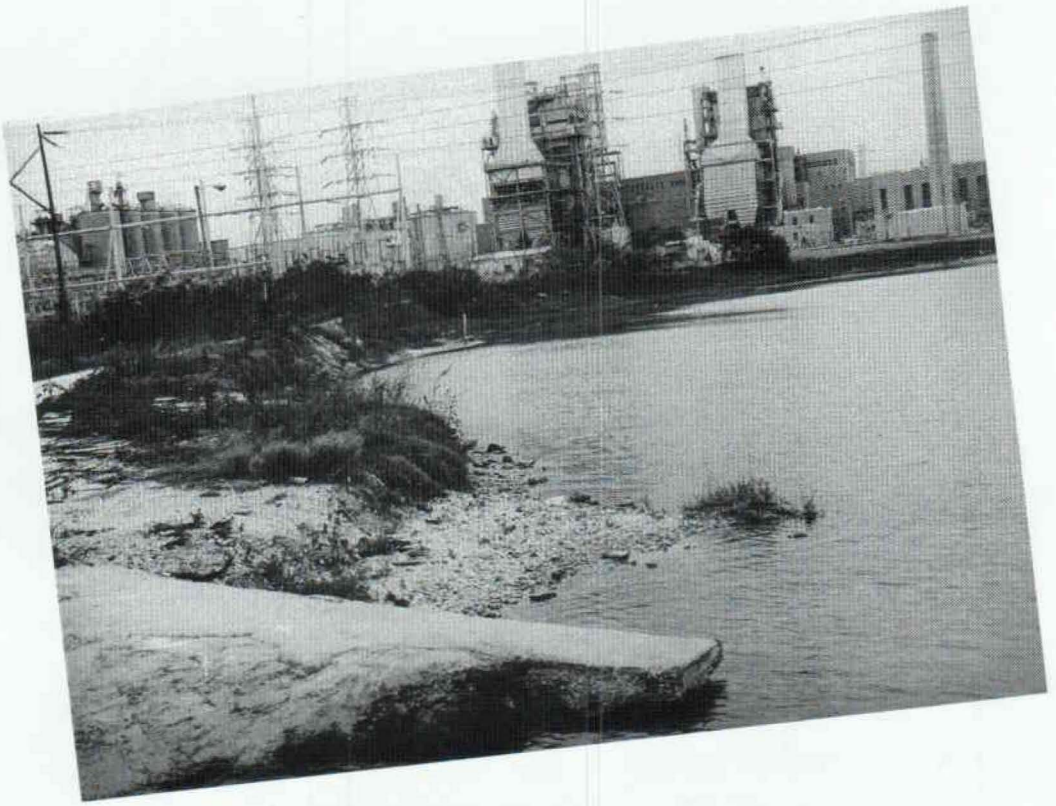
Although the estuaries of the Coastal Bend are in pretty good condition overall, there are some trouble areas that need attention. The Inner Harbor stands out among these "hot spots" due to high concentrations of nutrients and heavy metals in the sediments, and organic chemicals such as chlorinated aromatic hydrocarbons (which include PCBs) and polycyclic aromatic hydrocarbons (PAHs) in the sediments.

Zinc concentrations in the sediments of the Inner Harbor are 10 times higher than those documented in the Houston Ship Channel. Elevated concentrations of metals, however, are not confined to the Inner Harbor. Existing information indicates that elevated concentrations of copper, nickel, and



An exotic species, the edible brown mussel, was first observed in the Coastal Bend in 1990, inhabiting the jetties in Port Aransas. The mussel probably arrived from its native South America attached to a ship's hull or in a ship's ballast water. Within four years after its discovery, the mussel had expanded over 1,300 miles to the south of Port Aransas. Although this species is edible, it probably will not support a commercial industry in the Coastal Bend. It requires hard substrate for establishment and growth and this habitat is somewhat limited in the Coastal Bend. The introduction of this mussel may lead to higher maintenance requirements for navigation buoys and water intake systems. It could also displace some native species.

Maintaining good water and sediment quality in the face of an expanding population is important to human health, aquatic life, and the economic vitality of the region.



Water and sediment quality in estuaries is a result of the amount and kinds of different substances that enter the estuaries and the rate at which those substances are diluted or flushed. Many substances, such as copper, are naturally occurring and essential elements for plant or animal growth in small quantities; however, they can be harmful and are considered "pollutants" at abnormally high concentrations. Likewise, nutrients such as nitrogen and phosphorus are essential for plant growth but heavy concentrations of these substances can cause detrimental algal blooms and other negative consequences. High suspended sediment concentrations caused by eroding soil can be harmful to marine life, but a regular inflow of sediment to the estuaries is essential.

zinc occur in sediments throughout Corpus Christi Bay. Compared to concentrations of metals in other regions of the country considered to be "polluted", copper levels throughout the system and zinc in Nueces Bay and the Inner Harbor would probably be considered "heavy pollution". Other "hot spots" of high contaminant levels exist in Baffin Bay, the upper Laguna Madre near Bird Island, La Quinta Channel, Copano Bay, and the Redfish Bay area near Aransas Pass.

The sources of these contaminants are not clear. However, their existence despite a reduction in loads from industrial and municipal discharges over time suggests that these may be historic, but nevertheless persistent, problems. For instance, it has been asserted that there are currently no PCBs entering the estuaries from industrial or municipal discharges, but PCB contamination is still a problem. In Nueces Bay, it is possible that the current pattern of water circulation through the Inner Harbor and into Nueces Bay may contribute to the metal contamination problem.

Runoff from rural land can contribute pollutants to streams and rivers that eventually find their way into bays and estuaries. These pollutants, derived from natural processes and from human activities such as crop production, ranching, and feed lot operations, include nutrients, pesticides, sediments, and organic materials. Information compiled from several studies of local rural runoff shows a wide range in concentrations of several important components, including both nutrients and pesticides. Data collected from the Oso Creek over an 11 year period indicate that



Sediments are a "sink" for pollutants such as metals and pesticides. Sediments accumulate and concentrate pollutants over a long period of time. When activities such as dredging disturb contaminated sediments, the result can be a reintroduction of pollutants into the water.



pollutant concentration levels from local agricultural lands are similar to those reported from studies in other parts of the state. Nutrient levels are generally higher than those reported for the Galveston Bay area and pesticide levels are relatively low. Data from recent one year studies of crop land on the King Ranch and Odem Ranch showed much lower nutrient concentrations in crop land runoff than the Oso Creek study. These results suggest that sound agricultural practices can reduce pollutants in agricultural runoff. More data are needed, however, to provide values representative of all conditions. The long-term study of Oso creek shows that runoff and pollutant concentrations are quite variable over time.

Potential pollutants in runoff from urban landscapes include nutrients, bacteria, oil and grease, and various heavy metals. These pollutants are derived from such diverse urban activities as fertilizer and pesticide applications on lawns and landscapes, motor vehicle operation, construction, and operations at commercial and industrial sites. Pollutants in urban runoff from coastal communities present a potential problem in the estuaries because the runoff is concentrated into a relatively small number of storm drains that empty directly into these waters. A survey of pollution concentrations, benthic animal densities, and potential toxicity of sediments around a number of storm water outfalls found that some sites have elevated levels of contaminants that are toxic to sensitive life stages of test organisms, and low species diversity. Two sites had no living organisms at all. The storm drain sites at the Corpus Christi Marina near the L-Head and Cole Park and the Padre Island storm water outfall are specific areas of concern where more comprehensive monitoring should be conducted.



A better grasp of the sources and accumulations of pollutants can be obtained using models that predict the amount of each pollutant entering the bays from all point source and nonpoint source contributions. A mathematical model created and used by local scientists estimates inputs of nitrogen, phosphorus, oil and grease, copper, zinc, and cadmium into Coastal Bend estuaries. To estimate the contribution of nonpoint source pollutants, the calculations combine freshwater runoff with the pollutant concentrations from various land uses that enter the streams and ditches. The amounts of pollutants that flow into the estuaries can then be predicted. The contribution of pollution from airborne particles is estimated separately from the land contribution.

Preliminary results indicate that the primary source of phosphorus and most metals is from land runoff. About one-half of the nitrogen comes from land runoff but almost one third is derived from the air as a component of rainfall. Therefore, much of the nitrogen and phosphorus and most metals reach the estuaries largely from nonpoint sources. Oil and grease is contributed primarily from point sources and about one-third of the cadmium, copper, and zinc is from these sources. Although 35 percent of the freshwater inflow to Coastal Bend estuaries comes down the Nueces River, the river contributes less than 6 percent of the nitrogen and phosphorus and virtually no metals are delivered by the river.

The passage of the Clean Water Act in 1972, and the subsequent control of point source discharges, has steadily improved water quality in certain, previously impaired areas. Industries and municipalities are investing money and working hard to do their part to achieve clean water. However, historic loads of metals already present in the environment and urban and rural runoff still need our attention. Unlike the situation in numerous other urbanized estuaries around the

world, where communities are struggling to regain clean water standards, part of the challenge faced by the Coastal Bend is to maintain the relatively good water quality we enjoy today.



©


Victoria
Port Lavaca
Corpus Christi
Aransas Pass
Inglesside
Port Aransas
Kingsville
Alice
Mathis
Sinton
Beeville
Refugio
Rockport
Fulton
Palm Harbor
Port O'Connor
Seadrift
Austwell
Matagorda Island S.P.
MATAGORDA ISLAND
SAN JOSE ISLAND
PADRE ISLAND NATIONAL SEASHORE
PADRE ISLAND
GULF OF MEXICO
Griffins Pt.
Falfurrias
Raymondville
Harlingen
Weslaco
McAllen
Edinburg
Pharr
Mission
Mercedes
Reynosa
Rio Bravo
Matamoros
South Padre Island
Port Isabel
Boca Chica
BRAZOS ISLAND
Kopernik Shores
Laguna Madre
Laguna Atascosa N.W.R.
Aransas N.W.R.
Goose Island S.P.
Choke Canyon S.P.
Bentsen-Rio Grande S.P.
Mustang Island S.P.
Chase Field N.A.S.
Kingsville N.A.S.
Corpus Christi N.A.S.
Corpus Christi Int'l Airport
Rio Hondo
Brownsville Int'l Airport
Victoria Regional Airport
Telferner
Vanderbilt
Francitas
La Ward
Olivia
Port Alto
El Campo Club
Palacios
Weedhaven
Magnolia Beach
La Salle
Indianola
Port Lavaca
Bloomington
Placedo
Point Comfort
Da Costa
Guadalupe
La Salle
Tivoli
Long Mott
Vidauri
Ryanville
Humble Camp
Woodsboro
Bayside
Holiday Beach
Copano Vil.
Lamar
Fulton Mansion St. Hist. Site
Estes
Millsville
Gregory
Portland
Odem
Sodville
Taft
Edroy
Sandia
Wade
Midway
Banquete
Rabb
Violet
Robstown
San Juan
Driscoll
Petronila
Agua Dulce
Bluntzer
Alfred
Orange Grove
Pernitas Pt.
Wesley Seale Dam
Lake Corpus Christi S.P.
Lake Corpus Christi
Mt. Lucas
Lagarto
Clegg
Annarose
Loma Alta
Seven Sisters
Rancho de la Parita
Rosita
San Diego
Rancho Alegre
Palito Blanco
Ben Bolt
Guajillo
Benavides
San Jose
King Ranch
Kings Ranch
Texas A&I Univ.
Ricardo
Realitos
Concepcion
Cruz Calle
Ramirez
Sejita
Premont
Rios
Loyola Beach
Riviera Beach
Riviera
Sarita
Los Olmos
Laguna Salado
Encino
Rachal
Armstrong
Norias
Agua Nueva
Santa Elena
La Gloria
San Isidro
La Reforma
Puerto Rico
Delmita
Rincon
McCook
Red Gate
Linn
La Sal Vieja
Lasara
Hargill
Faysville
Univ. of Texas-Pan American
Delta Lake
Lyford
Monte Alto
Edcouch
La Blanca
San Carlos
Citrus City
Sullivan City
La Joyas
Palmview
Lopezville
Elsa
La Villa
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Palm Valley
Santa Rosa
Combes
Rio Grande Valley Int'l Airport
Sebastian
Santa Monica
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Port Mansfield
San Perlita
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Bayview
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Hts.
Laguna
Vista
Indian L.
San Benito
San Lorenzo
La Feria
Tourist Info
Las Rusias
Rancho Viejo
Los Fresnos
Rio del Sol
Port Isabel
Los Indios
Palomo
Santa Maria
Progreso
Donna
Las Milpas
San Juan
Hidalgo
Alamo
Edinburg
Mission
McAllen
Pharr
Weslaco
Harlingen
Mercedes
Reynosa
Rio Bravo
Matamoros
Brownsville
Port Isabel Lighthouse St. Hist. Site
Port Isabel Fishing Pier
Port Eagle St. Fishing Pier
Goliad St. Hist. Park
Presidio La Bahia Mission
Fannin Battleground St. Hist. Site
Fannin
Goliad
Cologne
Raisin
Aloe
Weser
Schroeder
Meyersville
Upper Meyersville
Weesatche
Runge
Helena
Nordheim
Hobson
Karnes City
Coy City
Kenedy
Lenz
Sainville
El Oso
Green
Choate
Charco
Tulsita
Pettus
Tuleta
Berclair
Normanna
Sarco
Oakville
Cadiz
Orangedale
Blanconia
Olmos
Skidmore
Papalote
Tynan
Agua
St. Paul
Bonnie View
Clareville
George West
Simmons
Three Rivers
Tilden
Calliham
Choke Canyon Lake
Cross
Whitsett
Campbellton
Christine
McCoy
Fashing
Peggy
Oaks
Pawnee
Zunker-ville
Neil
Burdell
Monteola
Mineral
Ray Point
Pettus
Karnes
GOLIAD
BEE
REFUGIO
CALHOUN
ARANSAS
SAN PATRICIO
NUECES
KLEBERG
KENEDY
BROOKS
HIDALGO
WILLACY
CAMERON
JIM WELLS
LIVE OAK
DUVAL
MCMULLEN
Gulf Intracoastal Waterway
Laguna Madre
Laguna Largo
Caye Del Grullo
Baffin Bay
Corpus Christi Bay
Aransas Bay
Mission Bay
Copano Bay
St. Charles Bay
Matagorda Bay
Cavallo Pass
Aransas Pass
Port Aransas
Texas A&M Univ. at Brownsville
Univ. of St. Thomas
Univ. of Corpus Christi
Corpus Christi St. Univ.
Free Ferry
Bypass
Loop
Alt.

THE STATE OF THE BAY: WHAT CAN YOU DO?

Man and nature work hand in hand. The throwing out of balance of the resources of nature throws out of balance also the lives of men." Franklin Delano Roosevelt

This report has characterized the estuaries of the Coastal Bend as "moderately healthy". Unlike many other estuaries across the nation, our scientific findings do not show major problems. The abundant and diverse habitats of the Coastal Bend provide food and shelter for a variety of living resources. Fishery resources are among the richest in Texas. An astonishing number of bird species live in or migrate through the Coastal Bend. Our bays and estuaries return billions of dollars to the regional economy and provide countless hours of recreational pleasure to residents and visitors alike. The Coastal Bend has, thus far, escaped the well publicized problems with toxic contamination of fish and shellfish experienced in other coastal areas. Relatively good water and sediment quality support healthy living resources as well as the economic vitality of the region.

This "moderately healthy" report, however, should not lull us into complacency. Our economic well being and our high quality of life are dependent on keeping our estuaries healthy. Like most other nearshore areas, the Coastal Bend population is expected to grow significantly over the next 20 to 30 years, placing significant stress on our waters and other natural resources. Other factors somewhat unique to the Coastal Bend, including our semi-arid climate and shallow wind driven bays, will combine to magnify any human impacts. The total amount of freshwater inflow to Coastal Bend estuaries is relatively low compared to many other coastal areas along the Gulf and Atlantic seaboards. In addition, average annual freshwater inflow from the Nueces River has decreased by approximately 53 percent since about 1940.

Low freshwater inflow and high evaporation rates together produce a water residence time of 50 months, quite long relative to other estuaries. This means that our estuaries have a greater tendency to concentrate waterborne substances, including pollutants. Warm water temperatures and high salinities result in oxygen levels that are already near levels likely to cause physiological stress to living resources. There is little capacity to absorb any additional pollutants without harm. We must be careful and vigilant in how our population growth occurs.

More than 50,000 new single family homes are projected to be built in the metropolitan area in the next 30 years. The way in which we grow can destroy or fragment wildlife habitat, overrun farmlands, displace valuable streamside vegetation, threaten wetlands, contribute to air pollution, and increase the runoff of sediments, nutrients, and toxics into our estuaries. Growth will place additional competing demands on our freshwater resources. By the year 2050, water demand for residential and business uses is expected to increase by about 50 percent, while industrial water use is expected to double.

The projected development of Padre and Mustand barrier islands requires careful thought to ensure that the natural shore processes are maintained and that cost effective strategies are in place to minimize coastal erosion and loss of life and property.

THE COASTAL BEND BAYS PLAN

Over 300 citizens of the Coastal Bend have worked for three years to develop a management plan for the estuaries. This plan (the Coastal Bend Bays Plan) describes a series of actions to address the problems confronting the estuaries (as summarized in this document) and protect them for future use and enjoyment. Get involved in this management process by communicating your views to local, state, and federal officials, and by volunteering or contributing resources for appropriate actions. For a copy of the management plan, contact the Coastal Bend Bays & Estuaries Program at 512-980-3420.



Proper planning and decision-making now are essential to address the cumulative impacts of an additional quarter million people in the Coastal Bend and to sustain the balance between the needs of our environment and this human community -- our ultimate quality of life.

In moving from science to prudent action, we must recognize that the problems of coastal ecosystems today are different from the past. Successful solutions in the past relied on traditional approaches such as mandated regulations or end-of-pipe controls. These traditional approaches do not work with the complex problems of pervasive habitat loss or fragmentation, diffuse sources of nonpoint pollution, or freshwater inflow which are often intertwined. Today's problems are also not limited to political boundaries and will often require coordinated, regional approaches.

Our stakeholders and resource managers have looked at the potential problems of the Coastal Bend and have taken a first cut at a regional plan. This Coastal Bend Bays Plan provides the framework for all levels of government -- local, state, and federal -- to join together in a partnership for the Coastal Bend. It funnels the collective wisdom, expertise, and financial resources of the partners to a common focus on the Coastal Bend.

"Never doubt that a small group of thoughtful, committed citizens can change the world. Indeed, it's the only thing that ever has." Margaret Mead

Sustaining a healthy environment in the Coastal Bend is also about an informed public making responsible individual decisions. Each of us, in our everyday lives, has the ability to be a steward of the estuaries. For example, we should all use water saving, low flow units in our bathrooms, practice recycling, plant native species of shrubs and grasses, and never disturb nesting birds. We should also:

- Join organizations and participate in programs that work to save the Coastal Bend bays and estuaries.

- Adopt an area within the watershed and help keep it clean and beautiful.

- Teach our relatives and friends about the estuaries and their role in the ecosystem.

- Above all, educate ourselves about the estuaries and their resources and cherish them as the national treasures that they are.

Our lifestyles and livelihoods depend on healthy bays and estuaries. And each of us, in our everyday lives, has the ability to preserve these valuable resources. Become a steward of the Bay!

At Home

- When replacing or installing toilets, use water saving, low flow units.
- Install low flow shower heads. They're inexpensive and they save on hot water heating bills.
- Fix leaky faucets.
- Turn your hot water heater down a few degrees. You will never notice

the difference.

Waste/Recycling

- Recycle all glass, metal cans, aluminum, corrugated cardboard, plastic, and motor oil.
- Bring your own washable canvas or string bags to the grocery store and reuse them for years.
- Avoid purchasing disposable, non-recyclable items -- razors, cameras, and plates, for example.

Yard and Garden

- Plant species of shrubs and grasses that are native to the Coastal Bend environment and require little watering.
- Minimize the use of pesticides, herbicides, insecticides, and fertilizers that may contribute to pollution.
- Choose plants that won't need fertilizer.
- Keep pet waste, leaf litter, grass clippings, and debris out of the street and storm drains. These drains flow directly into our streams, rivers, bays, and estuaries.

Toxics

- Do not pour solvents, paints, and preservatives down drains or toilets.
- Dispose of used oil , paints and solvents at recycling facilities or collection centers.

Septic System

- Conduct regular inspection and maintenance activities.
- Call a septic tank service at least every few years.



Minesweeper in Texas coastal waters

Boating

- Spread the word that discarded fishing line, plastic bags, or plastic six-pack rings are not only harmful to marine animals but they may also damage boats by tangling props and clogging intakes.
- Empty portable toilets at home. If you have an installed facility aboard, dispose of your waste at the nearest pumpout station.
- Use only antifouling paints available from marinas and boat supply stores.
- Keep a trash receptacle handy for use by every boat passenger.
- Avoid "prop dredging" through seagrasses or other shallow areas. Use marked channels, especially in unfamiliar waters . "Pole" in.
- Stay at least 1,000 feet away from nesting birds islands during the months of February through August to avoid disturbance to nesting colonial waterbirds.

THE STATE OF THE BAY: GLOSSARY

Atmospheric deposition: A complex phenomenon that occurs when emissions of sulfur, nitrogen compounds, and other substances are transformed by chemical processes in the atmosphere and then deposited on earth in either a dry or wet form.

Benthos (benthic): The community of animals living in and on the bottom sediments of a body of water. Occurring at the bottom of a body of water.

Bycatch: The unintended taking of a species while net fishing for another species.

Coliform (bacteria): Widely distributed microorganisms found in the intestinal tract of humans and other animals and in soils. Their presence in water indicates fecal pollution and potentially dangerous contamination by disease-causing microorganisms.

Ecosystem: An ecological community and its environment functioning as a unit in nature.

Fetch: The uninterrupted distance that the wind can blow over water.

Food web: A sequence of organisms, each of which uses the next, lower member of the sequence as a food source.

Habitat: The environment in which an animal or plant can normally be found or normally grows.

Heavy metals: Materials like cadmium, lead, arsenic, mercury, and copper that enter the water from both human and natural sources; in high enough amounts, they may be extremely toxic to biological life and may accumulate from low levels in the water to dangerous levels in the flesh of organisms high in the food web.

Hypersalinity: Having extremely high levels of salinity or salt content.

Loading: The rate at which a pollutant enters a system, such as a water body.

Nonpoint source: An indirect discharge, not from a pipe or other specific source.

Nutrients: Essential chemicals needed by plants or animals for growth. Excessive amounts of nutrients can lead to degradation of water quality by promoting excessive growth, and subsequent decay of plants, especially algae. Some nutrients can be toxic to animals at high concentrations.

PAHs (polycyclic aromatic hydrocarbons): A class of complex organic compounds, some of which are persistent and cause cancer. These compounds are formed from the combustion of organic material and are ubiquitous in the environment. PAHs are commonly formed by forest fires and by the combustion of gasoline and other petroleum products. They often reach the environment through atmospheric deposition and highway runoff.

Pathogen: An agent such as bacteria or viruses that cause disease.

PCBs (polychlorinated biphenyls): A group of manufactured chemicals formerly used for such purposes as insulation in transformers and lubrication in gas pipeline systems. Production, sale, and new use was banned by law in 1977 following passage of the Toxic Substances Control Act. PCBs have a strong tendency to bioaccumulate. They are quite stable, and therefore persist in the environment for long periods of time. They are classified by USEPA as probable human carcinogens.

Photosynthesis: The process by which plants use energy derived from sunlight to make simple carbohydrates from carbon dioxide and water.

Phytoplankton: Free floating aquatic plants, usually algae; an important food source for many animals.

Polychaetes: Marine segmented worms.

Point source: A specific source or point of origin, such as a discharge pipe or outfall.

Primary producers: Plant life (in the water, algae or plankton); the organisms that first convert sunlight into food and are then consumed by higher organisms; the base of the food web.

Subsidence: A geological process whereby the land sinks.

Turbidity: A cloudy condition in water due to suspended silt or organic matter.

Water column: An inclusive term, covering the area that extends from the bottom sediments to the surface, of the water in a lake, estuary, or ocean.

Water quality standards: State regulations that outline permissible levels of individual pollutants in specific bodies of water.

Watershed: The land area that drains into a stream, river, estuary, or other water body; same as drainage area.

Zooplankton: Free-floating aquatic animals ranging in size from microscopic, single-celled organisms to large jellyfish. Zooplankton are an important food source for many types of fish and animals.

