CHAPTER 5

GULF COAST NATIONAL ESTUARY PROGRAM COASTAL CONDITION

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Background

The Gulf Coast region extends from the lush tropical southern tip of Florida, including the Florida Keys, westward to the saline lagoons of South Texas at the Mexican border. The Gulf of Mexico receives runoff from almost two-thirds of the continental United States, primarily funneled through the Mississippi River drainage basin (NOAA, 1985). Within the Gulf Coast region, there are seven NEP estuaries—Charlotte Harbor, Sarasota Bay, Tampa Bay, Mobile Bay, the Barataria-Terrebonne Estuarine Complex, Galveston Bay, and the Coastal Bend Bays (Figure 5-1).

The entire Gulf Coast region is characterized by flat coastal plains and high levels of sediment deposition. Some of the estuaries in this region have large deltas at their river mouths (e.g., Mobile-Tensaw River Delta in Mobile Bay), where suspended sediment carried by runoff is deposited in shallow coastal waters. In other areas, sediment deposited by ocean currents has formed offshore sand bars that enclose shallow saline lagoons known as bar-built estuaries (e.g., Laguna Madre of the Coastal Bend Bays), which are most common along the Texas coast. The inlets to these estuaries are often narrow, and the exchange of water with the ocean is highly restricted; as a result, the circulation patterns in these waterbodies are driven primarily by wind (NOAA, 1985). In general, the shallow coastal plain estuaries characteristic of the Gulf Coast region receive little tidal influence, and tidal range in the region is small, with a minimum of 1 foot in Louisiana and Texas and a maximum of 3.6 feet in Florida (NOAA, 1985). Hurricanes and their accompanying heavy rains, an ever-present risk during the June-to-late-November hurricane season, have a dramatic effect on the Gulf Coast NEP estuaries by increasing freshwater inflow from storm precipitation and saltwater intrusion from wind-driven storm surge. Annual rainfall averages 48 inches in western Florida; increases to 56 inches in Alabama, Mississippi, and Louisiana; and then dramatically decreases to 24 inches in south Texas (NOAA, 1985).

The Gulf Coast NEP estuaries provide critical feeding, spawning, and nursery habitats for a rich assemblage of fish, wildlife, and plant species, including endangered species such as sea turtles, the Gulf

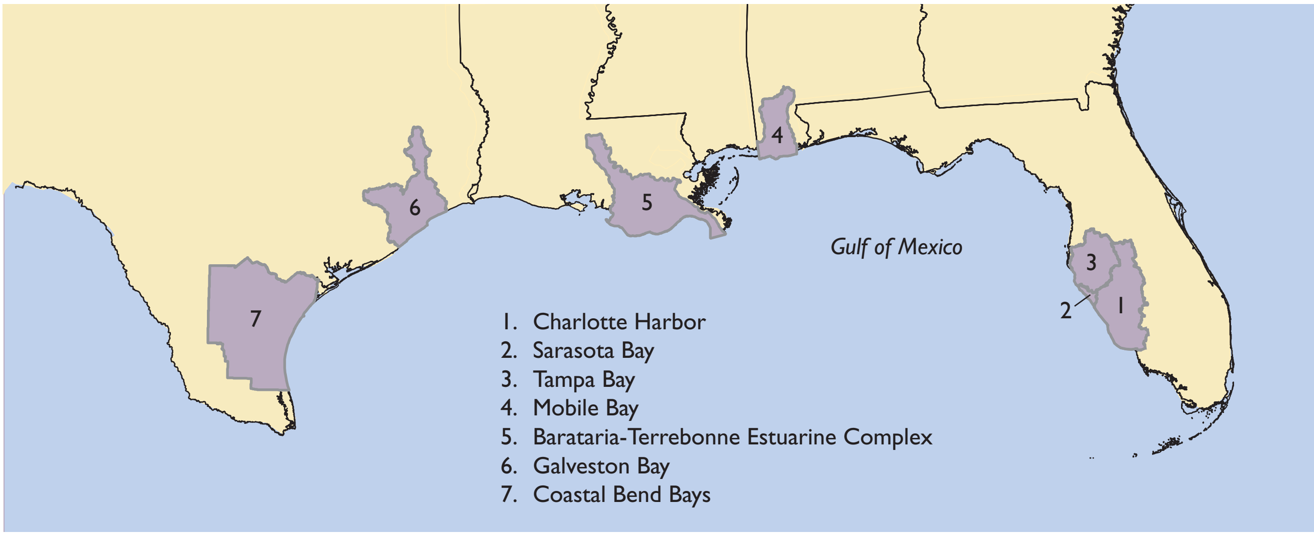


Figure 5-1. The Gulf Coast region is home to seven NEP estuaries.

sturgeon, the Perdido Key beach mouse, the manatee, the white-topped pitcher plant, and the red-cockaded woodpecker. These estuaries also support SAV communities that stabilize shorelines from erosion, reduce non-point source loadings, improve water clarity, and provide wildlife habitat. Increasingly, the varied estuarine habitats found along the Gulf Coast region are under pressure from human development.

Population Pressures

The population of the 48 NOAA-designated coastal counties coincident with the study areas of the Gulf Coast NEP estuaries increased by more than 133% during a 40-year period, from 4.9 million people in 1960 to 11.3 million people in 2000 (Figure 5-2) (U.S. Census Bureau, 1991; 2001). Population density for these coastal counties was 287 persons/mi^2 in 2000; however, the population densities of the individual NEP study areas varied considerably, from a high of 651 persons/mi^2 in Galveston Bay to 53 persons/mi^2 in the Coastal Bend Bays (U.S. Census Bureau, 2001). Development and population pressures are especially strong in these 48 Gulf Coast counties because the coincident NEP study areas serve as centers of commerce, contain substantial commercial and recreational fisheries, and provide recreational areas for coastal communities.

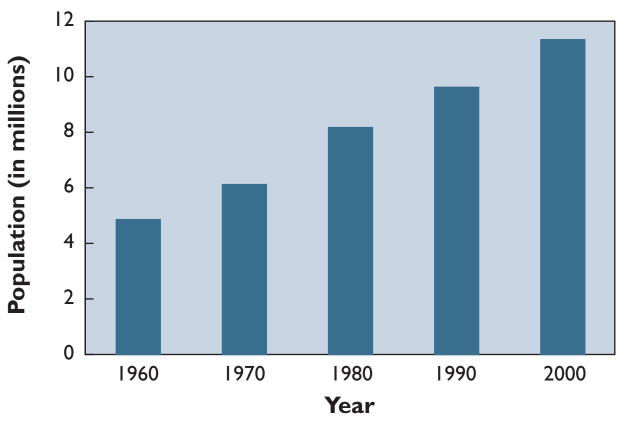


Figure 5-2. Population of the 48 NOAA-designated coastal counties of the Gulf Coast NEP study areas, 1960–2000 (U.S. Census Bureau, 1991; 2001).

The following sections of this report discuss two different approaches for characterizing estuarine condition.

Approach 1 – The NCA provides unbiased, quality-assured data that can be used to make consistent "snapshot" comparisons among the nation's estuaries. These comparisons are expressed in terms of the percent of estuarine area in good, fair, or poor condition.

Approach 2 – Each individual NEP collects site-specific estuarine data in support of local problem-solving efforts. These data are difficult to compare among NEPs, within regions or nationally, because the sampling and evaluation procedures used by the NEPs are often unique to their individual estuaries. However, these assessments are important because NEP-collected data can evaluate spatial and temporal changes in estuarine condition on a more in-depth scale than can be achieved by the NCA snapshot approach.

Atmospheric deposition is often monitored in NEP study areas because it can contribute to estuarine nitrogen loadings (Mobile Bay NEP).

NCA Indices of Estuarine Condition—Gulf Coast Region

The overall condition of the collective NEP estuaries of the Gulf Coast region is rated fair based on the four indices of estuarine condition used by the NCA (Figure 5-3). The region's water quality index is rated fair, the sediment quality and benthic indices are rated fair to poor, and the fish tissue contaminants index is rated good to fair. Figure 5-4 provides a summary of the percentage of estuarine area rated good, fair, poor, or missing for each parameter considered. This assessment is based on data collected by the NCA and its state partners from 221 sites sampled in the Gulf Coast region's NEP estuaries in 2000, 2001, and 2002. Samples were collected during the summer, the most stressful period of the year, and neither environmental stressors (e.g., nutrients, TOC) nor aquatic life communities showed any major evidence of degradation. Please refer to Tables 1-24, 1-25, and 1-26 (Chapter 1) for a summary of the criteria used to develop the rating for each index and component indicator.

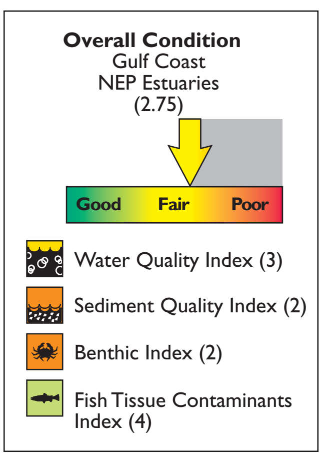


Figure 5-3. The overall condition of the Gulf Coast region's NEP estuarine areas is fair (U.S. EPA/NCA).

The sampling conducted by EPA's NCA has been designed to estimate the percent of estuarine area (nationally or in a region or state) in varying conditions, which are displayed as pie diagrams. Many of the figures in this report illustrate environmental measurements made at specific locations (colored dots on maps); however, these dots (color) represent the value of the indicator specifically at the time of sampling. Additional sampling may be required to define variability and confirm impairment or the lack of impairment at specific locations.

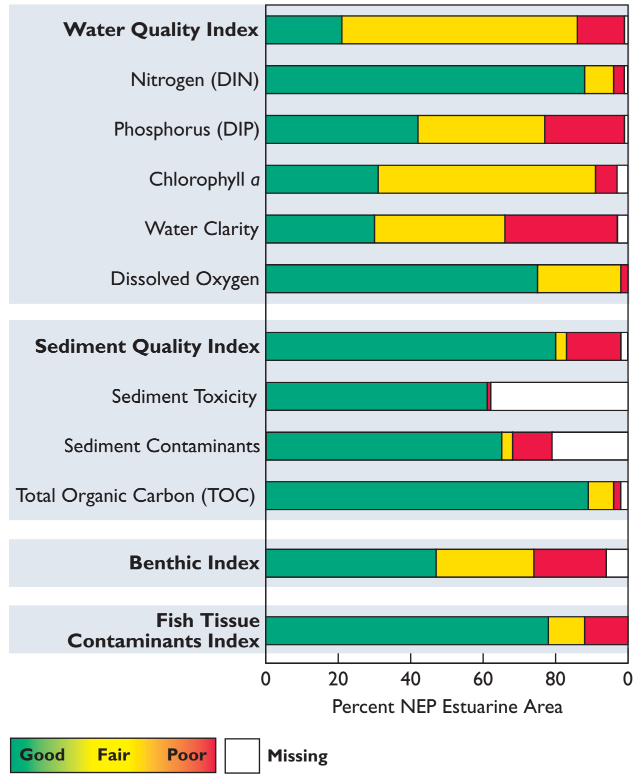


Figure 5-4. Percentage of NEP estuarine area achieving each rating for all indices and component indicators — Gulf Coast region (U.S. EPA/NCA).

Gulf Coast NEP estuaries provide breeding and wintering habitat for royal terns (*Sterna maxima*) (Mobile Bay NEP).

Water Quality Index

Based on NCA results, the water quality index for the collective NEP estuaries of the Gulf Coast region is rated fair (Figure 5-5). This index was developed using NCA data on five component indicators: DIN, DIP, chlorophyll *a*, water clarity, and dissolved oxygen. The NCA survey data indicates that 21% of the Gulf Coast region's NEP estuarine area was rated good for water quality, 65% of the area was rated fair, and 13% of the area was rated poor. In NOAA's Estuarine Eutrophication Survey (NOAA, 1997), the Gulf of Mexico as a whole was ranked poor for eutrophic condition, with an estimated 38% of the estuarine area having a high expression of eutrophication.

Dissolved Nitrogen and Phosphorus | The Gulf Coast region is rated good for DIN concentrations, with 88% of the region's NEP estuarine area rated good for this component indicator, 8% rated fair, and 3% rated poor. Elevated DIN concentrations are not expected to occur during the summer in Gulf Coast waters because freshwater input is generally lower and dissolved nutrients are more rapidly utilized by phytoplankton during this season. The Gulf Coast region is rated fair for DIP concentrations because 22% of the NEP estuarine area was rated poor for this component indicator.

Chlorophyll a | The Gulf Coast region is rated fair for chlorophyll *a* concentrations. Although poor chlorophyll *a* conditions occurred rarely in this region (6% of the NEP estuarine area), 60% of the area was rated fair for this component indicator, and 31% of the area was rated good. NCA data on chlorophyll *a* concentrations were unavailable for 3% of the Gulf Coast NEP estuarine area.

Water Clarity | Water clarity in the Gulf Coast NEP estuarine area is rated poor. Thirty-one percent of the Gulf Coast region's NEP estuarine area was rated poor, 30% was rated good, and 36% was rated fair. NCA data on water clarity were unavailable for 3% of the Gulf Coast NEP estuarine area.

Dissolved Oxygen | The Gulf Coast region is rated good for dissolved oxygen conditions in its NEP estuaries. The NCA results for these estuaries show that only 2% of the estuarine area was rated poor for dissolved oxygen concentrations, 23% of the estuarine area was rated fair, and 75% of the area was rated good.

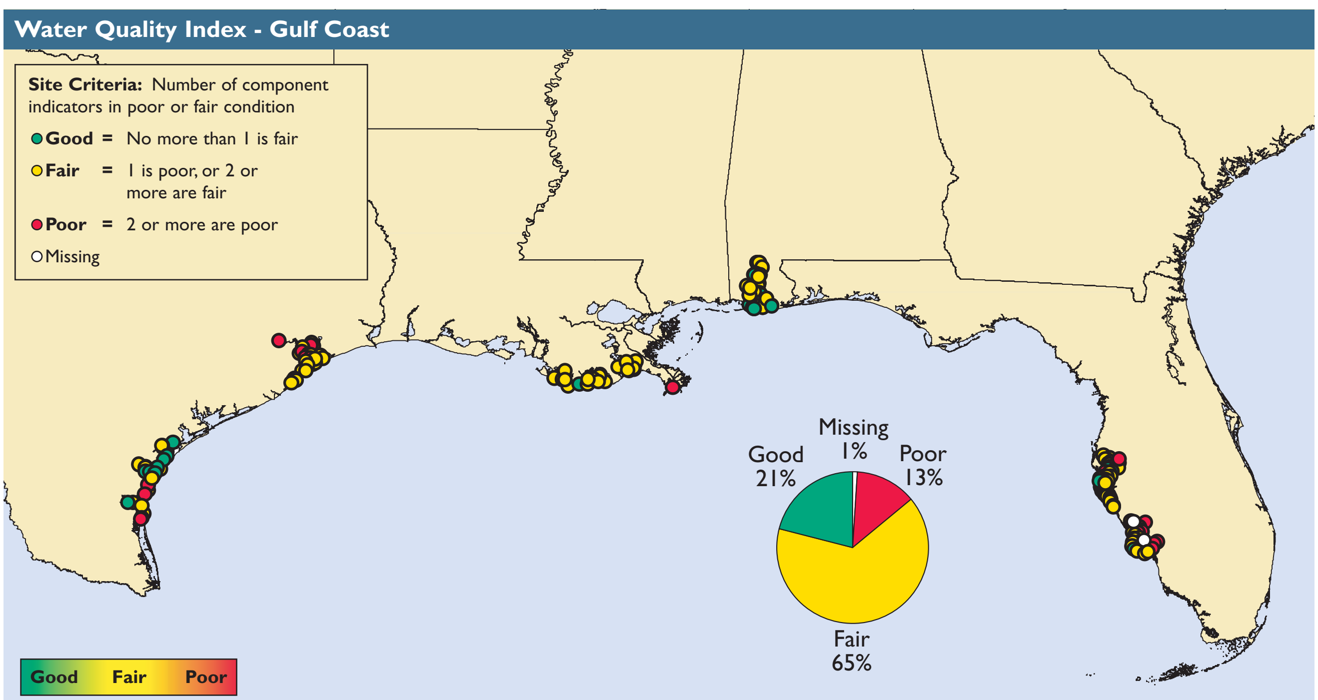


Figure 5-5. Water quality index data for the Gulf Coast NEP estuarine area, 2000–2002 (U.S. EPA/NCA).

Sediment Quality Index

The sediment quality index for the collective NEP estuaries of the Gulf Coast region is rated fair to poor because 18% of the region's NEP estuarine area was rated either fair or poor for sediment quality (Figure 5-6). This index was developed using NCA data on three component indicators: sediment toxicity, sediment contaminants, and sediment TOC.

Sediment Toxicity | Sediment toxicity in the Gulf Coast region is rated good because only 1% of the region's NEP estuarine area was rated poor for this component indicator. It should be noted that data on sediment toxicity were unavailable for 38% of the Gulf Coast NEP estuarine area, including the region's three Florida estuaries (Charlotte Harbor, Sarasota Bay, and Tampa Bay).

Sediment Contaminants | The Gulf Coast region is rated fair for sediment contaminant concentrations, with 11% of the region's NEP estuarine area rated poor for this component indicator. It should be noted that NCA data on sediment contaminant concentrations were unavailable for 21% of the Gulf Coast NEP estuarine area, including the region's three Florida estuaries (Charlotte Harbor, Sarasota Bay, and Tampa Bay).

Total Organic Carbon | The Gulf Coast region is rated good for sediment TOC. Eighty-nine percent of the estuarine area was rated good for TOC concentrations, and 2% of the area was rated poor.

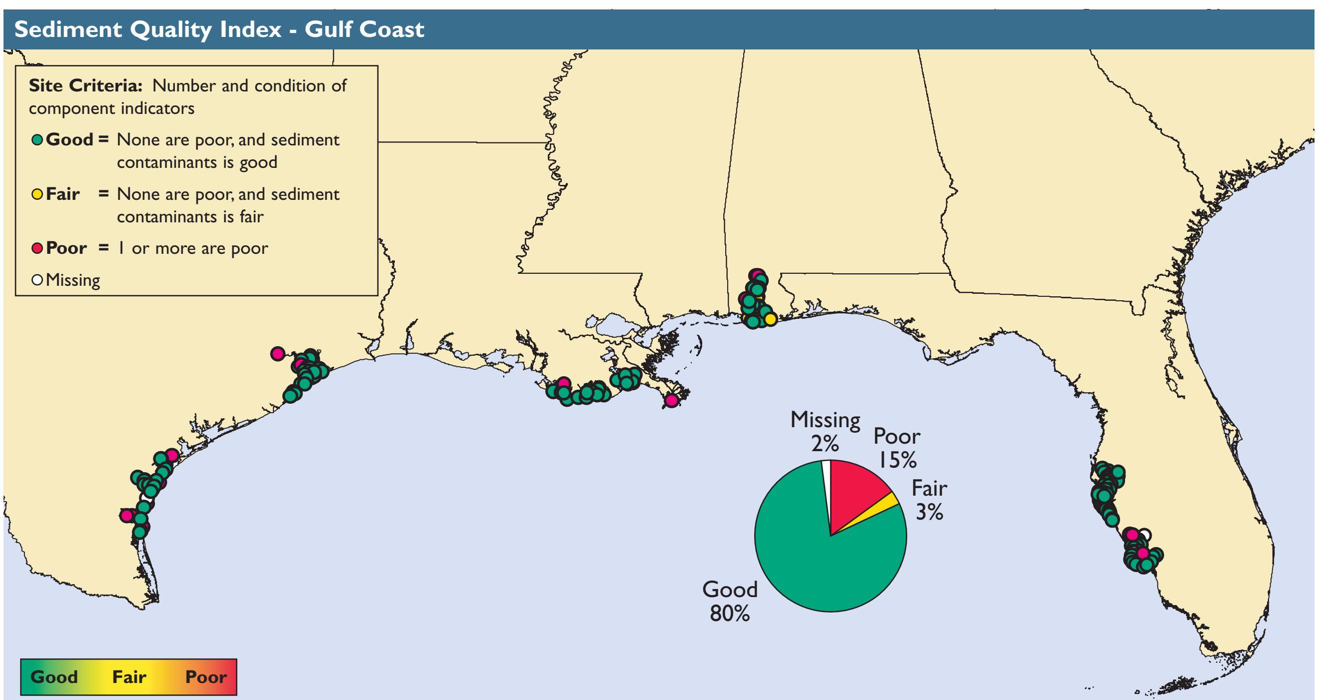


Figure 5-6. Sediment quality index data for the Gulf Coast NEP estuarine area, 2000–2002 (U.S. EPA/NCA).

Benthic Index

The condition of benthic invertebrate communities in the collective Gulf Coast NEP estuaries is rated fair to poor. The composition of benthic invertebrate communities reflects long-term exposure to sediment quality in estuaries, and short-term changes in benthic communities occur in response to hypoxic events and disturbance. Indices of biotic integrity have been developed for aquatic systems to describe the condition of biotic communities. Engle and Summers (1999) developed a Gulf Coast Benthic Index that integrates measures of diversity and populations of indicator species to distinguish between degraded and reference benthic communities. Based on NCA survey data and the Gulf Coast Benthic Index, 20% of the Gulf Coast region's NEP estuarine area showed degraded benthic resources (Figure 5-7).

Field trips can be used to teach students about Gulf Coast NEP estuaries (CHNEP).

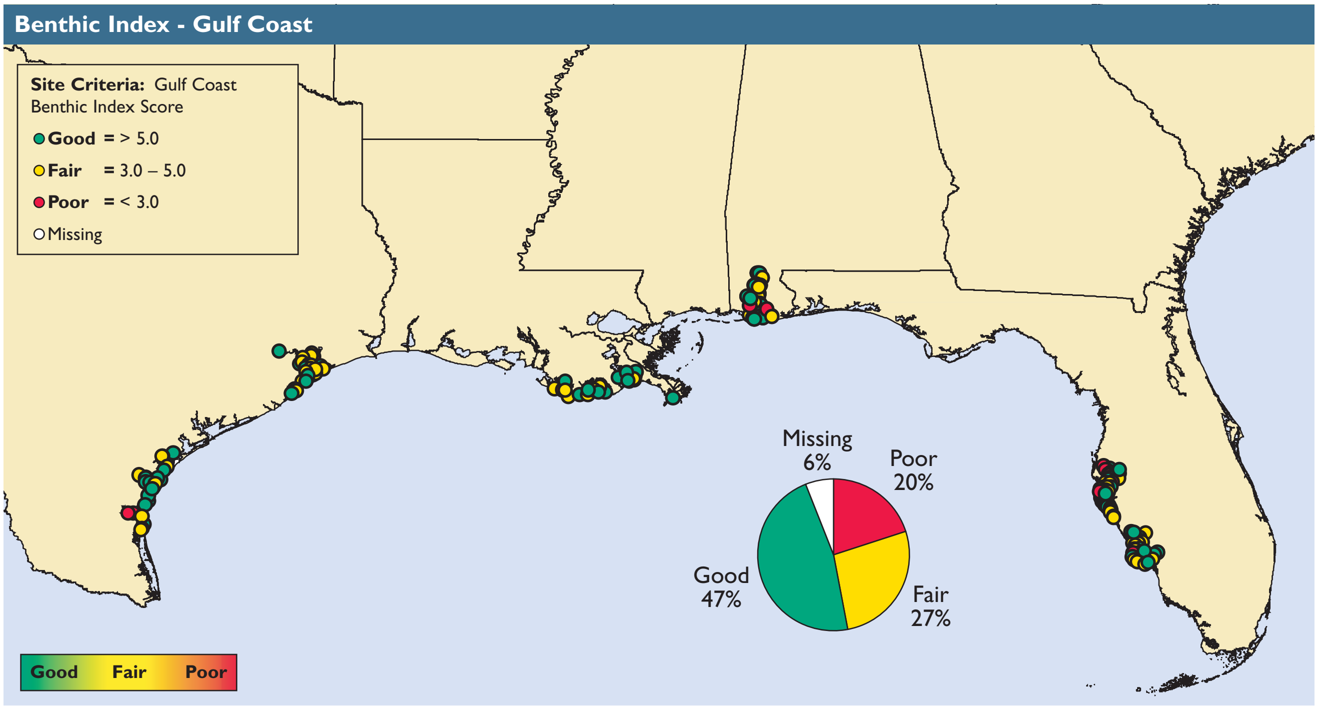


Figure 5-7. Benthic index data for the Gulf Coast NEP estuarine area, 2000–2002 (U.S. EPA/NCA).

A great blue heron looking for its next meal (CBBEP).

Fish Tissue Contaminants Index

The fish tissue contaminants index for the Gulf Coast NEP estuarine area is rated good to fair. It should be noted that fish tissue contaminants were measured in only four of the seven Gulf Coast NEP estuaries, and NCA fish tissue data were not collected for the three Florida estuaries (Charlotte Harbor, Sarasota Bay, and Tampa Bay). Figure 5-8 shows that 12% of all stations sampled where fish were caught exceeded the EPA Advisory Guidance values used in this assessment and were rated poor. The whole-fish contaminant concentrations measured in this survey can be higher or lower than the concentrations associated with fillets only; only those contaminants that have an affinity for muscle tissue (e.g., mercury) are likely to have higher fillet concentrations. Fillet contaminant concentrations for most other contaminants will likely be lower; however, for some populations that consume whole fish, these risk calculations are appropriate.

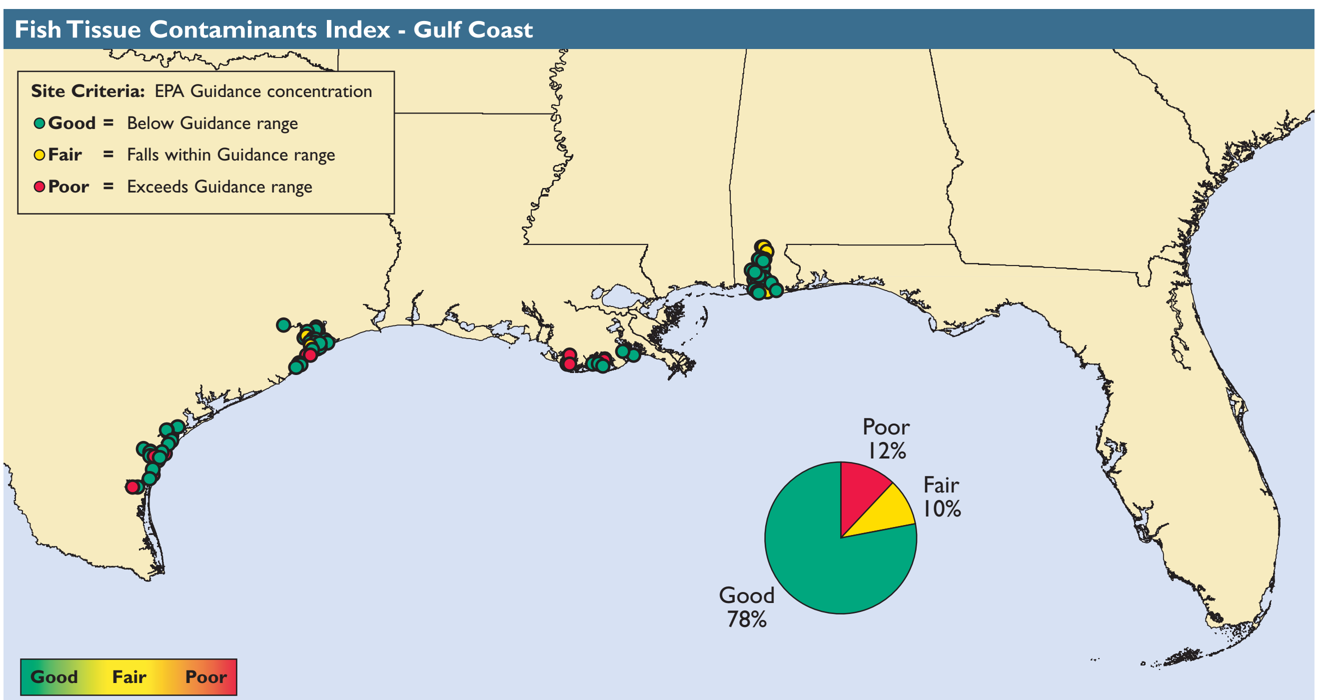


Figure 5-8. Fish tissue contaminants index data for the Gulf Coast NEP estuarine area, 2000–2002 (U.S. EPA/NCA).

NEP Estuaries and the Condition of the Gulf Coast Region

The purpose of the NEP is to identify, restore, and protect the nationally significant estuaries of the United States. Most of the seven NEP estuaries located in the Gulf Coast region need this extra protection, in part because their size and societal significance have led to intense human development; a diversity of uses, including municipal drinking water sources, industrial and agricultural production, and international commerce and shipping; and the associated environmental concerns throughout their watersheds. Does the condition of the Gulf Coast NEP estuaries accurately reflect the condition of all Gulf Coast estuaries (both NEP and non-NEP)? Based on the NCA survey results, the collective Gulf Coast NEP estuaries and all Gulf Coast estuaries combined are both rated fair for overall condition, with both groups receiving an overall condition score of 2.75 (Figure 5-9). Although the overall condition scores for the two groups of estuaries are the same, and both groups received similar ratings for the NCA estuarine indices, a comparison of NCA data reveals that the NEP estuaries had a greater percentage of area rated poor for almost every index than the non-NEP estuaries of the Gulf Coast region (Engle, 2004).

A comparison of NCA data for both groups of estuaries shows that the collective Gulf Coast NEP estuaries are rated fair for the water quality index; fair to poor for the sediment quality and benthic indices; and good to fair for the fish tissue contaminants index. In contrast, the group of all Gulf Coast estuaries combined are rated fair for the water quality, sediment quality, and fish tissue contaminants indices and fair to poor for the benthic index. In addition, the two groups of estuaries are rated comparably for most of the water quality and sediment quality component indicators, with both groups of estuaries rated good for DIN and dissolved oxygen concentrations, sediment toxicity, and sediment TOC and fair for DIP and sediment contaminant

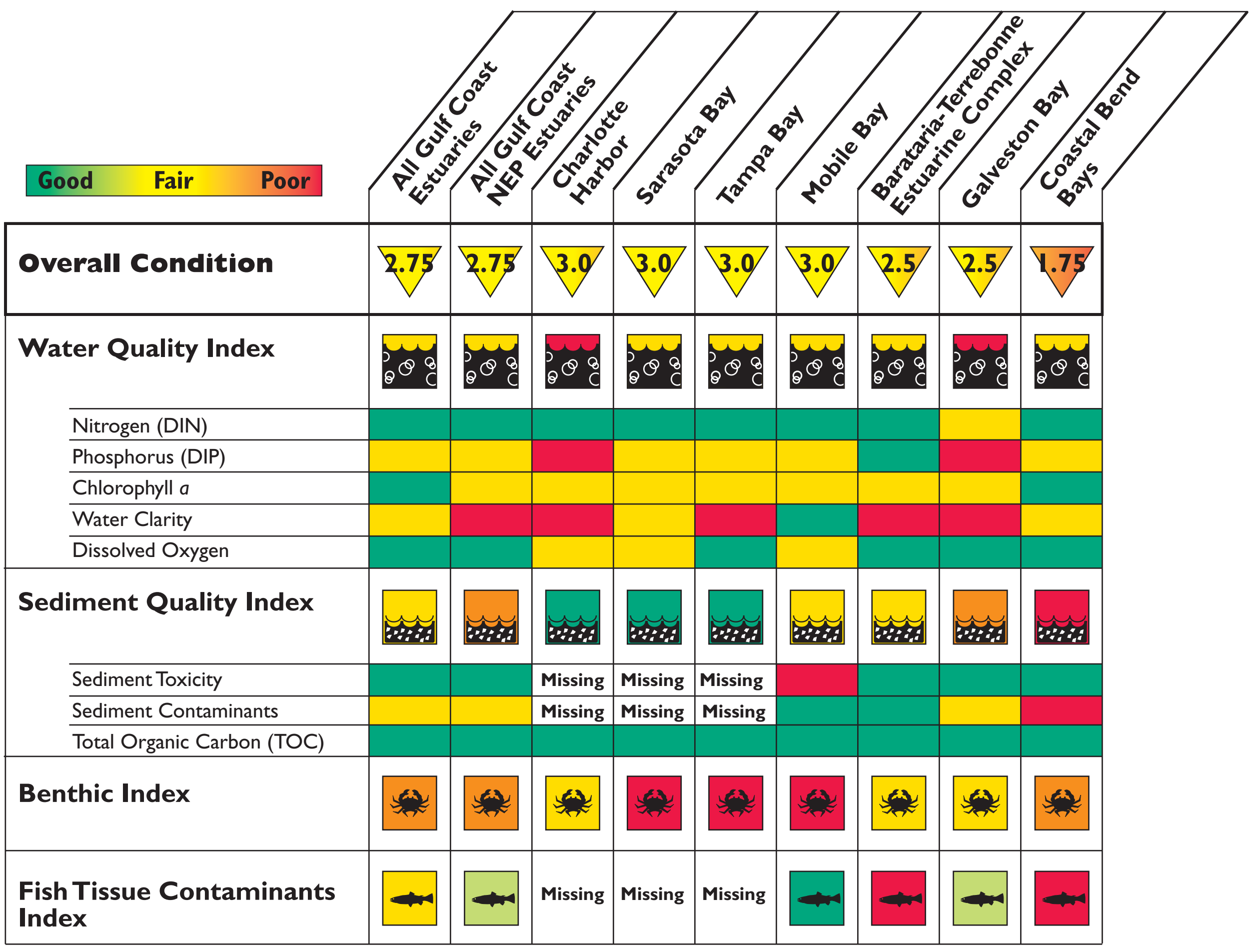


Figure 5-9. Comparison of NCA results for Gulf Coast NEP estuaries and all Gulf Coast estuaries (U.S. EPA/NCA).

concentrations. For the remaining two component indicators, the collective Gulf Coast NEP estuaries are rated fair for chlorophyll *a* concentrations and poor for water clarity, whereas the Gulf Coast estuaries combined are rated good and fair for these indicators, respectively.

With respect to the individual NEP estuaries, four of the seven estuaries received higher overall condition scores than the overall condition score for the collective Gulf Coast NEP estuaries (2.75, rated fair). These four estuaries are Charlotte Harbor (3.0), Sarasota Bay (3.0), Tampa Bay (3.0), and Mobile Bay (3.0) which are all rated fair. Galveston Bay (2.5, rated fair), the Barataria-Terrebonne Estuarine Complex (2.5, rated fair), and the Coastal Bend Bays (1.75, rated poor) received lower overall condition scores than the score for the collective Gulf Coast NEP estuaries.

A review of the NCA data for the water quality index and component indicators shows that the ratings vary between the individual Gulf Coast NEP estuaries. None of the NEP estuaries are rated good for the water quality index; Sarasota Bay, Mobile Bay, the Barataria-Terrebonne Estuarine Complex, and the Coastal Bend Bays are rated fair; Tampa Bay is rated fair to poor, largely driven by poor water clarity and fair concentrations of chlorophyll *a* and DIP; and Charlotte Harbor and Galveston Bay are rated poor, primarily due to poor DIP concentrations and poor water clarity ratings. All Gulf Coast NEP estuaries are rated good for DIN concentrations, except for Galveston Bay, which is rated fair. The Barataria-Terrebonne Estuarine Complex is rated good for DIP concentrations; Sarasota Bay, Tampa Bay, Mobile Bay, and the Coastal Bend Bays are rated fair; and Charlotte Harbor and Galveston Bay are rated poor. All the Gulf Coast NEP estuaries are rated fair for chlorophyll *a* concentrations, except for the Coastal Bend Bays, which are rated good for this component indicator. Although most Gulf Coast NEP estuaries (Charlotte Harbor, Tampa Bay, the Barataria-Terrebonne Estuarine Complex, and Galveston Bay) are rated poor for water clarity, Sarasota Bay and the Coastal Bend Bays are rated fair for this component indicator, and Mobile Bay is rated good. Four Gulf Coast NEP estuaries (Tampa Bay, the Barataria-Terrebonne Estuarine Complex, Galveston Bay, and the Coastal Bend Bays) are rated good for dissolved oxygen concentrations, but the three remaining NEP estuaries (Charlotte Harbor, Sarasota Bay, and Mobile Bay) are rated fair.

Kayaking is a popular pastime in Gulf Coast NEP estuaries (CBBEP).

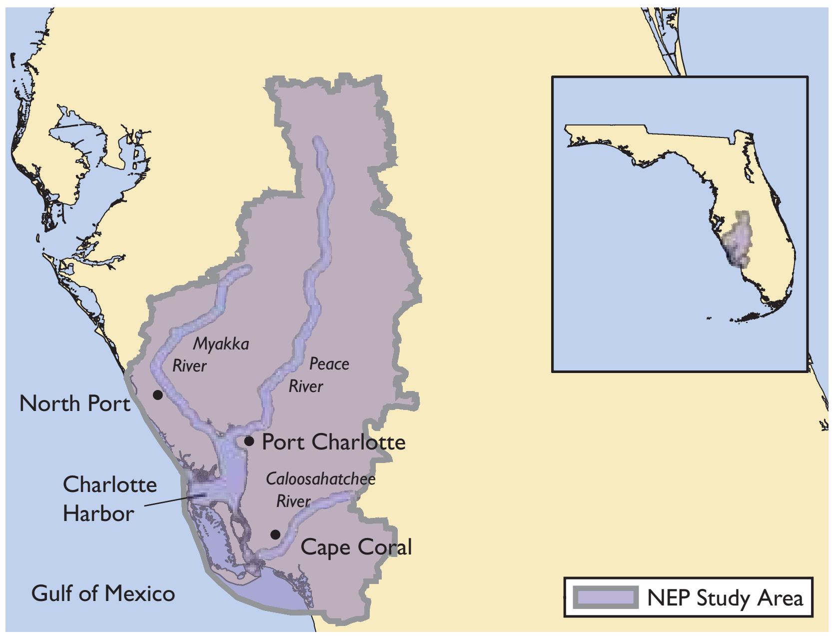
The sediment quality index scores for the individual Gulf Coast NEP estuaries range from good to poor. For the three Florida NEP estuaries (Charlotte Harbor, Sarasota Bay, and Tampa Bay), the sediment quality index is rated good; however, it should be noted that NCA data on the sediment toxicity and sediment contaminants component indicators were not collected for these estuaries. For the remaining NEP estuaries, sediment quality index ratings decrease from east to west, with Mobile Bay and the Barataria-Terrebonne Estuarine Complex rated fair for sediment quality; Galveston Bay rated fair to poor; and the Coastal Bend Bays rated poor. Sediment toxicity is rated good for the Barataria-Terrebonne Estuarine Complex, Galveston Bay, and the Coastal Bend Bays and poor for Mobile Bay. Sediment contaminant concentrations are rated good for Mobile Bay and the Barataria-Terrebonne

Estuarine Complex, fair for Galveston Bay, and poor for the Coastal Bend Bays. Sediment TOC content is rated good for all Gulf Coast NEP estuaries, both collectively and individually, as well as for all Gulf Coast estuaries combined.

The benthic index scores for the individual NEP estuaries range from poor to fair. The benthic index is rated fair for Charlotte Harbor, the Barataria-Terrebonne Estuarine Complex, and Galveston Bay; fair to poor for the Coastal Bend Bays; and poor for Sarasota Bay, Tampa Bay, and Mobile Bay. The fish tissue contaminants index is rated good for Mobile Bay, good to fair for Galveston Bay, and poor for the Barataria-Terrebonne Estuarine Complex and the Coastal Bend Bays. NCA survey data on fish tissue contaminants were unavailable to evaluate any of the Gulf Coast NEP estuaries in Florida (Charlotte Harbor, Sarasota Bay, and Tampa Bay).

Nationally, the overall condition score for the collective NEP estuaries of the Gulf Coast region (2.75) is lower than the overall condition score for the collective NEP estuaries of the Southeast Coast region (4.0), comparable to the score for the West Coast region (2.5), and higher than the scores for the Northeast Coast (1.5) and Puerto Rico (1.5) regions. Population pressures, measured as population density (number of persons/mi^2), did not correlate well with the overall condition ratings for the individual Gulf Coast NEP estuaries. For example, the Coastal Bend Bays had the lowest population density of 53 persons/mi^2 in 2000, yet this estuary is rated poor for overall condition, with an overall condition score of 1.75. The two estuaries with the highest population densities in 2000, Galveston Bay (651 persons/mi^2) and Tampa Bay (640 persons/mi^2), are both rated fair for overall condition and received overall condition scores of 2.5 and 2.66, respectively. Mobile Bay (191 persons/mi^2), Charlotte Harbor (306 persons/mi^2), and Sarasota Bay (364 persons/mi^2), which had more intermediate population densities in 2000, each received an overall condition score of 3.0 and are rated fair for overall condition.

Charlotte Harbor National Estuary Program



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Background

Located on the west coast of Florida's peninsula, Charlotte Harbor is created by the inflow and confluence of the Myakka, Peace, and Caloosahatchee rivers and empties into the Gulf of Mexico via Boca Grande, Gasparilla Pass, and San Carlos Bay. The fluctuations of river flow between the wet (summer) and dry (winter) seasons affect the Harbor's salinity and dissolved oxygen levels (NOAA, 1985). The Harbor itself is 30 miles long and 7 miles wide, with a total area of 270 mi^2 (CHNEP, 2005a). The Charlotte Harbor watershed is home to a highly diverse natural ecology, as well as to a growing human population and a variety of economic activities, including phosphate mining, residential development, tourism, intensive agriculture, and commercial fishing. Population growth is a major concern in the Charlotte Harbor watershed because county populations are projected to grow by more than 33% between 2000 and 2020 (CHNEP, 2000).

The estuarine area of the Charlotte Harbor NEP (CHNEP) contains waters listed as drinking water supplies (e.g., Shell and Horse creeks and parts of the Myakka River) and waters listed for shellfish propagation or harvesting (e.g., the tidal portion of the Myakka and Peace rivers). The CHNEP estuarine area also includes most of the Peace River (U.S. EPA, 2005c). Those areas located within the Charlotte Harbor Aquatic and State Buffer Preserve and the Myakka River State Park have been designated as Outstanding Florida Waters. Charlotte Harbor and its contiguous coastal waters serve as a home, feeding ground, or nursery area for more than 270 resident, migrant, and commercial fish species of the Gulf of Mexico (CHNEP, 2005a). For numerous species, the most critical use of Charlotte Harbor is as a protected nursery area for both larval and juvenile stages of fish. Mangrove trees line the Harbor's shore and provide important habitat for plants, fish, birds, and other wildlife, such as manatees, sea turtles, wood storks, and dolphins.

Environmental Concerns

The environmental concerns of highest priority in Charlotte Harbor are hydrologic alterations, water quality degradation, and habitat loss. Management challenges for the CHNEP include protecting mangrove habitats; protecting seagrass areas from boat damage and water pollution; securing new water supply sources for the watershed's growing human populations and businesses; managing waste generated by septic tanks and sewer outfalls; protecting wetland areas for water retention, groundwater recharge, and wildlife habitat; and improving the overall efficiency of freshwater usage. Hydrologic alterations have occurred in the Harbor's three major tributary rivers, adversely effecting the location, timing, and volume of freshwater flows to this estuary (CHNEP, 2003a). The major causes of habitat loss in Charlotte Harbor include the degradation and elimination of headwater streams and other habitats by commercial development; the conversion of natural shorelines; the cumulative impacts of dock construction and boating; the invasion of exotic species; and other cumulative and future impacts of population growth (CHNEP, 2005a). In general, dissolved oxygen levels and surface water quality have declined in several areas of the Harbor's southern basins, including the Cape Coral peninsula south of Interstate 75, the north shore of the Caloosahatchee River, the coastal bays near Pine Island, and the Estero Bay watershed. Water quality in other areas of Charlotte Harbor is stable or improving (CHNEP, 2003b).

Population Pressures

The population of the 10 NOAA-designated coastal counties (Charlotte, Collier, DeSoto, Glades, Hardee, Hillsborough, Lee, Manatee, Polk, and Sarasota) coincident with the CHNEP study area increased by 251% during a 40-year period, from 0.8 million people in 1960 to 3.0 million people in 2000 (Figure 5-10) (U.S. Census Bureau, 1991; 2001). This rate of population growth for the CHNEP study area was almost double the growth rate of 133.3% for the collective Gulf Coast NEP-coincident coastal counties and was the second-highest rate of growth of all NEPs in the Gulf Coast region, behind Sarasota Bay. In 2000, the population density of these 10 coastal counties was 306 persons/mi^2, slightly higher than the population density of 287 persons/mi^2 for the collective Gulf Coast NEP-coincident coastal counties (U.S. Census Bureau, 2001). Development and population pressures are especially strong in NEP study areas that serve as major shipping ports and as centers for commercial and recreational fisheries and other activities.

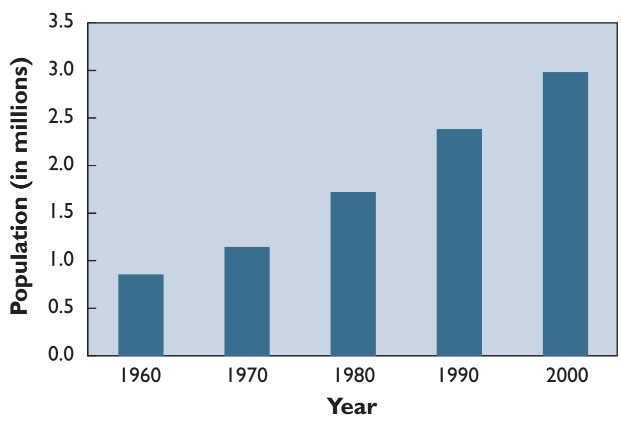


Figure 5-10. Population of NOAA-designated coastal counties of the CHNEP study area, 1960–2000 (U.S. Census Bureau, 1991; 2001).

NCA Indices of Estuarine Condition—Charlotte Harbor

The overall condition of Charlotte Harbor is rated fair based on three of the four indices of estuarine condition used by the NCA (Figure 5-11). The water quality index is rated poor, the sediment quality index is rated good, and the benthic index is rated fair; NCA data were unavailable to calculate a fish tissue contaminants index for Charlotte Harbor. Figure 5-12 provides a summary of the percentage of estuarine area rated good, fair, poor, or missing for each parameter considered. This assessment is based on data collected by the Florida Fish and Wildlife Research Institute, in partnership with the NCA, from 30 sites sampled in the CHNEP estuarine area in 2002. Please refer to Tables 1-24, 1-25, and 1-26 (Chapter 1) for a summary of the criteria used to develop the rating for each index and component indicator.

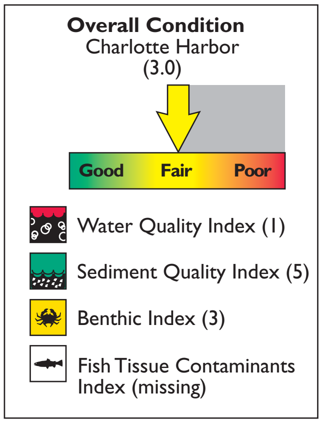


Figure 5-11. The overall condition of the CHNEP estuarine area is fair (U.S. EPA/NCA).

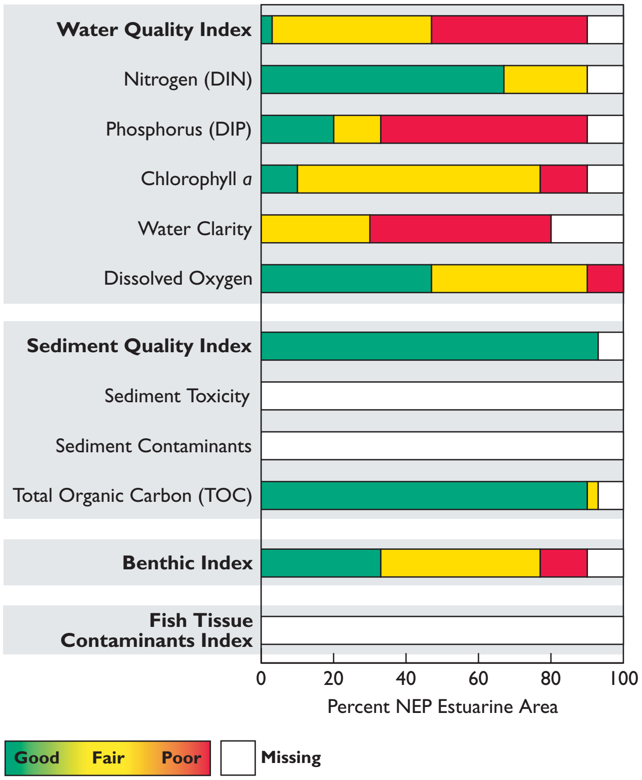


Figure 5-12. Percentage of NEP estuarine area achieving each rating for all indices and component indicators — Charlotte Harbor (U.S. EPA/NCA).

Water Quality Index

The water quality index for Charlotte Harbor is rated poor (Figure 5-13). This index was developed using NCA data on five component indicators: DIN, DIP, chlorophyll *a*, water clarity, and dissolved oxygen. Elevated DIP concentrations and poor water clarity contributed to the Harbor's poor water quality condition. The NOAA's Estuarine Eutrophication Survey listed Charlotte Harbor as having low-to-high DIN concentrations, high DIP concentrations, and medium-to-hypereutrophic chlorophyll *a* levels (NOAA, 1997).

Dissolved Nitrogen and Phosphorus | The Charlotte Harbor is rated good for DIN concentrations. None of the estuarine area was rated poor for this component indicator, 23% of the area was rated fair, and 67% of the area was rated good. NCA data on DIN concentrations were unavailable for 10% of the CHNEP estuarine area. In contrast, DIP concentrations are rated poor for Charlotte Harbor; however, it should be noted that phosphorus levels in Charlotte Harbor are naturally high because of a commercially mined phosphate deposit, the Bone Valley deposit. Fifty-seven percent of the estuarine area was rated poor for DIP concentrations, 20% of the area was rated good, and 13% of the area was rated fair.

Chlorophyll a | Chlorophyll *a* concentrations in Charlotte Harbor are rated fair. Thirteen percent of the estuarine area was rated poor for this component indicator, 67% of the area was rated fair, and 10% was rated good. NCA data on chlorophyll *a* concentrations were unavailable for 10% of the CHNEP estuarine area.

Water Clarity | Water clarity in Charlotte Harbor is rated poor. Water clarity was rated poor at a sampling site if light penetration at 1 meter was less than 20% of surface illumination. Expectations for water clarity are high for Charlotte Harbor because one of the CHNEP's goals is to maintain SAV coverage and quality at levels of natural variability. Fifty percent of the estuarine area was rated poor for water clarity, 30% of the area was rated fair, and none of the area was rated good. NCA data on water clarity were unavailable for the remaining 20% of the CHNEP estuarine area.

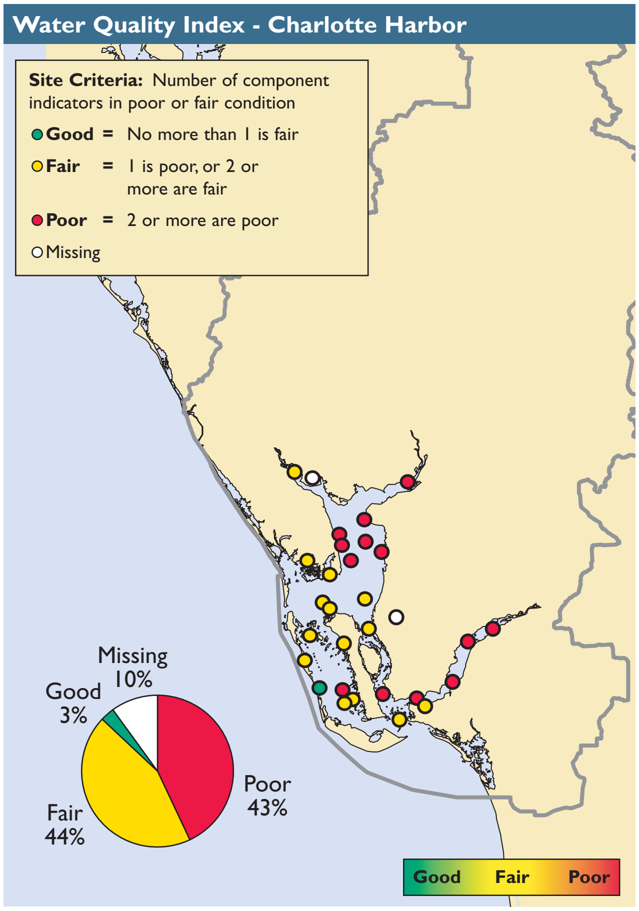


Figure 5-13. Water quality index data for Charlotte Harbor, 2002 (U.S. EPA/NCA).

Dissolved Oxygen | The Charlotte Harbor is rated fair for dissolved oxygen concentrations. NCA estimates show that only 10% of the CHNEP estuarine area was rated poor for this component indicator, 43% of the estuarine area was rated fair, and 47% of the area was rated good.

Sediment Quality Index

The sediment quality index for Charlotte Harbor is rated good; however, this rating is based on measurements of sediment TOC only (Figure 5-14). Ninety-three percent of the estuarine area was rated good for sediment quality, with NCA data unavailable for 7% of the CHNEP estuarine area.

Sediment Toxicity | The NCA did not collect sediment toxicity data for Charlotte Harbor in 2002; therefore, sediment toxicity in the Harbor has not been rated for this report.

Sediment Contaminants | The NCA did not collect sediment contaminants data for Charlotte Harbor in 2002; therefore, sediment contaminant concentrations in the Harbor have not been rated for this report.

Total Organic Carbon | Charlotte Harbor is rated good for TOC concentrations, with 90% of the estuarine area rated good and 3% rated fair for this component indicator. NCA data on TOC concentrations were unavailable for 7% of the CHNEP estuarine area.

Benthic Index

The condition of benthic invertebrate communities in Charlotte Harbor is rated fair based on the Gulf Coast Benthic Index and data from the NCA. Benthic index estimates indicate that 13% of the Harbor's estuarine area was rated poor for benthic condition, 44% was rated fair, and 33% was rated good (Figure 5-15).

Fish Tissue Contaminants Index

The NCA did not assess the level of fish tissue contaminants in the CHNEP estuarine area in 2002; therefore, a fish tissue contaminants index for Charlotte Harbor was not developed for this report.

Charlotte Harbor National Estuary Program Indicators of Estuarine Condition

The major indicators of estuarine condition used by the CHNEP are species composition and coverage of SAV; coverage and quality of fish and wildlife habitat; quantity and timing of freshwater flows and groundwater levels; and water quality conditions that lead to or are indicative of eutrophication. The CHNEP manages an interagency monitoring program that collects data on a variety of parameters, including Secchi disk, temperature, salinity, specific conductance, dissolved oxygen, pH, color, turbidity, total suspended solids, chlorophyll *a*, total nitrogen, total Kjeldahl nitrogen, total ammonia nitrogen, total nitrite+nitrate nitrogen, dissolved orthophosphate, total phosphorus, and TOC.

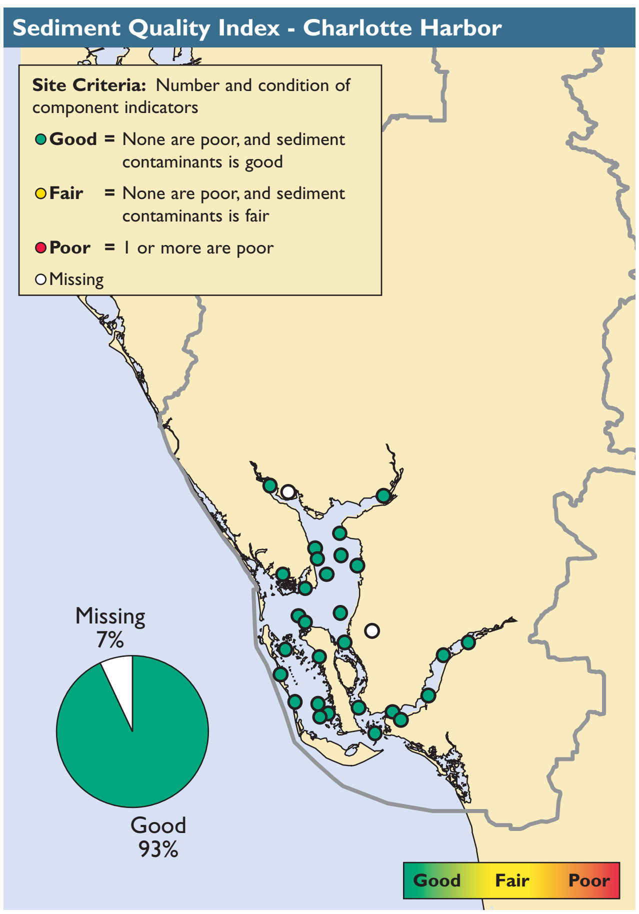


Figure 5-14. Sediment quality index data for Charlotte Harbor, 2002 (U.S. EPA/NCA).

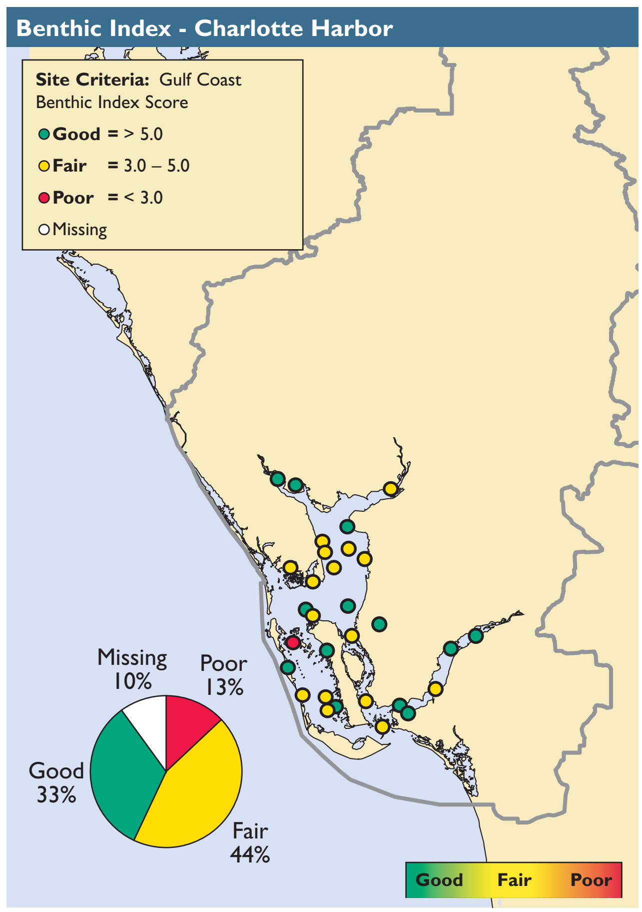


Figure 5-15. Benthic index data for Charlotte Harbor, 2002 (U.S. EPA/NCA).

The results from this monitoring program can be found at the following NEP-supported Web sites: http://www.checflorida.org and http://ws13.ipowerweb.com/checflor/chec/waterquality_home.htm.

Water and Sediment Quality

The presence of algal blooms; high concentrations of DIN, DIP, and chlorophyll *a*; and low levels of dissolved oxygen are the key indicators of potential eutrophic conditions in Charlotte Harbor. In recent decades, population growth, stormwater runoff from residential and commercial development, agricultural and industrial practices, and the burning of fossil fuels have been major sources of increased inputs of nutrients to Charlotte Harbor. Results from March 2004 show elevated levels of DIN and slightly higher than normal DIP concentrations in the Harbor, but normal chlorophyll *a* levels. Dissolved oxygen and turbidity values were rated better than normal by the CHNEP. The Caloosahatchee River basin has ongoing water quality problems, with excess nutrients, low dissolved oxygen, and noticeable increases in levels of copper and lead (CHNEP, 2005a). Recent maps of water and sediment quality indicators, as reported by the CHNEP on a monthly basis, can be found at http://www.chnep.org.

Declines in dissolved oxygen levels and worsening surface water quality were observed in the southern basins of Charlotte Harbor. Overall, there have been major increases in total suspended solids in the entire southern portion of the CHNEP estuarine area, including the full extent of Charlotte Harbor. Florida surface water standards have been exceeded frequently for dissolved oxygen (both instantaneous readings and daily average readings) and ammonia in many basins, and to a lesser extent, for chlorophyll *a* and bacteria levels (CHNEP, 2003b).

Habitat Quality

The natural habitats of the Charlotte Harbor estuarine area span a wide range of environments, from xeric oak scrubs to subtidal soft-bottoms to mangrove forests. Mangrove forests provide habitat for more than 2,300 species of animals, including at least 42 federally listed and state-listed endangered or threatened animal species, such as the Florida black bear, manatee, bald eagle, wood stork, Florida scrub jay, and American crocodile. In Charlotte Harbor, the acreage, type, and health of seagrass systems are monitored as one of the major indicators of estuarine condition. Informal habitat indicators monitored by the CHNEP include shellfish-area closures, number of fish kills, presence of fish lesions, acres of stable seagrass areas, and presence or lack of HABs (red tides). Some other useful response indicators include the effectiveness of riprap under docks, the effectiveness of artificial reefs in enhancing habitat value along seawalls, the length of shoreline restored, and the effectiveness of exotic vegetation removal (CHNEP, 2005a).

Seagrasses within the northern portion of the CHNEP study area have been found to be stable, and analysis is still being conducted on the southern portion of the area (CHNEP, 2005a). Seagrass habitats exist throughout all of the riverine and estuarine regions of the CHNEP study area, providing food sources, solid foundations, and protective structures for living resources. Historically, dredge-and-fill activities within coastal bottom and wetland areas have reduced the extent of these habitats. One specific goal of the CHNEP is to reduce propeller damage to SAV by 2010 (CHNEP, 2000). At the present time, the CHNEP's data is sufficient to evaluate significant losses of SAV acreage due to direct impacts, such as water management (e.g., losses in the Caloosahatchee River's *Vallisneria americana*) and channel and causeway island construction (e.g., losses in IntraCoastal Waterway and Sanibel Causeway). Dissolved and suspended matter within the water column, rather than chlorophyll *a*, largely limit light availability for seagrass beds in Charlotte Harbor, and water clarity in the Harbor increases with salinity and distance from the tributaries (McPherson and Miller, 1987; McPherson and Miller, 1994; Dixon and Kirkpatrick, 1999; Doering and Chamberlain, 1999; Tomasko and Hall, 1999); thus, seagrass coverage shows inter-annual variability largely due to inter-annual freshwater flow changes (Corbett et al., 2005). In some areas of Charlotte Harbor, unrestricted development has resulted in large losses of habitats, such as high marshes and salterns.

Charlotte Harbor National Estuary Program

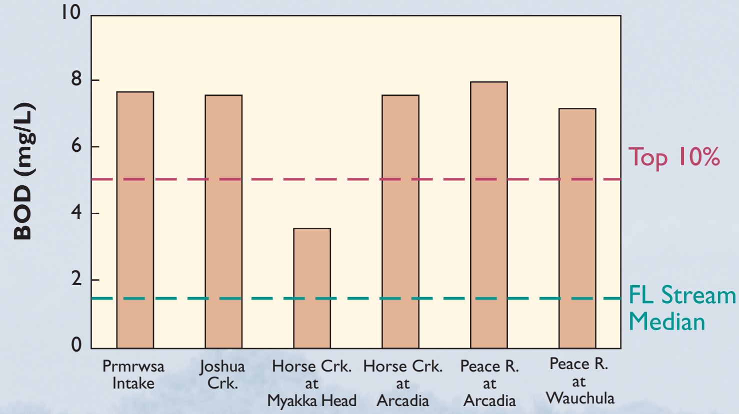
Hurricanes and Hypoxia in 2004

Over a two-month period in 2004, four major hurricanes and five named tropical storms battered Florida, with three hurricanes directly impacting the CHNEP study area (CHNEP, 2005b; Everham 2005). On August 13, 2004, Hurricane Charley—the strongest hurricane to hit the United States since Hurricane Andrew in 1992—passed through the heart of Charlotte Harbor (Pasch et al., 2005). The destruction from Hurricane Charley was not limited to the land and homes of the Charlotte Harbor watershed, but included damage to the Harbor and its rivers, creeks, and tributaries. Many of Charlotte Harbor's local islands, man-made canals, tributaries, and other waterways are lined with homes and boat docks. In calm weather, these settings provide an idyllic existence and magical vistas; however, the scenario changed in the face of Hurricane Charley, as waterways were made impassable by fallen trees, uprooted vegetation, and enormous quantities of debris (Fletcher, 2005).

One week after Hurricane Charley moved through Florida, state agencies began receiving complaints of foul-smelling water, prompting an unscheduled sampling effort that measured low dissolved oxygen levels for many areas of the estuary. Although the sampling found that turbidity and total suspended solid values for the estuary were not unusual, and that color was typical of values normally found during the wet season the biological oxygen demand (BOD) for the estuary was very high. The low dissolved oxygen values in Charlotte Harbor were associated with the decomposition of large amounts of dissolved organic matter that resulted in the high levels of BOD (see bar graph) (Tomasko et al., 2005b). Although hypoxia is a normal, wet season phenomenon in the Harbor (Camp Dresser & McKee, 1998) and a hypoxic zone was apparent in Charlotte Harbor two weeks after Hurricane Charley passed through the area (see map), hypoxia has never been recorded over such an extensive area of the Charlotte Harbor watershed (Tomasko et al., 2005b).

Satellite image of Hurricane Charley at landfall (NOAA National Climatic Data Center).

Subsequently, Hurricane Frances passed through Florida over the Labor Day weekend. Three weeks later, on National Estuary Day, Hurricane Jeanne followed Frances over the Peace River basin. The impacts of this string of hurricanes on the water quality of Charlotte Harbor were felt for months following the storms. Water quality characteristics in Charlotte Harbor, such as dissolved oxygen and water clarity, were degraded into the fall of 2004, but were showings signs of recovery by 2005 (Beever, 2005).



Five-day BOD values one week after Hurricane Charley (Tomasko et al., 2005a).

Large hypoxic zone (ca. 30 mi^2) apparent two weeks after Hurricane Charley. BLUE TRIANGLE: Sites with no hypoxia (DO < 2 mg/L) in surface or bottom waters. RED TRIANGLE POINTING UP: Sites with hypoxia in bottom waters only. RED TRIANGLE POINTING DOWN: Sites with hypoxia in both bottom and surface waters. YELLOW TRIANGLE: Sites not visited due to an oncoming storm. The red line delimits area believed to exhibit hypoxia for this event, based on event data and historical monitoring data demonstrating that hypoxia is associated with flows out of the Peace River and along the western "wall" of Charlotte Harbor. Some smaller areas (unknown in size) exhibited hypoxia in both bottom and surface waters (Tomasko et al., 2005a).

Living Resources

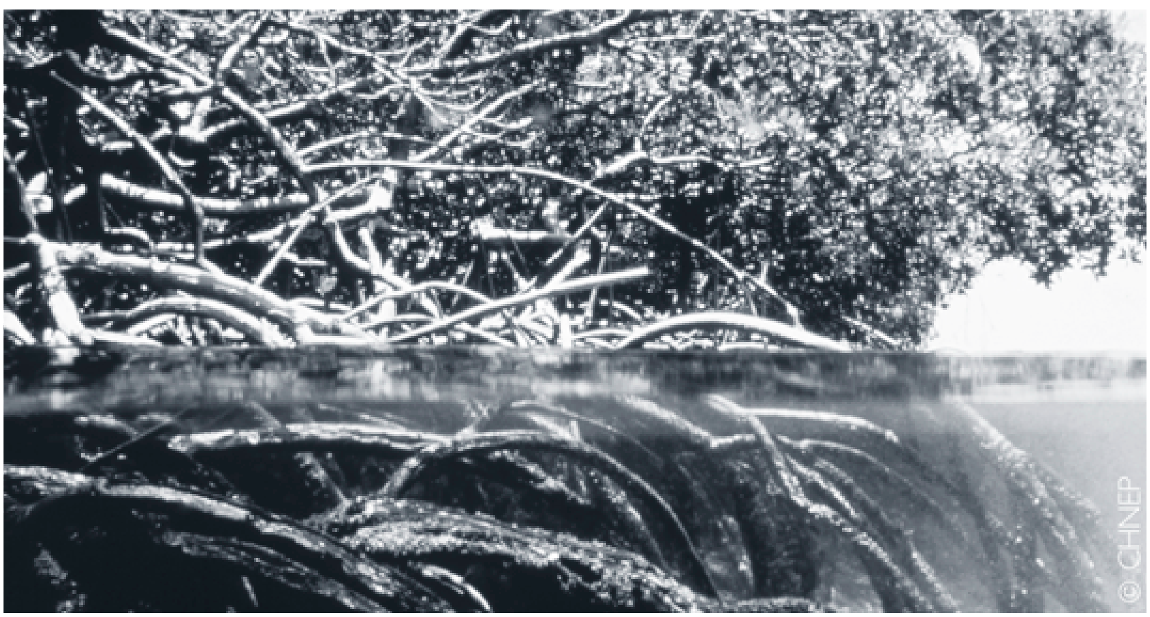
Charlotte Harbor provides habitat for 39 species of mammals, 331 species of birds, 67 species of reptiles, 27 species of amphibians, and 452 species of fish (CHNEP, 2005a); however, the growing human population and increasing urban development have resulted in habitat loss throughout the study area. This loss of habitat can negatively affect plant communities and wildlife. For example, since the 1920s, pine flatwoods habitat acreage has decreased; communities of pines, wax myrtle, and saw palmetto have been lost; and animals, including pileated woodpeckers, American kestrels, sandhill cranes, black bears, panthers, indigo snakes, and gopher tortoises, have been displaced (CHNEP, 2000).

Shellfish are a reliable measure of the environmental health of an estuary. Because they feed by filtering estuary water, shellfish assimilate and concentrate the materials carried in the water in their tissues. More than 275 species of shellfish are found throughout the waters of Charlotte Harbor. People have been harvesting shellfish in the area since the Calusa Indians of southwest Florida gathered enormous amounts of shellfish by digging canals and constructing immense shell mounds. In the more recent past, oysters, clams, and scallops have been harvested commercially and recreationally throughout Lemon Bay, Gasparilla Sound, Charlotte Harbor, and Pine Island Sound. The height of the shellfish industry in the Charlotte Harbor area occurred during the 1940s, and the commercial harvest of shellfish has declined since that time (CHNEP, 2000).

Environmental Stressors

Adverse changes in the location, timing, and volume of freshwater flows; overall function of flood plain systems; and natural river flows are the major hydrologic concerns in Charlotte Harbor. Man-made canals and waterfront lots are two major developments that alter surface water hydrology and degrade estuarine conditions in Charlotte Harbor. The construction of drainage channels for transportation, agricultural activities, urbanization, and hurricane flood relief have been just as prevalent. Although changes to groundwater systems in the Charlotte Harbor watershed have been less obvious, the increased drainage of surface systems reduces recharge to groundwater, altering the general flow of underground aquifers. Saltwater intrusion is an indicator of these changes.

Hydrologic alterations have occurred in many regions of the Charlotte Harbor area. For example, the Caloosahatchee River was channelized and artificially connected to Lake Okeechobee in the late 1800s and early 1900s to provide flood protection, serve as a navigational channel, and supply water for agricultural and



Prop roots of mangrove trees below the water surface provide substrate for many other organisms (CHNEP).

urban use. Three locks and dams have been constructed along the Caloosahatchee River, one of which artificially truncates the river's estuarine system by blocking the natural gradient of fresh water to salt water that historically had extended upstream during the dry season. The flow through this river is highly manipulated because water management juggles the often conflicting needs of estuary resources, public water supply, and agricultural uses (CHNEP, 2003a). In addition, the upper Peace River has changed from a gaining stream with flow all year long to a losing stream with river flows being lost in sinkholes along the upper Peace River. Kissingen Springs, located along the upper Peace River, ceased flowing in the early 1950s, which is a sign of a lowered groundwater table in the Charlotte Harbor watershed (Corbett, 2003). The Myakka River flows have been artificially augmented because of the overland surface flow of groundwater pumped for agricultural use in the dry season. Also, the upper Myakka River demonstrates an increasing trend in specific conductivity (sulfate and calcium levels), and an extensive tree die-off has occurred in this area due to hydrologic stress (CHNEP, 2003b; Minnis, 2003).

Current Projects, Accomplishments, and Future Goals

The CHNEP set a variety of goals in *Committing to Our Future: A Comprehensive Conservation and Management Plan for the Greater Charlotte Harbor Watershed, Volume 1* (CHNEP, 2000). A goal of the CHNEP is to increase conservation, preservation, and stewardship lands by 25% by the year 2018. To combat hydrological alterations, the CHNEP plans to improve waterbodies affected by artificial structures by the year 2020. To help improve water quality, the program will gather information for the State of Florida to use in developing TMDLs (except for mercury) for high-priority, 303(d)-listed water segments by 2004 and for all remaining 303(d) waters in the CHNEP estuarine area by 2009. The CHNEP also plans to develop a sense of stewardship by providing information on living resources and water quality to the public, as well as by maintaining environmental education efforts with partners (CHNEP, 2000).

Conclusion

Urban development in the Charlotte Harbor study area has been rapid and has contributed to water quality degradation, habitat loss, and hydrologic changes. In addition, there have been ongoing declines in water quality in many of the Charlotte Harbor basins. NCA data classify the overall condition of Charlotte Harbor as fair. Water quality in the Harbor is rated poor, with DIN concentrations rated good; chlorophyll *a* and dissolved oxygen concentrations rated fair; and DIP concentrations and water clarity rated poor. Sediment quality in the Harbor is rated good; however, this rating is based only on measurements of one sediment quality component indicator (sediment TOC). The benthic index is rated fair, and 2002 NCA data were unavailable to develop a fish tissue contaminants index for Charlotte Harbor.

A young student conducts water quality tests in Charlotte Harbor (CHNEP).

Sarasota Bay Estuary Program

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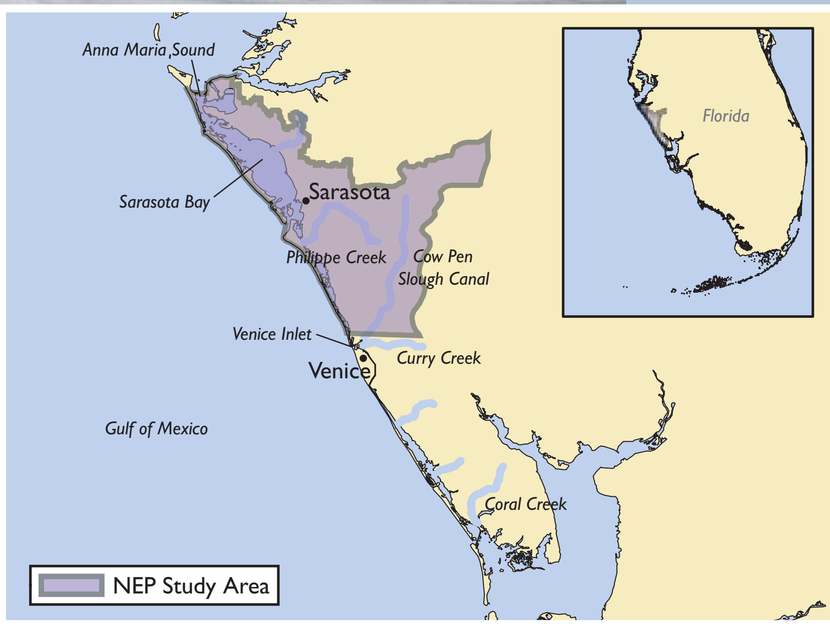

Background

Sarasota Bay is a small, subtropical estuary that is located on the southwestern coast of Florida and covers 52 mi^2 of surface water area. The Bay's watershed spreads across Manatee and Sarasota counties and covers 150 mi^2 of land area. This watershed extends from Venice Inlet to Anna Maria Island and includes the barrier islands and mainland east to Interstate 75 (SWFWMD, 2002). Sarasota Bay is classified as an Outstanding Florida Water Body and was classified as an Estuary of National Significance in 1987 (SBNEP, 2000; FDEP, 2005). The Sarasota Bay Estuary Program (SBEP) estuarine area includes Sarasota, Roberts, Little Sarasota, and Blackburn bays, which are characterized by stretches of barrier islands. The Bay region is home to a wide variety of marine life, including dolphins, manatees, black mullet, red drum, spotted sea trout, snook, blue crab, stone crab, bait shrimp, and the endangered loggerhead sea turtle. Common birds in this region include the great blue heron, cattle egret, great egret, white ibis, brown pelican, osprey, wood stork, yellow-crowned night heron, bald eagle, and the endangered Florida scrub jay.

Sarasota Bay proper is the largest and deepest bay between Tampa Bay and Charlotte Harbor. The Bay is well flushed by three passes (Big Sarasota, New, and Longboat), and its water is much clearer than the waters of the smaller bays to the south (Roberts, Little Sarasota, and Blackburn bays) (Florida Center for Community Design and Research, 2004). Improved drainage levels in the urban watersheds around Sarasota Bay provide more fresh water than historical levels, and numerous improvements have been made in the Bay's water quality, seagrass coverage, and natural habitat areas. Most of the waterbodies in the SBEP estuarine area are designated as recreational-use waters, which means that waters should be fishable and swimmable. Some waterbodies, including Palma Sola Bay and parts of Sarasota Bay, are suitable for shellfish propagation or harvesting (U.S. EPA, 2005c). Of all of the Gulf Coast NEP estuaries, the Sarasota Bay watershed has the greatest percentage of urban land use.

The tourism industry is the largest industry in Sarasota County and the second-largest industry in Manatee County. Seasonal residents are estimated to represent up to 25% of the study area's total population and more than 70% of the population on the barrier islands. Although this multi-million dollar industry helps to raise the revenue used to fund monitoring and conservation efforts, tourism and recreational activities can also take a toll on the water quality, habitat, and wildlife of Sarasota Bay. Human activities, including the management of waste and the operation of automobiles and watercraft, can contribute nitrogen and other contaminants to Sarasota Bay and degrade the Bay's water quality. In addition, dredging has been conducted in the area to create navigable waterways and new home sites and has destroyed habitat and reduced the populations of fish and shellfish in the Bay (SBNEP, 2000). Tourism and recreational activities can also directly harm wildlife; for example, more than 30% of the annual manatee deaths in Sarasota Bay are caused by collisions with boats (Sarasota Dolphin Research Program, 2005).

Environmental Concerns

Population increases and the accompanying development around Sarasota Bay between 1930 and 1990 resulted in the loss of historic seagrass habitat and mangrove wetlands (SBNEP, 2000). For example, 2,495 acres of tidal wetlands were lost between 1950 and 1990 due to dredge-and-fill activities, construction, and invasive species (SBNEP, 1992). Over time, loss of habitat areas has been accompanied by declines in marine life, fish, birds, and shellfish. Increased development has also resulted in excess nitrogen pollution and stormwater runoff, both priority concerns of the SBEP. Nitrogen is the major pollutant of concern in Sarasota Bay, with nitrogen loads transported to the Bay through baseflow, wastewater, stormwater, and atmospheric deposition (Figure 5-16) (SBNEP, 2000). In 1990, nitrogen loadings were approximately 300% of the levels that existed prior to development of the region (U.S. EPA, 2005b), and loadings are projected to increase by another 8% during the next 20 years and by 16% when the area is fully developed according to existing plans. Tributaries to Sarasota Bay act as pipelines for dispensing stormwater and suspended matter into the estuary. Although the overall trophic status index for Sarasota Bay is good, the Bay segments that receive water from the tributaries have the poorest water quality. Chlorinated pesticides, PAHs, and metals have been found in tributary sediments; those tributaries with the highest levels of these contaminants are Hudson Bayou, Cedar Hammock Creek, and Whitaker Bayou (Lowrey et al., 1992).

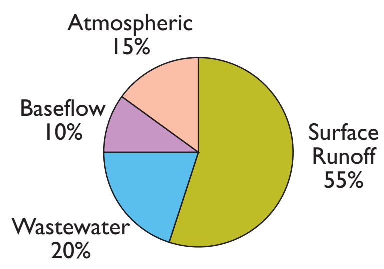

Figure 5-16. Percentages of nitrogen distributed to Sarasota Bay (SBNEP, 2000).

Population Pressures

The population of the 2 NOAA-designated coastal counties (Manatee and Sarasota) coincident with the SBEP study area increased by 304% during a 40-year period, from 0.14 million people in 1960 to 0.59 million people in 2000 (Figure 5-17) (U.S. Census Bureau, 1991; 2001). This rate of population growth for the SBEP study area substantially exceeded the population growth rate of 133.3% for the collective NEP-coincident coastal counties of the Gulf Coast region and was the highest rate of population growth for any of the individual Gulf Coast NEPs. In 2000, the population density of these 2 coastal counties was 447 persons/mi^2, significantly higher than the population density of 287 persons/mi^2 for the collective NEP-coincident coastal counties of the Gulf Coast region (U.S. Census Bureau, 2001). Development and population pressures are especially strong in NEP study areas that serve as major shipping centers for commercial and recreational activities.

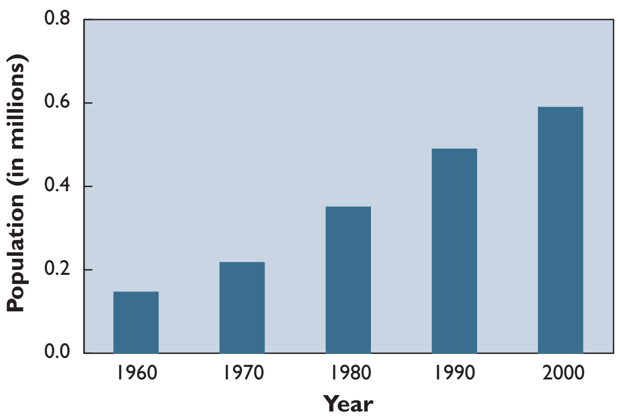

Figure 5-17. Population of NOAA-designated coastal counties of the SBEP study area, 1960–2000 (U.S. Census Bureau, 1991; 2001).

NCA Indices of Estuarine Condition—Sarasota Bay

The overall condition of Sarasota Bay is rated fair based on three of the four indices of estuarine condition used by the NCA (Figure 5-18). The water quality index for Sarasota Bay is rated fair, the sediment quality index is rated good, and the benthic index is rated poor; no data were available to calculate a fish tissue contaminants index for this estuary. Figure 5-19 provides a summary of the percentage of estuarine area rated good, fair, poor, or missing for each parameter considered. This assessment is based on data collected by the Florida Fish and Wildlife Research Institute, in partnership with the NCA, from 20 stations sampled in the SBEP estuarine area in 2000. Please refer to Tables 1-24, 1-25, and 1-26 (Chapter 1) for a summary of the criteria used to develop the rating for each index and component indicator.

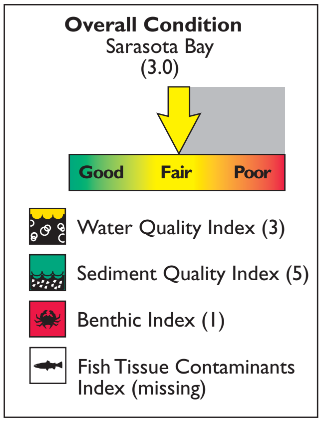

Figure 5-18. The overall condition of the SBEP estuarine area is fair (U.S. EPA/NCA).

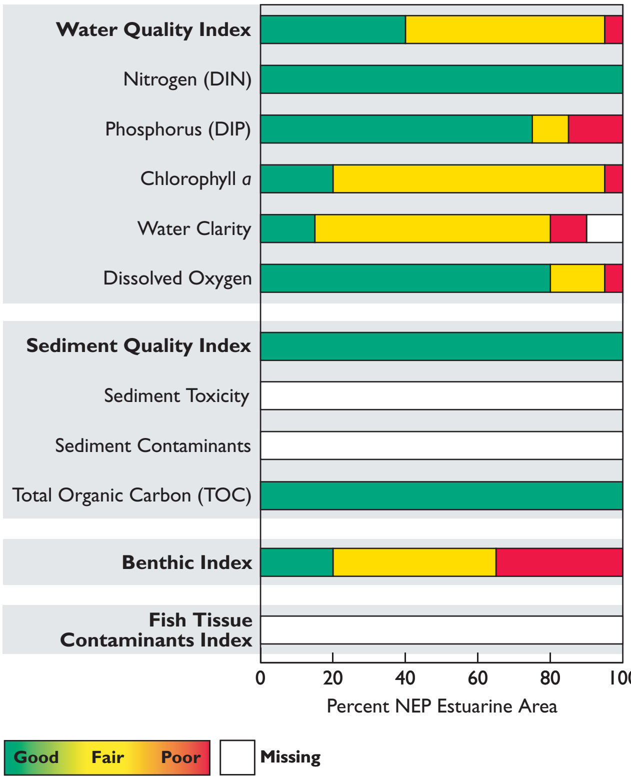

Figure 5-19. Percentage of NEP estuarine area achieving each rating for all indices and component indicators — Sarasota Bay (U.S. EPA/NCA).

Water Quality Index

Based on NCA survey results, the water quality index for Sarasota Bay is rated fair (Figure 5-20). This index was developed using NCA data on five component indicators: DIN, DIP, chlorophyll *a*, water clarity, and dissolved oxygen. In NOAA's Estuarine Eutrophication Survey, Sarasota Bay was listed as having medium DIN concentrations, high DIP concentrations, and high chlorophyll *a* levels (NOAA, 1997). Results from the 2000 NCA survey show some improvement over the previous study, with low DIN, moderate DIP, and moderate chlorophyll *a* concentrations measured.

Dissolved Nitrogen and Phosphorus | Sarasota Bay is rated good for DIN concentrations, with 100% of the estuarine area rated good for this component indicator. NCA data for Sarasota Bay were collected in the summer, when elevated DIN concentrations are less likely to occur because freshwater inputs are low and dissolved nutrients are more rapidly utilized by phytoplankton populations. Sarasota Bay is rated fair for DIP concentrations, with 15% of the estuarine area rated poor, 10% of the area rated fair, and 75% of the area rated good for this component indicator.

Chlorophyll a | Chlorophyll *a* concentrations in Sarasota Bay are rated fair. Although only 5% of the estuarine area was rated poor for this component indicator, 75% was rated fair, and 20% was rated good.

Water Clarity | Water clarity in Sarasota Bay is also rated fair; however, expectations for water clarity are high because one of the goals of the SBEP is to re-establish SAV. Water clarity in Sarasota Bay was rated poor at a sampling site if light penetration at 1 meter was less than 20% of surface illumination. Ten percent of the estuarine area was rated poor for water clarity, 15% of the area was rated good, and 65% of the area was rated fair. NCA data on water clarity were unavailable for 10% of the SBEP estuarine area.

Dissolved Oxygen | Dissolved oxygen conditions in Sarasota Bay are rated fair. NCA estimates show that 5% of the estuarine area was rated poor for dissolved oxygen concentrations, 15% of the area was rated fair, and 80% of the area was rated good.

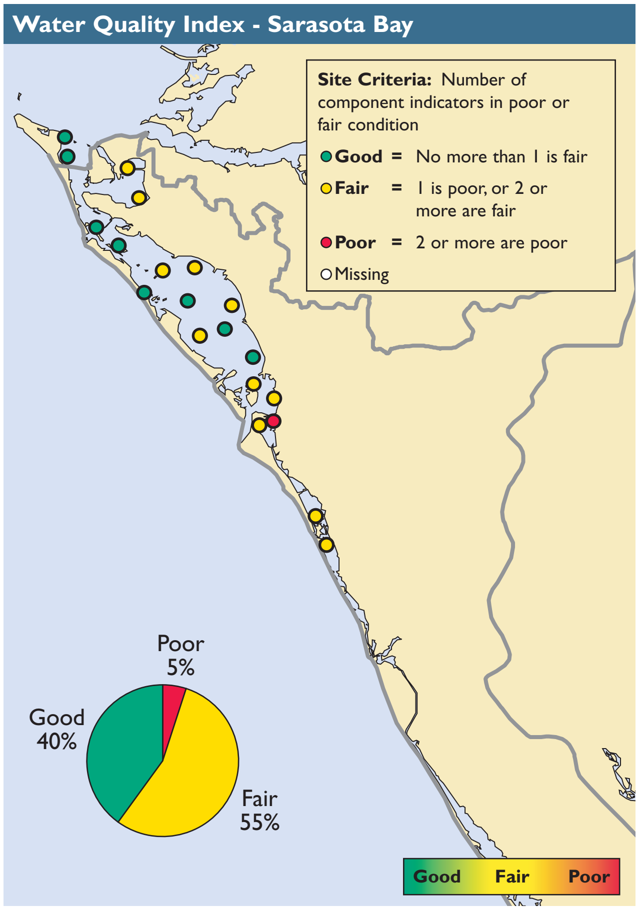

Figure 5-20. Water quality index data for Sarasota Bay, 2000 (U.S. EPA/NCA).

Sediment Quality Index

The sediment quality index for Sarasota Bay is rated good; however, this rating is based on measurements of sediment TOC only (Figure 5-21). Sediment quality was rated good in 100% of the Bay's estuarine area.

Sediment Toxicity | The NCA surveys did not collect sediment toxicity data for Sarasota Bay in 2000; therefore, sediment toxicity in the Bay has not been rated for this report.

Sediment Contaminants | The NCA surveys did not collect sediment contaminants data for Sarasota Bay in 2000; therefore, sediment contaminant concentrations in the Bay have not been rated for this report.

Total Organic Carbon | Sediment TOC concentrations were the only sediment quality component indicator monitored in Sarasota Bay by the NCA in 2000. TOC concentrations in Sarasota Bay sediments are rated good, with 100% of the estuarine area rated good for this component indicator.

Benthic Index

The condition of benthic invertebrate communities in Sarasota Bay is rated poor, based on the Gulf Coast Benthic Index and data from the NCA. Benthic index estimates indicate that 35% of the estuarine area in Sarasota Bay has degraded benthic resources and is rated poor (Figure 5-22).

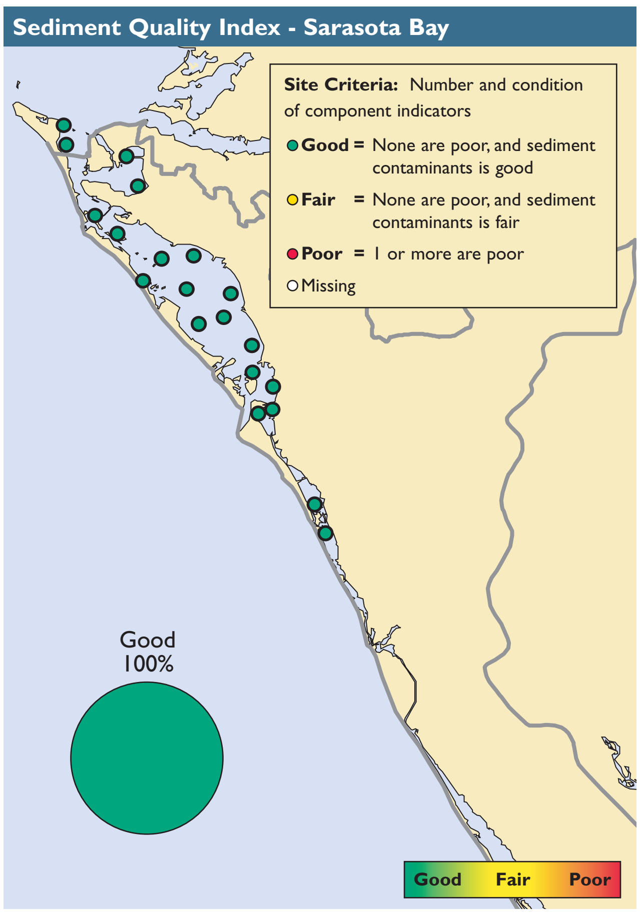

Figure 5-21. Sediment quality index data for Sarasota Bay, 2000 (U.S. EPA/NCA).

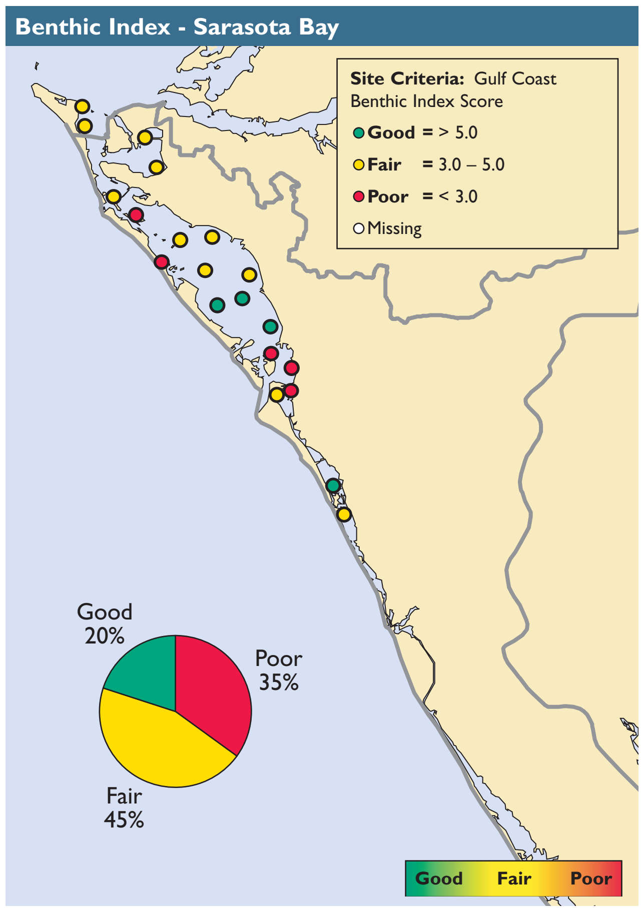

Figure 5-22. Benthic index data for Sarasota Bay, 2000 (U.S. EPA/NCA).

Fish Tissue Contaminants Index

The NCA did not assess the level of fish tissue contaminants in the SBEP estuarine area in 2002; therefore, a fish tissues contaminants index for Sarasota Bay was not developed for this report.

Sarasota Bay Estuary Program Indicators of Estuarine Condition

Water and Sediment Quality

The SBEP's specific indicators for measuring water quality in Sarasota Bay are the following:

- Chlorophyll *a*
- Nitrogen (e.g., DIN levels, total nitrogen levels, nitrogen load)
- Inorganic phosphorus
- Transparency (as measured using Secchi depth).

In general, water quality trends for Sarasota Bay have shown improvements with time. Data from 1968 through 1991 indicate that nutrient and chlorophyll *a* levels are decreasing in the Bay, and Secchi depths are increasing over time. For northern Sarasota Bay, regional trends in chlorophyll *a* levels, inorganic nitrogen, organic nitrogen, total nitrogen, and inorganic phosphorus have been declining since 1980; however, Manatee County data have shown significant increases in these parameters. The middle portion of Sarasota Bay has displayed declining trends similar to those observed in the northern portion of the Bay, with the exception of chlorophyll *a* and total phosphorus concentrations, which were increasing. SBEP data for the southern portion of Sarasota Bay indicate a regional increase in both chlorophyll *a* and ammonium nitrogen levels. Other significant improvements observed in the trend analysis for the southern portion of the Bay were long-term declines in nitrate-nitrite, total nitrogen, and inorganic phosphorus. The transparency of Sarasota Bay waters is measured by Secchi depth and can be used to help indicate overall water quality or the effects of erosion and increased rainfall. Data from 1968 to 1991 show that Secchi depth has increased (greater water transparency) in all segments that demonstrated significant trends (Lowrey et al., 1992), and recently collected monthly data show that Secchi depth generally fluctuates between 4 and 8 feet (Florida Center for Community Design and Research, 2004). Trend analyses that examined data from 1980 to 2002 suggest that inorganic nitrogen and chlorophyll *a* levels have declined during the long term; inorganic phosphorus levels have also declined, although increases were noted in total phosphorus, particularly from 1995 to 2002 (Dixon, 2003).

In addition to the SBEP's formal indicators, other water quality parameters monitored for the Bay include salinity, temperature, dissolved oxygen, pH, *Enterococci*, and fecal coliform. Salinity in the Bay has increased over time, except for the period from 1995 to 1998, when salinity declined (Dixon, 2003). Beach water samples are collected every 2 weeks at 14 different beach sites in Sarasota County and are analyzed for *Enterococci* and fecal coliform bacteria (Florida Center for Community Design and Research, 2004).

A great egret (*Ardea alba*) hunts in the waters of an SBEP restoration site (SBEP).

Sarasota Bay Estuary Program

Improving Water Quality in the Sarasota Bay Watershed

Reducing nitrogen inputs to Sarasota Bay has been recognized as a primary water quality concern since the 1980s. A central tenet of these reduction efforts has been to address all contributors to water quality degradation in the restoration of Sarasota Bay. Nutrient loads in Sarasota Bay in 1988 were approximately 400% higher than those expected from a pristine, undeveloped watershed (SBNEP, 2000). By comprehensively addressing the sources of nitrogen and other pollutants, the water quality throughout most of Sarasota Bay has steadily improved during the past decade.

The SBEP and its partners have been working with the community to cost-effectively limit and control the amount of nitrogen entering Sarasota Bay. The integration of different water quality improvement components that address wastewater, stormwater, groundwater, and atmospheric deposition as a whole is an important step to ensure that issues of timing, cost, and effectiveness are considered.

The widespread implementation of advanced wastewater treatment, required by federal legislation in 1990, resulted in reductions of more than 80% of nitrogen loadings from wastewater to Sarasota Bay. At the present time, stormwater from all areas is the primary source of nitrogen pollution, with stormwater from residential areas estimated to contribute more than

Urban stormwater runoff deposits large amounts of sediments and other pollutants into Sarasota Bay through drainage ditches (above) and tributaries (Gary Raulerson, SBEP).

one-third of the total nitrogen load to Sarasota Bay. Currently, an unquantified number of stormwater pipelines that discharge directly into Sarasota Bay or its tributaries do not receive any type of wastewater treatment (SBNEP, 2000). Beginning in September 2005, a new SBEP project will identify and prioritize water quality control retrofits for urban stormwater, especially in direct-discharge locations. Information to be gained will include project price, maintenance accessibility, and a receiving water of high resource value. This information can be used by local, state, and federal agencies to help determine where to direct resources to continue the restoration of Sarasota Bay.

The Florida Yards and Neighborhoods (FYN) Program was developed in 1993 to promote environmentally friendly landscaping using plants suited to the southwest Florida climate, natural conditions, and wildlife. Using FYN's principles, homeowners can reduce fertilizer and pesticide use, thereby helping to maximize the quality of stormwater runoff. Improvements in stormwater conveyance and treatment systems also impact water quality. Designed primarily for flood and sediment control, these systems have an important effect on toxic loading, as well as a smaller, but significant impact on nutrients.

The SBEP is also pursuing other management strategies, including septic tank replacement (such as that currently underway within the Phillippi Creek watershed). This strategy is being pursued primarily from a public health perspective, but should also reduce nitrogen loadings to Sarasota Bay. Regionally instituted water conservation policies can also help improve the water quality of Sarasota Bay. Through the creation and implementation of a master reuse plan, the discharge of wastewater to the Bay is being substantially reduced. At the same time, this wastewater is offsetting withdrawals from the Floridian aquifer.

Human-related atmospheric deposition (from auto emissions, industry, and other sources) plays a role within the Sarasota Bay watershed; however, this role is not as large as previously believed. Although nitrogen emissions from automobiles and other mobile sources (such as lawn mowers) may not be as great as originally thought, this may become an important area for further reductions.

Habitat Quality

The following indicators are used to evaluate habitat quality in Sarasota Bay:

- Freshwater wetlands coverage
- SAV (seagrass) coverage
- Intertidal habitat coverage
- Abundance of juvenile fish in restored areas vs. abundance in natural areas
- Effectiveness of artificial reef construction.

Freshwater wetlands have declined 16% since 1975, and non-forested freshwater wetlands have declined by 35% (U.S. EPA, 2005b). Since 1950, the area of saltwater wetlands in Sarasota Bay has declined 39%, and seagrass acreage has generally declined by 30%, mainly due to nitrogen pollution and dredging impacts (SBNEP, 2000). Seagrass coverage in the Bay is an indicator of the success or failure of restoration activities and the area of suitable habitat, as well as an indirect indicator of the effects of water quality changes, sediment contamination, or other human-induced impacts on the ecosystem.

Approximately every two years, the Southwest Florida Water Management District (SWFWMD) uses aerial photography to analyze seagrass communities in waterbodies (including Sarasota Bay) located within its watershed. The SWFWMD's analysis distinguishes between patchy seagrass beds (less than 75% coverage within a given area) and continuous seagrass beds (greater than 75% coverage within a given area). Since 1988, approximately 600 new acres of seagrasses have appeared in the Sarasota Bay estuarine area. Additionally, the amount of continuous seagrass beds in Sarasota Bay has increased by more than 120% (SBEP, 2006). Figure 5-23 illustrates the percent changes in seagrass coverage in Sarasota Bay (from the Anna Maria Sound at State Road 64 to Venice Inlet), both for continuous and patchy distributions of seagrass.

At least 15 artificial reefs are being established in Sarasota Bay to help create additional juvenile fish habitat (U.S. EPA, 2005b). To help monitor the abundance of fish species in natural areas in comparison with fish abundance in restored areas, the SBEP continues to study the effectiveness of artificial structures in providing juvenile fish nursery habitat. The SBEP, with funding from EPA and the Florida Department of Environmental Protection (FDEP), has sponsored the development of inexpensive seawall modules to attract larval, juvenile, and adult fish. An early pilot project demonstrated the potential benefit of deploying artificial reefs along hardened seawalls, with some types of structures showing fish abundances more than 100 times that of nearby areas without artificial reefs (SBNEP, 2000). In a recent shoreline survey, researchers found that more than 200 miles of armored and altered shoreline exist in Sarasota Bay (U.S. EPA, 2003); altered shorelines typically do not provide enough complex or suitable habitat for fish.

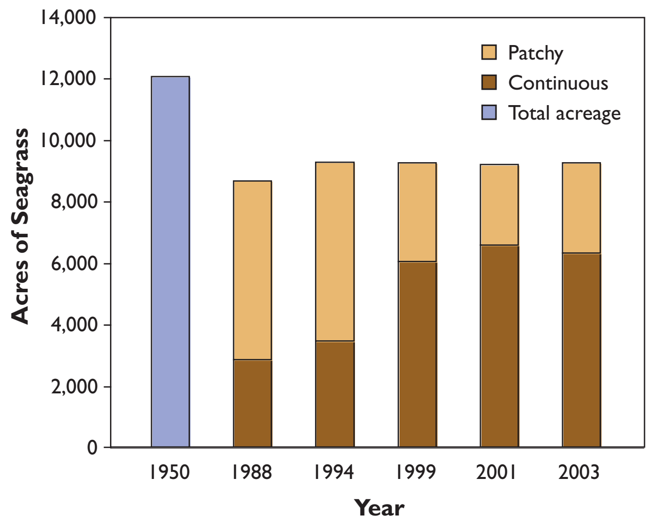

Figure 5-23. Changes in continuous, patchy, and total seagrass coverage areas in Sarasota Bay (SBEP, 2006).

Living Resources

Sarasota Bay is home to a variety of fish and wildlife, including the great blue heron, cattle egret, bald eagle, Florida scrub jay, red drum, spotted seatrout, flounder, blue crab, manatee, and bottlenose dolphin. The SBEP and other organizations monitor the populations of fish and wildlife in the SBEP study area.

Aerial surveys used to monitor manatee populations in Sarasota Bay indicate that the number of manatees in the Bay has increased since the early 1990s (Florida Center for Community Design and Research, 2004). Manatees are typically found along the fringes of the Bay from April to December, with seasonal migration patterns reducing the number of manatees in the Bay between January and February.

The bottlenose dolphins that use Sarasota Bay have been monitored since the 1970s, and mark-recapture estimates in 1976 and 1983 indicated that about 100 dolphins were present on a regular basis. Since 1984, researchers have monitored individual dolphins using distinctive dorsal fin features. The bottlenose dolphin population in Sarasota Bay has increased since the mid-1990s due to the dolphin immigration from other areas, seasonal migration patterns of dolphins from Tampa Bay, and high birth rates of native dolphins. These increases correlate with presumed fish stock increases since the net ban, but cause-effect relationships have not been conclusively established (Florida Center for Community Design and Research, 2004).

Current Projects, Accomplishments, and Future Goals

Much of Sarasota Bay's habitat for young fish was recently destroyed when the natural mangrove shoreline was replaced by concrete seawalls during the development of waterfront communities. As a result, the SBEP is embarking on an artificial habitat enhancement and wetland restoration strategy to increase its young fish population and overall fishery production. A recent study by the SBEP indicated that intertidal restoration sites less than 10 years old provide habitat for more than 68,000 fish per acre (Serviss and Sauers, 2003). Because most of the seawalls cannot be removed without causing severe damage to homes, the SBEP seeks to convert them into an asset for the Bay rather than a liability. Four different styles of small artificial reefs attached to seawalls are being tested for their ability to provide a home for young fish (SBNEP, 2000). Early results show more than 400 young fish living near these artificial reefs (U.S. EPA, 2006d), whereas only a few young fish have been seen in similar areas without reefs.

EPA plans to restore or create at least 18 acres of intertidal wetlands and 11 acres of non-forested, freshwater wetlands per year, as well as to increase the quantity, improve the quality, and protect the diversity of freshwater and saltwater wetlands in the Sarasota Bay watershed (U.S. EPA, 2005b). Twenty-one wetland-enhancement projects have been proposed and funded since 1989, and 13 significant habitat-restoration initiatives have been completed, with 12 more initiatives currently in the design phase (SBNEP, 2000; U.S. EPA, 2005b). In addition, new channel markers are being installed in Sarasota Bay (with artificial reefs built on each) to protect seagrass beds. The SBEP and the surrounding community has achieved a number of environmental success stories:

- Nitrogen pollution to the Bay has been reduced by 47% since 1990
- Seagrass habitat has increased by 7% (592 acres) since 1988
- More than 200 acres of intertidal wetland habitat have been restored since 1990
- More than 20 artificial reef projects have been permitted and constructed
- The Bay supports an estimated 110 million more fish, 71 million more crabs, and 330 million more shrimp than it did in 1988
- Several urban watershed areas around Sarasota Bay have been retrofitted for improved stormwater management
- Scallops have been reintroduced to the Bay to re-establish stocks
- SBEP policies have been integrated into local government CCMPs (SBNEP, 2000; SBEP, 2006).

Conclusion

Based on NCA survey results, the overall condition of Sarasota Bay is rated fair. SBEP analyses have shown that although temporal trends by segment indicate that water quality in Sarasota Bay is improving, water quality problems still exist in the tributaries and the Bay segments receiving water from the tributaries. Seagrass coverage in Sarasota Bay has improved substantially in the past few years, with declines in SAV occurring at a much slower rate. Although there is no substitute for natural habitat with respect to the diversity and productivity of organisms, engineering options for some environments (e.g., dredge holes, canal communities, and channel markers) exist to create artificial habitats for juvenile and adult finfish, shellfish, and other invertebrates.

Tampa Bay Estuary Program

TAMPA BAY Estuary Program

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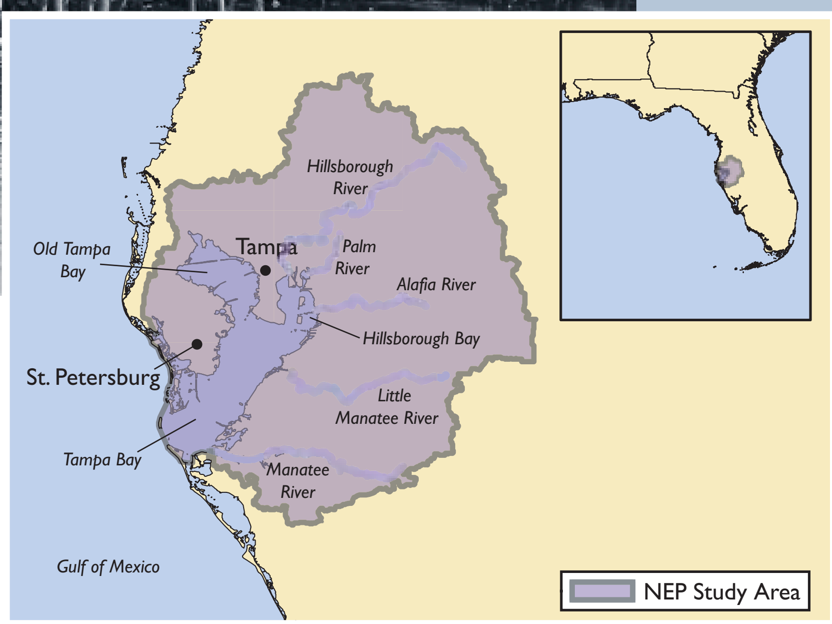


Background

Tampa Bay, Florida's largest open-water estuary, spans almost 400 mi^2 and drains 2,300 mi^2 of land (TBEP, 2003). The Tampa Bay watershed extends north of the Bay to the upper reaches of the Hillsborough River, east to the headwaters of the Alafia River, and south to the headwaters of the Manatee River. The Bay receives freshwater inflow from the Lake Tarpon Canal and the Hillsborough, Palm, Alafia, Little Manatee, and Manatee rivers. Tampa Bay empties into the Intracoastal Waterway via Boca Ciega Bay and into the Gulf of Mexico via the Southwest Channel and Passage Key Inlet.

Tampa Bay is an important nursery for young fish, shrimp, and crabs, and provides habitat for many other types of wildlife, including wading birds, dolphins, sea turtles, and manatees. In addition to its ecological diversity, Tampa Bay boasts three major seaports and contributes more than $5 billion annually from trade, tourism, development, and fishing (TBEP, 2005). More than 100,000 boats are registered to anglers and sailing enthusiasts in the Tampa Bay area, and more than 2 million people live in the Bay's watershed, with the population expected to grow 10% to 20% during the next 10 years (U.S. Census Bureau, 2001; TBEP, 2005). Developing a plan to deal with the region's growth and the associated pollution and stress on natural habitats is the primary mission of the Tampa Bay Estuary Program (TBEP) (TBEP, 2005).

Environmental Concerns

Habitat loss, declines in living resources, and the atmospheric deposition of nitrogen are major concerns for the TBEP. Since population growth began to soar in 1950, nearly half the Bay's marshes and 40% of its seagrass areas have disappeared (TBEP, 2005). Although the abundance of many Bay species has increased in recent years, populations of other native species have declined as their habitats have shrunk. For example, the destruction of vital seagrass meadows caused a rapid decline in spotted seatrout and other fish populations in the Bay from the early 1970s through the 1980s (Murphy, 2003). In addition, atmospheric deposition of total nitrogen directly to the surface of Tampa Bay accounts for about one-quarter of the nitrogen loadings to the Bay (about 780 tons/year) (Poor et al., 2001). This estimate does not include total nitrogen from atmospheric sources deposited in the watershed and washed to the estuary as stormwater. When both direct and indirect pathways are considered, more than half of the total nitrogen loading originates from atmospheric sources (Poe et al., 2005a). The prevention of future nitrogen loading to the Bay will continue to be a challenge because population growth in the Bay area is projected to continue at a high rate.

Rare white-phase reddish egret. Tampa Bay boasts about 60 nesting pairs of reddish egrets, the largest population in Florida (Gerold Morrison).

Population Pressures

The population of the 6 NOAA-designated coastal counties (Hillsborough, Manatee, Pasco, Pinellas, Polk, and Sarasota) coincident with the TBEP study area increased by more 190% during a 40-year period, from 1.2 million people in 1960 to 3.3 million people in 2000 (Figure 5-24) (U.S. Census Bureau, 1991; 2001). This rate of population growth for the TBEP study area exceeded the population growth rate of 133.3% for the collective NEP-coincident coastal counties of the Gulf Coast region and was the third-highest growth rate for all of the Gulf Coast NEPs. In 2000, these 6 counties had a population density of 640 persons/mi^2, more than double the density of 287 persons/mi^2 for the collective NEP-coincident coastal counties of the Gulf Coast region (U.S. Census Bureau, 2001). Development and population pressures are especially strong in NEP study areas that serve as major shipping centers for commercial and recreational activities.

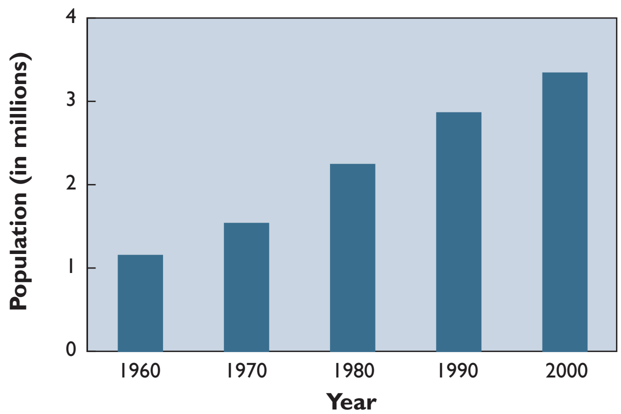


Figure 5-24. Population of NOAA-designated counties of the TBEP study area, 1960–2000 (U.S. Census Bureau, 1991; 2001).

NCA Indices of Estuarine Condition—Tampa Bay

The overall condition of Tampa Bay is rated fair based on three of the four indices of estuarine condition used by the NCA (Figure 5-25). The water quality index for Tampa Bay is rated fair, the sediment quality index is rated good, and the benthic index is rated poor; no data were available to calculate a fish tissue contaminants index for Tampa Bay. Figure 5-26 provides a summary of the percentage of estuarine area rated good, fair, poor, or missing for each parameter considered. This assessment is based on data collected by EMAP from 25 NCA stations sampled in the TBEP estuarine area in 2000. Please refer to Tables 1-24, 1-25, and 1-26 (Chapter 1) for a summary of the criteria used to develop the rating for each index and component indicator.

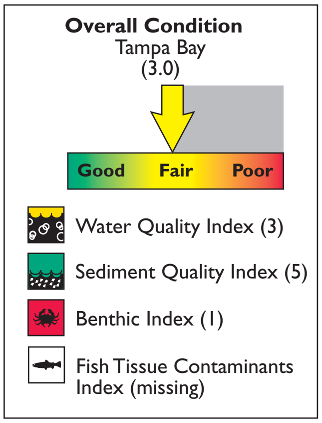


Figure 5-25. The overall condition of the TBEP estuarine area is fair (U.S. EPA/NCA).

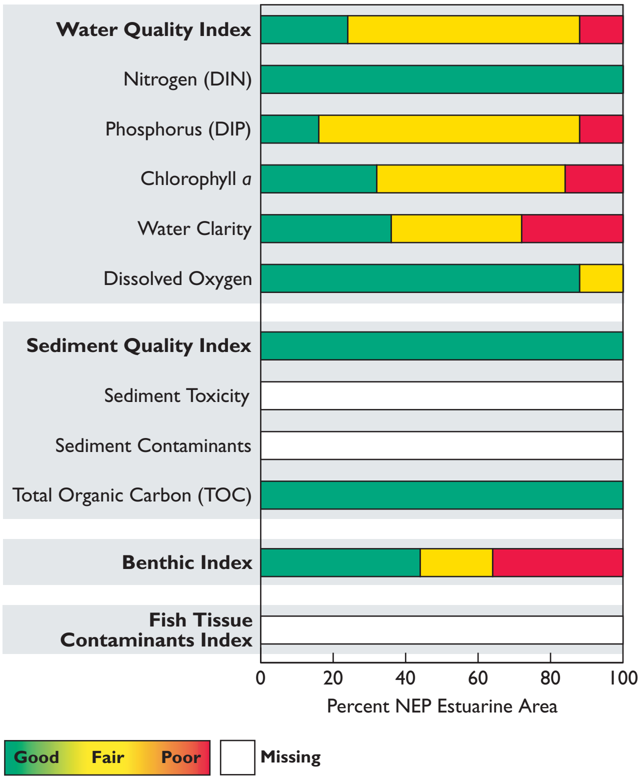


Figure 5-26. Percentage of NEP estuarine area achieving each rating for all indices and component indicators — Tampa Bay (U.S. EPA/NCA).

Water Quality Index

The water quality index for Tampa Bay is rated fair (Figure 5-27). This index was developed using NCA data on five component indicators: DIN, DIP, chlorophyll *a*, water clarity, and dissolved oxygen. In NOAA's Estuarine Eutrophication Survey, Tampa Bay was listed as having medium-to-very-high chlorophyll *a* levels and medium-to-high DIN and DIP concentrations (NOAA, 1997). Results from the 2000 NCA survey show some improvements over the previous study, with low DIN, moderate DIP, and moderate chlorophyll *a* concentrations measured.

Dissolved Nitrogen and Phosphorus | Tampa Bay is rated good for DIN concentrations, with concentrations rated good throughout the TBEP estuarine area. Elevated DIN concentrations are not expected to occur during the summer in Gulf Coast waters because freshwater input is lower and dissolved nutrients are more rapidly utilized by phytoplankton during this season. Tampa Bay is rated fair for DIP concentrations, with 12% of the estuarine area rated poor for this component indicator, 72% of the area rated fair, and 16% of the area rated good.

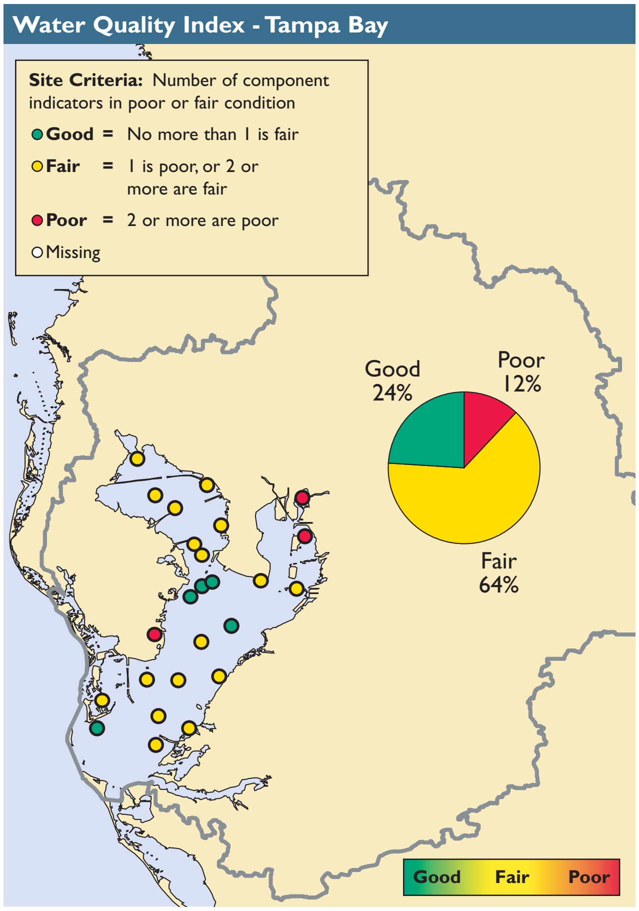


Figure 5-27. Water quality index data for Tampa Bay, 2000 (U.S. EPA/NCA).

Chlorophyll a | Tampa Bay is rated fair for chlorophyll *a* concentrations, with 16% of the estuarine area rated poor for this component indicator, 52% of the area rated fair, and 32% of the area rated good.

Water Clarity | Water clarity in Tampa Bay is rated poor. Water clarity was rated poor at a sampling site if light penetration at 1 meter was less than 20% of surface illumination. Expectations for water clarity are high because one of the TBEP's goals is to re-establish SAV. Twenty-eight percent of the TBEP estuarine area was rated poor for water clarity, 36% of the area was rated good, and 36% of the area was rated fair.

Dissolved Oxygen | Dissolved oxygen conditions in Tampa Bay are rated good. NCA estimates for Tampa Bay show that none of the Bay's bottom waters exhibited hypoxia in late summer. Twelve percent of the estuarine area was rated fair for dissolved oxygen concentrations, and 88% of the area was rated good.

Sediment Quality Index

The sediment quality index for Tampa Bay is rated good; however, this index is based on measurements of sediment TOC only (Figure 5-28). One-hundred percent of the TBEP estuarine area was rated good for sediment quality.

Sediment Toxicity | The NCA did not collect sediment toxicity data for Tampa Bay in 2000; therefore, sediment toxicity in the Bay has not be rated for this report.

Sediment Contaminants | The NCA did not collect sediment contaminants data for Tampa Bay in 2000; therefore, sediment contaminant concentrations in the Bay have not been rated for this report.

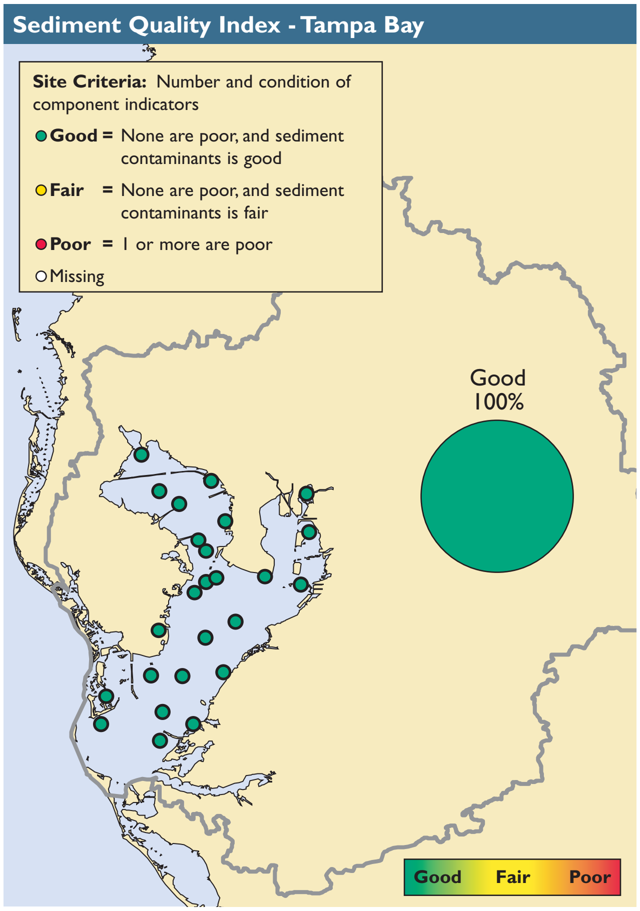


Figure 5-28. Sediment quality index data for Tampa Bay, 2000 (U.S. EPA/NCA).

Total Organic Carbon | TOC concentrations in Tampa Bay sediments were rated good throughout 100% of the TBEP estuarine area; therefore, Tampa Bay is rated good for sediment TOC.

Benthic Index

The condition of benthic invertebrate communities in Tampa Bay is rated poor, based on the Gulf Coast Benthic Index and data collected by the NCA. Benthic index estimates indicate that 36% of the estuarine area has degraded benthic resources (Figure 5-31).

Fish Tissue Contaminants Index

The NCA did not assess the level of fish tissue contaminants in the TBEP estuarine area in 2000; therefore, a fish tissue contaminants index for Tampa Bay was not developed for this report.

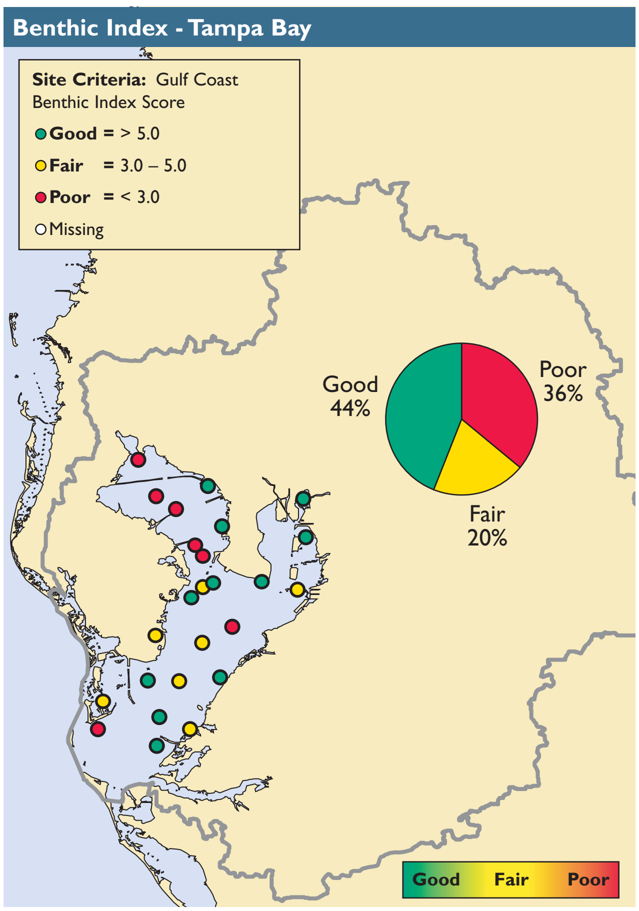


Figure 5-31. Benthic index data for Tampa Bay, 2000 (U.S. EPA/NCA).

Tampa Bay Estuary Program Indicators of Estuarine Condition

The Tampa Bay resource management community has developed monitoring programs and environmental indicators to measure progress towards adopted measurable goals for three major areas of concern: (1) water and sediment quality; (2) habitat restoration and protection; and (3) fish and wildlife protection. In many cases, the TBEP also uses target indicators to help assess progress towards these goals. Although some of these indicators are similar to those evaluated by the NCA, other indicators have been customized to suit the ecology and ecosystems that are unique to Tampa Bay. The TBEP's major indicators are chlorophyll *a* concentrations, water clarity, nitrogen loading (tons/year), acres of seagrass, and habitat restoration and protection (acres of oligohaline/brackish habitat). The TBEP also monitors other indicators, including bacteria; metals; organochlorine pesticides and other organic chemicals; benthic resources; boater compliance with posted speed zones; and trends in fishery stocks.

Local high school students plant marsh grass as part of a habitat restoration project coordinated by Tampa Bay Watch (Tampa Bay Watch).

Water and Sediment Quality

Chlorophyll *a* concentrations and light attenuation data help the TBEP track its progress toward improving water clarity to meet seagrass habitat goals for Tampa Bay. The TBEP calculates that sufficient water clarity will be maintained for the desired level of seagrass recovery if average annual chlorophyll *a* concentrations can be maintained at levels adequate to support seagrass recovery to depths observed in 1950 and equal to those measured between 1992 and 1994 (TBEP, 2003; Greening and Janicki, 2006). Similarly, light attenuation (a measure of water clarity) goals that are needed to maintain a minimum of 20% light to target depths have been adopted for seagrass recovery. Although this is the same light attenuation level used by the NCA, the TBEP uses the average annual estimate from monthly measurements taken throughout the year rather than the summertime index period used by the NCA. Based on the most recent assessment by the TBEP, all four major Bay segments met target levels for chlorophyll *a* concentrations in 1999 through 2002, and three of four segments met these targets in 2003 and 2004; however, none of the segments met chlorophyll *a* targets during the El Niño year (1998). Figure 5-29 shows that mean annual chlorophyll *a* concentrations in the Bay have generally declined during the past 20 years. From 1998 to 2001, light attenuation did not meet target levels in three of the four major Bay segments (Figure 5-30). This indicates that particles in the water, including non-chlorophyll particles, were preventing enough light from reaching seagrass growing on the Bay's floor, likely hindering the growth and expansion of seagrass beds (Poe et al., 2005b). These data correlate well with the NCA component indicator ratings of poor for water clarity and fair for chlorophyll *a* concentrations. The TBEP has been able to track the trends in these conditions because the program collects data from multiple seasons and for multiple years, rather than the snapshot approach used by the NCA.

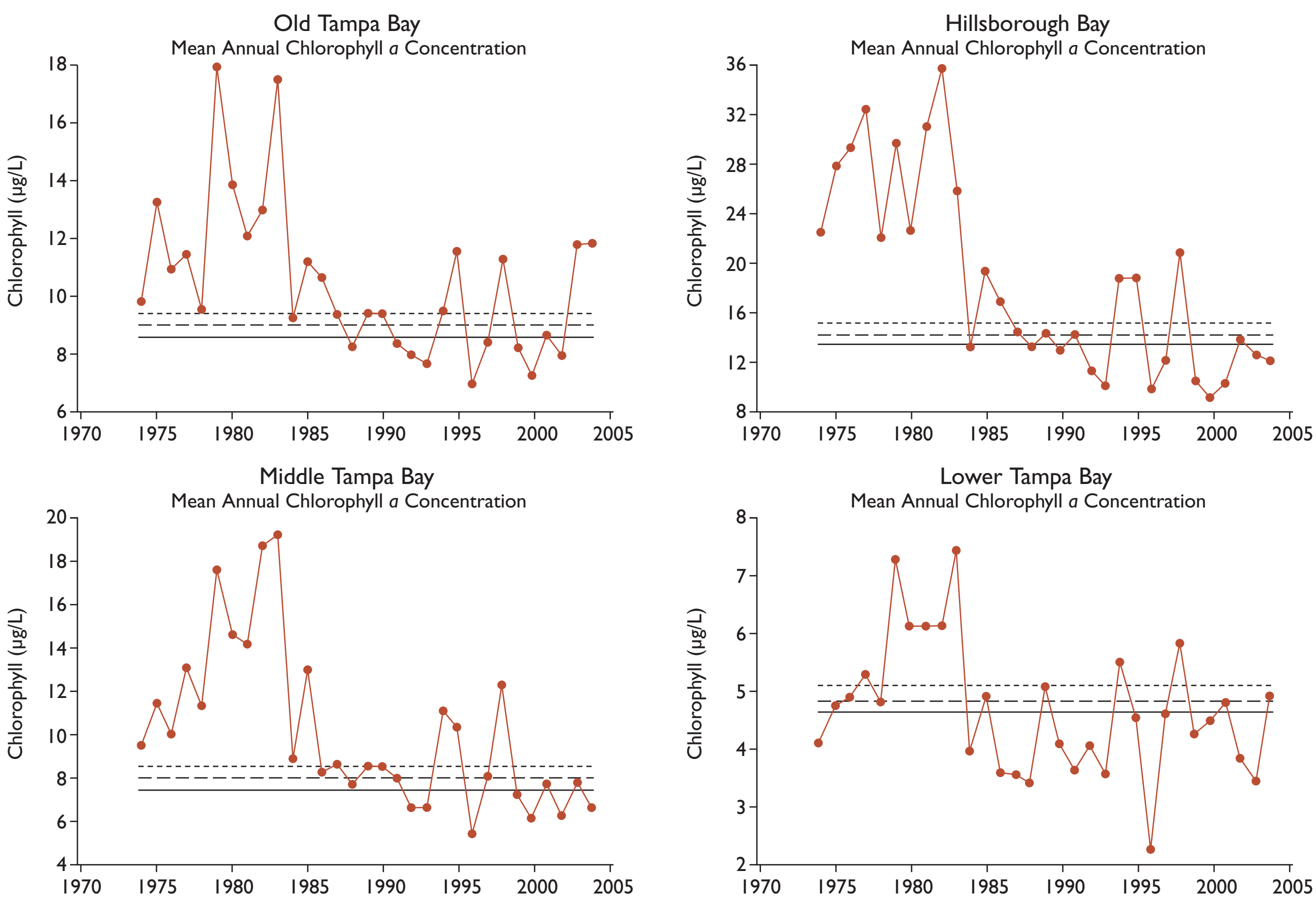


Figure 5-29. Mean annual chlorophyll *a* concentrations have generally declined over the past 20 years. The solid line indicates adopted target levels, with ± 1 and 2 standard deviation (dashed lines) (Poe et al., 2005b).

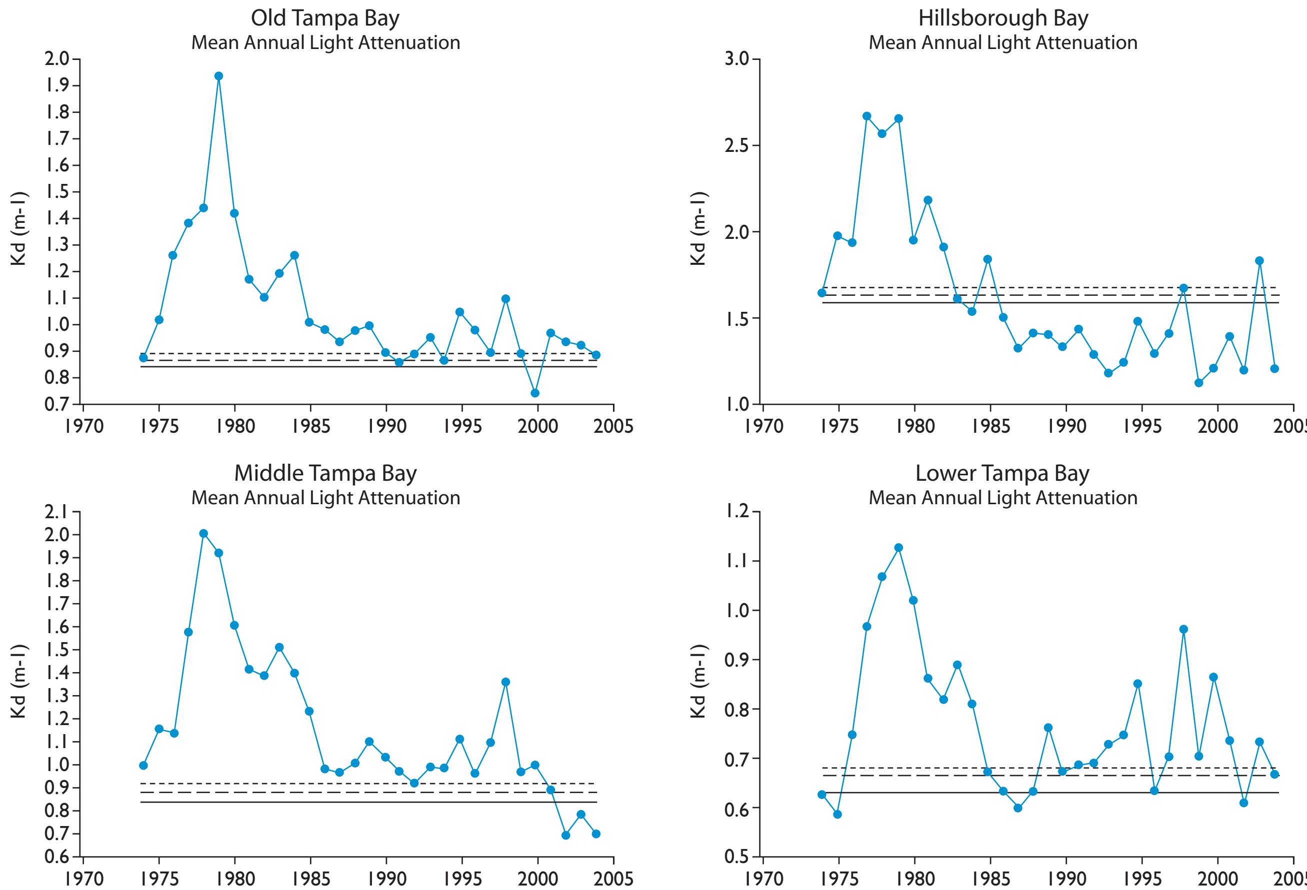


Figure 5-30. Light attenuation indicators met target levels only in one major Bay segment (Middle Tampa Bay). The solid line indicates light attenuation targets for each major Bay segment; dashed lines indicate 1 and 2 standard deviation (Poe et al., 2005b).

The TBEP uses nitrogen loading as an indicator of overall water quality because excess nitrogen can lead to algal blooms and decreased water clarity. The TBEP's goal is to prevent increases in the Bay's nitrogen loading to maintain levels measured between 1992 and 1994. The TBEP's estimates showed that nitrogen loading from 1995 to 2003 was higher than for the previous period (1985–1994), primarily due to heavy rains and runoff associated with El Niño in 1997–1998; however, when adjusted for rainfall, nitrogen loadings showed no change since 1985 (Poe et al., 2005a).

Elevated levels of bacteria in Tampa Bay waters can result from septic system malfunctions and stormwater runoff, especially during rainfall events. These elevated levels are a potential public health concern to people who use Tampa Bay for recreational swimming and boating activities. In 2000, the Healthy Beaches Tampa Bay one-year survey showed that the human health risk from bacterial contamination was low throughout the Bay; however, samples from 2 of the 22 sites around the Bay and its beaches consistently exceeded suggested guidelines for human health (Rose et al., 2001). Although the TBEP has not yet finalized specific indicators for tracking changes in bacterial contamination levels, it is considering several indicators, including fecal coliform bacteria and *Enterococci*. For areas where identifying the source of contamination is important, the TBEP is considering conducting multiple antibiotic resistance (MAR) tests for fecal coliform bacteria. Bacteria develop patterns of resistance to antibiotics that they are exposed to by their host organisms, and MAR tests can identify the source of the bacteria based on these patterns of resistance. When the source of contamination is known, it becomes easier to target specific areas for cleanup and pollution prevention.

To improve sediment quality, the TBEP's goal is to reduce toxic chemicals in contaminated sediments and to protect clean areas. Despite the input of chemical contaminants, including metals, organochlorine pesticides, and the organic chemicals PCBs and PAHs, TBEP data show that the overall benthic condition of the Bay is good, with elevated contaminant levels typically found in only a few areas (TBEP, 2003). NCA data on sediment contaminants and sediment toxicity were not collected for Tampa Bay.

Both the TBEP and NCA collected monitoring data on the condition of benthic resources. During the past 10 years, TBEP partners and a national advisory group have worked together to implement a probabilistic benthic monitoring program based on EPA's EMAP design and to develop narrative and numerical sediment quality targets for key indicators of sediment quality. The newly developed Tampa Bay Benthic Index (TBBI) classifies sediments as healthy or degraded based on the diversity and abundance of the observed benthos. Using the TBBI, "hot spots" of contaminated sediments have been found to occur in relatively concentrated areas around large marinas, ports, and urban stormwater outfalls (Malloy et al., in press) (Figure 5-32). No trends in sediment quality have been observed since monitoring was initiated in 1993 (Karlen, 2003). Although the TBEP collected more sediment samples than the NCA, both programs used the same benthic index method to determine the health of the benthic community.

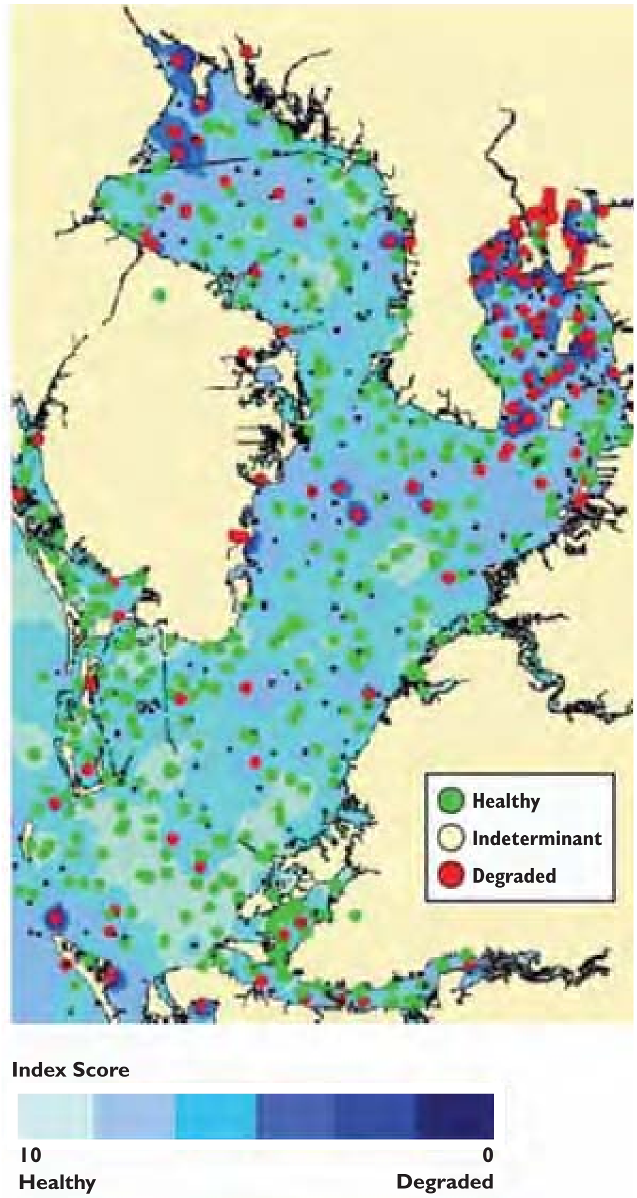


Figure 5-32. Tampa Bay Benthic Index classification (David Wade, Janicki Environmental, Inc.).

Tampa Bay Estuary Program

Summary: Tampa Bay Habitat Restoration/Protection Master Plan

TBEP participants have agreed to the implementation of a watershed strategy for coastal habitat restoration and protection, with a focus on preventing habitat "bottlenecks" for the survival and growth of estuarine-dependent fauna. Since the 1950s, more than 20% of Tampa Bay's saltwater marsh and mangrove habitat has been lost to development, and more than 50% of the shoreline has been altered by seawalls, dredge-and-fill, or other hardening activities (Lewis and Robison, 1995).

Step 1: Identify Estuarine-dependent "Indicator" Faunal Guilds

Although the TBEP Technical Advisory Committee (TAC) attempted to identify indicator species and their habitat requirements, the group was not comfortable with selecting individual species to drive this process. A total of 38 species were identified as potential indicators, ranging from filter-feeding zooplankton species to manatees —an unmanageable number for determining specific habitat requirements. Each species was considered to be a critical indicator by at least one TAC member, and determining the relative importance of one species over another proved an impossible task within the group (Lewis and Robison, 1995).

To address this problem, members of the TAC agreed on 10 faunal guilds (based roughly on trophic guilds and taxonomic groups) in which all the potential indicator species could be grouped. Several species were separated into different guilds, depending upon life stage. For example, larvae of some fish may be classified as open-water filter feeders, but then reclassified as shallow-water forage fish as they mature. The 10 adopted Tampa Bay guilds were the following:

- Open-water filter feeders
- Shallow-water forage fish
- Recreational/commercial finfish and shellfish
- Subtidal invertebrates
- Intertidal invertebrates
- Estuarine mollusks
- Estuarine-dependent birds
- Estuarine-dependent birds requiring freshwater forage areas
- Estuarine reptiles
- Marine mammals (Lewis and Robison, 1995).

Step 2: Identify Habitats Critical to Support Guilds

Based on the habitat requirements of each of the 10 guilds, 6 habitat types were identified as critical to support the full suite of guilds:

- Open estuarine water
- Oligohaline (low-salinity) marsh
- Mangrove/*Spartina*
- Salt barrens
- Associated uplands
- Freshwater "frogponds" (Lewis and Robison, 1995).

Step 3: Compare Historic and Existing Extent of Habitats

In 1950, Tampa Bay coastal areas were flown to collect aerial photographs to examine the potential for draining coastal wetlands with mosquito ditches to combat an ongoing malaria epidemic at that time. Using these historic aerial photographs, the areal extents of each of three target habitat types (mangrove/marsh, oligohaline marsh, and salt barren) in 1950 were estimated. Current areal estimates for each of these habitat types were similarly constructed using 1995 aerial photographs (Lewis and Robison, 1995).

Change in Acres of Mangrove/Marsh, Oligohaline Marsh, and Salt Barren Habitat between 1950 and 1995 (Lewis and Robison, 1995)

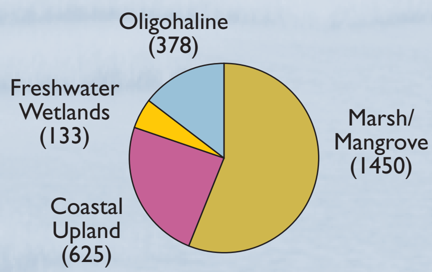
Habitat Type	1950 Acres	1950 Percent	1995 Acres	1995 Percent	Net Change (Acres)	Net Change (Percent)
Mangrove/marsh	15,894	67%	13,764	73%	-2,130	-13%
Oligohaline marsh	6,621	28%	4,117	22%	-2,504	-38%
Salt barren	1,371	5%	877	5%	-494	-36%
Total	23,886	100%	18,758	100%	-5,128	-21%

The table compares the acreage of these three target habitats in 1950 and 1995. Although a total of 21% of the total acreage for these three habitats was lost between 1950 and 1995, oligohaline habitat and salt barren acreage losses were approximately 38% and 36% of the 1950s acreage, respectively. Marsh and mangrove acreage loss was approximately 13% of the 1950s acreage. If mangrove/marsh habitat acreage remains constant, an increase of 1,800 acres of oligohaline habitat would be necessary to restore the historic balance of coastal habitats to support estuarine-dependent faunal guilds in Tampa Bay (Lewis and Robison, 1995).

Step 4: Focus Efforts on Restoring the Balance

Existing habitat-restoration efforts by agencies and local governments in Tampa Bay from 1990 to 1995 were successful in procuring funds for the restoration of 86 acres of coastal habitat. It was expected in 1995 that some additional funds would be available through 2005. Based on the results of this analyses and the recognized need for a reasonable expectation of funding sources, a target of restoring 100 acres of oligohaline habitat every five years was considered equivalent to the current rate of restoration. Thus, it was not assumed that additional funds would be available, but rather that funds be directed toward oligohaline marsh where possible. Mangrove/marsh habitat restoration has continued on an opportunity basis when appropriate sites are available and public support and funding exist (Lewis and Robison, 1995).

Between 1995 and 2003, the TBEP partners met and exceeded the adopted goal to restore at least 100 acres of oligohaline habitat every five years. A total of 2,357 acres of estuarine habitat was restored through 2003, including 378 acres of oligohaline habitat (see figure) (Greening et al., 2005).



Total acres of Tampa Bay estuarine habitat restored between 1995 and 2003 (Greening et al., 2005).

Habitat Quality

The TBEP monitors Bay acreage and changes in acreage over time to assess the quality of coastal wetland, salt marsh, and mangrove and seagrass habitats in the study area. The preservation of salt marsh and mangrove habitats in Tampa Bay is focused on 28 priority sites. These 28 sites were given the highest priority for Florida's Save Our Rivers and Preservation 2000 land-acquisition programs conducted by the SWFWMD. A total of 11,494 acres of estuarine habitat was preserved through direct land acquisitions between 1996 and 2003 (Figure 5-33) (Greening et al., 2005).

The area of historical seagrass coverage in Tampa Bay has been reduced as a result of excessive nitrogen loading and dredge-and-fill activities. To track and quantify changes in the seagrass beds, aerial photographs and mapping have been conducted every two years since 1988 to assess recovery trends. As shown in Figure 5-34, seagrass acreage in Tampa Bay declined between 1950 and 1982. Figure 5-35 illustrates the areas of seagrass cover lost between 1950 and 1990. Since 1992, overall seagrass acreage in the Bay has been increasing at a average rate of about 500 acres per year. Data from the 2004 survey show an increase in Bay-wide seagrass coverage by 2,183 acres between 1999 and 2004 (Tomasko et al., 2005c). One exception is the Old Tampa Bay area, which has experienced a 24% loss of seagrass during this time period and sustained previous losses between 1994 and 1996, suggesting a more serious condition could exist in this area. In addition to aerial photography and interpretation every two years, the Seagrass Condition Monitoring Program (70 transects Bay-wide) is conducted to better assess seagrass changes in the Bay (Avery and Johansson, 2004).

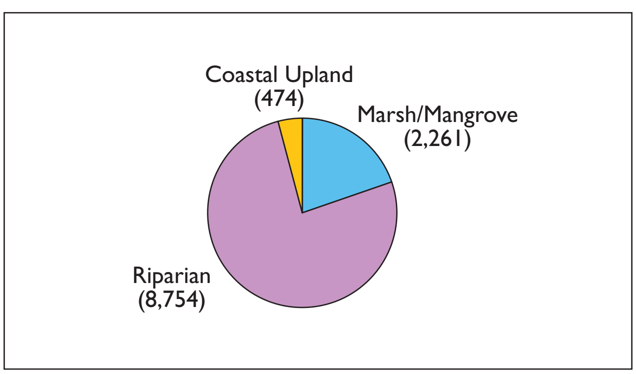


Figure 5-33. Total acres of habitat acquired through land acquisitions from 1996–2003 (Greening et al., 2005).

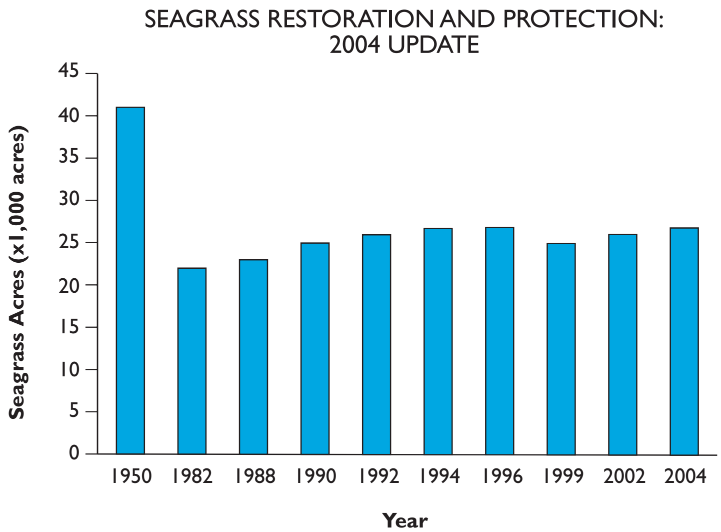


Figure 5-34. Decline in seagrass acreage in Tampa Bay between 1950 and 1982 and restoration after 1982 (Tomasko et al., 2005c).

Figure 5-35. Seagrass cover lost between 1950 and 1990 in Tampa Bay (Janicki et al., 1994).

Living Resources

The TBEP has been working to protect manatees and ensure healthy fishing stocks in Tampa Bay. The program uses boater compliance with posted speed zones and trends in fishery stocks as indicators for monitoring the success of these activities.

Manatees, which graze on seagrass beds, are often injured or killed by power boats in shallow areas of Tampa Bay. Boater-education efforts and a number of different manatee-protection efforts, such as signs marking mandatory and voluntary "go slow" areas, may reduce the number of manatee deaths each year. The TBEP's Manatee Awareness Coalition (MAC) has developed intensive boater-education programs aimed at protecting manatees and the seagrass habitats they depend upon. The MAC has also assisted in the development of federal, state, and local boating speed zones in Tampa Bay. The success of these efforts is being assessed by monitoring the numbers of boaters complying with posted speed zones, including both voluntary and mandatory compliance.

The TBEP is also interested in ensuring that healthy fishery stocks are maintained in the Bay. Although no target population levels have been designated, fish and shellfish population estimates, as measured by the Florida Wildlife Commission's Fisheries Independent Monitoring Program, have shown species-specific patterns in fish abundance since 1989. The results of monitoring efforts have documented the Bay's yearly fluctuations in major fish species and have not recorded any overall declining trends in the fishery stocks of Tampa Bay (Matheson et al., 2005).

Current Projects, Accomplishments, and Future Goals

Since the Tampa Bay master plan was first adopted in 1996, the TBEP has made aggressive strides toward defining goals and taking actions for the restoration and protection of Tampa Bay. The program has set goals for water quality, habitat restoration and protection, and fish and wildlife.

The TBEP's goals for water quality are to reduce nitrogen loadings, improve water quality in the Bay for recreation, and improve water clarity for the protection of seagrass habitat. The TBEP is measuring its progress toward these goals through the monitoring of water clarity and bacteria, chlorophyll *a*, and nitrogen concentrations. The TBEP also aims to gain a better understanding of atmospheric deposition and to identify sources of air pollution that are adding excess nitrogen to the Bay (Poor et al., 2001). To learn more, the TBEP plans to continue supporting the careful monitoring needed to identify and track any changes in atmospheric deposition to the Bay.

Habitat restoration and protection goals for Tampa Bay are directed primarily toward restoring the historic balance of coastal wetland habitats, preserving the Bay's salt marsh and mangrove acreage, and protecting and restoring the Bay's seagrass beds. The primary indicators of success toward these goals involve tracking the acreage of each habitat and the changes in acreage over time. In some cases, the TBEP has set specific goals for habitat preservation. For example, one of the program's estuarine habitat protection goals is to preserve the Bay's 18,800 acres of salt marsh and mangrove habitat (TBEP, 2003).

Fish and wildlife goals for Tampa Bay are directed primarily toward developing recommendations for local manatee protection zones and improving on-water enforcement of fishing and environmental regulations. The improvement of on-water enforcement was greatly facilitated by the merger of the Florida Fish and Wildlife Commission and the Florida Game and Freshwater Fish Commission. This merger increased the on-water presence in Tampa Bay.

Conclusion

The overall condition of Tampa Bay is rated fair based on three indices of estuarine condition used by the NCA. The TBEP has taken strong actions to establish short- and long-term goals for the protection and restoration of this estuary. NCA and TBEP monitoring data show that many aspects of environmental quality in the Bay are improving, such as nitrogen load and chlorophyll *a* levels and seagrass coverage. Attaining the TBEP's ambitious goals will require continued strong scientific involvement through monitoring, research, and pollution management, as well as the cooperation and dedication of a wide spectrum of stakeholders, including the public.

Mobile Bay National Estuary Program

www.mobilebaynep.com

Background

Mobile Bay is a submerged river valley that acts as a coastal transition zone between the Mobile Bay watershed and the Gulf of Mexico. The Mobile Bay watershed covers approximately 44,600 mi^2, including two-thirds of Alabama and portions of Mississippi, Georgia, and Tennessee (NOAA, 1985; Mobile Bay NEP, 2002a). It is the nation's fourth-largest watershed in flow volume and the sixth-largest river system in area (Mobile Bay NEP, 2002a).

Although the Mobile Bay watershed covers a vast area, the Mobile Bay NEP study area is limited to the portions of the watershed in Baldwin and Mobile counties in Alabama. The study area also includes Mobile Bay, the Mobile-Tensaw Delta, the surface waters between the Mississippi Sound and Alabama-Mississippi state line, and the Alabama state marine waters in the north-central portion of the Gulf of Mexico, which extend three miles south of Dauphin Island and the Fort Morgan Peninsula. The surface waters of Mobile Bay cover 409 mi^2, and the average depth of the Bay is about 10 feet, which is very shallow for a bay of this size (NOAA, 1985; Mobile Bay NEP, 2002a). Fresh water flows into the Bay through the Mobile-Tensaw, Blakely, Apalachee, Dog, Deer, Fowl, and Fish rivers. The Bay's primary opening to the Gulf of Mexico is the Main Pass, located between Dauphin Island and the Fort Morgan Penninsula. The Mobile-Tensaw River Delta is the largest intact delta in the United States and covers approximately 289 mi^2 of marsh, swamp, and forested wetlands (Wallace 1994; Auburn University, 2004). The Bay basin is characterized by barrier islands, tidal marshes, cypress swamps, bottomland hardwoods, and oyster reefs. The Mobile Bay NEP study area is home to 49 species of mammals, 126 species of reptiles and amphibians, 337 species of freshwater and saltwater fish, and 355 species of birds (Mobile Bay NEP, 2002a). Portions of Mobile Bay and the Mobile-Tensaw Delta, including the Tennessee-Tombigbee Waterway and the Port of Alabama, are subject to a number of human uses with national implications, such as commercial fisheries, industry, tourism and recreation, and coastal development.

An estimated 4.85 million metric tons of sediment enter this estuary annually, with 33% being deposited in the Mobile-Tensaw Delta, 52% in Mobile Bay, and the remainder flowing through to the Gulf of Mexico (Mobile Bay NEP, 2002a). Mobile Bay's salinity regime is complex. At times, the predominant influence is freshwater inflow from the large Mobile Bay watershed; however, salinity levels are highly variable in Mobile Bay because winds and tidal regimes affect the inflow of salty Gulf of Mexico waters into the Bay from the south. A recent hydrologic study indicated that salinity also varies with depth in the Bay and in the major river channels, shallower embayments, and stream channels of the Mobile-Tensaw Delta (Braun and Neugarten, 2005).

Environmental Concerns

Habitat loss is a high-priority environmental concern for the Mobile Bay NEP. Development, natural erosion processes, sedimentation, dredge-and-fill practices, exotic species, and hydrologic modifications are some of the causes of habitat loss in the Mobile Bay NEP study area (Mobile Bay NEP, 2002a). Between the mid-1950s and the late 1970s, 34% of the wetlands in northern Mobile Bay were lost, compared to the national and southeastern wetland loss average of 8% (U.S. EPA, 1998). Loss of habitat can result in a decreased number and/or diversity of faunal species in the Bay, increased flooding, and impaired water quality (Mobile Bay NEP, 2002a). For example, the Mobile Bay Causeway, a major hydrologic modification in the Mobile-Tensaw Delta, was built in the 1920s and acts as an unintentional barrier between the Delta waters to the north and the saline waters to the south. Recent studies indicate that the causeway has significantly impacted the ecological function of the lower Mobile-Tensaw Delta and may also have impacted the region's biodiversity (Mobile Bay NEP, 2002a; Valentine et. al., 2004).

Coastal cleanup along the Mobile Bay Causeway (Mobile Bay NEP).

Population Pressures

The population of the 2 NOAA-designated coastal counties (Baldwin and Mobile) coincident with the Mobile Bay NEP study area increased by 49% during a 40-year period, from 0.36 million people in 1960 to 0.54 million people in 2000 (Figure 5-36) (U.S. Census Bureau, 1991; 2001). This population growth rate for the Mobile Bay NEP study area was less than half the population growth rate of 133.3% for the collective NEP-coincident coastal counties of the Gulf Coast region. The population density of these two counties in 2000 was 191 persons/mi^2, which was about one-third less than the population density of 287 persons/mi^2 for the collective Gulf Coast NEP-coincident coastal counties (U.S. Census Bureau, 2001). Development and population pressures are especially strong in NEP study areas that serve as major shipping centers for commercial and recreational activities.

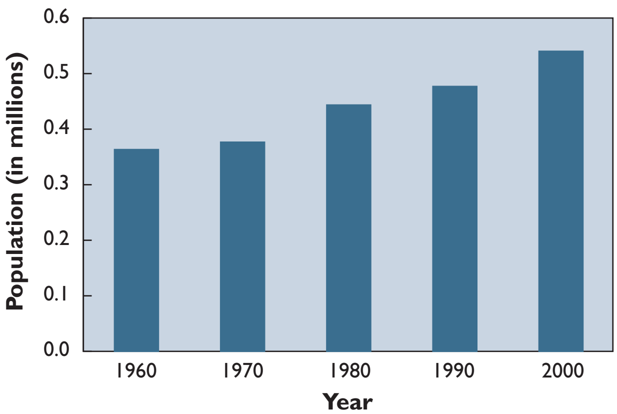


Figure 5-36. Population of NOAA-designated counties of the Mobile Bay NEP study area, 1960–2000 (U.S. Census Bureau, 1991; 2001).

NCA Indices of Estuarine Condition—Mobile Bay

The overall condition of Mobile Bay is rated fair based on the four indices of estaurine condition used by the NCA (Figure 5-37). The water quality and sediment quality indices are rated fair, the benthic index is rated poor, and the fish tissue contaminants index is rated good. Figure 5-38 provides a summary of the percentage of estuarine area rated good, fair, poor, or missing for each parameter considered. This assessment is based on data collected by the Alabama Department of Environmental Management (ADEM), in partnership with the NCA, from 66 sites sampled in the Mobile Bay NEP estuarine area in 2000 and 2001. Please refer to Tables 1-24, 1-25, and 1-26 (Chapter 1) for a summary of the criteria used to develop the rating for each index and component indicator.

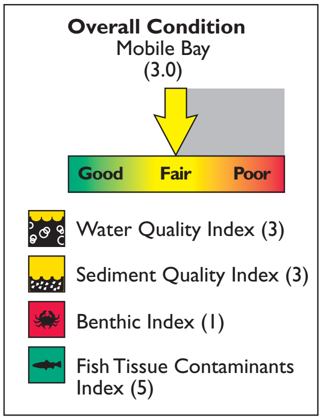


Figure 5-37. The overall condition of the Mobile Bay NEP estuarine area is fair (U.S. EPA/NCA).

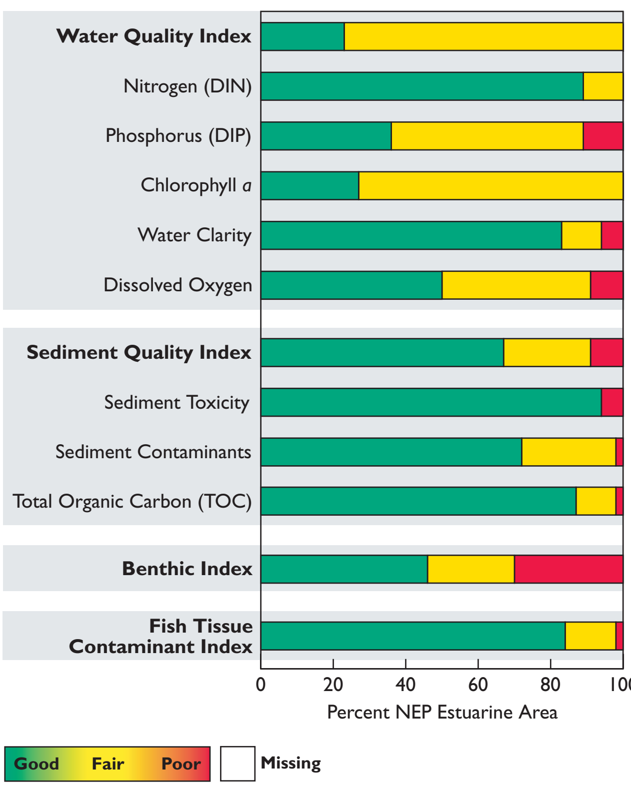


Figure 5-38. Percentage of NEP estuarine area achieving each rating for all indices and component indicators — Mobile Bay (U.S. EPA/NCA).

Water Quality Index

Based on NCA survey results, the water quality index for Mobile Bay is rated fair (Figure 5-39). This index was developed using NCA data on five component indicators: DIN, DIP, chlorophyll *a*, water clarity, and dissolved oxygen. In NOAA's Estuarine Eutrophication Survey, Mobile Bay was listed as having medium levels of chlorophyll *a* and medium-to-low DIN and DIP concentrations (NOAA, 1997).

Dissolved Nitrogen and Phosphorus | DIN concentrations in Mobile Bay are rated good, whereas DIP concentrations are rated fair. Concentrations of DIN were rated good in 89% of the estuarine area and fair in the remaining 11%. Eleven percent of the estuarine area was rated poor for DIP concentrations, 53% of the area was rated fair, and 36% of the area was rated good.

Chlorophyll a | Chlorophyll *a* concentrations in Mobile Bay are rated fair. Although no poor chlorophyll *a* conditions occurred in Mobile Bay, 73% of the estuarine area was rated fair, and the remaining 27% of the area was rated good for this component indicator.

Water Clarity | Water clarity in Mobile Bay is rated good. Expectations for water clarity in Mobile Bay are low due to high river flow and naturally high turbidity. Water clarity was rated poor at a sampling site if light penetration at 1 meter was less than 5% of surface illumination. Water clarity was rated poor in only 6% of the estaurine area, 11% of the area was rated fair, and 83% of the area was rated good.

Dissolved Oxygen | Dissolved oxygen conditions in Mobile Bay are rated fair. NCA estimates show that 9% of the estuarine area was rated poor for this component indicator, 41% of the area was rated fair, and 50% of the area was rated good.

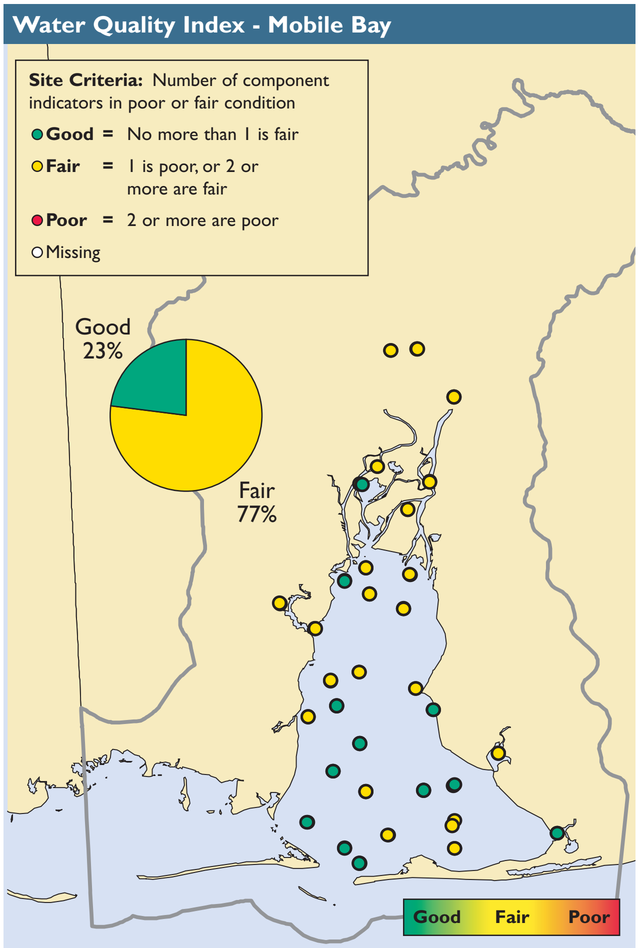


Figure 5-39. Water quality index data for Mobile Bay, 2000–2001 (U.S. EPA/NCA).

Throwing a cast net for bait fish, shrimp, and mullet is a popular local tradition (Mobile Bay NEP).

Mobile Bay National Estuary Program

Sediment Quality Index

The sediment quality index for Mobile Bay is rated fair because 9% of the estuarine area was rated poor for sediment quality (Figure 5-40). This index was developed using NCA data on three component indicators: sediment toxicity, sediment contaminants, and sediment TOC.

Sediment Toxicity | Mobile Bay is rated poor for sediment toxicity because 6% of the estuarine area was rated poor for this component indicator.

Sediment Contaminants | Only 2% of the estuarine area was rated poor for sediment contaminant concentrations; therefore, this component indicator is rated good for Mobile Bay.

Total Organic Carbon | Mobile Bay is rated good for sediment TOC. Eighty-seven percent of the estuarine area was rated good for this component indicator, 11% of the area was rated fair, and only 2% of the area was rated poor.

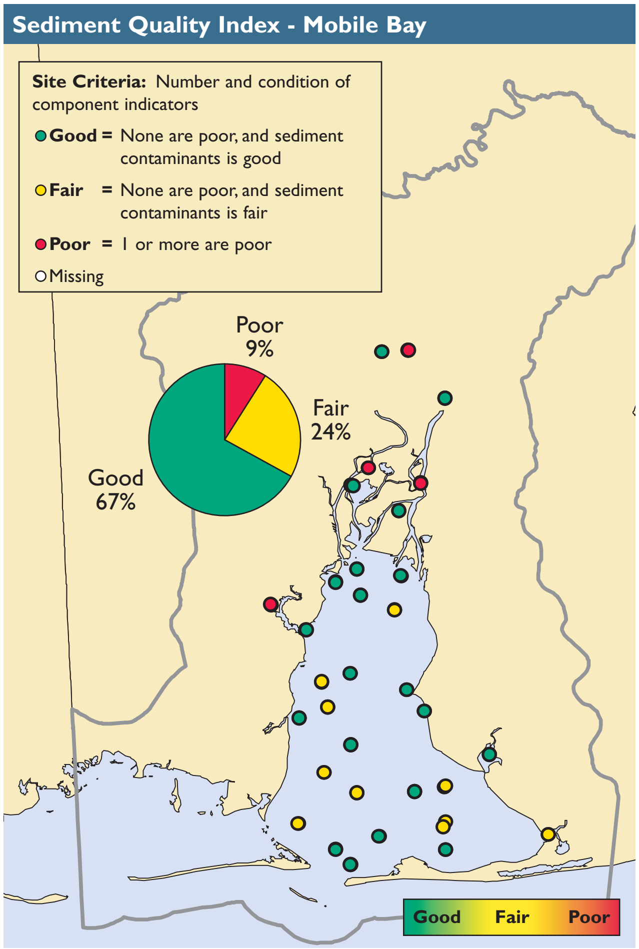


Figure 5-40. Sediment quality index data for Mobile Bay, 2000–2001 (U.S. EPA/NCA).

Navy Cove along Fort Morgan Peninsula, Alabama (Mobile Bay NEP).

Benthic Index

Based on the Gulf Coast Benthic Index and data from the NCA, the condition of benthic invertebrate communities in Mobile Bay is rated poor. Benthic index estimates indicate that 30% of the estuarine area has degraded benthic resources and another 24% of the area is rated fair (Figure 5-41).

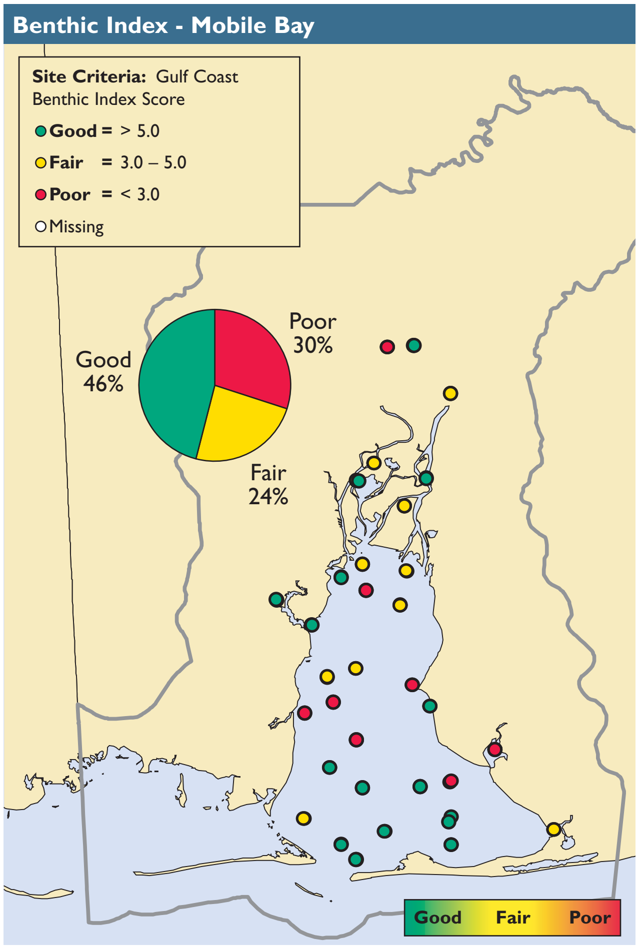


Figure 5-41. Benthic index data for Mobile Bay, 2000–2001 (U.S. EPA/NCA).

Fish Tissue Contaminants Index

The fish tissue contaminants index for Mobile Bay is rated good, based on concentrations of contaminants in fish tissues (whole fish). Figure 5-42 shows that 2% of all stations sampled where fish were caught exceeded the EPA Advisory Guidance values used in this assessment and were rated poor.

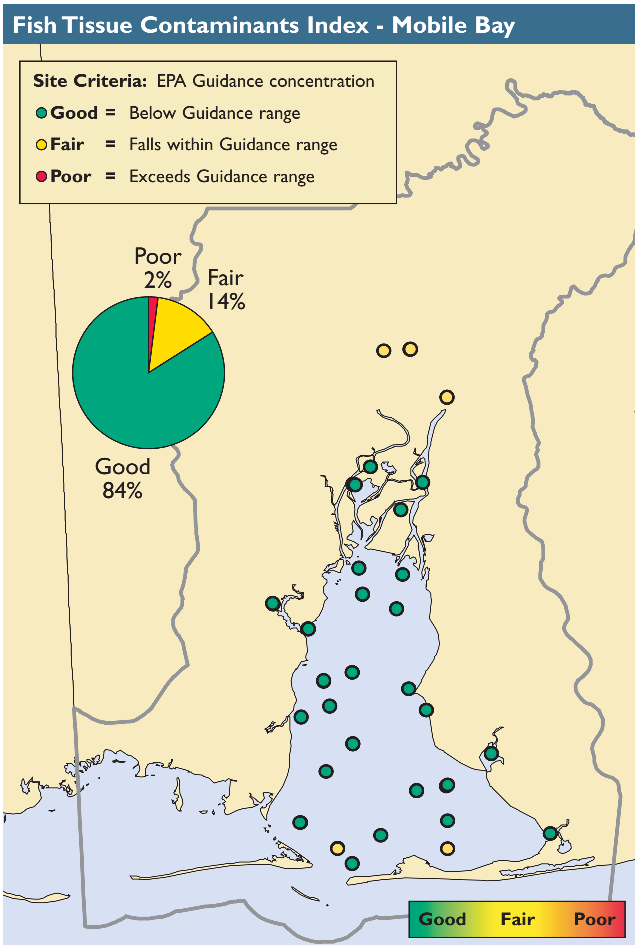


Figure 5-42. Fish tissue contaminants index data for Mobile Bay, 2000–2001 (U.S. EPA/NCA).

Mobile Bay National Estuary Program

Invasive Species of Coastal Alabama and Mississippi

The invasion of non-indigenous aquatic species is recognized as one of the five most-critical environmental issues facing the ocean's marine life (NRC, 1995). Broad efforts are underway nationwide to combat the entry of new species into our country and to effectively control and manage those that have already made their way here. This is particularly important in Gulf Coast waters because numerous vectors exist for the introduction of non-native aquatic plant and animal species in this region. These invasive species pose ecological, economic, and even human health threats.

Identifying these "alien" species was the goal of the newly formed Alabama-Mississippi Rapid Assessment Team (AMRAT) during the largest coast-wide rapid assessment of living resources ever held in the Gulf of Mexico. This team carried out rapid assessment surveys of non-native plant and animal species in Mobile Bay over several days in September 2003, as well as along the Mississippi coast in August and September 2004. The result was a "snapshot" inventory of coastal species from which potentially invasive or nuisance species could be identified. Such surveys offer an opportunity for the early detection of newly introduced non-native species, can result in early actions to curb the spread of invasive species, and provide insight into the ways these plants and animals arrive in a region. The assessments can also serve as a basis for the development of management plans to deal with potential nuisance species. The data collected provides a baseline against which future status and trends in non-native populations can be assessed (Mobile Bay NEP, 2005).

During the assessment surveys, researchers used a variety of sampling techniques to collect and identify as many different non-native organisms as possible. These techniques included aerial surveys, diving, electroshocking, plankton and algae sampling, trawling, seine netting, hand netting, hand picking, and scraping fouling organisms from surfaces. Ballast water was also sampled from ships in port and analyzed for pathogens by an FDA laboratory. Collectively, more than 120 researchers, technicians, and support personnel from 22 state, federal, and research institutions and agencies took part in these intensive field and laboratory efforts (Mobile Bay NEP, 2005).

The AMRAT is a continuing effort led by a unique partnership between co-founders Harriet Perry, Director of the Center for Fisheries Research and Development at the University of Mississippi's Gulf Coast Research Laboratory (GCRL), and David Yeager, Director of the Mobile Bay NEP. The team was founded is based on the premise that few individual organizations have all the resident scientific expertise or logistical ability to carry out a survey of this scale. The AMRAT partnership represents an innovative way to provide this capability. The surveys were coordinated with the Gulf and South Atlantic Regional Panel on Aquatic Invasive Species. The Gulf States Marine Fisheries Commission administers this panel and manages the data from the surveys.

More than 730 samples were collected during the AMRAT assessment surveys (Yeager and Perry, 2004). Many native and non-native animals and plants were classified and accessioned into the GCRL museum to serve as type specimens and aid in future study and identification. The surveys validated the presence of previously identified or suspected non-native plants and animals and added some new information. New arrivals include a population of Nile tilapia (*Oreochromis niloticus*) and the wild taro plant (*Colocasia antiquorum*), both noted in Mississippi, and the Asian clam (*Corbicula fluminea*), noted in both Alabama and Mississippi. In addition, two new state records for molluscs in Alabama were established: a marine snail (*Turbonila puncta*) and a bicolor purse-oyster (*Isognomon bicolor*). Changes in the distribution of certain native plants such as smooth cord grass (*Spartina alterniflora*) and their replacement by an invasive, *Phragmites*, were also noted. This was also the first time seaweeds and benthic algae in Alabama coastal waters were cataloged.

A researcher collects samples during AMRAT 2004 (Pam Fuller, USGS).

The AMRAT assessment surveys were unqualified successes and were highly acclaimed by participants, observers, and reviewers. In 2006, the AMRAT program was awarded a first place Gulf Guardian Award by EPA's Gulf of Mexico Program. The survey is identified by the Gulf and South Atlantic Regional Panel on Aquatic Invasive Species in their current strategic plan as a model for Gulf–wide assessment efforts, and other areas of the Gulf Coast are considering implementing similar programs. Current plans for coastal Louisiana surveys, led by the Louisiana Sea Grant Program and the Barataria-Terrebonne NEP (BTNEP), are using the lessons learned from AMRAT. Discussions also are underway to extend the AMRAT surveys into areas of the Florida panhandle as early as 2006. Additional information about AMRAT and a full list of its partners and participants is available from the following Web sites: http://www.mobilebaynep.com, http://nis.gsmfc.org, and http://www.gsmfc.org.

Mobile Bay National Estuary Program Indicators of Estuarine Condition

The Mobile Bay NEP has not yet finalized indicators for tracking the health of Mobile Bay, but will complete this task in 2006. Several successful public participation workshops resulted in a preliminary list of indicators that may be used to easily communicate the ecological condition of the Bay to the public. These indicators are either currently monitored or considered sufficiently important to warrant additional monitoring. Progress has also been made in developing status and trends data in preparation for a future report on the five issue areas identified in the Mobile Bay NEP *Comprehensive Conservation and Management Plan*, *Volume I—A Call to Action* (Mobile Bay NEP, 2002a). This progress includes initiating a new sub-estuary water quality monitoring project; instituting a continuous Bay-wide time series monitoring project; performing rapid assessments to monitor invasive species; analyzing more than 20 years of collected fish population data to evaluate trends; performing the first comprehensive modern survey of SAV and a comparison with historical data; establishing a completely updated NWI wetland survey and upland habitat survey for Mobile and Baldwin counties; utilizing a land-use cover map for Baldwin County; and performing other baseline data collection to provide a solid scientific basis for evaluating status and trends.

Water and Sediment Quality

The Mobile Bay NEP has established explicit goals and objectives for Mobile Bay and its subbasins, including developing allowable water quality-based loadings sufficient to maintain water quality standards (or TMDLs) for pathogens, nutrients, toxic chemicals, and other pollutants. Water quality indicators for Mobile Bay include chlorophyll *a*, total phosphate, ammonia, nitrates+nitrites, dissolved oxygen, salinity, pH, biochemical oxygen demand, turbidity, and water temperature. ADEM also monitors the Bay for several toxic chemicals, including mercury, cadmium, chromium, DDT, and PAHs (Hutchings and Yokel, 2000).

Portions of some rivers in the Mobile Bay NEP study area do not fully support their current or proposed water-use classifications because of nutrient enrichment and/or low dissolved oxygen levels; however, dissolved oxygen standards were actually achieved in 95% of the coastal waters across the Bay (Baya et al., 1998). Nutrient levels in the Bay are affected by point and non-point sources of nitrogen and phosphorus, rainfall levels, freshwater flows in the Mobile Bay River Delta, and a variety of cycling processes between the sediment and water column. Data collected between 1993 and 1995 show that more than 55% of Mobile Bay had bottom dissolved oxygen levels below 4 mg/L and that 30% of the Bay had levels below 2 mg/L, indicating poor conditions for dissolved oxygen (Mobile Bay NEP, 2002a). Eight percent of the sites monitored by the Alabama Monitoring and Assessment Program (ALAMAP) indicated dissolved oxygen deficiencies (below the 5-mg/L criteria) (ADEM, 2004).

ADEM's pathogen indicators for Mobile Bay are fecal coliform and *Enterococci*. Existing pathogen data have been deemed insufficient for developing a true status and trends relationship because these data have focused on short time frames and narrow geographic regions. In 1996, 412 of 451 mi^2 (91%) of shellfish waters in the study area did not fully support their intended use classifications due to pathogen indicators (Mobile Bay NEP, 2002a). The 2002 303(d) list of impaired stream segments in the Mobile Bay NEP study area indicates that, of the 23 stream segments listed, 11 were listed in part due to pathogen contamination (ADEM, 2002).

Metals and chemicals that are slow to break down in the environment accumulate in Mobile Bay sediments over time, and the Mobile Bay NEP uses a variety of indicators to assess the Bay's sediment quality. These indicators include analyzing sediments for metals and pesticides, monitoring human activities such as fuel spills and pesticide use, and assessing shellfish contamination levels (Mobile Bay NEP, 2002b). Of the 23 303(d)-listed streams located in the Mobile Bay NEP study area, 8 were impaired, in part due to mercury contamination (ADEM, 2002).

Habitat Quality

The Mobile Bay NEP monitors indicators of habitat quality and habitat loss, including upland habitat extent and conversion. Changes in SAV habitat acreage, wetland areas, beach and dune extent, and shoreline habitats are all indicators that have been monitored to evaluate habitat loss in the Mobile Bay system (Hutchings and Yokel, 2000). Probable impacts of habitat loss include population declines and/or the extinction of native species. More than 50% of Alabama's wetland acreage was lost between 1780 and 1980 (Mobile Bay NEP, 2002a). In 2002, the Mobile Bay NEP used aerial photography and GIS technology to assess the extent of SAV in Mobile Bay. The study showed that Mobile Bay's SAV acreage decreased by more than 55% in Mobile County (1940–2002) and by more than 88% in Baldwin County (1955–2002) (Barry A. Vittor & Associates, Inc., 2005). In light of this trend, the relationship between water quality (including nutrient loading and water clarity) and SAV loss is a subject for further evaluation by the Mobile Bay NEP and its partners.

The brown pelican population has made a remarkable recovery on Gaillard Island (Mobile Bay NEP).

Living Resources

Indicators for monitoring living resources include distribution, diversity, and composition of benthic assemblages; distribution and diversity of native fishes; abundance of exotic species; number of rare listed species by year and habitat acreage; and other measures. The population of many wildlife species in the Mobile Bay NEP study area have been diminished due to over-harvesting, pollution, and habitat loss. The Bay and coastal waters of the study area are home to many rare and endangered species of wildlife, including five species of sea turtles; the West Indian manatee; sperm whales; bottlenose dolphins; and the American bald eagle. Thirty-six of the Bay's 337 fish species are listed as at risk (Mobile Bay NEP, 2002a).

More than 350 species of birds can be found in the Mobile Bay NEP study area each year. Some of the birds are year-round residents, whereas others pass though the area during migrations or reside in the area for part of the year. These birds include waterfowl, colonial wading birds, and seabirds. Gaillard Island supports the only nesting colonies of the brown pelican, laughing gull, Caspian tern, and sandwich tern in Alabama. Nests of brown pelicans on the island increased from 4 in 1983 to 4,597 in 1997 (Stout et al., 1998).

Although there are no fish advisories specific to Mobile Bay, the State of Alabama has issued a statewide advisory for mercury in king mackerel from all estuarine/coastal Alabama waters (U.S. EPA, 2005a). The State of Alabama currently employs the FDA standards set for the sale of seafood in issuing fish consumption advisories based on mercury contamination. Discussion is underway to adopt the stricter EPA standards for fish tissue contamination. Using EPA standards would significantly expand the number of streams in Alabama with fish consumption advisories based on mercury contamination (Bouma, 2005).

Environmental Stressors

A variety of human activities are used as indicators to help evaluate environmental stressors in Mobile Bay. These indicators include population growth, sanitary waste per capita, changes in land use and land cover, increase in impervious surfaces, the number and type of development permits, the number of boating and fishing licenses, the number of municipal sewage violations, and the air pollution index for Mobile Bay. Indicators of hydrologic modification are also monitored and include the acres of floodways impacted by development, extent of bulkheading, areal extent of dredging activities, areal extent of wetland filling and excavation, linear extent of stream and creek channelization, shoreline loss and erosion, and other parameters (Hutchings and Yokel, 2000).

Current Projects, Accomplishments, and Future Goals

Major goals of the Mobile Bay NEP include attaining and maintaining water and sediment quality that is sufficient to support healthy aquatic communities and designated human uses; providing optimum fish and wildlife habitat; and restoring historic plant and animal populations. The Mobile Bay NEP is also concerned with providing consistent and enforceable land- and water-use management that ensures smart growth for sustainable development. High-priority issues of the Mobile Bay NEP are habitat loss, rapid coastal growth and development and attendant non-point source pollution, water quality, growth management, municipal treatment facilities, public education, and industrial impacts on the Bay. Several of the Mobile Bay NEP's current projects and accomplishments are described below:

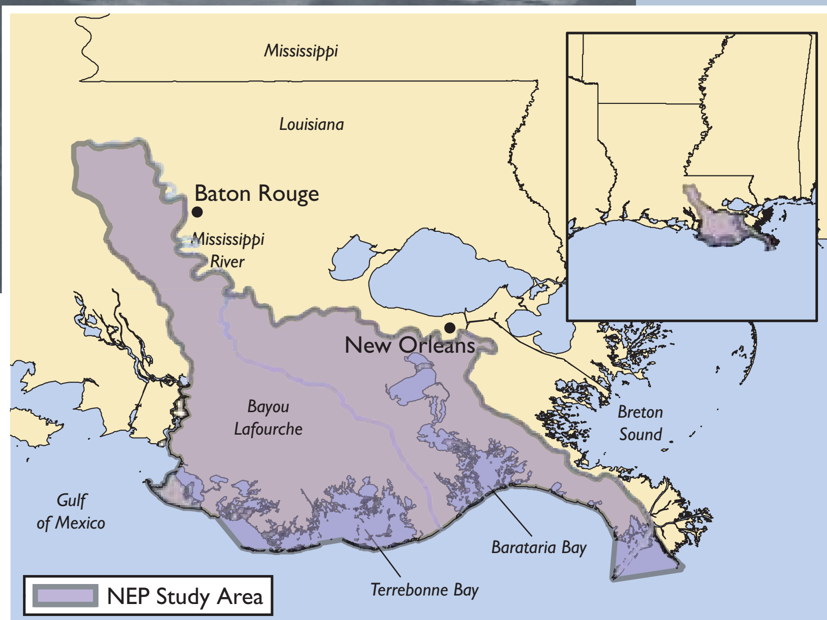
- The Mobile Bay NEP, in partnership with the Dauphin Island Sea Lab, the University of South Alabama's Center for Estuarine Studies, and the Weeks Bay NERR, has established the first long-term network of real-time, continuous time-series water monitoring stations in Mobile Bay. This project provides basic data from three new sites in Mobile Bay and links an established site at the Weeks Bay NERR. The most recent addition to the network, the site at Middle Bay, is unique in that its vertical water-profiling system provides information throughout the water column. The measured meteorological and hydrographic parameters include wind speed and direction, air temperature, barometric pressure, solar radiation, quantum radiation, precipitation, water temperature, water height, salinity, dissolved oxygen, and turbidity.
- A major GIS study and water monitoring program is now underway to identify the sources of pathogen introduction into one of the local 303(d)-listed streams, with an aim toward taking necessary remediation or corrective actions.
- Two major habitat-restoration grants have been awarded to local organizations by the Mobile Bay NEP. The first grant helped eliminate the world's second-most invasive weed, cogon grass, on a portion of a 2,400-acre site bordering the Tensaw River. The second grant provides for purchase and further restoration of an 8-acre marsh on Mon Luis Island.
- A SAV restoration manual has been completed and printed, and a SAV restoration project involving numerous volunteers is in progress (Turner et al., 2005).
- In concert with the USACE and other partners, several restoration projects are in the planning stages, including the use of dredge material to restore nesting habitat on a barrier island; the creation of additional oyster bottom, emergent marsh, and SAV habitat; and the examination of the feasibility of increased public access.
- In partnership with the Nature Conservancy, the Mobile Bay NEP has completed an assessment of habitat-protection needs and identified priority sites for acquisition and conservation protection, as well as other priority sites for restoration efforts. The first efforts toward implementing these goals are underway. In addition, a database is being created in partnership with the Mississippi-Alabama Sea Grant to catalogue restoration and acquisition efforts on the Mississippi and Alabama coasts and to help better direct and refine efforts in this area.

- The Mobile Bay NEP facilitated discussions and planning between conservation, recreational, and commercial interests through a public process. These activities resulted in the closure of a portion of the upper reaches of Mobile Bay to shrimp trawling, thereby reducing the impacts of bycatch on juvenile finfish and of trawling on SAV habitat.
- The Mobile Bay NEP is partnering with the City of Mobile and the State Lands Division on the creation of a significant public access site and the restoration of its adjoining marsh area.
- A preliminary report has been prepared concerning the probable impacts of the Mobile Bay Causeway on freshwater and saltwater hydrology in the Mobile-Tensaw River Delta, as well as its attendant impact on aquatic living resources (Valentine et al., 2004).
- Since 2001, the Mobile Bay NEP has helped to conduct an Oyster Gardening Program. This program has many purposes, including collecting data on oysters, improving water quality through oyster filtration, protecting young oysters by improving their conditions, creating habitat for other marine species that form the base of the food chain, and educating the community about oysters.

Conclusion

Based on data collected by the NCA, the overall condition of Mobile Bay is rated fair. The Mobile Bay NEP has not yet finalized its indicators for tracking the health of Mobile Bay, but this task will be completed in 2006. The preliminary list of indicators includes a variety of parameters used to assess water, sediment, and habitat quality; habitat loss; living resources; hydrologic modifications; and the effects of human activities on the estuary. Several of these parameters are currently being monitored in the study area, and the Mobile Bay NEP is making progress towards developing status and trends data for these indicators.

Barataria-Terrebonne National Estuary Program



BTNEP
BARATARIA-TERREBONNE NATIONAL ESTUARY PROGRAM

www.btnep.org

Background

The study area of the Barataria-Terrebonne National Estuary Program (BTNEP) is located between the Mississippi and Atchafalaya rivers in southern Louisiana and covers approximately 6,500 mi^2 (Caffey and Breaux, 2000). Bayou Lafourche separates this area into two basins: Barataria Basin to the east and Terrebonne Basin to the west. The integration of salt water and fresh water begins offshore, where water, sediment, nutrients, and pollutants from the Mississippi River mix with the salt water of the Gulf of Mexico. Approximately 735 species of birds, finfish, shellfish, reptiles, amphibians, and mammals spend all or part of their life cycle in the estuary, with several of these species categorized as either threatened or endangered (BTNEP, 2005).

Significant industrial and municipal effluents enter the Mississippi River between Baton Rouge and New Orleans, contributing to nutrient and contaminant loadings in the estuary system. Several natural and man-made waterways transect the estuary system, including the Gulf Intracoastal Waterway and the Barataria Waterway. Open water and wetlands are the predominant land-use classifications in the region and have been increasing in area since 1956 (Figure 5-43). More than three quarters of the BTNEP study area (3.2 million acres) is classified as open water or wetlands, leaving approximately one million acres for urban and agricultural uses (Moore and Rivers, 1996).

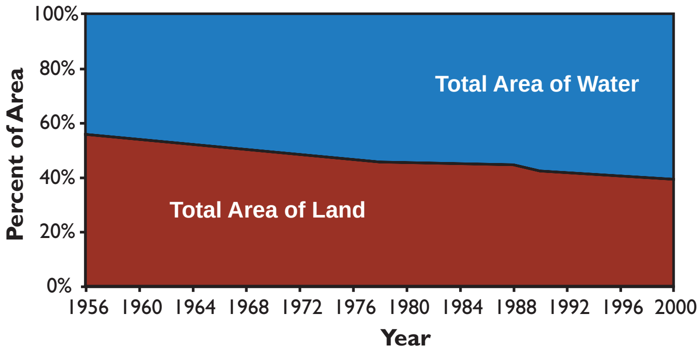


Figure 5-43. Change in the total area of water in the BTNEP estuarine area between 1956 and 2000 (BTNEP, 2002).

Environmental Concerns

The priority issues affecting the BTNEP study area include habitat loss, hydrological modification, reduced sediment flows (reduction in sediment inputs), eutrophication, pathogen contamination from untreated sewage and stormwater discharges, toxic substances, and declines in living resources (Battelle, 2003). Sediment loss (depletion), in conjunction with the subsidence (sinking) of marshes, is the most significant problem in the Barataria-Terrebonne Estuarine Complex. The construction of levees to protect human communities from floods has eliminated vital inputs of fresh water and sediments from reaching the estuaries; these inputs are needed to keep the marshes above water. Sea-level rise, erosion, canal dredging, and the construction of navigation and oil-exploration channels further contribute to this problem. The impacts of hydrological modifications in the BTNEP study area are numerous; man-made canals create paths for waters of higher salinity to intrude inland, destroying freshwater plants and forcing animals either to adapt or to relocate. Each year, about 15 mi^2 of wetlands in the study area are lost, and a half-acre of the Complex's coastal wetlands turns to open water every 15 minutes (BTNEP, 2002; Focazio, 2006b). Because this coastal marsh habitat provides a considerable buffer from the flooding, storms, and hurricanes that threaten the Louisiana coastline, this loss of habitat is detrimental to the health of fish and wildlife populations and to human development. Many species that depend on habitat in the Barataria-Terrebonne Estuarine Complex are either threatened or endangered, including the American bald eagle, brown pelican, piping plover, least tern, Louisiana black bear, and American alligator.

Population Pressures

The population of the 16 NOAA-designated coastal parishes coincident with the BTNEP study area increased by 28% during a 40-year period, from 1.3 million people in 1960 to 1.6 million people in 2000 (Figure 5-44) (U.S. Census Bureau, 1991; 2001). This rate of population growth for the BTNEP study area was the lowest growth rate of any of the Gulf Coast NEPs and constitutes less that one-fourth of the population growth rate of 133.3% for the collective NEP-coincident coastal counties of the Gulf Coast region. In addition, the population density of the BTNEP study area in 2000 was 184 persons/mi^2, the second-lowest density of the Gulf Coast NEPs and about one-third less than the population density of the region's collective NEP-coincident counties (287 persons/mi^2) (U.S. Census Bureau, 2001). Development and population pressures are moderate in this study area, which serves as a major center for commercial fishing and shellfish, the petrochemical industry, and recreational activities.

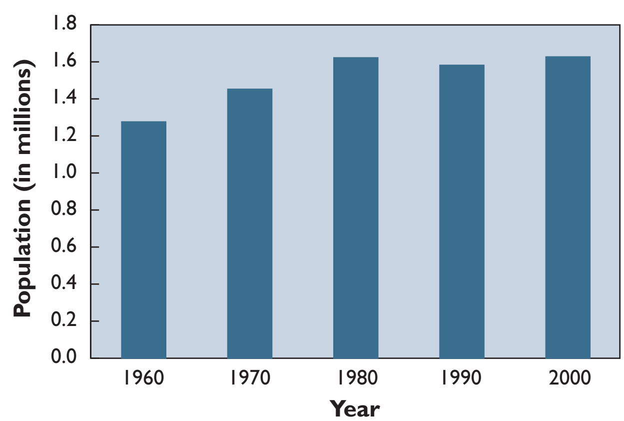


Figure 5-44. Population of NOAA-designated counties of the BTNEP study area, 1960–2000 (U.S. Census Bureau, 1991; 2001).

NCA Indices of Estuarine Condition—Barataria-Terrebonne Estuarine Complex

The overall condition of the Barataria-Terrebonne Estuarine Complex is rated fair based on the four indices of estuarine condition used by the NCA (Figure 5-45). The water quality, sediment quality, and benthic indices are rated fair, and the fish tissue contaminants index is rated poor. Figure 5-46 provides a summary of the percentage of estuarine area rated good, fair, poor, or missing for each parameter considered. This assessment is based on data collected by the State of Louisiana and the NCA from 25 stations sampled in the BTNEP estuarine area in 2000 and 2001. Please refer to Tables 1-24, 1-25, and 1-26 (Chapter 1) for a summary of the criteria used to develop the rating for each index and component indicator.

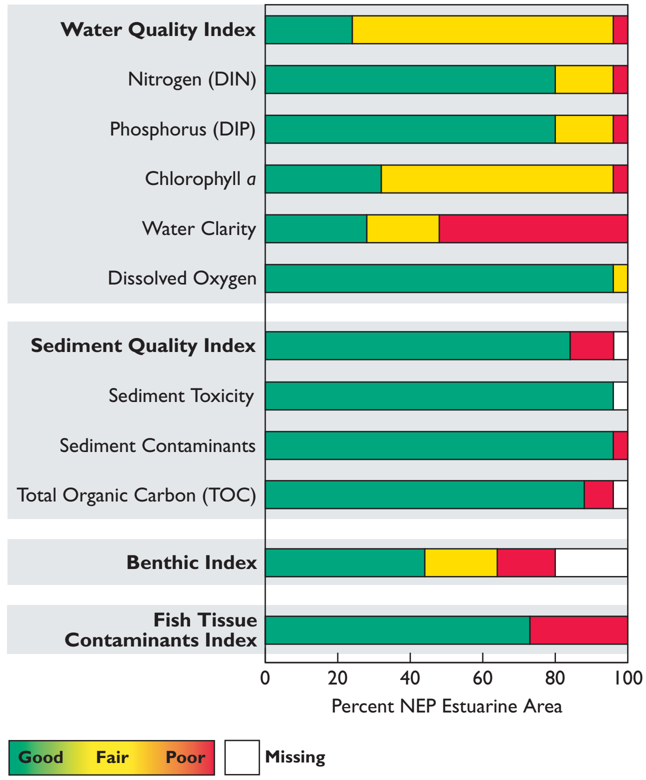


Figure 5-46. Percentage of NEP estuarine area achieving each rating for all indices and component indicators — Barataria-Terrebonne Estuarine Complex (U.S. EPA/NCA).

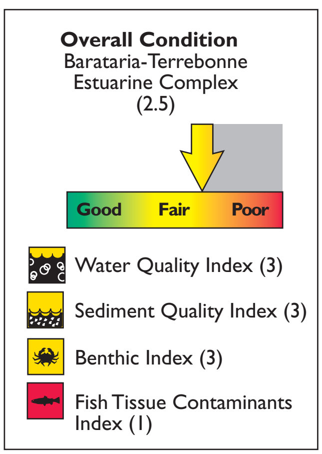


Figure 5-45. The overall condition of the BTNEP estuarine area is fair (U.S. EPA/NCA).

Water Quality Index

Based on NCA survey results, the water quality index for the Barataria-Terrebonne Estuarine Complex is rated fair (Figure 5-47). This water quality index was developed using NCA data on five component indicators: DIN, DIP, chlorophyll *a*, water clarity, and dissolved oxygen. In NOAA's Estuarine Eutrophication Survey, Barataria Bay was listed as having high to hypereutrophic chlorophyll *a* concentrations and high DIN and DIP concentrations (NOAA, 1997). In the same report, the Terrebonne and Timbalier bays were listed as having high chlorophyll *a* and DIP concentrations and moderate DIN concentrations.

Dissolved Nitrogen and Phosphorus | DIN and DIP concentrations in the BTNEP estuarine area are rated good. For both component indicators, 4% of the estuarine area was rated poor, 16% of the area was rated fair, and 80% of the area was rated good.

Chlorophyll a | Chlorophyll *a* concentrations in the Barataria-Terrebonne Estuarine Complex are rated fair. Although only 4% of the estuarine area was rated poor for chlorophyll *a* concentrations, 64% of the area was rated fair, and 32% of the area was rated good.

Water Clarity | Water clarity in the BTNEP estuarine area is rated poor. Expectations for water clarity are low due to high river flow and naturally high turbidity for these estuaries. Water clarity was rated poor at a sampling site if light penetration at 1 meter was less than 5% of surface illumination. Fifty-two percent of the estuarine area was rated poor for water clarity, 20% of the area was rated fair, and 28% of the area was rated good.

Dissolved Oxygen | Dissolved oxygen conditions in the BTNEP estuarine area are rated good. NCA estimates show that none of the estuarine area was rated poor for this component indicator, 4% of the estuarine area was rated fair, and 96% of the area was rated good.

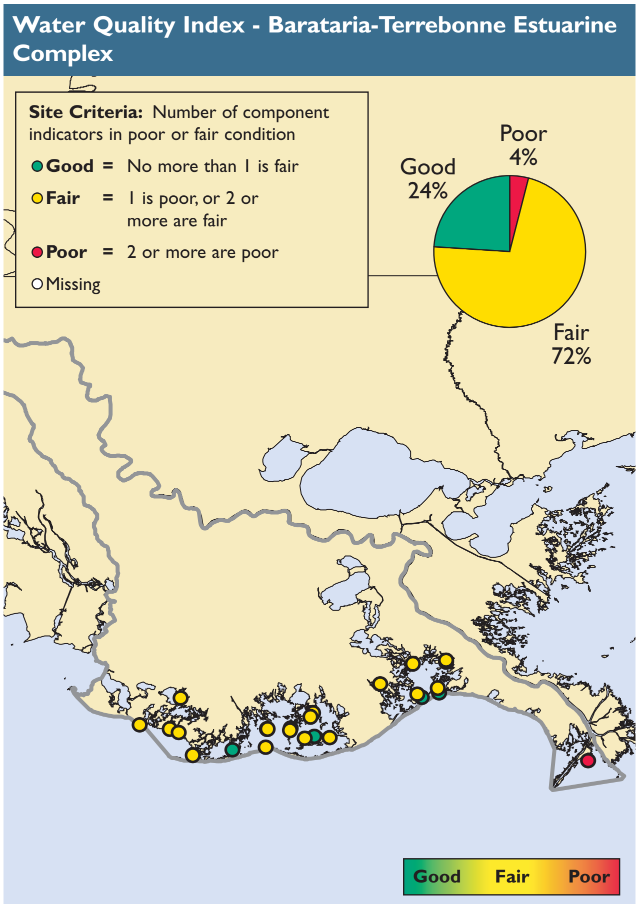


Figure 5-47. Water quality index data for the Barataria-Terrebonne Estuarine Complex, 2000–2001 (U.S. EPA/NCA).

Sediment Quality Index

The sediment quality index for the Barataria-Terrebonne Estuarine Complex is rated fair. This index was developed using NCA data on three component indicators: sediment toxicity, sediment contaminants, and sediment TOC. Although all three component indicators received good ratings for the Barataria-Terrebonne Estuarine Complex, the index is rated fair because greater than 5% of the estuarine area was rated poor for sediment quality (Figure 5-48).

Sediment Toxicity | Sediment toxicity is rated good for the BTNEP estuarine area because none of the area was rated poor for this component indicator.

Sediment Contaminants | Only 4% of the BTNEP estuarine area was rated poor for sediment contaminant concentrations; therefore, the Complex is rated good for this component indicator.

Total Organic Carbon | Sediment TOC is rated good for the BTNEP estuarine area. Eighty-eight percent of the estuarine area was rated good for this component indicator, and only 8% of the area was rated poor. NCA data on TOC concentrations were unavailable for 4% of the BTNEP estuarine area.

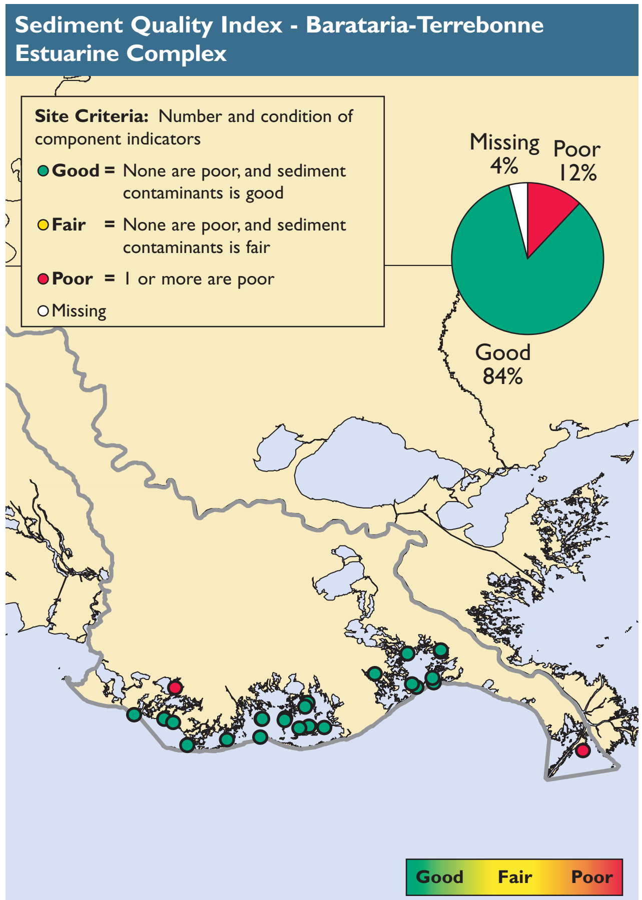


Figure 5-48. Sediment quality index data for the Barataria-Terrebonne Estuarine Complex, 2000–2001 (U.S. EPA/NCA).

Eroding marsh peninsula between Bayous Perot and Rigolettes, Barataria Basin (Dr. Terry McTigue, NOAA, NOS, ORR).

Benthic Index

Based on NCA survey data and the Gulf Coast Benthic Index, the condition of benthic invertebrate communities in the Barataria-Terrebonne Estuarine Complex is rated fair. Benthic condition index estimates indicate that 16% of the area had degraded benthic resources, and NCA data on benthic condition were unavailable for 20% of the BTNEP estuarine area (Figure 5-49).

Fish Tissue Contaminants Index

The fish tissue contaminants index for the Barataria-Terrebonne Estuarine Complex is rated poor. Figure 5-50 shows that 27% of all stations sampled where fish were caught exceeded the EPA Advisory Guidance values used in this assessment and were rated poor.

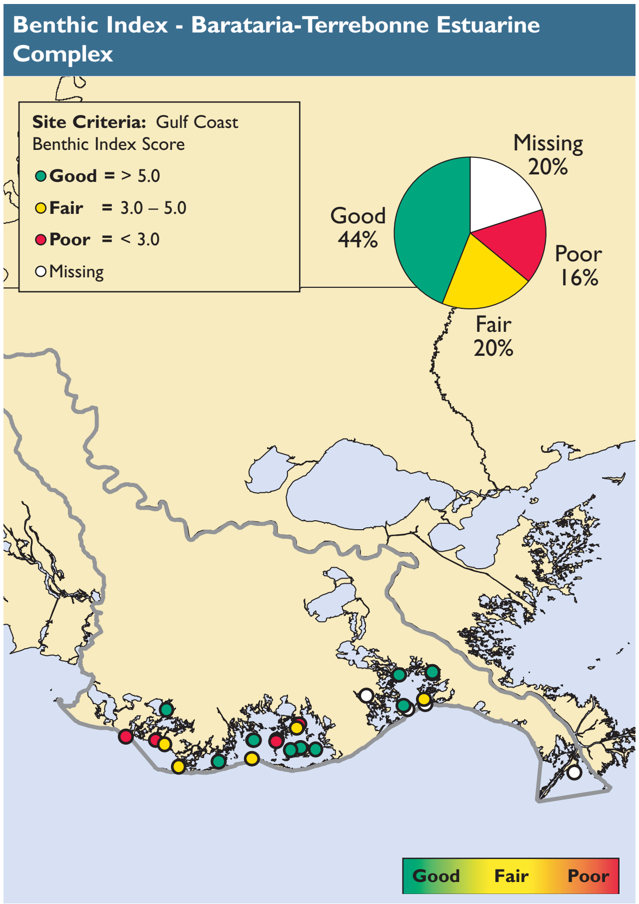


Figure 5-49. Benthic index data for the Barataria-Terrebonne Estuarine Complex, 2000–2001 (U.S. EPA/NCA).

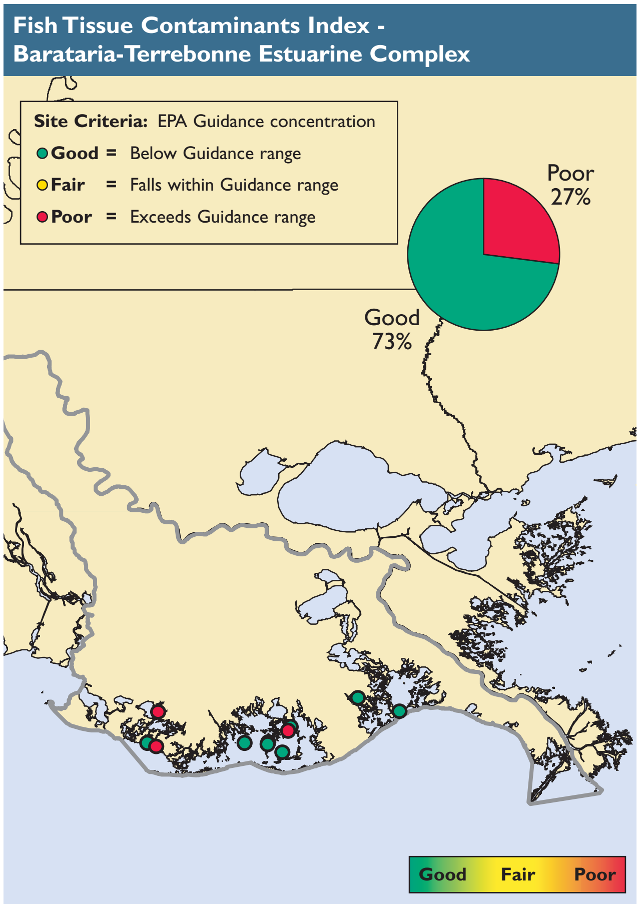


Figure 5-50. Fish tissue contaminants index data for the Barataria-Terrebonne Estuarine Complex, 2000–2001 (U.S. EPA/NCA).

Barataria-Terrebonne National Estuary Program

Maritime Forest Ridge and Marsh Restoration at Port Fourchon, Louisiana

The Maritime Forest Ridge and Marsh Restoration (MFRMR) at Port Fourchon, LA, is a vital migratory bird habitat-restoration project that is intended to serve as an example for similar coastal ridge restoration work and to provide useful scientific data for future coastal restoration projects. To achieve these goals, the BTNEP has offered its assistance in many capacities. For example, the BTNEP and its Migratory Bird Action Plan Team worked as liaisons between the bird-watching community and the Greater Lafourche Port Commission to encourage the project. The BTNEP has also served as a liaison between the Greater Lafourche Port Commission and various federal and state agencies during the permitting process.

The project's vision includes plans to restore a historic maritime forest ridge that has eroded and subsided since the 1950s; vegetate the ridge with woody plant species that provide excellent habitat for migratory birds; and eventually add boardwalks, trails, and an interpretive center.

More than 60 acres each of salt marsh and maritime forest ridge have been created. The construction phase of this project involved grading the land to transform a linear mound into a sloped ridge habitat, with a elevation gradient ranging from marsh elevation at 1.6 feet above sea level in the tidal zone to 8 feet above sea level at the peak of the ridge. Future phases of the MFRMR project development include plans to extend the project area linearly by several thousand feet over the next few years. Funding for the initial conceptualization and construction phase came from several sources, including $100,000 of direct project support from the Louisiana Department of Natural Resources (LDNR); a $100,000 grant from the Shell Oil Company; and $45,000 in project support from various project partners (Personal communication, Blanchard, 2005). The partners for this phase of the project listed below.

Partners for Restoring the Historic Maritime Forest Ridge	
Barataria-Terrebonne National Estuary Program	Barataria-Terrebonne Estuary Foundation
Greater LaFourche Port Commission	Gulf of Mexico Foundation
Gulf of Mexico Program	The Louisiana Nature Conservancy
Louisiana Department of Natural Resources	Natural Resource Conservation Service
National Oceanic and Atmospheric Administration	Orleans Audubon
Shell Oil Company	Terrebonne Bird Club

Now that this phase of the MFRMR project is nearing completion, the BTNEP is working closely with another group of partners (e.g., NOAA, the Gulf of Mexico Partners) to vegetate and monitor the MFRMR project area. The newly formed BTNEP Volunteer Program has hosted three volunteer planting events at the MFRMR project area. These events involved more than 150 volunteers who planted nearly 11,000 plants (Personal communication, Blanchard, 2005). Because of the logistics involved in transporting people and plants to the MFRMR site, project partners were needed to ferry materials and volunteers to the site by boat, as well as to provide lunches, drinks, and T-shirts to the volunteers. Partners who contributed to the volunteer efforts on the ridge include the BTNEP, Barataria-Terrebonne Estuary Foundation, Greater Lafourche Port Commission, USDA NRCS Plant Materials Center, ES&H Environmental Safety Consulting, Inc., Louisiana Department of Wildlife and Fisheries (LDWF), and Lafourche Parish Coastal Zone Management (CZM). Groups that volunteered their efforts for the different planting events on the ridge include the Lockport Middle School, Bayou Lafourche Marine Institute, Boy Scouts of America, Shell Oil Company Summer Interns, and University of New Orleans PIES Camp students. The efforts of these volunteers are important because the vegetation helps to stabilize the shoreline and slopes of this restored habitat against hurricanes. A future large-scale volunteer effort is also planned, where volunteers will plant woody trees and shrubs on the crown of the ridge.

The BTNEP recognizes that any efforts to restore the rapidly vanishing coastal lands of south Louisiana not only require sound scientific footing, but also the full support and involvement of the citizens who live, work, and play in the lands and waterways of coastal Louisiana. By engaging residents through volunteerism, the BTNEP not only forges new community partnerships and fosters public support for coastal restoration, but it also puts a face on the efforts to save this landscape by allowing citizen volunteers to work shoulder-to-shoulder with the biologists, geologists, engineers, and other scientists who work on the immense problems faced by the coastal Louisiana region. Additional information about the MFRMR and other restoration projects in the BTNEP study area is available by contacting the BTNEP or by visiting the program's Web site at: http://www.btnep.org.

BTNEP volunteers plant marsh plants to restore vegetation to the ridge site (BTNEP).

Barataria-Terrebonne National Estuary Program Indicators of Estuarine Condition

Water and Sediment Quality

The following water and sediment quality indicators are used by the BTNEP to assess estuarine condition:

- Eutropic conditions and nutrient levels
- Hypoxia (i.e., area of dead zone)
- Pathogens (e.g., fecal coliform at swimming and shellfish-harvesting areas)
- Levels of toxic substances in water and sediment
- Oyster bed closures.

Eutrophic conditions and nutrient levels in the Barataria-Terrebonne Estuarine Complex are monitored at a series of 15 sites within the region, and trend studies show that all sites have been classified as having either medium or high nutrient conditions under EPA/NOAA's guidelines for evaluating nutrient concentrations. Measurements of chlorophyll *a* levels during the past 20 years provide strong evidence that eutrophication is occurring in this system because many sites show an increase in chlorophyll *a* concentrations over time (Rabalais et al., 1995).

The extent of mid-summer hypoxia (dissolved oxygen levels below 2.0 mg/L) in bottom waters often affects up to 8,000 mi^2 of the Louisiana and Texas continental shelf and has been associated with large fish kills in the Barataria-Terrebonne Estuarine Complex (Battelle, 2003). Hypoxic events are good indicators for monitoring nutrient pollution loads associated with wastewater treatment and agricultural runoff. Over time, nearshore bottom dissolved oxygen concentrations have typically varied from 4 to 8 mg/L in the Complex, with sampling results indicating that persistent hypoxia tends to occur from mid-May to mid-September (Rabalais et al., 1995). Overall, data on dissolved oxygen in bottom waters are limited, but research has shown that hypoxic conditions (area of dead zone) in the Complex are most likely to occur in poorly flushed areas, deeper channels, and areas receiving organic loading from sewage or other wastewater outfalls.

Pathogens from sewage pollution in the Complex are associated with illnesses in humans who swim in contaminated waters or who eat contaminated oysters. To help reduce the consumption of pathogen-contaminated oysters, the Louisiana Department of Heath and Hospitals Molluscan Shellfish Program monitors fecal coliform bacteria levels in surface waters on a monthly basis in the oyster bed areas of the Barataria-Terrebonne Estuarine Complex (Battelle, 2003). Fecal coliform in the Complex comes from a variety of sources, including poorly functioning on-site septic systems, pasture land runoff, and waste from marsh animals, nutria, and waterfowl.

The presence of toxic substances in BTNEP waters can be measured by testing the surface water and sediment or by testing the fish that feed in these waters. Atrazine is a concern in the surface waters of the BTNEP study area and is measured through the direct testing of these waters. Concentrations of atrazine in the surface waters of the Upper Terrebonne basin have exceeded the EPA maximum contaminant level (MCL) of 3 ppb for drinking water (Battelle, 2003). Copper, lead, arsenic, chromium, and cadmium concentrations have declined since the 1980s, whereas mercury levels have remained fairly constant. Although contamination is fairly widespread in scope, the areas of most concern are on the periphery of the Complex, such as Oyster Bayou and Tiger Pass. Other contaminants have been detected in fish or shellfish, which accumulate toxic substances from the food they eat and from the surrounding water and sediments. Toxics detected in fish and crustaceans of the Barataria-Terrebonne Estuarine Complex include pesticides, metals, volatile organic compounds (VOCs), and PCBs (Rabalais et al., 1995).

Habitat Quality

The LDNR, NRCS, and other programs collectively monitor the number of acres of salt marshes and oligohaline (low salinity) habitat that have been restored in the BTNEP study area since 1986; however, the data needed to make actual assessments of habitat quality and functionality on a Complex-wide basis do not yet exist (Battelle, 2003). A large number of data sets specific to individual restoration projects are available, but these data sets can not be readily combined to report on status and trends for habitat restoration across the entire Barataria-Terrebonne Estuarine Complex. The Louisiana Coastwide Reference Monitoring System has been proposed to help make large restoration efforts a possibility. This effort requires collecting estuary-wide information, including land/water ratios; vegetation composition and cover; frequency of flooding; salinity; and sedimentation and erosion.

Living Resources

The following list of indicators is used by the BTNEP to measure changes in living resources:

- Endangered or threatened species (e.g., abundance and nesting success of brown pelican and American bald eagle)
- Waterfowl (e.g., abundance of mottled duck)
- Density of alligator nests
- Invasive species (e.g., acres of marsh damaged by invasive nutria)
- Number of fish consumption advisories and mercury levels in fish tissue.

Both the bald eagle and the brown pelican populations show signs of recovery following near extinction in the area due to reproductive failures associated with pesticide exposures. Today, Louisiana's brown pelicans occur throughout their historic range, and this reintroduction program is a success story in Louisiana's conservation efforts. The number of successful nests in the Barataria-Terrebonne Estuarine Complex has risen from 675 in 1990 to more than 6,500 in 2001 (BTNEP, 2002). Bald eagles are monitored for the number of successful nests, active nests, and fledglings produced (Battelle, 2003).

Status and trend reports indicate that 35 species of waterfowl have been reported in the Complex, which is of international significance as a wintering ground for migratory waterfowl species. Drought, marsh loss, commercial development, and predation all affect the Complex's duck population on an annual basis and can provide information about degradation or loss of habitat (Condrey et al., 1995). The Audubon Society's Christmas bird count is another indicator used by the BTNEP, and monitoring the abundance of shorebird species has been suggested as a priority indicator need.

The density of alligator nests in the Barataria-Terrebonne Estuarine Complex is directly indicative of population size and indirectly indicative of the abundance of fresh marsh habitats. The LDWF has been conducting an annual nest survey since 1991 to establish quotas, measure abundance, and assess productivity. The number of alligator nests is often affected by drought conditions and salinity levels (Battelle, 2003).

The growth of invasive species and the resultant damage they cause is another priority concern of the BTNEP. Among the most serious invasive species found in the Barataria-Terrebonne Estuarine Complex are water hyacinth, water spangle, Eurasion watermilfoil, *Hydrilla*, alligatorweed, Chinese tallow tree, and zebra mussel. The LDWF spends about $1.5 million annually on non-native aquatic plant control (BTNEP, 2002) and also collects data on the damage caused by nutria herbivory using periodic aerial surveys over brackish marsh areas (Figure 5-51). Nutria are a concern because they damage agricultural crops and irrigation dikes and consume the roots of marsh plants, thereby accelerating land loss. Damage and control costs for zebra mussels is also a good indicator of the magnitude of this invasive species problem.

The number of fish consumption advisories issued in the Barataria-Terrebonne Estuarine Complex is an indicator of the overall human health risk associated with toxic contaminants in seafood. Fish sampling is conducted by the Louisiana Department of Environmental Quality near facilities that have experienced chemical spills or demonstrated poor waste management practices. There are no waterbody-specific fish consumption advisories within the BTNEP study area; however, Louisiana has issued a statewide mercury advisory for king mackerel in all coastal waters, which includes BTNEP estuarine waters (U.S. EPA, 2005a).

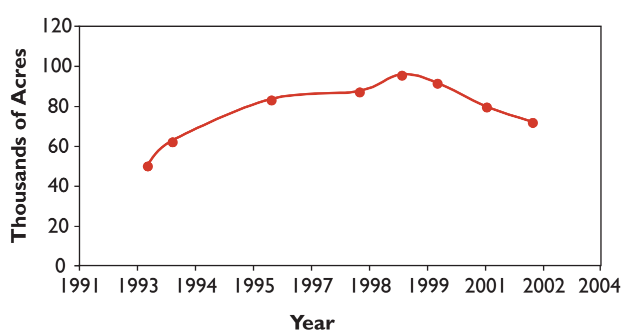


Figure 5-51. Estimated acreage damaged by nutria herbivory (BTNEP, 2002).

Environmental Stressors

In coastal Louisiana, more than 160,000 registered recreational vessels share the water with thousands of commercial vessels. Dumping sewage overboard can contaminate surface waters, sediments, and fishery stock with pathogens and was the suspected cause of at least two outbreaks of illness due to the consumption of contaminated oysters in the 1990s. To reduce instances of overboard dumping, many marinas offer boat pump-out stations for the collection of sewage from recreational and commercial vehicles. The cumulative number of boat pump-out stations in the Barataria-Terrebonne Estuarine Complex is another indicator tracked by the LDWF, and the number of stations has risen considerably at both commercial and recreational marinas since the early 1990s. The availability of these stations is critical to reducing overboard discharge of sewage to swimming and oyster-growing areas in the region and to controlling outbreaks of gastroenteritis that have been associated with Norwalk viruses and site closures since 1982 (Battelle, 2003).

Current Projects, Accomplishments, and Future Goals

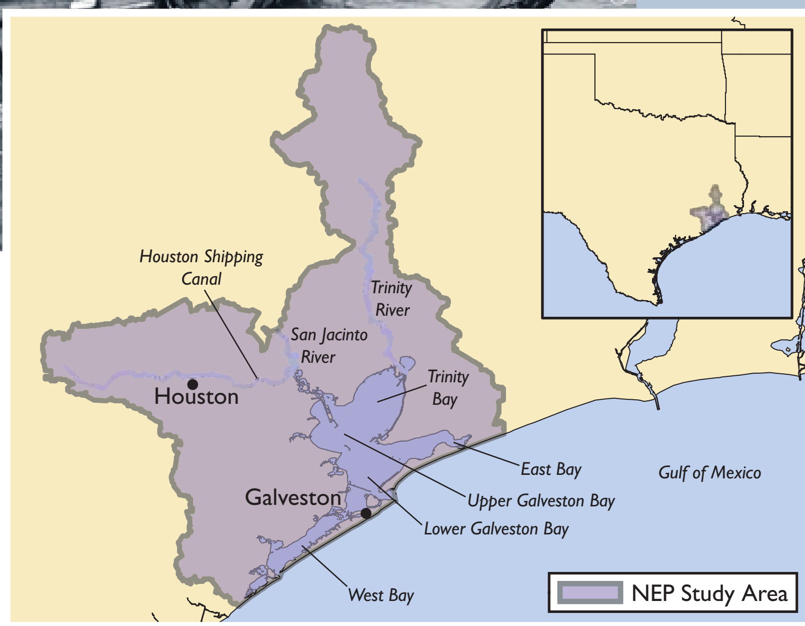
The BTNEP has produced videos, posters, brochures, booklets, and presentations and has made them available to teachers and other educators through their Web site. Materials are available for kindergarten through 12th grade and feature a range of media, including coloring books, videos, slides, and posters. The BTNEP has also created Action Plan Teams to implement its CCMP, *The Estuary Compact: A Public Promise to Work Together to Save the Barataria and Terrebonne Basins* (Moore and Rivers, 1996), in each of five different areas: Water Quality, Habitat, Living Resources, Cultural Heritage, and Economic Development. The BTNEP is actively implementing a large habitat-restoration program, which includes numerous projects to rebuild wetlands, ridges, barrier islands, and other habitats, such as the following:

- **Point Aux Chenes stormwater redirection** – This pilot-scale restoration project is diverting stormwater discharge into the Point Aux Chenes wetlands. These discharges are expected to reduce salinity, stimulate the growth of emergent vegetation, and encourage sedimentation in the wetland.
- **SAV research** – The BTNEP is working to assess the habitat value and to develop new methods for restoring various SAV throughout the Complex.
- **Invasive species workshops** – These workshops educate the public about which invasive species have infiltrated the BTNEP study area, how these species impact the region's ecosystem, and what steps government agencies and individuals need to take to combat these invasive species.

Conclusion

The data from the NCA suggest that the overall condition of the BTNEP study area is rated fair and that water quality is rated fair. Water quality indicators used by the BTNEP show that eutrophication is a continuing concern across the Complex and will require ongoing monitoring of nutrient and dissolved oxygen concentrations. In addition, the monitoring of chlorophyll *a* levels helps provide the more conclusive data needed to support future analyses of eutrophic conditions. Although the NCA's dissolved oxygen measurements show that none of the Complex's bottom water areas exhibited hypoxia, these measurements were made during a relatively short time period and provide only a snapshot of the summer dissolved oxygen concentrations. The BTNEP's partner agencies conduct monitoring on a year-round basis rather than during a single summer-sampling period, as is used by the NCA. The more intensive year-round monitoring allows researchers to evaluate more subtle changes and trends that may only be discernable when comparing data over a more extensive period of time. For example, NCA sampling may not have occurred during one of the periods of hypoxia that often occur in the Complex during late summer; however, these hypoxic events are sometimes detected when more frequent monitoring intervals are used by the BTNEP. The BTNEP's indicators also demonstrate that pathogens are an issue within the estuarine system. Sediment quality tests have provided limited information, but indicate contamination around discharge areas in the estuary basin.

Galveston Bay Estuary Program



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Background

Galveston Bay is a subtropical estuary located on the southeastern shore of the upper Texas Gulf coast. The Bay is composed of five major subbays: Trinity, Upper Galveston, Lower Galveston, East, and West bays. The combined area of the five subbays is 384,000 acres (600 mi^2), surrounded by 1,171 miles of shoreline (GBEP, 2005; HARC, 2005b). The estuary is fed by two major rivers (Trinity and San Jacinto rivers) and is bordered by low-lying wetlands, two barrier islands, and a peninsula. The waters of Galveston Bay can be characterized as well mixed and quite shallow (averaging 7 feet) and are made shallower in some places by extensive oyster reefs (GBEP, 2005). The Bay has increased in volume during the past 50 years due to natural and anthropogenic subsidence, as well as sea level rise and dredging operations (Lester and Gonzalez, 2003). Major habitats in the Bay include estuarine and freshwater marsh, mudflats, seagrass beds or SAV, oyster reefs, and open water.

Galveston Bay is used extensively for recreational and commercial activities, and the potential for large-scale human impacts is great. Galveston Bay is one of the largest sources of seafood for Texas, as well as one of the major oyster-producing estuaries in the country. The oysters, crabs, shrimp, and finfish harvested from Galveston Bay are worth a combined $19 million annually (Sage and Gallaway, 2002). One-third of the state's commercial fishing income and more than half of the state's recreational fishing expenditures are derived from Galveston Bay (GBEP, 2005). The Port of Houston is the second-largest port in the United States in tonnage and the eighth-largest port in the world (Sage and Gallaway, 2002). Along with the ports of Texas City and Galveston, the Port of Houston supports the region's petrochemical industries, which are the largest in the nation and the second-largest in the world (Port of Houston Authority, 2006). These industries combine to produce one-half of the nation's chemicals and one-third of the nation's petroleum refining (U.S. EPA, 2002a).

Extending back from the river mouths, the entire Galveston Bay watershed covers 33,000 mi^2, includes the metropolitan areas of Houston-Galveston and Dallas-Ft. Worth, and is home to nearly half of the population of Texas (GBEP, 2005). The surrounding watershed is composed of a variety of habitats, ranging from open prairies and coastal wetlands to riparian hardwoods and pine-dominant forests, and these habitats support numerous plant, fish, and wildlife species.

To increase public awareness and help address negative trends in wetland loss, habitat degradation, and non-point source pollution, the Galveston Bay Estuary Program (GBEP) was formed in 1989. Efforts of the GBEP are concentrated in the 4,200-mi^2 lower watershed, which is demarked by the dams that form Lake Houston on the San Jacinto River and Lake Livingston on the Trinity River. Following the establishment of its CCMP, *The Galveston Bay Plan: The Comprehensive Conservation and Management Plan for the Galveston Bay Ecosystem*, the GBEP now continues its work as part of the Texas Commission on Environmental Quality (TCEQ) (GBNEP, 1995).

Environmental Concerns

With Galveston Bay in the shadow of the nation's fourth-largest city, the environmental concerns of highest priority for the GBEP are wetland loss and habitat degradation, point and non-point source pollution, and chemical and petroleum product spills from barges and industry (Sage and Gallaway, 2002). Non-point source pollution in Galveston Bay is attributed to a variety of sources, including runoff from thousands of gas stations, residential lawns, failing septic systems, driveways, parking lots, industries, farms, and other sources. Accidental spills and the deliberate dumping of oil and other contaminants potentially harm the habitat and living resources of Galveston Bay. Other priority issues for Galveston Bay include new and existing introductions of aquatic and terrestrial exotic nuisance species, contaminated runoff from urbanized areas, and the increasing and often competing demands for fresh water. Additionally, sediment in the Houston Ship Channel exceeds levels of concern for a number of hazardous chemicals, including PCBs, DDT, dioxin, and heavy metals.

Population Pressures

The population of the 7 NOAA-designated coastal counties (Brazaria, Chambers, Fort Bend, Galveston, Harris, Liberty, and Waller) coincident with the GBEP study area increased by 182% during a 40-year period, from 1.6 million people in 1960 to 4.4 million people in 2000 (Figure 5-52) (U.S. Census Bureau, 1991; 2001). This rate of population growth for the GBEP study area exceeded the population growth rate of 133.3% for the collective NEP-coincident coastal counties of the Gulf Coast region. In 2000, the GBEP-coincident coastal counties had a population density of 651 persons/mi^2 (the highest of all the Gulf Coast NEPs).

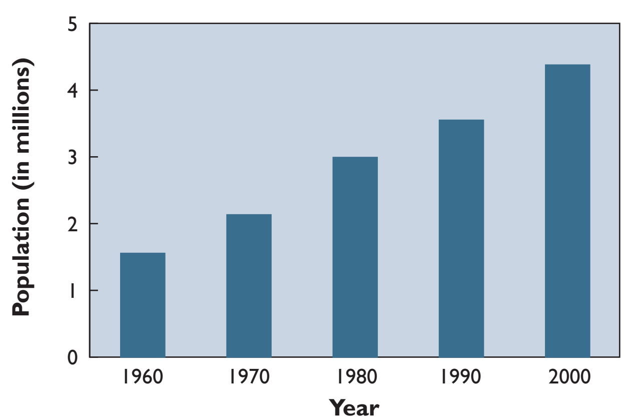


Figure 5-52. Population of NOAA-designated counties of the GBEP study area, 1960–2000 (U.S. Census Bureau, 1991; 2001).

This density was more than double the density of 287 persons/mi^2 for the collective NEP-coincident coastal counties of the Gulf Coast region (U.S. Census Bureau, 2001). Development and population pressures are especially strong in this NEP because it serves as a major center for international commerce; oil refinery and other petrochemical industries; commercial fish and shellfishing operations; and recreational activities for these coastal communities.

NCA Indices of Estuarine Condition—Galveston Bay

The overall condition of Galveston Bay is rated fair based on the four indices of estuarine condition used by the NCA (Figure 5-53). The water quality index is rated poor, the sediment quality index is rated fair to poor, the benthic index is rated fair, and the fish tissue contaminants index is rated good to fair. Figure 5-54 provides a summary of the percentage of estuarine area rated good, fair, poor, or missing for each parameter considered. This assessment is based on data collected by the Texas Park and Wildlife Department (TPWD) and NCA from 28 stations sampled in the GBEP estuarine area in 2000 and 2001. Please refer to Tables 1-24, 1-25, and 1-26 (Chapter 1) for a summary of the criteria used to develop the rating for each index and component indicator.

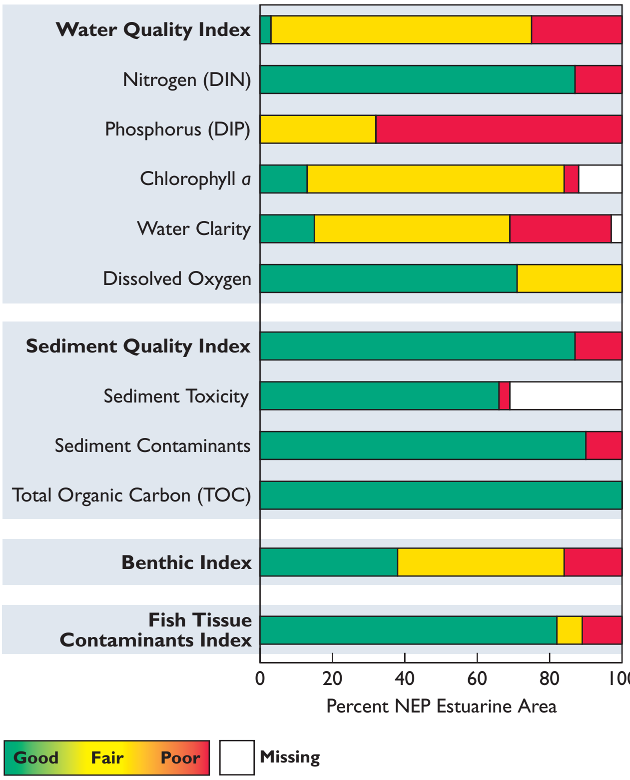


Figure 5-54. Percentage of NEP estuarine area achieving each rating for all indices and component indicators — Galveston Bay (U.S. EPA/NCA).

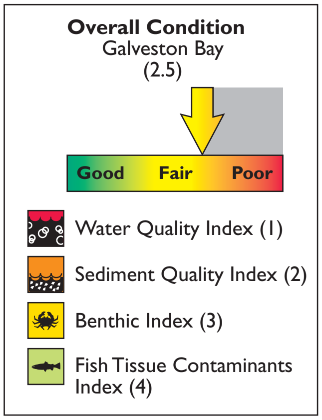


Figure 5-53. The overall condition of the GBEP estuarine area is fair (U.S. EPA/NCA).

Significant declines in the number of blue crabs have been noted in the West Bay (Texas Sea Grant College Program).

Water Quality Index

Based on NCA survey results, the water quality index for Galveston Bay is rated poor (Figure 5-55). This water quality index was developed using NCA data on five component indicators: DIN, DIP, chlorophyll *a*, water clarity, and dissolved oxygen. In NOAA's Estuarine Eutrophication Survey, Galveston Bay was listed as having medium chlorophyll *a* and medium-to-low DIN and DIP concentrations, with elevated concentrations occurring in tidal freshwater areas (NOAA, 1997).

Dissolved Nitrogen and Phosphorus | Galveston Bay is rated fair for DIN concentrations and rated poor for DIP concentrations. Thirteen percent of the estuarine area was rated poor for DIN concentrations, whereas 68% of the estuarine area was rated poor for DIP concentrations. As discussed later in this profile, the GBEP also monitors nutrients in the bays and tributaries of the GBEP estuarine area.

Chlorophyll a | Galveston Bay is rated fair for chlorophyll *a* concentrations. Although only 4% of the estuarine area was rated poor for chlorophyll *a* concentrations, 71% of the area was rated fair, and 13% of the area was rated good. NCA data on chlorophyll *a* concentrations were unavailable for 12% of the GBEP estuarine area.

Water Clarity | Water clarity in Galveston Bay is rated poor because 28% of the estuarine area was rated poor. Expectations for water clarity are similar to those for normally turbid estuaries, with water clarity rated poor at a sampling site if light penetration at 1 meter was less than 10% of surface illumination.

Dissolved Oxygen | Dissolved oxygen conditions in Galveston Bay are rated good. Seventy-one percent of the estuarine area was rated good for dissolved oxygen concentrations, 29% of the area was rated fair, and none of the area was rated poor.

Water Quality Index - Galveston Bay

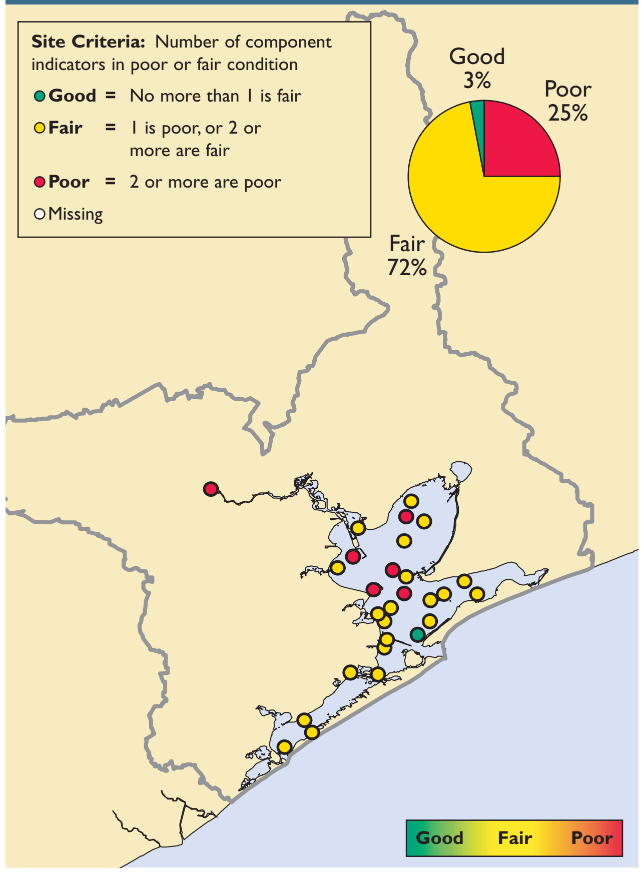


Figure 5-55. Water quality index data for Galveston Bay, 2000–2001 (U.S. EPA/NCA).

Sediment Quality Index

The sediment quality index for Galveston Bay is rated fair to poor because greater than 5% of the estuarine area was rated poor for sediment quality (Figure 5-56). This index was developed using NCA data on three component indicators: sediment toxicity, sediment contaminants, and sediment TOC.

Sediment Toxicity | Sediment toxicity is rated good for Galveston Bay because only 3% of the estuarine area was rated poor; however, NCA data on sediment toxicity were unavailable to evaluate 31% of the GBEP estuarine area.

Sediment Contaminants | Sediment contaminant concentrations were rated poor in 10% of the GBEP estuarine area; therefore, this component indicator is rated fair.

Total Organic Carbon | TOC concentrations in Galveston Bay sediments were rated good in 100% of the estuarine area; therefore, Galveston Bay is rated good for this component indicator.

Benthic Index

Based on NCA survey data and the Gulf Coast Benthic Index, the condition of benthic invertebrate communities in Galveston Bay is rated fair. Benthic index estimates indicate that 16% of the estuarine area had degraded benthic resources (Figure 5-57).

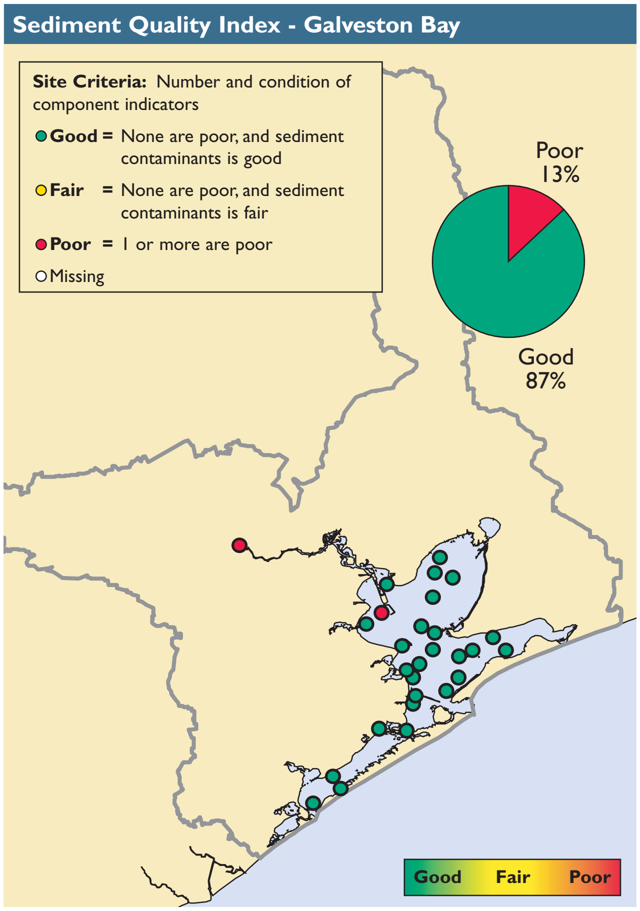


Figure 5-56. Sediment quality index data for Galveston Bay, 2000–2001 (U.S. EPA/NCA).

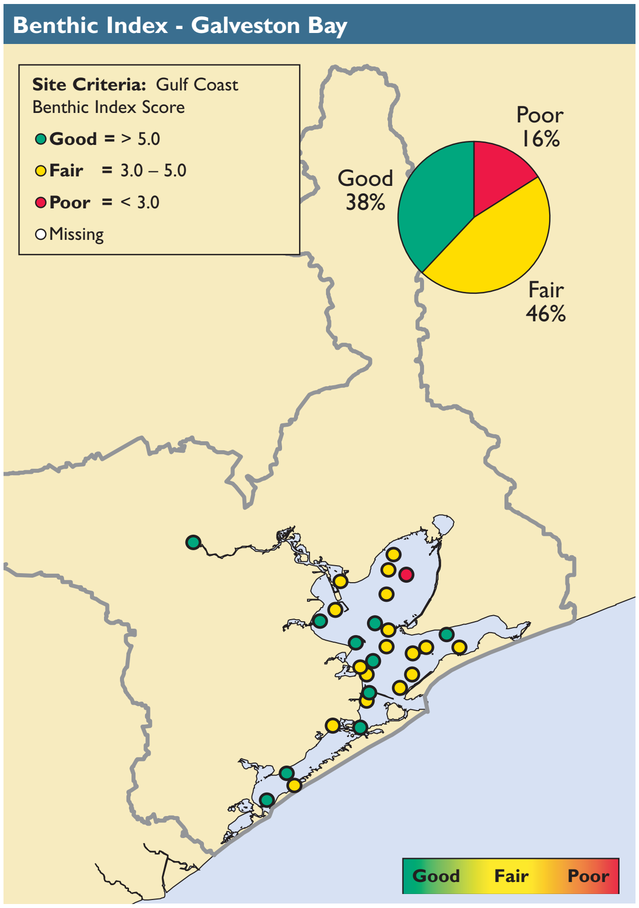


Figure 5-57. Benthic index data for Galveston Bay, 2000–2001 (U.S. EPA/NCA).

Fish Tissue Contaminants Index

The fish tissue contaminants index for Galveston Bay is rated good to fair. Figure 5-58 shows that 11% of all stations sampled where fish were caught exceeded the EPA Advisory Guidance values used in this assessment and were rated poor.

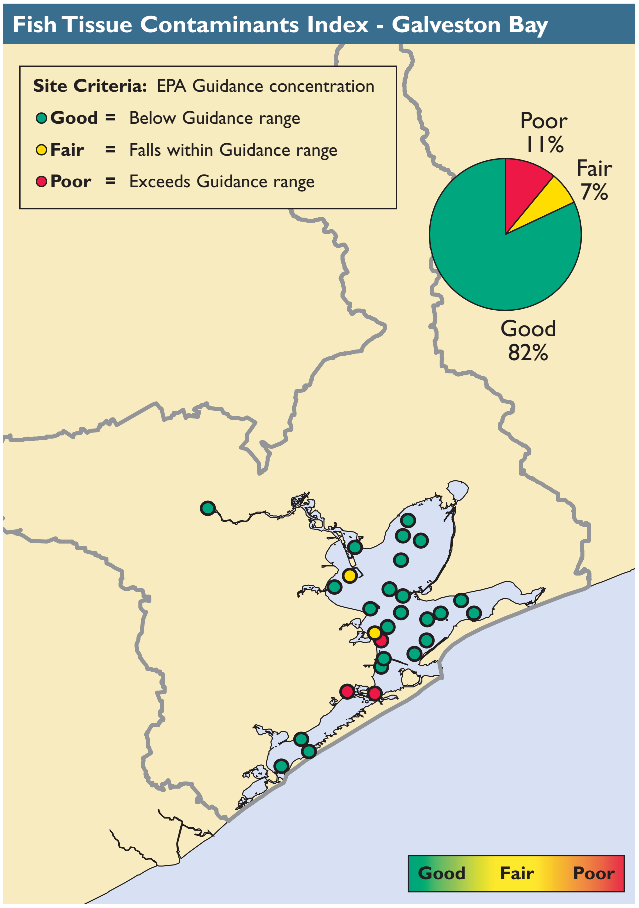


Figure 5-58. Fish tissue contaminants index data for Galveston Bay, 2000–2001 (U.S. EPA/NCA).

Galveston Bay Estuary Program Indicators of Estuarine Condition

The GBEP implements a regional monitoring program to foster effective cooperation by all agencies that participate in monitoring activities for Galveston Bay and to help prevent duplication of effort. Through the coordination of monitoring efforts, the GBEP's regional monitoring program ensures that data are available to assess trends in ecological condition and provides online access to this data at http://www.gbep.state.tx.us. The GBEP partners include the TCEQ Surface Water Quality Monitoring Program, which collects data describing surface water quality, sediment quality, and benthic organisms; the Texas Clean Rivers Program (administered locally by the Houston-Galveston Area Council), which collects water quality data; and the TPWD, which collects fishery independent and dependent data, as well as data on fish tissue contamination, water quality, and sediment quality in conjunction with the NCA. Other monitoring data tracked by the GBEP include oil spill incidents (Texas General Land Office [GLO]), colonial nesting bird counts (FWS), freshwater inflows (Texas Water Development Board), and fish advisories, oyster harvest area closures, and illnesses related to seafood consumption (Texas Department of State Health Services [DSHS]).

Water and Sediment Quality

The GBEP's formal indicators for monitoring water quality conditions in the estuary include dissolved oxygen, nitrogen (e.g., nitrate, nitrite, ammonia), total phosphorus, chlorophyll *a*, total suspended solids/turbidity, salinity, water temperature, pH, pathogens (e.g., *Enterococci*, fecal coliform), BOD, and TOC. Of the five subbays in the GBEP study area, only Christmas Bay exhibited a slightly increasing trend in dissolved oxygen concentrations, which rose from 7.0 to 8.0 mg/L between 1969 and 2001 (Lester and Gonzalez, 2003).

To help measure changes in nutrient levels over time, the TCEQ monitors ammonia, total nitrogen, and total phosphorus. Declines in annual average ammonia levels have been observed in several areas of Galveston Bay, with the most dramatic decline seen in the Houston Ship Channel. For the most part, annual average concentrations remain below screening levels. Nitrate-nitrite concentrations were highest in the Houston Ship Channel, which demonstrated an increasing trend from about 0 mg/L in 1969 to 1.75 mg/L in 2001. The Intracoastal Waterway East exhibited a significant declining trend in nitrate-nitrite, and the Trinity River had a significant declining trend in phosphorus (since 1969), which has slowed in recent years. None of the five subbays of Galveston Bay showed trends exceeding the estuarine screening levels for nutrients (Lester and Gonzalez, 2003).

Annual average concentrations of chlorophyll *a* have declined across all Galveston Bay subbays and tributaries since 1969, with the largest decreasing trend in chlorophyll *a* concentrations found in the Houston Ship Channel, San Jacinto River, and Texas City Ship Channel. Monthly average concentrations of chlorophyll *a* did not show a significant trend in any of the five subbays in Galveston Bay. NCA data collected in 2000 and 2001 for the West Bay region had annual averages similar to those of the TCEQ data, but chlorophyll *a* concentrations were slightly higher in this region (Lester and Gonzalez, 2003).

The Galveston Bay Indicators Project rates the area's subbays and tributaries based on the percentage of data samples that exceed the state's screening criteria (Figure 5-59). Using water quality screening levels developed by the TCEQ and indicator criteria developed specifically for Galveston Bay, the project rates Galveston Bay water quality (for nutrients and chlorophyll *a*) in the subbays as moderate to good for the period 1990–2003, as compared to the poor rating based on NCA survey data for 2000–2001 (Lester and Gonzalez, 2005). It should be noted that the DIN and DIP criteria used by the NCA survey are much more stringent than those used by the State of Texas; TCEQ estuarine screening levels for nitrogen and phosphorus are 0.26 and 0.22 mg/L, respectively. In addition, NCA sampling does not differentiate between criteria levels for Bay versus tributary waters. Nutrients in Galveston Bay proper remain fairly constant during the year; however, nutrient concentrations in Galveston Bay tributaries are highest in the summer months, when NCA data are collected. In the Galveston Bay Indicators Project evaluation, the tributary Buffalo Bayou was the only Bay segment to receive a poor rating for nutrients and chlorophyll *a* data because it exceeded the screening level more than 30% of the time between 2000 and 2003. It is also worth noting the improving trend overall for Galveston Bay since the 1970s (Lester and Gonzalez, 2005); however, the TCEQ is currently reviewing its estuarine nutrient criteria, which might change the results for this indicator.

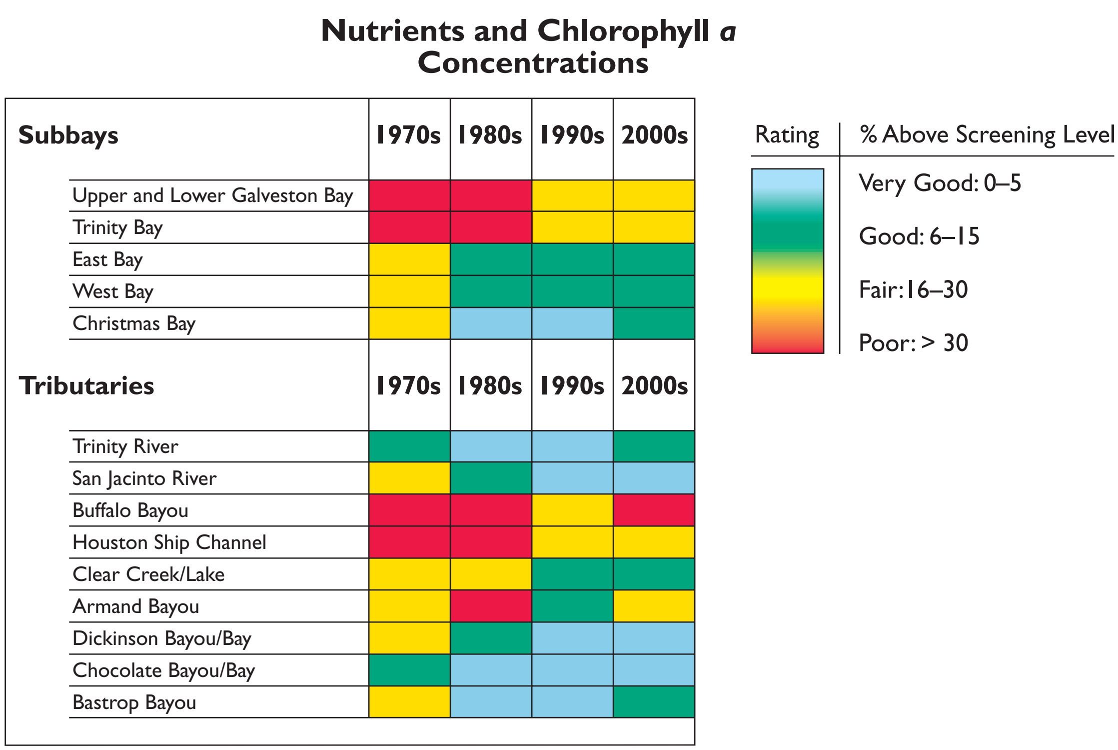


Figure 5-59. TCEQ water quality ratings for Galveston Bay nutrients and chlorophyll *a* concentrations (Lester and Gonzalez, 2005).

Galveston Bay Estuary Program

Case Study on Changes in Freshwater Wetland Habitat

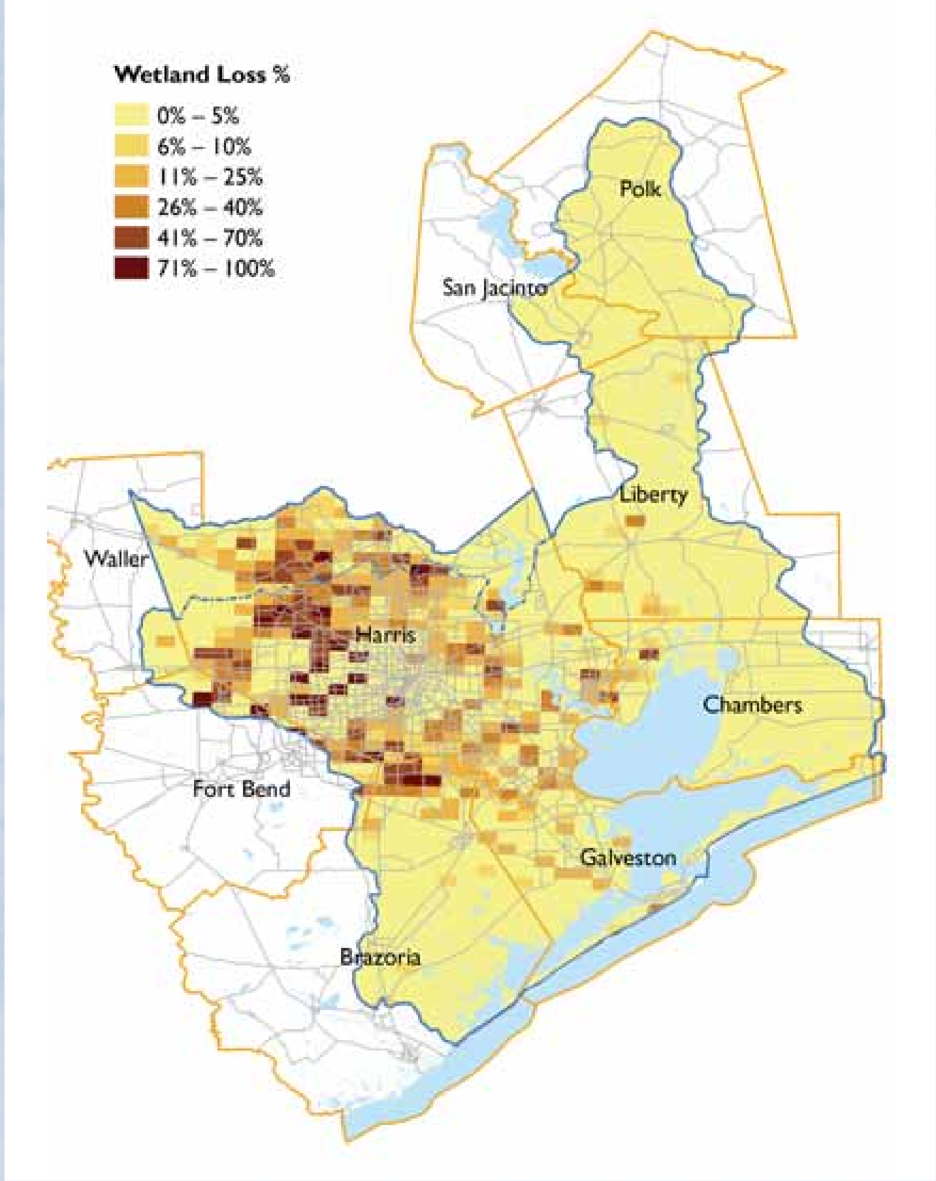
The Galveston Bay region is attracting a growing urban and industrial sector, and the region's population is expected to double to approximately 8 million by 2025 (Sage and Gallaway, 2002; H-GAC, 2003). The Galveston Bay watershed contains a wealth of unique freshwater wetland complexes that provide critical human and ecological services, including attenuation of water pollution, floodwater retention, wildlife habitat, and recreational opportunities. The GBEP recognizes that preserving these valuable resources requires a better understanding of the status and trends of the wetland habitat; therefore, the GBEP partnered with the Texas Coastal Watershed Program of the Texas Cooperative Extension in 2003 to determine the status and trends in the wetlands of Galveston Bay.

To perform a wetlands analysis, the partners conducted an inventory that was similar to the FWS's NWI program. The last FWS NWI for the Galveston Bay region was completed in 1992; however, the 1992 data are not directly comparable to those gathered during the new wetland inventory. The methods of identifying wetland areas have improved since the 1992 NWI, and the new inventory might identify areas that were missed in 1992. To account for this, the GBEP and Texas Cooperative Extension chose to consider the 1992 NWI data as a subset of the wetlands in the region at the time. To analyze changes in the wetlands, these data were directly compared to aerial photographs of the same areas taken in 2000 or 2002 as part of the new inventory.

Coastal prairie wetlands in Texas (Dr. John Jacobs, Texas Cooperative Extension/ Texas Sea Grant).

In 1992, the Galveston Bay watershed contained 294,556 acres of freshwater, non-tidal wetlands (e.g., palustrine, lacustrine, riverine). The new inventory results showed that 285,432 acres remained in the subset, representing a loss of 9,124 acres or 3.1%. These losses were attributed to industrial, commercial, and residential development (70%); fill activities (26%); and open-water development, such as man-made ponds and lakes (3%). These loss estimates are conservative figures, and resource experts believe that actual losses are much higher due to the wetland areas that were likely missed in the 1992 NWI. Consistent with the pattern of urban growth spreading into more rural areas, the greatest wetland losses (13%) occurred in Harris County, which includes the city of Houston (see figure) (Jacob and Lopez, 2005).

The results of the GBEP/Texas Cooperative Extension inventory study will be used to educate citizens on the implications of wetland loss, as well as to work with local governments and others to identify key parcels for preservation.



Wetland loss due to urban growth (Jacob and Lopez, 2005).

Total suspended solids showed declining trends in annual average concentrations across all subbays and tributaries of the Galveston Bay system, with the exception of Upper Galveston Bay, Lower Galveston Bay, and Cedar Bayou (Lester and Gonzalez, 2003). Galveston Bay is naturally turbid because of its shallow depth and fine sediments; however, dredging activities, commercial fisheries, and natural and man-made erosion assist in promoting this turbid nature.

The pathogen indicators monitored by the TCEQ in Galveston Bay are *Enterococci*, *E. coli*, and fecal coliform, with concentrations of fecal coliform sampled since 1973. According to the 2005 Galveston Bay Indicators Project, the areas of Galveston Bay with the greatest number of TCEQ criteria-level exceedences for fecal coliform bacteria are Buffalo Bayou, the Houston Ship Channel, Clear Creek, and Dickinson Bayou (Figure 5-60). In addition, Buffalo Bayou, White Oak Bayou, and Dickinson Bayou are the subjects of ongoing TMDL studies (Lester and Gonzalez, 2005). A declining trend in fecal coliform was found in the East Intracoastal Waterway area, but the other four major subareas of the Bay did not show a significant trend for fecal coliform. Elevated concentrations of fecal coliform in the middle reach of Bastrop Bayou have drawn considerable attention from the public in the past. The areas with the highest concentrations of *Enterococci* were the Houston Ship Channel, East Intracoastal Waterway, San Jacinto River, and Trinity Bay, whereas areas with the lowest concentrations were the Galveston Channel, Texas City Channel, Christmas Bay, Bastrop Bayou Complex, Dickinson Bayou/Dickinson Bay, and East Bay (Lester and Gonzalez, 2003).

Organic matter content in Galveston Bay is measured as TOC, and annual average TOC concentrations have declined in all subbays and tributaries of Galveston Bay since 1973. The TCEQ also reports five-day BOD to help measure the breakdown and decomposition of organic matter in the Bay. Sufficient data only exist for three of the five subbays in Galveston Bay, and none of these subbays exhibited significant trends for BOD (Lester and Gonzalez, 2003). This finding aligns with NCA data, which found Galveston Bay to be in good condition for TOC concentrations.

In Galveston Bay, sediments, metals, and commonly measured organic compounds appear to follow the same general spatial distribution, as do most of the other water quality parameters. Elevated concentrations of these contaminants occur in regions of runoff, freshwater inflow, and waste discharges, and lower, relatively

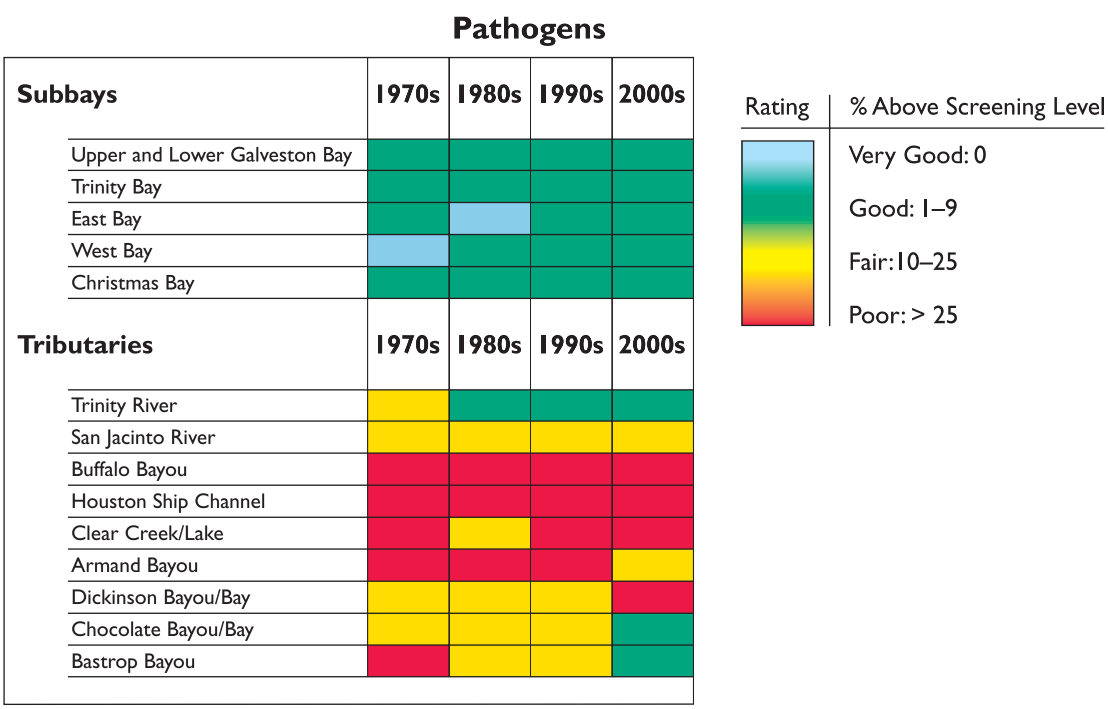


Figure 5-60. TCEQ water quality ratings for Galveston Bay pathogens (Lester and Gonzalez, 2005).

uniform concentrations occur in the open bay. The upper Houston Ship Channel generally has the maximal concentration of these contaminants (Lester and Gonzalez, 2005).

Habitat Quality

Wetland loss and declines in SAV are of significant concern for the GBEP, but support from federal, state, and local agencies; area non-profit organizations; and industry activities are slowly helping to mitigate losses through restoration and preservation. *The Galveston Bay Plan* calls for the restoration of 8,600 acres of estuary marsh and 1,400 acres of SAV (GBNEP, 1995).

Wetland loss between 1950 and 1989 has been estimated to be between 700 and 1,000 acres a year, or a net loss of over 30,000 acres (White et al., 1993). The total acreage of wetlands lost to dredge-and-fill activities over time has increased to 20% of the net losses estimated for Galveston Bay (Sage and Gallaway, 2002). A recent estuarine wetland inventory indicated that more than 1,181 of the 118,072 acres of emergent marsh identified in 1995 were lost by 2002. The loss of approximately 830 of these acres was induced by human activities (Webb, 2005). The GBEP continues to work with its partners to monitor trends in wetlands loss.

Salinity, turbidity, and rainfall patterns seem to be the controlling factors for natural seagrass growth in Galveston Bay. In the 1950s, SAV was estimated at 2,500 acres; in 1989, SAV was estimated to be approximately 700 acres—more than a 70% decline. Since 1989, evidence suggests a rebound, with new areas being established adjacent to wetland restoration sites in West Bay (Sage and Gallaway, 2002).

Living Resources

The GBEP uses several indicators to measure trends in living resources. Data are collected from a variety of sources, including the TPWD, Texas DSHS, and FWS. These indicators are the following:

- Abundance of selected colonial waterbird species (e.g., great blue heron, white ibis)
- Abundance of selected finfish species (i.e., measured from bag seine, shrimp trawl, or gill net)
- Episodes of seafood contamination and issuance of advisories (e.g., oyster harvest-area closures, fish consumption advisories, and elevated chemical contaminant levels in fish tissue).

Figure 5-61 shows 20-year population trends for several bird and finfish species monitored in the GBEP study area. Of the 19 species of colonial nesting water birds tracked between 1973 and 2001, 9 exhibit negative trends, whereas others appear stable or are

BIRDS

Feeding Guild	Species	20-Year Trend
Marsh Feeders	Great Blue Heron	Declining
	Reddish Egret	Declining
	Roseate Spoonbill	Stable
	Snowy Egret	Stable
	Tricolored Heron	Declining
	White Ibis	Stable
Open-Water Feeders	Black Skimmer	Declining
	Brown Pelican	Increasing
	Least Tern	Stable
	Royal Tern	Stable
	Sandwich Tern	Stable

FISH

Species	20-Year Trend
Black Drum	Stable
Red Drum	Stable
Sand Seatrout	Stable
Southern Flounder	Stable
Spotted Seatrout	Increasing

Increasing
Stable
Declining

Figure 5-61. Bird and finfish population trends in Galveston Bay (Lester and Gonzalez, 2005).

increasing. As with other parts of the country, brown pelicans have been a success story in returning from the brink of extinction (HARC, 2005a). Significant declines in blue crab numbers have been noted in West Bay. Gulf killifish have demonstrated a significant decline in the estuary and could indicate a declining quantity of fringing wetlands. Bay anchovy have demonstrated a significant increasing trend in West Bay, and pink shrimp have demonstrated a significant increasing trend in Upper and Lower Galveston Bay (Lester and Gonzalez, 2003). For areas of the Houston Ship Channel and Upper Galveston Bay, the Texas DSHS has issued several seafood consumption advisories for contaminants, including PCBs and dioxins, in species such as blue crab, catfish, and speckled trout (Figure 5-62) (Lester and Gonzalez, 2005).

Environmental Stressors

The GBEP's regional monitoring program also uses human activities as indicators to assess the health of the estuary. The Texas GLO has monitored the amount, type, date, and location of 11 petroleum products spilled into the waters of 4 counties in the Galveston Bay watershed (Brazoria, Chambers, Galveston, and Harris). Between 1998 and 2002, a total of 262,010 gallons of petroleum products were spilled into the waters of Galveston Bay (Lester and Gonzalez, 2003).

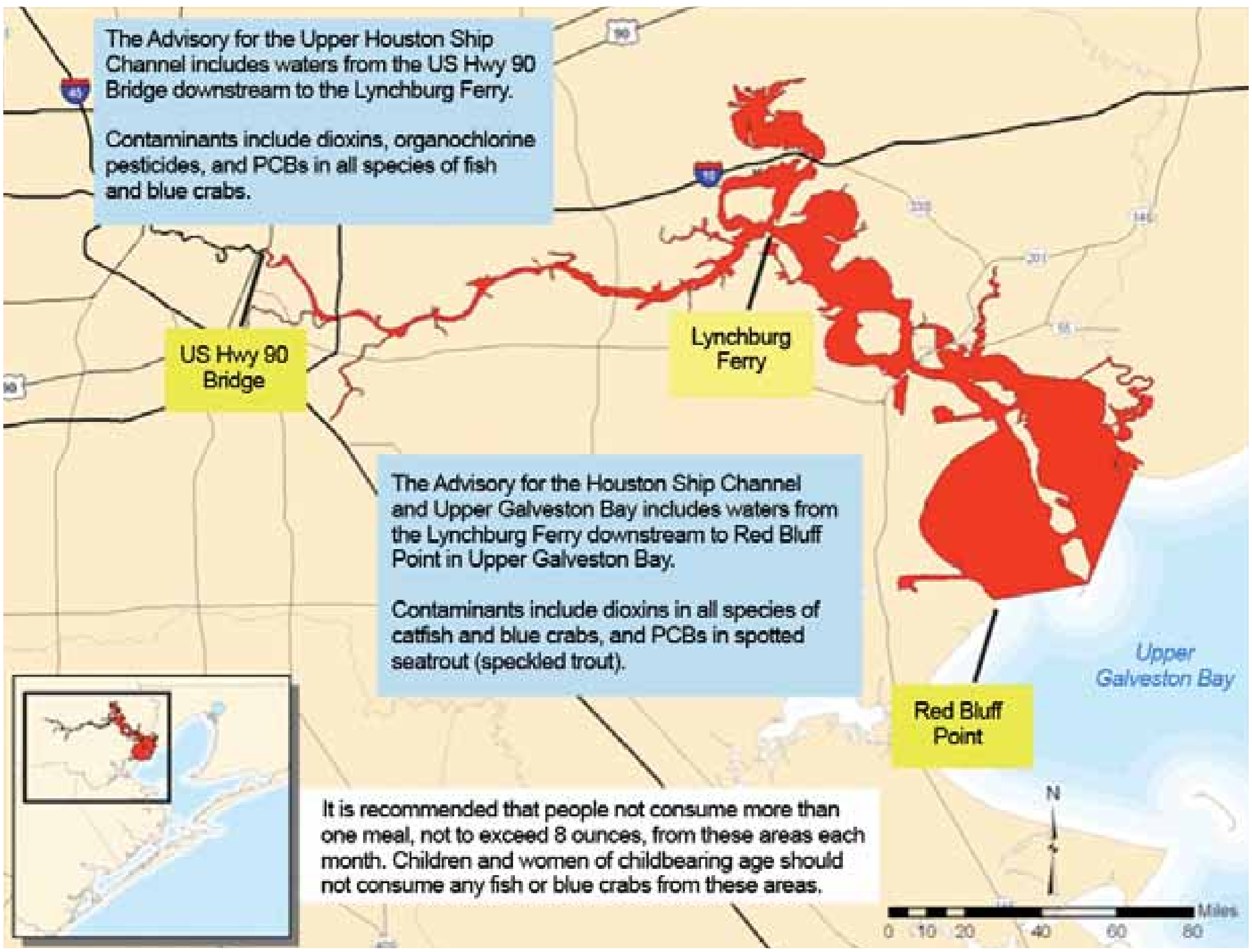


Figure 5-62. Seafood consumption advisory areas designated in 1990, 2001, and 2005 (Lester and Gonzalez, 2005).

Current Projects, Accomplishments, and Future Goals

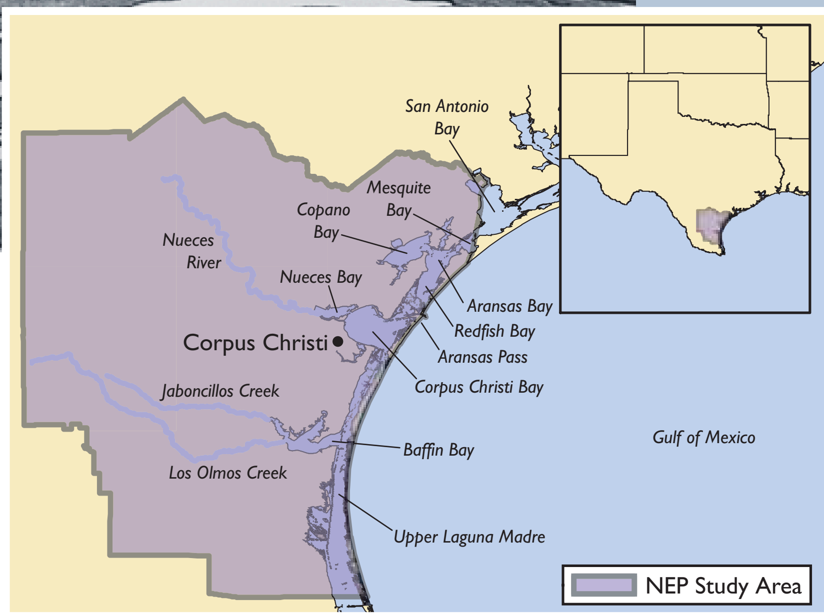
To protect and restore wetland habitats, the GBEP is encouraging better use of dredge material. When disposed of improperly, dredge materials can adversely modify wetland habitats; however, these materials also can be beneficial if used to create, restore, or enhance estuary habitats (e.g., bird rookery islands). The efforts of the GBEP and its partners have led to the restoration of 8,000 acres of habitat (Personal communication, Johnston, 2006). The GBEP is also working with local governments toward increasing wetland and habitat conservation through the promotion of water quality, recreation, and flood-control benefits and by assisting with grant writing and the development of stormwater management plans. Other priorities of the GBEP include controlling harmful exotic species; promoting water conservation, stormwater management, and technical assistance programs; assessing the safety of consuming seafood from Galveston Bay; and assisting septic system owners and small WWTP operators. Some of the invasive species of highest ecological concern in Galveston Bay include Chinese tallow, giant salvinia, *Hydrilla*, red imported fire ant, Brazilian pepper, water hyacinth, and channeled apple snail.

Conclusion

Based on data from the NCA estuarine survey, the overall condition of Galveston Bay is rated fair. Data from the GBEP and its partners indicate that, in spite of the large human population and increasing resource demands, Galveston Bay remains productive and, for the most part, healthy. The Bay as a whole is not threatened by eutrophication, and nutrient concentrations are decreasing in many areas of this estuary. Several aquatic species exhibit stable trends in abundance. Galveston Bay is not rapidly degrading in terms of increasing concentrations of toxic or organic pollutants; rather, trends in pollution are mixed. Concentrations of contaminants are decreasing in the most polluted areas of the Bay, but are rising in other areas. Even with these stable and, in some cases, improving trends, focus remains on strategic habitat conservation and pollution control as the region's population continues to expand and land-use patterns trend towards urbanization.

Extensive oyster reefs are found in Galveston Bay (Texas Sea Grant College Program).

Coastal Bend Bays and Estuaries Program



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Background

The estuarine area of the Coastal Bend Bays and Estuaries Program (CBBEP) is located within an area known as the Coastal Bend and includes three of the seven estuaries found in Texas. The most northerly portion of the CBBEP study area encompasses the San Antonio, Mesquite, Redfish, Copano, and Aransas bays. The middle estuarine portion includes Nueces Bay and Corpus Christi Bay (the largest of the bays) and discharges into the Gulf of Mexico at Aransas Pass. The most southerly estuarine portion includes Upper Laguna Madre and Baffin Bay. The CBBEP study area includes 75 miles of Texas coastline and 515 mi^2 of water (CBBEP, 2005a). In addition to the tidal marshes and the barrier islands of the CBBEP estuarine area, this area also includes seagrass meadows, open bays, oyster and serpulid worm reefs, wind tidal flats, and freshwater marshes.

The CBBEP study area is an important resource for recreational, commercial, industrial, and residential uses. Popular for sportboat fishing, bird watching, and wind-surfing, the Bays also support a commercial fishing industry that harvests, on average, more than 8 million pounds of finfish, shrimp, and crab from the area's estuarine waters (Tunnell et al., 1996). This area contains 40% of the state's total seagrass acreage, which provides nursery areas for fish and shellfish and habitat for other wildlife, including birds, sea mammals, and marine turtles (CBBEP, 1998). Corpus Christi Bay is the nation's fifth-largest port and holds the third-largest refinery and petrochemical complex in the United States (CBBEP, 2005a). Although the region's population was 550,000 in 1995, it is projected to be nearly 1 million people by 2050 (CBBEP, 1998).

Environmental Concerns

Fresh water is in short supply in semi-arid southern Texas, and because of the state's ever-increasing coastal population and growing industry, there will always be competing demands for this limited resource. Residential and business water use in this region is expected to increase by 50% by 2050, and industrial demand is expected to double (CBBEP, 1998). Fresh water is not only vital to the survival of the human population, but it is also closely tied to the survival of the entire ecosystem. Fresh water inflows provide three vital functions essential to an estuary. First, inflows blend with Gulf seawater to create a range of salinities in the Bays' waters. Second, inflows of surface runoff carry nutrients (nitrogen, phosphorus, and decomposing organic matter) that are essential to the productivity of estuarine ecosystems. Phytoplankton and large plants need these nutrients to survive, multiply, and provide food and nursery areas for a multitude of aquatic and terrestrial species. Lastly, inflows bring sediment to the estuaries, and these sediments are deposited as river waters slow down upon entering the Bays. Without the replenishing of these sediments, wave action would eventually wash away the existing wetlands. The annual streamflow for the Nueces River demonstrated a declining trend from 1940–1996 due to the construction of the Choke Canyon Reservoir, evaporative loss from the surface of the reservoir, increased water use in the river basin, and a long-term regional drought.

Population Pressures

The population of the 11 NOAA-designated coastal counties coincident with the CBBEP study area increased by 36% during a 40-year period, from 0.40 million people in 1960 to 0.55 million people in 2000 (Figure 5-63) (U.S. Census Bureau, 1991; 2001). This rate of population growth for the CBBEP study area was about one-fourth of the population growth rate of 133.3% for the collective Gulf Coast NEP-coincident counties and the second-lowest population growth rate of the Gulf Coast NEP study areas. In addition, the population density of these 11 coastal counties in 2000 was 53 persons/mi^2, which was the lowest density of any NEP study area in the Gulf Coast region (U.S. Census Bureau, 2001). Development and population pressures are less dramatic for this NEP study area, which serves as a center for commercial fishing and recreational activities for its coastal communities.

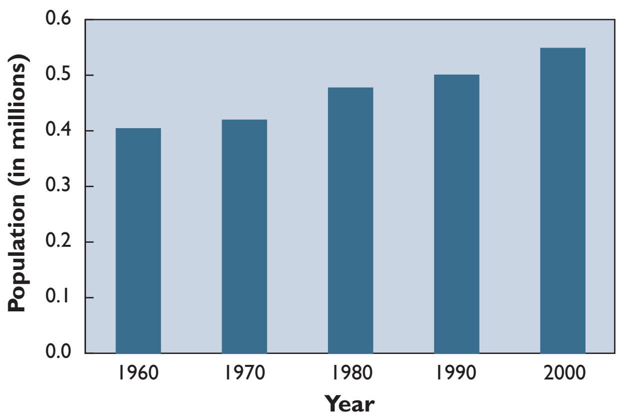


Figure 5-63. Population of NOAA-designated counties of the CBBEP study area, 1960–2000 (U.S. Census Bureau, 1991; 2001).

NCA Indices of Estuarine Condition—Coastal Bend Bays

The overall condition of the Coastal Bend Bays is rated poor based on the four indices of estuarine condition used by the NCA (Figure 5-64). The water quality index is rated fair, the sediment quality and fish tissue contaminants indices are rated poor, and the benthic index is rated fair to poor. Figure 5-65 provides a summary of the percentage of estuarine area rated good, fair, poor, or missing for each parameter considered. This assessment is based on data collected by the TPWD and NCA from 27 stations sampled in the Coastal Bend Bays in 2000 and 2001. Please refer to Tables 1-24, 1-25, and 1-26 (Chapter 1) for a summary of the criteria used to develop the rating for each index and component indicator.

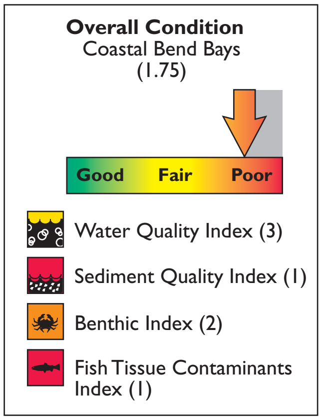


Figure 5-64. The overall condition of the CBBEP estuarine area is poor (U.S. EPA/NCA).

Water Quality Index

Based on NCA survey results, the water quality index for the Coastal Bend Bays is rated fair (Figure 5-66). This index was developed using NCA data on five component indicators: DIN, DIP, chlorophyll *a*, water clarity, and dissolved oxygen. In NOAA's Estuarine Eutrophication Survey, the Coastal Bend Bays were listed as having medium to hypereutrophic chlorophyll *a* levels and low to high DIN and DIP concentrations, with elevated concentrations occurring in tidal freshwater areas (NOAA, 1997).

Dissolved Nitrogen and Phosphorus | The Coastal Bend Bays are rated good for DIN concentrations, with 99% of the estuarine area rated good for this component indicator. The Bays are rated fair for DIP concentrations, with 4% of the estuarine area rated poor, 46% of the area rated fair, and 50% of the area rated good for this component indicator.

Chlorophyll a | Chlorophyll *a* concentrations in the Coastal Bend Bays are rated good. Although only 5% of the estuarine area exhibited poor chlorophyll *a* concentrations, 40% of the estuarine area was rated fair for this component indicator, and 55% of the area was rated good.

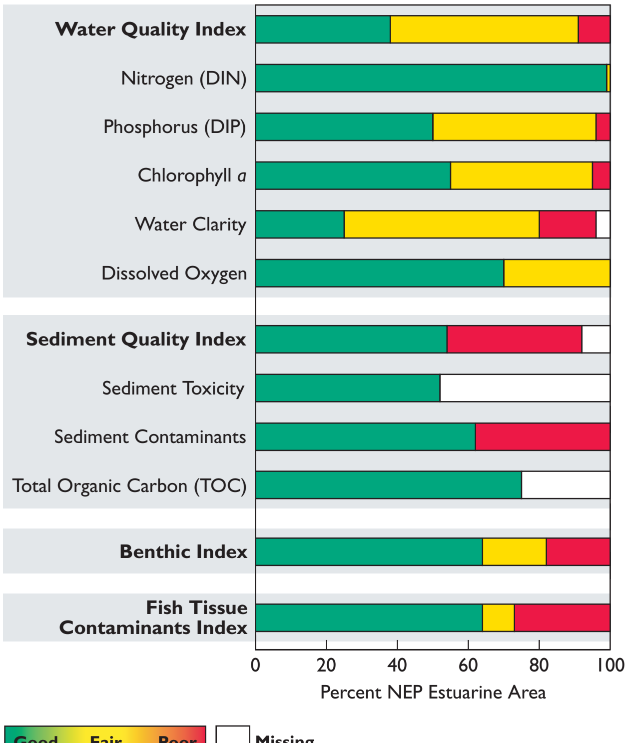


Figure 5-65. Percentage of NEP estuarine area achieving each ranking for all indices and component indicators — Coastal Bend Bays (U.S. EPA/NCA).

Water Clarity | Water clarity in the Coastal Bend Bays is rated fair because 16% of the estuarine area was rated poor for this component indicator. In Corpus Christi and Aransas bays, expectations for water clarity are similar to those for normally turbid estuaries, and water clarity was rated poor at a sampling site if light penetration at 1 meter was less than 10% of surface illumination. However, because one of the CBBEP's goals is to re-establish SAV beds in Upper Laguna

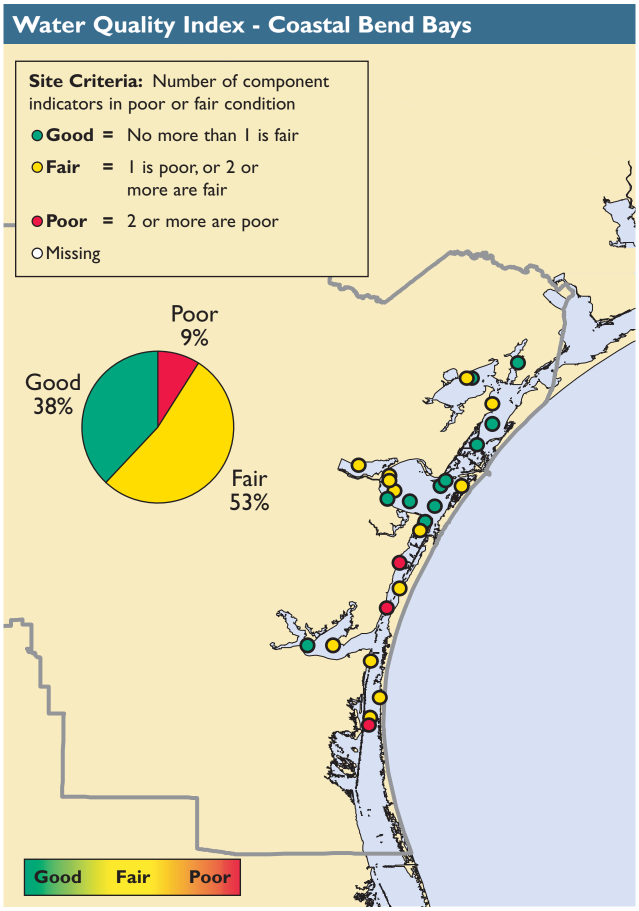


Figure 5-66. Water quality index data for the Coastal Bend Bays, 2000–2001 (U.S. EPA/NCA).

Madre and Baffin Bay, expectations for water clarity in these areas are high; therefore, water clarity was rated poor at a sampling sites in this area if light penetration at 1 meter was less than 20% of surface illumination.

Dissolved Oxygen | Dissolved oxygen conditions in the Coastal Bend Bays are rated good. NCA data show that 70% of the estuarine area was rated good for dissolved oxygen concentrations, 30% of the area was rated fair, and none of the area was rated poor.

Sediment Quality Index

The sediment quality index for the Coastal Bend Bays is rated poor because more than 15% of the estuarine area was rated poor for sediment quality (Figure 5-67). This index was developed using NCA data on three component indicators: sediment toxicity, sediment contaminants, and sediment TOC.

Sediment Toxicity | Sediment toxicity is rated good for the Coastal Bend Bays because none of the estuarine area was rated poor for this component indicator; however, NCA data on sediment toxicity were unavailable for 48% of the CBBEP estuarine area.

Sediment Contaminants | The Coastal Bend Bays are rated poor for sediment contaminant concentrations because 38% of the estuarine area was rated poor for this component indicator.

Total Organic Carbon | The Coastal Bend Bays are rated good for sediment TOC concentrations. None of the estuarine area was rated poor for this component indicator, and 75% of the area was rated good. NCA data on TOC concentrations were unavailable for 25% of the CBBEP estuarine area.

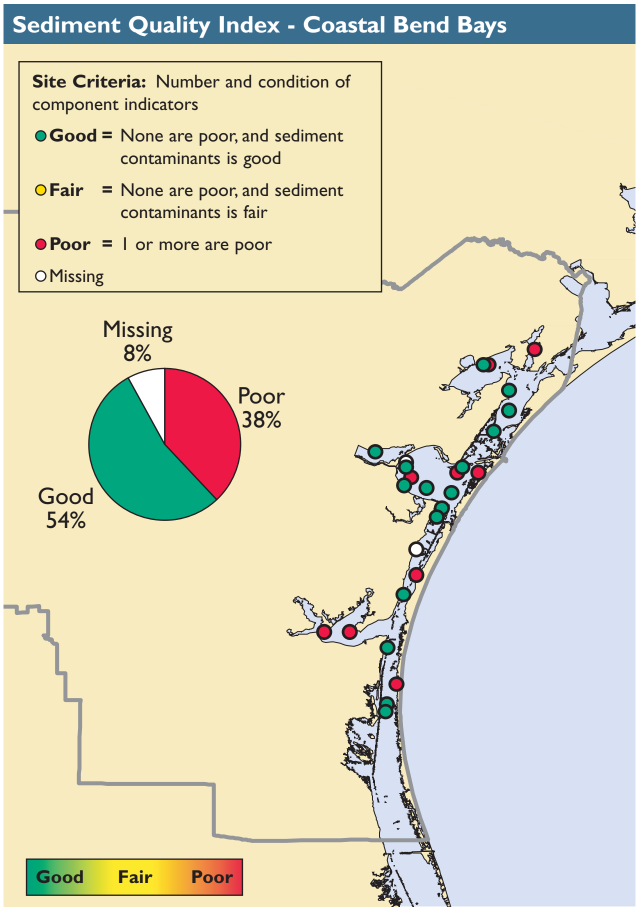


Figure 5-67. Sediment quality index data for the Coastal Bend Bays, 2000–2001 (U.S. EPA/NCA).

Benthic Index

Based on NCA survey data and the Gulf Coast Benthic Index, the condition of benthic invertebrate communities in the Coastal Bend Bays is rated fair to poor. Benthic index estimates indicate that 18% of the estuarine area had degraded benthic resources and was rated poor and another 18% was somewhat degraded and was rated fair (Figure 5-68).

Fish Tissue Contaminants Index

The fish tissue contaminants index for the Coastal Bend Bays is rated poor. Figure 5-69 shows that tissue concentrations exceeded the EPA Advisory Guidance values used in this assessment at 27% of all the stations sampled where fish were caught.

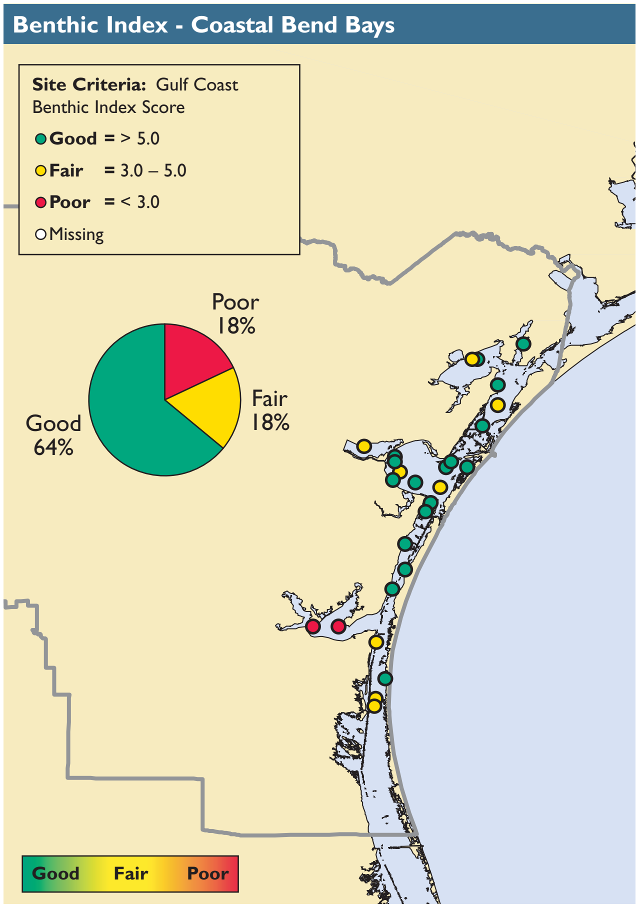


Figure 5-68. Benthic index data for the Coastal Bend Bays, 2000–2001 (U.S. EPA/NCA).

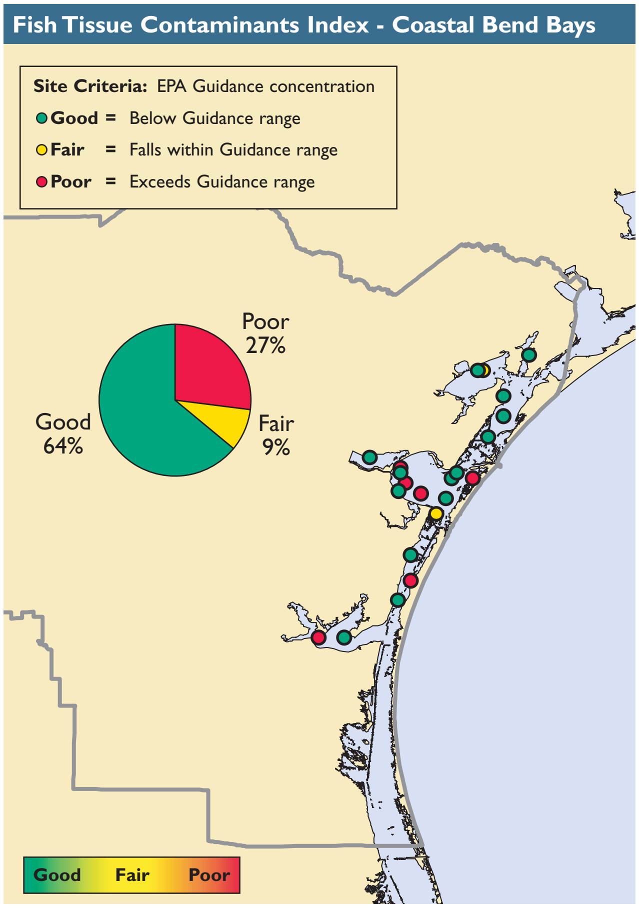


Figure 5-69. Fish tissue contaminants index data for the Coastal Bend Bays, 2000–2001 (U.S. EPA/NCA).

Coastal Bend Bays and Estuaries Program Indicators of Estuarine Condition

The CBBEP uses specific indicators to monitor the overall health of the estuarine area, and a scoring system is used to assign relative values for indicator measures. This system allows analysts to assess trends and identify the areas showing the greatest improvements. A summary of the key resources and the types of indicators used to monitor system-wide environmental trends is presented below.

Water and Sediment Quality

The CBBEP uses a number of indicators to monitor water quality in the study area, including temperature, salinity, dissolved oxygen, transparency, fluorescence, pH, nitrogen, ammonia, phosphorus, dissolved oxygen, sulfide, chlorophyll *a* and *b*, total suspended solids, and BOD. The program also tests waters for trace metals, organic compounds, and pathogens, including fecal coliform, *E. coli*, and *Enterococci*. The Inner Harbor, which is affected by wastewater discharges, exhibits high levels of several parameters, including ammonia nitrogen, organic compounds, TOC, metals, and fecal coliform. Other parameters, such as nitrate-nitrogen and phosphorus, are typically highest in regions affected by runoff and inflow. In general, levels of copper, nickel, and zinc are elevated throughout Corpus Christi Bay (Ward and Armstrong, 1997).

Hypoxic events have been documented every summer in the southeastern region of Corpus Christi Bay since 1988. When hypoxia occurs in the Bay, the low dissolved oxygen levels are limited to the waters within 3–6 feet of the Bay's bottom surface. Hypoxia is caused by a combination of respiration, low mixing potential, small tidal ranges, and high temperatures. The extent and intensity of hypoxic events in the Bays has been increasing over time, which corresponds to rising temperatures in the region during the past 20 years. These events are primarily due to the increase in temperature because nutrient levels in this area of the Bay have not increased (Morehead et al., 2002).

Freshwater flow affects the quality of surface waters in the estuary, and the CBBEP uses several freshwater-flow indicators to help assess water quality in the region. These indicators include the flux, volume, timing, and locations of freshwater flows (point and river sources) into the CBBEP area, as well as rainfall trends and freshwater demand. Annual precipitation rates range from 24 inches per year in the southern end of the study area to 40 inches per year in the northern end. Between 2% (at the southern end) and 10% (at the northern end) of this precipitation reaches the Bays as runoff. The non-point loadings of total nitrogen and total phosphorus to the Bays are largely driven by runoff from agricultural lands (Quenzer et al., 1998).

Sediment quality is also monitored in the CBBEP study area. The CBBEP assesses sediments for grain size, TOC, redox potential discontinuity, contaminant levels, and toxicity. The diversity of benthic communities and other benthic community indicators are also used to characterize sediment quality. Arsenic, cadmium, mercury, and zinc concentrations in Corpus Christi Bay sediments are generally elevated. The highest levels of common pesticides have been measured in Baffin and Copano bays (Ward and Armstrong, 1997). Elevated levels of PAHs, metals, pesticides, PCBs, and fecal coliform have also been measured in sediments collected near stormwater outfall sites and other areas of concern in the CBBEP study area (Carr et al., 1998).

Area fishermen participate in the Texas Abanded Crab Trap Removal Project by collecting derelict crab traps in area bays (CBBEP).

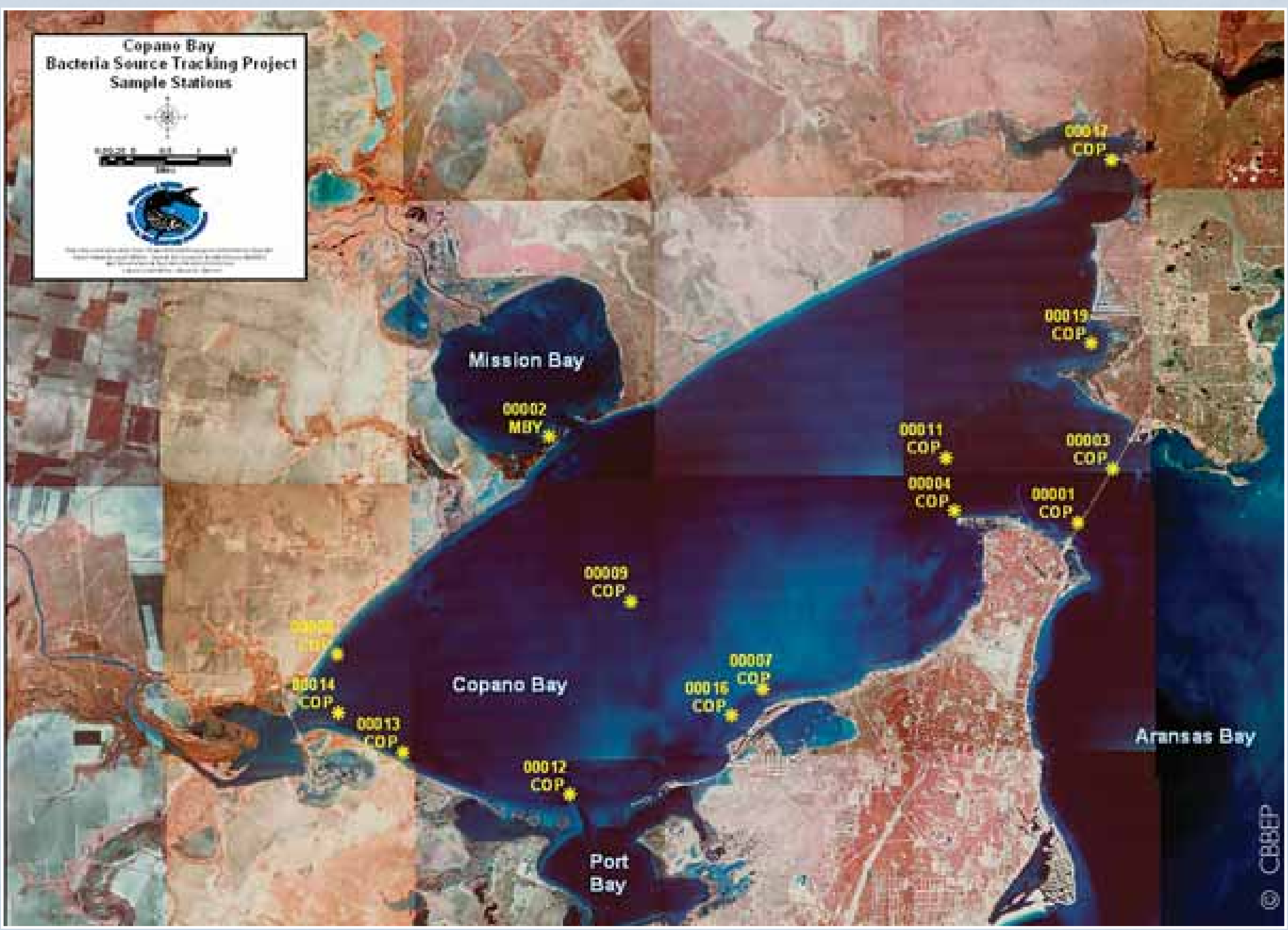
Coastal Bend Bays and Estuaries Program

HIGHLIGHT

CBBEP Bacteria Source Tracking in Copano Bay

In Copano Bay, there are a number of waterbody segments identified in Section 303(d) of the Clean Water Act that are listed as having high concentrations of coliform bacteria. The monitoring data used for this assessment are derived from various sources. The Texas DSHS collects data for use in assessing the health risks of exposure to bacteria in estuarine waters and for posting closures of shellfish harvesting areas. The TPWD and several academic research institutions, collect water quality monitoring data as contractors for the Regional Coastal Assessment Program. Monitoring data have shown that microbial contamination is occurring and that elevated concentrations of bacteria are usually present following heavy rainfall events; however, identifying the source or sources of the contamination is more difficult.

The CBBEP, TCEQ, the Texas DSHS, and Texas GLO are working with Dr. Joanna Mott at Texas A&M University/Corpus Christi, Center for Coastal Studies, to determine the source of bacterial contamination in Copano Bay through bacterial DNA source tracking and the development of a database of fecal samples collected from numerous animals within the watershed,



Copano Bay Bacteria Source Tracking Project sampling stations (CBBEP).

including humans. The University uses samples from 14 stations in Copano Bay that are part of the Texas DSHS Shellfish Sanitation Program. Filtration of these water samples yields isolated *E. coli* bacteria samples, which are then verified using BIOLOG. Isolates from these samples are also fingerprinted for their DNA by Pulse Field Gel Electrophoresis. In addition, antibiotic resistance profiling is also conducted on some of the *E. coli* samples. The goal of this sampling effort is to develop a screening tool that can be used to determine if the coliform bacteria are coming from human, domestic animal, or wildlife sources so that steps can be taken to reduce the contamination.

The results of this project will assist several state resource agencies in determining the source of bacteriological contamination to the Copano Bay area. The Texas DSHS can use this data to review needed changes to shellfish harvesting rules, and the TCEQ can use this same data to develop a TMDL for Copano Bay. In addition, a watershed model for coliform bacteria is being developed by the University of Texas, and data from the Copano Bay Source Tracking Project will be used to assist in model calibration. Since the project's inception in 2003, the two major rivers (Aransas and Mission rivers) discharging into Copano Bay have been added to the 303(d) list due to elevated levels of coliform bacteria. The CBBEP plans to extend this effort to identify and evaluate sources of coliform bacteria throughout the entire watershed with the hope of reducing microbial contamination of estuarine waters and protecting and maintaining healthy shellfishing resources.

Habitat Quality

Eight major tidally influenced habitats are represented in the CBBEP study area, including coastal marshes, wind tidal flats, seagrass meadows, open bays, oyster and serpulid worm reefs, barrier islands, and freshwater marshes. Loss of habitat in the study area results from the following contributing factors: conversion to other land uses, dredge-and-fill activities, natural erosion, altered freshwater inflow, and degraded water quality (CBBEP, 1998).

The CCBEP monitors the acreage of each key habitat. Although losses and gains have been observed for specific habitat types, habitat acreage has been fairly stable over time. Wind tidal flats have suffered the most significant losses in the study area (CBBEP, 2002). More than 24,500 acres of wind tidal flats were converted to other habitat classes between the 1950s and 1979 due to rising sea levels and dredge-and-fill activities. The most extensive losses were observed on Mustang Island, San Jose Island, and Harbor Island, and in the upper portion of the Laguna Madre-Corpus Christi estuarine complex (CBBEP, 1998; Withers and Tunnell, 1998).

Dredge-and-fill activities also alter the region's habitat. Maritime commerce is important to the CBBEP's regional economy, and dredging is required to maintain the region's more than 175 miles of navigable waterways, including the Intracoastal Waterway and the Corpus Christi and La Quinta Ship channels (Tunnell et al., 1996). Between 1958 and 1994, dredging was part of construction and maintenance activities for the Intracoastal Waterway and other shipping channels in Redfish Bay. During this time frame, more than 950 acres of seagrass were lost due to channel impacts and the deposition of dredged materials on seagrass beds (Pulich et al., 1997; CBBEP, 1998). Habitat for nesting birds can also be created when dredged materials are stacked high enough to create islands. For example, Pelican Island was created from dredged material and is now the largest brown pelican nesting area in Texas (CBBEP, 1998).

The CBBEP also measures habitat quality to assess the overall health and productivity of the estuarine area. Habitat quality can be affected by a variety of factors, including changes in circulation patterns from freshwater inflow alterations, dredge-and-fill activities, shoreline alterations, road construction, point and nonpoint discharges, and activities associated with oil and gas exploration. For example, historical brine discharges have degraded habitat at White's Point in Nueces Bay (CBBEP, 1998). Some of the indicators used to monitor the habitat quality of SAV include maximum depth and width of vegetative growth, shoot density, patchiness, vegetative species composition, and percent cover (CBBEP, 2002). Preliminary assessment activities indicate that certain habitat types in the CBBEP study area are stressed or at risk (CBBEP, 1998).

Black skimmer chicks exploring while the mother is out foraging for food (CBBEP).

Living Resources

The CBBEP assesses the quality and quantity of the living resources within the study area. The program monitors the area's fisheries and several species of concern, including species of birds, marine mammals, and sea turtles. The fishery indicators include the relative abundance of fish and shellfish; standing crops versus fishing pressure; CPUE for several species, including spotted seatrout and blue crab; commercial fish landings by type from within the system areas; TPWD creel surveys data; catch-and-release data; contaminant concentrations in edible tissue of fish and shellfish; and bacteria levels in the waters where the fish live. The program also monitors the population size and reproduction statistics for birds, colonial bird nesting pairs, number of rookery sites visited or vandalized, the numbers of strandings and mortalities of marine mammals, number of strandings and sea turtle condition, and numbers of nesting sea turtles and turtle nests.

The varied habitats across the CBBEP study area support a wide range of finfish and shellfish species that are of commercial and recreational value. The area is also home to many resident and migratory birds and to marine mammals such as the bottlenose dolphin. Although the study area is one of the richest fishery areas in Texas, particularly for finfish, shrimp, and crab, data suggest that some population declines have occurred in species such as Atlantic croaker, summer flounder, Gulf menhaden, white shrimp, and blue crabs (Lacson and Lee, 1997). Benthic communities in some bays (Corpus Christi, Baffin, and Nueces bays) are characterized by low diversity, a dominance of pioneer species, and a high variance of community and physical variables (Montagna et al., 1998). Although the CBBEP area supports almost 500 species of birds, the nesting populations of colonial waterbirds, with the exception of the brown pelican, have declined. The FWS is concerned about two issues that impact migratory species: rapid habitat loss in Latin and South American countries and the need to preserve wooded riparian corridors and coastal prairies along the Gulf Coast. Some evidence also suggests that there is an increasing trend in the number of dolphin strandings. This issue is of particular concern for bottlenose dolphins (Tunnell et al., 1996).

Environmental Stressors

The CBBEP monitors several human indicators in the study area, including the length, area, and location of hardened shoreline, bulkheads, and other hydrological modifications; the number of vessels and amount of cargo crossing the Bays; and the number of oil and chemical spills in the region. Almost 200 miles of CBBEP shoreline are protected by seawalls and other man-made structures, whereas 1,118 miles remain in their natural state (White et al., 1998). Approximately 80,000 vessels annually cross the Coastal Bend Bays, and recent analysis indicates that the amount of freight transported and the number of vessels in CBBEP waters is increasing (CBBEP, 1998). More than 90% of the region's maritime cargo tonnage is composed of oil and petrochemicals. Although the number of oil and chemical spills in the region has decreased since 1990, some spills do occur (CBBEP, 1998). These spills have the potential to impact the region's water, sediment, and habitat quality, as well as to injure or kill fish and wildlife.

Current Projects, Accomplishments, and Future Goals

The CBBEP and its partners are actively collecting data that will provide a system-wide assessment of the environmental trends in the Coastal Bend Bays resulting from the cumulative effects of action implementation. Several CBBEP projects and numerous partner projects are underway to quantify changes to habitat, water and sediment quality, freshwater resources, commercial and recreational fisheries, species of concern, and shoreline management; however, several factors limit the CBBEP's ability to report on system-wide progress at this time. Some projects are still in progress, and results may not be available for some time. In addition, significant resources are being directed toward water and sediment quality assessment projects to determine the statistical confidence of these data, and some partners have not submitted data to the program's information clearinghouse. For these reasons, reporting system-wide environmental changes as a result of CBBEP or partner action is premature.

A partnership between the CBBEP and the City of Corpus Christi will help restore freshwater flow to the Nueces River Delta and revitalize a wetland that is crucial to the Gulf Coast. The Nueces Delta Preserve is a dynamic ecosystem of highly productive wetlands, open water, islands, prairie, and river and bay shorelines. The river provides vital riparian habitat, whereas brackish wetlands are home to shrimp, crabs, juvenile fish, and birds. The uplands contain an attractive diversity of native vegetation that host a variety of wildlife. Approximately 3,000 acres of wetlands-associated uplands have been acquired for the purpose of habitat protection as part of a long-term regional water and land management plan to meet human and environmental needs for fresh water (CBBEP, 2005b).

The Delta provides highly productive wetlands and critical habitat for numerous shorebirds, as well as recreationally and commercially important fish and shellfish species (e.g., shrimp, crabs, and juvenile finfish). Part of the new Nueces Delta Preserve will be purchased by the City of Corpus Christi for use as an overflow channel and pipeline corridor to deliver much-needed fresh water directly to the upper Nueces River Delta.

Conclusion

The CBBEP has taken actions to establish aggressive goals for the protection and restoration of the Coastal Bend Bays by obtaining consensus among a variety of different stakeholder groups. NCA monitoring data classify the Coastal Bend Bay's overall condition as poor. Because many of the CBBEP's own monitoring data are still being collected or evaluated, it is not known whether the comprehensive list of CBBEP indicators will show a pattern similar to the NCA data. Attaining the CBBEP's goals will require continued strong monitoring efforts, as well as comprehensive pollution and resource management. Projected population increases in the CBBEP area will require increasing cooperation among stakeholder groups in developing a strong regional water management plan that will balance the long-term environmental needs of the human inhabitants and living resources of the Coastal Bend Bays to maintain a sustainable freshwater system.

Outdoor enthusiasts getting ready to hit the waves in their catamarans on North Padre Island (CBBEP).