



*This document contains the regional discussion of the West Coast estuaries, from the National Estuary Program 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

### 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

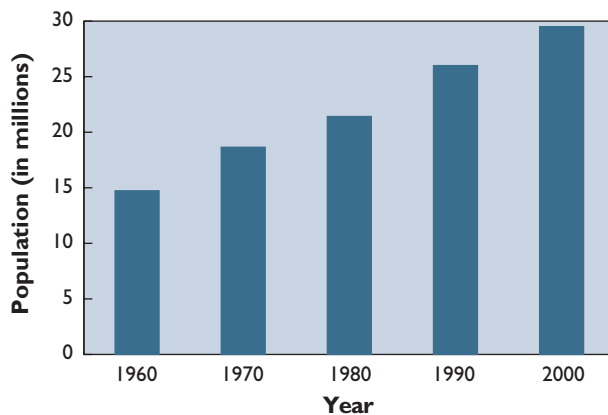
northern California to Washington due to extensive forested lands that help reduce sediment runoff (NOAA, 1985). However, historic logging activities, steep slopes, and heavy rainfall in some of the Northwest Coast estuaries combine to result in high levels of sediment and lower water clarity in some 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<sup>2</sup> 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<sup>2</sup> for the San Francisco Estuary to a low of 22 persons/mi<sup>2</sup> 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.

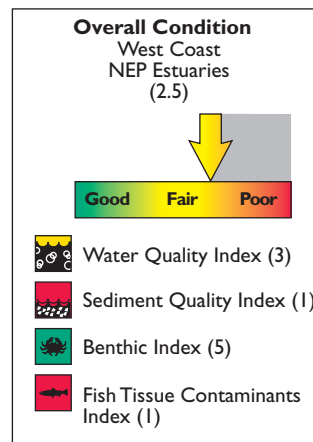


**Figure 6-2.** Population of the 41 NOAA-designated coastal counties of the West Coast NEP study areas, 1960–2000 (U.S. Census Bureau, 1991; 2001).

## 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.



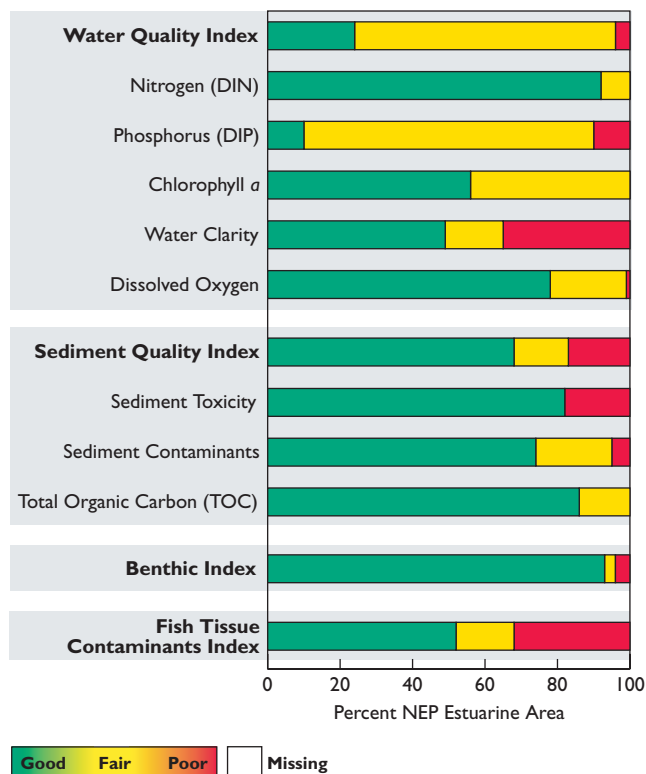
**Figure 6-3.** The overall condition of the West Coast NEP estuarine area is fair (U.S. EPA/NCA).

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.

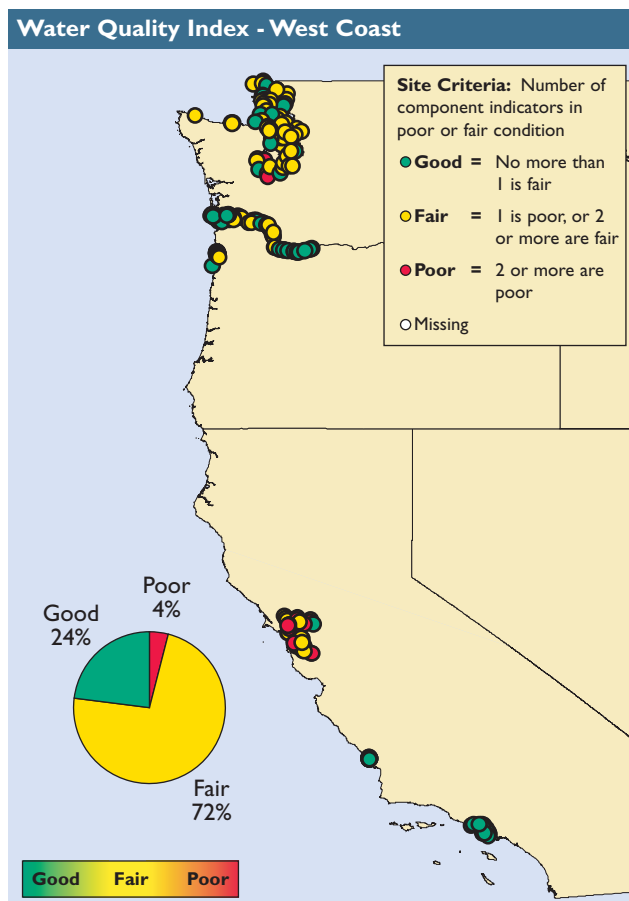


**Figure 6-4.** Percentage of NEP estuarine area achieving each ranking for all indices and component indicators — West Coast region (U.S. EPA/NCA).

### 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)

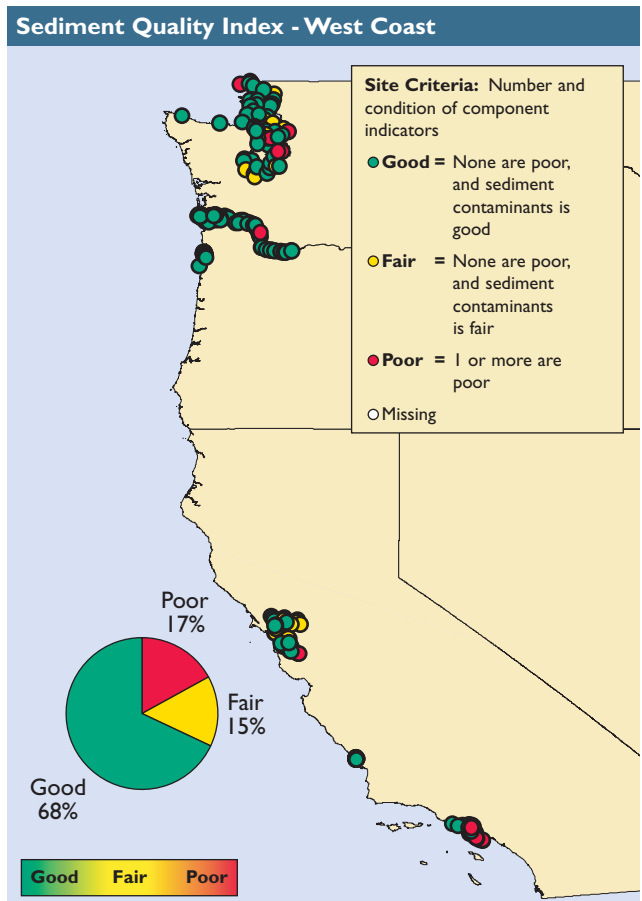
**ERM (Effects Range Median)**—Determined for each chemical as the 50th percentile (median) in a database of ascending concentrations associated with adverse biological effects.

**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.

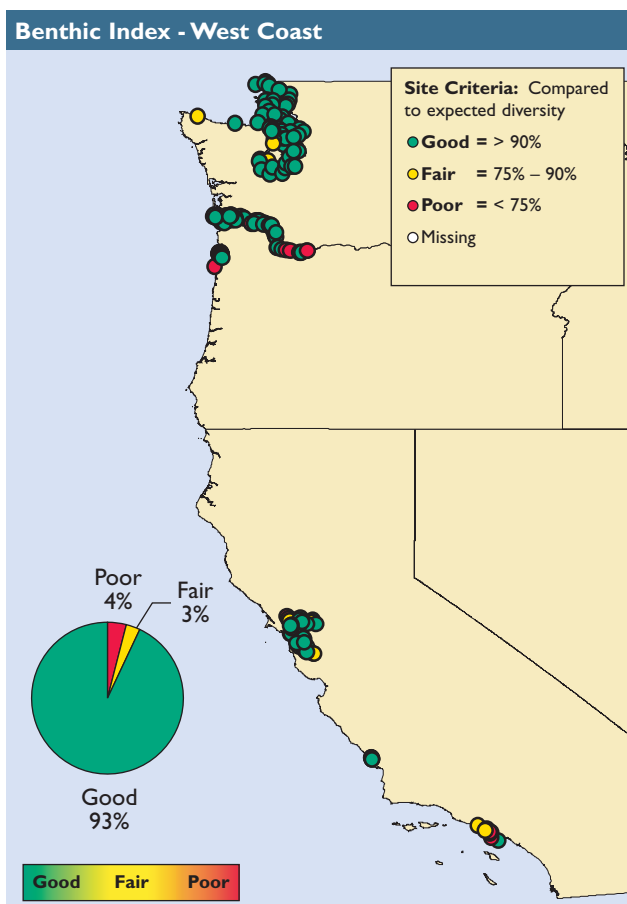
 **Benthic Index**

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).



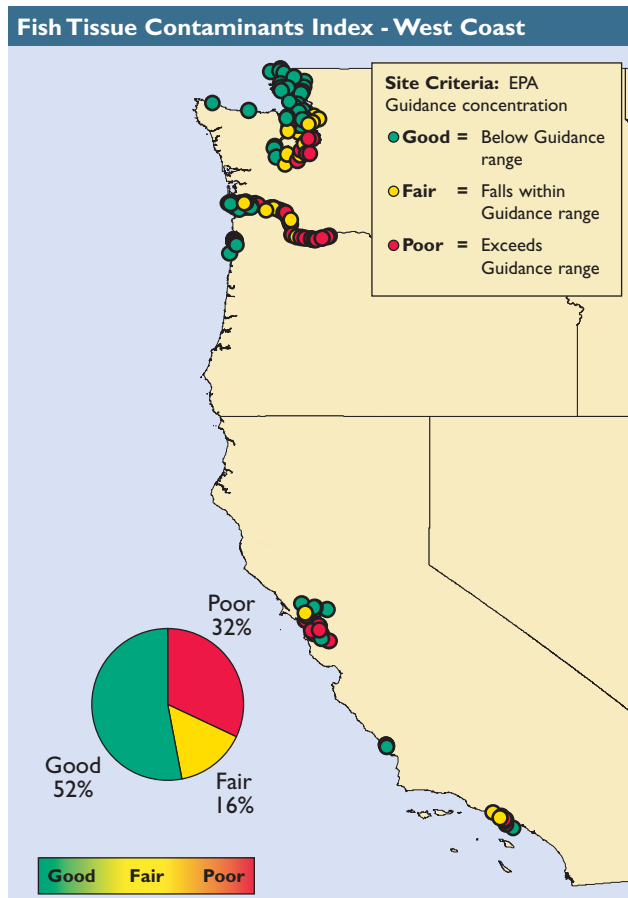
## Fish Tissue Contaminants Index

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.

## 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



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

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



	All West Coast Estuaries	All West Coast NEP Estuaries	Puget Sound	Lower Columbia River Estuary	Tillamook Bay	San Francisco Estuary	Morro Bay	Santa Monica Bay
<b>Overall Condition</b>	2.25	2.5	3.0	2.33	4.5	2.75	4.33	2.33
<b>Water Quality Index</b>								
Nitrogen (DIN)	Good	Good	Good	Good	Good	Fair	Good	Good
Phosphorus (DIP)	Fair	Fair	Fair	Fair	Fair	Poor	Fair	Good
Chlorophyll <i>a</i>	Good	Good	Fair	Good	Good	Good	Good	Good
Water Clarity	Poor	Poor	Poor	Poor	Poor	Poor	Good	Good
Dissolved Oxygen	Good	Good	Good	Good	Good	Good	Good	Good
<b>Sediment Quality Index</b>								
Sediment Toxicity	Poor	Poor	Poor	Fair	Good	Good	Poor	Poor
Sediment Contaminants	Good	Fair	Good	Good	Good	Good	Good	Poor
Total Organic Carbon (TOC)	Good	Good	Good	Good	Good	Good	Good	Good
<b>Benthic Index</b>				Missing			Missing	Missing
<b>Fish Tissue Contaminants Index</b>								

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<sup>2</sup>), 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<sup>2</sup>, 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<sup>2</sup>) and Puget Sound (205 persons/mi<sup>2</sup>), 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<sup>2</sup>, respectively).



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