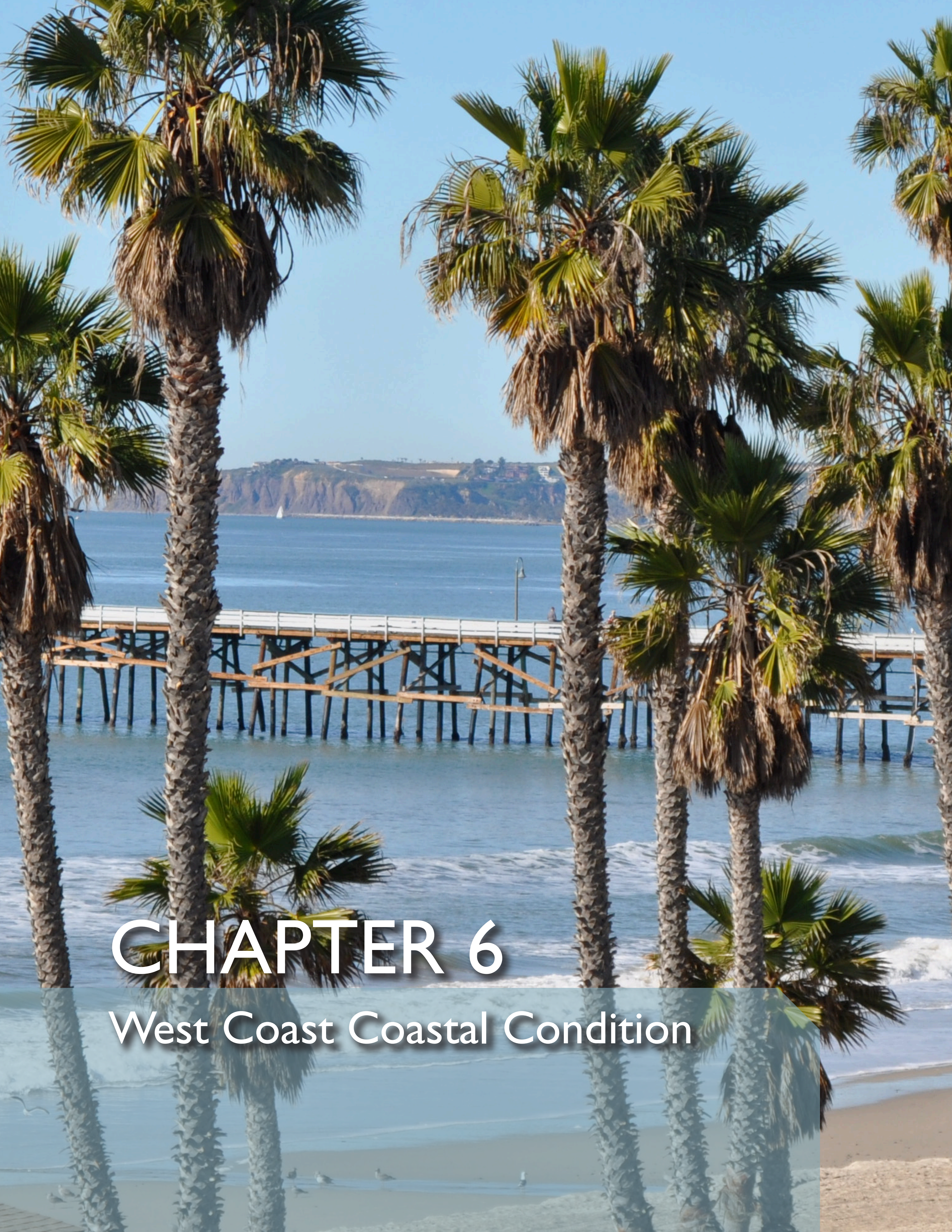


CHAPTER 6

West Coast Coastal Condition

6. West Coast Coastal Condition

As shown in Figure 6-1, the overall condition of the coastal waters of the West Coast region based on the 2004–2006 assessment period is rated good to fair, with an overall score of 3.8. The water quality, benthic, and fish tissue contaminants indices are rated good, the sediment quality index is rated fair; and the coastal habitat index is rated poor. Figure 6-2 provides a summary of the percentage of coastal area in good, fair, poor, or missing categories for each index and component indicator. This assessment is based on environmental stressor and response data collected by NCA from 139 sites in 2004 and 165 sites in 2005 through 2006 throughout West Coast coastal waters using comparable methods and techniques.

> Please refer to Chapter 1 for information about how these assessments were made, the cutpoints used to develop the rating for each index and component indicator, and the limitations of the available data.

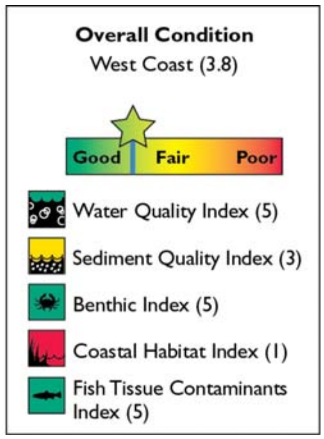


Figure 6-1. The overall condition of West Coast coastal waters is rated good to fair (U.S. EPA/NCA).

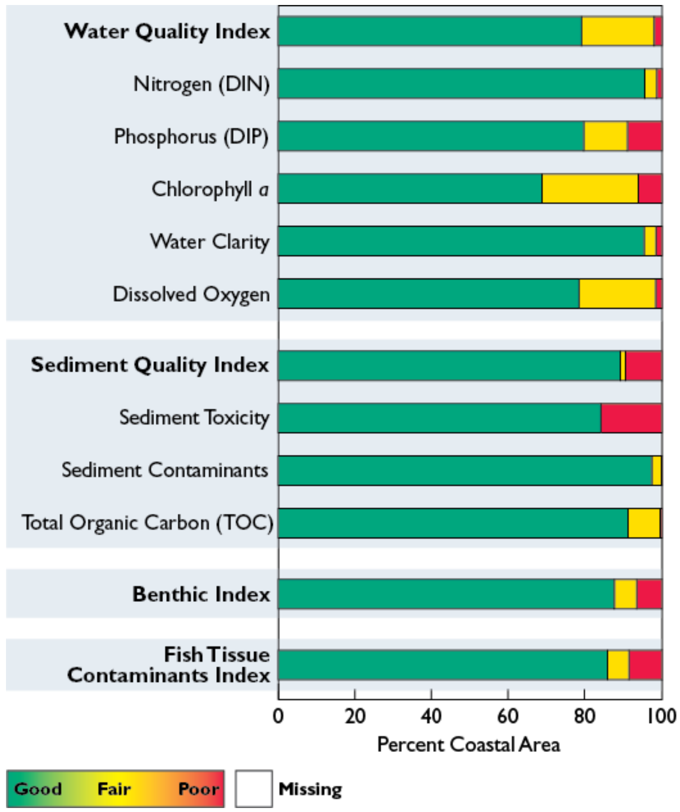


Figure 6-2. Percentage of coastal area achieving each ranking for all indices and component indicators—West Coast region (U.S. EPA/NCA).

The West Coast coastal area comprises more than 410 estuaries and bays, including the sub-estuary systems that are associated with larger estuaries. The size range of these West Coast coastal waterbodies is illustrated by five order-of-magnitude size classes of the systems sampled by EMAP/NCA—from less than 1 square mile (Yachats River, OR) to 2,551 square miles (Puget Sound and the Strait of Juan de Fuca, WA). The total coastal area of the West Coast estuaries, bays, and sub-estuaries is 3,940 square miles, 61.5% of which consists of three large estuarine systems—the San Francisco Estuary, Columbia River, and Puget Sound (including the Strait of Juan de Fuca). Sub-estuary systems associated with these large systems make up another 26.8% of the West Coast coastal area. The remaining West Coast coastal waterbodies, combined, comprise only 11.7% of the total coastal area of the West Coast region.

West Coast coastal waters are located in two provinces: the Columbian Province and the Californian Province. The Columbian Province extends from the Washington–Canada border south to Point Conception, CA. Within the United States, the Californian Province extends from Point Conception south to the Mexican border. There are major transitions in the distribution of human population along the West Coast, with increased population density occurring in the Seattle–Tacoma area of Puget Sound, around San Francisco Bay, and generally around most of the coastal waters of southern California. In contrast, the section of coastline north of the San Francisco Bay through northern Puget Sound has a much lower population density.

The NCA monitoring data used in this assessment are based on single-day measurements collected at sites throughout the United States during a 9- to 12-week period during the summer. Data were not collected during other time periods.

The coastal waters of the West Coast region represent a valuable resource that contributes to local economies and enhances the quality of life for those who work in, live in, and visit these areas. In the West Coast states of California, Oregon, and Washington, the majority of the population lives in coastal counties. Between 1980 and 2006, the coastal population of the West Coast region increased by 44%, from 23.1 million to 33.3 million people (Figure 6-3). This was the largest increase in the number of individuals for any coastal region in the United States over this time period. Population density in these coastal counties has also increased over this time period, from 299 to 431 persons/square mile (NOEP, 2010). Figure 6-4 maps the population density by county for the West Coast region in 2006. These population growth rates suggest that human pressures on West Coast coastal resources will increase substantially in future years.

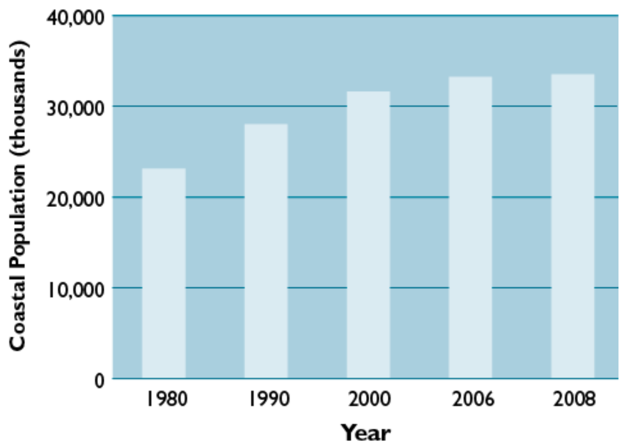


Figure 6-3. Population of coastal counties in the West Coast region from 1980 to 2008 (NOEP, 2010).

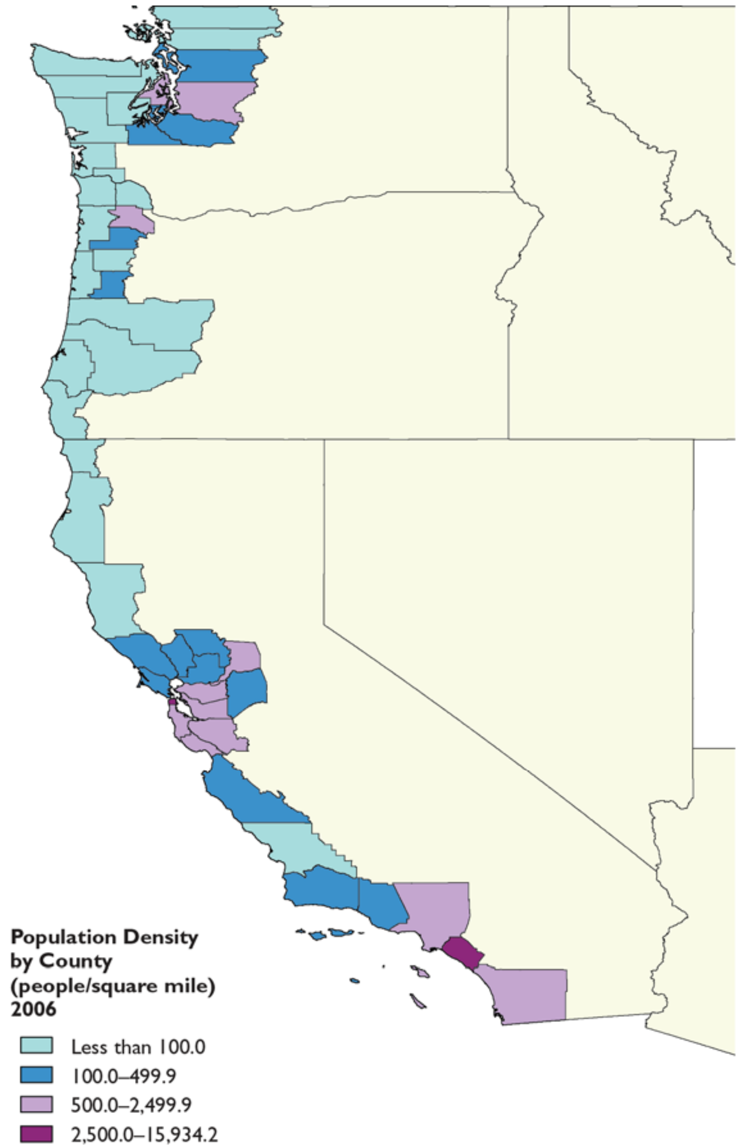


Figure 6-4. Population density in the West Coast region's coastal counties in 2006 (NOEP, 2010).

Coastal Monitoring Data—Status of Coastal Condition

The sampling program for the West Coast under NCA differed somewhat from other regions of the country. As a part of the EMAP Western Pilot Project, a variety of new initiatives were conducted. The NCA sampled small, western estuaries in 1999 and 2001 (Oregon only), large estuaries in 2000, the intertidal areas of small and large estuaries in 2002, and the waters of the continental shelf in 2003. Results of these surveys have been published in a series of reports (Nelson et al., 2004, 2005, 2007a, 2008; Hayslip et al., 2006, 2007; Partridge, 2007; Sigmon et al., 2006; Wilson and Partridge, 2007). The assessment results from 1999–2000 were previously reported in the NCCR III (U.S. EPA, 2008c).

All coastal waters of the West Coast region were included in the sampling framework for the 2004 survey, and this framework also was used in a sampling effort spread out over 2 years in 2005–2006. Both surveys were conducted using probability-based sampling designs, with sampling conducted during the summer. In 2004, 34 sites were sampled in Washington, 50 in Oregon, and 49 in California. In 2005–

2006, 50 sites were sampled each in Washington and Oregon, and 100 sites were sampled in California, equally divided between northern and southern California. Sampling categories for the randomized designs differed somewhat between the 2004 and 2005–2006 time periods, so all sample locations were post-stratified into 10 categories by area (e.g., Puget Sound, WA; remaining coastal waters, WA; San Francisco Bay, northern CA; remaining coastal waters, northern CA). These areas were used in the areal weightings for the final statistical analyses. Actual sample numbers obtained or analyzed varied due to various factors, including equipment failure. For example, benthic samples were obtained from 136 of 144 stations in 2004 and from all 200 stations in 2005–2006.

The West Coast regional ratings for the sediment contaminants component indicator and the fish tissue contaminants index were principally driven by results for the harbor areas of southern California. Compared to the results from the 1999–2000 survey, contamination indicators showed fewer poor stations from Puget Sound and San Francisco Bay. Sites from the majority of smaller estuarine systems along the West Coast were estimated to be in generally good condition.

The sampling conducted in the EPA NCA survey is designed to estimate the percent of coastal area (nationally or in a region or state) in varying conditions, and the results are displayed as pie diagrams. Many of the figures in this report illustrate environmental measurements made at specific locations (colored dots on maps); however, these dots (color) represent the value of the indicator specifically at the time of sampling. Additional sampling would be required to define temporal variability and to confirm environmental condition at specific locations.

Water Quality Index

The water quality index for the coastal waters of the West Coast region is rated good, with 19% of the coastal area rated fair and 2% rated poor for water quality condition (Figure 6-5). The water quality index is based on measurements of five component indicators: DIN, DIP, chlorophyll *a*, water clarity, and dissolved oxygen. In the NCCR III report (U.S. EPA, 2008c), a large percentage of West Coast survey area was rated in fair or poor condition for the DIP indicator, and it was suggested that re-evaluation of this indicator's cutpoints was required to better reflect natural background conditions. For this report, the rating cutpoints for DIN and DIP have been revised and computational approaches for the water clarity indicator have been changed to better reflect the attenuation of light through the water column rather than just in the shallow surface layer.

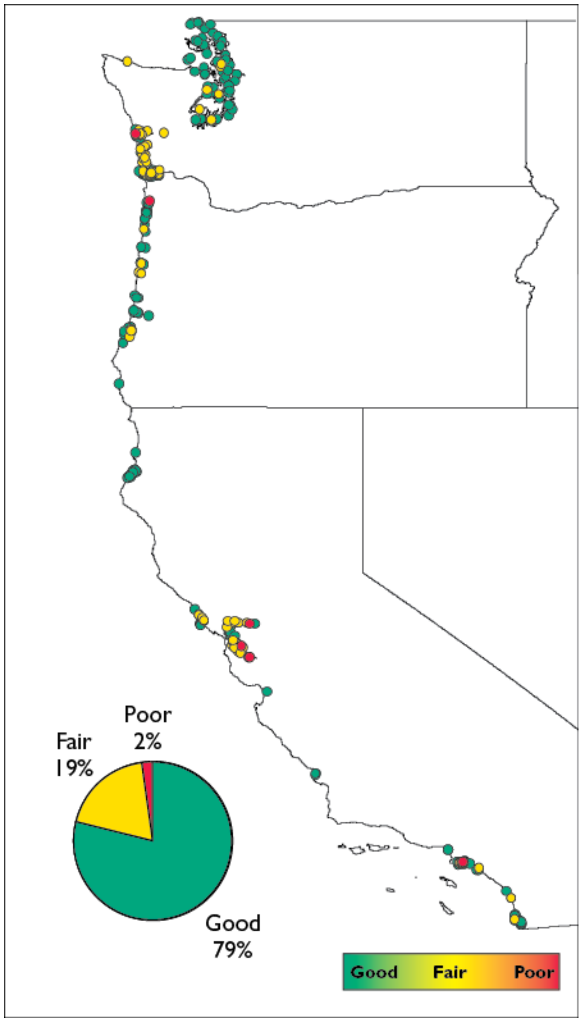


Figure 6-5. Water quality index data for West Coast coastal waters (U.S. EPA/NCA).

Nutrients: Nitrogen and Phosphorus

The West Coast region is rated good for DIN concentrations, with 3% of the coastal area rated fair and 1% of the area rated poor. The West Coast region is rated good for DIP concentrations, with 11% of the coastal area rated fair and 9% rated poor.

Chlorophyll *a*

The West Coast region is rated good for the chlorophyll *a* component indicator, with 25% of the coastal area rated fair and 6% of the area rated poor. The majority of sites rated poor were located in the outer coast estuaries of Washington and Oregon, particularly Willapa Bay and Gray's Harbor in Washington. It is questionable whether these poor conditions result from anthropogenic impacts since this portion of the coast has low population densities and limited anthropogenic sources for nitrogen inputs. Percentiles for chlorophyll *a* data were also computed from the GLOBEC data set (Wetz et al., 2004), and the measured concentrations at NCA sites rated poor are in considerable excess of the 95th percentiles calculated from the GLOBEC study. The extremely high values measured by NCA may reflect upwelling-related nutrient sources for phytoplankton blooms. It appears that phytoplankton blooms may take place even closer to the coastline than the locations where the GLOBEC data were recorded, potentially in the surf zone. Menge et al. (2009) report similarly high values of chlorophyll *a* from very nearshore sites along the Oregon coast. Although long-term mean chlorophyll *a* concentrations at these Oregon sites were often above the NCA rating cutpoints for poor water quality, these concentrations are the result of natural upwelling processes. Menge et al. (2009) also document significant interdecadal variation in chlorophyll *a* levels. Further assessment of the chlorophyll *a* rating cutpoints is warranted.

How were the new DIN and DIP rating cutpoints assigned?

Research has shown that coastal waters in the West Coast region may be strongly influenced by upwelled water entering the estuaries on flood tides, especially during the summer months when NCA sampling occurs (Hickey and Banas, 2003; Brown and Ozretich, 2009). Upwelling activity is an important contributing factor determining the DIN and DIP concentrations measured in the coastal waters of the West Coast region during the summer. Thus, the highest values of nitrogen and phosphorus observed in summer months tend to be associated with the upwelled water moving into the estuary. The concentration values for assigning condition ratings for DIN and DIP used for the West Coast in the NCCR II and NCCR III were based on literature from the East Coast, and it was recognized that a reassessment of West Coast rating cutpoints in light of new research was warranted. Based on the DIP cutpoints used in the NCCR III, much of the West Coast was rated either fair or poor for phosphorus, in spite of the fact there was no source of anthropogenic inputs of phosphorus in much of the region assessed. The DIP cutpoints were too low to be appropriate for reference conditions in the West Coast region. The DIN cutpoints also appeared to be somewhat high and did not appear to be particularly sensitive.

Upwelling activity along the West Coast is at a maximum during the summer months. Between 1997 and 2004, nutrient data were collected in waters at seven locations from Newport, OR, to near Pt. Arenas, CA, from the Global Ocean Ecosystems Dynamics (GLOBEC) Northeast Pacific Long Term Observation Program (Wetz et al., 2004). Data for DIN and DIP from April through September were extracted for the most inshore station for depths below 66 feet, and percentiles were computed for the pooled data from the seven stations. For DIN and DIP, the 75th percentile values appear to be reasonable to use as a basis for a rating cutpoint for good condition based on comparison to estuarine nutrient data sets in the region (Brown et al., 2007; Nelson and Brown, 2008). Because the NCCR series has used units of mg/L for rating cutpoints, values were converted from μM to mg/L. The revised rating cutpoints for DIN and DIP used for the West Coast region in the NCCR IV are given in Tables 1-2 and 1-3 of Chapter 1.

Water Clarity

The West Coast region is rated good for water clarity, with 2% of coastal area rated poor and 3% rated fair. The same rating cutpoints were used to assess water clarity across the region, with a sampling site receiving a rating of poor if less than 10% of surface illumination was measured at a depth of 1 meter.

Dissolved Oxygen

The West Coast region is rated good for dissolved oxygen concentrations, with 20% of the coastal area rated fair and 2% of the coastal area rated poor. The sites with the lowest measured values of dissolved oxygen were located in Dabob Bay, and the southern arm of Hood Canal, both in Washington. Three stations sampled in the Los Angeles – Long Beach Harbor area were also rated poor for this component indicator.

Sediment Quality Index

The sediment quality index for the coastal waters of the West Coast region was rated fair, with 10% of the coastal area rated poor and 1% rated fair (Figure 6-6). The sediment quality index used is based on measurements of three component indicators: sediment toxicity, sediment contaminants, and sediment TOC; however, there was some variation in the areas assessed and the methods used to assess the sediment toxicity component indicator. Sediment toxicity testing was not conducted by Oregon in 2005–2006 because of the cost involved; however, the 2004 sampling included samples across all estuaries, such that an adequate coverage for Oregon was available, although data density was lower than for Washington and California. Also, California used *Eohaustorius estuarius* as a test organism in 2005–2006 instead of the NCA standard organism, *Ampelisca abdita*, since *A. abdita* was viewed by the state as insufficiently sensitive. In spite of this difference, the results of the sediment toxicity indicator were virtually the same from the two sample periods.

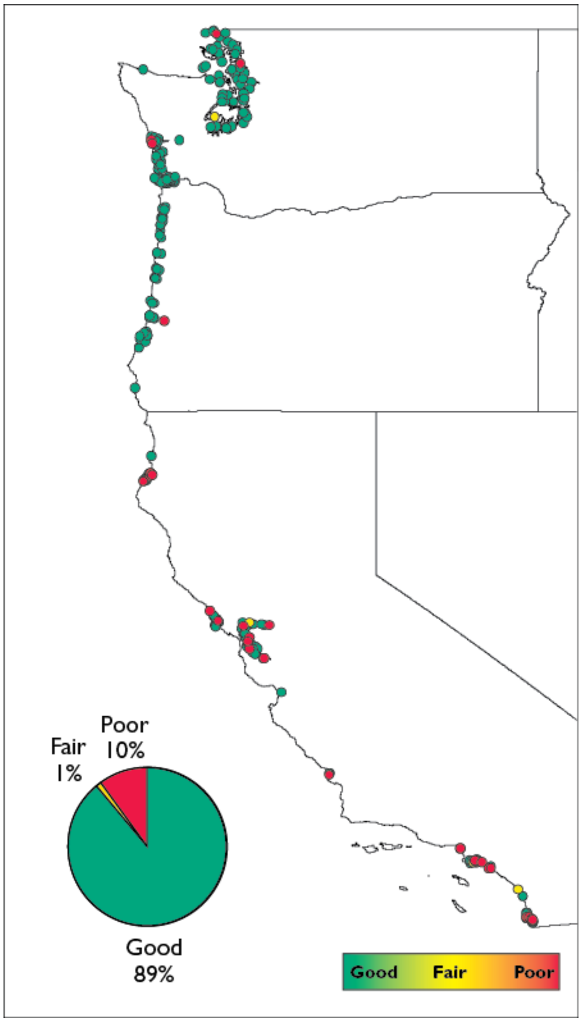


Figure 6-6. Sediment quality index data for West Coast coastal waters (U.S. EPA/NCA).

Sediment Toxicity

The West Coast region is rated poor for sediment toxicity, with 16% of the coastal area rated poor. This rating should be considered provisional for several reasons. There were only a total of 238 stations with sediment toxicity data. Many of the 2004 sediment samples exceeded the holding times specified by the NCA quality assurance project plan (U.S. EPA, 2001a) due to a hurricane that damaged the testing laboratory, and this may have potentially increased the rate of false positives. The toxicity testing involved use of two species with distinctly different sensitivities; *Eohaustorius estuarius* is more sensitive than *Ampelisca adita*. Interpretation of the toxicity results is unclear because of the low association (30%) of poor sediment toxicity ratings and a poor sediment contaminant rating at a station. There was no association of the toxicity results with percent TOC at a station. There was a significant, but weak ($r^2 = 0.1$), negative association of survivorship of *E. estuarius* with percent fines in the sediment.

Sediment Contaminants

The West Coast region is rated good for the sediment contaminants component indicator, with 3% of the coastal area rated fair and less than 1% rated poor. With the exception of one ERM exceedance for zinc in Grays Harbor, WA, all other ERM exceedances were in harbors in southern California (e.g., Newport Bay, San Diego Bay, Marina del Rey, Long Beach Harbor). ERMs for copper, mercury, zinc, total DDT, and 4,4'-DDE were exceeded in California. There were few ERL exceedances for total PCBs, and no exceedances for total PAHs.

Guidelines for Assessing Sediment Contamination (Long et al., 1995)

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

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

Sediment TOC

The West Coast region is rated good for the sediment TOC component indicator, with 8% of the coastal area rated fair and 1% of the area rated poor.

Benthic Index

Benthic condition in West Coast coastal waters is rated good, with 6% of the coastal area rated fair and 7% rated poor (Figure 6-7). In lieu of a formal West Coast benthic index, the deviation of species richness from an estimate of expected species richness was used as an approximate indicator of benthic condition. Log species richness was regressed on salinity, to establish expected species richness across varying salinity levels. A highly significant ($p < 0.0001$) linear regression between log species richness and salinity was found for the region, although variability was high ($R^2 = 0.33$).

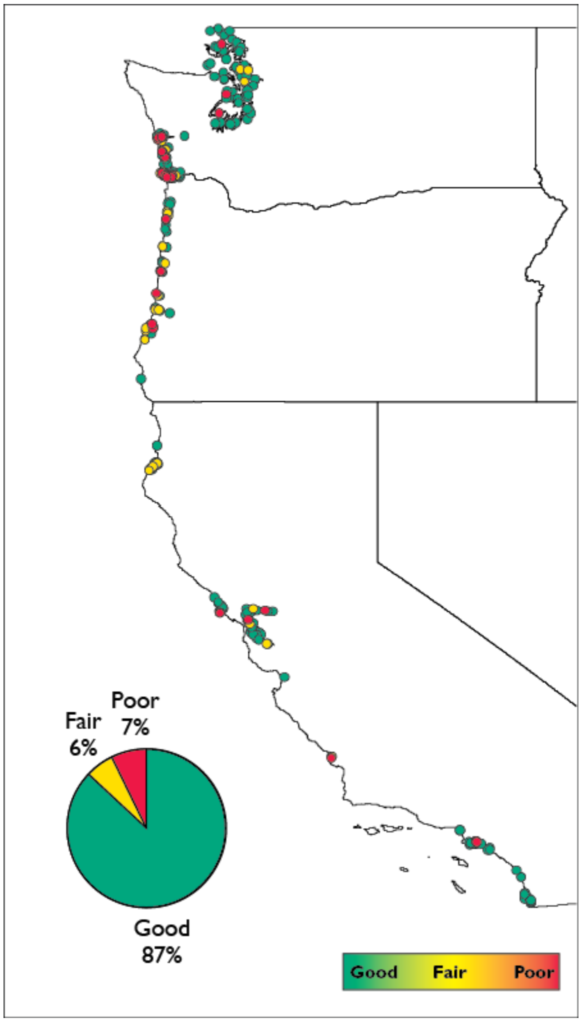


Figure 6-7. Benthic index data for West Coast coastal waters (U.S. EPA/NCA).

Coastal Habitat Index

The coastal habitat index for the coastal waters of the West Coast region is based on the same information as that prepared for the NCCR III. The coastal habitat index is rated poor. From 1990 to 2000, the West Coast region experienced a loss of 1,720 acres (0.53%) of coastal wetlands (Dahl, 2010). The long-term, average decadal loss rate of West Coast wetlands is 3.4%. Although the number of coastal wetland acres lost for the West Coast region was less than the losses noted in other regions of the United States, the relative percentage of existing coastal wetlands lost in the West Coast region was the highest nationally. West Coast wetlands constitute only 6% of the total coastal wetland acreage in the conterminous 48 states; thus, any loss will have a proportionately greater impact on this regionally limited resource.

Fish Tissue Contaminants Index

The fish tissue contaminants index is rated good. Based on EPA Advisory Guidance values, 5% of the stations where fish were caught rated fair and 9% of stations rated poor (Figure 6-8). Fish for contaminant analysis were collected at 197 stations, and with multiple species collected at some stations; this yielded a total of 272 tissue analyses. The available data represent a mixture of tissue analysis types. Depending on state, year, and size of fish collected, the data available may be for filets or for whole fish. Stations with poor or fair ratings for the fish tissue contaminants index were found principally in the harbors in southern California (e.g., Newport Bay, San Diego Bay, Los Angeles – Long Beach Harbor), a few locations in Puget Sound in Washington, and two locations in the Columbia River Estuary. The contaminants found most often in fish tissue samples included total PCBs and DDTs.

> If the fish tissue contaminants index were computed based on an areally weighted basis similar to the other indicators, the index would be rated good, based on a cutpoint of less than 10% of coastal area in poor condition. Based on fish contaminant concentrations and EPA Advisory Guidance values, 4% of area was rated fair and 4% of area was rated poor.

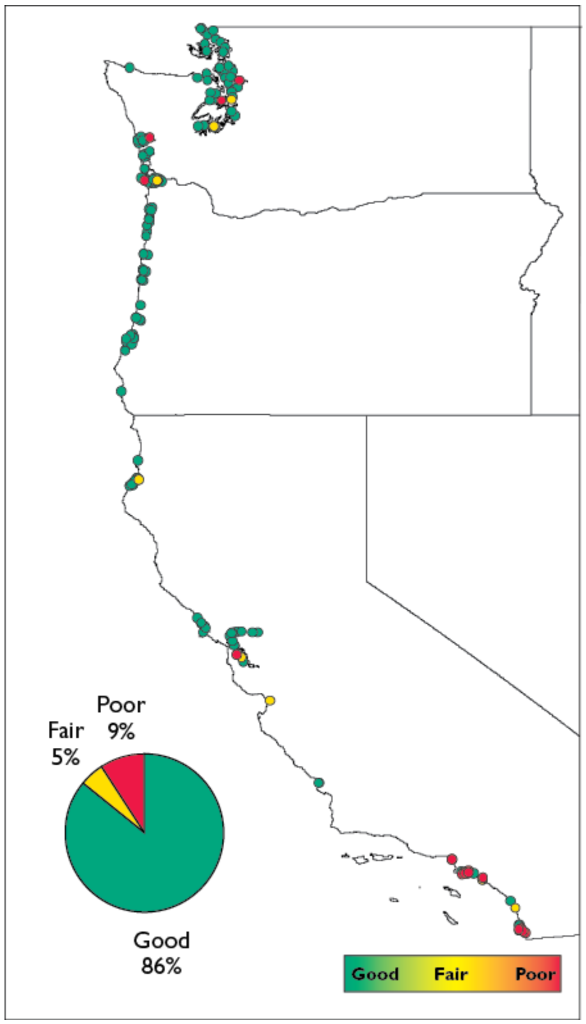


Figure 6-8. Fish tissue contaminants index data for West Coast coastal waters (U.S. EPA/NCA).

Trends of Coastal Monitoring Data—West Coast Region

A temporal trends analysis for the West Coast region was not conducted in previous NCCRs due to lack of appropriate comparison data sets. The sampling efforts in 2001, 2002, and 2003 are not directly comparable to the other sampling efforts, so the most reasonable temporal comparison for the West Coast region is the aggregated sample data from 1999–2000 (U.S. EPA, 2008c) compared to the aggregated sample data from 2004 through 2006. The 1999–2000 assessment is based on data collected by NCA from 210 sites in 1999 and 171 sites in 2000, for a total of 381 stations. Data on sediment contaminants for 41 of the 71 sites within Puget Sound were collected by NOAA's NS&T Program in 1997–1999.

NOAA NS&T also provided sediment and infauna data for 33 of the 50 sites in San Francisco Bay in 2000.

For this report, the rating cutpoints for DIN and DIP were revised, and the 1999–2000 data were reanalyzed using the modified rating cutpoints. Rating cutpoints for the chlorophyll *a*, water clarity, and dissolved oxygen component indicators were not changed; however, computational approaches for the water clarity indicator were changed to better reflect the attenuation of light through the water column rather than just in the shallow surface layer. The 1999–2000 water clarity indicator data were reanalyzed to reflect this change. Based on this reanalysis of the DIN, DIP, and water clarity indicators, the water quality index for 1999–2000 received a revised rating of good, with 18% of the coastal area rated fair and 7% rated poor. In the NCCR III, the water quality index received a rating of fair, with the lower ratings driven primarily by the DIP and water clarity indicators. The revised rating resulted from the application of more appropriate rating cutpoints for the DIN and DIP indicators and from the more appropriate computation methods used for the water clarity component indicator.

Figure 6-9 presents a comparison of the percent of coastal waters rated good, fair, and poor for the water quality index and its component indicators between the data collected in the 1999–2000 and the 2004–2006 surveys. In both time periods, the water quality index was rated good, although the area rated poor decreased slightly in 2004–2006. DIN and DIP were rated good in both time periods, with a slightly greater area rated fair for DIP in 2004–2006. The West Coast region was rated good for the chlorophyll *a* component indicator in both time periods. More area was rated poor and less area was rated fair in 2004–2006. The water clarity component indicator was rated good in for both time periods, with slightly less area rated poor in 2004–2006. The West Coast region was rated good for dissolved oxygen concentrations during both time periods, with less of the area rated fair in 2004–2006. Low dissolved oxygen levels were measured in sub-estuaries of Puget Sound (Dabob Bay and southern Hood Canal) during both periods. These areas of Puget Sound are known to often have low dissolved oxygen concentrations in the bottom waters, due to restriction on flushing in these fjord-like embayments. The relative contribution of anthropogenic nutrient inputs versus climatic alterations in water replacement is still under scientific assessment. Additional information is available online at: http://www.hoodcanal.washington.edu/index.jsp.

How was the water clarity component indicator recalculated?

The computation of percent light at 1 meter used in the NCCR II and NCCR III reports calculated a light extinction coefficient (k_d) using the shallowest in-water readings only. To make the 1999–2000 water clarity index comparable to that from the 2004–2006 analysis, raw data for the photosynthetically active radiation (i.e., PAR) were reexamined, new analysis routines were applied, and additional QA inspection was used. This resulted in exclusion of data from some stations that were included in the NCCR III analysis. A number of stations in Puget Sound were rejected because the in-water readings were taken only at the surface, mid-depth, and bottom locations. At deep water stations, the mid-depth reading was often zero, so there was no way to estimate the depth interval at which light went to zero in order to be able to calculate a meaningful k_d. After reanalysis, the percentage area in the three rating categories was very similar between sample periods.

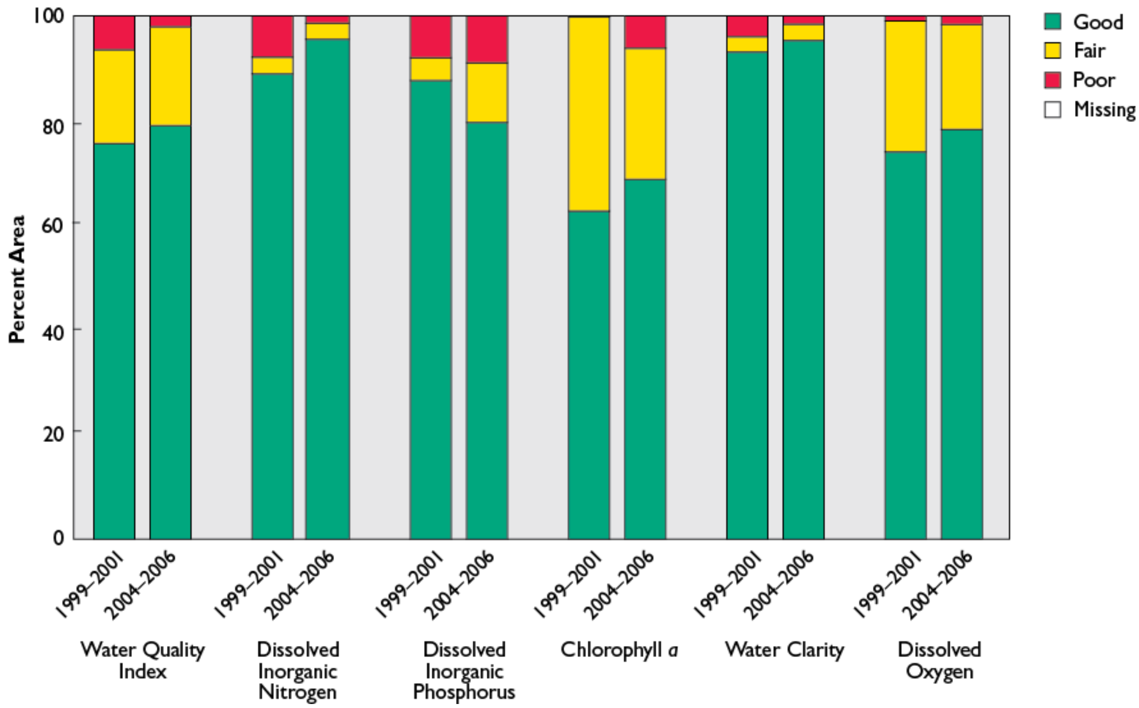


Figure 6-9. Comparison of percentage of coastal area of the West Coast in good, fair, and poor condition for the water quality index and its component indicators between data collected in 1999–2000 and data collected in 2004–2006 (U.S. EPA/NCA).

The percentages of coastal area in the West Coast region rated in good, fair, and poor condition for the sediment quality index and its component indicators are compared in Figure 6-10 for data collected in 1999–2000 and 2004–2006 sampling periods. The rating for the sediment quality index improved from fair to poor in the 1999–2000 sampling period to fair in 2004–2006. Although the species used to measure sediment toxicity varied in the 2004–2006 time period, the West Coast region was rated poor for the sediment toxicity component indicator during both time periods and the percentage of coastal area rated poor was comparable. Although the West Coast region was rated good for the sediment contaminants component indicator during both time periods, much less of the coastal area was rated fair and poor in 2004–2006. The West Coast region was also rated good for the sediment TOC component indicator for both time periods, with similar percentages of the coastal area rated fair and poor in both 1999-2000 and 2004–2006. The apparent improvement in the sediment quality index should be interpreted cautiously because the trend comparison includes only two points in time.

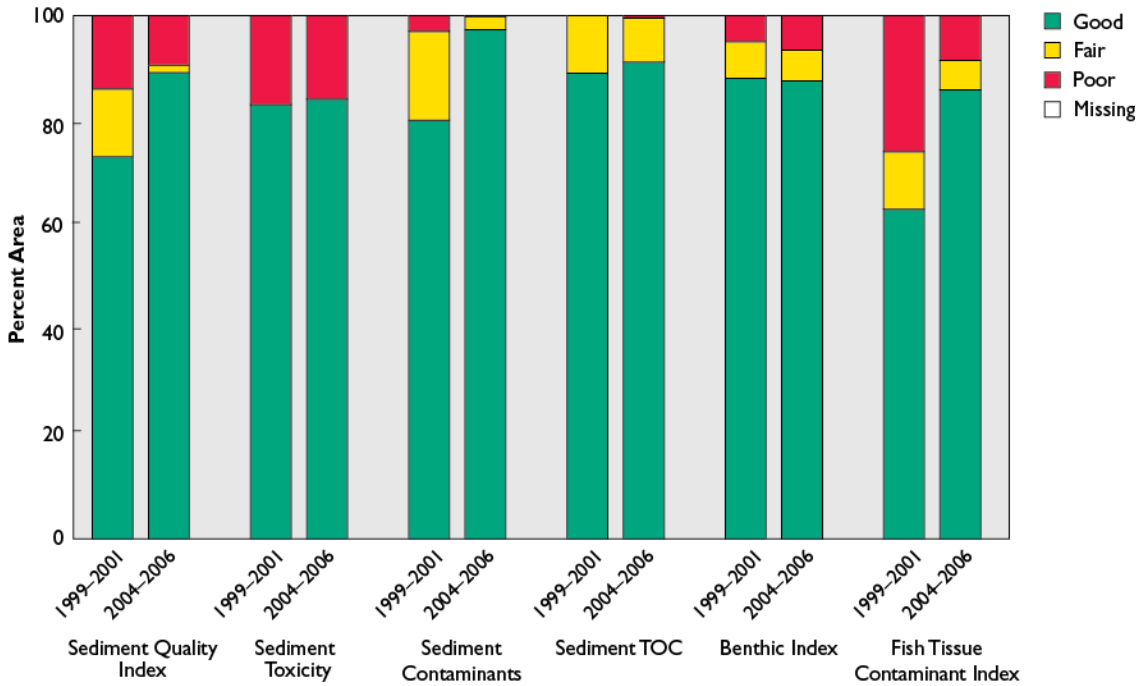


Figure 6-10. Comparison of percentage of coastal area of the West Coast in good, fair, and poor condition for the sediment quality index and its component indicators, the benthic index, and the fish tissue contaminants index* between data collected in 1999–2000 and 2004–2006.

*The fish tissue contaminants index is measured as a percentage of stations where fish were caught rather than as percentage of coastal area (U.S. EPA/NCA).

Benthic condition in West Coast coastal waters was rated good in 1999–2000 and in 2004–2006, with similar percentages of the area rated fair and poor (see Figure 6-10). During both time periods, a significant ($p < 0.01$ for 1999–2000 and $p < 0.0001$ for 2004–2006) linear regression between log species richness and salinity was found for the region, although variance was high ($R^2 = 0.43$ in 1999–2000 and $R^2 = 0.33$ in 2004–2006) in both cases.

Based on EPA Advisory Guidance values, the fish tissue contaminants index was rated poor for 1999–2000 and good for 2004–2006. As shown in Figure 6-10, the percentage of stations that were rated poor decreased from 26% to 9% in the latter time period. It should be noted that the 1999–2000 assessment data were based on analysis of whole-fish contaminant concentrations while the 2004–2006 data included both fillet and whole-fish concentrations. Although the inclusion of fillet samples might be expected to result in the observation of lower concentrations than whole fish, the total number of analyzed fish composites that were scored either fair or poor in 2004–2006 was virtually the same for fillet and whole fish samples. However, a possible impact of inclusion of fillet samples on the overall fish tissue result cannot be excluded, however. The contaminants found most often in fish tissue samples included total PCBs and DDTs.

Coastal Ocean Condition—West Coast

This assessment area covers coastal ocean waters along the western U.S. continental shelf, from the Strait of Juan de Fuca in Washington to the U.S./Mexican border, which coincides roughly with the U.S. portion of the California Current LME (U.S. Commission on Ocean Policy, 2004). In summer 2003, the western NCA, NOAA's NOS and NMFS, western states (Washington, Oregon, and California), and the Southern California Coastal Water Research Project (Bight '03 program) coordinated various monitoring efforts to assess status of ecological condition and stressor impacts throughout this offshore coastal ocean area and to provide information as a baseline for evaluating future changes due to natural or human-induced disturbances.

To address these objectives, the study incorporated standard methods and indicators applied in previous coastal EMAP/NCA projects and NCCRs (U.S. EPA, 2001b; 2004a; 2008c), including multiple measures of water quality, sediment quality, and biological condition. A total of 257 stations were sampled (Figure 6-11) at target depths of 98–393 feet.

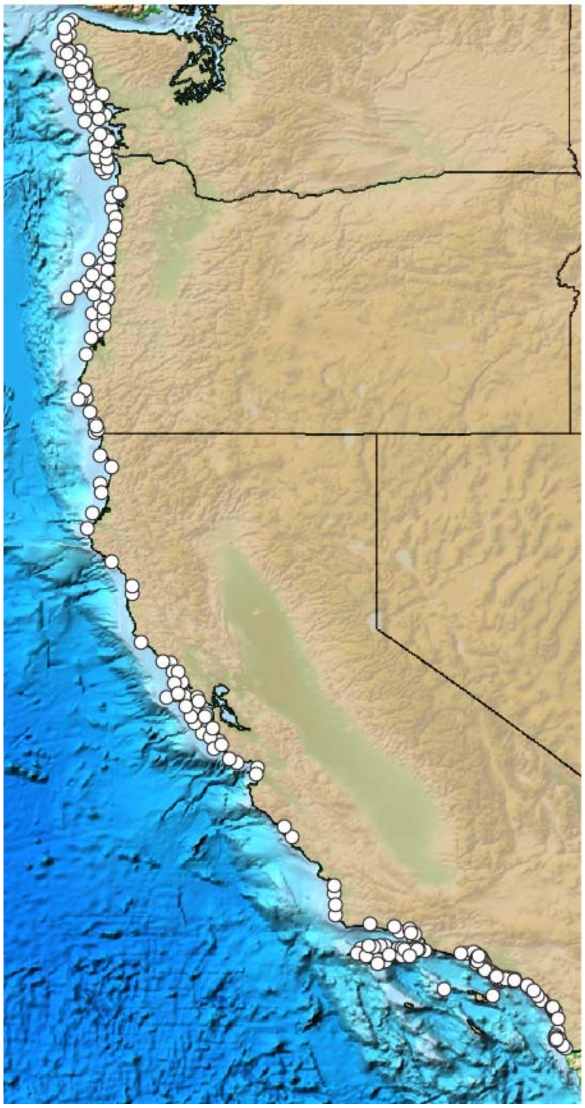


Figure 6-11. Map of West Coast coastal ocean sampling stations (Nelson et al., 2008).

Another key feature was the incorporation of a stratified-random sampling design with stations stratified by state and by NMS status. Each of the three states was represented by at least 50 random stations. In addition, a total of 84 random stations were located within NOAA's NMS sites along the west coast, including the Olympic Coast, Cordell Bank, Gulf of Farallones, Monterey Bay, and Channel Islands sanctuaries. Collection of flatfish via hook-and-line for fish-tissue contaminant analysis was successful at 50 of the offshore stations distributed along the entire coast.

Condition of these offshore coastal ocean waters is presented here on a region-wide basis and compared to West Coast estuaries, based on data from related NCA surveys conducted in 2004–2006 (featured in the previous section). A detailed report on results of the West Coast coastal-ocean assessment, including more in-depth comparisons of condition by state and by NMS vs. non-sanctuary status, is provided by Nelson et al. (2008).

Water Quality

Nutrients: Nitrogen and Phosphorus

The average concentration of DIN (nitrogen as nitrate + nitrite + ammonium) in coastal-ocean surface waters, exclusive of the Southern California Bight stations wherein ammonium was not measured, was 0.106 mg/L (Figure 6-12). Concentrations were much higher at sites in California than in Washington or Oregon, reflecting the influence of upwelling events in the central California area at the time of sampling.

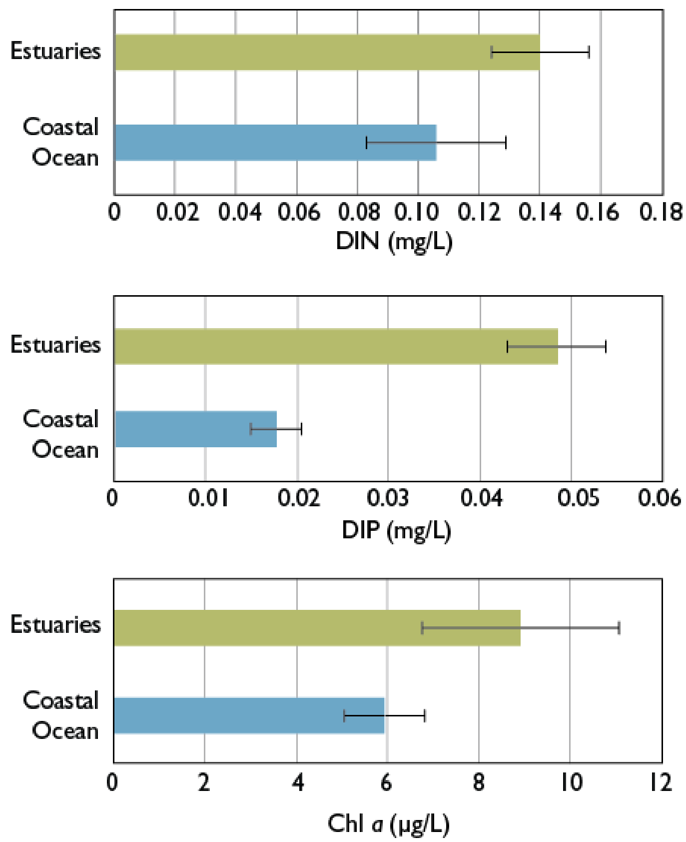


Figure 6-12. Mean concentrations ± 95% C.I.s of (a) DIN, (b) DIP, and (c) chlorophyll *a* in coastal ocean vs. estuarine surface waters (Nelson et al., 2008; U.S. EPA/NCA).

Estuarine surface waters had higher DIN concentrations, which averaged 0.140 mg/L (see Figure 6-12). Although water quality assessment endpoints for DIN have been defined for estuaries, none are available for coastal ocean waters to use as a basis for evaluating whether observed levels reflect good vs. poor conditions. However, for comparison, less than 1% of offshore coastal-ocean area would be rated poor for the DIN component indicator using the NCA cutpoints. Near-bottom concentrations of DIN in offshore waters, which averaged 0.421 mg/L, were slightly higher in comparison to the offshore surface-water mean of 0.106 mg/L.

Concentrations of DIP in offshore surface waters averaged 0.018 mg/L for the 188 stations with DIP data (see Figure 6-12). These levels are lower than those measured in estuaries of the region, which averaged 0.048 mg/L. Similar to DIN, there are no available water-quality assessment cutpoints for rating observed levels of DIP in offshore coastal ocean-waters of the region. However, for comparison, none of the coastal ocean area would be rated poor for the DIP component indicator based on the NCA cutpoints. DIP levels in offshore surface waters in the West Coast region also appear to be lower than those observed along the Atlantic coast of the United States (e.g., average of 0.04 mg/L for Mid-Atlantic Bight, Chapter 3; Balthis et al., 2009). Coastal-ocean, Nnar-bottom concentrations of DIP collected in the West Coast region, which averaged 0.061, were slightly higher in comparison to the surface water mean of 0.018 mg/L.

DIN/DIP ratios were calculated as an indicator of which nutrient may be controlling primary production (phytoplankton growth). A ratio above 16 indicates that phosphorus limits growth, while a ratio below 16 indicates that nitrogen is limiting (Geider and La Roche, 2002). DIN/DIP ratios for offshore coastal ocean waters averaged 12.7, with the vast majority of the survey area (about 93%) having values ≤ 16, indicating that nitrogen levels are limiting primary production in these areas.

Chlorophyll a

Concentrations of chlorophyll *a* in offshore surface waters averaged 6.04 µg/L (see Figure 6-12). In general, these levels were lower than those measured in estuaries of the region, which averaged 9.07 µg/L. As a further comparison, relative to the NCA rating cutpoints for chlorophyll *a* concentrations, 4% of the offshore survey area would be rated poor. In contrast, chlorophyll *a* levels in offshore surface waters along the West Coast were much higher than those observed along the Atlantic coast of the United States (e.g., average of 0.23 µg/L for the Mid-Atlantic Bight, see Chapter 3; Balthis et al., 2009). Near-bottom concentrations of chlorophyll *a* along the West Coast, which averaged 0.36 µg/L, were much lower in comparison to the surface-water mean of 6.04 µg/L.

Water Clarity

Concentrations of TSS were used as a surrogate indicator of water clarity for offshore waters. TSS in coastal ocean surface waters averaged 4 mg/L, considerably lower than averages for estuaries in the region (11.5 mg/L). While most offshore surface waters had TSS concentrations under 7.4 mg/L, the 90th percentile of all measured values, 38% of the estuarine survey area surface waters had TSS above this level, which is not surprising given the proximity of these sites to land. Near-bottom concentrations of TSS in the offshore waters, averaging 3 mg/L, were slightly lower in comparison to surface waters.

Dissolved Oxygen

Near-bottom concentrations of dissolved oxygen in offshore waters averaged 3.7 mg/L. Although none of the coastal-ocean area would be rated poor for the dissolved oxygen component indicator based on NCA cutpoints, 92% of the survey area would be rated fair and 8% of the area would be rated good (Figure 6-13). The stations rated as good tended to be grouped at the extreme southern and northern ends of the survey region.

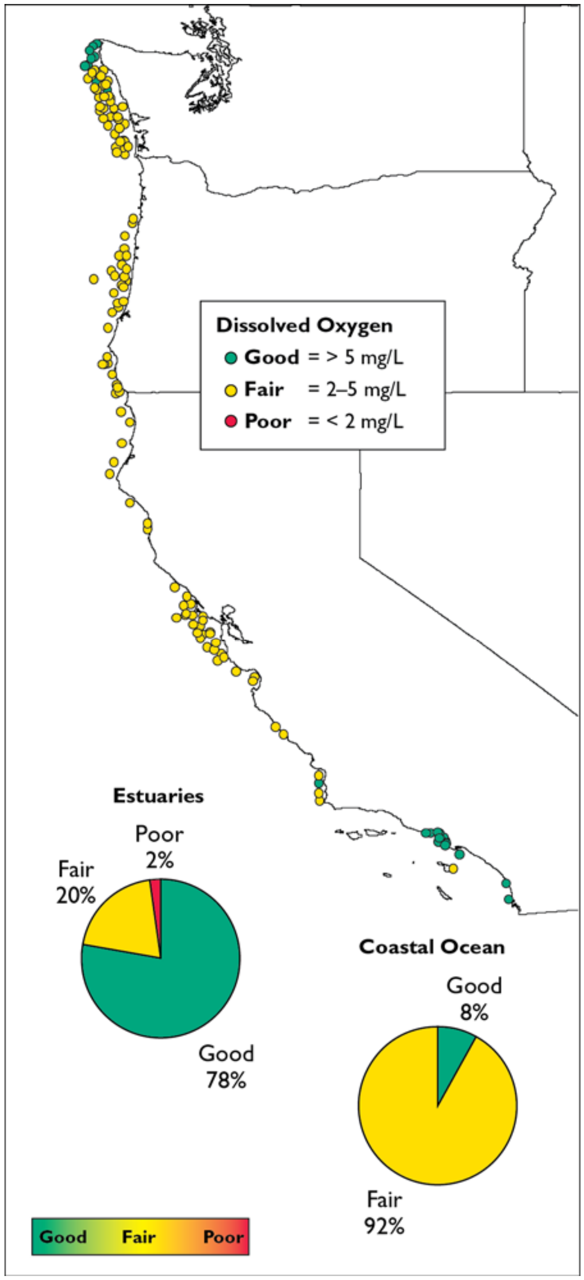


Figure 6-13. Dissolved oxygen data in near-bottom coastal-ocean waters of the West Coast region (Nelson et al., 2008; U.S. EPA/NCA).

Pie charts compare offshore and estuarine dissolved oxygen levels.

In comparison to these offshore waters, only 20% of the estuarine area was rated fair and a much larger portion (78%) was rated good (see Figure 6-13). Near-bottom dissolved oxygen levels in coastal ocean waters in the West Coast region also tended to be lower than levels observed in other coastal ocean regions, for example, in comparison to the Mid-Atlantic Bight, where 100% of the survey area would be rated good (Chapter 3, Balthis et al., 2009) based on NCA cutpoints. Hypoxia along the continental shelf appears to be associated with upwelling conditions in the region, while severe hypoxic events in inshore shelf areas (< 70 meters) may be associated with changes in cross-shelf current patterns (Grantham et al., 2004).

Dissolved oxygen levels in coastal-ocean surface waters along the west coast, averaging 9.4 mg/L, were generally higher than those in near-bottom waters. The vast majority of surface waters (about 98% of the area) was rated good using the NCA rating cutpoints for dissolved oxygen (Nelson et al., 2008).

Sediment Quality

Sediment Contaminants

Sediments throughout the region were relatively uncontaminated except for a group of stations in the Southern California Bight (Figure 6-14). Based on the cutpoints used by NCA, about 99% of the offshore survey area would be rated good, less than 1% would be rated fair, and less than 1% would be rated poor for the sediment contaminants component indicator.

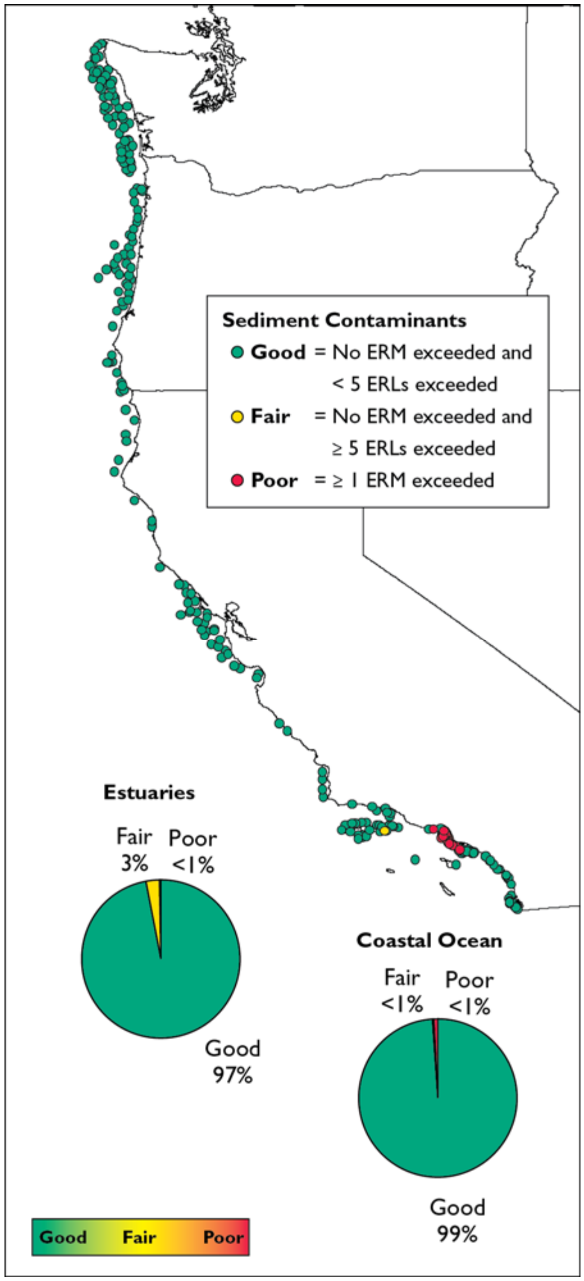


Figure 6-14. Sediment contaminants data in coastal ocean sediments of the West Coast region (Nelson et al., 2008; U.S. EPA/NCA).

Pie charts compare offshore and estuarine conditions.

All stations rated poor for the sediment contaminants component indicator were located in the coastal ocean waters near Los Angeles. The poor designation is based primarily on 4,4'-DDE and total DDT concentrations exceeding their corresponding ERM vales. No other locations outside of the Los Angeles area had ERM exceedances. Ten other contaminants, including seven metals (i.e., arsenic, cadmium, chromium, copper, mercury, silver, zinc), 2-methylnaphthalene, low-molecular-weight PAHs, and total PCBs exceeded corresponding ERLs. The most prevalent chemicals exceeding ERLs in terms of coastal area were chromium (31%), arsenic (8%), 2-methylnaphthalene (6%), cadmium (5%), and mercury (4%). The chromium contamination may be related to natural background sources common to the region. The 2-

methylnaphthalene exceedances were conspicuously grouped around the Channel Islands NMS. The mercury exceedances were all at non-sanctuary sites in California, particularly in the Los Angeles area.

In comparison, estuarine habitats in the West Coast region show a relatively higher incidence of sediment contamination (see Figure 6-14), with many contaminants above ERM values (including mercury, copper, zinc, DDT, and 4,4′-DDE). Based on the 2004–2006 NCA data, 97% of survey area is rated good, 3% is rated fair, and >1% is rated poor.

Sediment TOC

High levels of TOC in sediments can serve as an indicator of adverse conditions and is often associated with increasing proportions of finer-grained sediment particles (i.e., silt-clay fraction) that tend to provide greater surface area for sorption of both organic matter and the chemical pollutants that bind to organic matter. Given the association between TOC levels and finer-grain sediment particles, it is useful to note that about 44% of the offshore survey area had sediments composed of sands (< 20% silt-clay), 47% consisted of intermediate muddy sands (20–80% silt-clay), and 9% consisted of mud (> 80% silt-clay). Washington and Oregon sites were dominated by sands, while the majority of California sites had intermediate muddy sands; all sites classified as muds were in California (Nelson et al., 2008).

TOC levels (% total sediment weight) throughout the region exhibited a wide range (0.0% to 7.6%, with an overall mean of 0.7%), consistent with the broad range of sediment types. Based on the NCA rating cutpoints, the majority of the survey area (97%) would be rated good; about 3% would be rated fair; and less than 1% of the area, represented by two sites in California, would be rated poor (Figure 6-15). The cause of the elevated TOC at these latter two sites, both in the Channel Islands NMS, is unknown at this time.

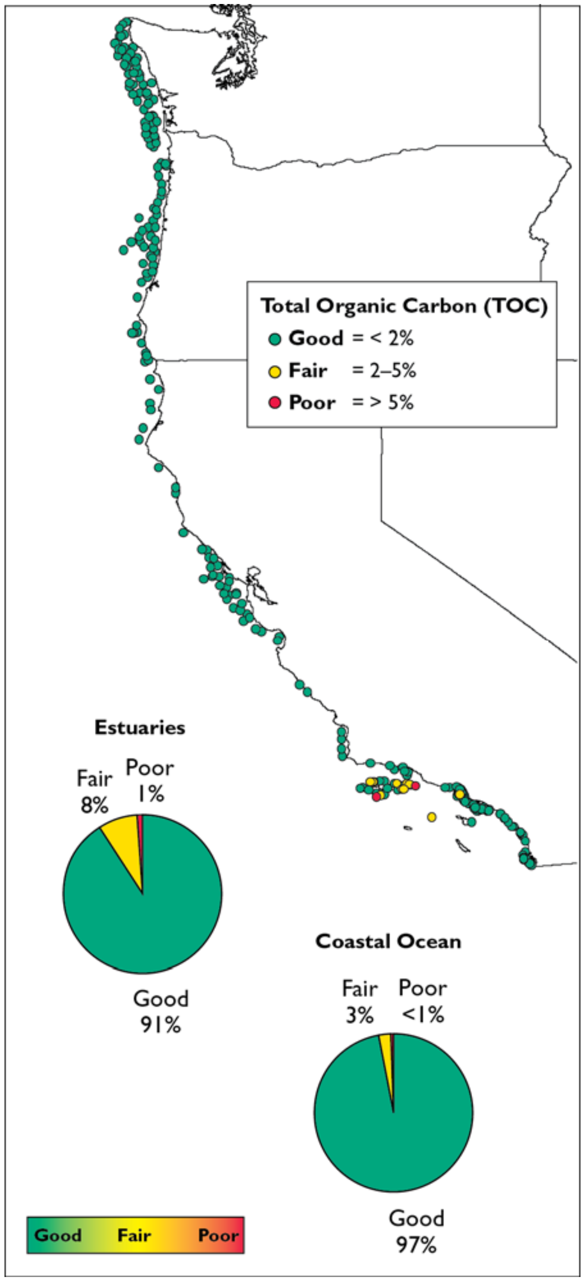


Figure 6-15. Sediment TOC data in coastal-ocean sediments in the West Coast region (Nelson et al., 2008; U.S. EPA/NCA).
Pie charts compare offshore coastal ocean and estuarine conditions.

Estuaries of the region, which are often in closer proximity to both natural and anthropogenic sources of organic materials, had slightly higher levels of TOC. While 91% of estuarine area was rated good, 8% was rated fair, and 1% was rated poor.

Benthic Condition

Coastal ocean waters along the West Coast support a diverse assemblage of macrobenthic infauna (those retained on a 1-millimeter sieve). A total of 99,135 individual specimens representing 1,482 taxa (1,108 distinct species) were identified in 259 0.1-m^2 grab samples collected throughout the 2003 coastal-ocean survey area. Polychaetes were the dominant taxa, both by percent abundance (59%) and percent taxa (44%). Crustaceans and molluscs were the second and third most-dominant taxa, respectively, both by percent abundance (17% crustaceans, 12% molluscs) and percent taxa (25% crustaceans, 17% molluscs). Collectively, these three groups represented 88% of total faunal abundance and 86% of the species throughout these offshore waters.

Density, mean diversity and mean number of taxa were all higher offshore than in NCA estuarine habitats (Figure 6-16). Approximately 50% of the coastal-ocean survey area had less than or equal to 67 taxa per grab sample, while only about 29% of the estuarine sediments had 67 or more taxa per grab. The diversity and number of taxa in the offshore sediments tended to be higher at California sites than at Washington and Oregon sites and were similar between NMS and non-sanctuary sites (Nelson et al., 2008).

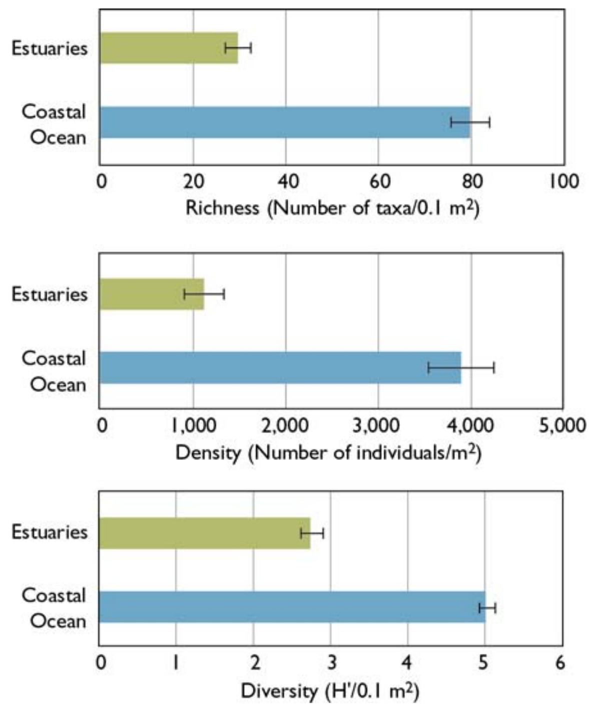


Figure 6-16. Comparison of benthic species richness (# of taxa/0.1 m^2), density (#/m^2), and diversity (H′/0.1 m^2, base 2 logs) in coastal ocean vs. estuarine sediments along the U.S. West Coast (Nelson et al., 2008; U.S. EPA/NCA).

The 10 most abundant taxa were the polychaete worms *Mediomastus* spp., *Magelona longicornis*, *Spiophanes berkeleyorum*, *Spiophanes bombyx*, *Spiophanes duplex*, and *Prionospio jubata*; the bivalve *Axinopsida serricata*; the brittle star *Amphiodia urtica*; the decapod crustacean *Pinnixa occidentalis*; and the ostracod crustacean *Euphilomedes carcharodonta*. *Mediomastus* spp. and *A. serricata* were the two most abundant taxa overall. Although many of these dominant taxa have broad geographic distributions throughout the region, the same species were not ranked among the 10 most abundant taxa consistently across states. The closest similarities among states were between Oregon and Washington. At least half of the 10 most abundant taxa in NMSs were also dominant in corresponding non-sanctuary waters.

Multi-metric benthic indices are often used as indicators of pollution-induced degradation of the benthos (see review by Diaz et al., 2004). An important feature is the ability to combine multiple biological attributes into a single measure that maximizes the ability to distinguish between degraded vs. non-degraded benthic condition, while accounting for the influence of natural controlling factors. Although a related index has been developed for the southern California mainland shelf (Smith et al., 2001), there is currently no such index available for offshore applications across the West Coast.

In the absence of a benthic index, Nelson et al. (2008) assessed potential stressor impacts in the West Coast offshore study by looking for obvious linkages between reduced values of key biological attributes (numbers of taxa, diversity, and abundance) and synoptically measured indicators of poor sediment or water quality. Low values of species richness, H′, and density were defined for the purpose of this analysis as the lower 10th percentile of values within each individual state. Evidence of poor sediment or water quality was defined as less than or equal to 1 chemical in excess of ERMs, TOC greater than 5%, or dissolved oxygen in near-bottom water less than 2 mg/L.

Many of the abundant benthic species have wide latitudinal distributions in the coastal-ocean waters of the West Coast region, with some species ranging from southern California into the Gulf of Alaska and Aleutians. Of the 39 taxa on the list of 50 most abundant taxa that could be identified to species level, 85% have been reported at least once from estuaries of California, Oregon, or Washington, exclusive of Puget Sound. Such broad latitudinal and estuarine distributions are suggestive of wide habitat tolerances.

Non-Indigenous Species

Benthic species lists were examined for presence of non-indigenous species in the offshore shelf environment by comparison to the PCEIS classification scheme, a geo-referenced database of native and non-indigenous species of the Northeast Pacific (Lee et al., 2008). Of the 1,108 taxa identified to species level, 13 were classified as non-indigenous, 121 as cryptogenic (of uncertain origin), and 208 as undetermined with respect to potential invasiveness. Spionid polychaetes and the ampharetid polychaete *Anobothrus gracilis,* were a major component of the non-indigenous species collected on the shelf. A more detailed analysis of the occurrence of non-indigenous species in this region is available in Nelson et al. (2008).

Despite uncertainties of classification, the number and densities of non-indigenous species appear to be much lower in the coastal ocean than in estuaries of the West Coast region. For example, 42 non-indigenous species were noted in a survey of tidal wetlands of the West Coast (Nelson et al., 2007a) and over 200 non-indigenous species have been reported from San Francisco Bay (Cohen and Carlton, 1995).

Fish Tissue Contaminants

Analysis of chemical contaminants in fish tissues was performed on whole-fish composites from 55 samples of four fish species collected from 50 West Coast coastal-ocean stations. Fish were collected from 21 stations in Washington, 20 in Oregon, and 9 in California. The fish species selected for analysis were Pacific sanddab (*Citharichthys sordidus*), speckled sanddab (*Citharichthys stigmaeus*), butter sole (*Isopsetta isolepis*), and Dover sole (*Microstomus pacificus*). Concentrations of a suite of metals, pesticides, and PCBs were compared to risk-based EPA advisory guidelines for recreational fishers (U.S. EPA, 2000c).

None of the 50 stations where fish were caught would have been rated poor based on NCA cutpoints. Nine stations had cadmium concentrations between the corresponding lower and upper endpoints, and one station had total PCB concentrations between these endpoints. Therefore, these10 stations would be rated fair based on the NCA cutpoints (see Table 1-21). The remaining 40 stations had concentrations of contaminants below corresponding lower endpoints and would be rated good based on the NCA cutpoints. Based on the NCA Fish Tissue Contaminants Index (see Table 1-22) the overall offshore region would receive the same rating, good, as the West Coast coastal waters.

West Coast Sanctuaries

NOAA's five NMS areas in the West Coast region appeared to be in good ecological condition, based on the measured indices and component indicators, with no evidence of major anthropogenic impacts or unusual environmental qualities compared to nearby non-sanctuary waters (Nelson et al., 2008). Benthic communities in sanctuaries resembled those in corresponding non-sanctuary waters, with similarly high levels of species richness and diversity and low incidence of non-indigenous species. Most oceanographic features were also similar between sanctuary and non-sanctuary locations. Exceptions (e.g., higher concentrations of some nutrients in sanctuaries along the California coast) appeared to be attributable to natural upwelling events in the area at the time of sampling.

In addition, sediments within the sanctuaries were relatively uncontaminated, with none of the samples having any measured chemical in excess of ERM values. The ERL value for chromium was exceeded in sediments at the Olympic Coast NMS, but at a much lower percentage of stations (4 of 30) compared to Washington and Oregon non-sanctuary areas (31 of 70 stations). ERL values were exceeded for arsenic, cadmium, chromium, 2-methylnaphthalene, low-molecular-weight PAHs, total DDT, and 4,4′-DDE at multiple sites within the Channel Islands NMS. However, cases where total DDT, 4,4′-DDE, and chromium exceeded the ERL values were notably less prevalent than in non-sanctuary waters of California. In contrast, 2-methylnaphthalene above the ERL was much more prevalent in sediments at the Channel Islands NMS compared to non-sanctuary waters off the coast of California. While there are natural background sources of PAHs from oil seeps throughout the Southern California Bight, we cannot, at present, either confirm or exclude this as a possible cause of the higher incidence of 2-methylnaphthalene contamination around the Channel Islands NMS.

Ocean Condition Summary—West Coast

The 2003 West Coast offshore assessment showed no major evidence of poor water quality, and there were indications of poor sediment quality only in limited areas. Based on NCA cutpoints, the majority (97%) of sediments had TOC levels in the good range, 3% was rated fair, and less than 1% was rated poor. Relative to chemical contamination of sediments, 99% of the survey area was rated as good, less than 1% was rated fair, and less than 1% was rated poor. None of the offshore sampling area was rated poor for the dissolved oxygen component indicator.

An analysis of potential biological impacts (see text box) revealed no major evidence of impaired benthic condition linked to measured stressors. There was only one station, in California, where low values of any of the targeted benthic attributes co-occurred with poor sediment or water quality. This one station (off Los Angeles) had low benthic species richness and abundance accompanied by high sediment contamination, with eight chemicals in excess of corresponding ERL values and two in excess of ERM values. There were two stations located in California waters (Channel Islands NMS) that had TOC levels in a range (> 5%) potentially harmful to benthic fauna, but low values of benthic community attributes were not observed at either of these sites. High sediment contamination from chemicals was a more prevalent stressor, occurring at 23 stations (all in California), but not at any of the sites where low values of benthic attributes were observed. In fact, most of these latter stations with high sediment contamination had more than 100 species per grab.

Such lack of concordance suggests that these offshore waters are currently in good condition, with the lower-end values of the various biological attributes representing parts of a normal reference range controlled by natural factors (e.g., latitude, depth, sediment type). Alternatively, it is possible that for some of these sites the lower values of benthic variables reflect symptoms of disturbance induced by other unmeasured stressors, including human activities causing physical disruptions of the seafloor (e.g., commercial bottom trawling, cable placement, minerals extraction). Future monitoring efforts in these offshore areas should include indicators of such alternative sources of disturbance.

Large Marine Ecosystem Fisheries—California Current LME

The California Current LME extends along the Pacific Coast of North America from the northwestern corner of Washington to the southern end of the Baja California Peninsula in Mexico (Figure 6-17). The California Current LME is temperate and represents a transition zone between subtropical and subarctic water masses. Major driving forces in this LME are the effects of shifting oceanic climate regimes and intensive commercial fishing. The LME is considered to have moderately high productivity based on primary productivity (phytoplankton) estimates. The major commercial fisheries are salmon (e.g., Chinook, coho, sockeye, pink, chum), pelagic (water-column dwelling) species (e.g., Pacific hake, Pacific sardine, northern anchovy, jack mackerel, chub, Pacific mackerel, Pacific herring), groundfish (bottom-dwelling) species (e.g., Pacific halibut, Dover sole, shortspine thornyhead, longspine thornyhead, sablefish), tuna, and invertebrates (e.g., Pacific oyster, Dungeness crab, California market squid).Coastal upwelling, El Niño, and the El Niño-Southern Oscillation result in strong inter-annual variability in California Current LME productivity. There is evidence of a decline in zooplankton abundance in the 1980s, a possible indication of a major oceanic regime shift. There is speculation about the causes of these fluctuations and the role of climate on seasonal change in the regulation of community structure, energy flow, and population dynamics (NOAA, 2010b).

Figure 6-17. California Current LME (NOAA, 2010b).

From 2003 to 2006, commercial fisheries in the California Current LME generated over $1.6 billion for Washington, Oregon, and California. These fisheries are dominated by invertebrates, particularly crab, oysters, and squid. Other important fisheries in this LME include salmon, which are harvested for recreational and subsistence purposes, pelagics (mostly hake and sardines), salmon, tuna, and groundfish (particularly sablefish and sole). See Figure 6-18 for revenues and landings of the top commercial fisheries in the California Current LME. Resources in this LME are shared by the United States, Canada, Mexico, and numerous tribes, and are harvested by a mixture of commercial, recreational, and subsistence fishermen. Consequently fisheries management is a mix of regulations from several international organizations, federal agencies, state governments, and tribes.

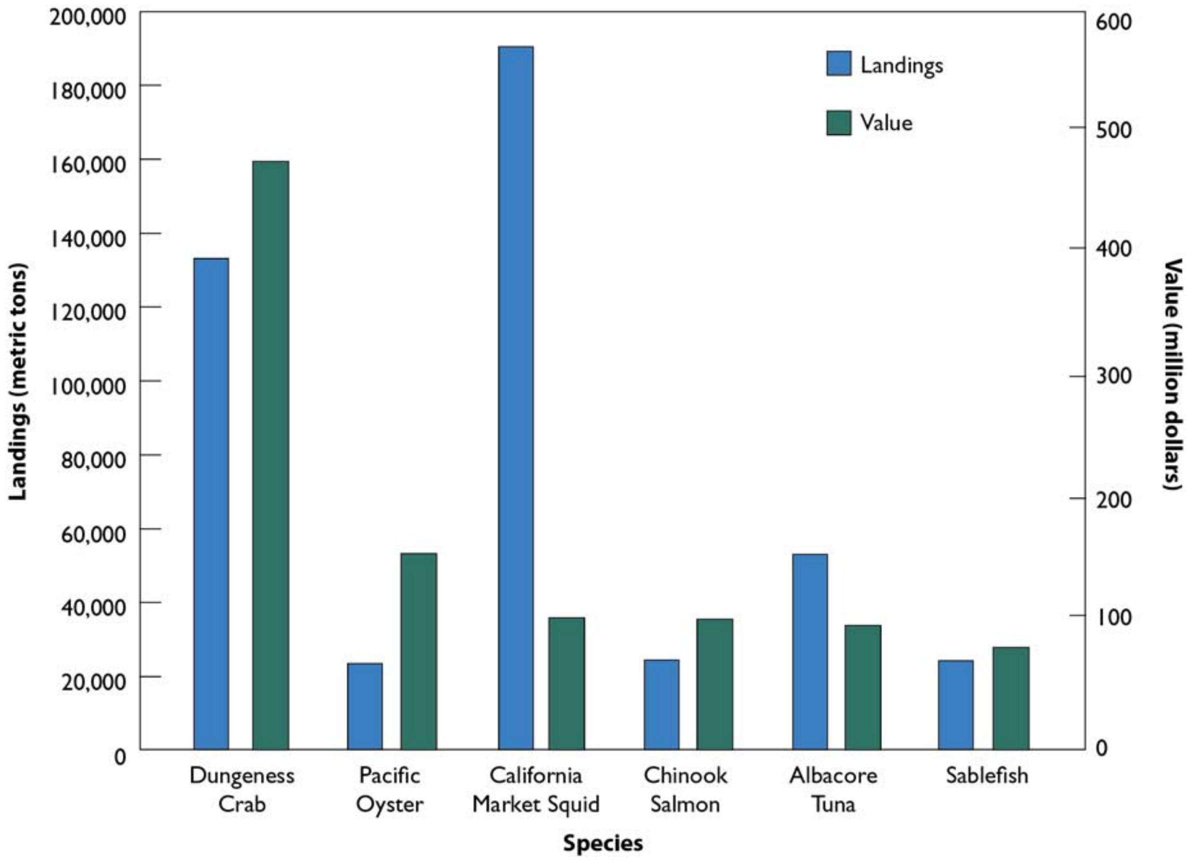


Figure 6-18. Top commercial fisheries for the California Current LME: landings (metric tons) and value (million dollars) from 2003–2006 (NMFS, 2010).

Invertebrate Fisheries

In the California Current LME, the greatest revenue is generated by the invertebrate fisheries, dominated by the Dungeness crab (*Metacarcinus magister)*. Indeed, this fishery yielded over $480 million in total ex-vessel (preprocessing) revenues from 2003 to 2006, over three times the value of the next highest commercial fishery, the Pacific oyster (Figure 6-18). The Dungeness crab, named after Dungeness, WA, has a range that spans from the Aleutian Islands of Alaska to Point Conception, CA. Although landings of this crab species (130,000 metric tons) are only about a third of those for pelagic fisheries, the higher market value for crab generates greater total revenues. Other crab species harvested in this LME are Red Rock crab and Southern Tanner crab, which have much lower revenues. Crabs are harvested with the use of traps or pots and, because they are largely caught in state waters, are regulated by the relevant state agencies. State agencies consult on issues affecting this crab fishery under the Pacific States Marine Fisheries Commission.

In terms of revenue, the Pacific oyster (*Crassostrea gigas)* comprises the second largest fishery, with commercial landings between 2003 and 2006 totaling only 23,000 metric tons, but worth over $156 million in total ex-vessel revenues (see Figure 6-18) (NMFS, 2010). The Pacific oyster is an introduced species from Japan, cultivated primarily in aquaculture farms throughout estuaries. Farmed mostly in state waters, these oysters are regulated by state agencies.

California market squid (*Loligo opalescens*), the third largest commercial fishery in this LME, is mostly harvested in northern and southern California. Between 2003 and 2006, this fishery generated approximately $103 million in total ex-vessel revenues for the California Current LME (see Figure 6-18) (NMFS, 2010). The California market squid fishery fluctuates in response to environmental conditions, coupled with rapid changes in the export market. California landings plummet during the cyclical El Niño oceanographic regimes, but increase considerably when these relatively warm water oceanic events are displaced by cool-water processes (i.e., La Niña). Volume increased during the 1990s because of new Asian and European markets and higher prices paid for squid from California Current LME waters. Despite the increased demand, the market value of squid remains low. Of the top commercial species in this LME, squid had the largest landings (60,000 metric tons greater than the next highest), but the third-largest revenues. Squid are fished at night with powerful lights that attract them to the surface, where they are either directly vacuumed into a boat's hold or are caught with an encircling net. This fishery is regulated under the Pacific Fishery Management Council's Coastal Pelagic Species FMP (PFMC, 2011a), which also includes northern anchovy, market squid, Pacific sardine, Pacific mackerel, and jack mackerel. This FMP regulates coastal pelagic fisheries largely by limiting entry and restricting allowable harvests.

Pacific Salmon Fisheries

Pacific salmon include five species: Chinook, coho, sockeye, pink, and chum salmon. Commercially, the most valuable species is Chinook salmon (*Oncorhynchus tshawytscha)*, with combined catches from 2003 to 2006 worth over $103 million in total ex-vessel revenues (see Figure 6-18) (NMFS, 2010). All species are harvested for commercial, recreational, and subsistence uses. All are anadromous (migratory); they are born in freshwater and swim to the ocean, where they may undergo extensive migrations. At maturity, they return to their home stream to spawn and complete their life cycles. The abundance of individual stocks of Pacific salmon and the mixture of stocks contributing to fisheries fluctuates considerably. Consequently, annual landings also fluctuate. During 2004–2006, the annual commercial salmon catch in the California Current LME averaged 16,300 metric tons and provided revenues averaging approximately $40 million at dockside. During the same period, recreational catches averaged about 4,700 metric tons (NMFS, 2010). Since 2003, stocks originating south of the Columbia River have declined sharply, culminating in the 2008 closure of all commercial salmon fisheries in California and most of the Oregon coast.

Chinook salmon has an average yield of 8,919 metric tons and is harvested recreationally and commercially throughout the LME. Chinook salmon production tends to fluctuate considerably, depending on hatchery production, freshwater habitat conditions, and ocean productivity. Since a warming of the waters in the California Current LME in the late 1970s, abundance of Chinook salmon has declined. Nevertheless, Chinook salmon are still the fourth-largest fishery for the California Current LME, with landings generating over $103 million in total ex-vessel revenues from 2003 to 2006. Recreational landings of Chinook salmon have averaged about 480,000 fish annually for the period 2004–2006 (NMFS, 2010). In recent years, freshwater habitat loss and degradation have been exacerbated by drought in many areas in the western United States, resulting in historically low abundance for a number of stocks and reduced commercial and recreational catches in many areas.

Pacific salmon depend on freshwater habitat for spawning and juvenile rearing and are particularly vulnerable to habitat degradation. Dam construction, logging, agriculture, grazing, urbanization, and pollution have degraded freshwater habitat throughout their range. Water extraction and flow manipulation for hydropower, irrigation, flood control, and municipal needs directly competes with salmon for the fresh water on which they depend. In recent years, freshwater habitat loss and degradation have been exacerbated by drought in many areas in the west, resulting in historically low abundance for a number of stocks and reduced commercial and recreational catches in many areas.

Declines in Chinook salmon abundance have forced reductions and closures of ocean fisheries in recent years. These reductions, in some cases, follow earlier, legally mandated salmon allocations to interior-water fisheries for harvest by Native American tribes. The proportion of Chinook salmon production originating from hatcheries (fish breeding and raising centers) has been increasing, though hatcheries still play a larger role in coho salmon production. The number of salmon farms is also on the rise. The key difference is that farmed salmon are raised entirely in pens until they are adults, whereas hatcheries release raised young. The increasing role of aquaculture in salmon fisheries is raising concerns about the interactions of these fish with wild stocks. Another problem faced by commercial salmon fisheries in the California Current LME is price declines driven by market competition from record landings of Alaskan salmon and steadily increasing aquaculture production. Since 2003, prices have somewhat rebounded as greater niche markets for local ocean-caught fish have developed.

The management of the salmon resource is complex, involving many stocks originating from various rivers and the interactions of various jurisdictions, including international commissions and federal, state, and tribal agencies. The Pacific Salmon Commission oversees the allocation of salmon between the United States and Canada, based on aggregate stock abundance. The Pacific Fishery Management Council (PFMC), in cooperation with the States and tribal fishery agencies, manages ocean fisheries for Chinook and coho salmon under a framework FMP (PFMC, 2011c). Fisheries within state waters are managed by state agencies or tribal governments.

Groundfish Fisheries

The PFMC's Groundfish FMP (PFMC, 2011b) contains 89 species that are organized into several sub-fisheries, including the Dover sole, thornyheads, and sablefish complex; nearshore, shelf, and slope rockfishes; and Pacific hake (whiting). Most vessels targeting groundfish deliver to shore-side processors. From 2004–2006, the recent average yield of California Current LME groundfish in the United States was 288,604 metric tons. In 2006, U.S. commercial landings of California Current LME groundfish totaled 288,990 metric tons, generating $81 million in ex-vessel revenues. Pacific hake accounted for 91% of the 2006 landed catch and 44% of the associated ex-vessel value. Other important species in 2006 were Petrale sole ($6 million), Dover sole ($5 million), and thornyhead rockfish ($3 million; PSMFC, 2008). The trawl fleet is the largest sector of the commercial fishery, generating 75% of the ex-vessel revenues (PSMFC, 2008).

Although Pacific hake (*Merluccius productus)* accounts for a majority of the landing tonnage, sablefish (also known as black cod) (*Anoplopoma fimbria)* is the highest grossing groundfish fishery in the California Current LME, generating over $79 million in total ex-vessel revenues from 2003 to 2006 with landings of nearly 30,000 metric tons (see Figure 6-18). This species is considered highly valuable, making up only 2% of groundfish catch, but generating 28% of total groundfish revenues in 2006 (Hastie and Bellman, 2007). Sablefish is a long-lived groundfish species that resides on muddy bottoms between 1,000 and 9,000 feet in the North Pacific. Adult sablefish are opportunistic feeders, consuming various invertebrates and other fish. Sablefish larvae are prey for many invertebrate and vertebrates, while adults are generally targets for seabirds, sharks, killer whales, and other fish. Because the sablefish is highly mobile, with migration up to 2,000 miles, it is also managed under the Gulf of Alaska and the Bering Sea/Aleutian Islands FMPs (NPFMC, 2011; 2010a).

The PFMC, which manages the groundfish fishery stocks in the California Current LME, has recently brought sweeping managerial changes. The Council implemented a catch-share program for the groundfish fisheries in January of 2011. The use of these types of fisheries management schemes is increasing in popularity throughout the Regional Councils. In essence, the annual allowable harvest or quota is divided by sectors, with allocations based on catch history. For the Pacific Coast groundfish fishery, there are currently three participating sectors—Shoreside Trawl, Mothership Trawl, and Catcher-Processor. For more information on this new regulatory regime within the Pacific Fishery Management Council, see http://www.pcouncil.org/groundfish/fishery-management-plan/fmp-amendment-20/.

Highly Migratory Fisheries

The other major class of revenue-generating fisheries in the California Current LME is comprised of highly migratory species, the most commercially important of which is Albacore tuna (*Thunnus alalunga)*. From 2003 to 2006, the Albacore tuna fishery generated nearly $96 million in total ex-vessel revenues, with landings over 50,000 metric tons, ranking it the fifth-largest commercial fishery for this region (NMFS, 2010). This tuna resides throughout the world's temperate waters, migrating thousands of miles annually. In the Pacific Northwest, its diet largely consists of pelagic species and squid.

Due to its migratory nature, this tuna is regulated by the Inter-American Tropical Tuna Commission, developing policies implemented by NMFS and respective state agencies. The regulations are largely based on a permit system (for both commercial and recreational fisheries), logbooks, and seasonal restrictions on certain gear types. Because this species is heavily targeted by sports fishermen, managers have recently implemented bag limits on sport-caught albacore. Other tuna fisheries in this LME include yellowfin, bigeye, skipjack, and Pacific bluefin.

Fishery Trends and Summary

Figure 6-19 shows landings of the top commercial fisheries in the California Current LME since 1950. Until 1980, landings in the squid fisheries were reported as a group, rather than on a single species–specific basis. Catches of California market squid have dropped precipitously (by 70,000 metric tons) since peaking in 2000 at 120,000 metric tons. Dramatic fluctuations in this fishery are a regular occurrence, as the Californian market squid is highly vulnerable to alterations in the El Nino cycle. Landings of the other top species have remained below 40,000 metric tons since 1950, with considerable fluctuations in the Albacore tuna and Dungeness crab fisheries, though both have been trending upwards since 1990. Recent landings of Pacific oyster, Chinook salmon, and sablefish have been under 10,000 metric tons. The Chinook salmon and sablefish fisheries have both had decreasing landings since the 1980s, while harvests of the Pacific oyster have remained consistent.

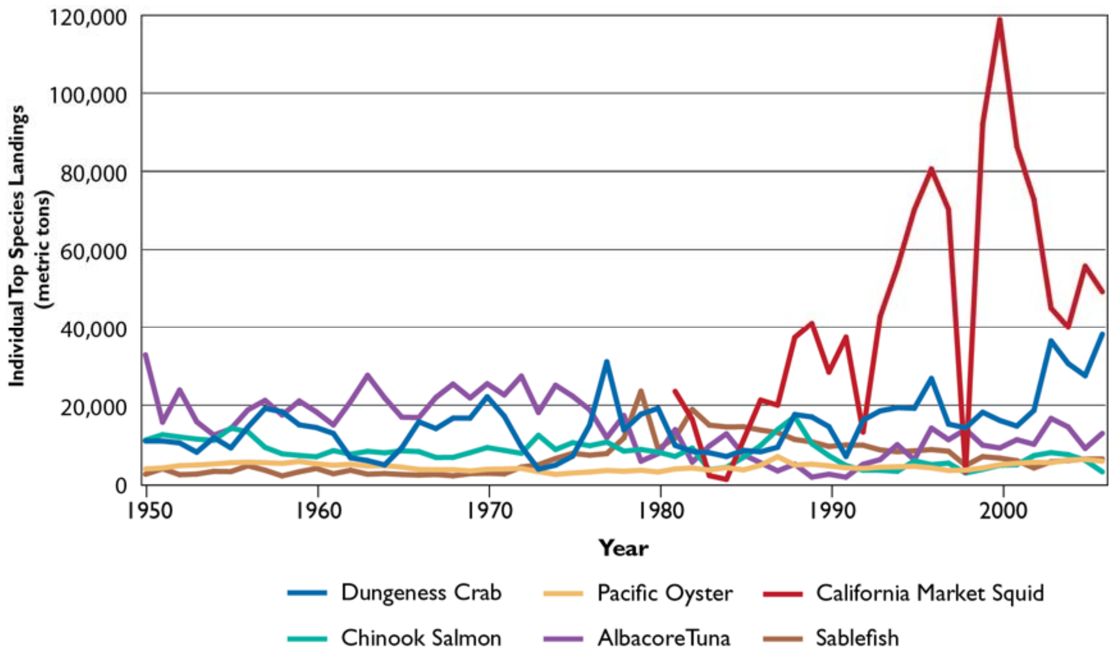


Figure 6-19. Landings of top commercial fisheries in the California Current LME from 1950 to 2006, metric tons (NMFS, 2010).

Currently, Dungeness crab, Pacific oyster, California market squid, Chinook salmon, Albacore tuna, and sablefish comprise the top commercial fisheries for the California Current LME because they generate the highest ex-vessel revenues. This LME generated over $1.6 billion from 2003–2006, $480 million of which was from Dungeness crab alone. Currently, the most important recreational fisheries are for various species of salmon, flatfish, and tuna, which support tourism, bait and tackle shops, and recreational boating and other activities, all of which contribute significantly to the value derived from the ecosystem service of fishery production. In terms of landed tonnage, this LME is dominated by hake and squid; however, the hake fishery is not one of the top six commercial fisheries due to lower market prices. Aside from their commercial and recreational values, all fish species have important roles in their ecosystems. Smaller species serve as prey for larger predators, which themselves may be food for seabirds or marine mammals. When fishermen over-harvest specific species, this can undermine a critical balance in ecosystem function, and through a cascade of events, can inadvertently eliminate both predator and prey species. Interestingly, in this LME, there seems to be a pronounced effect on fishery production from El Niño, causing seasonal changes in fishery community structure and population dynamics.

Advisory Data

Fish Consumption Advisories

In 2006, 42 fish consumption advisories were in effect for the estuarine and coastal waters of the West Coast region (Figure 6-20). A total of 39% of the estuarine square miles on the West Coast were under advisory in 2006, and most of the estuarine area under advisory was located within the San Francisco Bay/Delta region or within Puget Sound. Only 13% of the region's coastal miles were under advisory; more than one-half of these miles were located in southern California, and the rest were located on the coastal shoreline of Washington's Puget Sound. None of the West Coast states (California, Oregon, or Washington) had statewide coastal advisories in effect during 2006 (U.S. EPA, 2007c).

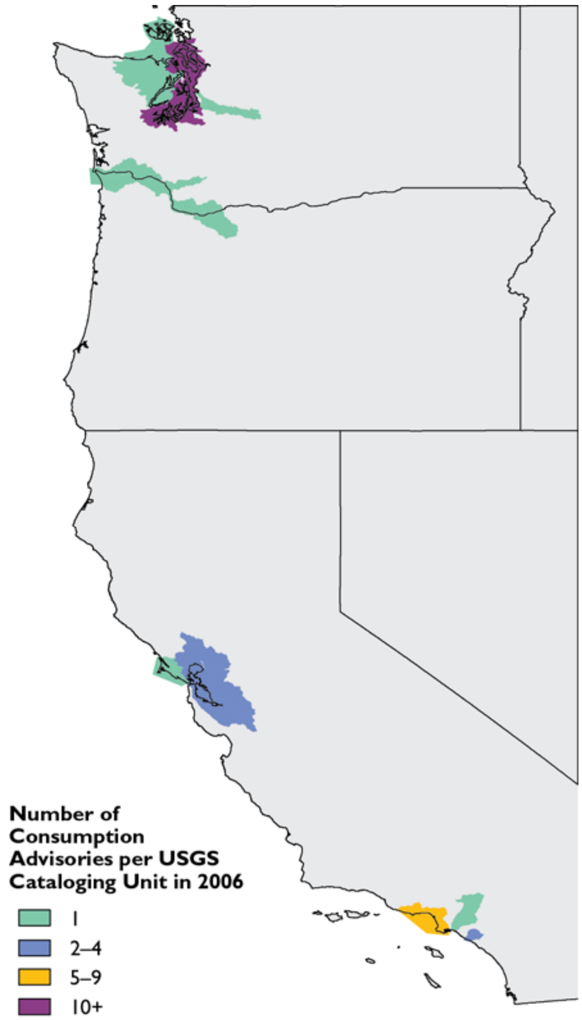


Figure 6-20. The number of fish consumption advisories active in 2006 for the West Coast coastal waters (U.S. EPA, 2007c).

Seventeen different contaminants or groups of contaminants were responsible for West Coast fish advisories in 2006, and 10 of those contaminants were listed only in the waters of Puget Sound and the bays emptying into the Sound. These contaminants were arsenic, creosote, diethylphthalates, industrial and municipal discharge, metals, multiple contaminants, PAHs, pentachlorophenol, tetrachloroethene, and volatile organic compounds. In California, Oregon, and Washington, PCBs used to be the major pollutant, accounting for 71% of advisories in 2003, but they are now responsible for only 38% of advisories (Figure 6-21). DDT was partly responsible for 12 advisories issued in California. Although only three advisories were issued for mercury on the West Coast, the entire San Francisco Bay was covered by one of these advisories. Among the other pollutants, the chemicals with most advisories were inexplicit pollutants, such as not-specified pollutants, which were issued under the advisories in Puget Sound (U.S. EPA, 2007c). Table 6-1 lists the species and/or groups under fish consumption advisory in 2006 for at least some part of the coastal waters of the West Coast region is provided below.

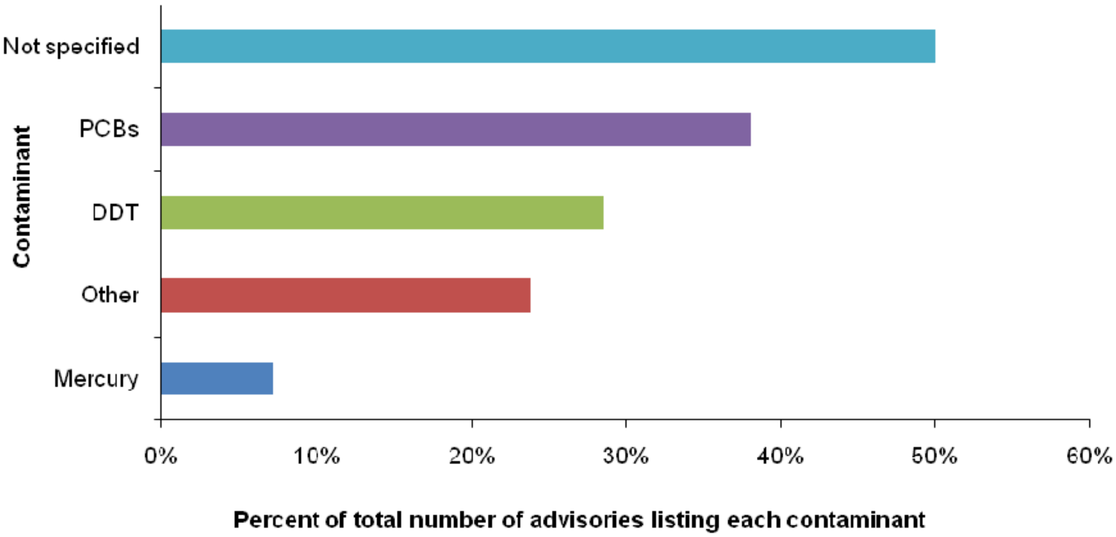


Figure 6-21. Pollutants responsible for fish consumption advisories in West Coast coastal waters.

An advisory can be issued for more than one contaminant, so percentages may add up to more than 100 (U.S. EPA, 2007c).

Table 6-1. Species and/or Groups under Fish Consumption Advisory in 2006 for at Least Some Part of the Coastal Waters of the West Coast Region

Species and/or Groups under Fish Consumption Advisory		
Bat ray	Bivalves	Black croaker
Brown smooth hound shark	Bullhead	California halibut
Chinook salmon	Clams	Corbina
Crabs (whole, shell, and hepatopancreas)	English sole	Gobies
Jacksmelt	Kelp bass	Leopard shark
Pacific angel shark	Pile surfperch	Queenfish
Red rock crabs	Redtail surfperch	Rockfish
Salmon	Sculpin	Shark
Shellfish	Shiner perch	Starry flounder
Striped bass	Sturgeon	Surfperch
White croaker	Yelloweye rockfish	

Source: U.S. EPA, 2007c

Beach Advisories and Closures

How many notification actions were reported for the West Coast between 2004 and 2008?

Table 6-2 presents the number of total and monitored beaches, as well as the number and percentage of beaches affected by notification actions from 2004 to 2008 for the West Coast region. Over the past several years, the total number of beaches identified by the West Coast states increased substantially, from 501 in 2004 to 1,829 in 2008, largely resulting from changes in State delineations of beaches rather than increasing acreage. During this same period, the number of monitored beaches increased from 501 to 516. Of these monitored beaches, the percentage of beaches that were closed or under advisory for some period of time during the year has consistently hovered between 31% and 33% (or 160 beaches) (U.S. EPA, 2009d). Annual national and state summaries are available on EPA's Beaches Monitoring site: http://www.epa.gov/waterscience/beaches/seasons/.

Table 6-2. Beach Notification Actions, West Coast, 2004–2008 (U.S. EPA, 2009d)

Numbers and Percentages	2004	2005	2006	2007	2008
Total number of beaches	501	1227	1227	1226	1829
Number of monitored beaches	501	519	525	509	516
Number of beaches affected by notification actions	160	170	167	160	160
Percentage of monitored beaches affected by notification actions	32%	33%	32%	31%	31%

What pollution sources impacted monitored beaches?

Table 6-3 presents the numbers and percentages of monitored West Coast beaches affected by various pollution sources for 2007. Nearly all beach advisories on the West Coast were attributed to unidentified and/or other sources (85%) and non-investigated sources (about 15%). With septic system leakage and "no known pollution source," together contributing less than 1% of all beach advisories (U.S. EPA, 2009d).

Table 6-3. Reasons for Beach Advisories, West Coast, 2007 (U.S. EPA, 2009d)

Reason for Advisories	Total Number of Monitored Beaches Affected	Percent of Total Monitored Beaches Affected
Other and/or unidentified sources	425	84%
Pollution sources not investigated	75	15%
No know pollution sources	5	< 1%
Septic system leakage	4	< 1%

Note: A single beach advisory may have multiple pollution sources. Additional reasons for beach advisories exist, but were not documented for the West Coast states for 2007.

How long were the 2007 beach notification actions?

Over three-quarters of beach notification actions on the West Coast in 2007 lasted a week or less, with the highest frequency (40%) ranging from 3 to 7 days. While actions lasting 8 to 30 days accounted for nearly 20% of all the notifications, those of the greatest duration (above 30 days) only comprised 5% of all beach actions (U.S. EPA, 2009d). For more information on state beach closures, please visit the EPA's Beaches Web site: http://www.epa.gov/beaches/plan/whereyoulive_state.html.

Summary

Based on data from the NCA assessment of 2004–2006, the overall condition of West Coast coastal waters is rated good to fair. Indicators for overall water quality, tissue contaminants, and benthic condition were all rated good for the West Coast region; however, coastal habitat and sediment quality were rated poor and fair, respectively, and driven primarily by the harbor areas of southern California. Although assessments from 2001–2003 are not directly comparable to the 2004–2006 sampling efforts, the current contamination indicators showed fewer poor stations from Puget Sound and San Francisco Bay compared to the results from the 1999–2000 survey. Sites from the majority of smaller estuarine systems along the West Coast were estimated to be in generally good condition.

The 2003 West Coast region offshore assessment showed that these waters are in generally good condition, with no major evidence of poor water quality. Poor sediment quality was indicated only in limited areas. While some areas of impaired benthic condition were found, they did not appear to be linked to sediment quality indicators. High sediment contamination from chemicals was found at 23 stations (all in California), but not at any of the sites where low values of benthic attributes were observed. This indicates that the areas of biological impairment may just be within the normal range, or it is possible that there are some other types of disturbances that have not yet been measured, including human activities such as commercial bottom trawling, cable placement, and minerals extraction. Future monitoring efforts in these offshore areas should include indicators of other sources of disturbance.

In the California Current LME, the greatest revenue is generated by the invertebrate fisheries, dominated by the Dungeness crab, Pacific oyster, and California market squid. The California market squid fishery fluctuates in response to environmental conditions, coupled with rapid changes in the export market. Since 2003, stocks originating south of the Columbia River have declined sharply, culminating in the 2008 closure of all commercial salmon fisheries in California and most of the Oregon coast. In recent years, freshwater habitat loss and degradation have been exacerbated by drought in many areas in the west, resulting in historically low abundance for a number of salmon stocks. The Albacore tuna fishery is the fifth-largest commercial fishery for this region. Although Pacific hake accounts for a majority of the landing tonnage, sablefish is the highest grossing groundfish fishery in the California Current LME. Recent years have brought sweeping changes to the management of Pacific Coast groundfish fishery and the research necessary to support the fishery's management. Harvest rates for most assessed groundfish stocks have been reduced in recent years, and new permitting and observation programs have been implemented to help stocks recover. The states of California, Oregon, and Washington are developing and implementing protected areas within their waters to guard sensitive habitats of particular concern for groundfish fish production.

Contamination in West Coast coastal waters has affected human uses of these waters. In 2006, 39% of the estuarine square miles on the West Coast and 13% of the region's coastal miles were under fish consumption advisory. Advisories were issued for a number of contaminants, including PCBs and mercury. In addition, 32% of the region's monitored beaches were closed or under advisory for some period of time during 2006. Elevated bacteria levels in the region's coastal waters were primarily responsible for the beach closures and advisories.

Chapter 7

Great Lakes Coastal Condition

7. Great Lakes Coastal Condition

As shown in Figure 7-1, the overall condition of the U.S. coastal waters of the Great Lakes region between 2003 and 2006 is rated fair to poor, with an overall condition score of 2.2. The water quality and fish tissue contaminants indices for the Great Lakes are rated fair, the coastal habitat and benthic indices are rated fair to poor, and the sediment quality index is rated poor. The overall condition and index ratings were derived from indicator findings and the ecological condition of the St. Lawrence River, each of the five Great Lakes, and the St. Clair River-Lake St. Clair-Detroit River Ecosystem, presented in the document *State of the Great Lakes 2009* (Environment Canada and U.S. EPA, 2009b). This report is the sixth biennial report issued jointly by the governments of Canada and the United States. NCA survey strategies are being implemented in the Great Lakes region during the 2010 sampling season, and future assessments will be more similar to those for other regions. This assessment will allow for a more direct comparison of coastal conditions found in the Great Lakes to those of the marine coastal environment.

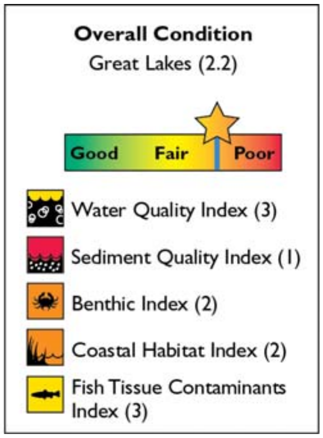


Figure 7-1. The overall condition of Great Lakes coastal waters is rated fair to poor (based on data from Environment Canada and U.S. EPA, 2009a, b).

The Great Lakes ecosystem covers 295,000 square miles, with nearly 11,000 miles of shoreline, and holds 5,500 cubic miles of water. This watershed includes a broad range of habitats, from the coniferous forests and rocky shorelines of Lake Superior to the fertile soils and sandy shores of Lake Michigan and Lake Erie. The coastal ecosystems of the Great Lakes include about 30,000 islands, wetlands, coastal marshes, sand dunes, savannas, prairies, and alvars.

The coastal counties of the U.S. Great Lakes region represent the third-largest coastal population in the nation. The population of Great Lakes coastal counties increased by 1% between 1980 and 2006, from 19.4 million to 19.7 million people (Figure 7-2). Over the same time period, the region's coastal population density increased slightly from 271 to 275 persons per square mile (NOEP, 2010). Figure 7-3 presents a map of the U.S. Great Lakes region population density in 2006.

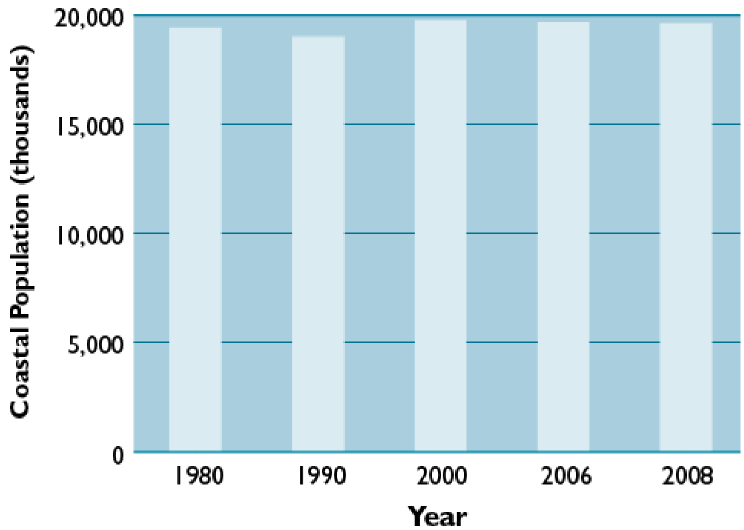


Figure 7-2. Population of U.S. coastal counties in the Great Lakes region from 1980 to 2008 (NOEP, 2010).

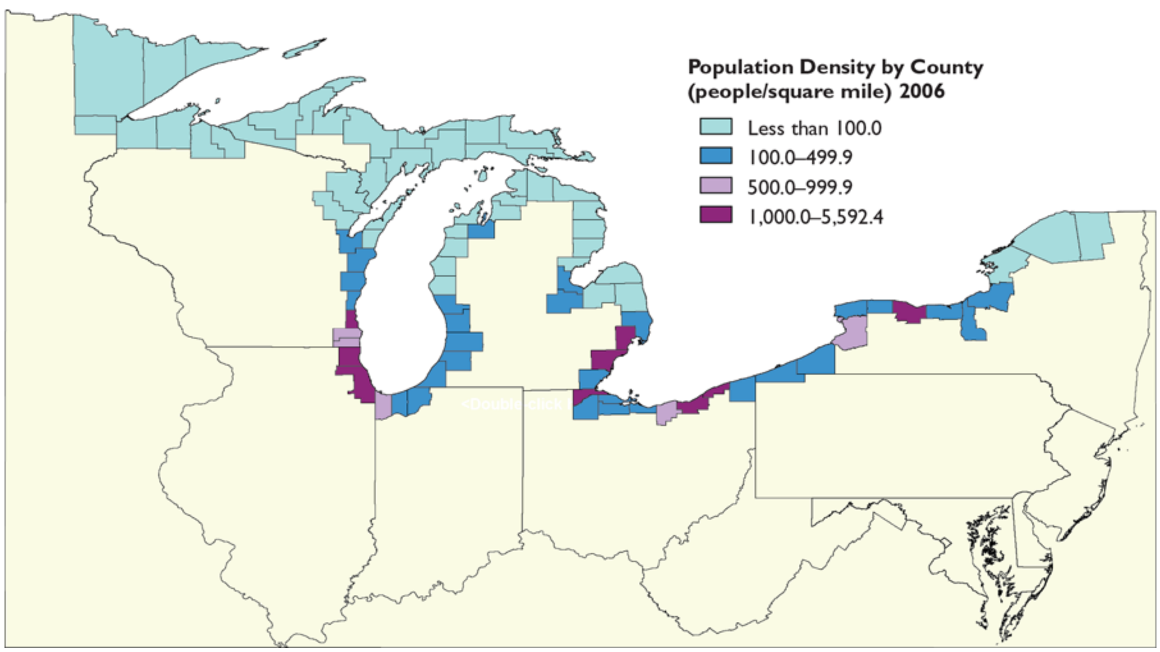


Figure 7-3. Population density in the Great Lakes region's coastal counties in 2006 (NOEP, 2010).

Coastal Monitoring Data—Status of Coastal Condition

Although an extensive monitoring network exists for the Great Lakes region, Great Lakes monitoring is not directly comparable to monitoring conducted under NCA for coastal estuaries and marine waters. The GLNPO uses best scientific judgment to select monitoring sites that represent the overall condition of the Great Lakes, whereas the NCA survey uses a probabilistic survey design to represent overall ecosystem condition and to attain a known level of uncertainty. The two programs use different methods, and spatial estimates of coastal condition cannot be assigned to the Great Lakes because they would be inconsistent and incomparable with those calculated for the marine coastal regions of the United States. The GLNPO and Great Lakes scientists assess the overall status of eight ecosystem components of the Great Lakes, some of which are similar to NCA indices and indicators. The results of these efforts, along with relevant technical information, are available from two Web sites: the State of the Lakes Ecosystem Conferences (SOLEC) site, available at http://www.epa.gov/grtlakes/solec, and the GLNPO site, available at http://www.epa.gov/glnpo. These results are used to quantify and categorize NCA indices and component indicators for the Great Lakes in the NCCR IV and will be summarized briefly in the following sections. The condition values are based primarily on expert opinion and were integrated with other regional condition data to evaluate the overall condition of the nation's coastal environment. NCCA sampling was being implemented during 2010 through coordination with EPA and multiple state agencies. Information on binational programs contributing to overall assessment of the Great Lakes from both Environment Canada and the EPA is available at http://www.binational.net.

Water Quality Index

The NCCR IV assessment combines several SOLEC indicators and GLNPO Water Quality Survey results (e.g., eutrophic condition, water clarity, dissolved oxygen levels, phosphorus concentrations) into a water quality index to allow comparison of water quality condition estimates for the Great Lakes with the NCA water quality index for U.S. marine coastal waters. Based on these component indicators, the Great Lakes water quality index is rated fair to poor. Starting with this report, the SOLEC indicators used for the water quality index include nearshore waters and open waters. Nearshore waters are defined as having a depth of 66 feet or less. Of the four SOLEC indicators used to develop the water quality index, eutrophic condition is rated fair to poor, phosphorus concentrations are rated poor, water clarity is rated good to fair, and dissolved oxygen concentrations are rated good. It should be noted that low dissolved oxygen levels continue to be a problem in the central basin of Lake Erie during the late summer due to seasonal stratification in areas greater than 66 feet deep.

Eutrophic Condition

Eutrophic conditions for the nearshore areas of the Great Lakes are rated fair to poor. Eutrophic conditions were determined using a surface water quality index developed by Chapra and Dobson (1981), and summarized data of nearshore water quality parameters of total phosphorus and chlorophyll *a* concentrations from *Nearshore Areas of the Great Lakes 2009* (Environment Canada and U.S. EPA, 2009a). The upper lakes (Lake Superior and Lake Huron) and Lake Ontario coastal waters were described as oligiotrophic waters, whereas Lake Erie coastal waters were described as having eutrophic conditions. Data suggest that *Cladophora* algal blooms have become more problematic by fouling beaches in the lower lakes during the past decade. This may be due in part to consumption of plankton by dreissenid mussels (the zebra and quagga mussels), which promotes *Cladophora* growth by increasing water clarity (Environment Canada and U.S. EPA, 2009a).

Nutrients: Phosphorus

Phosphorus concentrations and loadings for the nearshore areas of the Great Lakes region were rated poor. After strong efforts to reduce phosphorus concentrations were implemented during the 1970s, phosphorus concentrations declined steadily. Recent evidence suggests that although total phosphorus concentrations have remained relatively constant, the proportion of phosphorus present in an available dissolved form has increased dramatically. Point-source controls have been effective in decreasing phosphorus levels in the past; however, the primary driver of phosphorus loadings is now related to nonpoint sources such as stormwater runoff (Environment Canada and U.S. EPA, 2009a). This finding has strong implications for nearshore areas and embayments. Elevated levels of phosphorus in these regions are likely to contribute to nuisance algae growths, such as the attached green algae *Cladophora*, and toxic cyanophytes, such as *Microcystis*.

Water Clarity

Water clarity, measured by Secchi disk, was rated as good to fair for the Great Lakes region. In general, the upper lakes exhibited good water clarity, and the lower lakes, especially Lake Erie and Lake Michigan, had fair water clarity due in part to harmful algal blooms along the coastline during the latter part of the summer. Increasing water clarity is an indicator of declining algal populations, which form the base of the aquatic food chain in the Great Lakes. This is not necessarily an indication of improving conditions.

Dissolved Oxygen

Dissolved oxygen concentrations are rated good for the Great Lakes region, with levels that are capable of supporting life in most coastal regions of the Great Lakes. However, portions of the offshore central basin of Lake Erie are still experiencing anoxic (< 2 mg/L) conditions during summer stratification periods, and at times, these conditions may persist until late summer turnover. This condition is variously hypothesized to be a result of regional climate effects or of invasive species, particularly dreissenid mussels, improving water clarity, or altering the cycling of nutrients. Some of these alterations lead to algal blooms that die and sink to the bottom and consume dissolved oxygen during the decay process, resulting in summer anoxia in the bottom waters.

Sediment Quality Index

The NCCR II and III assessments indicated that, for the SOLEC indicators measured, the primary problem in the Great Lakes coastal waters was degraded sediment quality. The sediment quality index for the coastal waters of the Great Lakes region continues to be rated as poor for the NCCR IV, with sediment contamination contributing to the poor condition assessed in many harbors and tributaries and affecting the beneficial uses at all 30 of the U.S. Great Lakes Areas of Concern (AOCs) throughout the region (Figure 7-4). Contaminated sediments are also the leading cause of fish consumption advisories for this region and serve as a source of contaminants to open water as a result of sediment re-suspension activities (Environment Canada and U.S. EPA, 2009b). In addition, sediment contamination continues to be a problem affecting the sediment quality in this region.

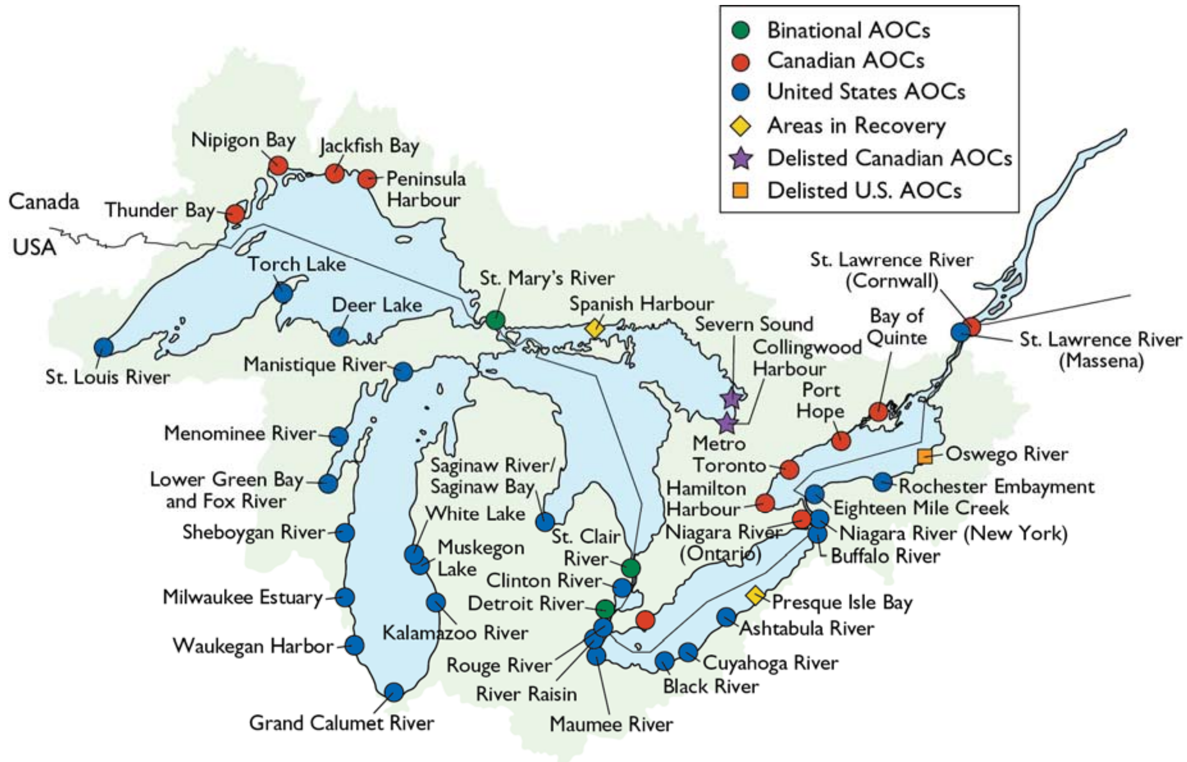


Figure 7-4. Great Lakes Areas of Concern (U.S. EPA, 2009a).

Benthic Index

The benthic condition of the Great Lakes, as measured by benthic community health, is rated fair to poor, although conditions in individual lakes vary. This rating was based on results of the GLNPO's benthic invertebrate monitoring and surveillance monitoring programs. Populations of the benthic invertebrates *Diporeia* (in cold, deepwater habitats) and *Hexagenia* (in mesotrophic habitats) were used for evaluating benthic health because of their importance at the base of the Great Lakes food web. Benthic conditions for 2003–2006 have an unchanging trend: some Great Lakes have good benthic conditions while areas of other lakes have fair or poor conditions. Further explanation of this evaluation states that a good status indicates oligotrophic conditions, while a fair or poor status indicates mesotrophic to eutrophic conditions at locations that have historically been oligotrophic. This rating is based on the Milbrink's index of oligochaete worm densities, which was used as a component of the Benthos Diversity and Abundance SOLEC indicator.

The status and trend of the benthic invertebrate *Diporeia* are mixed and deteriorating (Environment Canada and U.S. EPA, 2009b). Although the cause of declines is unknown, populations are dramatically declining in Lakes Michigan, Huron, and Ontario, and they are extremely rare and even absent in some areas of Lake Erie. However, *Diporeia* populations in Lake Superior remain good and stable despite what is occurring in the other lakes. The decline of *Diporeia* populations began to occur 2 to 3 years after the invasion of the dreissenid mussels. Figure 7-5 illustrates the decline of *Diporeia* populations in Lake Huron. One initial hypothesis is that mussels are outcompeting *Diporeia* for food. Yet, *Diporeia* seem to be persisting in the presence of mussels in the New York Finger Lakes, and they have also disappeared in some areas where food is available and mussels are absent. Therefore, it appears that a more complex situation responsible for the decline of *Diporeia*.

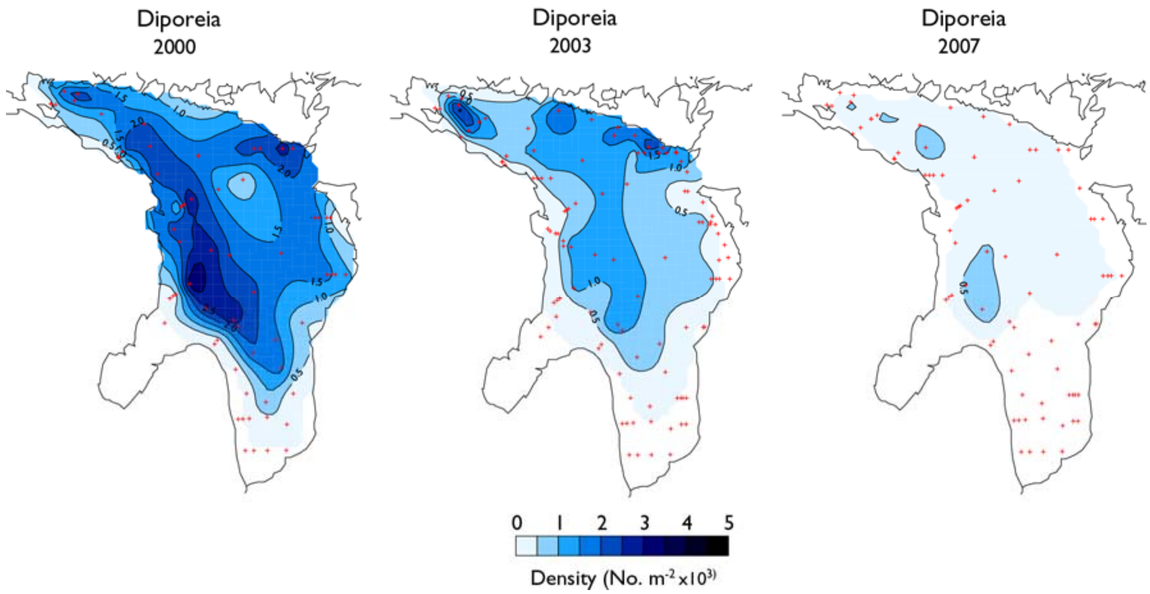


Figure 7-5. Distribution and abundance (number per square meter) of the amphipod *Diporeia* spp. in Lake Huron in 2000, 2003, and 2007.

Small crosses indicate location of sampling stations (Environment Canada and U.S. EPA, 2009b).

Currently, the status of *Hexagenia* is mixed, with a mixed-to-improving trend. *Hexagenia* is used as a mestrophic indicator to the Great Lakes because it is important to many species of fish and because it is sensitive to pollution and changes in habitat. *Hexageni*a was very abundant in the 1930s–1940s; however, in the 1950s, anoxic conditions caused populations to collapse in many of the embayments and coastal areas where they were formerly abundant. Anecdotal reports of *Hexagenia* recovery in the Great Lakes started to occur in the 1990s, which led to the investigation of its distribution in western Lake Erie. In 2002, nymph density drastically increased; however, that was followed by a steady decrease from 2002–2006 (Environment Canada and U.S. EPA, 2009b).

Coastal Habitat Index

The coastal habitat index for the Great Lakes region is rated fair to poor and has a deteriorating trend. This index is based on amphibian abundance and diversity, wetland-dependent bird diversity and abundance, the areal extent of coastal wetlands by type, and the effects of water level fluctuations.

The Great Lakes support a diversity of coastal wetlands types despite significant losses. More than one-half of the Great Lakes coastal wetlands was lost between 1780 and 1980 (Turner and Boesch, 1988; Dahl, 1990). The extent of coastal wetlands in the Great Lakes has a mixed status with a deteriorating trend. This assessment was made based on the Great Lakes Coastal Wetland Consortium coordination of a binational coastal wetland database (Albert et al., 2005). This database identified that approximately 535,584 acres of coastal wetlands exist within the Great Lakes basin.

Amphibian communities are often used to assess wetlands because amphibians are very sensitive to wetland contamination and degradation. The Marsh Monitoring Program (MMP) has been collecting amphibian data since 1995 across the Great Lakes basin. During this time, the MMP has recorded 13 different species of amphibians, with the spring peeper being the mostly frequently detected. Currently, the coastal wetland amphibian communities of the Great Lakes have a mixed status and deteriorating trend. The MMP has detected significantly declining trends in the American toad, chorus frog, green frog, and northern leopard frog. There has also been no significantly increasing trend in any common species of amphibian (Environment Canada and U.S. EPA, 2009b). However, it should be noted that there is high among-year variability in amphibian populations and that they are very sensitive to changes in water level. Further monitoring would determine if the declines observed reflected environmental fluctuations that caused water level changes, or if other factors influenced individual amphibian species.

The status of coastal wetland bird communities is mixed with a deteriorating trend. The MMP has been collecting data on coastal wetland birds since 1995, with 610 routes around the Great Lakes basin. The MMP recorded that the most common nonaerial foraging bird species was the red-winged blackbird, followed by the swamp sparrow, yellow warbler, and the marsh wren. Another common species that exclusively nests in marshes are the undifferentiated common moorhen and American coot, Virginia rail, black tern, common moorhen, pied-bille grebe, American bittern, American coot, sora, and least bittern. Lastly, the most common bird species that typically forage above the marsh are the tree swallow and bank swallow. Overall, 17 species of wetland birds exhibit significant declines across the Great Lakes basin while only 6 species of birds exhibit a significantly positive trend (Environment Canada and U.S. EPA, 2009b). One stressor to waterfowl populations in some areas of the lower Great Lakes is avian botulism. It is thought that recurring outbreaks of botulism are due to the effects of dreissenid mussels and round gobies, because the mussels create environmental conditions that promote the pathogen, and the gobies transfer it from the mussels to higher levels of the food web (Environment Canada and U.S. EPA, 2009b). Additionally, further monitoring would determine the degree to which changes in wetland bird species occurrences reflect changing marsh conditions as a consequence of changing water levels.

Fish Tissue Contaminants Index

The fish tissue contaminants index for the coastal waters of the Great Lakes region is rated fair, with an improving trend for the NCCR IV based on SOLEC indicator 121. Fish advisory programs are well established in the Great Lakes states and offer advice to residents regarding the amount, frequency, and species of fish that are safe to eat. Such advice is based primarily on concentrations of PCBs, mercury, chlordane, dioxin, and toxaphene in fish tissues. Concentrations of these contaminants are generally declining in fish tissues, as shown in Figure 7-6, but are still present at levels that support continuation of existing fish advisories for all five Great Lakes. Whole-fish composite samples of top-predatory fish are analyzed for contaminants in the United States, and fillets are analyzed in Canada; however, the guidelines are similar in both countries. The represented top-predatory fish used are walleye for Lake Erie and lake trout for the other four Great Lakes. Each lake is rated individually based on the concentrations of PCBs and DDT and the corresponding fish advisory category; the final overall rating is an average of all five individual ratings (Environment Canada and U.S. EPA, 2009b).

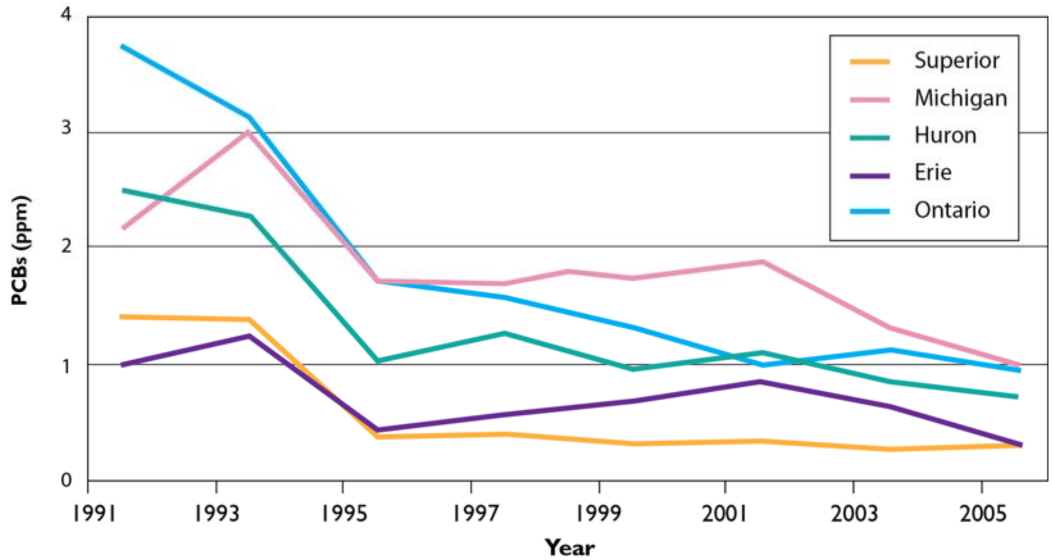


Figure 7-6. Total PCBs in composites of lake trout (walleye in Lake Erie), 1991–2005 (Environment Canada and U.S. EPA, 2009b).

Lake Trout = 600–700 mm size range. Walleye = 450–550 mm size range.

Trends of Coastal Monitoring Data—Great Lakes Region

The NCCR II rated the overall condition of the Great Lakes as fair to poor for the period 1998 through 2000. No additional assessment data for the Great Lakes were collected in 2001 and 2002 (the time period of the NCCR III), and ratings in this report for 2003–2006 remain the same as in 1998 through 2000. Therefore, the analysis of trends in environmental condition estimates for the Great Lakes cannot be made at this time. Comparisons of previously reported conditions with current conditions are briefly discussed in the previous sections.

Fisheries—Great Lakes

Once home to over 150 unique fish species, fishery production in the Great Lakes continues to decrease due to the combined effects of overfishing, invasive species, and habitat destruction (Ontario Ministry of Natural Resources, 2009; Environment Canada and U.S. EPA, 2007). By the 1950s, stocks of many of the most commercially valuable species (lake trout, lake sturgeon, blue pike, Atlantic salmon, and lake herring) had nearly collapsed, having been replaced by their less valuable native counterparts (whitefish and yellow perch) and introduced species (Pacific, Chinook, and Coho salmon; smelt; and alewife) (GLFC, 2008). From 1970 to 2007, commercial landings declined again from 65 to 20 million pounds (Figure 7-7).

Fisheries of the Great Lakes are shared by the United States and Canada and mostly occur in offshore waters. Presently, the U.S. commercial fishery is dominated by lake whitefish, yellow perch, smelt, and bloater chubs, with Lake Michigan representing the largest portion of these catches (Kinnunen, 2003). From 2003 to 2006, the commercial fisheries in the Great Lakes generated over $52.7 million in total ex-vessel revenues (preprocessing value) (NMFS, 2009a). The annual Canadian commercial harvest, which is estimated at 28 million pounds, primarily consists of walleye and yellow perch catches from Lake Erie (Kinnunen, 2003). Both U.S. and Canadian fisheries are managed at the regional level, by state, provincial, and intertribal agencies.

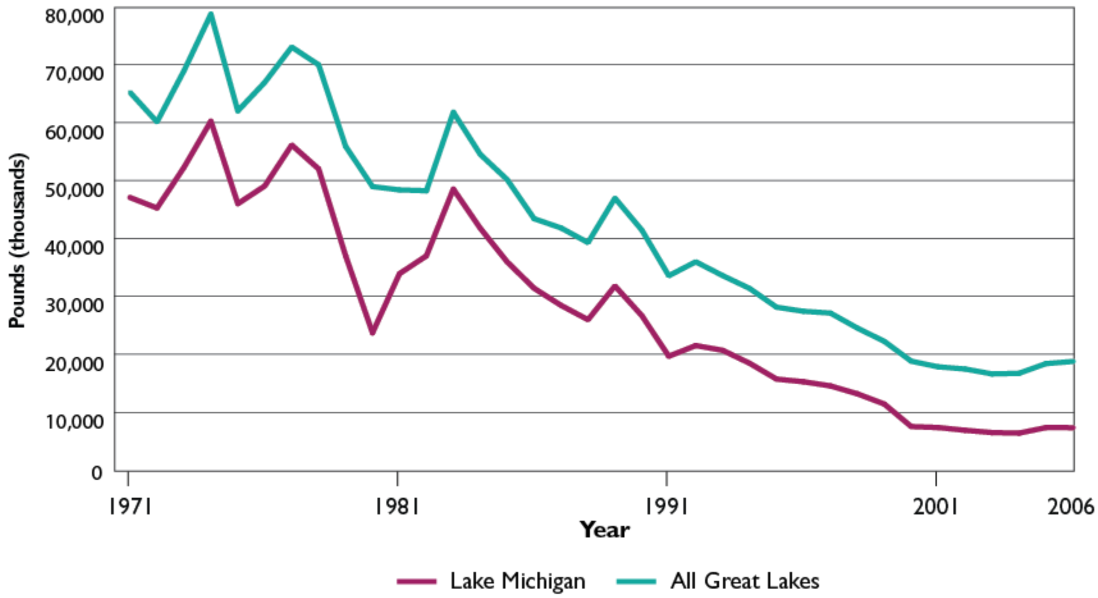


Figure 7-7. U.S. Great Lakes commercial fish landings totals in pounds, 1971–2007 (NMFS, 2009a).

Lake Whitefish and Yellow Perch Fisheries

Lake whitefish (*Coregonus clupeaformis)*, a member of the salmon family, dominates U.S. commercial fishery landings in the Great Lakes. From 2003 to 2006, the total ex-vessel revenues generated by the U.S. commercial harvests of lake whitefish were over $28 million (NMFS, 2009a). Lake whitefish averages one to three pounds at harvest and is valued for its meat as well as its roe, which is made into caviar (Fisheries and Oceans Canada, 2009). The small mouth of this fish limits its diet to small fish, fish eggs, insect larvae, clams, and zooplankton (primarily *Diporeia*, a small shrimp-like crustacean). This fishery increased markedly beginning in the early 1980s, and despite declines in landings in the late 1990s, seems to be increasing again (Figure 7-8).

Yellow perch (*Perca flavescens*) is another valuable commercial fishery species because of its favorable taste and texture, yielding over $11 million in total U.S. ex-vessel revenues from 2003 to 2006 (NMFS, 2009a). This species has a vast geographic range spanning from Nova Scotia to South Carolina along the Atlantic Coast and west to Kansas and the Montana border, reaching the southern portions of the Northwest Territories of Canada. Small fish and minnows are the favored diet of adult yellow perch, which are themselves an important prey for many predatory fish, including walleye, bass, northern pike, and muskellunge (University of Wisconsin Sea Grant Institute, 2010). Populations of yellow perch have considerable interlake variability, although recently commercial harvests throughout the Great Lakes stabilized at around 2 million pounds (Figure 7-8) (NMFS, 2009a).

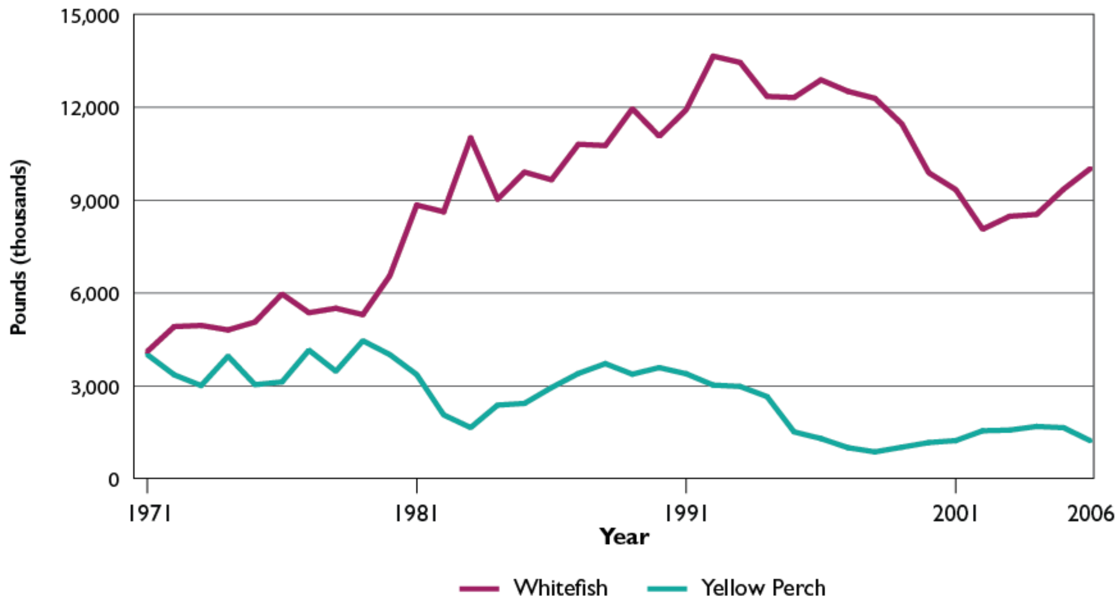


Figure 7-8. U.S. Great Lakes whitefish and yellow perch commercial landings totals in pounds, 1971–2006 (NMFS, 2009a).

Note: Yellow perch is often considered a prey species.

Lake Trout and Walleye Fisheries

Lake trout and walleye were once dominant predatory fish in the Great Lakes, but current populations only allow for a limited commercial fishery (Figure 7-9). From 2003 to 2006, the total U.S. ex-vessel revenues from this fishery were $683,000 (NMFS, 2009a). Lake trout (*Salvelinus namaycush*) inhabits all five Great Lakes and has a geographical range that extends to the northernmost reaches of North America. On average, lake trout weighs around 7 pounds, though some trophy specimens have weighed in at 25 pounds. The diet of lake trout consists of several prey species, including native chubs and sculpins and introduced alewives and smelt (University of Wisconsin Sea Grant Institute, 2010). Before nearing complete extinction in the 1950s, lake trout was a valuable commercial species in the Great Lakes. It now survives in sufficient numbers to allow commercial harvesting only in Lake Superior. Stocking programs, which raise fish in controlled conditions, continue in the other lakes.

After peak harvests from the mid-1980s to early 1990s, the walleye (*Stizostedion vitreum*) landings declined from the mid-1990s through 2000, possibly due to shifts in environmental states, variable reproductive success, influences from invasive species, and changing fisheries (Environment Canada and U.S. EPA, 2007). Since 2000, harvests have increased primarily due to improvements in environmental conditions around spawning and nursery habitats (Environment Canada and U.S. EPA, 2007).The commercial harvests in this fishery remain small, generating just over $173,000 from 2003 to 2006, with the vast majority occurring in Lake Erie (NMFS, 2009a). However, walleye is a very important recreational fishery in all the Great Lakes with the exception of Lake Superior, where harvests are mostly tribal (Environment Canada and U.S. EPA, 2007).Walleye remain in the darkness of bottom waters during the day, emerging at night to feed on bullheads, freshwater drum, yellow perch, and other small fish. Walleye and yellow perch have a special relationship that allows effective population control of both species. While adult walleye feed on the smaller yellow perch, adult perch feed on the young of walleye (Mecozzi, 1989). This fish averages only one to three pounds in size, but is a popular commercial and recreational fishing target because it is considered one of the best-tasting freshwater species (University of Wisconsin Sea Grant Institute, 2010). Walleye reproduction is largely driven by uncontrollable environmental events (i.e., spring weather patterns and alewife abundance); however, degraded spawning and nursery habitats in some areas due increased human use of nearshore and watershed environments also impede reproduction (Environment Canada and U.S. EPA, 2007).

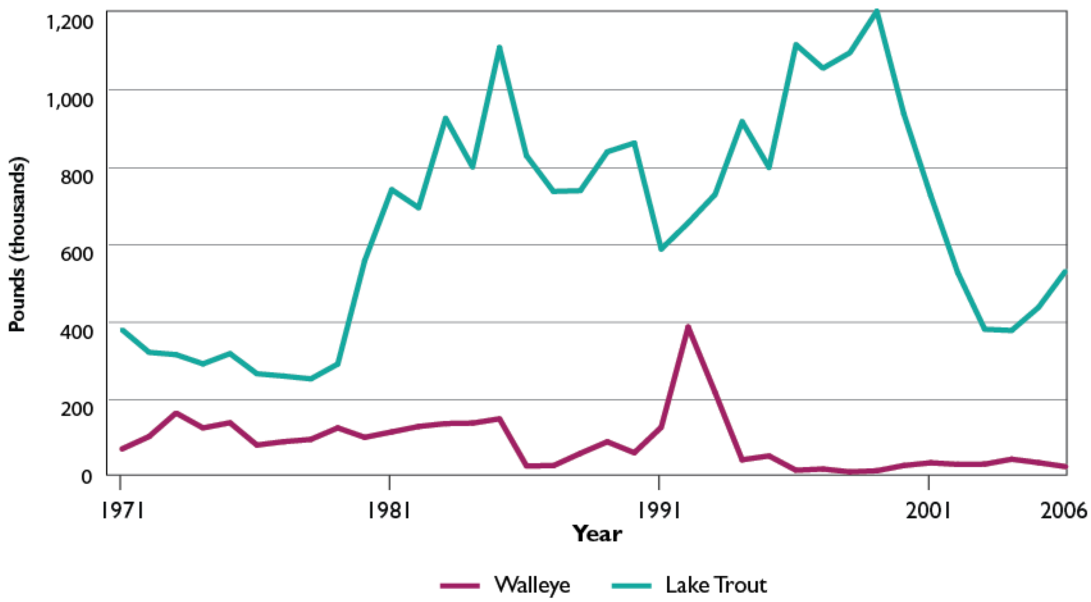


Figure 7-9. U.S. Great Lakes walleye and lake trout commercial landings totals in pounds, 1971–2006 (NMFS, 2009a).

Preyfish Fisheries

Predator-prey relationships are important to the maintenance of healthy fisheries, but these relations have been changing for several decades throughout the Great Lakes. Preyfish are characterized as both pelagic (water-column dwelling) and demersal (bottom-dwelling) species that prey on invertebrates their entire lives. Invasive prey species such as alewives and smelt were first found in the Great Lakes in the 1920s, but were widespread by the 1940s, causing vast changes in ecosystem dynamics. In the 1990s, the invasive round goby was introduced, likely via ballast water, and its populations have been increasing in several of the Great Lakes (Walsh et al., 2006). Alewives, smelt, and gobies outcompete native preyfish species (e.g., lake herring, chubs, sculpins) for food and spawning habitat. In fact, fishery managers introduced non-native salmon species to the lakes in the 1950s in order to curtail the growing populations of invasive preyfish (Environment Canada and U.S. EPA, 2007).

Despite the negative impacts of non-native preyfish species, they have become an important component of the Great Lakes ecosystem and even the commercial fishing industry. From 2003 to 2006, the preyfish commercial fishery in the Great Lakes (i.e., chubs, cisco-herring, and rainbow smelt) generated over $7.3 million in ex-vessel revenues. The alewife supported a fishery of 50 million pounds in the late 1970s, and the bloater chubs fishery is currently the second-largest in the Great Lakes (NMFS, 2009a). Over the past several years landings of non-native preyfish has decreased throughout all the lakes (Figure 7-10), with the exception of Lake Superior (Environment Canada and U.S. EPA, 2007). Preyfish populations are under pressure from predation by salmon and lake trout and other preyfish and from the population collapse of a major food source, the deepwater amphipod *Diporeia*. The collapse of *Diporeia* is hypothesized to be the result of successful colonization of the Great Lakes by invasive dreissenid mussels, which also consume pelagic plankton (Environment Canada and U.S. EPA, 2007). These mussels outcompete native species for food and attach to the shells of native mussels, interfering with their feeding, respiration, and locomotion (Environment Canada and U.S. EPA, 2007). The effects on the alewife population have been particularly significant, resulting in the near elimination of the commercial harvest of this species by the early 1990s. As a result of these declines in preyfish populations, fishery managers have implemented a variety of harvest restrictions.

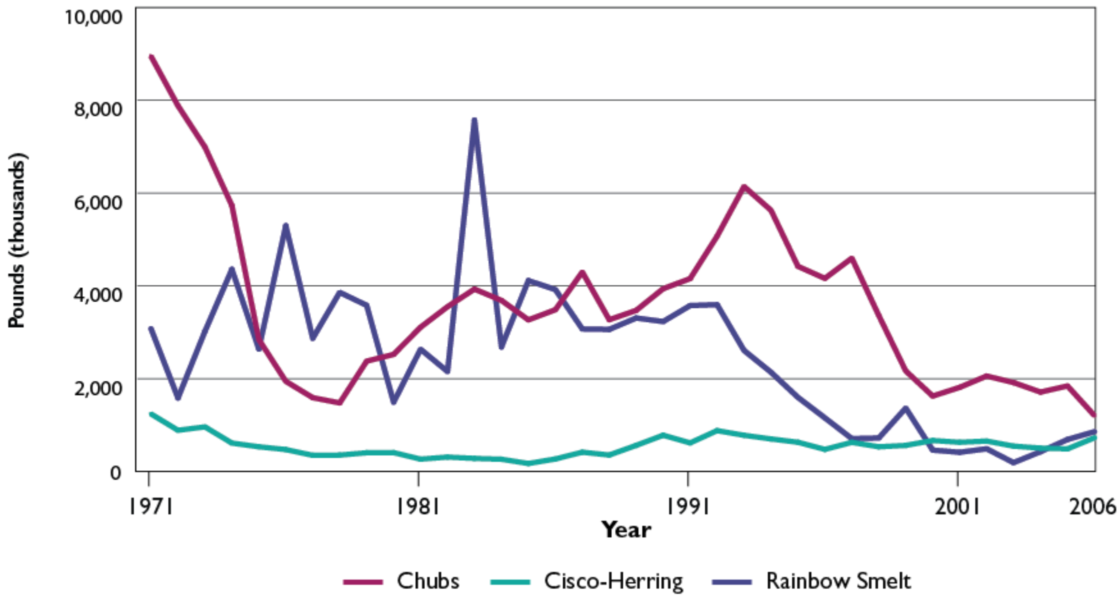


Figure 7-10. U.S. Great Lakes preyfish commercial landings totals in pounds, 1971–2006 (NMFS, 2009a).

Stresses

To varying degrees, fishery resources in the Great Lakes have been impacted by three major disturbances: non-native species introductions, overfishing, and habitat degradation (GLFC, 2008). Non-native species introductions are extensive throughout the Great Lakes via shipping activities (e.g., ballast waters, ship hulls), unintentional releases from aquaculture and aquariums, and stocking efforts by fishery managers. Impacts associated with non-native species introductions are varied; this differentiation is also reflected in the terminology used for non-native species. According to the 1999 Executive Order 13112 (64 FR 6183), invasive species are those that cause harm to ecosystems, economies, or human health; other terms applied to this class of species that do not cause harm include “non-native,” “alien,” or “introduced” (NISC, 2008). Whereas some invasives have had severe negative impacts on the Great Lakes ecosystem, as in the case of zebra and quagga mussels, non-native species have also played beneficial roles. Stocked salmon have curtailed the growth of alewife populations (a non-native prey species that competes with its native counterpart) and reinstituted important predator-prey relationships while creating new recreational fishing opportunities (Environment Canada and U.S. EPA, 2007). Another invasive species, the parasitic sea lamprey, greatly contributed to the decimation of lake trout populations in the Great Lakes. The lamprey has a suction-cup like mouth and sharp teeth that are used to feed on the tissue and blood of the host fish, resulting in death from either direct blood loss or secondary infections.

Decades of overfishing, which also contributed to the sharp decline in lake trout populations, have undermined the health of fish stocks throughout the Great Lakes. Commercial fishing in the Great Lakes began in the 1820s and increased by about 20% annually until peaking in the late 1800s (Environment Canada and U.S. EPA, 1995). Serious efforts at harvest controls were not instituted until the creation of the Great Lakes Fishery Commission (GLFC) in the mid 1950s; however, inadequate stock assessments, poor monitoring, and overall incompliance limited the efficacy of regulatory measures implemented by the GLFC.

Since the arrival of the Europeans, vital fish habitats, such as wetlands and streams, have been degraded by agriculture, damming, urbanization, shoreline development, and invasive species (especially the common carp and purple loosestrife) (Environment Canada and U.S. EPA, 2007). Two-thirds of Great Lakes coastal wetlands have been lost since colonialization; a particularly extensive loss in Hamilton Harbor is just one example. Wetlands have been filled or drained for agriculture and development, polluted by excess nutrient deposition and urban runoff, and degraded by dredging for commercial and recreational water traffic. Common carp damage habitat by uprooting coastal vegetation and reducing water clarity during feeding. Purple loosestrife, a tall aquatic plant from Eurasia, can cause wetlands to dry out and thereby impede the survival of species that thrived there (Environment Canada, 1995).

Fisheries Management

Governance of fisheries in the Great Lakes is complicated by the multiple and often overlapping jurisdictions in this area. For example, fisheries in Lake Superior are subject to the regulatory authority of Michigan, Minnesota, Wisconsin, Ontario province, the Chippewa Ottawa Resources Authority, and the Great Lakes Indian Fish and Wildlife Commission (Read, 2003). In recognition of the potentially negative impact of multiple authorities regulating single fisheries, the GLFC was formed under the jurisdiction of the International Joint Commission to manage and promote the health of Great Lakes fisheries.

The five Great Lakes Committees within the GLFC set annual harvest limits for each lake. Great Lakes fishery managers largely rely on harvest limits, fishing licenses, area and time restrictions, and gear restrictions. Particularly unique to fishery management in the Great Lakes are the numerous fish stocking programs, including trout, salmon, sturgeon, herring, muskellunge, walleye, and yellow perch. Fishery stocking is under the jurisdiction of the States and ministries of the Great Lakes, as well as the Province of Ontario.

Advisory Data

Fish Consumption Advisories

Fishing in the Great Lakes region is a way of life and a valued recreational and commercial activity for many people. To protect citizens from the risks of eating contaminated fish, six of the eight states bordering the Great Lakes had advisories, for a total of 29 fish consumption advisories in effect during 2006 for the waters and connecting waters of the Great Lakes. During 2006, every Great Lake had at least one advisory, and advisories covered 100% of the Great Lakes shoreline that year (Figure 7-11). Michigan, which borders four of the five Great Lakes and encompasses four of the six connecting waterbodies, issued the largest number (13) of fish consumption advisories (U.S. EPA, 2007c).

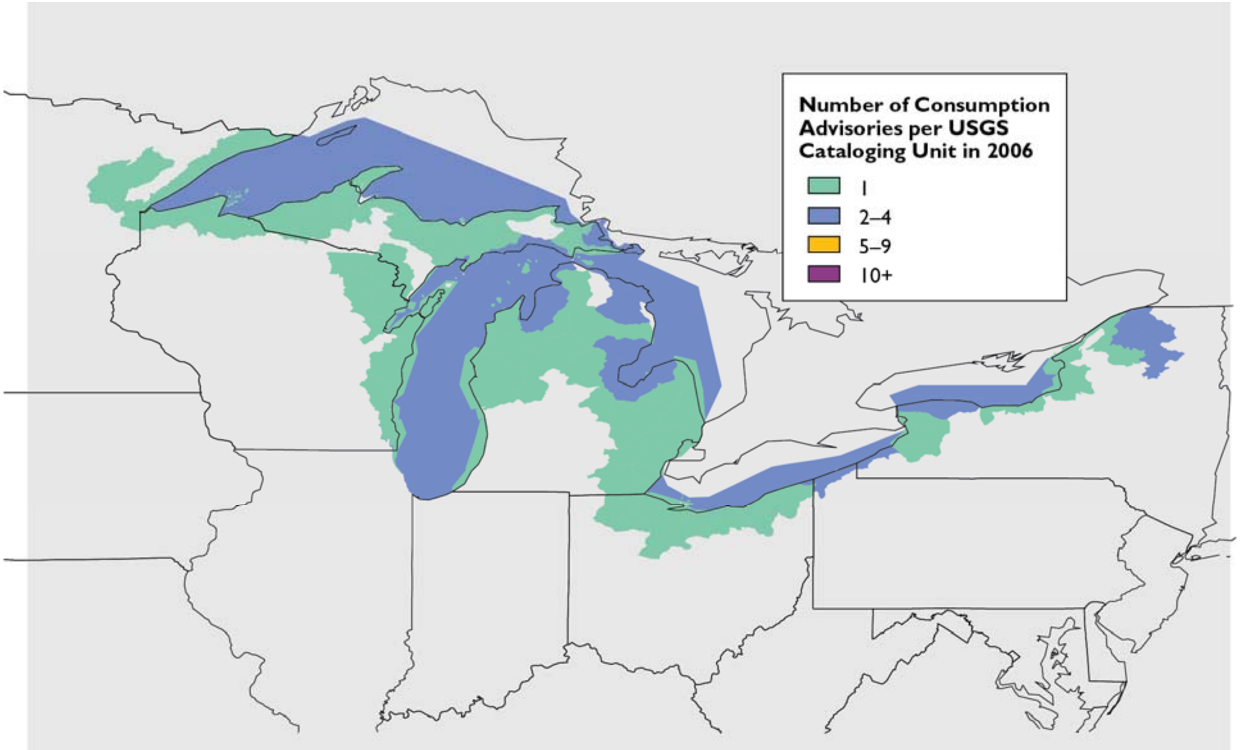


Figure 7-11. The number of fish consumption advisories in effect in 2006 for the U.S. Great Lakes waters (U.S. EPA, 2007c).

Great Lakes fish consumption advisories were issued for six pollutants: mercury, mirex, chlordane, dioxins, PCBs, and DDT. All of the advisories listed PCBs, and one-half (52%) also listed dioxins (Figure 7-12). Lake Superior, Lake Michigan, and Lake Huron were under advisory for at least four pollutants each in 2006 (Table 7-1); however, some of the advisories were of limited geographic extent, and advisories in most locations were applied primarily to larger, older individual fish high in the food web (U.S. EPA, 2007c).

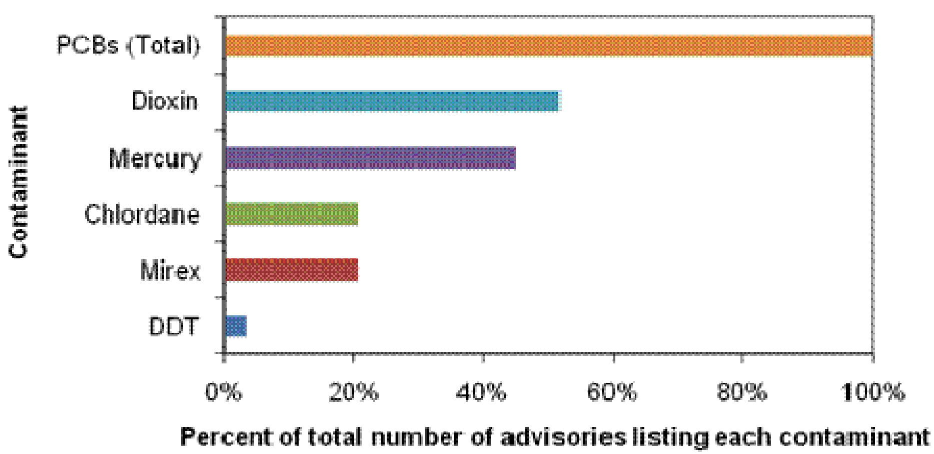


Figure 7-12. Pollutants responsible for fish consumption advisories in Great Lakes waters. An advisory can be issued for more than one contaminant, so percentages may add up to more than 100 (U.S. EPA, 2007c).

Table 7-1. Fish Advisories Issued for Contaminants in Each of the Great Lakes (U.S. EPA, 2007c)

Great Lakes	PCBs	Dioxins	Mercury	Chlordane	DDT	Mirex
Lake Superior	Yes	Yes	Yes	Yes	—	—
Lake Michigan	Yes	Yes	Yes	Yes	Yes	—
Lake Huron	Yes	Yes	Yes	Yes	—	—
Lake Erie	Yes	Yes	Yes	—	—	—
Lake Ontario	Yes	Yes	—	—	—	Yes

Species and/or groups under fish consumption advisory in 2006 for at least one of the Great Lakes or their connecting waters:		
American eel	Bluegill sunfish	Bowfin
Brown bullhead	Brown trout	Burbot
Channel catfish	Chinook salmon	Chub
Coho salmon	Common carp	Freshwater drum
Gizzard shad	Lake herring	Lake sturgeon
Lake trout	Lake whitefish	Largemouth bass
Longnose sucker	Northern pike	Rainbow trout
Redhorse	Rock bass	Sheepshead Siscowet trout
Smallmouth bass	Smelt	Splake trout
Steelhead trout	Sturgeon	Walleye
White bass	White perch	White sucker
Whitefish	Yellow perch	

Source: U.S. EPA, 2007c.

Beach Advisories and Closures

How many notification actions were reported for the Great Lakes between 2004 and 2008?

Table 7-2 presents the number of total and monitored beaches, as well as the number and percentage of monitored beaches affected by notification actions from 2004 to 2008, for the U.S. Great Lakes (summed for New York's Great Lakes beaches, Minnesota, Indiana, Illinois, Pennsylvania, Ohio, Wisconsin, and Michigan). Data from New York are not included for 2004 and 2005, nullifying comparison with the 2006 to 2008 information. Nevertheless, the percentage of beaches with notifications remained nearly constant between 2004 and 2005. The number of total and monitored beaches decreased for the whole region between 2006 and 2008, but the percentage of beaches affected by notification actions remained constant (U.S. EPA, 2009d). Annual national and state summaries are available on EPA's Beaches Monitoring site: http://www.epa.gov/waterscience/beaches/seasons/.

Table 7-2. Beach Notification Actions, Great Lakes, 2004–2008 (U.S. EPA, 2009d)

Numbers and Percentages	2004[a]	2005[b]	2006	2007	2008
Total number of beaches	766	852	1,441	1,446	1,379
Number of monitored beaches	514	525	566	551	542
Number of beaches affected by notification actions	207	203	276	276	269
Percentage of monitored beaches affected by notification actions	40%	39%	49%	50%	50%

[a] Data from Pennsylvania and New York are not included for this year. New York data are available for the entire state; however, the data do not differentiate between Great Lakes and coastal beaches for 2004 and 2005.

[b] Data from New York are not included for this year because coastal and Great Lakes beaches were not differentiated.

What pollution sources impacted monitored beaches?

Table 7-3 presents the numbers and percentages of monitored Great Lakes beaches affected by various pollution sources for 2007. Unidentified and unknown pollution sources together affected over 90% of Great Lakes beaches. Other significant contributors to notification actions included storm-related runoff (19%), wildlife (14%), and non-storm related runoff (8%) (U.S. EPA, 2009d).

Table 7-3. Reasons for Beach Advisories, Great Lakes, 2007 (U.S. EPA, 2009d)

Reason for Advisories	Total Number of Monitored Beaches Affected	Percent of Total Monitored Beaches Affected
Other and/or unidentified sources	306	57
No known pollution sources	186	35
Storm-related runoff	102	19
Wildlife	73	14
Non-storm related runoff	44	8
Septic system leakage	27	5
Sanitary/combined sewer overflow	23	4
Sewer line leak or break	10	2
Agricultural runoff	9	2
Concentrated animal feeding operations	9	2
Boat discharge	6	1
Publicly owned treatment works	6	1
Pollution sources not investigated	1	< 1

Note: A single beach advisory may have multiple pollution sources.

How long were the 2007 beach notification actions?

Most (80%) of beach advisories for the Great Lakes in 2007 lasted either 1 day (65%) or 2 days (15%). Notifications lasting 3 to 7 days comprised 17% of all advisories, and the other 3% of notifications were of the 8- to 30-day duration (U.S. EPA, 2009d). For more information on state beach closures, please visit the EPA's Beaches Web site: http://www.epa.gov/beaches/plan/whereyoulive_state.html.

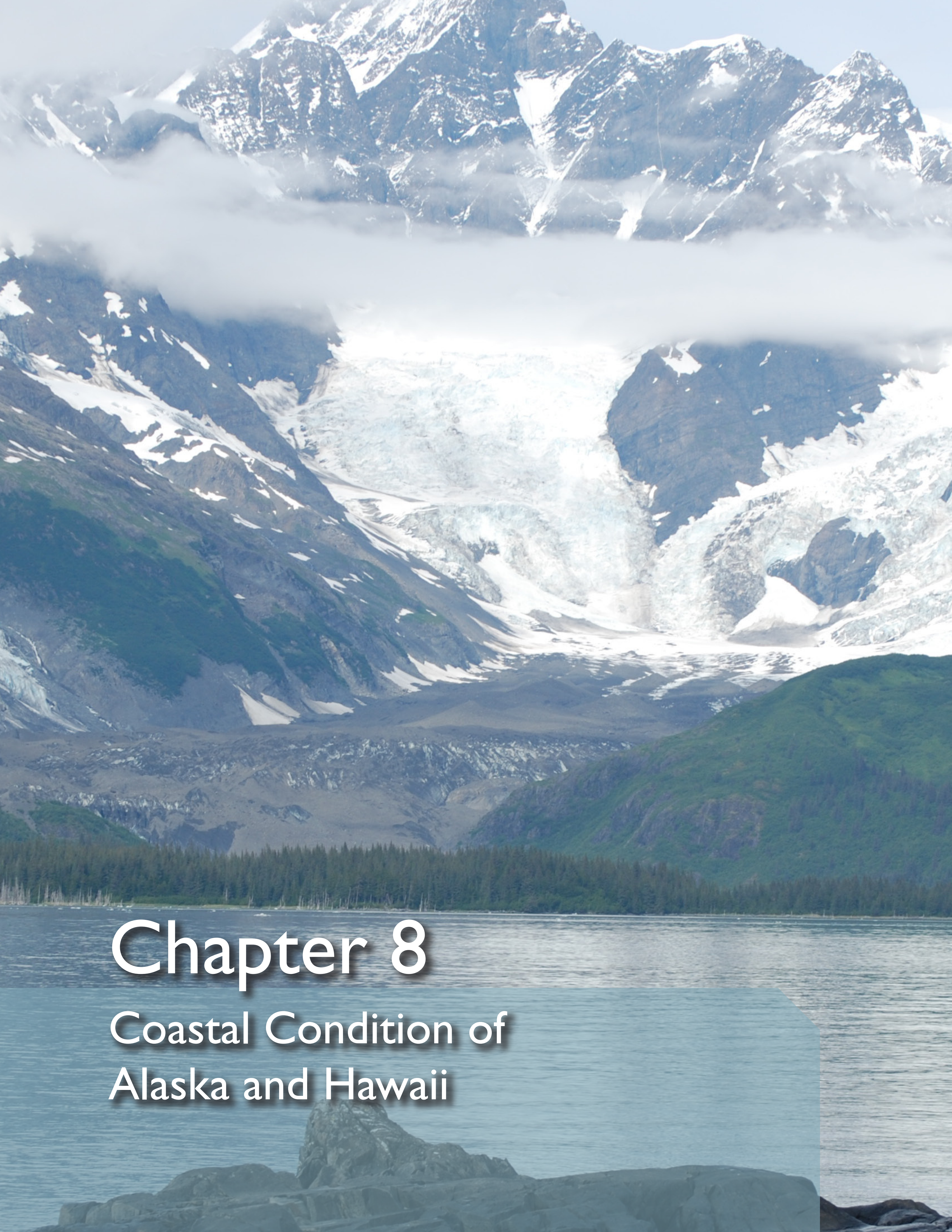
Summary

Although the Great Lakes has an extensive monitoring network with respect to objectives, design, and approaches, Great Lakes monitoring is not directly comparable with monitoring done by the NCA for estuarine and coastal waters. For example, the assessments conducted by SOLEC apply in most cases to the whole of the Great Lakes, rather than only nearshore or coastal conditions. Although a nearshore framework and suite of indicators have been evolving, this is a relatively recent development. Additionally, GLNPO monitoring sites are at locations selected according to best scientific judgment to represent the overall condition of the Great Lakes, whereas the NCA survey monitoring sites are at locations selected using a probabilistic sampling design to yield direct, representative estimates of overall condition with known levels of uncertainty. Consequently, coastal condition spatial estimates that are consistent and comparable with those prepared for the marine coastal regions surveyed by NCA cannot be calculated for the Great Lakes. Instead, the best professional judgment of knowledgeable scientists was used to assess the overall status of eight ecosystem components in relation to established endpoints or ecosystem objectives, when available.

The Great Lakes were rated fair to poor using available assessment information. Future assessments of coastal condition will use the NCCR series as a baseline for the overall health of the Great Lakes to determine if conditions improve in the future as a result of management and control strategies. The results of these future assessments will be used as a basis to compare and integrate the overall condition of the Great Lakes with other coastal resources in this report. NCA strategies and monitoring of nearshore areas of the Great Lakes is currently being implemented by U.S. EPA Region 5, which will allow for the next NCCA reporting on the Great Lakes to be comparable to the findings and trends assessed for the marine coastal areas.

The vastness of the Great Lakes watershed and the consequent diversity of its ecosystems allowed this area to be home to numerous unique fish species. However, non-native species invasions, habitat degradation, and overfishing have led to the collapse and diminution of many commercially valuable fishery species. Lake trout have recovered after nearing extinction in the 1950s, although commercial fishing for this species is now sustainable only in Lake Superior. Walleye stocks have also shown signs of recovery after a population collapse in the mid-1990s. Despite improvements in fisheries management, commercial landings have continued to decline.

Contamination in the Great Lakes has affected human uses of these waters. The data indicate that fish tissue contamination is decreasing over time, although mercury contamination is still a problem in many areas. In 2006, every Great Lake had at least one fish consumption advisory, and advisories covered 100% of the Great Lakes shoreline that year. All of these advisories were issued for PCB contamination (alone or in conjunction with other contaminants). In addition, 49% of the region’s monitored beaches were closed or under advisory for some period of time during 2006. Elevated bacteria levels in the region’s coastal waters were primarily responsible for the beach closures and advisories.



Chapter 8

Coastal Condition of Alaska and Hawaii

8. Coastal Condition of Alaska and Hawaii

Southeastern Alaska

As shown in Figure 8-1, the overall condition of Southeastern Alaska's coastal waters is rated good, with an overall condition score of 5.0. The water quality, sediment quality, coastal habitat, and fish tissue contaminants indices are rated good, and the benthic index for this region could not be evaluated. Figure 8-2 provides a summary of the percentage of Southeastern Alaska coastal area in good, fair, poor, or missing categories for each index and component indicator. This assessment is based on environmental stressor and response data collected from 42 locations (three samples for water quality and sediments were lost, resulting in only 39 sample sets used to assess water quality and sediment condition) along Southeastern Alaska's coastline in 2004. The NCCR III presented an assessment of coastal waters in Southcentral Alaska; therefore, the results of the two surveys cannot be compared for changes in condition.

Please refer to Chapter 1 for information about how these assessments were made, the cutpoints used to develop the rating for each index and component indicator, and limitations of the available data.

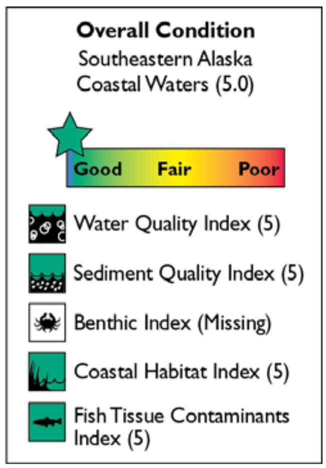


Figure 8-1. The overall status of Southeastern Alaska's coastal waters is rated good (U.S. EPA/NCA).

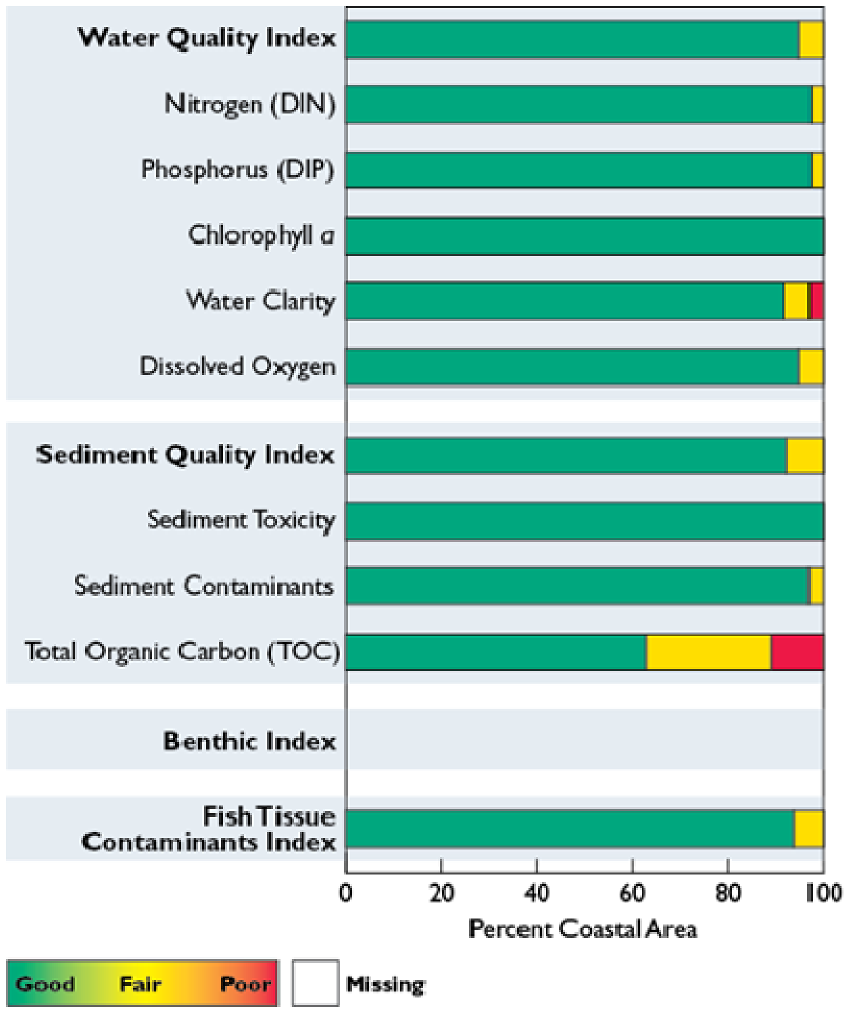


Figure 8-2. Percentage of coastal area achieving each ranking for all indices and component indicators – Southeastern Alaska region (U.S. EPA/NCA).

The sheer scale and geographic complexity of Alaska's shoreline dictate that comprehensive assessments of its coastal resources are inherently difficult. Alaska's marine shoreline of approximately 45,000 miles constitutes more than 50% of total U.S. coastline miles, and the state's coastal bays and estuaries have a total surface area of 33,211 square miles. Much of the southeastern coast of Alaska is very convoluted, containing hundreds of bays, estuaries, coves, fjords, and other coastal features; it is estimated to contain approximately 63% of the total Alaskan coastline (Sharma, 1979). The Gulf of Alaska LME is located offshore of this region. Southeastern Alaska, also known as the Alaskan panhandle, encompasses several national parks and monuments, as well as the largest national forest in the United States, the Tongass National Forest. The region is ecologically unique: a lush temperate rain forest with a coastline that is buffered from the open ocean by an extensive chain of islands. It is home to a vast array of terrestrial and marine wildlife, including black and brown bears, mink, waterfowl, several salmon species, and various marine mammal species.

Alaska's coastal resources are not subject to population and development pressures to the same extent as the rest of the U.S. coastline, because of the state's low population density, the distance between most of its coastline and major urban or industrial areas, the lack of road access to most coastal areas, and its limited agriculture activities. Consequently, some contaminant concentrations have been measured as having levels significantly lower than those in the rest of the coastal United States, although localized sources of trace metal and organic contaminants such as PCPs and mercury exist in Alaska (AMAP, 2010; Landers et al., 2010). Indeed, the principal input of organic contaminants is from global sources; however, concentrations of trace metals and organic contaminants in marine fish from Alaska are low and not a public health concern according to studies conducted by Alaskan authorities (Alaska H&SS, 2010). Nevertheless, Southeastern Alaska includes several population centers, as well as the state's capital city of Juneau, and the port city of Ketchikan, which is a popular destination for cruise ships. Large-scale timber and fishery industries also inflict pressures on the coastal resources of this area.

Between 1980 and 2006, the population of coastal counties along the Alaskan Coast increased 72% from 331,000 to 569,000 people (Figure 8-3), and the area experienced the second largest rate of population increase of any coastal region in the entire United States. However, Alaska has a relatively small population and a large coastal area, so the population density is low, and Alaska is home to less than 1% of the total U.S. coastal population. Population density has increased from approximately 0.9 persons per square mile in 1980 to 1.5 persons per square mile in 2006 (Figure 8-4) (NOEP, 2010).

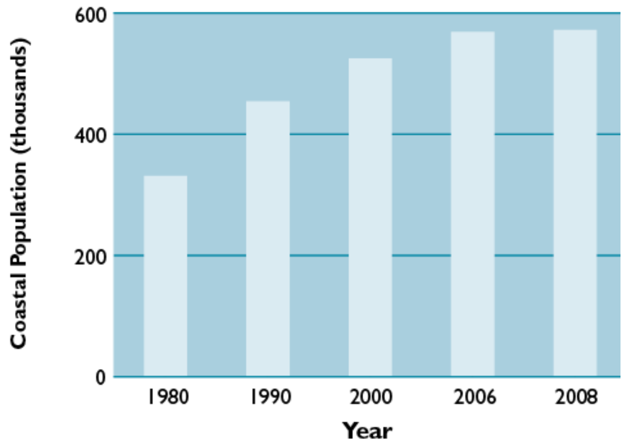


Figure 8-3. Population of coastal counties in Alaska, 1980–2008 (NOEP, 2010).

The NCA monitoring data used in this assessment are based on single-day measurements collected at sites throughout the U.S. coastal waters (excluding the Great Lakes) during a 9- to 12-week period during the summer. Each site was sampled once during the collection period of 2003 through 2006. Data were not collected during other time periods.

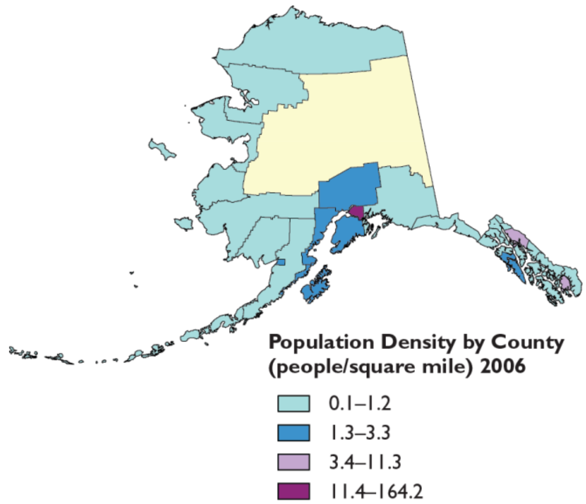


Figure 8-4. Population density in Alaska's coastal counties in 2006 (NOEP, 2010).

The scenario for Alaska's coastal aquatic resources is not one of existing degradation from agricultural, industrialization, and urbanization pollution drivers, but one of possible large-scale changes due to climate change and future resource development (AMAP, 2009, 2010; State of Alaska, 2010). Ocean acidification refers to the decrease in ocean pH due to the uptake of excess carbon dioxide, which results primarily from burning of fossil fuels and other human activities, such as cement production and deforestation. Human carbon dioxide emissions contributed 34 tons to the atmosphere in 2009 (Global Carbon Project, 2010; Friedlingstein et al., 2010). Monitoring for ocean acidification has not been a component of the NCA in Alaska's coastal oceans, where the effects of ocean acidification may be occurring more rapidly than in other regions (Bates et al., 2009; Fabry et al., 2009; Feely et al., 2010).

> The sampling conducted in the EPA NCA survey has been designed to estimate the percent of coastal area (nationally or in a region) in varying conditions and is displayed as pie diagrams. Many of the figures in this report illustrate environmental measurements made at specific locations (colored dots on maps); however, these dots (color) represent the value of the index specifically at the time of sampling. Additional sampling would be required to define temporal variability and to confirm environmental condition at specific locations.

Large-scale resource development of Alaska's oil, gas, and mineral reserves is likely to occur in the future as world resources grow more scarce. A recent USGS report (Bird et al., 2008) placed Arctic Alaska as the second-ranked province likely to contain major deposits of undiscovered oil, gas, and natural gas liquids. Alaska's coastal regions also contain potentially significant mineral resources, such as chromium, coal, copper, "oil-shale," silver, and zinc (Alaska DNR, 2010).

It is crucial that future Alaska NCCA designs take into account the overall focus for Alaska waters. This focus includes developing a current status for much of Alaska's "pristine" aquatic resources for future reference. The National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling found the scientific understanding of environmental conditions in the Arctic to be inadequate (National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling, 2011). Understanding the primary drivers for the region's potential aquatic resource degradation, which differ from the contiguous populated United States, is also important in order to apply the correct indicators to assess condition and trends resulting from climate change and future large-scale resource development. An important consideration is that a rapidly evolving climate may be presenting us with an ecosystem already in a state of flux (Wang et al., 2010).

Coastal Monitoring Data—Status of Coastal Condition

The geographic expanse of Alaska, the reduced sampling window in the Arctic regions, and the unique fiscal and logistical challenges of sampling the state's coastal resources (which are mostly inaccessible by road) necessitated a comprehensive federal-state sampling design. In 2001, under the NCA program, the Alaska DEC and EPA Region 10 developed a design to assess all of the state's coastal resources by monitoring 250 sites throughout the state during five phases—Southcentral Alaska, Southeastern Alaska, the Aleutian Islands, the Bering Sea, and the Beaufort Sea. In 2005, the Alaska DEC established the Alaska Monitoring and Assessment Program to conduct these marine surveys. As of 2010, the Southcentral Alaska, Southeastern Alaska, and the Aleutian Islands phases have been surveyed, and the plan has been modified to split the Arctic coastal phase into lower and upper Chukchi Sea and Beaufort Sea (Figure 8-5). The ability to complete the remaining phases and begin a repeat sampling for long-term trend analysis remains uncertain due to funding constraints. Before this collaboration between Alaska's resource agencies and the EPA, the Alaska DEC routinely assessed only about 1% of the state's coastal resources, focusing its efforts on water bodies known or suspected to be impaired (Alaska DEC, 1999). In June 2005, the Alaska DEC released its *Water Quality Monitoring and Assessment Strategy* and *Environmental Monitoring & Assessment Program Implementation Strategy* to guide its stewardship of Alaska's marine and freshwater resources (Alaska DEC, 2005a, 2005b).

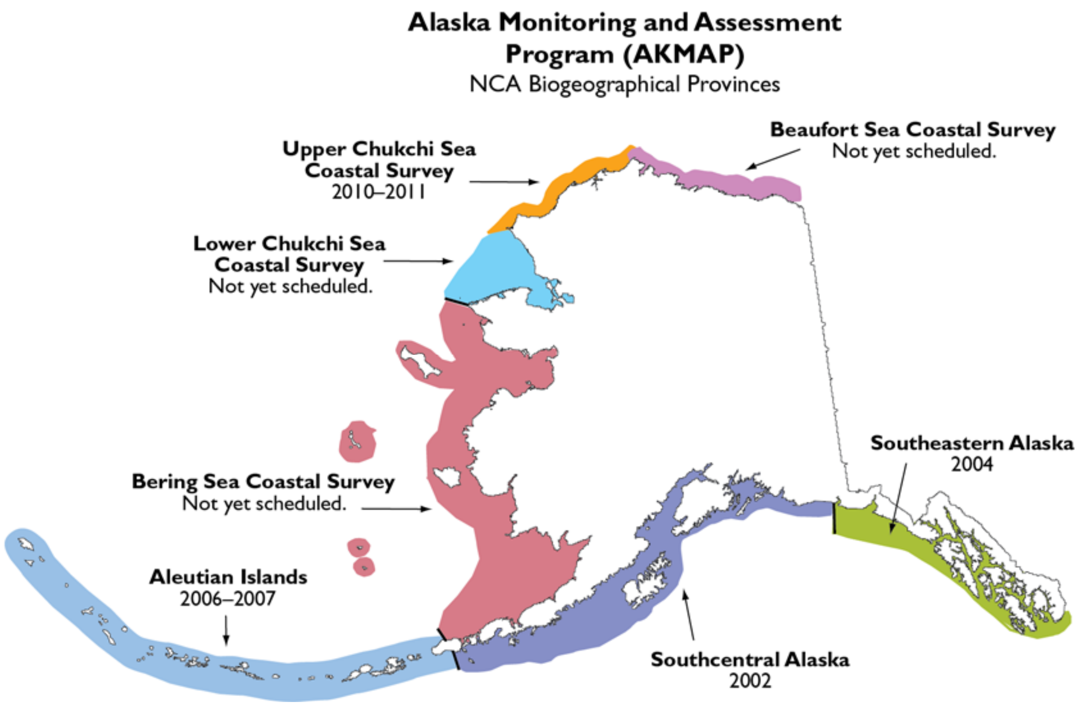


Figure 8-5. Alaska Monitoring and Assessment Program survey status (Alaska DEC, Division of Water).

In 2004, Alaska's southeastern coast (Alaskan Province) was the second portion of the state to be assessed by the NCA because of the importance of this area's major estuarine resources, high cruise-ship use, and importance to local and state economies. Because of the long distances between sites and the area that needed to covered, the surveys were conducted using a large (100-foot), oceangoing research vessel equipped with a powered skiff for shallow-water work. Depths ranged from approximately 60 to 1,500 feet for the 39 sites used to calculate this report's water quality and sediment indices.

Water Quality Index

The water quality index for the coastal waters of Southeastern Alaska is rated good. This index was developed based on measurement of five component indicators: DIN, DIP, chlorophyll *a*, water clarity, and dissolved oxygen. Most (95%) of the coastal area was rated good, with the remainder of the area rated fair (Figure 8-6). Fair conditions were largely due to low water clarity measurements or low dissolved oxygen concentrations, which are most likely the result of naturally occurring conditions and not human influences. Low water clarity measurements are associated with glacial silt input by nearby glaciers or river systems draining glaciated watersheds, and low dissolved oxygen levels are associated with deeper waters of fjords in this region.

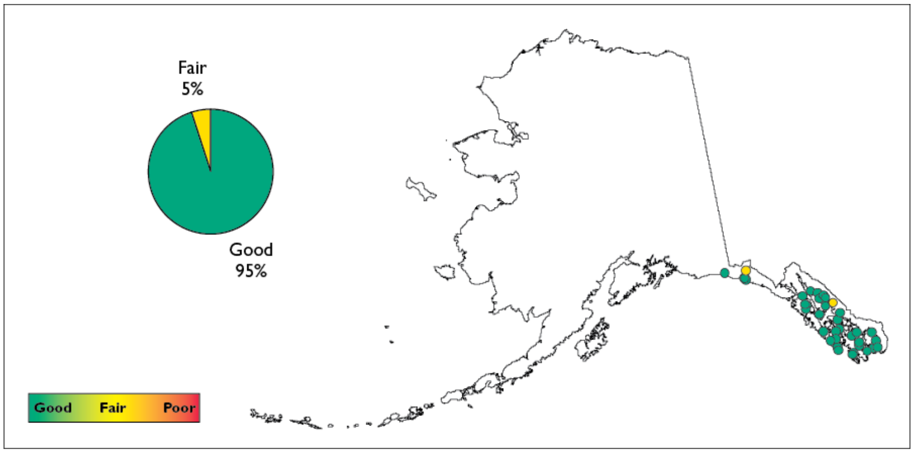


Figure 8-6. Water quality index data for Southeastern Alaska coastal waters (U.S. EPA/NCA).

Nutrients: Nitrogen and Phosphorus

Southeastern Alaska's coastal waters are rated good for DIN and DIP concentrations, with 97% of the coastal area rated good and 3% rated fair for both indicators. These rating were based on the NCA DIN and DIP cutpoints for the western United States (see Chapter 1). Although these cutpoints have been adjusted to reflect the effects of West Coast regional upwelling events, further work is needed to determine if these or alternate cutpoint values are the best to apply to Southeastern Alaska coastal waters. The 3% of the area rated fair should be considered a provisional assessment. Given the low human population density in Southeastern Alaska, the fair values may reflect an upper range of natural conditions rather than human influences.

Chlorophyll *a*

Chlorophyll *a* concentrations in Southeastern Alaska's coastal waters are rated good, with 100% of the coastal area rated good for this component indicator.

Water Clarity

Water clarity in the coastal waters of the Southeastern Alaska region is rated good, with 5% and 3% of the coastal area, respectively, rated fair and poor for this component indicator. Water clarity was rated poor at a sampling site if light penetration at 1 meter was less than 10% of surface illumination.

Dissolved Oxygen

Dissolved oxygen conditions in the coastal waters of Southeastern Alaska are rated good, with 95% of the coastal area rated good and 5% rated fair for this component indicator. Although conditions in the

Southeastern Alaska region appear to be generally good for dissolved oxygen, the measured values reflect surface conditions and do not include natural hypoxic conditions in the deep fjords sampled.

Sediment Quality Index

The sediment quality index for the coastal waters of Southeastern Alaska is rated good, with 8% of the coastal area rated fair (Figure 8-7). The sediment quality index was calculated based on measurements of three component indicators: sediment toxicity, sediment contaminants, and sediment TOC.

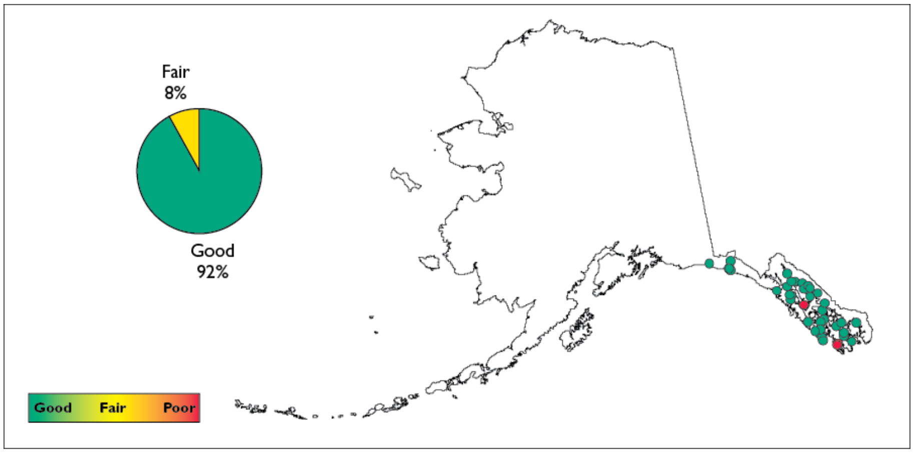


Figure 8-7. Sediment quality index data for Southeastern Alaska coastal waters (U.S. EPA/NCA).

Sediment Toxicity

Sediment toxicity for Southeastern Alaska coastal waters is rated good, with none of the coastal area rated poor. Sediment toxicity was determined using a static, 10-day acute toxicity test with the amphipod *Ampelisca abdita*. Although use of *Ampelisca* standardizes the sediment toxicity test within the EMAP/NCA process, this test may or may not reflect the actual response of the specific benthic organisms indigenous to Southeastern Alaska. The State of Alaska has yet to select specific benthic species for use in sediment toxicity studies but considers the NCA work important in supporting future efforts to develop a sediment toxicity test for Alaska.

Guidelines for Assessing Sediment Contamination (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 values for each chemical as the 10th percentile in a database of ascending concentrations associated with adverse biological effects.

Sediment Contaminants

The coastal waters of Southeastern Alaska are rated good for the sediment contaminants component indicator, with approximately 2% of the coastal area rated poor and approximately 3% of the area rated fair. It should be noted that this evaluation of sediment contamination excluded nickel because the ERM value for this metal has a low reliability for areas of the West Coast, where high natural crustal concentrations of nickel exist (Long et al., 1995). A study of metal concentrations in cores collected along the West Coast determined the range of historic background concentrations of nickel to be 35–70 ppm (Lauenstein et al., 2000), which brackets the value of the ERM (51.6 ppm). Some researchers have also suggested that West Coast crustal concentrations for mercury may be naturally elevated; however, no conclusive evidence is available to support this suggestion. Therefore, mercury data were not excluded from this assessment of Southeastern Alaska's coastal waters. In addition, only one exceedance was counted if a site exceeded the ERL for low molecular weight PAHs, high molecular weight PAHs, and/or total PAHs to ensure that the analysis was not biased by PAHs.

Sediment TOC

The coastal waters of Southeastern Alaska are rated good for the sediment TOC component indicator, with 11% of the area rated poor, 26% rated fair, and 63% rated good.

Benthic Index

The benthic index for the coastal waters of Southeastern Alaska could not be evaluated. Although several efforts are underway and indices of benthic community condition have been developed for some regions of the West Coast (e.g., Smith et al., 1998), there is currently no benthic community index applicable for Southeastern Alaska. In lieu of a benthic index for Southeastern Alaska, the deviation of species richness from an estimate of expected species richness was used as an approximate indicator of the condition of the benthic community. This approach requires that species richness be predicted from salinity, and, in the case of the Southeastern Alaska survey data, the regression was not significant.

Coastal Habitat Index

The coastal habitat index for Alaska is rated good. Although estimates of habitat loss are available for Alaska as a whole, data were not available to correspond with the geographic region sampled by the NCA survey (i.e., Southeastern Alaska); therefore, overall trends for the whole state are presented. The Alaska coast region experienced a loss of 900 acres (0.04%) of coastal wetlands from 1990 to 2000 (Dahl, 2010), and the statewide, long-term, average decadal wetlands loss rate is 0.01%. Arctic coastal wetlands may be especially vulnerable to climate change. Average annual erosion rates in some coastal areas of northern Alaska have increased from 20 feet per year in the 1950s to 45 feet per year in the mid-2000s (Jones et al., 2009).

Fish Tissue Contaminants Index

The fish tissue contaminants index for the coastal waters of Southeastern Alaska is rated good, with 6% of the stations where fish were caught rated fair and none of the stations rated poor (Figure 8-8).

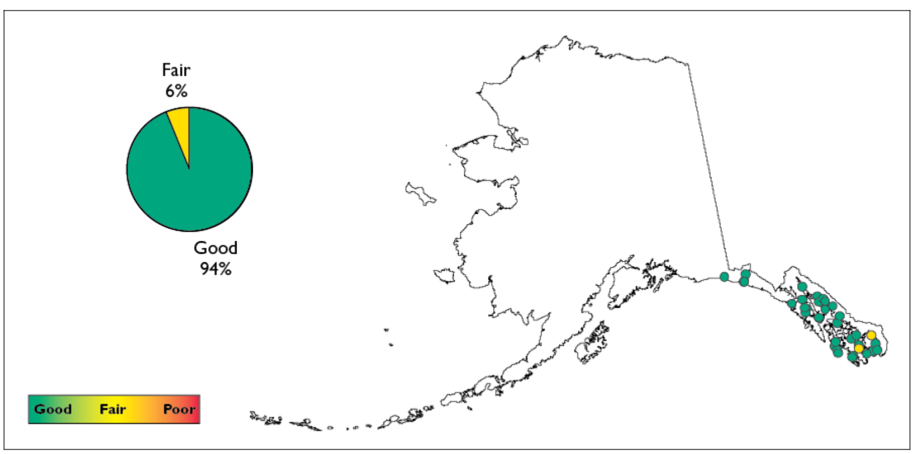


Figure 8-8. Fish tissue contaminants index data for Southeastern Alaska coastal waters (U.S. EPA/NCA).

Large Marine Ecosystem Fisheries—Gulf of Alaska and East Bering Sea LMEs

Alaska is surrounded by five sub-arctic LMEs: Gulf of Alaska, East Bering Sea, West Bering Sea, Chukchi Sea, and Beaufort Sea (Figure 8-9). The total commercial fishery landings in all five of Alaska's LMEs generated over $4.8 billion in total ex-vessel revenues (preprocessing value) from 2003 to 2006 (NMFS, 2010). This summary focuses on two of these LMEs, the East Bering Sea LME and the Gulf of Alaska LME, in order to provide an update of the information presented in NCCR III. The East Bering Sea LME is considered to have moderately high productivity based on estimates of primary production (photoplankton). The ability of many East Bering Sea LME juvenile fish and crabs to reach harvest size is linked to decadal-scale patterns of climate variability (Minobe and Mantua, 1999). Like the East Bering Sea, the Gulf of Alaska LME is sensitive to climate variations on time scales ranging from years to decades. These variations and large-scale atmospheric and oceanographic conditions have an effect on the overall productivity of the LME, including plankton production and plankton species composition. The Gulf of Alaska LME is considered a moderately productive ecosystem with nutrient-rich waters that support rich biological diversity.

Figure 8-9. Alaska is surrounded by five LMEs (NOAA, 2010b).

The groundfish (bottom-dwelling fish) complex (mostly pollock, halibut, cod, and sablefish) is the most important in terms of both landings and revenue for Alaskan commercial fishermen, generating nearly $2.9 billion in total ex-vessel revenues from 2003 through 2006. Walleye pollock dominates this group, with harvests worth over $1.1 billion during the same period. The other top fisheries are for salmon, with total commercial ex-vessel revenues of nearly $1 billion from 2003 through 2006, and for crab, with revenues over $500 million for this same period (NMFS, 2010). See Figure 8-10 for landing and revenues of the top commercial fisheries for Alaska. Fisheries within Alaskan LMEs are managed through a combination of international commissions, federal councils, and state and tribal agencies.

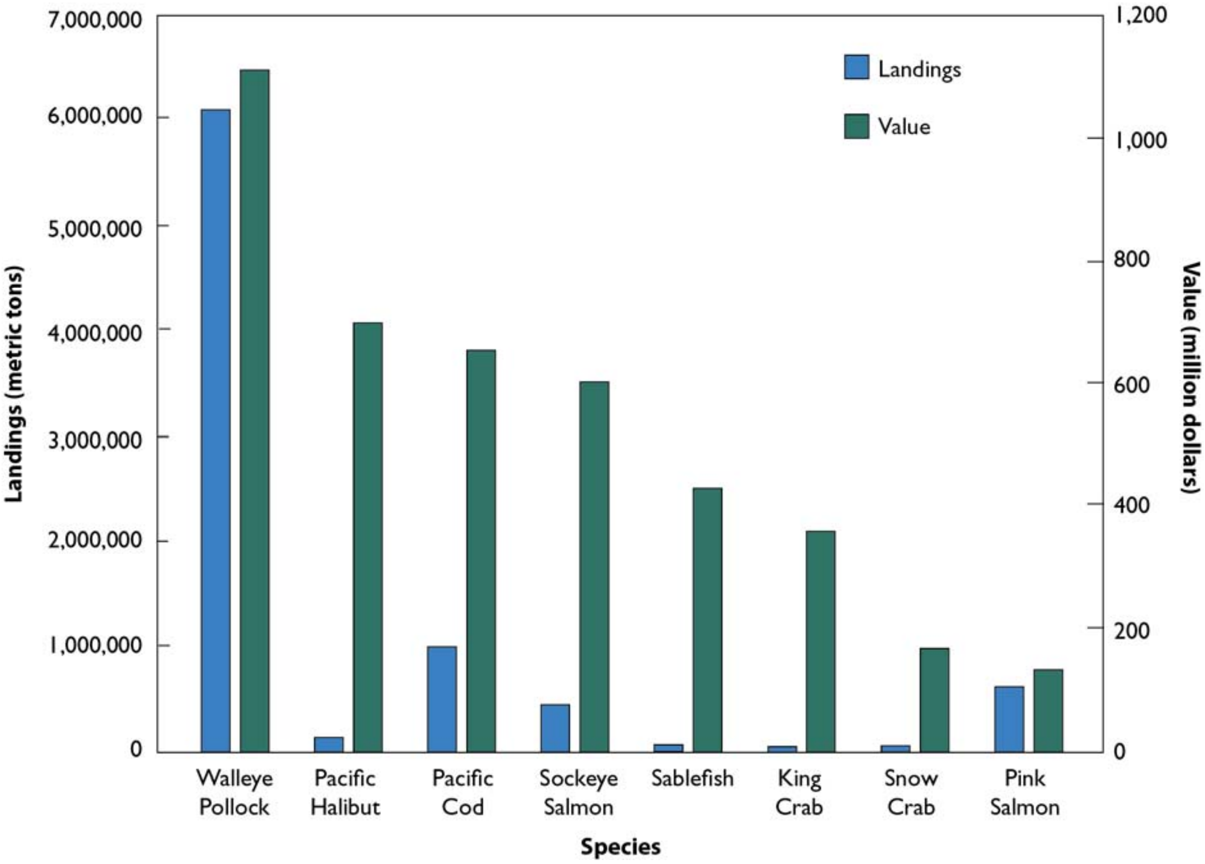


Figure 8-10. Top commercial fisheries for Alaska's LMEs: landings (metric tons) and value (million dollars) from 2003 to 2006 (NMFS, 2010).

Alaska Groundfish Fisheries

The groundfish complex is the most abundant fisheries resource off Alaskan LMEs, with a combined biomass of more than 21.8 million metric tons. About 76% of the biomass is found in the East Bering Sea LME, with the remainder in the Gulf of Alaska LME. From 2004 to 2006, groundfish catches averaged nearly 2.2 million metric tons, or about 10% of the total groundfish biomass. The dominant species harvested were walleye pollock (75%), Pacific cod (11%), yellowfin sole (4%), Atka mackerel (3%), and rock sole (2%) (NMFS, 2009b). In terms of commercial fishing revenue, the top groundfish species are walleye Pollock (*Theragra chalcogramma*), Pacific halibut (*Hippoglossus stenolepis*), Pacific cod (*Gadus macrocephalus*), and sablefish (*Anoplopoma fimbria*); the discrepancy resulting from higher market prices for these species. Walleye pollock catches are the largest of any single species within the U.S. EEZ, with average landings over 1.5 million metric tons and total revenues of $1.1 billion from 2003 through 2006 (see Figure 8-10). During this same period, revenues from other top groundfish fisheries, including Pacific halibut, Pacific cod, and sablefish, were $697 million, $652 million, and $424 million, respectively (see Figure 8-10) (NMFS, 2010).

As a species group, groundfish inhabit near-bottom waters, with diets that include all sorts of species of invertebrates and vertebrates, depending on their role within the water column. These fish are generally harvested for direct human consumption, with various gear types. The North Pacific Fisheries Management Council manages Alaska groundfish fisheries within the U.S. EEZ, beyond state waters (0–3 miles), which are managed by the Alaska Department of Fish and Game. Pacific halibut is managed by a bilateral treaty between the United States and Canada, and through the recommendations of the International Pacific Halibut Commission.

East Bering Sea LME Groundfish

The groundfish FMP (NPFMC, 2010a) for the East Bering Sea LME caps catch quotas for this group at 2 million metric tons. Current landings for walleye pollock are 1.4 million metric tons in the East Bering Sea and 44,500 metric tons in the Aleutian Islands. Recent trends indicate that the stock has declined since 2003 due to poor survival rates of juveniles from 2001 through 2005 (NMFS, 2009b). However, surveys conducted in 2010 show positive changes. The 2010 bottom trawl survey biomass estimate for pollock was 3.75 million metric tons, up 64% from the 2009 estimate, but still below average for the 1987–2010 time series. The estimate from the acoustic-trawl survey was 2.32 million metric tons, up 151% from the 2009 estimate, but still below average for the 1979–2010 time series (NPFMC, 2010b). Management of this fishery has produced differing results throughout Alaskan waters, with some areas, including the Bogoslof Island region and the Aleutian Islands, experiencing long-term fishery closures. On the other hand, the East Bering Sea stock is considered fully utilized and is well managed for by-catch and other issues, such as minimizing impacts on Steller sea lion populations and benthic habitats (NMFS, 2009b).

Another management issue in this LME is the pollock fishery occurring in the "Donut Hole" area of the Bering Sea. It has come under regulation with the implementation of the Convention on the Conservation and Management of Pollock Resources in the Central Bering Sea in 1997. Under this Convention, signed by the Russian Federation, Japan, Poland, China, the Republic of Korea, and the United States, a central Bering Sea pollock fishery has not been authorized because of low biomass of the Aleutian Basin Pollock stock.

Pollock, Atka mackerel, and Pacific cod are carefully managed and regulated due to concerns about the impact of fisheries on endangered and threatened Steller sea lions, which feed on pollock. The impact of fish removals on Steller sea lions has been implicated as an important factor in the decline of sea lion populations. NMFS has proposed some alternatives to disperse the intensity of pollock, Atka mackerel, and Pacific cod fisheries in the critical habitat of sea lions and have enacted additional prohibitions, including 10–20 nautical mile no-trawl zones around sea lion rookeries and haul-out areas.

Gulf of Alaska LME Groundfish

Groundfish abundance in the Gulf of Alaska LME in 2007 was 5.3 million metric tons, primarily due to increasing arrowtooth flounder biomass. From 2004 to 2006, the recent average yield was just over 188,000 metric tons, with catches dominated by walleye pollock, flatfish, Pacific cod, and rockfish. The Pacific cod stock is considered healthy but declining and is fully utilized. Flatfishes in the LME are in general very abundant and underutilized due to halibut by-catch considerations, while rockfish stocks in general appear to be in good condition due to precautionary management practices. Current landings for walleye pollock from the Gulf of Alaska are approximately 68,000 metric tons. Pollock abundance in the Gulf of Alaska LME is at a low level and may be negatively impacted by increases in predatory fish species in this LME.

Alaska Salmon

Pacific salmon have played an important role in the Gulf of Alaska and East Bering Sea LMEs. For Alaska native peoples, salmon is an economic, cultural, and subsistence necessity (Betts and Wolf, 1992). Subsistence use accounts for around one million fish per year (Alaska DFG, 2005; NPAFC, 2005).

Commercial salmon harvests have increased over the past three decades, reaching an all time high in 2005 at 22 million metric tons of salmon (NMFS, 2009b). Sockeye (*Oncorhynchus nerka*) is the most lucrative salmon species for Alaska's LMEs, yielding over $604 million in total commercial fishery revenues from 2003 to 2006 (see Figure 8-10). Sockeye salmon provide a greater dollar value than all other commercially caught salmon in Alaskan LMEs combined, usually yielding between 60% and 70% of the ex-vessel value of the annual harvest. Bristol Bay sockeye salmon in the East Bering Sea LME is the most valuable wild-capture fishery for salmon in the world. The second-largest commercial salmon fishery is for pink salmon (*Oncorhynchus gorbuscha)*, which generated about $130 million in total ex-vessel revenues from 2003 to 2006 and has the greatest landings in tons of all the salmon species (see Figure 8-10), accounting for 40% to 70% of the total harvest each year, mostly harvested by purse seines.

All five species of Alaskan salmon (pink, sockeye, chum, coho, and Chinook) are fully utilized, and stocks in the Gulf of Alaska and East Bering Sea LMEs have rebuilt to near or beyond previous high levels. The factors contributing to the current high abundance of Alaska salmon in the two LMEs are the following:

- Pristine habitats with minimal impacts from extensive development;
- Generally favorable oceanic conditions that allow high survival of juveniles;
- Improved fisheries management by state and Federal agencies;
- Elimination of high-seas drift-net fisheries by foreign nations;
- A well managed hatchery

Although commercial harvests of salmon have been at high levels in recent years, the value of the catch has declined significantly. Along with this general decline is a rising trend in total worldwide salmon production, due to a rapid growth of the worldwide production of farmed salmon, in addition to the record catches of wild salmon (including fish produced from hatcheries and ocean ranching programs) in Alaskan, Japanese, and Russian waters. Total world production from capture and farmed fisheries in 2002 was about 1.8 million metric tons, including 983,000 metric tons of farmed salmon. Over 70% of the farmed production of salmon comes from Norway, Chile, and the United Kingdom (Knapp, 2003).

Since salmon are highly mobile species that traverse international boundaries, management of these fisheries is best conducted on a multilateral basis. For example, management of some Gulf of Alaska LME salmon fisheries has been negotiated with Canada under the 1985 Pacific Salmon Treaty, though some issues regarding transboundary catches remain. On a broader international scale, the need to manage the salmon harvest in the high seas led to the establishment of the North Pacific Anadromous Fish Commission in 1993. Because salmon are anadromous (migratory) and spend a portion of their lives in freshwater streams, rivers, and lakes, the health of salmon populations in Alaskan LMEs is directly influenced by land management practices. The quality of freshwater habitats determines the success of both reproduction and initial rearing of juveniles.

Alaska Shellfish Fisheries

Shellfish landings in 2006 generated an estimated ex-vessel value of over $153 million, with king and snow crab accounting for a majority of this value, about $127 million (NMFS, 2010). Three king crab species (red, blue, and golden or brown), snow crab (*C. opilio*), and southern Tanner crab have traditionally been harvested commercially in Alaskan LMEs. Alaska crab resources are considered to be fully utilized. The recent average yields for king (10,537 metric tons) and snow (14,711 metric tons) crabs were below their respective sustainable yields (NMFS, 2009b). The harvest of snow crab has been lower than the sustainable yield since 2000 due to low abundance and lower harvest rates established under a rebuilding plan. Almost all recent crab production came from the East Bering Sea LME, because almost all Gulf of Alaska king crab fisheries have been closed since 1983.

Because shellfish are generally landed within the three-mile boundary of state waters, the Alaska Department of Fish and Game is the primary management authority for a majority of Alaska shellfish resources. Seasonal closures are set to avoid fishing during times when crabs are molting or mating, and during soft-shell periods. These regulations are in place both to protect the crab resource and to maintain product quality.

Fishery Trends and Summary

Figure 8-11 shows landings of the walleye pollock commercial fishery in Alaska from 1950 to 2006 in metric tons. The walleye pollock fishery is displayed on a separate graph because catches of this species are too large to display on the same scale as the rest of Alaska's fisheries. Until 1975, harvests in the walleye pollock fishery were not reported on the individual species level. This fishery witnessed tremendous growth in catches from the mid 1980s to 1990. Despite net declines in the 1990s, landings in the walleye pollock fishery rebounded in 2000, with recent harvests above 1.5 million metric tons (NMFS, 2010).

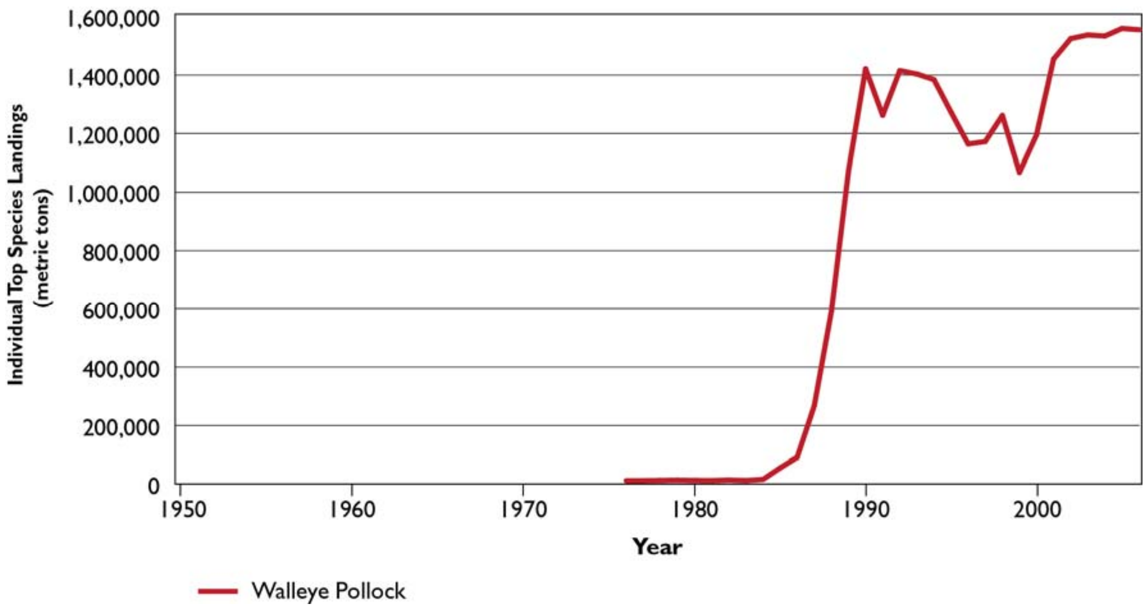


Figure 8-11. Landings of walleye pollock commercial fishery in Alaska from 1950 to 2006, metric tons (NMFS, 2010).

Figure 8-12 displays landings of the other top commercial fisheries in Alaska from 1950 to 2006. In terms of landed tons, the Pacific cod fishery ranks second amongst the top commercial species in Alaska. Harvests in this fishery peaked in the mid 1990s at just over 300,000 metric tons, declined for several years, and despite increasing again from 2000 to 2003, have been in general decrease for the past several years, with 2006 landings at about 240,000 metric tons. Both of the top commercial salmon species (sockeye and pink) currently have landings of about 100,000 metric tons. This represents a significant decline for pink salmon, which peaked at 225,000 metric tons in 2004. Landings of Pacific halibut remain around 35,000 metric tons, where they have hovered for the past two decades. Both crab fisheries (snow and king) have had stabilized landings around 25,000 metric tons since 2000. Although no species-specific data were available for the snow crab fishery until 1980, this fishery has witnessed a severe decline since peaking in the early 1990s at about 150,000 metric tons. Landings in the sablefish fishery have remained under 50,000 metric tons since species-specific data became available in the mid-1980s.

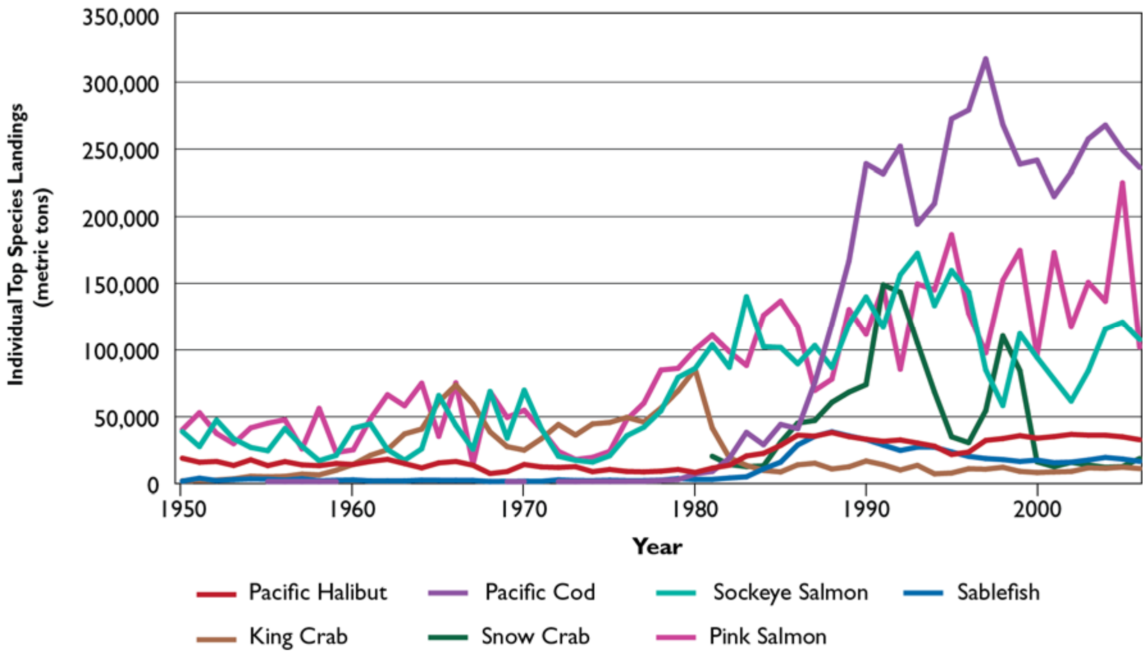


Figure 8-12. Landings of the top commercial fisheries in Alaska from 1950 to 2006, metric tons (NMFS, 2010).

Like other LMEs, Alaska's five LMEs are economically important, generating over $4.8 billion from 2003–2006 (NMFS, 2010). In addition to the large commercial and recreational fisheries that also contribute to the Alaskan economy, there are subsistence fisheries that are important to native Alaskans. This cultural ecosystem service is difficult to quantify in terms of money, but is very important to the health, well being, and cultural identity of native Alaskans. Tourism and recreational fisheries are also important contributors to the Alaskan economy.

Advisory Data

Fish Consumption Advisories

In 2006, no consumption advisories were in effect for chemical contaminants in fish and shellfish species harvested in Alaskan waters (U.S. EPA, 2007c).

Beach Advisories and Closures

How many notification actions were reported for Alaska between 2004 and 2008?

Table 8-1 presents the number of total beaches and monitored beaches, as well as the number and percentage of monitored beaches affected by notification actions from 2005 to 2008 for Alaska. Alaska's beach monitoring program remains limited. The total number of beaches identified and the number monitored has increased from 2 to 3 between 2005 and 2008. Of these monitored beaches, the percentage closed or under advisory for some period of time during the year has decreased from 100% to 0% (U.S. EPA, 2009d). Annual national and state summaries are available on EPA's Beaches Monitoring site: http://www.epa.gov/waterscience/beaches/seasons/.

Table 8-1. Beach Notification Actions, Alaska, 2004–2008 (U.S. EPA, 2009d)

Numbers and Percentages	2004	2005	2006	2007	2008
Total number of beaches	No data	2	3	3	3
Number of monitored beaches	No data	2	3	3	3
Number of beaches affected by notification actions	No data	2	0	0	0
Percentage of monitored beaches affected by notification actions	No data	100%	0%	0%	0%

What pollution sources impacted monitored beaches in Alaska?

Table 8-2 presents the numbers and percentages of monitored beaches in Alaska that were affected by various pollution sources in 2007. States can identify potential reasons for beach advisories even if they do not issue any notification actions. Alaska reported that both publicly owned treatment works and sanitary/combined sewer overflow affected 33%, or one, of its beaches. For two of the beaches, "no known pollution sources" caused concern (U.S. EPA, 2009d).

Table 8-2. Reasons for Beach Advisories, Alaska, 2007 (U.S. EPA, 2009d)

Reason for Advisories	Total Number of Monitored Beaches Affected	Percent of Total Monitored Beaches Affected
No known pollution sources	2	67%
Publicly owned treatment works	1	33%
Sanitary/combined sewer overflow	1	33%

Note: A single beach may have multiple sources.

Since Alaska did not report any advisories or closure notifications for 2007, there is no information on beach advisory duration (U.S. EPA, 2009d). For more information on state beach closures, please visit EPA's Beaches website: http://www.epa.gov/beaches/plan/whereyoulive_state.html.

Hawaii

The overall condition of Hawaii's coastal waters is rated fair based on assessment of two of the indices assessed by NCA (Figure 8-13). The water quality index is rated good, and the sediment quality index is rated poor. The overall rating of fair represents a change from a rating of good from the 2002 NCA survey of Hawaii. The NCA was unable to evaluate the benthic, coastal habitat, or fish tissue contaminant indices for Hawaii's coastal waters in the 2006 survey, and this limitation should be considered when interpreting the overall condition score for the state. Figure 8-14 provides a summary of the percentage of coastal area in good, fair, and poor categories for each index and component indicator. This assessment is based on environment stressor and response data collected under the NCA program, in conjunction with the Hawaii Department of Health and the University of Hawaii, from 50 locations along the main islands of the Hawaiian chain in 2006.

Please refer to Chapter 1 for information about how these assessments were made, the cutpoints used to develop the rating for each index and component indicator, and limitations of the available data.

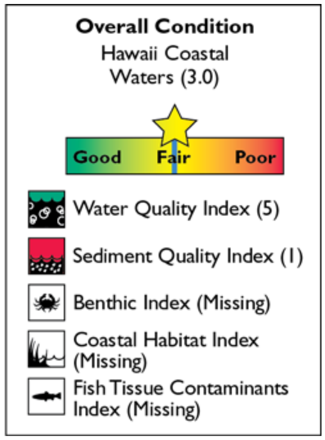


Figure 8-13. The overall condition of Hawaii coastal waters is rated fair (U.S. EPA/NCA).

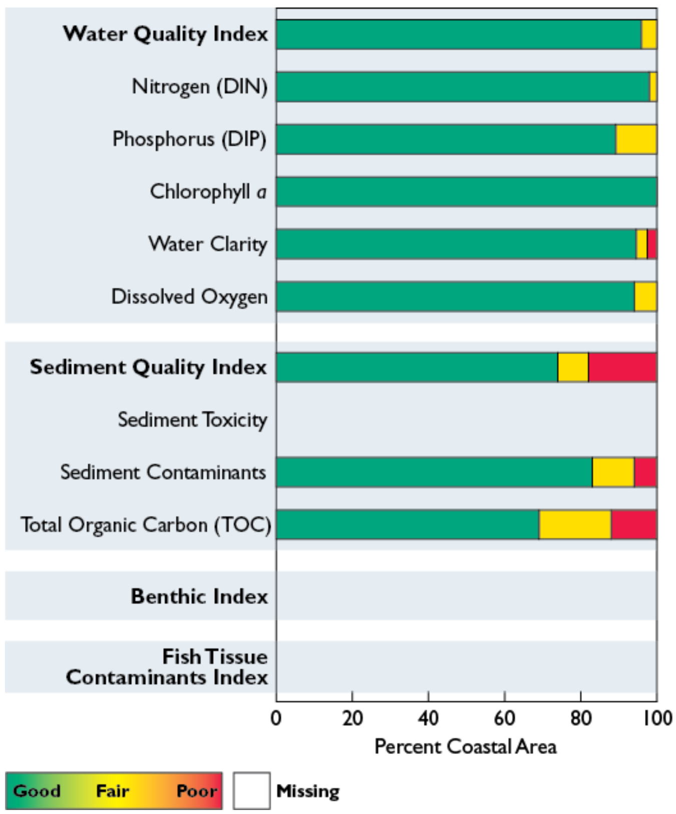


Figure 8-14. Percentage of coastal area achieving each ranking for all indices and component indicators—Hawaii (U.S. EPA/NCA).

Compared to other regions considered in the NCCR IV, estuaries are a small, but ecologically significant, component of Hawaii's coastal resources. These coastal waters represent less than 1% of the coastal ocean area around the Hawaiian Islands and are best developed on the older islands (Kauai and Oahu). Pearl Harbor, with a surface area of approximately 22 square miles, is one of the country's largest naval ports, and is also the largest remaining Hawaiian estuary. Most of Hawaii's estuaries are small, occupying less than 0.5 square miles. Historically, these coastal waters were more significant than they are today.

For example, in the Moiliili-Waikiki-Kewalo districts of Honolulu on Oahu, approximately 48% of the land area was occupied by wetland/estuarine habitat in 1887. Today, these aquatic features are absent, and the remaining estuarine waters are channelized conduits that rapidly transport stormwater runoff to the sea (Cox and Gordon, 1970; Meier et al., 1993).

Corals covered with sediment in Maunalua Bay, Oahu.

(Source http://hawaii.gov/dlnr/dar/coral/coral_las_lbsp.html Hawaii Division of Aquatic Resources)

Estuaries serve as important nursery habitat for a number of commercial and recreational Hawaiian fishery resources. Several species that are estuarine-dependent are important to the economy of Hawaii, including mullet, milkfish, shrimp, and the nehu, a tropical anchovy used as live bait in the pole-and-line skipjack tuna fishery. In the Hawaii NCA, the coastal area assessed included semi-enclosed coastal embayments, in addition to the more spatially limited true estuaries. These embayments often include nearshore coral reef habitats, which are highly important to Hawaii, both ecologically and economically. The direct economic benefits of Hawaii's coral reefs have been estimated as $360 million per year (Friedlander et al., 2008).

Continued increases in population and economic growth will tend to exacerbate the impacts to native ecosystems because of the relatively small land area of the Hawaiian Islands. Changing land uses, such as reduction of agriculture and increased residential and commercial development, may alter the magnitude and types of stressors that impact the coastal waters of Hawaii. Problems associated with runoff (e.g., sediments, nutrients, bacteria, toxics) may be especially acute in the coastal areas of Hawaii because of the combination of steeply sloped coastal watersheds and high seasonal rainfall (Cox and Gordon, 1970; Meier et al., 1993). Sediment run off is probably the most important stressor on coral reef habitats in the coastal embayments (Friedlander et al., 2008).

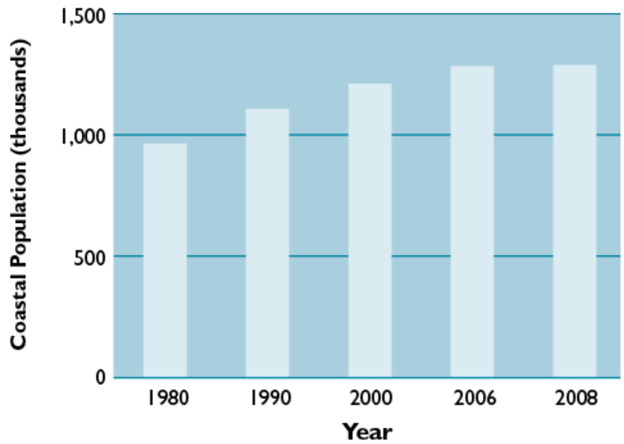


Figure 8-15. Population of Hawaiian counties, all of which are coastal, from 1980 to 2008 (NOEP, 2010).

Between 1980 and 2006, the Hawaiian population increased by 33%, from 0.96 million to 1.11 million people (Figure 8-15) (NOEP, 2010). Figure 8-16 shows a map of population density in 2006 for Hawaiian counties. The principal population and commercial center for the Hawaiian Islands is located on the south shore of Oahu in an area encompassing Pearl Harbor, the Port of Honolulu, and several other estuaries or embayments. Some 70% of the population of Hawaii lives on Oahu (Crossett et al., 2008). The coastal systems on the south shore of Oahu are often highly altered and surrounded by a high-density, urban setting. The rest of the Hawaiian Islands have a much lower population density. Honolulu County has a population density of 1,551 persons per square mile, while the second-most populous county is Maui, with a density of 126 persons per square mile (Crossett et al., 2008). The average population density for Hawaii's counties, all of which are coastal, has increased from 150 persons per square mile in 1980 to 200 persons per square mile in 2006 (NOEP, 2010). Although one might presume that the magnitude of anthropogenic impacts would be highest in the urbanized estuaries of Oahu, there are also potential areas of anthropogenic impacts in other areas of the Hawaiian Islands.

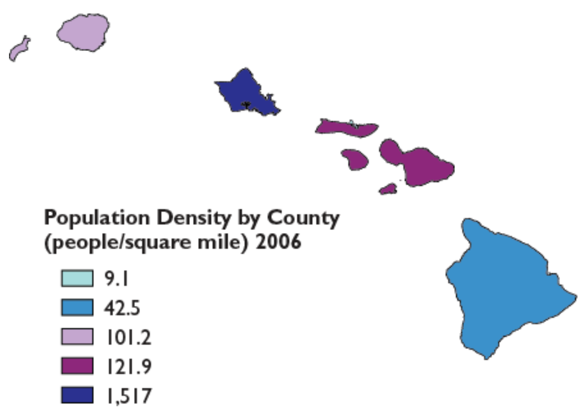


Figure 8-16. Population density of Hawaii's counties in 2006 (NOEP, 2010).

Coastal Monitoring Data—Status of Coastal Condition

Hawaii does not yet have a comprehensive coastal monitoring program. Coral reef monitoring activities are probably the most spatially and temporally extensive and are summarized in Friedlander et al. (2008). Most coastal resource monitoring is targeted to address specific bays and/or issues, such as nonpoint-source runoff and offshore discharges. For example, Mamala Bay has been sampled intensively since 1983 to examine effects of wastewater treatment plant (WWTP) outfalls from Oahu into the Bay (Ambrose et al., 2009). The NCA conducted the first comprehensive, probability-based survey of the coastal condition of Hawaii in 2002, sampling 50 stations across the main islands and 29 stations within the urbanized estuaries of Oahu (Nelson et al., 2007b). The 2006 assessment of coastal waters of Hawaii was restricted to the main Hawaiian Islands and did not include the waters of the Northwestern Hawaiian Islands. The coastal waters assessed for the main Hawaiian Islands included estuaries, lagoons, and harbors, as well as more open coastal embayments.

Water Quality Index

The water quality index for Hawaii's coastal waters is rated as good in the 2006 survey. This index was developed based on measurements of five component indicators: DIN, DIP, chlorophyll *a*, water clarity, and dissolved oxygen. Most (96%) of the coastal area was rated good for water quality condition, with 4% of the area was rated fair and no area rating poor (Figure 8-17). The two instances of fair condition ratings were driven by a poor rating for the water clarity component indicator at a station in Pearl Harbor and a poor rating for the DIN component indicator at a station in Hilo Bay.

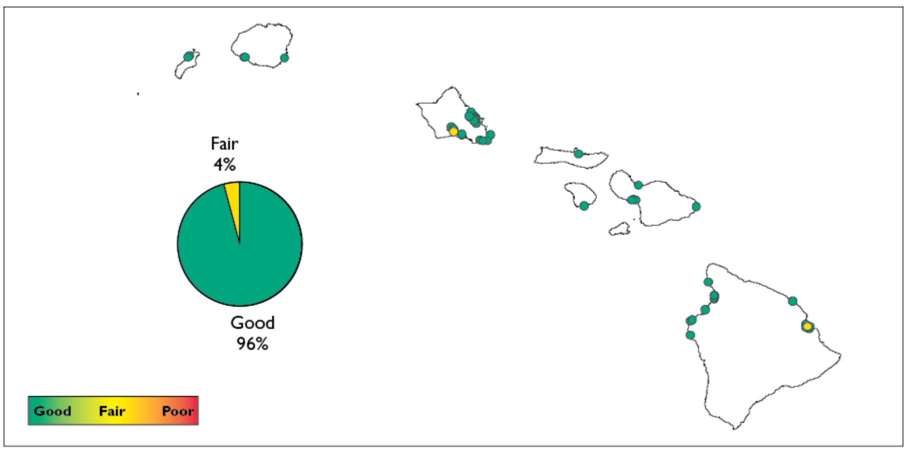


Figure 8-17. Water quality index data for the Hawaii coastal waters (U.S. EPA/NCA).

Nutrients: Nitrogen and Phosphorus

Hawaii's coastal waters are rated good for DIN concentrations, with only 2% of the coastal area rated fair for this component indicator. Hawaii's coastal waters are also rated good for DIP concentrations, with 11% of the coastal area rated fair for this component indicator.

Chlorophyll *a*

Hawaii's coastal waters are rated good for chlorophyll *a* concentrations, with 100% of the coastal area rated good.

Water Clarity

Water clarity in Hawaii's coastal waters is rated good. Water clarity was rated poor at a sampling site if light penetration at 1 meter was less than 20% of surface illumination. Approximately 2% of the coastal area was rated poor and 3% of area was rated fair for this component indicator. The single site rated poor for water clarity was in Pearl Harbor, and the single site rated fair was in Keehi Lagoon, a boat basin near downtown Honolulu.

Dissolved Oxygen

Dissolved oxygen conditions in Hawaii's coastal waters are provisionally rated good, with only 6% of the area rated fair and none of the coastal area rated poor for this component indicator. An equipment malfunction with the dissolved oxygen probe occurred during the sampling of several of the Hawaiian Islands, in particular the island of Hawaii. Data were collected for dissolved oxygen at only 26 stations, and thus the magnitude of confidence limits is larger than the NCA target. The sites rated fair were located in Pearl Harbor (1 site) and Kaneohe Bay (1 site), with the dissolved oxygen concentration at the latter location just below 5 mg/L. Although conditions in Hawaii appear to be generally good for dissolved oxygen, measured values reflect daytime conditions, and some areas with restricted circulation may still experience hypoxic conditions at night.

Sediment Quality Index

The sediment quality index for Hawaii's coastal waters is rated poor, with 8% of the coastal area rated fair and 18% of the area rated poor for sediment quality condition (Figure 8-18). The sediment quality index in 2006 was calculated based on measurements of only two component indicators: sediment contaminants and sediment TOC. The sediment toxicity bioassay organism used by NCA in 2006 was not deemed appropriate for the sediments found in Hawaii. High levels of TOC contributed more stations rated as poor (5) than did sediment contaminants (2), and this was also the case for stations rated fair (8 vs. 5).

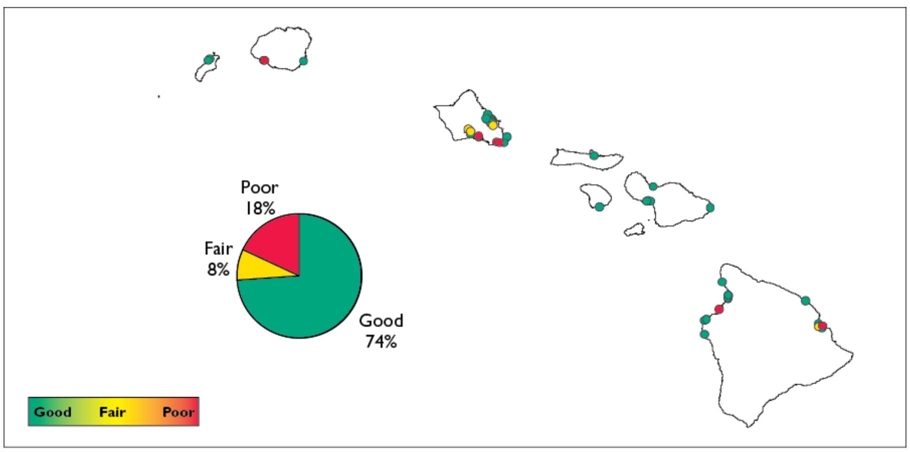


Figure 8-18. Sediment quality index data for Hawaii coastal waters (U.S. EPA/NCA).

Sediment Toxicity

The sediment toxicity component indicator was not measured in 2006 because the sediment toxicity bioassay organism used by NCA in 2006 was not deemed appropriate for the sediments found in Hawaii.

Sediment Contaminants

Hawaii's coastal waters are rated fair for sediment contaminant concentrations, with 11% of the coastal area rated fair and 6% of the area rated poor for this component indicator. The two sites rated poor were located in Waimea Bay, Kauai, where the ERM for chromium was exceeded. The sites rated fair were primarily in Pearl Harbor and other harbor areas such as Keehi Lagoon on Oahu and Hilo Bay on Hawaii, resulting from exceedances of the ERL for metals and some individual PAHs. Nickel was excluded as a component of the sediment contamination index because the ERM value for this metal has a low reliability for areas where high natural crustal concentrations of nickel exist (Long et al., 1995). A study of metal concentrations in cores collected along the U.S. West Coast determined the range of historic background concentrations of nickel to be 35–70 ppm (Lauenstein et al., 2000), which brackets the value of the ERM (51.6 ppm).

Sediment TOC

The coastal waters of Hawaii are rated good for the sediment TOC component indicator. A total of 12% of the coastal area was rated poor, and 19% of the area was rated fair. Sites rated poor for sediment TOC were located in waters off the suburban development of Hawaii Kai east of Honolulu, Keehi Lagoon, and Hilo Bay. The majority of sites rated fair were located in Kaneohe Bay on Oahu.

Benthic Index

A benthic index for Hawaii is not currently available.

Coastal Habitat Index

As was the case in the 2002 survey, the quantitative estimates of coastal habitat loss from two time periods are still not available for Hawaii; therefore, a coastal habitat index could not be calculated. The best available estimate of total wetland loss in Hawaii is 12% over the period 1780–1980 (Dahl, 1990), and no separate estimate for coastal wetlands was provided.

Fish Tissue Contaminants Index

The fish tissue contaminant index was not assessed in the 2006 survey. In the 2002 survey, a feasibility study was conducted to determine whether sea cucumbers could be utilized to assess tissue body burdens. Results had a high degree of uncertainty because of small sample size, and analytical issues were present with the tissue matrix. Fish and shellfish contaminant studies have been limited in Hawaii (Friedlander et al., 2008). Evidence of elevated levels of some metals was observed in outplanted oysters near stream mouths in the southern portion of Kaneohe Bay, Oahu (Hunter et al., 1995).

Trends of Coastal Monitoring Data—Hawaii

The NCA and its partners conducted probabilistic sampling in 2002 and again in 2006. A comparison of the results of these assessments is discussed below.

Figure 8-19 compares the percentage of Hawaii's coastal area rated good, fair, or poor for the water quality index and its component indicators in the 2002 and 2006 surveys. The water quality index for Hawaii's coastal waters was rated good for both surveys, with a higher percentage of the coastal area rated fair and poor in the 2002 survey. The higher percentage area estimated as fair and poor is most likely associated with the focused sampling on the urbanized estuaries of Honolulu, which was a part of the design in the 2002 survey. Both the DIN and DIP component indicators were rated as good in both surveys, and less of the coastal area was rated fair and poor in the 2006 survey. The chlorophyll *a* component indicator was also rated fair in the 2002 survey and good in the 2006 survey, with significantly more area rated fair and poor in the 2002 survey. This difference is due to the much greater sampling focus in 2002 on the urbanized estuaries of Honolulu, where approximately two-thirds of sites rated poor for chlorophyll *a* concentrations were found. The water clarity component indicator was also provisionally rated good in both timeframes. Although the water clarity rating in 2002 was provisional because a valid reading of Secchi depth for estimating water clarity could not be obtained, this provisional rating was confirmed by the use of a PAR meter in the 2006 survey. The dissolved oxygen component indicator was also rated good in both surveys, with similar amounts of the coastal area rated fair and none of the area rated poor.

The NCA monitoring data used in this assessment were based on single-day measurements collected at sites throughout the U.S. coastal waters (excluding the Great Lakes) during a 9- to 12-week period during the summer. Each site was sampled once during the collection period of 2003 through 2006. Data were not collected during other time periods.

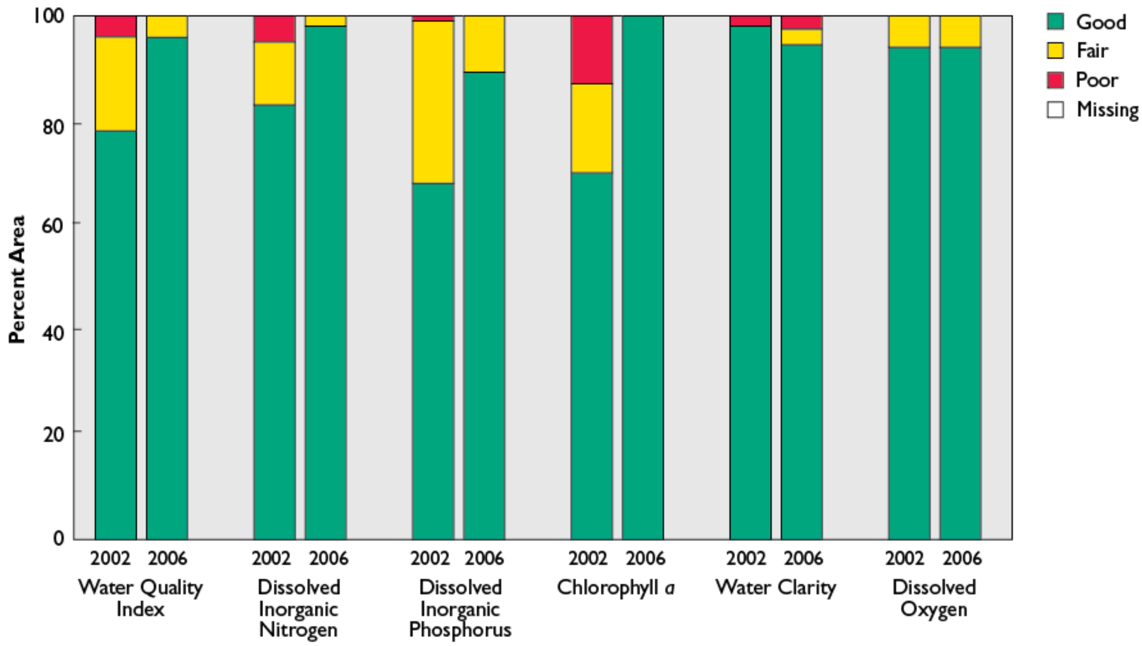


Figure 8-19. Percentage of Hawaii coastal area achieving each ranking for the water quality index and its component indicators compared between the 2002 and 2006 surveys (U.S. EPA/NCA).

Figure 8-20 compares the percentage of Hawaii's coastal area rated good, fair, or poor for the sediment quality index and its component indicators in the 2002 and 2006 surveys. The sediment quality index was rated good to fair in the 2002 survey and poor in the 2006 survey, with significantly less of the coastal area rated poor during the 2002 survey. It should be noted that the 2002 sediment quality index was calculated based on measurements of three component indicators (i.e., sediment toxicity, sediment contaminants, and sediment TOC), and the 2006 sediment quality index rating was based on two component indicators (i.e., sediment contaminants and sediment TOC). More of the coastal area was rated fair and poor for the sediment contaminants component indicator in 2006, and the rating decreased from good to fair. The sediment TOC component indicator was rated good in both surveys; however, the total area estimated as in either fair or poor condition increased from 8% in 2002 to 30% in 2006. The range of values of TOC recorded in the 2006 data set was also much greater than in 2002. Given the high carbonate content of sediments in Hawaii, it is possible that laboratory analytical differences in the degree to which inorganic carbon was removed from sediments may have contributed to this difference.

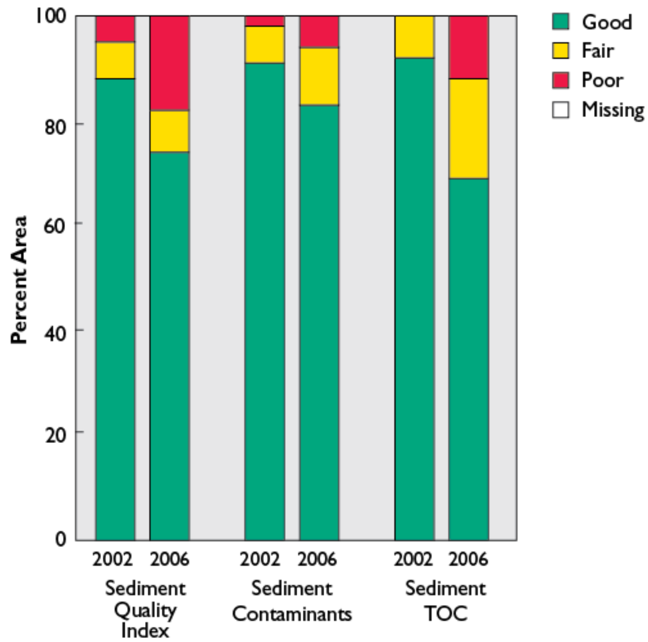


Figure 8-20. Percentage of Hawaii coastal area achieving each ranking for the sediment quality index and component indicators compared between the 2002 and 2006 surveys (U.S. EPA/NCA).

Large Marine Ecosystem Fisheries—Insular Pacific-Hawaiian LME

The Insular Pacific-Hawaiian LME comprises a range of islands, atolls, islets, reefs, and banks, which extend 1,500 nautical miles on a west-northwest axis (Figure 8-21), and their surrounding waters. In 2000, President Clinton, through Executive Orders 13178 and 13196, established the Northwestern Hawaiian Islands Coral Reef Ecosystem Reserve, in which fishing activities are prohibited. To continue protection of the NWHI, President George Bush in 2006 established the Papahānaumokuākea Marine National Monument, which is cooperatively managed by the FWS and NOAA/NMFS, in close coordination with the State of Hawaii. This monument encompasses 105,564 square nautical miles (139,797 square miles) of emergent and submerged lands and waters of the Northwestern Hawaiian Islands, providing protection to 4,500 square miles of coral reefs, 14 million seabirds, and over 7,000 marine species. For more information, visit http://www.papahanaumokuakea.gov/.

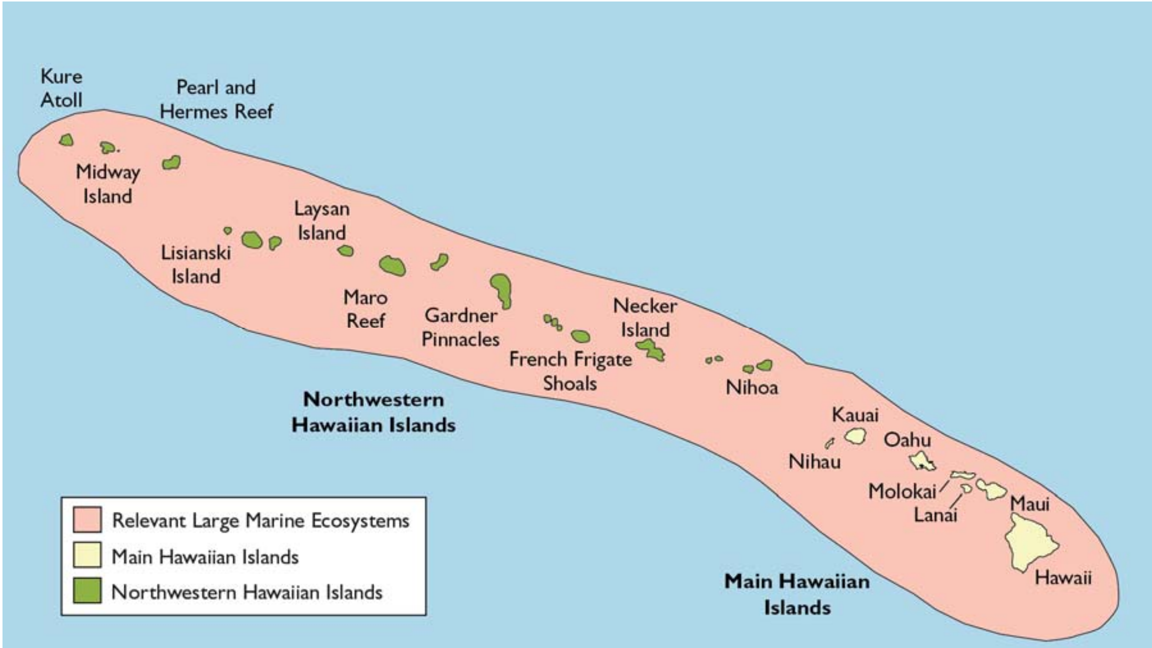


Figure 8-21. The Main Hawaiian Islands (MHI) and the Northwestern Hawaiian Islands (NWHI) of in the Insular Pacific-Hawaiian LME.

From 2003 to 2006, Hawaii generated over $247 in commercial fisheries total ex-vessel revenues within this LME. In terms of both landings and revenues, Hawaiian fisheries are dominated by the tuna group, including bigeye, yellowfin, albacore, skipjack, and kawakawa. The bigeye and yellowfin commercial tuna fisheries are the most important, generating over $124 million and $30 million in total ex-vessel revenues from 2003 to 2006, respectively (NMFS, 2010). Other important commercial species include dolphinfish, swordfish, wahoo, opah, and striped marlin. Yellowfin tuna and dolphinfish are the most important recreational species as well. See Figure 8-22 for revenues and landings of the top Hawaiian commercial fisheries harvested within the Insular Pacific-Hawaiian LME. Fisheries in this LME are managed jointly by the Western Pacific Fishery Management Council and the State of Hawaii, in accordance with terms determined under international agreements for transboundary species.

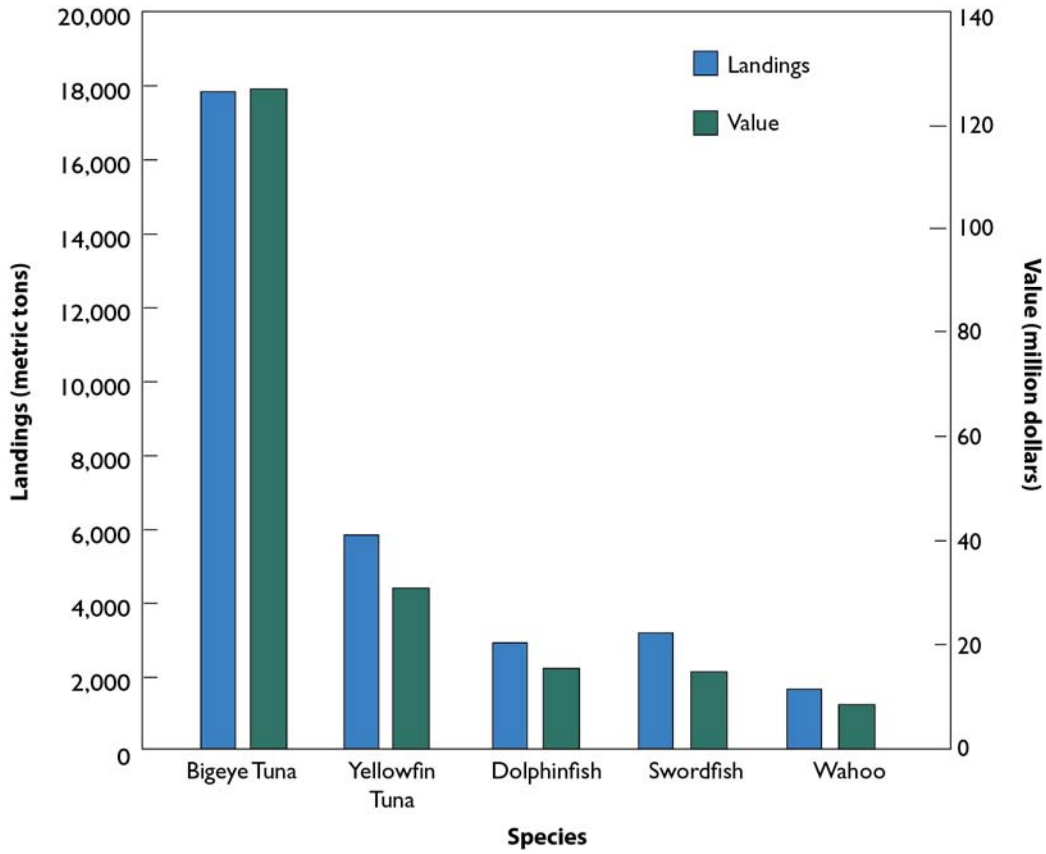


Figure 8-22. Top commercial fisheries for Hawaii from the Insular-Pacific LME: landings (metric tons) and value (million dollars) from 2003 to 2006 (NMFS, 2010).

Pacific Highly Migratory Pelagic Fisheries

Large pelagic (water-column dwelling) predators routinely travel great distances across the Pacific Ocean, crossing the waters of several nations and the high seas in their pursuit of forage and ideal habitat for reproduction. Highly migratory pelagic species include tropical tunas (yellowfin, bigeye, and skipjack), temperate tunas (Pacific bluefin and albacore), billfishes (marlins and sword-fish), oceanic sharks (thresher, blue, and mako), dolphinfish, and wahoo. In Hawaii, pelagic species are caught mostly by trollers (65%) and longline fishermen (28%). These fish are also caught for recreational and subsistence purposes.

For Hawaii, tuna landings are dominated by bigeye (*Thunnus obesus*), with total landings from 2003 to 2006 of 18,000 metric tons generating over $120 million in total ex-vessel revenues (see Figure 8-22). Yellowfin tuna (*Thunnus albacares)* is another prized species used principally for canning, with landings of 6,000 metric tons worth around $30 million from 2003 to 2006 (NMFS, 2010). Both yellowfin and bigeye tuna are known as ahi in Hawaii and used in raw fish dishes, such as sashimi. Tuna mostly inhabit the upper 300 feet of the water column, are capable of high speeds, travel long distances, and can reach up to 400 pounds due to their relatively long life spans. Although bigeye and yellowfin dominate Hawaii's tuna landings, skipjack is the volume leader throughout the Pacific Ocean.

Billfishes, including swordfish, marlins, and spearfish, are more abundant near islands, continental slopes, seamounts, and oceanic fronts, and many are important to the local economy. They are categorized by their long length and sword-like bills. Commercial fisheries in this group generated nearly $26 million in total ex-vessel revenues for Hawaii from 2003 to 2006. Swordfish (*Xiphias gladius)* dominates this group, with landings of over 3,000 metric tons generating over $10 million in total ex-vessel revenues from 2003 to 2006 (see Figure 8-22) (NMFS, 2010). This species, named after its spear-like bill, can reach over 14 feet in length and weigh over 1,400 pounds. It is a popular fish for cooking and is most often sold for steaks.

Other Pacific highly migratory species are wahoo (*Acanthocybium solandri)* and dolphinfish (*Coryphaena hippurus*), primarily caught commercially using longline, troll, and handline gears. The U.S. landings of dolphinfish and wahoo are worth about $4,200 per ton. From 2003 to 2006, the total ex-vessel revenues for dolphinfish were over $15 million, and over $8 million for wahoo (see Figure 8-22) (NMFS, 2010). Dolphinfish, also known as mahi-mahi, can reach up to 30 pounds and live about 4 to 5 years. The wahoo is a much bigger fish, reaching up to 8 feet in length and weighing as much as 180 pounds. Both fish are targeted by recreational and sports fishermen.

In the Pacific waters of the United States, pelagic species are managed by the Western Pacific Regional Fishery Management Council under the *Pacific Pelagics Fishery Ecosystem Plan* (WPRFMC, 2009b), in accordance with international conventions. In 2000, after 5 years of negotiations involving 24 nations, 19 Pacific nations adopted the Convention on the Conservation and Management of Highly Migratory Fish Stocks in the Western and Central Pacific (WCPFC) in Hawaii, which entered into force in 2004. The WCPFC has authority to manage catch, by-catch, fishing capacity, and effort in order to conserve and manage the stocks of tuna and tuna-like species west of 150°W longitude. A management issue closely aligned with fishing capacity is the problem of illegal, unreported, and unregulated fishing by vessels that operate outside the control of regional management regimes. This is particularly problematic with the highly migratory species that are of such commercial importance to Hawaii. Another issue in the Pacific is the high fishing mortality (and subsequent reduction in future spawning biomass) on juvenile bigeye and yellowfin tuna with increasing use of fish aggregating devices by purse seiners and domestic fisheries of the Philippines and Indonesia.

Other Important Fisheries

Other fisheries off Hawaii include coral reef, bottomfish (fish that dwell on the bottom), and crustaceans. The coral reef fisheries (i.e., coastal pelagic scad, soldierfish, parrotfish, surgeonfish, and goatfish) and the crustacean fisheries (i.e., lobsters and crabs) are primarily conducted in nearshore waters under Hawaiian management. Harvests of bottomfish (i.e., snappers, jacks, and grouper) take place both in State and federal waters. Management of these fisheries in federal waters is conducted by the Western Pacific Regional Fishery Management Council under the *Fishery Ecosystem Plan for the Hawaii Archipelago* (WPRFMC, 2009a), which utilizes an ecosystem-based management approach that emphasizes habitat, ecosystem, protected species, and community participation. See http://www.wpcouncil.org/HawaiiArchipelago.htm for more details.

A unique characteristic of this LME is the harvest of various coral species, which do not generate enough monetary value to rank within the top commercial fisheries, but are important locally. Gold, bamboo, and pink deepwater corals, and shallower black corals represent a precious resource in the Hawaiian Islands. Black coral is harvested mostly in State waters from a bed located in the Auau Channel. This coral was sustainably harvested for over 40 years, beginning in the late 1950s. Unfortunately, increased fishing pressure and the introduction of an invasive species are threatening the stability of this fishery. There is a biannual quota of 11,000 pounds for the Auau coral bed.

Fishery Trends and Summary

Figure 8-23 shows landings of the top commercial fisheries for Hawaii within the Insular-Pacific LME since 1980, when consistent data collection began. No species-specific data for the dolphinfish and wahoo fisheries until 2002. Landings of bigeye tuna, which have increased continuously since the mid-1980s, currently dominate this LME at just over 4,500 metric tons. Landings of the other top commercial tuna species, yellowfin, seem to have stabilized around 1,500 metric tons, after considerable annual variability beginning in the mid-1980s, when the fishery peaked at 5,000 metric tons. The swordfish fishery, which yielded the largest landings for Hawaii in the early 1990s at 6,000 metric tons, now hovers over 1,000 metric tons. Current catches of both dolphinfish and wahoo are about 500 metric tons.

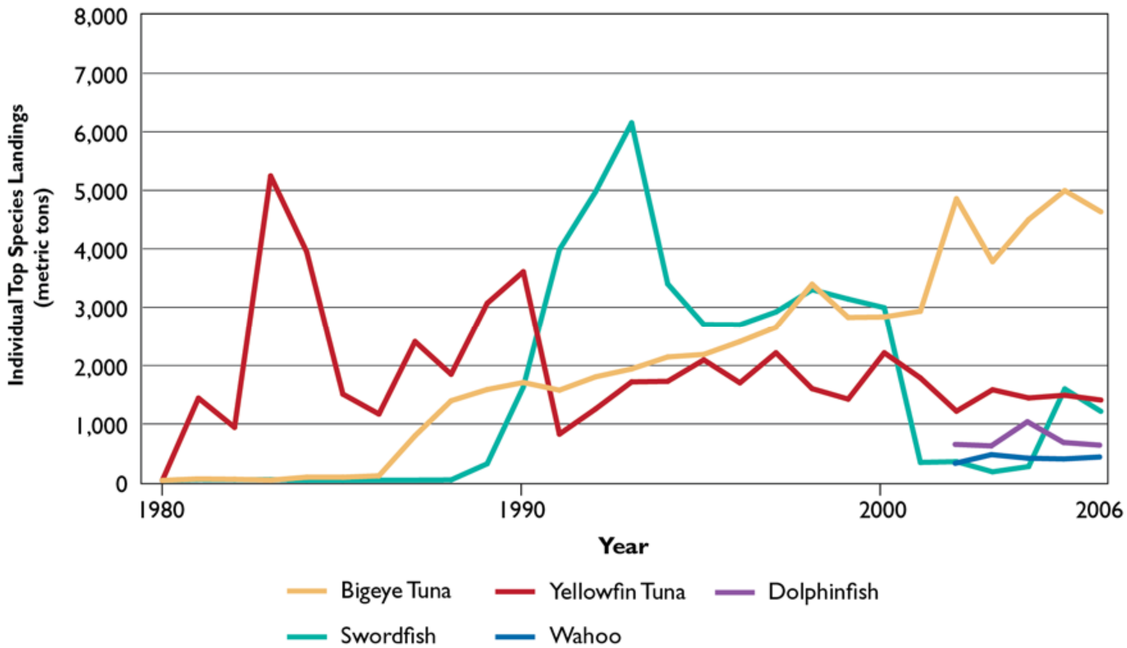


Figure 8-23. Landings of top commercial fisheries in the Insular-Pacific LME for Hawaii from 1980 to 2006, metric tons (NMFS, 2010).

Advisory Data

Fish Consumption Advisories

Since 1998, the State of Hawaii has advised the general population not to consume fish or shellfish caught in the Pearl Harbor area on the island of Oahu due to PCB contamination (Figure 8-24). In addition to the estuarine advisory, a statewide advisory took effect in 2003. The statewide advisory targets sensitive populations (e.g., pregnant women, nursing mothers, children) and provides data on mercury contamination for several species of marine fish (U.S. EPA, 2007c).

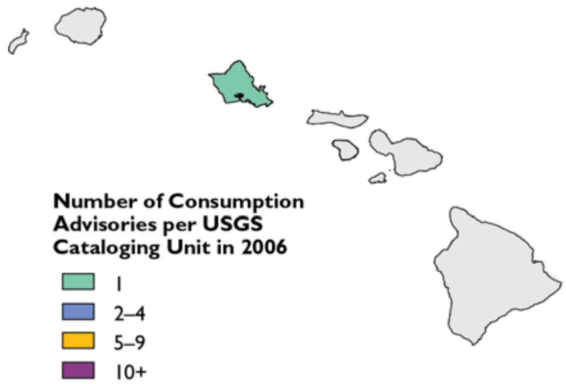


Figure 8-24. Fish consumption advisory for Hawaii, location approximate.

Hawaii also has a statewide advisory for marine fish consumption by sensitive populations, although this is not mapped (U.S. EPA, 2007c).

Beach Advisories and Closures

How many notification actions were reported for Hawaii between 2004 and 2008?

Table 8-3 presents the number of total and monitored beaches, as well as the number and percentage of beaches affected by notification actions from 2004 to 2008 for Hawaii. Over the past several years, the total number of beaches identified by Hawaii increased from 376 in 2004 to 444 in 2008. During this same period, monitoring efforts also increased significantly, from 50 to 248 beaches between 2004 and 2008. Of these monitored beaches, the percentage closed or under advisory during the year has also decreased substantially from 52% in 2004 to 3% (or 7 beaches) in 2008 (U.S. EPA, 2009d). Annual national and state summaries are available on EPA's Beaches Monitoring site: http://www.epa.gov/waterscience/beaches/seasons/.

Table 8-3. Beach Notification Actions, Hawaii, 2004–2008 (U.S. EPA, 2009d)

Numbers and Percentages	2004	2005	2006	2007	2008
Total number of beaches	376	483	438	444	444
Number of monitored beaches	50	134	112	115	248
Number of beaches affected by notification actions	26	13	16	8	7
Percentage of monitored beaches affected by notification actions	52%	10%	14%	7%	3%

What pollution sources impacted monitored beaches?

Table 8-4 presents the numbers and percentages of monitored Hawaii beaches affected by various pollution sources for 2007. Storm-related runoff was a pollution source for all of Hawaii's beaches in 2007, while combined sewer overflow contributed to 10% of beach advisories that year. Other identified pollution sources included septic system leakage and publicly owned treatment works (U.S. EPA, 2009d).

Table 8-4. Reasons for Beach Advisories, Hawaii, 2007 (U.S. EPA, 2009d)

Reason for Advisories	Total Number of Monitored Beaches Affected	Percent of Total Monitored Beaches Affected
Storm-related runoff	444	100%
Sanitary/combined sewer overflow	44	10%
No known pollution sources	13	3%
Other and/or unidentified sources	13	3%
Publicly owned treatment works	13	3%
Septic system leakage	4	1%

Note: A single beach may have multiple sources.

How long were the 2007 beach notification actions?

Of the 2007 beach advisories, half lasted 3 to 7 days. Actions lasting only a day accounted for one-fifth of the total advisories, as did those of the 8- to 30-day duration. Only 10% of actions were over 30 days (U.S. EPA, 2009d).

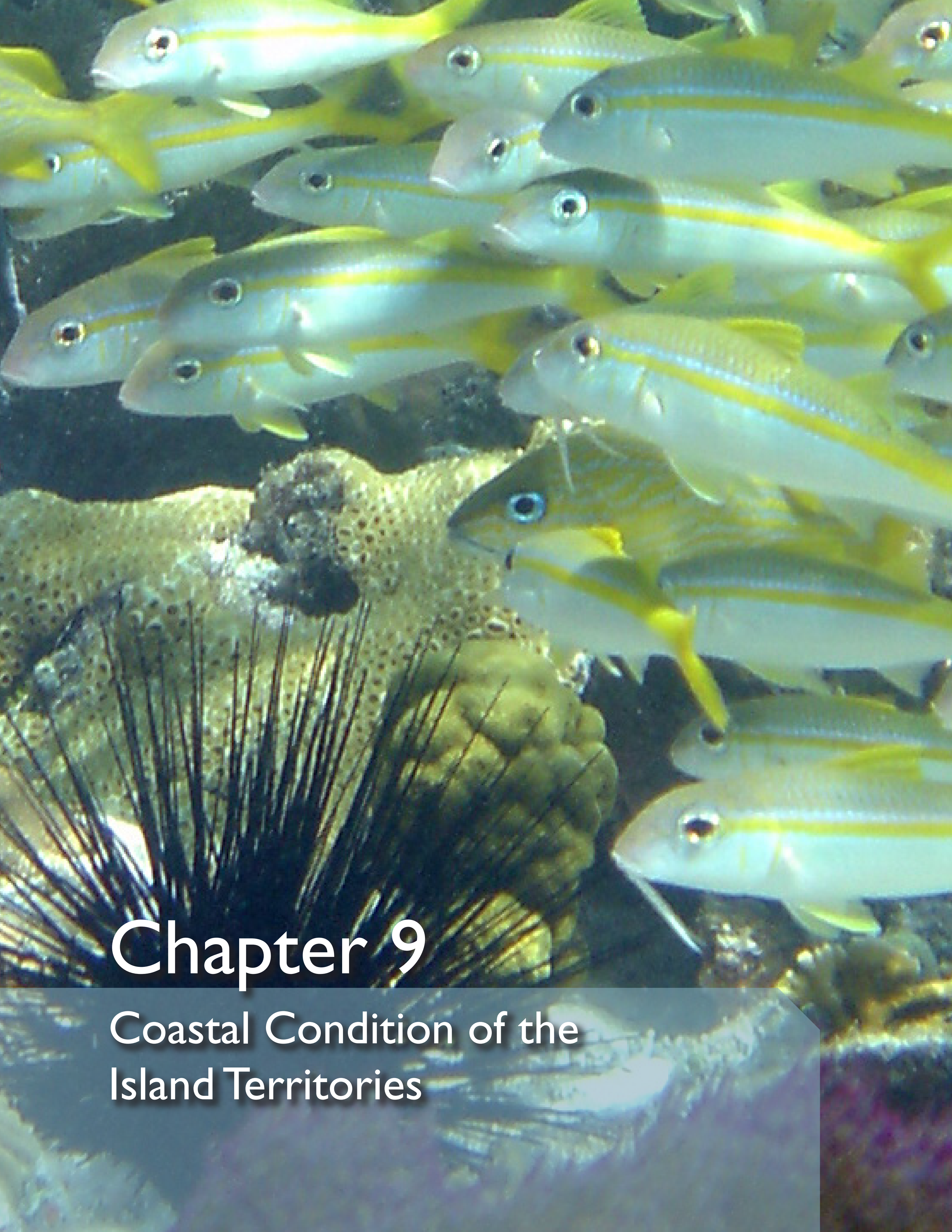
Summary

NCA conducted sampling in the coastal waters of Southeastern Alaska in 2004 and in Hawaii in 2006. These assessments resulted in an overall condition rating of good for Southeastern Alaska's coastal waters, where water quality, sediment quality, coastal habitat, and fish tissue contaminants are all rated good. The benthic index for Southeastern Alaska could not be evaluated. Hawaii received an overall coastal condition rating of fair. Hawaii's coastal water quality index is rated good, and the sediment quality index is rated poor. The NCA was unable to evaluate the benthic, coastal habitat, or fish tissue contaminants indices for Hawaii's coastal waters in the 2006 survey.

NOAA's NMFS manages several fisheries in the LMEs bordering Alaska and Hawaii. The East Bering Sea LME and the Gulf of Alaska LME are two of the LMEs that surround Alaska, and NMFS manages the salmon, groundfish, and shellfish fisheries in these waters. The groundfish group, dominated by walleye pollock, is the most important in terms of both landings and revenue for Alaskan commercial fishermen. The other top fisheries are for salmon and crab. Recent trends indicate that the walleye pollock stock in the East Bering Sea LME has declined since 2003 due to poor survival rates of juveniles from 2001 through 2005. Pollock abundance in the Gulf of Alaska LME is also at a low level, and this stock is carefully managed to help protect the endangered and threatened Steller sea lions, which feed on pollock. All five species of Alaskan salmon are fully utilized, and stocks in the Gulf of Alaska and East Bering Sea LMEs have rebuilt to near or beyond previous high levels. In addition to the large commercial and recreational fisheries that also contribute to the Alaska economy, there are subsistence fisheries that are important to the health, well being, and cultural identity of native Alaskans.

The Insular Pacific-Hawaiian LME consists of the waters around Hawaii. In terms of both landings and revenues, Hawaiian fisheries are dominated by the tunas, especially bigeye and yellowfin. Catches of bigeye tuna have increased continuously since the mid-1980s. Other highly migratory species (i.e., dolphinfish, swordfish, and wahoo) are the next most valuable fisheries in this LME. The coral fishery is open, but only shallow-water, black coral is being harvested.

Contamination in the coastal waters of Hawaii has affected human uses of its waters. In 2006, there was one fish consumption advisory in effect for Pearl Harbor, Hawaii, for PCBs. Alaska did not have any fish consumption advisories in effect in 2006. Alaska monitored three beaches in 2006, but none of them were closed or under advisory for any part of the year due to contamination.



Chapter 9

Coastal Condition of the Island Territories

9. Coastal Condition of the Island Territories

In 2004, NCA efforts were expanded to include the coastal areas of the U.S. territories of American Samoa, Guam, and the U.S. Virgin Islands. A second survey of the Commonwealth of Puerto Rico was also completed in 2004. This chapter briefly describes assessment findings for each of these 2004 NCA surveys and represents baseline ecological assessments for the island territories. The Commonwealth of the Northern Mariana Islands was not included in the baseline ecological assessments for the island territories.

Please refer to Chapter 1 for information about how these assessments were made, the cutpoints used to develop the rating for each index and component indicator, and the limitations of the available data.

American Samoa

The overall condition presented for American Samoa coastal waters is good based on two of the five indices of ecological condition (Figure 9-1). The water quality and fish tissue contaminants indices are rated good. A sediment quality index was not calculated for American Samoa because sediment samples were not collected for the majority of sites. In addition, no information was collected to calculate the benthic or coastal habitat indices. Figure 9-2 provides a summary of the percentage of coastal area in good, fair, or poor categories for each index and component indicator.

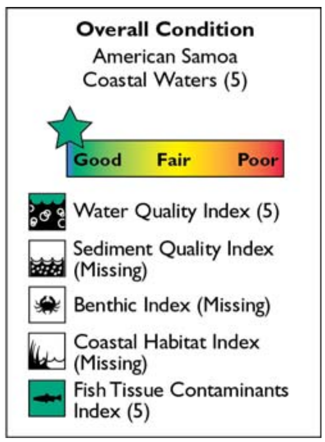


Figure 9-1. The overall condition of American Samoa coastal waters is rated good (U.S. EPA/NCA).

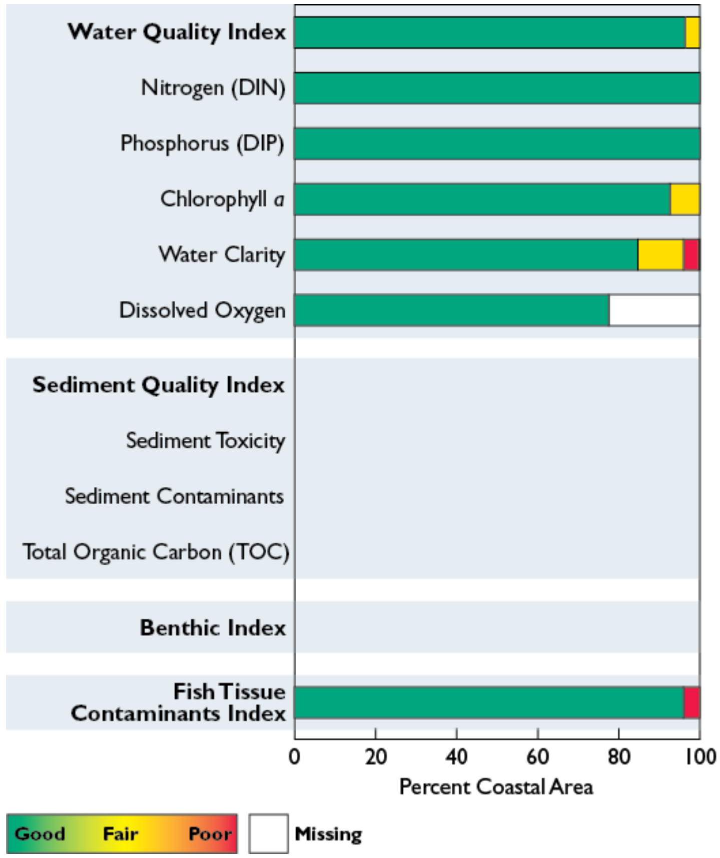


Figure 9-2. Percentage of area receiving each ranking for all indices and component indicators – American Samoa (U.S. EPA/NCA).

American Samoa is part of the Central Polynesian Province and is the southern-most U.S. territory. The territory consists of five volcanic high islands (Tutuila, Aunu'u, Ofu, Olosega, and Ta'u) and two atolls (Rose and Swains). The combined land area of American Samoa is approximately 77 square miles. The surveyed resources include estuaries, embayments, and nearshore waters within approximately 0.22 nautical miles of the shoreline. Forty-nine sites were sampled in 2004, with 50% of the sites falling within National Park boundaries.

Although American Samoa represents far less than half a percent of the U.S. population, the population of this island territory has grown by 95% between 1980 and 2006, from 32,000 to 63,000 people (Figure 9-3). Over the same period, the territory's population density has increased from 416 persons per square mile to 818 persons per square mile (U.S. Census Bureau, 2010).

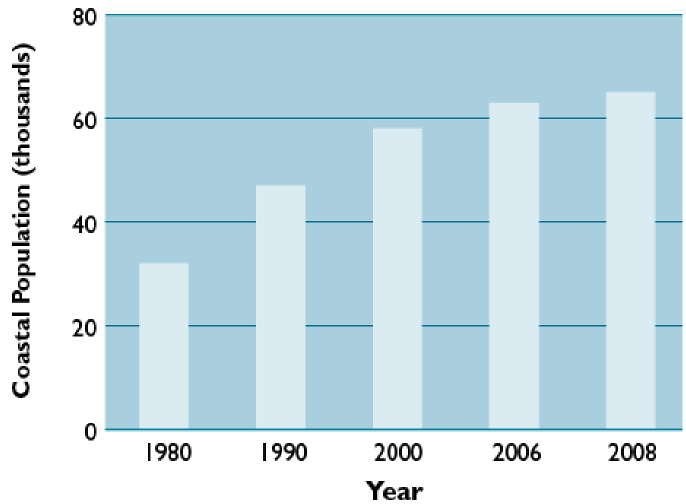


Figure 9-3. Population of coastal counties in American Samoa from 1980 to 2008 (U.S. Census Bureau, 2010).

Coastal Monitoring Data—Status of Coastal Condition

The NCA monitoring data used in this assessment are based on single-day measurements collected at sites throughout the U.S. coastal waters (excluding the Great Lakes) during a 9- to 12-week period during the summer. Each site was sampled once during the collection period of 2003 through 2006. Data were not collected during other time periods.

Water Quality Index

The water quality index for American Samoa is rated good, with 96% of the coastal area rated good and 4% of the area rated fair (Figure 9-4). The water quality index was developed based on measurements of five component indicators: DIN, DIP, chlorophyll *a*, water clarity, and dissolved oxygen. Reduced water clarity contributed to the fair water quality ratings.

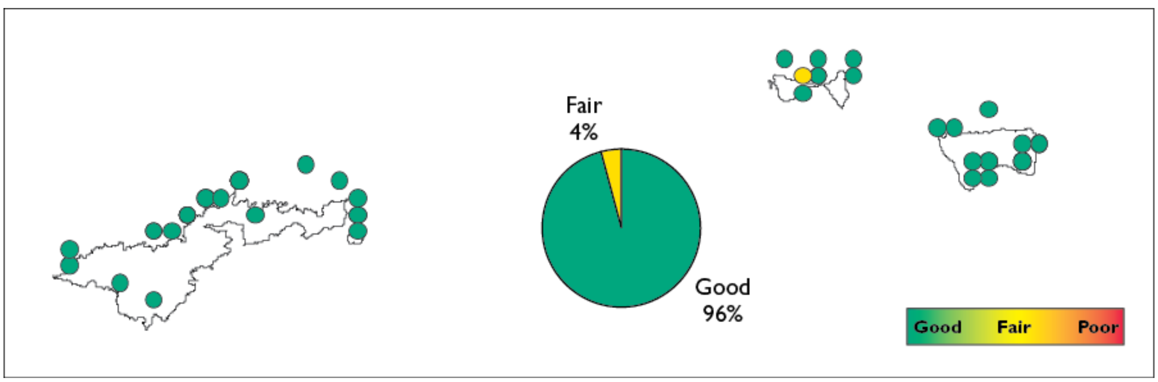


Figure 9-4. Water quality index data for American Samoa coastal waters (U.S. EPA/NCA).

Nutrients: Nitrogen and Phosphorus

American Samoa is rated good for DIN, with all of the coastal area rated good for this component indicator. Similarly, the DIP component indicator is rated good for 100% of the coastal area.

Chlorophyll *a*

The chlorophyll *a* component indicator is rated good for American Samoa, with 7% of the coastal area rated fair.

Water Clarity

American Samoa is rated good for water clarity, with 11% of the coastal area rated fair and 4% rated poor for this component indicator.

Dissolved Oxygen

American Samoa is rated good for the dissolved oxygen component indicator, with 77% of the coastal area rated good. Dissolved oxygen data were missing for the remainder of the coastal area.

Sediment Quality Index

Guidelines for Assessing Sediment Contamination (Long et al., 1995)

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

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

A sediment quality index was not calculated for American Samoa because only 25% and 16% of the area were sampled for sediment contaminants and TOC, respectively. Scores for these two component indicators are presented in Figure 9-5 for the sites sampled. Two sites, representing 15% of the sites sampled, exceeded ERM concentrations for nickel and were rated poor. ERL concentrations were also exceeded for arsenic, nickel, and chromium in sediments from 6 of the 13 sites sampled. No TOC concentrations were observed greater than 5%. No sediment toxicity data were collected.

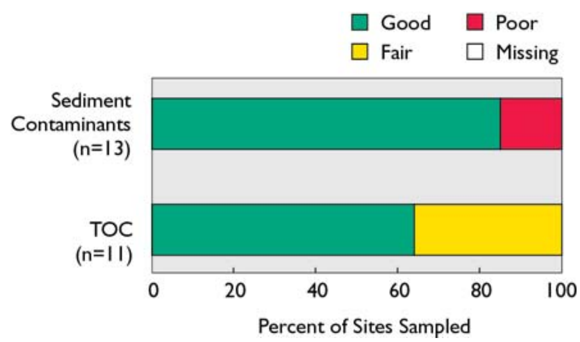


Figure 9-5. Results of the limited data collected for the sediment contaminants and sediment TOC component indicators (U.S. EPA/NCA).

Benthic Index

Benthic data are not available for American Samoa; therefore, the benthic index could not be calculated.

Coastal Habitat Index

Estimates of coastal habitat loss are not available for American Samoa; therefore, the coastal habitat index could not be calculated.

Fish Tissue Contaminants Index

The fish tissue contaminants index for American Samoa is rated good based on fish tissue samples collected at 47 sites. The fish tissue contaminants index is rated poor at 4% of the sites at which fish were caught due to concentrations of PAHs and mercury in fish tissue (Figure 9-6).

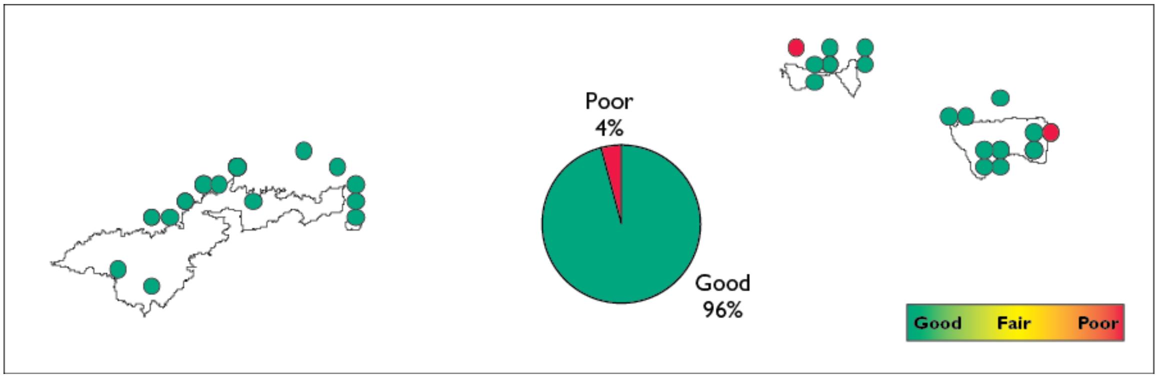


Figure 9-6. Fish tissue contaminants index data for American Samoa (U.S. EPA/NCA).

Large Marine Ecosystem Fisheries—American Samoa

American Samoa is not located within an LME, as designated by NOAA. Landings from American Samoan waters are dominated by pelagic (water-column dwelling) species (mostly albacore tuna), with about 30 longline vessels harvesting 11 million pounds annually (WPRFMC, 2011b). Annually, commercial vessels also land about 6,000 to 30,000 pounds of bottomfish (bottom-dwelling fish), 20,000 pounds of coral reef fish, and 1,200 pounds of spiny lobster (WPRFMC, 2011a). Coral reef species and crustaceans are also harvested by subsistence fishermen. Within 3 miles of shore, American Samoa's fisheries are managed by the Territorial government. Between the 3-mile mark and the boundary of the U.S. EEZ, the fisheries are managed by the NMFS Western Pacific Regional Fishery Management Council, which regulates all fisheries by archipelago except for the pelagic fisheries, which are managed under a fishery ecosystem plan for pacific pelagics (WPRFMC, 2009b). *The American Samoa Fishery Ecosystem Plan* (WPRFMC, 2009a) utilizes an ecosystem-based management approach that emphasizes habitat, ecosystem, protected species, and community participation.

Advisory Data

Fish Consumption Advisories

Since 1993, American Samoa has had a fish consumption advisory in effect for chromium, copper, DDT, lead, mercury, zinc, and PCBs in Inner Pago Pago Harbor (Figure 9-7). In 2006, arsenic was added to the list of potential contaminants to this estuary. The advisory recommends that all members of the general population (including sensitive populations of pregnant women, nursing mothers, and children) not consume any fish, fish liver, or shellfish from the Inner Pago Pago Harbor. In addition, these same waters are also under a commercial fishing ban that precludes the harvesting of fish or shellfish for sale in commercial markets (U.S. EPA, 2007c).

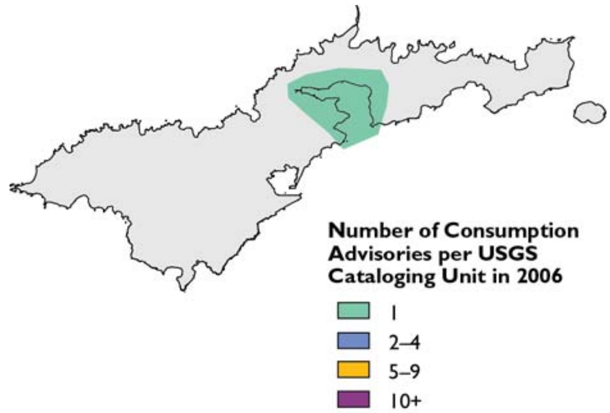


Figure 9-7. Fish consumption advisory for American Samoa, location approximate (U.S. EPA, 2007c).

Beach Advisories and Closures

How many notification actions were reported for American Samoa between 2004 and 2008?

Table 9-1 presents the number of total beaches and monitored beaches for the U.S. Pacific island territory of American Samoa, as well as the number and percentage of beaches affected by notification actions from 2005 to 2008. Since 2005, the total number of beaches and the number of monitored beaches decreased from 77 to 42. Of these monitored beaches, the percentage closed or under advisory for some period of time during the year increased from 43% in 2005 to 100% in 2008 (or 42 beaches) (U.S. EPA, 2009d). Annual national and state summaries are available on EPA's Beaches Monitoring Web site: http://www.epa.gov/waterscience/beaches/seasons.

Table 9-1. Beach Notification Actions, American Samoa, 2004–2008 (U.S. EPA, 2009d)

Numbers and Percentages	2004	2005	2006	2007	2008
Total number of beaches	No data	77	74	74	42
Number of monitored beaches	No data	77	45	45	42
Number of beaches affected by notification actions	No data	33	42	42	42
Percentage of monitored beaches affected by notification actions	No data	43%	93%	93%	100%

Data on pollution sources for American Samoan beaches were not available under the EPA Beaches program at the time of publication.

How long were the 2007 beach notification actions for American Samoa?

Over 99% of beach notification actions in American Samoa lasted between 3 to 7 days in 2007. Less than 1% of the actions lasted longer than 30 days (U.S. EPA, 2009d). For more information on state beach closures, please visit the EPA's Beaches Web site: http://www.epa.gov/beaches/plan/whereyoulive_state.html.

Guam

The overall condition of Guam's coastal waters is rated good based on four of the indices assessed by the NCA (Figure 9-8). The water quality index is rated good, the sediment quality index is rated good, the benthic community index is rated good to fair, and the fish tissue contaminants index is rated good. The NCA was unable to evaluate the coastal habitat index for Guam. Figure 9-9 provides a summary of the percentage of coastal area in good, fair, or poor categories for each index and component indicator. This assessment is based on environment stressor and response data collected by the Guam Environmental Protection Agency, through collaboration with NCA, from 50 locations within coastal waters of the island of Guam.

Please refer to Chapter 1 for information about how these assessments were made, the cutpoints used to develop the rating for each index and component indicator, and the limitations of the available data.

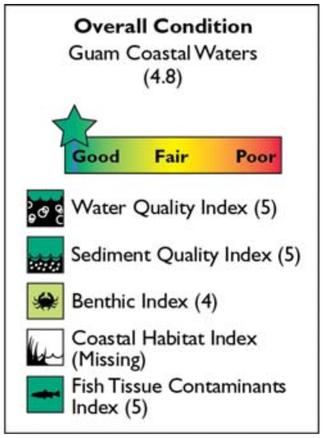


Figure 9-8. The overall condition of Guam's coastal waters is rated good (U.S. EPA/ NCA).

The NCA monitoring data used in this assessment are based on single-day measurements collected at sites throughout the U.S. coastal waters (excluding the Great Lakes) during a 9- to 12-week period during the summer. Each site was sampled once during the collection period of 2003 through 2006. Data were not collected during other time periods.

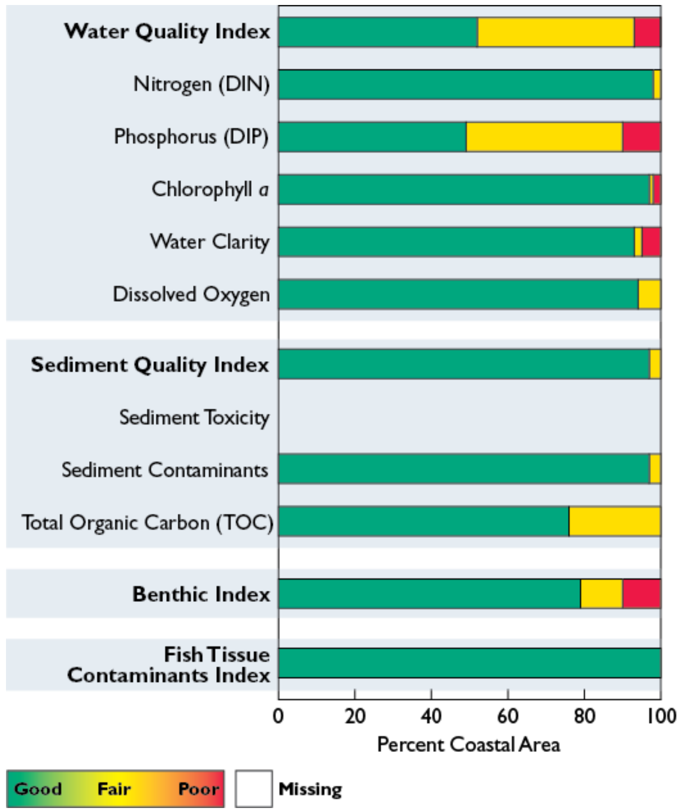


Figure 9-9. Percentage of coastal area achieving each ranking for all indices and component indicators—Guam (U.S. EPA/NCA).

The Island of Guam is a territory of the United States with an estimated population of about 171,000 in 2006, an area of 210 square miles, and a population density of 815 persons per square mile (Crossett et al., 2008; U.S. Census Bureau, 2010). Between 1980 and 2006, the island's population increased by 60%, from 107,000 to 171,000 people (Figure 9-10; U.S. Census Bureau, 2010), and the population is projected to continue to increase by an additional 13% between 2008 and 2015 (Crossett et al., 2008). However, this estimated additional increase does not account for the planned immigration of some 26,000 military personnel and dependents, in part due to transfer of a U.S. Marine Corps base from Okinawa to Guam by 2014. With associated economic immigrants, the population may increase by up to 38% in less than 10 years, to over 230,000 (Burdick et al., 2008).

Guam is the westernmost point of the United States (latitude 13° 28' N, longitude 144°45' E), and approximately 1.1 million tourists visit Guam annually, largely drawn by its tropical climate, coral reefs, and recreational waters. Guam's 117 miles of shoreline consist of an estimated 62% rocky coastline and 31% sandy beaches, with the remainder consisting of mangrove mud flats. There is also an estimated 1.2 square miles of seagrass beds (Guam Coastal Atlas, 2010). Compared to other regions considered in the NCCR IV, estuaries and coastal embayments are a small, but ecologically significant, component of Guam's coastal resources. Within the definition of the sampling area for the NCA assessment in Guam, estuarine systems make up only about 1.4 square miles along the coast, although there are an additional 10 square miles of marine bays, including the deepwater lagoon of Apra Harbor, the principle commercial and military anchorage and harbor on the island (Guam Coastal Atlas, 2010).

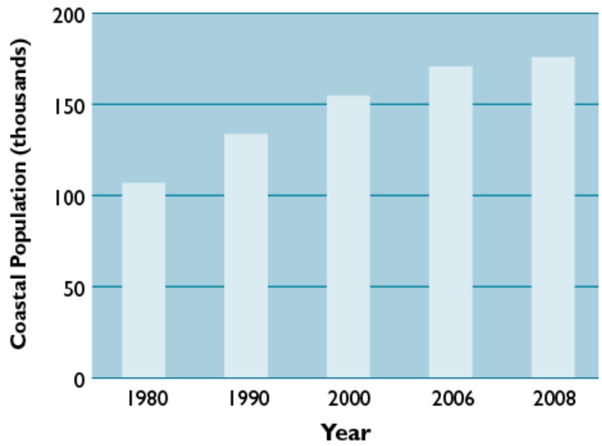


Figure 9-10. Population of counties in Guam from 1980 to 2008 (U.S. Census Bureau, 2010).
All counties in Guam are coastal.

Assigned designated uses for the marine waters of Guam are aquatic life preservation, protection, support, and propagation; primary recreation/whole body contact recreation and secondary recreation/limited body contact; and consumption. Likely stressors affecting these designated uses include sedimentation, point- and nonpoint-source inputs of nutrients and contaminants, thermal effluent, and impacts from shipping, boating, marinas, and tourist activities. Of particular concern with respect to coral habitats are sedimentation, freshwater runoff and associated pollutants, and heavy fishing pressure (Burdick et al., 2008).

The population of Guam is concentrated on the central and northern portions of the island (Crossett et al., 2008). Tumon Bay, the Waikiki of Guam, has high-density commercial development for the tourist industry along its shoreline. Apra Harbor houses both the commercial port for Guam, as well as a major naval base. The coastal systems in this area of Guam have shorelines that are, for the most part, highly altered, although Sasa Bay Marine Preserve, an area of mangrove habitat, is also located in Apra Harbor. The southern portion of Guam has a much lower population density (Crossett et al., 2008). Although one might presume that the magnitude of anthropogenic impacts would be highest in the waters bordering the most urbanized shorelines of Guam, geologic differences between the north and south sides of the island must also be taken into account. The northern karst terrain is highly porous and therefore has no rivers, so the northern coastal waters are relatively devoid of sedimentation due to the lack of discharge points. The southern portion of the island is volcanic with fine soils and small rivers. Due to challenges with land-based sources of pollution (e.g., fires, erosion, stormwater, aquaculture, farming), the southern watersheds tend to have poorer water quality.

Coastal Monitoring Data—Status of Coastal Condition

The Guam Environmental Protection Agency conducts monitoring of the physical and chemical condition of marine receiving waters, and there are a number of studies of point-source impacts or of marine water quality at localized scales (Bailey-Brock and Krause, 2007; Denton et al., 1999, 2005; Tsuda and Grosenbaugh, 1977). NOAA has conducted a series of rapid assessments of coral reef condition and is instituting a longer-term coral monitoring program on Guam (Burdick et al., 2008). However, there is a general lack of quantitative baseline information for water, sediment, and tissue pollutant concentrations for island marine waters as a whole. The NCA program, therefore, developed a collaborative project with the Guam Environmental Protection Agency to conduct a comprehensive assessment of Guam's coastal waters within the 60-foot depth contour. Field sampling commenced in Guam in 2004 and was completed in 2005.

Tumon Bay, Guam, with a view of coastal development.

Water Quality Index

The water quality index for Guam's coastal waters is rated good. The Guam water quality index was developed based on measurements of five component indicators: nitrate as nitrogen (NO_3-N), DIP, chlorophyll *a*, water clarity, and dissolved oxygen. This index differs from the standard NCA water quality index in substituting NO_3-N for DIN as the component indicator of nitrogen because the Guam Environmental Protection Agency has established a numeric water quality standard for NO_3-N in marine waters (Guam EPA, 2001); there is no such numeric standard for DIN. The cutpoints for assessing condition for the DIP and dissolved oxygen component indicators were also adopted from the water quality standards adopted by the Guam Environmental Protection Agency and thus differ from those used by NCA in other tropical locations.

Over half (52%) of the coastal area was rated good for the water quality index, 41% of the area was rated fair, and 7% of the coastal area was rated poor (Figure 9-11). Most cases of fair condition were driven by elevated concentrations of DIP. The finding that 41% of the area has fair water quality should be considered preliminary. As described below, water clarity measurements were not obtained at many stations. In addition to the five indicators incorporated into the water quality index, the Guam Environmental Protection Agency assessed concentration of *Enterococci* bacteria. All 50 sites sampled would rate good based on the Guam Environmental Protection Agency numeric cutpoints for a measurement at a single point in time.

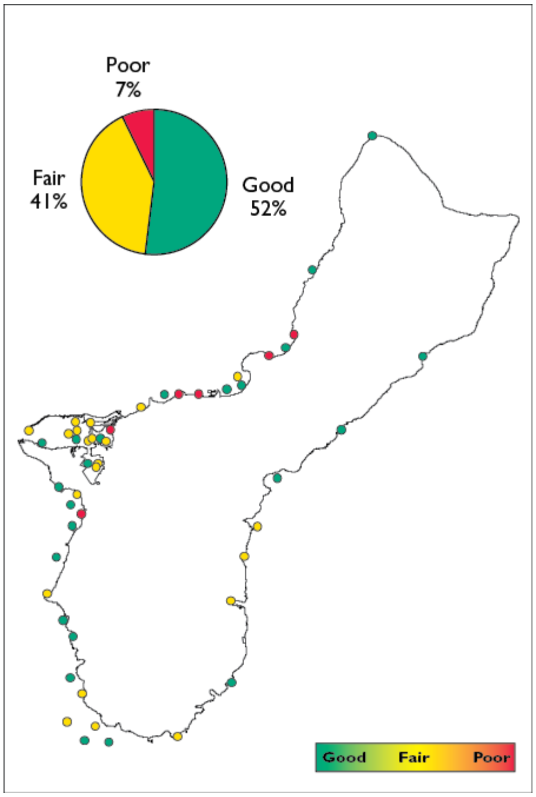


Figure 9-11. Water quality index data for Guam's coastal waters (U.S. EPA/NCA).

View of Talofofo Bay, Guam. Aquaculture ponds near the Talofofo River can be seen at the head of the Bay (photo – R. Calvo, Guam EPA).

Nutrients: Nitrogen and Phosphorus

Guam is rated good for NO_3-N concentrations, with only 2% of the coastal area rated fair for this component indicator. Sites with highest nitrate levels were located in Tumon Bay and near the mouth of the commercial port area within Apra Harbor. Blooms of green algae have been observed along the shoreline of Tumon Bay. The source of nutrients for these blooms has been identified as freshwater seepage, which was enriched by runoff from the urbanized developments in the region through the porous limestone substrate of this portion of the island (Denton et al., 2005).

Guam is rated fair for DIP concentrations based on the Guam Environmental Protection Agency water quality cutpoints for marine waters, with 10% of the coastal area rated poor and 41% rated fair for this component indicator. Stations rated poor for the DIP component indicator were located near the mouth of the commercial port area within Apra Harbor and within Talofofo and Ylig bays on the east coast of Guam. There is a considerable area of aquaculture ponds adjacent to Talofofo Bay, although it cannot be determined from this study if there is a relation of this land use to the water quality in the Bay.

Chlorophyll *a*

Guam is rated good for the chlorophyll *a* component indicator, with 2% of the coastal area rated poor and 1% rated fair. Sites rated poor or fair for chlorophyll *a* concentrations were located within Talofofo Bay and within the Sasa Bay mangrove area of Apra Harbor.

Water Clarity

Water clarity in Guam's coastal waters is rated good, based on an assessment of photosynthetically active radiation (PAR) in the water column. Water clarity was rated poor at a sampling site if light penetration at 1 meter was less than 20% of surface illumination. Approximately 5% of the coastal area was rated poor for this component indicator, 2% of the area was rated fair, and 93% of the area was rated good. The evaluation of water clarity should be considered provisional. Due to equipment problems and implementation issues at very shallow water sites, data were collected at only 31 stations, which is minimal for attaining area estimates with the magnitude of error targeted by NCA. Poor water clarity was found at stations in Hagåtña and Agat bays, while fair water quality was found at Talofofo Bay. There is a WWTP outfall in the vicinity of the Hagåtña Bay stations.

Dissolved Oxygen

Dissolved oxygen condition in Guam's coastal waters is rated good based on the Guam Environmental Protection Agency marine waters standard, with only 6% of the area rated fair and none of the coastal area rated poor for this component indicator. The sites rated fair were widely distributed and included Talofofo Bay, the entrance to the commercial port, Sasa Bay at a shallow water mangrove site, and several locations in Agat Bay. At each of these stations, the dissolved oxygen concentrations were in the range of 4.3 to 4.8 mg/L. Although conditions in Guam appear to be generally good for dissolved oxygen, measured values reflect daytime conditions, some areas with restricted circulation may still experience hypoxic conditions at night.

Sediment Quality Index

The sediment quality index for Guam's coastal waters is rated good, with 3% of the coastal area rated fair and 97% of the area rated good for the sediment quality index (Figure 9-12). The sediment quality index was calculated based on measurements of three component indicators: sediment toxicity, sediment contaminants, and sediment TOC. Fair sediment quality ratings were driven by the fair ratings of the sediment contaminants component indicator.

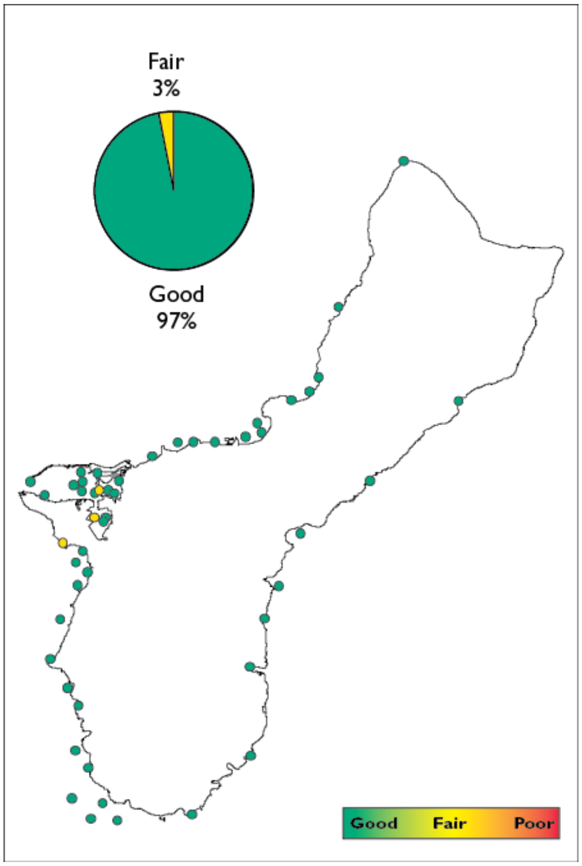


Figure 9-12. Sediment quality index data for Guam's coastal waters (U.S. EPA/NCA).

View of the commercial port area of Guam within Apra Harbor. Power plants are located at the head of the port area.

Sediment Toxicity

Guam's coastal waters received a highly qualified rating of good for sediment toxicity, with 71% of the coastal area rated good and 29% of the area rated fair for this component indicator. Guam sediments were tested for toxicity using sediment bioassays with the amphipod *Ampelica abdita*. Inspection of the sediment data showed no relationship between presence of sediment contaminants or sediment TOC and the survivorship of the bioassay species. The survival of this species may be negatively affected by sediments composed of more than 95% sandy sediments (U.S. EPA, 1996); approximately 72% of the Guam sediment samples contained greater than 95% sandy sediments. Thus, this bioassay may not be entirely suitable for Guam sediments. As a result of this issue, Guam toxicity results were determined differently from other NCA regions. For toxicity to be rated poor, survivorship of the test organism had to be less than 80% and the site also had to have a rating or poor for either the sediment contaminants index or the benthic community index. If survivorship was less than 80% and the sediment contaminants index or benthic community index was rated other than poor, the sediment toxicity index was rated fair. A fair rating in this context is considered as potentially toxic, but this status is not confirmed.

Sediment Contaminants

Guam's coastal waters are rated good for sediment contaminant concentrations, with 3% of the coastal area rated fair and 97% of the area rated good for this component indicator. Two of the three sites rated fair were located within Apra Harbor, where a high percentage of fine materials in the sediments indicated a depositional environment. The remaining site was located along the south shore of the Orote Peninsula, adjacent to the Apra Harbor Naval Reservation. These three sites were primarily rated fair due to elevated concentrations of metals (e.g., arsenic, chromium, copper, lead, mercury), although several sites also showed levels above the ERL for DDT and PCBs.

Nickel was excluded from the evaluation of sediment contamination in Guam's coastal waters. The ERM value for this metal has been shown to have a low reliability for areas of the U.S. Pacific Coast, where high natural crustal concentrations of nickel exist (Long et al., 1995). A study of metal concentrations in cores collected along the West Coast determined the range of historic background concentrations of nickel to be 35–70 ppm (Lauenstein et al., 2000), which brackets the value of the ERM (51.6 ppm).

Sediment TOC

The coastal waters of Guam are rated good for sediment TOC. A total of 24% of the coastal area was rated fair and 76% of the area was rated good. Sites that were rated fair for sediment TOC were widely distributed and showed no particular spatial pattern.

Benthic Index

The benthic community index for Guam's coastal waters is rated good to fair. A total of 11% of the coastal area was rated fair and 10% of the area was rated poor for benthic community condition (Figure 9-13). Insufficient data on benthic infaunal communities in the coastal waters of Guam were available to construct a fully validated benthic condition index; however, a provisional assignment of benthic community condition was made by inspection of benthic community indicators, such as soft sediment infaunal species richness and total abundance. A regression of species richness versus percent fines in the sediments indicated that a significant negative relationship was present. Sediments with more than 10% fines generally had decreased species richness and abundance, sometimes markedly so. Break points in the distribution of species richness and total abundance were used to assign condition scores. Stations with species richness greater than 20 per sample and abundance greater than 100 per sample were considered in good condition; stations with species richness less than 12 per sample and abundance less than 50 per sample were considered in poor condition; and stations with one of these two indicators in good range and neither indicator in the poor range were considered in fair condition.

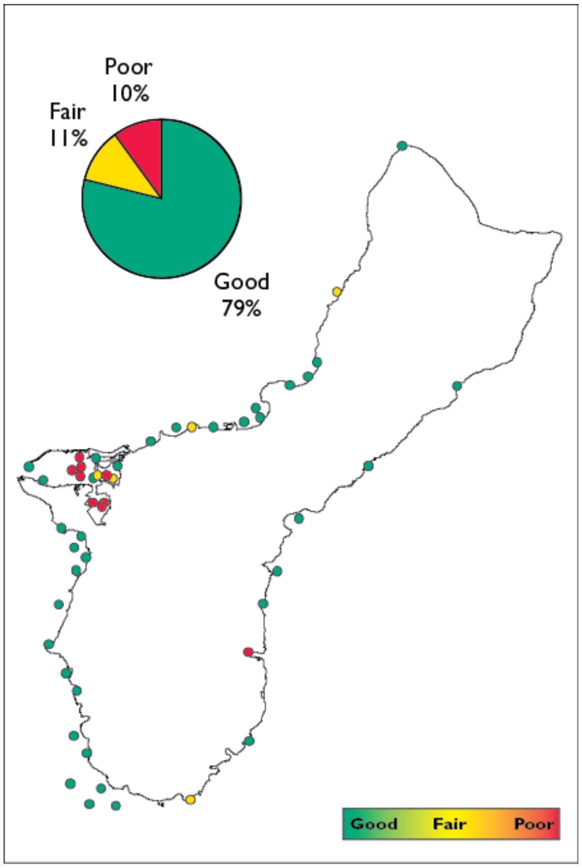


Figure 9-13. Benthic index data for Guam's coastal waters (U.S. EPA/NCA).

Coastal Habitat Index

Quantitative estimates of coastal habitat loss over time are not available for Guam; therefore, a coastal habitat index could not be calculated. It is clear that there have been major alterations and losses of coastal wetlands in Guam. Ellison (2009) lists a total present area of 173 acres for mangrove habitat on Guam. Modification of coastal wetlands prior to western contact was probably generally limited to the conversion of marshes into taro cultivation ponds. An estimated 1,236 acres of mangroves and freshwater marshes were destroyed between 1945 and 1950 (Wiles and Ritter, 1993), but the estimate does not separate the two habitat types.

Fish Tissue Contaminants Index

The fish tissue contaminants index for Guam is rated good, with 100% of the stations where fish were caught rated good (Figure 9-14). The fish tissue contaminant index rating is considered provisional because data are available for only 28 stations. Additionally, it is worth noting that only one sample was collected from some of the areas where contaminants have historically been present in Guam's waters (e.g., Apra Harbor and Cocos Lagoon).

The NCA survey of Guam conducted a feasibility study to determine whether sea cucumbers could be utilized to assess tissue body burdens of chemical contaminants. Various species of sea cucumbers were encountered (i.e., *Actinopyga mauritiana, Bohadschia argus, Bohadsia marmorata, Holothuria atra, Holothuria edulis, Holothuria nobulis, Holothuria* sp.), depending on station location, and generally one species per station was collected for analysis. Some heavy metals (e.g., arsenic, cadmium, zinc) were detected in sea cucumber tissue samples, but all metals were below levels of concern. Pesticides were almost never detected in the sea cucumber tissue samples, while PCBs were detected at low levels at only two stations.

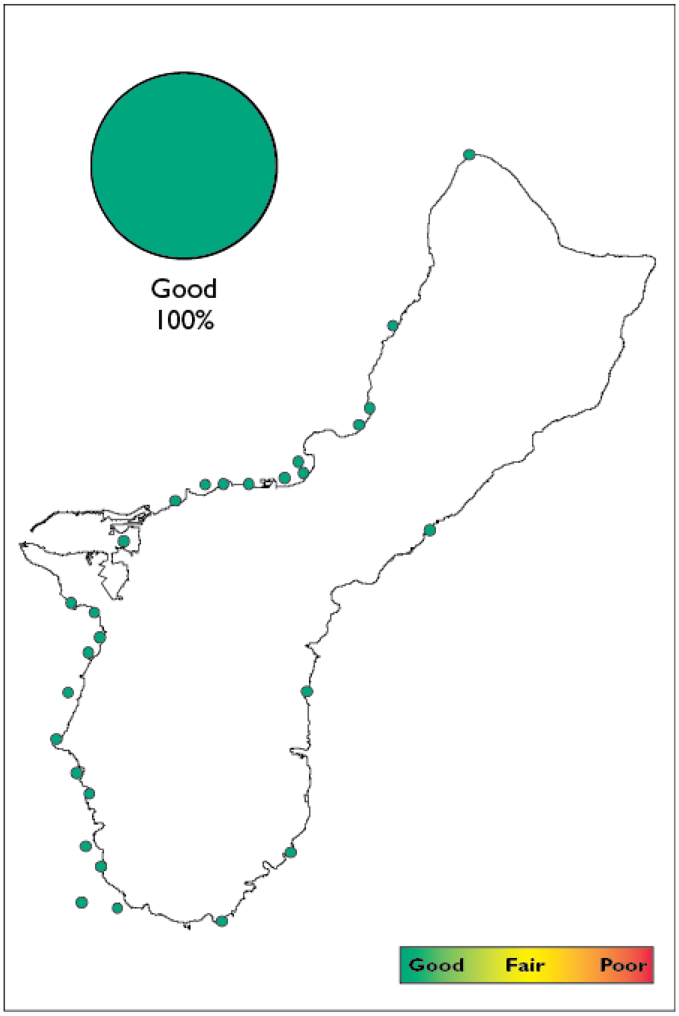


Figure 9-14. Fish tissue contaminants index data for Guam's coastal waters (U.S. EPA/NCA).

Large Marine Ecosystem Fisheries—Guam

Guam is not located within an LME, as designated by the NOAA. Fish landings in Guam are dominated by pelagic (water-column dwelling) species (about 510,000 pounds in 2006), primarily mahi mahi, wahoo, skipjack tuna, yellowfin tuna, and Pacific blue marlin (WPRFMC, 2011b). These fish are harvested using small trolling boats by fishermen who are generally employed in other industries, although most at some point sell portions of their catch. Fishermen also participate in the bottomfish (bottom-dwelling fish), crustacean, and coral reef fisheries, mostly for subsistence and cultural sharing purposes (e.g., fiestas, food exchanges). Within 3 miles of shore, Guam's fisheries are managed by the Territorial government. Between the 3-mile mark and the boundary of the U.S. EEZ, the fisheries are managed by the NMFS Western Pacific Regional Fishery Management Council, which regulates all fisheries by archipelago accept for the pelagic fisheries. Pelagic fisheries are managed under the *Pacific Pelagics Fishery Ecosystem Plan* (WPRFMC, 2009b). Guam's non-Territorial fisheries are managed under the *Mariana Archipelago Fishery Ecosystem Plan* (WPRFMC, 2009c), which utilizes an ecosystem-based management approach that emphasizes habitat, ecosystem, protected species, and community participation.

Advisory Data

Fish Consumption Advisories

Guam issued two coastal fish consumption advisories in 2001 (Figure 9-15) due to the presence of chlorinated pesticides, dioxins, and PCBs. Both advisories recommend that the general population not consume seafood from waters under advisory (U.S. EPA, 2007c).

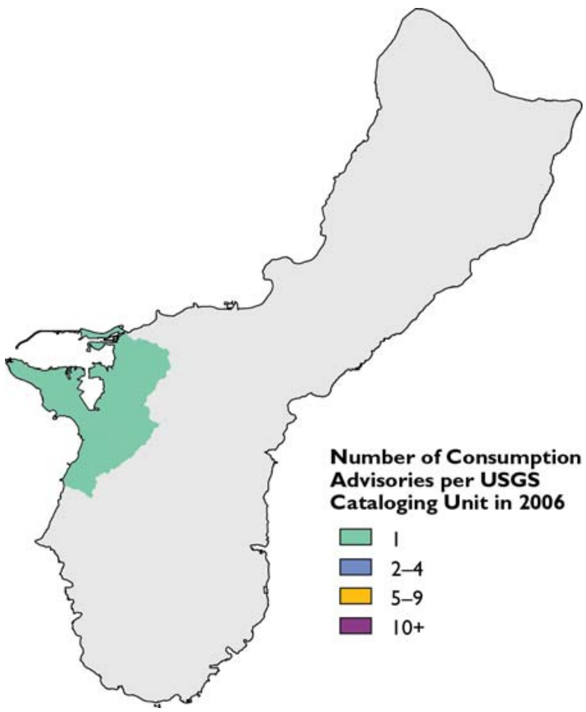


Figure 9-15. Fish consumption advisory for Guam, location approximate (U.S. EPA, 2007c).

Beach Advisories and Closures

How many notification actions were reported for Guam between 2004 and 2008?

Table 9-2 presents the number of total beaches and monitored beaches for the U.S. Pacific island territory of Guam, as well as the number and percentage of beaches affected by notification actions from 2005 to 2008. Since 2005, the total number of beaches and the number of monitored beaches decreased significantly, from 141 to 31 in 2008. Of these monitored beaches, the percentage closed or under advisory for some period of time during the year increased from 31% in 2005 to 100% in 2008 (or 31 beaches) (U.S. EPA, 2009d). Annual national and state summaries are available on EPA's Beaches Monitoring Web site: http://www.epa.gov/waterscience/beaches/seasons/.

Table 9-2. Beach Notification Actions, Guam, 2004–2008 (U.S. EPA, 2009d)

Numbers and Percentages	2004	2005	2006	2007	2008
Total number of beaches	No data	141	33	33	31
Number of monitored beaches	No data	141	33	33	31
Number of beaches affected by notification actions	No data	43	33	29	31
Percentage of monitored beaches affected by notification actions	No data	31%	100%	88%	100%

Data on pollution sources for Guam's beaches were not available under the EPA BEACH Program at the time of publication.

How long were the 2007 beach notification actions for Guam?

In 2007, all of the beach notification actions in Guam lasted between 3 to 7 days (U.S. EPA, 2009d). For more information on state beach closures, please visit the EPA's Beaches Web site: http://www.epa.gov/beaches/plan/whereyoulive_state.html.

Northern Mariana Islands

The Commonwealth of the Northern Mariana Islands consists of 14 islands in the North Pacific Ocean, formed by underwater volcanoes along the Marianas Trench about three-quarters of the way from Hawaii to the Philippines. The total land area of the Commonwealth is just 179 square miles, but the islands have a total coastline of 920 miles, which varies between the fringing coral reefs of the south and the volcanic northern islands. Between 1980 and 2006, the population of the Commonwealth grew by 259%, from 17,000 to 61,000 people (see Figure 9-16), with a population density of 453 persons per square mile in 2006.

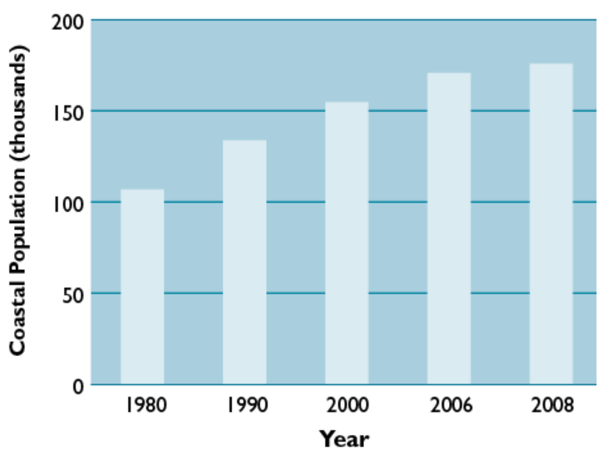


Figure 9-16. Population of counties in the Northern Mariana Islands from 1980 to 2008 (U.S. Census Bureau, 2010).
All counties are coastal.

Over 90% of the Commonwealth's 55,000 inhabitants (2008 estimate) reside on the island of Saipan, and the remaining 10% inhabit the Tinian and Rota islands. These three southern islands also encompass many of the Northern Mariana Islands' coral reefs. The island of Saipan offers diverse coral habitats, with both fringing and barrier coral reefs. Unfortunately, these reefs are also subject to pressures associated with coastal populations, including pollution from sewage outflows, wastewater disposal systems, sedimentation from rural runoff, and chemicals and nutrients from urban runoff. Since the economy of the Northern Mariana Islands is largely dependent on tourism, which centers on recreational marine activities, the maintenance of these reefs should be assessed in terms of their economic value.

Coastal Monitoring Data—Status of Coastal Condition

The Northern Mariana Islands have not been assessed by the NCA.

Large Marine Ecosystem Fisheries—Northern Mariana Islands

The Northern Mariana Islands are not located within an LME. Fish landings in the Northern Mariana Islands are dominated by pelagic (water-column dwelling) species, primarily skipjack tuna (about 250,000 pounds in 2007) harvested by small trolling boats for the local market (WPRFMC, 2011b) Fishermen also participate in the bottomfish (bottom-dwelling fish), crustacean, and coral reef fisheries, mostly for subsistence and cultural sharing purposes (fiestas and food exchanges). All waters around the Northern Mariana Islands are considered federal, and thereby under the jurisdiction of the Western Pacific Regional Fishery Management Council, which regulates all fisheries by archipelago, except for the pelagic fisheries. Pelagic fisheries are managed through the *Fishery Ecosystem Plan for Pacific Pelagic Fisheries of the Western Pacific Region* (WPRFMC, 2009b). The fisheries of the Northern Mariana Islands are managed under the *Mariana Archipelago Fishery Ecosystem Plan* (WPRFMC, 2009c), which utilizes an ecosystem-based management approach that emphasizes habitat, ecosystem, protected species, and community participation. .

Advisory Data

Fish Consumption Advisories

The Northern Mariana Islands did not report fish consumption advisory information to EPA in 2006 (U.S. EPA, 2007c).

Beach Advisories and Closures

How many notification actions were reported for the Northern Mariana Islands between 2004 and 2008?

Table 9-3 presents the number of total beaches and monitored beaches for the Northern Mariana Islands, as well as the number and percentage of beaches affected by notification actions from 2005 to 2008. Since 2005, the total number of beaches, as well as the number of monitored beaches, decreased by one-third, from 75 to 50 in 2008. Of these monitored beaches, the percentage closed or under advisory for some period of time during the year remained fairly constant around 80% (U.S. EPA, 2009d). Annual national and state summaries are available on EPA's Beaches Monitoring Web site: http://www.epa.gov/waterscience/beaches/seasons.

Table 9-3. Beach Notification Actions, Northern Mariana Islands, 2004–2008 (U.S. EPA, 2009d)

Numbers and Percentages	2004	2005	2006	2007	2008
Total number of beaches	No data	75	76	76	50
Number of monitored beaches	No data	75	76	76	50
Number of beaches affected by notification actions	No data	61	56	61	39
Percentage of monitored beaches affected by notification actions	No data	81%	74%	80%	78%

Data on pollution sources for the beaches of the Northern Mariana Islands were not available under the EPA BEACH Program at the time of publication.

How long were the 2007 beach notification actions for the Northern Mariana Islands?

In 2007, all of the beach notification actions in the Northern Mariana Islands lasted between 3 to 7 days (U.S. EPA, 2009d). For more information on state beach closures, please visit the EPA's Beaches Web site: http://www.epa.gov/beaches/plan/whereyoulive_state.html.

Puerto Rico

As shown in Figure 9-17, the overall coastal condition of Puerto Rico's coastal waters is rated fair, with an overall condition score of 2.7 based on three of the indices used by the NCA. Data to assess the water quality, sediment quality, and benthic indices were collected for the majority of the 50 sites sampled in 2004. The water quality index is rated good to fair, the benthic index is rated fair, and the sediment quality index is rated poor. NCA was unable to evaluate the coastal habitat or fish tissue contaminants indices for Puerto Rico. Figure 9-18 provides a summary of the percentage of coastal area in good, fair, poor, or missing categories for each index and component indicators for the Puerto Rico coastal resources survey in 2004.

Please refer to Chapter 1 for information about how these assessments were made, the cutpoints used to develop the rating for each index and component indicator, and the limitations of the available data.

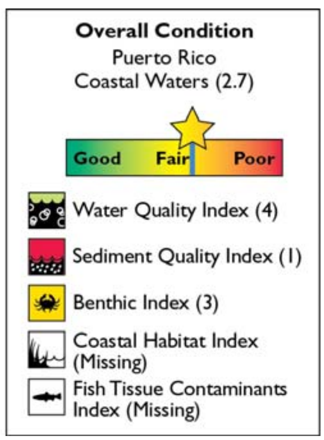


Figure 9-17. The overall condition of Puerto Rico's coastal waters is rated fair to poor (U.S. EPA/NCA).

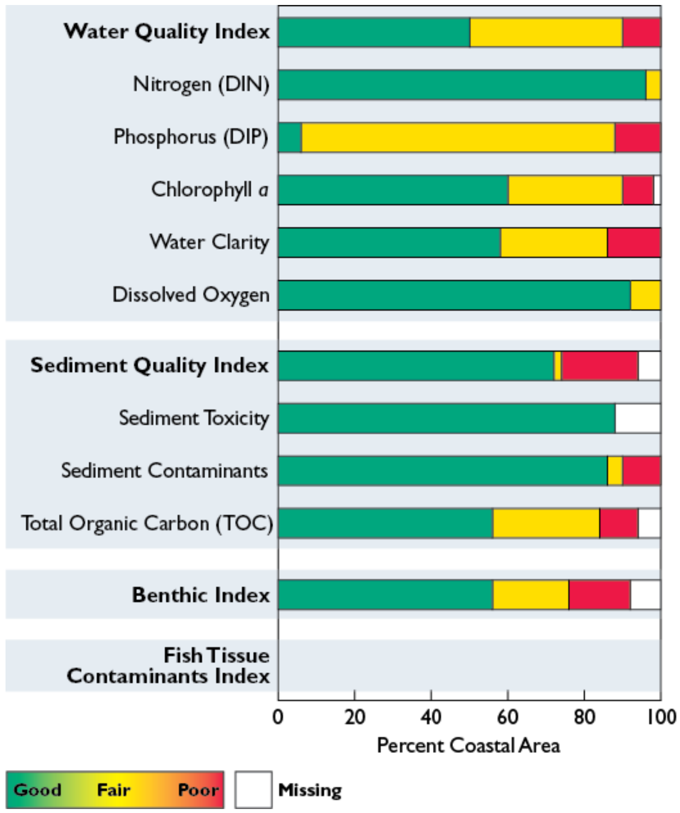


Figure 9-18. Percentage of coastal area achieving each ranking for all indices and component indicators—Puerto Rico (U.S. EPA/NCA).

The island of Puerto Rico is the smallest island of the Greater Antilles and part of the West Indian Province. The volcanic island's geography is mostly mountainous, with a coastal plain belt to the north consisting of sandy beaches along most of the coastal area. Puerto Rico is a densely populated Island Commonwealth of the United States, with approximately 1,146 people per square mile in 2006. Puerto Rico is home to 1.3% of the U.S. population, and the population has increased by 22% between 1980 and 2006, from 3.2 million to 3.9 million people (Figure 9-19) (U.S. Census Bureau, 2010). The majority of the population is concentrated in and around the coastal areas. The estuarine areas are heavily developed, with the island's industries focused in the vicinity of San Juan Bay.

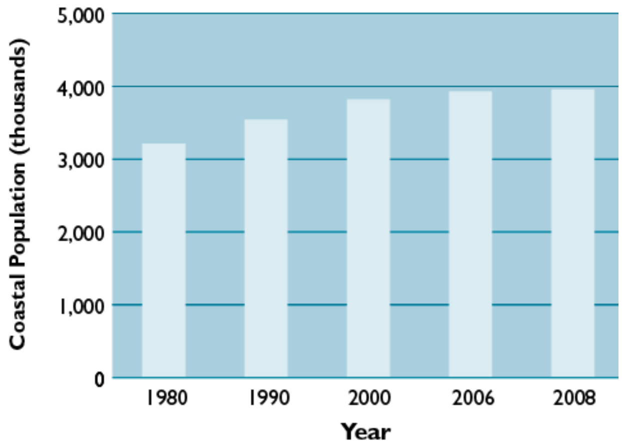


Figure 9-19. Population of Puerto Rico, 1980–2008 (U.S. Census Bureau, 2010).

Coastal Monitoring Data—Status of Coastal Condition

The 2004 assessment of Puerto Rico's coastal resources indicated that, for the indices and component indicators measured, the primary problems in Puerto Rico's coastal waters are degraded sediment quality, degraded benthos (low diversity), and some areas of poor water quality. Sampling stations with consistently low scores for the water quality, sediment quality, and benthic indices were located in San Juan Bay, Guanica Bay, Puerto Yabucoa, and Laguna San José.

Water Quality Index

The water quality index for Puerto Rico's coastal waters is rated fair to good. This water quality index was developed using five water quality indicators: DIN, DIP, chlorophyll *a*, water clarity, and dissolved oxygen. Although only 10% of the coastal area was rated poor, 50% of the area was rated poor and fair, combined (Figure 9-20). Poor water clarity ratings paired with elevated DIP or chlorophyll *a* concentrations at individual sites resulted in poor water quality index scores.

The NCA monitoring data used in this assessment are based on single-day measurements collected at sites throughout the U.S. coastal waters (excluding the Great Lakes) during a 9- to 12-week period during the summer. Each site was sampled once during the collection period of 2003 through 2006. Data were not collected during other time periods.

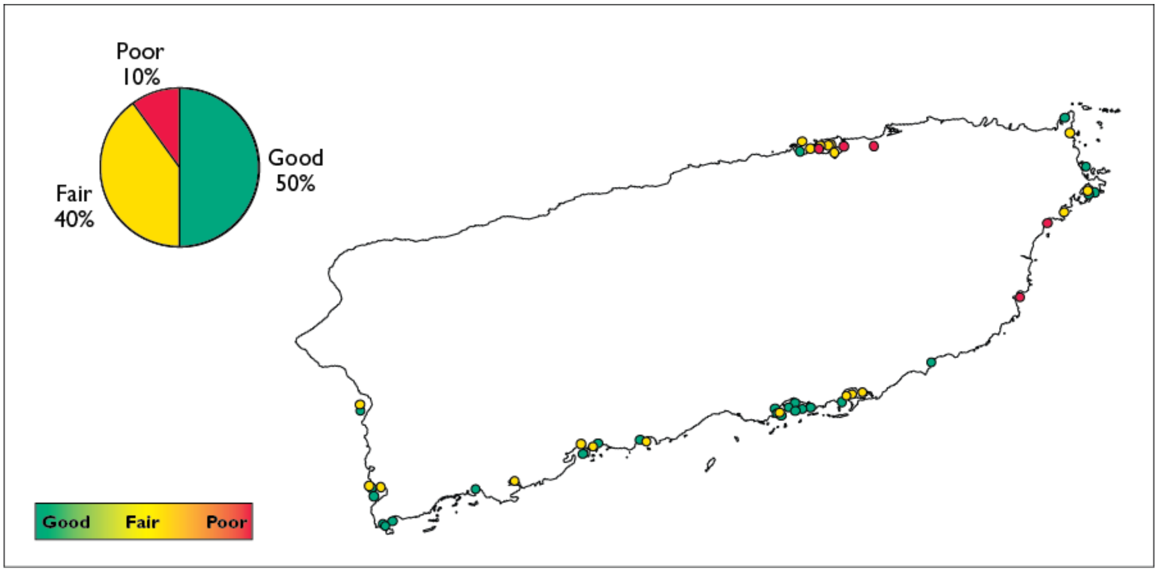


Figure 9-20. Water quality index data for Puerto Rico coastal waters (U.S. EPA/NCA).

Nutrients: Nitrogen and Phosphorus

DIN concentrations were rated good in Puerto Rico's coastal waters, and DIP concentrations were rated fair. For DIN, 4% of the coastal area was rated fair and none of the area was rated poor. The DIP component indicator was rated fair in 82% of the coastal area and poor in 12% of the area.

Chlorophyll *a*

Puerto Rico's coastal waters are rated good for the chlorophyll *a* component indicator, with 30% of the area rated fair and 8% rated poor.

Water Clarity

Water clarity for Puerto Rico is rated fair, with 28% of the coastal area rated fair and 14% of the area rated poor.

Dissolved Oxygen

The dissolved oxygen component indicator is rated good for Puerto Rico because only 8% of the coastal area is rated fair and the rest of the area is rated good.

Sediment Quality Index

Overall, sediment quality in Puerto Rico's coastal waters is rated poor. A sediment quality index was developed for Puerto Rico's coastal waters using three sediment quality component indicators: sediment toxicity, sediment contaminants, and sediment TOC. An estimated 20% of Puerto Rico's coastal area is rated poor for this index, and 2% of the area is rated fair (Figure 9-21). No overlap was identified for areas with elevated TOC concentrations and contaminated sediments.

Sediment Toxicity

Puerto Rico's sediment toxicity was rated good, with none of the coastal area rated poor. Sediment toxicity was not tested for 12% of the area.

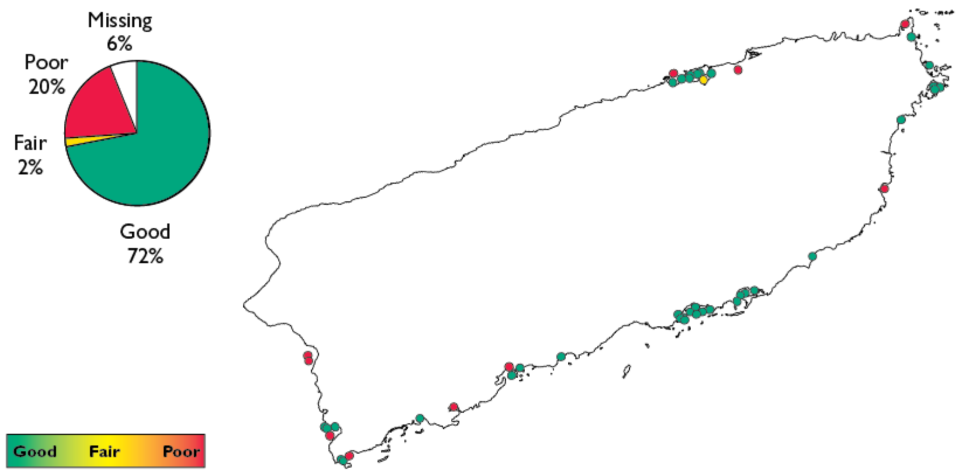


Figure 9-21. Sediment quality index data for Puerto Rico's coastal waters (U.S. EPA/NCA).

Sediment Contaminants

The sediment contaminants component indicator was rated poor for 10% of the coastal area and fair for 4% of the area, resulting in a fair rating for this indicator.

Sediment TOC

The sediment TOC component indicator is rated good for Puerto Rico, with 10% of the coastal area rated poor and 28% rated fair.

Benthic Index

The benthic index for Puerto Rico's coastal waters is rated fair based on deviation from the mean benthic diversity. Approximately 16% of the coastal area is rated poor and 20% is rated fair for this index (Figure 9-22). An additional 8% of the area had missing values.

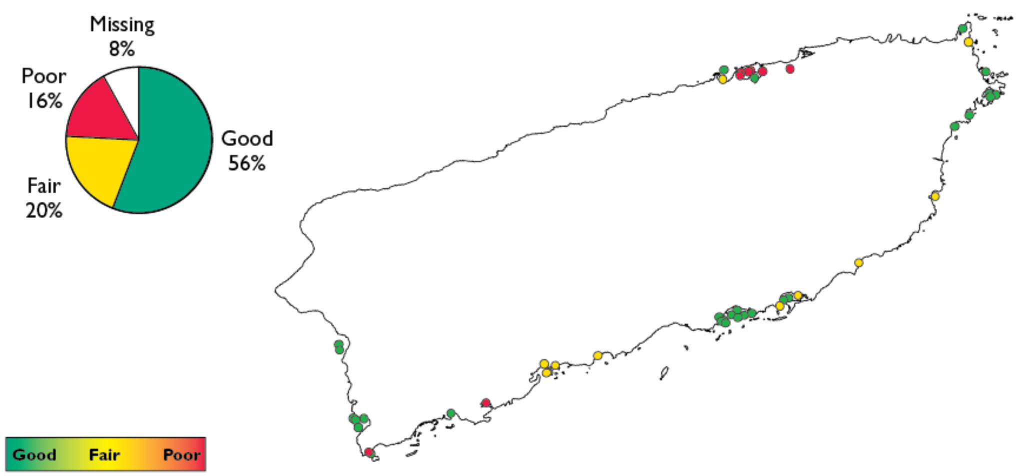


Figure 9-22. Benthic index data for Puerto Rico's coastal waters (U.S. EPA/NCA).

Coastal Habitat Index

Table 9-4 presents the types of wetlands in Puerto Rico between 1990 and 2005. Estimates of coastal habitat loss are not available for Puerto Rico; therefore, the coastal habitat index could not be calculated.

Table 9-4. Marine and Estuarine Wetlands of Puerto Rico (Dahl, 2010)

Type of Wetland	1990–2005 Era Status (acres)
Marine Intertidal	2,174
Estuarine Non-Vegetated	3,685
Estuarine Emergent	13,885
Estuarine Shrub/Forested	23,964
Estuarine Vegetated (subtotal)	37,849
All Intertidal Wetlands	43,708

Fish Tissue Contaminants Index

Fish tissue samples were not collected for 2004 NCA survey of Puerto Rico; therefore, a fish tissue contaminants index could not be calculated. A fish tissue index was calculated from samples collected from San Jose Lagoon and reported for the San Juan Bay Estuary in the 2006 *National Estuary Program Coastal Condition Report* (U.S. EPA, 2006). Based on concentrations of contaminants found in fish and crustacean tissues during the San Jose Lagoon survey, 40% of the sites sampled exceeded EPA Advisory Guidance values for consumption, rendering the calculated fish tissue contaminant index poor for this National Estuary Program waterbody (U.S. EPA, 2006).

Trends of Coastal Monitoring Data—Puerto Rico

In 2000, the first NCA survey conducted in Puerto Rico indicated that the ecological condition of the estuarine resources were in fair to poor condition. Poor condition was mainly attributed to consistently low scores for water quality, sediment quality, and benthic diversity within the areas of San Juan Harbor, the Caño Boquerón, Laguna del Condado, and Laguna San José (U.S. EPA, 2004a). In 2000, the sampling efforts were intensified in San Juan Bay. Differences in results from the 2000 survey and the 2004 assessment presented here may be due to the changes in sample design. However, in areas with recurring degraded ecological conditions, further investigation of potential causes is warranted.

In both surveys, the water quality index was rated fair. In the NCCR II for the 2000 Puerto Rico survey, the water quality scores were attributed to poor chlorophyll *a* scores and fair water clarity. The percent of the coastal area in poor condition for the sediment quality index decreased from over 60% in the 2000 survey to 20% in the 2004 survey. Puerto Rico's rating for the benthic index improved from poor for the 2000 survey to fair for the 2004 survey. With two surveys completed (2000 and 2004) for Puerto Rico, there is sufficient information to develop a benthic index for the island commonwealth. Such an index is needed to examine the relationship between benthic diversity and benthic community structure and habitat to determine whether or not benthic communities are considered degraded for Puerto Rico coastal areas.

Large Marine Ecosystem Fisheries—Caribbean Sea LME

The semi-enclosed Caribbean Sea LME, bounded by the Southeast U.S. Continental Shelf and Gulf of Mexico LMEs, Central America, South America, and the Atlantic Ocean, is considered a moderate-productivity ecosystem with localized areas of higher productivity along the coast of South America (Figure 9-23). This LME is bordered by 38 countries and dependencies (NOAA, 2007a). Commercial fishermen in the Caribbean Sea LME focus mostly on the reef and invertebrate groups. Recreational fishers mainly target dolphinfish, barracuda, snappers, tuna, and wahoo.

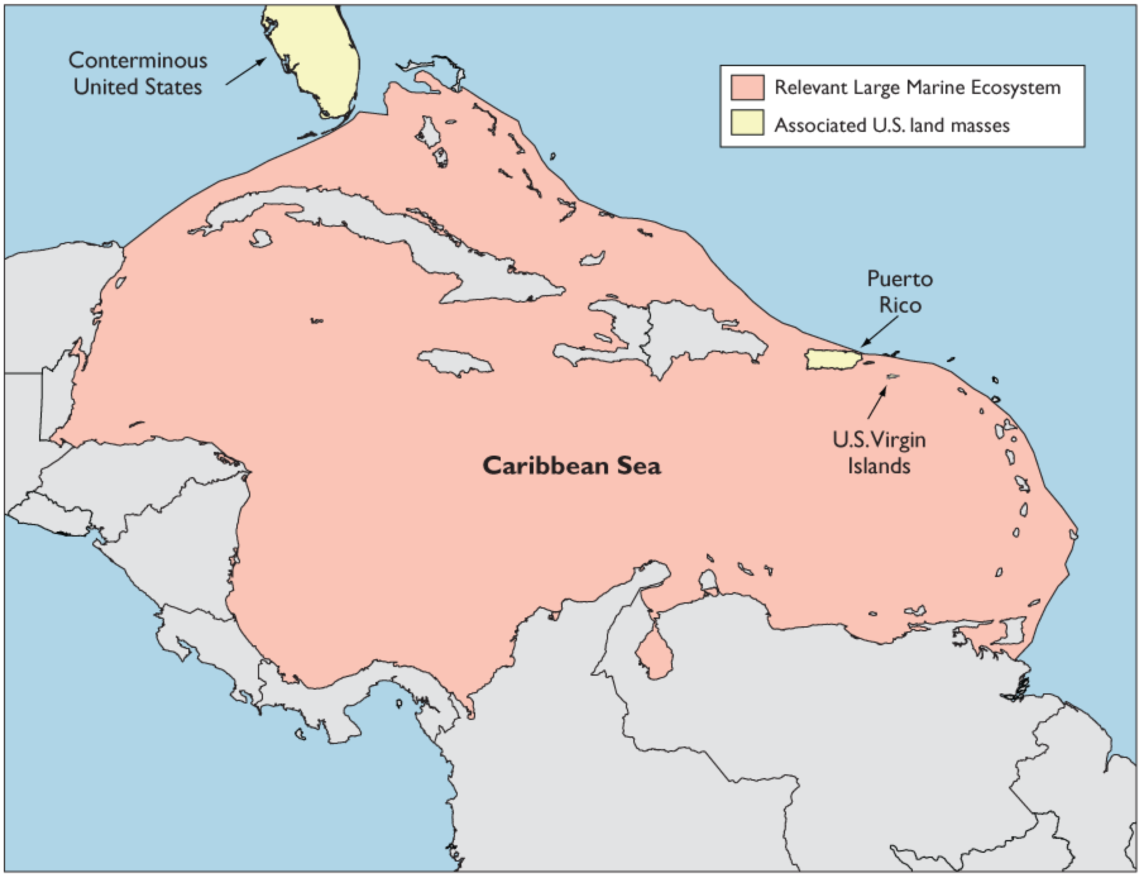


Figure 9-23. Caribbean Sea LME (NOAA, 2010b).

Reef Fisheries

Reef fish of the Caribbean Sea LME include a variety of structure-associated species that reside on coral reefs, artificial structures, or other hard-bottom areas, as well as tilefish that live in muddy-bottom and continental shelf areas. These fish, which include red snapper and grouper, occur at depths ranging from 6 to over 650 feet. Reef -fish fisheries are extremely diverse; vary greatly by location and species; and are utilized by commercial, subsistence, and recreational fisheries for food, commerce, sport, and trophies. These fisheries operate from charter boats, head boats, private boats, and the shore and utilize a range of gear such as fish traps, hook and line, longlines, spears, trammel nets, bang sticks, and barrier nets. Reef fish are associated closely with fisheries for other reef animals, including spiny lobster, conch, stone crab, corals, and live rock and ornamental aquarium species. Non-consumptive uses of reef resources (e.g., ecotourism, sport diving, education, scientific research) also are economically important and may conflict with traditional commercial and recreational fisheries.

Many reef fishes are vulnerable to overfishing due to life-history characteristics, such as slow growth, late maturity, ease of capture, and large body size. Consequently, many stocks are currently considered overfished, including red snapper and gray triggerfish. Fishing may have direct and indirect effects on reef fish ecosystem structure and production. Removals of apex predators from the reef complex may result in shifts of species composition (i.e., trophic and ecological cascades), increased variability in population dynamics of targeted species, and potential evolutionary effects on targeted species. Bycatch is also an area of concern, increasing mortality rates for non-targeted species. Information on species interactions (e.g., predator-prey dynamics) is necessary to guide multi-species assessments and facilitate the movement towards ecosystem management.

Total U.S. reef fish landings in the Caribbean Sea LME have decreased since 1980 (Figure 9-24). At the same time, international pressure on these fishery resources has increased due to growing human populations, greater demands for fishery products, and technological improvements. The Caribbean Fishery Management Council (CFMC) manages reef-fish fisheries within the U.S. EEZ off of the Commonwealth of Puerto Rico and the U.S. Virgin Islands. The Council has developed a FMP for reef fisheries that includes a combined total of 117 reef fish species harvested for human consumption or for the aquarium trade (CFMC, 1996b).

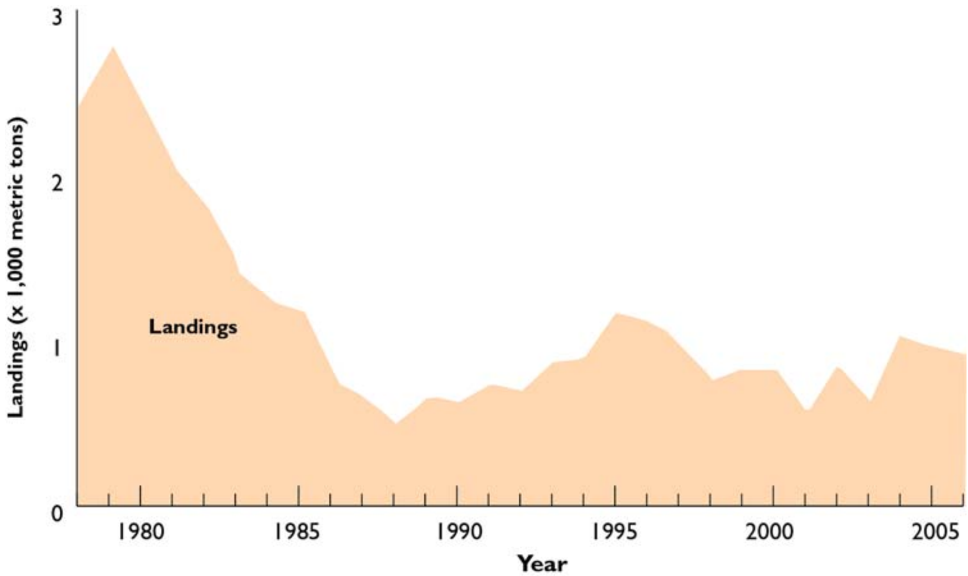


Figure 9-24. U.S. Caribbean Sea LME reef fish landings in metric tons, 1978–2006 (NMFS, 2009b).

Invertebrate Fisheries

Invertebrate fisheries in the Caribbean Sea LME harvest shrimp, spiny lobster, stone crab, and conch. The fishery for spiny lobster in the U.S. Caribbean territories is small. Annual spiny lobster landings for Puerto Rico have averaged 104 metric tons since 1990. U.S. Virgin Islands landings for 1980–2006 were fairly stable, averaging 28 metric tons. In the U.S. Caribbean, spiny lobster is caught primarily by fish traps, lobster traps, and divers (NMFS, 2009b). The CFMC's *Spiny Lobster Fishery Management Plan* (CFMC et al., 2008) is based on a 3.5-inch minimum carapace length and protection of egg-bearing female lobsters (Bolden, 2001).

The conch fishery targets the queen conch (*Strombus gigas*), most of which are taken by divers. Queen conch is a mollusk with a spiral-shaped shell and a pink or orange interior. It can reach a weight of 5 pounds and a length of 12 inches. Conch are mostly harvested for direct human consumption, though their meat may also be used for bait, and their shells are often used for jewelry. The resource can be easily depleted, and the queen conch is covered by an FMP (CFMC, 1996a). For the 2004−2006 time period, the recent conch average yield is 110 metric tons (NMFS, 2009b). Queen conch is considered overfished, largely due to trap fishing and bycatch associated with the reef fisheries (NMFS, 2009b).

Habitat concerns impact many of the Caribbean invertebrate fishery resources. Estuarine and marsh loss removes critical habitat used by young shrimp (Minello et al., 2003). Spiny lobsters depend on reef habitat and shallow water algal flats for feeding and reproduction, but these habitat requirements may conflict with expanding coastal development.

Advisory Data

Fish Consumption Advisories

Puerto Rico did not report fish consumption advisory information to the EPA in 2006 (U.S. EPA, 2007c).

Beach Advisories and Closures

How many notification actions were reported for Puerto Rico between 2004 and 2008?

Table 9-5 presents the number of total and monitored beaches for Puerto Rico from 2004 to 2008, as well as the number and percentage of beaches affected by notification actions over this same time period. Over the past several years, the total number of identified and monitored beaches in Puerto Rico has fluctuated between 22 and 23. Of these monitored beaches, the percentage closed or under advisory for some period of time during the year increased from 5% in 2004 to 50% in 2008 (or 11 beaches) (U.S. EPA, 2009d). Annual national and state summaries are available on EPA's Beaches Monitoring Web site: http://www.epa.gov/waterscience/beaches/seasons.

Table 9-5. Beach Notification Actions, Puerto Rico, 2004–2008 (U.S. EPA, 2009d)

Numbers and Percentages	2004	2005	2006	2007	2008
Total number of beaches	22	23	23	23	22
Number of monitored beaches	22	23	23	23	22
Number of beaches affected by notification actions	1	5	8	14	11
Percentage of monitored beaches affected by notification actions	5%	22%	35%	61%	50%

Data on pollution sources is not available under the EPA BEACH Program for Puerto Rico.

How long were the 2007 beach notification actions?

Just over half of beach notification actions in Puerto Rico in 2007 lasted from 3 to 7 days. The other half of the notification actions was comprised of those lasting from 8 to 30 days (U.S. EPA, 2009d). For more information on state beach closures, please visit the EPA's Beaches Web site: http://www.epa.gov/beaches/plan/whereyoulive_state.html.

U.S. Virgin Islands

As shown in Figure 9-25, the overall coastal condition of the U.S. Virgin Islands' coastal waters is rated fair to good based on three of the indices used by NCA. Both the water quality and benthic diversity indices are rated good, and the sediment quality index is rated fair to poor. NCA was unable to evaluate the coastal habitat or fish tissue contaminant indices for the U.S. Virgin Islands. Figure 9-26 provides a summary of the percentage of coastal area in good, fair, or poor categories for each index and component indicator. This assessment for the U.S. Virgin Islands is based on results from 47 sites sampled in 2004.

Please refer to Chapter 1 for information about how these assessments were made, the cutpoints used to develop the rating for each index and component indicator, and the limitations of the available data.

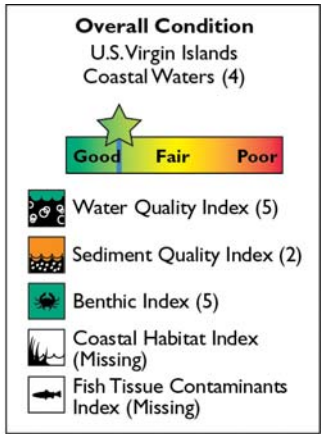


Figure 9-25. The overall condition of the U.S. Virgin Islands' coastal waters is rated fair to poor (U.S. EPA/NCA).

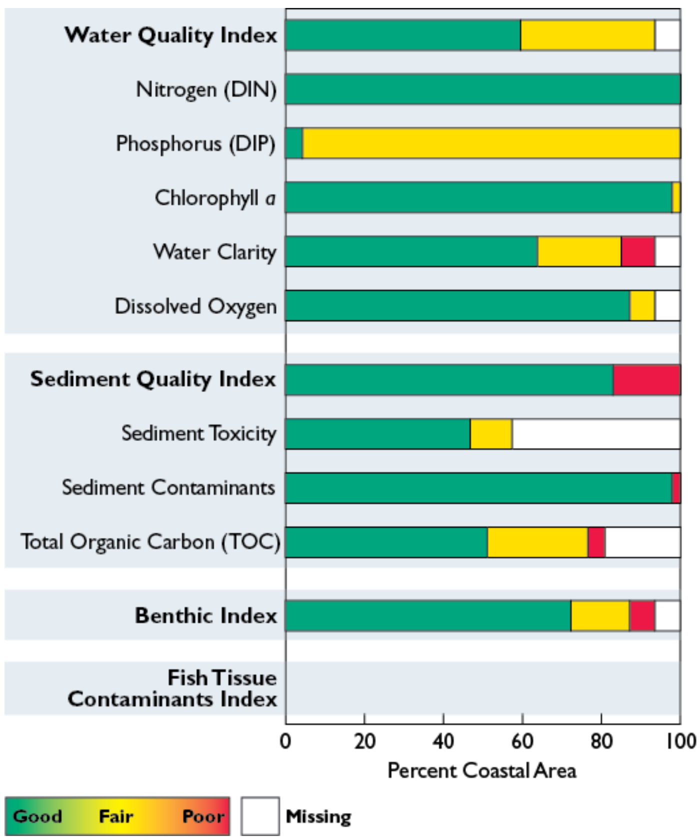


Figure 9-26. Percentage of coastal area achieving each ranking for all indices and component indicators—U.S. Virgin Islands (U.S. EPA/NCA).

The U.S. Virgin Islands are part of the West Indian Province. The combined coastline of the islands is approximately 117 miles. The islands of St. John and St. Thomas are of volcanic origin, with hilly terrains, while St. Croix has a gentle sloping topography and is built of coral reefs. Between 1980 and 2006, the population of the U.S. Virgin Islands increased by approximately 12%, from 98,000 people to

110,000 people (Figure 9-27). In 2006, the population density was 613 persons per square mile (U.S. Census Bureau, 2010). Charlotte Amalie, the capital city of the U.S. Virgin Islands, is a popular port of call for cruise ships in St. Thomas, with more than a million passengers passing through each year. The islands are characterized by natural deep-water harbors, beautiful beaches, and National Park areas, all of which draw industry, trade, and tourism to these U.S. island territories.

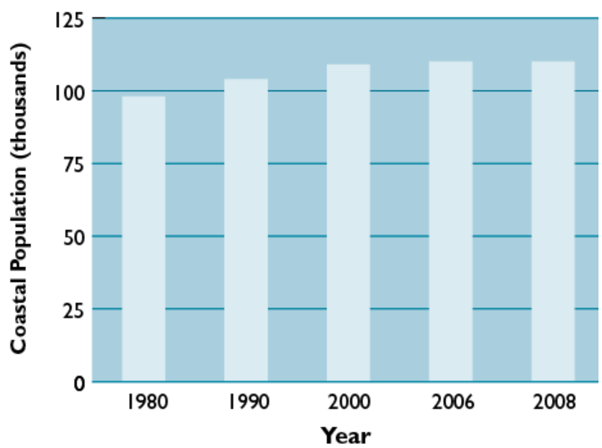


Figure 9-27. Population of the U.S. Virgin Islands, 1980–2008 (U.S. Census Bureau, 2010).

Coastal Monitoring Data—Status of Coastal Condition

Water Quality Index

The water quality index for the U.S. Virgin Islands coastal waters is rated good, with 34% of the coastal area rated fair and none rated poor (Figure 9-28). This water quality index was developed using five water quality indicators: DIN, DIP, chlorophyll *a*, water clarity, and dissolved oxygen. Decreased water clarity and elevated DIP concentrations (fair) contributed to fair water quality scores.

The NCA monitoring data used in this assessment are based on single-day measurements collected at sites throughout the U.S. coastal waters (excluding the Great Lakes) during a 9- to 12-week period during the summer. Each site was sampled once during the collection period of 2003 through 2006. Data were not collected during other time periods.

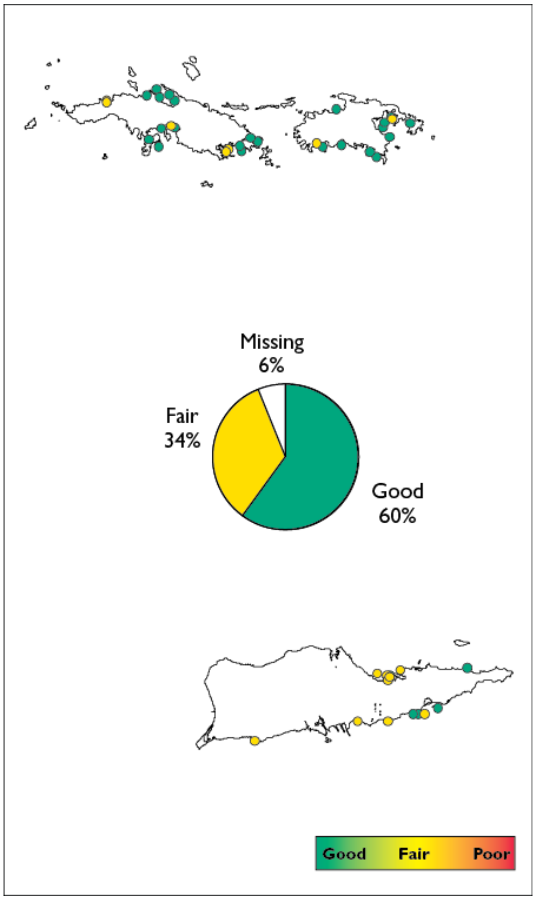


Figure 9-28. Water quality index data for the U.S. Virgin Islands coastal waters (U.S. EPA/NCA).

Nutrients: Nitrogen and Phosphorus

The U.S. Virgin Islands are rated good for DIN, with 100% of the coastal area rated good for this component indicator. The DIP component indicator is rated fair because 96% of the U.S. Virgin Islands coastal area is rated fair.

Chlorophyll *a*

The chlorophyll *a* component indicator is rated good for the U.S. Virgin Islands, with 98% of the coastal area rated good and 2% rated fair.

Water Clarity

Water clarity is rated good in the U.S. Virgin Islands. Approximately 21% of the coastal area is rated fair and 9% is rated poor.

Dissolved Oxygen

The U.S. Virgin Islands are rated good for dissolved oxygen, with 7% of the coastal area rated fair and none rated poor for this component indicator.

Sediment Quality Index

The sediment quality index is rated fair to poor for the U.S. Virgin Islands. The sediment quality index was calculated for the U.S. Virgin Islands using component indicators for sediment toxicity, sediment contaminants, and sediment TOC. Approximately 17% of the survey area exhibited poor sediment quality (Figure 9-29). Elevated TOC and sediment toxicity were found at various sites across the islands of St. Croix, St. Thomas, and St. Johns.

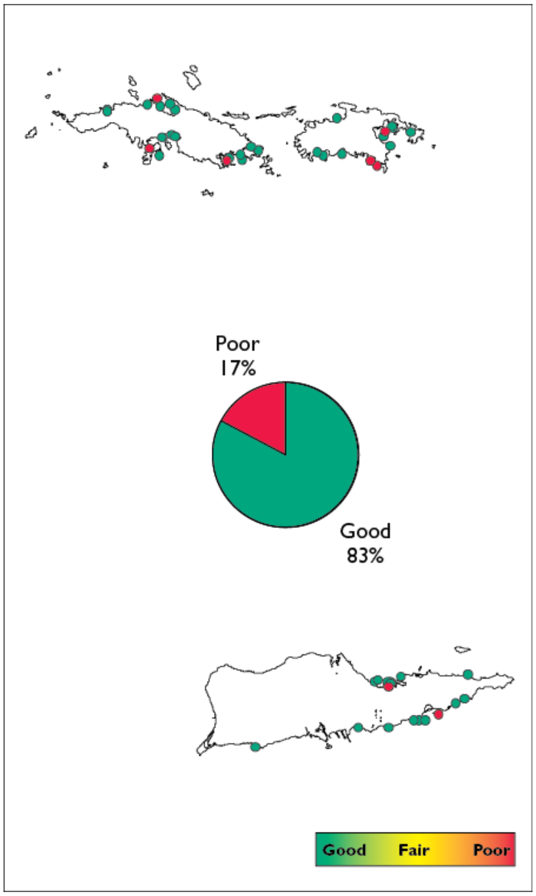


Figure 9-29 Sediment quality index data for U.S. Virgin Islands' coastal waters (U.S. EPA/NCA).

Sediment Toxicity

The sediment toxicity component indicator is rated poor for the U.S. Virgin Islands. Although only 11% of the coastal area is rated poor for this indicator, results are missing for 42% of the area.

Sediment Contaminants

The U.S. Virgin Islands are rated good for the sediment contaminants component indicator, with 2% of the coastal are rated poor and 98% rated good. The sites rated poor were located in Christenstead Harbour, a capital city port of the island of St. Croix, and demonstrated elevated levels of chromium, copper, and lead.

Sediment TOC

The sediment TOC component indicator is rated good for the U.S. Virgin Islands, with 26% of the area rated fair and 4% rated poor. Results were missing for 19% of the coastal area.

Benthic Index

The benthic index for the U.S. Virgin Islands is rated good based on deviation from the mean benthic diversity. Approximately 6% of the coastal area is rated poor and 15% is rated fair for this index (Figure 9-30). An additional 7% had missing values.

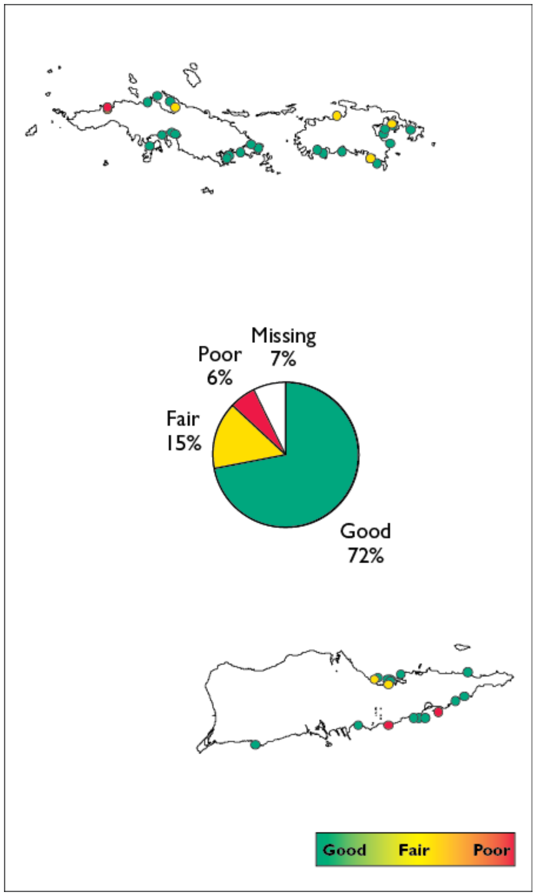


Figure 9-30. Benthic index data for U.S. Virgin Islands' coastal waters (U.S. EPA/NCA).

Coastal Habitat Index

Table 9-6 presents the types and extents of wetlands in U.S. Virgin Islands between 1990 and 2005, as well as the change in the wetlands' extents over this timeframe. These estimates of coastal habitat loss do not cover the time period necessary to calculate the coastal habitat index (see Chapter 1 for more information); therefore, the coastal habitat index could not be calculated.

Table 9-6. Marine and Estuarine Wetlands of U.S. Virgin Islands (Dahl, 2010)

Type of Wetland	1990 Era (acres)	2005 Era (acres)	Change (acres)
Marine intertidal	18	112	94
Estuarine non-vegetated	467	405	-62
Estuarine emergent	1	8	7
Estuarine shrub/forested	663	617	-46
Estuarine vegetated (subtotal)	664	625	-39
All intertidal wetlands	1149	1142	-7

Fish Tissue Contaminants Index

Estimates of fish tissue contaminants were not available for U.S. Virgin Islands; therefore, the fish tissue contaminants index could not be calculated.

Large Marine Ecosystem Fisheries—Caribbean Sea LME

The U.S. Virgin Islands are located within the Caribbean Sea LME, which is discussed in the Puerto Rico section of this chapter.

Advisory Data

Fish Consumption Advisories

The U.S. Virgin Islands did not report fish consumption advisory information to the EPA in 2006 (U.S. EPA, 2007c).

Beach Advisories and Closures

How many notification actions were reported for the U.S. Virgin Islands between 2004 and 2008?

Table 9-7 presents the total number of beaches, the number of monitored beaches, the number of beaches affected by notification actions, and the percentage of monitored beaches affected by notification actions from 2005 to 2008 for the U.S. Virgin Islands. Over the past several years, the total number of beaches and the number of monitored beaches has decreased from 45 in 2005 to 43 in 2008. Of these monitored beaches, the percentage closed or under advisory for some period of time during the year has decreased markedly from 71% in 2005 to 19% in 2008 (or 8 beaches) (U.S. EPA, 2009d). Individual state summaries are available on EPA's Beaches Monitoring Web site: http://www.epa.gov/waterscience/beaches/seasons.

Table 9-7. Beach Notification Actions, Virgin Islands, 2004–2008 (U.S. EPA, 2009d)

Numbers and Percentages	2004	2005	2006	2007	2008
Total number of beaches	No data	45	45	45	43
Number of monitored beaches	No data	45	45	45	43
Number of beaches affected by notification actions	No data	32	8	3	8
Percentage of monitored beaches affected by notification actions	No data	71%	18%	7%	19%

Data on pollution sources is not available under the EPA BEACH Program for the U.S. Virgin Islands.

How long were the 2007 beach notification actions?

For 2007, all of the beach notification actions lasted between 3 to 7 days (U.S. EPA, 2009d). For more information on state beach closures, please visit the EPA's Beaches Web site: http://www.epa.gov/beaches/plan/whereyoulive_state.html.

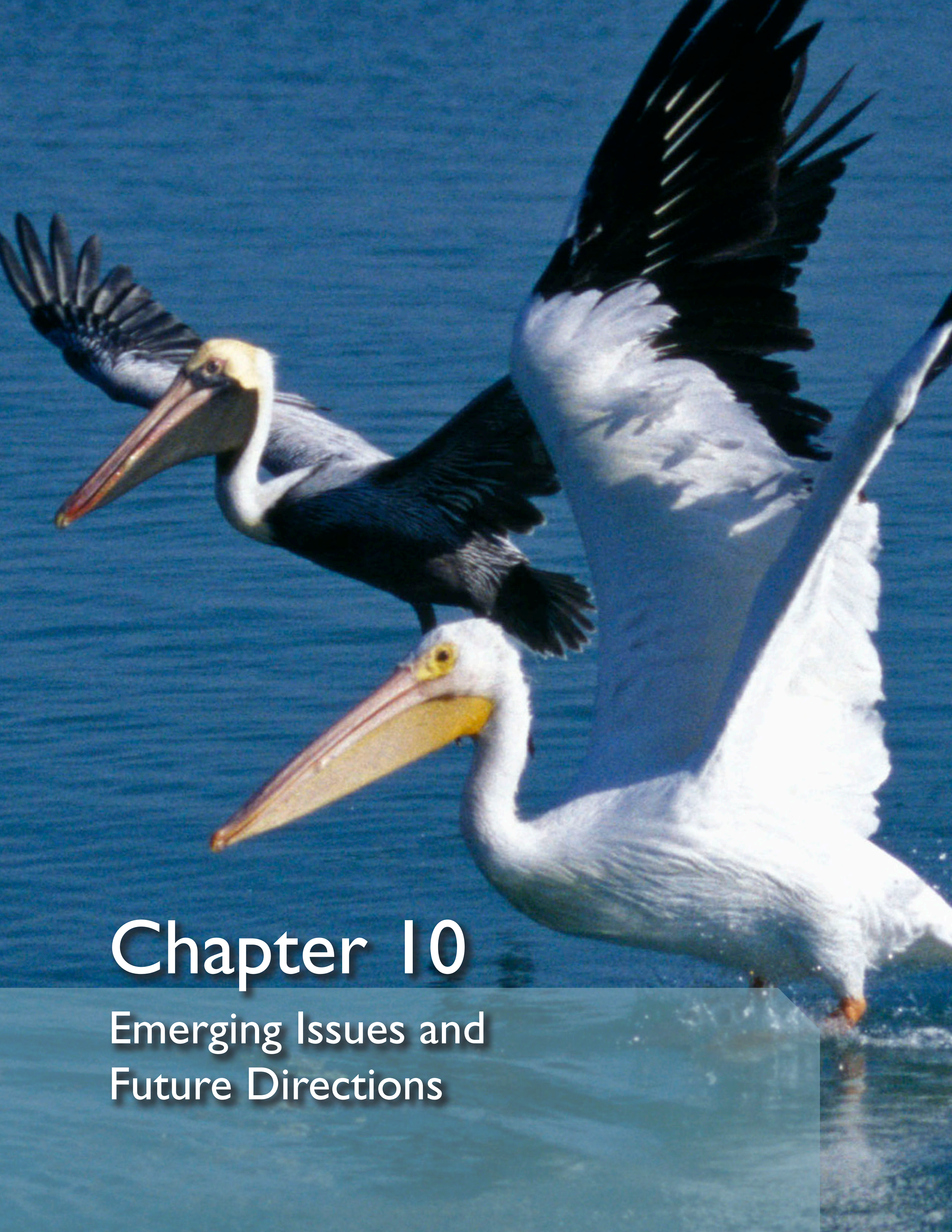
Summary

In 2004, NCA assessed the coastal areas of the U.S. territories of American Samoa, Guam, and the U.S. Virgin Islands, and the Commonwealth of Puerto Rico. The overall condition of American Samoa coastal waters is good based on ratings for water quality and fish tissue contaminants. Guam's coastal waters are also rated good, with all indices measured rated good except benthic condition, which was rated good to fair. NCA did not perform assessments for the Northern Mariana Islands. The overall coastal condition of Puerto Rico's coastal waters is rated fair, with the water quality index rated good to fair, the benthic index rated fair, and the sediment quality index rated poor. The U.S. Virgin Islands' coastal waters are rated fair to good, with both water quality and benthic diversity indices rated good, and the sediment quality index rated fair to poor.

Guam and American Samoa are not located within LMEs. The NMFS Western Pacific Region manages the fisheries in these waters in conjunction with those of the Insular Pacific-Hawaiian LME. Landings from the waters surrounding American Samoa, Guam, and the Northern Mariana Islands are dominated by highly migratory pelagic species. Puerto Rico and the U.S. Virgin Islands are located in the Caribbean Sea LME, and the reef fish stocks in their coastal waters are managed by the CFMC. Fishing pressure in these areas has increased over time, along with growing human populations, greater demands for fishery products, and technological improvements. Many stocks with a known status are currently considered overfished.

Contamination in the coastal waters of American Samoa and Guam has affected human uses of these waters. American Samoa had one advisory in effect in 2006 for Inner Pago Pago Harbor due to arsenic, chromium, copper, DDT, lead, mercury, zinc, and PCBs. Two advisories were in effect for Guam's Orote Point and Apra Harbor for chlorinated pesticides, dioxins, and PCBs. Puerto Rico, the Northern Mariana Islands, and the U.S. Virgin Islands did not report fish consumption advisory information to EPA in 2006.

Ninety-three percent of American Samoa's monitored beaches were closed or under advisory for some period of time during 2006 due to contamination. Guam monitored 33 beaches in 2006, all of which were closed or under advisory at some time during the year due to contamination. The Northern Mariana Islands issued beach advisories or closures for 74% of monitored beaches in 2006. In Puerto Rico and the U.S. Virgin Islands, 35% and 18% of beaches, respectively, were affected by advisories or closures in 2006.



Chapter 10

Emerging Issues and Future Directions

10. Emerging Issues and Future Directions

Over the past decade, national coastal monitoring programs have consistently adapted to changing national priorities and emerging issues. As demand for coastal and marine resources increases due to growing populations and development, ecosystems are affected by the resulting environmental stress. The combination of multiple coastal stressors (e.g., invasive species, hypoxia, emerging contaminants, climate change) will impact ecosystem function, likely undermining the provision of ecosystem services to human well-being. This chapter presents the complexities of these combinations and stresses the need for targeted coastal monitoring efforts.

Each consecutive report in the NCCR series has presented an expanded spatial extent of sampling, improved indices, and the current state of coastal monitoring science. Such improvements will continue as the NCA becomes the National Coastal Condition Assessment (NCCA), under the purview of the EPA's Office of Water (OW), for the next NCCR (*National Coastal Condition Report V*). The NCCA will be part of the National Aquatic Resource Survey program, an effort to assess the quality of various U.S. aquatic resources, including lakes, rivers and streams, and wetlands (see http://www.epa.gov/OWOW/monitoring/nationalsurveys.html). As part of this transformation, the NCCA will reflect changing priorities with greater focus on human health and evolving coastal issues. The NCCA will also include, for the first time, sampling in the Great Lakes and updated sampling for the non-conterminous U.S. states and territories (with the exception of Alaska). The latest addition to the NCCR list of indicators under the NCCA is bacterial contamination. This indicator reflects the evolution of the NCCA program towards prioritizing human health, as well as a general effort to expand estuarine monitoring efforts to assess other existing and emerging coastal issues. In addition, EPA has formed indicator workgroups to reassess the indices, component indicators, and cutpoints prior to the data analysis for the NCCR V.

Improvements in coastal programs are occurring on a much greater scale as well. Under a directive from President Obama, an Interagency Ocean Policy Task Force was formed in June of 2009 to streamline management of our nation's coastal and ocean waters. The task force drafted a set of recommendations that highlighted nine priority areas, including regional ecosystem protection and the integration of ocean observing systems and data platforms (White House Council on Environmental Quality, 2009). The NCA program is particularly relevant to this effort because it provides geospatially referenced coastal environmental data that are based on regional ecosystem delineations and integrate information from other federal agencies. The Task Force also drafted the CMSP Framework (discussed in Chapter 2), which provides for a comprehensive and integrated approach to facilitating multiple uses and activities in the nation's coastal waters without undermining the services generated by coastal ecosystems.

Ecosystem Services

Our nation's ecosystems provide vast amounts of services that generate numerous social and economic benefits to individuals and society as a whole. These benefits range from energy production and nutrient cycling to education and recreational activities. For example, although estuaries comprise only 13% of the land area of the continental United States, they account for a large proportion of national ecosystem services, including the provision of seafood and pharmaceuticals, waste treatment, waste cycling, coastal protection, and income generation from tourism and recreational activities.

Despite the benefits to human health and social well-being ensured by these services, a lack of scientific and socioeconomic knowledge has prevented policy makers from fully considering ecosystem services in planning efforts. In order to minimize this gap, researchers in EPA's Office of Research and Development developed the Ecosystem Services Research Program (ESRP) to identify, map, model, and quantify ecosystem services. The decision support framework generated by this program will provide managers with the tools to make decisions with knowledge of the value ecosystem services provide and the potential costs of their alteration. For the ESRP, see http://www.epa.gov/ecology/.

Climate Change

The priority areas identified by the Interagency Ocean Policy Task Force included resiliency and adaptation to climate change and ocean acidification, issues that are being tackled by numerous federal agencies, including the EPA. There are three overarching impacts on coastal waters from climate change: sea-level rise, rising sea surface temperatures, and ocean acidification. These impacts interact in various ways. The impacts may correlate directly, as is the case with higher sea temperatures leading to sea-level rise, or the combination of these impacts may magnify individual impacts. For example, rising temperatures and ocean acidification could mutually and concurrently undermine the viability of coral reefs. Rising sea temperatures may cause coral bleaching events, while ocean acidification may directly undermine the skeletal structures of reefs. On the other hand, these three impacts may also counteract one another. For example, increased freshwater input from melting glaciers may actually counterbalance some of the saltwater intrusion (i.e., the movement of salt water into freshwater aquifers or waterbodies) caused by sea-level rise, although this effect would be regionally specific. Overall landward saltwater movement will depend on a combination of sea level rise, as well as changes in precipitation, runoff, and recharge in coastal watersheds (Barlow, 2003). Despite uncertain interactions, climate change effects will likely significantly alter the composition, productivity, and functioning of coastal ecosystems.

Despite overwhelming scientific consensus on the inevitability of climate change, significant uncertainty as to the degree of impact remains. Furthermore, regional differences in geomorphology (i.e., landscape elevation and shape), biogeochemistry, ecology, and even coastal communities will affect sensitivity to climate change around the United States (Field et al., 2000). This inherent complexity makes the science of climate change a dynamic field; therefore, the information presented below is meant as an introduction to current understanding, areas of research, and some relevant programs.

Sea Surface Temperature

Since the 1880s, the Earth’s surface temperature has been rising. According to NASA estimates (NASA, 2010), the rate of temperature increase has accelerated over the past 30 years, and the previous decade (2000–2009) was the warmest on record (Figure 10-1). Sea surface temperatures rose by approximately 0.3 degree Celsius during the past 10 years.

Sea temperature directly affects oceanic biophysical and chemical processes, as well as ecosystem functions, such as the distribution, function, and reproduction of plant and animal species. Several severe consequences for coastal ecosystems are associated with rising sea surface temperatures, including changes in the frequency and extent of harmful algal blooms, altered or disrupted migrations of marine organisms, increased hurricane intensity, and sea-level rise (discussed below). The rate of sea surface temperature increase will not be uniform across the world. High latitudes will warm faster than low latitudes due to differences in the reflective qualities of ice and water. Sea water is less reflective than ice; therefore, the melting of ice near the poles would result in the oceans absorbing more solar radiation and energy, causing additional warming closer to the poles (GFDL, 2007). Between 1955 and 2003, the temperature of the North Atlantic Ocean increased by twice the global average rate (Smith et al., 2010).

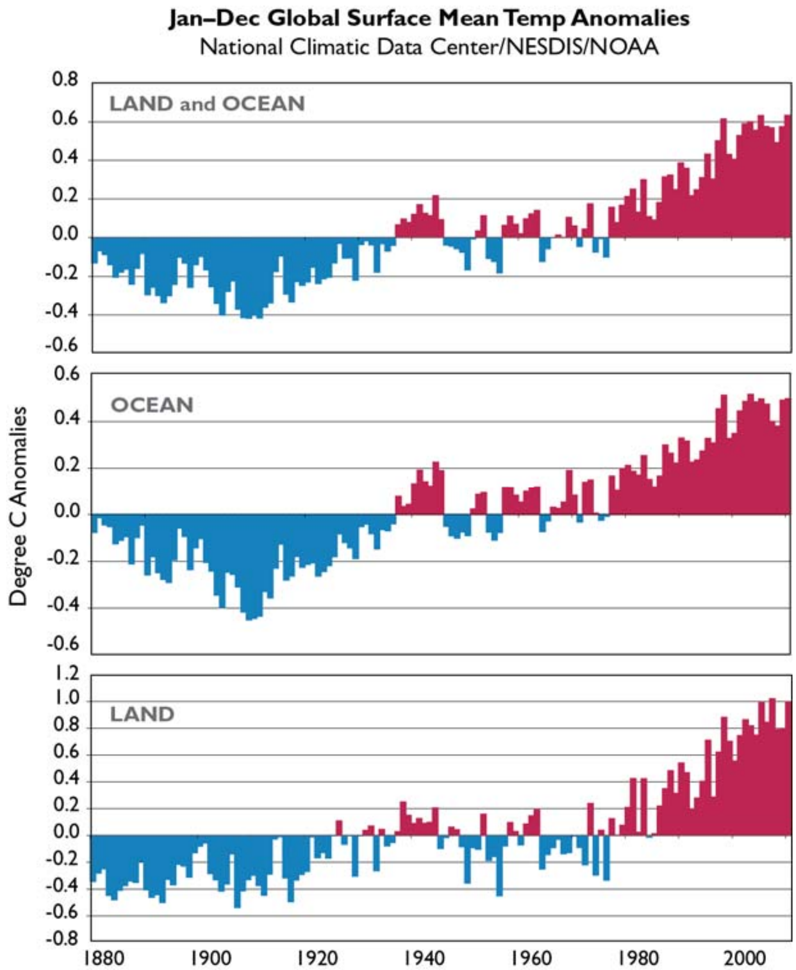


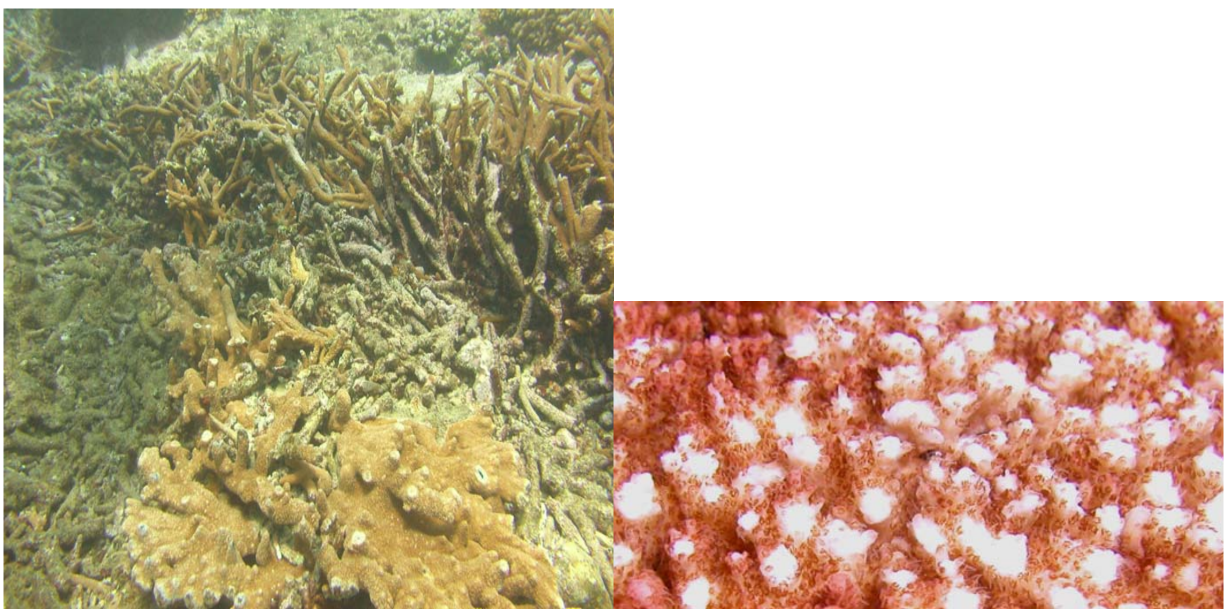
Figure 10-1. Global mean surface temperatures over time (NCDC, 2010).

Effects on marine species will also vary based on particular biological characteristics and local conditions. Generally, mobile organisms will be able to move to more hospitable habitats whereas stationary organisms (e.g., coral) will be more susceptible to any changes. However, increasing air, soil, and water temperatures may have positive effects for some flora (e.g., mangroves, salt marshes, forested wetlands) for which low temperatures and freezing events are the limiting factors for geographic distribution (Scavia et al., 2002). For example, demersal (bottom-dwelling) species (e.g., cod, plaice, haddock, redfish, flounder) that are found in the Atlantic Ocean are expected to migrate northward, with current mid-Atlantic species (e.g., butterfish, herring, mackerel, menhaden) expanding as far north as the Gulf of Maine (Scavia et al., 2002; Field et al., 2000). Population shifts for individual species may alter predator-prey relationships and community dynamics, ultimately impacting whole ecosystems (Field et al., 2000). Other mechanisms, including feeding, growth, and reproduction, will be impacted in diverse and complex ways by rising sea temperatures (Smith et al., 2010).

Warming waters favor algal blooms, some of which can produce toxins consumed by filter-feeders like mussels and clams. These toxins accumulate and can cause paralytic shellfish poisoning in humans who eat them. Harmful algae can also cause deterioration of water quality through the buildup of high biomass, which degrades aesthetic, ecological, and recreational values. Evidence indicates that climate warming may benefit some species of harmful blue-green algae (cyanobacteria) by providing more optimal conditions for their growth (Paerl and Huisman, 2008; 2009). Rising sea surface temperatures have also been associated with increases in dinoflagellates (many harmful algal bloom species are dinoflagellates) and with an earlier appearance of dinoflagellates in the seasonal cycle (Dale et al., 2006).

Living in above-optimal temperatures may increase stress on individual organisms, reducing growth, slowing metabolism, and weakening immune systems (Scavia et al., 2002). High-temperature variability leaves organisms stressed and vulnerable to marine diseases, which favor warmer waters. For example, when the El Niño Southern Oscillation cycle increased in frequency and severity in the mid-1970s, the Caribbean became a disease hot spot, with virtual eradication of staghorn and elkhorn corals and a sea urchin species (Harvell et al., 1999).

Rising sea surface temperatures are already altering tropical ecosystems via coral bleaching. Corals lose their symbiotic algae and/or their pigments under stressful conditions, most notably anomalously high sea surface temperatures (~1 degree C above average seasonal maxima), resulting in a whitening of corals known as bleaching (though bleaching events have also occurred with anomalously low sea surface temperatures). Major bleaching events have been noted throughout the world's oceans since the 1980s, with a particularly severe bleaching event affecting the Caribbean in late 2005 (Donner, 2009). This event resulted in a 51.5% decline in mean coral cover between 2005 and 2006, due to the bleaching effects coupled with a spread of marine diseases (Woody et al., 2008). The predicted rise in future sea surface temperatures will likely increase the occurrence of bleaching events and marine diseases, exacerbating existent coral stressors, including pollution, destructive fishing, diseases, and loss of key herbivores.



"A partially bleached Acropora coral. The white portions have lost the golden brown algae (zooxanthellae) that normally give the tissues their color" (U.S. EPA, 2007b; photo by Eric Mielbrecht).

The socioeconomic consequences of rising sea surface temperatures could affect numerous coastal communities throughout the United States. Unsightly algal blooms will likely decrease swimming, boating, and tourism activities, while noxious algae may actually have detrimental impacts on human health (NSTC, 2003). Harmful algal blooms in coastal waters have been conservatively estimated to result in economic impacts in the United States of at least $82 million/year with the majority of impacts in the public health and commercial fisheries sectors (Hoagland and Scatasta, 2006). Impacts of a single bloom event on commercial fisheries can be very significant. In 2005, a major toxic algae bloom caused state agencies to close the shellfish beds from Maine to Martha's Vineyard, resulting in an estimated $20 million loss to the Massachusetts shellfish industry (NOAA, 2010).

The economies of the U.S. Virgin Islands, Puerto Rico, Hawaii, and Pacific island territories rely heavily upon their surrounding coral reefs for numerous ecosystem services, including fisheries, recreation, tourism, and coastal protection. Reefs are important habitat, spawning, and nursery grounds for numerous commercially viable fish species. In Hawaii, surrounding coral reefs are largely responsible for annual contributions of $60 million from the fishery industry and $800 million from the marine tourism industry (Friedlander et al., 2008). A 2001 study estimated the annual use value of Florida's southeastern coral reefs at over $250 million, with a capitalized value of $8.5 billion (Johns et al., 2001). Therefore, the long-term survival of coral reefs is crucial for coastal communities and economies. Coral reefs also serve as buffers against storm surges. With increasing hurricane strength, resulting from climate change, the role of reefs as protective buffers will likely be diminished. For more information on the potential impacts of rising sea surface temperatures on coastal and marine ecosystems, see NOAA's Ocean and Coastal Resource management Web site at http://coastalmanagement.noaa.gov/climate.html.

Sea-Level Rise

Rising sea surface temperatures may also impact our coasts by contributing to sea-level rise via a process known as thermal expansion (when water warms, it expands and thereby increases in volume). This volume increase along with freshwater input from melting ice sheets, glaciers, and ice caps will cause sea levels to rise. During the 20th century, the average global sea-level rise was 4.8 to 8.8 inches (U.S. EPA, 2010a). Regional rates, known as relative sea-level rise, differ because they are measured as the sum of global sea-level rise and regional vertical land movements (resulting from regional tectonics, post-glacial isostatic adjustments, natural sediment compaction, or subsidence due to the withdrawal of subsurface fluids such as groundwater, oil, and natural gas) (Figure 10-2). Throughout the 20th century, sea-level rise in the mid-Atlantic and Gulf was 5 to 6 inches more than the global average. Rising sea levels may cause beach erosion, land submersion, wetland loss, coastal flooding, saltwater intrusion into estuaries and aquifers, and greater damages from hurricanes due to higher storm surge.

Figure 10-2. Trends in sea level (NOAA, 2008).

The impacts associated with sea-level changes will be varied based on relative sea-level rise and local geographic, biological, ecological, and socioeconomic conditions. Shallow coastal aquifers in places like the Everglades are susceptible to salinity increases (i.e., saltwater intrusion), which can potentially impact communities of plants and animals with limited tolerance to salinity fluctuations and complicating water intakes for coastal communities. The East and Gulf coasts are more susceptible to inundation because of their gently sloping coasts and developed barrier islands, which are prone to erosion (Scavia et al., 2002). In Florida, where 90% of state residents live on the coast, a rise of 23 inches by 2050 would cost the state $92 billion per year due to losses in tourism and real estate; a rise of 27 inches by 2060 would result in 70% of the city of Miami being under water (Schrope, 2010).

For several coastal communities throughout the United States, the effects of sea-level rise are already visible. On Alaska's Sarichef Island, reductions in protective sea ice, thawing permafrost, and alterations to natural hydrography resulting from armoring shorelines have caused massive storm surge erosion. Located on this island is the 400-year old village of Shishmaref, which is facing potential evacuation because of this erosion (NOAA, 2006). In Rhode Island, the relative sea level rose by over 10 inches during the 20th century, causing coastal freshwater wetlands to begin transitioning to salt marshes (Goss, 2002).

Predictions of future sea-level rise range between 0.6 and 2 feet by the end of the 21st century (relative to the base period, 1980–1999) (Parry et al., 2007). Migration of ecosystems like coastal marshes, mangroves, and wetlands will be hampered by coastal armoring infrastructure (e.g., dikes, bulkheads). This would result in a critical loss of the services, such as nursery, refuge, and forage habitats; nutrient cycling; and waste management. Sea-level rise would undermine other services as well, with saltwater intrusion affecting fishery productivity, beach erosion destroying crucial habitats, and flooding altering the infrastructure of coastal communities. For example, researchers estimate that Delaware may lose the services generated by 21% of its wetlands by 2100 and become subject to 100-year floods three to four times more frequently (Najjar et al., 2000). For more information on potential impacts and current preparation strategies, see the EPA's Web site on coastal zones and sea-level rise: http://epa.gov/climatechange/effects/coastal/index.html.

Ocean Acidification

The third major impact of climate change on coastal ecosystems will be ocean acidification, which is a decrease in pH due to oceanic uptake of atmospheric carbon dioxide. When carbon dioxide dissolves in seawater, it acts as an acid, ultimately causing decreases in the amount of available calcium carbonate, a compound necessary for the growth and maintenance of calcifying marine organisms, such as corals, crustaceans, and mollusks (Figure 10-3). About one-third of the carbon dioxide released by human activity over the past 200 years has been taken up by the oceans (Fabry, 2008). In fact, without this sink for carbon dioxide, current atmospheric concentrations would be 55% higher than present levels (Fabry et al., 2009; Sabine et al., 2004). This uptake is reflected in changing ocean chemistry. Since the beginning of the Industrial Revolution, ocean pH has decreased by approximately 30%, a rate of change not witnessed in over 800,000 years (Ridgewell and Zeebe, 2005).

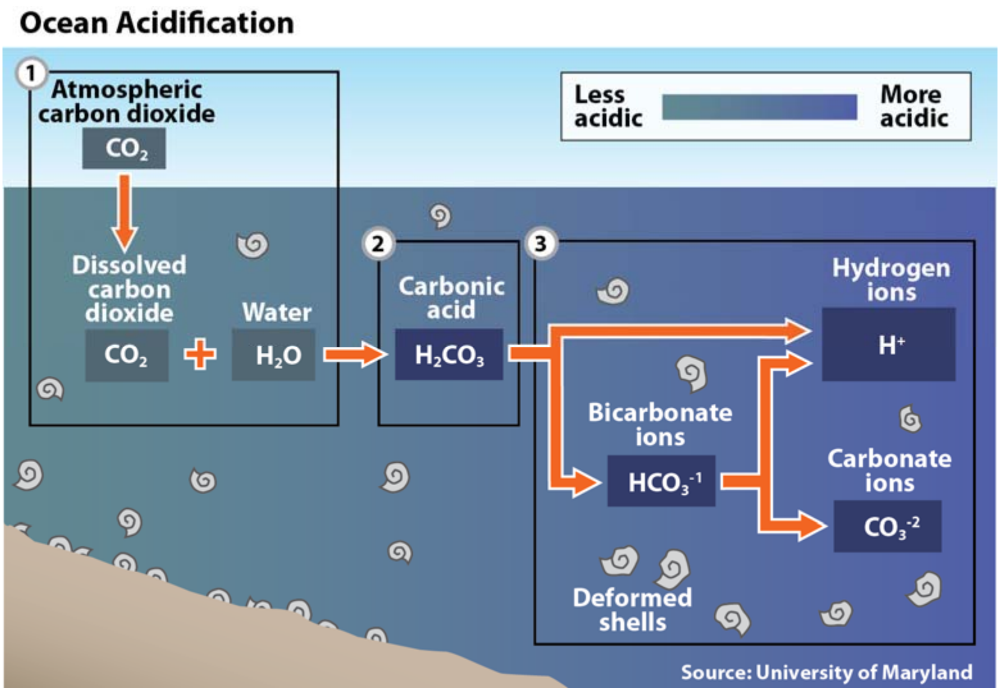


Figure 10-3. Process of ocean acidification.

Many important marine organisms like reef-building corals, mollusks (oysters), and echinoderms (sea urchins, starfish, sea cucumbers) use calcium carbonate to form their skeletons. Reductions in the availability of this compound may negatively impact various organism functions, including metabolism, reproduction, development, immunity, and skeletal density, potentially increasing vulnerability to physical damage, coral bleaching events, erosion, predation, and diseases, which often favor warmer temperatures (Scavia et al., 2002). Corals near the poles will likely be impacted first. Because cold water can hold more gas than warm water, the oceans closest to the poles will absorb more carbon dioxide and be more acidic.

Although there is no decisive number for future carbon dioxide concentrations, current models estimate that atmospheric carbon dioxide concentrations will likely exceed 500 ppm by mid-century. This would result in approximately a 0.4 decrease in surfacewater pH and a corresponding 50% decrease in calcification rates (Feely et al., 2008). Ocean acidification may have important long-term socioeconomic impacts on valuable commercial fisheries like shellfish. In 2007, mollusks contributed 19%, or $748 million, of the ex-vessel commercial harvest revenues in the United States (Cooley and Doney, 2009). Effects on lower-level organisms may also impact the food web, as larger predators effectively lose a food source.

Climate Change Effects Summary

The additive effects of increasing sea surface temperatures, sea-level rise, and ocean acidification will compound existing stresses from population growth and development (e.g., sediment, nutrient, and toxic pollution; habitat loss or degradation; resource consumption). These effects increase with climate change, doubling or tripling the impacts of existent stressors. For instance, northward migrations of commercially valuable fishery species such as cod, haddock, and halibut would have serious regional impacts on fishing communities in the Northeast Coast region, where fish stocks have already declined due to overfishing and pollution. Communities reliant upon tourism in the Southeast Coast region and island territories, which are already subject to pressures from development, would be adversely impacted by coral depletion resulting from the combination of higher sea surface temperatures and ocean acidification. Rising sea levels could also accelerate current wetland losses and damage from excessive sediment and nutrient runoff from coastal development.

Comprehensive monitoring programs of potential indicators, such as sea surface temperature, pH, and relative sea-level rise, are integral to effective initiatives addressing climate-change effects. Secondary effects such as species migration, reproduction, and juvenile survival rates; coral bleaching, skeleton density, and reef building; and changes in salinity, sediment, and nutrient concentrations may also need to be assessed. Current conditions can serve as reference points or benchmarks against which future changes can be measured.

Monitoring of climate change impacts on ecosystems is complicated by the aforementioned regional variations and complex interactions of rising sea surface temperature, ocean acidification, and sea-level rise. These interactions, along with cumulative effects of other coastal stressors, may complicate the evaluation of the impacts of separate factors, especially with regards to impacts on whole ecosystems. Furthermore, although physical parameters (e.g., sea-level rise) and chemical parameters (e.g., temperature, salinity, oxygen, nutrients, total alkalinity, pH) can be measured, monitoring of biological effects of climate change on our oceans cannot take place until appropriate parameters exist. More research is necessary to determine biological effects (on organism function) from the species, population, community, and ecosystem levels. Changes to these functions may not become apparent until there are severe impacts on populations.

Furthermore, trend analysis requires years of data to separate the influence of seasonal variations and anomalies (including those associated with the El Niño cycle and storm events) from climate change-related trends. For instance, researchers have shown that pH can vary with depth and time. Strong seasonal and interannual variability has been noted in surface pH in the central North Pacific. In addition, there is evidence of pH stratification that is influenced by physical and biogeochemical processes (Dore et al., 2009). Trend analysis of pH in coastal waters is also hampered by a general lack of data, complex nearshore circulation processes, and coarse model resolution in global ocean-atmosphere coupled models (Fabry et al., 2009). Although the presence of distinct strata is more relevant for ocean monitoring, vertical gradients in oxygen, pH, and sea surface temperature do occur in estuaries as well. Furthermore, these gradients are influenced by seasonal fluxes. These factors are important to consider when developing and interpreting ocean monitoring programs. It should be noted that the drawback to needing long-term trends to separate seasonal variability from trends in climate change indicators is that by the time the trends are identified, they may be irreversible.

Programs

The EPA and other federal, state, and local agencies are developing new means and expanding existing programs to address the unique challenges posed by the potential effects of climate change. Below is a list of an abbreviated list of some of these programs:

- U.S. Global Change and Research Program (GCRP)
  - Integrates research from 13 federal agencies
  - http://www.globalchange.gov/
- U.S. Global Ocean Ecosystem Dynamics (GLOBEC)
  - Examines the effects of climate change on marine ecosystems and fisheries
  - http://www.usglobec.org/features/overview.php
- Integrated Ocean Observing System (IOOS)
  - Network of coastal and ocean monitoring efforts
  - http://ioos.gov/about/basics.html
- EPA's Climate Change Program
  - Provides information on current science and research initiatives
  - http://www.epa.gov/climatechange/
- NOAA's Prototype Climate Service
  - Comprehensive source for all climate-related information generated by NOAA
  - http://www.noaa.gov/climate.html
- EPA's Climate Ready Estuaries (U.S. EPA, 2009f)
  - An initiative to assist the National Estuary Programs to assess climate change vulnerabilities and develop and implement adaptation strategies
  - http://www.epa.gov/climatereadyestuaries/

Invasive Species

Climate-change impacts on populations of marine organisms and community dynamics may increase ecosystem susceptibility to invasive species. As defined under a 1999 Executive Order, invasive species are "non-native species that cause or are likely to cause harm to the economy, environment, or human health" (NISC, 2008). As highlighted in the Great Lakes regional chapter (Chapter 7), invasive species are already an issue in our aquatic ecosystems. Negative impacts of invasive species include reduced biodiversity, altered habitats, changes in water chemistry and biogeochemical processes, hydrological modifications, and changes to food webs. Although the impact of invasive species is by definition negative, non-native species can have positive contributions to ecosystem sustainability. For example, some non-native species, which do not meet the definition as invasive species, have been introduced purposefully as a means of biological control for invasive species. For example, salmon have been introduced to the Great Lakes to control alewives. Even species that are invasive and harmful in one ecosystem may have a different effect in another ecosystem.

Invasive species are present in virtually all coastal waters of the United States. This fact can be attributed to the pathways of introduction, including ship-borne vectors, aquaculture escapes, and accidental or intentional releases. These pathways are prevalent throughout our coasts and have increased in both frequency and magnitude over the past several decades (NISC, 2008). Shipping activities account for over two-thirds of recent introductions, with ballast water as the most common method of introduction (U.S. EPA, 2010c).

Although the EPA and other agencies are working to control invasive species, interactions with climate change will likely complicate these efforts. Climate change may alter pathways of introduction; influence the establishment, spread, or distribution of species; or change resiliency of native habitats, which could change the impacts of non-native species so that they meet the definition of invasive species. For instance, rising sea surface temperatures will likely force some marine organisms to shift poleward, and species with limited capacity for migration will decline in their southern ranges or even become extinct, leaving niches open for invasive species. Even in instances where the native species remain viable in warmer habitats, altered food availability, reduced reproduction rates, and diminished protective habitat may undermine population health and resistance to invasive species.

Although many federal, state, and regional governing bodies have established programs to address invasive species, these efforts most often do not address potential impacts of climate change. In recognition of this informational and regulatory gap, the EPA hosted two workshops in 2006 to assess management needs and to specifically highlight potential considerations for aquatic invasive species. The latter workshop laid the groundwork for the report *Effects of Climate Change on Aquatic Invasive Species and Implications for Management and Research* (U.S. EPA, 2008b), which highlights both the potential interactions of climate change and invasive species and the role of expanding management.

Below is a list of other sources of information on invasive species:

- EPA's Invasive Species Program
  - General information on invasive species and control initiatives
  - http://www.epa.gov/owow/invasive_species/
- Aquatic Nuisance Species Task Force
  - Intergovernmental agency dedicated to preventing and controlling aquatic nuisance species
  - http://www.anstaskforce.gov/default.php
- USDA's National Invasive Species Information Center
  - Comprehensive source of information for aquatic and terrestrial invasive species
  - http://www.invasivespeciesinfo.gov/
- Smithsonian Environmental Research Center – Marine Invasions Research Laboratory
  - Research on biological invasions in coastal marine ecosystems
  - http://serc.si.edu/labs/marine_invasions/

Hypoxia

Climate change may also worsen hypoxic conditions (low oxygen availability in water), which are already undermining ecosystem health throughout coastal waters as outlined in Chapter 1 (Introduction) and Chapter 5 (Gulf Coast). Bays and estuaries that have limited water exchange and experience water column stratification resulting from massive freshwater input into a saltwater system are particularly susceptible to hypoxia, as evidenced in the Gulf of Mexico (Diaz and Rosenberg, 2008). In fact, eutrophication is affecting over half of all national estuaries (NSTC, 2003). Areas of heightened upwelling are also susceptible to hypoxia. Upwelling is the process by which coastal winds push surface waters offshore, allowing nutrient-rich, oxygen-poor waters from the deep to replace them. These nutrient-rich waters stimulate plankton growth, which ultimately depletes oxygen levels. Increased upwelling is hypothesized to be the cause of dead zones off the coast of Oregon that began to arise during the summer of 2002 (Juncosa, 2008).

The frequency and extent of hypoxic conditions are increasing in coastal and estuarine waters (Rabalais et al., 2002b), mostly as a result of increasing nitrogen from agricultural runoff (NSTC, 2003). Increased levels of nutrients (i.e., nitrogen and phosphorus) in coastal waters can lead to toxic or noxious algal blooms, decreased water clarity, hypoxic conditions, and habitat degradation, all of which will impact the provision of ecosystem services (NSTC, 2003). The lack of oxygen in deeper, cooler water during the summer decreases the availability of these waters to marine species and may undermine the reproductive capacity of many fish species that tend to spawn or nurse in these waters during this time of year (Diaz and Rosenberg, 2008), decreasing fishery productivity with subsequent impacts on the recreational and commercial fishing industries (NSTC, 2003). Effects on higher trophic levels may also result if demersal species are deprived of a valuable food source due to reductions in benthic populations caused by lower bottom-water oxygen levels or if predation in benthos is limited by predators' low tolerance to reduced oxygen concentrations (Diaz and Rosenberg, 2008).

Climate Change and Hypoxia

The future extent and severity of hypoxia in coastal ecosystems will depend on the success of efforts to limit nutrient input and the impacts of climate change, which may alter oxygen concentrations, precipitation, and mixing within the water column. Warmer waters may cause reduced oxygen concentrations due to decreased oxygen solubility and increased production of oxygen-consuming bacteria, while simultaneously increasing the metabolic rate, and thereby oxygen needs, of cold-blooded aquatic species.

Climate models also predict alterations to other processes affecting hypoxia, including precipitation and coastal winds. Precipitation variability predicted under some climate models could cause more dry years followed by extreme rain events, resulting in nutrient influxes to coastal waters from fertilizers that build up on soils during dry years (Scavia et al., 2002). Potential increases in precipitation and extreme rainfall events would lead to greater agricultural and urban runoff, ultimately increasing the amount of nutrients, sediment, and contaminants entering coastal waters. The timing of freshwater inflows may also be a factor as increased air temperatures may lead to earlier snowmelt and earlier inflows to coastal waters (Field et al., 2000). Reductions in summerflows due to earlier snowmelt may deprive estuaries of important freshwater input during times of greatest evapotranspiration, increasing estuarine salinities and stratification (Field et al., 2000), a process already occurring in San Francisco Bay. Climate change may also increase the upwelling process by creating stronger coastal winds and greater storm intensity, both of which can increase water-column mixing (Juncosa, 2008). On the other hand, because warmer waters are less efficient at absorbing oxygen, increased sea surface temperatures may strengthen stratification by preventing oxygen from reaching deeper ocean layers (Diaz and Rosenberg, 2008). Precise predictions of future effects are limited by the complicated interactions of these variables impacting coastal ecosystems.

Climate variability may already be influencing the size of the hypoxic zone (i.e., dead zone) in the Gulf of Mexico. By one estimate this variability may have contributed as much as 20% of variance to the size of the Gulf of Mexico hypoxic zone since the 1950s (Cronin and Walker, 2006). According to recent model simulations (Cronin and Walker, 2006), Gulf of Mexico hypoxia is highly sensitive to riverine nitrate influx, freshwater discharge, and ambient water temperatures. These modeling efforts indicated that although a 30% decrease in the nitrate flux of the Mississippi River would correspond to a 37% reduction in the size of the hypoxic zone, a 20% increase in Mississippi River discharge would produce an equal increase in size of the hypoxic zone (Cronin and Walker, 2006). According to climate projections, such an increase in Mississippi River discharge is possible, which would mean that reductions in nitrate flux would have to be greater to make up the difference (Justic et al., 2003).

Below is a list of other sources of information on hypoxia:

- Mississippi River/Gulf of Mexico Watershed Nutrient Task Force
  - Consists of 5 federal and 10 state agencies, established to reduce hypoxia in the Gulf
  - http://www.epa.gov/msbasin/

- NOAA's Gulf of Mexico Hypoxia Watch
  - Partnership between NOAA, NCDC, NMFS, and CoastWatch to develop real-time data of the Gulf hypoxic area
  - http://ecowatch.ncddc.noaa.gov/hypoxia

Emerging Contaminants

As monitoring efforts evolve to include indicators of climate change, invasive species, and hypoxia, research is also being directed toward indentifying contaminants of emerging concern (CECs). This term encompasses a broad range of contaminants, including pharmaceuticals and personal care products (PPCP); endocrine disruptors; pesticides; persistent organic pollutants such as perfluoronated compounds; and nanomaterials. Although the term "emerging" can refer to a completely new contaminant, such as nanoparticles, the term also refers to new byproducts of production, new metabolites of a parent compound, and newly detectable chemicals. Categorically, CECs often have certain similar characteristics, including low detectable levels, multiple sources, limited toxicological information, and the perception of being a long-term threat to human health, public safety, or the environment.

The sheer number and pathways of entry of potential CECs make monitoring and analysis of potential effects a formidable task. According to the American Chemical Society, less than 300,000 of the 39 million chemicals in use today are either inventoried or regulated, and the number of available chemicals increases every day. The pathways of entry into the environment for CECs are numerous and may include effluents from WWTPs, which do not for the most part treat sewage for pharmaceuticals; concentrated animal feeding operations; septic systems; aquaculture operations; and surface application of manure and biosolids.

Pharmaceuticals are a good example of the potential effects of CECs. These compounds are designed to have biological effects at low doses; therefore, even limited exposure may have subtle effects on non-target populations. The thousands of distinct compounds in pharmaceuticals can also have potential effects when combined with other pharmaceuticals or contaminants. These compounds may bioaccumulate in the food web or persist in the environment, affecting multiple generations. Of particular concern is the potential for pharmaceuticals to act as endocrine disruptors, mimicking, inhibiting, stimulating, or blocking the endocrine system that regulates hormones. For estuarine ecosystems, observed effects on fish and amphibians are particularly noteworthy. Endocrine-active contaminants have been identified as a potential cause of fish that have developed organs of both sexes downstream of a WWTP in Boulder Creek, CO (Woodling et al., 2006), and around high-density population and farming areas on the Potomac River (Blazer et al., 2007). Other CECs may also act as endocrine disruptors. Atrazine, the most commonly applied herbicide in the United States, has been in use for over 40 years and acts as an endocrine disruptor in amphibians. Feminization of male frogs exposed to atrazine has occurred in the laboratory and in the wild and has led to speculations that this pesticide may be associated with global amphibian declines (Hayes et al., 2002a,b).

Increased documentation of such ecological impacts and rising concerns about the effects of pharmaceuticals in our drinking waters have led to increased research and monitoring efforts. The EPA's Office of Science and Technology recently conducted a pilot study of PPCPs in fish tissue and found anti-depressants, anti-histamines, anti-hypertension, antilipemic, and anti-seizure drugs, along with personal care products, in the samples (Ramirez et al., 2009). In 2008 and 2009, this effort expanded under the National Rivers and Streams Assessment to include sampling for PPCPs in fish tissue at 150 sites (U.S. EPA, 2010b). The upcoming NCCA will include sampling for PFCs, PBDEs, and pharmaceuticals in fish tissue collected from the Great Lakes. The EPA is also assessing the capacity of existing regulatory tools to address CECs, see below.

In comparison to legacy pollutants, monitoring for CECs is relatively new. As understanding of which contaminants fit into this category expands, monitoring will become more comprehensive. This necessitates more research on all categories of CECs and the development of better detection methods for compounds that are present in complex ecosystems. Also, water quality standards/maximum concentrations for ambient water do not exist for most CECs; therefore, even detectable contaminants may not be included in managerial decisions. Monitoring for effects of CECs, such as alterations to reproductive organs in individuals or the gender balance of populations, would require establishing often questionable cause-and-effect relationships (changes to species or populations may be due to other environmental variables) and be overly reactive to have positive effects on management decisions.

Below is a list of other sources of information on CECs:

- EPA's Aquatic Life Criteria (U.S. EPA, 2008a)
  - White paper on Aquatic Life Criteria for CECs
  - http://www.epa.gov/waterscience/criteria/aqlife/cec.html
- EPA's Endocrine Disruptor Screening Program
  - Information on EPA's approach and progress for screening and testing chemicals for endocrine disrupting potential
  - http://www.epa.gov/endo/index.htm
- USGS: Emerging Contaminants Project
  - Information on chemicals about their threat to the environment and human health
  - http://toxics.usgs.gov/regional/emc/

Microbial Pathogens

While monitoring programs for CECs are in relative infancy or an early developmental phase, testing waters for pathogens (e.g., disease-causing bacteria, viruses, microorganisms) is well established. The upcoming NCCA will include an assessment of coastal water pathogen contamination, using *Enterococci* as an indicator of fecal bacteria contamination. As revealed in the Beach Advisory sections of this report, the majority of beach closings in the United States are due to the presence of harmful pathogens from untreated or under-treated sewage (including from combined sewer overflows, septic systems, and WWTPs). States establish their own guidance for bacterial contamination, although their criteria must be as minimally as protective of human health as EPA's 1986 bacteria criteria (U.S. EPA, 1986). Some states have adopted even more restrictive guidance. Beach closures present a non-uniform picture of coastal water contamination because the criteria used to trigger a beach closure vary from state to state. The inclusion of microbial pathogens as an NCCA indicator will allow more comparability between regions and across states.

Monitoring pathogens in recreational coastal waters is also indicative of the EPA OW's focus on human health. The chosen pathogen for monitoring, *Enterococci*, is recommended by the EPA as the best indicator of health risk in salt water used for recreation because of its ability to survive in saline environments. This recommendation was based on a series of studies conducted by the EPA to determine the correlation between different bacterial indicators and the occurrence of digestive system illnesses at swimming beaches (U.S. EPA, 2009e). Detection of *Enterococci* may indicate the possible presence of pathogenic bacteria and the potential health risk of swimming in and eating shellfish harvested from contaminated waters. Microbial contamination is addressed under the Safe Drinking Water Act, which regulates contamination of finished drinking water and source waters, and under the Clean Water Act, which enables protection of surface water for drinking water, recreational, and aquatic food source uses.

For more information on microbial pathogens:

- EPA's Water Quality Criteria: microbial pathogens
  - Information on how existing regulations address microbial pathogens
  - http://www.epa.gov/waterscience/criteria/humanhealth/microbial/

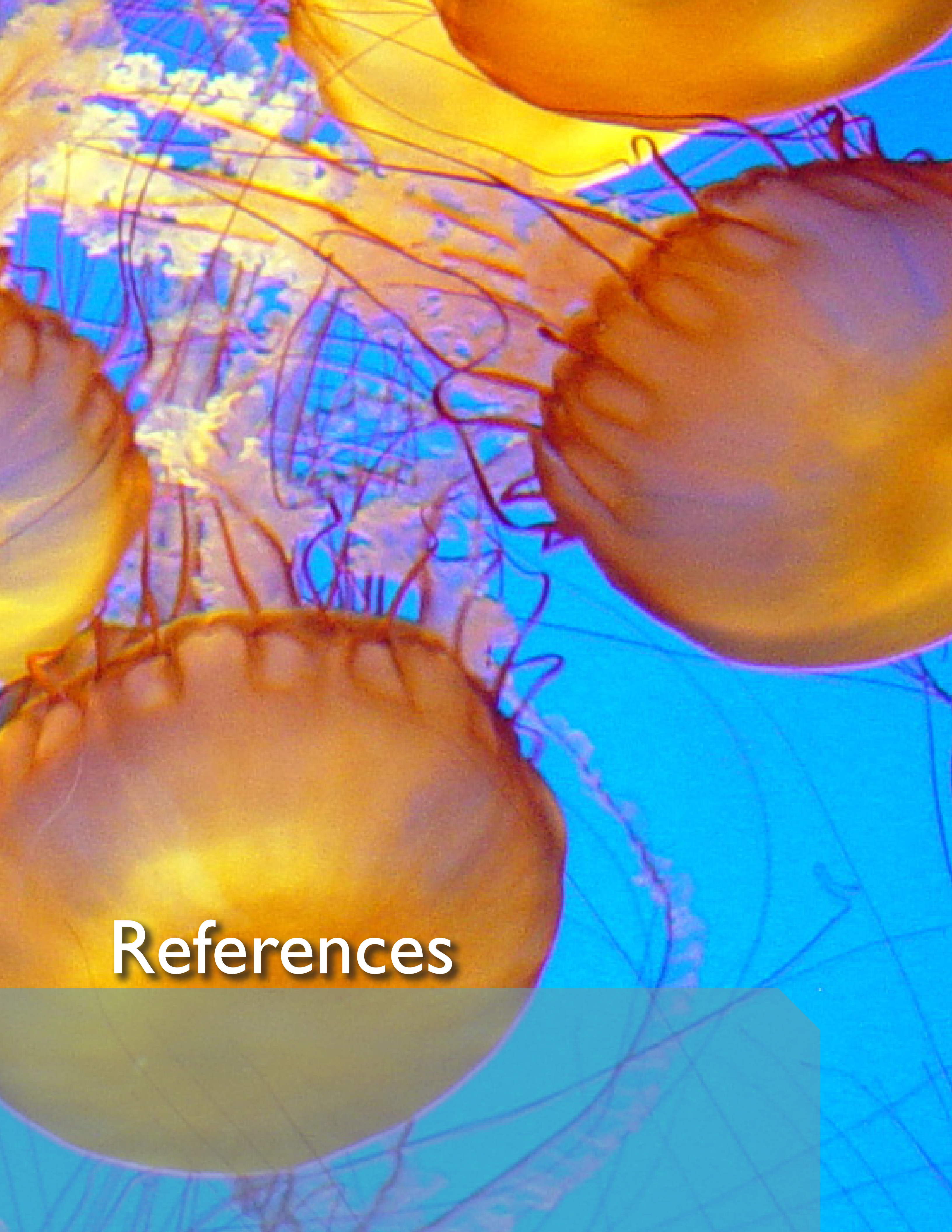
Conclusion

The inclusion of *Enterococci* as an indicator of microbial pathogens is indicative of the evolving process of coastal monitoring and the NCA program. This chapter highlighted other emerging concerns for coastal waters and their invariable, although uncertain, interactions with the effects of climate change. Although monitoring of pathogens is a relatively straightforward process based on predetermined unhealthy concentrations of microbials, establishing indicators for CECs and the impacts of climate change is complicated.

Where monitoring of direct climate change effects is limited or prohibitive in cost, secondary effects on marine organisms, populations, community dynamics, predator–prey relationships, and whole ecosystems may be observed. Identifying trends from monitoring is complicated by anomalies (e.g., El Niño/La Niña, storm events), interactions between effects, and data duration (analyses on time-series data require several years of regular recording).

Despite the intrinsic difficulty of incorporating these issues into the NCCA program, EPA and other federal agencies recognize the evolving nature of coastal issues, links with potential climate change effects, and the need to perpetually update monitoring programs. As shown throughout this chapter, many programs already exist to address these emerging issues, and the scientific community is researching new indicators to adopt in monitoring programs.

References



References

Adams, D.A., J.S. O'Connor, and S.B. Weisberg. 1998. *Sediment Quality of the NY/NJ Harbor System: An Investigation under the Regional Environmental Monitoring and Assessment Program (REMAP). Appendix C: A Benthic Index of Biotic Integrity (B-IBI) for the NY/NJ Harbor*. EPA/902-R-98-001. U.S. Environmental Protection Agency, Region 2, Edison, NJ.

Alaska DEC (Department of Environmental Conservation). 1999. *Alaska's 1998 FINAL 303(d) List*. Alaska Department of Environmental Conservation, Division of Water, Anchorage, AK.

Alaska DEC (Department of Environmental Conservation). 2005a. *Environmental Monitoring & Assessment Program Implementation Strategy*. Alaska Department of Environmental Conservation, Division of Water, Anchorage, AK.

Alaska DEC (Department of Environmental Conservation). 2005b. *Water Quality Monitoring & Assessment Strategy*. Alaska Department of Environmental Conservation, Division of Water, Anchorage, AK.

Alaska DFG (Department of Fish and Game). 2005. *Alaska Subsistence Fisheries 2003 Annual Report*. Alaska Department of Fish and Game, Division of Subsistence, Juneau, AK.

Alaska DNR (Department of Natural Resources). 2010. *Welcome to the Alaska Division of Geological and Geophysical Surveys*. Online information. Alaska Department of Natural Resources, Division of Geological and Geophysical Surveys, Fairbanks, AK. Available at: http://www.dggs.alaska.gov (accessed June 2010).

Alaska H&SS (Health and Social Services). 2010. *Fish Facts & Consumption Guidelines*. Online information. Alaska Health and Social Services, Division of Epidemiology, Environmental Public Health Program, Juneau, AK. Available at: http://www.epi.hss.state.ak.us/eh/fish/default.htm#guidelines (accessed June 2010).

Albert, D.A., Wilcox, D.A. Ingram, J.W., and Thompson, T.A. 2005. Hydrogeomorphic classification for Great Lakes coastal wetlands. *J. Great Lakes Res* 31(1):129-146.

Alegria, H.A., J.P. D'Autel, and T.J. Shaw. 2000. Offshore transport of pesticides in the South Atlantic Bight: Preliminary estimate of export budgets. *Marine Pollution Bulletin 40*(12):1178–1185.

Allen, J.S., R.C. Beardsley, J.O. Blanton, W.C. Boicourt, B. Butman, L.K. Coachman, A. Huyer, T.H. Kinder, T.C. Royer, J.D. Schumacher, R.L. Smith, W. Sturges, and C.D. Winant. 1983. Physical oceanography of continental shelves. *Reviews of Geophysics and Space Physics* 21:1149–1181.

AMAP (Arctic Monitoring and Assessment Programme). 2009. *AMAP 2009 Update on Selected Climate Issues of Concern*. Arctic Monitoring and Assessment Programme, Oslo, Norway.

AMAP (Arctic Monitoring and Assessment Programme). 2010. *Welcome to AMAP - the Arctic Monitoring and Assessment Programme*. Online information. Arctic Monitoring and Assessment Programme, Oslo, Norway. Available at: http://www.amap.no/ (accessed June 2010).

Ambrose, W.G. Jr., J.H. Bailey-Brock, W. J. Cooke, C.L. Hunter, and R.K. Kawamoto. 2009. *Benthic Faunal Sampling Adjacent to the Barbers Point Ocean Outfall, O'ahu, Hawai'i, March 2009*.

Project Report PR-2010-01. University of Hawaii at Manoa, Water Resources Research Center, Honolulu, HI.

Bailey-Brock, J.H. and E.R. Krause. 2007. *Benthic Infaunal Communities Adjacent to the Sewage Outfalls at Agana and Northern District, Guam, Northern Mariana Islands, 2005–2007.* Technical Report WRRC-2007-01, University of Hawaii at Manoa, Water Resources Research Center, Honolulu, HI.

Balthis, W.L., J.L. Hyland, M.H. Fulton, E.F. Wirth, J.A. Kiddon, and J. Macauley. 2009. *Ecological Condition of Coastal Ocean Waters Along the U.S. Mid-Atlantic Bight: 200*6. NOAA Technical Memorandum NOS NCCOS 109. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service, Charleston, SC.

Barlow, P.M. 2003. *Ground water in fresh water-salt water environments of the Atlantic Coast*. Online information. U.S. Geological Survey circular 1262. Available at: http://pubs.usgs.gov/circ/2003/circ1262/pdf/circ1262.pdf.

Bates, N.R., J.T. Mathis, and L.W. Cooper. 2009. Ocean acidification and biologically induced seasonality of carbonate mineral saturation states in the western Arctic Ocean. *Journal of Geophysical Research 114*:C11007.

Bergondo, D., D.R . Kester, H.E. Stoffel, and W.L. Woods. 2005. Time series observations during the low sub-surface oxygen events in Narragansett Bay during summer 2001. *Marine Chemistry 97*:90–103.

Betts, M. F. and R. J. Wolfe. 1992. Commercialization of fisheries and the subsistence economies of the Alaska Tlingit. *Society and Natural Resources 5*:277–295.

Bird, K.J., R.R. Charpentier, D.L. Gautier, D.W. Houseknecht, T.R. Klett, J.K. Pitman, T.E. Moore, C.J. Schenk, M.E. Tennyson, C.J. Wandrey. 2008. *Circum-Arctic Resource Appraisal: Estimates of Undiscovered Oil and Gas North of the Arctic Circle*. USGS Fact Sheet 2008-3049. U.S. Department of the Interior, U.S. Geological Survey, Denver, CO.

Blazer, V.S., L.R. Iwanowicz, D.D. Iwanowicz, D.R. Smith, J.A. Young, J.D. Hedrick, S.W. Foster, and S.J. Reeser. 2007. Intersex (testicular oocytes) in smallmouth bass from the Potomac River and selected nearby drainages. *Journal of Aquatic Animal Health 19*(4):242–253.

Boesch, D.F., V.J. Coles, D.G. Kimmel, and W.D. Miller. 2007. *Coastal Dead Zones & Global Climate Change: Ramifications of Climate Change for Chesapeake Bay Hypoxia*. Prepared for the Pew Center on Global Climate Change, Arlington, VA. Available online at http://www.pewclimate.org/docUploads/Regional-Impacts-Chesapeake.pdf. Not cited but used for general information.

Bolden, S.K. 2001. *Status of the U.S. Caribbean Spiny Lobster Fishery 1980-1999*. Contribution Number PRD-99/00-17. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Southeast Fisheries Science Center, Miami, FL.

Bricker, S.B., C.G. Clement, D.E. Pirhalla, S.P. Orlando, and D.R.G. Farrow. 1999. *National Estuarine Eutrophication Assessment: Effects of Nutrient Enrichment in the Nation's Estuaries*. Prepared for the U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service, Special Projects Office and the National Centers for Coastal Ocean Science, Silver Spring, MD.

Brown, C.A. and R.J. Ozretich. 2009. Coupling between the coastal ocean and Yaquina Bay, Oregon: importance of oceanic inputs relative to other sources. *Estuaries and Coasts 32*:219–237.

Brown, C.A., W.G. Nelson, B.L. Boese, T.H. DeWitt, P.M. Eldridge, J.E. Kaldy, H. Lee II, J.H. Power, and D.R. Young. 2007. *An Approach to Developing Nutrient Criteria for Pacific Northwest Estuaries: A Case Study of Yaquina Estuary, Oregon*. U.S. Environmental Protection Agency, Office of Research and Development, National Health and Environmental Effects Laboratory, Western Ecology Division, Corvallis, OR.

Burdick, D., V. Brown, J. Asher, M. Gawel, L. Goldman, A. Hall, J. Kenyon, T. Leberer, E. Lundblad, J. McIlwain, J. Miller, D. Minton, M. Nadon, N. Pioppi, L. Raymundo, B. Richards, R. Schroeder, P. Schupp, E. Smithand, and B. Zgliczynski. 2008. The State of Coral Reef Ecosystems of Guam. Pp. 465-509. In: Waddell, J.E. and A.M. Clarke (eds.), 2008. *The State of Coral Reef Ecosystems of the United States and Pacific Freely Associated States: 2008*. NOAA Technical Memorandum NOS NCCOS 73. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Centers for Coastal Ocean Science, Center for Coastal Monitoring and Assessment, Biogeography Team, Silver Spring, MD.

Caillouet, C.W., Jr., R.A. Hart, and J.M. Nance. 2008. Growth overfishing in the brown shrimp fishery of Texas, Louisiana, and adjoining Gulf of Mexico EEZ. *Fisheries Research 92*:289–302.

CENR (Committee on the Environment and Natural Resources). 2000. *Integrated Assessment of Hypoxia in the Northern Gulf of Mexico*. National Science and Technology Council, Committee on Environment and Natural Resources, Washington, DC.

CFMC (Caribbean Fishery Management Council), NMFS (National Marine Fisheries Service), GMFMC (Gulf of Mexico Fishery Management Council), and SAFMC (South Atlantic Fishery Management Council). 2008. Final Amendment 4 to the Fishery Management Plan for the Spiny Lobster Fishery of Puerto Rico and the U.S. Virgin Islands and Amendment 8 to the Joint Spiny Lobster Fishery Management Plan of the Gulf of Mexico and South Atlantic (Including the Final Environmental Impact Statement, Regulatory Impact Review, and Initial Regulatory Flexibility Analysis. Caribbean Fishery Management Council, San Juan, PR; U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, St. Petersburg, FL; Gulf of Mexico Fishery Management Council, Tampa, FL; and South Atlantic Fishery Management Council, North Charleston, SC.

CFMC (Caribbean Fishery Management Council). 1996a. *Fishery Management Plan, Regulatory Impact Review, and Final Environmental Impact Statement for the Queen Conch Resources of Puerto Rico and the United States Virgin Islands*. Caribbean Fishery Management Council, San Juan, PR.

CFMC (Caribbean Fishery Management Council). 1996b. *Regulatory Amendment to the Fishery Management Plan for the Reef Fish Fishery of Puerto Rico and the United States Virgin Islands Concerning Red Hind Spawning Aggregation Closures Including a Regulatory Impact Review and an Environmental Assessment*. Caribbean Fishery Management Council, San Juan, PR.

Chan, F., J.A. Barth, J. Lubchenco, A. Kirincich, H. Weeks, W. T. Peterson, and B.A. Menge. 2008. Emergence of anoxia in the California Current Large Marine Ecosystem. *Science 319*:920.

Chapra, S.C., and H.F.H. Dobson. 1981. Quantification of the lake trophic typologies of Naumann (surface quality) and Thienemann (oxygen) with special reference to the Great Lakes. *Journal of Great Lakes Research 7*(2):182-193.

Cohen, A., and J.T. Carlton. 1995. *Non-indigenous Aquatic Species in a United States Estuary: A Case Study of the Biological Invasions of the San Francisco Bay and Delta*. Report No. PB 96-166525. Prepared for the National Sea Grant College Program, Connecticut Sea Grant, Groton, CT and the U.S. Department of the Interior, Fish and Wildlife Service, Washington, DC.

Cohen, A.N. 2005. *Guide to the Exotic Species of San Francisco Bay*. Online information. San Francisco Estuary Institute, Oakland, CA, Available at: http://www.exoticsguide.org (accessed August 2011).

Coiro, L., S.L. Poucher, and D. Miller. 2000. Hypoxic effects on growth of *Palaemonetes vulgaris* larvae and other species: Using constant exposure data to estimate cyclic exposure response. *Journal of Experimental Biology and Ecology 247*:243–255.

Cooksey, C., J. Harvey, L. Harwell, J. Hyland, and K. Summers. 2010. *Ecological Condition of Coastal Ocean and Estuarine Waters of the U.S. South Atlantic Bight: 2000–2004*. NOAA Technical Memorandum NOS NCCOS. National Oceanic and Atmospheric Administration, National Ocean Service, Center for Coastal Environmental Health and Biomolecular Research, Charleston, SC.

Cooley, S.R., and S.C. Doney. 2009. Anticipating ocean acidification's economic consequences for commercial fisheries. *Environmental Research Letters 4*(2):024007.

Cox, D.C., and L.C. Gordon, Jr. 1970. *Estuarine Pollution in the State of Hawaii. Vol. 1: Statewide Study*. University of Hawaii at Manoa, Water Resources Research Center, Honolulu, HI.

Cronin, T.M., and H.A. Walker. 2006. Restoring coastal ecosystems and abrupt climate change. *Climate Change 74*(4):369–376.

Crossett, K.M., C.G. Clement, S.O. Rohmann. 2008. *Demographic Baseline Report of U.S. Territories and Counties Adjacent to Coral Reef Habitats*. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service, Special Projects, Silver Spring, MD.

Cunningham, C., and K. Walker. 1996. Enhancing public access to the coast through the CZMA. *Current: The Journal of Marine Education 14*(1):8–12.

Dahl, T.E. 1990. *Wetlands – Losses in the United States, 1780s to 1980s*. Report to Congress. U.S. Department of the Interior, Fish and Wildlife Service, National Wetlands Inventory Group, St. Petersburg, FL.

Dahl, T.E. 2003. *Results of the 2000 National Wetlands Inventory*. Report to Congress. U.S. Department of the Interior, Fish and Wildlife Service, Washington, DC.

Dahl, T.E. 2010. U.S. Fish and Wildlife Service. Personal Communication with V. Engle, U.S. Environmental Protection Agency, Office of Research and Development, Gulf Ecology Division; Gulf Breeze, FL.

Dahl, T.E. 2011. *Status and trends of wetlands in the conterminous United States 2004 to 2009*. U.S. Department of the Interior, Fish and Wildlife Service, Washington, DC.

Dahl, T.E., C.E. Johnson, and W.E. Frayer. 1991. *Status and Trends of Wetlands in the Conterminous United States, Mid-1970's to Mid-1980's*. Report to Congress. U.S. Department of Interior, Fish and Wildlife Service, Washington, DC.

Dale B., M. Edwards, and P.C. Reid. 2006. Climate change and harmful algal blooms. Pp. 367–378. In: Graneli, E., and J.Turner. *Ecology of Harmful Algae. Ecological Studies Vol 189*. Dordrecht, The Netherlands: Springer-Verlag.

Daskalakis, K.D., and T.P. O'Conner. 1994. *Inventory of Chemical Concentrations in Coastal and Estuarine Sediments*. NOAA Technical Memorandum NOS ORCA 76. Prepared for the U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service, Silver Spring, MD.

Deacutis, C.F. 2006. Personal communication from Christopher F. Deacutis, Narragansett Bay Estuary Program, to Emaly N. Simone, RTI International. December 6.

Denton, G.R.W., C.M. Sian-Denton, L.P. Concepcion, and H.R. Wood. 2005. *Nutrient Status of Tumon Bay in Relation to Intertidal Blooms of the Filamentous Green Alga*, Enteromorpha clathrata. Technical Report No. 110. University of Guam, Water and Environmental Research Institute (WERI) of the Western Pacific, Mangilao, GU.

Denton, G.R.W., L.P. Concepcion, H.R. Wood, V.S. Eflin, and G.T. Pangelinan. 1999. *Heavy Metals, PCBs, and PAHs in Marine Organisms from Four Harbor Locations on Guam - A Pilot Study*. Technical Report No. 87. University of Guam, Water and Environmental Research Institute (WERI) of the Western Pacific, Mangilao, GU.

Diaz, R.J., and R. Rosenberg, 2008. Spreading dead zones and consequences for marine ecosystems. *Science 321*(5891):926–929.

Diaz, R.J., and R. Rosenberg. 1995. Marine benthic hypoxia: A review of its ecological effects and the behavioral responses of benthic macrofauna. *Oceanography and Marine Biology Annual Review 33*:245–303.

Diaz, R.J., M. Solan, and R.M. Valente. 2004. A review of approaches for classifying benthic habitats and evaluating habitat quality. *Journal of Environmental Management 73*:165–181.

Diaz-Ramos, S., and D.L. Stevens, Jr., and A.R. Olsen. 1996. EMAP Statistical Methods Manual. EPA/620/R-96/XXX. U.S. Environmental Protection Agency, Office of Research and Development, National Health and Environmental Effects Research Laboratory, Environmental Monitoring and Assessment Program, Corvallis, OR.

DiToro, D.M., C.S. Zarba, D.J. Hansen, W.J. Berry, R.C. Swartz, C.E. Cowan, S.P. Pavlou, H.E. Allen, N.A. Thomas, and P.R. Paquin. 1991. Technical basis for establishing sediment quality criteria for nonionic organic chemicals using equilibrium partitioning. *Environmental Toxicology Chemistry 10*:1541–1583.

Donner, S.D. 2009. Coping with commitment: Projected thermal stress on coral reefs under different future scenarios. *PLoS (Public Library of Science) 4*(6):e5712.

Dore, J.E., R. Lukas, D.W. Sadler, M.J. Church, and D.M. Karl. 2009. Physical and biogeochemical modulation of ocean acidification in the central North Pacific. *Proceedings of the National Academy of Sciences 106*(30):12235–11240.

Ellsion, J.C. 2009. Wetlands of the Pacific Islands region. *Wetlands Ecology and Management 17*:169–206.

Engle, V.D., and J.K. Summers. 1999. Refinement, validation, and application of a benthic condition index for northern Gulf of Mexico estuaries. *Estuaries 22*(3A):624–635.

Engle, VD., J.K. Summers, and G.R. Gaston. 1994. A benthic index of environmental condition of Gulf of Mexico estuaries. *Estuaries 17*:372–384.

Environment Canada and U.S. EPA (Environmental Protection Agency). 1995. *The Great Lakes: An Environmental Atlas and Resource Book, Third Edition*. Environment Canada, Toronto, Ontario, and the U.S. Environmental Protection Agency, Great Lakes National Program Office, Chicago, IL.

Environment Canada and U.S. EPA (Environmental Protection Agency). 2007. *State of the Great Lakes Ecosystem 2007*. ISBN 978-0-662-47328-2, EPA/905-R-07-003, Cat No. En161-3/1-2007E-PDF. Environment Canada, Federal Great Lakes Program, Gatineau, Quebec, and the U.S. Environmental Protection Agency, Great Lakes National Program Office, Chicago, IL.

Environment Canada and U.S. EPA (Environmental Protection Agency). 2009a. *Nearshore Areas of the Great Lakes 2009.*EPA/905-R-09-013. Environment Canada, Federal Great Lakes Program, Gatineau, Quebec, and the U.S. Environmental Protection Agency, Great Lakes National Program Office, Chicago, IL.

Environment Canada and U.S. EPA (Environmental Protection Agency). 2009b. *State of the Great Lakes 2009.*EPA/905-R-09-031. Environment Canada, Federal Great Lakes Program, Gatineau, Quebec, and the U.S. Environmental Protection Agency, Great Lakes National Program Office, Chicago, IL.

Environment Canada. 1995. *Amphibians and Reptiles in Great Lakes Wetlands: Threats and Conservation*. Online information. Environment Canada. Available at: http://www.on.ec.gc.ca/wildlife/factsheets/fs_amphibians-e.html (accessed September 2011).

Fabry, V.J. 2008. Marine calcifiers in a high CO_2 Ocean. *Science Express*, DOI: 10.1126/science.1157130, April 17, 2008, pp. 1020–1022.

Fabry, V.J., B.A. Seibel, R.A. Feely, and J.C. Orr. 2009. Impacts of ocean acidification on marine fauna and ecosystem processes. *ICES Journal of Marine Science 65*(3):414–432.

Feely, R.A., C.L. Sabine, M. Hernandez-Ayon, D. Ianson, and B. Hales. 2008. Evidence for upwelling of corrosive “acidified” water onto the continental shelf. *Science 320*(5882):1490–1492.

Feely, R.A., V.J. Fabry, A.G. Dickson, J.P. Gattuso, J. Bijma, U. Riebesell, S. Doney, C. Turley, T. Saino, K. Lee, K. Anthony, and J. Kleypas. 2010. An International Observational Network for Ocean Acidification. In Hall, J., Harrison, D.E. & Stammer, D., Eds. *Proceedings of OceanObs’09: Sustained Ocean Observations and Information for Society (Vol. 2), Venice, Italy, September 21–25, 2009.* ESA Publication WPP-306.

Field, J.C., D.F. Boesch, D. Scavia, R. Buddemeier, V.R. Burkett, D. Cayan, M. Fogarty, M. Harwell, R. Howarth, C. Mason, L.J. Pietrafesa, D. Reed, T. Royer, A. Sallenger, M. Spranger, and J.G. Titus. 2000. Potential consequences of climate variability and change on coastal areas and marine resources. Chapter 16 in *Climate Change Impacts on the United States – The Potential Consequences of Climate Variability and Change – Foundation Report*. Prepared by National Assessment Synthesis Team for the U.S. Global Change Research Program, Washington, DC, and published by Cambridge University Press, Cambridge, UK.

Fisheries and Oceans Canada. 2009. *Ontario - Great Lakes Area Fact Sheets: Lake Whitefish*. Online information. Fisheries and Oceans Canada, Ottawa, Canada. Available at http://www.dfo-mpo.gc.ca/regions/central/pub/factsheets-feuilletsinfos-ogla-rglo/lakewhitefish-grandcoregone-eng.htm (accessed December 2009).

Friedlander, A., G. Aeby, R. Brainard, E. Brown, K. Chaston, A. Clark, P. McGowan, T. Montgomery, W. Walsh, I. Williams and W. Wiltse, with additional contributors. 2008. The State of Coral Reef Ecosystems of the Main Hawaiian Islands. Pp. 219–261. In: Waddell, J.E. and A.M. Clarke (eds.), 2008. *The State of Coral Reef Ecosystems of the United States and Pacific Freely Associated States: 2008*. NOAA Technical Memorandum NOS NCCOS 73. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Centers for Coastal Ocean Science, Center for Coastal Monitoring and Assessment, Biogeography Team, Silver Spring, MD.

Friedlingstein, P., R.A. Houghton, G. Marland, J. Hackler, T.A. Boden, T.J. Conway, J.G. Canadell, M.R. Raupach, P. Ciais, and C. Le Quéré. 2010. Update on CO2 emissions. *Nature Geoscience 3*:811–812.

Geider, R. J. and J. La Roche. 2002. Redfield revisited: Variability of C:N:P in marine microalgae and its biochemical basis. *European Journal of Phycology 37*(1):1–17.

GFDL (Geophysical Fluid Dynamics Laboratory). 2007. The shrinking Arctic ice cap. GFDL *Climate Modeling Research Highlights 1*(1):1–2.

GLFC (Great Lakes Fishery Commission). 2008. *Strategic Vision of the Great Lakes Fishery Commission for the First Decade of the New Millennium*. Great Lakes Fishery Commission, Ann Arbor, MI.

Global Carbon Project. 2010. *Carbon Budget – Highlights*. Online information. Global Carbon Project, Canberra, ACT, Australia. Available at: http://www.globalcarbonproject.org/carbonbudget/09/hl-full.htm#ffcement (accessed January 2011).

GMFMC (Gulf of Mexico Fishery Management Council). 2011. Shrimp Management Plans. Online information. Gulf of Mexico Fishery Management Council, Tampa, FL. Available at: http://www.gulfcouncil.org/fishery_management_plans/shrimp_management.php (accessed November 2011).

Goss, H. 2002. Rhode Island's Rising Tide. *ClimateWatch Magazine*. October 22.

Grantham, B.A., F. Chan, K.J. Nielsen, D.S. Fox, J.A. Barth, A. Huyer, J. Lubchenco, and B. A. Menge. 2004. Upwelling-driven nearshore hypoxia signals ecosystem and oceanographic changes in the northeast Pacific. *Nature 429*:749–754.

Guam Coastal Atlas. 2010. *Benthic Habitat Data Summary*. Online information. University of Guam Marine Laboratory, Mangilao, GU. Available at http://www.guammarinelab.com/coastal.atlas/htm/Data_Summary.htm (accessed November 10, 2010).

Guam EPA (Environmental Protection Agency). 2001. *Guam Water Quality Standards*. 2001 Revision. Guam Environmental Protection Agency, Barrigada, GU.

Hagy, J.D. 2002. *Eutrophication, Hypoxia and Trophic Transfer Efficiency in Chesapeake Bay*. Ph.D. Dissertation. University of Maryland, College Park, MD.

Hagy, J.D., W.R. Boynton, C.W. Keefe, and K.V. Wood. 2004. Hypoxia in Chesapeake Bay, 1950–2001: Long-term change in relation to nutrient loading and river flow. *Estuaries 27*(4):634–658.

Hale, S.S., and J.F. Heltshe. 2008. Signals from the benthos: Development and evaluation of a benthic index for the nearshore Gulf of Maine. *Ecological Indicators 8*:338–350.

Hare, J.A., and P. E. Whitfield. 2003. *An integrated assessment of the introduction of lionfish (*Pterois volitans/miles *complex) to the western Atlantic Ocean*. NOAA Technical Memorandum NOS NCCOS 2. Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service, Beaufort, NC.

Hart, D.R., and P. J. Rago. 2006. Long-term dynamics of U.S. Atlantic sea scallop *Placopecten magellanicus* populations. *North American Journal of Fisheries Management. 26*:490–501.

Hart, R. and J.M. Nance. 2007. *A Biological Review of the Tortugas Pink Shrimp Fishery Through December 2006*. Report to the Gulf of Mexico Fishery Management Council, Tampa, FL.

Harvell, C.D., K. Kim, J.M. Burkholder, R.R. Colwell, P.R. Epstein, D.J. Grimes, E.E. Hofmann, E.K. Lipp, A.D.M.E. Osterhaus, R.M. Overstreet, J.W. Porter, G.W. Smith, and G.R. Vasta. 1999. Emerging marine diseases – climate links and anthropogenic factors. *Science 285*(5433):1505–1510.

Harvey, J., L. Harwell, and J.K. Summers. 2008. Contaminant concentrations in whole-body fish and shellfish from U.S. estuaries. *Environmental Monitoring and Assessment 137*:403–412.

Hastie, J., and M. Bellman. 2007. Estimated 2006 Discard and Total Catch of Selected Groundfish Species. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Northwest Fisheries Science Center, Fishery Resource Analysis and Monitoring Division, Seattle, WA.

Hayes, T., K. Haston, M. Tsui, A. Hoang, C. Haeffele, and A. Vonk. 2002a. Feminization of male frogs in the wild. *Nature 419*:895–896.

Hayes, T.B., A. Collins, M. Lee, M. Mendoza, N. Noriega, A.A. Stuart, and A. Vonk. 2002b. Hermaphroditic, demasculinized frogs after exposure to the herbicide atrazine at low ecologically relevant doses. *Proceedings of the National Academy Science 99*(8):5476–5480.

Hayslip, G., L. Edmond, V. Partridge, W. Nelson, H. Lee, F. Cole, J. Lamberson, and L. Caton. 2006. *Ecological Condition of the Estuaries of Oregon and Washington*. EPA 910-R-06-001. U.S.

Environmental Protection Agency, Office of Environmental Assessment, Region 10, Seattle, Washington.

Hayslip, G., L. Edmond, V. Partridge, W. Nelson, H. Lee, F. Cole, J. Lamberson , and L. Caton. 2007. *Ecological Condition of the Columbia River Estuary*. EPA 910-R-07-004. U.S. Environmental Protection Agency, Office of Environmental Assessment, Region 10, Seattle, Washington.

Hickey, B.M and N.S. Banas. 2003. Oceanography of the U.S. Pacific northwest coastal ocean and estuaries with application to coastal ecology. *Estuaries 26*:1010–1031.

Hoagland, P., and S. Scatasta. 2006. The economic effects of harmful algal blooms. Chap. 29. In: Graneli, E., and J. Turner (eds.), *Ecology of Harmful Algae. Ecology Studies Series.* Dordrecht, The Netherlands: Springer-Verlag.

Hunter, C.L., M.D. Stephenson, R.S. Tjeerdema, D.G. Crosby, G.S. Ichikawa, J.D. Goetzl, K.S. Paulson, D.B. Crane, M. Martin, and J.W. Newman. 1995. Contaminants in oysters in Kaneohe Bay. *Marine Pollution Bulletin 30*:646–654.

Hyland, J., L. Balthis, I. Karakassis, P. Magni, A. Petrov, J. Shine, O. Vestergaard, and R. Warwick. 2005. Organic carbon content of sediments as an indicator of stress in the marine benthos. *Marine Ecology Progress Series 295*:91–103.

Ingersoll, C.G., S.M. Bay, J.L. Crane, L.J. Field, T.H. Gries, J.L. Hyland, E.R. Long, D.D. MacDonald, and T.P. O'Connor. 2005. Ability of SQGs to estimate effects of sediment-associated contaminants in laboratory toxicity tests or in benthic community assessments. In: R.J. Wenning, G.E. Batley, C.G. Ingersoll, and D.W. Moore, (eds). *Use of Sediment Quality Guidelines & Related Tools for the Assessment of Contaminated Sediments (SQG)*. SETAC Press, Pensacola, FL.

Interagency Ocean Policy Task Force. 2009. *Interim Framework for Effective Coastal and Marine Spatial Planning*. Executive Office of the President, Interagency Ocean Policy Task Force, Washington, DC. December 9. Available at: http://www.whitehouse.gov/sites/default/files/microsites/091209-Interim-CMSP-Framework-Task-Force.pdf (accessed November 2010).

Johns, G.M., V.R. Leeworthy, F.W. Bell, and M.A. Bonn. 2001, *Socioeconomic Study of Reefs in Southeast Florida*. Hazen and Sawyer, P.C., Hollywood, FL.

Jones, B.M., C.D. Arp, M.T. Jorgenson, K.M. Hinkel, J.A. Schmutz, and P.L. Flint. 2009. Increase rate and uniformity of coastline erosion in arctic Alaska. *Geophysical Research Letters 36*:L03503.

Juncosa, B. 2008. Climate change may be sparking new and bigger 'dead zones'. *Scientific American October 2008*.

Justic, D., N.N. Rabalais, and R.E. Turner. 2003. Simulated responses of the Gulf of Mexico hypoxia to variations in climate and anthropogenic nutrient loading. *Journal of Marine Systems 42*(3–4):115–126.

Kemp, W.M., W.R. Boynton, J.E. Adolf, D.F. Boesch, W.C. Boicourt, G. Brush, J.C. Cornwell, T.R. Fisher, P.M. Gilbert, J.D. Hagy, L.W. Harding, E.D. Houde, D.G. Kimmel, W.D. Miller, R.I.E. Newell, M.R. Roman, E.M. Smith, and J.C. Stevenson. 2005. Eutrophication of Chesapeake Bay: Historical trends and ecological interactions. *Marine Ecology Progress Series 303*:1–29.

Kidlow, J.T., C.S. Colgan, and J. Scorse. 2009. *State of the U.S. Ocean and Coastal Economies – 2009.* National Ocean Economic Program, Nevada City, CA.

Kinnunen, R.E. 2003. *Great Lakes Commercial Fisheries*. Michigan Sea Grant Extension, Marquette, MI.

Knapp, G. 2003. *Estimates of World Salmon Supply*. Excel datafiles. University of Alaska, Anchorage, AK.

Kott, P. 2004. A new species of Didemnum (*Ascidiacea, Tunicata*) from the Atlantic coast of North America. *Zootaxa 732*:1–10.

Landers, D., S.M. Simonich, D. Jaffe, L. Geiser, D.H. Campbell, A. Schwindt, C. Schreck, M. Kent, W. Hafner, H.E. Taylor, K. Hageman, S. Usenko, L. Ackerman, J. Schrlau, N. Rose, T. Blett, and M.M. Erway. 2010. The Western Airborne Contaminant Assessment Project (WACAP): An interdisciplinary evaluation of the impacts of airborne contaminants in western U.S. national parks. *Environmental Science and Technology 44*(3):855–859.

Lauenstein, G.G., E.A. Crecelius, and A.Y. Cantillo. 2000. *Baseline Metal Concentrations of the U.S. West Coast and Their Use in Evaluating Sediment Contamination*. Presented at the Society for Environmental Toxicology and Chemistry Annual Meeting, Nashville, TN, November 12–15.

Lee, H., II, D.A. Reusser, M. Ranelletti, R. Nehmer, K. Welch, and L. Hillmann. 2008. *Pacific Coast Ecosystem Information System (PCEIS) V. 2.0*. Database. U.S. Environmental Protection Agency, Washington, DC, and U.S. Department of the Interior, U.S. Geological Survey, Reston, VA. **Ch1**

Leeworthy, V.R., and P.C. Wiley. 2001. *Current Participation Patterns in Marine Recreation, National Survey of Recreation and the Environment (NSRE) 2000*. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service, Special Projects, Silver Spring, MD.

Llansó, R.J., L.C. Scott, D.M. Dauer, J.L. Hyland, and D.E. Russell. 2002a. An estuarine benthic index of biotic integrity for the Mid-Atlantic region of the United States. I. Classification of assemblages and habitat definition. *Estuaries 25*:1219–1230.

Llansó, R.J., L.C. Scott, J.L. Hyland, D.M. Dauer, D.E. Russell, and F.W. Kutz. 2002b. An estuarine benthic index of biological integrity for the Mid Atlantic region of the United States. II. Index development. *Estuaries 25*:1231–1242.

Long, E.R., A. Robertson, D.A. Wolfe, J. Hameedi, and G.M. Sloane. 1996. Estimates of the spatial extent of sediment toxicity in major U.S. estuaries. *Environmental Sciences & Technology 30*:3585–3592.

Long, E.R., D.D. MacDonald, S.L. Smith, and F.D. Calder. 1995. Incidence of adverse biological effects within ranges of chemical concentrations in marine and estuarine sediments. *Environmental Management 19*(1):81–97.

LUMCON (Louisiana Universities Marine Consortium). 2003. *Tropical Storms Put the Oxygen Bank into the Dead Zone*. Press Release. LUMCON, Cocodrie, LA. July 29.

LUMCON (Louisiana Universities Marine Consortium). 2006. *LUMCON Researchers Report Current Hypoxic Zone at Over 6600 Square Miles*. Press Release. LUMCON, Cocodrie, LA. July 28.

Macauley, J.M., J.K. Summers, and V.D. Engle. 1999. Estimating the ecological condition of the estuaries of the Gulf of Mexico. *Environmental Monitoring and Assessment 57*:59–83.

MAFMC (Mid-Atlantic Fishery Management Council). 2011. *History of the Surfclam Ocean Quahog FMP*. Online information. Mid-Atlantic Fishery Management Council, Dover, DE. Available at: http://www.mafmc.org/fmp/history/scoq.htm (accessed November 2011).

Matte, A., and R. Waldhauer. 1984. *Mid-Atlantic Bight Nutrient Variability*. Report No. 84-15. National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Sandy Hook, NJ.

May, E.B. 1973. Extensive oxygen depletion in Mobile Bay, Alabama. *Limnology and Oceanography 18*:353–366.

Mecozzi, M. 1989. *Walleye (*Stizostedion vitreum vitreum*)*, PUBL FH-70 89. Wisconsin Department of Natural Resources, Bureau of Fisheries Management and Habitat Protection, Madison, WI.

Meier, K., J.P. Laurel, and J.E. Maragos. 1993. Hawaii (USA). In: Scott, D.A. (ed.) 1993. *A Directory of Wetlands in Oceania*. IWRB, Slimbridge, U.K. and AWB, Kuala Lumpur, Malaysia.

Menge, B.A. F. Chan, K. J. Nielsen, E. Di Lorenzo, and J. Lubchenco. 2009. Climatic variation alters supply-side ecology: Impact of climate patterns on phytoplankton and mussel recruitment. *Ecological Monographs 79*(3):379–395.

Minello, T.J., K.W. Able, M.P. Weinstein, and C.G. Hays. 2003. Salt marshes as nurseries for nekton: Testing hypotheses on density, growth and survival through metaanalysis. *Marine Ecology Progress Series 246*:39–59.

Minobe, S., and N. Mantua. 1999. Interdecadal modulation of interannual atmospheric and oceanic variability over the North Pacific. *Progress in Oceanography 43*:163–192.

Najjar, R.G., H.A. Walker, P.J. Anderson, E.J. Barron, R.J. Bord, J.R. Gibson, V.S. Kennedy, C.G. Knight, J.P. Megonigal, R.E. O’Connor, C.D. Polsky, N.P. Psuty, B.A. Richards, L.G. Sorenson, E.M. Steele, and R.S. Swanson. 2000. The potential impacts of climate change on the mid-Atlantic coastal region. *Climate Research 14*(3):219–233.

Nance, J., W. Keithly, Jr., C. Caillouet, Jr., J. Cole, W. Gaidry, B. Gallaway, W. Griffin, R. Hart, and M. Travis. 2006. *Estimation of Effort, Maximum Sustainable Yield, and Maximum Economic Yield in the Shrimp Fishery of the Gulf of Mexico*. Report of the Ad Hoc Shrimp Effort Working Group to the Gulf of Mexico Fishery Management Council, Tampa, FL.

NAS (National Academy of Sciences). 2001. *Compensating for Wetland Losses Under the Clean Water Act*. Prepared by the Committee on Mitigating Wetland Losses, National Research Council, National Academy of Sciences. Published by National Academy Press, Washington, DC.

NASA (National Aeronautics and Space Administration). 2010. 2009: Second warmest year on record, end of warmest decade. *Research News*, January 21. NASA, Goddard Institute for Space Studies, New York, NY. Available online at http://www.nasa.gov/topics/earth/features/temp-analysis-2009.html.

National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling. 2011. *Deep Water: The Gulf Oil Disaster and the Future of Offshore Drilling.* Report to the President. National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling, Washington, DC.

National Safety Council. 1998. *Coastal Challenges: A Guide to Coastal and Marine Issues*. National Safety Council, Environmental Health Center, Washington, DC.

NCDC (National Climatic Data Center). 2010. *Global Surface Temperature Anomalies*. National Oceanic and Atmospheric Administration, NCDC, Asheville, NC. Available online at http://www.ncdc.noaa.gov/cmb-faq/anomalies.html#grid (accessed October 2010).

NEFMC (New England Fishery Management Council). 2011a. *Monkfish*. Online Information. New England Fishery Management Council, Newburyport, MA. Available at: http://www.nefmc.org/monk/index.html (accessed November 2011).

NEFMC (New England Fishery Management Council). 2011b. *Scallops*. Online Information. New England Fishery Management Council, Newburyport, MA. Available at: http://www.nefmc.org/scallops/ (accessed November 2011).

Nelson, W.G., and C.A. Brown. 2008. Use of probability-based sampling of water quality indicators in supporting development of quality criteria. *ICES Journal of Marine Science 65*:1421–1427.

Nelson, W.G., H. Lee II, and J.O. Lamberson. 2005. *Ecological Condition of the Estuaries of California for 1999: A Statistical Summary*. EPA/620/R-05/004. U.S. Environmental Protection Agency, Office of Research and Development, Washington, DC.

Nelson, W.G., H. Lee II, J.O. Lamberson, F.A. Cole, C. Weilhoefer, and P.J. Clinton. 2007a. *The Condition of Tidal Wetlands of Washington, Oregon, and California - 2002*. U.S. Environmental Protection Agency, Office of Research and Development, Washington, DC.

Nelson, W.G., H. Lee II, J.O. Lamberson, V. Engle, L. Harwell, and L.M. Smith. 2004. *Condition of Estuaries of Western United States for 1999: A Statistical Summary*. EPA/620/R-04/200. U.S. Environmental Protection Agency, Office of Research and Development, Washington, DC.

Nelson, W.G., J.L. Hyland, H. Lee II, C.L. Cooksey, J.O. Lamberson, F.A. Cole, and P.J. Clinton. 2008. *Ecological Condition of Coastal Ocean Waters Along the U.S. Western Continental Shelf: 2003*. EPA 620/R-08/001 and NOAA Technical Memorandum NOS NCCOS 79, U.S. Environmental Protection Agency, Office of Research and Development, National Health and Environmental Effects Research Laboratory, Western Ecology Division, Newport, OR, and National Oceanic and Atmospheric Administration, National Ocean Service, Charleston, SC.

Nelson, W.G., R. Brock, H. Lee II, J.O. Lamberson, F. Cole. 2007b. *Condition of Estuaries and Bays of Hawaii for 2002: A Statistical Summary*. EPA/620-R-07/001.U.S. Environmental Protection Agency, Office of Research and Development, National Health and Environmental Effects Research Laboratory, Corvallis, OR.

NISC (National Invasive Species Council). 2008. *2008 – 2012 National Invasive Species Management Plan*. National Invasive Species Council, Washington, DC. Available online at http://www.invasivespecies.gov/home_documents/2008-2012%20National%20Invasive%20Species%20Management%20Plan.pdf.

NMFS (National Marine Fisheries Service). 2007a. *Fisheries of the United States 2006*. Current Fishery Statistics, No. 2006. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Silver Spring, MD.

NMFS (National Marine Fisheries Service). 2007b. *Report to Congress on the Impact of Hurricanes Katrina, Rita, and Wilma on Commercial and Recreational Fishery Habitat of Alabama, Florida, Louisiana, Mississippi, and Texas*. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service. Silver Spring, MD.

NMFS (National Marine Fisheries Service). 2009a. *Great Lakes Commercial Fishery Landings*. Online information. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Office of Science and Technology, Fisheries Statistics, Silver Spring, MD. Available at http://www.st.nmfs.noaa.gov/st1/commercial/landings/gl_query.html (accessed December 2009).

NMFS (National Marine Fisheries Service). 2009b. *Our Living Oceans – Report on the Status of U.S. Living Marine Resources, 6th Edition*. NOAA Tech. Memo. NMFS-F/SPO-80. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Silver Spring, MD.

NMFS (National Marine Fisheries Survey). 2010. *Annual Commercial Landing Statistics*. Personal communication from the National Marine Fisheries Service, Fisheries Statistics Division, Silver Spring, MD. Available at: http://www.st.nmfs.noaa.gov/st1/commercial/landings/annual_landings.html (accessed September 2010).

NOAA (National Oceanic and Atmospheric Administration). 2006. *Arctic Change: Human and Economic Indicators – Shishmaref*. U.S. Department of Commerce, NOAA, Arctic Website. Available online at http://www.arctic.noaa.gov/detect/human-shishmaref.shtml.

NOAA (National Oceanic and Atmospheric Administration). 2007a. *Large Marine Ecosystems—Information Portal*. Online information hosted by the University of Rhode Island. Information prepared by U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Northeast Fisheries Science Center, Narragansett, RI. Available at: http://www.lme.noaa.gov (accessed May 2007).

NOAA (National Oceanic and Atmospheric Administration). 2007b. *Fisheries Management: Building a Sustainable Future for America's Fisheries*. Online information. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Washington, DC. Available at: http://celebrating200years.noaa.gov/visions/fisheries/welcome.html (accessed July 2007).

NOAA (National Oceanic and Atmospheric Administration). 2008. *Regional Mean Sea Level Trends*. U.S. Department of Commerce, NOAA, Tides and Currents, Silver Spring, MD. Available online at http://tidesandcurrents.noaa.gov/sltrends/slrmap.html.

NOAA (National Oceanic and Atmospheric Administration). 2010a. *Hypoxia in the Northern Gulf of Mexico: Areal Extent of Hypoxia, 1985–2005*. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Louisiana Universities Marine Consortium, Chauvin, LA. Available at http://www.gulfhypoxia.net/Research/Shelfwide%20Cruises/all_cruises.asp (accessed November 2010)

NOAA (National Oceanic and Atmospheric Administration). 2010b. *Large Marine Ecosystems—Information Portal*. Online information hosted by the University of Rhode Island. Information prepared by U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Northeast Fisheries Science Center, Narragansett, RI. Available at: http://www.lme.noaa.gov/ (accessed November 2010).

NOAA (National Oceanic and Atmospheric Administration). 2010c. Researchers issue outlook for a significant New England 'red tide' in 2010. *NOAA News*, February 24. U.S. Department of Commerce, NOAA, Washington, DC. Available online at http://www.noaanews.noaa.gov/stories2010/20100224_redtide.html.

NOEP (National Ocean Economics Program). 2010. *Coastal Demographics Database.* Online information. National Ocean Economics Program, Nevada City, CA. Available at: http://www.oceaneconomics.org/Demographics/demogSearch.asp (accessed April 2010).

NPAFC (North Pacific Anadromous Fish Commission). 2005. *Statistical Yearbook, 1999–2001*. Vancouver, British Columbia, Canada.

NPFMC (North Pacific Fishery Management Council). 2010a. *Fishery Management Plan for Groundfish of the Bering Sea and Aleutian Islands Management Area.* North Pacific Fishery Management Council, Anchorage, AK.

NPFMC (North Pacific Fishery Management Council). 2010b. *Stock Assessment and Fishery Evaluation Report for the Groundfish Resources of the Bering Sea/Aleutian Islands Region*. North Pacific Fishery Management Council, Anchorage, AK.

NPFMC (North Pacific Fishery Management Council). 2011. *Fishery Management Plan for Groundfish of the Gulf of Alaska.* North Pacific Fishery Management Council, Anchorage, AK.

NSTC (National Science and Technology Council). 2003. *An Assessment of Coastal Hypoxia and Eutrophication in U.S. Waters.* NSTC, Committee on Environment and Natural Resources, Washington, DC. Available online at http://oceanservice.noaa.gov/outreach/pdfs/coastalhypoxia.pdf.

O'Connor, T.P., and J.F. Paul. 2000. Misfit between sediment toxicity and chemistry. *Marine Pollution Bulletin 40*:59–64.

O'Connor, T.P., K.D. Daskalakis, J.L. Hyland, J.F. Paul, and J.K. Summers. 1998. Comparisons of sediment toxicity with predictions based on chemical guidelines. *Environmental Toxicology and Chemistry 17*(3):468–471.

Ontario Ministry of Natural Resources. 2009. *Great Lakes Fisheries*. Online information. Ontario Ministry of Natural Resources, Petersborough, Ontario. Available at: http://www.mnr.gov.on.ca/en/Business/GreatLakes/2ColumnSubPage/STEL02_173913.html (accessed December 2009).

Paerl, H.W., and J. Huisman. 2008. Blooms like it hot. *Science 320*:57–58.

Paerl, H.W., and J. Huisman. 2009. Climate change: A catalyst for global expansion of harmful cyanobacterial blooms. *Environmental Microbiology Reports 1*(1):27–37.

Paerl, H.W., J.L. Pinckney, J.M. Fear, and B.L. Peierls. 1998. Ecosystem responses to internal and watershed organic matter loading: Consequences for hypoxia in the eutrophying Neuse River Estuary, North Carolina, USA. *Marine Ecology Progress Series 166*:17–25.

Parry, M.L., O.F. Canziani, J.P. Palutikof, P.J. van der Linden, and C.E. Hanson (eds.). 2007. *Climate Change 2007 – Impacts, Adaptation, and Vulnerability: Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press, Cambridge, United Kingdom.

Partridge, V. 2007. *Condition of Coastal Waters of Washington State, 2000–2003: A Statistical Summary*. Publication No. 07-03-051. Washington State Department of Ecology, Environmental Assessment Program, Olympia, WA.

Paul, J.F., K.J. Scott, D.E. Campbell, J.H. Gentile, C.S. Strobel, R.M. Valente, S.B. Weisberg, A.F. Holland, and J.A. Ranasinghe. 2001. Developing and applying a benthic index of estuarine condition for the Virginian Province. *Ecological Indicators 1*:83–99.

Pearson, T.H., and R. Rosenberg. 1978. Macrobenthic succession in relation to organic enrichment and pollution of the marine environment. *Oceanography and Marine Biology: An Annual Review 16*:229–311.

PFMC (Pacific Fishery Management Council). 2008. *Pacific Coast Groundfish Fishery Management Plan for the California, Oregon, and Washington Groundfish Fishery – As Amended Through Amendment 19 (Including Amendment 15)*. Pacific Fishery Management Council, Portland, OR.

PFMC (Pacific Fishery Management Council). 2011a. *Coastal Pelagic Species: Fishery Management Plan and Amendments.* Online information. Pacific Fishery Management Council, Portland, OR. Available at: http://www.pcouncil.org/coastal-pelagic-species/fishery-management-plan-and-amendments/ (accessed November 2011).

PFMC (Pacific Fishery Management Council). 2011b. *Groundfish: Fishery Management Plan and Amendments: Adopted/Approved Amendments.* Online information. Pacific Fishery Management Council, Portland, OR. Available at: http://www.pcouncil.org/salmon/fishery-management-plan/adoptedapproved-amendments/ (accessed November 2011).

PFMC (Pacific Fishery Management Council). 2011c. *Salmon: Fishery Management Plan and Amendments: Adopted/Approved Amendments.* Online information. Pacific Fishery Management Council, Portland, OR. Available at: http://www.pcouncil.org/salmon/fishery-management-plan/adoptedapproved-amendments/ (accessed November 2011).

PSMFC (Pacific States Marine Fisheries Commission). 2008. *Pacific Coast Fishery Information Network (PacFIN)*. Online information. Pacific State Marine Fisheries Commission, Portland, OR. Available at: http://www.psmfc.org/pacfin (accessed 2008).

Rabalais, N.N., R.E. Turner, and D. Scavia. 2002b. Beyond science into policy: Gulf of Mexico hypoxia and the Mississippi River. *BioScience 52*(2):129–142. Available online at http://caliber.ucpress.net/doi/pdf/10.1641/0006-3568%282002%29052%5B0129%3ABSIPGO%5D2.0.CO%3B2.

Rabalais, N.N., R.E. Turner, and W.J. Wiseman, Jr. 2002a. Gulf of Mexico hypoxia, a.k.a. "The Dead Zone." *Annual Review of Ecology and Systematics 33*:235–263.

Ramirez, A.J., R.A Brain, S. Usenko, M.A. Mottaleb, J.G. O'Donnell, L.L. Stahl, J.B. Wathen, B.D. Snyder, J.L. Pitt, P. Perez-Hurtado, L.L. Dobbins, B.W. Brooks, C.K. Chambliss. 2009. Occurrence of pharmaceuticals and personal care products in fish: Results of a national pilot study in the United States. *Environmental Toxicology and Chemistry 28*(12):2587–2597.

Read, J.G. 2003. *Institutional Arrangements for Great Lakes Fisheries Management*. Michigan Sea Grant, University of Michigan, Ann Arbor, MI.

Ridgewell, A., and R.E. Zeebe. 2005. The role of the global carbonate cycle in the regulation and evolution of the Earth system. *Earth and Planetary Science Letters 234*(3-4):299–315.

Sabine, C.L., R.A. Feely, N. Gruber, R.M. Key, K. Lee, J.L. Bullister, R. Wanninkhof, C.S. Wong, D.W. Wallace, B. Tilbrook, F.J. Millero, T.H. Peng, A. Kozyr, T. Ono, and A.F. Rios. 2004. The oceanic sink for anthropogenic CO2. *Science 305*(5682):367–71.

SAFMC (South Atlantic Fishery Management Council). 2011a. *Coastal Migratory Pelagics*. Online information. South Atlantic Fishery Management Council, Charleston, SC. Available at: http://www.safmc.net/Library/CoastalMigratoryPelagicsmackerel/tabid/387/Default.aspx (accessed November 2011).

SAFMC (South Atlantic Fishery Management Council). 2011b. *Shrimp*. Online information. South Atlantic Fishery Management Council, Charleston, SC. Available at: http://www.safmc.net/Library/Shrimp/tabid/413/Default.aspx (accessed November 2011).

Scavia, D., J.C. Field, D.F. Boesch, R.W. Buddemeier, V. Burkett, D.R. Cayan, M. Fogarty, M.A. Harwell, R.W. Howarth, C. Mason, D.J. Reed, T.C. Royer, A.H. Sallenger, and J.G. Titus. 2002. Climate change impacts on U.S. coastal and marine ecosystems. *Estuaries and Coasts 25*(2):149–164.

Schrope, M. 2010. Unarrested development. *Nature Reports: Climate Change 4*:36–39. Available online at http://www.nature.com/climate/index.html.

Sharma, G.D. 1979. *The Alaskan Shelf: Hydrographic, Sedimentary, and Geochemical Environment*. Springer-Verlage, New York.

Sherman, K., J. Kane, S. Murawski, W. Overholz, and A. Solow. 2002. The U.S. Northeast Shelf Large Marine Ecosystem: Zooplankton trends in fish biomass recovery. Pp. 195–215. In: *Large Marine Ecosystems of the North Atlantic*. K. Sherman and H.R. Skjoldal (eds.). Elsevier, Amsterdam.

Sigmon, C.L.T., Caton, L., Coffeen, G., Miller, S., 2006. *Coastal Environmental Monitoring and Assessment Program - The Condition of Oregon's Estuaries in 1999, a Statistical Summary*. DEQ04-LAB-0046-TR. Oregon Department of Environmental Quality, Laboratory Division, Watershed Assessment Section, Hillsboro, OR.

Smith, L.M., S. Whitehouse, and C.A. Oviatt. 2010. Impacts of climate change on Narragansett Bay. *Northeastern Naturalist 17*(1):77–90.

Smith, L.M., V.D. Engle, and J.K. Summers. 2006. Assessing water clarity as a component of water quality in Gulf of Mexico estuaries. *Environmental Monitoring and Assessment 115*:291–305.

Smith, R.W., M. Bergen, S.B. Weisberg, D. Cadien, A. Dalkey, D. Montagne, J.K. Stull, and R.G. Velarde. 2001. Benthic response index for assessing infaunal communities on the southern California mainland shelf. *Ecological Applications 11*:1073–1087.

Smith, R.W., M. Bergen, S.B. Weisberg, D. Cadien, A. Dalkey, D. Montagne, J.K. Stull, and R.G. Velarde. 1998. *Benthic Response Index for Assessing Infaunal Communities on the Mainland Shelf of Southern California*. 1997–98 Annual Report. Southern California Coastal Water Research Project, Westminster, CA .

State of Alaska. 2010. *Climate Change in Alaska*. Online information. State of Alaska, Juneau, AK. Available at: http://www.climatechange.alaska.gov/ (accessed June 2010).

Stedman, S. and T.E. Dahl. 2008. *Status and Trends of Wetlands in the Coastal Watersheds of the Eastern United States 1998 to 2004*. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Silver Spring, MD, and U.S. Department of the Interior, Fish and Wildlife Service, Onalaska, WI.

Stedman, S.M., and J. Hanson. 2000. *Habitat Connections: Wetlands, Fisheries and Economics in the South Atlantic Coastal States*. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Silver Spring, MD.

Strobel, C. J., H. A. Walker, D. Adams, R.Connell, N. Immesberger, and M. Kennish. 2008. Development of benthic indicators for nearshore coastal waters of New Jersey - a REMAP project. Presentation at May 18 – 22, 2008 meeting of the National Water Quality Monitoring Council, Sixth National Monitoring Conference, Atlantic City, NJ.

Tsuda, R.T., and D.A. Grosenbaugh. 1977. *Agat Sewage Treatment Plant: Impact of Secondary Treated Effluent on Guam Coastal Water*s. Technical Report No. 3. University of Guam, Water Resources Research Center, Mangilao, GU.

Turner, R.E., and D.F. Boesch. 1988. Aquatic animal protection and wetland relationships: Insights gleaned following wetland loss or gain. In: *The Ecology and Management of Wetlands. Volume 1: Ecology of Wetlands*. D.D. Hook, W.H. McKee, Jr., H.K. Smith, J. Gregory, V.G. Burrell, Jr., M.R. Devoe, R.E. Sojka, S. Gilbert, R. Banks, L.H. Stolzy, C. Brooks, T.D. Matthews, and T.H. Shear (eds.). Timber Press, Portland, OR.

U.S. Census Bureau. 2010. Puerto Rico and the island areas. Section 29. In *Statistical Abstract of the United States*. 129th Edition. U.S. Department of Commerce, U.S. Census Bureau, Washington, DC.

U.S. Commission on Ocean Policy. 2004. *An Ocean Blueprint for the 21st Century*. Final Report ISBN#0–9759462–0–X. U.S. Commission on Ocean Policy, Washington, DC.

U.S. EPA (Environmental Protection Agency). 1986. *Ambient Water Quality Criteria for Bacteria – 1986*. EPA/440-5-84-002. U.S. Environmental Protection Agency, Office of Water Regulations and Standards, Criteria and Standards Division, Washington, DC.

U.S. EPA (Environmental Protection Agency). 1993. *Proposed Sediment Quality Criteria for the Protection of Benthic Organisms: Acenaphthene*. EPA/822-F-93-006. U.S. Environmental Protection Agency, Office of Science and Technology, Washington, DC.

U.S. EPA (Environmental Protection Agency). 1995. *National Water Quality Inventory—1994 Report to Congress*. EPA/841-R-95-005. U.S. Environmental Protection Agency, Office of Water, Washington, DC.

U.S. EPA (Environmental Protection Agency). 1995a. *Environmental Monitoring and Assessment Program (EMAP): Laboratory Methods Manual—Estuaries, Volume 1: Biological and Physical Analyses*. EPA/620-R-95-008. U.S. Environmental Protection Agency, Office of Research and Development, Narragansett, RI.

U.S. EPA (Environmental Protection Agency). 1996. Ecological Effects Test Guidelines: OPPTS 850:1740: Whole Sediment Acute Toxicity Invertebrates, Marine. Technical Report EPA 712 C-96-355. U.S. Environmental Protection Agency, Washington, DC.

U.S. EPA (Environmental Protection Agency). 1998b. *The Beach and Your Coastal Watershed*. EPA/842-F-98-10. U.S. Environmental Protection Agency, Office of Water, Washington, DC.

U.S. EPA (Environmental Protection Agency). 1999. *Ecological Condition of Estuaries in the Gulf of Mexico*. EPA/620-R-98-004. U.S. Environmental Protection Agency, Office of Research and Development, National Health and Environmental Effects Research Laboratory, Gulf Ecology Division, Gulf Breeze, FL.

U.S. EPA (Environmental Protection Agency). 2000a. *A Framework for an Integrated and Comprehensive Monitoring Plan for Estuaries on the Gulf of Mexico*. EPA-620/R-00/005. U.S. Environmental Protection Agency, Gulf of Mexico Program, Stennis Space Center, MS.

U.S. EPA (Environmental Protection Agency). 2000b. *Ambient Water Quality Criteria for Dissolved Oxygen (Saltwater): Cape Cod to Cape Hatteras*. EPA/822-R-00-012. U.S. Environmental Protection Agency, Office of Water, Washington, DC.

U.S. EPA (Environmental Protection Agency). 2000c. *Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories, Volume 2: Risk Assessment and Fish Consumption Limits*. EPA-823-B-00-008. U.S. Environmental Protection Agency, Office of Water, Washington, DC.

U.S. EPA (Environmental Protection Agency). 2000c. *Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories, Volume 2: Risk Assessment and Fish Consumption Limits*. EPA/823-B-00-008. U.S. Environmental Protection Agency, Office of Water, Washington, DC.

U.S. EPA (Environmental Protection Agency). 2001a. *National Coastal Assessment Quality Assurance Project Plan*. EPA/620-R-01-002. U.S. Environmental Protection Agency, Office of Research and Development, Washington, DC.

U.S. EPA (Environmental Protection Agency). 2001b. *National Coastal Condition Report*. EPA-620/R-01/005. U.S. Environmental Protection Agency, Office of Research and Development and Office of Water, Washington, DC.

U.S. EPA (Environmental Protection Agency). 2001c. *National Sediment Quality Survey Database: 1980–1999*. Database. EPA/823-F-01-002. U.S. Environmental Protection Agency, Office of Water, Washington, DC.

U.S. EPA (Environmental Protection Agency). 2001d. *Water Quality Criterion for the Protection of Human Health: Methylmercury*. EPA/823-R-01-001. U.S. Environmental Protection Agency, Office of Water, Office of Science and Technology, Washington, DC.

U.S. EPA (Environmental Protection Agency). 2004a. *National Coastal Condition Report II*. EPA/620-R-03-002. U.S. Environmental Protection Agency, Office of Research and Development and Office of Water, Washington, DC.

U.S. EPA (Environmental Protection Agency). 2004b. *The Incidence and Severity of Sediment Contamination in Surface Waters of the United States, National Sediment Quality Survey: Second Edition*. EPA/823-R-04-007. U.S. Environmental Protection Agency, Office of Science and Technology, Standards and Health Protection Division, Washington, DC.

U.S. EPA (Environmental Protection Agency). 2006. *National Estuary Program Coastal Condition Report*. EPA/842-B-06-001. U.S. Environmental Protection Agency, Office of Water and Office of Research and Development, Washington, DC.

U.S. EPA (Environmental Protection Agency). 2007a. *Aquatic Resources Monitoring*. Online information. U.S. Environmental Protection Agency, Office of Research and Development, National Health and Environmental Effects Research Laboratory, Corvallis, OR. Available at: http://www.epa.gov/nheerl/arm/index.htm (accessed October 2007).

U.S. EPA (Environmental Protection Agency). 2007b. *Climate Change and Interacting Stressors: Implications for Coral Reef Management in American Samoa (Final Report)*. EPA/600/R-07/069. U.S. EPA, Global Change Research Program, Washington, DC.

U.S. EPA (Environmental Protection Agency). 2007c. *National Listing of Fish and Wildlife Database—2006*. U.S. Environmental Protection Agency, Office of Water, Office of Science and Technology, Standards and Health Protection Division, Washington, DC.

U.S. EPA (Environmental Protection Agency). 2008a. *Aquatic Life Criteria for Contaminants of Emerging Concern, Part I: General Challenges and Recommendations.* Draft white paper. U.S Environmental Protection Agency, Office of Water and Office of Research and Development Emerging Contaminants Workgroup, Washington, DC.

U.S. EPA (Environmental Protection Agency). 2008b. *Effects of Climate Change on Aquatic Invasive Species and Implications for Management and Research.* EPA/600/R-08/014. U.S. Environmental Protection Agency, Office of Research and Development, National Center for Environmental Assessment, Washington, DC.

U.S. EPA (Environmental Protection Agency). 2008c. *National Coastal Condition Report III.* EPA/842-R-08-002. U.S. Environmental Protection Agency, Office of Water and Office of Research and Development, Washington, DC.

U.S. EPA (Environmental Protection Agency). 2009a. *Areas of Concern (AoCs) On-line*. Online information. U.S. Environmental Protection Agency, Great Lakes National Program Office, Chicago, IL. Available at http://www.epa.gov/glnpo/aoc/index.html (accessed June 2009).

U.S. EPA (Environmental Protection Agency). 2009b. *Detroit River – Western Lake Erie Basin Indicator Project: Lake Whitefish Spawning*. Online information. U.S. Environmental Protection Agency, Office of Research and Development, Mid-Continent Ecology Division, Large Lakes and Rivers

Forecasting Research Branch, Duluth, Minnesota. Available at http://www.epa.gov/med/grosseile_site/indicators/whitefish.html (accessed December 2009).

U.S. EPA (Environmental Protection Agency). 2009c. *Guidance for Implementing the January 2001 Methylmercury Water Quality Criterion - Final.* EPA/823-R-09-002. U.S. Environmental Protection Agency, Office of Science and Technology, Washington DC.

U.S. EPA (Environmental Protection Agency). 2009d. *PRAWN Database (November 2009)*. U.S. Environmental Protection Agency, Office of Water, Washington, DC.

U.S. EPA (Environmental Protection Agency). 2009e. *Review of Published Studies to Characterize Relative Risks from Different Sources of Fecal Contamination in Recreational Waters*, EPA 822-R-09-001, U.S. Environmental Protection Agency, Office of Water, Health and Ecological Criteria Division, Washington, DC.

U.S. EPA (Environmental Protection Agency). 2009f. *Synthesis of Adaptation Options for Coastal Areas*. EPA 430-F-08-024. U.S. Environmental Protection Agency, Office of Water, Climate Ready Estuaries Program, Washington, DC.

U.S. EPA (Environmental Protection Agency). 2010a. *Climate Change-Science: Sea Level Changes*. Online information. U.S. EPA, Washington, DC. Available online at: http://epa.gov/climatechange/science/recentslc.html#ref (accessed September 2010).

U.S. EPA (Environmental Protection Agency). 2010b. *Expanded Investigations of Pharmaceuticals in Fish Tissue*. Online information. U.S. Environmental Protection Agency, Washington, DC. Available at: http://water.epa.gov/scitech/swguidance/ppcp/fish-expand.cfm (accessed October 2010).

U.S. EPA (Environmental Protection Agency). 2010c. *Invasive Species*. Online information. U.S. EPA, Washington, DC. Available online at http://www.epa.gov/owow/invasive_species/ (accessed April 2010).

University of Wisconsin Sea Grant Institute. 2010. *Fish of the Great Lakes: Fish Profiles.* Online information. University of Wisconsin Sea Grant Institute, Madison, WI. Available at http://seagrant.wisc.edu/greatlakesfish/framefish.html (accessed January 2010).

USGS (U.S. Geological Survey) 2010. *USGS Non-indigenous Aquatic Species Database*. Accessed October 31, 2010. Available at: http://nas.er.usgs.gov/queries/.

Van Dolah, R.F., J.L. Hyland, A.F. Holland, J.S. Rosen, and T.T. Snoots. 1999. A benthic index of biological integrity for assessing habitat quality in estuaries of the southeastern USA. *Marine Environmental Research 48*:(4–5):269–283.

Walsh, M.G., O'Gorman, R., Lantry, B.F., Strang, T., and Maloy, A.P. 2006. Status of sculpins and round goby in the U.S. waters of Lake Ontario, 2005. *Annual Report Bureau of Fisheries Lake Ontario Unit and St. Lawrence River Unit to Great Lakes Fishery Commission's Lake Ontario Committee*. Section 12, 20-31. Available online: http://www.glsc.usgs.gov/_files/reports/2005LakeOntarioPreyfishReport.pdf.

Wang, F., R.W. MacDonald, G.A. Stern, and P.M. Outridge. 2010. When noise becomes signal: Chemical contaminants of aquatic ecosystems under a changing climate. *Marine Pollution Bulletin 60*: 1633–1635.

Weisberg, S.B., J.A. Ranasinghe, D.D. Dauer, L.C. Schnaffer, R.J. Diaz, and J.B. Frithsen. 1997. An estuarine benthic index of biotic integrity (B-IBI) for Chesapeake Bay. *Estuaries 20*(1):149–158.

Wetz, J.J., J. Hill, H. Corwith, and P.A. Wheeler. 2004. *Nutrient and Extracted Chlorophyll Data from the GLOBEC Long-Term Observation Program, 1997–2004*. Data Report 193. COAS Reference 2004-1. Oregon State University, College of Oceanic and Atmospheric Sciences, Corvallis, OR. Revised 2005.

White House Council on Environmental Quality. 2009. *Final Recommendations of the Interagency Ocean Policy Task Force.* Executive Office of the President of the United States, White House Council on Environmental Quality, Interagency Ocean Policy Task Force, Washington, DC.

Wiles, G. J., and M.W. Ritter. 1993. Guam. pp. 129-178, In: Scott, D.A. [ed.]. *A Directory of Wetlands in Oceania*: IWRB, Slimbridge, U.K. and AWB. Kuala Lumpur, Malaysia.

Wilson, S., and V. Partridge. 2007. *Condition of Outer Coastal Estuaries of Washington State, 1999: A Statistical Summary*. Publication No. 07-03-012. Washington State Department of Ecology, Olympia, WA.

Woodling, J.D., E.M. Lopez, T.A. Maldonado, D.O. Norris, and A.M. Vajda. 2006. Intersex and other reproductive disruption of fish in wastewater effluent dominated Colorado streams. *Comparative Biochemistry and Physiology C-Toxicology & Pharmacology 144*(1):10–15.

Woody, K., A. Atkinson, R. Clark, C. Jeffrey, I. Lundgren, J. Miller, M. Monaco, E. Muller, M. Patterson, C. Rogers, T. Smith, T. Spitzak, R. Waara, K. Whelan, B. Witcher, and A. Wright. 2008. Coral bleaching in the U.S. Virgin Islands in 2005 and 2006. In: Wilkinson, C., and D. Souter (eds). *Status of Caribbean Coral Reeds After Bleaching and Hurricanes in 2005.* Global Coral Reed Monitoring Network, Townsville, Australia.

WPRFMC (Western Pacific Regional Fishery Management Council). 2009a. *Fishery Ecosystem Plan for the Hawaii Archipelago*. Western Pacific Regional Fishery Management Council, Honolulu, HI.

WPRFMC (Western Pacific Regional Fishery Management Council). 2009b. *Fishery Ecosystem Plan for Pacific Pelagic Fisheries of the Western Pacific Region*. Western Pacific Regional Fishery Management Council, Honolulu, HI.

WPRFMC (Western Pacific Regional Fishery Management Council). 2009c. *Fishery Ecosystem Plan for the Mariana Archipelago*. Western Pacific Regional Fishery Management Council, Honolulu, HI.

Yoskowitz, D. 2009. The productive value of the Gulf of Mexico. In “Gulf of Mexico origin, waters, and biota, Volume 2, Ocean and Coastal Economy.” James C. Cato, Ed. Texas A&M University Press. ISBN-13: 978-1-60344-086-8.

Zwanenburg, K.C.T., D. Bowen, A. Bundy, K. Drinkwater, K. Frank, R.O’Boyle, D. Sameoto, and M. Sinclair. 2002. Decadal changes in the Scotian Shelf large marine ecosystem. In: *Large Marine Ecosystems of the North Atlantic: Changing States and Sustainability*. K. Sherman and H.R. Skjoldal (eds.). Elsevier, Amsterdam.

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