This document contains Chapter 6: West NEPs, Chapter 7: Puerto Rico NEP, Appendix A and References of the National Estuary Program National Coastal Condition Report. The entire report can be downloaded from ***http://www.epa.gov/owow/oceans/nepccr/index.html***

National Estuary Program Coastal Condition Report

West NEPs, Puerto Rico NEP, Appendix A and References

June 2007

CHAPTER 6

WEST COAST NATIONAL ESTUARY PROGRAM COASTAL CONDITION

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Background

The West Coast region extends from the Mexican border north to the Canadian border and, due to its unique geological history, has the fewest estuaries of any coastal region of the United States. With the exception of parts of the Washington coast that have become coastal flats and islands due to the erosion of sedimentary rocks, the West Coast is characterized by uplifted, resistant rock. The proximity of coastal mountains to the shoreline in this region has restricted the area of coastal plain and rivers that flow to the sea (NOAA, 1985).

Within the West Coast region, there are six NEP estuaries: Puget Sound, the Lower Columbia River Estuary, Tillamook Bay, the San Francisco Estuary, Morro Bay, and Santa Monica Bay (Figure 6-1). The larger West Coast estuaries, Puget Sound and the San Francisco Estuary, were formed when sections of the coastline containing former river valleys sank below sea level during mountain-building processes (NOAA, 1985). Puget Sound was further deepened and elongated as a result of glacial activity, resulting in the development of a fjord that is narrow, deep, and steep-sided, with several internal sills. Both of these estuaries are dominated by tidal flow rather than by freshwater inputs. In contrast, the Lower Columbia River Estuary is heavily influenced by freshwater riverine discharge. During high river-flow periods, the Estuary is almost entirely composed of fresh water that is well connected to the ocean; however, during low-flow periods, discharge is insufficient to maintain a good connection with the ocean, and tidal action along the shoreline tends to affect the entrance to the Estuary.

Sediment loads delivered to West Coast estuaries vary considerably throughout the region, with high sediment loading in southern California, moderate loading in central California, and generally low loading from northern California to Washington due to extensive forested lands that help reduce sediment runoff (NOAA, 1985). However, historic logging activities, steep slopes, and heavy rainfall in some of the Northwest Coast estuaries combine to result in high levels of sediment and lower water clarity in some river systems.

Figure 6-1. The West Coast region is home to six NEP estuaries.

Population Pressures

The population of the 41 NOAA-designated coastal counties coincident with the estuarine study areas of the West Coast NEPs increased by 100.3% during a 40-year period, from 14.7 million people in 1960 to 29.5 million people in 2000 (Figure 6-2) (U.S. Census Bureau, 1991; 2001). This growth resulted in a population density of 421 persons/mi^2 in 2000 for these NEP-coincident coastal counties; however, the population densities of the individual NEP study areas varied considerably, from a high of 844 persons/mi^2 for the San Francisco Estuary to a low of 22 persons/mi^2 for Tillamook Bay (U.S. Census Bureau, 2001). Development and population pressures are especially strong surrounding some of the West Coast NEP estuaries, which are centers of international commerce, major fishing ports, and recreational areas for these coastal communities.

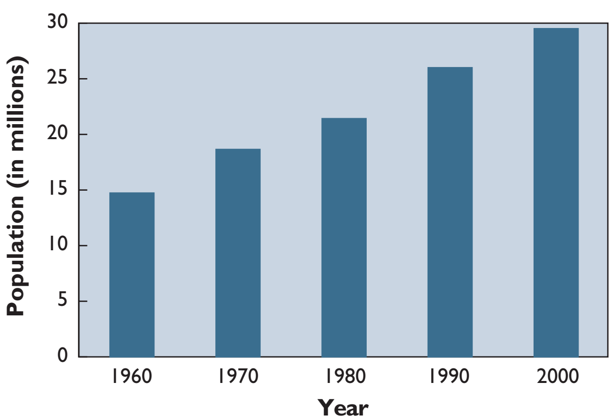


Figure 6-2. Population of the 41 NOAA-designated coastal counties of the West Coast NEP study areas, 1960–2000 (U.S. Census Bureau, 1991; 2001).

NCA Indices of Estuarine Condition—West Coast Region

Researchers with the Washington State Department of Ecology (WSDE), the Oregon Department of Environmental Quality (ODEQ), NOAA's NS&T Program, and the Moss Landing Marine Laboratories, under contract to the Southern California Water Resources Research Project, collected NCA data from 308 locations in the six West Coast NEP estuaries in 1999, 2000, and 2003. The NS&T Program also provided sediment contaminants data from some Puget Sound sites based on samples collected in 1997, 1998, and 1999. With the assumption that sediment contaminant concentrations will change slowly, these stations were incorporated into the 2000 sampling design and supplemented with water quality and biological data. The NS&T Program collected additional data during 2001 within the San Francisco Estuary, but these data have not been included in the current report. The Morro Bay and Santa Monica Bay estuarine areas were not sampled until 2003.

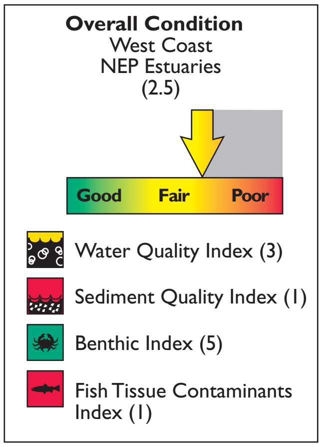


Figure 6-3. The overall condition of the West Coast NEP estuarine area is fair (U.S. EPA/NCA).

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.

The overall condition of the collective West Coast NEP estuaries is rated fair based on the four indices of estuarine condition used by the NCA (Figure 6-3). The water quality index for the region is rated fair, the sediment quality and fish tissue contaminants indices are rated poor, and the benthic index is rated good. Figure 6-4 shows the percent of estuarine area rated good, fair, poor, or missing for each parameter considered. 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.

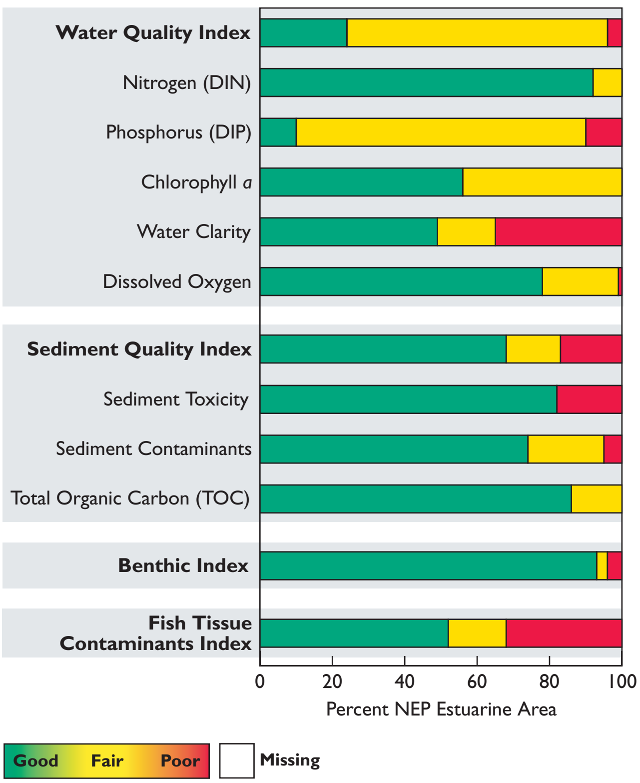


Figure 6-4. Percentage of NEP estuarine area achieving each ranking for all indices and component indicators — West Coast region (U.S. EPA/NCA).

Water Quality Index

Based on NCA survey results, the water quality index for the collective West Coast NEP estuaries is rated fair. This index was developed using NCA data on five component indicators: DIN, DIP, chlorophyll *a*, water clarity, and dissolved oxygen. Seventy-two percent of the estuarine area was rated fair for water quality because of limited water clarity and elevated levels of DIP (Figure 6-5).

Dissolved Nitrogen and Phosphorus | The West Coast region is rated good for DIN concentrations, with 92% of the NEP estuarine area rated good for this component indicator. The region is rated fair for DIP concentrations, with 10% of the NEP estuarine area rated poor and 80% of the area rated fair for this component indicator. It should be noted that the threshold for a West Coast site to be rated poor for DIN was a concentration in excess of 1 mg/L and for DIP was a concentration in excess of 0.1 mg/L. These values correspond to the levels used by the NOAA/EPA Team on Near Coastal Waters to indicate high nutrient levels in its report on the susceptibility of West Coast estuaries to nutrient discharges (NOAA/U.S. EPA, 1991). Along much of the West Coast, summer wind conditions result in an upwelling of nutrient-rich deep water, which enters the West Coast estuaries during flood tides (Landry et

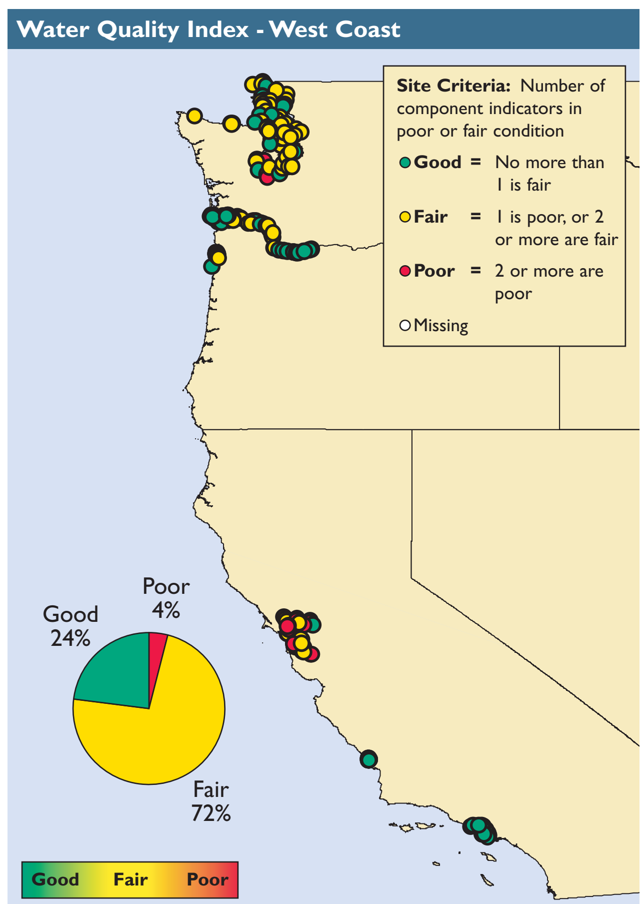


Figure 6-5. Water quality index data for the West Coast NEP estuarine area, 1999, 2000, and 2003 (U.S. EPA/NCA).

al., 1989) and constitutes a potentially important, natural source of nutrient inputs for many of these estuaries.

Chlorophyll a | Chlorophyll *a* concentrations for the West Coast region are rated good, with 44% of the NEP estuarine area rated fair for this component indicator and 56% of the area rated good. None of the West Coast region's NEP estuarine area was rated poor for chlorophyll *a* concentrations.

Water Clarity | NCA data show that water clarity in the NEP estuaries of the West Coast region is rated poor. For all of the West Coast NEP estuaries, water clarity was rated poor at a sample site if light penetration at 1 meter was less than 10% of surface illumination. Approximately 35% of the West Coast NEP estuarine area was rated poor for water clarity, and 16% of the area was rated fair. It should be noted that the West Coast typically experiences strong seasonal variations in freshwater flow between the wet conditions of winter and the dry conditions of summer. In interpreting water clarity for the West Coast NEP estuaries, the light penetration levels recorded represent water clarity only in late summer and do not represent high-flow, wet season conditions in the winter. In addition, the large tidal amplitude found in many estuaries along the West Coast may result in high natural levels of turbidity in the water column due to sediment suspension; however, phytoplankton and other particulate matter may also decrease water clarity. The NOAA Eutrophication Survey (NOAA, 1998) has previously reported high turbidity in the West Coast NEP estuarine areas and for the West Coast estuaries in general (20 of 38 estuaries surveyed).

Dissolved Oxygen | The West Coast region is rated good for dissolved oxygen conditions, with 78% of the NEP estuarine area rated good for this component indicator, 21% of the area rated fair, and only 1% of the area rated poor. Although conditions in West Coast NEP estuaries appear to be generally good for dissolved oxygen, measured values reflect daytime conditions, and some areas may still experience hypoxic conditions at night.

Sediment Contaminant Criteria (Long et al., 1995)

ERM (Effects Range Median)—Determined for each chemical as the 50th percentile (median) in a database of ascending concentrations associated with adverse biological effects.

ERL (Effects Range Low)—Determined for each chemical as the 10th percentile in a database of ascending concentrations associated with adverse biological effects.

Sediment Quality Index

The sediment quality index for the collective NEP estuaries of the West Coast region is rated poor, with 17% of the estuarine area exceeding thresholds for sediment toxicity, sediment contaminants, or sediment TOC (Figure 6-6). The sediment contaminants component of the sediment quality index for the West Coast NEP estuaries excluded phenanthrene (a PAH) and

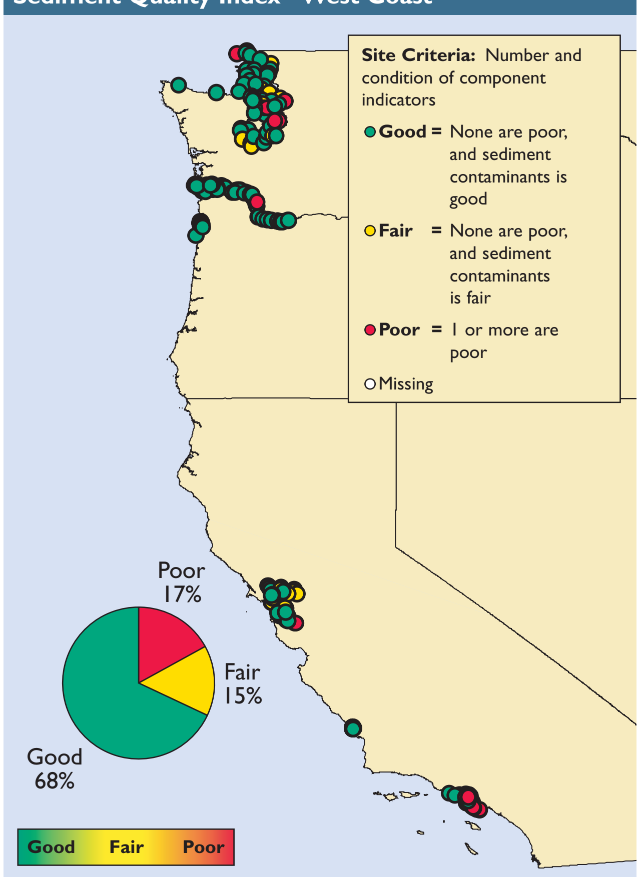


Figure 6-6. Sediment quality index data for the West Coast NEP estuarine area, 1997–2000, and 2003 (U.S. EPA/NCA).

nickel. Phenanthrene was excluded because concentrations were not available from all West Coast NEP estuaries, and nickel was excluded because its ERM value has a low reliability for West Coast conditions, where high natural crustal concentrations of nickel exist (Long et al., 1995).

Sediment Toxicity | The West Coast region is rated poor for sediment toxicity because 18% of the NEP estuarine area was rated poor for this component indicator. Toxicity was determined using a static 10-day acute toxicity test with the amphipods *Ampelisca abdita* or *Hyalella azteca*. Sediment toxicity was observed in all West Coast NEP estuaries except Tillamook Bay and the San Francisco Estuary.

Sediment Contaminants | The West Coast region is rated fair for sediment contaminant concentrations. Approximately 5% of the region's NEP estuarine area was rated poor for this component indicator, and 21% of the area was rated fair.

Total Organic Carbon | The West Coast NEP estuarine area is rated good for TOC concentrations because concentrations in sediment were rated good in 86% of the NEP estuarine area and fair in 14% of the area. None of the estuarine area was rated poor for this component indicator.

Benthic Index

Currently, there is no single benthic community index applicable to the entire West Coast region, although work on such an index is ongoing. In lieu of a West Coast Benthic Index, the deviation of species richness from an estimate of the expected species richness was used as an approximate indicator of the condition of the West Coast benthic community. The log10 transformed number of species per 0.1-square-meter grab sample was regressed on bottom salinity. The benthic condition of any station with fewer species than 75% of the lower 95% confidence limit of the mean from the regression was rated poor, whereas the condition of stations with 75% to 90% of the lower 95% confidence limit was rated fair.

The condition of the benthic invertebrate communities in the collective West Coast NEP estuaries is rated good based on deviations from the expected species richness (Figure 6-7). This analysis was based on a total of 245 benthic samples collected in 1999 and 2000 for the NEP estuarine areas of Tillamook Bay, Puget Sound, the San Francisco Estuary, and the Lower Columbia River Estuary, as well as in 2003 for Morro Bay and Santa Monica Bay.

A significant linear regression was found between salinity and the log of species richness that was moderately strong ($r^2 = 0.39$, $p < 0.01$). Based on this regression, 47 sites, representing 4% of the estuarine area, were rated poor, and another 36 sites, representing 3% of the area, were rated fair. Of the 47 sites rated poor, 25 sites (53%) were in the Lower Columbia River Estuary, which may reflect the naturally low diversity of this system, or potentially, the effects of stressors such as channel dredging on the benthic communities.

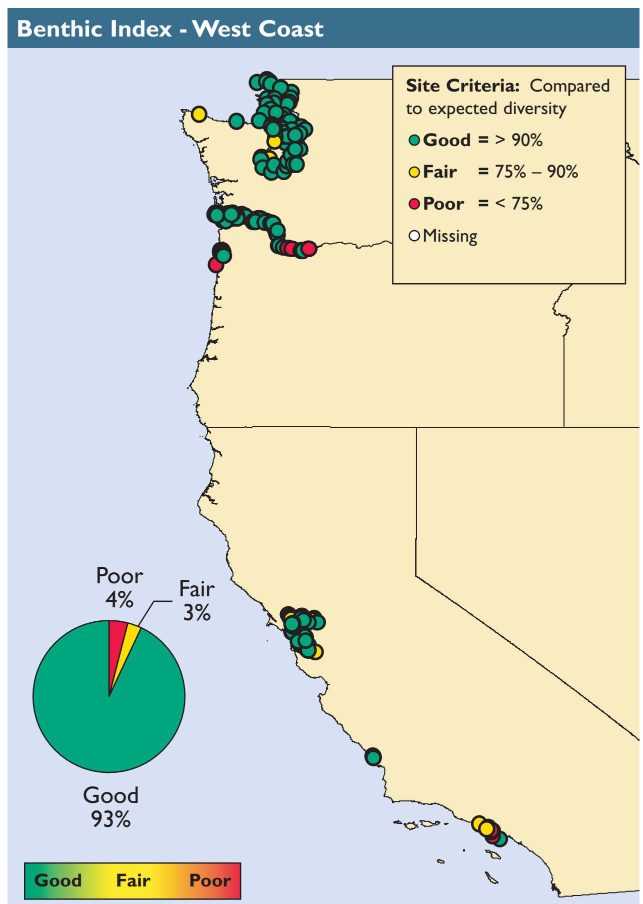


Figure 6-7. Benthic index data for the West Coast NEP estuarine area, 1999, 2000, and 2003 (U.S. EPA/NCA).

Fish Tissue Contaminants Index

The fish tissue contaminants index for the collective West Coast NEP estuaries is rated poor based on fish samples collected from 198 stations (Figure 6-8). Thirty-two percent of all stations sampled where fish were caught were rated poor for fish tissue contaminants, which most often included total PCBs, DDTs, and mercury.

Fish tissue contaminant levels were compared to EPA Advisory Guidance values using whole-fish contaminant concentrations. For populations that consume whole fish, these risk calculations are appropriate. Whole-fish contaminant concentrations 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 be lower than whole fish analyses. In contrast to the NEP estuaries of the Northeast, Southeast, and Gulf coasts, PAHs were not analyzed in fish tissue samples collected from the West Coast NEP estuaries.

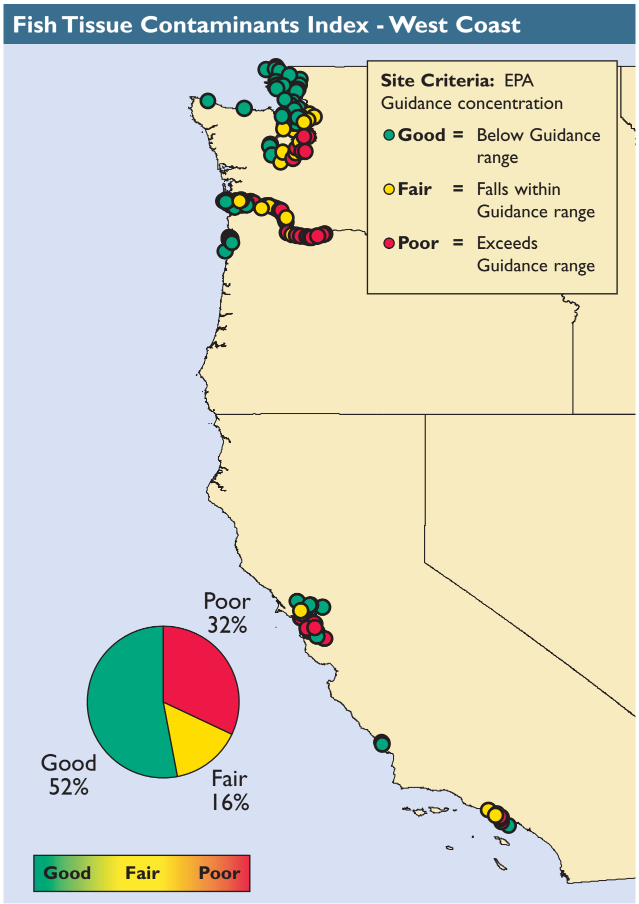


Figure 6-8. Fish tissue contaminants index data for the West Coast NEP estuarine area, 1999, 2000, and 2003 (U.S. EPA/NCA).

NEP Estuaries and the Condition of the West Coast Region

The purpose of the NEP is to identify, restore, and protect the nationally significant estuaries of the United States. The six West Coast NEP estuaries include a wide range of estuary types, from large estuaries, such as the San Francisco Estuary and Puget Sound, to much smaller estuaries, such as Tillamook Bay and Morro Bay. The larger estuaries are important to the nation as major centers of commerce and international trade, areas for commercial or recreational fisheries, and centers for coastal recreational activities; however, these diverse uses can create environmental stresses that may result in environmental degradation. Does the condition of the West Coast NEP estuaries accurately reflect the condition of all West Coast estuaries (both NEP and non-NEP)? Based on the NCA survey results, the collective West Coast NEP estuaries and all West Coast estuaries combined are both rated fair for overall condition, with the group of NEP estuaries receiving an overall condition score of 2.5, just slightly higher than the overall condition score of 2.25 for all West Coast estuaries (Figure 6-9). The overall condition scores for the two groups of West Coast estuaries were derived from estimates presented in the NCCR II and based on NCA data collected between 1999 and 2000 from all West Coast estuaries, except for Morro Bay and Santa Monica Bay, which were sampled in 2003. A higher overall condition score for the group of collective NEP estuaries has also been noted in some of the other regions outlined in this report.

A comparison of NCA data shows that the collective West Coast NEP estuaries are rated fair for the water quality index, poor for the sediment quality index, good for the benthic index, and poor for the fish tissue contaminants index. The group of all West Coast estuaries combined are rated fair for the water quality index, fair to poor for sediment quality index, fair for the benthic index, and poor for the fish tissue contaminants index. Both groups of estuaries are also rated comparably for almost all of the water and sediment quality component

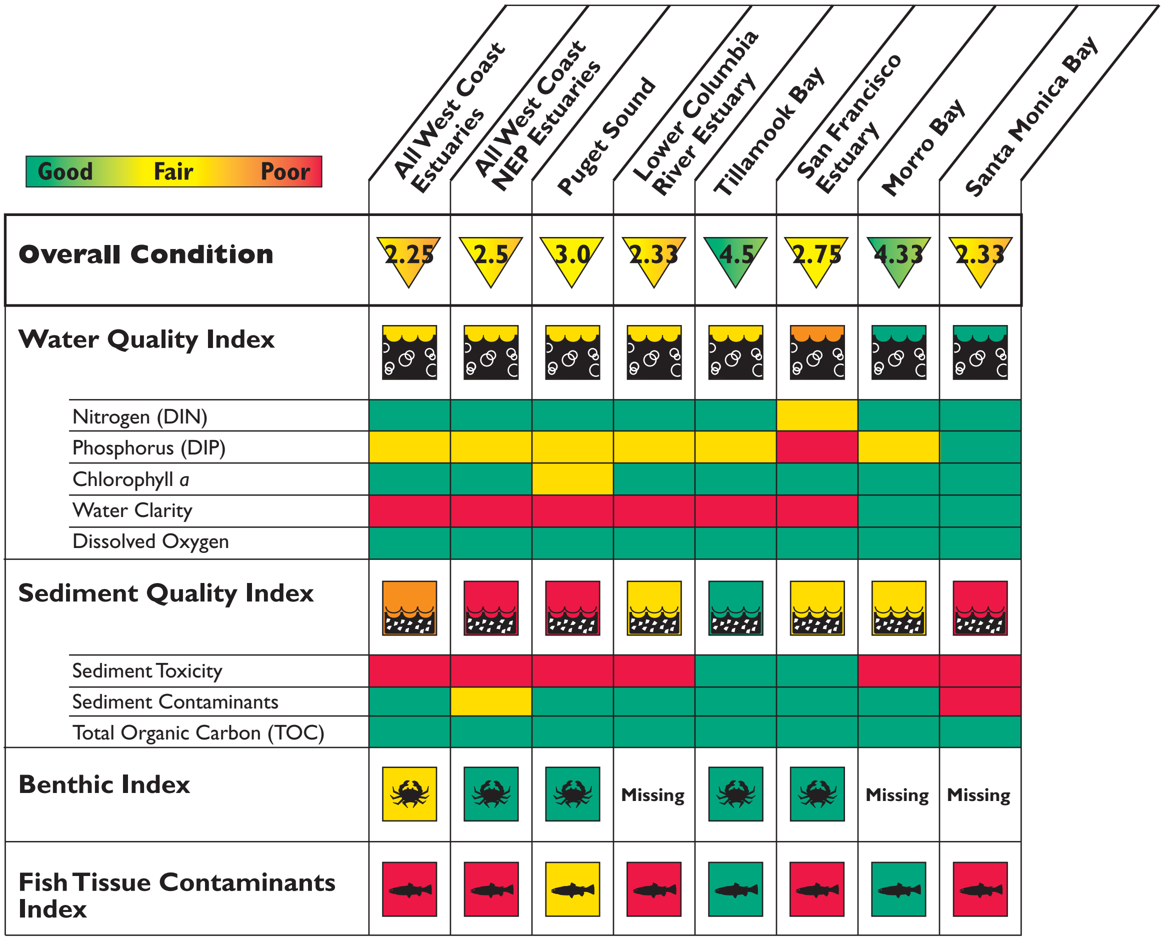


Figure 6-9. Comparison of NCA results for West Coast NEP estuaries and all West Coast estuaries (U.S. EPA/NCA).

indicators, with both groups rated good for DIN, chlorophyll *a*, dissolved oxygen, and TOC concentrations; fair for DIP concentrations; and poor for water clarity and sediment toxicity. However, the two groups of estuaries received different ratings for one sediment quality component indicator (sediment contaminants). The collective West Coast NEP estuaries are rated fair for sediment contaminant concentrations, whereas the group of all West Coast estuaries combined are rated good for this component indicator. Based on these ratings, the condition of the West Coast NEP estuaries is relatively representative of the condition of all West Coast estuaries, with the exception of sediment quality, where the group of all West Coast estuaries received better ratings.

With respect to the individual West Coast NEP estuaries, four of the six estuaries are rated higher for overall condition to the overall condition score for the collective West Coast NEP estuaries (2.5, rated fair). These NEP estuaries are Puget Sound (3.0, rated fair), Tillamook Bay (4.5, rated good), the San Francisco Estuary (2.75, rated fair), and Morro Bay (4.33, rated good). Only the Lower Columbia River Estuary (2.33) and the Santa Monica Bay (2.33), which are both rated fair, received overall condition scores below the overall condition score for the collective NEP estuaries of the West Coast region.

The water quality index is rated good for two of the six West Coast NEP estuaries (Morro Bay and Santa Monica Bay), both of which are located in the southernmost portion of the region. Three NEP estuaries (Puget Sound, the Lower Columbia River Estuary, and Tillamook Bay) are rated fair for the water quality index, whereas the San Francisco Estuary is rated fair to poor. With respect to the water quality component indicators, all of the West Coast NEP estuaries are rated good for DIN concentrations, except for the San Francisco Estuary, which is rated fair. The majority of the NEP estuaries (Puget Sound, the Lower Columbia River Estuary, Tillamook Bay, and Morro Bay) are rated fair for DIP concentrations, although the San Francisco Estuary is rated poor and Santa Monica Bay is rated good for this component indicator. All the estuaries are rated good for chlorophyll *a* concentrations, except for Puget Sound, which is rated fair. Four of the six West Coast NEP estuaries (Puget Sound, the Lower Columbia River, Tillamook Bay, and the San Francisco Estuary) are rated poor for water clarity, whereas the remaining two estuaries (Morro Bay and Santa Monica Bay) are rated good. Finally, all six estuaries are rated good for dissolved oxygen concentrations.

The sediment quality index ratings for the individual West Coast NEP estuaries range from good to poor. The sediment quality index is rated good for Tillamook Bay; fair for the Lower Columbia River Estuary, San Francisco Estuary, and Morro Bay; and poor for Puget Sound and Santa Monica Bay. Sediment toxicity is rated good in Tillamook Bay and the San Francisco Estuary and poor in Puget Sound, the Lower Columbia River Estuary, Morro Bay, and Santa Monica Bay. Sediment contaminant concentrations are rated good for five of the West Coast NEP estuaries, but poor for Santa Monica Bay. Finally, sediment TOC is rated good in all West Coast NEP estuaries.

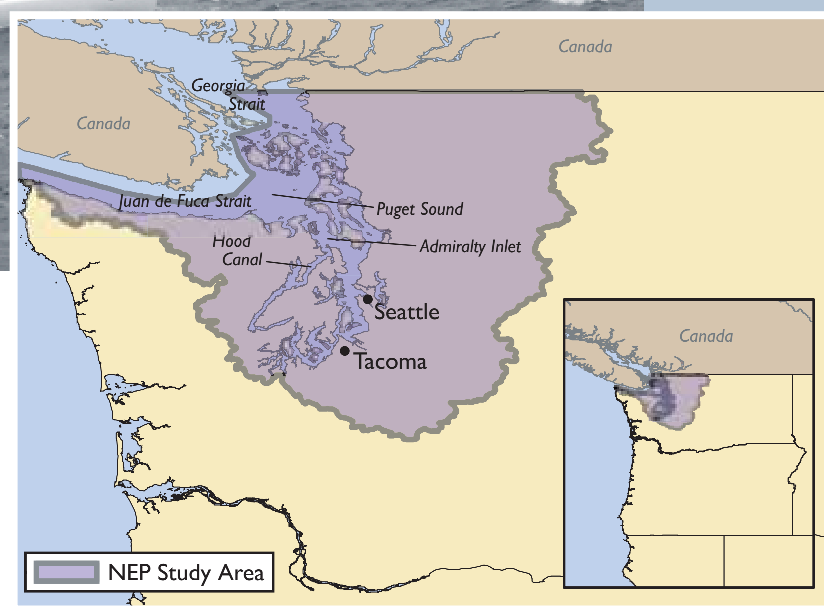
The benthic index is rated good for all West Coast NEP estuaries where a rating was applicable (Puget Sound, Tillamook Bay, and the San Francisco Estuary). Benthic index ratings were not applicable for the Lower Columbia River Estuary, Morro Bay, or Santa Monica Bay because the index used was based on deviations from the expected species richness. The benthic index methodology used by the NCA requires a significant regression between salinity and the log of species richness; however, a lack of significant regression existed for the two southernmost NEPs (Morro Bay and Santa Monica Bay) because of the small variation in salinity. For the Lower Columbia River Estuary, there was a lack of significant regression because of this area's low species richness, possibly associated with either dredging or naturally low species diversity.

The fish tissue contaminants index is rated good for Tillamook Bay and Morro Bay; fair for Puget Sound; and poor for the Lower Columbia River Estuary, San Francisco Estuary, and Santa Monica Bay.

Nationally, the overall condition score for the collective West Coast NEP estuaries (2.5) ranks higher than the overall condition scores for the Northeast Coast (1.5) and Puerto Rico (1.5) regions and lower than the overall condition scores for the Southeast Coast (4.0) and Gulf Coast (2.75) regions. Population pressures, measured as population density (number of persons/mi^2), correlated somewhat with the overall condition score for the West Coast NEP estuaries. For example, Morro Bay and Tillamook Bay had the lowest population densities of 75 and 22 persons/mi^2, respectively, and these estuaries had the highest overall condition scores of 4.33 and 4.5 (both rated good). The two largest estuaries with the highest population densities, San Francisco Estuary (844 persons/mi^2) and Puget Sound (205 persons/mi^2), were both rated fair for overall condition, with overall condition scores of 2.75 and 3.0, respectively. The Lower Columbia River Estuary and Santa Monica Bay had the lowest overall condition scores (both 2.33 and rated fair) of any of the six West Coast NEP estuaries and were intermediate in population density (138 and 533 persons/mi^2, respectively).

Harbor seals can be seen at sandy beaches, mudflats, bays, and estuaries along the West Coast (Jim Young).

Puget Sound Action Team



PUGET SOUND ACTION TEAM
Office of the Governor, State of Washington

www.psat.wa.gov

Background

Carved by glaciers, Puget Sound is a place where the salt water of the ocean meets fresh water flowing from about 10,000 rivers and streams (PSAT, 2003a). Together, these waters commingle to form a deep, complex system that provides invaluable habitat for fish and wildlife, including the region's renowned Pacific salmon and orca whales. The Sound covers 2,800 mi^2 of inland marine waters, with an average depth of 450 feet, and encompasses 2,500 miles of shoreline (PSAT, 2003a; 2006).

Much of the promise and potential of the Puget Sound estuarine area is based on natural resources and the industries these resources support, such as tourism, lumber, shellfish, and recreation. The region's natural resources and high quality of life have led to good economic growth, resulting in ever-increasing numbers of people who live and work in the counties surrounding Puget Sound. By 2020, the population in the Puget Sound basin is expected to be greater than five million people—almost 30% more people than the present population (PSAT, 2002). This region supports one of the leading trade centers on the West Coast and is a gateway to some of the continent's busiest ports, including Seattle, Tacoma, Anacortes, Everett, Port Angeles, and Olympia. The port facilities within Puget Sound collectively handled more than 64 million tons of cargo during 2003 (PSAT, 2002; USACE, 2004b).

EPA declared Puget Sound to be an Estuary of National Significance in 1988, an action that included the Puget Sound in the NEP (PSAT, 2003a). Created in 1996, the Puget Sound Action Team (PSAT) is composed of state agencies and federal, tribal, and local governments. The federal government and the State of Washington have both adopted the *2000 Puget Sound Water Quality Management Plan* (PSAT, 2000) as the comprehensive plan to protect and restore Puget Sound. This partnership is leading efforts to implement the PSAT plan and to protect and restore Puget Sound (PSAT, 2003a).

Environmental Concerns

A growing human population means increasing stress on Puget Sound. Human development has modified significant portions of the Sound's shoreline, and stormwater runoff from developed areas is a substantial water pollution problem because of the contaminants from those surfaces. Toxic contamination, nearshore habitat modifications, habitat loss, declines in some fish and wildlife populations, Endangered Species Act listings of salmon and eight other species in the nearshore habitat, and shellfish bed closures remain among the primary concerns for Puget Sound. The Sound has experienced significant physical changes to its nearshore habitat, as well as population declines in some of its most important plant and animal species (PSAT, 2002).

Population Pressures

The population of the 14 NOAA-designated coastal counties coincident with the PSAT study area increased by about 120% during a 40-year period, from 1.8 million people in 1960 to 4.1 million people in 2000 (Figure 6-10) (U.S. Census Bureau, 1991; 2001). This rate of population growth for the PSAT study area surpassed the population growth rate of 100.3% for the collective West Coast NEP-coincident coastal counties; however, the 2000 population density in the PSAT-coincident coastal counties remained fairly low at 205 person/mi^2, well below the West Coast NEP-coincident coastal county population density of 421 persons/mi^2 (U.S. Census Bureau, 2001). Development and population pressures are especially strong in NEP study areas that serve as major shipping centers for commercial, fishing industry, and recreational activities in their coastal communities.

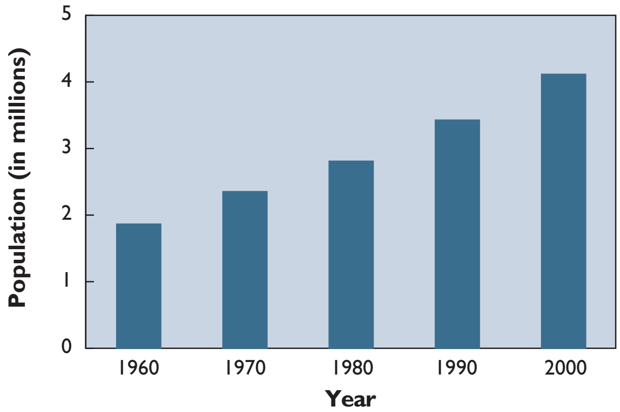


Figure 6-10. Population of NOAA-designated coastal counties of the PSAT study area, 1960–2000 (U.S. Census Bureau, 1991; 2001).

NCA Indices of Estuarine Condition—Puget Sound

The overall condition of Puget Sound is rated fair based on the four indices of estuarine condition used by the NCA (Figure 6-11). The water quality and fish tissue contaminants indices are rated fair, the sediment quality index is rated poor, and the benthic index is rated good. Figure 6-12 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 WSDE, in collaboration with NOAA, from 73 sites sampled in the PSAT estuarine area between 1997 and 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.

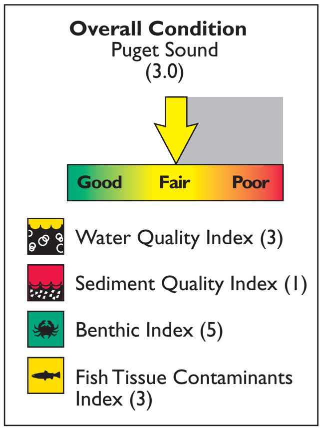


Figure 6-11. The overall condition of the PSAT estuarine area is fair (U.S. EPA/NCA).

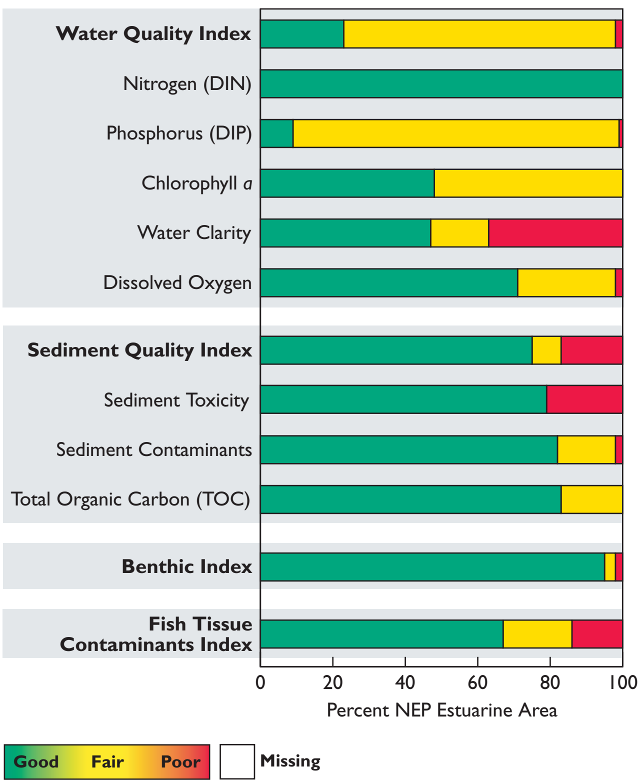


Figure 6-12. Percentage of NEP estuarine area achieving each ranking for all indices and component indicators — Puget Sound (U.S. EPA/NCA).

Water Quality Index

Based on NCA survey results, the water quality index for Puget Sound is rated fair. This index was developed using information from five component indicators: DIN, DIP, chlorophyll *a*, water clarity, and dissolved oxygen. Most (75%) of the estuarine area received fair ratings for water quality, whereas 2% of the area was rated poor because of limited water clarity and moderate levels DIP and chlorophyll *a* (Figure 6-13).

Dissolved Nitrogen and Phosphorus | Puget Sound is rated good for DIN concentrations, but rated fair for DIP concentrations. Concentrations of DIN were rated good in 100% of the PSAT estuarine area. In contrast, fair DIP concentrations occurred in 90% of the estuarine area, and only 1% of the area was rated poor for this component indicator.

Chlorophyll a | Chlorophyll *a* concentrations in Puget Sound are rated fair. Fifty-two percent of the estuarine area was rated fair for this component indicator, and the remaining 48% of the area was rated good.

Water Clarity | Water clarity in Puget Sound is rated poor. Approximately 37% of the estuarine area was rated poor for water clarity, and 16% of the area was rated fair.

Dissolved Oxygen | Dissolved oxygen conditions in Puget Sound are rated good. Twenty-seven percent of the estuarine area was rated fair for this component indicator, and less than 2% of the estuarine area was rated poor, primarily for sites located in Hood Canal. Although dissolved oxygen conditions in Puget Sound appear to be generally good, measured values reflect daytime conditions, and some areas may still experience hypoxic conditions at night.

Puget Sound Action Team

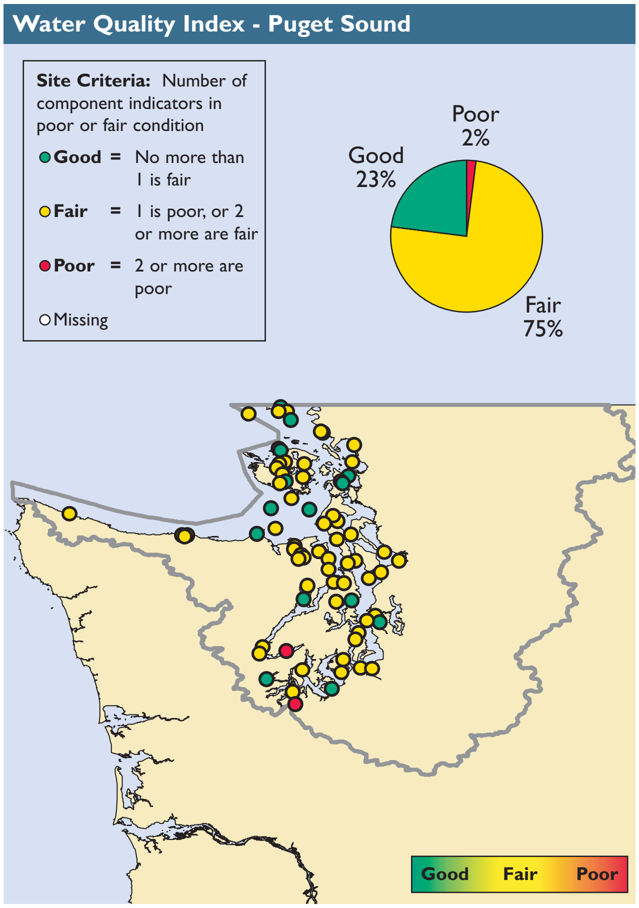


Figure 6-13. Water quality index data for Puget Sound, 1999–2000 (U.S. EPA/NCA).

Sediment Quality Index

The sediment quality index for Puget Sound is rated poor, with 17% of the area exceeding thresholds for one or more of the three component indicators—sediment toxicity, sediment contaminants, or sediment TOC (Figure 6-14).

Sediment Toxicity | Puget Sound is rated poor for sediment toxicity. Sediments in 21% of the estuarine area were rated poor; however, this percentage is based on poor ratings at only two sites, one of which had a 79% survival rate. The effect of these two sites on the area estimate of poor condition was augmented by the fact that both sites were located within the statistical stratum with the largest area and that only five other sites had acceptable sediment toxicity data within the stratum.

Sediment Contaminants | Puget Sound is rated good for sediment contaminant concentrations, with 2% of the estuarine area rated poor for this component indicator and 16% of the area rated fair.

Total Organic Carbon | Puget Sound is rated good for sediment TOC, with sediment concentrations rated good in 83% of the estuarine area and fair in 17% of the area. None of the PSAT estuarine area was rated poor for sediment TOC concentrations.

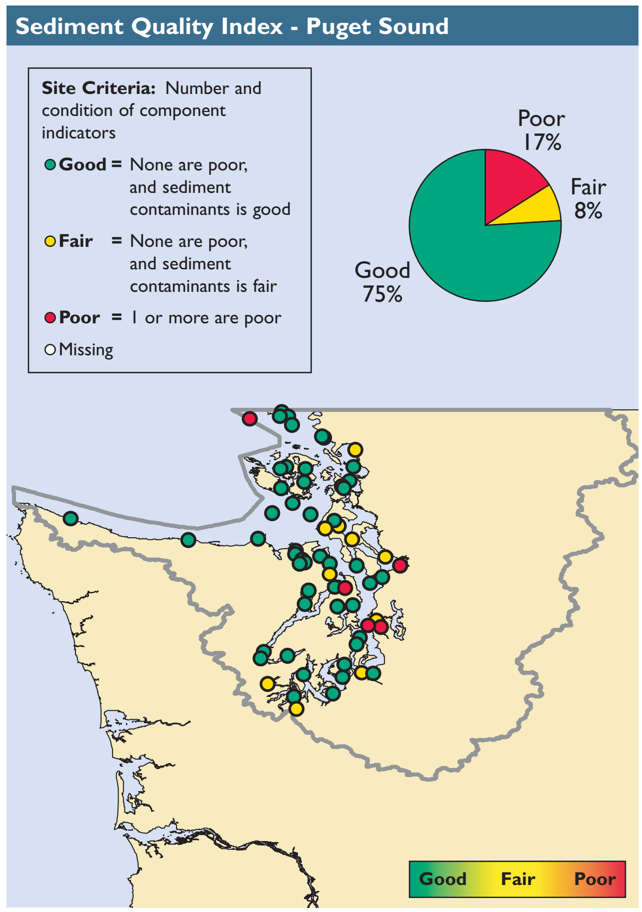


Figure 6-14. Sediment quality index data for Puget Sound, 1997–2000 (U.S. EPA/NCA).

Puget Sound Action Team

Benthic Index

The benthic condition of Puget Sound is rated good based on deviations from the expected species richness (Figure 6-15). This analysis was based on 62 benthic samples collected in Puget Sound, including 8 samples collected in the embayments along the Strait of Juan de Fuca in 1999 and 54 from within Puget Sound proper in 2000.

A significant linear regression between log species richness and salinity was found in the Puget Sound estuary, although this regression was weak ($r^2 = 0.09$, $p < 0.01$). A potential reason for the weak relationship between species richness and salinity is that bottom salinity ranged only from 25.7 to 33.0 ppt among these sites. Using this regression, four sites (representing 2% of the estuarine area) were rated poor based on a lower-than-predicted species richness, and another four sites, representing 3% of the area, were rated fair. The remaining 95% of the estuarine area was rated good for benthic condition. The cause for the less-than-expected species richness at the sites rated poor is not readily apparent because all of these sites were rated good for sediment contaminant concentrations. In addition, sediment TOC was rated fair at three of the four sites surveyed, although a number of other sites with equivalent TOC measurements did not display depressed species richness.

Fish Tissue Contaminants Index

The fish tissue contaminants index for Puget Sound is rated fair. Fourteen percent of all stations sampled where fish were caught exceeded EPA Advisory Guidance values using whole-fish contaminant concentrations (Figure 6-16). For populations that consume whole fish, these risk calculations are appropriate. The contaminants found in fish tissues in Puget Sound most often included total PCBs.

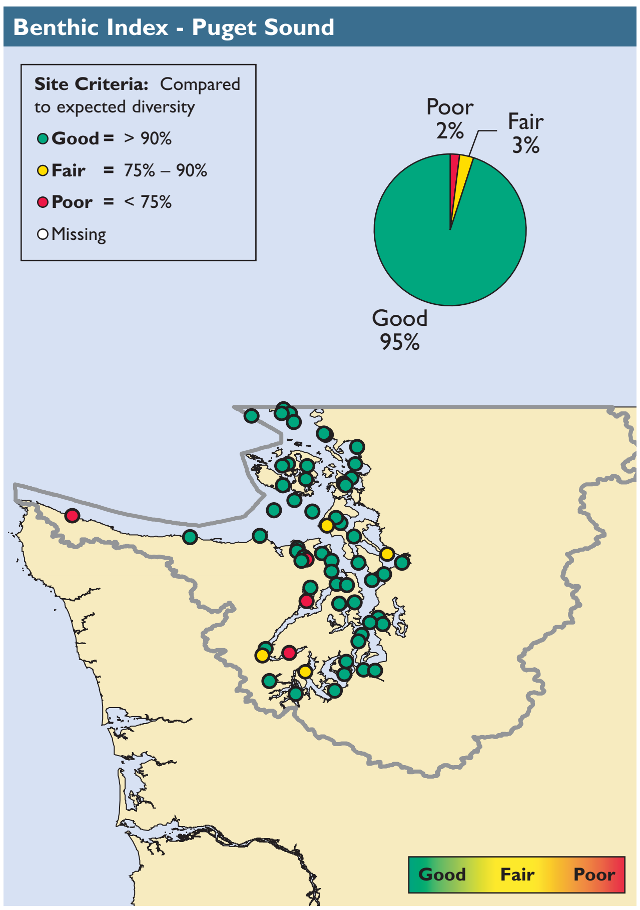


Figure 6-15. Benthic index data for Puget Sound, 1999–2000 (U.S. EPA/NCA).

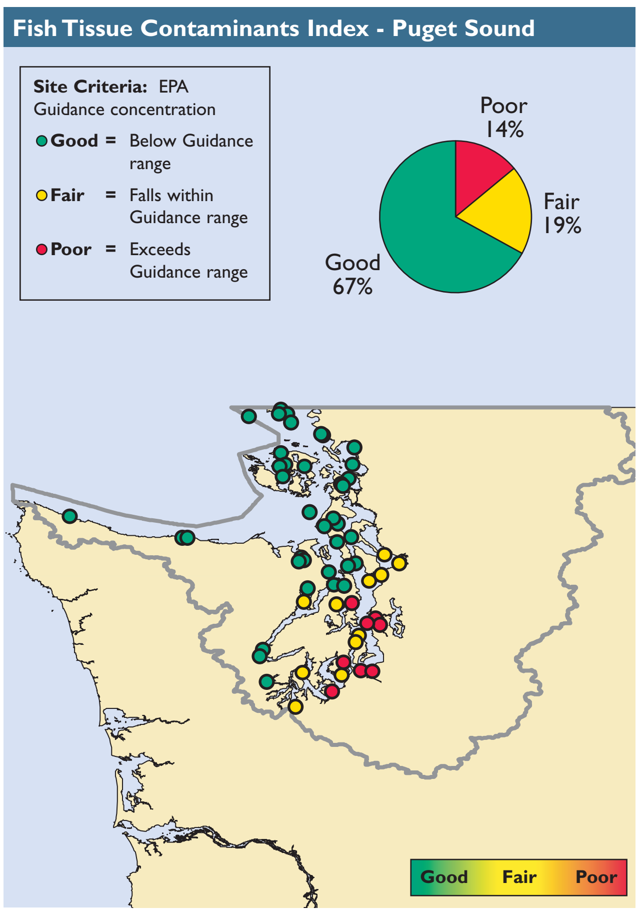


Figure 6-16. Fish tissue contaminants index data for Puget Sound, 1999–2000 (U.S. EPA/NCA).

Puget Sound Action Team

HIGHLIGHT

Efforts to Address Low Dissolved Oxygen Levels in Hood Canal, Washington

Hood Canal, a 60-mile-long, glacially carved fiord (see map), is one of the most scenic marine environments of Puget Sound, a region long renowned for its commercial and sport fishing and shellfish harvesting. Nestled between the Olympic Mountains and the central channel of Puget Sound, Hood Canal is experiencing increased growth and associated development. This activity may be at the heart of the reoccurring hypoxic conditions in Hood Canal, a problem that hit the spotlight in the spring of 2002 and again in the fall of 2003, when dead fish and other marine life washed up on Hood Canal's beaches. During 2004, the oxygen levels in Hood Canal dropped to all-time lows (PSAT, 2005a).

In 2005, the Washington State legislature acted on this problem, designating the PSAT as the state's lead agency for Hood Canal and the Hood Canal Coordinating Council as the local management board. The 2005 legislature charged both entities to work together to restore marine water quality and dissolved oxygen to levels adequate to support healthy marine life. The legislature also designated Hood Canal as the first Aquatic Rehabilitation Zone in Washington State. Most significantly, the legislature and Governor approved $22 million of new funds to scale-up corrective actions for Hood Canal (PSAT, 2005a).

Twenty-eight organizations, including state and federal agencies, universities, local and tribal governments, non-profit organizations, and research institutes, have formed a partnership to address low dissolved oxygen levels in Hood Canal and the effect of this problem on marine life. This partnership, the Hood Canal Dissolved Oxygen Program (HCDOP), will use data from monitoring, computer modeling, and demonstration projects to further develop and target the corrective actions designed to restore and maintain healthy levels of dissolved oxygen in Hood Canal (PSAT, 2005a).

For more information on the HCDOP's coordinated effort to recover Hood Canal, go to http://www.psat.wa.gov/Programs/hood_canal.htm.

Puget Sound Estuary and the Hood Canal (PSAT).

Puget Sound Action Team Indicators of Estuarine Condition

Factors such as water quality and the health of some marine animals signal improvements in the health of Puget Sound. Unfortunately, other environmental indicators warn of concerns for the Sound's overall ecosystem. In 2002, the PSAT issued its third biennial report on the health of Puget Sound, *Puget Sound's Health 2002* (PSAT, 2002). This report summarizes the condition of the Sound's marine waters, shoreline, 200 species of fish, 26 species of marine mammals, 100 species of sea birds, and thousands of species of marine invertebrates, using 19 indicators to determine whether the Sound's health is getting better or worse. As shown in Table 6-1, 8 of the 19 indicators classify Puget Sound's health as improving, 2 indicators classify the Sound's health as declining, 3 indicators show mixed results, 4 indicators document continued concerns about persistent toxic contamination problems, and 2 indicators are new indicators of nearshore habitat conditions. Additional information about recent conditions in Puget Sound and the PSAT's actions to restore the estuary is available at http://www.psat.wa.gov.

Water and Sediment Quality

Freshwater quality in the streams and rivers of the PSAT estuarine area is assessed using 8 parameters measured at 38 sites on a monthly basis. These eight parameters include measures of nutrients (e.g., total nitrogen, total phosphorus), pathogens (e.g., fecal coliform bacteria), and other physical parameters (e.g., water temperature, dissolved oxygen, pH, total suspended solids, and turbidity). Trend analysis for temperature based on data collected from 1995–2004 showed improvements in overall water quality index scores in all areas except the Stillaguamish River. The majority of rivers and streams monitored had good fecal coliform conditions (28 of 38 stations), the remainder of sites were rated fair, and none of the sites were rated poor for coliform conditions. The same percentage of sites were scored in good condition during wateryear 2005 as compared with wateryear 2000 (Personal communication, Brace, 2006).

Marine water quality monitoring in Puget Sound measures temperature, conductivity, salinity, density, dissolved oxygen, pH, light transmission, and nutrient (e.g., nitrate, nitrite, phosphate, silicate, and ammonium) and fecal coliform bacteria concentrations.

Table 6-1. Summary of Indicator Results from *Puget Sound's Health 2002* (PSAT, 2002)

Rating	Results
Improving	Area of commercial shellfish beds approved for harvesting Beaches used by recreational shellfish harvesters Water quality for recreation (measuring bacteria contamination) Size and frequency of major oil spills Reduced acreage of *Spartina* infestation, an aquatic nuisance plant species Freshwater habitat available to salmon (culverts allowing fish migration) Water temperature in rivers and streams Marine survival of Puget Sound wild coho salmon
Mixed	Harbor seal populations Herring populations Marine water quality
Declining	Scoter populations Rockfish populations
Persistent Toxic Contamination	Area of contaminated sediments (bottom of waterways) Contamination in mussels Contamination in harbor seals Occurrence of liver disease in English sole
New	Abundance and distribution of eelgrass beds Modifications to marine shorelines

Most of these parameters are monitored on a monthly basis. In general, regions of high concern with respect to marine water quality were located near urban areas or in poorly flushed areas such as Budd Inlet, Port Gardner, Bellingham Bay, Nisqually Reach, Carr Inlet, Case Inlet, and Henderson Inlet (Personal communication, Brace, 2006).

As of 2001, the WSDE had identified 112 contaminated sediment cleanup sites, representing an estimated 3,400 acres of marine sediments in Puget Sound (Figure 6-17) (WSDE, 2001; PSAT, 2002). Twenty-two of these sites have been cleaned up or require no further action. In 2002, cleanup activities were underway at 11 more sites. Action was still needed at an additional 79 sites, and 65 of these sites were in the investigation and design phases leading to cleanup. Between 1997 and 1999, 8,700 acres (1.5%) of soft sediment in Puget Sound (excluding the San Juan Islands and the Strait of Juan de Fuca) were contaminated, and approximately 83,000 acres were less severely contaminated. Long-term monitoring by the WSDE indicates that concentrations of some contaminants (e.g., naphthalene, low molecular-weight PAHs) have increased during the past few years, whereas concentrations of other contaminants (e.g., copper, mercury) have decreased (PSAT, 2002).

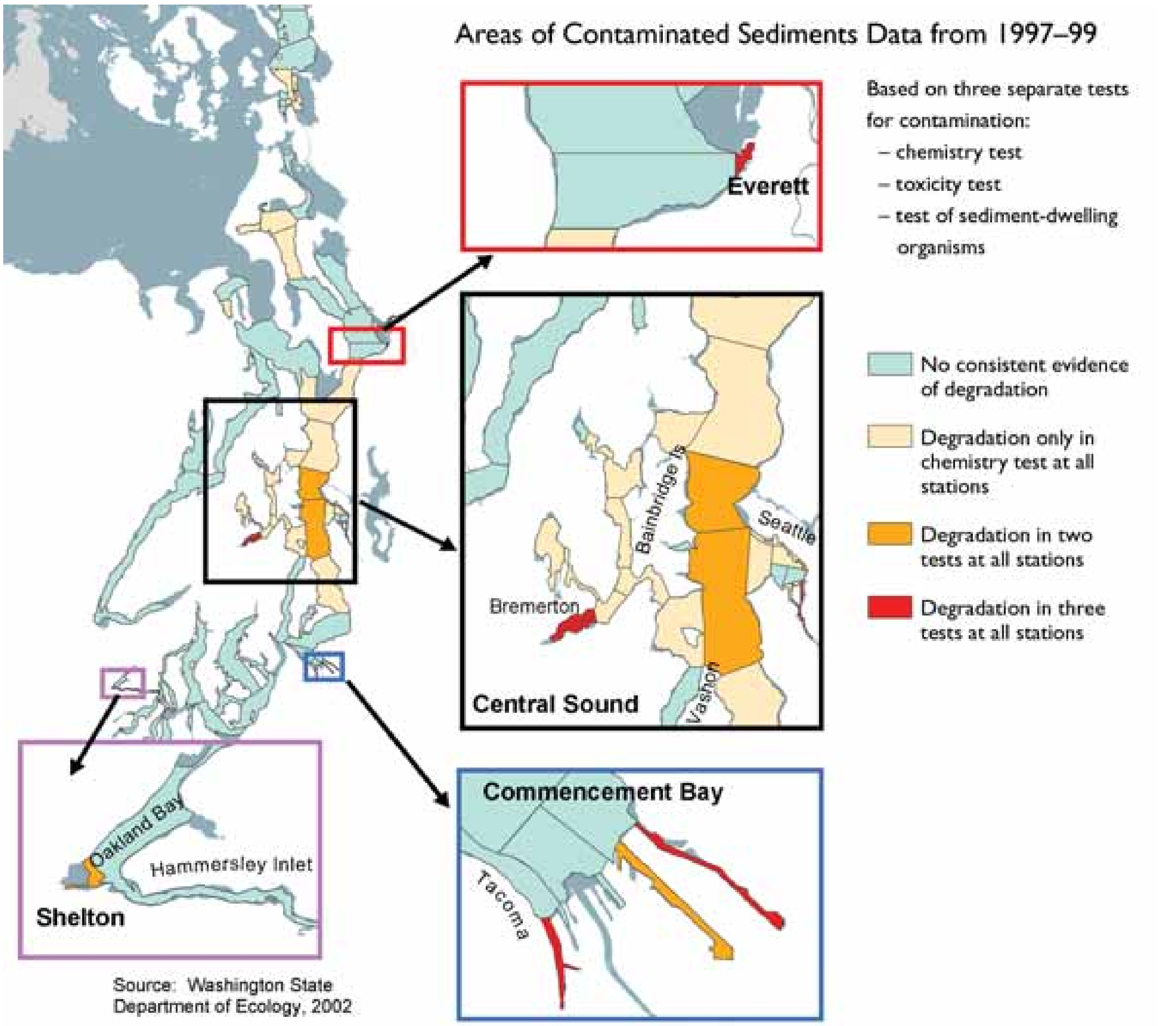


Figure 6-17. Sediment contamination map of Puget Sound (PSAT, 2002).

Habitat Quality

Human development significantly alters the Puget Sound environment, and habitat loss and degradation are major threats to the health of the Sound's fish and wildlife. Protecting and restoring habitat is a key element of the strategy to recover wild salmon and a priority of the PSAT. Habitats at risk from direct human development and construction activities include freshwater habitat for salmon and other fish, as well as Puget Sound's fringe of shallow subtidal, intertidal, and shoreline habitats known as the marine nearshore. For example, infestations of *Spartina*, a salt marsh grass native to the eastern United States, can overtake native western grass species, making these habitats less useful to the area's fish, shellfish, and birds. Between 1999 and 2001, the Washington Department of Agriculture and its partners reduced *Spartina* infestations throughout most of the study area, except in Snohomish County (PSAT, 2002).

Eelgrass beds are also an environment of particular interest in considering habitat quality in Puget Sound. Based on the first year of a new eelgrass monitoring project, the Washington Department of Natural Resources (WDNR) estimates that Puget Sound is home to approximately 26,000 acres (or nearly 41 mi^2) of eelgrass. Eelgrass beds are divided into two habitat types. A significant amount of eelgrass occurs in flats, which can be large shallow bays or small pocket beaches, and close to one-fifth of all the eelgrass in Puget Sound grows in one large flat, Padilla Bay. Eelgrass also occurs in narrow fringing beds along steeper shorelines. These fringing beds are used as corridors for migrating salmon and other wildlife, and about one-half of all eelgrass in Puget Sound occurs in fringing beds. Eelgrass and other seagrass species are used as an indicator of estuary health because they respond to many natural and human-caused environmental variables, and changes in the abundance or distribution of this resource are likely to affect other species that depend on eelgrass habitat (PSAT, 2002).

Living Resources

A variety of living resource indicators are used to assess the health of Puget Sound. Population trends in fish and wildlife can provide insight into the state of the region's ecosystem. The extent of area open to shellfish harvesting is an indicator of the amount of contamination in the Sound. In addition, the PSAT examines the levels of several chemicals in the tissue of mussels and harbor seals to determine how these contaminants are behaving in the food chain. In general, the levels of pollutants in Puget Sound vary regionally, with higher levels found in marine life near urban areas. The effects of contaminants on the health of the area's wildlife is assessed by monitoring the occurrence of liver lesions in English sole (PSAT, 2002).

The PSAT uses the population trends and spawning potential of several key fish and wildlife species as indicators of estuary health. In 2000 and 2001, coho salmon appeared to be returning to Puget Sound in small but increased numbers compared with returns in the late 1990s. Rockfish, which can live for 80 to 100 years, are declining at an alarming rate, and the spawning potential for rockfish measured in 2000 was only 7% to 12% of the levels recorded in the late 1970s (PSAT, 2002; 2005b). Scientists believe that this decline, coupled with the decline of many other marine fish species, may point to significant problems with the entire Puget Sound ecosystem. A number of marine bird species have declined by 50% or more in the past 20 years. Populations of scoters, which are large black diving ducks with orange bills, have declined by 57% in the past 20 years. During the same period, 13 out of 18 other marine diving birds in Puget Sound have shown significant population declines. Some bird species, such as the marbled murrelets, have experienced population declines of more than 90% (PSAT, 2002).

Washington is among the top shellfish-producing states in the nation, and the health of shellfish beds and the suitability of shellfish for consumption closely reflect conditions of the state's shellfish-growing environment. The Washington Department of Health (WDOH) classifies shellfish-growing areas to provide information about the extent to which contamination restricts the ability to harvest shellfish, and changes in the classification of these areas can reflect problems related to how land is used and cared for in the nearby watersheds. Since 1980, nearly one-quarter of the approximately 140,000 acres available for direct commercial shellfish harvesting has been downgraded in classification because of bacterial contamination. During 2000–2001, the WDOH downgraded 849 acres and upgraded 1,540 acres. These areas were relatively small when compared to the approximately 33,000 acres that were downgraded in the 1980s; however, the net upgrade of 691 acres in 2000 and 2001 indicates that pollution-control efforts appear to be balancing increasing water quality threats (PSAT, 2002).

Mussels filter large quantities of water and can accumulate any toxic contaminants that are present in the water or adsorbed on phytoplankton. The NOAA National Mussel Watch Program data collected through 1998 demonstrated that multiple Puget Sound locations experienced long-term declining trends in the concentrations of banned pesticides (e.g., chlordane, DDT) and several metals (e.g., lead, mercury) in mussel tissue. However, it also appeared that PCB levels in mussels were no longer decreasing and possibly increasing during the mid- to late 1990s. NOAA scientists have used newly available data from 1999–2001 to construct a 16-year record of PCB levels and to identify three important patterns. First, concentrations of PCB in mussels have generally been declining during the two decades following the ban on most PCB uses in the 1970s. Second, the highest concentrations were consistently found in mussels from central Puget Sound sites, such as Four Mile Rock (north Elliott Bay) and adjacent areas, confirming that this urban area is a long-term source for PCBs. Finally, the long-term downward trend was interrupted in the mid-1990s by increases in PCB levels at many locations. Between 1999 and 2000, PCB concentrations in mussels began to decrease again. These patterns indicate that it is uncertain whether PCBs will continue to decline at the rates seen from the 1970s to early 1990s (PSAT, 2002).

Harbor seals feed relatively high in the food chain and accumulate contaminants from their food (primarily fish) in their fatty tissue. As a result of the widespread restrictions placed on PCB and DDT use in the early 1970s, there was a sharp decline in measured levels of these contaminants in Puget Sound harbor seals through the 1970s and afterwards. These declines have leveled off since the mid-1980s as contaminated land and sediments continue to release PCBs into the marine food chain (PSAT, 2002).

Scientists who routinely monitor English sole at six Puget Sound locations have found significantly elevated occurrences of liver lesions at two urban sites and one near-urban site (O'Neill et al., 2001). PAH concentrations in sediments were also elevated at these three sites. These results indicate that the health of bottom-dwelling fish in Puget Sound is worse in areas where sediments are contaminated (Figure 6-18). The risk of developing liver disease increased in English sole sampled along the Seattle waterfront between 1989 and 1998, but decreased in 1999 and remained low in 2000; no increasing or decreasing trends were evident at the other sites. The lower occurrence of liver lesions in English sole during 1999 and 2000 may have resulted from the numerous sediment-capping projects that have been completed to the north and south, as well as in the immediate vicinity of the Seattle waterfront, since 1989. Collectively, these projects may have lowered the PAH concentrations in sediments and reduced exposures to English sole feeding in this area (PSAT, 2002).

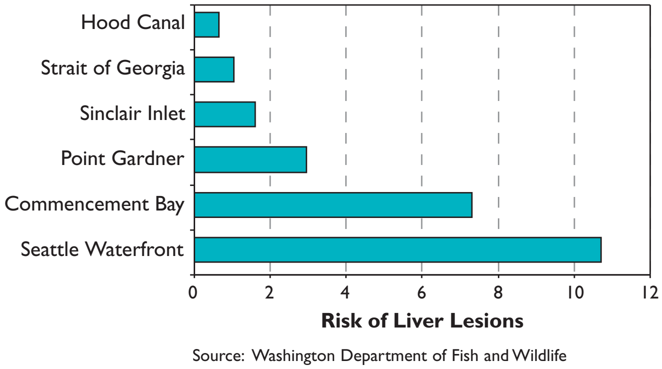


Figure 6-18. Risk of liver disease in English sole based on geographical location (PSAT, 2002).

Environmental Stressors

Shoreline modifications, such as bulkheads or seawalls, tend to harm habitat through the conversion of tidelands to uplands. Modification also indirectly affects habitat by altering nearshore processes. The amount of modified shoreline in an area can be a useful indicator of the effect people have on the nearshore environment. In 2000, scientists with the Nearshore Habitat Program at the WDNR completed a statewide inventory to assess the extent of modification along saltwater shorelines (Berry et al., 2001). Approximately one-third of all saltwater shorelines in Washington have some kind of shoreline modification structure. In the PSAT study area, Snohomish and King counties have the most extensively modified shorelines (PSAT, 2002).

Current Projects, Accomplishments, and Future Goals

Protecting and restoring Puget Sound is a long-term commitment that requires continuing efforts by government, tribes, private industry, environmental and citizen groups, and individual residents throughout the region. Although progress has been made on many fronts, new challenges have emerged, and many existing problems persist as the region's population grows and the area of developed lands expands within the basin. The PSAT's partnership prepared the *Puget Sound Water Quality Work Plan: 2003–2005* (PSAT, 2003b) as the fourth biennial effort to specify and articulate actions to continue implementing the *2000 Puget Sound Water Quality Management Plan* (PSAT, 2000). The work plan outlines a two-year strategy to achieve measurable progress in protecting Puget Sound. More specifically, the plan identifies ongoing issues (that require more than two years to address), as well as associated priorities and recommended actions to pursue during the biennium. These issues for the 2003–2005 work plan include the following:

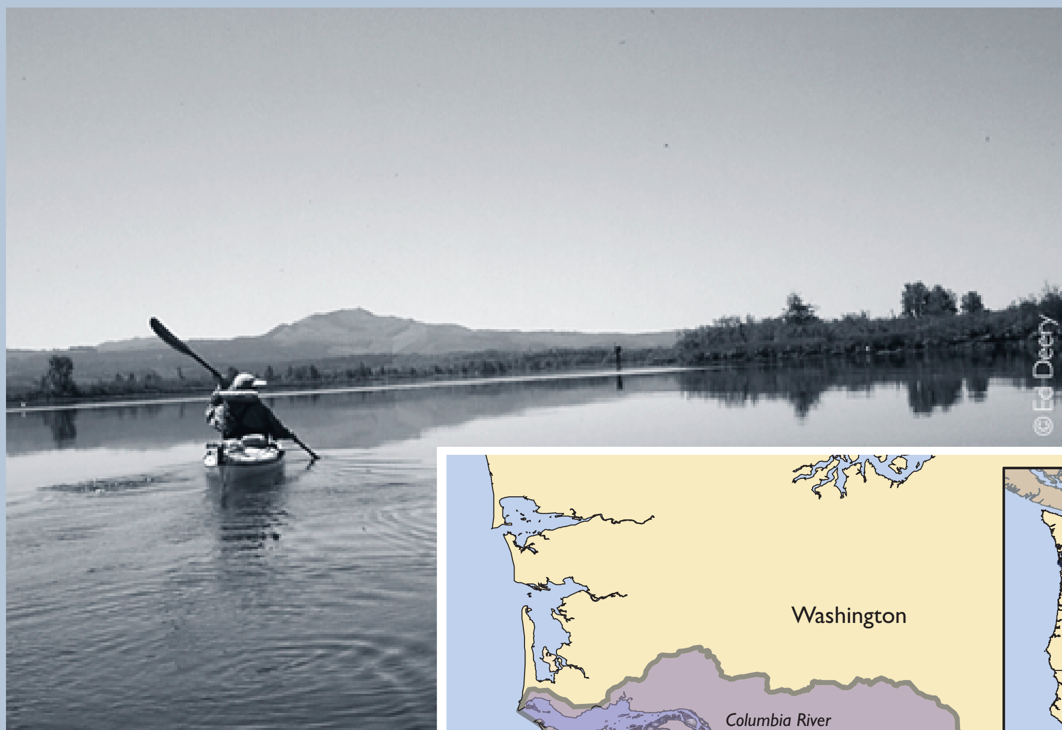
- Declines in marine species (e.g., salmon, groundfish, and orcas)
- Freshwater and marine habitat loss and alteration
- Water quality problems that continue to threaten the safe harvest of shellfish
- Stormwater runoff impacts on water quality, streams and wetlands, and biological resources
- Bacterial contamination from on-site sewage systems
- Non-native aquatic species that threaten the biodiversity, ecological stability, and commercial, agricultural, or recreational activities that depend on the Sound.

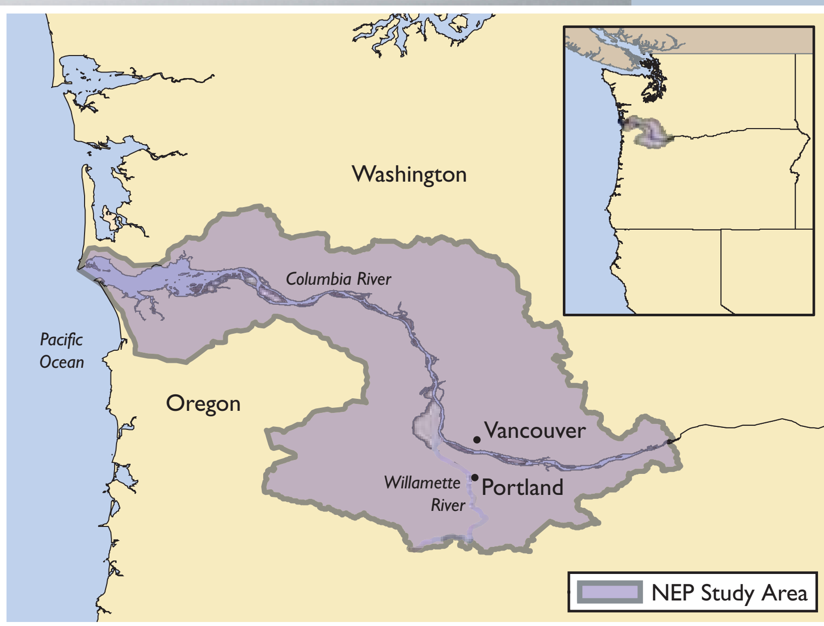
Conclusion

The overall view of the health of Puget Sound is clearly complex, with different indicators demonstrating different environmental quality results and trends over time. Encouraging signs have been noted for about half of the indicators measured by the NCA survey, as well as for the PSAT's shellfish harvesting, swimming, *Spartina* infestation, and salmon population indicators. Mixed or discouraging signals for the other NCA indicators and for a variety of fish, wildlife, and persistent toxic contamination indicators were observed by both EPA and the PSAT. PCB contamination remains a major concern, and several other chemicals are being closely watched to determine potential human health and ecological risks. Based on data from the NCA estuarine survey, the overall condition of Puget Sound is rated fair.

The Puget Sound provides invaluable habitat for orca whales (Captain Budd Christman, NOAA Corps).

Lower Columbia River Estuary Partnership





www.lcrep.org

Background

The 4,300-mi^2 Lower Columbia River Estuary extends downstream from the Bonneville Dam at river mile 146 to the mouth of the Columbia River and into the Pacific Ocean to the 3-mile limit, which represents the point where coastal waters are no longer influenced by the plume of fresh water flowing into the ocean. This estuarine system contains a wide variety of habitats associated with marine, estuarine, and freshwater influences. These habitats range from open water to bottom sediments, tidal flats, and the riparian zone. The Lower Columbia River Basin drains approximately 18,000 mi^2, about 7% of the entire Columbia River Basin (LCREP, 1999).

The Lower Columbia River Estuary Partnership's (LCREP's) *Comprehensive Conservation and Management Plan, Volume 1* (LCREP, 1999) identifies many actions that can be conducted in the study area to improve water quality and habitat in the Lower Columbia River Estuary. The LCREP recognizes that many impacts in the study area are the result of problems or sources elsewhere in the Columbia River basin; therefore, efforts in the study area will be less effective if changes in the entire basin do not occur. For this reason, it is important not to separate the Lower Columbia River Estuary from the larger watershed. Although the LCREP's CCMP includes many actions that specifically address the study area, it also considers the impacts from the larger watershed and incorporates actions to address these impacts, where needed.

Environmental Concerns

The LCREP completed its CCMP for the Lower Columbia River Estuary in June 1999. The CCMP contains 43 specific actions to address 7 priority issues: biological integrity, impacts of human activity and growth, habitat loss and modification, conventional pollutants, toxic contaminants, institutional constraints, and public awareness and stewardship. As part of the planning process, a comparative risk assessment process helped prioritize the LCREP's activities and identified loss of habitat as the greatest risk to the health of the Estuary. Based on this assessment, the LCREP has chosen to direct much of its energy toward the protection and restoration of habitat.

Population Pressures

The population of the 11 NOAA-designated coastal counties coincident with the LCREP study area increased by 78.4% during a 40-year period, from 0.9 million people in 1960 to 1.6 million people in 2000 (Figure 6-19) (U.S. Census Bureau, 1991; 2001). This rate of population growth was one of the lowest for the West Coast NEPs and was much lower than the population growth rate of 100.3% for the collective NEP-coincident counties of the West Coast region. In addition, the LCREP study area's population density of 138 persons/mi^2 was the third-lowest density of the West Coast NEPs (U.S. Census Bureau, 2001). This estuary is not surrounded by the large metropolitan areas that are characteristic of some other West Coast NEPs, such as Puget Sound or the San Francisco Estuary.

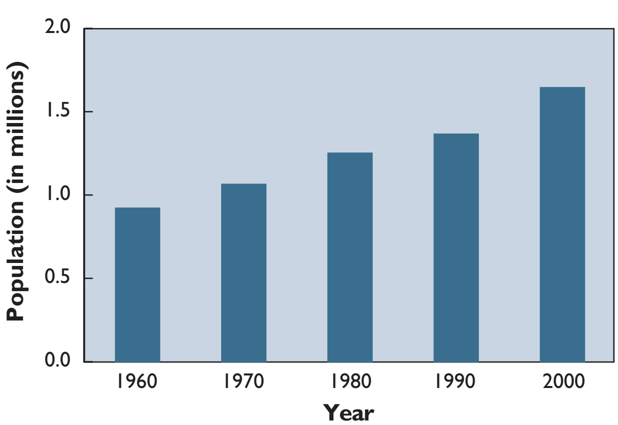


Figure 6-19. Population of NOAA-designated coastal counties of the LCREP study area, 1960–2000 (U.S. Census Bureau, 1991; 2001).

NCA Indices of Estuarine Condition—Lower Columbia River Estuary

The overall condition of the Lower Columbia River Estuary is rated fair based on three of the indices of estuarine condition used by the NCA (Figure 6-20). The water quality and sediment quality indices are rated fair, and the fish tissue contaminants index is rated poor. Although data on the condition of the benthic community were collected for this estuary, the Lower Columbia River Estuary could not be rated using an index based on deviations from the expected species richness. Figure 6-21 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 ODEQ and the WSDE from 79 stations sampled in the LCREP estuarine area in 1999 and 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.

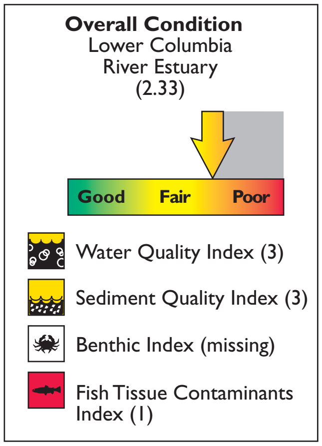


Figure 6-20. The overall condition of the LCREP estuarine area is fair (U.S. EPA/NCA).

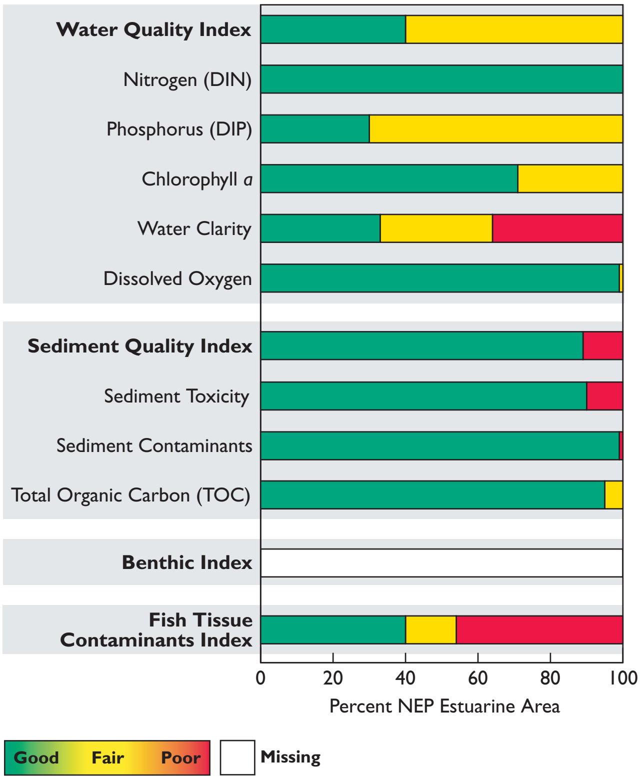


Figure 6-21. Percentage of NEP estuarine area achieving each ranking for all indices and component indicators — Lower Columbia River Estuary (U.S. EPA/NCA).

Coho salmon are found in the Lower Columbia River Estuary (Oregon Department of Fish and Wildlife).

Water Quality Index

Based on NCA survey results, the water quality index for the Lower Columbia River Estuary is rated fair (Figure 6-22). This index was developed using NCA data on five component indicators: DIN, DIP, chlorophyll *a*, water clarity, and dissolved oxygen. Water quality was rated fair in 60% of the estuarine area due to limited water clarity and moderate DIP concentrations.

Dissolved Nitrogen and Phosphorus | The Lower Columbia River Estuary is rated good for DIN concentrations and fair for DIP concentrations. One-hundred percent of the estuarine area was rated good for DIN concentrations, and 70% of the estuarine area was rated fair for DIP concentrations.

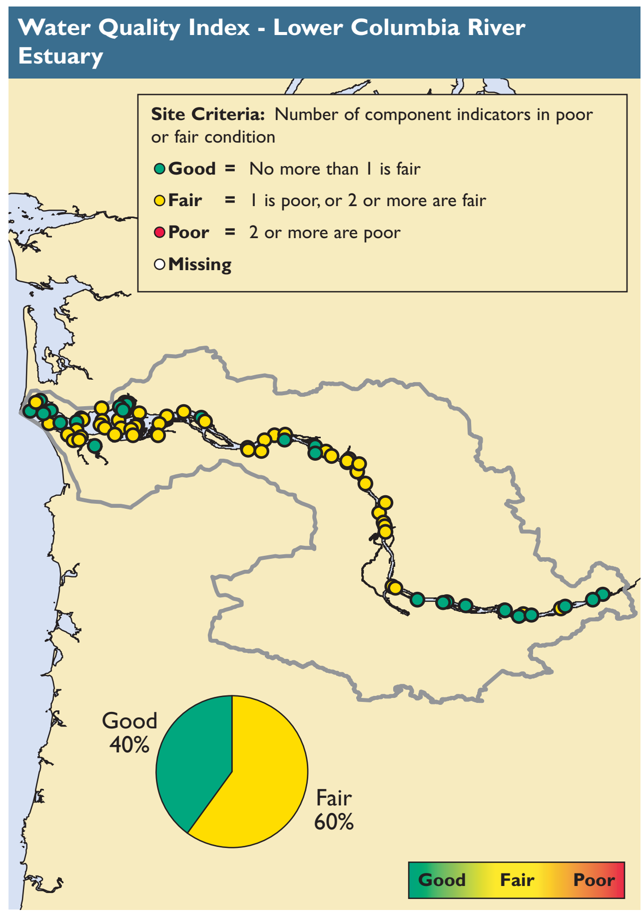


Figure 6-22. Water quality index data for the Lower Columbia River Estuary, 1999–2000 (U.S. EPA/NCA).

Lower Columbia River Estuary Partnership

Chlorophyll a | Chlorophyll *a* concentrations in the Lower Columbia River Estuary are rated good. Approximately 29% of the estuarine area was rated fair for this component indicator, with the remaining 71% of the area rated good. None of the LCREP's estuarine area was rated poor for chlorophyll *a* concentrations.

Water Clarity | Water clarity in the Lower Columbia River Estuary is rated poor. Approximately 35% of the estuarine area was rated poor for water clarity, and an additional 31% of the area was rated fair.

Dissolved Oxygen | Dissolved oxygen conditions in the Lower Columbia River Estuary are rated good, with 99% of the estuarine area rated good for this component indicator. Although conditions in the Estuary appear to be good for dissolved oxygen, measured values reflect daytime conditions, and some areas of the Estuary may still experience hypoxic conditions at night.

Sediment Quality Index

The sediment quality index for the Lower Columbia River Estuary is rated fair, with 11% of the estuarine area exceeding thresholds for one or more of the three component indicators: sediment toxicity, sediment contaminants, or sediment TOC (Figure 6-23).

Sediment Toxicity | The Lower Columbia River Estuary is rated poor for sediment toxicity, with 10% of the estuarine area rated poor for this component indicator.

Sediment Contaminants | The Lower Columbia River Estuary is rated good for sediment contaminant concentrations, with only 1% of the estuarine area rated poor for this component indicator and none of the area rated fair.

Total Organic Carbon | The Lower Columbia River Estuary is rated good for sediment TOC. Ninety-five percent of the estuarine area was rated good for this component indicator, and 5% of the area was rated fair. None of the LCREP's estuarine area was rated poor for sediment TOC concentrations.

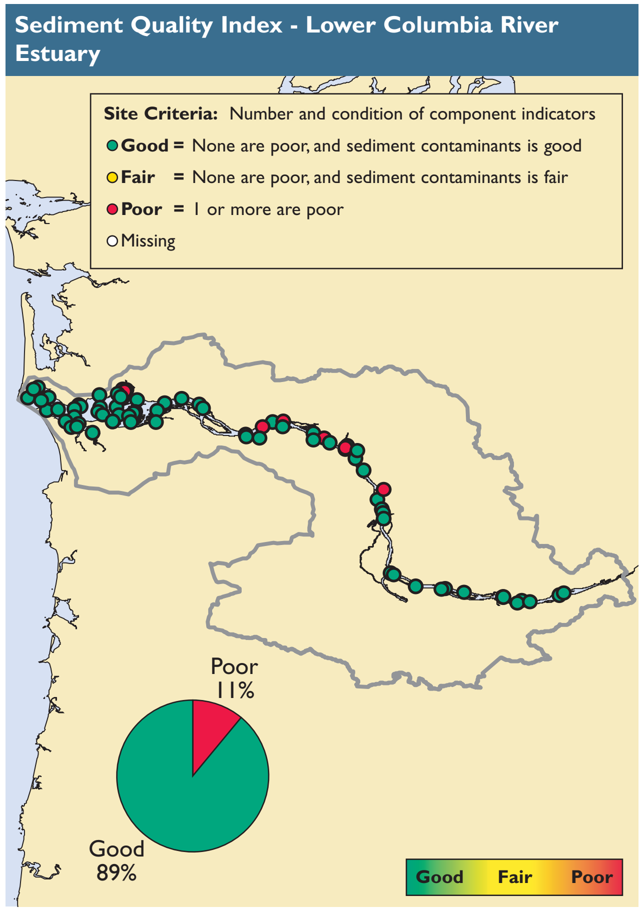


Figure 6-23. Sediment quality index data for the Lower Columbia River Estuary, 1999–2000 (U.S. EPA/NCA).

Benthic Index

The condition of the benthic invertebrate community in the Lower Columbia River Estuary currently cannot be rated using an index based on deviations from the expected species richness. This conclusion was based on 75 benthic samples taken in the LCREP estuarine area, of which 29 samples were collected in the side embayments in 1999 and 46 were taken in the main stem of the Columbia River in 2000. The NCA approach requires a significant regression between salinity and the log of species richness; however, this relationship was not significant in the Lower Columbia River Estuary ($r^2 = 0.03$, $p > 0.10$). The lack of a significant regression was not due to an inadequate range in salinity because salinity for the Estuary ranged from 0.04 to 31.3 ppt. Species richness was low in the Estuary, averaging only 6.0 species per sample over all the samples and 4.4 species per sample in the samples collected along the main stem of the Columbia River. It is possible that stressors (e.g., dredging of the channel) or naturally low diversity in the Estuary obscured any simple relationship between salinity and species richness; however, when samples collected within 99 feet of the shipping channel were removed from the regression analysis, the regression relationship improved, but was still not significant due to the wide range of species richness values at freshwater sites. EPA was unable to provide a relative benthic index assessment for the Lower Columbia River Estuary using the NCA survey data, and additional data analysis will be required to find an alternate approach for the Estuary.

Fish Tissue Contaminants Index

The fish tissue contaminants index for the Lower Columbia River Estuary is rated poor. Forty-six percent of all stations sampled where fish were caught exceeded the EPA Advisory Guidance values using whole-fish contaminant concentrations and were rated poor (Figure 6-24). For populations that consume whole fish, these risk calculations are appropriate. The contaminants found in fish tissues at elevated concentrations in the Lower Columbia River Estuary most often included total PCBs, DDT, DDD, DDE, and mercury.

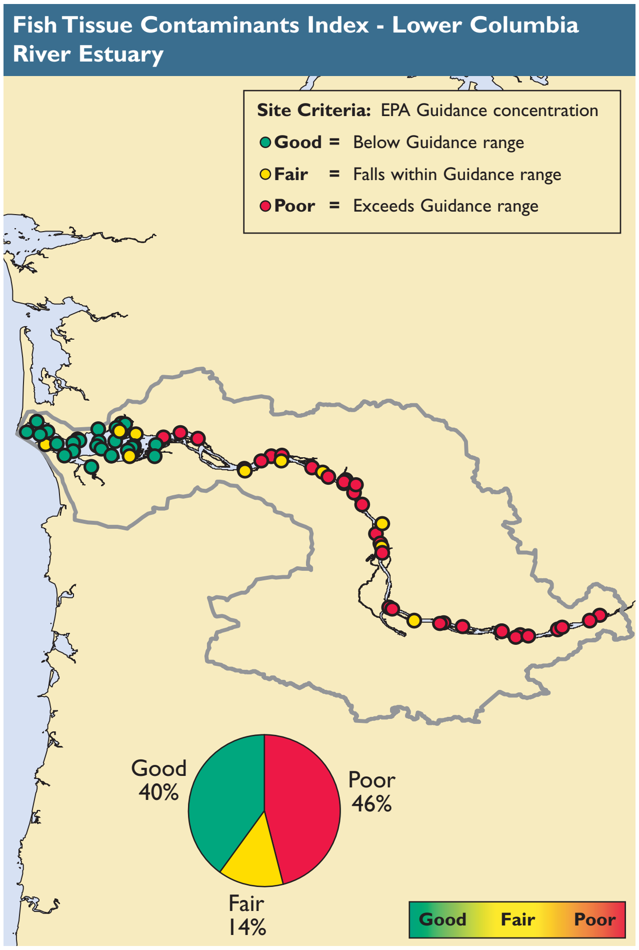


Figure 6-24. Fish tissue contaminants index data for the Lower Columbia River Estuary, 1999–2000 (U.S. EPA/NCA).

Astoria Bridge (LCREP).

Lower Columbia River Estuary Partnership

Habitat Protection and Restoration in the Lower Columbia

The floodplain of the Lower Columbia River Estuary historically contained extensive and diverse wetland and riparian habitats critical to fish and wildlife; however, the impacts of development over the past 150 years have significantly altered this complex system. Although the Estuary still provides essential habitat for a great number of freshwater and saltwater fish, numerous shellfish, a variety of marine and water-dependent land mammals, and over 175 species of birds, it is a very different area from the one explored by Lewis and Clark (ANEP, 2001a; LCREP, 2006). Loss of wetland habitat is one of the greatest problems being addressed by the LCREP. Evidence indicates that more than one-half of the wetland areas in the Estuary have been lost since 1870 as a result of diking, draining, filling, dredging, and flow regulation. Forested marshes in the lower 46 miles of the Lower Columbia River have decreased as much as 75%, whereas barren lands and open water areas have increased substantially (ODEQ, 2000).

The LCREP has made habitat restoration and protection a top priority. The Partnership's CCMP (LCREP, 1999) presents six actions specifically directed toward habitat protection and restoration, and several other actions involve a habitat element. The LCREP is working to establish a coordination structure to ensure that projects are developed using the best available scientific information and prioritized according to the life-cycle needs of endangered species, such as salmon and other native organisms.

Since 1999, the LCREP's habitat restoration program has funded 22 projects, resulting in the protection of more than 1,200 acres and the restoration of more than 850 acres. The program has also spent $2.7 million to leverage nearly $9 million in restoration funding with over 50 partners throughout Oregon and Washington, resulting in 4,600 total acres protected or restored in the Lower Columbia River Estuary (LCREP, 2005b). Some examples of these restoration projects are discussed in the following sections.

Reconnecting historic floodplains to regular tidal wetting, such as seen on this 80-acre parcel, is one of the habitat restoration techniques used by partners of the LCREP (Columbia Land Trust).

Scappoose Bay Conservation Plan and Restoration Projects

The LCREP worked with The Wetlands Conservancy to conduct an inventory of naturally valuable habitat within the 8,960 acres of the Scappoose Bay Bottomlands. Partnering with the Scappoose Bay Watershed Council, the LCREP allocated grant funding to remove multiple fish barriers, install fish-friendly bridges, and fence stream riparian areas. The planning area for these activities covers 200 acres of cattle farmland (The Wetlands Conservancy, 2004).

Grays Bay Area Conservation/Restoration Projects

Partnering with the Columbia Land Trust, the LCREP funded a multi-level restoration effort with grant funding from the EPA Watershed Initiative and the Bonneville Power Administration. At 5 different sites, the project resulted in the conservation of 880 acres of floodplain, the reconnection of 500 acres of historic floodplain, the restoration of 300 acres of salmon habitat, and the enhancement of 3 miles of riparian habitat (CREST, 2006).

Strategic Prioritization for Habitat Restoration

As a next step in the Partnership's habitat restoration program, the LCREP has initiated an effort with partners and interested parties to develop a focused Strategic Habitat Restoration Plan, which will detail the most ecologically beneficial locations for restoration and describe the most appropriate types of restoration strategies to undertake in those areas. Beginning in 2006, the LCREP will employ this tool in the restoration project selection process, which will identify project value based on its significance to the Columbia River ecosystem. Ultimately, projects selected through this framework will provide greater cumulative benefits to the entire system, while adaptive management and effectiveness monitoring of these projects will ensure continued progress and improvements to the system's health over the long term (Evans et al., 2006).

Replacing undersized, non-performing culverts, such as the one seen here on Honeyman Creek, allows for full fish passage and tidal influence in tributary streams. The photo on the left is a pre-restoration representation, whereas the photo on the right is after restoration (Scappoose Bay Watershed Council [left] and the LCREP [right]).

Lower Columbia River Estuary Partnership Indicators of Estuarine Condition

The LCREP has developed a set of six environmental indicators that attempt to provide accessible information about the health of the Lower Columbia River Estuary. These indicators are considered key measures of the Estuary's ecological integrity and are meant to be a step in the process of relaying important information about the estuarine system to policy makers and the public. The LCREP's environmental indicators are the following:

- Habitat (loss, opportunity, protection and conservation, restoration, net change)
- Biotic integrity (native species assessment)
- Land use (land-use changes, riparian integrity)
- Water quality (concentrations of toxic contaminants and convention pollutants, temperature, and dissolved oxygen)
- Stewardship (children's educational and field programs, volunteer monitoring, and restoration)
- Appreciation (park visitors, recreational and shellfish permits, membership in environmental non-governmental organizations).

The LCREP's indicators were carefully chosen based on a number of factors. Each indicator had to be a measurable and quantifiable value, be understandable to the public, have sufficient historical records to show trends, relate to the overall condition of the Estuary, allow for an assessment of present conditions and a prediction of future trends, provide sufficient facts to support goal-setting and program management, and provide targets and endpoints for the restoration of the Estuary.

Water and Sediment Quality

In 2004 and 2005, the LCREP partnered with USGS and the ODEQ to monitor water quality at three fixed stations along the Lower Columbia River and the Willamette River. Selected water samples were analyzed for a variety of parameters, including nutrients, chlorophyll *a*, suspended sediment, total coliforms, trace elements, and a variety of chemical contaminants (LCREP, 2006). Water quality sampling using semipermeable membrane devices (SPMDs) was also conducted in the Lower Columbia River and its tributaries during 2003 and 2004. SPMDs are used to mimic the accumulation of contaminants in the fatty tissues of fish. During this study, concentrations of dieldrin and PCBs commonly exceeded human health criteria; DDT compound concentrations exceeded the criteria less frequently; and PAH concentrations were below the criteria (Johnson and Norton, 2005). Additional SPMD samples were collected in 2005. More information about the LCREP's water quality monitoring efforts is available at http://www.lcrep.org.

Water temperatures and dissolved oxygen concentrations are also monitored in the Lower Columbia River Estuary. Cool (68 degrees Fahrenheit or less) water temperatures in the Estuary are essential for native aquatic species, which experience stress as temperatures rise. Average and maximum summer water temperatures have increased by approximately 4 degrees since 1938. In 2002, measured dissolved oxygen concentrations in the Estuary were above Washington's and Oregon's state standard of 8 mg/L (LCREP, 2005a).

Habitat Quality

Habitats in the LCREP study area have been changing over time, and the acreage of developed land and open water in the Lower Columbia River Estuary has increased substantially since the 1880s. At the same time, the areal extents of the Estuary's tidal swamps and marsh habitat have decreased by 77% and 57%, respectively. Although the average tree cover in most of the study area (the region near Longview, WA, was excluded from this analysis) decreased from 46% to 24% between 1972 and 2000, the amount of area with thick, dense canopy tree cover has increased since 1986 (LCREP, 2005a).

The LCREP and its partners have undertaken several measures to monitor, assess, and map habitats in the Estuary. The Partnership's habitat status monitoring program was established to create a long-term data set used to assess the status and trends of the Estuary's aquatic habitats (LCREP, 2006). The Lower Columbia River and Estuary Ecosystem Classification System is under development by the LCREP, USGS, and the University of Washington to delineate the Estuary's different landscape structures and guide habitat monitoring efforts (Simenstad et al., 2005). Field work has also been combined with satellite images, digital aerial photos, bathymetry, LIght Detection And Ranging (LIDAR), and high-resolution hyperspectral images to develop detailed and comprehensive habitat maps and habitat data layers (LCREP, 2006).

Living Resources

Approximately 24 threatened and endangered species of plants, fish, animals, and birds can be found in the Lower Columbia River Estuary. Although populations of some of these species (e.g., bald eagles) are slowly recovering, others (e.g., chinook salmon) are not. The number of occupied bald eagle nests along the Columbia River has been increasing slowly since 1978; however, the productivity of those nests located below river mile 60 remains low due to significant contaminant concentrations (e.g., DDE, PCBs, and dioxins) found in the egg shells collected from this portion of the Estuary. During the past hundred years, the number of chinook salmon returning to spawn in the Estuary has decreased from a range of 450,000–550,000 fish to an average of 100,000 salmon. Although a variety of factors (e.g., hydropower operations, harvest, ocean conditions) contributed to this population decline, habitat loss and degradation is cited as the leading cause. Since reaching a low of 25,000 returning fish in 1999, chinook salmon returns have improved slightly (LCREP, 2005a).

At least 81 invasive species (e.g., American shad, purple loosestrife, Chinese mystery snail, Eastern snapping turtle, nutria) have been introduced to the Lower Columbia River Estuary since the mid-1880s. The majority of these species originated in North America, and domestic shipping is most likely an important vector for the introduction of new species to the Estuary. The rate at which new species are discovered has increased from one every five years between the 1880s and the 1970s to one every five months since 1994. Although this rate of increase can be attributed to more new species being introduced to the Estuary, an increasing number of improved surveys to monitor invasive species has also contributed to the growing number of species detected. For example, an invasive species survey conducted at 134 stations in the LCREP study area during 2002 and 2003 identified 269 aquatic species. Twenty-one percent of these were invasive species, and the origins of another 45% of the identified species were unknown (Sytsma et al., 2004; LCREP, 2005a).

Toxic contaminants have been detected in the fatty tissues of fish and wildlife living in the Lower Columbia River Estuary, and interim health advisories have been issued for dioxins, PCBs, and pesticides in the fatty tissue of all fish in the Estuary (LCREP, 2005a; U.S. EPA, 2005a). Starting in 2005, the LCREP and NOAA began testing juvenile salmon tissue and stomach contents for concentrations of chemical contaminants. The resulting data will be used to assess the effects of toxic contaminants on the survival and productivity of the Estuary's juvenile salmon and to assist with the development of three models designed to identify contaminant sources; describe potential modes and routes of transport, exposure, and uptake; and analyze the possible effects on survival and productivity of listed salmon species (LCREP, 2006).

Environmental Stressors

The LCREP uses the percentage of the study area's impervious surface and the number of innovative stormwater management projects implemented as indicators of estuarine condition. Between 2000 and 2005, the amount of impervious cover in the LCREP study area has increased significantly. Innovative stormwater management projects have been implemented in the study area, especially in the Portland and Vancouver areas (LCREP, 2005a). These projects are highlighted in the LCREP's *Lower Columbia River Field Guide to Water Quality Friendly Development*, which provides local examples of different stormwater management techniques and is available online at http://www.lcrep.org/fieldguide.

Current Projects, Accomplishments, and Future Goals

Monitoring the Estuary to track its condition over time and to develop a better understanding of the highly complex ecosystem is another critical element of the LCREP. During the development of its CCMP, the LCREP and a highly dedicated group of monitoring organizations spent almost two years developing the *Lower Columbia River Estuary Plan, Volume 2: Aquatic Ecosystem Monitoring Strategy for the Lower Columbia River-Information Management Strategy* (LCREP, 1998). The Monitoring Strategy of this report lays out a phased-in approach to implementing a comprehensive monitoring plan for the Lower Columbia River Estuary. Special projects have been initiated to enhance understanding of the Estuary, with attention paid to addressing the monitoring needs of salmon restoration.

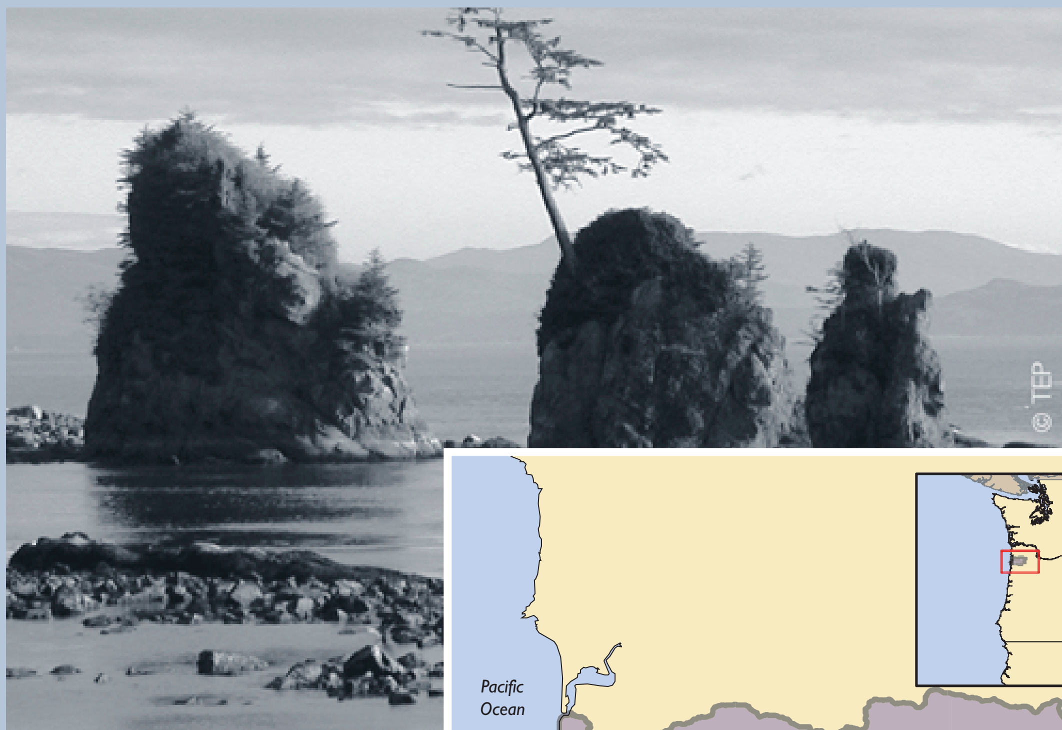
Data management is another focus of the LCREP's current efforts. Currently, there is no single place where one can go to find all the existing information about the Lower Columbia River Estuary. The Information Management Strategy of this report (LCREP, 1998) lays out a multi-phase approach for improving access to and management of data. An example of progress is the availability of technical data regarding the condition of the Estuary, including data from the Bi-State Water Quality Study, is available online at http://www.lcrep.org.

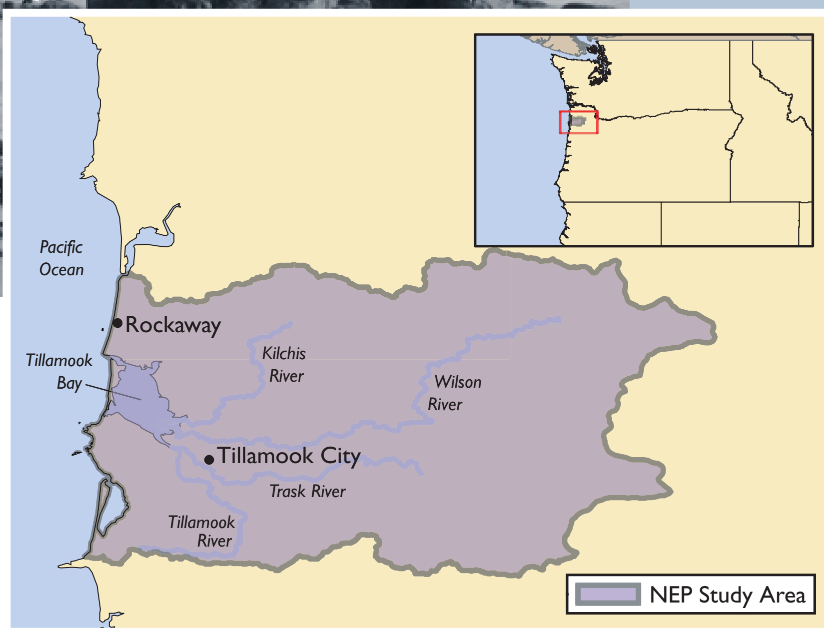
The LCREP has also focused its resources on developing educational programs for the area's students and volunteer opportunities for residents. Since 2000, the Partnership has developed more than 50 different field-based Columbia River education curricula for more than 32 school districts and assisted with classroom programs, field trips, and on-river trips for more than 45,000 students. The Partnership has also provided over 8,000 volunteers the opportunity to help plant more than 11,000 native trees and shrubs at 18 habitat restoration sites (LCREP, 2005a).

Conclusion

Based on data from the NCA estuarine survey, the overall condition of the Lower Columbia River Estuary is rated fair. The LCREP has been working collaboratively with many other organizations to monitor the ecosystem; educate the public; and assess, protect, and restore the extensive and diverse habitats that comprise the Lower Columbia River Estuary. These efforts have had positive effects in several areas of estuarine health (e.g., bald eagle population increases, acreage of restored habitat); however, other areas (e.g., water temperature increases, toxic contaminant concentrations in fish tissue) remain a concern.

Tillamook Estuaries Partnership





Tillamook Estuaries Partnership
A National Estuary Project

www.tbnep.org

Background

Although it is Oregon's second-largest estuary, Tillamook Bay is relatively small (approximately 13 mi^2) and shallow (average depth of 6 feet) compared to other NEP estuaries. Located on Oregon's northern coast, Tillamook Bay is part of a coastal, temperate rainforest ecosystem. Annual precipitation averages 90 inches in the lower basin and close to 200 inches in the uplands. This rainfall supplies fresh water to the basin's five major rivers (Tillamook, Trask, Wilson, Kilchis, and Miami), which drain a 597-mi^2 watershed that includes some of North America's richest timber and dairy lands (TBNEP, 1999). Known as the "land of cheese, trees, and ocean breeze," Tillamook County boasts a greater population of cows than people and is dominated by federal, state, and private forest land, which comprises almost 90% of the county (TBNEP, 1998). Tillamook Bay supports an oyster aquaculture industry, a commercial/recreational port, and a recreational salmon fishery (TBNEP, 1999).

Historically dependent on resource-extraction industries, the local economy of Tillamook County increasingly relies on tourism and transfer payments to provide for the county's 25,000 citizens (TBNEP, 1999). The county's median household income is well below the state average and was only 80% of the national average in 2002 (U.S. Census Bureau, 2006). Although the service sector is expanding because of tourism and a growing population of retirees, dairy farming, logging, and fishing still define the cultural landscape of the area (TBNEP, 1999).

By the early 1990s, local citizens began to voice concerns about the basin's declining natural resources. Loss of spawning and rearing habitat had reduced salmon runs, and decreasing water quality regularly violated federal water quality standards and led to closures of commercial shellfish beds. Erosion and sediment deposition, combined with development in the floodplain, exacerbated water quality issues and habitat degradation while increasing the magnitude and frequency of flood events. To reverse these trends, the Tillamook Estuaries Partnership (TEP) undertook five years of research, public outreach, and policy analysis, resulting in completion of the *"Restoring the Balance": Comprehensive Conservation and Management Plan for Tillamook Bay, Oregon* in 1999 (TBNEP, 1999). The TEP implements its CCMP under three program areas: habitat enhancement, education, and research and monitoring. The TEP also supports partner-led projects through its Local Grant Program.

Environmental Concerns

The most significant environmental problems in the Tillamook Bay watershed are habitat loss and simplification, water quality, erosion and sedimentation, and flooding, and the TEP researched and characterized these problems during its CCMP development. The Tillamook Bay basin has lost almost 85% of its historical intertidal wetlands to agricultural and urban development (TBNEP, 1999). In addition, populations of four of the five anadromous salmonid species (coho and chum salmon, steelhead and cutthroat trout) have dramatically decreased from historical levels. Loss of spawning and rearing habitats are the major contributors to the declining populations. None of Tillamook County's major watersheds meets the Clean Water Act standards established by EPA and ODEQ, and bacterial contamination and elevated water temperatures are the two parameters of highest priority. The flood of 1996, as well as the many floods that came before it, displaced residents and caused major environmental degradation and millions of dollars in property damage. Loss of floodplain function and stream complexity are the key contributors to increased flooding and are a focus of the TEP's enhancement efforts (TBNEP, 1999).

Population Pressures

The population of the NOAA-designated coastal county (Tillamook) coincident with the TEP study area increased by only 28% during a 40-year period, from 18,955 people in 1960 to 24,262 people in 2000 (Figure 6-25) (U.S. Census Bureau, 1991; 2001). This rate of population growth for the TEP study area was one of the lowest rates of population growth for the West Coast NEPs, and only one-fourth the population growth rate of 100.3% for the collective NEP-coincident coastal counties of the West Coast region. Tillamook County also had the lowest population density (22 persons/mi^2) of any of the West Coast NEPs (U.S. Census Bureau, 2001). This estuary is not surrounded by the large metropolitan areas that are characteristic of some West Coast NEP estuaries, such as Puget Sound or the San Francisco Estuary.

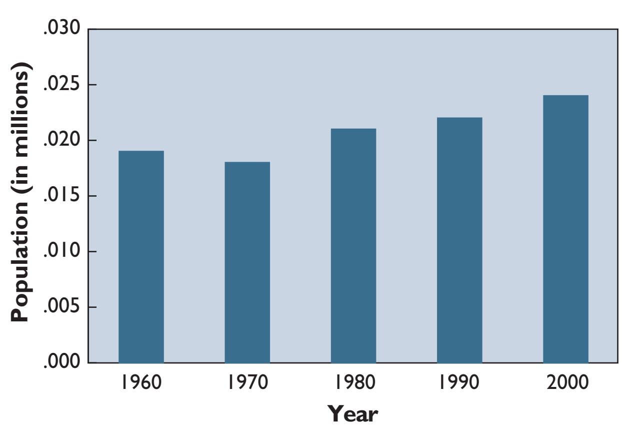


Figure 6-25. Population of NOAA-designated coastal county of the TEP study area, 1960–2000 (U.S. Census Bureau, 1991; 2001).

NCA Indices of Estuarine Condition—Tillamook Bay

The overall condition of Tillamook Bay is rated good based on the four indices of estuarine condition used by the NCA (Figure 6-26). The water quality index is rated fair, and the sediment quality, benthic, and fish tissue contaminants indices are rated good. Figure 6-27 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 ODEQ from 29 stations sampled in 1999. 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.

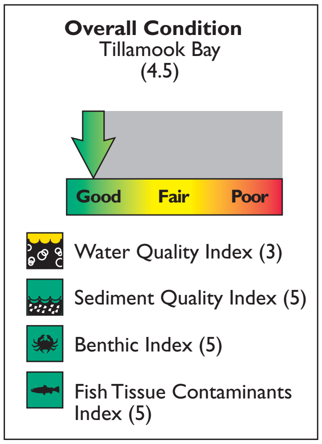


Figure 6-26. The overall condition of the TEP estuarine area is good (U.S. EPA/NCA).

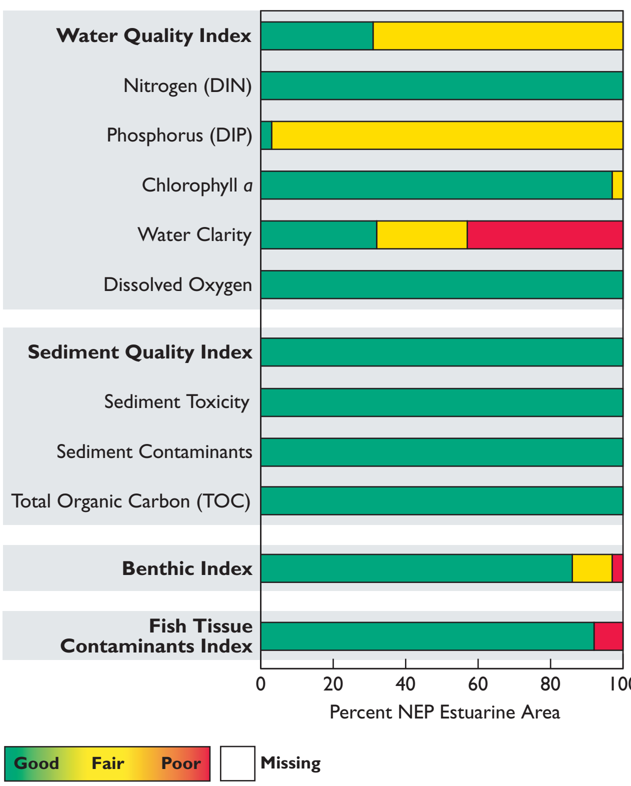


Figure 6-27. Percentage of NEP estuarine area achieving each ranking for all indices and component indicators — Tillamook Bay (U.S. EPA/NCA).

Water Quality Index

Based on NCA survey results, the water quality index for Tillamook Bay is rated fair. This index was developed using NCA data on five component indicators: DIN, DIP, chlorophyll *a*, water clarity, and dissolved oxygen. Most (69%) of the estuarine area was rated fair because of limited water clarity and moderate levels of DIP (Figure 6-28).

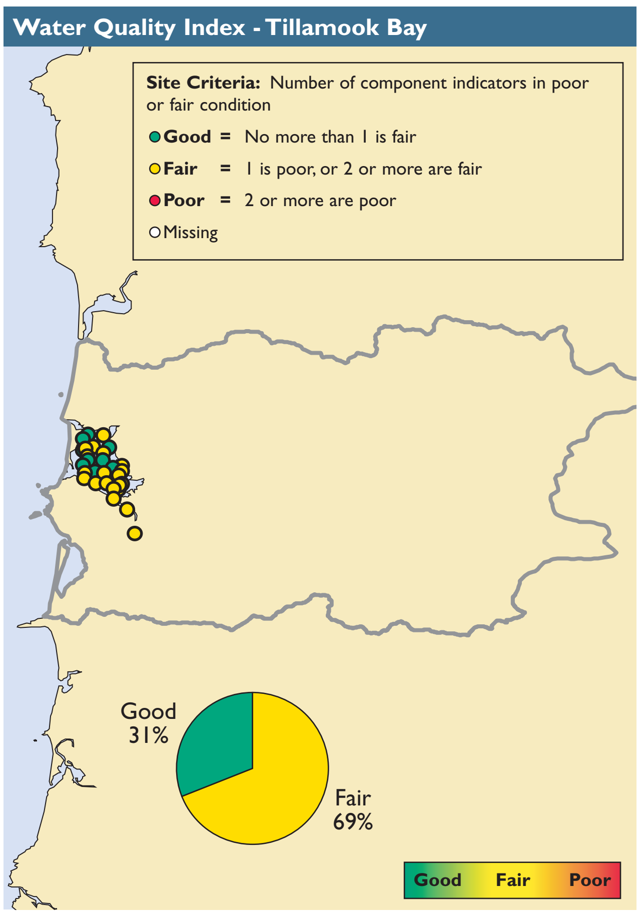


Figure 6-28. Water quality index data for Tillamook Bay, 1999 (U.S. EPA/NCA).

Tillamook Estuaries Partnership

Dissolved Nitrogen and Phosphorus | Tillamook Bay is rated good for DIN concentrations and fair for DIP concentrations. Concentrations of DIN were rated good in 100% of the estuarine area, and DIP concentrations were rated fair in 97% of the area.

Chlorophyll a | Chlorophyll *a* concentrations in Tillamook Bay are rated good. Three percent of the estuarine area was rated fair for this component indicator, with the remainder of the area (97%) rated good. None of the TEP estuarine area was rated poor for chlorophyll *a* concentrations.

Water Clarity | Water clarity in Tillamook Bay is rated poor. Approximately 43% of estuarine area was rated poor for this component indicator, and 25% of the area was rated fair.

Dissolved Oxygen | Dissolved oxygen conditions in Tillamook Bay are rated good, with 100% of the estuarine area rated good for this component indicator. Although conditions in Tillamook Bay appear to be generally good for dissolved oxygen, measured values reflect daytime conditions, and some areas of the Bay may still experience hypoxic conditions at night.

Fishing for Chinook salmon is popular in Tillamook Bay (TEP).

Sediment Quality Index

The sediment quality index for Tillamook Bay is rated good (Figure 6-29). This index was developed using NCA data on three component indicators: sediment toxicity, sediment contaminants, and sediment TOC. No area of the Bay exceeded thresholds for any of these component indicators.

Sediment Toxicity | Sediment toxicity for Tillamook Bay is rated good, with none of the estuarine area rated poor for this component indicator.

Sediment Contaminants | Tillamook Bay is rated good for sediment contaminant concentrations, with 100% of the estuarine area rated good for this component indicator.

Total Organic Carbon | Tillamook Bay is rated good for TOC concentrations, with 100% of the estuarine area rated good for this component indicator.

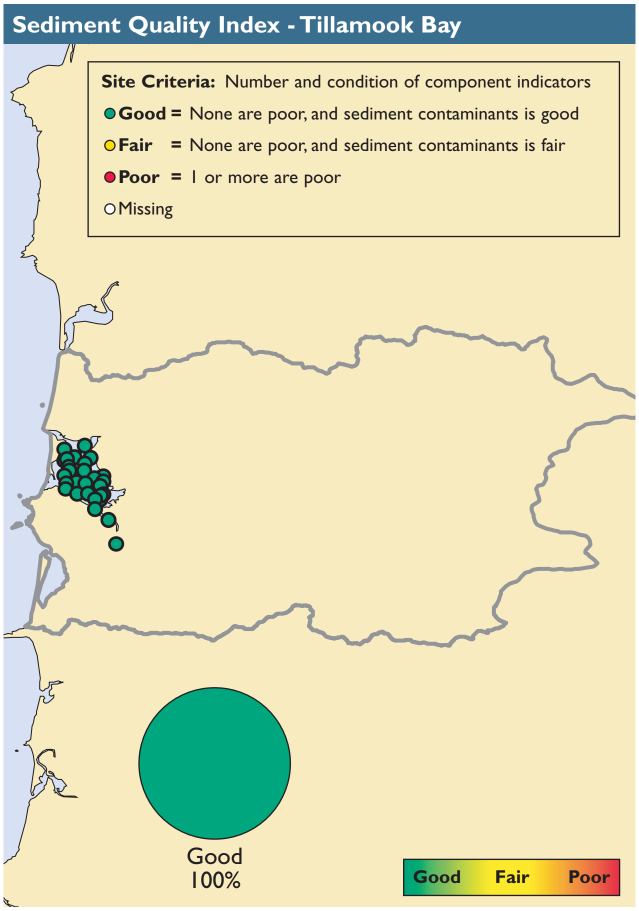


Figure 6-29. Sediment quality index data for Tillamook Bay, 1999 (U.S. EPA/NCA).

Benthic Index

The condition of the benthic invertebrate communities in Tillamook Bay is rated good based on deviations from the expected species richness (Figure 6-30). This analysis was based on 28 benthic samples collected during 1999. A significant linear regression between log species richness and salinity was found in Tillamook Bay, although it was not strong ($r^2 = 0.31$, $p < 0.01$). One site, representing about 3% of the estuarine area, was rated poor based on a lower-than-predicted species richness. The cause for the less-than-expected species richness at this site is not readily apparent because no sediment ERMs were exceeded, only three ERLs were exceeded, and TOC concentrations were within the range found in the Bay. Another three sites, representing 11% of the estuarine area, were rated fair, and 24 sites, representing 86% of the area, were rated good.

Fish Tissue Contaminants Index

This fish tissue contaminants index for Tillamook Bay is rated good (Figure 6-31), with only 8% of all stations sampled where fish were caught exceeding EPA Advisory Guidance values for whole-fish contaminant concentrations. These risk calculations are appropriate for populations that consume whole fish. The contaminant found most often in fish tissues from Tillamook Bay was total PCBs.

Sediment Contaminant Criteria (Long et al., 1995)

ERM (Effects Range Median)—Determined for each chemical as the 50th percentile (median) in a database of ascending concentrations associated with adverse biological effects.

ERL (Effects Range Low)—Determined for each chemical as the 10th percentile in a database of ascending concentrations associated with adverse biological effects.

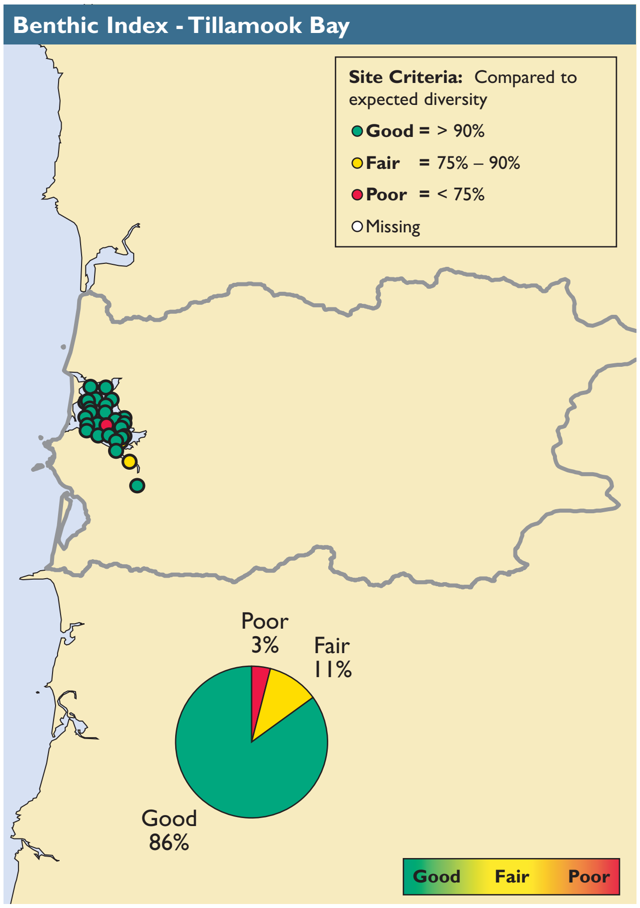


Figure 6-30. Benthic index data for Tillamook Bay, 1999 (U.S. EPA/NCA).

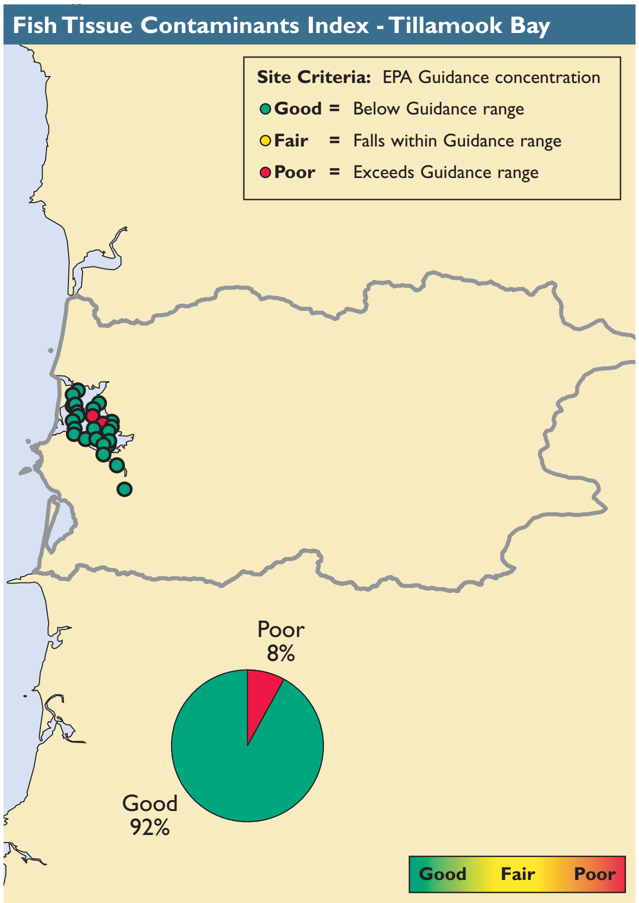


Figure 6-31. Fish tissue contaminants index data for Tillamook Bay, 1999 (U.S. EPA/NCA).

Tillamook Estuaries Partnership

HIGHLIGHT

Addressing Bacterial Contamination in Tillamook Bay

The driving force behind Tillamook Bay's nomination to the NEP was bacterial contamination. Inputs of fecal coliform bacteria have resulted in frequent water quality standard exceedences in the Bay's tributaries and periodic closures of the Bay's oyster shellfishing industry (Sullivan et al., 2005). To combat this problem, the TEP has initiated an innovative monitoring strategy to answer three key questions relating to bacteria in the Bay and its watershed:

1. Is bacteria loading to the lower reaches of the Bay's tributary rivers increasing or decreasing over timescales of years to decades?

2. Where, how often, and for what length of time does each of the Bay's five major tributary rivers violate state water quality standards for bacteria?

3. What are the sources of the contamination, and how much pollution do they contribute?

The TEP has instituted two complementary monitoring approaches to try and answer these questions: the Storm-Based Monitoring Program and the Volunteer Monitoring Program. In addition, the TEP has partnered with Oregon State University to embark on a complementary three-year Genetic Marker Study.

The Storm-Based Monitoring Program measured fecal coliform bacteria concentrations and loads (as well as other water quality parameters) to the Bay during storm events. Between 1996 and 2002, the program monitored approximately 28 separate storms on the Bay's five tributary rivers. Results of this effort included the following insights: (1) fall storm events exhibited the highest levels of bacterial loading to the Bay; (2) bacteria concentrations increased dramatically during storm events, but varied greatly among the Bay's five rivers; (3) bacteria concentrations measured in the rivers appeared to be strongly influenced by precipitation patterns prior to a storm and by rainfall intensity during the storm; and (4) drier conditions prior to a storm and greater rainfall during a storm generally resulted in higher bacteria concentrations in the rivers (Sullivan et al., 2002).

In addition to the initial set of storm-sampling sites, the Storm-Based Monitoring Program also conducted an intensive storm-monitoring effort during a two-year period on two river reaches identified as major bacteria-contributing areas. Potential bacteria sources were documented and mapped using photos, global positioning systems (GPSs), and field surveys to attempt to link bacteria concentration spikes to likely sources. Results of this effort are being used to identify those source areas that appear to be the largest bacteria contributors to the rivers and to prioritize the areas for corrective action (Sullivan et al., 2002).

Since 1995, participants in TEP's Volunteer Monitoring Program have braved wind, rain, sleet, and occasional sun to collect water samples from 37 sites across all 5 of the major tributaries entering Tillamook Bay. Monitoring results from this effort are entered into a long-term database that is shared with both local and state partners (TEP, 2006b). This information assisted in the development of a bacteria TMDL (ODEQ, 2001) for the watershed and has guided the TEP's process to prioritize sites for enhancement. Results of the Volunteer Monitoring Program revealed the following insights: all five of Tillamook Bay's main tributary rivers routinely violate Oregon's bacteria water quality standard for water contact recreation; bacteria concentrations peak during the summer low-water period and during some fall, winter, and spring storms; and the Tillamook River routinely has the highest bacteria concentrations of the five rivers (ODEQ, 2001).

Because bacterial contamination is largely a problem resulting from non-point source pollution, researchers are searching for new methods to differentiate among potential sources, such as manure from pastures, failing septic systems, and STP overflows. A joint study by Oregon State University and the TEP seeks to identify bacteria sources by detecting genetic marker sequences that are specific to the host species that produced the feces. The intent of the study is to enable researchers to discriminate among human, cow, domestic pet, waterfowl, and other wildlife bacteria sources. Preliminary results indicate that ruminants (e.g., cows, elk) are a source of widespread bacterial contamination and that human contributions to the contamination in some river segments are also significant (TEP, 2006b).

The results of these efforts have led the TEP to undertake several priority projects to reduce bacterial contamination in the Bay. In collaboration with the Tillamook County On-Site Sanitation Division, private septic systems in the watershed will be inspected and repaired as needed. The City of Tillamook has recently completed a Stormwater Management Plan that will identify measures to reduce bacterial loading and other contaminants. In addition, a buffer-strip effectiveness study is testing an experimental demonstration buffer strip to determine its effectiveness in removing bacteria from pasture runoff and help select BMPs for manure management. Finally, a pilot project has begun to develop and implement performance-based policies for agriculture to meet or exceed water quality standards in the lower Tillamook Bay basin (TEP, 2006b).

A volunteer collects a plankton sample in Tillamock Bay (TEP).

Tillamook Estuaries Partnership Indices of Estuarine Condition

The TEP has developed a set of environmental indicators to assess water quality, habitat extent, and the status of living resources in Tillamook Bay. Each of the draft indicators is tied to objectives/goals from the TEP's CCMP and seek to answer one of the TEP's focus questions. For example, the number of stream miles opened through fish passage enhancement projects measures progress towards the CCMP goal of enhancing 100 miles of upland instream habitat by 2010 and determines whether more freshwater habitat is becoming available to native salmon and trout (TEP, 2004).

Water and Sediment Quality

Although not part of the NCA's water quality index, bacterial contamination is the priority water quality issue in Tillamook Bay and its tributaries (TBNEP, 1999). Sewer outfalls, leaking or malfunctioning septic tanks, and runoff from the watershed's dairy farms contribute fecal coliform bacteria to the Bay. Although bacterial loading has increased historically as farming and development in the area increased, recent monitoring has shown improving trends in some river reaches (TEP, 2006a). This is likely due to the implementation of the TEP's CCMP. The TEP indicators for water quality include ongoing monitoring in the Bay and tributaries to continue tracking changes in fecal coliform bacteria concentrations (TEP, 2004).

Dissolved oxygen concentrations and rises in stream temperatures are also major water quality concerns in the TEP study area (TEP, 2006a). Eutrophication and low dissolved oxygen concentrations have not been a problem in Tillamook Bay proper; however, low dissolved oxygen levels have been observed in some of the Bay's lowland sloughs and tributaries (TBNEP, 1999). Although the NCA data noted good dissolved oxygen concentrations throughout the Bay, the NCA sampling sites were primarily located in the main portion of the Bay. The TEP is working with ODEQ to further evaluate the extent and impact of low dissolved oxygen levels in Tillamook Bay sloughs. Low water temperatures in the Bay's streams are important for maintaining the area's salmon habitat; however, water temperatures in the Wilson, Trask, and Tillamook rivers

Dairy herds are a prominent agricultural use of land in Tillamook County (TEP).

have exceeded water quality standards for temperature (TBNEP, 1999). The TEP's indicators include monitoring water temperature in streams and dissolved oxygen levels in sloughs (TEP, 2004).

Habitat Quality

Maintaining and improving the habitats necessary to support this estuary's declining salmonid populations is an important priority for the TEP. Healthy freshwater and riparian habitats are important for maintaining low water temperatures and for providing spawning grounds for salmonids, whose young need salt marshes, tidal channels, and eelgrass beds for food and protection (TEP, 2006a). The TEP has developed several draft indicators for assessing habitat quality and quantity in Tillamook Bay, including changes in the distribution and type of riparian vegetation along the Bay's tributary rivers, the number of stream miles affected by fish passage enhancement projects, the areal extent of wetlands and open water restored through the removal of tidal restrictions, and changes in the extent of seagrass beds (TEP, 2004).

The amount of historical information available for the TEP indicators varies. For example, historic and recent data indicate that Tillamook Bay has lost roughly 85% of its intertidal wetlands to agricultural and residential development. To address these losses, the CCMP establishes a goal of restoring 750 acres of these habitats (TBNEP 1999), and the Partnership will have restored approximately 400 acres by the summer of 2007. In cases where the TEP knows little about historic habitats, indicators characterize the status of the resource and track change from the present. For example, the TEP monitors the change in eelgrass distribution from its current coverage of 897 acres (TEP, 2005).

Living Resources

The TEP has been implementing projects aimed at evaluating the status and trends of the abundance and distribution of aquatic species. Examples of these projects include an exotic species detection effort, a rapid bioassessment, and a study on fish use of the estuary. In addition, the TEP's living resource indicators of estuarine condition include the annual number of coho salmon adults returning to the study area for spawning, as well as the annual number of coho, chum, Chinook, steelhead, and cutthroat smolts migrating downstream from the Little North Fork Wilson River and Little South Fork Kilchis River (TEP, 2004).

The Exotic Species Project, which is being pursued for the LCREP, TEP, and PSAT, is seeking to develop a consistent approach for monitoring aquatic nuisance species. Together, these three NEPs and other partners in these basins will develop a regionally coordinated approach for monitoring aquatic nuisance species in the Pacific Northwest using models developed and tested in the San Francisco Estuary watershed (TEP, 2006b). As an initial step for this project, the TEP has developed *An Exotic Species Detection Plan for Tillamook Bay* (Cohen, 2004).

The TEP's Tillamook Bay Rapid Bio-Assessment is designed to quantify the abundance and distribution of four species of juvenile salmonids throughout the Bay's watershed. The full basin view of each species' distribution and their spatial shifts in abundance will provide valuable information for the development of a restoration strategy based on passage barriers, peak spawning and rearing reaches, temperature-limiting habitats, and upstream-migration behaviors. The three-year inventory began in 2005 and is encompassing approximately 350 stream miles. In 2005, the inventory found that the number of coho salmon returning to the Bay's streams for spawning was insufficient to adequately seed the watershed's available habitat (Bio-Surveys, L.L.C., 2005; TEP, 2006b).

The primary objectives of the Fish Use of the Estuary study were to develop baseline information on fish use of the Tillamook Bay estuary and to test and evaluate a sampling approach for long-term monitoring of fish abundance and distribution across major habitat types within the estuary. The sampling design for the long-term monitoring program was structured to allow the testing of hypotheses regarding the use of three regions of the estuary (lower, middle, and upper), two major substrate types (fine-grained and coarse-grained), and the effect-sampling time (months, within months, and years) for relatively abundant anadromous salmonid and non-salmonid species. Monitoring data from 1999 through 2001 indicated that fish species composition in the estuary has been relatively stable since the mid-1970s (Ellis, 2002; TEP, 2006b).

Current Activities, Accomplishment, and Future Goals

The TEP's primary goals are to enhance water quality to meet state and federal standards, restore native salmonid populations, reduce the frequency and impacts of catastrophic flooding, and encourage stewardship among residents and visitors. To attain these goals, the TEP and its many partners are implementing targeted resource-enhancement projects, characterizing the estuary and its watersheds, and educating citizens and visitors about the Bay's natural resources and the importance of stewardship. The TEP plans to continue pursuing these activities through three programs: the Habitat Enhancement Program (developing and implementing on-the-ground projects aimed at improving the production and function of natural systems); the Research and Monitoring Program (characterizing the interactions of human and natural systems, tracking system-wide trends, and evaluating the effectiveness of CCMP implementation); and the Education Program (working to facilitate a stewardship ethic among visitors and residents of Tillamook County through hands-on learning and outreach activities).

The TEP's annual workplan details the projects that the Partnership undertakes within each of these programs. One of the tools the TEP is using to track CCMP implementation is an innovative Web site known as the Performance Indicators Visualization and Outreach Tool (PIVOT), which is available at http://gisweb.co.tillamook.or.us/mapping/pivot/tillamook.htm. The TEP is also currently developing a comprehensive monitoring program to more fully characterize long-term, system-wide trends and the impact of CCMP implementation (TEP, 2005).

To implement the CCMP's actions aimed at reconnecting intertidal wetlands and enhancing tidal marshes, the TEP raised more than $1.3 million to acquire three properties that form a 375-acre peninsula at the confluence of the Wilson and Trask rivers. Currently underway, this project is expected to result in the protection and restoration of a natural, functioning ecosystem on approximately 200 acres within the formerly-diked tidelands and forested wetlands at the Bay's southern end. The remaining 175 acres will be restored under a "muted tidal connection" to ensure flood mitigation. Primarily, the fully reconnected areas will be restored to intertidal habitats consisting of high salt marsh, brackish marsh, and forested wetlands. Existing remnant floodplain forests will be permanently protected and managed to maintain their natural values (USACE, 2004a).

In 2003, the TEP initiated its Backyard Planting Program (BYPP) to help landowners on high-priority streams restore degraded riparian zones. The BYPP coordinator collaborates with interested landowners to develop an enhancement plan for their property. The BYPP provides free removal of invasive vegetation, plants native trees and shrubs, and maintains the site for three years. By the end of its third year, the BYPP will have enrolled more than 80 landowners and restored 15 miles and 75 acres of high-priority riparian habitat (TEP, 2006b).

Conclusion

Tillamook Bay is representative of many small Pacific Northwest estuaries. Dominated by rugged mountains with narrow coastal plains, it presents a challenging combination of environmental concerns. Elevated bacteria levels have closed oyster beds to shellfishing, and loss of habitat and increasing stream temperatures have impacted local salmonid populations. Based on the results of the NCA survey, the overall condition of Tillamook Bay is rated good. Although fair and poor conditions were noted for several indicators, this was the highest rating received by any of the six West Coast NEP estuaries monitored. The TEP is finding ways to protect both the area's natural resources and its natural resource-dependent economy. The TEP has focused on reducing bacteria contamination in the Bay and its tributaries and improving the area's habitat quality for salmonid populations.

San Francisco Estuary Project

San Francisco Estuary Project

sfep.abag.ca.gov

Background

The San Francisco Estuary is one of the largest estuaries on the West Coast, encompassing about 460 mi^2 of open water. The Estuary is shallow, and approximately one-third of the total water area has a depth of less than six feet. The Sacramento and San Joaquin rivers supply approximately 90% of the Estuary's freshwater input and drain about 40% of California's land area. These rivers enter the Estuary through the Sacramento-San Joaquin River Delta, a large area of diked and drained swampland in the northern portion of the Estuary (SFEP, 1999). Major embayments within the San Francisco Estuary include the Suisun, San Pablo, Central, South, and Lower South bays.

The San Francisco Estuary and its associated tributaries encompass roughly 1,600 mi^2, provide drinking water to 23 million Californians (two-thirds of the state's population), and irrigate 4.5 million acres of farmland. The Estuary also enables the residents of the nation's fifth-largest metropolitan region to pursue diverse activities, including shipping, fishing, recreation, and commerce. Finally, the Estuary hosts a rich diversity of flora and fauna, with nearly half of the birds that migrate along the Pacific Flyway and about two-thirds of the state's salmon passing through the Estuary (SFEP, 2004).

Environmental Concerns

Freshwater management is an environmental concern in the San Francisco Estuary region. Each day, millions of people, industries, and municipalities around the Estuary use river water for an array of activities, then collect, recycle, treat, and discharge their wastewater into the Estuary. In rural areas, farmers irrigate crops and water their livestock. Maintaining river flows under the pressure of exporting water to southern California is a major environmental concern in the Estuary, and during droughts and heavy rain years, this pressure makes managing the system even trickier. Add to these needs other issues, such as pesticides and other pollutants that get washed into the creeks, rivers, and bays, and water quality management for the Estuary becomes even more challenging.

Population Pressures

The population of the 12 NOAA-designated coastal counties coincident with the San Francisco Estuary Project (SFEP) study area increased by 96.1% during a 40-year period, from 4.5 million people in 1960 to 8.7 million people in 2000 (Figure 6-32) (U.S. Census Bureau 1991; 2001). This rate of population growth for the SFEP study area was slightly lower than the population growth rate of 100.3% for the collective NEP-coincident coastal counties of the West Coast region. However, the coastal counties surrounding the SFEP had the highest population density (844 persons/mi^2) of any of the West Coast NEP study areas (U.S. Census Bureau, 2001). The San Francisco Estuary is surrounded by major metropolitan areas that serve as large centers for international commerce and industrial and recreational activities.

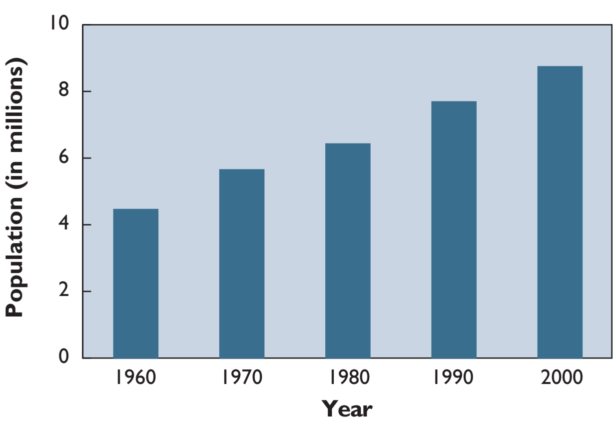


Figure 6-32. Population of NOAA-designated coastal counties of the SFEP study area, 1960–2000 (U.S. Census Bureau, 1991; 2001).

NCA Indices of Estuarine Condition—San Francisco Estuary

The overall condition of the San Francisco Estuary is rated fair based on the four indices of estuarine condition used by the NCA (Figure 6-33). The water quality index is rated fair to poor, the sediment quality index is rated fair, the benthic index is rated good, and the fish tissue contaminants index is rated poor. Figure 6-34 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 NS&T Program and Moss Landing Marine Laboratories, under contract to the Southern California Water Resources Research Project (SCWRRP), from 50 stations sampled in the San Francisco Estuary 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.

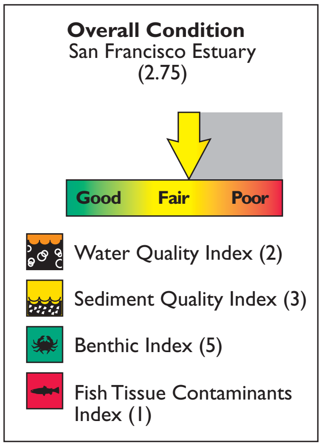


Figure 6-33. The overall condition of the SFEP estuarine area is fair (U.S. EPA/NCA).

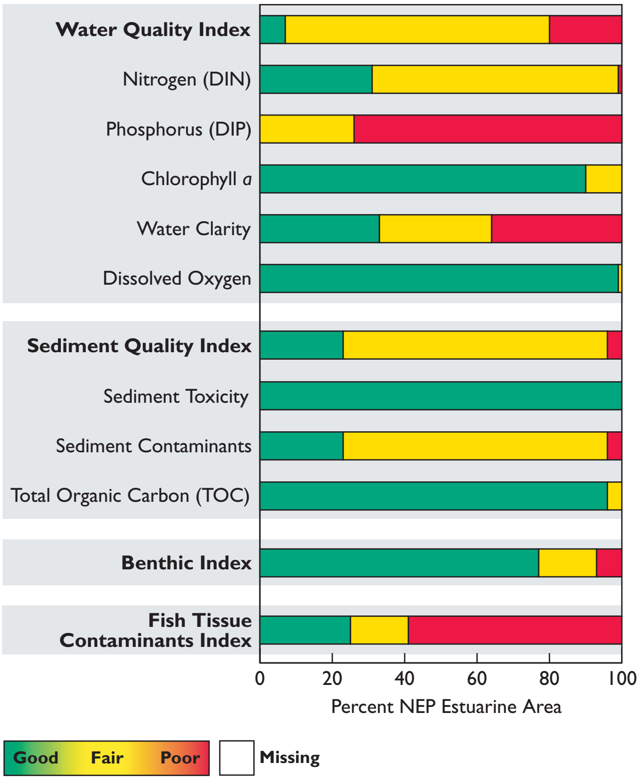


Figure 6-34. Percentage of NEP estuarine area achieving each ranking for all indices and component indicators — San Francisco Estuary (U.S. EPA/NCA).

Water Quality Index

Based on NCA survey results, the water quality index for the San Francisco Estuary is rated fair to poor (Figure 6-35). This index was developed using NCA data on five component indicators: DIN, DIP, chlorophyll *a*, water clarity, and dissolved oxygen. Some 20% of the estuarine area was rated poor for water quality, and 73% of the area was rated fair. Diminished water quality in the Estuary was primarily due to limited water clarity and to elevated levels of DIN and DIP.

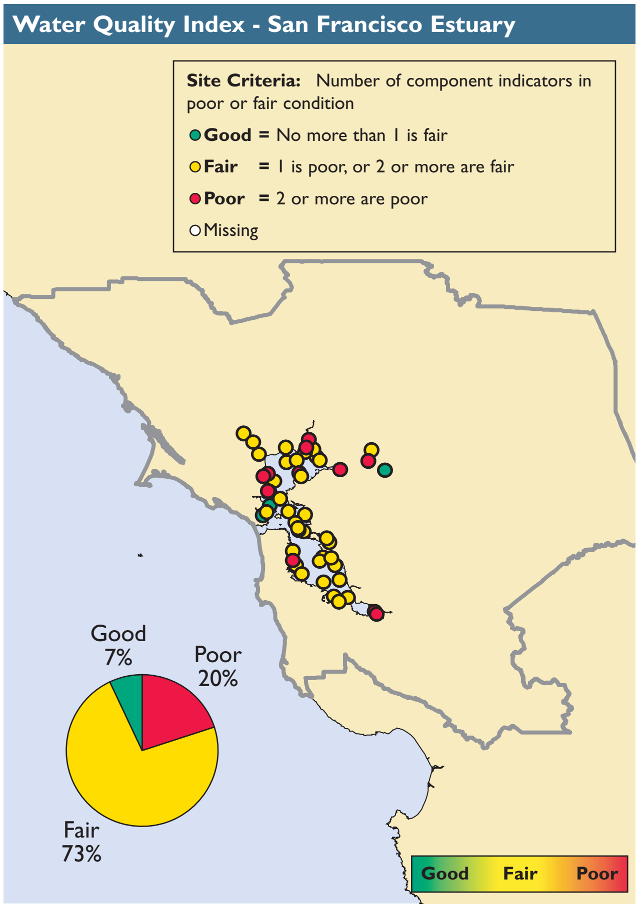
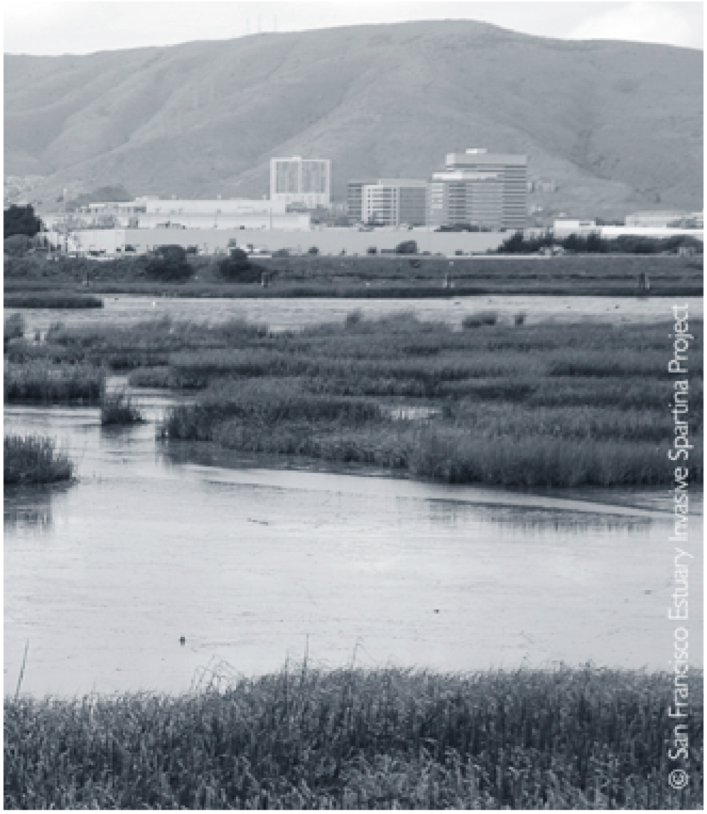


Figure 6-35. Water quality index data for the San Francisco Estuary, 2000 (U.S. EPA/NCA).



The dominant marsh vegetation in this area of the San Bruno Marsh is an invasive, non-native *Spartina*, which is a hybrid of an introduced and a native species (San Francisco Estuary Invasive Spartina Project).

Dissolved Nitrogen and Phosphorus | The San Francisco Estuary is rated fair for DIN concentrations and poor for DIP concentrations. Concentrations of DIN were rated fair in 68% of the estuarine area, and DIP concentrations were rated poor in 74% of the area. In addition to natural inputs of nutrients from offshore coastal upwelling, high levels of urban and agricultural runoff into the Sacramento River may also be major contributors to the elevated nutrient levels found in the San Francisco Estuary.

Chlorophyll a | Chlorophyll *a* concentrations in the San Francisco Estuary are rated good. Ten percent of the estuarine area was rated fair for this component indicator, and the remaining 90% was rated good.

Water Clarity | Water clarity in the San Francisco Estuary is rated poor. Approximately 36% of the estuarine area was rated poor for this component indicator, and 31% of the area was rated fair.

Dissolved Oxygen | Dissolved oxygen conditions in the San Francisco Estuary are rated good, with 99% of the estuarine area rated good for this component indicator. Although conditions in the San Francisco Estuary appear to be generally good for dissolved oxygen, measured values reflect daytime conditions, and some areas of the Estuary may still experience hypoxic conditions at night.

Sediment Quality Index

The sediment quality index for the San Francisco Estuary is rated fair (Figure 6-36). This index was developed using NCA data on three component indicators: sediment toxicity, sediment contaminants, and sediment TOC. Four percent of the estuarine area was rated poor for sediment quality, exceeding thresholds for at least one of these component indicators, and 73% of the area was rated fair, primarily as a result of sediment contaminant levels.

Sediment Toxicity | Sediment toxicity in the San Francisco Estuary is rated good, with 100% of the estuarine area rated good for this component indicator.

Sediment Contamination | The San Francisco Estuary is rated good for sediment contaminant concentrations, with 4% of the estuarine area rated poor for this component indicator and 73% of the area rated fair.

Total Organic Carbon | The San Francisco Estuary is rated good for sediment TOC. TOC concentrations were rated good in 96% of the estuarine area and fair for the remaining 4% of the area.

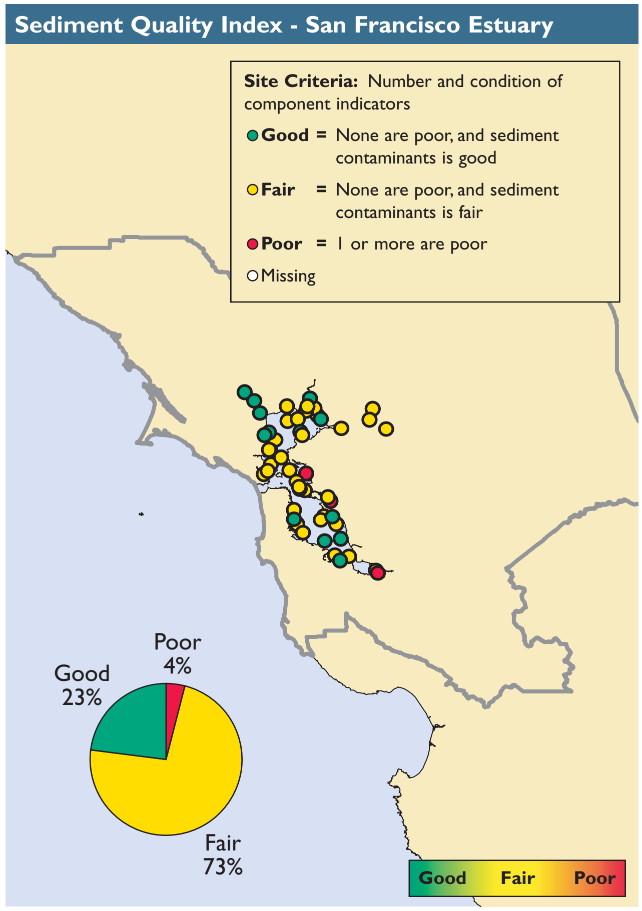


Figure 6-36. Sediment quality index data for the San Francisco Estuary, 2000 (U.S. EPA/NCA).

Benthic Index

The condition of the benthic invertebrate communities in the San Francisco Estuary is considered good based on deviations from the expected species richness (Figure 6-37). A significant linear regression between log species richness and salinity that was moderately strong ($r^2 = 0.54$, $p < 0.01$) was found in the Estuary. Six percent of the estuarine area was rated poor based on a lower-than-predicted species richness, and 16% of the area was rated fair. The remaining 78% of the estuarine area was rated good for benthic condition. It is possible that sediment contamination contributed to the lower species richness in several of the areas rated poor and fair because 6 ERLs were exceeded at 6 of the 11 sampling sites in these areas. However, the reduced species richness is not simply related to sediment contamination because 21 of the 39 sites rated good for the benthic index had an equivalent or greater number of contaminants exceeding their ERLs.

Fish Tissue Contaminants Index

The fish tissue contaminants index for the San Francisco Estuary is rated poor. Fifty-eight percent of all stations sampled where fish were caught exceeded EPA Advisory Guidance values using whole-fish contaminant concentrations (Figure 6-38). These risk calculations are appropriate for populations that consume whole fish. The contaminants found in the fish tissues sampled included total PCBs and, occasionally, mercury.

Sediment Contaminant Criteria (Long et al., 1995)

ERM (Effects Range Median)—Determined for each chemical as the 50th percentile (median) in a database of ascending concentrations associated with adverse biological effects.

ERL (Effects Range Low)—Determined for each chemical as the 10th percentile in a database of ascending concentrations associated with adverse biological effects.

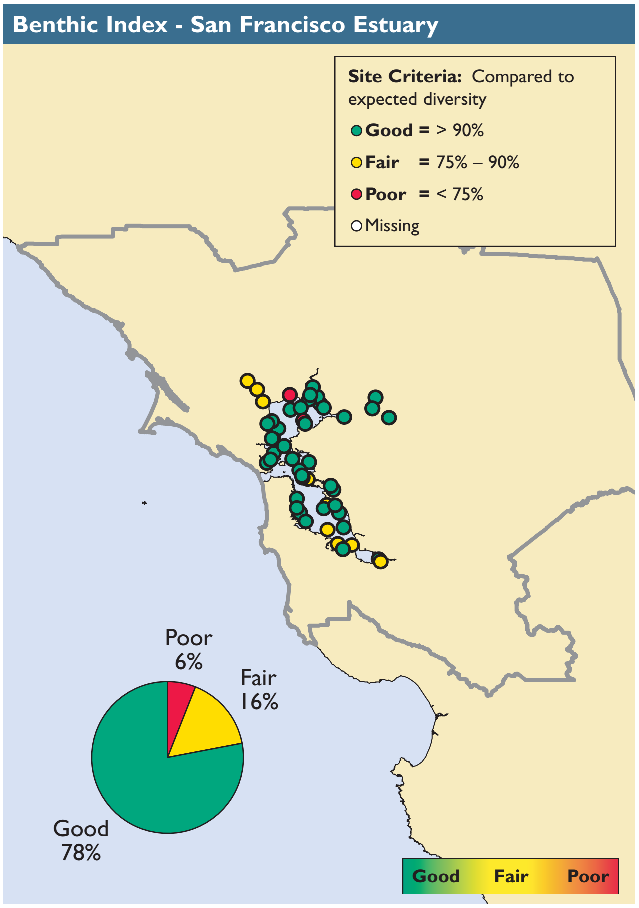


Figure 6-37. Benthic index data for the San Francisco Estuary, 2000 (U.S. EPA/NCA).

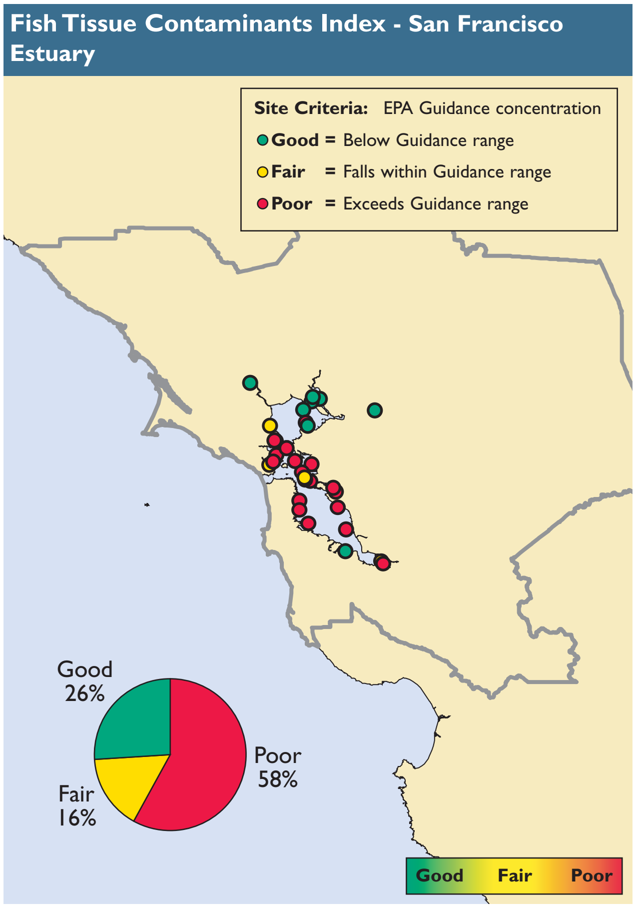


Figure 6-38. Fish tissue contaminants index data for the San Francisco Estuary, 2000 (U.S. EPA/NCA).

San Francisco Estuary Project

Ecosystem Indicators for the San Francisco Estuary

The San Francisco Estuary is considered one of the best-studied ecosystems in the world; however, the myriad of disparate data-collection efforts for the Estuary has not resulted in a coherent performance-measurement system. Currently, no single, objective, and comprehensive assessment of the health of the San Francisco Estuary and its watersheds is widely recognized as valid by ecosystem managers and policy makers. Such an assessment would identify problems early, direct agency efforts towards real priorities, and measure the impacts that collective actions are having on the system's health so that the SFEP can continue to adapt and improve its management strategies. The assessment would be conducted using a variety of environmental indicators, which are the vital signs derived from the chemical, biological, and physical measurements that mark the improvement or deterioration of the ecosystem. A recently released U.S. Government Accountability Office (GAO) report (U.S. GAO, 2004) recommends that leadership at the highest levels of government mesh the disparate efforts of multiple agencies and organizations into a coherent, science-based environmental management system for the Estuary.

Although no program in the San Francisco Estuary area is currently charged with integrating measurements and indicators into an assessment of ecosystem condition, identifying attributes that define ecosystem condition, or pinpointing gaps in that knowledge, progress is being made towards these goals. In 2004, The Bay Institute (TBI) and its partners made the first attempt to assess the ecological condition of the Estuary and reported the results using language accessible to the general public in its Ecological Scorecard (TBI, 2003). Additional partnerships between organizations studying the Estuary have been created to develop a consensus set of indicators for use by all stakeholders. These partnerships recently completed a report (Thompson and Gunther, 2004) documenting 47 separate recommended environmental indicators and have organized indicator workshops. These efforts build on previous indicator identification efforts and existing Bay-region monitoring programs, including the Interagency Monitoring Program and the USGS Regional Monitoring Program.

The Ecological Scorecard was a collaborative project between the San Francisco Estuary Institute (SFEI), the Center for Ecosystem Management, and TBI. Assisted by a grant from the SFEP, this project evolved over a three-year period, with input from a wide-range of local scientists and a panel of nationally recognized experts. The Scorecard's Bay Index uses science-based indicators to grade the condition of the San Francisco Bay region, the first of a series of four major ecological regions of the Estuary (i.e., San Francisco Bay, San Francisco Delta, San Joaquin River, and Sacramento River) to be assessed. The Scorecard's indicators are combined into eight indices that track the Estuary's environment (e.g., habitat, freshwater inflow, water quality); its fish and wildlife (e.g., food web, shellfish, fish); and the management of its resources (e.g., fishable, swimmable, drinkable). The grading system compares current conditions in the Bay and its watershed to historical conditions, environmental and public health standards, and restoration goals. Grades in the 2005 Scorecard (see figure) range from B to F, reflecting the long-term decline in the Bay's ecological health; however, there are some small but noticeable short-term improvements in the area's habitat and shellfish populations (TBI, 2003; 2005).

Another effort to develop environmental indicators is being led by the SFEP and its partner, SFEI. These agencies have formed a Bay Area Indicator Consortium to provide direction in strategizing the development of ecosystem indicators for the San Francisco Estuary. The Consortium recommends that the same indicators developed for the Ecological Scorecard be expanded and used as the starting point for the ecosystem indicators. In May 2004, the SFEP partnered with the SFEI and the Consortium to produce the report *Development of Environmental Indicators of the Condition of San Francisco Estuary: A Report to the San Francisco Estuary Project*, which was submitted to EPA Headquarters in September 2004 (Thompson and Gunther, 2004).

With support from EPA, the Consortium organized an Indicators Workshop in January 2005. Workshop participants explored new state and federal initiatives highlighting the need for "performance-based environmental management," as well as recent successes by the SFEP to develop a meaningful environmental indicator system. The workshop's purpose was to build consensus on the importance of and the need for scientifically valid, leading environmental indicators; to develop a framework for interagency cooperation and collaboration on the development, refinement, and use of environmental indicators; and to attract commitments of ongoing financial and programmatic support. Workshop attendees included approximately 40 participants representing the agencies developing and entities using the data (SFEP, 2006).

AREA	GRADE	SUMMARY	LONG-TERM	SHORT-TERM
	D+ Score = 31	**Habitat** Bay habitat loss is slowly being reversed, but pace of restoration unchanged since 2003 – at current rate, more than 150 years to reach tidal marsh restoration goal.	▼	▲
	C+ Score = 58	**Freshwater Inflow** Reduced inflows still degrade the Bay ecosystem – inflow improved in 2004, but overall conditions since 2000 are worse than two previous decades.	▼	◀▶
	B- Score = 65	**Water Quality** Open waters are cleaner than in 2003, but not all standards are met in parts of the Bay. Toxic sediments, stormwater runoff are major problems. South and San Pablo Bays are most polluted.	▲	▲
	F Score = 10	**Food Web** Plankton levels in Suisun Bay are still critically low, reducing food resources for fish and birds. Phytoplankton levels in all other parts of the Bay are improving.	▼	◀▶
	B Score = 73	**Shellfish** Crab and shrimp numbers rise in Central and South Bays, but not in the upper Bay. Estuarine species lose ground to marine shellfish.	▼	▲
	C- Score = 45	**Fish** Recent upward trend reverses, fish populations return to critically low levels. Estuarine species of the upper Bay are hardest hit.	▼	◀▶
	C- Score = 38	**Fishable-Swimmable-Drinkable** More fish were caught but most are still unsafe to eat. Beach closures continue to rise, drinking water violations hold steady.	▼	◀▶
	C- Score = 46	**Stewardship** Little progress towards conserving more water, reducing pesticide use, and restoring freshwater inflows, but some efforts to issue pollution limits move forward.	▼	◀▶

Grades are for the 2002-2005 period

A = Excellent
B = Good
C = Fair
D = Poor
F = Critical

Short-term = trend over last 5 years
Long-term = trend over last 25 years or more

▲ = improving
▼ = declining
◀▶ = stable

San Francisco Bay Index 2005 Scorecard (TBI, 2005).

San Francisco Estuary Project Indicators of Estuarine Condition

The San Francisco Estuary has had the benefit of several long-term monitoring programs, including the Regional Monitoring Program for Trace Substances (RMP), sampling and analysis by USGS, and the Interagency Ecological Project (IEP). The RMP has investigated chemical contamination in the water, sediments, and biota of the Estuary since 1993 and provides data on spatial patterns and long-term trends for use in management of the Estuary (SFEI, 2003). The USGS has more than 35 years of water quality data on various parameters, such as chlorophyll, nutrients (phosphorus and nitrogen), suspended sediments, salinity, and dissolved oxygen. The USGS data provide a record of biological and chemical changes in the Estuary. These data have been used to show improvements in dissolved oxygen concentrations in the South Bay and changes in phytoplankton production in Suisun Bay (USGS, 2006b). The IEP has monitored fisheries and the effects of freshwater diversions on the biota of the San Francisco Bay proper and the Sacramento-San Joaquin Delta since 1971 (IEP, 2006). Recent IEP data have shown drastic declines in important delta fish species, such as striped bass, delta smelt, and longfin smelt (Hieb et al., 2005). Other local, state, and national programs, such as the Bay Protection and Toxic Cleanup Program, Coastal Intensive Sites Network (CISNet), EMAP, and NOAA's NS&T Program, have also provided data on the water, sediments, and biota of the San Francisco Estuary. It is beyond the scope of this writeup to comprehensively discuss all of these indicators; however, several indicators of particular interest are discussed in the following sections. Additional information about the San Francisco Estuary is available from http://sfep.abag.ca.gov or http://www.sfei.org.

Water and Sediment Quality

Current and historical activities in California have contributed PCBs, pesticides, and mercury and other heavy metals (e.g., silver and copper) to the sediments of the San Francisco Estuary. Urban runoff in area watersheds is a significant, contemporary source of various contaminants, including mercury and PCBs, which are currently the topic of TMDLs proposing large reductions in urban runoff (CRWQCB, 2004). Although many of these contaminants have been banned, they are persistent in the environment, biomagnify through the food web, and bioaccumulate in fish and wildlife. The issue of sediment contamination in the Estuary is exacerbated by the waterbody's current levels of turbidity. Hydraulic gold mining in the Sierra Nevada foothills during the Gold Rush washed hundreds of millions of metric tons of sediment into the Estuary (Wright and Schoellhamer, 2004), which was enough sediment to decrease water depths by as much as five to ten feet (CRWQCB, 2004). Sediments within the shallow Estuary continue to be resuspended by daily tidal actions and winds. Resuspension of contaminated sediments introduces biologically available contaminants into the water column. The turbidity that is caused by this resuspension also controls the depth to which natural light can penetrate in the water column, limiting photosynthesis and affecting the food web.

The highest concentrations of contaminants in the sediments are most often found at the urbanized edges of the Estuary, and the distribution of these contaminants is primarily driven by two factors: inputs from industrial and military sources near San Jose, southern San Francisco, and Oakland, as well as the East Bay shoreline; and the distribution of the fine particles to which these contaminants are sorbed. Many of the areas with high concentrations of PCBs, DDT, and/or chlordane in sediment correspond to the areas of the Estuary (e.g., South San Francisco Bay, San Pablo Bay, and along the East Bay shoreline) with high percentages of fine sediments (Connor et al., 2004).

PCB contamination remains one of the greatest water quality concerns in the Estuary, and PCB cleanup is a primary focus of the San Francisco Regional Water Quality Control Board (SFRWQCB). PCB contamination is greatest in the South Bay; all samples from the South Bay exceeded the PCB water quality objective, with maximum concentrations measured at the southern end of the South Bay. The few samples that did not exceed the objective were from the northern portion of the San Francisco Estuary (CRWQCB, 2004). In another study, the California Toxic Rule (CTR) water quality criteria for PCBs were exceeded in 90% of RMP water samples collected from the Estuary from 1993 to 2003, and regression analyses have shown exponential declines in PCB concentrations in mussels at most transplant locations from 1980 to 2003 (Davis et al., in prep).

Although concentrations of legacy pesticides (i.e., pesticides that have been banned, including DDTs, chlordane, and dieldrin) in the Estuary continue to be an issue, there are some indications that water quality has improved over time. Legacy pesticide concentrations exceeded CTR water quality criteria in 5% to 20% of water samples collected during 1993–2001 (Connor et al., 2004); however, declining concentrations of legacy pesticides have been observed in transplanted mussels from the Estuary (Davis et al., in prep).

Mercury contamination in the Estuary dates back to 19th-century mining practices, and sediment cores from the South Bay reflect the historic changes in concentrations over time (SFEI, 2004). Pre-mining concentrations were about four to five times lower than today's concentrations (Conaway et al., 2003). The legacy of mercury mining in the South Bay has created a reservoir of high mercury concentrations within the Bay's water and sediments (Figure 6-39). Old mines are also a continuing source of mercury, which can be mobilized from land and transported to the Estuary during rainfall events. In 2002, the concentration of total mercury exceeded the water quality objective in 32% of samples and was above the sediment target concentration in 84% of the samples (SFEI, 2004).

Other contaminants, such as copper, have demonstrated declines in the San Francisco Estuary. Copper concentrations in water, clams, and sediments collected from the South Bay declined from 1979 to 2003. RMP water data show statistically significant declines in copper concentrations at all historical South Bay stations, and USGS data show corresponding declines in copper concentrations measured in the clam *Macoma balthica* and in sediments from the South Bay. Declines of copper in *Macoma* have been correlated with declines in copper in effluents from the Palo Alto WWTP, located in the South Bay (SFEI, 2004).

Primary production of phytoplankton in the San Francisco Estuary has historically been light-limited because of the waterbody's turbidity (SFEI, 2004). In recent years, chlorophyll levels in the Estuary have

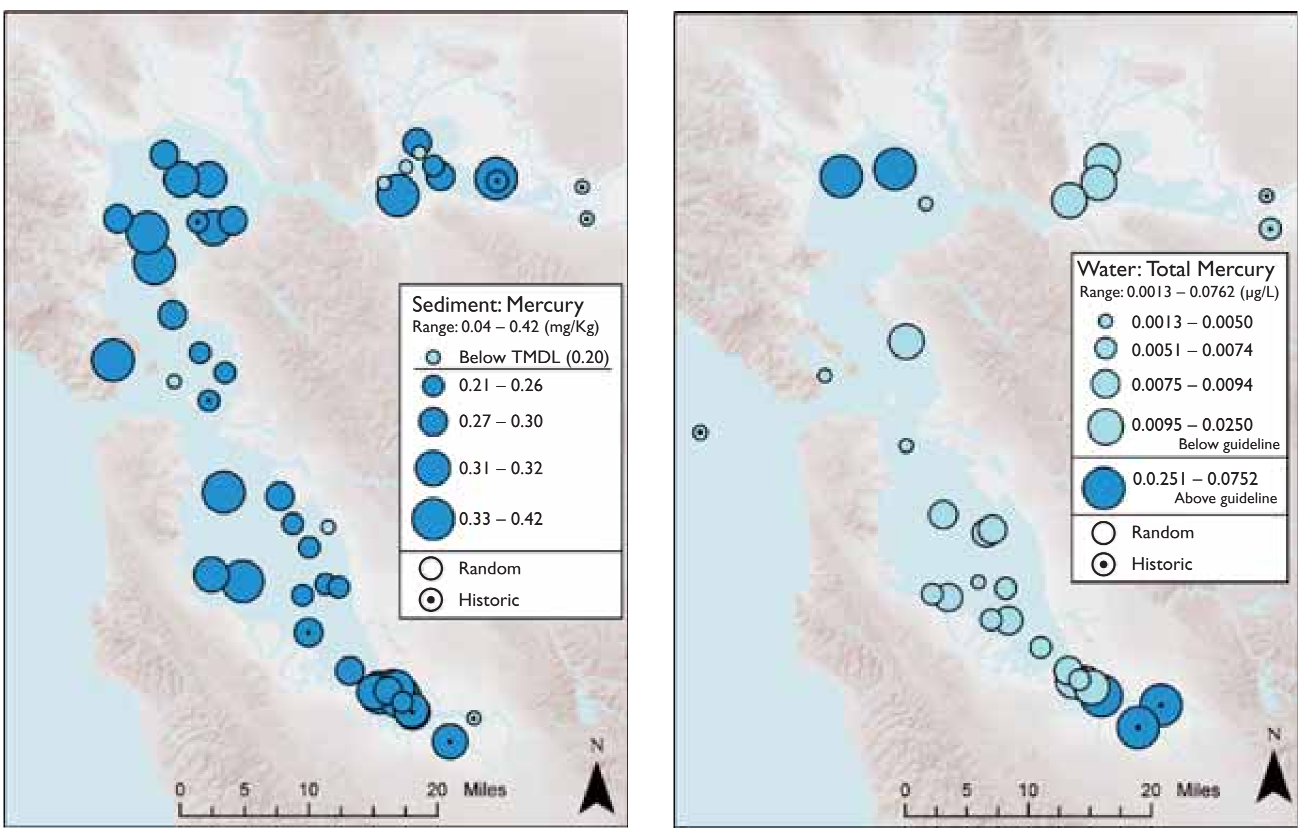


Figure 6-39. Maps of mercury concentrations in water and sediment of the San Francisco Estuary (SFEI, 2004).

increased, while turbidity in the Bay has declined (SFEI, 2006). A South Bay suspended-sediment model, developed by USGS, predicts that increases in wetland area (as proposed under the South Bay Salt Pond Project) could result in increased sediment deposition onto wetlands and a subsequent decrease in suspended sediments in the water column (Shellenbarger et al., 2004). The resulting increase in light penetration could cause higher phytoplankton productivity. In the northern reaches of the Estuary, chlorophyll concentrations have dramatically decreased in Suisun Bay sites since the invasion of the freshwater clam *Potamocorbula* in 1986. The high abundance of this filter-feeding clam has resulted in declines in chlorophyll in this Bay, from an average of 9.8 mg/L (pre-invasion) to 2.1 mg/L (post-invasion) (SFEI, 2003).

Habitat Quality

Wetlands serve several important functions in the San Francisco Estuary, including acting as natural filters, trapping sediment, and providing habitat for a variety of fish, shellfish, waterfowl, and other wildlife. It is estimated that the Estuary has lost more than 500,000 acres of tidal wetlands since 1850 (SFEP, 1999). The acquisition and restoration of the region's wetlands is a top implementation priority of the SFEP's *Comprehensive Conservation and Management Plan* (SFEP, 1993), and the SFEP has focused on tracking this issue as an indicator of the health of the Estuary. Since 2001, 15,000 acres of Cargill salt ponds and related lands have been acquired in the South Bay, and 1,400 acres have been acquired in the North Bay (SFEP, 2004).

Habitat in the Estuary has been affected by the introduction of invasive species. For example, giant reed (*Arundo donax*) was originally introduced into California by the Spanish in the late 1800s for erosion control along drainage canals. Since then, this species has become a significant problem along riparian areas around the Estuary because it spreads easily, requires large amounts of water, can smother native riparian vegetation, and is highly flammable. The reed has been found from Sacramento River tributaries to small urban streams throughout the Estuary. Eradication and education programs for this invasive species are currently underway in areas of the Estuary (SFEP, 2000).

Living Resources

Public attention has focused on invasive species in the Estuary since the 1990s, when the first comprehensive study was pursued (Cohen and Carlton, 1998). Some of the many invasive species present in the San Francisco Estuary include the green crab, shimofuri goby, *Spartina alterniflora* and its hybrids, Asiatic clams, and Asiatic zooplankton. For example, the green crab (*Carcinus maenas*), native to the Atlantic coast of Europe, was first found in the southern portion of the San Francisco Estuary in the early 1990s and has spread north at least as far as the Carquinez Strait. Researchers have found that, in contrast to their slow growth rates in Europe, green crabs grow rapidly and reach sexual maturity during their first year in the Estuary. During the course of a 9-year study, the green crab significantly reduced the abundance of 20 invertebrate species, and within just 3 years of being introduced, reduced densities of native clams and native shore crabs by 5% to 10% (SFEP, 2000). Studies are still underway to determine the full impacts of these recent invaders on the estuarine ecosystem.

Chemical contaminant levels in fish and wildlife are a concern in the San Francisco Estuary. For example, 25 years after the ban on the use of PCBs in California, concentrations in some Estuary sport fish remain 10 times higher than human health consumption guidelines (Davis et al., in prep). An interim human health consumption advisory issued by the California Office of Environmental Health Hazard Assessment (OEHHA), in response to elevated levels of mercury, PCBs, and other contaminants, has been in place since 1994 (SFEI, 2005). Between 1994 and 2003, 93% of all fish sampled by the RMP exceeded the California OEHHA screening value for PCBs; roughly 50% exceeded the screening value for mercury; and 3.5% exceeded the screening value for DDT. In addition, all leopard shark samples and almost all striped bass samples exceeded the mercury screening value (Greenfield et al., 2005). The SFRWQCB has calculated that a 40% reduction in mercury levels in striped bass would be necessary to meet the TMDL target of 0.2 ppm (Looker and Johnson, 2004). Over the long term, concentrations of lipid-normalized DDTs in leopard shark, shiner, and white croaker suggest statistically significant declines in concentrations from 1994 to 2003. Decreases in chlordane concentrations in leopard sharks, striped bass, and white croaker were also observed (Connor et al., 2004). No long-term trends have been detected in lipid-normalized PCB data. PCB levels in leopard shark, white croaker, and striped bass were higher in 1994 compared to other years, but the interannual variation since 1994 has fluctuated without a clear decline. Mercury concentrations in striped bass have shown no decline during the period from 1970 to 2003 (Greenfield et al., 2005).

Similarly, mercury levels in bird eggs remain a concern for Estuary managers. Concentrations of mercury in eggs from area terns and endangered California clapper rails have been close to the wet-weight threshold-effects level target of 0.5 ppm proposed in the draft TMDL for mercury (Schwarzbach and Adelsbach, 2003). Recent RMP data show median wet-weight concentrations of mercury in least tern eggs to be 0.6 ppm (SFEI, 2006). A more conservative threshold may be established to protect more sensitive species, such as the endangered least tern.

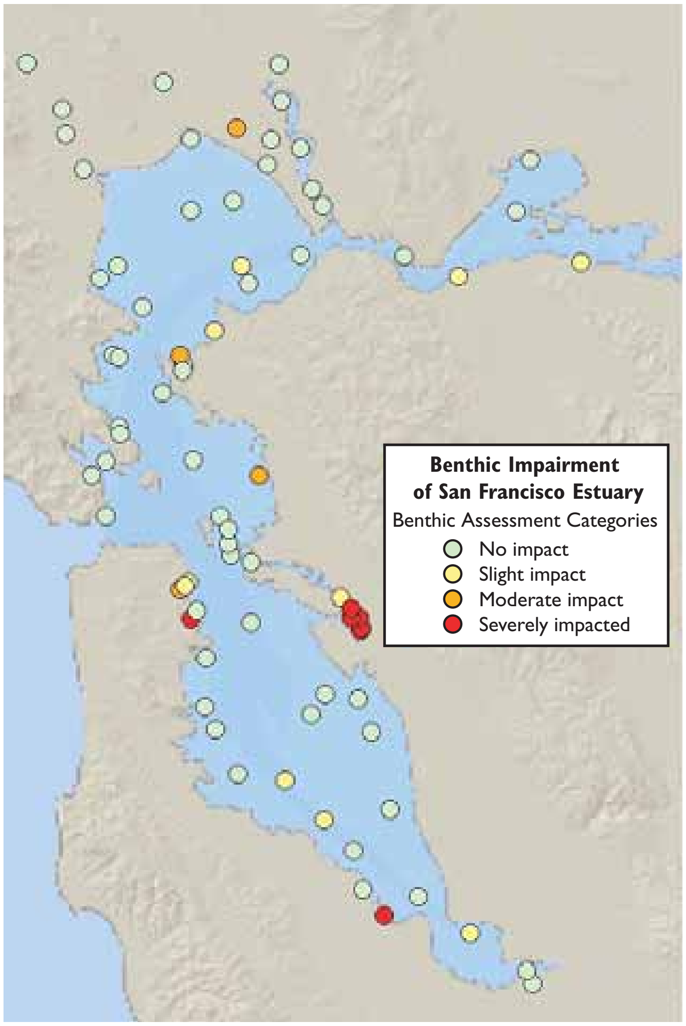
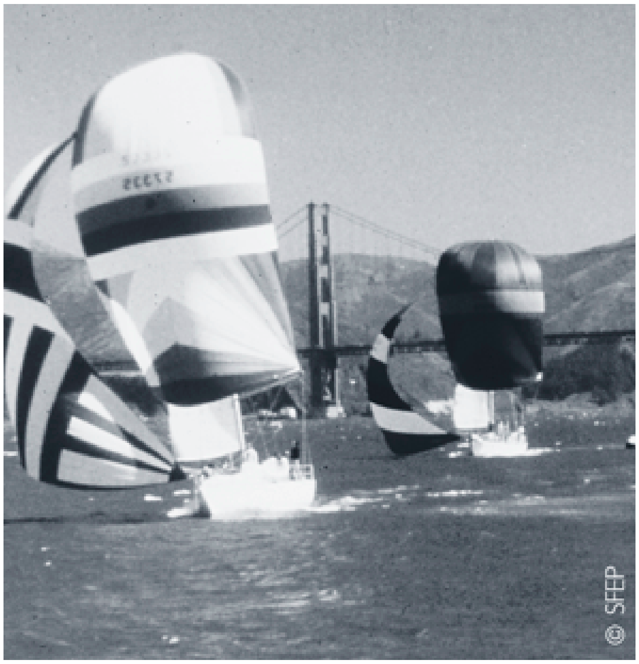


Figure 6-40. Map of benthic impact based on assessment of benthic assemblage. Data from from NOAA-EMAP, RMP, Bay Protection and Toxic Cleanup Program, and CISNet (SFEI).

Scientists from the RMP and the Southern California Coastal Water Research Project (SCCWRP) have developed a multi-metric approach for measuring the effects of contaminants on benthic communities. Benthic communities were assessed based on taxa diversity, abundance of organisms per sample, number of contaminant-tolerant organisms, and the proportion of contaminant-sensitive benthic amphipods to sensitive mollusks. Highly impacted sites were concentrated in the lower-central and southern portions of the Estuary, and the most severely impacted benthic sites were located in sub-embayments, coves, and channels along the margins of the Estuary (Figure 6-40). In particular, all samples from San Leandro Bay were classified as severely impacted, and samples from the deeper areas of the Estuary indicated minimal impact. Combining this method with other measures of contamination, such as sediment toxicity and sediment chemistry, can help support the link between contamination and benthic impact (SWRCB, 2004).



Racing on the San Francisco Estuary (SFEP).

Current Activities, Accomplishments, and Future Goals

Probably the biggest, most visible accomplishment of the SFEP is the large number of environmental education and outreach efforts taking place around the San Francisco Estuary, as well as an incredible number of watershed management planning activities. Almost every city or town now has a "friends of" creek or river group that has adopted the waterway running through its midst, and parks, ponds, and marshes have likewise been taken under someone's wing. Interest and a sense of ownership in the Estuary—in part encouraged by the improved public access offered by the San Francisco Bay Trail—is on the rise. As the state's population increases and open space and wildlife habitat continue to be lost to housing and development, the Estuary becomes yet an even more important resource to Bay-area residents. This grassroots energy in turn feeds regulatory efforts to protect and enhance the Estuary.

Water supply reliability and adequate inflows to protect aquatic resources are priorities of the SFEP's CCMP (SFEP, 1993). Cutoff of California's surplus water supplies from the Colorado River by the U.S. Department of Interior (DOI) provided the impetus for a historic shift from an era of centralized state and federal water planning to a more regionally and market-driven approach. Working together several years ago, water and environmental interests helped pass Proposition 50, the largest water bond in California history.

Data from the RMP and other programs have been integral in the development of TMDL reports by the SFRWQCB. TMDLs are action plans that set targets for acceptable levels of the contaminants that threaten the beneficial uses of the Estuary, such as sport fishing, wildlife habitat, and the preservation of rare and endangered species. The SFRWQCB plans to issue TMDLs for mercury and PCBs within the next year; these contaminants have exceeded thresholds of concern by factors of almost 4 to 10 (SFEI, 2005). TMDLs for other contaminants are also planned. Except for diazinon, which is driven by aquatic toxicity, these TMDLs are mostly driven by the impacts of the contaminants on human and wildlife consumers of contaminated fish (Figure 6-41) (SFEI, 2005). Since many contaminants partition to the sediments, the SFRWQCB is proposing sediment targets as a means of reducing contaminant levels in fish and wildlife to safe levels. Fish targets are also likely to be included.

Stronger planning, improved regulations, and increased acquisition and restoration are the main thrust of 12 wetland management actions called for in the SFEP's CCMP. One element, the setting of goals for the types, locations, and quantities of wetlands desired to maintain the ecosystem's health, will provide the biological foundation for the regional wetlands management plan.

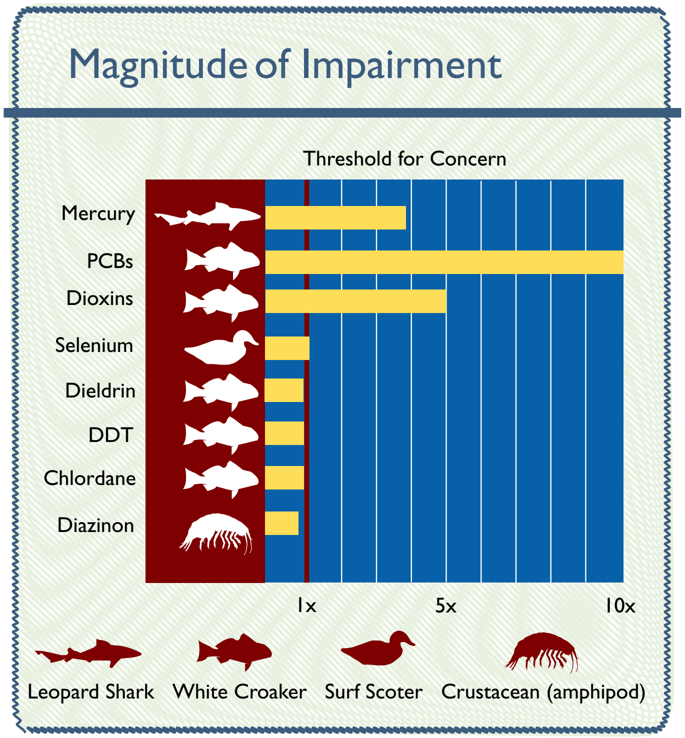


Figure 6-41. Summary of degree of Estuary impairment by high-priority pollutants in various species (SFEI, 2005).

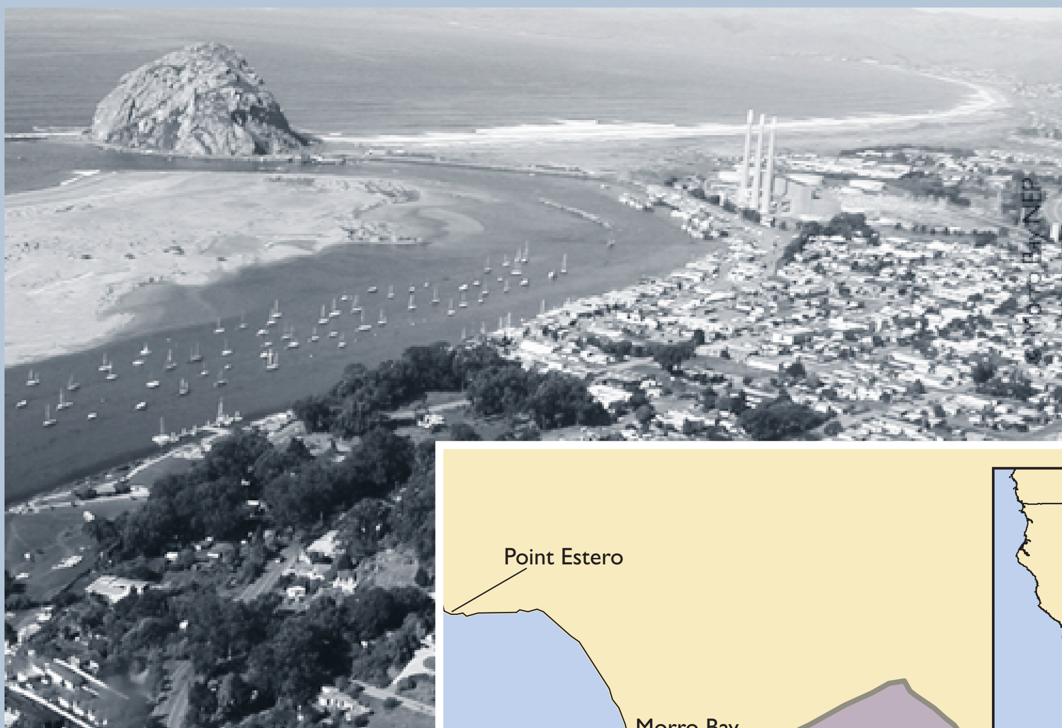
Public support for wetlands and creek restoration has been tremendous, as indicated by the large numbers of volunteers who have adopted creeks and participated in restoration activities. One SFEP Implementation Committee member reported that, in his organization alone, more than 12,000 people logged 36,000 volunteer hours. Planned restoration projects include about 19,000 acres in the North Bay (13,000 acres of tidal marsh and 6,000 acres of non-tidal or mixed hydrology) and 18,000 acres in the South Bay (SFEP, 2004).

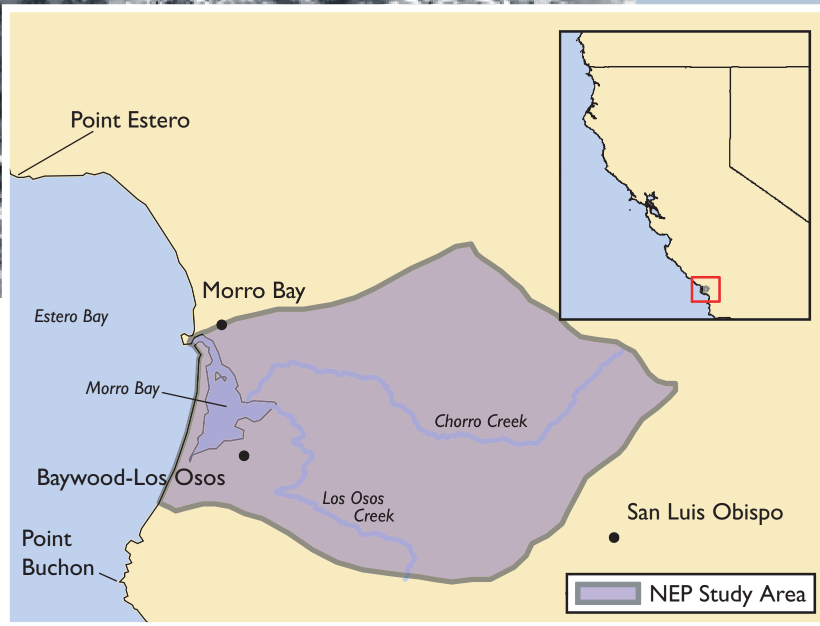
Conclusion

The task confronting those working on assessing and managing the San Francisco Estuary and its watershed is complex because of the diversity and scale of the human demands on the Estuary. Many potentially competing needs must be carefully balanced by many different agencies and stakeholder groups. Within this context, there are a variety of monitoring and assessment initiatives and concerns. Based on data from the NCA, the overall condition of the San Francisco Estuary is rated fair; however, data from the SFEP and other sources indicate that chemical contaminants are affecting the beneficial uses of the Estuary. Water quality guidelines continue to be exceeded for PCBs and legacy pesticides; chemical contaminant levels in many popular sport fish continue to exceed human health screening values; and evidence exists that benthic communities are affected by high levels of contamination. The aquatic food web of the San Francisco Estuary is continually exposed to multiple contaminants, and these contaminant levels pose a threat to the fish and wildlife in the Estuary, as well as to sport fish consumers. Estuary managers, through the TMDL process, are establishing target values for protection of the Estuary's beneficial uses. Long-term monitoring is crucial in illuminating changes in contaminant levels in the waters, sediments, and wildlife of the Estuary. Integrating this information into policy allows for a scientifically sound basis for the management of the San Francisco Estuary.

Alcatraz Island is located in the San Francisco Estuary (Jennifer Lloyd Blough).

Morro Bay National Estuary Program





MORRO BAY NATIONAL ESTUARY PROGRAM

www.mbnep.org

Background

Morro Bay is a 3.6-mi^2, semi-enclosed body of water located along the central California coast. This shallow estuarine system includes a diverse array of wetland habitats, including subtidal and intertidal eelgrass beds, mudflats, salt marsh, and brackish and freshwater wetlands on the Bay fringe. The Morro Bay watershed covers approximately 75 mi^2 of San Luis Obispo County. The predominant land use in the watershed is rangeland for beef cattle, and other uses include irrigated agriculture, open space, and developed lands. The area is seismically active, and several earthquake faults are located within or near the watershed. Morro Rock, a local landmark, is the most westerly visible in a chain of extinct volcanic plugs that divide the two coastal valleys that drain into the Bay (Morro Bay NEP, 2000).

Morro Bay is a major tourist attraction, with more than 25,000 people living within the Bay's watershed and an average of 1.5 million visitors per year. The area's economy is dominated by tourism and visitor-serving businesses, which generate 37% of all jobs and one-third of the general fund revenues for the City of Morro Bay. The Bay provides critical resources to fishing and recreational boating industries, with more than

100 commercial vessels providing a value of roughly $7 million to the local economy. Recreational fishing takes place from shore, docks, piers, and a variety of boats, and catches include a diversity of species, such as Pacific halibut, shark, jacksmelt, black surfperch, and starry flounder. More than 270 acres of the estuary are leased for commercial shellfish operations focused on the Pacific oyster. The estuary and surrounding habitats are an important stop-over area on the Pacific Flyway for migratory birds and are home to 16 federally threatened or endangered species, some of which are found nowhere else in the world (Morro Bay NEP, 2000).

In 1995, the Morro Bay National Estuary Program (Morro Bay NEP) was established to address the environmental concerns facing this nationally significant estuary, and the program's *Morro Bay Comprehensive Conservation & Management Plan* was finalized in 2000 (Morro Bay NEP, 2000). The Morro Bay NEP study area includes Morro Bay, its watershed, and to some extent, Estero Bay from Point Buchon in the south to Point Estero in the north.

Environmental Concerns

Erosion in the watershed and the resulting sedimentation of the estuary is one of the most severe threats facing Morro Bay. Sediment delivery has increased over time due to changes in land use, as well as to the alteration and loss of streams and flood plains. The Bay has lost more than a quarter of its tidal volume in the past century, and left unchecked, sedimentation will continue to degrade and destroy subtidal and intertidal habitats. In addition to sedimentation, development, and other land-use changes, changes in drainage patterns, erosion, and growth of invasive species such as *Arundo donax* (giant reed) in riparian corridors and veldt grass in the coastal dunes have contributed to the loss of natural habitat in the study area. Some obvious effects of habitat loss in Morro Bay include the likely extinction of the Morro Bay kangaroo rat and decreases in populations of steelhead trout, a federal endangered species (Morro Bay NEP, 2000).

Population Pressures

The population of the NOAA-designated coastal county (San Luis Obispo) coincident with the Morro Bay NEP estuarine study area increased by 204.4% during a 40-year period, from 0.08 million people in 1960 to 0.25 million people in 2000 (Figure 6-42) (U.S. Census Bureau, 1991; 2001). This rate of population growth for the Morro Bay NEP was the highest rate observed for any of the six West Coast NEPs and was more than double the average growth rate of 100.3% for the collective NEP-coincident coastal counties of the West Coast region. In contrast, San Luis Obispo County had the second-lowest population density (75 persons/mi^2) of any of the West Coast NEPs (U.S. Census Bureau, 2001). This estuary is not surrounded by a large metropolitan area, but is a major recreational area and agricultural center for the local coastal community.

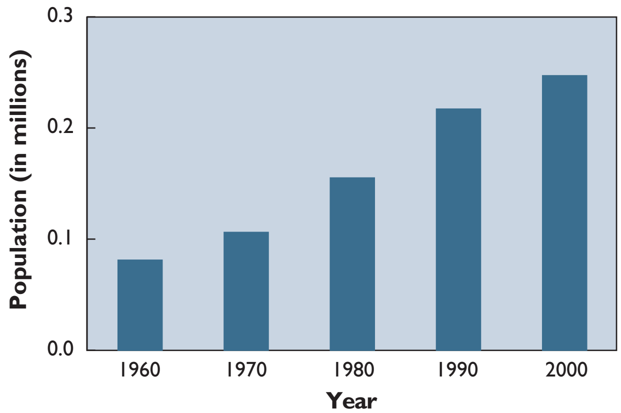


Figure 6-42. Population of the NOAA-designated coastal county of the Morro Bay NEP study area, 1960–2000 (U.S. Census Bureau, 1991; 2001)

NCA Indices of Estuarine Condition—Morro Bay

The overall condition of Morro Bay is rated good based on three of the indices of estuarine condition used by the NCA (Figure 6-43). The water quality and fish tissue contaminants indices are rated good, and the sediment quality index is rated fair. Although data on the condition of the benthic community were collected for this estuary, Morro Bay could not be rated using an index based on deviations from the expected species richness. Figure 6-44 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 Moss Landing Marine Laboratories, under contract to the SCWRRP, from 30 sites sampled in the Morro Bay NEP estuarine area in 2003. 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.

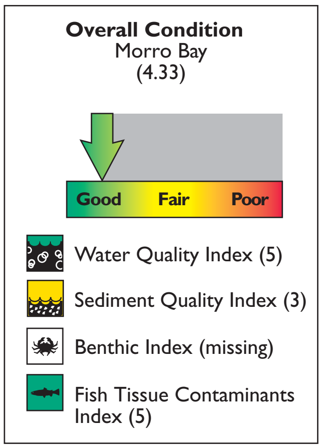


Figure 6-43. The overall condition of the Morro Bay NEP estuarine area is good (U.S. EPA/NCA).

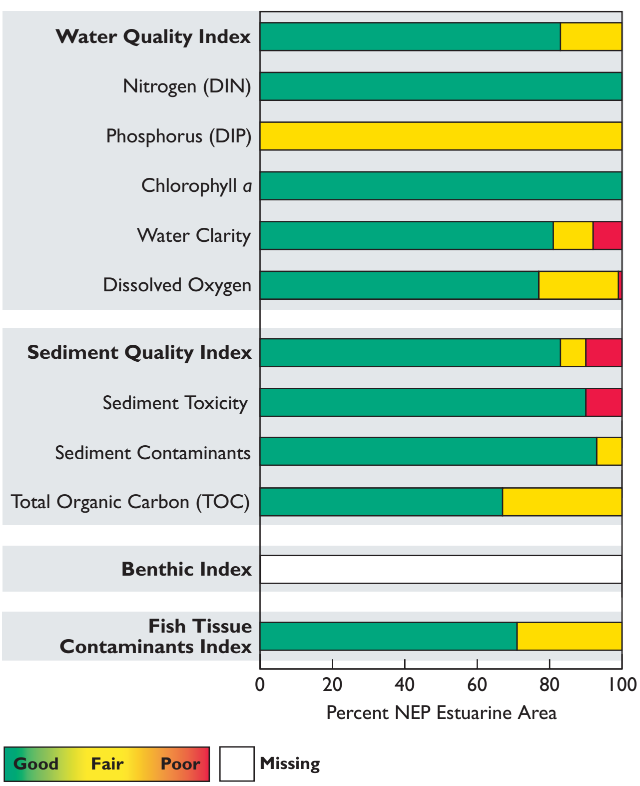


Figure 6-44. Percentage of NEP estuarine area achieving each ranking for all indices and component indicators — Morro Bay (U.S. EPA/NCA).

Water Quality Index

Based on NCA survey results, the water quality index for Morro Bay is rated good (Figure 6-45). This index was developed using NCA data on five component indicators: DIN, DIP, chlorophyll *a*, water clarity, and dissolved oxygen. Seventeen percent of the estuarine area was rated fair for water quality, and 83% of the area was rated good. Diminished water quality was primarily due to limited water clarity and elevated levels of DIP.

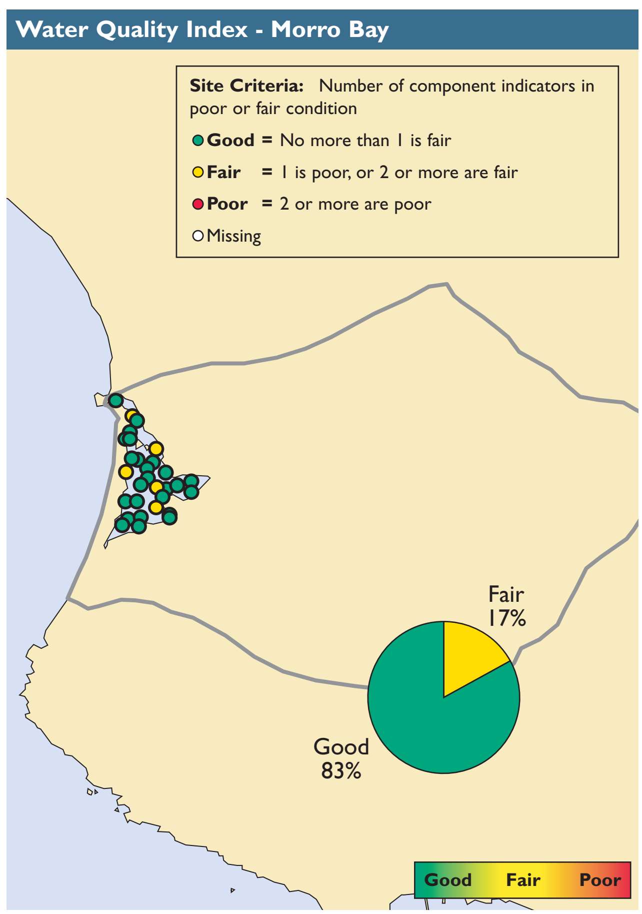


Figure 6-45. Water quality index data for Morro Bay, 2003 (U.S. EPA/NCA).

Dissolved Nitrogen and Phosphorus | DIN concentrations in Morro Bay are rated good, but DIP concentrations are rated fair. Concentrations of DIN were rated good in 100% of the estuarine area, whereas fair DIP concentrations occurred in 100% of the area. In addition to natural inputs of nutrients from offshore coastal upwelling, high levels of urban and agricultural runoff may also be major contributors to the elevated nutrient levels found in Morro Bay.

Chlorophyll a | Chlorophyll *a* concentrations in Morro Bay are rated good, with 100% of the estuarine area rated good for this component indicator.

Water Clarity | Water clarity in Morro Bay is rated good. Approximately 8% of the estuarine area was rated poor for this component indicator, and 11% was rated fair.

Dissolved Oxygen | Dissolved oxygen conditions in Morro Bay are rated good, with 77% of the estuarine area rated good and 22% of the area rated fair. Only 1% of the estuarine area was rated poor for this component indicator; however, these measured values reflect daytime conditions, and some areas of the Bay may still experience hypoxic conditions at night.

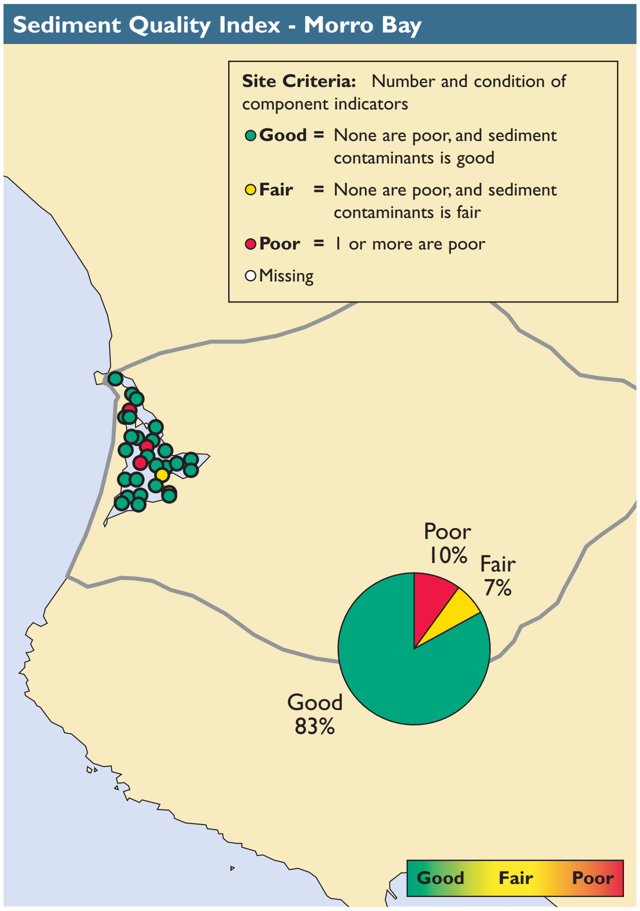


Figure 6-46. Sediment quality index data for Morro Bay, 2003 (U.S. EPA/NCA).

Sediment Quality Index

The sediment quality index for Morro Bay is rated fair (Figure 6-46). This index was developed using NCA data on three component indicators: sediment toxicity, sediment contaminants, and sediment TOC. Ten percent of the estuarine area was rated poor for sediment quality, and 7% of the area was rated fair, primarily as a result of sediment toxicity.

Sediment Toxicity | Sediment toxicity for Morro Bay is rated poor, with 10% of the estuarine area rated poor for this component indicator.

Sediment Contaminants | Morro Bay is rated good for sediment contaminant concentrations because none of the estuarine area was rated poor for this component indicator and 7% of the area was rated fair.

Total Organic Carbon | Morro Bay is rated good for sediment TOC because 67% of the estuarine area was rated good for TOC concentrations and the remaining 33% of the area was rated fair.

Benthic Index

Currently, the condition of the benthic invertebrate communities in Morro Bay cannot be rated using an index based on deviations from the expected species richness because this approach requires a significant regression between salinity and the log of species richness. This relationship was not significant in the Morro Bay data collected during the 2003 NCA survey. The lack of a significant regression was probably due to an inadequate range in salinity because the Bay's salinity ranged only from 33.9 to 35.1 psu (or salinity values indicative of ocean water). Species richness in the Bay ranged between 2 and 19 species per sample.

Fish Tissue Contaminants Index

The fish tissue contaminants index is rated good for Morro Bay, although this rating should be interpreted cautiously because of the small number of sample stations where fish tissues were obtained (7 of 30 stations). Figure 6-47 shows that fish tissue at 71% of stations (5 of 7) where fish were caught had tissue contaminant levels below EPA Advisory Guidance values using whole-fish contaminant concentrations. These risk calculations are appropriate for populations that consume whole fish. Samples from two Morro Bay stations were rated fair based on concentrations of mercury and DDT.

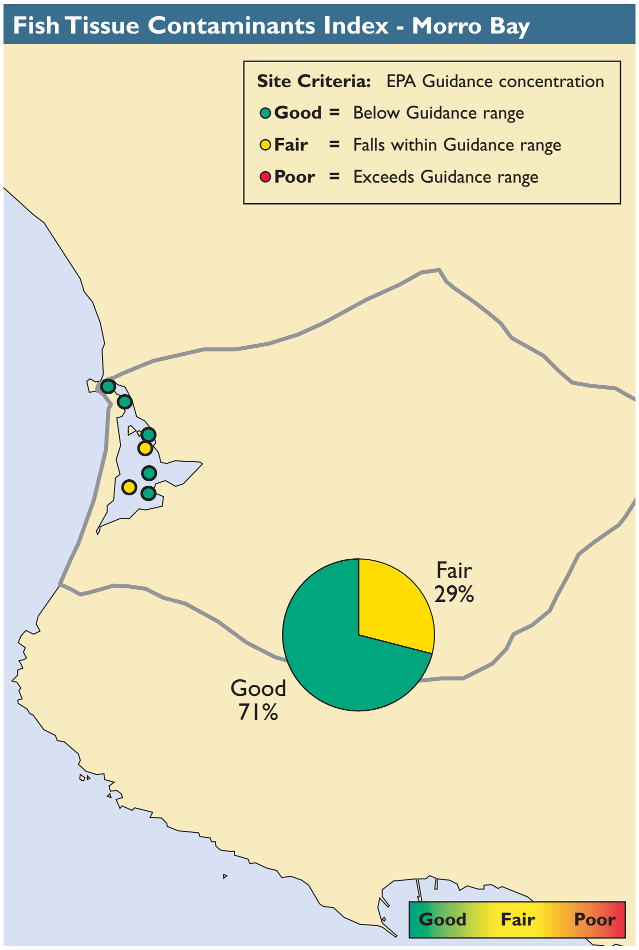


Figure 6-47. Fish tissue contaminants index data for Morro Bay, 2003 (U.S. EPA/NCA).

A great egret lazily takes flight across Morro Bay (Morro Bay NEP).

Morro Bay National Estuary Program

Kids' Beach Cleanup Event and Aerial Art a Success

Two hundred second-grade students traveled from the Central Valley to Cayucos State Beach, CA, on May 13, 2005, for the Kids' Beach Clean-up Event. In an effort to protect marine resources, the students volunteered to collect trash and other debris from the beach to keep these materials from entering the ocean. The participating students were from Strathmore and Seville, CA, two small towns in the Central Valley county of Tulare. This was the first visit to the seashore for many of the students. A week before the field trip, Morro Bay NEP staff member Cheryl Lesinski gave a classroom presentation to students that focused on the impacts that marine debris and pollution can have on beach resources. This project was funded by the California Coastal Commission's Whaletail License Plate program.

As part of the beach cleanup event, the entire group took part in an aerial art formation (see photo). Standing together in lines, the children spelled out the word "PROTECT" as a reminder to all Californians that the ocean is a valuable resource that needs our help (Morro Bay NEP, 2005).

California students involved in beach cleanup event (Morro Bay NEP).

Morro Bay National Estuary Program Indicators of Estuarine Condition

The Morro Bay NEP and its partners employ a variety of monitoring methods and use a suite of indicators to track changes in water quality, suitable habitat areas, and the health of living resources in the Morro Bay estuary. The following section discusses selected key indicators that are used by the Morro Bay NEP to evaluate the health of the estuary and its watershed. Additional information is available at http://www.mbnep.org.

Water and Sediment Quality

The Morro Bay NEP's Volunteer Monitoring Program (VMP) is the main program conducting water quality monitoring in the study area. The Morro Bay VMP monitors monthly for total coliform and *E. coli*, nutrients, dissolved oxygen levels, pH, salinity, flow, temperature, and HABs (Kitajima, 2003). In accordance with EPA's recommendations, the Morro Bay VMP has begun using *Enterococci* as the main pathogen indicator for marine waters (Morro Bay NEP, 2006b).

Ongoing monitoring indicates that bacterial contamination and nutrient over-enrichment are key water quality concerns in the estuary and watershed. From 2002 to 2004, bacteria sampling results indicated that the majority of the creek sites sampled were unsafe for human contact in at least 30% of the samples collected and that three of the seven sites in the estuary were unsafe in 10% to 20% of the samples collected (Morro Bay NEP, 2006a). High fecal bacteria levels are of concern for shellfish beds, as well as for human health impacts from recreational contact with creek and Bay waters. Two of the three commercial shellfish lease areas in Morro Bay are partially closed because of elevated bacteria levels, and all harvesting areas are closed following storm events (Morro Bay NEP, 2000; 2006a). High levels of nitrates and phosphates are present in portions of the Chorro and Los Osos drainages. These increased levels of nutrients are mostly attributed to agricultural runoff, WWTP effluent, grazing lands, and poorly functioning septic systems (Morro Bay NEP, 2000).

Habitat Quality

One of the key indicator measures used to evaluate habitat changes in Morro Bay is the acres and/or linear miles of habitat protected and restored. Since 2001, more than 3,000 acres of valuable wildlife habitat have been permanently protected in the Morro Bay watershed, and 4.5 miles of stream habitat have been restored (Morro Bay NEP, 2006a).

The monitoring of changes in the areal extent of different estuarine habitat areas (e.g., eelgrass, mudflats, salt marsh) is also useful. In particular, the Morro Bay NEP has found that the number of acres of eelgrass in Morro Bay is a good indicator of the health of living resources in the watershed. In 2003, the estuary contained approximately 330 acres of subtidal and intertidal eelgrass, 380 acres of salt marsh, 1,200 acres of intertidal mud flats, and 175 acres of subtidal habitat (USACE, 2003). The Morro Bay eelgrass beds are some of the largest and healthiest in central and southern California and support the highest diversity of invertebrates of any habitat in the estuary (Morro Bay NEP, 2000).

Sediment deposition is being tracked carefully to observe its impact on habitat conditions in the Morro Bay estuary because modeling of future sedimentation has suggested that the area suitable for eelgrass could be reduced by 48% during the next 50 years if sedimentation rates are not slowed (USACE, 2003). One specific goal of the Morro Bay NEP is a 15% reduction in average annual sediment loads in stream and estuary waters by 2010 (Morro Bay NEP, 2000). The recently adopted sediment TMDL calls for a 50% reduction in average annual sediment load during the next 50 years (CCRWQCB, 2002a). Monitoring stations to track deposition rates in the estuary were recently established, and detailed bathymetric surveys of the Bay will provide ongoing information about overall sedimentation rates (Morro Bay NEP, 2006a).

The number of invasive species in Morro Bay is another potentially useful indicator that is still under development by the Morro Bay NEP, but which may become a useful measure for habitat quality and the health of living resources over time. Portions of the estuary's various habitat have been impacted by invasive plant species. During a habitat survey conducted in

1998, the invasive species cape ivy was a dominant plant in the herb layer of Chorro Creek and was also present along the lower reaches of Los Osos Creek (Morro Bay NEP, 2000).

Living Resources

Measurements of macroinvertebrate populations and diversities are also used to indicate the health of living resources in Morro Bay. Benthic infauna have been monitored annually at a number of creek sites in the Morro Bay watershed. Water quality monitoring provides a snapshot of conditions at that time, whereas macroinvertebrate analysis reflects stream health over a longer time period because long-term water quality affects which species ultimately establish themselves or thrive in the estuary watershed (Kitajima, 2003). The abundance of macroinvertebrates and the ease of sampling also make benthic infauna good environmental indicators.

Central Coast steelhead trout have been listed as a federal threatened species by the NMFS because of declining habitat quality throughout the species range. By 2000, the steelhead population in Morro Bay had decreased to less than 1% of the 1950 population size. Anadromous (migratory) fish are good indicators of resource health because they depend on the entire ecosystem, from the upper watershed to the coastal ocean, for their life cycle (Morro Bay NEP, 2000). Local population size and availability of habitat for this species are two of the indicators used to evaluate living resources in Morro Bay.

Morro Bay is also increasingly being recognized as an area that is critical in supporting resident and migratory bird species. Black brant and other migratory waterfowl utilize the Bay as an overwintering site and as a feeding and resting site during their migration along the Pacific Flyway. Surveys of the black brant population are used to study the density, age composition, and habitat delineation of this species. Average mid-winter, single-day counts of the brant have declined from about 7,000 in the 1930s to roughly 3,000 in 2000 (Roser, 2003). The Morro Bay NEP coordinates biannual surveys of shorebird abundance and diversity, which have shown relatively stable trends since the mid-1990s (Morro Bay NEP, 2006a). The Audubon Society consistently rates Morro Bay as among the top 5 areas (out of 963 sites nationwide) for diversity of winter bird species, with around 200 species and more than 50,000 individual birds counted in a single day in December (Morro Bay NEP, 2000).

Schools of top smelt are common in Morro Bay (Morro Bay NEP).

Current Projects, Accomplishments, and Future Goals

Some of the recent environmental success stories and restoration efforts in Morro Bay include the following:

- Project Clearwater (formerly the Morro Bay Watershed Enhancement Project) has helped farmers and ranchers improve land management practices. These efforts have resulted in the implementation of more than 235 BMPs and helped prevent more than 172,000 tons of soil erosion (CSLRCD, 2006).
- The 1,860-acre Maino Ranch Conservation Easement has been purchased to protect the natural resources, rural character, and working landscape of the Maino Ranch in the Morro Bay watershed. The easement greatly restricts the subdivision and development potential of the ranch (Morro Bay NEP, 2000).
- A 580-acre property spreading below Hollister Peak and across Chorro Creek has become one of California's newest ecological reserves. The Chorro Creek Ecological Reserve, once slated for a golf course and resort, includes approximately two miles of Chorro and San Luisito creeks, as well as large swaths of restorable flood plain near scenic Highway 1. The Morro Bay NEP is working with the California Department of Fish and Game to restore the natural floodplain and freshwater wetlands on this property (Morro Bay NEP, 2006a).
- The Morro Bay NEP's efforts to reduce bacterial pollution include working with the boating community, limiting cattle access to watershed creeks, and encouraging the implementation of a centralized WWTP for the bayside community of Los Osos, which is currently on individual septic systems (Morro Bay NEP, 2000).
- The Central Coast Regional Water Quality Control Board (CCRWQCB) has declared Morro Bay and its creeks as impaired waters for a number of pollutants and has adopted TMDLs covering the estuary and creeks for pathogens, sedimentation, nutrients, and dissolved oxygen (CCRWQCB, 2002a; 2002b; 2004a; 2004b; 2004c; 2005). The Morro Bay NEP is a key component of the implementation and monitoring for these efforts to improve water quality. Specific actions taken to control nutrient inputs to the Bay include implementing nitrogen-control measures for wastewater effluent, improving wastewater treatment in Los Osos, and assisting farmers and ranchers with BMPs (Morro Bay NEP, 2000; 2004).

Conclusion

Based on data from the NCA survey, the overall condition of Morro Bay is rated good. The Morro Bay NEP considers the primary threats facing the estuary and its watershed to be erosion and sedimentation, bacterial contamination, low freshwater flows to the Bay, elevated levels of heavy metals and other toxics in Bay sediments, nutrient over-enrichment, loss of wildlife habitat, and the decline of the local steelhead trout population. The Morro Bay NEP is a collaborative effort that brings local citizens, local government, non-profit agencies, and landowners together to protect and restore the physical, biological, economic, and recreational values of the Morro Bay estuary. The primary goals of the NEP are to slow the process of Bay sedimentation; protect and enhance steelhead trout populations and habitat; protect and restore the integrity of the diverse habitats in the watershed and the wildlife that depend on them; promote public awareness and involvement in estuarine management through outreach, education, and volunteering; and ensure that estuary and creek waters are clean and fully support healthy eelgrass beds, safe recreational uses, and thriving fish and shellfish populations.

Santa Monica Bay Restoration Commission

www.santamonicabay.org

Background

Santa Monica Bay is a 306-mi^2 estuary located west of Los Angeles on the Pacific Coast of California and bordered on the north by the Santa Monica mountains. The Bay reaches depths of up to 1,640 feet and has a total volume of about 6.8 trillion gallons. The Santa Monica Bay watershed encompasses more than 400 mi^2 and includes a large number of highly populated communities, including Beverly Hills, Calabasas, Culver City, El Segundo, Malibu, Redondo Beach, Santa Monica, West Hollywood, and part of Los Angeles. More than 3 million people live within the watershed, and between 50 to 60 million visits are made to Santa Monica Bay each year. The Bay receives freshwater inputs from 28 stream drainage basins, with the largest flows coming from Malibu Creek and Ballona Creek (Martin et al., 1996).

The Santa Monica region features a range of habitat types, including coastal scrub, wetland and rocky intertidal zones, kelp beds, open water, and both hard- and soft-bottom areas (Martin et al., 1996). The Bay serves as home to more than 5,000 species of birds, fish, mammals, plants, and other wildlife. The Bay's 50 miles of coastline provide recreational opportunities for an estimated 500,000 visitors a day at the height of the summer season (ANEP, 2001d). Sport fisheries are a booming industry, and the Bay is home to chub mackerel, barred sand bass, kelp bass, and California spiny lobster, among other species (Martin et al., 1996). Human development has replaced more than 95% of the Bay's historic coastal wetlands and degraded the remaining 5%, putting some species in danger of local extinction (ANEP, 2001d). Only a few thousand acres of wetlands (e.g., riparian zones, lakes, ponds, coastal marshes, and lagoons) remain in the watershed (Martin et al., 1996).

The State of California and EPA established the Santa Monica Bay Restoration Project (SMBRP) as an NEP in December 1988. The project was formed to develop a plan that would ensure the long-term health of the Bay and its watershed. In January 2003, the SMBRP formally became an independent state organization and is now known as the Santa Monica Bay Restoration Commission (SMBRC) (SMBRC, 2006).

Environmental Concerns

Research suggests that there are 19 pollutants of immediate concern in Santa Monica Bay (SMBRC, 2006). Sources and pathways of contaminants include industrial discharges, urban runoff into creeks and storm drains, municipal WWTPs, boating and shipping activities, dredging, and advection of pollutants from other areas (Martin et al., 1996). About 645 million gallons of treated wastewater are discharged to Santa Monica Bay each day via 7 major point-source facilities and more than 160 permitted smaller commercial and industrial facilities (Martin et al., 1996; SMBRC, 2006). Urban and stormwater runoff carried through the region's massive storm drain systems and few remaining streams is a serious year-round concern. Each year, an average of 30 billion gallons of storm water and urban runoff are discharged through more than 200 outlets into Santa Monica Bay (Martin et al., 1996).

Population Pressures

The population of the 4 NOAA-designated coastal counties (Los Angeles, Orange, San Bernardino, and Ventura) coincident with the SMBRC study area increased by 99.2% during a 40-year period, from 7.4 million people in 1960 to 14.8 million people in 2000 (Figure 6-48) (U.S. Census Bureau 1991; 2000). This rate of population growth for the SMBRC study area was slightly less than the average growth rate of 100.3% observed for the collective NEP-coincident coastal counties of the West Coast region; however, the SMBRC-coincident coastal counties had the second-highest population density in 2000 with 553 persons/mi^2 (U.S. Census Bureau, 2001). This estuary is surrounded by a large, sprawling metropolitan area and is a major recreational area for the local coastal community.

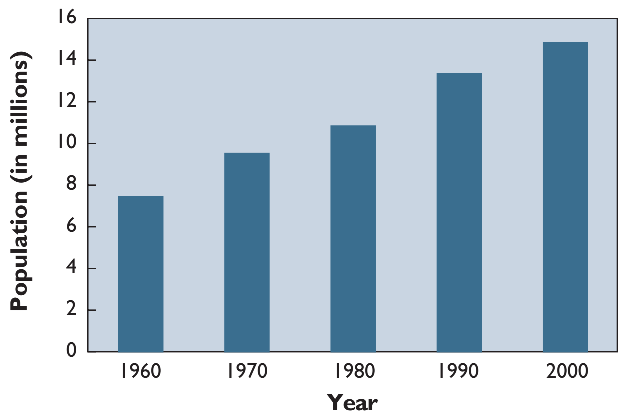


Figure 6-48. Population of NOAA-designated coastal counties of the SMBRC study area, 1960–2000 (U.S. Census Bureau, 1991; 2001).

NCA Indices of Estuarine Condition—Santa Monica Bay

The overall condition of Santa Monica Bay is rated fair based on three of the indices of estuarine condition used by the NCA (Figure 6-49). The water quality index is rated good, and the sediment quality and fish tissue contaminants indices are rated poor. Although data on the condition of the benthic community were collected for this estuary, Santa Monica Bay could not be rated using an index based on deviations from the expected species richness. Figure 6-50 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 Moss Landing Marine Laboratories, under contract to the SCWRRP, from 47 sites sampled the SMBRC estuarine area in 2003. 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.

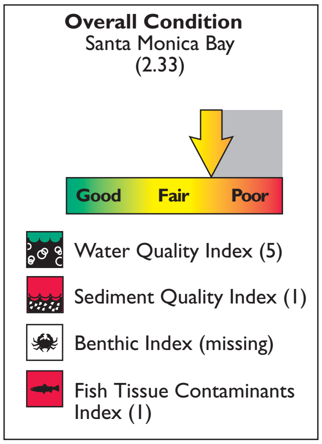


Figure 6-49. The overall condition of the SMBRC estuarine area is fair (U.S. EPA/NCA).

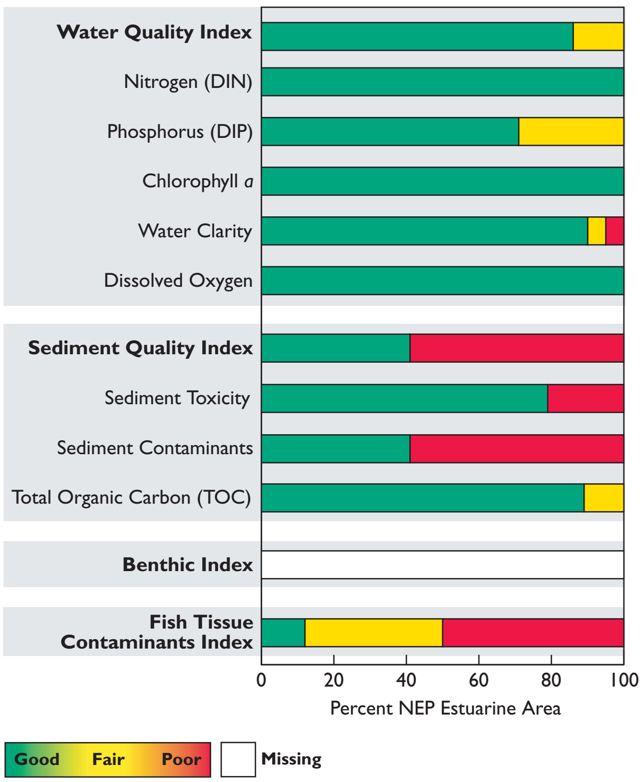


Figure 6-50. Percentage of NEP estuarine area achieving each ranking for all indices and component indicators — Santa Monica Bay (U.S. EPA/NCA).

Water Quality Index

Based on NCA survey results, the water quality index for Santa Monica Bay is rated good. This index was developed using NCA data on five component indicators: DIN, DIP, chlorophyll *a*, water clarity, and dissolved oxygen. Fourteen percent of the estuarine area was rated fair for water quality, and 86% of the area was rated good (Figure 6-51).

Dissolved Nitrogen and Phosphorus | DIN and DIP concentrations in Santa Monica Bay are rated good. All of the estuarine area was rated good for DIN concentrations, whereas 29% of the area was rated fair for DIP concentrations. In addition to natural inputs of nutrients from offshore coastal upwelling, high levels of urban and agricultural runoff may also be major contributors to the nutrient levels found in Santa Monica Bay.

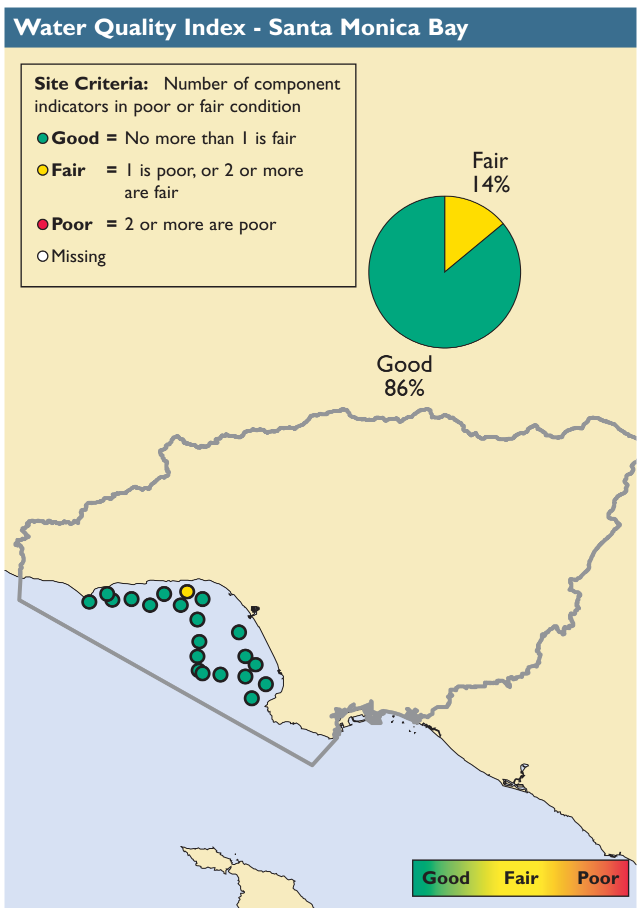


Figure 6-51. Water quality index data for Santa Monica Bay, 2003 (U.S. EPA/NCA).

Santa Monica Bay Restoration Commission

Chlorophyll a | Chlorophyll *a* concentrations in Santa Monica Bay are rated good, with 100% of the estuarine area rated good for this component indicator.

Water Clarity | Water clarity in Santa Monica Bay is rated good. Approximately 5% of the estuarine area was rated poor for this component indicator, and 5% of the area was rated fair.

Dissolved Oxygen | Dissolved oxygen conditions in Santa Monica Bay are rated good, with 100% of the estuarine area rated good for this component indicator. It should be noted that these measured values reflect daytime dissolved oxygen conditions, and some areas of the Bay may still experience hypoxic conditions at night.

Sediment Quality Index

The sediment quality index for Santa Monica Bay is rated poor. This index was developed using NCA data on three component indicators: sediment toxicity, sediment contaminants, and sediment TOC. Fifty-nine percent of the estuarine area exceeded thresholds for at least one of these component indicators and was rated poor, and 41% of the estuarine area was rated good (Figure 6-52).

Plover (Brad Ashbaugh).

Sediment Toxicity | Sediment toxicity for Santa Monica Bay is rated poor, with 21% of the estuarine area rated poor for this component indicator.

Sediment Contaminants | Santa Monica Bay is rated poor for sediment contaminant concentrations, with 59% of the estuarine area rated poor for this component indicator.

Total Organic Carbon | Sediment TOC for Santa Monica Bay is rated good, with 89% of the estuarine area rated good for this component indicator.

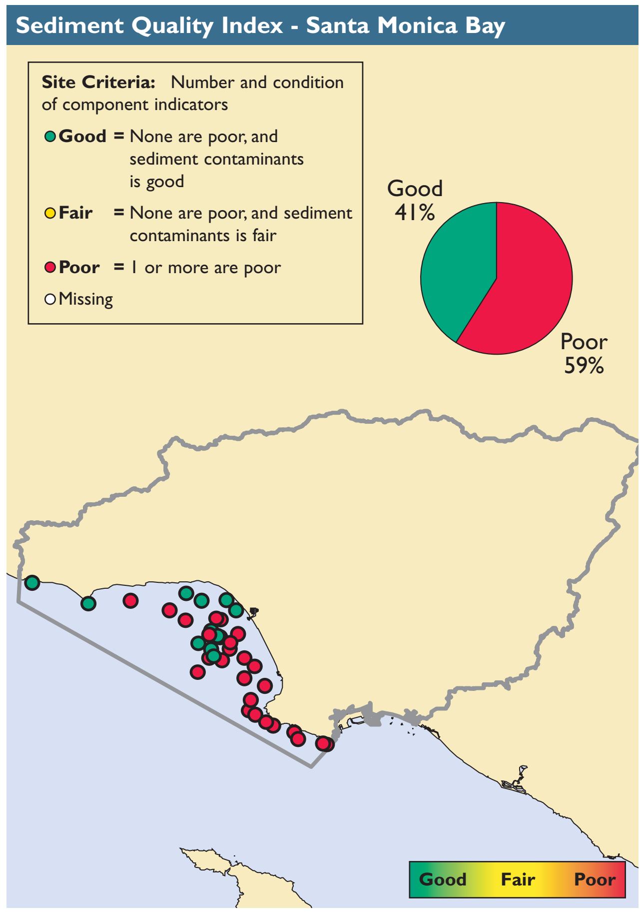


Figure 6-52. Sediment quality index data for Santa Monica Bay, 2003 (U.S. EPA/NCA).

Benthic Index

Presently, the condition of the benthic invertebrate communities in Santa Monica Bay can not be rated using an index based on deviations from the expected species richness because this approach requires a significant regression between salinity and the log of species richness. This relationship was not significant in the Santa Monica Bay data collected during the 2003 NCA survey.

Fish Tissue Contaminants Index

The fish tissue contaminants index for Santa Monica Bay is rated poor because 50% of the stations where fish were caught were rated poor (Figure 6-53). However, this rating should be interpreted cautiously because of the small number of Bay stations (8) where fish tissues were collected.

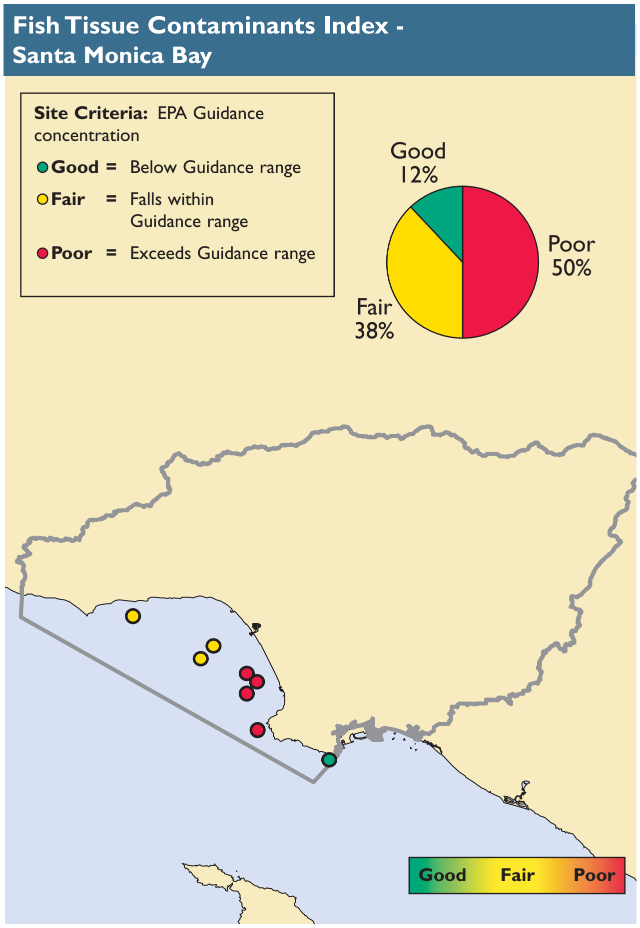


Figure 6-53. Fish tissue contaminants index data for Santa Monica Bay, 2003 (U.S. EPA/NCA).

Santa Monica Bay Restoration Commission Indicators of Estuarine Condition

The SMBRC is using or developing several indicators to evaluate water and sediment quality, habitat conditions, and stressors for the SMBRC estuarine area. Indicators are typically ranked with regard to availability of data for reporting on the state of the Bay; some of the indicators of higher quality are described below.

Water and Sediment Quality

Indicators used by the SMBRC for water and sediment quality include the following:

- Concentrations of five heavy metals: cadmium, copper, lead, silver, and zinc
- Concentrations of fecal and total coliform bacteria and *Enterococci* (pathogen indicators)
- Beach Report Card grades (summer and winter) based on measurement of bacterial indicators
- Number and effectiveness of pathogen-reduction projects along the Bay's beaches (SMBRC, 2004).

Since the early 1970s, the loading of seven heavy metals from the two largest WWTPs has decreased by 67% to 99%, and the loading of total suspended solids has decreased by more than 80%. As a result, impaired estuary bottom habitats near discharge outfalls have shown signs of recovery (SMBRC, 2006).

Monitoring of bacterial indicators on beaches is usually conducted on a daily basis (Heal the Bay, 2004). In general, the number of days per year during which at least one beach is closed due to sewage spills has greatly decreased (ANEP, 2001d). The environmental group Heal the Bay compiles grades for a Beach Report Card system based on bacterial indicator measurements. The 2003–2004 Annual Beach Report Card (Heal the Bay, 2004) shows that most beaches had very good water quality, with 268 of 373 (72%) locations receiving A grades for the year during dry weather. In addition, other grade ratings included 44 B grades (12%), 27 C grades (7%), 15 D grades (4%), and 19 F grades (5%). The monitored beach with the poorest dry weather water quality during 2003 and 2004 was Surfrider Beach (Heal the Bay, 2004).

Santa Monica Bay Restoration Commission

Santa Monica Bay Stormwater Projects

The SMBRC is taking many different approaches to address the issue of pollutants found in stormwater runoff (see table). Since 1992, the SMBRC has secured more than $30 million in state and local bond funding for more than 30 pollution-control projects, including dry-weather runoff diversions from storm drain outlets along Santa Monica Bay beaches, a state-of-the-art urban runoff treatment and reclamation facility in Santa Monica, and many devices to capture trash, oil, grease, and sediments in storm drains throughout the watershed (SMBRC, 2006).

Many of the SMBRC projects funded to date have been in the Ballona Creek watershed. Before its extensive settlement and urbanization, Ballona Creek was a meandering perennial stream that was lined with dense vegetation and met the Pacific Ocean in a broad expanse of tidal lagoons, salt marshes, and wetlands. Today, Ballona Creek is a nine-mile long flood-protection channel that drains the Los Angeles basin, including all or parts Beverly Hills, Culver City, Inglewood, Los Angeles, Santa Monica, West Hollywood, and unincorporated Los Angeles County. To address impairments to waterbodies in the Ballona Creek watershed, the SMBRC, in partnership with the Los Angeles County Department of Public Works, the City of Los Angeles, and the Ballona Creek Renaissance, led the efforts of the Ballona Creek Task Force and developed a comprehensive watershed management plan for Ballona Creek. This work is essential towards efforts to restore the water quality and ecology of Santa Monica Bay and its watershed (SMBRC, 2006).

Examples of Approaches to Managing Stormwater Runoff

- Structural BMPs, such as dry-weather runoff diversion, installation of in-stream trash capture devices and catchbasin retrofits, and installation of filtration devices along roadways or in parking lots
- Public education and outreach
- Elimination of illicit connections and illegal discharges to the storm drains via enhanced storm drain inspections and improved ordinances
- Non-structural BMPs, such as catchbasin stenciling, enhanced catchbasin/trash can cleanings, and street sweeping
- New land-use practices to increase on-site stormwater infiltration and reduce erosion
- Promotion and enforced implementation of BMPs at industrial facilities and construction sites (SMBRC, 2006).

Santa Monica Bay Restoration Commission

Recent Stormwater Pollution-Prevention Projects (SMBRC, 2006)

Project	Jurisdiction	Cost	Treatment Device(s)	Purpose
Ballona Creek Litter Collection Project	County of Los Angeles	$600,000	200 catchbasin debris-excluder devices and several vortex separation systems	Capture, analyze, and characterize trash from eight different land-use types
Ballona Creek Water Quality Improvement Project	City of Culver City	$168,500	Continuous deflective separation (CDS) device	Reduce total suspended solids, hydrocarbons, oil, grease, and trash
Pollutant Removal Devices in Storm Drain System	City of Los Angeles	$1,336,000	Urban stormwater devices in Ballona Creek watershed. Trash collection devices will be installed at four locations in south central Los Angeles and a gravity system will be installed in an industrial land-use area of Manchester	Remove sediment, metals, oil, and grease
Pollutant Removal Devices in Storm Drain System	City of Santa Monica	$500,000	Two-stage filter system to remove pollutants from a catchment discharging to Ballona Creek	Remove gross solids and floatables (Stage 1) and additional trash, sediment, and soluble compounds (Stage 2)
Pollutant Removal Devices in Storm Drain System	City of Manhattan Beach	$215,000	CDS devices	Reduce total suspended solids, hydrocarbons, oil, grease, and trash
Catchbasin Debris Excluder Devices	City of West Hollywood	$30,000	20 catchbasin debris-excluder devices	Reduce the amount of litter and debris

Habitat Quality

A variety of indicator measures are being evaluated by the SMBRC to help monitor the range and condition of habitats that exist in this estuary system. Examples of the indicator measures being considered for habitat loss or change over time are the following:

- Acres of wetlands gained or lost and the number of acres of riparian habitat (e.g., wetlands and open habitat areas)
- Size of kelp canopy and abundance of kelp beds along the Palos Verdes Shelf and Malibu coast
- Concentration of metals in Bay sediments and condition of benthic community (benthic habitat) (SMBRC, 2004).

Measurements of the size and abundance of kelp beds in this estuary system are considered to be good indicators for evaluating this important habitat and resource. From the mid-1970s to 1997, improved wastewater treatment processes resulted in an 80% reduction in discharge of total suspended solids from the White Point outfall. This reduction, along with kelp replanting efforts in the 1970s, resulted in a remarkable increase in kelp canopy, from a low of 5 acres in 1974 to a peak of more than 1,100 acres in 1989 (SMBRC, 2006).

Concentrations of heavy metals (e.g., lead, copper, zinc, mercury) in Bay sediments are considered an important indicator for evaluating the condition of benthic habitats. The City of Los Angeles' Environmental Monitoring Division has data from 1974–2003 and has indicated that soft-bottom habitats have been one of the most highly impacted habitats in this estuary, primarily due to discharges from STPs. The Marina Del Rey Harbor, the Palos Verdes Shelf, and the Ballona Creek Entrance Channel have typically been some of the hot spots for concentrations of DDT, PCBs, copper, zinc, or other contaminants in sediment (SMBRC, 2006).

Living Resources

One of the key indicators used by the SMBRC for evaluating living resources is the CPUE of select resident species in Santa Monica Bay. Species that can serve as indicators include rockfish, surf perches, kelp bass, sand bass, sheepshead, and halibut. Species that could be potential indicators, but for which no current data exist, include red sea urchins and spiny lobsters (SMBRC, 2006).

Changes in the abundance of target species (e.g., rockfish, sea stars, mussels) and in species diversity within intertidal zones are considered two good quality indicators, but adequate data are not yet available. The

The SMBRC evaluates the size and abundance of kelp beds in Santa Monica Bay (NOAA).

condition of runs for the amazing grunion fish population is also an indicator being considered (SMBRC, 2004). Evidence suggests that many rockfish species have been experiencing significant population declines due to overfishing along the West Coast, including species in Santa Monica Bay. According to federal assessments, bocaccio (one type of rockfish) has declined to about 5% of its historic abundance (SMBRC, 2006). Another source of concern is the rapid decline of black abalone, a rocky intertidal species. Although the cause of the decline of this species is not completely understood, researchers have speculated that a combination of over-harvesting, predation, competition, environmental changes, and disease may be responsible (SMBRC, 2006).

One of the major environmental concerns facing the SMBRC is improving the status of threatened and endangered species in Santa Monica Bay, while minimizing and/or eliminating the varied effects of invasive species. The measurement of the number of acres of invasive plant species and the number of invasive predators are indicators under development to assess the threats to the ecosystems and living resources in Santa Monica Bay. Invasive plants and animals (e.g., the giant reed, castor bean, wild tree tobacco, crayfish, bullfrog, mosquito fish, and largemouth bass) have decreased the biological diversity of native ecosystems by outcompeting or displacing native species. They also reduce habitat availability and water quality for native species in Santa Monica Bay (SMBRC, 2006).

Data on levels of DDT and PCBs in white croaker and kelp bass tissue are reported by the Los Angeles County Sanitation Districts, EPA, and the Montrose Settlements Restoration Program. These indicators are considered to be the most useful for evaluating health risks associated with seafood consumption (SMBRC, 2004). Average concentrations of DDT and PCBs in most seafood species have fallen to near or below levels of concern for human consumption, but remain high in white croaker collected on the Palos Verdes shelf (ANEP, 2001d; U.S. EPA, 2006e). Fish consumption advisories have been posted in the Bay area since 1985 (U.S. EPA, 2005a).

Environmental Stressors

Information collected on the amount of trash in Bay waterways shows that more than 4,000 tons of trash are collected from Santa Monica Bay beaches each year (Martin et al., 1996). Additionally, a 1994 survey found that 25% of bottom sediments sampled in Santa Monica Bay contained man-made materials of some kind (SMBRC, 2006).

Pelicans following a fishing boat into the harbor (William B. Folsom, NMFS).

Santa Monica Bay Restoration Commission

Current Projects, Accomplishments, and Future Goals

Some of the environmental accomplishments and restoration efforts in the Santa Monica Bay area include the following:

- Development of a comprehensive Bay-wide monitoring program and funding for an in-depth study to assess the loading of toxic air pollutants to the watershed (ANEP, 2001d).
- Completion of upgrades to full secondary treatment by the Los Angeles Hyperion Wastewater Treatment Plant and Wastewater Pollution Control Plant operated by the Los Angeles County Sanitation District, which greatly reduces the amount of direct waste discharge to the Bay.
- Approval of a Santa Monica ordinance to reduce the amount of urban runoff pollution that reaches Santa Monica Bay, requiring a 0.75" reduction in rainfall leaving impermeable surfaces of newly developed parcels in the city (City of Santa Monica, 2006).
- An EPA-conducted pilot program to cap contaminated sediments with clean sediment in DDT/PCB-contaminated areas of the Palos Verdes shelf.
- Provision of more than $450,000 by the SMBRC to community groups, local governments, and schools to educate and inspire people of all ages to take care of Santa Monica Bay (ANEP, 2001d).
- Acquisition by the State of California of 483 acres of the Ballona wetlands, the largest remaining coastal wetland in the Santa Monica Bay ecosystem (The Trust for Public Land, 2003).
- Restoration of the Zuma Lagoon and wetland, the first coastal freshwater wetland project in the area (ANEP, 2001).

Conclusion

Santa Monica Bay faces a series of environmental challenges. Sediment quality in the Bay is still threatened by levels of DDT, PCBs, copper, and zinc. Most recreational beaches in the estuary have very good water quality, as evidenced by the local Beach Report Card system, but the amount of trash and debris entering the Bay is still a significant concern. The monitoring of certain target species of fish and wildlife (e.g., rockfish, black abalone) and other threatened resources in this estuary is important to control population declines. In addition, invasive species still have an impact on the natural plant and animal populations in the watershed because they crowd out native biota and damage functioning ecosystems. Habitat conditions in the Santa Monica Bay estuary are being continually monitored by the SMBRC and its partners to prevent declines in the size and quality of wetlands, riparian habitat, kelp beds, and intertidal habitats. In addition, the SMBRC is faced with educating Los Angeles' diverse audiences about the importance of pollution prevention and environmental restoration, as well as implementing a comprehensive monitoring program to more effectively assess the condition across the Bay. Based on data from the NCA estuarine survey, the overall condition of Santa Monica Bay is rated fair.

Seagulls rest on a sand bar (John H. McShane).

CHAPTER 7

PUERTO RICO NATIONAL ESTUARY PROGRAM COASTAL CONDITION

San Juan Bay Estuary Partnership

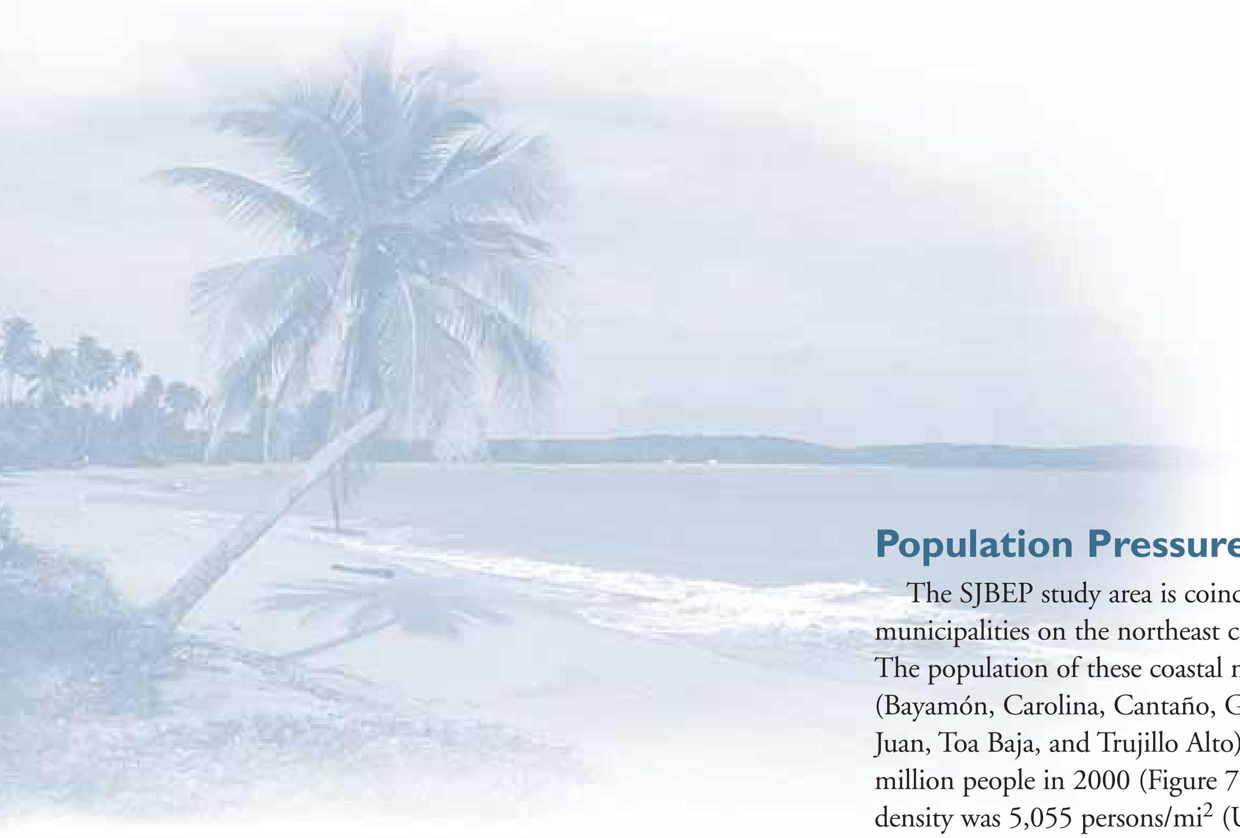
CONSORCIO DEL Estuario de la Bahía de San Juan

www.estuario.org

Background

Located on the northern coast of the island territory of Puerto Rico, the San Juan Bay Estuary (Estuario de la Bahía de San Juan) is semi-enclosed by the surrounding mainland, mangroves, and wetlands and is linked to the Atlantic Ocean via a series of interconnected bays, channels, and lagoons. This estuarine system includes San Juan Bay; the Martín Peña, San Antonio, and Suárez channels; and the Condado, Los Corozos, San José, Torrecilla, and Piñones lagoons. Multiple tributaries flow into the San Juan Bay Estuary, the largest being the Puerto Nuevo River. Salt water enters the Estuary from the Atlantic Ocean through the Boca del Morro to San Juan Bay, through El Boquerón to Condado Lagoon, and through Boca de Cangrejos to Torrecilla Lagoon. The limited flushing capacity and low tidal range of this estuarine system make the San Juan Bay Estuary susceptible to the retention of toxic pollutants (Martin et al., 1996).

For centuries, the San Juan Bay Estuary has provided a number of invaluable resources for the residents of Puerto Rico, including commercial port facilities, beaches, recreational parks, and natural and historic areas; however, the societal needs associated with the



growth of the surrounding population have resulted in the degradation of the natural resources of this system. Recognizing the constant threats to the Estuary, the Governor of Puerto Rico nominated San Juan Bay Estuary for inclusion into EPA's NEP in 1992, leading to the official creation of the San Juan Bay Estuary Partnership (SJBEP).

Environmental Concerns

One of the SJBEP's first tasks was to identify the priority problems of the San Juan Bay Estuary. To carry out this task, the SJBEP considered information from different scientific studies, expert scientific opinion, and public meetings and workshops. Based on these combined inputs, the SJBEP is addressing the following problems (listed in order of importance):

- Poor water circulation
- Illegal sanitary discharges
- Contamination by toxic substances and nutrients
- Lack of an ecosystem management plan
- Lack of community participation.

Population Pressures

The SJBEP study area is coincident with eight urban municipalities on the northeast coast of Puerto Rico. The population of these coastal municipalities (Bayamón, Carolina, Cantaño, Guaynabo, Loiza, San Juan, Toa Baja, and Trujillo Alto) was almost 1.18 million people in 2000 (Figure 7-1), and the population density was 5,055 persons/mi^2 (U.S. Census Bureau, 2001). This represents the highest population density observed for any of the 28 NEPs—more than 60% higher than the population density of the counties coincident with the HEP study area. Development and population pressures are especially strong surrounding the San Juan Bay Estuary, which has long served as a center of commerce and shipping in the Caribbean and is currently a center for commercial and recreational fisheries and recreational activities for the area's highly urbanized island community.

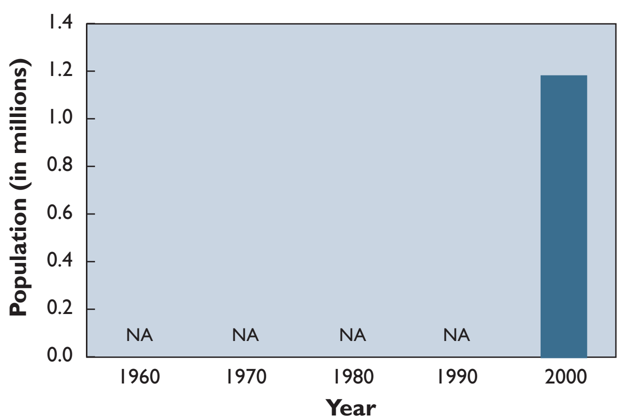


Figure 7-1. Population of the coastal municipalities coincident with the SJBEP study area, 1960–2000 (U.S. Census Bureau, 1991; 2001).

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.

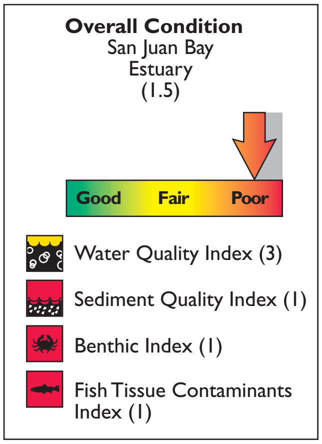


Figure 7-2. The overall condition of the SJBEP estuarine area is poor (U.S. EPA/NCA).

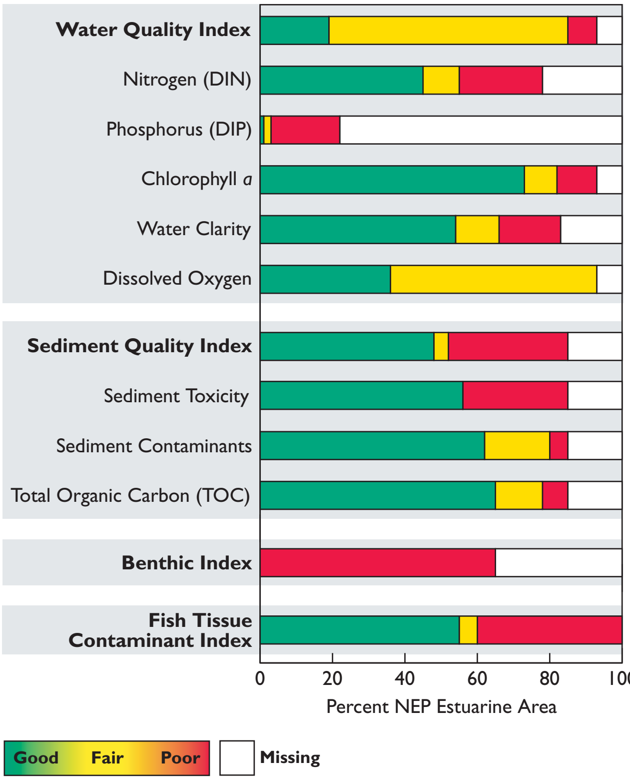


Figure 7-3. Percentage of NEP estuarine area achieving each ranking for all indices and component indicators — San Juan Bay Estuary.

NCA Indices of Estuarine Condition—San Juan Bay Estuary

In the winter of 2002, EPA's Region 2 conducted a survey in the San Juan Bay Estuary that focused on generating a comprehensive biological and chemical assessment of sediment throughout the Estuary (U.S. EPA, 2002b). In partnership with the NCA, a survey design and data-collection strategy that was compatible with EPA's NEP assessment effort was employed. Thirty-four sites were visited during this survey for the SJBEP assessment. Additionally, Region 2 conducted an independent fish tissue contaminants survey in San José Lagoon—a coastal lagoon within the San Juan Bay Estuary system—and the data from this survey contributed to the fish tissue contaminants evaluation for this Estuary.

Based on the data collected during the Region 2 survey efforts, the overall condition of the San Juan Bay Estuary is rated poor (Figure 7-2). The water quality index for the Estuary is rated fair, and the sediment quality, benthic, and fish tissue contaminants indices are rated poor. Figure 7-3 shows the percent of estuarine area rated good, fair, poor, and missing for each parameter considered. 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.

Water Quality Index

The water quality index for San Juan Bay Estuary is rated fair because 74% of the estuarine area was rated fair or poor for water quality (Figure 7-4). This index was developed using NCA data on five component indicators: DIN, DIP, chlorophyll *a*, water clarity, and dissolved oxygen. Threshold values used to determine the condition of individual water quality parameters were based on those used by the NCA for assessing tropical waters (see Chapter 1 for additional details), and all water quality component indicators were rated fair.

Water Quality Index - San Juan Bay Estuary

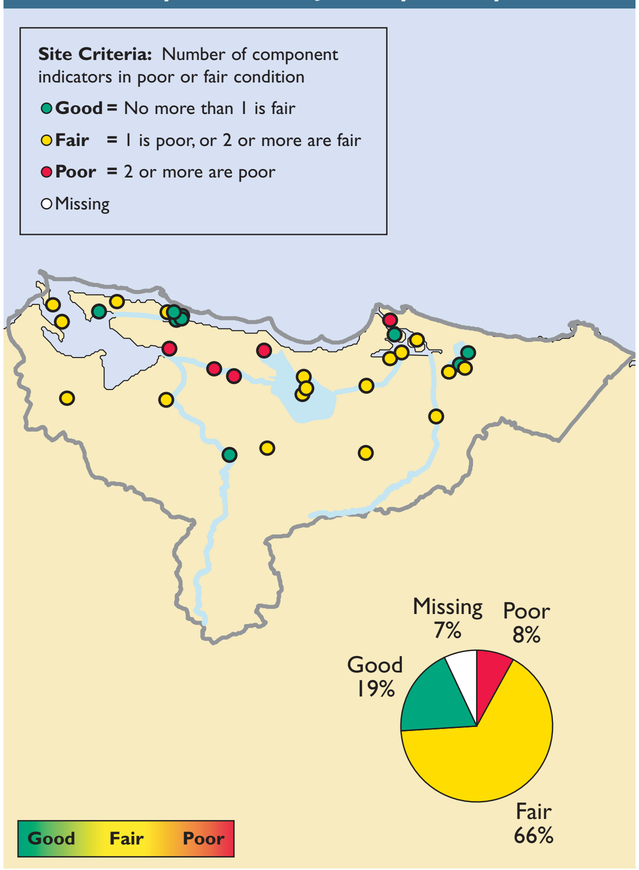


Figure 7-4. Water quality index data for San Juan Bay Estuary, 2002 (U.S. EPA/NCA).

Dissolved Nitrogen and Phosphorus | The San Juan Bay Estuary is rated fair for both DIN and DIP concentrations. With respect to DIN concentrations, 45% of the estuarine area was rated good, 10% was rated fair, and 23% was rated poor. Poor DIP levels occurred in 19% of the estuarine area, with 2% of the area rated fair and only 1% of the area rated good; however, NCA data on DIP concentrations were unavailable for 78% of the SJBEP estuarine area.

Chlorophyll a | Chlorophyll *a* concentrations in the San Juan Bay Estuary are rated fair. The NCA survey results showed good chlorophyll *a* conditions for 73% of the estuarine area, with 9% of the area rated fair and 11% of the area rated poor. NCA data on chlorophyll *a* concentrations were unavailable for 7% of the SJBEP estuarine area.

Water Clarity | Water clarity for the San Juan Bay Estuary is rated fair. For tropical waters, a range of 20% to 40% expected light penetration at 1 meter is considered fair. Measurements above this range are considered good, and those below are considered poor. In the San Juan Bay Estuary, only Secchi depth measurements were available to assess water clarity. A light extinction coefficient was calculated for each Secchi depth reading and compared to the light extinction coefficient of the expected or reference value (at 1 meter) appropriate for the region (Smith et al., 2006). These evaluations show that 54% of the estuarine area was rated good for water clarity, 12% was rated fair, and 17% was rated poor. Water clarity data were unavailable for 17% of the SJBEP estuarine area.

Dissolved Oxygen | The San Juan Bay Estuary is rated fair for dissolved oxygen concentrations. Estimates show that 57% of the estuarine area was rated fair, 36% of the area was rated good, and none of the area was rated poor. NCA data on dissolved oxygen concentrations were unavailable for 7% of the SJBEP estuarine area.

Sediment Quality Index

The sediment quality index for San Juan Bay Estuary is rated poor (Figure 7-5). This index was developed using NCA data on three component indicators: sediment toxicity, sediment contaminants, and sediment TOC. About one-third (33%) of the estuarine area was rated poor for sediment quality, and another 4% was rated fair. NCA data on sediment quality were unavailable for 15% of the SJBEP estuarine area.

Sediment Toxicity | The San Juan Bay Estuary is rated poor for sediment toxicity. Twenty-nine percent of the estuarine area was rated poor for this component indicator, and 56% of the area was rated good. NCA data on sediment toxicity were unavailable for 15% of the SJBEP estuarine area.

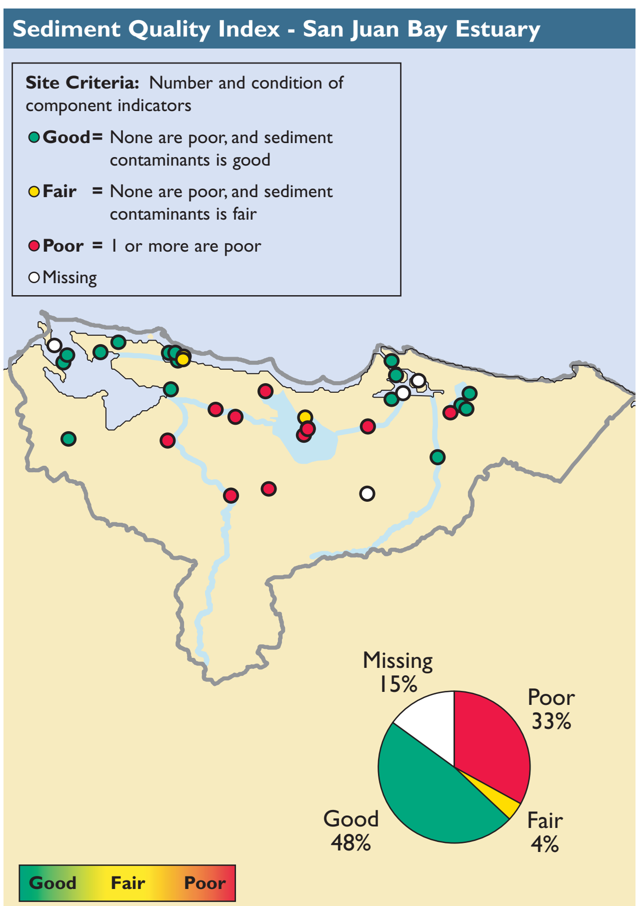


Figure 7-5. Sediment quality index data for San Juan Bay Estuary, 2002 (U.S. EPA/NCA).

Sediment Contaminants | The San Juan Bay Estuary is rated fair for sediment contaminant concentrations. Five percent of the estuarine area was rated poor for sediment contaminants, and 18% of the area was rated fair. NCA data on sediment contaminant concentrations were unavailable for 15% of the SJBEP estuarine area.

Total Organic Carbon | TOC concentrations in the sediments of the San Juan Bay Estuary are rated good, with 65% of the estuarine area rated good for this component indicator. TOC concentrations were rated fair and poor in 13% and 7% of the estuarine area, respectively, and NCA data on this component indicator were unavailable for 15% of the SJBEP estuarine area.

Benthic Index

A benthic index has not been developed for Puerto Rico. As a surrogate for benthic condition, benthic samples from the San Juan Bay Estuary were examined using ecological community indicators that contribute to all of the benthic indices developed by the NCA for the Northeast Coast, Southeast Coast, and Gulf Coast regions, and benthic diversity was used directly to evaluate benthic condition. If benthic diversity was less than 75% of the observed mean diversity for all locations sampled in Puerto Rico during the NCA surveys, the site was rated poor.

The benthic index for the San Juan Bay Estuary is rated poor because 65% of estuarine area had low benthic diversity and was rated poor (Figure 7-6). Benthic diversity data were unavailable for the remaining 35% of the estuarine area. When the areas that were rated poor for benthic condition were compared with the areas rated poor for water and sediment quality, it was determined that all of the SJBEP areas with low benthic diversity were also rated poor for at least one other index. Eighty-three percent of the area with low benthic diversity co-occurred with both poor sediment and water quality condition; 10% co-occurred with only poor sediment quality conditions; and 7% occurred with only poor water quality conditions.

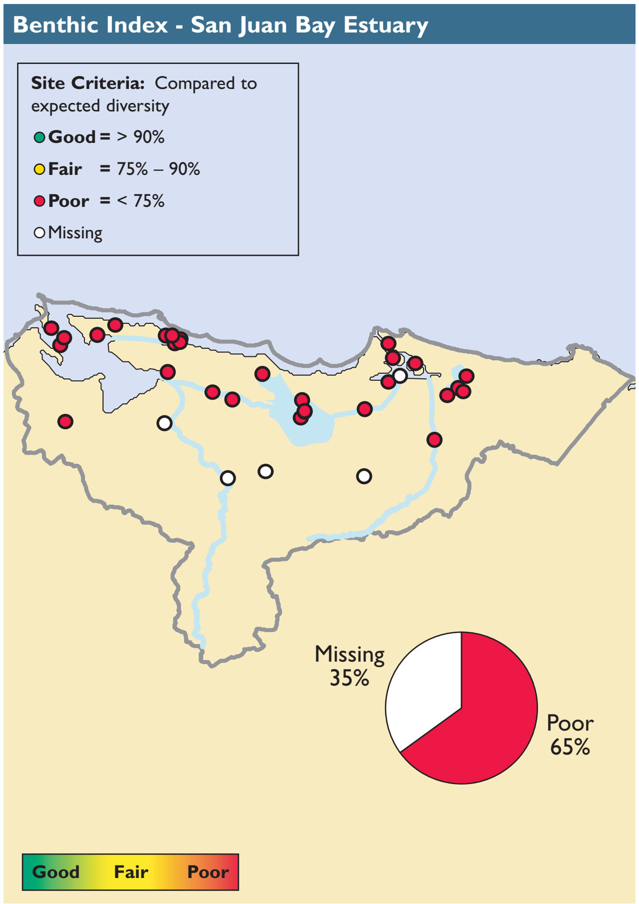


Figure 7-6. Benthic index data for San Juan Bay Estuary, 2002 (U.S. EPA/NCA).

Fish Tissue Contaminants Index

The results from a separate survey conducted in the San José Lagoon, one of the larger coastal lagoons within the San Juan Bay Estuary, were used as a surrogate for the NCA's fish tissue contaminants evaluation. The goals of the San José Lagoon survey were to evaluate whether toxic compounds were present in edible fish and shellfish tissues and to develop risk-based human health consumption advisories for the Lagoon. The survey design partitioned the Lagoon into four quadrants that were as equal in size as geographically possible. Trawls were conducted in each of these quadrants to collect tissue samples from four target species: blue crab (*Callinectes sapidus*), yellowfin mojarra (*Eugerres cinereus*), striped mojarra (*Eugerres brasilianus*), and snook (*Centropomus sp.*). Five individuals of each species were culled for contaminant analysis. Finfish fillets (with skin) and separate crab tissue and hepatopancreas samples were used for analysis (U.S. EPA, 2000d).

Based on the concentrations of contaminants found in fish and crustacean tissues during the San José Lagoon survey, the fish tissue contaminants index for the San Juan Bay Estuary is rated poor because 40% of all samples analyzed for contaminants exceeded EPA Advisory Guidance values (Figure 7-7).

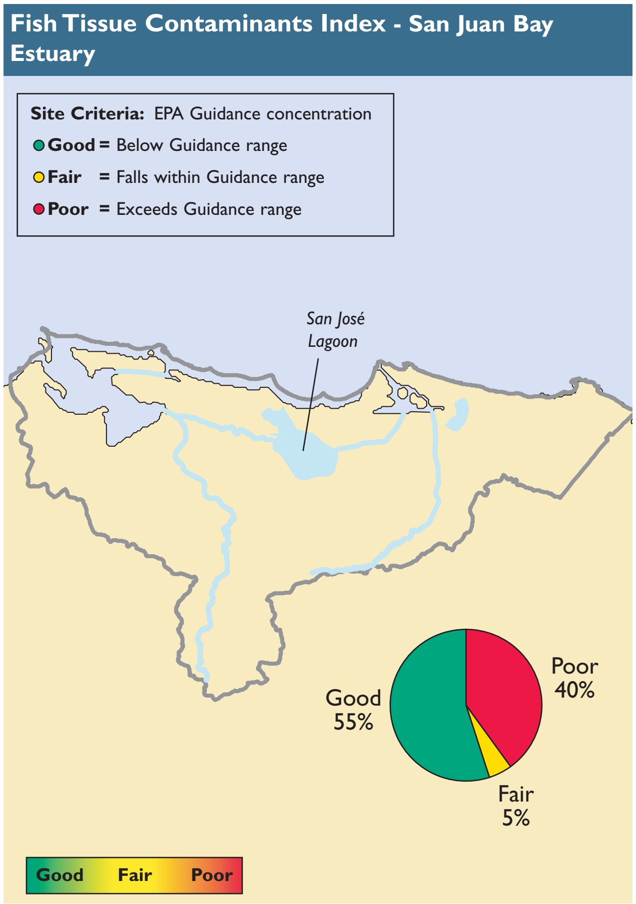


Figure 7-7. Fish tissue contaminants index data for San Juan Bay Estuary, 2002 (U.S. EPA/NCA).

San Juan Bay Estuary Partnership

HIGHLIGHT

Getting the Message to the People—The San Juan Bay Estuary Partnership Educational Outreach Efforts

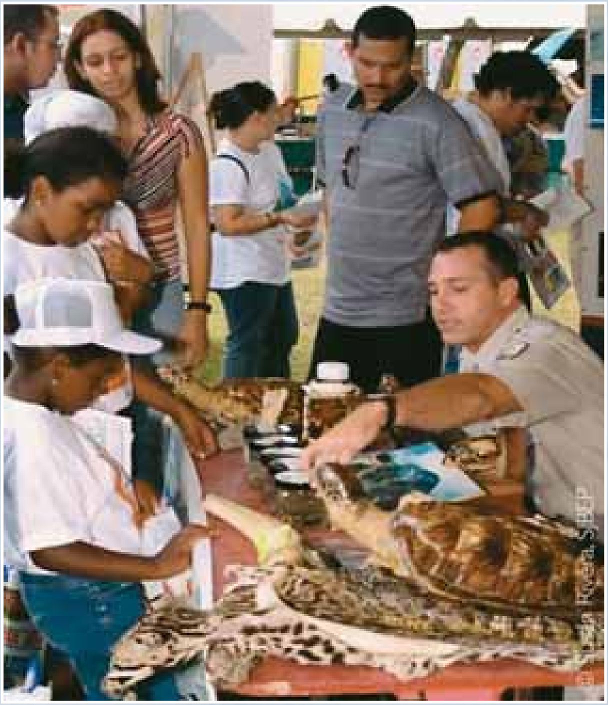
The SJBEP has been working very hard in the area of educational outreach. Several projects have been implemented to increase public awareness of the Estuary and its ecological importance.

Bay Day Festival of the Estuary

The SJBEP held its first Bay Day Festival of the Estuary: Two Windows, Land and Sea (Festival del Estuario: Dos Ventanas, Tierra y Mar) in May 2003. A large number of people participated in the festival, which included more than 30 environmental art exhibitions and presentations; diving and kayaking lessons; and environmental arts and crafts workshops, as well as a number of activities specifically designed for children. Numerous local artists participated in the festival, which received significant coverage from various media, including television, radio, and newspaper. The event also provided the setting for the expansion and continuation of cooperative efforts and collaborations between federal and local government agencies, community groups, and the SJBEP.

Teacher Training Workshops

Workshops developed and presented on environmental topics train local teachers about the effective use of San Juan Bay Estuary environmental education curriculum and related educational materials. In October 2004, one workshop for private school science teachers drew more than 100 participants. These one-day workshops take place periodically and have the support of the Department of Education, which sent out an official announcement to the schools located around San Juan Bay Estuary. The workshops provide a session on the use and application of the curriculum and feature information on the ecological values of the San Juan Bay Estuary system, environmental threats to the Estuary, and proposed solutions. Workshops also include environmental games and presentations by representatives from the Puerto Rico Department of Natural and Environmental Resources, Environmental Quality Board, Solid Waste Management Authority Agency, Highway and Transportation Agency, and the group working on restoration of the Cucharillas marsh.



This fish and wildlife exhibit shows species that are in danger of extinction (Susan Rivera,SJBEP).

School Day for the San Juan Bay Estuary

The School Day for the San Juan Bay Estuary encourages students to complete a project related to the Estuary. Students from the municipalities coincident with the SJBEP study area are invited to participate and submit abstracts of possible projects. The participating schools then plan an environmental activity that focuses on conservation efforts for the Estuary, and these activities are normally completed in April as part of the Earth Day celebration. Past student projects have involved a variety of activities, including beach cleanups, recycling, theater plays, monologues, and poster- and wall-painting contests. These activities create awareness about the importance of protecting, restoring, and conserving the San Juan Bay Estuary.

Volunteer Program

Long-term public support and participation in Estuary protection and restoration activities is necessary and critical for the successful implementation of the SJBEP's *Comprehensive Conservation and Management Plan for the San Juan Bay Estuary* (SJBEP, 2001). A volunteer program was created to encourage and facilitate active involvement by citizens in the Estuary's restoration process. University students participating in this program are encouraged to work with the SJBEP, using the SBJEP's objectives as potential subjects for developing their own research. These environmental volunteers will provide the resources needed to complete many of the SJBEP's proposed projects.

Outdoor activities accomplished during the 2005 Teacher Training Workshop included teachers kayaking or paddling to several areas of the Estuary, providing a first-hand, unforgettable experience for most of the participants (SJBEP).

San Juan Bay Estuary Partnership Indicators of Estuarine Condition

A Long-Term Environmental Indicator Program (LTEIP) has been proposed for the San Juan Bay Estuary to help assess the effectiveness of the area's conservation and restoration efforts. The indicators monitored by the LTEIP will be divided into four groups: Water-Sediment Quality, Biological Productivity and Respiration, Biota Distribution, and Biota-Pollutant Interactions. An important component of the LTEIP will be the preparation and dissemination of educational material as part of the SJBEP's outreach component. Other monitoring efforts have been proposed in the SJBEP's CCMP (SJBEP, 2001) to focus on the consequences of such events as petroleum spills, discharges from boats and ships, and high-temperature cooling water releases from thermoelectric plants. These events reduce the capacity of the Estuary's waters to retain oxygen.

Water and Sediment Quality

The SJBEP uses both chemical and bacteriological indicators to evaluate point and non-point sources of contamination. The most common indicators reported in the SJBEP CCMP are concentrations of nitrogen and phosphorus, dissolved oxygen, fecal coliform bacteria, and toxic substances (e.g., mercury, lead, arsenic, PCBs). Although the SJBEP does not monitor for these indicators directly, the indicators have been monitored for previous studies conducted by independent consultants, EPA, and the Puerto Rico Environmental Quality Board (EQB), as well as for previous studies supported by the SJBEP. Some of these indicators are currently evaluated for the Puerto Rican Water Quality Standards to define designated uses for different waterbodies.

The most common and widespread impairments to the Estuary's waters are nutrient enrichment/eutrophication and fecal contamination caused primarily by sewage discharges through non-point sources. Malfunctioning on-site septic systems, illegal connections to storm sewers, and direct discharges from unsewered areas are some of the current non-point sources of nutrients and fecal contamination related to sewage discharges into the San Juan Bay Estuary and its tributaries.

Nutrient and dissolved oxygen concentrations have been used to assess water quality in the San Juan Bay Estuary. No evidence of use impairments due to nitrogen and phosphorus loads have been reported in most of the San Juan Bay Estuary since point-source discharges from the Puerto Nuevo STP outfall into the Estuary were eliminated in 1985 (Tetra Tech, Inc., 1992). Dissolved oxygen levels in the Estuary's eutrophic waters vary widely depending on the time of day. This variation in dissolved oxygen concentrations is typically found in the San José and Los Corozos lagoons; however, the control of oxygen-consuming substances from industrial point-source discharges has gradually improved the dissolved oxygen levels in some areas of the Estuary (Webb and Gómez-Gómez, 1998).

Fecal coliform concentrations in most areas of the Estuary remain above the levels required to meet water quality standards (SJBEP, 2001), and as a result, the SJBEP sponsored a study to determine the public health risks from direct and indirect contact activities (e.g., bathing, fishing) in areas where fecal coliform concentrations were measured. These concentrations were measured in single samples collected at 16 sites in the Estuary. Although the fecal coliform concentrations measured in samples from six of the sites exceeded water quality standards, the study concluded that risk levels associated with water contact activities were within acceptable levels. The study also interviewed area residents about their fish-consumption habits and found that, although more than 40% of the people interviewed consumed food from Estuary waters, none reported any illnesses as a result of this consumption (Seguinot-Barbosa & Vázquez, 1999).

The San Juan Bay Estuary is also affected by other types of pollutants (e.g., metals, oils, and other substances) that gain access to the Estuary through storm sewers or runoff. The total volume of runoff can be much greater than the volume from other sources, causing significant contribution of contaminants (Horsley & Witten, Inc., 1995). Furthermore, the urbanization of drainage basins, removal of in-stream and bank vegetation, and alteration of streams and rivers due to channelization contribute to erosion and sedimentation rates in the area, as well as to the degradation of water quality in the Estuary and its tributaries. In the upper part of the watershed, erosion accounts for an average loss of 4 inches of soil per year, much of which enters the Estuary (Webb and Gómez-Gómez, 1998).

PCBs, the pesticide DDT (and its metabolites DDD and DDE), the common elasticizing agent bis(2-ethylhexl)phthalate, lead, and mercury are the most abundant contaminants in the sediments of the SJBEP system. Figures 7-8 and 7-9 show the trends in the sediment contaminant concentrations from 1925 through 1995 (SJBEP, 2001). Although the occurrence of these contaminants in San Juan Bay Estuary sediments is expected to decrease with time, toxic pollutants in the surface bottom sediments of some areas may persist at relatively high concentrations for some time. The average sediment deposition rate for the San Juan Bay Estuary (excluding Martín Peña Channel) is about two

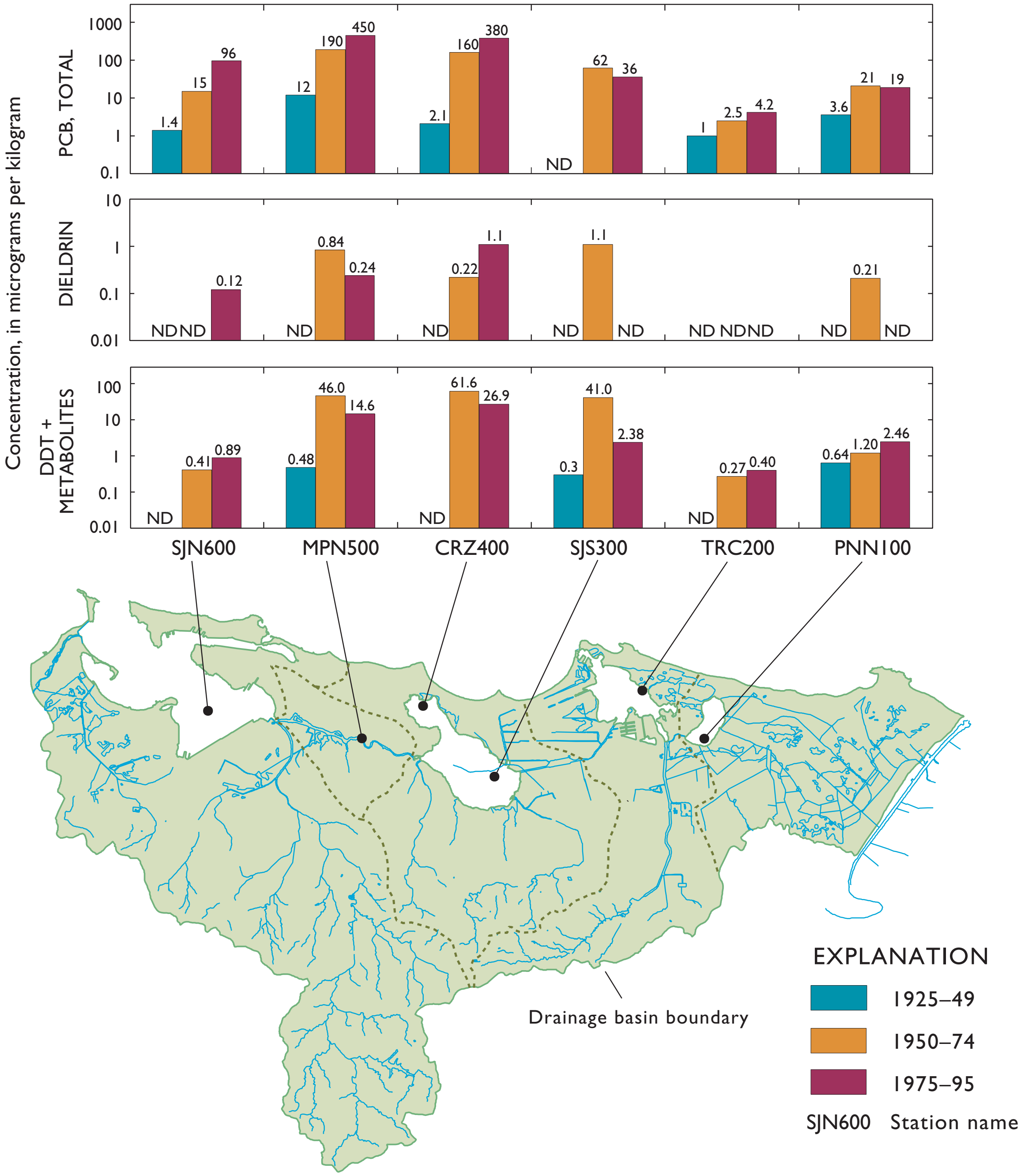


Figure 7-8. Sediment concentrations (μg/kg) of PCB, dieldrin, and DDT and its metabolites at different locations in the San Juan Bay Estuary and during different time periods (SJBEP, 2001).

San Juan Bay Estuary Partnership

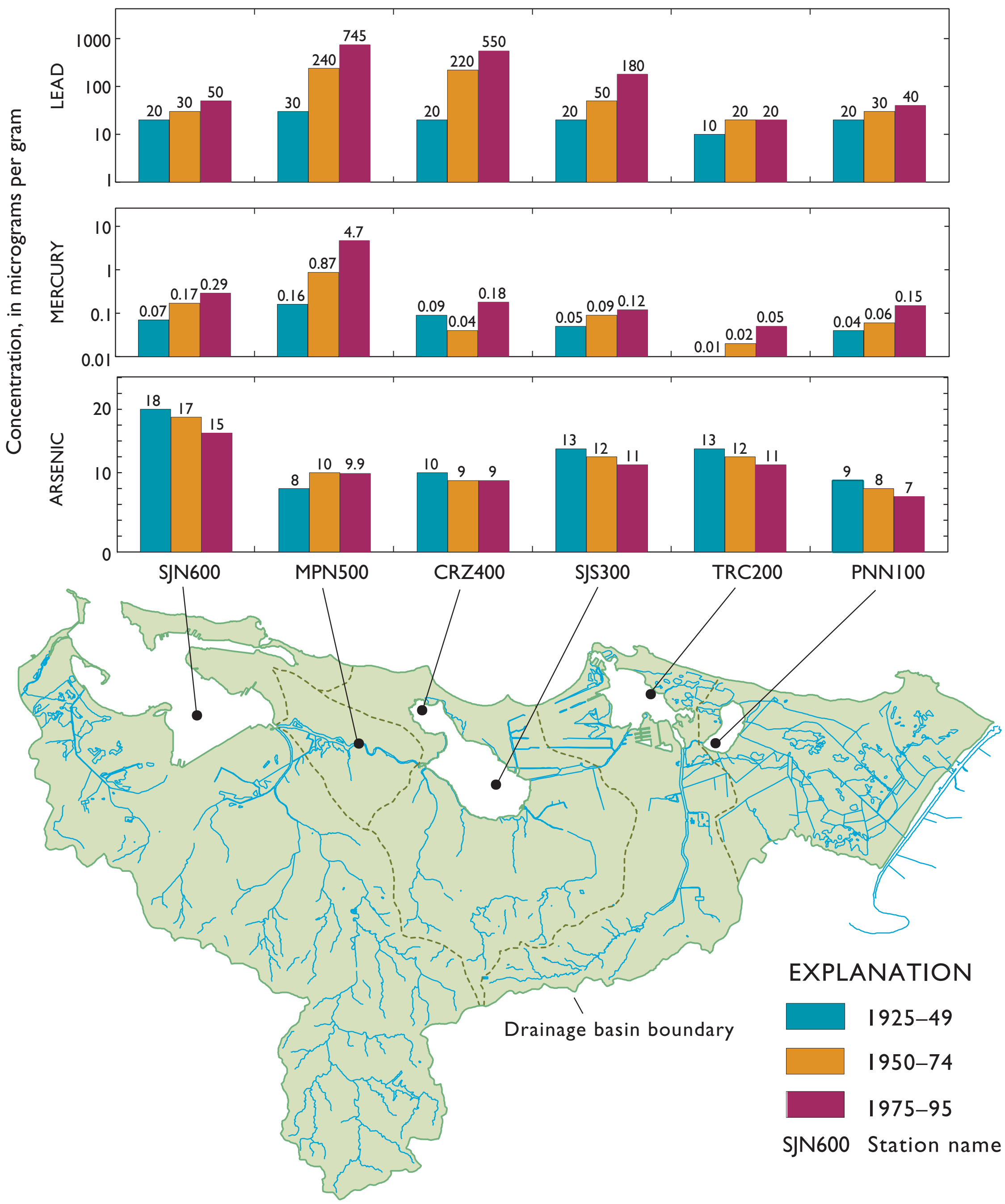


Figure 7-9. Sediment concentrations (µg/kg) of mercury, lead, and arsenic at different locations in the San Juan Bay Estuary and during different time periods (SJBEP, 2001).

inches per decade; therefore, contaminated sediments will need significant time to be buried by incoming, less-contaminated sediments (Webb & Gómez-Gómez, 1998). For these reasons, Webb & Gómez-Gómez (1998) concluded that contaminated sediments in such areas of the estuary as the Martín Peña Channel and the San José and Los Corozos lagoons present a potential threat to human health; however, EPA reviewed this assessment and concluded that, based on the confined nature of the contaminated sediments, there was no threat to human health by direct contact (U.S. EPA, 1996). This determination certified that a CERCLA removal action, consisting of identifying and remediating hazardous waste sites, was not warranted.

Habitat Quality

Swamps, marshes, mangroves, aquatic vegetation, coral reefs, and sandy beaches are some of the habitats that are found in the San Juan Bay Estuary, which harbors very rich and diverse aquatic communities. Marshes and mangroves support a great variety of juvenile fish and invertebrates and provide food and nesting habitat for many different bird species. Marshes also play an important role in the cycle of nutrients and filter contaminants that have been washed into the Estuary from the upper parts of the basin by runoff. The preservation of marsh and mangrove habitats is clearly included as an objective in the SJBEP CCMP (SJBEP, 2001).

Table 7-1 shows the area of marsh and mangrove habitats, as well as the change in area between 1936 and 1995, in different locations within the Estuary. The area between the Torrecilla and Piñones lagoons showed a significant net increase based on an increase in the mangrove area; however, this increase could be due to the succession of one kind of mangrove habitat by another, and not necessarily due to an improvement in the original habitat. This was the only area around San Juan Bay Estuary that exhibited a positive gain in total marsh and mangrove acreage between 1936 and 1995 (SJBEP, 2001).

Puerto Rico has one of the most diverse ecosystems of seagrass and SAV in the North Atlantic Ocean. Table 7-2 shows the areal coverage of these habitats, which are very important in supporting biodiversity and a variety of other ecological resources. For example, these habitats provide nutrients and primary energy for different fish species. The SJBEP places high emphasis on improving the overall condition of these habitats by improving the San Juan Bay Estuary's water quality (SJBEP, 2001).

Table 7-1. Trends in the Acreage of San Juan Bay Estuary Marsh and Mangrove Habitats Over Time (SJBEP, 2001)

Location	Time Period	Mangrove Area (Acres)	Marsh Area (Acres)	Total Change (Acres)
San Juan Bay and Condado Lagoon	1936	458	1,327	1,785
	1995	329	566	895
	% change	-28%	-57%	-50%
Martín Peña Channel	1936	1,029	578	1,607
	1995	327	197	524
	% change	-67%	-84%	-73%
San José Lagoon to Suárez Channel	1936	704	68	772
	1995	327	197	524
	% change	-54%	+190%	-32%
Torrecilla and Piñones areas	1936	2,790	1,904	4,694
	1995	4,561	1,101	5,662
	% change	+63%	-42%	+21%

Table 7-2. Areal Extent of Seagrass (acres) and Surface Water (mi^2) in the San Juan Bay Estuary (SJBEP, 2001)

Habitat	San Juan Bay	Condado Lagoon	San José Lagoon	Torrecilla Lagoon
Surface water area (mi^2)	4.56	0.15	2.11	0.95
Seagrass area (acres)	31	35	0	0.1

Living Resources

In 1998, the SJBEP supported a study to investigate the levels of seven heavy metals in the tissue of mojarra, blue crabs, and false mussels taken from the San José and Corozos lagoons. This study found that the concentrations of mercury and lead in some samples were above the standards recommended by the FDA. Although the average mercury concentration in mojarra was below the FDA standard, two samples had concentrations that exceeded the FDA standard. In addition, the average lead concentration in mojarra exceeded the lead standard. None of the blue crab samples exceeded the standard for mercury or lead; nevertheless, the regular consumption of blue crabs, particularly the hepatopancreas tissue, from these lagoons poses a potential public health problem resulting from elevated PCB levels in the tissue. Concentrations in some samples of false mussels exceeded the standard for lead, but not the standard for mercury; however, false mussels are typically not consumed by humans (Delgado-Morales et al., 1999).

The green heron (*Butorides virescens*) is a common resident of the San Juan Bay Estuary. This small, gray-green waterbird forages mostly in shallow waters, such as mangrove swamps, searching for small fish and invertebrates (SJBEP).

Environmental Stressors

The discharge of nutrients and bacteria from septic systems and illegal sewer connections impacts water quality in the San Juan Bay Estuary; therefore, monitoring septic system performance and/or the number of illegal sewer connections may provide insight into ways of resolving the problem. At the present time, information about the number of septic systems functioning properly or malfunctioning, as well as how frequently these on-site systems are maintained, is not available. Illegal connections of sanitary sewers to storm sewers, as well as direct discharges of sewage, have been reported throughout the Estuary and its watershed; however, this condition is most common in the communities closest to the Estuary (Puerto Rico EQB, 1989; 1994; 1996). In a study performed by the Puerto Rico EQB from 1986 to 1989, almost 40% of the structures surveyed in the communities adjacent to the Martín Peña Channel were found to discharge raw sewage into storm sewers or directly into the Estuary or its tributaries (Puerto Rico EQB, 1989). The SJBEP CCMP recommends the construction of a sanitary sewer system that would connect to the existing regional STPs for those communities bordering the Estuary (SJBEP, 2001). As shown by a similar effort undertaken in the Condado Lagoon during the 1960s and 1970s (Rivera-Cabrera, 1990), a sanitary sewer system is expected to be the most effective and efficient way of eliminating illegal storm sewer connections and direct sewage discharges to the Estuary.

Current Projects, Accomplishments, and Future Goals

The SJBEP has implemented 41 projects—10 new projects financed by grants from past years, 14 new projects financed in this fiscal year, and 17 projects that were in progress and scheduled to be completed during the 2004–2005 fiscal year. Simultaneously, the SJBEP has been able to finalize 15 projects from past years, complying with 11 actions proposed in the Partnership's CCMP (SJBEP, 2005). The SJBEP will base its future goals on goals already established in the CCMP, which are divided into three areas of concern:

- **Improve the water and sediment quality of San Juan Bay Estuary to ensure suitability for fishing and swimming and to promote other compatible recreational and commercial activities** – The SJBEP will accomplish part of this goal through the LTEIP, which will provide the NEP with data to inform the public about the health of the Estuary and to take corresponding actions. The SJBEP is also actively working as a new member of the Ecological Corridor Commission of San Juan, which was created as part of the Law of the San Juan Ecological Corridor in 2003 (Law 206) to oversee the acquisition of parcels of land and transform them into an ecological corridor of approximately 1,000 acres.
- **Enhance and maintain an ecosystem that supports an optimum diversity of living resources on a sustained basis** – The SJBEP will continue to implement 18 actions conceptualized to fulfill this important goal through its Volunteer Program. In 2006, the SJBEP will implement 6 of the 18 actions and will build partnerships to reinforce future conservation projects.
- **Maximize public involvement in the implementation of the CCMP** – Nine projects have been approved by the SJBEP Board of Directors to support 100% of the actions under this area of concern, and the SJBEP Volunteer Program will help to achieve this goal.

The following new activities were implemented during 2005 to enrich the SJBEP and its CCMP:

- **Integrated Media and Communications Program** – In 2002, 84% of the Estuary's local residents interviewed did not recognize the word or concept of an "estuary" (Personal communication, Bauza-Ortega, 2006). In order to resolve this challenge, the Partnership conducted a focus group study in which a comprehensive media plan was developed. The integrated media approach outlined in the plan conveyed a message of restoration and conservation for the Estuary using multiple resources, including electronic media (e.g., interactive Web page), traditional media (e.g., newsletter, radio programs), and monthly seminars.
- **Christmas Card Competition** – During this project, Puerto Rico elementary school students learned about San Juan Bay Estuary and helped promote the SJBEP's mission through the development of a Christmas card exhibit. One card design, selected by a jury, was printed and delivered to all members of the SJBEP mailing list and contacts.
- **Collaboration with the Enlace del Caño Martín Peña Project** – This project is responsible for dredging the Martín Peña Channel, relocating people affected by dredging activities, constructing new homes, and developing and implementing the complex educational strategy that requires relocating people who have lived in a particular community for decades. The SJBEP collaborates with the Enlace Project in the educational phase and has completed several important activities through the years, such as theater workshops, community concerts, contests, publications, and technical support and environmental consulting through the staff scientist.
- **Annual Audubon Society Bird Census** – For the past nine years, the annual Audubon Society Bird Census has helped identify bird species density in the SJBEP study area. Local species data are updated through this annual census.

Conclusion

Based on data from the NCA estuarine survey, the overall condition of the San Juan Bay Estuary is rated poor. Although the Estuary's water quality index is rated fair, the sediment quality, benthic, and fish tissue contaminant indices are rated poor. The data used by the SJBEP to assess water quality in the Estuary indicate that bacterial contamination caused by the discharge of sewage from non-point sources is a concern in the area and has negatively affected water quality. A variety of toxic chemicals have been detected in Estuary sediments and may persist at relatively high concentrations for some time. The development of a maritime and air transportation infrastructure, as well as of residential and industrial areas, have caused significant modification and loss of important habitats in the Estuary. Most of these modifications have occurred in the western half of the Estuary basin, where the pressures of urban growth and development on the San Juan Bay Estuary are greatest. The SJBEP is focusing its attention on developing a strong outreach program to inform the local population about conditions in the Estuary.

The green iguana (*Iguana iguana*), locally known as "gallina de palo", is an invasive species that was introduced into Puerto Rico from Central and South America by the pet trade in the 1970s. The SJBEP plans to study the ecology of the green iguana and evaluate its potential for negative impact to the local biodiversity (SJBEP).

APPENDIX A

PROCEDURES FOR CALCULATING TOTAL POPULATION, POPULATION GROWTH RATE, AND POPULATION DENSITY FOR VARIOUS GEOGRAPHIC AREAS

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PROCEDURES FOR CALCULATING TOTAL POPULATION, POPULATION GROWTH RATE, AND POPULATION DENSITY FOR VARIOUS GEOGRAPHIC AREAS

Introduction

Human population pressures can be evaluated using several measures. For the U.S. Environmental Protection Agency's (EPA's) National Estuary Program Coastal Condition Report (NEP CCR), three measures were used to evaluate the impact of human population pressures on the 28 NEP estuaries of the United States: total population, population growth rate over a specified time interval, and population density (persons/mi^2 of land area). These population pressures were measured for each individual NEP estuary and compared to those calculated for other NEP estuaries, all coastal areas, all non-coastal areas, and the conterminous United States to assess the relative impacts of human populations on estuarine condition.

The National Oceanic & Atmospheric Administration (NOAA) recently published the report *Population Trends along the Coastal United States: 1980–2008* (Crossett et al., 2004), which presents an overview of coastal population trends from 1980 through 2003, projected changes in coastal populations through 2008, and the definition of a NOAA-designated coastal county. The NOAA Special Projects office designates a county as a coastal county if one of the following criteria is met:

- At a minimum, 15% of the county's total land area is located within a coastal watershed
- A portion of a county or an entire county accounts for at least 15% of a cataloging unit.

It should be noted that this NOAA report and the other NOAA report (Culliton et al.,1990) referenced in this Appendix differ from the NEP CCR in that the NOAA reports include the Great Lakes region as a coastal area. In addition, the NEP CCR only covers marine coastal areas in the conterminous 48 states because none of the NEP estuaries are located in Alaska or Hawaii. Population pressures for the one NEP estuary located in Puerto Rico (San Juan Bay Estuary) were evaluated separately for this NEP CCR due to a lack of comparable population data for this region. An overview of this evaluation is provided later in this Appendix.

In order to determine the human population pressures exerted on counties coincident with individual NEP study areas, population data were obtained from the U.S. Census Bureau (1991; 2001). These data were used to calculate total population for 1960, 1970, 1980, 1990, and 2000; population density in 2000; and the population growth rate between 1960 and 2000 for the following:

- Each NEP study area (using all NOAA-designated coastal counties or municipalities coincident with an individual NEP study area)
- All NEP coastal counties collectively (using the NOAA-designated coastal counties coincident with all 27 NEPs located in the conterminous 48 states)
- All NOAA-designated coastal counties (using both NEP and non-NEP coastal counties in the 48 conterminous U.S. states and excluding coastal counties in Puerto Rico and those adjacent to the Great Lakes)

- All non-coastal counties (using all counties in the 48 conterminous U.S. states that are not considered NOAA-designated coastal counties, as well as the NOAA-designated coastal counties that are adjacent to the Great Lakes)
- All counties in the 48 conterminous U.S. states, as a whole.

Population statistics for the study area for Puerto Rico's NEP, the San Juan Bay Estuary Partnership (SJBEP), were calculated differently because of variances in available data for the region. Population data for the SJBEP study area were only available for the year 2000. In addition, Puerto Rico was not included in the available list of NOAA-designated coastal counties, and a separate section in this text has been devoted to describing the processes employed for deriving population density estimates for the SJBEP study area. Due to the differences in methodology and available source data for the SJBEP study area, the results for this NEP estuary are not included in the values cited in Chapter 1 that provide national population data for Figure 1-2.

Selection of Coastal Counties in the NEP Study Areas

Geographic information systems (GIS) technology was used to identify which NOAA-designated coastal counties are spatially coincident with NEP study area boundaries. These counties were identified using the following steps:

- A GIS shapefile was developed delineating the NOAA-designated coastal counties
- A separate GIS shapefile delineating the 2003 boundaries of each NEP study area was obtained from EPA
- GIS was used to compare the two shapefiles electronically and identify which NOAA-designated coastal counties overlap the boundaries of a specific NEP study area
- A visual inspection was conducted to refine the selection of NOAA-designated coastal counties in the NEP study area.

For comparison purposes in the NEP CCR, only the NOAA-designated coastal counties in the U.S. regions that contain NEP estuaries were processed as coastal counties. The NOAA-designated coastal counties bordering the Great Lakes were processed as non-coastal counties because there are no NEP estuaries in this region. In addition, this analysis was limited to coastal and non-coastal counties in the conterminous United States because no NEP-designated estuaries are located in Alaska or Hawaii and because insufficient data were available for the island territory of Puerto Rico.

Methodology for the 27 NEPs in the Conterminous U.S.

To identify the NEP-coincident coastal counties for the 27 NEPs in the conterminous United States, a shapefile of NOAA-designated coastal counties was created by electronically linking coastal county data from NOAA (Culliton et al.,1990) to a GIS shapefile of all U.S. counties (National Atlas of the United States, 2005). The coastal county data were obtained from the NOAA report *50 Years of Population Change Along the Nation's Coasts 1960–2010, A Special Earth Week Report* (Culliton et. al., 1990), which contains a table entitled "Population and Development in Coastal Areas Coastal Counties List," hereafter referred to as the NOAA Coastal Counties Table. This table presents the land area (in mi^2), population, and unique Federal Information Processing Standards (FIPS) code for each coastal county in the conterminous United States.

The NOAA Coastal Counties Table was divided into sections based on the waterbody associated with each coastal county. The sections of the table associated with Great Lakes, Hawaiian, and Alaskan waters were excluded so that only the sections that provided data for the Atlantic, Gulf, and Pacific coasts of the conterminous United Sates were used. The FIPS codes in these sections of the NOAA Coastal Counties Table were linked electronically with the matching FIPS codes in the U.S. counties shapefile to create a subset of NOAA-designated coastal counties. This subset was saved as a separate shapefile and used in the population calculations described below.

Once the NOAA-designated coastal counties shapefile was created, GIS technology was used to determine which NOAA-designated coastal counties were coincident with NEP study areas. A spatial comparison of the NOAA-designated coastal county boundaries and the NEP study area boundaries was performed. GIS technology automatically selected those counties from the NOAA-designated coastal counties shapefile that spatially intersected NEP study area polygons in the NEP boundary shapefile obtained from EPA.

This automatic selection of spatially coincident counties was further refined using a visual inspection in GIS. When GIS shapefiles are obtained from different sources, slight discrepancies in the scale or accuracy of the polygons in the file are common. For example, when an NEP study area boundary coincided with a county border, the automatic selection process often included the neighboring county due to discrepancies between the two shapefiles. The objective of this visual inspection was to identify any counties that were included in the automatic selection as a result of discrepancies between the polygonal boundaries of the NOAA-designated coastal counties shapefile and the NEP boundary shapefile. These counties were then removed from the NEP-coincident coastal counties shapefile.

Figure A-1 provides an example of how GIS analysis was used to generate the final shapefile of NEP-coincident coastal counties. The NOAA Coastal Counties Table was used to select all of the NOAA-designated coastal counties (shown in yellow and purple). Note that Highlands County (shown in orange) does not meet the NOAA Special Projects office's definition of a coastal county and was not included in the spatial selection. The Indian River Lagoon NEP (IRLNEP) study area boundary polygon from EPA's NEP boundary shapefile is outlined in green. The automatic GIS selection of coincident coastal counties generated an initial data set that included Volusia, Brevard, Indian River, Okeechobee, St. Lucie, Martin, and Palm Beach counties. Visual inspection of the GIS selections revealed that the NEP boundary polygon intersected significant portions of Volusia, Brevard, Indian River, Okeechobee, St. Lucie, and Martin counties, and these counties were included in the final shapefile (shown in purple). However, the NEP boundary polygon did not intersect a significant portion of Palm Beach County, and the inclusion of this county was likely due to a discrepancy. As a result, Palm Beach County was deselected and excluded from the final NEP-coincident coastal county shapefile for the IRLNEP.

Methodology for the San Juan Bay Estuary Partnership (SJBEP)

Puerto Rico is divided into municipalities rather than counties, and these municipalities were not included in the NOAA Coastal Counties Table or the NOAA-designated coastal counties shapefile. As a result, the methodology for determining the NEP-coincident municipalities for the SJBEP study area differed from the methodology used to identify the NEP-coincident coastal counties for the other 27 NEPs. For Puerto Rico, each NEP-coincident municipality was selected by hand using a visual inspection. The inspection selected all of the municipalities that significantly intersected the boundary of the SJBEP study area polygon. The selected municipalities were then used to create a shapefile for the SJBEP study area.

Calculation of Population Statistics for all U.S. NEPs

When data were available, the total population in 1960, 1970, 1980, 1990, and 2000; population growth rate (1960–2000); and population density in 2000 were calculated for several geographic areas of interest. These geographic areas are the conterminous United States, all NOAA-designated coastal counties (collectively), all NEP-coincident coastal counties (collectively), the coastal counties coincident to each individual NEP study area, and all non-coastal counties (collectively). A unique data set of population and land area data was created for each area of interest, and the same general formulas were used to calculate total population, population growth rate, and population density for each data set. It should be noted that Puerto Rico's population growth rate and total population figures for 1960, 1970, 1980, and 1990 were not calculated because population data for Puerto Rico prior to 2000 were unavailable from the U.S. Census Bureau (1991).

In order to develop a data set for the conterminous United States, land area values and 1960, 1970, 1980, 1990, and 2000 population data for all of the states

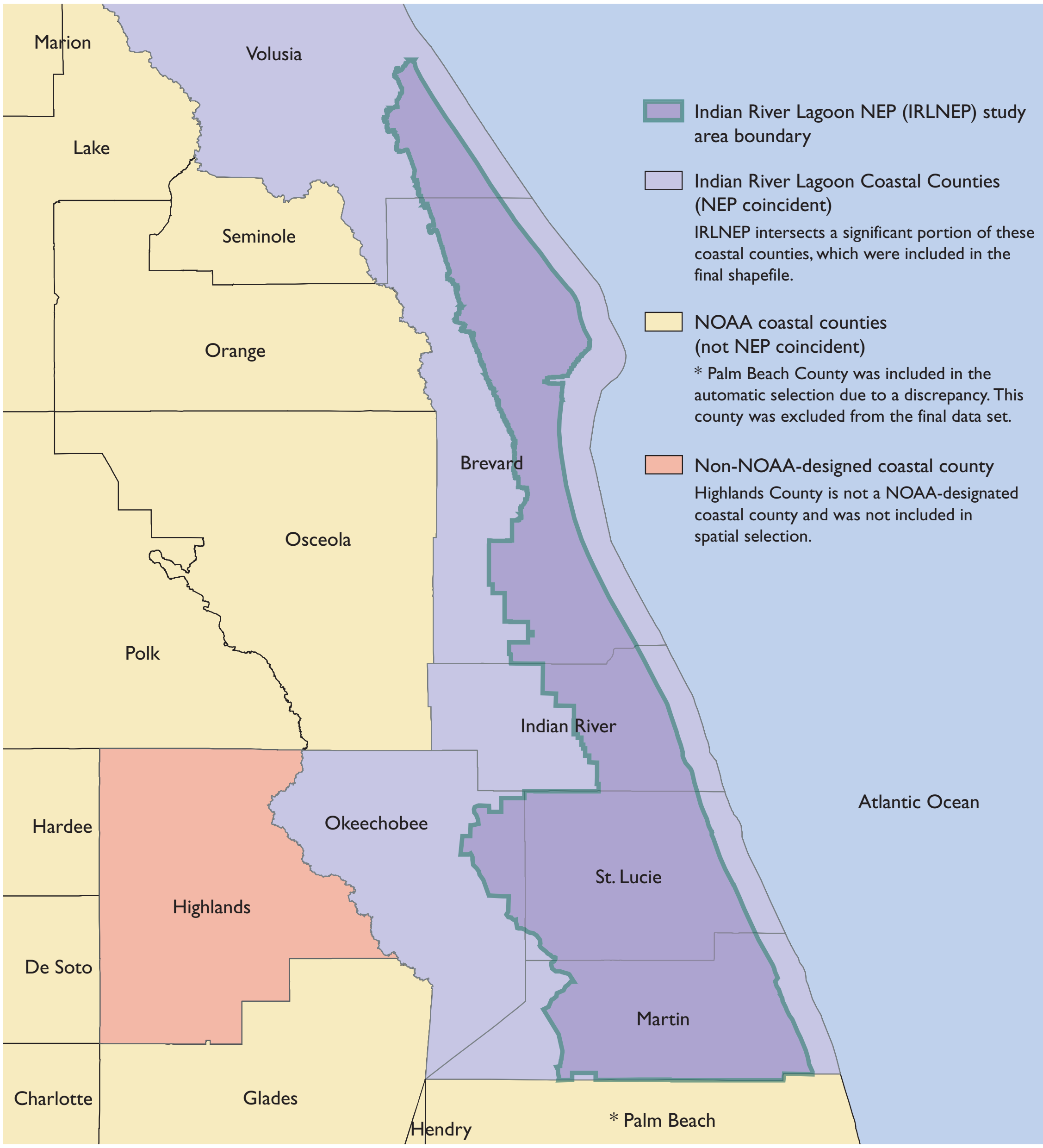

Figure A-1. An example of the spatial selection process used to identify NEP-coincident coastal counties for the Indian River Lagoon NEP.

(excluding Puerto Rico and other commonwealths, territories, and protectorates) were obtained from the U.S. Census Bureau (1991; 2001). The data set was refined to include only the 48 conterminous states by subtracting population data and land area values for Alaska and Hawaii.

The raw data necessary to calculate total population, population growth rate, and population density for all the NOAA-designated coastal counties were obtained from several sources. The land area of each county in 2000 and the population data for each county in 1960, 1970, 1980, and 1990 were obtained from the portions of the NOAA Coastal Counties Table providing data for the Atlantic, Gulf, and Pacific coasts. The population data for each county in 2000 was obtained from the U.S. Census Bureau (2001) and are hereafter referred to as the 2000 Census Counties Table. Both tables were linked by the county FIPS codes to create a population data set that ranged from 1960 to 2000 for all NOAA-designated coastal counties.

The NOAA-designated coastal counties data set was refined to create the NEP-coincident coastal county data set. During this process, FIPS codes were used to link the NOAA-designated coastal counties data set with the NEP-coincident coastal counties shapefile to isolate the population and land area data for the NEP-coincident coastal counties.

The NEP-coincident coastal counties shapefile contains a field that associates each NEP-coincident coastal county with an individual NEP. This field was retained in the NEP-coincident coastal counties data set and used to create the data sets for each of the 27 individual NEPs in the conterminous United States. For the San Juan Bay Estuary, land area and population data for the SJBEP study area in 2000 were obtained from the U.S. Census Bureau (2001). The SJBEP data set was created by linking the FIPS codes in the SJBEP shapefile to those in the data from the U.S. Census Bureau.

The non-coastal counties data set was generated using the NOAA-designated coastal counties data set and the data set for the conterminous United States. The population and land area data for all of the non-coastal counties in the 48 conterminous U.S. states were calculated by subtracting the data for the NOAA-designated coastal counties from the data for all of the 48 conterminous U.S. states. This process is demonstrated in the text box below.

The data in each data set were then used to calculate the total population, population growth rate, and population density for each geographic area of interest. The general formulas used to calculate these statistics are presented in the text box below. The results of these calculations and the corresponding variables for the conterminous United States, all NOAA-designated coastal counties (collectively), all NEP-coincident coastal counties (collectively), the coastal counties coincident to each individual NEP study area, and all non-coastal counties (collectively) are summarized in Table A-1. The results for the data sets of coastal counties coincident with each individual NEP study area are presented in the individual NEP discussions within the main body of the NEP CCR.

Formulas:

$$2000Population_{48States} - 2000Population_{CoastalCounties} = 2000Population_{NonCoastalCounties}$$

$$TotalPopulation_{GivenArea} = \Sigma\ Population_{EachCounty}$$

$$Population\ Growth\ Rate = \frac{2000Population_{Total} - 1960Population_{Total}}{1960Population_{Total}}$$

$$2000\ Population\ Density = \frac{2000Population_{Total}}{TotalLandArea}$$

Table A-1. Comparison of U.S. Trends in Total Population, Population Growth Rate, and Population Density for the Nation, NOAA-designated Coastal Counties, NEP-coincident Coastal Counties, and Non-coastal Counties*

Year	Total population (millions)	Growth rate since 1960 (%)	Population density (persons/mi^2)	Land area (mi^2)
National (Conterminous U.S.)				
1960	178.46		60	
1970	202.23		68	
1980	225.18		76	
1990	247.34		84	
2000	279.58	56.66	94	2,959,065
NOAA-designated coastal counties				
1960	70.05		181	
1970	82.99		214	
1980	92.50		239	
1990	105.89		273	
2000	119.25	70.24	308	387,473
NEP-coincident coastal counties				
1960	51.42		313	
1970	60.55		368	
1980	65.48		398	
1990	73.68		448	
2000	81.91	59.28	498	164,382
Non-coastal counties				
1960	108.42		42	
1970	119.24		46	
1980	132.68		52	
1990	141.45		55	
2000	160.33	47.88	62	2,571,592

* Excludes population data and land area from Alaska, Hawaii, and Puerto Rico and other commonwealths, territories, and protectorates.

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National Estuary Program Coastal Condition Report

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