CHAPTER 8 – STATE OF THE BAY, THIRD EDITION

The Bay’s Living Resources

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Early European colonists had an abundance of wildlife to serve subsistence needs. Seemingly endless flocks of ducks, geese and swans . . . and a bounty of fish and shellfish. This abundance quickly established a viewpoint that the New World’s wildlife resources were inexhaustible.
—Milton Friend in LaRoe et al. (1995)

Introduction

Galveston Bay and its watershed are home to a diverse array of organisms. Fish and wildlife resources provide some of the area’s greatest economic, recreational, and aesthetic assets. These organisms also serve as useful indicators of the overall condition of the watershed and estuary. Therefore, considerable scientific and management resources are devoted to studying these populations.

Long-term commercial and recreational harvest records show no dramatic examples of collapsing fish or wildlife in the recent past. Historically, a few fishing stocks were overexploited and no longer support a fishery, such as the diamondback terrapin fishery. Most current harvests and fisheries have been productive for many years, albeit with large population fluctuations of most commercial species. There are some wildlife species in the watershed that experienced collapses of populations, such as the Attwater’s prairie chicken (*Tympanuchus cupido attwateri*).

Many factors determine the population size of a given species; among them are habitat quality and quantity, fishing (harvest) pressure, and a host of natural forces such as reproductive rates, predation, competition, and disease. The causal mechanisms affecting the population dynamics of a given species are seldom obvious. Therefore, resource managers must work with the scientific knowledge and tools available while awaiting more research.

Figure 8.1. No examples of collapsing fisheries have occurred in the recent past. The diamondback-terrapin fishery is one historically overexploited Galveston Bay fishery. Image courtesy TPWD.
This chapter summarizes recent findings describing the bay’s living resources. Major taxonomic categories in the food web are considered in separate sections, beginning with the base of the food chain and progressing to higher levels.

**Monitoring the Bay’s Food Web**

The food web is a way of describing how plants and animals relate to each other as consumer and consumed. Food webs can be used to understand how an ecosystem functions and some species or groups of species can be used as indicators. These “indicator species” can be chosen to help evaluate particular environmental conditions (for example, degraded water quality), or they can be chosen as representative of a class of species with similar roles in the food web. Feeding patterns are often summarized by assigning an organism to a particular position in a food chain, i.e. its trophic level. This chapter considers a spectrum of indicator categories with an eye to a generalized evaluation of the biological community in the bay. These categories are:

- **Primary producers**, including phytoplankton (free-floating algae), benthic microflora (microscopic bottom dwelling plants), and higher vascular plants which comprise the habitats discussed in Chapter 7.
- **Primary consumers** (including detritivores) that graze on the phytoplankton, bottom dwelling microflora, and detritus. They include microscopic floating zooplankton and benthic invertebrates. Some benthic invertebrates are good environmental indicators of contaminated sediments.
- **Economically important groups** generally utilizing middle trophic levels. These include finfish and most shellfish. Example species include white shrimp, brown shrimp, and blue crab.
- **Top predators** at the top of the food web, especially sensitive indicators of the trophic levels below them. Examples include spotted seatrout, black tipped shark, southern flounder, and red drum.
- **Species of special interest** including carnivores such as water birds and dolphins and endangered species such as sea turtles.

Species within each of these categories are marked by variability over different temporal and spatial scales, especially fluctuations over the seasonal cycle. Many species are migratory or time their reproduction based upon seasonal water temperatures or food supply. Not all the factors that contribute to changes in populations of these organisms are fully understood. Therefore, making clear distinctions about human induced causes of population change is difficult. Regardless, there are robust datasets that can be used to generate trends and derive other important information. The Texas Parks and Wildlife Department (TPWD) has been collecting fishery-independent monitoring data on the aquatic macroorganisms of Galveston Bay for more than 30 years. In addition, the U.S. Fish and Wildlife Service (USFWS) and National Marine Fisheries Service (NMFS) have long-term monitoring programs for other organisms that obtain important information from which to assess temporal and spatial patterns.
The food webs of Galveston Bay were modeled by McFarlane (1994) during the early status and trends projects of the Galveston Bay Estuary Program. Several of these models were used in the second edition of this volume (Lester et al. 2002). Our understanding of the estuarine food web has changed since the original Galveston Bay food web studies were commissioned, and this volume reflects those changes. A single food web model is presented for the biological community in Galveston Bay (see Chapter 2) and recognizes the trophic connections among all species in the estuary and the extensive trophic connections with the biological communities in the Gulf and freshwater tributaries.

The food web of Galveston Bay is similar to those of other Gulf of Mexico estuaries. We will extrapolate from studies done on other estuaries to describe Galveston Bay phenomena as long as there is ample justification of close similarity. Akin and Winemiller (2006) conducted an extensive study of the food web dynamics in Matagorda Bay at Mad Island Marsh. This estuary is the closest to Galveston Bay in geography and environmental conditions. In their study, Akin and Winemiller found that the food web obtains more energy from detritus than living plants and algae. Energy flows along short food chains, typically consisting of a consumer and 1 or 2 levels of predators. The food web is consistent over seasons, despite changes in species. For example, the shift from juvenile brown shrimp in spring to juvenile white shrimp in fall does little to alter the food web. An even more extensive compilation of trophic information has been compiled by Livingston (2003) from studies of estuaries in Western Florida, which share many species and characteristics with Galveston Bay.

**Primary Production**

As discussed in Chapter 2, primary producers form the base of the food chain. A healthy community of primary producers is necessary to maintain the populations of organisms that exist at higher trophic levels. In the Lower Galveston Bay watershed, there are 6 main primary producer communities ranging from phytoplankton (algae) in open bay water to trees and perennials in the riparian woodlands and swamps bordering the estuary. Each of these communities is partly responsible for the photosynthetic production of organic matter that sustains the estuary’s primary consumers and their predators (Sheridan et al. 1989).

Sheridan et al. (1989) used literature values to estimate primary production for 6 main categories of vegetative communities that occur in the Galveston Bay watershed. The study concluded that phytoplankton, benthic microflora, plants in salt and brackish marshes, and trees in woodlands and swamps all contribute roughly the same quantity of organic food to the estuary. Prairie wetland complexes are also major contributors. It is interesting to note that submerged vegetation had the highest productivity per square kilometer; however, the small area covered by submerged vegetation in the bay made it less significant in terms of the overall amount of energy contributed.

In Chapter 6, the trend in chlorophyll $a$ (see Figure 6.20) is plotted over the entire period of record. The trend shows a significant decline from 1973 to 1999 with a recent increase, such that the trend no longer meets our criteria for significance. As noted in Chapter 6, chlorophyll $a$ is an indicator of the concentration of photosynthetic plankton in the water. There are several possible explanations for decreases and increases in primary productivity. Changes in the concentration of limiting nutrients such as nitrogen and...
phosphorus, due to the improvement of wastewater treatment facilities and the assimilative capacity of reservoirs on the major rivers feeding the bay, are most likely. However, there is no equivalent trend in nitrogen compounds over the period of record. There is a significant downward trend in phosphorus over the time period, but no recent upturn to explain the rebound in chlorophyll $a$. Thus, we have no explanation for the observed pattern in phytoplankton abundance.

There is no clear relationship between the primary and secondary productivity of the food web as indicated by the analysis of data from monitoring of fish and shellfish populations by the TPWD and of the chlorophyll $a$ concentration by the TCEQ. The lack of a relationship suggests that the food web is not adequately defined and should have either additional inputs of energy or outputs to consumers of primary productivity. As explained below, we believe that the energy inputs to the estuary have been inadequately described.

There has been a historic debate about whether living or dead photosynthetic organisms are more important as an energy base in Gulf Coast estuaries. Zimmerman et al. (1991) indicated that, when marshes are drowned as a result of subsidence, they have a period of higher secondary productivity. This means that more energy is available for growth and reproduction of consumer species. As noted above, Akin and Winemiller (2006) conclude that detritus supplies more energy to the food web in Matagorda Bay. On the other hand, Armstrong (1987) concluded that only 5 percent of the carbon and primary nutrients in Galveston Bay originate from peripheral marshes. Sheridan et al. (1989) presented 3 reasons why marshes and detritus may be more important than phytoplankton: (1) zooplankton in the bay generally occur in low densities, indicating a relatively low level of direct grazing on phytoplankton (TDWR 1981); (2) Texas salt marshes are high producers of herbaceous matter when compared to marshes in other Atlantic and Gulf Coast states (Turner 1976); and (3) many bay species grow up to be omnivores or carnivores, relying upon phytoplankton only in their larval stages (Gosselink et al. 1979). In our opinion, the evidence supports the conclusion that the food web in Galveston Bay obtains more energy from detritus than from living plants.

Increased water coverage—due to factors such as subsidence, erosion, and relative sea-level rise—leads to a more rapid decomposition of organic matter than in stable marshes. This increase in the release of organic matter from the plants and the sediment continues until the marsh is succeeded by open-bay habitat. This creates a temporary benefit for fish, invertebrates, birds, reptiles, and mammals that use the marsh. The potential for relative sea level rise in the future may provide the opportunity to examine this phenomenon in greater detail.

The contribution of the watersheds of Galveston Bay’s tributaries to the nutrients and detritus supporting the biological resources in the bay is poorly understood. Much of the primary production contributing detritus to the bay is separated in time and space from the estuary’s primary consumers, which increases the uncertainty of its contribution to the estuarine food web. For example, woodlands, swamps, and freshwater marshes export less than 10 percent of their primary productivity as detritus to consumers in the bay because of their relative isolation from bay waters, whereas saltwater marshes may export 35–40 percent (Gosselink et al. 1979; TDWR 1981). It is clear that the addition of reservoirs has increased the ability of the bay’s watersheds to assimilate the nutrients and suspended solids from upstream sources before they can reach the bay (Gosselink et al. 1979; TDWR 1981; Jensen et al. 2003).
Phytoplankton

Phytoplankton are microscopic algae and bacteria that drift with the motion of the currents and produce organic matter by photosynthesis. A shortage of phytoplankton can deplete the food supply of primary and higher consumers such as oysters, shrimp, fish, and birds. Excessive production of phytoplankton, usually caused by enhanced levels of nutrients, can exert high oxygen demand on the water through nocturnal respiration and decomposition following death. Low dissolved oxygen levels resulting from excessive growth of phytoplankton and bacteria are commonly found in the tributaries of the bay, but not in the subbays. Galveston Bay shows no signs of becoming eutrophic (i.e. having an excess of nutrients and algal production, based on comparisons with other Gulf estuaries) (EPA 2006).

Over 132 species of phytoplankton have been documented in Upper Galveston and Trinity bays, with diatoms (54 taxa), green algae (45 taxa) and blue-green algae (14 taxa) being dominant (TDWR 1981). Armstrong and Hinson (1973) identified the dominant genera in 1969 for Trinity Bay, Upper Galveston Bay, Lower Galveston Bay, East Bay, and West Bay. Other studies revealed that diatoms and green algae were dominant during most seasons, whereas cyanobacteria can dominate during summer (Zotter 1979; Pinckney et al. 2002). Occasionally certain species of planktonic algae exhibit exponential growth in density and create algal blooms. Some blooms are of concern to resource managers or public safety personnel because they produce toxins.

Phytoplankton are commonly subdivided based on their size. In Texas estuaries, small nanoplankton (less than 20 microns) dominate both numerically and in total biomass when compared to larger phytoplankton (Stockwell 1989; Pinckney et al. 2002). In general, phytoplankton densities in Galveston Bay are lower than in many other estuaries (1981). During 2000 and 2001, Ornolfsdottir (2002) found that the standing biomass of phytoplankton was moderate compared to other estuaries and far from eutrophic as reported by U.S. Environmental Protection Agency in its Coastal Condition report (USEPA 2001). Diatoms were the major taxonomic group and the community composition changed little over seasons. Cyanobacteria became more abundant in the summer months. The total phytoplankton biomass increased in response to additional nutrients associated with freshwater inflow. However, the abundance of specific groups of phytoplankton was only weakly correlated with environmental conditions, such as nutrient concentration. In comparison to more temperate estuaries, the phytoplankton community structure in Galveston Bay is relatively stable over time and space.

Trends in Space and Time

Phytoplankton productivity in the bay can be monitored by sampling the water column for chlorophyll $a$, the green pigment used by plants during photosynthesis. Ward and Armstrong (1992) indicated some possible areas of high chlorophyll $a$ abundance, such as Clear Lake, Black Duck Bay, and Trinity Bay near the Cedar Bayou Generating Station outfall. Work performed by the Texas Department of Water Resources (1981) and Sheridan et al. (1989) suggested that, in low salinity regimes, cyanobacteria and green algae dominate, whereas higher salinity sites are dominated by diatoms. More recent work correlates prevalence of cyanobacteria with environments that exhibit high temperature, low salinity, high phosphate and high silica, whereas diatoms tend to have the opposite associations (Ornolfsdottir 2002). These correlations support an association of cyanobacteria with the upper bay and tributaries, and an association of
diatoms with the lower bay and the Gulf passes. In the same study, cryptophytes were the only group correlated with increased inorganic nitrogen; these phytoplankton are largely transported into the bay from the rivers.

There is some evidence of an increase in chlorophyll $a$ from the late 1950s to the 1970s (Buskey et al. 1992). Since the 1970s, routine monitoring data for chlorophyll $a$ indicate a declining trend in the measured concentration until 2000 (Ward and Armstrong 1992) (Figure 6.20). Mean chlorophyll $a$ concentrations fell by more than 75 percent throughout much of the Galveston Bay watershed from 1972 to 1999, but they have rebounded to moderate levels. In 1972, the monthly chlorophyll $a$ concentration averaged over all samples taken in the bay and tidal tributaries was 28.5 micrograms per liter ($\mu$g/L). Chlorophyll $a$ concentrations averaged over all samples collected in the bay and tidal tributaries for 2007 yield an average concentration of 7.9 $\mu$g/L. This trend in chlorophyll $a$ measurements indicates that phytoplankton biomass levels are lower than levels typical of Galveston Bay in the 1950s. Mean chlorophyll $a$ concentration from Zein-Eldin (1961), sampling an embayment of Galveston Bay in the late 1950s, was 16 $\mu$g/L, which compares closely to an overall mean of 13 $\mu$g/L and 17 $\mu$g/L for stations in Trinity Bay measured by Mullins (1979) and Strong (1977), respectively. Measurements of phytoplankton biomass at 7 stations in Galveston Bay collected from May 1999 to December 2001 using chlorophyll $a$ concentrations ranged from an average of 5.18 to 20.77 $\mu$g/L (Pinckney et al. 2002).

It should be noted that the methodologies of these studies are not all comparable. The long-term TCEQ database is limited by the spatial distribution of the samples it contains. Many of the water samples come from tributaries and not from open bay waters. The concentrations of chlorophyll $a$ in tributaries are not highly correlated with concentrations in the open bay, just as the species composition of the phytoplankton communities in the tributaries has little relationship to the species found in the open bay.

Possible Causes of Trends
Changes in abundance of primary producers in ecosystems are usually attributed to modifications in reproduction and growth or consumption. There are 3 potential hypotheses to explain the observed decline and subsequent rebound in chlorophyll $a$ concentration in Galveston Bay waters.

First, changing concentrations of one or more limiting nutrients could be causing a change in primary production and phytoplankton concentration (Ward and Armstrong 1992). A decline in nutrients could be inferred from reduced point source loadings from permitted discharges (Ward and Armstrong 1992; Jensen et al. 2003). The efficiency of wastewater treatment plants has improved since the passage of the federal Clean Water Act. In addition, there is a high assimilative capacity for nutrients in the reservoirs on the major rivers that were built near the time of implementation of wastewater permitting. In addition, the shift away from agricultural production in the lower watershed is likely to have resulted in reduced fertilizer use due to changes in land use. These likely changes in the availability of limiting nutrients are observable in the long-term data on nutrient concentrations when the entire watershed is considered, but the trends are considerably weaker when only the nutrient data obtained from stations in the bay are used. Total phosphorus measured at stations in the bay still showed a significant decline over the 34-year period, with the lowest means from 1994 to 1996. The indicator of nitrogen availability, which combines nitrate,
nitrite, and ammonia, shows a weaker declining trend with a similar minimum period from 1993 to 1997. The annual means of these nutrient measures started to trend upward in 1997 or 1998, whereas the upward trend in the indicator of phytoplankton abundance (i.e. chlorophyll $a$ plus pheophytin) did not start an upward trend until 2000. The wastewater treatment plants, reservoirs, and land use changes associated with the long-term downward trend have not been reversed to provide an explanation of the rebound in chlorophyll $a$ concentration since 1999. In addition, the period of rebound includes wet and dry years, which should differ in the loadings of nutrients from nonpoint sources.

Second, a decline in phytoplankton might be the result of an increased population of filter feeders, such as oysters, clams, or Gulf menhaden. In selected areas of San Francisco Bay, for example, the unintentional introduction of the Asian marine clam (*Potamocorbula amurensis*) resulted in a phenomenal tenfold reduction in phytoplankton levels in 2 years (Monroe et al. 1992). While this clam is not found in Galveston Bay, Powell et al. (1994) identified a substantially higher oyster reef area in 1992 than was documented for the 1950s and early 1970s (see Chapter 7). Whether the oyster population expanded between the studies in the 1950s and 1990s or the methodology used in the recent study was more sensitive, and better able to detect the presence of oyster shell, is unknown. The shift in chlorophyll $a$ concentration in recent years is not mirrored, to our knowledge, in a change in bivalve abundance. If filter feeding is controlling the concentration of phytoplankton, then the decimation of oyster reefs by sediment carried by the storm surge of Hurricane Ike might well result in an increase in phytoplankton abundance in the bay.

Third, the concentration of phytoplankton could be regulated by the grazing of zooplankton and other planktivorous species. There is limited information on the zooplankton community in Galveston Bay, as noted below, but this is a documented relationship in other water bodies. However, we do not currently have a process for examining relationships between chlorophyll $a$ concentration and zooplankton abundance in Galveston Bay.

**Toxic Blooms and Red Tides**

When present in large enough concentrations, some species of phytoplankton can harm the health of marine life and humans. Some toxic algae cause shellfish-associated illnesses in humans (see Chapter 9) while others have an effect on finfish populations.

Red tides are blooms, or high concentrations, of toxic phytoplankton often resulting in fish kills and water discoloration. These red tides are occasionally observed inside Galveston Bay, but are typically uncommon. The usual bloom organism is a species of dinoflagellate (*Karenia brevis*) commonly found in offshore waters, but in small concentrations. When conditions favor its growth (high salinity, calm waters and warm temperatures), the phytoplankton blooms to concentrations large enough to affect the health of marine life and humans.

The Texas red tide organism produces brevetoxin, a neurotoxin that can paralyze the muscles and nerves of fish, causing them to suffocate. At a concentration of 100 to 200 cells per milliliter of water, enough toxin is produced to affect fish populations (Denton 2001). Shellfish can also accumulate the toxin, causing neurotoxic shellfish poisoning (NSP) in humans who ingest the contaminated tissue. Additionally, wave
action can send the neurotoxin airborne allowing it to irritate the eyes and upper respiratory tract of humans.

A major outbreak of red tide occurred off much of the Texas coast in 1986. Between that time and the late 1990s, the frequency of red tide events along the Texas coast increased (Denton 2001). During the summer and fall of 2000, a large occurrence of red tide was observed along the coast from Sabine Pass to Mexico. Fish kills related to the 2000 bloom were reported in Lower Galveston Bay. Shellfish beds were closed to harvesting because cell concentrations exceeded the criterion of 5 cells per mL. Galveston Bay oyster beds were closed for many weeks in the summer of 2000, the first time they had been closed due to a toxic algal bloom (Denton 2001; Evans et al. 2001). Red tides were observed along the Texas coast south of Galveston Bay in 2005 and 2006. No K. brevis bloom has occurred in Galveston Bay since 2000 (Evans and Hiney 2001; Pinckney et al. 2002; TPWD 2009b).

In addition to K. brevis, blooms of other toxic dinoflagellates have been reported from Galveston Bay. *Prorocentrum minimum* appears to bloom in the winter and may grow to account for over 40 percent of the phytoplankton biomass; it was observed in winter 2001. In April 2010, elevated levels of *Dinophysis* caused the Texas Department of State Health Services (DSHS) to close (temporarily) Texas coastal waters from Galveston to Port Aransas to the harvest of oysters, clams, and mussels. *Dinophysis* is a dinoflagellate that produces okadaic acid, a toxin that can accumulate rapidly in shellfish tissue, causing diarrheic shellfish poisoning (DSP).

**Macrophytes**

As mentioned above, ecosystems with vascular plants as the dominant primary producers contribute as much or more carbon to the Galveston Bay system as phytoplankton. The dominant form of primary producers in swamps, marshes, and seagrass meadows are the grasses and trees familiar to humans. They reproduce by flowers and seeds and provide a 3-dimensional structure to habitats.

Marshes and seagrass beds have declined over historical time in the bay. It is estimated that over 35,000 acres of emergent wetlands have disappeared in the last 50 years. The majority was freshwater emergent marsh and around 9,000 acres was salt and brackish marsh. From a species perspective, this means that the population of wetland plant species, including *Spartina alterniflora* (smooth cordgrass), declined. Other plant species that are salt marsh specialists, such as *Salicornia virginica* (glasswort), will have experienced the same loss of abundance. Intertidal marsh restoration projects usually revegetate areas with *S. alterniflora* only. The diversity of macrophyte communities in these restored marshes is lower than natural marshes for some time (Minello et al. 1997). However, there are coastal preserves, national wildlife refuges, parks, and protected areas which are managed to maintain the historical biodiversity of such wetlands.

Submerged aquatic vegetation has also exhibited a decline in abundance over historical time in Galveston Bay. *Ruppia maritima* (widgeongrass) is much less abundant in Trinity and Upper Galveston Bays than it was in the 1950s. *Halodule wrightii* (shoalgrass), *Halophila engelmanii* (clovergrass), and *Thallasia testudinum* (turtlegrass) are less abundant than in the 1950s. The decline in abundance of seagrass affects other species through loss of habitat. Seagrass meadows are an ideal habitat for juveniles of many macroinvertebrates and fish species. Many of these seagrass species are important food items for overwintering waterfowl and sea
turtles. The animals that inhabit the vegetated beds are important prey for wading birds, shorebirds, and predatory fish.

Other macrophytes exhibit changes in abundance in the Galveston Bay system. During periods with warm winters, black mangrove, *Avicennia germinans*, can become established and grow near the Galveston Bay passes, only to be killed by low winter temperatures. Tolan and Fisher (2009) documented increasing winter temperatures in coastal waters south of Galveston Bay associated with concomitant increases in abundance of tropical fish species such as the gray snapper (*Lutjanus griseus*). Black mangrove is likely to become a permanent feature of the plant community with further warming.

Other species are influenced by the salinity regime of the bay system. Sedges, rushes, and cattails can grow among the cordgrass in low salinity areas, but may be killed by salinity rise during drought periods or by inundation due to surge from a tropical storm.

Among the terrestrial plant species found in the lower Galveston Bay watershed, very few are exhibiting population trends that elicit regulatory or management responses from agencies or conservation groups. Of 217 species on the list of Texas rare plants published by the Nature Conservancy in cooperation with the TPWD, only 5 species occur in the counties of the lower Galveston bay watershed: Texas prairie dawn (*Hymenoxys texana*), coastal gayfeather (*Liatris bracteata*), Grand Prairie evening primrose (*Oenothera pilosella ssp. Sessilis*), Houston daisy (*Rayjacksonia aurea*), and three flower broomweed (*Thurovia triflora*). Texas prairie dawn is listed as endangered by the TPWD (2009a) and is protected. Clearly, many species of native trees, shrubs, wildflowers, and grasses are less abundant today than 100 years ago because the density of human settlement has increased greatly. Some of these declining species are preferentially propagated in habitat restoration projects, such as the planting of tall prairie grass species in prairie restoration projects.

Introduced species, such as water hyacinth, can become a problem in some of the tidal reaches of bay tributaries, but their distribution is limited by their salinity intolerance. The Chinese tallow tree, a highly successful invader, is the dominant plant species on thousands of acres of native habitat, thereby reducing the abundance of native grasses and forbs. It is tolerant of hydric soil and has invaded and become dominant in numerous wetlands across the watershed. We are hopeful that other invasive plants will have less significant impacts on the native plant communities in this watershed.

**Zooplankton**

Zooplankton are microscopic drifting animals that feed on phytoplankton or smaller zooplankton. Factors controlling zooplankton abundance are not well understood in Texas estuaries. Large increases in zooplankton populations are often observed after extensive flushing of estuaries from high river runoff (Buskey 1989). Galveston Bay may have lower zooplankton abundance than many other Texas estuaries (Buskey and Schmidt 1992), with a typical range for Trinity Bay of 1,200 to 16,000 zooplankton per cubic meter of water. Buskey (1993) reported a mean abundance of mesozooplankton in Nueces Bay of 6,100 per m³ in daytime samples. Rey et al. (1991) measured zooplankton densities (size > 63µ) in the Indian River Lagoon in Florida that exceeded 400,000 per cubic meter. The status and trends of zooplankton in
Galveston Bay are more difficult to determine than those of phytoplankton because of the lack of long-term studies and use of variable sampling techniques by different researchers.

**Benthic Organisms**

*Benthos* refers to organisms that live in, on, or near the bottom, including plants, invertebrates, and fishes of all sizes. Benthic organisms are an important component of the estuarine food web. Fish (including Atlantic croaker, spot, mullet, and drum) and birds (including ducks and other waterbirds) feed upon benthic organisms. Recent research has determined that marsh benthos have a larger effect on estuarine fish populations than previously thought (i.e., juveniles of many fish species consume benthic organisms in tidally flooded marshes) and that the marsh edge is the most productive portion of this habitat (Zimmerman 1992; Whaley et al. 2002).

Benthic organisms are good environmental indicators of contaminant impacts because their relative immobility results in their continual exposure to any pollutants bound to sediments. Because anoxia is generally most severe near the bay bottom (e.g. in the Houston Ship Channel), they are first to experience the effect of oxygen depletion. Environmental stressors often cause a normally high benthic community diversity to decline to a suite of fewer, stress-tolerant species. Figure 8.2 shows the abundance and distribution of pollution-tolerant benthic oligocheate worms based on sampling surveys conducted by Broach (2007), NOAA (2007), and the TCEQ (2008). The studies were not designed to determine the effects of natural and anthropogenic stressors. The observations described below are limited to noting correlations and spatial similarities based on knowledge of the bay’s environment.

Sampling of benthic invertebrates is performed by dredging or coring to collect sediment samples, which are then sieved to separate organisms from the sediment. These organisms are then preserved for identification. During 1976 and 1977, White et al. (1985) collected core samples at 1 mile spacing in Galveston Bay to define benthic assemblages and to measure the physical and chemical characteristics of the sediment. Typically, 1 or 2 species dominated a community composed primarily of polychaetes (marine worms), mollusks, and crustaceans. Muddy bottoms supported a richer polychaete community, while sandy bottoms were found to support more crustaceans. Ray et al. (1993) concluded that observed patterns in benthic assemblages were primarily attributable to the prevailing salinity regime and secondarily influenced by substrate type.
White et al. (1985) reported that Galveston Bay exhibited low to moderate benthic diversity, with the highest diversity in areas with stable salinity regimes (e.g., near inlets such as Bolivar Roads and Rollover Pass). Clear Lake, the San Jacinto River, and the Houston Ship Channel had much lower species diversity than any of the open bay stations. Open bay benthos generally increased in abundance from the Trinity Bay—Upper Galveston Bay region to the Lower Galveston Bay—West Bay region (Harper 1992). Sampling surveys conducted by Broach (2007), NOAA (2007), and the TCEQ (2008) confirm this pattern. Collections from the Houston Ship Channel had lower diversity when compared to other less affected areas of the bay. For example, samples collected from West Bay in the summers of 1989 and 2000 had 80 and 48 species, respectively, whereas a sample from the Houston Ship Channel in the summer of 2000 contained 9 species.

A seasonal trend occurs, with peak abundance in the spring—between February and May—and decline in October and November (Harper 1992). As open bay benthos are very good indicators of salinity stress, freshwater floods can alter this cycle. Benthic organisms are also used as indicators of pollution due to the stress responses of individual species and the response of community composition.

Data describing benthic community composition were obtained from Dr. Linda Broach of the TCEQ. Her sampling survey was performed from 1988 to 2000 for water quality analysis. We combined her data and other benthic data from TCEQ’s SWQM database with the NOAA National Benthic Inventory (NBI) to create the maps described below. The entire database covers a period of record from 1972 to 2004. Several pollution-tolerant species were selected for analysis to illustrate the efficacy of benthic data in detecting pollution patterns.

Figure 8.2 depicts densities of oligochaetes (freshwater segmented worms). Oligochaetes are identified as indicators of pollution (Montagna et al. 1995). The highest densities in Galveston Bay (shaded red) occur in the Houston Ship Channel, the most polluted area of the bay in terms of sediment contaminants. Note that densities in other freshwater tributaries such as Clear Lake are low (shaded green), suggesting that salinity is not the only factor affecting the pattern (Gonzalez et al. 2008).

Figure 8.3 depicts densities of Streblospio (a marine polychaete worm). Streblospio is also identified as a genus that is indicative of pollution (Montagna and Kalke 1995). The highest densities in Galveston Bay (shaded...
red) occur in the Houston Ship Channel, Clear Lake and the Texas City channel. Other hot spots are seen near the prior location of Redfish Bar, in Trinity Bay, and near the Bolivar Peninsula. The area of Trinity Bay with high densities of \textit{Streblospio} has significant oil and gas exploration and production. The area of high \textit{Streblospio} abundance near the Bolivar Peninsula is close to several industrial facilities sited on the ICWW. Oligochaetes seem to exhibit a pattern in response to salinity as well as pollution. However, \textit{Streblospio} exhibits an abundance distribution illustrative of pollution from industrial or high-density development in low and high salinity areas.

Marsh areas are vital ecological components in nutrient cycling, and serve as habitat for many types of plants and animals. Zimmerman (1992) studied benthic fauna of 6 marshes in the Galveston Bay complex near Christmas Bay, Galveston Island State Park, Smith Point, Moses Lake, and Inner and Outer Trinity Delta. He concluded that marsh-dwelling benthos in the bay are generally composed of the same species found in other Gulf Coast estuaries, with over 90 percent of the infauna consisting of marine worms and small crustaceans. Densities of marsh infauna and epifauna were generally higher on the marsh surface than in bare subtidal habitat adjacent to the marsh. In the marsh itself, infauna were usually more numerous when associated with plants, than in the bare substrate of marsh embayments and channels. The relationship of marsh edge to high benthic abundance and high habitat use by consumer species has been confirmed (Whaley and Minello 2002).

Spatially, the highest densities and greatest species richness occur in the mid-salinity marshes near Moses Lake and Smith Point. Temporally, marsh infauna display a seasonal periodicity, peaking in abundance in the late winter and early spring (Zimmerman 1992). The abundance of benthic predators is strongly correlated with this seasonal pattern; shrimp, crab, and fish predators are more abundant in warm weather. Zimmerman et al. (1991) indicated that marshes drowned as a result of subsidence have a period of higher secondary productivity.

\textbf{Figure 8.3. Map depicting densities of pollution-tolerant \textit{Streblospio}.} Data sources: (Broach 2007; NOAA 2007; TCEQ 2008).
Oysters

Physical and Biological Factors

Water circulation is an important factor influencing oyster reef location. Accreting reefs are seldom located at the mouths of rivers or in the Gulf passes. Reefs form across a gradient of salinities and depths. The exact causal mechanisms that determine the relationships between freshwater inflow, salinity, and oyster production are complex and not completely understood. Periods of high freshwater inflows have a role in controlling the levels of parasites and predators on the reefs (Ray 1987; La Peyre et al. 2007), but there is disagreement on the relationship between freshwater inflow and productivity. Turner (2006) published an evaluation of the potential impact of a freshwater diversion in Louisiana on oyster harvests. Using historical harvest data from estuaries in the northern Gulf of Mexico that included Galveston Bay, he concluded that high freshwater inflows in the estuaries are correlated with low landings. This paper generated a response from biologists in Texas, who used the TPWD fishery independent data on oyster catch per unit effort (CPUE). Buzan et al. (2009) concluded that there is a linear relationship ($R^2 = 0.29$) between market oyster CPUE and annual freshwater discharge 2 years before the sample was collected. Differences in the methodologies of these analyses make them difficult to compare.

Montagna and Kalke (1995) state that only those Texas bays with high rates of freshwater inflow support a productive shellfish industry. Specific water flow requirements for Texas oysters are not determined (Quast et al. 1988). However, Wilson-Ormand et al. (1997) concluded that water flow rate is most likely a greater limiting factor than food concentration in determining oyster population densities.

While oysters are typically found in areas where long-term salinity ranges between 10 and 30 practical salinity units (psu), salinity effects on the population depend largely on the range of fluctuation and rate of change (Quast et al. 1988). Data from 23 years of reef sampling indicated the best spat sets (corresponding, in commercial terms, to an oyster crop) occurred when spring salinity ranged between 17 and 24 psu. The poorest sets occurred when salinity dropped below 8 psu (Hofstetter 1983).

Factors that stress oyster populations include competition, parasites, diseases, and predation. While the effect of salinity on oyster productivity and reef development is under debate, it is firmly established that salinity is a critical factor influencing oyster survival through its effect on predator abundance and rates of parasitic infection. The most important invertebrate predator, the oyster drill, experiences changes in activity and survival as salinity declines. Increased mortality is usually associated with a rapid drop in salinity to $< 10$ psu, but mobility, and thus prey destruction, is likely to decline at salinities below 15 psu (Butler 1985).

One of the most important of these biological stresses in Galveston Bay is infection by “Dermo” (*Perkinsus marinus*), a protozoan parasite that thrives in warm waters of relatively high salinity (Powell et al. 1994). Mortality of market oysters in Galveston Bay resulting from this parasite can range from 10 to 50 percent annually. A short-term lowering of salinity (less than 5 psu for 2 weeks) is beneficial to oysters because it reduces infection levels by *Perkinsus* (Powell et al. 1994; La Peyre et al. 2009). The quantity and timing of suitable freshwater inflows is significant because salinity directly affects mortality due to predators, and mortality or morbidity due to parasitic infection.
The Oyster Sentinel website (Ray et al. 2007) is one tool in the effort to manage Dermo in Galveston Bay. The website provides a continuous record of the incidence of this parasite at specific reefs in the Galveston Bay system since 1998.

**Trends in Space and Time**

Old maps of the Texas coast (Turney 1958; Rehkemper 1969) show more extensive shoreline oyster reefs than are seen today in Galveston Bay. Commercial shell dredging that operated until the 1970s greatly diminished oyster reefs.

Research by Powell et al. (1994) indicated an increase in overall oyster reef area since the 1970s. In the last edition of this book, we discussed the gradual temporal changes that have been documented in Galveston Bay oyster reefs. However, Hurricane Ike covered about 60 percent of the oyster reefs in Galveston Bay with sediment and completely changed the distribution of this organism (FEMA 2008). This event was the primary determinant of the health of oyster reefs in the bay at the time of preparing this manuscript. It will take a very long time for this resource to recover, and it will recover under a set of conditions that differ from when the now buried reefs established themselves. The TPWD is currently surveying the bay bottom with more advanced instrumentation to document the conditions and guide their strategy for restoration. The TPWD is using a swathe side-scan sonar system with integrated GPS. Powell’s system provided a small path of bottom coverage directly under the transducer and ground-truthed using a small oyster dredge. The TPWD’s system will provide 100 percent coverage of the bay bottom and is being ground-truthed using oyster dredges and geo-referenced digital video.

**Finfish, Shrimp and Crab Populations**

The Galveston Bay system maintains important recreational and commercial fisheries for shrimp, crabs, and fishes. Scientific monitoring of these biological resources conducted by TPWD (2010) will be used here to assess trends in fishery organisms because the data provide better information than commercial landings to estimate population sizes (Green et al. 1992; Green et al. 1993). These collections also play an important role in the effort to manage freshwater inflow to ensure a sound ecological environment for the bay.

TPWD has several techniques for monitoring finfish and shellfish communities, including bag seines for collecting smaller organisms in near-shore environments, trawls for collecting organisms found on or near the open bay bottoms, gill nets for catching larger fish near shore, and oyster dredges for sampling the oyster reef community. Data are compiled by the Galveston Bay Status and Trends program (Gonzalez and Lester 2008) as catch per unit effort (CPUE), defined as the number of individual fish or shellfish caught for a given area seined or time trawled, or as relative abundance (RA), in which the catch of a particular species is divided by the total number of animals captured.

The temporal trends for several selected species are presented in this section based on our analysis of the most recent TPWD data (inclusive of 2007) We arbitrarily set a criterion of 0.25 coefficient of determination (R²) to define whether a trend is increasing or decreasing. The data do not allow causal explanations of the trends. Changes in abundance of particular species could have many possible causes, such as changes in predation, disease, prey levels, or physical environment. White and brown shrimp and
blue crab were selected because of their commercial importance and association with sediment. Five finfish species were selected for detailed presentation. The spotted seatrout is a top carnivore of the open bay and an important recreational species. Gulf menhaden are important planktivores and detritivores in the open bay and useful as indicators of plankton biomass. Atlantic croaker and southern flounder are benthic predators useful as indicators of benthic community health. Gafftopsail catfish is a species of interest because it is involved in the recent seafood advisory covering most of the Galveston Bay system (see Chapter 9). We will also discuss the possibility of range expansion of more tropical species into Galveston Bay.

Trawling studies by the TPWD have identified about 13 species of shrimp, 17 species of crab, and over 150 finfish species in Galveston Bay (Parker 1965; McEachron et al. 1977; Green et al. 1992). The TPWD Coastal Fisheries monitoring data indicate that the overall status of the Galveston Bay aquatic community appears to be good.

Selected Species Summaries

White and Brown Shrimp
TPWD’s bag seine collections capture small shrimp (average size of 5 cm in length) along vegetated and non-vegetated shorelines. Shrimp trawl collections capture the larger shrimp (average size of 9 cm in length) as they occupy the open bay bottom and make their way to the Gulf. Sampling by bag seine of white shrimp (*Litopenaeus setiferus*) and brown shrimp (*Farfantepenaeus aztecus*) show large fluctuations among years in the abundance of both species in the nursery habitats. Figure 8.4 shows that the catch per unit effort (CPUE) of small white shrimp exhibits an increasing trend in Trinity Bay. They had densities of less than 500 per hectare in 1978 to 1981, but the CPUE rose to more than 2,000 per hectare in 2005 and 2006. However, this species does not show any trend in CPUE for bag seine samples in the other subbays. Shrimp species catches are naturally variable. No trend is apparent over the historical record for CPUE of small brown shrimp sampled with bag seines in any part of Galveston Bay. The record in West Bay has a range from just below 200 small shrimp per hectare to over 1,300 per hectare (Figure 8.5).

A strong decline in white shrimp was observed in trawl samples from 1982 through 1990 (Green et al. 1992). As seen in Figure 8.6 the sharp decline of white shrimp CPUE for trawl samples was followed by a period from 1992 to 2009 of highly variable years. Brown shrimp do not exhibit any trend in CPUE for shrimp trawl samples in Galveston Bay and its subbays (Figure 8.7).
Figure 8.4. White shrimp collected in bag seine in Trinity Bay, 1977–2009. Data source (TPWD 2010).

Figure 8.5. Brown shrimp collected in bag seine in West Bay, 1977–2009. Data source (TPWD 2010).
Figure 8.6. White shrimp collected in trawl in Upper and Lower Galveston Bay, 1982–2009. Data source (TPWD 2010).

Figure 8.7. Brown shrimp collected in trawl in Upper and Lower Galveston Bay, 1982–2009. Data source (TPWD 2010).
**Blue Crab**

In many years prior to 1998, more blue crabs (*Callinectes sapidus*) were commercially harvested in Galveston Bay than in any other Texas estuary. Since 1998, Galveston Bay has not produced the leading harvest of this species. In 2005 Galveston Bay was in fifth place in commercial harvest; Sabine Lake, Matagorda Bay, San Antonio Bay, and Aransas Bay had higher harvests (Sutton et al. 2007).

Blue crabs captured in shrimp trawls of Galveston Bay by the TPWD, in their fishery independent monitoring program, show a negative trend in CPUE in all subbays sampled. The trend is very strongly negative in Trinity and Upper and Lower Galveston Bays as shown in Figure 8.8 and Figure 8.9. The CPUE declines of blue crabs in Trinity Bay trawl samples (Figure 8.8) tracks consistently down from the mid 1980s through 2009. The pattern of decline in Upper and Lower Galveston Bays is similar (Figure 8.9). Recruitment does not appear to be a problem because CPUEs for bag seine samples are nearly flat from 1977 until 2009 as shown in Figure 8.10 and Figure 8.11.

![Figure 8.8. Blue crab collected in trawl in Trinity Bay, 1982–2009. Data source (TPWD 2010).](image)
Figure 8.9. Blue crab collected in trawl in Upper and Lower Galveston Bay, 1977–2009. Data source (TPWD 2010).

Figure 8.10. Blue crab collected in bag seine in Trinity Bay, 1977–2009. Data source (TPWD 2010).
The blue crab’s life cycle is fairly complex and may be altered by a variety of natural processes and human changes to the estuarine environment. Factors possibly affecting the blue crab population include habitat alteration, fishing pressure, pollutant contamination, and nutrient loadings. Over the last 10 years, fringing wetlands have been relatively stable in the area (See Chapter 7) and do not explain the decline of blue crabs. Engel and Thayer (1998) measured the amount of hemocyanin (the blue pigment responsible for oxygen transport in many arthropods) in blue crabs collected from the Houston Ship Channel. They found that hemocyanin concentrations varied inversely to the degree of organic contamination. However, the Houston Ship Channel has exhibited lower concentrations of most organic pollutants while the blue crab population has been declining. It is possible that the crab is affected by specific organic compounds that have not declined. The TDSHS has issued seafood consumption advisories for blue crab and finfish in the upper Houston Ship Channel (see Chapter 9).

While contaminant stress may play a role, fishing pressure (indirect) is more likely to provide an explanation of the decline in blue crab. In 1997, under its license management program, the TPWD capped the number of licenses available in the fishery and initiated a voluntary license buy-back program. To date there have been 10 buyback rounds in which 42 licenses—15 percent of the total—have been retired coastwide at an average price of $5,763 per license (Robinson 2009).
The TPWD has also introduced a program to remove lost crab traps. Neglected traps are no longer used by anglers but remain on the bay bottom lost or forgotten, continuing to catch their target species, blue crab. Additionally, the traps pose a safety hazard to recreational boaters and commercial and recreational anglers. Senate Bill 1410, signed into law by Governor Rick Perry in 2000, requires the TPWD to close the crab season during the months of February and March each year. This closure allows for the removal of thousands of lost and abandoned crab traps lying in Texas waters.

**Eastern Oyster**

The Eastern oyster (*Crassostrea virginica*) is one of 2 oyster species that are native to the Texas coast and is the primary species of oyster occurring in Galveston Bay. The reef habitat that oysters create is a dominant feature of the bay bottom, serving as habitat for other estuarine organisms. The hard substrate of oyster reefs sits in stark contrast to the soft muds and silts on the bay bottom that can be stirred up by wind and water-driven currents, causing bay waters to become a turbid brown. Oysters also influence water quality as they filter algae and organic particles out of the water.

Oyster reefs were mined heavily in the 20th century; the shell was a cheap and plentiful material used in the construction of roads around the Houston-Galveston region. Today, Eastern oysters are prized for their value as a commercial seafood species. TPWD uses oyster dredges to survey the oyster population of Galveston Bay. CPUE is calculated as number captured per hour. For the period of record, 1986 to 2009, Eastern oysters exhibit declining trends in East Bay (Figure 8.12), Trinity Bay (Figure 8.13), and Upper and Lower Galveston Bay.

Eastern oysters were heavily impacted by the storm surge of Hurricane Ike. TPWD estimates that 60 percent of the oyster reefs in Galveston Bay were covered by bay sediments.
Figure 8.12. Eastern oyster collected in oyster dredge in East Bay, 1986–2009. Data source (TPWD 2010).

Figure 8.13. Eastern oyster collected in oyster dredge in Trinity Bay, 1986–2009. Data source (TPWD 2010).
Gulf Menhaden

Gulf menhaden (*Brevoortia patronus*) feed on phytoplankton, zooplankton, and organic detritus. This species is an important link in the food chain as prey for larger fish species. It also supports a large Gulf commercial fishery. Because of the concerns over potential for increased fishing pressure in Texas waters, the Texas Parks and Wildlife Commission limited annual harvest to 35 million pounds in the Texas Territorial Sea (Gulf of Mexico waters extending seaward from the Texas shoreline out to 9 nautical miles). This annual catch quota went into effect on September 1, 2008 (Robinson 2009).

As seen in Figure 8.14, CPUE for juvenile menhaden captured in bag seines can fluctuate widely from year to year. In Trinity Bay, in 1998, over 40,000 Gulf menhaden per hectare were captured, but in many years over the period of record, the CPUE from this bay has been less than 1,000 per hectare. Abundance of this species relies in part on the concentration of chlorophyll $a$ in the bay. Concentrations have decreased over the past 30 years, but have recently shown a rebound (see Figure 6.20). Gulf menhaden collected in bag seines do not demonstrate a trend in any part of Galveston Bay.

![Figure 8.14. Gulf menhaden collected in bag seine in Trinity Bay, 1977–2009. Data source (TPWD 2010).](image)

Gulf menhaden captured in trawls also exhibit highly variable CPUE values. As shown in Figure 8.15, the range observed in Trinity Bay over the period of record extends from about 50 captured per hour (1997, 2002, and 2007) to about 2 per hour (1984). In all subbays, there is no trend (see examples in Figure 8.15 and Figure 8.16). This lack of a consistent pattern from bag seine to trawl and across subbays suggests that Gulf menhaden are responding to localized factors and are not indicative of patterns in the bay as a whole.
Figure 8.15. Gulf menhaden collected in trawl in Trinity Bay, 1982–2009. Data source (TPWD 2010).

Figure 8.16. Gulf menhaden collected in trawl in Upper and Lower Galveston Bay, 1982–2009. Data source (TPWD 2010).
Atlantic Croaker

The Atlantic croaker (*Micropogonias undulatus*) is a common target of recreational anglers using bottom gear. It is an abundant demersal omnivore, feeding commonly on invertebrate prey (Livingston 2003). Monitoring data for young-of-the-year croaker captured by bag seine show a decrease in abundance from 1977–2009 in Upper and Lower Galveston Bay ($R^2 = 0.36$); the decline in bag seine collections is not significant in other subbays. This trend may be an artifact of the sampling program because this species has exhibited significant increases in trawl samples from all of the major subbays of the system: Trinity, Upper and Lower Galveston, and East and West bays. Figure 8.17 and Figure 8.18 show the increase in capture of Atlantic croaker in trawls from 1982 to 2009. While CPUE has increased, the average size of Atlantic croaker captured by trawl has declined slightly (about 1 cm) but significantly since 1982 (Lester et al. 2006).

![Figure 8.17. Atlantic croaker collected in trawl in Trinity Bay, 1982–2009. Data source (TPWD 2010).](image)

Atlantic croaker of larger size (12 to 68 cm) are captured in gill nets. The CPUE for this species in gill net samples does not show a significant trend except in West Bay, where the CPUE has increased from about one croaker every 5 hours to nearly one every 1.4 hours (Figure 8.19). Mean size of Atlantic croaker captured in gill net has not changed significantly over the period of record (Lester and Gonzalez 2006). This species responds positively to freshwater inflow and low salinity as described below in the section on freshwater inflow. The increase in CPUE is unlikely to be related to enhanced food supply contributing to increased reproduction. The bag seine data do not suggest increased recruitment. Therefore, the most likely explanation is one related to lower mortality.
Figure 8.18. Atlantic croaker collected in trawl in Upper and Lower Galveston Bay, 1982–2009. Data source (TPWD 2010).

Figure 8.19. Atlantic croaker collected in gill net in West Bay, 1977–2009. Data source (TPWD 2010).
**Southern Flounder**

Southern flounder (*Paralichthys lethostigma*) are a prized seafood and recreational game fish. Southern flounder are demersal predators that feed on smaller carnivores, often moving into shallow waters at night to feed where they lie partially hidden along the bottom in wait for their prey. This feeding habit has historically made flounder an easy prey for anglers who use pole gigs to capture the fish at night. They are also commonly captured in trawl nets. Limits on size and number of flounder taken have been implemented by the TPWD to protect populations.

CPUE for flounder captured by bag seine shows no trend for young-of-the-year for 1977–2009. Flounder CPUE in bag seine collections reached its highest level of over 40 individuals per hectare in East Bay in 1982 and 1988 (Figure 8.20).

![Figure 8.20. Southern flounder collected in bag seine in East Bay, 1977–2009. Data source (TPWD 2010).](image)

Trawl samples also show no continuous trend in CPUE in any subbays (see an example in Figure 8.21). Southern flounder captured in trawls show no trend in size over the period of record, but flounder captured in gill nets have increased in mean length by approximately 2 cm (Lester and Gonzalez 2006).
Spotted Seatrout

The spotted seatrout (*Cynoscion nebulosus*), also referred to as speckled trout, is the premier recreational game species in Galveston Bay. It is a high-level carnivore even when young. The largest spotted seatrout are among the top predators in the bay.

CPUE for spotted seatrout captured in bag seines shows no trend in any subbay over the entire period of record from 1977 to 2009. During the last 30 years, older age classes captured in gill nets have shown notable increases in abundance. This species shows significant increasing trends in CPUE in East Bay, Trinity Bay, Upper and Lower Galveston Bay, and West Bay. However, there is no significant increase in Christmas Bay.

Collections of spotted seatrout using gill nets exhibit upward trends that are stronger in the subbays closest to the Gulf. The large spotted seatrout (28–73 cm) sampled by gill net in Upper and Lower Galveston Bay exhibit an increasing trend in CPUE from about one fish captured every 10 hours to approximately one fish every hour (Figure 8.22). Samples from West Bay show a similar pattern, but start from a higher CPUE (Figure 8.23). Fishing for spotted seatrout is subject to minimum size regulations and a bag limit. The effect of these regulations appears to have increased survival of smaller size classes. The average size of captured spotted seatrout has declined somewhat (Lester and Gonzalez 2006; Gonzalez and Lester 2008).
Spotted seatrout are also stocked into Galveston Bay by the TPWD. More than 20 million fingerling spotted seatrout have been stocked in the bay since 1992 (TPWD 2008). Similarly, the TPWD has stocked more than 100 million red drum (*Sciaenops ocellatus*) in Galveston Bay since 1980. The impact of these stocking programs on the abundance of these species in Galveston Bay is unknown. Large red drum captured in gill nets exhibit increasing trends in CPUE in Trinity Bay ($R^2 = 0.50$) and West Bay ($R^2 = 0.25$).

![Figure 8.22. Spotted seatrout collected in gill net in Upper and Lower Galveston Bay, 1976–2009. Data source (TPWD 2010).](image)
**Figure 8.23.** Spotted seatrout collected in gill net in West Bay, 1976–2009. Data source (TPWD 2010).

**Gafftopsail catfish**

Gafftopsail catfish (*Bagre marinus*) is a second-level carnivore (Livingston 2003) that feeds primarily on benthic invertebrates, but will also prey on fish in the water column. This species moves between the bay and the Gulf during its life cycle and is found in greater abundance in the higher salinity subbays. This species is commonly captured in trawl and gill net samples. Both gear types yield data with similar patterns. Gafftopsail catfish CPUEs are increasing, but the other common species of catfish, hardhead catfish (*Arius felis*) shows no trend.

Figure 8.24 shows the pattern for gafftopsail catfish over the period of record for CPUE in trawl samples collected in Upper and Lower Galveston Bay. The values range from fewer than one fish every 2 hours in the early 1980s to nearly 3 fish per hour in recent years. Gill net samples from all subbays, except East Bay, also show an increasing trend in CPUE.
This species has special significance for public health. Gafftopsail catfish is one of a small number of species that contain very high levels of fat-soluble contaminants in their tissue. According to studies by the TDSHS, gafftopsail catfish and spotted seatrout have higher mean lipid levels in their muscle tissue than many other species of fish captured by recreational anglers in Galveston Bay. While the physiology of this catfish plays a role in the level of contamination observed, the feeding habits of the fish may also contribute to the ingestion of the contaminants. The transport of these contaminants through the food web of Galveston Bay is not well understood.

**Gray snapper**

Gray snapper (*Lutjanus griseus*) is a high-level carnivore that uses estuaries as nursery grounds and may migrate between oceanic and estuarine habitats as an adult (Pattillo et al. 1997). The range of this species is tropical and subtropical, but it has been found in temperate waters on the Atlantic coast. The trend in capture of this fish is of interest as a possible indication of range expansion due to changes in climate. This species is rarely captured in trawl samples and as an adult is closely associated with marine waters. Therefore, the best record is from gill net samples collected in the higher salinity waters of West Bay.
Gill net collections of gray snapper do not appear in the West Bay record until the 1990s when it was captured sporadically (Figure 8.25). Gray snapper have been consistently captured since 2004. Tolan and Fisher (2009) found evidence of an increase in the abundance of gray snapper along the Texas coast correlated with increasing water temperatures during winter months in Texas bays south of Galveston Bay. If the increase in abundance of this tropical species is in response to warming waters, then it could become a regular component of the biological community in Galveston Bay. The addition of another high-level carnivore could cause changes in the organization of the Galveston Bay food web.

**Figure 8.25.** Gray snapper collected in gill net in West Bay, 1977–2009. Data source (TPWD 2010).
Meeting the Challenge of Invasive Species Introductions in the Lower Galveston Bay Watershed

By Lisa A. Gonzalez

The protection of fish, wildlife, and plant species is an important objective of The Galveston Bay Plan. However, when one thinks of species protection, one typically thinks of managing desirable species and their habitats. The protection of fish, wildlife, and plant species also requires management of undesirable species, commonly known as exotic or invasive species.

Exotic species are plants, animals, and microorganisms that exist in habitats outside of the geographic region in which they historically occur (i.e. outside their native range). Invasive species are exotic species that establish, reproduce, and spread in the region to which they were introduced. Additionally, invasive species disrupt ecological, social, or economic systems in the colonized region. This definition excludes beneficial exotic species such as the European honeybee, which is important to North American agricultural systems in its role as a pollinator of crops, and to economic systems in its ability to produce honey.

Invasive species are introduced either accidentally through release or intentionally, and can enter a new region through many pathways. Some examples of introduction pathways for aquatic invasive species include boats and boat trailers, ballast water and hulls of ocean-going vessels, escape from water gardens, and release of unwanted fish from aquaria. Invasive terrestrial plant species such as Brazilian peppertree (Figure 8.26), Chinese tallow, deep-rooted sedge, and numerous others escape from garden plantings and other places where non-native plants are used. These invaders then take up residence in natural habitats around the region and compete with native species for resources (such as nutrients, sunlight, and water) and niche space (position in the ecological community).

The introduction, establishment, and spread of invasive species is the result of a complex interaction between global trade, human culture, and ecological systems. Global transportation reaches evermore remote locations, at a faster rate of speed, and with a greater volume of goods than at any other time in human history. The commercial trade in pets and horticultural plants is quite large and is driven by both public demand for importation of new species and varieties, and the profitability of the trade. For cultural
Of the multitude of pressures facing our estuarine systems, invasive species can cause direct extinction of native species through direct competition, disease and/or predation or indirect changes to local ecosystems. Future efforts by resource managers to control invasive species will require (1) early detection strategies (surveys by Rapid Assessment Teams) so control measures can be implemented quickly; and (2) shifting to the use of “approved lists” for importation after thorough risk analyses to meet changing public demands.

—Lance Robinson, Regional Director, Upper Coast Regional Office, Texas Parks and Wildlife Department
**Probable Causes of Fish and Shellfish Trends**

Species declines noted above, particularly for blue crab populations, raise some concerns for the species and for potential bay conditions, which may have influenced the declines (Green et al. 1993). In addition, anecdotal information suggests that other species such as tarpon, snook, and striped bass have seen long-term declines compared to 19th-century levels. Some reasons for declines were discussed above, such as overfishing, loss of marsh habitat, changes in fresh water inflow, and changes in organic loads to the bay. More significant are the increasing trends that seem to dominate the TPWD monitoring record. Below we discuss drivers, factors that may hold explanatory value in understanding the observed changes.

**Habitat**

It is difficult to document a causal relationship between species abundance and habitat quantity or quality. The acreage of 2 important habitats, estuarine marsh and seagrass meadows, could affect the abundance of fish and shellfish that utilize these habitats. However, many of the fish and shellfish species that use marshes as nursery areas can survive and grow over open bay bottom. Their populations may maintain lower densities in unvegetated areas versus densities in optimal habitat, but the available data cannot document a quantitative relationship between acres of marsh and abundance or size of harvest. Despite the lack of a causal relationship with harvest, the information presented in Chapter 7 showing that decline in fringing marsh has been arrested is positive for the biological community. Evidence of correlated changes in abundance of species that use seagrass habitat is anecdotal since much of the loss of seagrass in Galveston Bay and West Bay occurred before scientific monitoring of species abundances by the TPWD. If seagrass habitat continues to increase in acreage and if the relationships are causal, then seagrass-dependent species could increase in the future.

How the habitat value of created marshes compares to natural marshes is relevant to an understanding of how habitat quality affects species abundance. Minello and Webb (1997) found that created marsh, 3 to 15 years after planting, had significantly lower densities of decapod crustaceans than natural marshes. This study suggests that the productivity of the estuary is reduced by loss of marsh habitat and the function of that habitat is not restored completely or rapidly by simply planting the appropriate vegetation.
Shrimp Trawl Bycatch

Bycatch is a broad term to describe unwanted incidental harvesting of organisms during pursuit of a different species. A study to assess shrimp trawl bycatch in Galveston Bay was conducted by the National Marine Fisheries Service (NMFS) Galveston Laboratory during the 1992 shrimp season (Martinez et al. 1993). One fish was captured as incidental bycatch for every 1.9 shrimp landed during the March to November shrimping season. Dominant bycatch species captured included Atlantic croaker, Gulf menhaden, sand seatrout, bay anchovy, sea catfish, spot, squid, and blue crab.

The TPWD conducted bycatch characterization studies in Galveston Bay during 1995 and had results similar to the NMFS study. Though bycatch ratios for Galveston Bay were the smallest seen on the coast, the numbers of individuals caught were still significant (i.e., finfish bycatch of trawling in the spring = 3,310 lbs./hour; finfish bycatch per hour of trawling in the fall = 1,844 lbs./hour) (Fuls et al. 2002).

Two regulatory actions by TPWD have a direct effect on the mortality of bycatch in shrimp trawls. Bycatch reduction devices have been required as additions to shrimp trawls in Texas waters. These devices allow fish to escape from the net and reduce the capture of non-shrimp species. The number of shrimping licenses is declining as a result of the profitability of the business and a TPWD license buyback program. A decrease in bycatch could have a positive effect of forage fish and piscivorous predators.

Recreational Bycatch

Recreational bycatch occurs when recreational anglers capture and release unwanted species or game fish of non-legal size or condition (e.g. incubating female crabs). When handled and released properly, these bycatch organisms often survive. However, mortalities can result from stress or physical damage. Public education is key to reducing mortality of recreational bycatch.

Based on federal and state fisheries data, Saul et al. (1992) concluded that recreational sport boat fishermen caught and released about 2 fish for every fish retained. TPWD has studied this issue and reported a coastwide recreational bycatch to landings ratio of 2.25 to 1 (Campbell et al. 1995). Approximately 5 percent of the released fishes were reported as having been released dead. Stunz and McKee (2006) report that only 11 percent of the spotted seatrout captured by hook and line and released alive died from injuries or stresses related to capture within 48 hours of release. They observed no mortality in a subsample held in the laboratory for 28 days. The increase and improvement in catch and release practices appears to be beneficial to the maintenance of abundance of preferred recreational species.

Industrial Incidental Capture

Industrial cooling water intake systems can cause incidental mortality of bay organisms through impingement and entrainment. Impingement occurs when a screen at a water intake structure incidentally collects organisms. Entrainment occurs when organisms too small to be intercepted at the intake screens pass through the cooling water system.

The impact of cooling water use on fishery resources was studied using historical data (Palafox et al. 1993). Using 1978–79 data from 5 Houston Lighting and Power (now NRG Energy) generating plants located on Galveston Bay, the authors concluded that about 84 million organisms, with a total biomass of 477,000 kg,
were impinged each year at the 5 locations on Galveston Bay. None of the historical data used to develop these conclusions focused on the overall scope of cooling water impingement and entrainment. In particular, there may be considerable environmental impact on marine eggs, larva, and other juvenile organisms entrained by the cooling systems.

Both industry and government recognize entrainment and impingement as an important issue. Texas Coastal Management Program rules (31 TAC 501.14) now address impingement and entrainment of estuarine organisms as it relates to electrical power generation facilities utilizing once-through cooling systems. The rules require that these facilities “shall be located and designed to have the least adverse effects practicable.”

Fish Kills

The Texas Gulf Coast has some of the nation’s largest and most frequent fish kills, partially because of the hot climate and physical features such as low circulation. Fish kills often occur because of low dissolved oxygen levels in the water column caused by human activity or naturally occurring events. Human activities include point source and nonpoint source loadings of nutrients and pollutants to estuarine waters.

In September 1998, Tropical Storm Frances produced a large amount of rainfall along the Southeast Texas coast. Stagnant waters were pushed into Galveston Bay resulting in major fish kills in East and West Bays (TPWD 1998). In late summer 2000, an extensive toxic algal bloom affected the coast of Texas. In Galveston Bay, fish kills were observed in West Bay, East Bay, Dickinson Bay, and Chocolate Bayou, and along the Texas City Dike (Contreras 2001). Subsequent to Hurricane Ike in September 2008, fish kills were observed in channels that drained the salt water inundation from freshwater marshes (Figure 8.28). Tropical storm surges are usually associated with mass mortalities of fish. Abnormal winter freezes in which temperature drops rapidly have also been responsible for mass mortalities, but such an event has not happened in Galveston Bay in the last decade.

Thronson and Quigg (2008) have analyzed the record of fish kills in coastal waters collected by TPWD over the period 1951 to 2006. Galveston and Matagorda Bays have the greatest number of kills and the largest in number of fish. Deaths tend to occur in summer months in shallow areas with limited circulation. Gulf menhaden is the most common species among the mortalities and constitutes more than 70 percent of those identified. Striped mullet is second in frequency, but makes up less than 15 percent of the identified fish. Fish kills do not appear to have lessened the capture rate of Gulf menhaden.

Birds

Bird populations in Galveston Bay have significant recreational, ecological, and aesthetic values. Many bird species observed on the bay are predators of fish, shellfish, or benthic organisms, and therefore are important indicators of the health of the food webs. Observers have noted 139 bird species associated with Galveston Bay wetlands and open-bay habitats (Arnold 1984).
Colonial Waterbirds

Data from the U.S. Fish and Wildlife Service Texas Colonial Waterbird Surveys from 1973 to 2006 were used to evaluate trends for bird species that use Galveston Bay to feed and nest nearby in colonies (USFWS 2007). This survey is conducted annually and attempts to count all of the nesting pairs in all of the colonies along the Texas coast. This excludes waterfowl and solitary nesters, but includes the herons, egrets, gulls, terns, ibises, etc. It may not include all nesting sites because new ones may take some time to be discovered. In addition, some species are so numerous in some colonies that numbers of nesting pairs can only be approximated. The 3 most commonly sighted species in the 2006 survey were the laughing gull (Larus atricilla), cattle egret (Bubulcus ibis), and royal tern (Sterna maxima). The numbers in the database are presented by colony and species. As part of the Galveston Bay Status and Trends program, we compile the species numbers over all colonies in the lower Galveston Bay watershed to assess trends in abundance. Only the last 20 years are used to assess current impacts on the populations of these species in the lower Galveston Bay watershed.

Factors that affect populations of colonial waterbirds can include predation, human disturbance of nesting areas, and habitat loss. Whatever the factors producing declines in nesting populations of these birds, it appears that the wading birds that nest in vegetation are experiencing the most serious impacts.

To enhance recognition of patterns in the abundance of bird species over time, bird species will be grouped into guilds dependent on similar feeding or nesting resources. Trends for all guild species are summarized in Figure 8.29.
The first guild to be considered consists of wading birds feeding in marshes or along shorelines and nesting above the ground in vegetation, i.e. great blue heron (Ardea herodias), great egret (Ardea alba), snowy egret (Egretta thula), tricolored heron (Egretta tricolor), little blue heron (Egretta caerulea), ibises (Subfamily Threskiornithinae) and roseate spoonbills (Ajaia ajaja). Reddish egret (Egretta rufescens) is placed in the guild of shoreline feeders, but is classified in the guild of ground nesters although it will also nest in vegetation. White-faced ibis also will sometimes nest on the ground.

Two species in this guild exhibiting significant negative trends are the great blue heron and the black-crowned night heron. The great blue heron is the largest member of this guild. It shows a significant negative trend (R² = 0.69) in abundance from 1987 to 2006, during which time the number of reported nesting pairs went from over 600 to around 200 (Figure 8.30). The black-crowned night heron shows a similar trend over approximately the same range of reported numbers.

Also in the guild of wading birds, the tri-colored heron and the reddish egret show significant negative trends over the 20 year period from 1987 to 2006 in number of nesting pairs reported. Over the same period, the white-faced ibis also declined. There were no significant positive trends in the reported nesting numbers of any members of the wading guild. Most members of this guild nest in vegetation, although the
reddish egret will nest on the ground. It is more probable that declines are related to nesting habitat rather than to a decline in food or feeding areas. The area of fringing marsh has not declined significantly in the last 20 years, and the trends of forage fish do not show significant decreases. Some specific yearly changes may be due to feeding resources, e.g., the effect of drought and diminished freshwater wetland feeding areas on white ibis numbers. In addition, some specific annual changes may be due to temporary alterations of nesting habitat, e.g., inundation of ground nesting areas by storm tides and subsequent nesting failure.

An open-water feeding group includes royal terns (*Sterna maxima*), Caspian terns (*Sterna caspia*), least terns (*Sterna antillarum*), sandwich terns (*Sterna sandvicensis*), black skimmer (*Rynchops niger*), neotropic cormorants (*Phalacrocorax brasilianus*), and brown pelican (*Pelecanus occidentalis*). These species depend primarily upon fish caught from open bay habitats. The data from 1987 to 2006 show that Forster’s tern (Figure 8.31) and least terns have highly variable abundance. Royal and sandwich tern numbers have declined since a high period during the early 1990s, but their decline does not reach our criterion for significance. These species showed a positive trend up to 1995. As seen in Figure 8.32, the black skimmers (*Rynchops niger*) were in decline until the mid 1990s, but have fluctuated between about 1,000 and 3,000 breeding pairs over the last 15 years.

Neotropical cormorant and brown pelican are also open water feeders, but use fishing methods that are quite different from those of terns and skimmers. The neotropical cormorants are reported to be declining in numbers of breeding pairs in this area over the 20 years of assessment. In most of the years after 1999, fewer than 500 nesting pairs have been reported, whereas more than 3,000 pairs were reported in 1987 and 1990. Numbers of nesting brown pelicans are exhibiting a dramatic positive trend. In the 1980s, no brown

![Figure 8.29](image1.png)  
*Figure 8.29. Trend in number of nesting pairs of great blue heron observed in Galveston Bay, 1987–2006. Data source: (USFWS 2007).*
pelicans were nesting; in 2005 and 2006, close to 2,000 pairs were reported in nesting colonies in the lower Galveston Bay watershed (Figure 8.33).

Curiously, laughing gulls, the most common waterbird around Galveston Bay, have shown a significant decline in reported nesting pairs over the 20-year assessment. In the first half of this period of record, the number of nesting pairs was commonly reported to be between 20,000 and 30,000. In the second half of the period, the number was more commonly near to or less than 20,000 (Figure 8.34).

All of these species are tied trophically to the aquatic life in the bay. Given the lack of evidence of decreasing abundance of prey in the TPWD fisheries independent data set, it is not possible to conclude that the prevalence of declining numbers among these waterbirds is due to a shortage of food. (It is possible that a relationship exists and the data are not adequate to detect it.) As noted above, an impact on habitat, either through loss or disturbance is more likely.

Figure 8.30. Trend in number of Forster’s tern nesting pairs observed in Galveston Bay, 1987–2006. Data source: (USFWS 2007).
Figure 8.31. Trend in number of black skimmer nesting pairs observed in Galveston Bay, 1987–2006.
Data source: (USFWS 2007).

Figure 8.32. Trend in number of brown pelican nesting pairs observed in Galveston Bay, 1987–2006.
Data source: (USFWS 2007).
Waterfowl

The marshes, coastal prairies, and rice fields of the upper Texas coast provide a vital winter foraging area for waterfowl as they migrate along the Central and Mississippi flyways each year. Species observed in the Galveston Bay system include the blue-winged teal (*Anas discors*), green-winged teal (*Anas crecca*), mallard (*Anas platyrhynchos*), Northern pintail (*Anas acuta*), American widgeon (*Anas americana*), gadwall (*Anas strepera*), Northern shoveler (*Anas strepera*), ring-necked duck (*Aythya collaris*), lesser scaup (*Aythya affinis*), red-breasted merganser (*Mergus serrator*), ruddy duck (*Oxyura jamaicensis*), Canada goose (*Branta canadensis*), snow goose (*Chen caerulescens*), and white-fronted goose (*Anser albifrons*).

Because of the nature of these and other migratory species, population regulation is impossible to evaluate by studying populations at any one location. Reduction in numbers utilizing a wintering area, while not necessarily reflecting population reductions, could reflect decreased use of habitat in response to its loss or deterioration. Breeding and wintering populations of waterfowl are monitored by state and federal surveys. The resulting population estimates form the basis for annual harvest regulations.

Duck breeding population estimates compiled by the U.S. Fish and Wildlife Service for 1955–2009 show that most species of ducks are increasing in abundance and only a few species exhibit a declining trend (Zimpfer et al. 2009). Breeding populations of mallard are estimated to be 13 percent above the long-term average. Increases that are even more dramatic are being documented for gadwall, green-winged teal, blue-winged teal, and northern shoveler, which are above their long-term average abundance by 73 percent, 79...
percent, 60 percent, and 92 percent, respectively. American widgeon and northern pintail are still in decline over the 54-year period and are below their long-term average abundances by 5 percent and 20 percent respectively (Zimpfer et al. 2009). While these numbers are national estimates, they should be indicative of the health of the wintering populations around Galveston Bay.

While some species of ducks have declined, all of the populations of geese that over winter in the Galveston Bay area have increased (USFWS 2008). These are primarily snow geese with some white-fronted geese and Canada geese on the prairie with them. Geese are more efficient at using winter rice fields and other uplands for their food supply and they are adaptable to a variety of breeding habitats (Bateman et al. 1988). The U.S. Fish and Wildlife Service manages significant acreage in the national wildlife refuges around Galveston Bay to support waterfowl populations.

The only species of waterfowl that is a resident in the area is mottled duck (Anas fulvigula), which needs coastal prairie and freshwater wetlands in which to nest and raise their broods. The interdune swale habitat on Galveston Island is extremely important for this bird as are palustrine emergent wetlands associated with prairie (Woodrow 2009). Threats to the species include loss and degradation of wetlands, hybridization with feral mallards (domesticated mallards released into the wild), and the possibility of excessive sport harvest (Moorman et al. 1994). Breeding-season surveys on national wildlife refuges in coastal Texas suggest a significant decline over the last 20 years (Johnson 2009).

**Shorebirds**

The Galveston Bay system is an important site for migrating shorebirds. The most common shorebirds identified in winter bird counts are the American avocet (Recurvirostra americana), willet (Catoptrophorus semipalmatus), sanderling (Calidris alba), western sandpiper (Calidris mauri), dunlin (Calidris alpina), dowitchers (Limnodromus sp.) and black-bellied plover (Pluvialis squatarola). The Christmas bird counts (HAS 2009b) and the Bolivar Flats Shorebird Survey (HAS 2009a) indicate a possible increase in shorebird numbers, although the data are difficult to interpret due to lack of standardization. With respect to diversity, counts of bird species over the last 3 winters in the Audubon Bolivar sanctuaries ranged from a low of 64 in January 2009 to a high of 101 in February 2008. The highest number of species recorded since January 2007 was 119 in May 2008 during spring migration.

Threats to shorebird populations include human disturbance of nesting areas, oil spills and habitat alteration. For these reasons, a number of areas along the upper Texas coast are designated as bird sanctuaries. This system of sanctuaries protects nesting and foraging areas used by shorebird species along their annual migratory route. Galveston Bay is home to several Houston Audubon Society bird sanctuaries, including the Jerry R. Smith Nature Sanctuary in West Bay, the North Deer Island Sanctuary, and the Bolivar Flats Shorebird Sanctuary located on Bolivar Peninsula adjacent to the North Jetty. Bird counts conducted by the Audubon Society at their Bolivar Peninsula sanctuaries show the diversity of species using the area and emphasize the value of providing protected areas to conserve this biodiversity.
Threatened or Endangered Bird Species

A number of bird species classed as endangered by the federal or state authorities can be found during some part of the year in and around Galveston Bay. Brown pelicans (*Pelecanus occidentalis*) have shown dramatic increases in Galveston Bay during the past 16 years due to the successful establishment of nesting colonies and the elimination of chlorinated pesticide use (see Figure 8.33). More than 1,800 breeding pairs were sighted in 2006. Other colonial waterbirds listed as threatened by the State of Texas include the reddish egret (*Egretta rufescens*) and white-faced ibis (*Plegadis chihi*). As seen in Figure 8.29, both of these threatened species have exhibited declining population trends over the last 20 years. The wood stork (*Mycteria americana*), a non-breeding visitor to Galveston Bay, is a threatened species on the Texas list.

The bald eagle (*Haliaeetus leucocephalus*), a Texas threatened species, has nesting sites in Chambers, Galveston, and Harris counties. The piping plover (*Charadrius melodus*) is a federal and state designated threatened species that has overwintering habitat along Bolivar and Galveston beaches. In the prairie around the bay, Attwater’s prairie chicken (*Tympanuchus cupido attwateri*) was once abundant. This state and federal endangered species has a refuge on Moses Lake north of Texas City, but the population is not self-sustaining.

Reptiles

Many species of amphibians and reptiles have been observed in the counties adjacent to Galveston Bay. Of particular interest is the American alligator (*Alligator mississippiensis*). This species was a once endangered species that made a remarkable recovery. Prior to Hurricane Ike, the alligator increased throughout much of its range due to regulation of alligator hunting and of trade in alligator products. The American alligator inhabits fresh and brackish waters and wetlands and can be found in the bayous and rivers that flow into the bay. The storm surge of Hurricane Ike heavily impacted these habitats, likely impacting the population of these large reptiles (FEMA 2008). Recent alligator surveys by resource agencies show a large decline in alligator nests from 2008 to 2009 (Sutherlin 2009). In addition to the impact of the hurricane, which may not be long-lasting, the greatest threat to alligator populations around Galveston Bay is that posed by encroaching development.

Three sea turtle species, the endangered Kemp’s ridley sea turtle (*Lepidochelys kempi*), the threatened green sea turtle (*Chelonia mydas*) and the threatened loggerhead sea turtle (*Caretta caretta*), can be found along the Texas coast. They are not known to permanently inhabit Galveston Bay waters, but use the bay as a seasonal foraging area as they make their way along the coast.
Kemp’s ridleys are by far the dominant species that occurs in nearshore waters of the upper Texas coast (Landry 2001). The species uses nearshore waters as nursery areas and developmental feeding grounds (Metz 2004). Manzella and Williams (1992) developed an atlas of Kemp’s ridley distribution along the Texas coast based on data collected from the late 1940s through 1990. The Galveston Bay region ranked third in Kemp’s ridley frequency distribution behind the Sabine Pass–High Island and Corpus Christi–North Padre Island regions. The NMFS laboratory in Galveston participated in a head start program for sea turtles and reared hundreds of Kemp’s ridley turtles for release in Texas waters.

In 2003, researchers began to see an increase in the number of female Kemp’s ridley sea turtles laying eggs on the beaches of the Upper Texas Coast. Of 194 confirmed nests on the Texas coast in 2009, 15 were located between Bolivar Peninsula and Surfside Beach—a slight decline compared to the number of nests found in 2008 (195 nests on the Texas Coast, including 16 on the Upper Texas Coast). Dr. André Landry and his students at Texas A&M University at Galveston believe the decline in nesting activity may be attributed to a natural population decline, beach and dune erosion due to Hurricane Ike, or sea turtles’ dislike of recently nourished beaches (Rice 2009).

Populations of another species of turtle, the diamondback terrapin (*Malaclemys terrapin*) (Figure 8.1), an inhabitant of brackish water marshes, have declined over the last 150 years. The terrapin was once valued as a delicacy and exploited heavily in the 1800s (Lovich 1995). Terrapin populations then recovered somewhat, but are now threatened by habitat loss and human impacts. Specifically, abandoned crab traps have been identified by state and federal agencies as a source of mortality of these turtles (see the section on blue crabs above for more information about abandoned crab traps). Very little is known about populations of diamondback terrapin in Texas. The Houston Zoo and partners including the TPWD, the USFWS, the University of Houston–Clear Lake, the Galveston Bay Foundation, Moody Gardens, and others are involved in a cooperative program to enhance our knowledge about the diamondback terrapin and the health of its population around Galveston Bay.

**Mammals**

Land mammals that inhabit wetlands around Galveston Bay include the swamp rabbit, gray squirrel, beaver, muskrat, roof rat, northern rice rat, nutria, raccoon, mink, and river otter. Nutria, a species introduced from South America via Louisiana, has been identified as an invasive species in the area (Lester and Gonzalez 2004). Nutria can consume large amounts of the emergent vegetation in wetlands, contribute to wetland loss, and can hinder wetland creation efforts.
The most commonly occurring marine mammal in Galveston Bay is the bottlenose dolphin (*Tursiops truncatus*). Maze and Würsig (1999) examined the occurrence, site fidelity, habitat use and movement of bottlenose dolphins at San Luis Pass at the western end of Galveston Bay. In a 12-month period, they identified 71 individuals, which included 37 bay residents and 34 transients. They concluded that some individuals exhibit long-term fidelity to a given site, while others tend to move between sites along the coast. They also found that dolphins frequent the bay’s shallow waters during the summer, but prefer the deeper waters of the Gulf in the winter. The navigation channels in Galveston Bay provide a year-round deepwater habitat for this popular species. Recreational anglers in West and Christmas bays, and property owners on West Galveston Island (Personal communication, Lance Robinson 2009) have occasionally sighted individual West Indian manatees. In 1995, a manatee was rescued from Buffalo Bayou in Houston and returned to Florida (Austin-American-Statesman 1995).

Bottlenose dolphins and other marine mammals are sometimes found stranded along the beach shoreline or in very shallow waters. The Texas Marine Mammal Stranding Network (TMMSN) was created to deal with this problem. The network rescues dolphins that are stranded, but alive, and studies dead animals to learn more about the causes of stranding. While the phenomenon of stranding is not fully understood, it can occur because of injury, illness or disease. As top predators of the food chain, marine mammals can serve as indicators of overall ecosystem health. In 2007 and 2008 unusual mortality events were observed for bottlenose dolphins in the Galveston area (NOAA 2008). In February and March of 2007, more than 60 dead dolphins were recovered from beaches in Galveston County (Tinsley 2007). In the same months in 2008, more than 70 dolphins were observed on the beaches of Galveston and adjoining counties (TMMSN 2009). Although pathology studies have been performed, the causes of these events are undetermined.

**Summary**

A wide variety of fish, wildlife, plant, and invertebrate populations either reside in or periodically utilize Galveston Bay and its associated habitats. Most of the bay's living resources appear to be in good health, with some exceptions posing management concerns.

Phytoplankton abundance, as measured through chlorophyll *a* concentrations, has changed significantly through the years, possibly in response to increases in nutrients peaking in the late 1960s, followed by nutrient reductions. Over wide expanses of the bay, the benthic community remains abundant and diverse, following a natural gradient of increasing diversity from the upper bay system seaward. Benthic species exhibit the clearest impact of pollution on a biological community.

Although oyster reefs appear to have expanded in recent years, the oyster population is nowhere near the levels found in Galveston Bay prior to shell dredging, and it was recently decimated by sediment brought into the bay by Hurricane Ike. Shell dredging and hurricanes are major habitat alterations. The bay may never obtain equivalent oyster resources to those that existed prior to commercial exploitation of this resource.
Most finfish populations appear to be in good health and many fish species exhibit increasing trends in catch per unit effort. This suggests that habitat is suitable and management of the biological resources is generally successful.

Monitoring data for large blue crabs exhibit a declining trend. Their complex life cycle makes the cause of this decline difficult to determine. White shrimp had been showing a declining trend in the 1980s, but have been variable in CPUE with no trend over the last 20 years. Brown shrimp have exhibited no trend in CPUE over the period of record.

Colonial waterbird species are showing some trends of concern, particularly those species in the guild of wading birds (great blue heron, tri-colored heron, reddish egret, black-crowned night heron, and white-faced ibis). In addition, the composition of the colonial waterbird community appears to be changing with stable numbers of terns, decreasing numbers of herons and egrets, and dramatically increasing numbers of brown pelicans. Shorebirds, including some rare and endangered species, also forage and nest in the Galveston Bay area. A system of bird sanctuaries located around the bay protects some of these areas and creates a great opportunity for nature viewing.

A variety of reptiles and mammals, including bottlenose dolphin and 3 species of sea turtles, can be found in and around the bay as well. Abundance of marine mammals has not been a concern in the area around Galveston Bay, despite some episodes of mass mortality. Populations of sea turtle seem to be responding to conservation efforts and are increasingly observed.

When compared to other estuaries of the eastern United States, Galveston Bay’s living resources appear to be relatively well preserved and well managed. As stewards of the bay’s living resources, it is important to promote continued monitoring of populations, to support habitat protection and restoration activities, and to encourage improvements in water quality.

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