An Environmental Inventory of the Christmas Bay Coastal Preserve

Galveston Bay
National Estuary Program
GBNEP-7
March 1991

An Environmental Inventory of the Christmas Bay Coastal Preserve

by
Robert W. McFarlane, Ph.D.
Principal Investigator

Galveston Bay Foundation

Linda R. Shead
Project Engineer

Galveston Bay National Estuary Program
GBNEP Publication - 7
March 1991

TABLE OF CONTENTS

PAGE

LIST OF FIGURES

FIGURE PAGE

LIST OF TABLES

AN ENVIRONMENTAL INVENTORY OF THE CHRISTMAS BAY COASTAL PRESERVE

Robert W. McFarlane, Ph.D.
Principal Investigator

EXECUTIVE SUMMARY

The goal of this report was to gather and integrate existing data, identify data gaps, and describe the environmental attributes of Christmas Bay relevant to the development of a management plan for the Christmas Bay Coastal Preserve. Christmas Bay can be influenced by events anywhere within its watershed.

Christmas Bay remains a near-pristine, 5,660-acre habitat worthy of Coastal Preserve protection. There are no known water quality problems, nor indications of potential water quality problems, in Christmas, Drum, or Bastrop Bays. The current water quality monitoring program is inadequate, however, in that the monitoring station at Christmas Point does not reflect conditions within Christmas Bay and samples are collected infrequently. Freshwater inflow is estimated to be 63,500 acre-feet per year, with point source discharges from permitted outfalls contributing 7.7 percent of the volume. It is recommended that one or more additional water quality monitoring stations be established. Sampling should be conducted monthly for at least two years to establish current baseline conditions, and quarterly, at a minimum, thereafter.

Christmas Bay is inhabited by 96 fish species, 68 crustacean species, 140 mollusk species, and numerous other invertebrate animals. Existing fisheries data, collected for other purposes, is inadequate to determine fisheries trends within Christmas Bay. The Christmas Bay complex is an important finfish and shellfish nursery area and a monitoring program designed specifically for the complex would provide useful information regarding the natural variability in fisheries productivity.

Christmas Bay harbors eight endangered or threatened species - bald eagle, brown pelican, peregrine falcon, whooping crane, piping plover, reddish egret, white-faced ibis, and green sea turtle - while three additional species - wood stork, white-tailed hawk, and swallow-tailed kite - inhabit the adjacent Brazoria National Wildlife Refuge. Seven waterbird nesting colonies surround the bay. Potential exists to create a colonial bird nesting island, of sufficient elevation and vegetated with suitable substrate, to stabilize and enhance colonial wading bird productivity.

The peripheral emergent wetlands experienced a 8.4 percent loss in total acreage of emergent vegetation between 1956 (4,701 acres) and 1979 (4304 acres). Changes in wetland vegetation type are difficult to interpret from the existing wetland maps. The seagrass meadows, composed of four species - shoalgrass, widgeon grass, clover grass, and turtle grass

- are the most valuable and productive habitat associated with the bay. Only widgeon grass is found elsewhere in the Galveston Bay ecosystem. The seagrass meadows have declined 36 percent in area, from 299 acres in 1956 to 191 acres in 1987, at an average rate of 3.5 acres per year. Studies should be undertaken to establish the relative abundance and seasonal dominance of these four species of submerged aquatic vegetation, for the extinction of turtle grass and clover grass may be eminent.

The 12,199-acre Brazoria National Wildlife Refuge has been a major, positive influence on the health and maintenance of the Christmas Bay ecosystem. The planned addition of 30,000 acres to the refuge will bring all of the Bastrop Bay shoreline into public ownership and further bay preservation. The presence of a hundred authorized cabins within the ecosystem has a negative impact on waterbird colonies, seagrass meadows, oyster reefs, and visual aesthetics.

Bastrop Bayou, Bastrop Bay, Drum Bay, Christmas Bay and Cold Pass function as an integral ecosystem. Drum Bay and Bastrop Bay would be valuable additions to the Christmas Bay Coastal Preserve.

INTRODUCTION

Christmas Bay, a small secondary bay at the southwestern extreme of the Galveston Bay ecosystem, has been incorporated into the joint Texas General Land Office/Texas Parks & Wildlife Department Coastal Preserves Program. The Texas Legislature has provided a mechanism by which the General Land Office can lease appropriate, state-owned, coastal lands to the Parks & Wildlife Department to be managed as preserves. The Parks & Wildlife Department has authority to acquire lands for parks and wildlife management areas and habitats for nongame and endangered species, and to establish scientific areas for the purpose of preserving flora and fauna of scientific or educational value.

The Texas Coastal Preserve Program was devised to ensure long-range protection, enhancement, and public use of unique coastal natural resources. The Program seeks to achieve these goals by identifying unique coastal areas, including their fragile biological communities and important colonial waterbird nesting sites, in need of protection, and actively involving all concerned and knowledgeable persons and organizations.

A crucial step toward the protection of a coastal preserve will be the development of a management plan for the preserve. This environmental inventory is designed to assist in the preparation of the management plan. Public interest in the bay has been demonstrated: a permit application to discharge treated domestic wastewater effluent into the bay sparked interest and resistance from local residents and Brazoria County officials, resulting in withdrawal of the application. Two essential questions need to be addressed. What are the actual resources to be preserved? What are the current conditions within the bay? The bay was studied intensively for a brief period in the 1970s but research has languished since then, with only sporadic, unconnected studies being conducted from time to time.

The goal of this report is to gather and integrate existing data currently held by the relevant agencies, to identify data gaps, and to describe the environmental attributes of the bay relevant to development of a management plan for the coastal preserve. Specific topics to be addressed include human occupancy, physical habitat alterations, water quality trends, freshwater inflows, infrastructure, hydrological and meteorological influences, and the living resources.

I. STRUCTURE AND FUNCTION OF THE ECOSYSTEM

Christmas Bay lies inland of a barrier island, Follets Island, southwest of West Bay and San Luis Pass. Christmas Bay is also listed as Oyster Bay on maps of the Texas General Land Office and the Brazoria County Tax Assessors Office. The boundaries of Christmas Bay are currently narrowly drawn, established as a line from Christmas Point to Mud Island at the northern passageway (Figures 1 and 2), the west end of Cold Pass (Fig. 1 and 2), and a line between Rattlesnake Point and Follets Island at the southern passageway (Figure 3). The peripheral boundary is the mean high tide line, the limit of state ownership.

West Bay is the primary bay in this portion of the Galveston Bay ecosystem, in that West Bay has the direct connection to the Gulf of Mexico, the San Luis Pass. Christmas Bay is a secondary bay (Britton & Morton, 1989) distinctly isolated from West Bay. Cold Pass is the umbilicus to the Gulf for the Christmas Bay complex. This natural passageway between San Luis Pass and Christmas Bay reaches depths of 8 to 15 feet in places. It is the escape vent for freshwater inflow and it provides the critical avenue for importation of larval and juvenile marine organisms and exportation of juveniles and adults.

Christmas Bay is the central body of a three-bay complex. It connects to Bastrop Bay in the north, and Drum Bay to the south. Bastrop and Drum Bays are tertiary bays but exhibit distinctly different environmental conditions. The lifeline for this system is Bastrop Bayou, which delivers freshwater, nutrients and sediments to the estuary. The freshwater maintains the salinity gradient critical to certain larval and juvenile organisms. The sediments maintain the estuarine marshes of emergent vegetation which provide shelter for these same creatures. The nutrients are the basis of the food web which nurtures these organisms.

Christmas Bay is analogous to a bi-level bathtub. Bastrop Bayou and Bay are the freshwater spigot delivering various amounts of water, at seasonally different temperatures, to Christmas Bay. The water spreads out in the bay but does not always reach the southern tip. Cold Pass forms a two-way drain, removing low salinity water and replacing it with higher salinity water with each tide. Christmas and Bastrop Bays are of equal shallowness, averaging 2.2 feet in depth (at mean lower low water). Drum Bay is shallower, averaging 1.1 feet in depth. The tidal exchange creates a current at the Christmas Point and Rattlesnake Point constrictions, fostering the growth of oyster reefs. Since both the spigot and the drain are found at the northeastern end of Christmas Bay, poor circulation exists and a salinity gradient is established from north to south. Drum Bay has two tiny, shallow outlets; the western terminus of the original Gulf Intracoastal Waterway, and Nick's Cut, which formerly drained Nick's Lake (See Fig. 3). Its principal tidal exchange is with Christmas Bay.

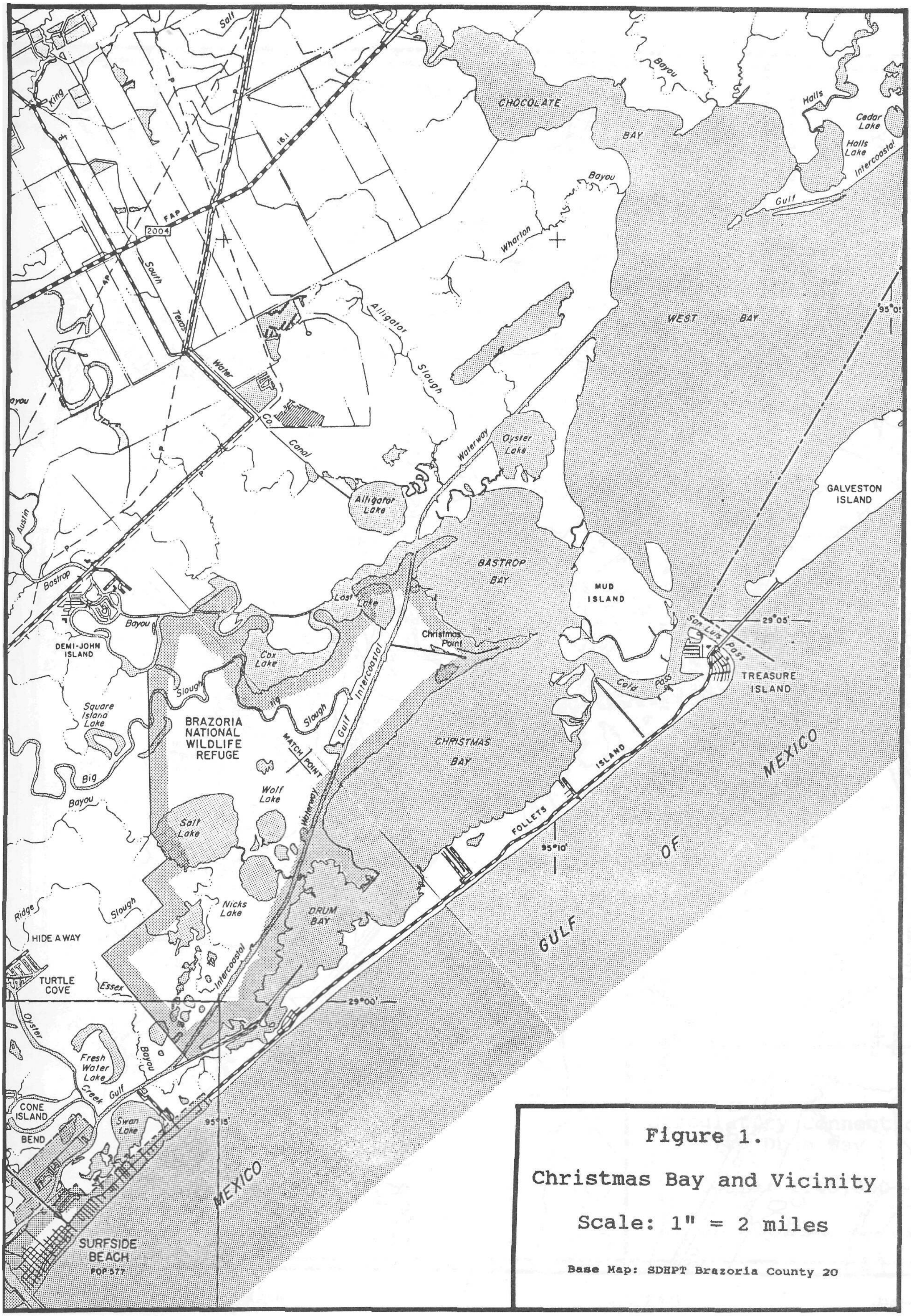


Figure 1.

Christmas Bay and Vicinity

Scale: 1" = 2 miles

Base Map: SDHPT Brazoria County 20

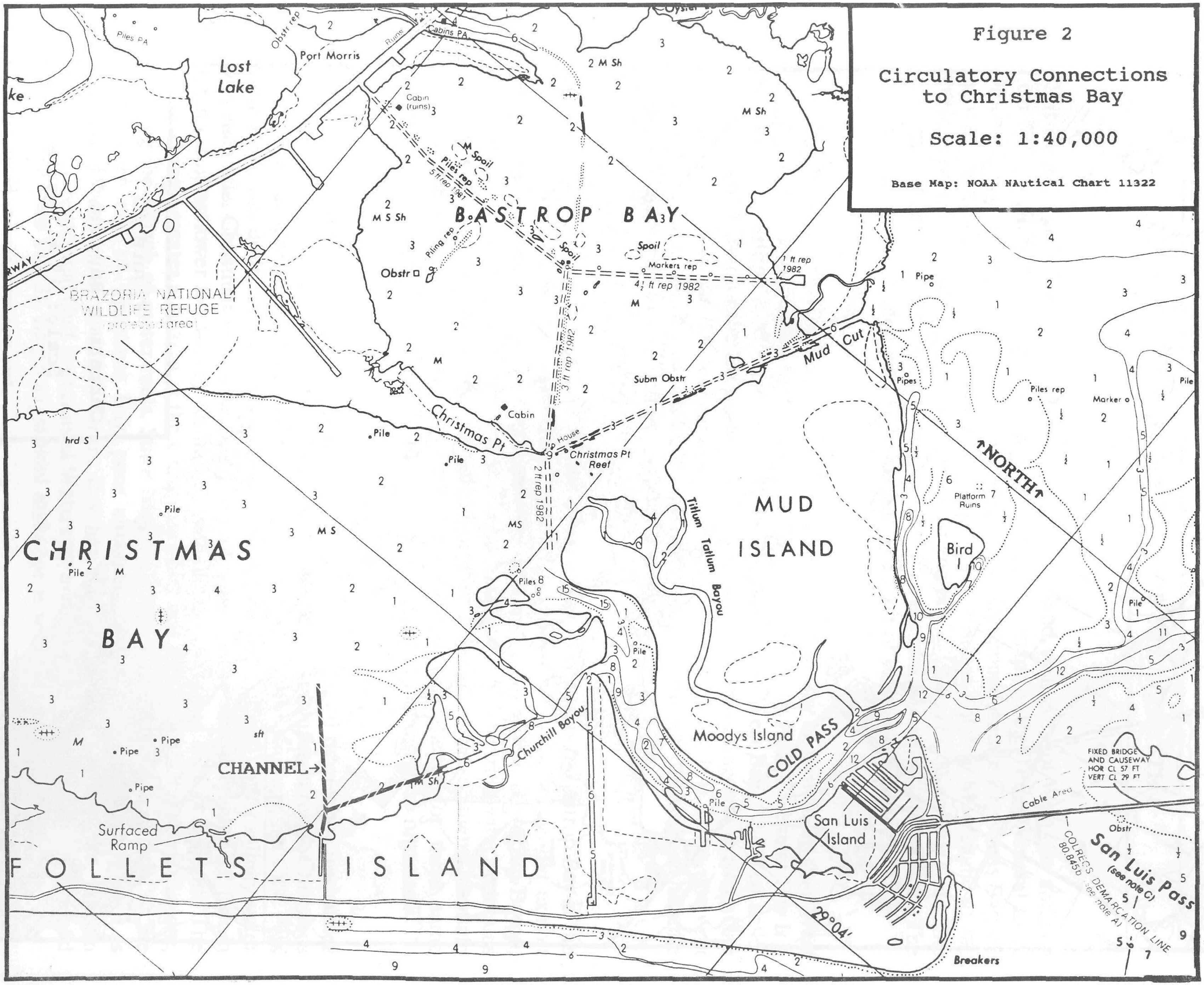


Figure 2

Circulatory Connections to Christmas Bay

Scale: 1:40,000

Base Map: NOAA NAutical Chart 11322

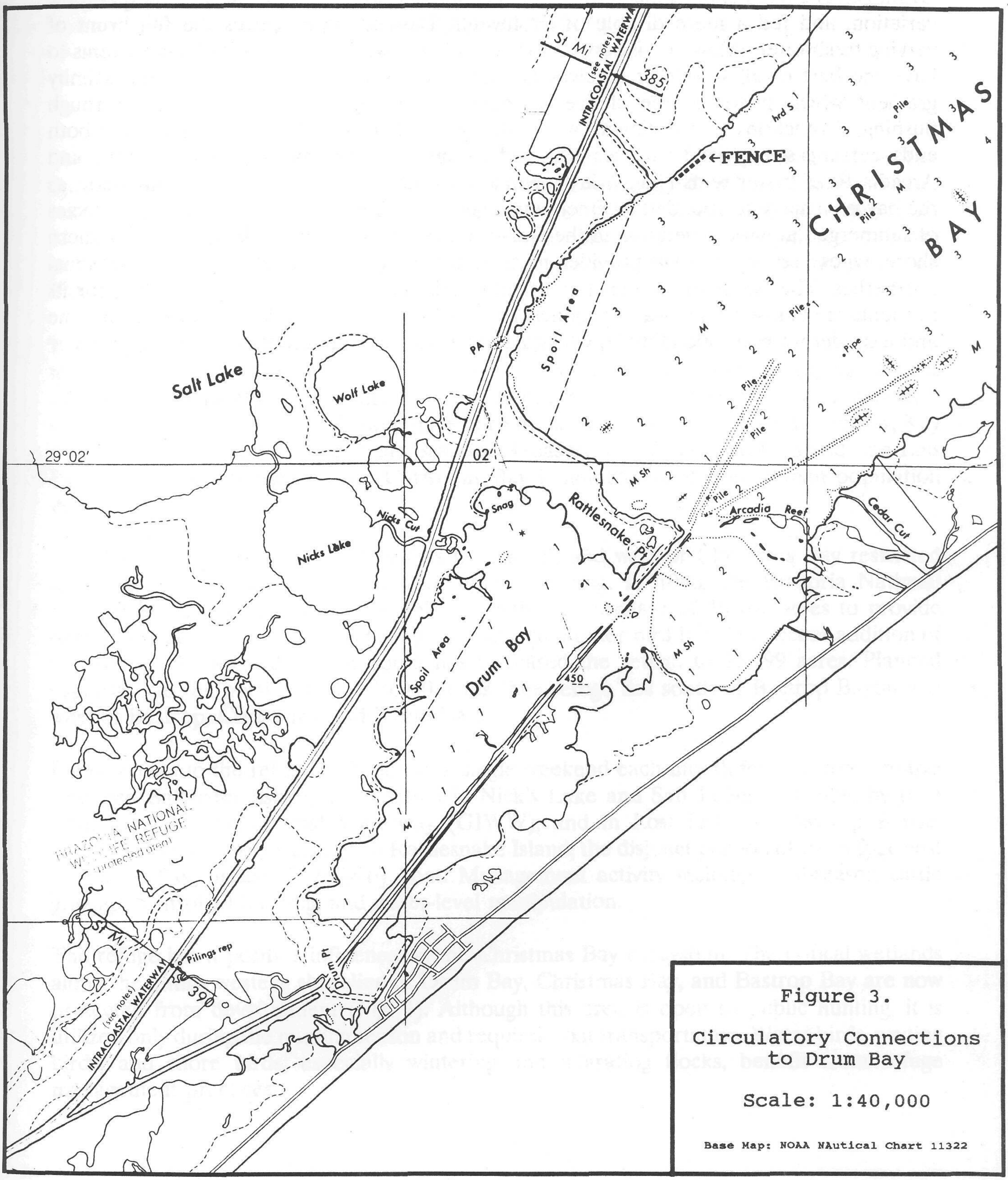


Figure 3.

Circulatory Connections to Drum Bay

Scale: 1:40,000

Base Map: NOAA NAutical Chart 11322

Drum Bay is a dead end, flushed only by tidal action and winds, subject to wide temperature variation, and fed a mere dribble of freshwater. Bastrop Bay receives the full brunt of varying freshwater inflow and is subject to wide salinity oscillations. Christmas Bay seems to have the best of all worlds. It receives adequate freshwater inflow to maintain a salinity gradient which provides free choice to many motile organisms. Without flow-through flushing, it functions as a sediment, and possibly nutrient, trap. With constrictions at both ends, currents sweep food particles past, and sediment away from, the Christmas Point and Arcadia Reef oyster reefs (Fig. 2 & 3). Nursery habitat for marine organisms abounds, as the bay is virtually surrounded by emergent vegetation. The last remnants of several species of submerged aquatic vegetation in the Galveston Bay ecosystem persist along its southern shore, whose scalloped edge provides mute testimony to the persistence of the seasonal northerlies. The bay is the beneficiary of substantial gravitational energy subsidies, for its nutrients are delivered and waste products removed free of charge. With abundant sunshine and a moderate maritime climate, Christmas Bay has become a model seafood factory.

II. ENVIRONMENTAL ELEMENTS

A. HUMAN OCCUPANCY

The Karankawa Indians were among the earliest inhabitants of the Christmas Bay area. The Spanish explorer Cabeza de Vaca became shipwrecked near the San Luis Pass and a brief resident of the area in 1528. Later a small town existed at San Luis. Mud Island and Moody's Island were used by Confederate blockade runners during the Civil War and two small forts were constructed. It is unlikely that these activities had significant impact on Christmas Bay.

Follets Island was included in an original land grant from Mexico to Stephen F. Austin in the 1820s. Currently the land is privately held in numerous small parcels, averaging 50 acres in size, which typically extend from Gulf beachfront to bayshore. Few of these parcels have been developed. Several subdivisions have been founded: San Luis Beach on Drum Bay, Key Lago and Lazy Palms on Christmas Bay, and Treasure Island on Cold Pass and San Luis Pass. Today Follets Island along Christmas Bay is notable for its low human population density.

The extensive area of wetland marshes lying north and west of Christmas Bay restricted agricultural use of the land except for limited grazing. In 1966, the Brazoria National Wildlife Refuge (Figure 4) was established with the purchase of 10,407 acres to provide quality habitat for wintering migratory waterfowl and other bird life. The recent addition of the Slop Bowl wetlands to the south has increased the refuge to 12,199 acres. Planned expansion to the north will add 30,000 acres. The refuge lies south of Bastrop Bayou and west of Bastrop, Christmas, and Drum Bays.

Public access to the refuge is limited to a single weekend each month for non-consumptive activities. Saltwater fishing is permitted in Nick's Lake and Salt Lake, accessible by boat from the Gulf Intracoastal Waterway (GIWW), and in Lost Lake on Bastrop Bayou. Waterfowl hunting is permitted on Rattlesnake Island, the disjunct portion of the refuge east of the GIWW, accessible only by boat. Management activity includes cool-season cattle grazing, controlled burning, and water-level manipulation.

The refuge has a positive influence on the Christmas Bay ecosystem. The critical wetlands along the entire western shoreline of Drum Bay, Christmas Bay, and Bastrop Bay are now protected from development (Fig. 4). Although this area is open to public hunting, it is utilized only during the hunting season and requires boat transportation. Water birds, wading birds, and shore birds, especially wintering and migrating flocks, benefit from refuge management practices.

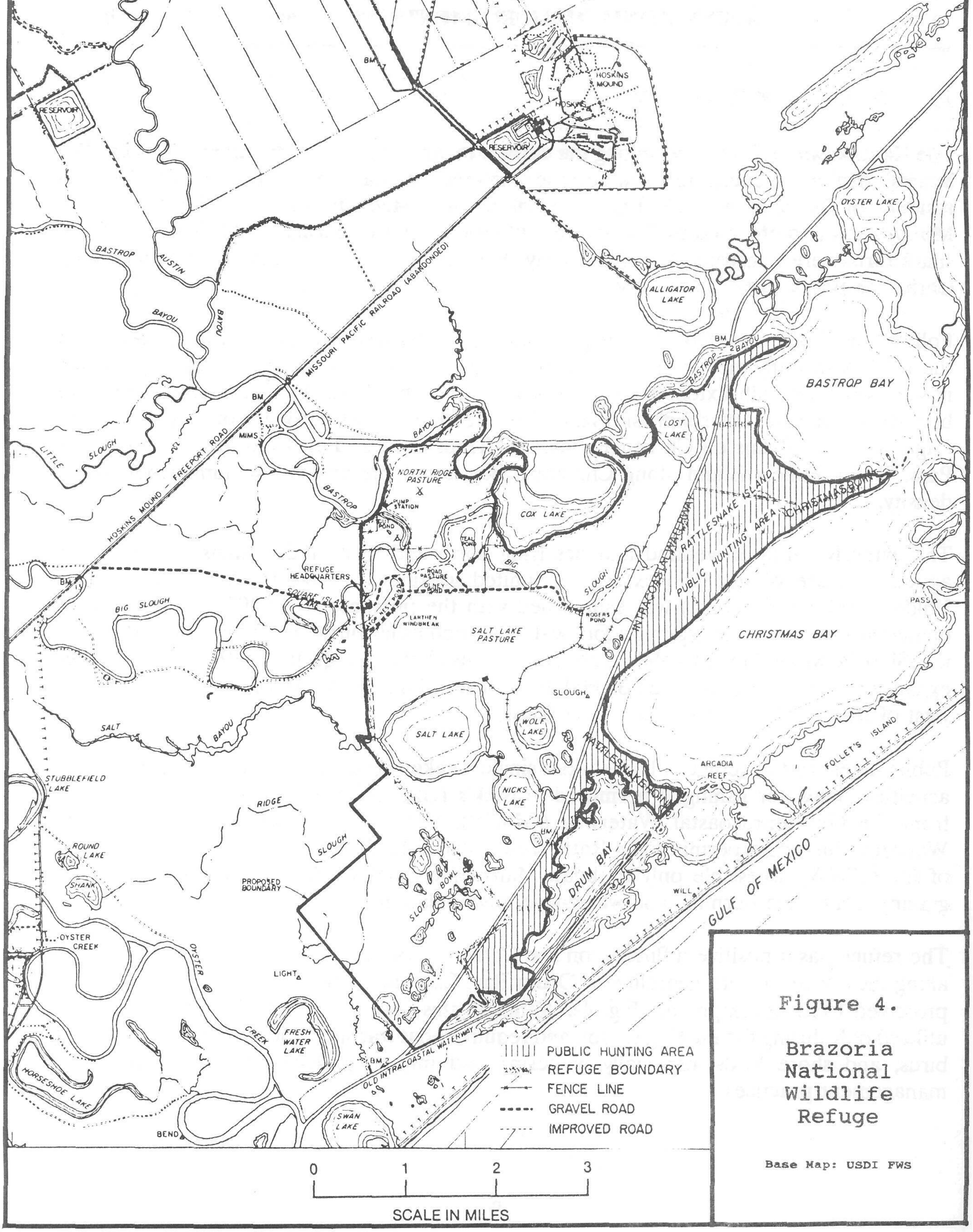


Figure 4.

Brazoria National Wildlife Refuge

Base Map: USDI FWS

Between 1900 and 1920 commercial and sport fishermen and duck hunters began to build fishing shacks on state-owned submerged lands and islands. Unauthorized, these shacks were illegal structures and their occupants were squatters on public land (Texas GLO, 1990). As coastal populations grew, the number of these cabins also increased. The Texas Coastal Public Lands Management Act of 1973 established specific guidelines by which previously unauthorized existing cabins could be authorized. This legislation created a management challenge because the General Land Office is required to protect natural resources on state lands while simultaneously encouraging orderly development of these lands through uses the public at large may enjoy as participants. Existing and prospective cabin owners have utilized this use-and-participation aspect to lobby for continuance and expansion of the cabin program.

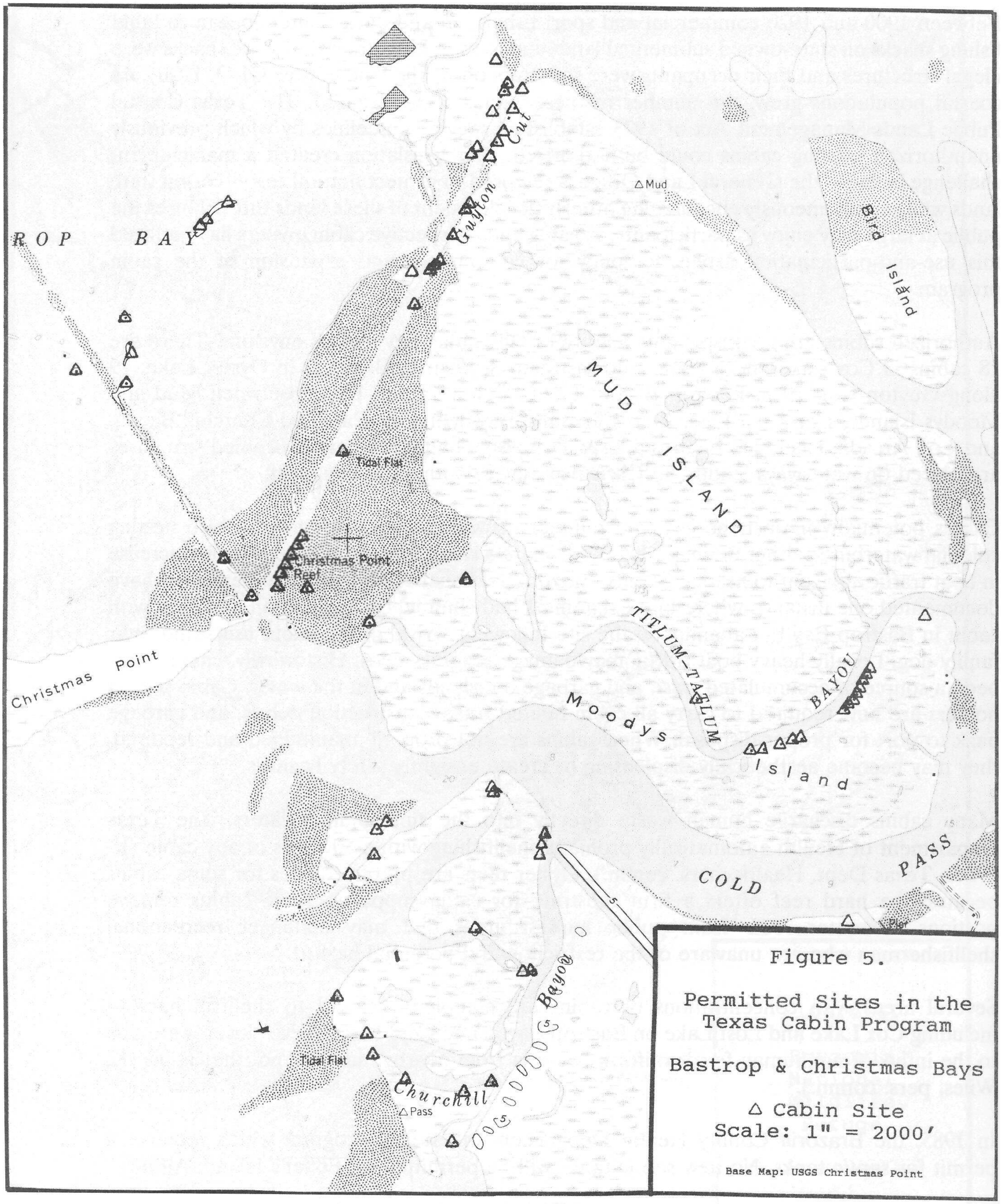
Authorized cabins are a conspicuous feature of Christmas Bay and its environs. There are 18 cabins in Cox Lake and 3 farther downstream in Bastrop Bayou, 2 in Oyster Lake, 19 along Guyton Cut, 19 in Bastrop Bayou, 17 on Titlum-Tatlum Bayou between Mud and Moodys Islands, 1 on Cold Pass, 19 in Christmas Bay near Cold Pass and Churchill Bayou, and 4 on Arcadia Reef (see Figures 5, 6, & 7). Thus, a hundred human-occupied structures are placed on waterways leading to Christmas Bay or within the bay itself.

Cabins potentially impact the bay in a number of ways. Cabin users may disturb nesting colonial waterbirds, either directly when both share a small islet, or indirectly by an increase in boat traffic adjacent to nesting islands. Brazoria National Wildlife Refuge personnel have documented one instance where black skimmers had commenced nesting on an island with cabin in Bastrop Bay but abandoned the site following arrival of the cabin users and their family dog. Locally heavy boat traffic may damage seagrass beds. Historically, cabins have been a source of accumulated trash and garbage on islands and in the water. Cabin permit holders are now required to carry all cabin-related trash, construction debris, and garbage back to port for proper disposal. When cabins are not properly maintained and repaired, they may become aesthetically displeasing or create unsightly safety hazards.

Many cabins discharge human waste directly into the surrounding waters. The Texas Department of Health automatically prohibits shellfishing within 50 yards of any cabin (K. Wiles, Texas Dept. Health, pers. comm.). Oyster reefs are preferred sites for some cabins because the hard reef offers a firm substrate for cabin supports. Thus, cabins remove portions of oyster reefs from public harvest areas and may endanger recreational shellfishermen who are unaware of the restriction and potential hazard.

Several areas with concentrations of cabins are completely closed to shellfish harvest, including Cox Lake and Lost Lake on Bastrop Bayou and Cold Pass. These closures are due to the influx of nonhuman fecal coliform bacteria from nearby marshes, not the cabins (K. Wiles, pers. comm.).

In 1985, the Brazoria County Health Department initiated a program which requires a permit for septic tanks. No new septic tanks will be permitted on Follet's Island. All new


ROP BAY
Guyton Cut
Mud
Bird Island
MUD ISLAND
Tidal Flat
Christmas Point Reef
Christmas Point
TITLUM-TATLUM BAYOU
Moodys Island
COLD PASS
Pier
Bayou
Tidal Flat
Churchill
Pass
Figure 5.
Permitted Sites in the Texas Cabin Program
Bastrop & Christmas Bays
△ Cabin Site
Scale: 1" = 2000'
Base Map: USGS Christmas Point

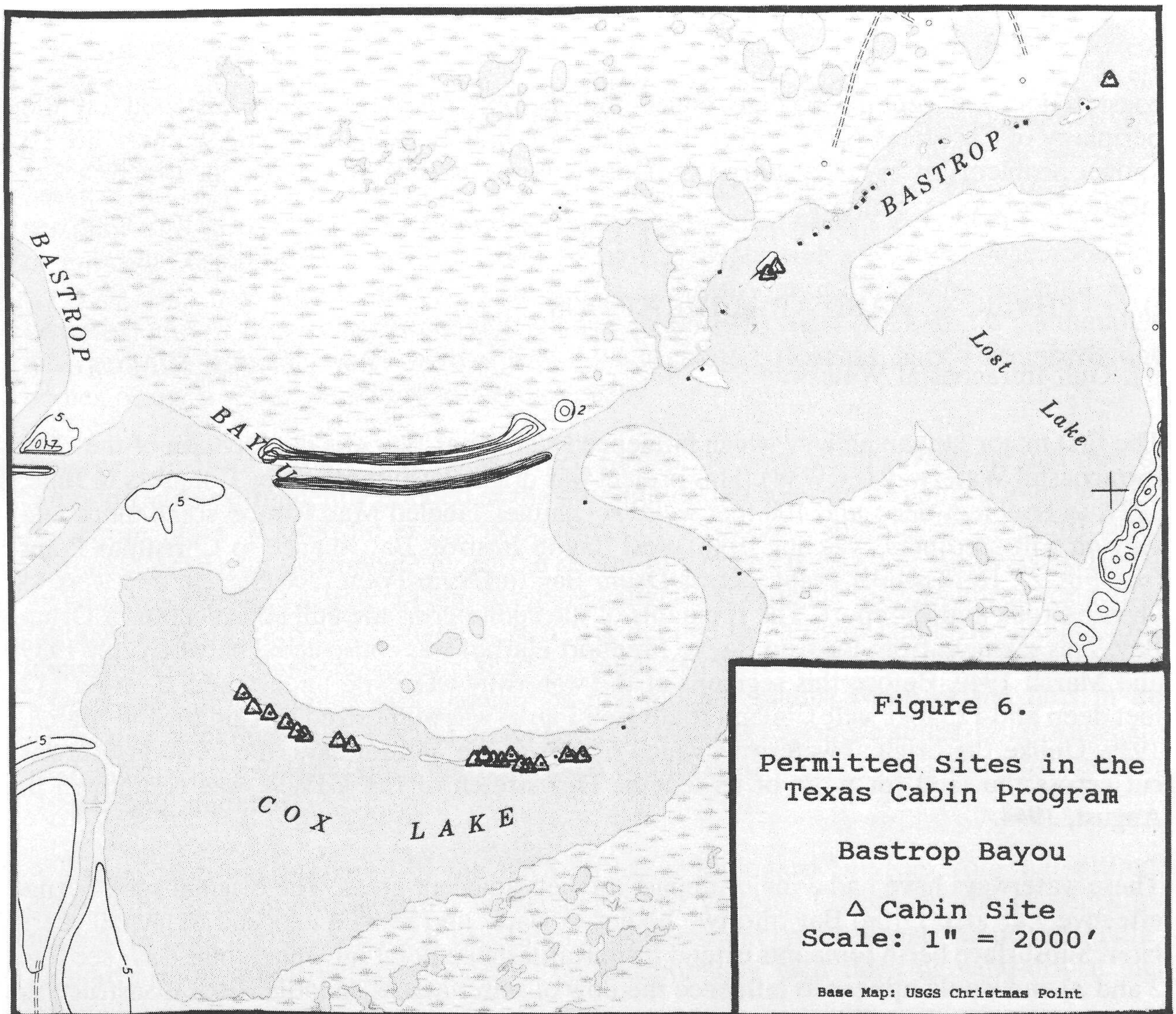


Figure 6.

Permitted Sites in the Texas Cabin Program

Bastrop Bayou

△ Cabin Site
Scale: 1" = 2000'

Base Map: USGS Christmas Point

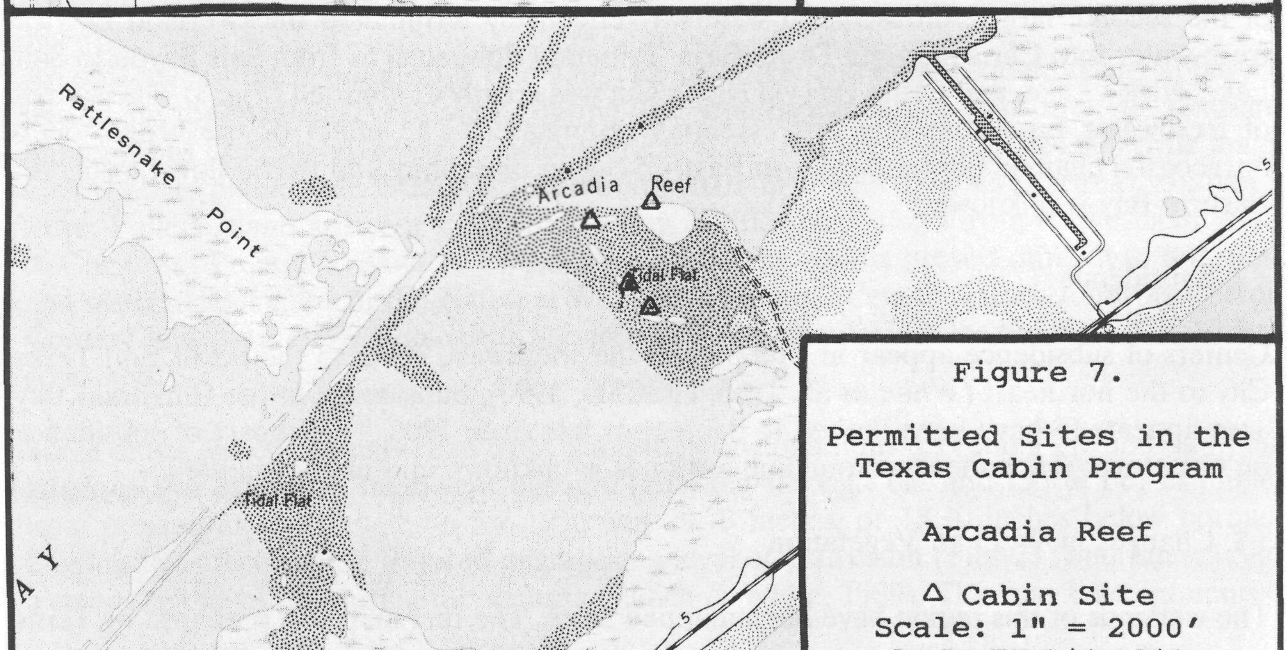


Figure 7.

Permitted Sites in the Texas Cabin Program

Arcadia Reef

△ Cabin Site
Scale: 1" = 2000'
Base Map: USGS Christmas Point

construction will require holding tanks. The number of septic tanks installed on the periphery of Christmas Bay prior to 1985 is unknown, but undoubtably small. There are no known problems at the Key Largo or Lazy Palms subdivisions (D. Mudd, Brazoria Co. Health Dept., pers. comm.).

B. PHYSICAL HABITAT ALTERATIONS

1. Gulf Intracoastal Waterway

The first major human activity which influenced Christmas Bay was the creation of the Gulf Intracoastal Waterway (GIWW). This project was originally authorized by Congress in June, 1927, to be 9 feet deep and 100 feet wide. A channel, labeled Mud Cut on some maps and Guyton Cut on others, was dug from West Bay to Bastrop Bay, thence to Christmas Point (see Fig. 2), Rattlesnake Point, across Drum Bay to Drum Point (see Fig. 3), and west to Oyster Creek and Freeport. The remnants of the spoil berms are still conspicuous in Drum Bay. This segment from Bastrop Bay to Freeport Harbor was constructed between July 1939 and March 1940. Before this segment of the waterway was even undertaken, a larger (12 feet deep and 125 feet wide), inland route (see Fig. 1) was authorized by Congress in March, 1939. Unlike the original waterway, which traversed the natural bays, the new version was cut across the land for most of its length. This stretch of the GIWW was completed in August, 1944.

These waterways have had a major impact on their adjacent areas. The original spoil berms effectively divided Drum Bay into two bodies of water and remain exposed today, 50 years later. Subsurface berm remnants extend from Rattlesnake Point into Christmas Bay (see Fig. 2 and 3) and would appear to influence the flow of water across Arcadia Reef. Construction of the second, larger, intra-coastal waterway effectively terminated the overland flow of fresh-water into Christmas and Drum Bays. Tributary flow, such as from Salt Bayou to Salt Lake, Nick's Lake, and Drum Bay via Nick's Cut was greatly diminished (Fig. 3). The source of freshwater for Drum Bay was essentially eliminated. The effect of the broad, deep intracoastal channel perpendicular to Bastrop Bayou on salinity and bayou flow-through to Bastrop Bay is unknown.

2. Subsidence

Centers of subsidence appear at Freeport to the southwest, Alvin to the north, and Texas City to the northeast (White et al., 1985, HGCSD, 1990). Subsidence in the Christmas Bay area appears to have been limited to 0.5 feet or less since 1906. The impact of subsidence on Christmas Bay and its surrounding wetlands is unknown and undocumented.

3. Changes in Wetland Vegetation

The wetlands of this region have been mapped twice. The first map was prepared by Texas

A&M University and based on black-and-white low-altitude photography from the 1950s (primarily 1956-57) provided by the U.S. Agricultural Stabilization and Conservation Service. This map was prepared for the U.S. Fish & Wildlife Service (FWS) Office of Biological Services as part of the Texas Barrier Islands Ecological Characterization. All wetlands surrounding Christmas Bay are from the estuarine ecological system and either the subtidal or intertidal ecological subsystem (coded E1 or E2, respectively). Subtidal vegetation, the seagrass beds, was very limited in areal extent and distribution. Intertidal wetlands were extensive and of three types; emergent grasses (code EM), flats (FL), and a combination emergent/flat (EM/FL) which were at least 65% vegetated. Beaches, bars, streambeds, and bodies of open water were very small and local.

Emergent hydrophytes are defined as "erect, rooted, herbaceous angiosperms that may be temporarily to permanently flooded at the base but do not tolerate prolonged inundation of the entire plant" (Cowardin et al., 1979). Smooth cordgrass (Spartina alterniflora) is the dominant emergent hydrophyte along the shores of Christmas Bay. On Rattlesnake Island, marshhay cordgrass (S. patens) and seashore saltgrass (Distichlis spicata) are prominent in the saltmarsh (Fleetwood, undated). A flat is defined as "a level landform composed of unconsolidated sediments, usually sand or mud" (Cowardin et al., 1979). Flats may be unvegetated or vegetated with pioneer or non-pioneer plants. None of the flats in the Christmas Point map have subclass designations to indicate vegetative status. On Rattlesnake Island, maritime saltwort (Batis maritima) and two glassworts (Salicornia spp.) are common (Fleetwood, undated).

A second map was prepared by the FWS Office of Biological Services from high-altitude color infrared photography dated November 1979. This map extended the classification scheme to note that all emergent vegetation was persistent (present year round) and either regularly (daily) or irregularly flooded (on exceptionally high tides or wind-driven high water).

An objective of the present study is to compare these wetland maps to identify any apparent trends in the wetland vegetation during the approximately 23-year interval between photographs used for mapping. Individual tracts were measured on the 1:24,000 scale maps with a polar planimeter. Minimum resolution (0.01 in^2) was 0.92 acres. Areas examined were: Follets Island adjacent to Christmas Bay, Rattlesnake Island from Rattlesnake Point to Christmas Point, and Mud and Moody's Islands. The results proved difficult to interpret and wetland specialists at the National Wetlands Research Center (James Johnson, Carroll Cordes) and local FWS Ecological Services unit (former project leader B.D. King) were consulted.

Some of the difficulties may stem from climatological conditions preceding the photographic missions. An extended, multi-year drought persisted through the mid-1950s. For example, total precipitation at Angleton for 1956 was 29.73 inches, or 18.30 inches below normal. Diminished precipitation lowered average sea level at Galveston (Pier 21) and interrupted a steady sea level rise during this century (Pulich & White, 1989). This may have influenced the salinity of intertidal pools or evaporation from irregularly flooded zones, increasing desiccation and soil salinity and affecting vegetation.

Conditions during 1979 were exaggerated in the opposite direction. Record rainfalls of 25.75 inches at Alvin and 14.36 inches at Angleton fell on July 26th. Widespread flooding was experienced across the entire countryside. Total precipitation for July was 35.70 inches at Alvin and 22.13 inches at Angleton. Additional rain fell in September, with 18.88 inches falling at Angleton on September 18-20. October was near normal (2.77 inches vs. 3.51 inches average) and November was dry (0.89 inches vs. 4.25 inches average). The influence of the exceptionally heavy precipitation on wetland vegetation during the midst of the growing season is unknown. The maps may be indicating dry versus wet conditions.

Regularly and irregularly flooded wetlands were combined since the earlier map did not distinguish these categories. The principal vegetation was categorized as emergent or emergent/flat. Some tracts were unchanged. For example, the islands of emergent grasses west of Churchill Bayou changed slightly in shape but not total area (222 vs. 221 acres) despite construction of an adjacent dredged channel. Other tracts experienced substantial change. Mud Island and Moody's Island went from 2% emergent and 98% emergent/flat in 1956 to 94% emergent and 6% emergent flat in 1979. A 3% loss in total acreage (1493 acres vs 1445 acres) may be attributed to shoreline erosion along West Bay or measurement error and is considered insignificant. At first glance, one is tempted to attribute this substantial change in vegetation to plant succession and improvement of habitat, but other clues suggest caution. These islands are wholly state-owned and undeveloped, except for the cabins along Titlum-Tatlum Bayou, and any changes detected should represent natural variation in vegetation.

Follets Island experienced a substantial increase in emergent vegetation from 650 acres in 1956 to 816 acres in 1979 while emergent /flats declined from 801 to 424 acres. Total acreage declined 15%, from 1451 acres in 1956 to 1240 acres in 1979, following construction of four canals and other development.

Rattlesnake Island is difficult to assess. Boundaries are missing between some vegetation zones affecting large areas. Acreage cannot be reliably calculated. The original photographs have been lost. Emergent/flats have changed to emergent tracts while other parcels have changed from emergent to emergent/flat. There is no consistent pattern except a 9% loss, from 1535 acres to 1398 acres, of total emergent vegetation.

The wetland experts consulted have indicated that the combination category emergent/flat has been controversial and they recommended that emergent/flat tracts be tallied as emergent vegetation. When this is done, trends are no longer apparent, except for the changes in total vegetation mentioned above. Figure 8 is a simplified wetland map showing emergent vegetation and upland areas. Small inclusions of flats and water bodies have been omitted for clarity.

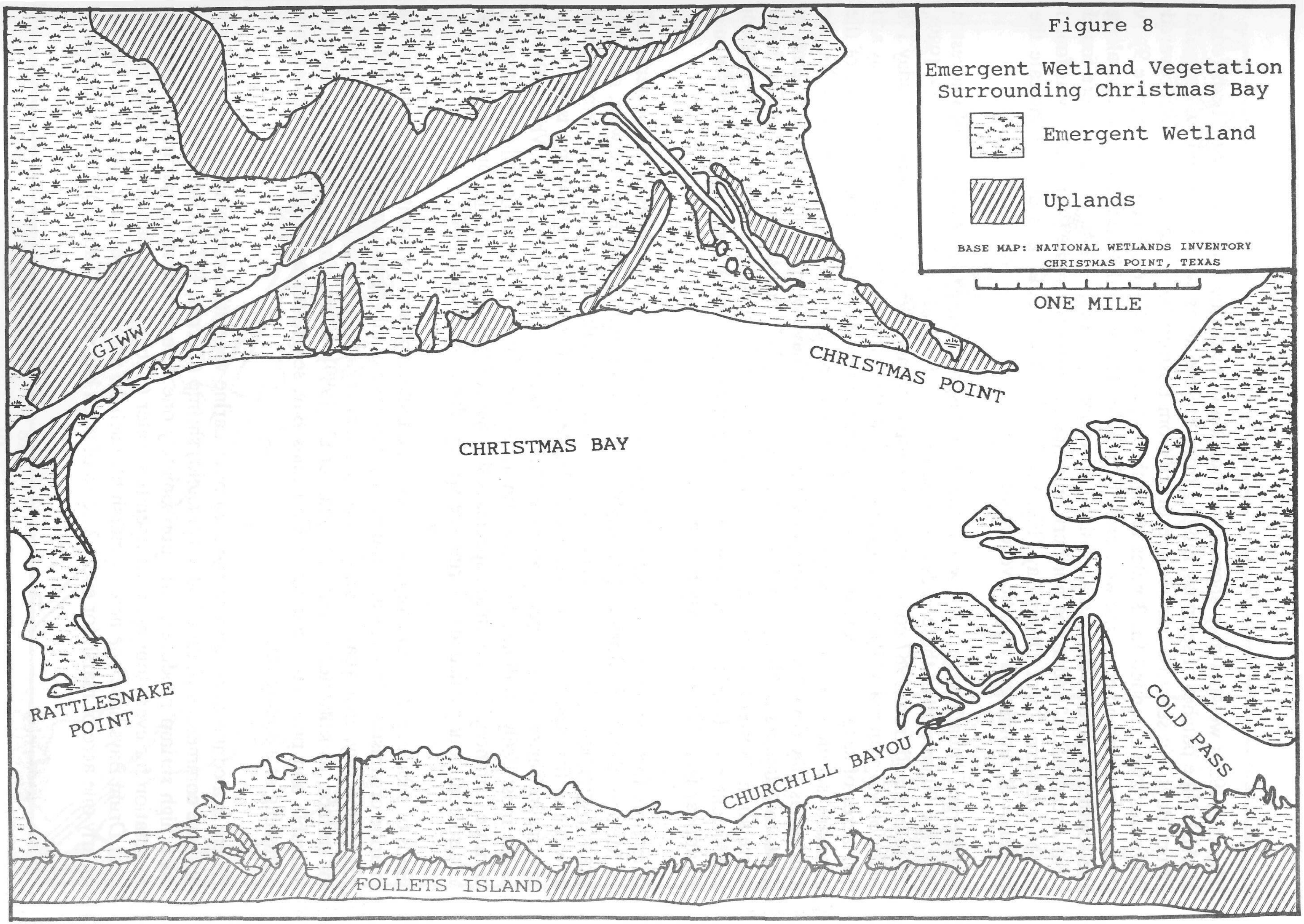


Figure 8
Emergent Wetland Vegetation Surrounding Christmas Bay

The mid-1950s wetland map showed the location of estuarine subtidal aquatic beds (code E1AB). Nine patches of seagrass, ranging from 1 to 206 acres, were found in Christmas and Drum Bays. No seagrass has been recorded from Bastrop Bay. The largest patch covered 206 acres and extended for 3 miles along the bayshore of Follets Island (see Figure 9). A 29-acre patch occurred at the west end of Churchill Bayou, and 30 acres were found along the southern curve of Rattlesnake Island. Five small patches, of 1 to 15 acres, were found near Arcadia Reef and at the northern entrance to Drum Bay; one 7-acre patch was found at the southern tip of Drum Bay (Fig. 9). The 1979 wetlands map did not indicate the presence of submerged aquatic vegetation.

Submerged aquatic vegetation was formerly widespread along the shoreline of Galveston Bay, but 90 percent of these beds have disappeared in recent years (Pulich & White, 1989), as determined from 1987 color infrared photography and 1988-89 field surveys. Today 148 acres of widgeon grass (Ruppia maritima) persist along the eastern shore of Trinity Bay and 191 acres of seagrasses persist in Christmas and Drum Bays. Although 56 percent of the remnant submerged aquatic vegetation in the Galveston Bay system is found in the Christmas Bay complex, the losses in Christmas Bay have been steady, from 299 acres in 1956, to 240 acres in 1975, and finally 191 acres in 1987 (Pulich & White, 1989). The linear correlation between these three estimates in time is striking (Figure 10; correlation coefficient r = -0.997). If this rate of loss (3.5 acres per year) continues, seagrasses may disappear from Christmas Bay by the year 2043.

There are five species of seagrasses which can be found along shorelines of the western Gulf of Mexico (Britton & Morton, 1989). Although it occurs both to the east and west, manatee grass (Syringodium filiforme) has not been reported from the Galveston Bay system; perhaps it was the first species to be extirpated. Turtle grass (Thalassia testudinum) is the rarest species in Christmas Bay, being restricted to several tiny patches (Pulich & White, 1989); it is the most likely candidate for extinction in the bay. Clover grass (Halophila engelmannii) is more common. The dominant species is shoalgrass (Halodule wrightii), but widgeon grass is also common, particularly during the spring (Pulich & White, 1989).

Beds of submerged aquatic vegetation provide important nursery habitat for many juvenile marine organisms. They are also the most productive of all vegetation types associated with Galveston Bay, each year creating twice as much organic plant material, per square meter of surface, as saltwater marsh (Sheridan et al., 1989). It is unfortunate that, as the most valuable and productive habitat in Christmas Bay, seagrasses are the least abundant and vanishing at a steady rate.

There is a connection between the area of estuarine vegetation surrounding an estuary and inshore commercial yields of table (penaeid) shrimp (Turner, 1977). Galveston Bay, known as a high shrimp producer, has approximately one acre of emergent salt marsh shoreline vegetation for every four acres of open bay water (Table 1; Sheridan et al., 1989). Bastrop and Drum Bays have one acre of marsh for each 2.5 acres of open bay; Christmas Bay has nearly one acre of marsh for every 2 acres of open bay water (Table 1). Other estimates of

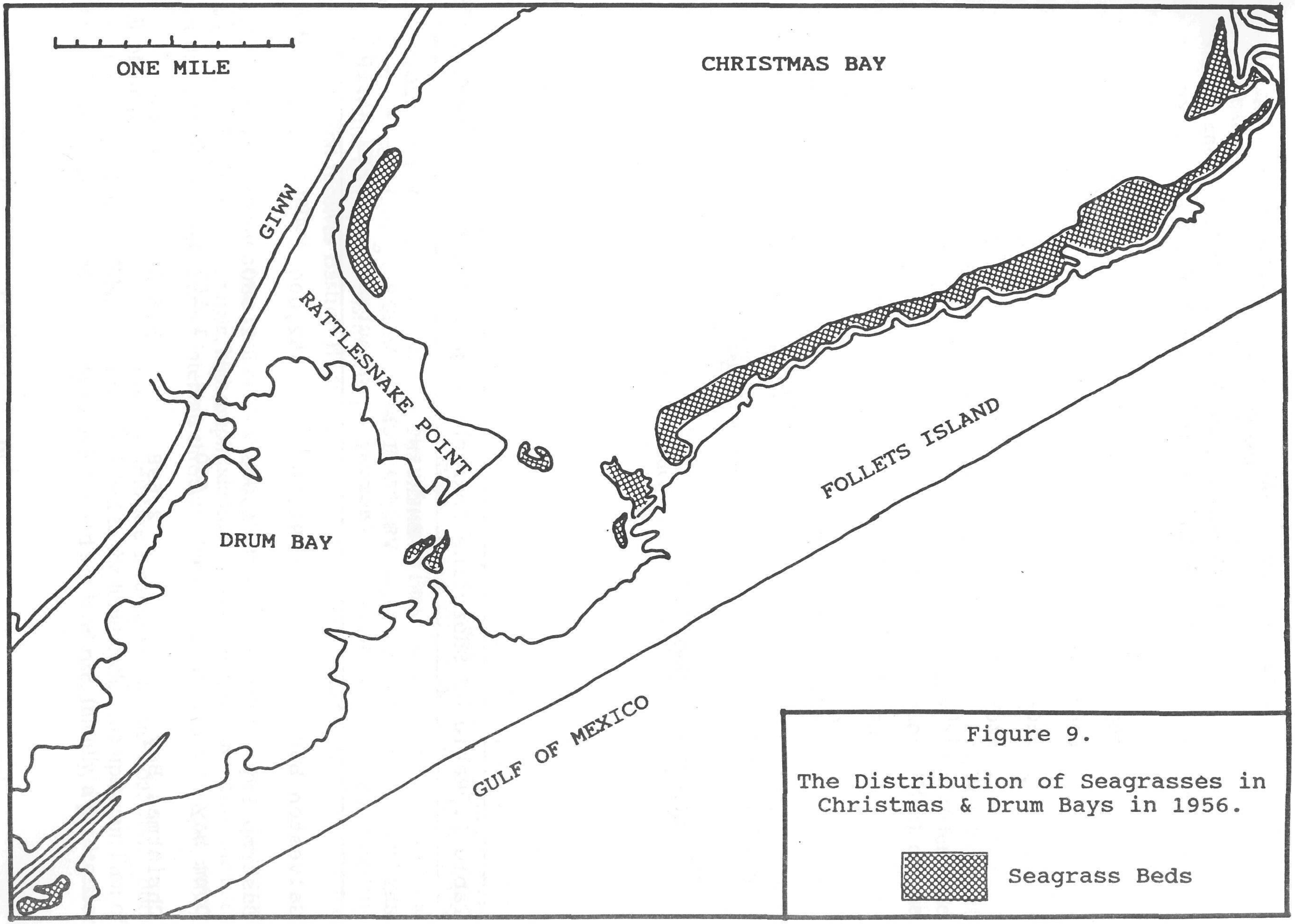
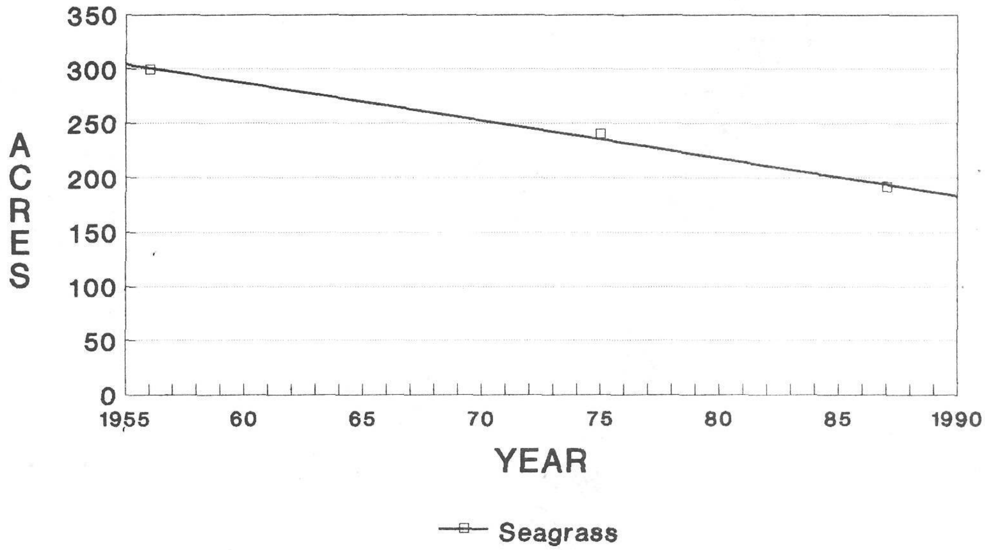


Figure 9.

The Distribution of Seagrasses in Christmas & Drum Bays in 1956.

FIGURE 10.
TREND OF SEAGRASS ACREAGE
IN CHRISTMAS & DRUM BAYS



Corr. Coeff. r=-0.997

Table 1. Ratio of Shoreline Emergent Vegetation to Open Water.

BAY	EMERGENT VEGETATION (acres)	OPEN WATER (acres)	EMER. VEG. / OPEN WATER
Galveston Bay	91,000	352,000	0.26
Bastrop Bay	1,003	2,580	0.39
Drum Bay	460	1,157	0.40
Christmas Bay	2,698	5,660	0.48

wetland vegetation surrounding Galveston Bay have been lower, particularly of contributing marsh or marsh affected by tidal action (Armstrong, 1987), indicating as little as one acre of marsh for each 26 acres of open water. Acre for acre, Christmas Bay is potentially a high shrimp producer, because of the high-value seagrass and salt marsh vegetation along its shoreline.

4. Dredged Boat Channel

The Brazoria County Park Commission has dredged a boat channel at the Brazoria County Boat Ramp adjacent to the Lazy Palms subdivision on Follets Island (See Figure 2, CHANNEL). The channel extends from the existing canal 600 feet into Christmas Bay and forks, continuing 3600 feet northwest into deeper water of Christmas Bay, and 3600 feet north-northeast to Churchill Bayou, which connects to Cold Pass. The channel is 40 feet wide and 4 feet deep. Interestingly, neither the permit application, the permit (#18476), nor the amended permit mentioned the seagrass beds traversed by the channels.

5. Smooth Cordgrass Plantings

The Soil Conservation Service (Angleton office) has transplanted smooth cordgrass from a site west of the GIWW to a 1000-foot shoreline plot along Rattlesnake Island on Christmas Bay (see Figure 3, FENCE). A double-row snow-fence was erected to reduce wave action and protect the plants until they become established. The Brazoria National Wildlife Refuge shoreline at this point is a low, eroding, cliff-face which has experienced an average loss of 0.8 feet per year (Paine & Morton, 1986).

C. WATER QUALITY TRENDS

Estuarine waters, which by definition are diluted with freshwater inflow from the adjacent land, will reflect the quality of that incoming water. The Bastrop Bayou watershed (59 square miles) receives treated sewage and industrial discharges and runoff from urban, industrial, and agricultural areas. The quality of Bastrop Bayou water will be described and compared to neighboring watersheds, Chocolate Bayou to the east and Oyster Creek to the west. Then the quality of Christmas Bay water will be described and compared to Bastrop Bay, which first receives Bastrop Bayou waters, and Drum Bay, which is the least affected by Bastrop Bayou inflow.

Tides along this segment of the Gulf of Mexico shoreline are mixed diurnal and semi-diurnal tides, alternating between a single, high amplitude tide and two, unequal, low amplitude tides per day, at approximately weekly intervals through a lunar cycle (Britton & Morton, 1989).

All of the monitoring stations discussed herein are located within the tidal zone. Both frequency and volume of tidal exchange are linked to the lunar cycle. The upstream limit of tidal exchange has been influenced by subsidence and sea-level rise. Initially, a predecessor of the Texas Water Commission divided Bastrop Bayou into tidal (1105) and above tidal (1106) segments, with the boundary 0.4 miles upstream from State Highway 523 (Ezell, 1977). The boundary was subsequently moved to a point 1.2 miles upstream of State Highway 288 [now SH227] (Ezell, 1977). Later, the boundary was moved again to a point 3.5 miles upstream of SH288 [now SH227] (Ottmers, 1980). Later still, after determining that, during low flow conditions, virtually the entire length of the bayou is tidal, the non-tidal Segment 1106 designation was eliminated.

The first monitoring station (1105.0050) on Bastrop Bayou was established at the intersection of the bayou and the Gulf Intracoastal Waterway. Data were obtained there from July 1969 to August 1973. The sampling locality was subsequently moved upstream to County Road 227 (Sta. 1105.0100) [not to be confused with State Highway 227] where data have been gathered since September 1973. A third station (1105.0200) was established at State Highway 288 [now SH227] and data were collected from August 1973 to May 1979. Additional data were gathered at Station 1105.0300 (South Front Road) from February 1976 to February 1982, a site of uncertain location. Comparative data are from Chocolate Bayou at FM2004 (Sta. 1107.0100) and Oyster Creek at FM523 (Sta. 1109.0100).

A monitoring station (2433.0100) was established in Bastrop Bay at the intersection of three private channels (see Figure 2) where data have been collected since November 1973. Near-bottom (0.8 total depth) conductivity samples at this site have ranged in depth from 3 to 6 feet (average 5 feet). Thus, this station may reflect channel conditions rather than the state of open bay waters, which average 2 feet in depth.

In Christmas Bay, a sampling station (2434.0100) was established midway between Rattlesnake Point and Christmas Point. Data collected from June 1971 to September 1977 indicate that near-bottom depths ranged from 3 to 5 feet. The sampling station was then moved to Christmas Point (Sta. 2434.0200). Data collected there since December 1977 indicate near-bottom depths have ranged from 3 to 15 feet (average 9 ft). These data may reflect conditions in Bastrop Bay and Cold Pass rather than open bay water within Christmas Bay.

The Drum Bay monitoring station (2435.0100) is located at midbay but in the old GIWW channel. Near-bottom samples there have ranged from 3 to 9 feet (average 5 ft). Since Drum Bay averages only 1 ft in depth at mean low tide, the data collected here since November 1973 may not be typical of open bay conditions. The locations of eight of these sampling stations are shown in Figure 11.

Intensive surveys take multiple readings (typically 4 or 5 times a day) at multiple sites on a given day. They provide a useful one-day longitudinal "snapshot" of a given stream reach for that day. They are indicative of stream conditions only under similar circumstances and usually are conducted during periods of low flow to minimize the dilution effect of above-normal stream flow; in this respect they represent "worst-case" conditions.

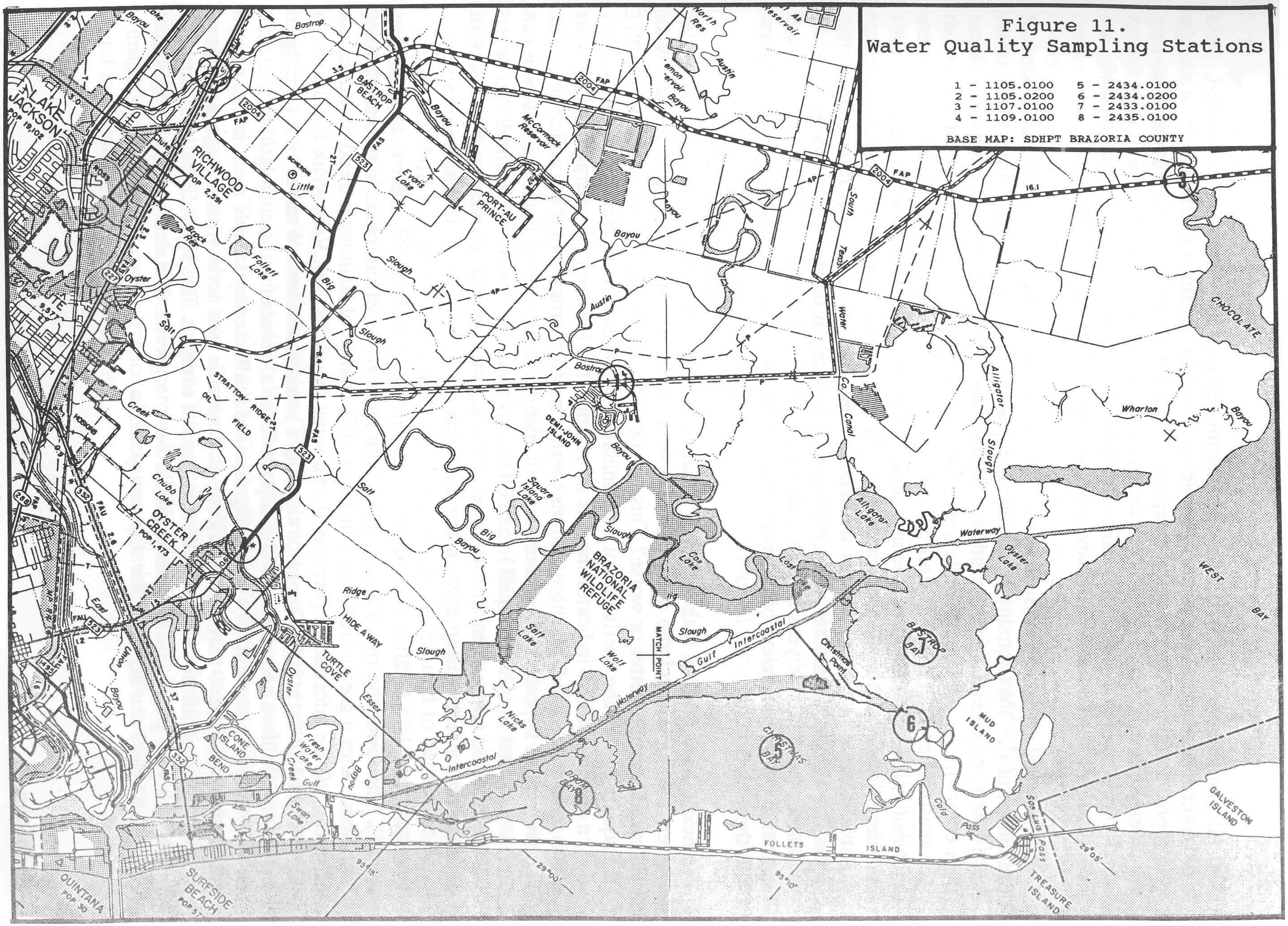


Figure 11. Water Quality Sampling Stations

Standard monitoring data, which may be monthly, quarterly, semi-annual, or annual, yield a different perspective. They represent conditions at different times of the year from a single geographic point; they do not reflect longitudinal conditions along a stream reach. They may be taken at low, average, or high flow rates, so dilution may occur. They may report conditions at midday, and totally miss instances of depressed oxygen, which typically are minimum just before dawn. They are more reflective of random conditions.

Data provided by the Texas Water Commission were analyzed without independent evaluation of the TWC quality assurance and quality control program. Rare blatant errors were noted and deleted from the analysis. Sample size is likely to be a more serious problem than errors in the data set. Sample size of one or two per year (for trends) or per month (for seasonal comparison), or entire years without data, were common. The data were analyzed to determine the presence of trends. The annual average for a given parameter was considered the dependent variable; the year the data were obtained was the independent variable. Simple linear regressions were performed to answer two questions. Given that values for a given parameter vary considerably, how much does introduction of a second parameter (time, as the year of data collection) reduce this variability? This reduction was estimated by the coefficient of determination, r^2. These coefficients were typically very low with these data.

The next question asked if there was a linear relationship between the annual average for a given parameter and the year the data were collected. Were averages increasing or decreasing, getting better or worse? This was determined with the correlation coefficient, r (the square root of the coefficient of determination). Correlation coefficients range from +1 to -1; a coefficient of 0 indicates there is no relationship between the average and the year it was measured. A null hypothesis states there is no correlation and the coefficient is zero. The alternative hypothesis, that there is a correlation, is accepted if the null hypothesis can be rejected, that is, it is not equal to zero. There is always a chance that the null hypothesis will be rejected when it is, in fact, true. Thus we want to determine the probability of claiming that a relationship exists when it does not.

Usually, a risk of 1 in 20 is acceptable (a probability of 0.05, or 5% chance, expressed as $P<.05$). The lower the risk, the better, and the more faith we can place in the trend being real. Sometimes a greater risk, say 1 in 10, or 10% chance of claiming a trend that does not exist, can still be informative (expressed as a weak trend, $P<.10$). Very weak trends, with a high risk of 1 in 5, or 20% chance of claiming a trend that does not really exist (expressed as $P<.20$) also have been noted in this report. Critical values for the correlation coefficient were obtained from a statistical table. Significance is affected by sample size; that is, a given correlation coefficient may be significant at a specific risk level with a large number of samples but insignificant with a smaller number of samples. The significance level for most trends was very poor, and all trends should be interpreted with caution. No inference of cause and effect can be made for any comparisons.

1. Intensive Surveys

Two intensive surveys have been conducted on Bastrop Bayou. The first survey (Ezell, 1977) sampled the bayou in September, 1976, at three locations; at Farm-to-Market Road 2004, at SH288 [now SH227], and a county road upstream (possibly FM1495, now SH288). The uppermost station, near but upstream of the Community Utilities Company discharge, experienced the lowest dissolved oxygen and highest concentrations of nutrients and biochemical oxygen demand (BOD_5). The sewage treatment plant was discharging into the bayou and tidal action was transporting the effluent upstream. The highest levels of copper, chromium, lead, manganese, zinc, and DDE (a derivative of the pesticide DDT), were found upstream and downstream of the treatment plant discharge, and PCB (polychlorobiphenyl) was detected.

The second intensive survey (Ottmers, 1980) was conducted August 8 to 10, 1978. A single location was involved, FM1495. Tidal action was documented for at least 2 miles upstream of FM1495, and the bayou ran dry one mile farther. Tidal amplitude varied at least 5.8 inches and 4.8 inches over a range of 9.2 inches in 48 hours. Dissolved oxygen was found to be critically low, 1.4 to 2.8 mg/L. Chlorophyll and its derivative, pheophytin, were very low (0.011 and 0.010 mg/L, respectively) and primary productivity was judged to be minimal. Again, the effluent from the sewage treatment plant was found to be stagnant and oscillating back and forth with the tide.

Table 2 compares samples from these stations.

2. Monitoring Long-term Trends

Bastrop Bayou at County Road 227 has been monitored quarterly in February, May, August, and November since 1974. Christmas Bay was monitored, at midbay or Christmas Point, quarterly from 1971 to 1981, not at all during 1982 or 1983, and once or twice a year since 1984. For the purposes of this report, the data were assembled in a year-by-month matrix to determine annual (all months in a given year) and monthly (all years for a given month) means, standard deviations, and sample size. Thus sample sizes used to determine annual means were small, typically 2 to 4, and standard deviations were large. Selected parameters will be addressed individually below.

Salinity - The Texas Water Commission (TWC) monitoring program records conductivity at their sampling stations, including both surface and bottom water (0.2 and 0.8 depth) where appropriate. The Texas Parks & Wildlife Department's (TPWD) Coastal Fisheries Branch records surface salinity when they sample the bays. These data sets complement one another in that the TWC data yield multiple observations at the same locality over time, while TPWD data provide data from numerous localities within a given bay. These data provide insight into the effects or occurrence of heavy precipitation, droughts, vertical stratification, and hypersalinity.

Table 2. Comparison of Bastrop Bayou Localities, 1976 & 1978

	FM2004 1976	SH227 1976	SH288 1976	SH288 1978
pH (units)	8.2	8.3	7.7	7.5
Salinity (ppt)	4.2	1.7	0.2	0
Total Dissolved Solids (mg/L)	4032	1827	546	-
Total Suspended Solids (mg/L)	27	22	20	22
Chloride (mg/L)	3040	900	207	71
Sulfate (mg/L)	305	120	33	19
Ammonia Nitrogen (mg/L)	<.01	<.01	0.1	.22
Nitrite Nitrogen (mg/L)	<.02	<.02	0.1	.06
Nitrate Nitrogen (mg/L)	<.02	<.02	.31	.21
Ortho-Phosphorus (mg/L)	.36	.24	1.1	.57
Total Phosphorus (mg/L)	.48	.35	1.2	.67
Total Organic Carbon (mg/L)	19	11	14	7
Biochemical Oxygen Demand (mg/L)	3.9	3.9	4.5	4
Dissolved Oxygen (mg/L)	5.9-8.5	5.2-8.2	2.6-4.9	1.4-2.8
Chlorophyll-a (μg/L)	15	28	21	11
Fecal Coliformes (/100ml)	30	100	80	-

Table 3 presents average, minimum and maximum salinity values along a gradient from the coastal bays upstream. The Christmas Bay composite values combine TWC and TPWD data for surface water (1 foot depth) only. The range is extraordinary, from freshwater (0.2 parts per thousand, ppt) to hypersaline (39.0 ppt), with both extremes recorded at Christmas Point. Bagnall (1976) sampled zooplankton from Cold Pass and Christmas Point toward Rattlesnake Point and reported a salinity gradient on 14 out of 26 dates sampled. She found that salinity declined from east to west, with a maximum gradient of 12 ppt. She reported mean salinities of 25.1 ppt at Cold Pass and 22.3 ppt near Rattlesnake Point. Although TWC sample sizes are limited and different years were sampled, the difference in average surface salinity at Christmas Point (26.1 ppt) versus the center of the bay (23.9 ppt) may reflect this salinity gradient across Christmas Bay.

Drum Bay, which lacks significant freshwater inflow other than direct precipitation, also exhibits a wide range in surface salinity, from 1.6 to 35.7 ppt (Table 3). Bastrop Bay, which receives all of the freshwater inflow, also is capable of hypersaline conditions, 38.3 ppt. Brackish water (greater than 0.5 ppt) extends as far inland as SH227 but may not reach SH288 (Table 3).

Vertical salinity stratification is very limited, indicating that bay waters are well mixed by wind and wave action. The average salinity difference between top and bottom waters in these very shallow bays is 1 ppt or less (Table 4), and the maximum differences do not exceed 6 ppt. A saltwater wedge is frequently present on the bottom at CR227, where the salinity differential averages 4 ppt and may reach 15 ppt.

It is clear that Christmas, Drum and Bastrop Bays can achieve salinities equal to Gulf waters (32-34 ppt) and occasionally become mildly hypersaline (38-39 ppt).

The relationship between freshwater inflow and bay salinity is shown in Figure 12. Data gathered by TPWD personnel indicated that wide salinity shifts occurred in Christmas Bay during 1986. Precipitation events greater than 1 inch at Angleton were grouped into 10-day periods; thus compressed, 19 days of significant (greater than 1 inch) rainfall were reduced to 11 periods, while 25 10-day periods had no rainfall greater than 1 inch in a 24-hr period. Salinity ranged from 23 to 31 ppt until May 1st. Three inches of rain lowered salinity to 17 ppt, and additional 6.6 inch and 1.6 inch rainfalls dropped salinity to 4 ppt. No precipitation greater than 1 inch occurred during July or August and salinity rose to 37 ppt. Three inches of rainfall in early September lowered salinity to 27 ppt by October 10th. The effect of precipitation events of 7.2 inches and 5.7 inches in October, 9.5 inches in November, and 3.4 inches in December are unknown as no salinity measurement was obtained until January 10th, when 27 ppt was recorded.

Although 1986 was not a typical year, as total precipitation was 62.78 inches, or 10.50 inches above normal, the data are instructive because 4 salinity measurements were 31 ppt or higher, and 2 measurements were 4 ppt, thus reducing the possibility of observer error regarding these extremes. This example demonstrates the rapidity of change from oligosaline

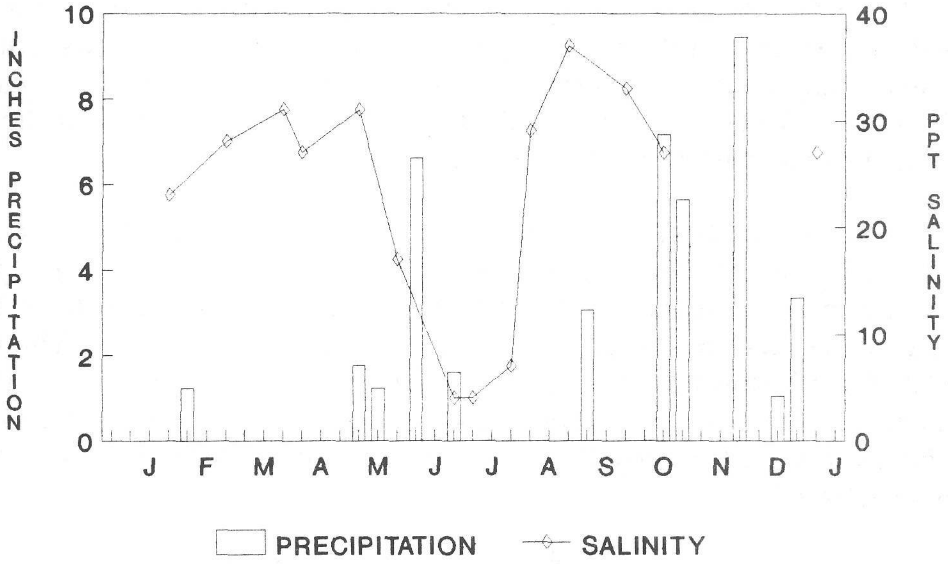
Table 3. Surface Salinities (PPT)

	Mean	Std Dev	Min	Max	Sample Number
Christmas Bay					
Composite	25.5	6.37	0.2	39.0	233
Center of Bay	23.9	6.74	7.1	33.5	22
Christmas Point	26.1	8.31	0.2	39.0	21
Drum Bay	24.1	7.57	1.6	35.7	26
Bastrop Bay	24.7	7.07	0.1	38.3	37
Bastrop Bayou					
County Road 227	8.0	6.88	0	26.6	46
Farm-to-Market 2004	3.5	0.25	3.2	3.9	5
State Highway 227	1.6	0.04	1.5	1.6	5
State Highway 288	0.2	0.05	0.2	0.3	5

Table 4. Vertical Salinity Stratification (PPT)

	Vertical Difference		Extreme Bottom Value	
	Mean	Maximum	Minimum	Maximum
Christmas Bay				
Center	1.0	2.8	6.9	34.2
Christmas Point	1.4	5.8	6.0	40.8
Drum Bay	0.6	6.1	2.2	35.7
Bastrop Bay	1.0	4.4	0	38.2
Bastrop Bayou				
County Road 227	4.0	15.3	3.4	30.3
Farm-to-Market 2004	0.2	0.4	3.3	3.9

FIGURE 12
ANGLETON PRECIPITATION >1"
AND CHRISTMAS BAY SALINITY



to hypersaline conditions, and the misleading nature of "average" salinity, 22.9 ppt, which perhaps existed for only a few days.

<u>Ammonia Nitrogen</u> - Concentrations of this nutrient above 0.15 mg/L are considered to be elevated (TWC, 1990). Annual average concentrations in Bastrop Bayou from 1973 to 1989 have ranged from 0.029 to 1.00 mg/L (Figure 13). The downward trend is significant at the 0.05 level. Seasonally, ammonia has exceeded the threshold only in the fall (Figure 14). High values (1.0 to 1.8 mg/L) occurred in the mid-1970s and have subsided. Over the past decade, only 14 percent of measurements have exceeded the threshold.

Annual average concentrations in Christmas Bay have exceeded the threshold only twice, in 1974 and 1975 (Figure 13). The average concentration at mid-bay (0.28 mg/L) from 1970-77 has declined an order of magnitude (to 0.03 mg/L) at Christmas Point from 1978-89. This likely reflects a true decline rather than just a different sampling point. The values are so low, from 0.094 mg/L down to the detection limit at 0.01 or 0.02 mg/L, that the very weak downward trend is significant only at the 0.20 level. Seasonal patterns (Figure 14) have been biased by high values in the early 1970s; all graph columns which rise above the threshold have been so affected.

Overall, ammonia nitrogen is currently not of concern in Bastrop Bayou or Christmas Bay.

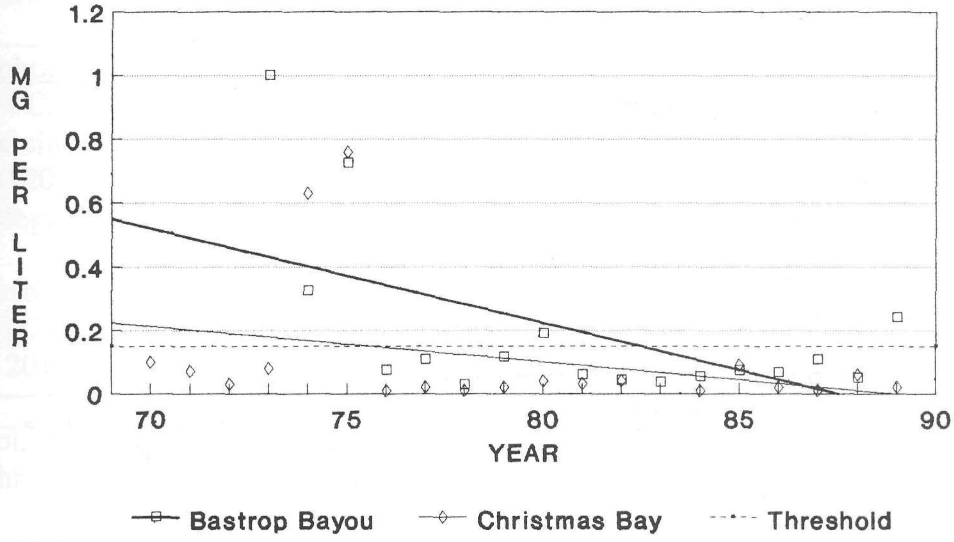
<u>Nitrate Nitrogen</u> - Concentrations of this nutrient above 0.4 mg/L are considered to be elevated (TWC, 1990). Annual average concentrations in Bastrop Bayou have exceeded this threshold only twice, in 1976 and 1982 (Figure 15); each resulted from a single high value. The downward trend is not significant. Likewise, the seasonal trend (Figure 16) is dominated by 3 values which exceeded the threshold; there does not appear to be any real seasonality to nitrate concentrations at this locality.

Annual average concentrations in Christmas Bay have never exceeded the threshold (Figure 15), nor have any individual values. The downward trend is significant at the 0.05 level. There is no distinct seasonal pattern to nitrate concentrations (Figure 16).

Nitrate nitrogen is currently not of concern in Bastrop Bayou or Christmas Bay.

<u>Total Phosphorus</u> - Concentrations of this nutrient above 0.4 mg/L are considered to be elevated (TWC, 1990). Annual average concentrations in Bastrop Bayou have exceeded this average on three occasions but not since 1979 (Figure 17). The declining trend is significant at the 0.05 level. The same two values that elevated the averages for 1974 and 1979 (Fig. 17) also biased the February average (Figure 18), resulting in levels above the threshold and distinct seasonality. Deletion of these data points removes any significant seasonality in the occurrence of phosphorus.

FIGURE 13
AMMONIUM NITROGEN



Correl. Coeff. r:
BB=-.559 (P<.05)
CB=-.118 (N.S.)

FIGURE 14
SEASONALITY OF
AMMONIA NITROGEN

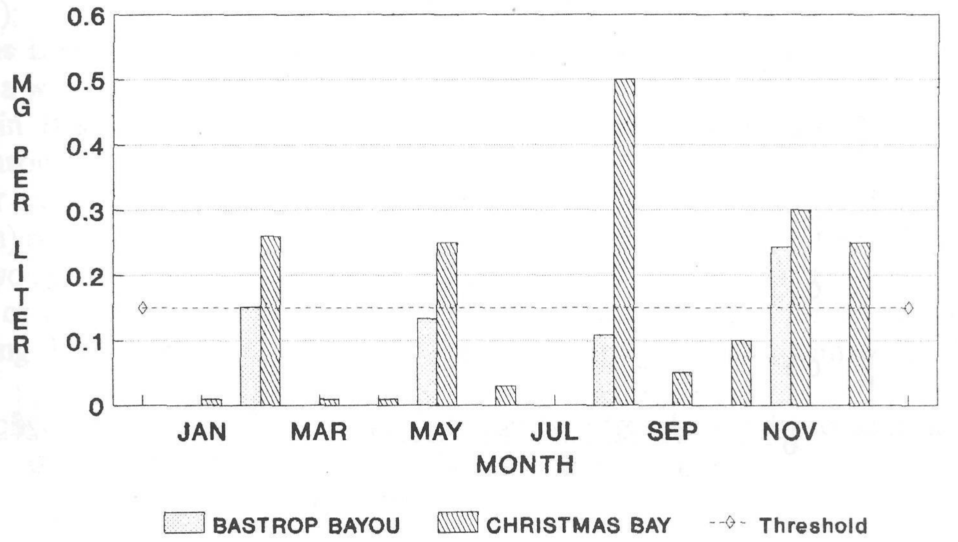
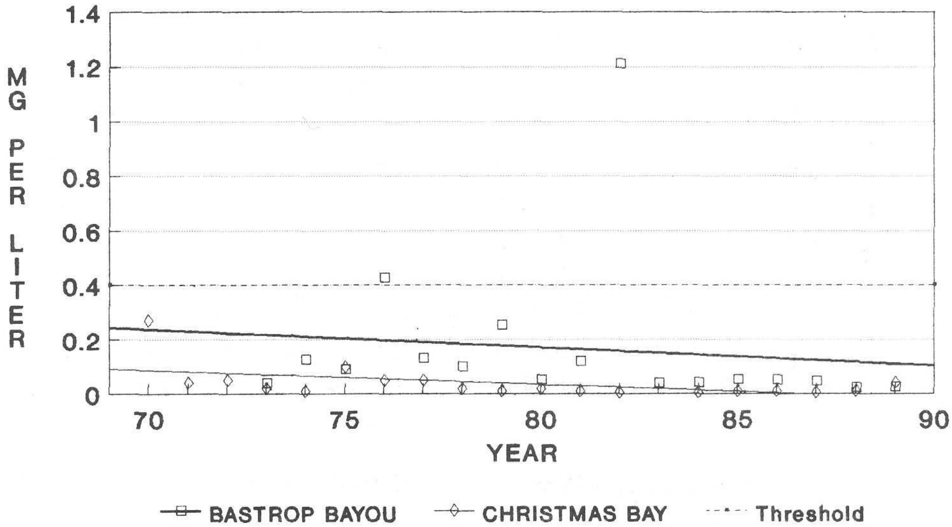
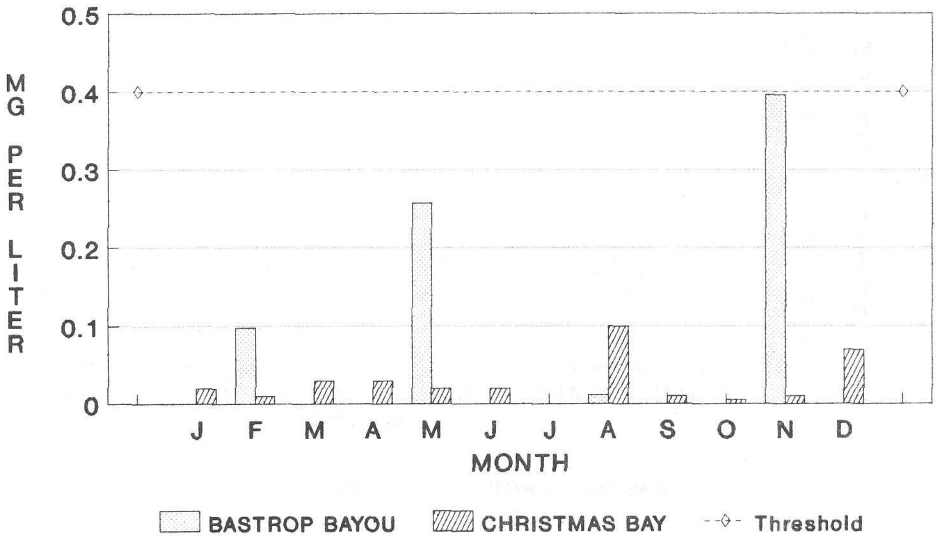


FIGURE 15
NITRATE NITROGEN



Correl. Coeff. r:
BB = -.118 (N.S.)
CB = -.52 (P<.05)

FIGURE 16
SEASONALITY OF
NITRATE NITROGEN



Annual average concentrations of total phosphorus in Christmas Bay have exceeded the threshold only once (Fig. 17). The downward trend is not significant. There is no seasonal trend in the values (Fig. 18).

Total phosphorus concentrations are currently not a management concern in either Bastrop Bayou or Christmas Bay.

Ortho-Phosphorus - Concentrations of this nutrient above 0.2 mg/L are considered to be elevated (TWC, 1990). Annual average concentrations in Bastrop Bayou have not exceeded the threshold since 1973 and 1974 (Figure 19). The very weak downward trend is significant only at the 0.20 level. Deletion of one 1974 datum removes the impression of seasonality (February) depicted in Figure 20.

No annual averages, and only two individual values, for Christmas Bay have exceeded the threshold (Fig. 19). The downward trend is not significant. There is no seasonal trend in the values (Fig. 20).

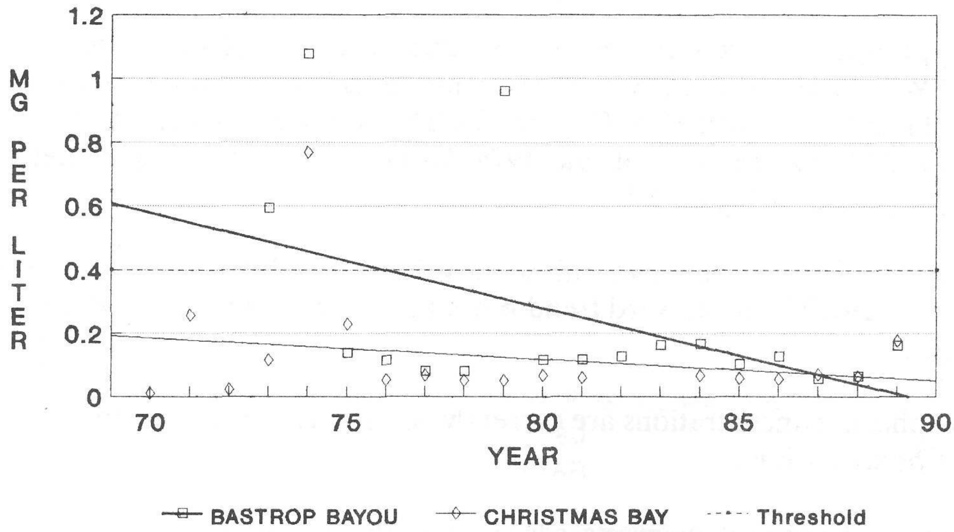
Ortho-phosphorus concentrations are currently not a management concern in either Bastrop Bayou or Christmas Bay.

Chlorophyll-a - Abundant nutrients can lead to the growth of algae and phytoplankton, which is reflected in the concentration of chlorophyll present in the water samples. Individual chlorophyll values greater than 50 μg/L, or averages greater than 20 μg/L, are indicative of conditions which may produce wide daily oscillations in dissolved oxygen concentrations, from supersaturation (very high) in the afternoon to hypoxia (very low) in the early morning hours (TWC, 1990).

No chlorophyll data are available from Bastrop Bayou for 1980 to 1984, or for Christmas Bay from 1975, 1980 to 1984, or 1986. Only one sample has exceeded 50 μg/L (Bastrop Bayou, 5/77); no annual average has exceeded 20 μg/L in Bastrop Bayou since 1979, or ever in Christmas Bay (Figure 21). There is a significant downward trend ($P<.05$) in Bastrop Bayou, and a weak downward trend ($P<.10$) in Christmas Bay (Fig. 21). Seasonal trends are prominent in Bastrop Bayou (Figure 22), with adequate sample sizes (7 or 8 for each month). Seasonal trends are less distinct in Christmas Bay (Fig. 22), with small sample sizes of 1 to 4 for each month. Data for the two stations were not collected on the same day (or same month) so upstream-downstream comparisons are not possible. The average value for Bastrop Bayou (17 μg/L) was higher than the average value for the center of Christmas Bay (11.4 μg/L) or Christmas Point (7.4 μg/L). Bastrop Bayou at CR227 may reflect freshwater algae washing downstream (see Table 2) more than estuarine phytoplankton.

The chlorophyll data indicate that eutrophication is currently not a problem in Christmas Bay.

FIGURE 17
TOTAL PHOSPHORUS



Correl. Coeff. r:
BB = -.483 (P<.05)
CB = .464 (P<.2)

FIGURE 18
SEASONALITY OF
TOTAL PHOSPHORUS

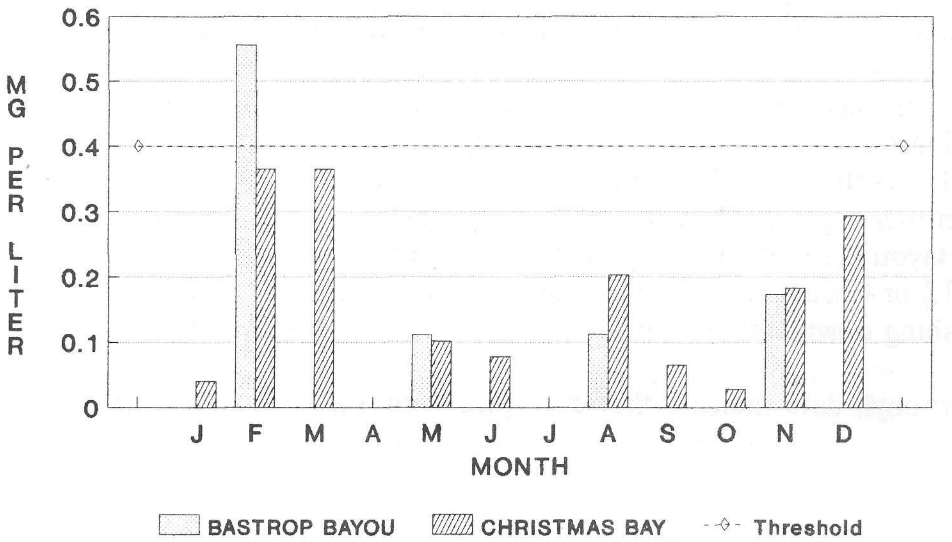
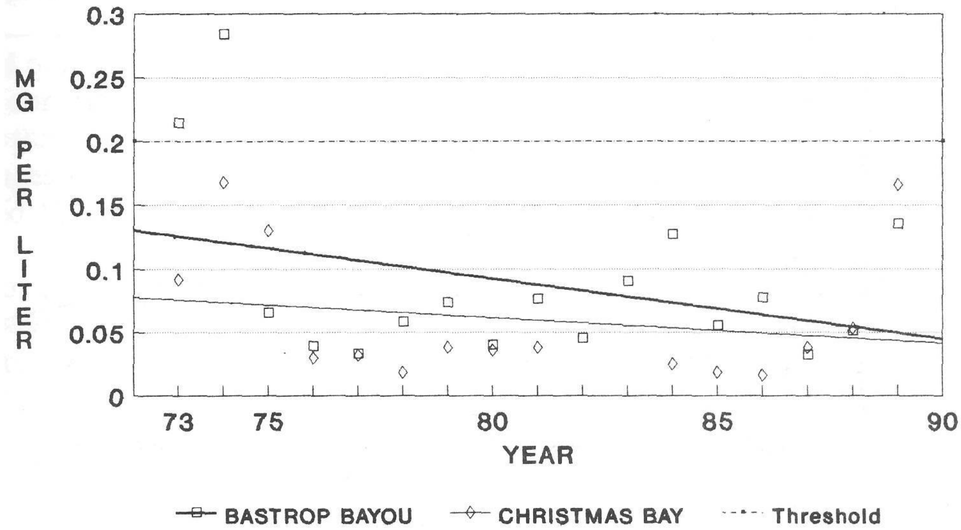


FIGURE 19
ORTHO-PHOSPHORUS



Correl. Coeff. r:
BB = -.35 (P<.2)
CB = -.202 (N.S.)

FIGURE 20
SEASONALITY OF ORTHO-PHOSPHORUS

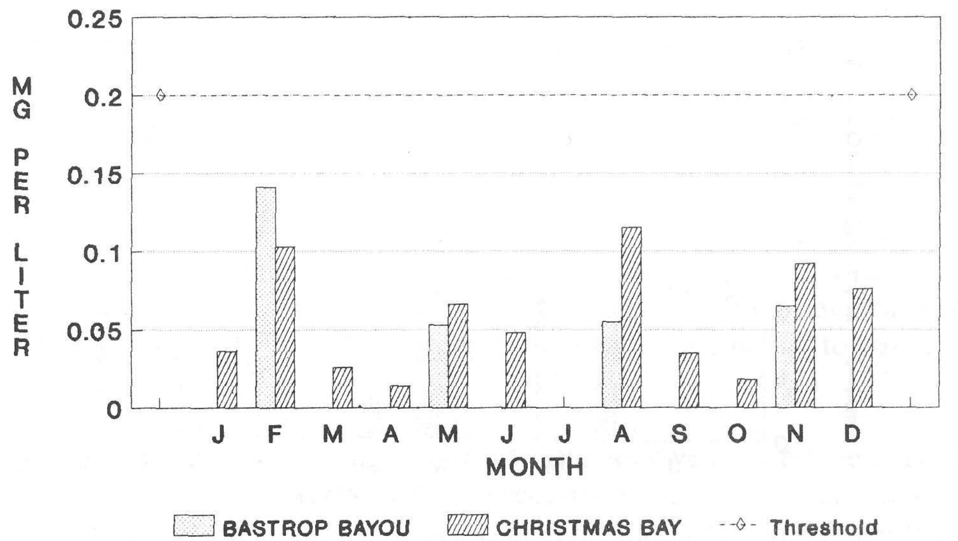
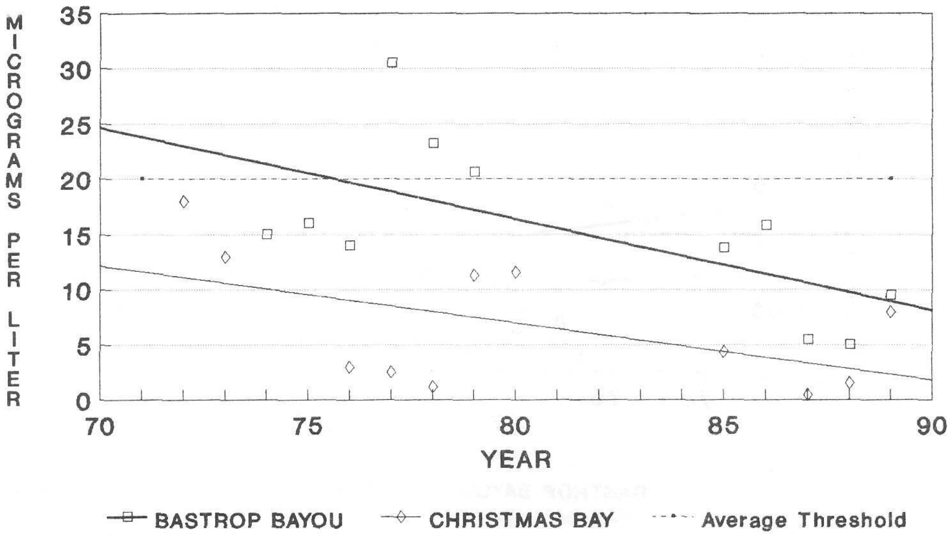
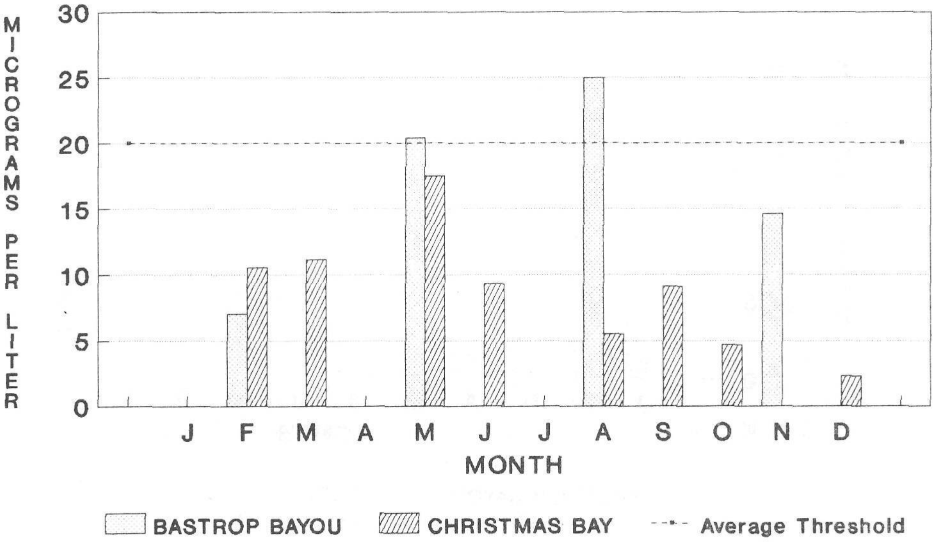


FIGURE 21
CHLOROPHYLL-a



Correl. Coeff. r:
BB = -.630 (P<.05)
CB = -.620 (P<.10)

FIGURE 22
SEASONALITY OF
CHLOROPHYLL-a



Dissolved Oxygen - The TWC water quality criterion for dissolved oxygen is 4.0 mg/L (minimum) for all water bodies addressed in this report. Values which exceed 12.0 mg/L indicate potential eutrophication and algal blooms, which release large amounts of oxygen from photosynthesis during daylight hours, but lead to the consumption of oxygen by decomposer organisms, which can depress dissolved oxygen to very low levels during the hours of darkness.

Low dissolved oxygen concentrations in upstream portions of Bastrop Bayou were noted by the intensive surveys (see Table 2). Downstream at CR288, 59 measurements taken since 1973 indicate that dissolved oxygen has always exceeded 4.0 mg/L at this monitoring station. Annual averages have ranged from 5.6 to 9.5 mg/L (Figure 23). Only two measurements have exceeded 12.0 mg/L.

The same is true for Christmas Bay, where the lowest values recorded have been 5.1 mg/L near the surface and 4.9 mg/L 10 feet below near the bottom at Christmas Point. There is very little vertical stratification of dissolved oxygen in Christmas Bay. Annual averages have ranged from 6.7 to 8.2 mg/L at bay center and 7.3 to 7.9 mg/L at Christmas Point (Fig. 23). Individual measurements have never exceeded 10.0 mg/L. No data were obtained in 1982 or 1983 and only one datum per year since 1984.

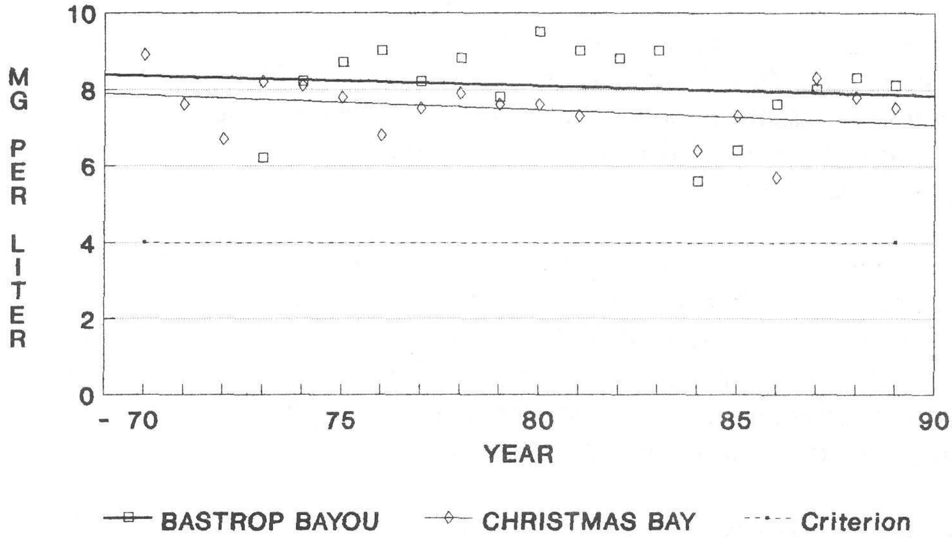
No significant trends are discernible in Bastrop Bayou or Christmas Bay. Averages are typically higher in February than during the remainder of the year (Figure 24). Dissolved oxygen is currently not a management concern for Christmas Bay.

Fecal Coliforms - The designated water uses for Bastrop Bayou and Christmas Bay are contact recreation and high quality aquatic habitat, with shellfish waters an additional use for Christmas Bay (TWC, 1990). The fecal coliform criterion for both bodies of water is 200/100ml. A significant violation occurs when the logarithmic average exceeds twice the criterion (i.e., 400/100ml), based on a minimum of four samples. If the logarithmic average of fecal coliform bacteria is greater than 200/100ml and/or 10% of measurements exceed 400/100ml, the station is designated as not swimmable. Bastrop Bayou is 25 miles in length and 18 miles of the bayou upstream of CR227 are designated as not swimmable due to pathogens from domestic point sources (TWC, 1988, 1990).

It has been noted in recent Water Quality Inventories that Bastrop Bayou at CR277 is where "fecal coliform bacteria frequently [56-89%] exceed 200/100ml" (TWC, 1988). Conditions have improved because two years later it was noted that "fecal coliform bacteria periodically [26-44%] exceed 200/100ml" (TWC, 1990), comparing data from 1983-87 to data from 1985-89.

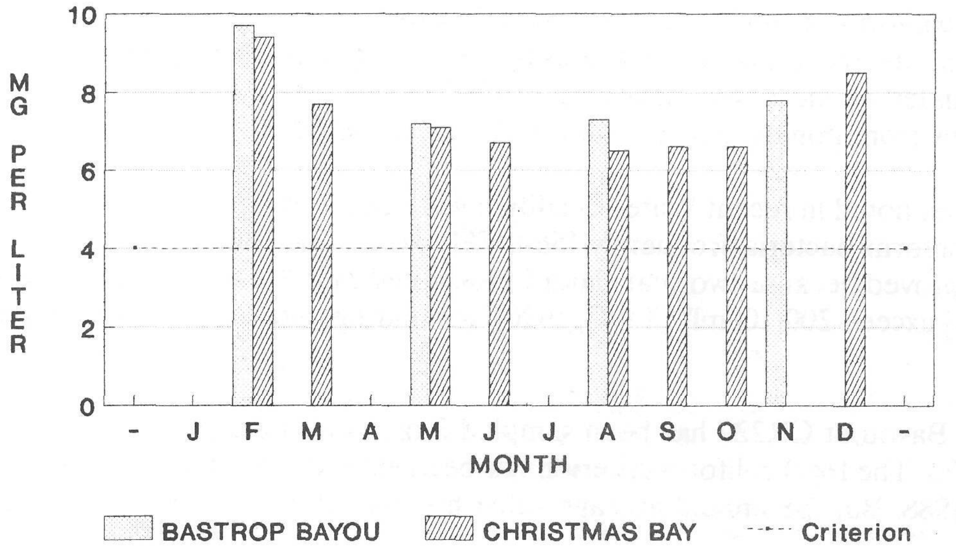
Bastrop Bayou at CR227 has been sampled 3 or 4 times per year, every year except 1986, since 1973. The fecal coliform criterion has been exceeded from one to four times every year except 1988. But the annual average value has exceeded the criterion in only five years

FIGURE 23.
DISSOLVED OXYGEN



Correlation Coefficient
BB: r = - .150 (P>.20)
CB: r = - .313 (P>.20)

FIGURE 24
SEASONALITY OF DISSOLVED OXYGEN



(Figure 25). Coliform contamination appears to be episodic, as high values are interspersed with values near or below the detection limit (10/100ml). There appears to be a distinct seasonal pattern based on monthly averages (Figure 26) but the pattern has not been consistent every year.

The effect of a single high value can also be seen in Figure 25. Only one sample was collected in 1986. It was the highest value ever recorded, 9,700/100ml, although not unreasonably so, since samples of 6,000, 3,300, and 3,200/100ml had been obtained in earlier years. Since there were no other samples collected that year, there was no "dilution" effect on the annual average. If that single value is considered to be the annual average, it represents the highest annual average ever recorded, and the only year with a single sample. With 1986 included, the null hypothesis that the regression trend is zero cannot be rejected ($r=-.127$, $N=17$, $P>.50$). If the 1986 value is judged to be an outlier, and omitted from the analysis, the regression trend is downward and significant ($r=-.503$, $N=16$, $P<.05$). Either way, the monitoring station fails the swimmable test.

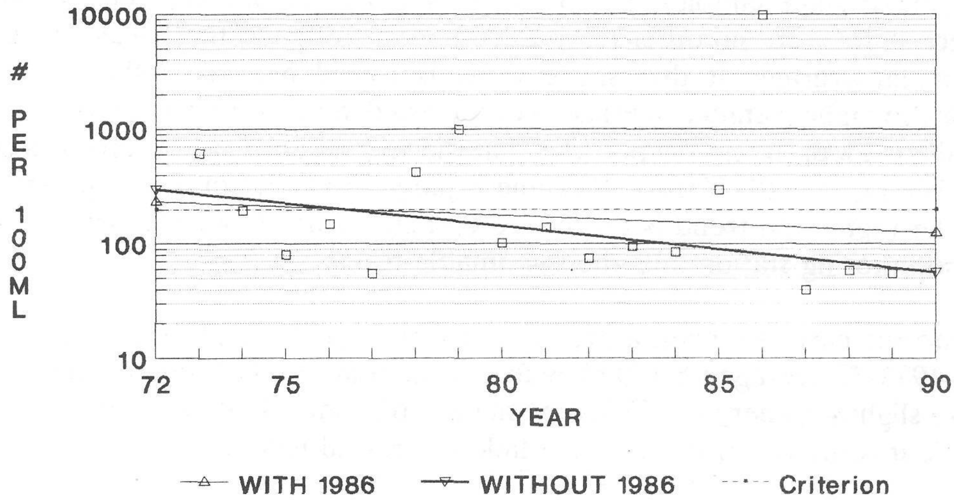
Fecal coliforms have not been a problem in Christmas Bay. Thirteen values from the bay center in 1973-77 averaged 8/100ml, with a maximum of 10/100ml. Values from Christmas Point were slightly higher in 1977-78, averaging 16/100ml. No data were collected from 1979 to 1985. Four samples since then have failed to reveal fecal coliforms.

Bacteria do have an effect on the Christmas Bay area, however. Nonhuman fecal coliforms enter the waterways from adjacent marshes. The Texas Department of Health has closed certain areas (Cold Pass, the lower reach of Bastrop Bayou) to shellfish harvesting for this reason (K. Wiles, Tx. Dept. Health, pers. comm.).

Sulfate - Since Bastrop Bayou is not a domestic water supply, there is no water quality criterion for sulfate. Individual values in Bastrop Bayou have ranged from 6,000 mg/L to below the detection limit, averaging 690 mg/L; annual averages have ranged from 135 to 1,530 mg/L. There is no discernible trend. In Christmas Bay individual values have ranged from 149 to 3,325 mg/L at midbay, averaging 1,935 mg/L; and 120 to 20,090 mg/L at Christmas Point, averaging 2,731 mg/L. One exceptional value, 20,090 mg/L for June 1989, the only value for that year, was sufficient to produce a weak, upward trend ($r=.429$, $N=16$, $P<.10$); removal of that datum eliminates any trend ($r=-.155$, $N=15$, $P>.50$). No seasonal pattern was discernible.

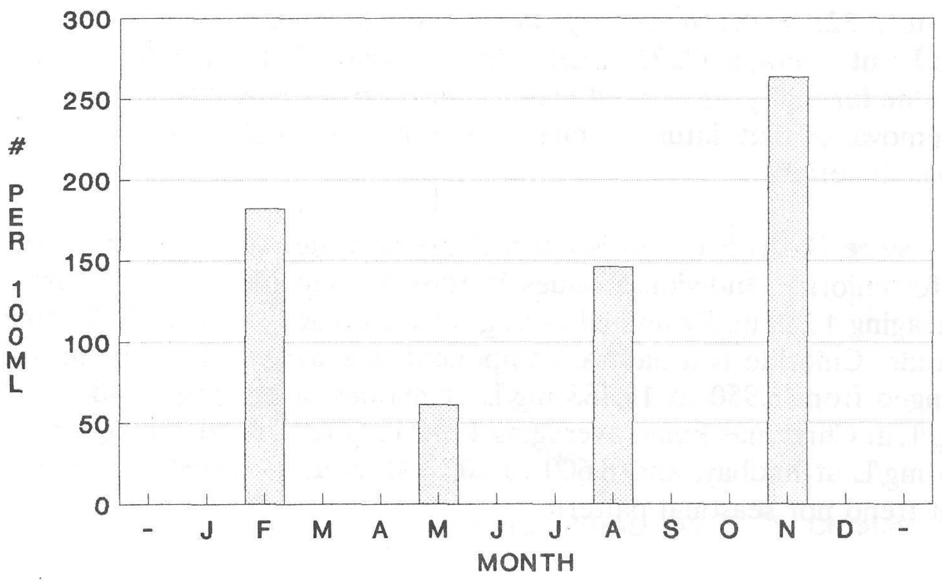
Chloride - Since Bastrop Bayou is not a domestic water supply, there is no water quality criterion for chloride. Individual values in Bastrop Bayou have ranged from 29 to 15,900 mg/L, averaging 4,289 mg/L; annual averages have ranged from 927 to 9,150 mg/L, an order of magnitude. Chloride is a natural component of seawater. In Christmas Bay, individual values ranged from 3,950 to 19,488 mg/L at midbay, averaging 14,487 mg/L; and 850 to 22,700 mg/L at Christmas Point, averaging 13,806 mg/L. Annual averages ranged from 5,990 to 17,583 mg/L at midbay, and 8,600 to 20,1000 mg/L at Christmas Point. There was no significant trend nor seasonal pattern.

FIGURE 25
FECAL COLIFORM BACTERIA
IN BASTROP BAYOU



Correlation Coefficient
With 1986 r = -.127 (P>.5)
Without 1986 r = -.503 (P<.05)

FIGURE 26
SEASONALITY OF
FECAL COLIFORM BACTERIA



Total Dissolved Solids (TDS) - This parameter was not measured directly at these stations but TDS can be estimated by multiplying specific conductance x 0.5 (TWC, 1990). Since Bastrop Bayou is not a domestic water supply, there is no water quality criterion for TDS. Individual values in Bastrop Bayou averaged 975 mg/L, ranging from 3 to 3,125 mg/L. Christmas Bay averaged 17,991 mg/L at midbay, ranging from 6,250 to 26,000 mg/L; at Christmas Point, TDS averaged 20,249 mg/L, ranging from 500 to 30,400 mg/L.

3. Eutrophication

The Texas Water Commission assesses the water quality of Texas waters every two years. These assessments are based on the most recent four years of monitoring data. As part of this inventory, TWC examines the status of nutrients which could lead to eutrophication, or nutrient enrichment, of the water body. Under favorable conditions, nutrients can lead to excessive growth of algae which, as they die and decompose, may result in the depletion of oxygen along the bottom of the waterway. The potential for oxygen depletion is indicated by high concentrations of chlorophyll (from the bodies of the algae) and oxygen (produced by living algae), particularly wide daily oscillations in dissolved oxygen, from very high values during the daylight hours to very low values during darkness.

The initial screening guidelines for eutrophication (TWC, 1990) applied to all waters, address the nutrients:

Ammonia + Nitrate Nitrogen greater than	1.0 mg/L
Total Phosphorus greater than	0.2 mg/L
Dissolved Phosphorus greater than	0.1 mg/L

Additional, more stringent, thresholds are applied to estuarine waters:

Ammonia Nitrogen greater than	0.15 mg/L
Nitrate Nitrogen greater than	0.4 mg/L
Total Phosphorus greater than	0.4 mg/L
Ortho-Phosphorus greater than	0.2 mg/L

Evidence of the potential for hypoxia (low dissolved oxygen) associated with algal blooms is:

Maximum Dissolved Oxygen greater than	12 mg/L
Maximum Chlorophyll-a greater than	50 µg/L
Mean Chlorophyll-a greater than	20 µg/L

Only 14% of individual values , and 29% of annual averages (both as recently as 1989) for ammonia nitrogen in Bastrop Bayou have surpassed 0.15 mg/L; only 21% of individual values and 11% of annual averages (neither since 1975) for Christmas Bay have exceeded the threshold.

Only 7% of individual values, and 12% of annual averages (neither since 1982) for nitrate nitrogen in Bastrop Bayou have exceeded 0.4 mg/L; neither individual values nor annual averages for Christmas Bay have ever exceeded the threshold.

Only 11% of individual values (none since 1984), and 18% of annual averages (none since 1979) for total phosphorus in Bastrop Bayou have exceeded 0.4 mg/L; only 3 individual values and 1 annual average (neither since 1974) for Christmas Bay have surpassed the threshold.

Only 2 individual values (none since 1984) and 2 annual averages (none since 1974) for ortho-phosphorus in Bastrop Bayou have exceeded 0.2 mg/L; only 2 individual values in 1974 and no annual averages for Christmas Bay have surpassed the threshold.

Only 2 individual values (1980 & 1981) and no annual averages for dissolved oxygen in Bastrop Bayou have exceeded 12 mg/L; no individual values or annual averages for Christmas Bay have ever surpassed the threshold.

Only one individual value (1977) for chlorophyll-a in Bastrop Bayou has exceeded 50 μg/L, but 3 annual averages (1977-79) have exceeded 20 μg/L; no individual value has ever exceeded 50 μg/L, nor has any annual average ever exceeded the 20 μg/L threshold in Christmas Bay.

It can be safely concluded that eutrophication is currently not a management problem in lower Bastrop Bayou or Christmas Bay.

4. Toxicants

There are no data for heavy metals, polychlorobiphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs), pesticides, or oil & grease in water or sediments for Bastrop Bayou.

The Texas Water Commission (TWC) has sampled sediments for heavy metals from three localities, and pesticides from two localities, in Christmas Bay. The central bay (Station 2434.0100) was sampled in 1974, 1975 (twice), 1976 and 1977; Christmas Point (Station 2434.0200) was sampled in 1978, 1979, 1980 and 1982; and the western bay (Station 2434.0300) was sampled in 1983. A single sample was obtained at each locality and date. In addition, the Bureau of Economic Geology (BEG) analyzed heavy metals in four sediment samples from Christmas Bay collected July 18-21, 1976 (White et al., 1985).

Heavy metals in sediment samples are known to vary significantly between samples for the same location and time but no estimate of within-locality variance is available. The data were pooled to calculate arithmetic means and standard deviations for this report (Table 5); TWC

Table 5. Toxicants in Sediment from Christmas Bay

mg/kg Mud (Dry Wt)		No. of Samples	Mean	Std. Dev.	Minimum	Maximum
Arsenic		6	3.9	1.61	2.24	6
Barium	(TWC)	5	54.5	6.10	49.4	64.5
	(BEG)	4	322.8	129.46	137	438
Cadmium		10	0.96	0.705	< 1.0	2.2
Chromium	(TWC)	7	20.6	11.19	11.0	44
	(BEG)	4	45.0	30.27	< 4.0	72.8
Copper	(TWC)	10	9.8	9.05	< 2.2	34
	(BEG)	4	7.4	6.02	< 4.0	16
Lead	(TWC)	10	23.4	19.49	1.4	70
	(BWG)	4			< 40.0	< 40.0
Manganese	(TWC)	10	398.8	64.66	296.4	505.6
	(BEG)	4	283.3	134.1	157	465
Mercury		9	0.147	0.265	< 0.1	0.85
Nickel	(TWC)	5	21.7	3.31	17.5	26.7
	(BEG)	4	23.0	16.91	< 10.0	40.2
Selenium		1	< 0.2			
Zinc	(TWC)	10	52.48	27.607	33.9	110.0
	(BEG)	4	80.65	28.96	57.8	122
µg/kg Mud (Dry Wt)						
PCBs		1	< 20			
Diazinon		1	7.1			
Aldrin		3	BDL*			
Chlordane		1	BDL			
DDD		3	BDL			
DDE		3	BDL			
DDT		3	BDL			
Dieldrin		3	BDL			
Endrin		3	BDL			
Heptachlor		3	BDL			
Heptachlor Epoxide		3	BDL			
Lindane		3	BDL			
Malathion		1	BDL			
Methoxychlor		3	BDL			
Parathion		1	BDL			
Toxaphene		3	BDL			

* - Below Detection Limit

Table 6. Metals in Christmas Bay and Texas Estuary Sediments.

mg/kg mud (dry wt)	Christmas Bay Mean	State Mean	State Median	Comment
Arsenic	3.94	5.59	3.70	
Barium	54.48	237.14	160.00	15th percentile = 61.00
Cadmium	1.42	1.40	0.50	
Chromium	20.64	22.17	16.00	
Copper	9.91	19.18	12.20	
Lead	23.41	31.69	16.00	
Manganese	398.75	731.50	540.00	
Mercury	.17	.23	.07	
Nickel	21.76	12.04	11.00	85th percentile = 19.00
Zinc	52.48	347.70	59.00	

All less-than-detection-limit values entered as the detection limit.

and BEG data were calculated separately. There were no great extremes between minima and maxima for any chemical so arithmetic averages, rather than logarithmic transformations, were used. Less-than-detection-limit values were treated as one-half the detection limit. In the absence of sediment quality criteria for metals, these data are difficult to evaluate. However, they can be compared to the existing data base for Texas estuaries (TWC, 1989). Only one sediment sample has been analyzed for PCBs, which were below the detection limit. Three samples have been analyzed for a number of pesticides; only diazinon has been found (Table 5).

The values are reported as milligrams of substance per kilogram of dry mud, equivalent to parts per million. These metals are ubiquitous; they do not reach zero concentrations although they may occur below our capability to detect them, particularly in older samples. The capability to detect low concentrations has greatly increased in recent years. There are three common ways to treat the less-than-detection-limit data: (1) omit these values, which biases the average value upward; (2) consider the detection limit as the value, which lessens the upward bias; or (3) multiply the detection limit x 0.5, or the average between the limit and zero. The latter method was used to prepare Table 5.

The Texas Water Commission has compiled data for Texas waterways using methods 1 and 2 above (TWC, 1989). TWC data for cadmium, copper, and mercury from Christmas Bay were recalculated to be comparable with method 2. Table 6 compares these values with the mean, the median (50th percentile), and selected percentiles for Texas estuaries (TWC, 1989). The substantial difference between the state mean and state median indicates that the data are not normally distributed, most likely influenced by a small number of very high concentrations. Most metals in Christmas Bay are equal to or less than state averages. Barium is in the lower 15 percent of samples. Only nickel is substantially higher than the state average, being in the upper 15 percent of state values. Diazinon was found in a single sample at a concentration of 7.1 μg/kg; the state average for estuaries is 7.02 μg/kg.

It can be safely concluded that contamination with heavy metals, PCBs, and pesticides currently will not be a management problem for Christmas Bay. There is no information regarding oil & grease or polyaromatic hydrocarbons but no evidence to suggest that these chemicals may be present in concentrations that would cause concern.

5. Local Comparison

To foster further evaluation of stream quality data, the average watershed values for Bastrop Bayou (Segment 1105) are compared to similar compilations for Oyster Creek (Segment 1109) to the west and Chocolate Bayou (Segment 1107) to the east (Table 7). The same comparison is provided for Christmas Bay, Bastrop Bay and Drum Bay (Table 7).

The state Water Quality Inventory (TWC, 1990) identifies both known and potential water quality problems for all stream and bay segments. The known problem for Bastrop Bayou is fecal coliform bacteria periodically [26-44% of samples] exceeding the 200/100ml criterion,

Table 7. Local Comparison of Average Values

	Oyster Creek Tidal	Bastrop Bayou Tidal	Chocolate Bayou Tidal
Temperature (°C)	23		23
Transparency (inches)	15	17	14
Conductivity (µmho)	13654	17581	18876
Dissolved Oxygen (mg/L)	7.4	7.2	7.7
pH	7.8	7.7	8.0
Ammonia Nitrogen (mg/L)	.176	.279	.216
Nitrite Nitrogen (mg/L)	.04	.03	.046
Nitrate Nitrogen (mg/L)	.246	.149	13
Total Phosphorus as P (mg/L)	.422	.348	.261
Ortho-Phosphorus (mg/L -P)	.309	.228	.120
Total Organic Carbon (mg/L)	10	15	13
Chloride (mg/L)	4094	3954	5226
Sulfate (mg/L)	595	520	689
Fecal Coliforms (#/100ml)	196	250	69
Chlorophyll-a (µg/L)	12.5	23.6	32
Pheophytin-a (µg/L)	2.3	2.5	10

	Drum Bay	Christmas Bay	Bastrop Bay
Temperature (°C)	24.9	28.7	23.6
Transparency (inches)	15	21	24
Conductivity (µmho)	36922	38210	38632
Dissolved Oxygen (mg/L)	7.4	7.4	7.5
pH	8.2	8.2	8.1
Ammonia Nitrogen (mg/L)	.25	.16	.19
Nitrite Nitrogen (mg/L)	.02	.02	.02
Nitrate Nitrogen (mg/L)	.04	.03	.03
Total Phosphorus as P (mg/L)	.176	.149	.131
Ortho-Phosphorus (mg/L -P)	.073	.061	.059
Total Organic Carbon (mg/L)	7	8	9
Chloride (mg/L)	13189	14109	12884
Sulfate (mg/L)	1776	2305	1866
Fecal Coliforms (#/100ml)	11	10	10
Chlorophyll-a (µg/L)	2	8	8
Pheophytin-a (µg/L)	5	1	2

thus rendering a portion of the stream unswimmable. In Chocolate Bayou, fecal coliform bacteria are occasionally [11-25% of samples] elevated. In Oyster Creek, there are no problems with fecal coliform bacteria, but dissolved oxygen is occasionally less than the 4.0 mg/L criterion.

Among potential water quality problems, orthophosphorus in Bastrop Bayou is occasionally elevated above the 0.2 mg/L threshold, and chlorophyll-a is rarely [1-10% of samples] elevated. In Chocolate Bayou, total phosphorus is occasionally elevated above the 0.4 mg/L threshold, orthophosphorus is elevated half the time, and chlorophyll-a is rarely elevated. In Oyster Creek, supersaturated dissolved oxygen occurs rarely, orthophosphorus levels are persistently [100%] elevated, and total phosphorus is frequently [56-89% of samples] high. Inorganic nitrogen is occasionally high. Fecal coliform bacteria are rarely elevated.

Bastrop Bayou, Chocolate Bayou, and Oyster Creek are all designated for contact recreation and high quality aquatic habitat water use. Chocolate Bayou and Oyster Creek are classified as effluent limited, indicating that conventional wastewater treatment is adequate to protect existing conditions. Bastrop Bayou is classified as water quality limited, indicating that significant violations have occurred and advanced wastewater treatment is required.

Currently, there are no known water quality problems, and no indications of potential problems, in Christmas Bay, Bastrop Bay or Drum Bay. Designated water uses for all three segments are contact recreation, high quality aquatic habitat, and shellfish waters, and all are classified as effluent limited segments.

D. FRESHWATER INFLOWS

The volume of freshwater which is transported by a coastal stream to its bay is determined by five factors: (1) the size of its watershed; (2) the amount of precipitation which falls within its watershed; (3) the soil type or surface cover across the watershed, which determines the amount of this rainwater which drains into the stream, as opposed to being absorbed by the soil and/or evaporated or transpired by plants directly back to the atmosphere; (4) the amount of water from outside of the watershed which is imported and discharged as wastewater effluent or irrigation drainage; and (5) the amount of water removed from the stream, for irrigation or other purposes, which is not returned to the stream. Each of these factors will be addressed in turn.

The Texas Department of Water Resources (1984) estimated that average annual runoff during the 1947-70 period was 802 acre-feet per square mile within the northern and central parts of the San Jacinto - Brazos Coastal Basin above the tidal-affected regions of the basin. The upper watershed of Bastrop Bayou extends into the central part of this basin.

The Texas Water Development Board has recently estimated average annual runoff from three sub-watersheds of Chocolate Bayou bordering the Bastrop Bayou watershed to the east; annual runoff was 1273, 1348, and 1373 acre-feet per square mile, yielding an area-weighted average of 1294 acre-feet per square mile for the 200 square mile area.

1. Watershed

This report has used a watershed map prepared by the University of Texas Bureau of Economic Geology (BEG) for the Christmas Bayou Coastal Preserve (Figure 27). Watershed area has been determined from the BEG map with a compensating polar planimeter, and estimated to be 58.74 square miles or approximately 37,600 acres.

2. Precipitation

The nearest National Weather Service precipitation station is positioned in Angleton, at the western perimeter of the watershed. The nearest precipitation stations beyond the watershed are Freeport, Alvin and Galveston. The long-term (1951-1980) average precipitation for these four stations (Angleton 52.28 inches, Alvin 47.99 inches, Galveston 40.24 inches, Freeport 51.01 inches) were used to construct precipitation isopleths across the Bastrop Bayou watershed. The isopleths are oriented north-south and decline from Angleton to Galveston. Within the watershed, the isopleths range from 53 inches in the west to 47 inches in the east, for an average of 50 inches of annual precipitation.

Angleton was selected as the most reliable indicator of precipitation for the watershed. Daily, monthly, and annual precipitation at Angleton for the years 1979 to 1988 have been analyzed in this report. The average annual precipitation during this period was 58.73 inches, varying from a low of 43.63 inches in 1980 to a record high of 86.25 inches in 1979; the record low occurred in 1956 when only 29.73 inches of precipitation occurred.

Only one (April 1983) of the 120 months analyzed experienced zero precipitation for a given month; the next lowest value was 0.20 inches in November of 1988. Twelve of the 120 months (10%) had total rainfall less than 1.00 inch. Eight months (6.7%) experienced more than 12 inches of rain, including three months with more than 21 inches. Precipitation episodes can stall in the area and release prodigious quantities of rainfall. For example, Angleton recorded 14.36 inches of rain on July 26, 1979 (nearby Alvin received 25.75 inches on that date). At Angleton, 18.61 inches fell during the 3-day episode, followed by an additional 18.88 inches on September 18 to 20. Average monthly precipitation for the 10 year period ranged from a low of 2.64 inches in April to a high of 8.90 inches in September (see Figure 28).

3. Runoff

Stormwater runoff will vary with soil type, vegetative ground cover, recent precipitation and human land use. The Bureau of Economic Geology (1989) has mapped land use within the watershed. The land use categories were agriculture, range-pasture, saline and brackish marsh, residential-urban area, wildlife refuge, state park, public beach, dredging spoil

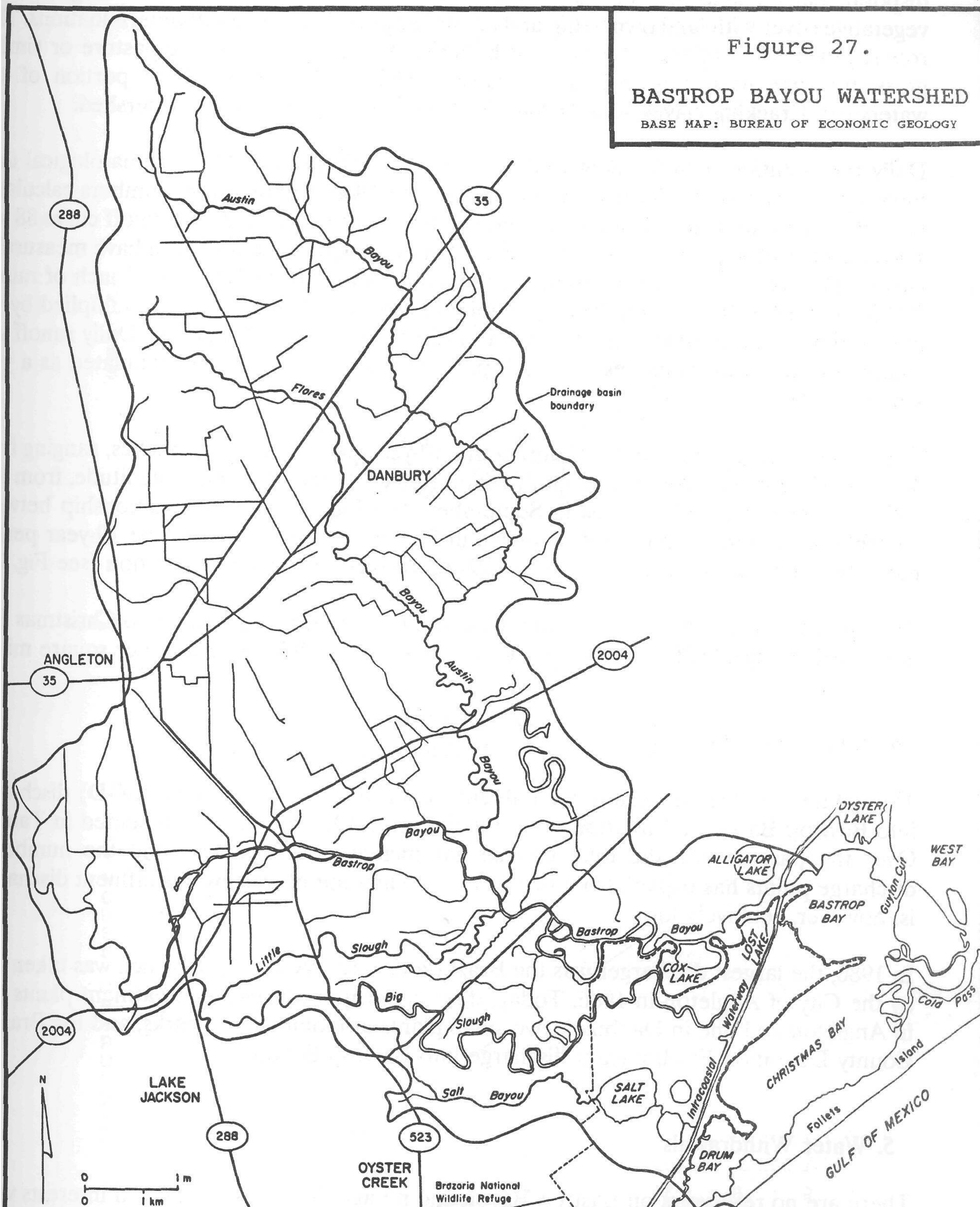


Figure 27.
BASTROP BAYOU WATERSHED
BASE MAP: BUREAU OF ECONOMIC GEOLOGY
Austin
Bayou
Flores
DANBURY
Bayou
Austin
Bayou
Drainage basin boundary
ANGLETON
288
35
2004
Bayou
Bastrop
Little
Slough
Big
Slough
Salt
Bayou
LAKE JACKSON
OYSTER CREEK
523
Brazoria National Wildlife Refuge boundary
OYSTER LAKE
ALLIGATOR LAKE
WEST BAY
BASTROP BAY
Guyton Cut
LOST LAKE
COX LAKE
Intracoastal Waterway
SALT LAKE
DRUM BAY
CHRISTMAS BAY
Cold Pass
Follets Island
GULF OF MEXICO
N
0 1 m
0 1 km

disposal, barren land, oil and gas fields, and artificial reservoirs. These categories mix vegetative cover with land ownership and are not appropriate for runoff determinations. This report judges 60% of the watershed to be agricultural, and 38% range-pasture or similar grassland vegetation, with all of the latter restricted to the southern portion of the watershed. Cracking clayey soils or loam over clay are typical for the watershed.

Daily precipitation data for Angleton were obtained from the NOAA climatological data monthly summaries for Texas for the years 1979 to 1988. Runoff curve numbers calculated for different ground covers and hydrologic soil types were consulted and runoff curve 88 was selected as most appropriate. Only precipitation events greater than 1 inch have measurable runoff. The fraction of precipitation which runs off varies from 26% with 1 inch of rain to 87.5% with 12 inches of rain. Daily precipitation greater than 1 inch was multiplied by the appropriate value from the runoff curve to estimate actual runoff per day. Daily runoff was summed to monthly estimates and both precipitation and runoff were tabulated as a year x month matrix.

Calculated average annual runoff during this 10-year period was 19.85 inches, ranging from 10.51 to 41.47 inches. Average monthly runoff ranged over an order of magnitude, from 0.36 inches in August to 3.70 inches in September (see Figure 29). The relationship between monthly precipitation and runoff is shown in Figure 29. Averaged over the 10-year period, monthly runoff ranged from 9.7% to 51.3% of average monthly precipitation (see Fig. 28).

Average annual runoff from Bastrop Bayou into Bastrop Bay, and thence to Christmas Bay, is approximately 63,000 acre-feet per year, equivalent to 1073 acre-feet per square mile.

4. Point Source Discharges

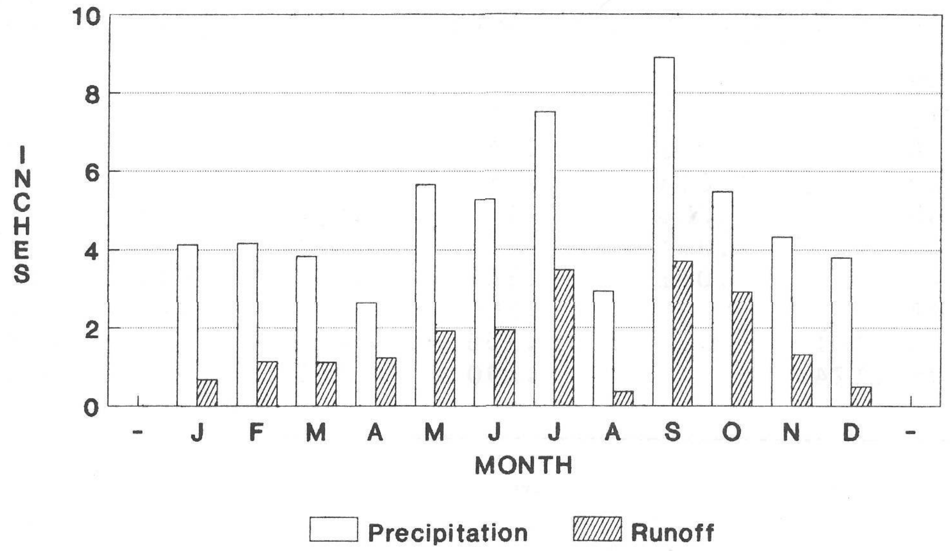
The volume of treated wastewater effluent (as million gallons per day, MGD) discharged into Bastrop Bayou and its tributaries, for the years 1980 to 1989, is presented in Table 8. Over the past decade the total volume has increased 250 percent and the number of discharge points has tripled, from two to six. The amount of wastewater effluent discharged is, however, relatively low.

In 1980, the largest discharger was the Brazoria County WCID No. 8, which was taken over by the City of Angleton in 1986. Today, three municipal wastewater treatment plants (two in Angleton and one in Danbury), two small plants at mobile home parks, and the Brazoria County Detention Facility plant discharge into Bastrop Bayou.

5. Water Withdrawals

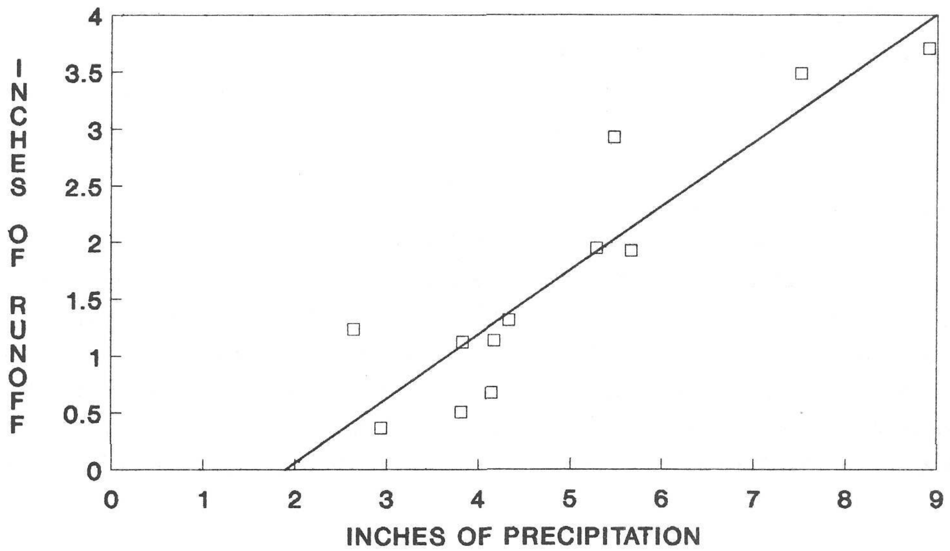
There are no reservoirs on Bastrop Bayou and no agricultural or municipal interests which withdraw water.

FIGURE 28
MONTHLY PRECIPITATION AND RUNOFF
BASTROP BAYOU WATERSHED, 1979-1988



Runoff Curve Number 88

FIGURE 29
RELATIONSHIP BETWEEN MONTHLY
PRECIPITATION AND RUNOFF



Correlation Coefficient
r = 0.909 (P<.001)

Table 8. Point Source Discharges into Bastrop Bayou Watershed

WASTEWATER (Million Gallons per Day)

	City of Angleton 001	City of Angleton 002	Community Utilities	City of Danbury	Orbit Systems	Angle Acres	Brazoria County Detent.	TOTAL
1980	.137		.053					.190
1981	.132		.043	.120				.295
1982	.139		.042	.148				.329
1983	.220		.043	.160				.423
1984	.168		.056	.178	.0007	.009		.412
1985	.168		.054	.160	.0013	.011		.394
1986	.140		.031	.181	.006	.012	.051	.421
1987	.142			.208	.014	.016	.027	.407
1988	.124	.101		.155	.010	.013	.020	.423
1989	.108	.124		.190	.003	.021	.025	.471

6. Water Importation

Much of the northern half of the watershed is criss-crossed with irrigation canals transporting water from the Brazos River to agricultural consumers. Water flooded onto rice fields can infiltrate into the soil, evaporate directly to the atmosphere, or be transpired by the rice plants. Some of this water is released as agricultural drainage. The relationship between the volume of water released onto the fields, and the volume of water released into the watershed drainage system at some later date is very complex and considered beyond the scope of this report.

In summary, an average of 5.625 MGD [63,000 acre-feet/year] of surface runoff and 0.471 MGD of wastewater discharge reach Bastrop and Christmas Bays annually. Point source discharge is 7.7% of the known volume; the quantity of agricultural "point-source" discharge (from irrigated fields) is unknown.

E. INFRASTRUCTURE

There are four pending government actions which may affect a management plan for Christmas Bay: enlargement of the Brazoria National Wildlife Refuge; development of Christmas Bay State Park; and the maintenance and potential enlargement of the Gulf Intracoastal Waterway.

1. Enlargement of the Brazoria National Wildlife Refuge

The U.S. Fish & Wildlife Service has proposed to acquire 30,000 acres of privately-owned coastal prairie and marshland north and east of the existing 12,199 acre refuge (Figure 30). This addition will serve to establish the Brazoria NWR as a major waterfowl refuge on the critical Gulf coast wintering grounds for North American waterfowl. It will also provide an opportunity to reintroduce the endangered Attwater's prairie chicken to a portion of its original natural habitat (U.S. Dept. Interior, 1990).

Expansion of the wildlife refuge will have important consequences for the Christmas Bay Coastal Preserve. It will provide permanent protection for more of the Bastrop Bayou watershed south of SH 2004, including Alligator Lake and Oyster Lake. It will also provide public ownership of the entire shoreline of Bastrop Bay; the existing wildlife refuge on the western shore from Christmas Point to Bastrop Bayou, the new refuge lands on the northern shore from Bastrop Bayou to Guyton's Cut, and the state-owned Mud Island to the east. When the expansion is accomplished, the only activity on Bastrop Bay associated with "private property" will be that involving the cabins on state-owned islands or subtidal lands.

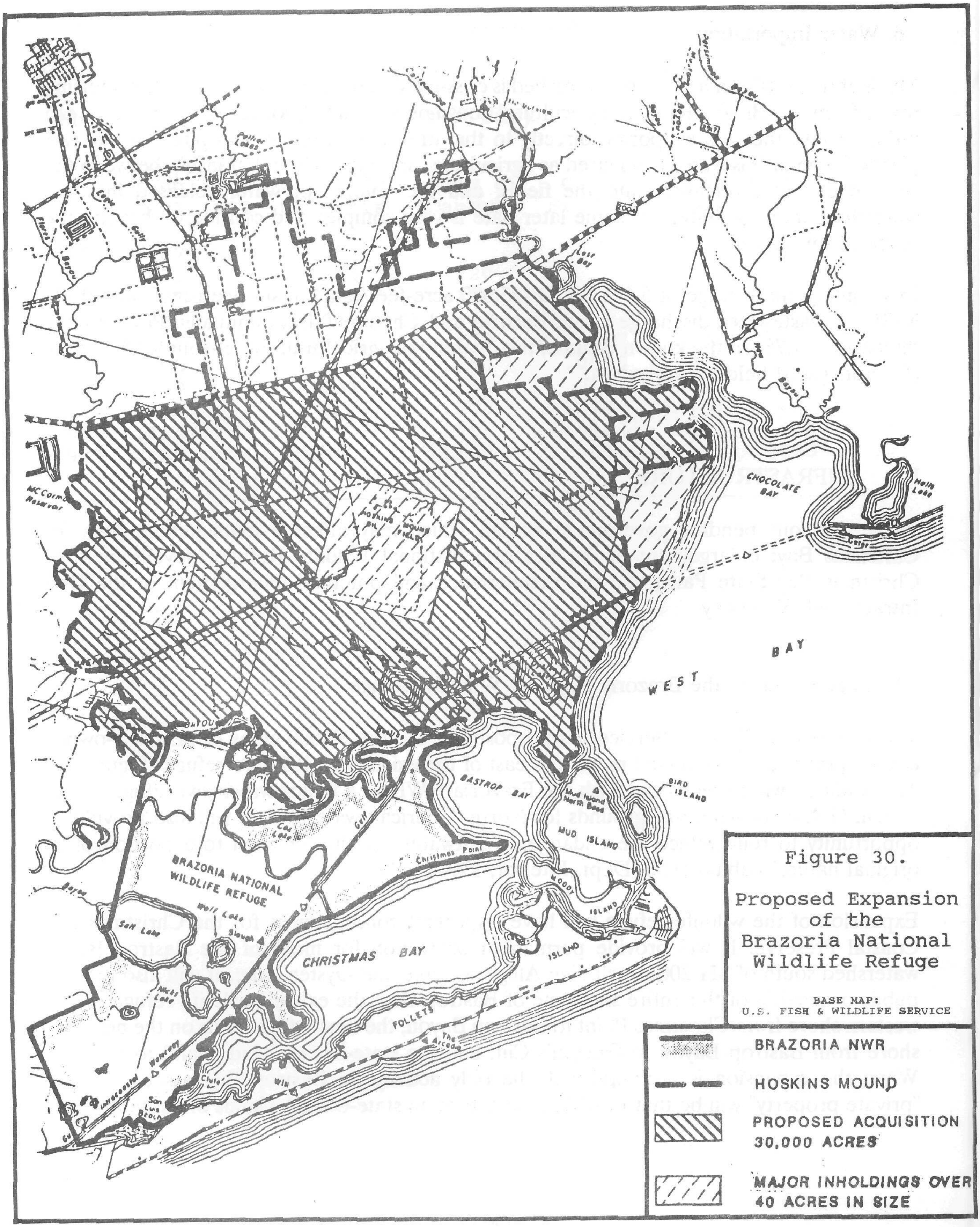


Figure 30. Proposed Expansion of the Brazoria National Wildlife Refuge

2. Development of the Christmas Bay State Park

The Texas Parks and Wildlife Department currently has land holdings of approximately 100 acres on Follets Island in the vicinity of Arcadia Reef. Development of this acreage and permissable activities under its management plan may affect protection of the living resources, public access to the bay, and the volume of boater and wade-fisherman traffic.

3. Maintenance and Expansion of the Gulf Intracoastal Waterway

Two aspects of the Gulf Intracoastal Waterway potentially may affect Christmas Bay in the future. Periodic maintenance dredging of the existing waterway will produce additional dredge spoil for disposal. Most of the disposal sites lie on the landward (western) side of the GIWW (Figure 31). There are three disposal sites which lie adjacent to Christmas or Drum Bays: one site on Rattlesnake Island at the western end of Christmas Bay; one site at the base of Rattlesnake Point which fronts on both Christmas Bay and Drum Bay; and one at the western end of Drum Bay (Fig. 31). Runoff from spoil disposal conceivably may drain into Christmas and Drum Bays.

The New Orleans District of the Corps of Engineers has been authorized by the U.S. Congress to investigate the need to modify the depth and width of the GIWW. Enlargement of the GIWW from its present 12 ft depth and 125 ft width to a 16 ft depth and 150 ft width has been authorized for the reach from the Sabine River to Galveston; this enlargement has not been initiated. The Galveston District of the Corps has determined that the State of Texas, as the local sponsor, has no interest in enlarging the GIWW at this time. All current activity regarding channel enlargement is restricted to Louisiana.

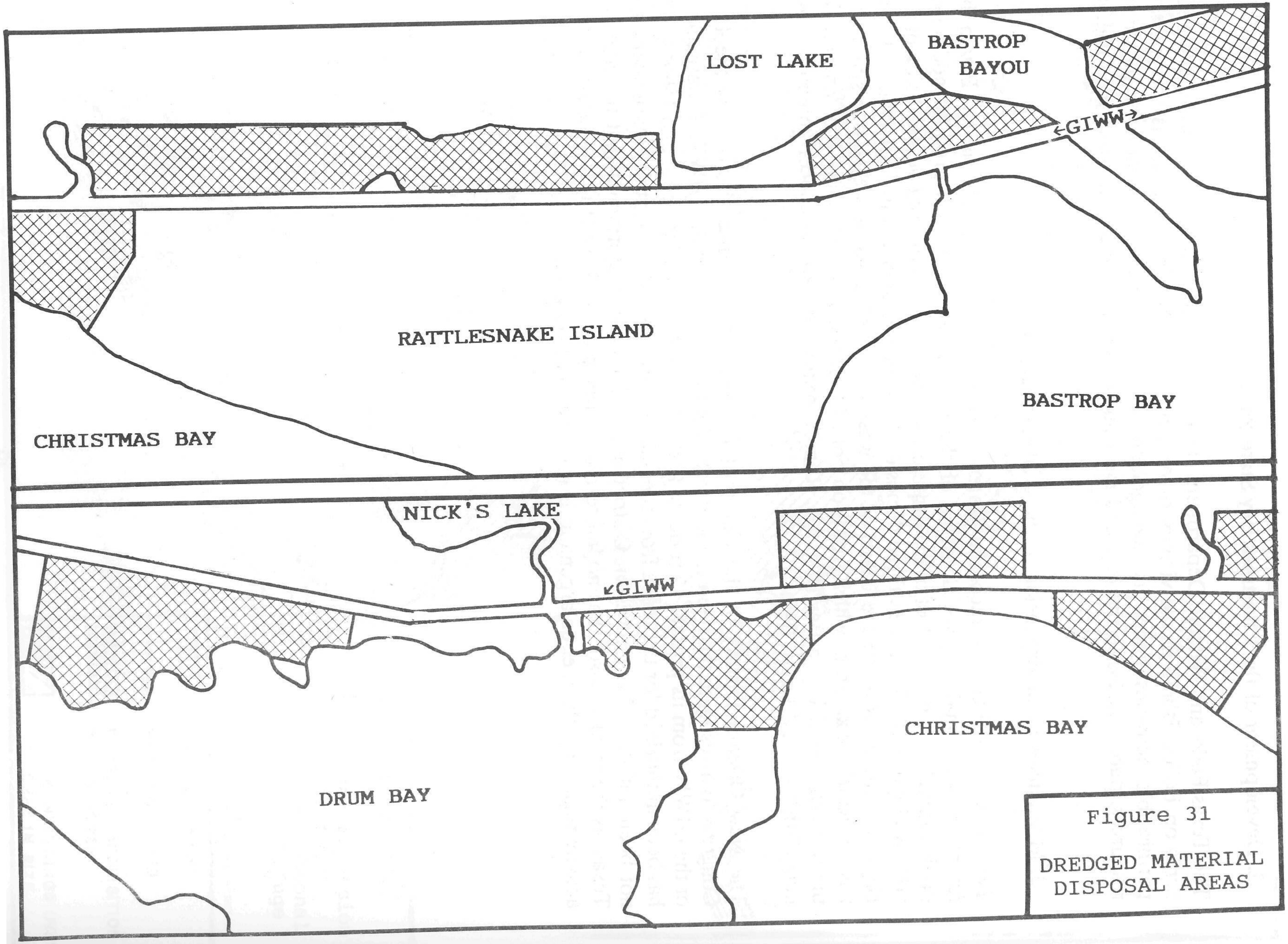


Figure 31

DREDGED MATERIAL DISPOSAL AREAS

F. HYDROLOGICAL AND METEOROLOGICAL INFLUENCES

1. Effects of Sea Level Rise

Maps of the Christmas Bay area depict topography at 5-foot contour intervals. Follets Island has no surface which reaches 10 feet above sea level. The 5-foot contour varies in width from 150 feet to 700 feet, and disappears completely at several points along the island. An increase in sea level of 5 feet will essentially submerge Follets Island; erosion of the remaining narrow beach strand would eliminate the barrier island completely and move the coast line inland a number of miles.

The only points on Rattlesnake Island which reach reach 10 feet above sea level have been artificially created by the deposition of dredge spoil. These unprotected spoil banks may be subjected to rapid erosion from wave-action following a rise in sea level. Virtually all of the intertidal marsh would be lost; emergent vegetation of the subtidal marsh would be unable to protrude above the water surface.

2. Effects of Tropical Cyclones

The probability that the center of a tropical cyclone, either a tropical storm (winds of 39-73 miles per hour, mph) or hurricane (winds 74 mph or more), will make landfall on this segment of the Texas coast in any given year is 1 in 8 (Bomar, 1983). The impact of hurricanes varies with their forward speed, wind speed, and wind angle to the shoreline. Each storm is unique. Onshore winds force water onto the coast and raise the water level, creating the storm surge. Normal astronomical tides add to this effect, producing the storm tide (surge + tide), while waves create additional height.

Hurricane Carla, the largest hurricane in Texas' history, came ashore more than 90 miles down the coast at Port Lavaca on September 11, 1961, with winds of 150 mph. This hurricane produced a storm surge of 11 to 12 feet at Follets Island and totally inundated the coast as far as 15 miles inland, reaching the outskirts of Angleton (BEG, 1971). Hurricane Beulah, the third-largest hurricane in Texas weather history, came ashore at Brownsville on September 20, 1967. The storm surge raised Christmas Bay water 4 feet, inundated most of Follets Island, and the coast as far as 6 and 7 miles inland.

Washover fans, caused by breaching of the island during the storm surge, are common on Follets Island (Shew et al., 1981). Initially unvegetated, these fans are slowly stabilized by plant growth. Washover channels are known near the eastern tip of Follets Island, crossing to Cold Pass; at the western end of Christmas Bay, east of Arcadia Reef, including the TPWD landholdings; and at Drum Bay. Unvegetated as recently as 1972, these channels are now partially covered with plants.

G. LIVING RESOURCES

The first published biological study from Christmas Bay appears to have been a survey of the microscopic unicellular foraminifers along a vegetational transect, from turtle grass to gulf cordgrass to marshhay cordgrass to salicornia, on Follets Island described by Phleger (1965). As many as four distinct assemblages of foraminifers could be discerned. These organisms have not been studied since.

The first studies of the fishes of Christmas, Bastrop, and Drum Bays were produced by the Texas Parks & Wildlife Department. In 1967, TPWD biologists noted the existence of nursery habitat for spotted seatrout and red drum along the southern shore of the bay (McEachron et al., 1977). Recognizing the importance of this relatively undisturbed habitat, state and federal biologists soon began describing the rooted aquatic vegetation, mollusks, and crustaceans found here. An intensive study was conducted from October 1971 to October 1973; the 29,291 fishes of 81 species collected remains the best description of seasonal and relative abundance of fishes in the bay system (McEachron et al., 1977). Oysters, shrimp and other invertebrates were also discussed.

The zooplankton of Christmas Bay were studied by Bagnall (1976) from September 1973 to December 1974. She distinguished a permanent zooplankton assemblage of three species - a ctenophore (<u>Mnemiopsis</u> <u>mccradyi</u>) and two copepods (<u>Acartia</u> <u>tonsa</u> and <u>Oithoina</u> <u>colcarva</u>) -that persisted throughout the year despite major changes in the physical and biotic environment. Another assemblage of a dozen coastal species entered the bay via Cold Pass during summer and early fall and were important predators of the bay residents.

As part of this same study, Fotheringham & Bagnall (1976) reported on the seasonal variation in the occurrence of the planktonic larvae of four hermit crabs sampled in Christmas Bay from November 1973 to April 1975.

Penn (1979) studied the decapod crustacean communities of Texas seagrass beds. He sampled three stations in Christmas Bay between February 1975 and May 1976. He found that the decapods inhabiting turtlegrass (narrow-leaved) were distinct from those inhabiting shoalgrass (very-narrow-leaved). More surprisingly, the shoalgrass communities were distinguishable as northern and southern components which differed in the abundance of individuals, number of species, diversity, dominant species, and characteristic species. The shoalgrass beds in Christmas Bay demonstrated seasonal changes in the dominant species over time.

The University of Texas Bureau of Economic Geology sampled sediments in the area, including 11 stations in Christmas Bay and 10 in Bastrop Bay, during July 1976 (White et al., 1985). The organisms collected in the samples were reported as pooled data, with Jones, Chocolate, Bastrop and Christmas Bays included in the West Bay locality. Information on mollusks, polychaetes, crustaceans, and other phyla are provided.

Between February 1976 and November 1981, 2,040 spotted seatrout were caught with hook and line at the Bastrop Marina on Bastrop Bayou, tagged, and released; 176 were recaptured (Baker et al., 1986). Analysis of the recapture patterns revealed that the fish left the bayou during the winter months but returned in the spring, to leave again during the summer and return in the fall. A number of the tagged fish were recaptured in West Bay. Others were recaptured along the gulf shoreline from Freeport to the Bolivar Penisula. Most of the tagged fish were recovered from Bastrop Bayou, Bastrop Bay, Cold Pass or the San Luis Pass to the Gulf. None were recovered from adjacent tributaries although seatrout were common in these streams. The authors suggest that tributaries may be inhabited by distinct subpopulations.

The Texas subspecies of the hard clam, or Texas quahog, (Mercenaria mercenaria texana) was studied at five localities in Christmas Bay and compared to other clams further south on the Texas coast (Craig & Bright, 1986). Christmas Bay was found to harbor a sparse population with few clams under five years old. The clams exhibited poor recruitment and slow first year growth.

From samples taken from July 1984 to June 1985, the abundance of juvenile blue crabs in adjacent nursery habitats was found to be highest in seagrass, intermediate in salt marsh, and lowest on bare sand in Christmas Bay, and intermediate in salt marsh and low on bare mud in West Bay, where seagrasses were absent (Thomas et al., 1990). Small crabs fed on shoalgrass epiphytes, amphipods, and mollusks. Salt marsh provided intermediate protection from predators to juvenile crabs but shoalgrass provided the greatest degree of protection (Thomas, 1989). Seasonal changes in shoalgrass leaf biomass were reported by Thomas et al. (1990).

Thomas (1989) determined the abundance and crab utilization of epifaunal and infaunal foods from seagrass, salt marsh, and bare sand habitats in Christmas Bay. She listed the relative abundance of polychaete, amphipod, tanaid, isopod, and mollusk species, and others - crabs, cumaceans, mysids, nemerteans, and oligochaetes -were enumerated by group.

Six Galveston Bay localities, including Christmas Bay, were sampled in 1987 to determine the utilization of marsh and associated habitats along a salinity gradient (Zimmerman et al., 1990). The relative abundances of 24 species of fishes and 17 species of decapod crustaceans were reported; 18 species of annelids, crustaceans, and mollusks were also noted as components of the epifauna and infauna. Density values were also provided for fish, decapod crustaceans, epifauna, and infauna.

1. Faunal Comparisons

A comparison of species collected in Christmas, Drum and Bastrop Bays with the known fauna for all of Galveston Bay indicates the richness of the Christmas Bay fauna. Detailed comparisons, which would involve not only examination of species overlap but resolution of taxonomic duplication and discrepancies, are beyond the scope of this report.

A list of the 81 species of fishes collected during the 1971-73 TPWD intensive survey (McEachron et al., 1977), plus 15 additional species collected by the TPWD Coastal Fisheries Branch monitoring program since 1976 (data base provided by TPWD for this report), is included as Appendix Table A.1. The total ichthyofauna of the Galveston Bay ecosystem has been reported as 162 species, including 19 freshwater species rarely found in the bay (Parker, 1965). Thus 59 percent (96 of 162 species) of the known Galveston Bay species have been captured in Christmas Bay. Sheridan and others (1989) report that a two year synoptic trawl survey in Galveston Bay collected 96 species: six species (Atlantic croaker, bay anchovy, star drum, spot, sand seatrout, and hardhead catfish) accounted for 91 percent of the total number of fish collected; these six species plus striped mullet accounted for 74 percent of the biomass (wet weight) of the fish collected in Galveston Bay.

The 68 species of crustaceans reported from Christmas Bay (McEachron et al., 1977; Thomas, 1989; Bagnall, 1976) are listed in Appendix Table A.2. White and others (1985) reported 77 species from Galveston Bay overall, and 41 species from the West Bay complex, including Christmas and Bastrop Bays. There is a 23 percent overlap (18 of 77 species) with Galveston Bay and 29 percent overlap (12 of 41 species) with West Bay. Sheridan and others reported 31 species of macrocrustaceans collected in trawl surveys of Galveston Bay; 28 of the species (90%) have been reported from Christmas Bay. Thus Christmas Bay appears to have a very rich crustacean fauna.

The 140 species of mollusks reported from Christmas Bay (McEachron et al., 1977; Thomas, 1989) are listed in Appendix Table A.3. Synonomy has been reduced (Andrews, 1981; synonyms listed in brackets) but several taxonomic uncertainties remain. White and others (1985) listed 195 species from the Galveston Bay complex, with 45 percent overlap (88 of 195 species) for Christmas Bay; there is a 70 percent overlap (66 of 94 species) with the BEG list for West Bay. The molluscan fauna of Christmas Bay seems especially rich.

Only 41 species of polychaetes (Appendix Table A.4) have been recorded from Christmas Bay (Thomas, 1989; McEachron et al., 1977), while 124 species have been reported from the Galveston Bay ecosystem and 61 species from the West Bay complex, including Christmas and Bastrop Bays (White et al., 1985). Species overlap amounts to 16 percent (20 of 124) for Galveston Bay and 33 percent (20 of 61) for West Bay. Other plants and animals known from Christmas Bay are listed in Appendix Table A.5.

2. Fish and Shellfish Population Trends

The TPWD Coastal Fisheries Branch has conducted a monitoring program in Galveston Bay since 1976. Monthly sampling stations are selected randomly across the bay. Christmas and Bastrop Bays are included in the sampling scheme. The program was designed to monitor commercial and recreational finfishes and shellfishes of the bay system. It works very well, as designed, for the entire bay. It is seldom appropriate for assessing the status of individual bay components, such as Christmas Bay. Samples vary by date, type of gear used, and specific sample site. In general, an inadequate number of samples have been collected using the same gear, at the same sampling sites, in the same months from year to year, to reliably predict the future status of these living resources in Christmas Bay.

3. Bird Population Trends

There are 139 species of birds associated with the wetlands and bay habitats of Galveston Bay (Sheridan et al., 1989). The major groups are waterfowl, shorebirds, and colonial nesting waterbirds. Little quantitative information is available specifically regarding the birds associated with Christmas Bay.

Hall and others (1959) published a list of the birds of Galveston Island, with comments on their relative abundance. The U.S. Fish & Wildlife Service (1987) has published a checklist of 273 species found on the Brazoria and San Bernard National Wildlife Refuges, noting their seasonal occurrence and relative abundance. The number of species actually associated with Christmas Bay habitats is a much smaller subset than either of these lists. The annual Audubon Christmas Bird Counts for Freeport include a portion of Drum Bay and the wildlife refuge in their 15-mile diameter count area but Christmas Bay lies outside of the boundary. These counts frequently record 200 species or more in late December.

The Texas Gulf coast waterfowl surveys count waterfowl on the wildlife refuge several times each winter but do not include waterfowl on Christmas Bay itself. These data reflect waterfowl utilization of the major wetland habitats on the refuge, rather than usage of open bay habitat. The exploitation of the seagrass beds by such species as red-headed ducks is unquantified.

Galveston Bay has been identified as a regionally significant reserve site by the Western Hemisphere Shorebird Reserve Network (Sheridan et al., 1989). Large populations of overwintering or migrating shorebirds feed on the intertidal flats of Bolivar Peninsula and the east and west ends of Galveston Island. Shorebird utilization of the Christmas Bay shoreline is unquantified.

The only quantitative data regarding the birds of Christmas Bay are the nesting records of the Texas Colonial Waterbird Society (1982) for 1973 to 1980, and the TPWD Texas Waterbird Colonies Survey, from 1981 to date. There are seven such colonies of interest. The colonies may be used by both ground-nesters (gulls, terns, and skimmers) and above-ground-nesters (herons, egrets, and spoonbills) which require bushes or trees for nest sites. Above-ground-nesters typically degrade their nesting habitat by stripping off small branches for nest material. Rotation of nesting sites from year to year is normal. The bushes benefit from the considerable volume of fertilizing nutrients imported by feeding adults and deposited as excrement by nestlings. The bushes suffer from branch removal and breakage by clambering juveniles before attainment of flight.

West Bay Bird Island (#600-560) is the largest colony in the area, in both area (121 acres) and birds, hosting from one to 2,863 pairs of breeding birds of eleven species, with as many as six species in a given year. The much smaller (4.9 acres) San Luis Island #1 colony (600-561) lies at the eastern end of Follets Island, adjacent to a developed area. This colony peaked at 740 breeding pairs and five species in 1977, then lay unused until 1986. Another small colony (7.4 acres) on Follets Island (600-562) has been used by up to 240 pairs of least terns and black skimmers since 1977.

A large, 124-acre colony (600-563) in Drum Bay has harbored up to 1,200 birds of as many as 9 species, both ground- and above-ground-nesters, nearly every year since 1979. A tiny 1/4 acre site on Arcadia Reef (600-565) has hosted 250 to 400 terns and egrets since 1984. An equally tiny site in Bastrop Bay (600-564) has been occupied by 500 to 1000 pairs of terns since 1982. On the far western end of Galveston Island, the 5-acre San Luis Pass colony (600-580) has been used by as many as 500 pairs of birds intermittently since 1973. The locations of these colonies are shown in Figure 32.

Since some birds may be shifting from one colony site to another each year due to reduction of nesting vegetation, the birds of all seven colonies will be analyzed together as a Christmas Bay "population" to examine trends.

Seven species of colonial ground-nesters are known from the area. Laughing Gulls (Larus atricilla) have been the most persistent, common ground-nesting species breeding near Christmas Bay, having appeared every year since 1973 except four (1974, 1979, 1981, 1983). Their numbers have fluctuated widely, from 20 pairs in 1975 to 1,220 in 1988 (Figure 33A), averaging 388 pairs per year. They are essentially limited to Bird Island: 200 nested once at San Luis Island; 20, 20, and 100 have nested thrice at Drum Bay since 1986; and 10 nested at Arcadia Reef in 1989. The trend toward increasing numbers is highly significant ($P=0.005$).

Black Skimmers (Rynchops niger) have been equally persistent, having nested every year since 1973 save two (1977, 1979). They nested at San Luis Pass and San Luis Island (sites on opposite sides of the San Luis Pass) in 1973 and 1974. Numbers declined and San Luis Pass was the sole site until 1982, when the population increased and they established a second colony in Bastrop Bay. Pioneers have tested all seven sites, one to three per year, ever since. The principal colony has been Bastrop Bay. The San Luis Pass site was abandoned from 1983 to 1988 but reoccupied in 1989. The number of breeding pairs has fluctuated widely, from 3 to 750, averaging 297 pairs per year (Figure 33B). The upward trend is not significant.

Forster's Terns (Sterna forsteri) were slow to appear as breeders in the area, with four pairs at San Luis Pass in 1976 and 70 in 1977. Following a two year hiatus, 140 pairs bred at Drum Bay in 1980 but none returned to the area the following year. Nearly 500 pairs established colonies on Bird Island and Bastrop and Drum Bays in 1982 and have returned these sites, and Arcadia Reef, ever since, reaching an unprecedented 2360 pairs in 1989 (Figure 33C). The trend line is significant ($P<.005$).

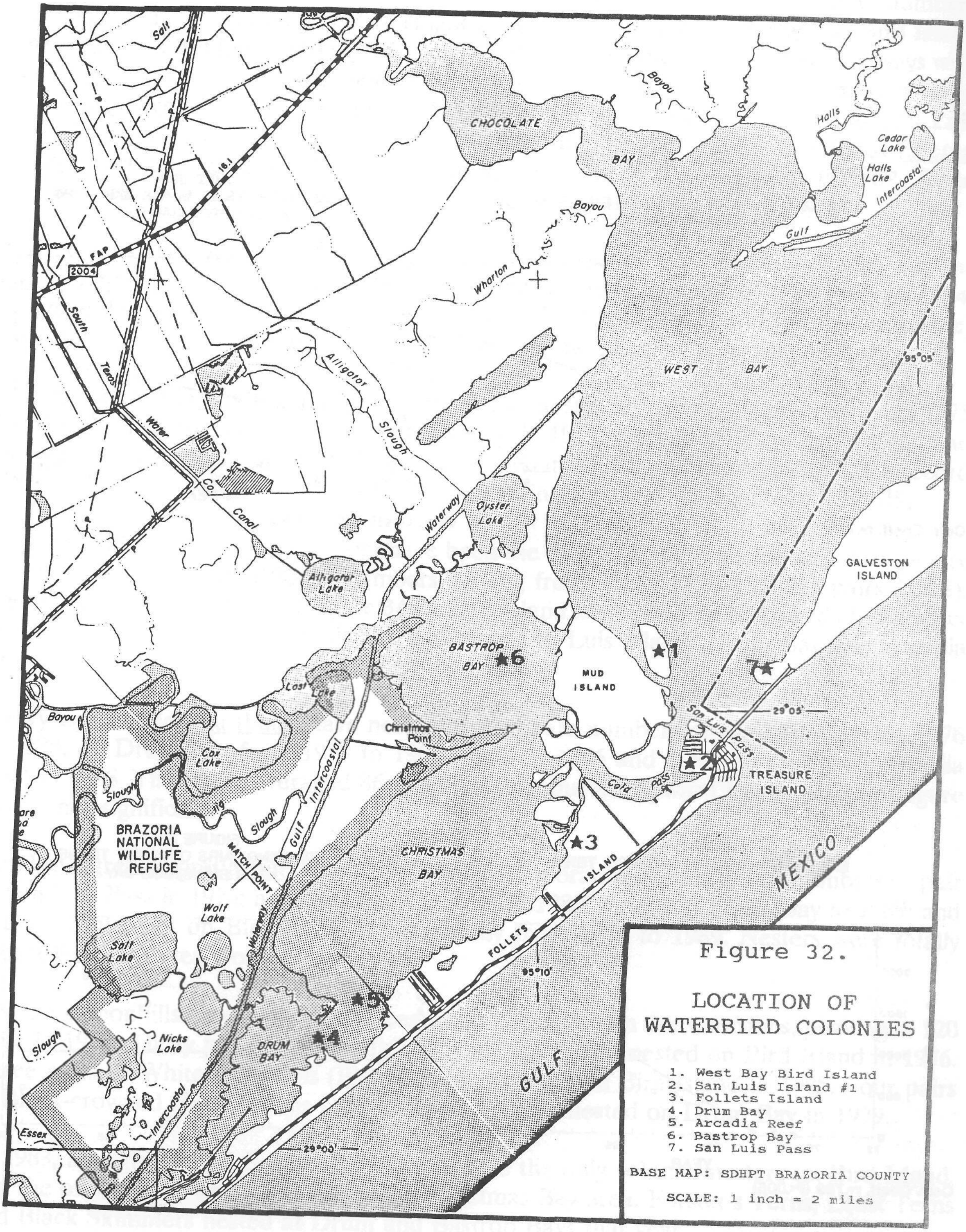


Figure 32.

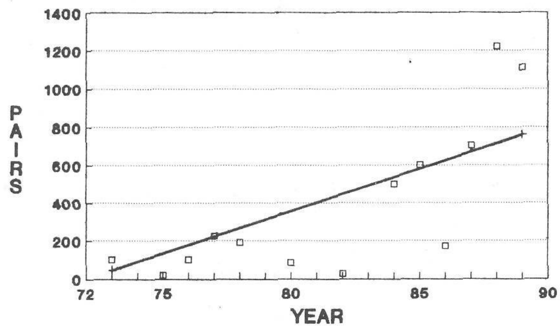
LOCATION OF WATERBIRD COLONIES

1. West Bay Bird Island
2. San Luis Island #1
3. Follets Island
4. Drum Bay
5. Arcadia Reef
6. Bastrop Bay
7. San Luis Pass

BASE MAP: SDHPT BRAZORIA COUNTY

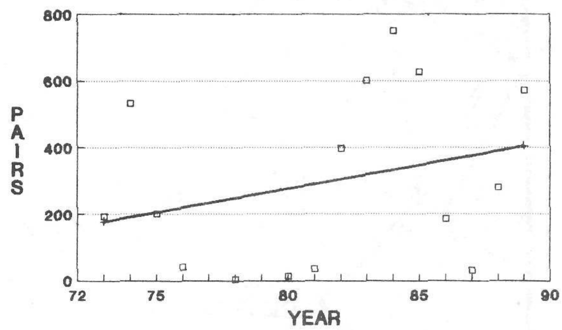
SCALE: 1 inch = 2 miles

FIGURE 33A.
BREEDING PAIRS OF LAUGHING GULLS
NEAR CHRISTMAS BAY



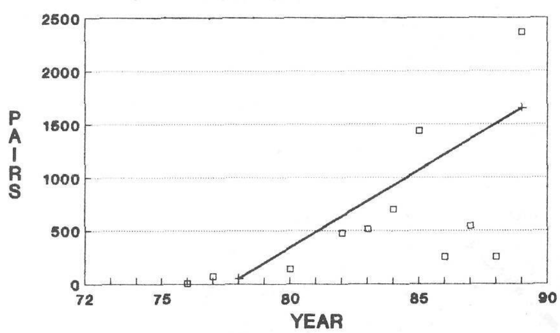
Corr. Coeff. r=.722 (P=.005)

FIGURE 33B.
BREEDING PAIRS OF BLACK SKIMMERS
NEAR CHRISTMAS BAY



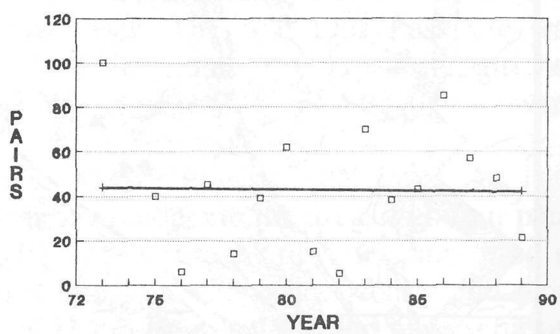
Corr. Coeff. r=.287 (N.S.)

FIGURE 33C.
BREEDING PAIRS OF FORSTER'S TERNS
NEAR CHRISTMAS BAY



Corr. Coeff. r=.789 (P<.005)

FIGURE 33D.
BREEDING PAIRS OF LEAST TERNS
NEAR CHRISTMAS BAY



Corr. Coeff. r=-.015 (N.S.)

In contrast, Least Terns (Sterna antillarum) have persistently appeared in small numbers since 1973, being absent only in 1974 (Figure 33D). They have never nested on Bird Island or Arcadia Reef but have used as many as four of the other sites in a given year, always with fewer than 100 total pairs, averaging 43 pairs a year. In 1977, 230 pairs of Sandwich Terns (Sterna sandvicensis) and 230 pairs of Royal Terns (Sterna maxima) nested at San Luis Island. Eight pairs of Royal Terns nested at Drum Bay in 1982. Gull-billed Terns (Sterna nilotica) have appeared at Drum Bay twice, two pairs in 1988 and 3 pairs in 1989. These three species must be considered as sporadic nesters in the area.

Ten species of above-ground colonial waders have bred in the area. Great Blue Herons (Ardea herodias) have appeared in small numbers every year since 1976, except 1984, averaging 20 pairs (Figure 34A). They have nested only on Bird Island (all but two years) and Drum Bay (intermittently since 1979). The downward trend is not significant.

Great Egrets (Casmerodius albus) nested in small but steadily increasing numbers from 1975 to 1978 on Bird Island, switched to Drum Bay in 1979, peaked at 95 pairs in 1982, and disappeared in 1983 (Figure 34B). Five pairs nested in 1986 but none followed until a record number, 138 pairs, appeared in 1989. The increasing trend line is significant ($P<.05$).

Tricolored Herons (Egretta tricolor) have been the most abundant wader, appearing every year since 1973, except 1983, in numbers varying from 1 pair (1982) to 845 pairs (1978), averaging 276 pairs per year (Figure 34C). Bird Island is the favorite site, used all years but two, while pioneers have sporadically nested at San Luis Island, Drum Bay and Arcadia Reef.

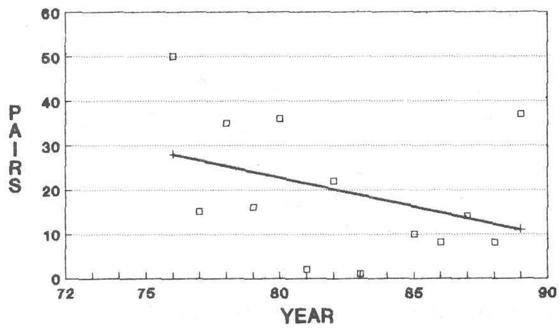
Snowy Egrets (Egretta thula) have nested in moderate numbers on Bird Island from 1976 to 1978, on Drum Bay from 1979 to 1982, again in 1986 and 1989, and once on Arcadia Reef in 1988. They have averaged 86 pairs per year but the upward trend shown in Figure 34D is not significant.

Reddish Egrets (Egretta rufescens) have appeared sporadically in very low numbers: a pair at San Luis Pass in 1975; a pair at Arcadia Reef in 1988; 4 pairs at Drum Bay in 1989; and one to eight pairs on Bird Island intermittently from 1976 to 1989. Nesters were totally absent from the area from 1978 to 1983.

Roseate Spoonbills (Ajaia ajaja) have nested on Drum Bay on five occasions, peaking at 120 pairs in 1982. Thirty pairs of White Ibis (Eudocimus albus) nested on Bird Island in 1976. Three pairs of White-faced Ibis (Plegadis chihi) nested on Bird Island in 1985. Four pairs of Black-crowned Night-herons (Nyticorax nycticorax) nested on Drum Bay in 1979.

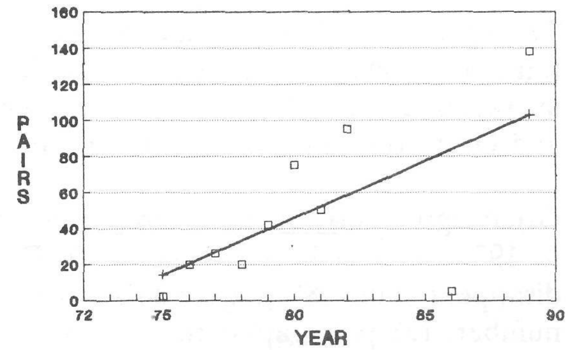
In 1983, a single pair of Great Blue Herons were the only colonial nesters on Bird Island, and the only waders nesting in the entire Christmas Bay area. Forster's Terns, Least Terns and Black Skimmers nested at Drum and Bastrop Bays that year.

FIGURE 34A.
BREEDING PAIRS OF GREAT BLUE HERONS
NEAR CHRISTMAS BAY



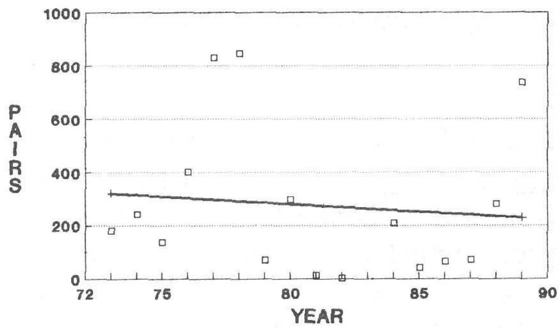
Corr. Coeff. r=-.370 (Not Sign.)

FIGURE 34B.
BREEDING PAIRS OF GREAT EGRETS



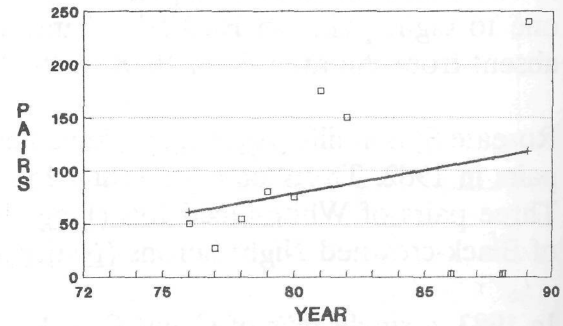
Corr. Coeff. r=.646 (P<.05)

FIGURE 34C.
BREEDING PAIRS OF TRICOLORED HERONS
NEAR CHRISTMAS BAY



Corr. Coeff. r=-.104 (Not Sign.)

FIGURE 34D.
BREEDING PAIRS OF SNOWY EGRETS
NEAR CHRISTMAS BAY



Corr. Coeff. r=.256 (Not Sign.)

There are no waterbird colonies on the Brazoria National Wildlife Refuge, although numerous species forage there in abundance. Refuge managers attribute this to the absence of vegetated islands on the refuge (R. Bisbee, pers. comm.). Predators, such as raccoons, are known to decimate waterbird colonies elsewhere in the southeastern states in the absence of "alligator-protected" island nesting sites.

The erratic annual variation in the number of active nesting sites, and the number of nesting pairs of colonial waterbirds, is typical of colonial waterbirds elsewhere in Galveston Bay (Sheridan et al., 1989) and the Gulf coast. Although Cattle Egrets (Bubulcus ibis) are the dominant wader bay-wide (Sheridan et al., 1989) and, indeed, in Texas (Martin, 1989), they have not appeared in the colonies surrounding Christmas Bay. This may reflect a scarcity of pastures and grazing range for cattle on the coast.

Woodlots along the upper Texas coast provide a valuable stopover habitat for trans-Gulf and circum-Gulf migrating birds, especially songbirds (Mueller, 1987). Woodlots are defined as wooded areas at least 0.5 hectares (1.2 acres) in size with trees over 6 meters (20 feet) tall. There are no woodlots on Follets Island or elsewhere around Christmas Bay. Small mounds, or mottes, covered with brush (trees or shrubs less than 20 feet tall) are also used by migrants. Several brush-mottes have been noted on Follets Island (Mueller, 1987). The value of these brush-mottes to migrating birds, their usage during migration, and their physical characteristics (size, structural vegetative diversity, tree height, and isolation) have not been determined.

4. Endangered and Threatened Species

The TPWD Endangered/Threatened Species Data File for Brazoria County lists 14 endangered species and 24 threatened species (Appendix B). The Brazoria NWR bird list and amphibians and reptiles list have been used to document the status of these species on Christmas Bay for this report (Appendix B).

Fourteen of the species are whales and dolphins unlikely to appear in this very shallow estuary. The jaguarundi has not been reported here. There is no suitable habitat for the red-cockaded woodpecker.

The endangered Atlantic Ridley sea turtle (Lepidochelys kempi) inhabits shallow coastal and estuarine waters, eating invertebrates primarily, mostly crabs, but also shrimp, snails, and, occasionally, marine plants (USDI, 1980). The endangered leatherback sea turtle (Dermochelys coriacea) has been known to occasionally enter shallow estuaries (USDI, 1980). It is omnivorous and consumes a broad variety of prey, but primarily feeds on jellyfish. The endangered hawksbill turtle (Eretmochelys imbricata) is known to frequent shallow coastal areas and narrow creeks and passes (USDI, 1980). It is omnivorous, feeding on a broad array of invertebrates. All three of these species can be expected to occasionally occur in Brazoria and Galveston Counties but there are no confirmed sightings from Christmas Bay.

The threatened green sea turtle (Chelonia mydas) is known to inhabit shallow bays with an abundance of marine grass and algae; adults are largely herbivorous. In October, 1989, National Marine Fisheries Service researchers captured a green turtle in a shrimp trawl in Christmas Bay (D. Moore, NMFS, pers. comm.). On August 20, 1990, an unidentified sea turtle was observed to surface twice in a seagrass bed in Christmas Bay. These are the only confirmed sightings of sea turtles in the coastal preserve.

Neither the endangered western smooth green snake (Opheodrys vernalis blanchardi) nor the threatened Texas scarlet snake (Cemophora coccinea lineri) have been verified on the refuge and both are listed as unlikely to occur. Likewise, the threatened timber rattlesnake (Crotalus horridus), Texas horned lizard (Phrynosoma cornutum), and alligator snapping turtle (Macroclemys temmincki) have not been reported.

The threatened rose-throated becard (Pachyramphus aglaiae) has not been reported from the upper Texas coast (Dauphin et al., 1989). The endangered Attwater's greater prairie chicken (Tympanuchus cupido attwateri) no longer occurs on this part of the coast. The sooty tern (Sterna fuscata) has been observed on the upper coast but not on the refuge.

The endangered brown pelican (Pelecanus occidentalis) occurs at Christmas Bay (pers. observ.). Although listed as a rare winter visitor on the refuge list, this species has experienced a recent comeback and moderate numbers of the birds were observed on Galveston Bay during the summer of 1990.

The endangered bald eagle (Haliaeetus leucocephalus) is listed as rare during the spring and summer and uncommon during the fall and winter. The abundance of fish in shallow water and overwintering ducks and geese on the refuge should prove attractive to eagles.

The endangered whooping crane (Grus americana) is not listed in the TPWD E/T Species data file as occurring in Brazoria County but it is considered to be a rare visitor to the wildlife refuge during the fall (USFWS, nd). Stragglers have also be seen in other counties in the region and Christmas Bay is likely to be an acceptable habitat for this species.

Least terns are listed as common in spring and summer, uncommon during the fall, and absent during the winter. The species nests in the area (see G.3 above, Fig. 33D). The occurrence of the endangered subspecies, Sterna antillarum athalassos, has not been documented. It may appear during the winter but would not be expected to breed on the coast.

The threatened reddish egret (Egretta rufescens) is listed as uncommon throughout the year on the refuge. It does occur on Christmas Bay (pers. observ.). It sporadically nests in the area in small numbers (see G.3 above). The threatened white-faced ibis (Plegadis chihi) is listed as common on the refuge during spring and fall but uncommon during the summer and winter. It has nested locally only once (see G.3 above). The threatened wood stork (Mycteria americana) is listed as common during the summer and uncommon during the fall on the refuge. Wood storks on the upper coast typically have dispersed from breeding colonies in Mexico after the breeding season.

The threatened arctic peregrine falcon (Falco peregrinus tundrius) is listed as uncommon on the refuge during fall, winter, and spring. These birds follow the shorebird migration, particularly along the beaches of the Texas coast. They are certain to occur in small numbers on Christmas Bay due to its close proximity to the beach.

The threatened piping plover (Charadrius melodus) is listed as uncommon during fall, winter, and spring on the refuge. A small but persistent population of these birds overwinters on Galveston Bay.

The threatened white-tailed hawk (Buteo albicaudatus) is listed as rare at all seasons on the refuge but known to nest locally. The threatened American swallow-tailed kite (Elanoides forficatus) is listed as rare on the refuge during spring and summer.

In summary, the Christmas Bay ecosystem is directly inhabited by eight species listed as endangered or threatened by the TPWD - brown pelican, bald eagle, whooping crane, reddish egret, white-faced ibis, peregrine falcon, piping plover and green sea turtle. Three additional species inhabit the adjacent Brazoria National Wildlife Refuge - wood stork, white-tailed hawk, and swallow-tailed kite.

CONCLUSIONS

1. A hundred authorized cabins are a conspicuous feature of Christmas Bay and its environs. These cabins, and their associated boat traffic, potentially impact the bay in several ways, including disturbance of colonial nesting waterbirds, damage to seagrass beds, discharge of human waste, closure of nearby oyster reefs, and accumulation of solid waste and garbage.

2. The Brazoria National Wildlife Refuge has a major positive influence on the health and functioning of the Christmas Bay ecosystem. The planned expansion of this refuge will bring the entire shoreline of Bastrop Bap into public ownership and further protect Christmas Bay.

3. Construction of the Gulf Intracoastal Waterway probably had a major impact on Christmas, Drum and Bastrop Bays by terminating the overland flow of freshwater into Christmas Bay and reducing tributary flow.

4. Changes in the peripheral emergent wetlands of Christmas Bay between 1956 and 1979 are difficult to interpret other than a 9 percent loss in total emergent vegetation acreage.

5. The seagrass beds composed of shoalgrass, widgeon grass, clover grass, and turtle grass continue to decline at a rate of 3.5 acres per year. Widgeon grass is the only species found elsewhere in the Galveston Bay ecosystem. Seagrasses are the most valuable and productive habitat of Christmas Bay.

6. There are no known water quality problems nor indications of potential water quality problems, in Christmas, Drum or Bastrop Bays.

7. Freshwater inflow is estimated to be 63,500 acre-feet per year. Point source discharges from permitted outfalls contribute 7.7 percent of the known volume.

8. As a narrow, low-lying, barrier island, Follets Island is at risk to washovers and inundation from tropical storms.

9. Christmas Bay is inhabited by a rich fauna of 96 species of fishes, 68 crustaceans, 140 mollusks, and numerous other invertebrate animals. Seven waterbird nesting colonies are found around the bay. Christmas Bay is directly inhabited by eight endangered or threatened species; 3 additional species inhabit the adjacent wildlife refuge.

RECOMMENDATIONS

1. One or more water quality monitoring stations should be established within Christmas Bay. The existing station at Christmas Point does not reflect bay conditions. Sampling should be conducted monthly for at least two years to establish baseline conditions, and quarterly, at a minimum, thereafter.

2. Studies should be undertaken to establish the relative abundance of the four species of seagrass. It appears that extinction of turtle grass and clover grass may be eminent.

3. The possibility of using maintenance dredge spoil from the Gulf Intracoastal Waterway to create a colonial bird nesting island within Christmas Bay should be investigated. A vegetated island of adequate elevation to avoid flooding would be a valuable resource for colonial wading birds of the bay and wildlife refuge.

4. Drum Bay and Bastrop Bay, as integral components of the Christmas Bay ecosystem, should be considered as additions to the Christmas Bay Coastal Preserve.

ACKNOWLEDGMENTS

Preparation of this report would have been impossible without the unselfish assistance of many people who cheerfully responded to my naive questions and requests for information. The following individuals were particularly helpful.

Dave Buzan, Jeff Kirkpatrick, George Guillen and Catherine Albrecht of the Texas Water Commission; Bruce Smith of the Texas General Land Office; Albert Green, Wen Lee, Dorinda Sullivan, Catrina Martin, Larry McKinney, Warren Pulich, and Fred LeBlanc of the Texas Parks and Wildlife Department; Frank Shipley, Russell Kiesling, and Carol Ward of the Galveston Bay National Estuary Program; Gary Powell and Rueben Solis of the Texas Water Development Board; Jerry Wermund and Tom Calnan of the University of Texas Bureau of Economic Geology; Mark Gerding of the Texas Railroad Commission; Kirk Wiles of the Texas Department of Health; Fred Werner, Allan Mueller, and B.D. King of the Ecological Services unit of the U.S. Fish & Wildlife Service; Ronald Bisbee and Mike Lang of the USFWS Brazoria National Wildlife Refuge; Carroll Cordes and James Johnson of the USFWS National Wetlands Research Center; Tom Minello, Roger Zimmerman, Janet Thomas, and Donald Moore of the U.S. National Marine Fisheries Service; Michael Kieslich of the U.S. Army Corps of Engineers; Scott Kiser of the National Weather Service; and D.R. Mudd of the Brazoria County Health Department.

REFERENCES

Andrews, J., 1981. Texas Shells. Univ. Texas Press, 175pp.

Armstrong, N.E., 1987. The Ecology of Open-Bay Bottoms of Texas: A Community Profile. U.S. Dept. Interior, Fish & Wildlife Serv. Biol. Rept. 85(7.12). 104pp.

Bagnall, R.A., 1976. Definition and persistence of an estuarine zooplankton assemblage. Ph.D. dissertation, University of Houston. 137pp.

Baker, W.B., Jr., G.C. Matlock, L.W. McEachron, A.W. Green, and H.E. Hegen, 1986. Movement, growth and survival of spotted seatrout tagged in Bastrop Bayou, Texas. Contrib. Mar. Sci. 29:91-101.

Beccasio, A.D. et al., 1982. Gulf Coast Ecological Inventory. U.S. Fish Wildl. Serv., Biol. Serv. Program FWS/OBS-82/55.

Bomar, G.W., 1983. Texas Weather. Univ. Texas Press, 265pp.

Britton, J.C., and B. Morton, 1989. Shore Ecology of the Gulf of Mexico. Univ. Texas Press, 387pp.

Craig, C.C., & T.J. Bright, 1986. Abundance, age distributions and growth of the Texas Hard Clam Mercenaria mercenaria texana in Texas Bays. Contr. Mar. Science 29:59-72.

Dauphin, D.T., A.N. Pettingell, and E.R. Rozenburg, 1989. A birder's checklist of the upper Texas coast. Ornithology Group, Houston Outdoor Nature Club.

Ezell, C.E., 1977. Intensive surface water monitoring survey for Segment No. 1106, Bastrop Bayou - above tidal. Texas Water Quality Board Report No. IMS 54, 33pp.

Fleetwood, R.J., undated. Plants of the Brazoria/San Bernard National Wildlife Refuges. U.S. Fish & Wildlife Service. 61pp.

Fotheringham, N., and R.A. Bagnall, 1976. Seasonal variation in the occurrence of planktonic larvae of sympatric hermit crabs. J. Exp. Mar. Biol. Ecol. 21(3):279-287.

Guillen, G., 1988. Natural Resource Survey of Christmas Bay Surrounding the Proposed Continental Savings Discharge (Requested Permit No. 13402-01). Texas Water Commission, Field Operations Office, Deer Park. 11pp.

Hall, C.E., J.E. Hildebrand, R.T. Binhammer, and O. Hall, 1959. The Birds of Galveston Island. Tex. J. Sci. 11(1):93-109.

Johnston, J.B., Compiler, 1984. Texas Barrier Islands Region Ecological Characterization Atlas: Biological Resources Narrative. U.S. Fish Wildl. Serv. FWS/OBS-82/16. 12pp.

Martin, C., 1989. Texas Colonial Waterbird Census Summary - 1989. Texas Parks & Wildlife Dept., Nongame Resources Program. 109pp.

McEachron, L.W., C.R. Shaw, & A.W. Moffett, 1977. A Fishery Survey of Christmas, Drum, and Bastrop Bayous, Brazoria County, Texas. Texas Parks & Wildlife Department, Technical Series No. 20, 83pp.

Mueller, A.J., 1987. An inventory of upper Texas coast woodlots, valuable migratory bird habitat. Bull. Texas Ornith. Soc. 20(1&2):14-20.

Ottmers, D.D., 1980. Intensive survey of Bastrop Bayou above tidal Segment 1106. Texas Dept. Water Resources IS-13, 24pp.

Paine, J.G., and R.A. Morton, 1986. Historical shoreline changes in Trinity, Galveston, West, and East Bays, Texas Gulf Coast. Bur. Econ. Geol., Geol. Circ. 86-3, 58pp.

Parker, J.C., 1965. An annotated checklist of the fishes of the Galveston Bay system, Texas. Publ. Mar. Sci. Univ. Texas 10:201-220.

Penn, G.J., 1979. Decapod crustacean communities in Texas seagrasses. Ph.D. Dissertation, University of Houston. 126pp.

Phleger, F.B., 1965. Patterns of marsh foraminifera, Galveston Bay, Texas. Limnol. & Oceanogr. 10:R169.

Pulich, W.M., and W.A. White, 1989. Decline of submerged vegetation in the Galveston Bay System: chronology and relationships to physical processes. Bur. Econ. Geol., Univ. Texas. 27pp.

Sheridan, P.F., R.D. Slack, S.M. Ray, L.W. McKinney, E.F. Klima, and T.R. Calnan, 1989. Biological components of Galveston Bay. p.23-51 in Galveston Bay: Issues, Resources, Status, and Management. U.S. Dept. Commerce, NOAA Estuary-of-the-Month Seminar Series No. 13.

Shew, D.M., R.H. Baumann, T.H. Fritts, and L.S. Dunn, 1981. Texas Barrier Islands Region Ecological Characterization: Environmental Synthesis Papers. U.S. Dept. Interior, Fish & Wildl. Serv. FWS/OBS-81/32, 413pp.

Texas Colonial Waterbird Society, 1982. An Atlas and Census of Texas Waterbird Colonies, 1973-1980. Caesar Kleberg Wildlife Research Institute, Texas A&I University, Kingsville. 358pp.

Texas Dept. of Health, 1989. Classification of Shellfish Harvesting Areas. Div. of Shellfish Sanitation Control. Galveston Bay, West Galveston Bay, Freeport Area.

Texas Department of Water Resources, 1984. Water for Texas. GP-4-1.

Texas Water Commission, 1988. The State of Texas Water Quality Inventory, 9th edition. LP 88-04.

Texas Water Commission, 1990. The State of Texas Water Quality Inventory, 10th Edition. LP 90-06.

Thomas, J.L., 1989. A comparative evaluation of Halodule wrightii Aschers, Spartina alterniflora Loisel and bare sand as nursery habitats for juvenile Callinectes sapidus (Rathbun). MS Thesis, Texas A&M University. 118pp.

Thomas, J.L., R.J. Zimmerman, and T.J. Minello, 1990. Abundance patterns of juvenile blue crabs (Callinectes sapidus) in nursery habitats of two Texas bays. Bull. Mar. Sci. 46(1):115-125.

U.S. Fish & Wildlife Service, 1987. Birds [of] Brazoria and San Bernard National Wildlife Refuges, Texas. (pamphlet)

Turner, R.E., 1977. Intertidal vegetation and commercial yields of penaeid shrimp. Trans. Amer. Fish. Soc. 106(5):411.

U.S. Dept. Interior, Fish & Wildlife Service, 1980. Selected Vertebrate Endangered Species of the Seacoast of the United States.

U.S. Dept. Interior, Fish & Wildlife Service, 1989. Hoskins Mound - A Gulf Coast Joint Venture of the North American Waterfowl Management Plan. Draft Environmental Assessment. Region 2, Albuquerque. November. 26pp.

U.S. Fish & Wildlife Service, nd. Amphibians and reptiles of Brazoria and San Bernard National Wildlife Refuges, Texas.
(pamphlet)

White, W.A., et al., 1988. Submerged Lands of Texas, Bay City-Freeport Area: sediments, geochemistry, benthic macroinvertebrates, and associated wetlands. Univ. Texas Bur. Econ. Geol. Spec. Publ., 130pp.

Zimmerman, R.J., T.J. Minello, M.C. Castiglione, and D.L. Smith, 1990. Utilization of marsh and associated habitats along a salinity gradient in Galveston Bay. U.S. Dept. Commerce, NOAA Tech. Memorandum NMFS-SEFC-250, 68pp.

APPENDIX A

Table A.1. Fishes of Christmas Bay

Achirus lineatus, Lined Sole
Adinia xenica, Diamond Killifish
Anchoa hepsetus, Striped Anchovy
Anchoa mitchilli, Bay Anchovy
Archosargus probatocephalus, Sheepshead
Arius felis, Hardhead Catfish
Bagre marinus, Gafftopsail Catfish
Bairdiella chrysura, Silver Perch
Brevoortia gunteri, Finescale Menhaden
Brevoortia patronus, Gulf Menhaden
Caranx hippos, Crevalle Jack
Carcharhinus brevipinna, Spinner Shark
Carcharhinus leucas, Bull Shark
Carcharhinus limbatus, Blacktip Shark
Carcharhinus obscurus, Dusky Shark
Centropristis philadelphica, Rock Sea Bass
Chaetodipterus faber, Atlantic Spadefish
Chaetodon ocellatus, Spotfin Butterflyfish
Chasmodes bosquianus, Striped Blenny
Chilomycterus schoepfi, Striped Burrfish
Chloroscombrus chrysurus, Atlantic Bumper
Citharichthys spilopterus, Bay Whiff
Cynoscion arenarius, Sand Seatrout
Cynoscion nebulosus, Spotted Seatrout
Cyprinodon variegatus, Sheepshead Minnow
Dasyatis sabina, Atlantic Stingray
Dorosoma cepedianum, Gizzard Shad
Elops saurus, Ladyfish
Etropus crossotus, Fringed Flounder
Eucinostomus argenteus, Spotfin Mojara
Eucinostomus gula, Silver Jenny
Fundulus grandis, Gulf Killifish
Fundulus similis, Longnose Killifish
Gobioides broussonneii, Violet Goby
Gobionellus boleosoma, Darter Goby
Gobionellus hastatus, Sharptail Goby
Gobiosoma bosci, Naked Goby
Gobiosoma robustum, Code Goby
Harengula pensacolae,
Hippocampus zosterae, Dwarf Seahorse
Hyporhamphus unifasciatus, Halfbeak

Table A.1. (continued) The Fishes of Christmas Bay

Hypsoblennius ionthas, Freckled Blenny
Lactophrys quadricornis, Scrawled Cowfish
Lagodon rhomboides, Pinfish
Larimus fasciatus, Banded Drum
Leiostomus xanthurus, Spot
Lepisosteus spatula, Alligator Gar
Lobotes surinamensis, Tripletail
Lucania parva, Rainwater Killifish
Lutjanus synagris, Lane Snapper
Megalops atlanticus, Tarpon
Membras martinica, Rough Silverside
Menidia beryllina, Inland Silverside
Menticirrhus americanus, Southern Kingfish
Menticirrhus littoralis, Gulf Kingfish
Microgobius gulosus, Clown Goby
Microgobius thalassinus, Green Goby
Micropogonius undulatus, Atlantic Croaker
Monocanthus hispidus, Planehead Filefish
Mugil cephalus, Striped Mullet
Mugil curema, White Mullet
Myrophis punctatus, Speckled Worm Eel
Oligoplites saurus, Leatherjacket
Ophichthus gomesi, Shrimp Eel
Ophiodon sp., Cusk-eel
Opsanus beta, Gulf Toadfish
Orthopristis chrysoptera, Pigfish
Paralichthys albigutta, Gulf Flounder
Paralichthys lethostigma, Southern Flounder
Peprilus triacanthus, Butterfish
Peprilus alepidotus, Harvestfish
Poecilia latipinna, Sailfin Molly
Pogonias cromis, Black Drum
Polydactylus octonemus, Atlantic Threadfin
Pomatopus saltatrix, Bluefish
Prionotus tribulus, Bighead Searobin
Rhizoprionodon terraenovae, Atlantic Sharpnose Shark
Sciaenops ocellata, Red Drum
Scomberomorus maculatus, Spanish Mackerel
Selene vomer, Lookdown
Seriola fasciata, Lesser Amberjack
Seriola rivoliana, Almaco Jack

Table A.1. (continued) The Fishes of Christmas Bay

Sphoeroides parvus, Least Puffer
Sphyrna lewini, Scalloped Hammerhead
Sphyrna tiburo, Bonnethead
Stellifer lanceolatus, Star Drum
Strongylura marina, Atlantic Needlefish
Strongylura notata, Redfin Needlefish
Symphurus parvus, Pygmy Tonguefish
Symphurus plagiusa, Blackcheek Tonguefish
Syngnathus floridae, Dusky Pipefish
Syngnathus louisianae, Chain Pipefish
Syngnathus scovelli, Gulf Pipefish
Synodus foetens, Inshore Lizardfish
Trinectes maculatus, Hogchoker
Urophycis floridana, Southern Hake

Sources: McEachron et al., 1977; TPWD data files.

Table A.2. Crustaceans of Christmas Bay

Acartia lilljeborgi, copepod
Acartia tonsa, copepod
Acetes americanus, sergestid shrimp
Alpheus heterochaelis, Big-clawed Snapping Shrimp
Ampelisca sp.
Balanus amphritrite, cirriped
Balanus improvisus, cirriped
Callanopia americana, copepod
Callinectes sapidus, Blue Crab
Callinectes similis, Lesser Blue Crab
Caprella sp.
Centropages velificatus, copepod
Clibinarius vittatus, Striped Hermit Crab
Corophium sp.
Corycaeus sp., copepod
Cymodusa compta, amphipod
Cymothoa excisa, isopod
Edotea montosa
Elasmopus levis
Emerita portoricensis, crab
Ergasilus sp., copepod
Erichsonella attenuata, isopod
Eucalanus pileatus, copepod
Euchaeta paraconcinna, copepod
Eurypanopeus depressus, Flat Mud Crab
Gammarus mucronatus, amphipod
Grandidiecella bonneiroides, amphipod
Hargeria rapax, tanaid
Heterocrypta granulata, Pentagon Crab
Hexapanopeus angustifrons, Narrow Mud Crab
Hippolyte pleuracantha,
Hippolyte zostericola
Labidocera aestiva, copepod
Lepidopa websteri, crab
Libinia dubia, Spider Crab
Lucifer faxoni, sergestid shrimp
Macrobrachium ohione, River Shrimp
Macrosetella gracilis, copepod
Melita nitida, amphipod
Menippe mercenaria, Stone Crab

Table A.2. (continued) Crustaceans of Christmas Bay

Mysidopsis bahia, mysid
Neopanope texana, xanthid crab
Nerocila acuminata, isopod
Oithoina colcarva, copepod
Olencira praegustator, isopod
Oncaea sp., copepod
Ovalipes guadulpensis, Lady Crab
Pachygrapsus transversus, grapsid crab
Pagurus longicarpus, Long-wristed (Long Claw) Hermit Crab
Pagurus pollicaris, Big Claw Hermit Crab
Palaemonetes intermedius,
Palaemonetes pugio, Grass Shrimp
Palaemonetes vulgaris,
Paracalanus parvus, copepod
Penaeus aztecus, Brown Shrimp
Penaeus duorarum, Pink Shrimp
Penaeus setiferus, White Shrimp
Petrolisthes armatus, porcellanid crab
Pseudodiaptomus coronatus, copepod
Rithropanpeus harrisii, xanthid crab
Squilla empusa, Mantis Shrimp
Temora stylifera, copepod
Temora turbinata, copepod
Tortanus setacaudatus, copepod
Tozeuma carolinense, Arrow Shrimp
Trachypeneus similis, Broken-neck Shrimp
Uca sp.
Xiphopeneus kroyeri, Seabob

Sources: McEachron et al., 1977; Thomas, 1989; Bagnall, 1976.

Table A.3. Mollusks of Christmas Bay

Abra aegualis, Common Atlantic Abra
Acteocina canaliculata, Channeled Barrel-Bubble
Aligena texasiana, Texas Lepton
Amygdalum papyrium, Paper Mussel
Anachis avara, Greedy Dove Shell
Anachis obesa, Fat Dove Shell
Anachis ostreicola
Anadara ovalis, Blood Ark
Anadara transversa, Transverse Ark
Anomalocardia auberiana [cuneimeris], Pointed Venus
Anomia simplex, Common Jingle Shell
Anticlimax pilsbry
Argopecten [Aequipecten] irradians, Atlantic Bay Scallop
Atrina seminuda, Spiny Pen Shell
Atrina serrata, Saw-toothed Pen Shell
Balcis [Melanella] arcuata, Curved Melanella
Barnea costata
Boonea [Odostomia] seminuda, Half-smooth Odostome
Brachidontes exustus, Scorched Mussel
Bulla striata, Striate Bubble
Busycon contrarium, Lightning Whelk
Busycon spiratum, Pear Whelk
Caecum glabrum, Smooth Caecum
Caecum pulchellum, Beautiful Little Caecum
Callocardia texasiana, Texas Venus
Cavolina tridentata, Three-toothed Cavolina
Ceritheum lutosum [variabile], Muddy [Dwarf] Cerith
Cerithidea pliculosa, Plicate Horn Shell
Cerithiopsis greeni, Green's Miniature Cerith
Chione cancellata, Cross-barred Venus
Cochliolepis parasitica
Corbula barattiana, Barratt's Corbula
Corbula swiftiana, Swift's Corbula
Crassinella lunulata, Lunate Crassinella
Crassostrea virginica, Eastern Oyster
Crepidula convexa, Faded Slipper Shell
Crepidula fornicata, Common Atlantic Slipper Shell
Crepidula plana, Eastern White Slipper Shell
Cumingia tellinoides, Tellin-like Cumingia
Cyclinella tenuis, Atlantic Cyclinella

Table A.3 (Continued) Mollusks of Christmas Bay

Cyclostremiscus pentagonus, Trilix Vitrinella
Cyclostremiscus suppressus
Cyrtopleura costata, Angel Wing
Dentalium texasianum, Texas Tusk
Diastoma [Bittium] varium, Variable Bittium
Diodora cayensis, Cayenne Keyhole Limpet
Diplodonta semiaspera, Pimpled Diplodon
Diplodonta soror
Diplothyra smithii, Oyster Piddock
Donax roemeri, Coquina Shell
Dosinia discus, Disk Dosina
Ensis minor, Jacknife Clam
Epitonium humpreysi, Humphrey's Wentletrap
Epitonium rupicola, Brown-banded Wentletrap
Epitonium multistriatum, Multiribbed Wentletrap
Epitonium sp., wentletrap
Eulimastoma [Odostomia] canaliculata
Eulimastoma harbisonae
Eulimastoma [Odostomia] teres
Eulimastoma [Odostomia] weberi, Weber's Eulimastoma
Eulimastoma emerge
Fargoa [Odostomia] gibbosa, Fat Odostome
Fargoa [Odostomia] dianthophila
Hydrobia barretti
Hydrobia sp.
Ischadium [Brachidontes] recurvum, Hooked Mussel
Ischnochiton papillosus, Meshpitted Chiton
Laevicardium [Dinocardium] robustum, Giant Atlantic Cockle
Laevicardium mortoni, Morton's Egg Cockle
Linga [Lucina] amiantus, Lovely Miniature Lucina
Lithophaga bisulcata, Mahogany Date Mussel
Littorina irrorata, Marsh Periwinkle
Littoridina sphinctostoma,
Lolliguncula brevis, Brief Squid
Lucina [Phacoides] pectinata, Thick Lucina
Lyonsia hyalina, Glassy Lyonsia
Macoma constricta, Constricted Macoma
Macoma mitchelli, Mitchell's Macoma
Macoma tenta, Tenta Macoma
Macoma pulleyi, Pulley's Macoma
Mactra fragilis, Fragile Atlantic Mactra

Table A.3 (Continued) Mollusks of Christmas Bay

Mangelia plicosa
Martesia sp.
Melampus coffeus
Melanella hemphilli
Melanella sp.
Mercenaria campechiensis, Southern Quahog
Mercenaria mercenaria texana
Microcardium peramabile
Mitrella lunata, Lunar Dove Shell
Modiolus americanus
Modiolus demissus, Ribbed Mussel
Mulima lateralis, Dwarf Surf Clam
Mysella planulata, Atlantic Flat Lepton
Mysella sp.
Mytilopsis [Congeria] leucophaeta, Conrad's False Mussel
Nassarius acutus, Sharp Knobbed Nassa
Nassarius vibex, Common Eastern Nassa
Natica [Tectonatica] pusilla, Miniature Natica
Neritina virginea
Noetia ponderosa, Ponderous Ark
Nuculana acuta, Pointed NutShell
Nuculana concentrica, Concentric Nut Clam
Odostomia bisuturalis, Double Sutured Odostome
Ostrea equestris, Crested Oyster
Pandora trilineata, Say's Pandora
Periploma margaritaceum
Petricola pholadiformis, False Angel Wing
Phytia sp.
Polinices duplicatus, Shark Eye
Polymesoda maritima [Pseudocyrena floridana], Florida Marsh Clam
Probythenella [Vioscalba] louisianae
Pyrgocythara [Mangelia] plicosa, Plicate Mangelia
Rangia cuneata, Common Rangia
Rangia flexuosa, Brown Rangia
Retusa candei
Rictaxis [Acteon] punctostriatus, Adam's Baby-Bubble
Sayella livida
Sayella sp.
Seila adamsi, Adam's Miniature Cerith
Semele proficua, White Atlantic Semele
Solariorbis blakei

Table A.3 (Continued) Mollusks of Christmas Bay

Solariorbis sp.
Tagelus divisus, Purplish Tagelus
Tagelus plebius [gibbus], Stout Tagelus
Teinostoma biscaynense
Tellina alternator, Alternate Tellin
Tellina iris, Iris Tellin
Tellina texana, Say's Tellin
Tellina versicolor, Dekay's Dwarf Tellin
Tellina sp.
Terebra protexta, Fine Ribbed Auger
Thais haemastoma, Southern Oyster Drill
Trachycardium muricatum, Yellow Cockle
Triphora perversa, Black-lined Trifora
Turbonilla aegualis
Turbonilla elegantula [elegans], Elegant Turbonilla
Turbonilla interrupta, Interrupted Turbonille
Turbonilla sp.
Vermicularia spirata [fargoi], Fargo's Worm Shell
Vitrinella floridana

Synonyms are listed within [brackets].

Sources: McEachron et al., 1977; Thomas, 1989; Andrews, 1981.

Table A.4. Polychaetes of Christmas Bay

Amphictes gunneri
Aricidea philbinae
Aricidea taylori
Axiothella mucosa
Branchioasychis americana
Capitella capitata
Chone sp.
Cirrophorus lyra
Diopatra cuprea
Drilonereis longa
Drilonereis magna
Eumida sanguinea
Glycera americana
Goniada maculata
Goniada teres
Goniodella sp.
Heteromastus filiformis
Jasmineira sp.
Laeonereis culveri
Lepidonotus sublevis
Lumbrineris verrilli
Mediomastus ambiseta
Melinna maculata
Neanthes succinea
Nematonereis hebes
Nereiphylla fragilis
Nereis lamellosa
Nereis occidentalis
Nereis succinea
Polydora ligni
Polydora socialis
Protula sp.
Pseudoeurythoe ambiqua
Sabella microphthalma
Scololepis texana
Scoloplos rubra
Spiochaetopterus costarum
Spiochaetopterus oculatus
Spiophanes bombyx
Streblospio benedicti
Tharyx marioni

Source: Thomas, 1989; McEachron et al., 1977.

Table A.5. Protists, Plants and Lower Invertebrates

FORAMINIFERANS
Ammonia beccarii
Ammotium salsum
Arenoparrella mexicana
Elphidium matagordanum
Elphidium gunteri
Miliammina fusca
Tiphotrocha comprimata
Triloculina sp.
Trochammina inflata

GREEN ALGAE
Enteromorpha sp.

BROWN ALGAE
Ectocarpus sp.
Dictyota sp.
Sargassum sp.

RED ALGAE
Gracilaria sp.

FLOWERING PLANTS
Halophila engelmanni, Clover Grass
Thalassis testudinum, Turtle Grass
Ruppia maritima, Widgeon Grass
Halodule [Diplanthera] wrightii, Shoal Grass

SPONGES
Cliona sp., boring sponge

COELENTERATES
Physalia physalis, Portuguese Man-of-War
Dactylometra sp., compass jelly
Stomolophus meleagris, Cabbagehead

CTENOPHORES
Beroe ovata, Oval Comb Jelly
Mnemiopsis sp.,

BRYOZOANS
Membranipora sp.
Bugula sp.

Source: McEachron et al., 1977; Phleger, 1965.

APPENDIX B

1. Texas Parks & Wildlife Department
   Endangered/Threatened Species Data File
   Brazoria County

2. U.S. Fish & Wildlife Service
   Birds [of] Brazoria and San Bernard
   National Wildlife Refuges, Texas

3. U.S. Fish & Wildlife Service
   Amphibians and Reptiles of Brazoria and
   San Bernard National Wildlife Refuges

COUNTY: **Brazoria**

ENDANGERED SPECIES

*WHALE, BLUE (*Balaenoptera musculus*)
*WHALE, FIN (*Balaenoptera physalus*)
*WHALE, RIGHT, BLACK (*Balaena glacialis*)
*WHALE, SPERM (*Physeter macrocephalus*)
*JAGUARUNDI (*Felis yagouaroundi*)
***PELICAN, BROWN (*Pelecanus occidentalis*)
***EAGLE, BALD (*Haliaeetus leucocephalus*)
***PRAIRIE-CHICKEN, GREATER, ATTWATER' (*Tympanuchus cupido attwateri*)
**TERN, LEAST, INTERIOR (*Sterna antillarum athalassos*)
*WOODPECKER, RED-COCKADED (*Picoides borealis*)
***RIDLEY, ATLANTIC (*Lepidochelys kempi*)
***LEATHERBACK (*Dermochelys coriacea*)
***LOGGERHEAD (*Caretta caretta*)
**SNAKE, GREEN, WESTERN SMOOTH (*Opheodrys vernalis blanchardi*)

THREATENED SPECIES

*DOLPHIN, ROUGH-TOOTHED (*Steno bredanensis*)
*DOLPHIN, SPOTTED, ATLANTIC (*Stenella plagiodon*)
*WHALE, SPERM, DWARF (*Kogia simus*)
*WHALE, KILLER, FALSE (*Pseudorca crassidens*)
*WHALE, GOOSE-BEAKED (*Ziphius cavirostris*)
*WHALE, BEAKED, GERVAIS' (*Mesoplodon europaeus*)
*WHALE, KILLER (*Orcinus orca*)
*WHALE, PILOT, SHORT-FINNED (*Globicephala macrorhynchus*)
*WHALE, KILLER, PYGMY (*Feresa attenuata*)
*WHALE, SPERM, PYGMY (*Kogia breviceps*)
***EGRET, REDDISH (*Egretta rufescens*)
***IBIS, WHITE-FACED (*Plegadis chihi*)
***STORK, WOOD (*Mycteria americana*)
***FALCON, PEREGRINE, ARCTIC (*Falco peregrinus tundrius*)
***PLOVER, PIPING (*Charadrius melodus*)
***HAWK, WHITE-TAILED (*Buteo albicaudatus*)
**KITE, SWALLOW-TAILED, AMERICAN (*Elanoides forficatus*)
**BECARD, ROSE-THROATED (*Pachyramphus aglaiae*)
**TERN, SOOTY (*Sterna fuscata*)
***LIZARD, HORNED, TEXAS (*Phrynosoma cornutum*)
***TURTLE, SNAPPING, ALLIGATOR (*Macroclemys temminckii*)
***RATTLESNAKE, TIMBER (*Crotalus horridus*)
**TURTLE, GREEN, ATLANTIC (*Chelonia mydas mydas*)
**SNAKE, SCARLET, TEXAS (*Cemophora coccinea lineri*)

***Confirmed species - verified recent occurrence
**Probable species - unconfirmed, but within general distribution pattern of the species
*Possible species - unconfirmed, but at periphery of known distribution of the species

BIRDS OF BRAZORIA AND SAN BERNARD NATIONAL WILDLIFE REFUGES

Welcome to Brazoria/San Bernard National Wildlife Refuges.

The Brazoria and San Bernard Refuges are two of the major goose wintering areas along the Texas Gulf Coast. Over 70,000 snow/blue geese use these refuges, located 10 miles northeast and 10 miles southwest of Freeport, respectively.

This list, containing 273 species, is in accordance with the 6th edition (1983) A.O.U. check-list. Vast cordgrass marshes provide excellent nesting cover for mottled ducks and mud flats exposed around lake edges during low tides create ideal conditions for shorebirds, gulls, and terns. Herons, egrets, and ibises are common sights in and around the many ponds in the lower marsh areas. Warblers, sparrows, and other passerine species are found in the upland wooded areas.

Birding on the refuge is most interesting during the fall and winter months when birds from the northern states have arrived here to spend the winter. Large concentrations of geese can be seen feeding and loafing in low marsh areas.

Symbols of the seasons and abundance status of each species are coded as follows:

S-Spring: March-May
S-Summer: June-August
F-Fall: September-November
W-Winter: December-February

A-Abundant	Common species, very numerous
C-Common	Certain to be seen in suitable habitat
U-Uncommon	Present, but not certain to be seen
O-Occasional	Seen only a few times during a season
R-Rare	Seen at intervals of 2 to 5 years
__________	Threatened or endangered species

*-Nests locally

	S	S	F	W
LOONS				
______ Common Loon				R
GREBES				
______ *Pied-billed Grebe	C	U	C	C
______ Horned Grebe				R
______ Eared Grebe	R		R	C
PELICANS				
______ American White Pelican	C	C	C	C
______ Brown Pelican				R
CORMORANTS				
______ Double-crested Cormorant	C	O	C	C
______ Olivaceous Cormorant	U	U	R	R
DARTERS				
______ Anhinga	O	O	O	O
FRIGATEBIRDS				
______ Magnificent Frigatebird	O	U	O	
BITTERNS AND HERONS				
______ American Bittern	U	O	O	O
______ *Least Bittern	U	U	U	O
______ *Great Blue Heron	A	A	A	A
______ *Great Egret	C	C	C	C
______ *Snowy Egret	C	C	C	C
______ *Little Blue Heron	C	C	C	C
______ *Tricolored Heron	C	C	C	C
______ *Reddish Egret	U	U	U	U
______ *Cattle Egret	A	A	A	A
______ *Green-backed Heron	C	C	U	U
______ *Black-crowned Night-Heron	C	C	C	C
______ Yellow-crowned Night-Heron	U	U	U	O
IBISES AND SPOONBILLS				
______ *White Ibis	C	C	C	C
______ White-faced Ibis	C	U	C	U
______ *Roseate Spoonbill	C	C	C	C
STORKS				
______ Wood Stork		C	U	
SWANS, GEESE, AND DUCKS				
______ Fulvous Whistling-Duck	R		R	R
______ Black-bellied Whistling-Duck	R		R	R
______ Greater White-fronted Goose	O		C	C
______ Snow Goose	O		A	A
______ Ross' Goose	R		R	R
______ Canada Goose	R		U	U
______ Wood Duck	O		O	O
______ Green-winged Teal	C		C	A
______ American Black Duck	R		R	R
______ *Mottled Duck	C	C	C	C
______ Mallard	R		U	U
______ Northern Pintail	U		C	C
______ *Blue-winged Teal	C	R	C	A
______ Cinnamon Teal	O	R	O	U
______ Northern Shoveler	C		A	A
______ Gadwall	U		C	C
______ American Wigeon	U		U	U
______ Canvasback	R		R	R
______ Redhead	U		U	U
______ Ring-necked Duck	O		R	O
______ Greater Scaup			R	R
______ Lesser Scaup	U		U	U
______ White-winged Scoter			O	
______ Common Goldeneye			R	R
______ Bufflehead	O		O	R
______ Hooded Merganser	R		O	U
______ Red-breasted Merganser	R		R	R
______ Ruddy Duck	O		U	U
AMERICAN VULTURES				
______ *Black Vulture	C	C	C	C

	S	S	F	W
______ Turkey Vulture	C	C	C	C
KITES, EAGLES AND HAWKS				
______ Osprey	R		R	R
______ American Swallow-tailed Kite	R	R		
______ *Black-shouldered Kite	C	U	C	C
______ Mississippi Kite	R	R		
______ Bald Eagle	R	R	U	U
______ *Northern Harrier	C	U	C	C
______ Sharp-shinned Hawk	U		U	U
______ Cooper's Hawk	U		U	U
______ Red-shouldered Hawk	C	C	C	C
______ Broad-winged Hawk	R		R	
______ Swainson's Hawk	U		U	
______ *White-tailed Hawk	R	R	R	R
______ Red-tailed Hawk	C	U	C	C
______ Rough-legged Hawk			R	R
CARACARAS AND FALCONS				
______ *Crested Caracara	R	R	R	O
______ American Kestrel	C		C	A
______ Merlin	R		R	R
______ Peregrine Falcon	U		U	U
QUAIL				
______ *Northern Bobwhite	C	C	C	C
RAILS, GALLINULES AND COOTS				
______ Yellow Rail	U		U	U
______ *Black Rail	R	R	R	R
______ *Clapper Rail	C	C	C	C
______ *King Rail	U	U	U	U
______ Virginia Rail	U		U	U
______ Sora	U		U	U
______ *Purple Gallinule	U	U	O	
______ *Common Moorhen	C	C	C	C
______ *American Coot	C	U	A	A
CRANES				
______ Sandhill Crane	U		C	C
______ Whooping Crane			R	
PLOVERS				
______ Black-bellied Plover	U		U	U
______ Lesser Golden-Plover	O	R	O	
______ Snowy Plover	U	U	U	U
______ *Wilson's Plover	C	C		
______ Semipalmated Plover	U	U	U	U
______ Piping Plover	U		U	U
______ *Killdeer	A	A	A	A
______ Mountain Plover	O			
STILTS AND AVOCETS				
______ *Black-necked Stilt	C	C	C	U
______ American Avocet	C	C	C	C
SANDPIPERS AND PHALAROPES				
______ Greater Yellowlegs	C	U	C	C
______ Lesser Yellowlegs	C	U	C	C
______ Solitary Sandpiper	R		U	O
______ *Willet	C	C	C	C
______ *Spotted Sandpiper	U	O	U	U
______ Upland Sandpiper	R		O	
______ Whimbrel	U		U	
______ Long-billed Curlew	C	U	C	C
______ Marbled Godwit	R		R	R
______ Ruddy Turnstone	C		C	C
______ Red Knot	R		R	
______ Sanderling	C	U	C	C
______ Semipalmated Sandpiper	U	R	U	U
______ Western Sandpiper	C	R	C	C
______ Least Sandpiper	C	U	C	C
______ White-rumped Sandpiper	R			
______ Baird's Sandpiper	R			
______ Pectoral Sandpiper	O		O	
______ Dunlin	C		C	C
______ Stilt Sandpiper	U	R	U	
______ Buff-breasted Sandpiper			U	
______ Short-billed Dowitcher	U		U	U
______ Long-billed Dowitcher	C	R	C	C
______ Common Snipe	C		C	C
______ Wilson's Phalarope	R		R	
GULLS, TERNS AND SKIMMERS				
______ *Laughing Gull	C	C	C	C
______ Franklin's Gull	U		U	
______ Bonaparte's Gull	U		R	U
______ Ring-billed Gull	C	U	C	C
______ *Herring Gull*	C	U	C	C
______ *Gull-billed Tern	U	C	U	U
______ Caspian Tern	U	U	U	U
______ *Royal Tern	U	U	U	U
______ *Sandwich Tern	U	U	U	R
______ Common Tern	U	R	U	U
______ *Forster's Tern	C	C	C	C
______ *Least Tern	C	C	U	
______ Black Tern	U	C	U	
______ *Black Skimmer	C	C	U	U
DOVES				
______ White-winged Dove	R	R	R	R
______ *Mourning Dove	C	C	C	C
______ Common Ground-Dove		R		
CUCKOOS AND ANIS				
______ Black-billed Cuckoo	R			
______ *Yellow-billed Cuckoo	O	U	O	
______ Groove-billed Ani	R	R	R	R
BARN-OWLS				
______ Common Barn-Owl	U	U	U	U
TYPICAL OWLS				
______ *Great Horned Owl	U	U	U	U
______ Burrowing Owl	R	R	R	R
______ Barred Owl	C	C	C	C
______ Short-eared Owl				R
GOATSUCKERS				
______ Lesser Nighthawk	R	R		
______ *Common Nighthawk	C	C	C	
______ Chuck-will's-widow	U		R	
______ Whip-poor-will	R		R	
SWIFTS				
______ Chimney Swift	C	C	U	
HUMMINGBIRDS				
______ Ruby-throated Hummingbird	C	U	U	
KINGFISHERS				
______ Belted Kingfisher	U		U	U
WOODPECKERS				
______ Red-headed Woodpecker	R	R	R	R
______ Red-bellied Woodpecker	U	U	U	U
______ Yellow-bellied Sapsucker	U		U	U
______ Downy Woodpecker	C	C	C	C
______ Northern Flicker	U		U	U
______ Pileated Woodpecker	U	U	U	U
TYRANT FLYCATCHERS				
______ Olive-sided Flycatcher	U		U	
______ Eastern Wood-Pewee	C	C	C	
______ Empidonax Sp	U	U	U	
______ Eastern Phoebe	U		U	C
______ Vermilion Flycatcher	C		C	C
______ Great Crested Flycatcher	U	U	U	U
______ Western Kingbird	O			
______ *Eastern Kingbird	C	C	C	
______ *Scissor-tailed Flycatcher	C	C	C	

	S	S	F	W
LARKS				
______ *Horned Lark	C	C	C	U
SWALLOWS				
______ *Purple Martin	C	C	U	
______ Tree Swallow	U		U	O
______ Northern Rough-winged Swallow	C		C	
______ Bank Swallow	U		U	
______ Cliff Swallow	O		R	
______ Barn Swallow	C	C	C	
JAYS AND CROWS				
______ *Blue Jay	C	C	C	C
______ *American Crow	C	C	C	C
CHICKADEES AND TITMICE				
______ *Carolina Chickadee	C	C	C	C
______ *Tufted Titmouse	C	C	C	C
CREEPERS				
______ Brown Creeper			R	R
WRENS				
______ *Carolina Wren	C	C	C	C
______ House Wren	R		U	U
______ *Marsh Wren	C	U	C	C
KINGLETS AND GNATCATCHERS				
______ *Golden-crowned Kinglet*			R	R
______ Ruby-crowned Kinglet	U		U	C
______ Blue-gray Gnatcatcher	U		U	U
THRUSHES				
______ *Eastern Bluebird	U	U	U	U
______ Veery	U			
______ Gray-cheeked Thrush	U			
______ Swainson's Thrush	U			
______ Hermit Thrush	U		O	O
______ *Wood Thrush	U		U	R
______ American Robin	C		C	C
MOCKINGBIRDS AND THRASHERS				
______ Gray Catbird	U		U	R
______ *Northern Mockingbird	C	C	C	C
______ Sage Thrasher			R	R
______ Brown Thrasher	U		U	C
PIPITS				
______ Water Pipit	C		C	C
______ Sprague's Pipit	R		R	R
WAXWINGS				
______ Cedar Waxwing	C			C
SHRIKES				
______ *Loggerhead Shrike	C	C	C	C
STARLINGS				
______ *European Starling	C	C	C	C
VIREOS				
______ *White-eyed Vireo	U	U	U	U
______ Solitary Vireo	O	O	R	O
______ Yellow-throated Vireo	R		R	
______ Warbling Vireo	U		C	
______ Philadelphia Vireo	U		U	
______ *Red-eyed Vireo	C	C	U	
WOOD-WARBLERS				
______ Blue-winged Warbler	U	U		
______ Golden-winged Warbler	U			
______ Tennessee Warbler	C		C	
______ Orange-crowned Warbler	U		U	U
______ Nashville Warbler	U		U	
______ *Northern Parula	C	C	U	
______ Yellow Warbler	C	U	U	
______ Chestnut-sided Warbler	U		U	
______ Magnolia Warbler	C		U	
______ Yellow-rumped Warbler	C		U	U
______ Black-throated Green Warbler	U		U	
______ Blackburnian Warbler	U			
______ Yellow-throated Warbler	U			
______ Palm Warbler	R			
______ Bay-breasted Warbler	C		U	
______ Blackpoll Warbler	U			
______ Cerulean Warbler	U			
______ Black-and-white Warbler	U	R	R	
______ American Redstart	C		U	
______ Prothonotary Warbler	U			
______ Worm-eating Warbler	U			
______ Ovenbird	U			
______ Northern Waterthrush	U		U	
______ Louisiana Waterthrush	U			
______ Kentucky Warbler	U			
______ Common Yellowthroat	C	C	C	C
______ Hooded Warbler	U		U	
______ Wilson's Warbler	U	U	U	C
______ Canada Warbler	U		U	
______ Yellow-breasted Chat	U			
TANAGERS				
______ Summer Tanager	R	R		
______ Scarlet Tananger	R			
CARDINALS, GROSBEAKS, AND BUNTINGS				
______ *Northern Cardinal	C	C	C	C
______ Rose-breasted Grosbeak	R		R	R
______ Blue Grosbeak	U		U	
______ Indigo Bunting	C	U	U	R
______ *Painted Bunting	U	U	U	
______ *Dickcissel	C	C	C	
SPARROWS				
______ Field Sparrow	U		U	U
______ Vesper Sparrow	U		U	
______ Lark Sparrow	O	R	O	R
______ Savannah Sparrow	C		U	C
______ Grasshopper Sparrow	R		R	R
______ LeConte's Sparrow	U		O	U
______ Sharp-tailed Sparrow	U	R	O	U
______ *Seaside Sparrow	C	C	C	C
______ Fox Sparrow				R
______ Song Sparrow	U		U	U
______ Lincoln's Sparrow	U		U	U
______ Swamp Sparrow	U		U	U
______ White-throated Sparrow	U		U	U
______ Dark-eyed Junco				O
MEADOWLARKS, BLACKBIRDS, AND ORIOLES				
______ Bobolink	U			
______ *Red-winged Blackbird	A	A	C	C
______ *Eastern Meadowlark	A	A	C	C
______ Yellow-headed Blackbird	U			
______ Brewer's Blackbird	U		U	U
______ *Great-tailed Grackle	C	C	C	C
______ *Boat-tailed Grackle	C	C	C	C
______ Common Grackle	C	C	C	C
______ *Brown-headed Cowbird	C	C	C	C
______ *Orchard Oriole	U	U	U	
______ Northern Oriole	C		U	
FINCHES				
______ American Goldfinch	U		R	U
OLD WORLD SPARROWS				
______ *House Sparrow	C	C	C	C

AMPHIBIANS AND REPTILES OF BRAZORIA AND SAN BERNARD NATIONAL WILDLIFE REFUGES

REPTILES: Reptiles are clad in scales, shields, or plates, and their toes bear claws. To this class belong the crocodilians, turtles, lizards, and snakes.

AMPHIBIANS: Amphibians have moist, glandular skins, and their toes are devoid of claws. Their young pass through a larval, usually aquatic stage before they metamorphose into the adult form. Belonging to the class Amphibia are the salamanders, frogs, and toads.

* - documented on the refuge
u - unlikely to occur in this area, but should be watched for

AMPHIBIANS

CAUDATA

*	Western Lesser Siren	Siren intermedia nettingi
	Central Newt	Notopthalmus viridescens louisianensis
*	Small-mouthed Salamander	Ambystoma texanum
u	Eastern Tiger Salamander	Ambystoma tigrinum tigrinum

ANURA

u	Hurter's Spadefoot Toad	Scaphiopus holbrooki holbrooki
*	Eastern Narrow-mouth Toad	Gastrophryne carolinensis
	Great Plains Narrow-mouth Toad	Gastrophryne olivacea
	Woodhouse's Toad	Bufo woodhousei woodhousei
u	Houston Toad	Bufo houstonensis
*	Gulf Coast Toad	Bufo valliceps
*	Green Treefrog	Hyla cinerea
	Northern Spring Peeper	Hyla crucifer crucifer
*	Squirrel Treefrog	Hyla squirella
	Gray Treefrog	Hyla chrysoscelis versicolor
u	Strecker's Chorus Frog	Pseudacris streckeri
*	Spotted Chorus Frog	Pseudacris clarki
	Upland Chorus Frog	Pseudacris triseriata feriarum
	Blanchard's Cricket Frog	Acris crepitans blanchardi
*	Bullfrog	Rana catesbeiana
*	Southern Leopard Frog	Rana sphenocephala
	Southern Crawfish Frog	Rana areolata areolata
	Bronze Frog	Rana clamitans clamitans

REPTILES

CROCODYLIA	
* American Alligator	Alligator mississippiensis
TESTUDINES	
* Snapping Turtle	Chelydra serpentina serpentina
u Alligator Snapping Turtle	Macroclemys temminckii
* Stinkpot	Sternotherus odoratus
u Razorback Musk Turtle	Sternotherus carinatus
Yellow Mud Turtle	Kinosternon flavescens flavescens
* Mississippi Mud Turtle	Kinosternon subrubrum hippocrepis
u Mississippi Map Turtle	Graptemys kohni
* Texas Diamondback Terrapin	Malaclemys terrapin littoralis
Texas River Cooter	Chrysemys concinna texana
* Red Eared Slider	Trachemys scripta elegans
* Three-toed Box Turtle	Terrapena carolina triunguis
* Ornate Box Turtle	Terrapena ornata ornata
* Western Chicken Turtle	Deirochelys reticularia miaria
u Texas Tortoise	Gopherus berlandieri
u Midland Smooth Softshell	Trionyx muticus muticus
Pallid Spiny Softshell	Trionyx spiniferus pallidus
Loggerhead Sea Turtle	Caretta caretta
Atlantic Green Sea Turtle	Chelonia mydas mydas
Leatherback	Dermochelys coriacea
Atlantic Hawksbill	Eretmochelys imbricata imbricata
Atlantic Ridley Sea Turtle	Lepidochelys kempi
SQUAMATA, Suborder LACERTILIA	
Mediterranean Gecko	Hemidactylus turcicus
* Green Anole	Anolis carolinensis carolinensis
Texas Horned Lizard	Phrynosoma cornutum
u Texas Spiny Lizard	Sceloporus olivaceus
* Northern Fence Lizard	Sceloporus undulatus hyacinthinus
Southern Prairie Skink	Eumeces septentrionalis oitusirastrus
* Five-lined Skink	Eumeces fasciatus
u Broad-headed Skink	Eumeces laticeps
* Ground Skink	Scincella lateralis
u Spotted Whiptail	Cnemidophorus gularis gularis
Six-lined Racerunner	Cnemidophorus sexlineatus sexlineatus
* Western Slender Glass Lizard	Ophisaurus attenuatus attenuatus

SQUAMATA, Suborder SERPENTES

*	Broad banded Water Snake	Nerodia fasciata confluens
*	Gulf Salt Marsh Snake	Nerodia fasciata clarki
*	Blotched Water Snake	Nerodia erythrogaster transversa
*	Diamondback Water Snake	Nerodia rhombifera rhombifera
	Green Water Snake	Nerodia cyclopian cyclopian
*	Graham's Crayfish Snake	Regina grahami
u	Gulf Crayfish Snake	Regina rigidasinicola
u	Checkered Garter Snake	Thamnophis marcianus marcianus
*	Eastern Garter Snake	Thamnophis sirtalis sirtalis
*	Gulf Coast Ribbon Snake	Thamnophis proximus orarius
	Plains Blind Snake	Leptotyphlops dulcis dulcis
*	Rough Earth Snake	Virginia striatula
*	Marsh Brown Snake	Storeria dekayi limnetes
	Dusty Hognose Snake	Heterodon nasicus gloydi
	Eastern Hognose Snake	Heterodon platyrhinos platyrhinos
u	Texas Night Snake	Hypsiglena torguatajani
	Mississippi Ringneck Snake	Diadophis punctatus stictogenyx
u	Western Smooth Green Snake	Opheodrys vernalis blanchardi
*	Rough Green Snake	Opheodrys aestivus
*	Western Mud Snake	Farancia abacura reinwardti
*	Eastern Yellow-bellied Racer	Coluber constrictor flaviventris
	Western Coachwhip	Masticophis flagellum testaceus
u	Texas Glossy Snake	Arizona elegans arenicola
u	Texas Scarlet Snake	Cemophora coccinea lineri
*	Texas Rat Snake	Elaphe obsoleta lindheimeri
u	Great Plains Rat Snake	Elaphe guttata emoryi
	Louisiana Milk Snake	Lampropeltis triangulum amaura
*	Prairie Kingsnake	Lampropeltis calligaster calligaster
*	Speckled Kingsnake	Lampropeltis getulus holbrooki
	Flat-headed Snake	Tantilla gracilis
*	Texas Coral Snake	Micrurus fulvius tenere
*	Western Cottonmouth	Agkistrodon piscivorous leucostoma
*	Eastern Cottonmouth	Agkistrodon piscivorous piscivorous
*	Southern Copperhead	Agkistrodon contortrix contortrix
u	Western Massasauga	Sistrurus catenatus tergeminus
	Western Pygmy Rattlesnake	Sistrurus miliarius streckeri
	Canebrake Rattlesnake	Crotalus horridus atricandatus
*	Western Diamondback Rattlesnake	Crotalus atrox