UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

National Coastal Condition Report III

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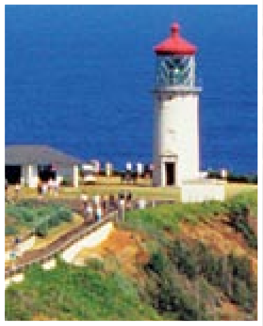

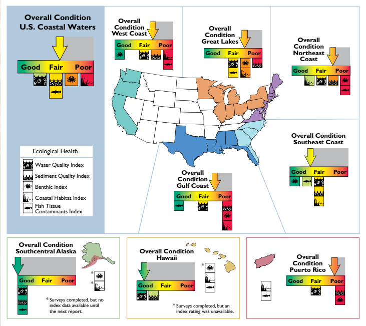

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EPA
Darrell Brown, Office of Water
Barry Burgan, Office of Water
Greg Colianni, Office of Water
Virginia Engle, Office of Research and Development
James Harvey, Office of Research and Development
John Kiddon, Office of Research and Development
Henry Lee, Office of Research and Development
Walt Nelson, Office of Research and Development
Lisa Smith, Office of Research and Development
Kevin Summers, Office of Research and Development
Henry Walker, Office of Research and Development

NOAA
Marie-Christine Aquarone, National Marine Fisheries Service
Donna Busch, National Marine Fisheries Service
Jeff Hyland, National Ocean Service
Thomas O'Connor, National Ocean Service
Anthony Pait, National Ocean Service
Kenneth Sherman, National Marine Fisheries Service
Dave Whitall, National Ocean Service

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Thomas Dahl, Division of Habitat and Resource Conservation

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Contents

Acronyms and Abbreviations

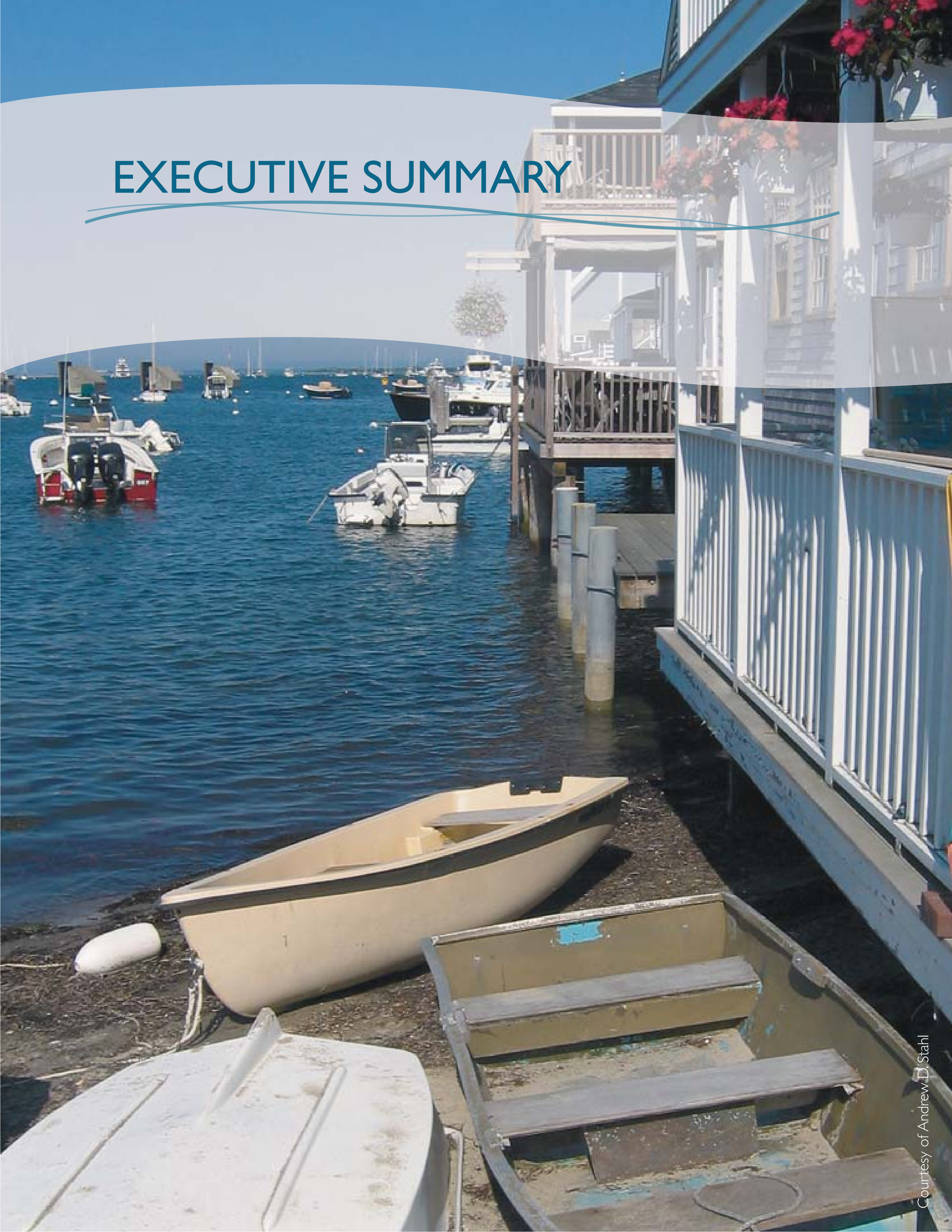
AKMAP	Alaska Monitoring and Assessment Program
AOC	Area of Concern
ASMFC	Atlantic States Marine Fisheries Commission
AVHRR	Advanced Very High Resolution Radiometer
AWQC	Ambient Water Quality Criterion
BEACH	Beaches Environmental Assessment, Closure, and Health Program
BEQ	benthic environmental quality
B-IBI	Benthic Index of Biotic Integrity
BRI	Benthic Response Index
CBP	Chesapeake Bay Program
C-CAP	Coastal Change Analysis Program
CDF	cumulative distribution function
CISNet	Coastal Intensive Sites Network
CPR	continuous plankton recorder
CPUE	catch per unit effort
CRD	Coastal Resource Division
CRMC	Coastal Resources Management Council
CSO	combined sewer overflow
CWCA	Coastal Watershed Condition Assessment Program
DEC	Department of Environmental Conservation
DDD	p,p'-diclorodiphenyldichloroethane
DDE	p,p'-diclorodiphenyldichloroethylene
DDT	p,p'-diclorodiphenyltrichloroethane
DIN	dissolved inorganic nitrogen
DIP	dissolved inorganic phosphorus
DMAC	data management and communications
DNR	Department of Natural Resources
DOI	U.S. Department of the Interior
DQO	data quality objective
EC50	effective concentration required to induce 50% reproductive failure
EC90	effective concentration required to induce 90% reproductive failure
ECOHAB	Ecology and Oceanography of Harmful Algal Blooms Program
EEZ	U.S. Exclusive Economic Zone
EMAP	Environmental Monitoring and Assessment Program
EMAP–VP	Environmental Monitoring and Assessment Program–Virginian Province

EPA	U.S. Environmental Protection Agency
ERL	effects range low
ERM	effects range medium
ESA	Endangered Species Act
FDA	U.S. Food and Drug Administration
FMP	fishery management plan
FRI	Fish Response Index
FWS	U.S. Fish and Wildlife Service
GCRC	Georgia Coastal Research Council
GEOSS	Global Earth Observation System of Systems
GIS	geographic information systems
GLERL	Great Lakes Environmental Research Laboratory
GLNPO	Great Lakes National Program Office
GMP	Joint Gulf States Comprehensive Monitoring Program
GNP	gross national product
GOOS	Global Ocean Observing System
HAB	harmful algal bloom
H'	benthic diversity
IEOS	U.S. Integrated Earth Observation System
IEP	Interagency Ecological Program
IFYLE	International Field Years on Lake Erie Program
IOOS	U.S. Integrated Ocean Observing System
IWGOO	Interagency Working Group on Ocean Observations
JWPCP	Joint Water Pollution Control Plant
kg/tow	kilogram per tow
LACSD	Los Angeles County Sanitation District
LIDAR	light detection and ranging technology
LME	Large Marine Ecosystem
LNG	liquid natural gas
m	meter
MAIA	Mid-Atlantic Integrated Assessment
MARMAP	Marine Resources Monitoring, Assessment, and Prediction Program
mg/L	milligram per liter
mg/m^3	milligram per cubic meter
MHI	Main Hawaiian Islands
mi^2	square mile
$mL/100m^3$	milliliter per 100 cubic meters
MMS	Minerals Management Service
MRLC	Multi-Resolution Land Characteristics Consortium
MWRA	Massachusetts Water Resources Authority
NAD	National Assessment Database
NBEP	Narragansett Bay Estuary Program

NCA	National Coastal Assessment
NCCR	*National Coastal Condition Report*
NCCR I	*National Coastal Condition Report I*
NCCR II	*National Coastal Condition Report II*
NCCR III	*National Coastal Condition Report III*
NCCR IV	*National Coastal Condition Report IV*
NEFMC	New England Fishery Management Council
NEP	National Estuary Program
NEP CCR	*National Estuary Program Coastal Condition Report*
NERR	National Estuarine Research Reserve
NERRS	National Estuarine Research Reserve System
NFRA	National Federation of Regional Associations
ng/g	nanogram per gram
NHEERL	National Health and Environmental Effects Research Laboratory
NIEHS	National Institute of Environmental Health Sciences
NLCD	National Land Cover Database
NLFA	National Listing of Fish Advisories
NMFS	National Marine Fisheries Service
NMS	National Marine Sanctuary
NOAA	National Oceanic and Atmospheric Administration
NOBOB	no ballast on board
NPS	National Park Service
NRCS	Natural Resources and Conservation Service
NS&T	National Status & Trends Program
NSF	National Science Foundation
NWHI	Northwestern Hawaiian Islands
NWI	National Wetlands Inventory
NY/NJ	New York/New Jersey
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
PCE	tetrachloroethylene
PFA	polyfluoroalkyl compound
POP	persistent organic pollutant
POTWs	Publicly Owned Treatment Works
ppb	parts per billion
ppm	parts per million
ppt	parts per thousand
PRAWN	BEACH PRogram tracking, beach Advisories, Water quality standards, and Nutrients database
PSAMP	Puget Sound Ambient Monitoring Program
PSP	paralytic shellfish poisoning
psu	practical salinity unit

QA	quality assurance
QAPP	quality assurance project plan
QC	quality control
REMAP	Regional Environmental Monitoring and Assessment Program
RIDEM	Rhode Island Department of Environmental Management
RMP	Regional Monitoring Program for Trace Substances
SAB	South Atlantic Bight
SAFMC	South Atlantic Fishery Management Council
SAV	submerged aquatic vegetation
SCB	Southern California Bight
SCCWRP	Southern California Coastal Water Resources Project
SCORE	South Carolina Oyster Restoration and Enhancement Program
SeaWiFS	Sea-viewing Wide Field-of-view Sensor
SOLEC	State of the Lakes Ecosystem Conference
SQO	sediment quality objective
SWiM	System-wide Monitoring Program (NMS)
SWMP	System-wide Monitoring Program (NEERS)
t	metric tons
TDN	total dissolved nitrogen
TDP	total dissolved phosphorus
TOC	total organic carbon
µg/g	microgram per gram
µg/L	microgram per liter
UME	unusual mortality event
URI	University of Rhode Island
USACE	U.S. Army Corps of Engineers
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey
VOC	volatile organic compound
WDOE	Washington State Department of Ecology
WHOI	Woods Hole Oceanographic Institution
WRD	Water Resources Division
WWTP	wastewater treatment plant

EXECUTIVE SUMMARY



Courtesy of Andrew D. Stahl

Executive Summary

Coastal waters in the United States include estuaries, bays, sounds, coastal wetlands, coral reefs, intertidal zones, mangrove and kelp forests, seagrass meadows, and coastal ocean and upwelling areas (deep water rising to surface). Coastal habitats provide spawning grounds, nurseries, shelter, and food for finfish, shellfish, birds, and other wildlife. These coastal resources also provide nesting, resting, feeding, and breeding habitat for 75% of waterfowl and other migratory birds.

Section 305(b) of the Clean Water Act (CWA) requires that the U.S. Environmental Protection Agency (EPA) report periodically on the condition of the nation's coastal waters. As part of this process, coastal states provide valuable information about the condition of their coastal resources to EPA; however, because the individual states use a variety of approaches for data collection and evaluation, it has been difficult to compare this information among states or on a national basis.

To better address questions about national coastal condition, EPA, the National Oceanic and Atmospheric Administration (NOAA), the U.S. Department of the Interior (DOI), and the U.S. Department of Agriculture (USDA) agreed to participate in a multi-agency effort to assess the condition of the nation's coastal resources. The agencies chose to assess condition using nationally consistent monitoring surveys to minimize the problems created by compiling data collected using multiple approaches. The results of these assessments are compiled periodically into a *National Coastal Condition Report*. This series of reports contains one of the most comprehensive ecological assessments of the condition of our nation's coastal bays and estuaries. The assessment presented in each report is based on data from more than 2,000 sites.

The nation's coasts are a popular vacation destination, with approximately 180 million people visiting U.S. beaches each year (courtesy of Andrew D. Stahl).

The first *National Coastal Condition Report* (NCCR I), published in 2001, reported that the nation's coastal resources were in fair to poor condition. The NCCR I used available data collected from 1990 to 1996 to characterize about 70% of the nation's conterminous coastal waters. Agencies contributing these data included EPA, NOAA, the U.S. Fish and Wildlife Service (FWS), and the USDA. The second *National Coastal Condition Report* (NCCR II) was based on available data from 1997 to 2000. The NCCR II data were representative of 100% of the coastal waters of the conterminous 48 states and Puerto Rico and showed that the nation's coastal waters were slightly improved and rated in fair condition. Agencies that contributed data to the NCCR II included EPA, NOAA, FWS, and the U.S. Geological Survey (USGS). Several state, regional, and local organizations also provided information on the condition of the nation's coasts.

This third *National Coastal Condition Report* (NCCR III) assesses the condition of the nation's estuaries and coastal embayments (collectively referred to as "coastal waters" in this report), including the coastal waters of Hawaii and Southcentral Alaska, based primarily on EPA's National Coastal Assessment (NCA) data collected primarily in 2001 and 2002. The NCA; NOAA's National Marine Fisheries Service (NMFS) and National Ocean Service; FWS's National Wetlands Inventory (NWI); and USGS contributed most of the information presented in this report. As shown in this report, the overall condition score (2.8) for the nation's coastal waters has improved since 1990, but continues to be rated fair. This report also presents analysis of temporal changes in coastal condition from 1990 to 2002 for the nation and by region.

With each *National Coastal Condition Report*, the collaborating agencies strive to provide a more comprehensive picture of the nation's coastal resources and to communicate these findings to the informed public, coastal managers, scientists, members of Congress, and other elected officials. The NCCR III builds on the foundation provided by the NCCR I and NCCR II, and efforts are underway to assess even more areas using comparable and consistent analysis methods. In addition to the areas previously assessed in the NCCR II, this report provides condition data for Hawaii and Southcentral Alaska. It should be noted that the Great Lakes data provided in this report are not directly comparable with the data provided for other regions; however, general comparisons of the Great Lakes condition ratings are provided. Although a freshwater ecosystem, the Great Lakes are included as a coastal resource because Congress has stipulated that the Great Lakes be considered in coastal legislation. Ongoing monitoring efforts in Alaska, Hawaii, and the island commonwealths and territories will support comprehensive assessments of coastal condition in future installments of the *National Coastal Condition Report* series.

The NCCR III includes an assessment of Hawaii's estuaries and coastal embayments (courtesy of ErgoSum88).

The NCCR III presents three main types of data: (1) coastal monitoring data, (2) offshore fisheries data, and (3) assessment and advisory data. The ratings of coastal condition in this report are based primarily on coastal monitoring data because these are the most comprehensive and nationally consistent data available related to coastal condition. One source of coastal monitoring data is EPA's NCA, which provides information on the condition of coastal waters for all regions of the United States. The NCCR III uses NCA and other data to evaluate five indices of coastal condition—water quality index, sediment quality index, benthic index, coastal habitat index, and fish tissue contaminants index—in each region of the United States (Northeast Coast, Southeast Coast, Gulf Coast, West Coast, Great Lakes, Southcentral Alaska, Hawaii, and Puerto Rico). The resulting ratings for each index are then used to calculate the overall condition ratings for the regions, as well as index and overall condition ratings for the nation. The NCCR III assessment applies to 30 coastal states (22 ocean states, 6 Great Lakes states, and 2 ocean/Great Lakes states) and Puerto Rico (Figure ES-1). Trends in the NCA data are discussed at the end of this Executive Summary.

In addition to rating coastal condition based on coastal monitoring data, the NCCR III summarizes available information related to offshore fisheries, fish consumption advisories, and beach advisories and closures. Although not directly comparable, this information, together with descriptions of individual monitoring programs, paints a picture of the overall condition of the nation's coastal resources.

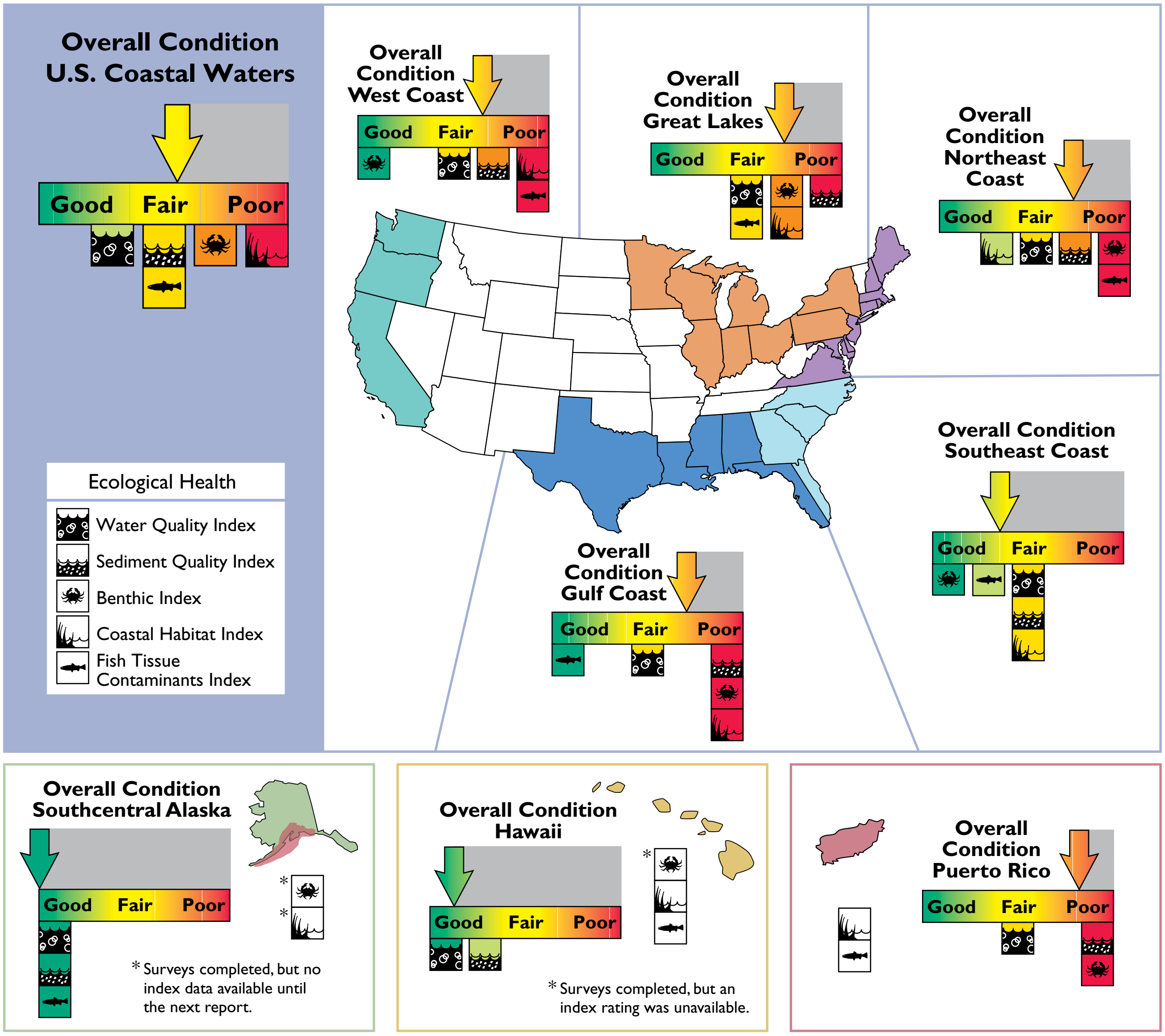


Figure ES-1. Overall national and regional coastal condition based on data collected primarily between 2001 and 2002 (U.S. EPA/NCA).

Summary of the Findings

This report is based on the large amount of monitoring data collected primarily between 2001 and 2002 on the condition of the coastal and Great Lakes resources of the United States. Ecological assessment of these data shows that the nation's coastal waters are rated fair for overall condition. With respect to the coastal waters of the geographic regions assessed in this report, the Puerto Rico region is rated poor; the Northeast Coast, Gulf Coast, and Great Lakes regions are rated fair to poor; the Southeast Coast and West Coast regions are rated fair; and the Southcentral Alaska and Hawaii regions are rated good. No overall condition assessments were available for Guam, American Samoa, the Northern Mariana Islands, or the U.S. Virgin Islands.

The major findings of the 2001–2002 study period are as follows:

- The overall condition of the nation's coastal waters is rated fair (overall condition score of 2.8) and has improved only slightly since the initial NCCR I in 2001. This rating is based on the five indices of ecological condition assessed in this report: water quality index, sediment quality index, benthic index, coastal habitat index, and fish tissue contaminants index (Tables ES-1 and ES-2). This report also assesses component indicators for the water quality index (dissolved inorganic nitrogen [DIN], dissolved inorganic phosphorus [DIP], chlorophyll *a*, water clarity, and dissolved oxygen) and the sediment quality index (sediment toxicity, sediment contaminants, and sediment total organic carbon [TOC]).
- The water quality index score for the nation has improved substantially, and smaller improvements in the sediment quality and benthic index scores were noted. The fish tissue contaminants and coastal habitat index scores have shown little or no improvement.
- The water quality index for the nation's coastal waters is rated good to fair, with 57% of the nation's coastal area rated good for water quality condition, 34% rated fair, and 6% rated poor.
- Eighteen percent of the NCA stations where fish were caught were rated poor for the fish tissue contaminants index, based on the EPA Advisory Guidance values used to assess the fish tissue contaminants index for this report.
- The coastal habitat, sediment quality, and benthic indices show the poorest conditions throughout the coastal United States, whereas the dissolved oxygen and DIN indicators are most often rated in good condition throughout the nation.

Table ES-1. Rating Scores[a] by Index and Region

Index	Northeast Coast	Southeast Coast	Gulf Coast	West Coast	Great Lakes	Southcentral Alaska	Hawaii	Puerto Rico	United States[b]
Water Quality Index	3	3	3[c]	3	3	5	5	3	3.9
Sediment Quality Index	2	3	1	2	1	5	4	1	2.8
Coastal Habitat Index	4	3	1	1	2	—[d]	—[d]	—[d]	1.7
Benthic Index	1	5	1	5	2	—[d]	—[d]	1	2.1
Fish Tissue Contaminants Index	1	4	5	1	3	5	—[d]	—[d]	3.4
Overall Condition	2.2	3.6	2.2	2.4	2.2	5.0	4.5	1.7	2.8

[a] Rating scores are based on a 5-point system, where a score of less than 2.0 is rated poor; 2.0 to less than 2.3 is rated fair to poor; 2.3 to 3.7 is rated fair; greater than 3.7 to 4.0 is rated good to fair; and greater than 4.0 is rated good.

[b] The U.S. score is based on an areally weighted mean of regional scores and includes the scores for Southcentral Alaska and Hawaii.

[c] This rating score does not include the impact of the hypoxic zone in offshore Gulf Coast waters.

[d] This index was not assessed for this region.

Describing Coastal Condition

Three types of data are presented in this report:

- **Coastal Monitoring Data**—Coastal monitoring data are obtained from programs such as EPA's Environmental Monitoring and Assessment Program (EMAP) and NCA, NOAA's National Status & Trends (NS&T) Program, and FWS's NWI, as well as Great Lakes information from the State of the Lakes Ecosystem Conference (SOLEC). These data are used to rate indices and component indicators of coastal condition for the geographic regions assessed in this report and for the nation. These index scores are then used to calculate overall condition scores and ratings for the regions and the nation. The rating criteria for each index and component indicator in each region are determined based on existing criteria, guidelines, interviews with EPA decision makers and other resource experts, and/or the interpretation of scientific literature.
- **Offshore Fisheries Data**—These data are obtained from programs such as NOAA's Marine Monitoring and Assessment Program and Southeast Area Monitoring and Assessment Program. These data are used in this report to assess the condition of coastal fisheries in large marine ecosystems (LMEs).
- **Assessment and Advisory Data**—These data are provided by states or other regulatory agencies and compiled in nationally maintained databases. These data provide information about designated-use support, which affects public perception of coastal condition as it relates to public health. The agencies contributing these data use different methodologies and criteria for assessment; therefore, the data cannot be used to make broad-based comparisons among the different coastal areas.

Table ES-2. Percent Area in Poor Condition[a] by Index (except Coastal Habitat Index) and Region

Index	Northeast Coast	Southeast Coast	Gulf Coast	West Coast	Great Lakes	Southcentral Alaska	Hawaii	Puerto Rico	United States
Water Quality Index[b]	13	6	14[c]	3	—	0	4	9	6
Sediment Quality Index[d]	13	12	18	14	—	1	5	61	8
Coastal Habitat Index[e]	—	—	—	—	—	—	—	—	—
Benthic Index	27	7	45	5	—	—	—	35	27
Fish Tissue Contaminants Index[f]	31	10	8	26	—	0	—	—	18

[a] The percent area of poor condition is the percentage of total surface area of estuaries and coastal embayments in the region or the nation (proportional area information not available for the Great Lakes or the coastal habitat index).

[b] The water quality index is based on measurements of five component indicators: DIN, DIP, chlorophyll *a*, water clarity, and dissolved oxygen.

[c] The area of poor condition does not include the hypoxic zone in offshore Gulf Coast waters.

[d] The sediment quality index is based on measurements of three component indicators: sediment toxicity, sediment contaminants, and sediment TOC.

[e] The fish tissue contaminants index is presented as the percentage of fish samples analyzed (Northeast Coast region) or monitoring stations where fish were caught (all other regions) and is based on analyses of whole-fish samples (not fillets).

Coastal Monitoring Data

The overall condition of the nation's coastal waters is rated fair (Figure ES-2), based on ratings for the five indices of coastal condition assessed for this report: water quality index, sediment quality index, benthic index, coastal habitat index, and fish tissue contaminants index. The national indices were assigned a good, fair, or poor rating based on a weighted average of the index scores for each coastal region of the United States. An average of the national index scores was used to determine an overall condition score and rating for the nation. Supplemental information on the water and sediment quality component indicators (e.g., DIN, DIP, chlorophyll *a*, water clarity, dissolved oxygen, sediment toxicity, sediment contaminants, and sediment TOC), when available, is also presented throughout this report.

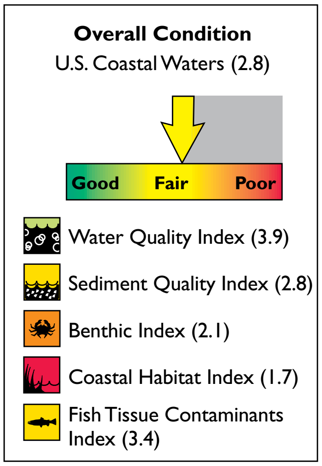
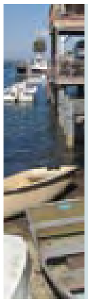


Figure ES-2. The overall condition of U.S. coastal waters is rated fair (U.S. EPA/NCA).

A summary of each index is presented below.

- **Water Quality Index**—The water quality index for the nation's coastal waters is rated good to fair. The percent of coastal area rated poor for water quality ranged from 0 in Southcentral Alaska to 14% in the Gulf Coast region. Most water quality problems in U.S. coastal waters are associated with degraded water clarity or increased concentrations of DIP or chlorophyll *a*. Low dissolved oxygen concentrations occur in only 4% of the U.S. coastal area.
- **Sediment Quality Index**—The sediment quality index for the nation's coastal waters is rated fair. The sediment quality index is rated poor for the Gulf Coast, Great Lakes, and Puerto Rico regions; fair to poor for the West Coast and Northeast Coast regions; fair for the Southeast Coast region; good to fair for Hawaii; and good for Southcentral Alaska. Many areas of the United States have significant sediment degradation, including elevated concentrations of polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), pesticides, and metals. Most of these sediments with elevated contaminant concentrations occur in the coastal waters of the Northeast Coast region and Puerto Rico. Sediment toxicity was observed most frequently in the coastal waters of the Gulf Coast and West Coast regions. High concentrations of sediment TOC (often associated with the deposition of human, animal, and plant wastes) were observed in 44% of Puerto Rico's coastal waters.
- **Benthic Index**—The benthic index for the nation's coastal waters is rated fair to poor. Poor benthic condition is observed in Gulf Coast, Northeast Coast, and Puerto Rico coastal waters, largely due to degraded sediment quality; however, in some cases, poor benthic condition is associated with poor water quality conditions, such as low dissolved oxygen and elevated nutrient concentrations. Both the Southeast Coast and West Coast regions are rated good for benthic condition. Benthic index data were unavailable for Southcentral Alaska or Hawaii.



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

- **Coastal Habitat Index**—The coastal habitat index for the nation's coastal waters is rated poor. Coastal wetland losses from 1780 to 2000 were greater than or equal to 1% per decade in each region. The index is rated poor for the coastal wetland areas of the West Coast and Gulf of Mexico. It should be noted that the coastal habitat scores and ratings for the NCCR III are identical to those presented in the NCCR II due to a lack of available new data.
- **Fish Tissue Contaminants Index**—The fish tissue contaminants index for the nation's coastal waters is rated fair, with 18% of the stations where fish were caught rated poor for this index. The fish tissue contaminants index is rated good for the Gulf Coast and Southcentral Alaska regions, good to fair for the Southeast Coast region, fair for the Great Lakes region, and poor for the Northeast Coast and West Coast regions. Fish tissue contaminants data were unavailable for the coastal waters of Hawaii, Puerto Rico, Florida, and Louisiana.

Offshore Fisheries Data

The NMFS fisheries data were categorized by LME. LMEs are areas of ocean characterized by distinct bathymetry, hydrography, productivity, and trophic relationships. LMEs extend from river basins and estuaries to the seaward boundaries of continental shelves and the outer margins of major current systems. Within these waters, ocean pollution, fishery overexploitation, and coastal habitat alteration are most likely to occur. Sixty-four LMEs surround the continents and most large islands and island chains worldwide and produce 95% of the world's annual marine fishery yields; 10 of these LMEs are found in waters adjacent to the conterminous United States, Alaska, Hawaii, Puerto Rico, and U.S. island territories (Figure ES-3). Organizing the NMFS fisheries data by LME allows readers to more easily consider fishery and coastal condition data together. These data are more comparable using LMEs for several reasons. Geographically, LMEs contain both the coastal waters assessed by NCA and the U.S. Exclusive Economic Zone (EEZ)

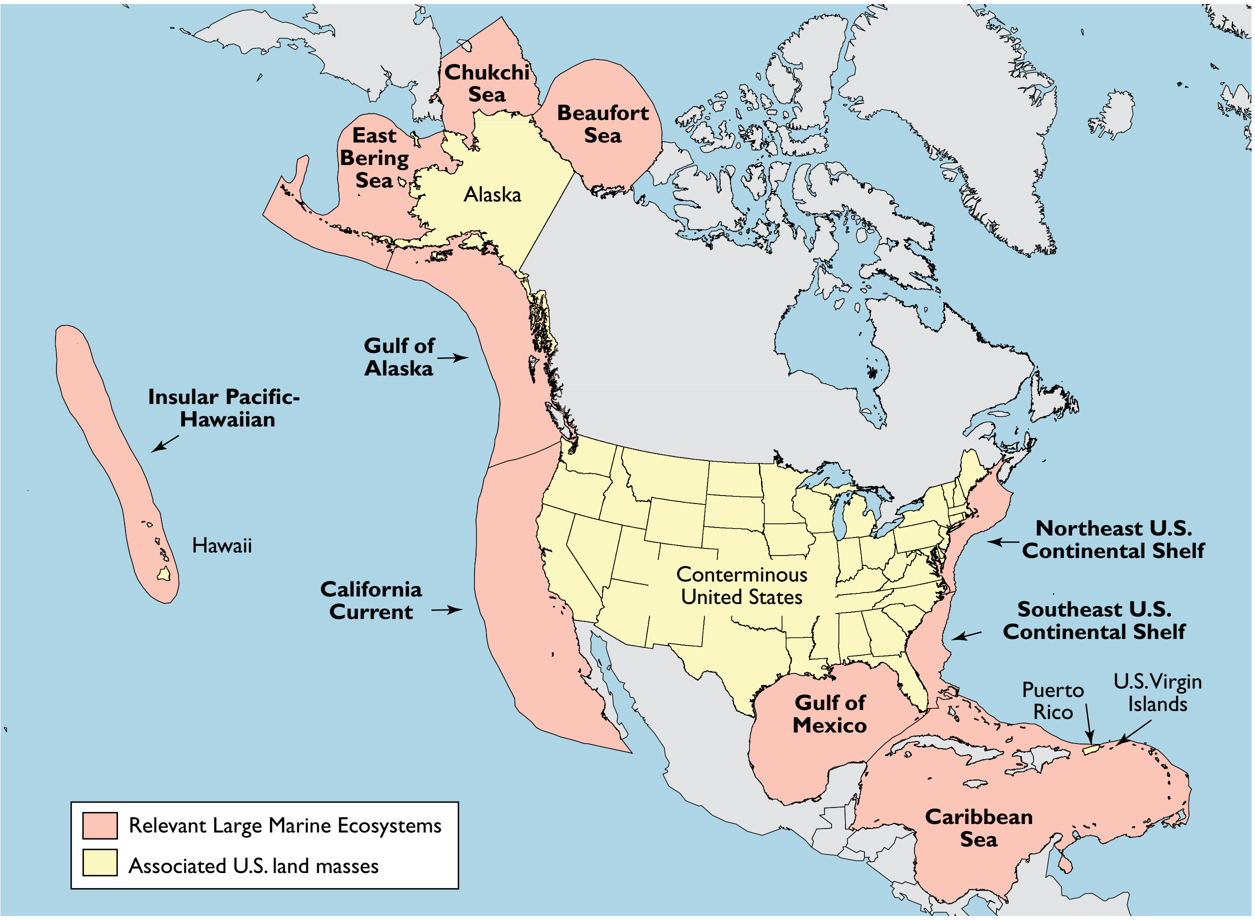


Figure ES-3. U.S. states and island territories are bordered by 10 LMEs (NOAA, 2007g).

waters containing the fisheries assessed by NMFS. In addition, the borders of the LMEs coincide roughly with the borders of the NCA regions.

This report presents offshore fisheries data by LME through 2004. The index period was limited to 2004 because this timeframe is more consistent with the coastal condition and advisory data presented in this report. This temporal consistency allows the reader to consider all three types of data together to get a clearer "snapshot" of conditions in U.S. coastal waters.

In 2004, NOAA's Office of Sustainable Fisheries reported on the status of 688 marine fish and shellfish stocks with respect to their overfished and overfishing condition. According to the Magnuson-Stevens Fishery Conservation and Management Act of 1996, a fishery is considered overfished if the stock size is below a minimum threshold, and overfishing is occurring if a stock's fishing mortality rate (rate of deaths due to fishing) is above a maximum level. These thresholds and levels are associated with maximum sustainable yield-based reference points and vary between individual stocks, stock complexes, and species of fish. Of the 200 fish stocks whose status with respect to overfished condition is known, 144 (72%) were not overfished and 56 (28%) stocks or stock complexes were overfished. The overfishing status of 236 stocks is known, of which 44 (19%) stocks or stock complexes have a fishing mortality rate that exceeds the overfishing threshold. The NMFS has approved rebuilding plans for the majority of overfished stocks. Five fishery management plan (FMP) amendments were approved in 2004 to implement final rebuilding plans for 23 stocks in the Northeast U.S. Continental Shelf, Southeast U.S. Continental Shelf, Gulf of Alaska, and East Bering Sea LMEs.

The number of stocks considered to be overfished has decreased from 92 in 2000 and 81 in 2001 to 56 in 2004. Some of the stocks whose status has changed are located in the Gulf of Alaska, California Current, Northeast U.S. Continental Shelf, and Gulf of Mexico LMEs. The Pacific whiting (a demersal or bottom-dwelling fish) stock of the Gulf of Alaska and California Current LMEs has been fully rebuilt, and overfishing is no longer occurring. Northeast U.S. Continental Shelf LME black sea bass stock is also no longer overfished. Three more stocks—lingcod, Pacific ocean perch (Gulf of Alaska and California Current LMEs), and king mackerel (Gulf of Mexico LME)—have increased in abundance to the point that they also are no longer overfished. Rebuilding measures for all these stocks will continue until each stock has been fully rebuilt to a level that provides the maximum sustainable yield.

Assessment and Advisory Data

States report water quality assessment information and water quality impairments under Section 305(b) of the CWA. States and tribes rate water quality by comparing measured values to their state and tribal water quality standards. The 305(b) assessment ratings (submitted by the states in 2002) are stored in EPA's National Assessment Database (NAD). These data are useful for evaluating the success of state water quality improvement efforts; however, it should be emphasized that each state monitors water quality parameters differently, so it is difficult to make generalized statements about the condition of the nation's coasts based on these data alone. Because the reporting of 2002 305(b) information was not complete for all coastal states and territories, it was decided that this information would not be summarized for inclusion in the NCCR III. In addition, 305(b) data are reported on a 2-year cycle, and there are no results for 2003. Therefore, only data from the EPA's National Listing of Fish Advisories (NLFA) database and the Beaches Environmental Assessment, Closure, and Health Program (BEACH) PRogram tracking, Beach Advisories, Water quality standards, and Nutrients (PRAWN) database are presented for calendar year 2003 in this report.

Flower Garden Banks is a National Marine Sanctuary (NMS) located in the Gulf of Mexico LME (courtesy of NOAA and the University of North Carolina at Wilmington).

According to the EPA's NLFA data for 2003, the number of coastal and estuarine waters under fish consumption advisories represent an estimated 77% of the coastal waters of the conterminous United States, including 81% of the coastal shoreline miles and 56% of the estuarine area along the Northeast Coast; 100% of the shoreline miles along the Southeast Coast; 100% of the shoreline miles and 23% of the estuarine area along the Gulf Coast; and 10% of the shoreline miles and 31% of the estuarine area along the West Coast (Figure ES-4). Every Great Lake is under at least one fish consumption advisory, and advisories cover 100% of the Great Lakes shoreline. Although advisories in U.S. estuarine and shoreline waters have been issued for a total of 23 individual chemical contaminants, most of the advisories issued resulted from four primary contaminants: PCBs; mercury; DDT and its degradation products, DDE and DDD; and dioxins and furans. These four chemical contaminants were responsible, at least in part, for 92% of all fish consumption advisories in effect for estuarine and coastal marine waters in 2003. These data are provided by states or other regulatory agencies and compiled in nationally maintained databases. The agencies contributing these data use different methodologies and criteria for assessment; therefore, the data cannot be used to make broad-based comparisons among the different coastal areas.

For the 2003 swimming season, EPA gathered information on 4,080 beaches monitored nationwide (both inland and coastal) through the use of a survey. The survey respondents were state and local government agencies from coastal counties, cities, or towns bordering the Atlantic Ocean, Gulf of Mexico, Pacific Ocean, and the Great Lakes, and included agencies in Hawaii, Puerto Rico, the U.S. Virgin Islands, Guam, and the Northern Mariana Islands.

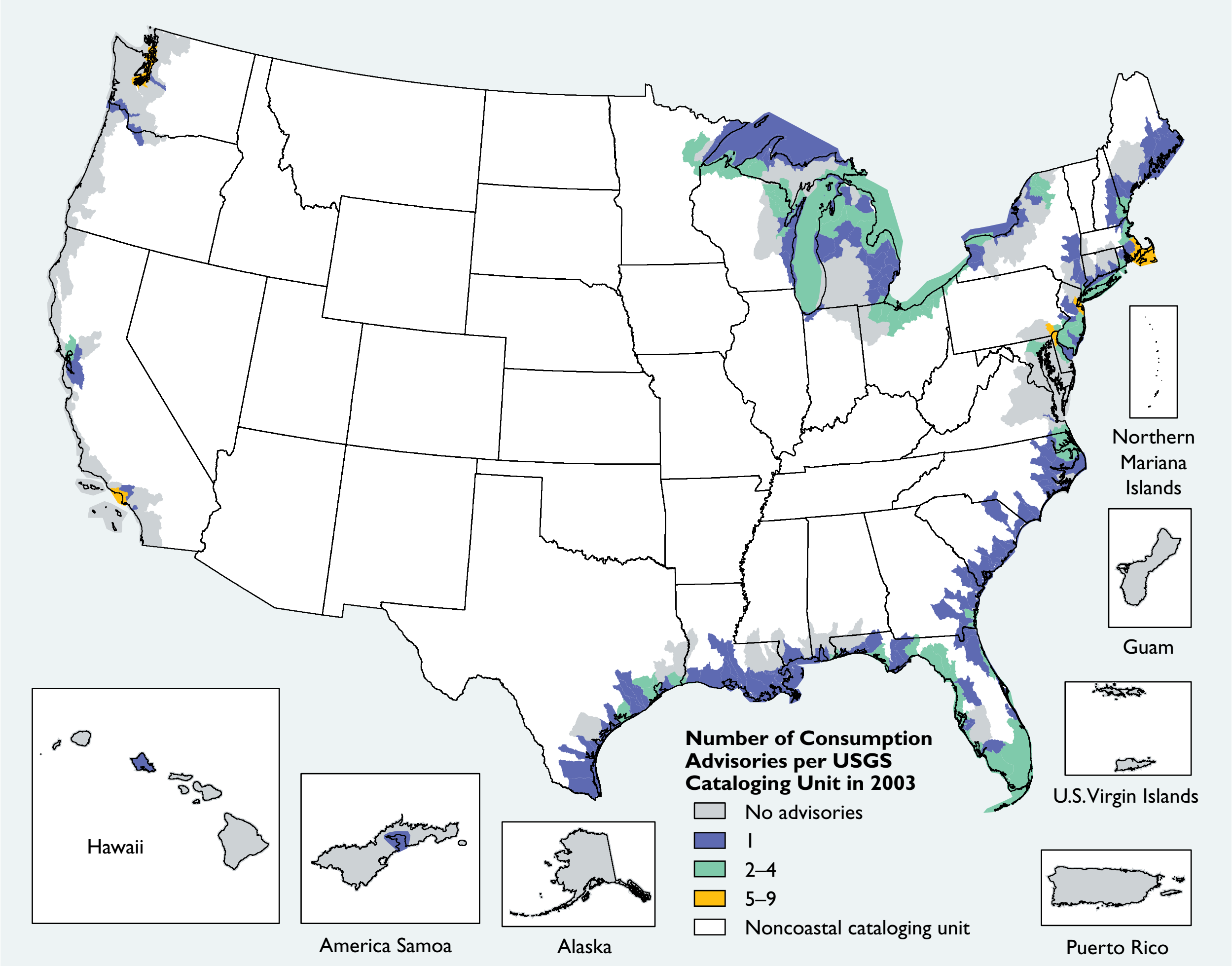


Figure ES-4. The number of fish consumption advisories active in 2003 for U.S. coastal waters (U.S. EPA, 2004b).

A few of these respondents were regional (multiple-county) districts. These respondents report the results of their local monitoring programs; therefore, the monitoring methods and closure criteria may vary between respondents. EPA's review of coastal beaches (U.S. coastal areas, estuaries, the Great Lakes, and the coastal areas of Hawaii and the U.S. territories) showed that, of the 4,080 beaches reported in the survey responses, 4,070 were marine or Great Lakes beaches. Of the coastal beaches monitored and reported, 839 (or 20.5%) had an advisory or closing in effect at least once during the 2003 swimming season (Figure ES-5). Beach advisories or closings were issued for a number of different reasons, including elevated bacterial levels in the water, preemptive reasons associated with rainfall events or sewage spills, and other reasons. Some of the major causes of public notifications for beach advisories and closures were stormwater runoff, wildlife, sewer line problems, and in many cases, unknown sources.

Beach advisories and closures are issued to protect people against contact with water potentially contaminated with pathogens (courtesy of Andrew D. Stahl).

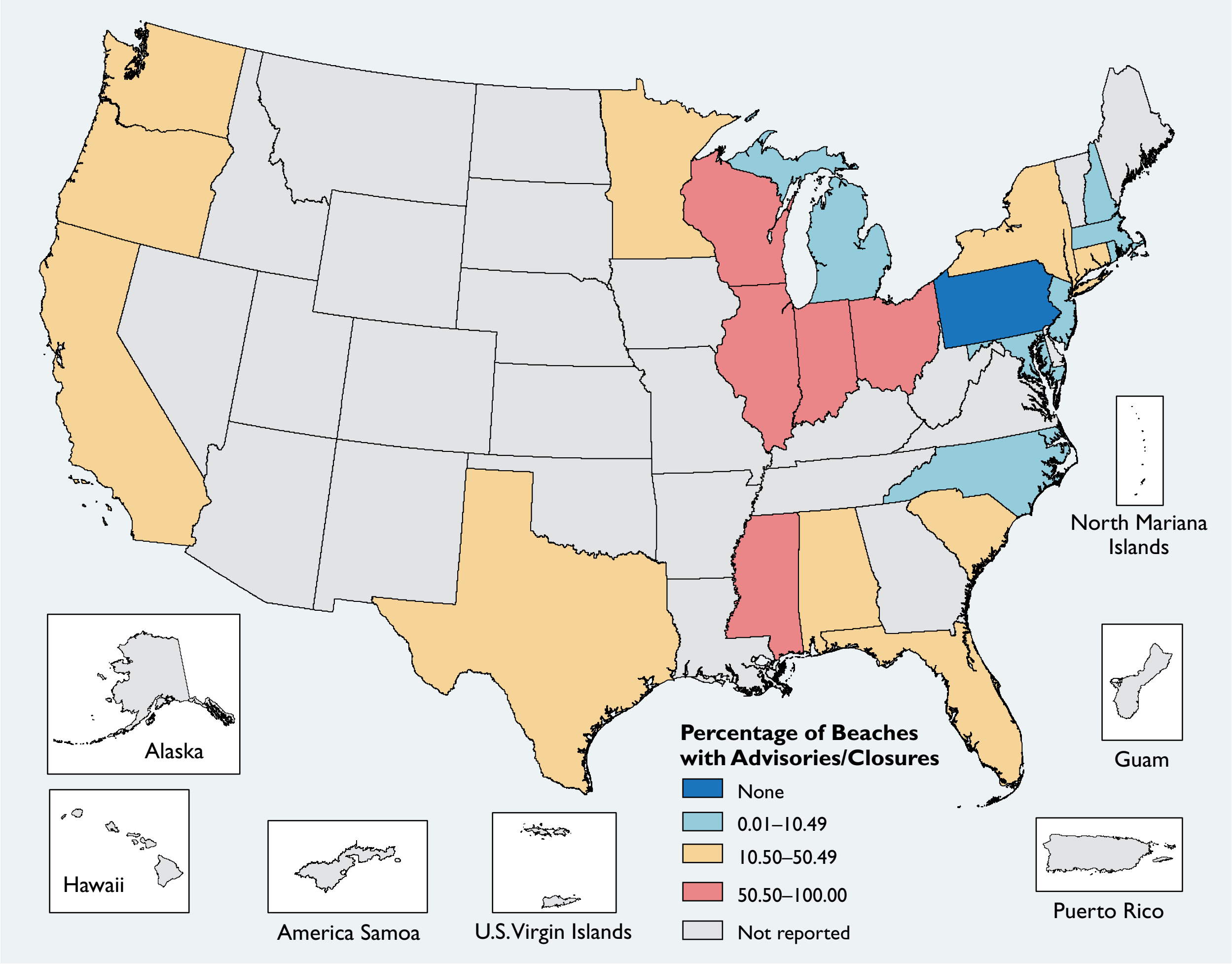


Figure ES-5. Percentages of beaches with advisories/closures by coastal state in 2003. Percentages are based on the number of beaches in each state that were reported, not the total number of beaches (U.S. EPA, 2006c).

Limitations of Available Data

This report focuses on coastal regions for which nationally consistent and comparable data are available. Such data are currently available for the conterminous 48 states, Southcentral Alaska, Hawaii, and Puerto Rico. Nearly 75% by area of all the coastal waters, including the bays, sounds, and estuaries in the United States, is located in Alaska, and no national report on coastal condition can be truly complete without information on the condition of living resources and use attainment of these waters. For this report, coastal monitoring data were only available for the southcentral region of Alaska. Other Alaskan regions will be assessed in future installments of the *National Coastal Condition Report* series. Coastal monitoring information has not been available for the U.S. Virgin Islands or the Pacific territories to support estimates of condition based on the indices used in this report. Although these latter systems make up only a small portion of the nation's coastal waters, they represent a set of estuarine subsystems (such as coral reefs and tropical bays) that are not located anywhere else in the United States, with the exception of the Florida Keys and the Flower Gardens off the Louisiana/Texas coast. These unique systems were surveyed in 2004 and will be included in future national coastal condition assessments.

This report makes the best use of available data to characterize and assess the condition of the nation's coastal resources; however, the report cannot represent all individual coastal and estuarine systems of the United States or all of the appropriate spatial scales (e.g., national, regional, and local) necessary to assess coastal condition. This assessment is based on a limited number of ecological indices and component indicators for which consistent data sets are available to support estimates of ecological condition on regional and national scales. Through a multi-agency and multi-state effort over the continuing decade, a truly consistent, comprehensive, and integrated national coastal monitoring program can be realized. Only through the cooperative interaction of the key federal agencies and coastal states will the next effort to gauge the health of the coastal ecosystems in the United States be successful.

Although most of the chapters in this report use ecological indicators to address the condition of coastal resources in each region, Chapter 9 addresses coastal condition in the context of how well coastal waters are meeting expectations for human use. Only one coastal waterbody, Narragansett Bay in Rhode Island and Massachusetts, was evaluated for human use expectations in this report. In the case of this estuary, it appears that human uses are being met; however, as with most other coastal waterbodies, there are limitations on some uses, such as public access to beaches, long-term changes in commercial fishing stocks, and fish consumption advisories.

Boating is one of the many ways people use Narragansett Bay (courtesy of Chris Deacutis).

Comparisons to Other National Coastal Condition Reports

A primary goal of the *National Coastal Condition Report* series is to provide a benchmark of coastal condition to measure the success of coastal programs over time. To achieve this end, the conditions reported in each report need to be comparable. For the first two reports (NCCR I and NCCR II), there was insufficient information to examine the potential trends in coastal condition that might be related to changes in environmental programs and policies. In the NCCR III, the information from 1990 through 2002 is evaluated for potential trends.

Comparing data between the NCCR I, NCCR II, and NCCR III is complicated because, in some cases, indices and component indicators were changed to improve the assessment. For example, in the NCCR I, three separate indicators (dissolved oxygen, water clarity, and eutrophication) were used for water quality, whereas a single water quality index (composed of five component indicators) was used in the NCCR II. In addition, reference conditions for some of the indices and component indicators were modified to reflect regional differences. In order to facilitate a comparison between the NCCR I and NCCR II, the values reported in the NCCR I Executive Summary were recalculated, to the extent possible, using the approaches followed in the NCCR II and NCCR III (Table ES-3). For additional information about how these values were recalculated, please refer to Appendix C of the NCCR II, which is available online at http//www.epa.gov/owow/oceans/nccr2.

Table ES-3. Rating Scores by Index[a] and Region Comparing the NCCR I, NCCR II, and NCCR III[b]

Region		Index					Overall Condition
		Water Quality	Sediment Quality	Coastal Habitat	Benthic	Fish Tissue Contaminants	
Gulf Coast	v1	1	3	1	1	3	**1.8**
	v2	3	3	1	2	3	**2.4**
	v3	3	1	1	1	5	**2.2**
Southeast Coast	v1	4	4	2	3	5	**3.6**
	v2	4	4	3	3	5	**3.8**
	v3	3	3	3	5	4	**3.6**
Northeast Coast	v1	1	2	3	1	2	**1.8**
	v2	2	1	4	1	1	**1.8**
	v3	3	2	4	1	1	**2.2**
Southcentral Alaska	v1	–	–	–	–	–	**–**
	v2	–	–	–	–	–	**–**
	v3	5	5	–	–	5	**5.0**[d]
Hawaii	v1	–	–	–	–	–	**–**
	v2	–	–	–	–	–	**–**
	v3	5	4	–	–	–	**4.5**[d]
West Coast[c]	v1	1	2	1	3	3	**2.0**
	v2	3	2	1	3	1	**2.0**
	v3	3	2	1	5	1	**2.4**
Great Lakes[c]	v1	1	1	1	1	3	**1.4**
	v2	3	1	2	2	3	**2.2**
	v3	3	1	2	2	3	**2.2**
Puerto Rico[c]	v1	–	–	–	–	–	**–**
	v2	3	1	–	1	–	**1.7**
	v3	3	1	–	1	–	**1.7**
United States[e]	v1	1.5	2.3	1.6	1.5	3.1	**2.0**
	v2	3.2	2.1	1.7	2.0	2.7	**2.3**
	v3[f]	3.3	1.6	1.7	2.1	2.9	**2.3**
	v3[g]	3.9	2.8	1.7	2.1	3.4	**2.8**

[a] Rating scores are based on a 5-point system, where a score of less than 2.0 is rated poor; 2.0 to less than 2.3 is rated fair to poor; greater than 2.3 to 3.7 is rated fair; greater than 3.7 to 4.0 is rated good to fair; and greater than 4.0 is rated good.

[b] AK and HI were not reported in the NCCR I or NCCR II. The NCCR I assessment of the Northeast Coast region did not include the Acadian Province. The West Coast ratings in the NCCR I were complied using data from many different programs.

[c] West Coast, Great Lakes, and Puerto Rico scores for the NCCR III are the same as NCCR II (no new data for the NCCR III except for the West Coast benthic index).

[d] Overall condition scores for Southcentral Alaska and Hawaii were based on 2–3 of the 5 NCA indices.

[e] U.S. score is based on an areally weighted mean of regional scores.

[f] U.S. score excluding Southcentral Alaska and Hawaii.

[g] U.S. score including Southcentral Alaska and Hawaii.

v1 = NCCR (adjusted scores from Table C-1 in NCCR II); v2 = NCCR II; v3 = NCCR III

Comparison of the overall condition scores presented in each report shows that the overall condition of U.S. coastal waters has improved slightly since the 1990s. Although the overall condition of U.S. coastal waters is rated fair to poor or fair in all three reports, the score increased from 2.0 in the NCCR I to 2.3 in the NCCR II and NCCR III (without Southcentral Alaska and Hawaii). With the addition of data for Southcentral Alaska and Hawaii, the score increased from 2.3 to 2.8 in the NCCR III. It should be noted that the overall condition scores for Southcentral Alaska and Hawaii are based on only 2 or 3 of the 5 NCA indices because data were not available for all indices (see Chapter 8 for more information). The water quality index score for U.S. coastal waters has improved substantially since the NCCR I, and smaller improvements in the sediment quality and benthic index scores were also noted during this time. The fish tissue contaminants and coastal habitat index scores have shown little or no improvement since the NCCR I. A more detailed comparison of the assessment results from the three reports appears in Chapter 2 of this report.

Future Efforts

NCA is continuing efforts to assess more U.S. coastal waters using common methods. The southeastern region of Alaska was surveyed in 2004, and assessment of the vast Aleutian Islands region of Alaska began in the summer of 2006, with field work completed in the summer of 2007. Puerto Rico, the U.S. Virgin Islands, Guam, and American Samoa were assessed in 2004–2005, and Hawaii was resurveyed in 2006. These results will be presented in the *National Coastal Condition Report IV* (NCCR IV). New ecological monitoring programs will permit a comprehensive and consistent assessment of all of the nation's coastal resources by 2008.

Icy Bay is located in the southeastern region of Alaska and was assessed for the NCA in 2004. The results of this assessment will be presented in the NCCR IV (courtesy of Captain Budd Christman, NOAA).

CHAPTER 1

Introduction

Courtesy of John Theilgard

Introduction

The *National Coastal Condition Report* series assesses the condition of the estuarine, Great Lakes, and coastal embayment waters (collectively referred to as "coastal waters" in this report) and offshore fisheries of the United States. The first *National Coastal Condition Report* (NCCR I; U.S. EPA, 2001c) assessed the condition of the nation's coasts using data collected from 1990 to 1996 that were provided by several existing coastal programs, including the U.S. Environmental Protection Agency's (EPA's) Environmental Monitoring and Assessment Program (EMAP), the U.S. Fish and Wildlife Service's (FWS's) National Wetlands Inventory (NWI), and the National Oceanic and Atmospheric Administration's (NOAA's) National Status & Trends (NS&T) Program. The second *National Coastal Condition Report* (NCCR II; U.S. EPA, 2004a) provided information similar to the information covered in the NCCR I, but contained more recent (1997–2000) data from these monitoring programs, as well as data from EPA's National Coastal Assessment (NCA) and NOAA's National Marine Fisheries Service (NMFS). The data provided by the NCA allowed for the development of coastal condition indicators for 100% of the coastal area of the conterminous 48 states and Puerto Rico.

This third *National Coastal Condition Report* (NCCR III) is a collaborative effort among EPA, NOAA, FWS, and the U.S. Geological Survey (USGS), in cooperation with other agencies representing states and tribes. The NCCR III continues the *National Coastal Condition Report* series by providing updated regional and national assessments of the condition of the nation's coastal waters, including the coastal waters of Hawaii and the southcentral portion of Alaska (henceforth referred to as Southcentral Alaska), based primarily on NCA data collected in 2001 and 2002. No new information was available for the regions of Puerto Rico or the Great Lakes; therefore, the chapters covering these regions represent summaries of the assessments presented in the NCCR II. The assessment of offshore fisheries provided in this report is based on long-term data collected since monitoring of the individual fisheries began. In addition, this report examines national and regional (Northeast, Southeast, and Gulf coasts) trends in coastal condition from the early 1990s to 2002.

NCA surveys of the nation's coastal waters have been conducted annually from 2000 to 2006. The results of surveys conducted after 2002 will be available in 2008 and will be presented in the fourth *National Coastal Condition Report* (NCCR IV) in 2011.

Purpose of This Report

The purpose of the NCCR III is to present a broad baseline picture of coastal condition for coastal waters across the United States for 2001 and 2002 and, where available, snapshots of the condition of fisheries in offshore waters. This report is written for the informed public, coastal managers, scientists, members of Congress, and other elected officials. English units are used in most of the report because these units are most familiar and best understood by the target audience in the United States. The NCCR III uses currently available data sets to discuss the condition of the nation's coastal waters and is not intended to be a comprehensive literature review of coastal information. Instead, this report uses NCA and other monitoring data on a variety of indicators to provide insight into current coastal condition. The NCCR III also examines national and regional trends in coastal condition from the early 1990s to 2002. The NCCR III will serve as a continuing benchmark for providing data to analyze the progress of coastal programs and will be followed in subsequent years by reports on more specialized coastal issues. This report will also serve as a reminder of the data gaps and other pitfalls that natural resource managers face and must try to overcome to make reliable assessments of how the condition of the nation's coastal resources may change with time.

In addition to the regional assessments provided in this report, the NCCR III includes special Highlight articles that describe several exemplary programs related to coastal condition at the federal, state, and local levels. The Highlight articles are intended to enhance the discussion of coastal condition as it is presented in the main body of the report text. These articles offer insight into other methods or indicators used to measure and assess coastal condition, programs used to improve coastal condition, and government programs developed in response to the coastal condition findings (including identified data limitations and areas found to be in poor condition). The Highlight articles are not intended to be comprehensive or exhaustive summaries of all coastal programs, but are presented to show that information about the health of coastal systems is being collected for decision making at the local, state, regional, and national levels.

The final chapter of this report (Chapter 9) explores the connections between the condition indicators and human uses of coastal areas. Although the type of assessment described in Chapter 9 cannot be conducted on scales larger than a single estuary, it is important to address coastal condition at several spatial scales (e.g., national, regional, state, and local). Chapter 9 also complements the national/regional approach by combining the site-specific information for a single estuary, Narragansett Bay, with the NCA results for this estuary to evaluate coastal condition.

Why Are Coastal Waters Important?

Coastal Waters Are Valuable and Productive Natural Ecosystems

Coastal waters include estuaries, coastal wetlands, seagrass meadows, coral reefs, intertidal zones, mangrove and kelp forests, and coastal ocean and upwelling areas. Critical coastal habitats provide spawning grounds, nurseries, shelter, and food for finfish, shellfish, birds, and other wildlife. The coasts also provide essential nesting, resting, feeding, and breeding habitat for 75% of U.S. waterfowl and other migratory birds (U.S. EPA, 1998b).

Estuaries are bodies of water that receive freshwater and sediment influx from rivers and tidal influx from the oceans, thus providing transition zones between the fresh water of a river and the saline environment of the sea. This interaction produces a unique environment that supports wildlife and fisheries and contributes substantially to the economy of coastal areas. Estuaries also supply water for industrial uses; lose water to freshwater diversions for drinking and irrigation; are the critical terminals of the nation's marine transportation system and the U.S. Navy; provide a point of discharge for municipalities and industries; and are the downstream recipient of nonpoint-source runoff.

Coastal wetlands are the interface between the aquatic and terrestrial components of estuarine systems. Wetland habitats are critical to the life cycles of fish, shellfish, migratory birds, and other wildlife and help improve surface water quality by filtering residential, agricultural, and industrial wastes. Wetlands also buffer coastal areas against storm and wave damage; however, because of their close interface with terrestrial systems, wetlands are vulnerable to land-based sources of pollutant discharges and other human activities.

Rocky intertidal zones provide habitat for a variety of species, including these sea stars in Kachemak Bay, AK (courtesy of NOAA).

Coastal Waters Have Many Human Uses

Coastal areas are the most developed areas in the United States. This narrow fringe of land—only 17% of the total conterminous U.S. land area—is home to more than 53% of the nation's population (Figure 1-1). The total coastal population between the years 1980 and 2003 increased by 33 million people (28%), which is roughly consistent with the nation's rate of increase; however, continued population growth in this limited coastal land area results in increased population density and pressure on coastal resources. The majority of the nation's most densely populated areas are located along the coast. In fact, 23 of the 25 most densely populated U.S. counties are coastal counties. The population density of U.S. coastal counties averages 300 persons/square mile (mi^2), much higher than the national average of 98 persons/mi^2 (Crossett et al., 2004).

In addition to being a popular place to live, the nation's coasts are of great recreational value. Beaches have become one of the most popular vacation destinations in the United States, with 180 million people visiting the nation's coasts each year (Cunningham and Walker, 1996). From 1999 to 2000, more than 43% of the U.S. population participated in marine recreational activities, including sport fishing, boating, swimming, and diving (Leeworthy and Wiley, 2001).

Human use of coastal areas also provides commercial services for the nation. The 425 U.S. coastal counties generate $1.3 trillion of the gross national product (GNP), and coastal and marine waters support more than 28 million jobs (Leeworthy, 2000; U.S. Senate, 2003). The annual landings total of U.S. commercial fisheries was 5 million metric tons (t) from 2001 through 2003, approximately 4.1% of the world's annual landings (NMFS, 2002; 2003; 2004). Roughly 35% of the nation's commercial landings are taken within 3 miles of shore (NMFS, 2004).

Why Be Concerned about Coastal Condition?

Because a disproportionate percentage of the nation's population reside in coastal areas, the activities of municipalities, commerce, industry,

Figure 1-1. Population distribution in the United States based on 2000 U.S. Census Bureau data (U.S. Census Bureau, 2001).

and tourism have created environmental pressures that threaten the very resources that make coastal living desirable. Population pressures include increased solid waste production; higher volumes of urban nonpoint-source runoff; loss of green space and wildlife habitat; declines in ambient water and sediment quality; and increased demands for wastewater treatment, irrigation and potable water, and energy supplies. Development pressures have resulted in substantial physical changes along many areas of the coastal zone. Coastal wetlands continue to be lost to residential and commercial development, and the quantity and timing of freshwater flow, which is critical to riverine and estuarine function, continue to be altered. In effect, the same human uses that are desired of coastal habitats also have the potential to lessen their value. This report not only discusses the indicators of coastal condition that gauge the extent to which coastal habitats and resources have been altered, but it also addresses connections between coastal condition and the ability of coastal areas to meet human expectations for their use.

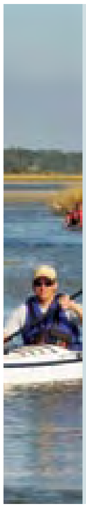
Assessment of Coastal Condition

Three sources of coastal information use nationally consistent data-collection designs and methods—EPA's NCA, NOAA's NS&T Program, and FWS's NWI. The NCA collects data from all coastal areas in the United States, except the Great Lakes region, and these data are representative of all coastal waters. The NS&T Program collects data from all coastal regions in the United States; however, the design of this survey does not permit extrapolation of the data to represent all coastal waters. The NWI provides estimates of wetland acreage (including coastal wetlands) by wetland type based on satellite reconnaissance of all U.S. states and territories.

This report examines several available data sets from different agencies and areas of the country and summarizes them to present a broad baseline picture of the condition of the nation's coastal waters. Three types of data are presented in this report:

- Coastal monitoring data from programs such as EPA's EMAP and NCA, NOAA's NS&T Program, and FWS's NWI, along with data from the Great Lakes National Program Office (GLNPO), have been analyzed for this report and were used to develop indices of coastal condition
- Fisheries data for Large Marine Ecosystems (LMEs) from NOAA's NMFS
- Assessment and advisory data provided by states or other regulatory agencies and compiled in national EPA databases.

This report presents available coastal monitoring information on a national scale for the 50 states and Puerto Rico; these data are then broken down and analyzed by geographic region in six chapters: Northeast Coast; Southeast Coast; Gulf Coast; West



Why Doesn't This Assessment Use More of the Available Data Sets?

Many other sets of monitoring data are available for estuarine and coastal areas around the United States; however, these data sets were not included in this report for several reasons. Most of these data sets were not collected using a probabilistic sampling design and, therefore, are not representative of the entire region covered by the sampling program. For example, the locations of the monitoring stations used to collect the data may have been selected to meet specific program goals, such as monitoring water quality near wastewater-discharge points. Also, these monitoring programs are conducted by different agencies or organizations and use various methods for data collection, analysis, and evaluation. The parameters and time frames monitored may also vary between monitoring programs. These types of monitoring programs often provide long-term data suitable for assessing program goals or coastal condition in the areas targeted by these efforts; however, it would be difficult to compare these data sets on a regional or national basis to assess coastal condition.

Coast; Great Lakes; and Alaska, Hawaii, and the Island Territories. In most cases, these geographic regions roughly coincide with the borders of the 10 LMEs surrounding U.S. states and island territories (Figure 1-2, Table 1-1). Assessment and advisory data for the regions are presented at the end of each chapter. Although inconsistencies in the way different state agencies collect and provide assessment and advisory data prevent the use of these data for comparing conditions between coastal areas, the information is valuable because it helps identify and illuminate some of the causes of coastal impairment, as well as the impacts of these impairments on human uses.

Table 1-1. Comparison of NCA's Reporting Regions and NOAA's LMEs

NCA Reporting Regions	NOAA LMEs
Northeast Coast	Northeast U.S. Continental Shelf LME
Southeast Coast	Southeast U.S. Continental Shelf LME
Gulf Coast	Gulf of Mexico LME
West Coast	California Current LME
Alaska	East Bering Sea LME, Gulf of Alaska LME, Chukchi Sea LME, Beaufort Sea LME
Hawaii	Insular Pacific-Hawaii LME
Puerto Rico	Caribbean Sea LME

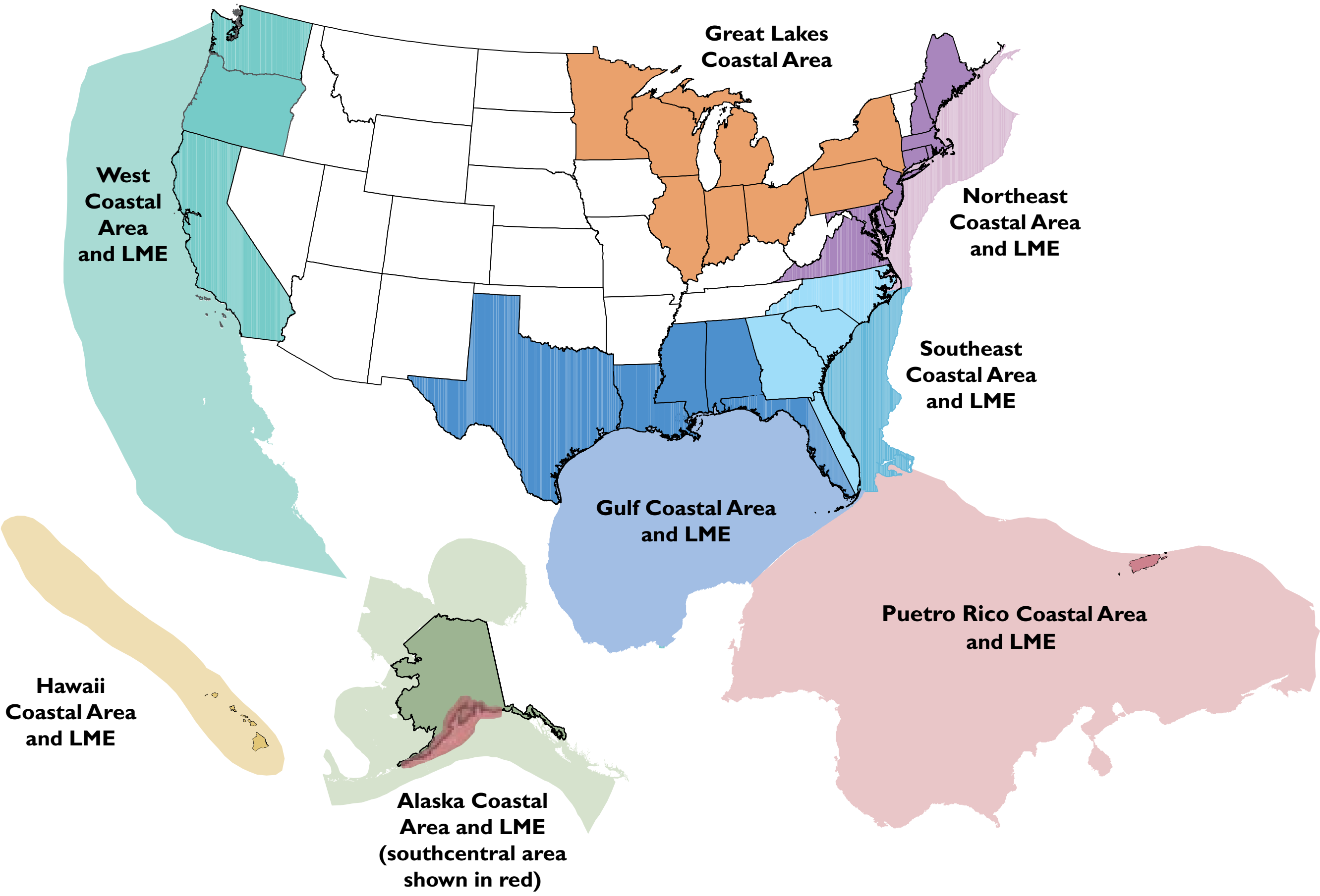
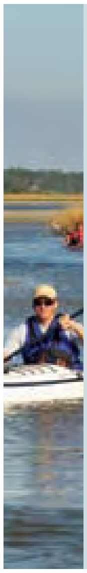


Figure 1-2. Coastal and Large Marine Ecosystem (LME) areas presented in the chapters of this report (U.S. EPA/NCA).



NCA Provides a "Snapshot" of Conditions in U.S. Coastal Waters

NCA uses a probabilistic sampling design to designate sampling-station locations and collects a single sample from each station on a single day in the summer of each year when sampling occurs. These samples are collected and analyzed in a consistent manner to create areal estimates of condition with a known level of uncertainty (see Appendix A), and the results can be compared across the United States to create a "snapshot" of coastal condition (U.S. EPA, 2001b).

Coastal Monitoring Data

A large percentage of the data used in this assessment of coastal condition comes from programs administered by EPA and NOAA. EPA's NCA provides representative data on biota (e.g., plankton, benthos, and fish) and potential environmental stressors (e.g., water quality, sediment quality, and tissue bioaccumulation) for all coastal states (except states in the Great Lakes region) and Puerto Rico (Diaz-Ramos et al., 1996; Summers et al., 1995; Olsen et al., 1999; U.S. EPA, 2007b). The NCA data are stored in the EMAP National Coastal Database, available online at http://www.epa.gov/emap/nca/html/data/index.html. NOAA's NS&T Program provides site-specific data on toxic contaminants and their ecological effects for all coastal regions and Puerto Rico. Coastal condition is also evaluated using data from the NWI, which provides information on the status of the nation's wetlands acreage.

Five primary indices of environmental condition were created using data available from these national coastal programs: a water quality index, sediment quality index, benthic index, coastal habitat index, and fish tissue contaminants index. The five indices were selected because of the availability of relatively consistent data sets for these parameters for most of the country. The indices do not address all of the coastal characteristics that are valued by society, but they do provide information on both the ecological condition and human use of coastal waters. Component indicators for the water quality index (dissolved inorganic nitrogen [DIN], dissolved inorganic phosphorus [DIP], chlorophyll *a*, water clarity, and dissolved oxygen) and the sediment quality index (sediment toxicity, sediment contaminants, and sediment total organic carbon [TOC]) are also assessed in this report.

Characterizing coastal areas using each of the five indices involves two steps. The first step is to assess condition at an individual monitoring site for each index and component indicator. The site condition rating criteria for each index and component indicator in each region are determined based on existing criteria, guidelines, interviews with EPA decision makers, feedback from state and local decision makers, and/or the interpretation of scientific literature. For example, dissolved oxygen conditions (a component indicator of the water quality index) are considered poor if the dissolved oxygen concentration measured at a site is less than 2 mg/L. This value is widely accepted as representative of hypoxic (low dissolved oxygen) conditions; therefore, this benchmark for poor condition is strongly supported by scientific evidence (Diaz and Rosenberg, 1995; U.S. EPA, 2000a). See Appendix A for additional information on how the rating criteria were determined.

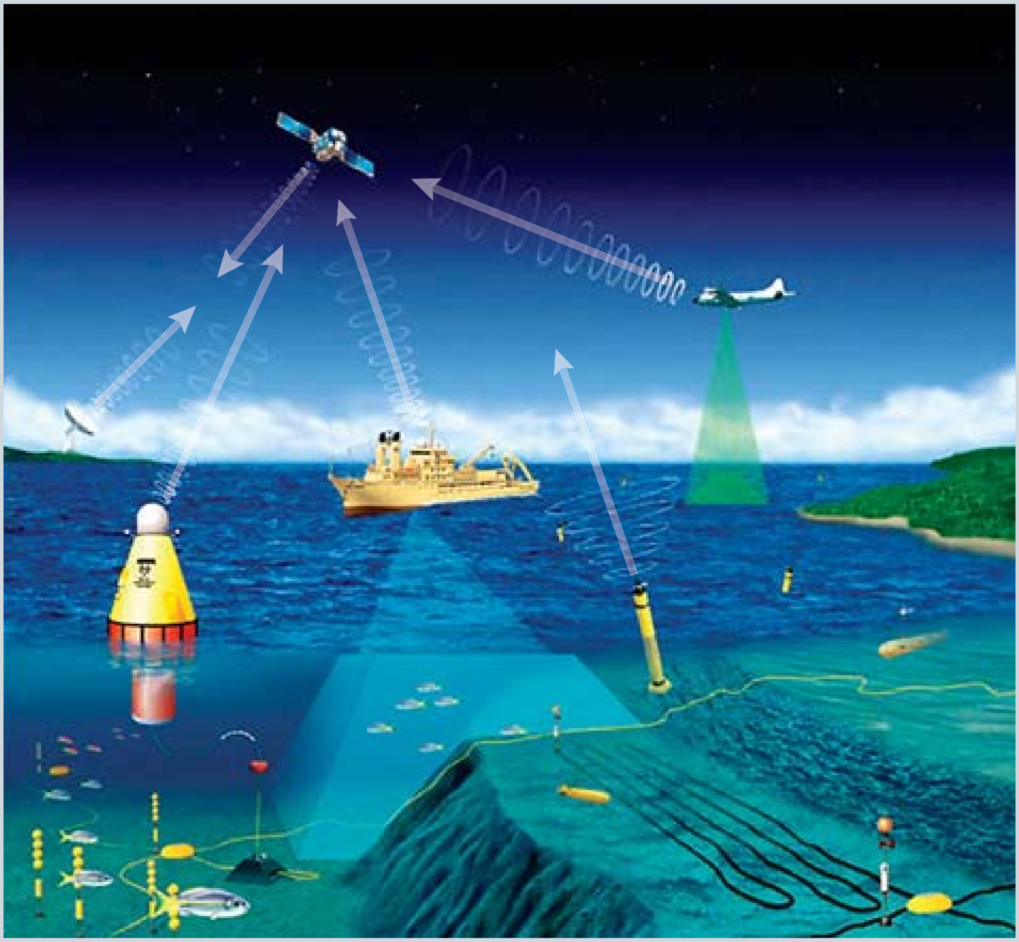
The second step is to assign a regional index rating based on the condition of the monitoring sites within the region. For example, for a region to be rated poor for the dissolved oxygen component indicator, sampling sites representing more than 15% of the coastal area in the region must have measured dissolved oxygen concentrations less than 2 mg/L and be rated poor. The regional criteria boundaries (i.e., percentages used to rate each index of coastal condition) were determined as a median of responses provided through a survey of environmental managers, resource experts, and the knowledgeable public. The following sections provide detailed descriptions of each index and component indicator, as well as the criteria for determining the regional ratings for the five indices as good, fair, or poor.

Highlight

U.S. Integrated Ocean Observing System

Today, many changes that profoundly affect our society are occurring in the oceans—from sea-level rise, hurricanes, and coastal flooding to the occurrence of harmful algal blooms (HABs), fish kills, declining fisheries, and environmental pollution. To address these problems, the U.S. Commission on Ocean Policy, the National Ocean Research Leadership Council, and the U.S. Ocean Action Plan (CEQ, 2004) have identified the development of the U.S. Integrated Ocean Observing System (IOOS) as a high priority. The IOOS will significantly improve the nation's ability to achieve the following goals:

- Improve predictions of weather and climate change and their effects on coastal communities and the nation



Data are collected at IOOS observation stations and transferred to the data management and communications subsystem (courtesy of Ocean.US).

- Improve the safety and efficiency of maritime operations
- More effectively mitigate the effects of natural hazards
- Improve national and homeland security
- Reduce public health risks
- More effectively protect and restore healthy coastal ecosystems
- Enable the sustained use of ocean and coastal resources.


Buoys are one type of observation platform used by IOOS (courtesy of Adrian Jones, IAN Network).

The IOOS will be a complex system that integrates several subsystems to meet these goals. These subsystems include observation, data management and communications (DMAC), and data modeling and analysis (Ocean.US, 2006). The IOOS observation subsystem will be a sustained network of buoys, satellites, ships, underwater vehicles, and other observation platforms that will routinely collect the data and information needed for rapid and timely detection of changes in our nation's estuaries, coastal waters, open ocean, and Great Lakes (Nowlin, 2001; Ocean.US, 2002). The DMAC subsystem will be composed of data systems, regional data centers, and archive centers that are connected by the Internet and use shared standards and protocols. The DMAC will integrate the coastal and global ocean components of the observation subsystem and serve as a link between the observation subsystem and the end users (Ocean.US, 2005a; 2005b). The data modeling and analysis subsystem will use real-time and historical data from the DMAC to evaluate and forecast the state of the marine environment (Ocean.US, 2005a).

The IOOS will be part of several larger systems that are used to assess the state of the environment worldwide. The IOOS is the U.S. contribution to the Global Ocean Observing System (GOOS) and will also serve as the estuarine-marine-Great Lakes component of the U.S. Integrated Earth Observation System (IEOS). IEOS includes ocean, terrestrial, atmospheric, and other observation systems and is the U.S. contribution to the Global Earth Observation System of Systems (GEOSS). The IOOS is a key contribution toward attaining the benefits of the GOOS, IEOS, and GEOSS.

The IOOS is currently under development. Under the oversight of the federal Interagency Working Group on Ocean Observations (IWGOO), the Ocean.US national office has generated and will continue to create various plans and documents for the development and implementation of the IOOS (Ocean.US, 2005a; 2006). Additional assistance is also being provided by the 11 U.S. IOOS Regional Associations that comprise the National Federation of Regional Associations (NFRA). Additional information about the IOOS, NFRA, and the Regional Associations' Regional Coastal Ocean Observing Systems may be found at Ocean.US's Web site at http://www.ocean.us or by contacting Brian Melzian (EPA/IWGOO) at melzian.brian@epa.gov.

Limitations of Available Data

Coastal surveys of Southcentral Alaska and Hawaii were completed in 2002, and assessments of these coastal waters are included in this report. These probabilistic surveys represented 20% of the Alaska's coastline and 100% of Hawaii's coastline (Sharma, 1979); however, NCA was unable to evaluate the benthic and coastal habitat indices for Southcentral Alaska and the benthic, coastal habitat, and fish tissue contaminants indices for Hawaii. Coastal condition in Alaska is difficult to assess because very little information is available for most of the state to support the type of analysis used in this report (i.e., spatial estimates of condition based on the indices and component indicators measured consistently across broad regions). Nearly 75% of the area of all the bays, sounds, and estuaries in the United States is located in Alaska, and no national report on coastal condition can be complete without information on the condition of the living resources and ecological health of these waters. Similarly, information to support estimates of condition based on the indices and component indicators used in this report is limited for Hawaii, the Pacific island territories (American Samoa, Northern Mariana Islands, and Guam), and the U.S. Virgin Islands. Although these latter systems make up only a small portion of the nation's coastal area, they represent a unique set of coastal subsystems (such as coral reefs and tropical bays) that are not located anywhere else in the United States, except for the Florida Keys and the Flower Gardens off the Texas/Louisiana coast. A survey of Puerto Rico's coastal condition was completed in 2000 and reported in the NCCR II. No new information has been collected for Puerto Rico since the NCCR II was published; therefore, a summary of that report's assessment is included in this NCCR III.

In order to attain consistent reporting for all the coastal ecosystems of the United States, fiscal and intellectual resources need to be invested in the creation of a national coastal monitoring program. The conceptual framework for such a program is outlined in the National Coastal Research and Monitoring Strategy (http://www.epa.gov/owow/oceans/nccr/H2Ofin.pdf), which calls for a national program that is organized at the state level and carried out by a partnership between federal departments and agencies (e.g., EPA, NOAA, the U.S. Department of the Interior [DOI], and the U.S. Department of Agriculture [USDA]), state natural resource and environmental agencies, academia, and industry. Such a monitoring program would provide the capability to measure, understand, analyze, and forecast ecological change at national, regional, and local scales. A first step in the development of this type of program was the initiation of EPA's NCA, a national coastal monitoring program organized and executed at the state level; however, the NCA is merely a starting point for developing a comprehensive national coastal monitoring program that can offer a coastal assessment of the entire nation at all appropriate spatial scales. The developers of the assessment continue to incorporate the new research findings and work with decision makers and coastal experts to improve the assessment methods and criteria. The NCA currently supports rigorous quality assurance (QA) and training programs for state, federal, and other partners collecting and analyzing the data to ensure consistency in the collection and analytical methods and to minimize discrepancies and other sources of error (see Appendix A). The NCA is designed to minimize spatial variability in national and regional estimates of coastal condition; however, the sampling index period does not address temporal

Bamboo coral provides refuge, settlement substrate, and feeding perches for crabs and larval fish on seamounts, such as this one in the Gulf of Alaska LME (courtesy of NOAA).

variability. One approach for examining coastal data at a more local spatial scale (an individual estuarine system) is presented in the assessment of Narragansett Bay provided in Chapter 9.

Indices Used to Measure Coastal Condition

Water Quality Index

The water quality index is based on measurements of five component indicators: DIN, DIP, chlorophyll *a*, water clarity, and dissolved oxygen. Some nutrient inputs to coastal waters (such as DIN and DIP) are necessary for a healthy, functioning estuarine ecosystem; however, when nutrients from various sources, such as sewage and fertilizers, are introduced into an estuary, their concentrations can increase above natural background levels. This increase in the rate of supply of organic matter is called eutrophication and may result in a host of undesirable water quality conditions (Figure 1-3), including excess plant production (phytoplankton or algae) and increased chlorophyll *a* concentrations, which can decrease water clarity and lower concentrations of dissolved oxygen.

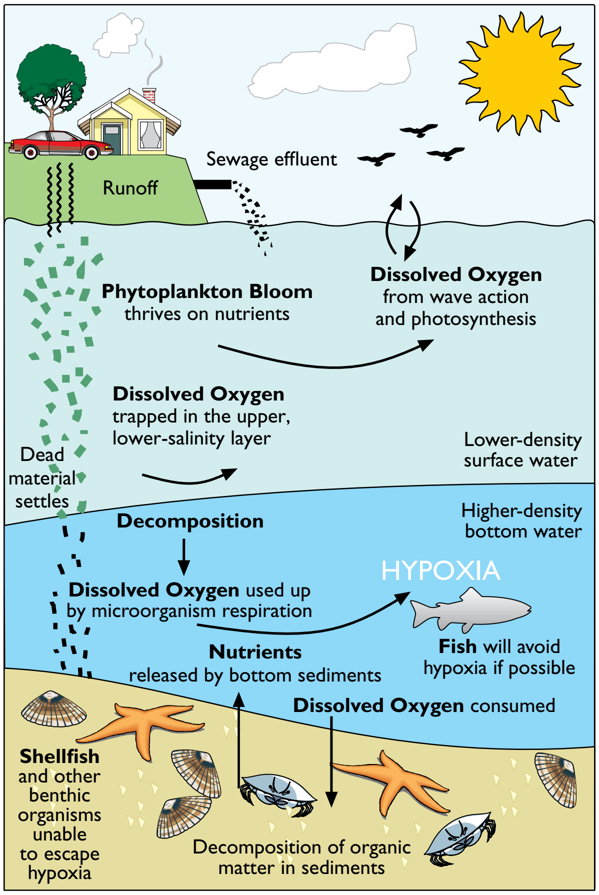


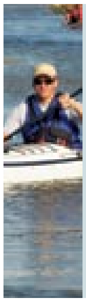
Figure 1-3. Eutrophication can occur when the concentration of available nutrients increases above normal levels (U.S. EPA/NCA).

The water quality index used in this report is intended to characterize acutely degraded water quality conditions and does not consistently identify sites experiencing occasional or infrequent hypoxia (low dissolved oxygen conditions), nutrient enrichment, or decreased water clarity. As a result, a rating of poor for the water quality index means that the site is likely to have consistently poor condition during the monitoring period. If a site is designated as fair or good, the site did not experience poor condition on the date sampled, but could be characterized by poor condition for short time periods. Increased or supplemental sampling would be needed to assess the level of variability in the index at a specific site.

Nutrients: Nitrogen and Phosphorus

Nitrogen and phosphorus are necessary and natural nutrients required for the growth of phytoplankton, the primary producers that form the base of the food web in coastal waters; however, excessive levels of nitrogen and phosphorus can result in large, undesirable phytoplankton blooms. DIN is the nutrient type most responsible for eutrophication in open estuarine and marine waters, whereas DIP is more likely to promote algal growth in the tidal-fresh water parts of estuaries.

NCA data were only available for the dissolved inorganic forms of nitrogen and phosphorus (i.e., DIN and DIP), which were determined chemically through the collection of filtered surface water at each site. DIN and DIP represent the portion of the total nitrogen and phosphorus pool in estuarine and coastal waters that remains once these nutrients have been assimilated by phytoplankton, benthic microalgae, or higher aquatic plants. Although DIN and DIP alone are not adequate indicators of the trophic state or water quality of coastal waters, susceptibility to eutrophication may be indicated when high concentrations of DIN and DIP are observed along with high chlorophyll levels, 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 in late summer. Data were not collected during other time periods.

water clarity, or hypoxia. This report also differs from results provided in the NOAA report because the nutrient assessment for the NCA surveys is based only on summer concentrations, rather than the annual average concentrations used by NOAA. Due to phytoplankton uptake and growth, nutrient concentrations in summer are generally expected to be lower than at other times of the year for most of the country (however, on the West Coast, Pacific upwelling events in summer often produce the year's highest nutrient concentrations). As a result, the DIN and DIP reference surface concentrations used to assess coastal condition in this report are generally lower than those in the NOAA report. Coastal monitoring sites were rated good, fair, or poor for DIN and DIP using the criteria shown in Tables 1-2 and 1-3. The site ratings were then used to calculate an overall rating for each region.

Chlorophyll a

One of the symptoms of degraded water quality condition is the increase of phytoplankton biomass as measured by the concentration of chlorophyll *a*. Chlorophyll *a* is a measure used to indicate the amount of microscopic algae (or phytoplankton) growing in a waterbody. High concentrations of chlorophyll *a* indicate the potential for problems related to the overproduction of algae. For this report, surface concentrations of chlorophyll *a* were determined from a filtered portion of water collected at each site. Surface chlorophyll *a* concentrations at a site were rated good, fair, or poor using the criteria shown in Table 1-4. The site ratings were then used to calculate an overall chlorophyll *a* rating for each region.

Water Clarity

Clear waters are generally valued by society for aesthetics and recreation. Water clarity in coastal waters is important for light penetration to support submerged aquatic vegetation (SAV), which serves as food and habitat for the resident biota. Water clarity is affected by physical factors such as wind and/or other forces that suspend sediments and particulate matter in the water; by chemical factors that influence the amount of dissolved organics

Table 1-2. Criteria for Assessing Dissolved Inorganic Nitrogen (DIN)

Area	Good	Fair	Poor
Northeast, Southeast, and Gulf Coast sites	< 0.1 mg/L	0.1–0.5 mg/L	> 0.5 mg/L
West Coast and Alaska sites	< 0.5 mg/L	0.5–1.0 mg/L	> 1 mg/L
Hawaii, Puerto Rico, and Florida Bay sites	< 0.05 mg/L	0.05–0.1 mg/L	> 0.1 mg/L
Regions	Less than 10% of the coastal area is in poor condition, and more than 50% of the coastal area is in good condition.	10% to 25% of the coastal area is in poor condition, or more than 50% of the coastal area is in combined poor and fair condition.	More than 25% of the coastal area is in poor condition.

Table 1-3. Criteria for Assessing Dissolved Inorganic Phosphorus (DIP)

Area	Good	Fair	Poor
Northeast, Southeast, and Gulf Coast sites	< 0.01 mg/L	0.01–0.05 mg/L	> 0.05 mg/L
West Coast and Alaska sites	< 0.01 mg/L	0.01–0.1 mg/L	> 0.1 mg/L
Hawaii, Puerto Rico, and Florida Bay sites	< 0.005 mg/L	0.005–0.01 mg/L	> 0.01 mg/L
Regions	Less than 10% of the coastal area is in poor condition, and more than 50% of the coastal area is in good condition.	10% to 25% of the coastal area is in poor condition, or more than 50% of the coastal area is in combined poor and fair condition.	More than 25% of the coastal area is in poor condition.

measured as color; and by phytoplankton levels in a waterbody. The naturally turbid waters of estuaries, however, can also be valuable to society. Turbid waters can support healthy and productive ecosystems by supplying building materials for maintaining estuarine structures (e.g., coastal wetlands) and providing food and protection to resident organisms; however, turbid waters can be harmful to coastal ecosystems if sediment loads bury benthic communities, inhibit filter feeders, or block light needed by seagrasses.

NCA estimates water clarity using specialized equipment that compares the amount and type of light reaching the water surface to the light at a depth of 1 meter, as well as by using a Secchi disk. Local variability in water clarity occurs between the different regions within an estuary, as well as at a single location in an estuary due to tides, storm events, wind mixing, and changes in incident light. The probabilistic nature of the NCA study design accounts for this local variability when the results are assessed on larger regional or national scales. Water clarity also varies naturally among various parts of the nation; therefore, the water clarity indicator is based on a ratio of observed clarity compared to regional reference conditions at 1 meter. The regional reference conditions were determined by examining available data for each of the U.S. regions (Smith et al., 2006). Reference conditions for a site rated poor were set at 10% of incident light available at a depth of 1 meter for normally turbid locations (most of the United States), 5% for locations with naturally high turbidity (Alabama, Louisiana, Mississippi, South Carolina, Georgia, and Delaware Bay), and 20% for regions of the country with significant SAV beds or active programs for SAV restoration (Laguna Madre, the Big Bend region of Florida, the region from Tampa Bay to Florida Bay, the Indian River Lagoon, and portions of Chesapeake Bay). Table 1-5 summarizes the rating criteria for water clarity for each monitoring station and for the regions.

Dissolved Oxygen

Dissolved oxygen is necessary for all aquatic life. Often, low dissolved oxygen conditions occur as a result of large algal blooms that sink to the bottom, where bacteria use oxygen as they degrade the algal mass. In addition, low dissolved oxygen conditions can be the result of stratification due to strong, freshwater river discharge on the surface,

Table 1-4. Criteria for Assessing Chlorophyll *a*

Area	Good	Fair	Poor
Northeast, Southeast, Gulf, and West Coast sites	< 5 µg/L	5–20 µg/L	> 20 µg/L
Hawaii, Puerto Rico, and Florida Bay sites	< 0.5 µg/L	0.5–1 µg/L	> 1 µg/L
Regions	Less than 10% of the coastal area is in poor condition, and more than 50% of the coastal area is in good condition.	10% to 20% of the coastal area is in poor condition, or more than 50% of the coastal area is in combined poor and fair condition.	More than 20% of the coastal area is in poor condition.

Table 1-5. Criteria for Assessing Water Clarity

Area	Good	Fair	Poor
Sites in coastal waters with naturally high turbidity	> 10% light at 1 meter	5–10% light at 1 meter	< 5% light at 1 meter
Sites in coastal waters with normal turbidity	> 20% light at 1 meter	10–20% light at 1 meter	< 10% light at 1 meter
Sites in coastal waters that support SAV	> 40% light at 1 meter	20–40% light at 1 meter	< 20% light at 1 meter
Regions	Less than 10% of the coastal area is in poor condition, and more than 50% of the coastal area is in good condition.	10% to 25% of the coastal area is in poor condition, or more than 50% of the coastal area is in combined poor and fair condition.	More than 25% of the coastal area is in poor condition.

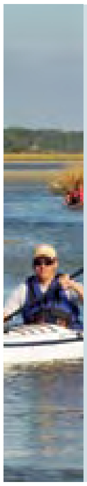
which overrides the heavier, saltier bottom water of a coastal waterbody. Many states use a dissolved oxygen threshold average concentration of 4 to 5 mg/L to set their coastal water quality standards, and concentrations below 2 mg/L are thought to be stressful to many organisms (Diaz and Rosenberg, 1995; U.S. EPA, 2000a). These low levels (hypoxia) or a lack of oxygen (anoxia) most often occur in bottom waters and affect the organisms that live in the sediments. Hypoxia frequently accompanies the onset of severe bacterial degradation, sometimes resulting in the presence of algal scums and noxious odors; however, in some coastal waters, low dissolved oxygen levels occur periodically or may be a part of the waterbody's natural ecology. Therefore, although it is easy to show a snapshot of the dissolved oxygen conditions in the nation's coastal waters, it is difficult to interpret whether any poor conditions in this snapshot are representative of eutrophication or the result of natural physical processes. In addition, the snapshot may not be representative of all summertime periods, such as variable daily conditions (see text box). Unless otherwise noted, the dissolved oxygen data presented in this report were collected by NCA at a depth of 1 meter above the sediment at each station on only one day during the year. Dissolved oxygen concentrations at individual monitoring sites and over regions were rated good, fair, or poor using the criteria shown in Table 1-6.

Table 1-6. Criteria for Assessing Dissolved Oxygen

Area	Good	Fair	Poor
Individual sampling sites	> 5 mg/L	2–5 mg/L	< 2 mg/L
Regions	Less than 5% of the coastal area is in poor condition, and more than 50% of the coastal area is in good condition.	5% to 15% of the coastal area is in poor condition, or more than 50% of the coastal area is in combined poor and fair condition.	More than 15% of the coastal area is in poor condition.

Calculating the Water Quality Index

Once DIN, DIP, chlorophyll *a*, water clarity, and dissolved oxygen were assessed for a given site, the water quality index rating was calculated for the site based on these five component indicators. The index was rated good, fair, poor, or missing using the criteria shown in Table 1-7. A water quality index was then calculated for each region using the criteria shown in Table 1-8.



Temporal variations in dissolved oxygen depletion can have adverse biological effects (Coiro et al., 2000). Stressful hypoxia may occur for a few hours before dawn in productive surface waters, when respiration depletes dissolved oxygen faster than it is replenished. The NCA does not measure these events because most samples are collected later in the day. The NCA estimates do not apply to dystrophic systems, in which dissolved oxygen levels are acceptable during daylight hours, but decrease to low (even unacceptable) levels during the night. Many of these systems and the biota associated with them are adapted to this cycle—a natural process of oxygen production during the day and respiration at night—which is common in wetland, swamp, and blackwater ecosystems. NCA sampling does not address the duration of hypoxic events because each station is sampled on only one day during the summer. In addition, year-to-year variations in estuarine dissolved oxygen levels can be substantial as a result of a variety of factors, including variations in freshwater inflow, factors affecting water-column stratification, and changes in nutrient delivery.

Table 1-7. Criteria for Determining the Water Quality Index Rating by Site

Rating		Criteria
Good	🟩	A maximum of one indicator is rated fair, and no indicators are rated poor.
Fair	🟨	One of the indicators is rated poor, or two or more indicators are rated fair.
Poor	🟥	Two or more of the five indicators are rated poor.
Missing	🟦	Two component indicators are missing, and the available indicators do not suggest a fair or poor rating.

Table 1-8. Criteria for Determining the Water Quality Index Rating by Region

Rating		Criteria
Good	🟩	Less than 10% of the coastal area is in poor condition, and more than 50% of the coastal area is in good condition.
Fair	🟨	10% to 20% of the coastal area is in poor condition, or more than 50% of the coastal area is in combined fair and poor condition.
Poor	🟥	More than 20% of the coastal area is in poor condition.

Tide pool in southern California (courtesy of Brad Ashbaugh).

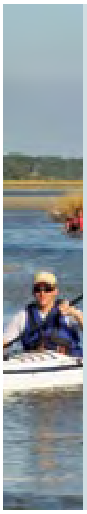
Sediment Quality Index

Another issue of major environmental concern in coastal waters is the contamination of sediments with toxic chemicals. A wide variety of metals and organic substances, such as polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), and pesticides, are discharged into coastal waters from urban, agricultural, and industrial sources in a watershed. These contaminants adsorb onto suspended particles and eventually accumulate in depositional basins, where they can disrupt the benthic community of invertebrates, shellfish, and crustaceans that live in or on the sediments. To the extent that the contaminants become concentrated in the organisms, they pose a risk to organisms throughout the food web—including humans.

Several factors influence the extent and severity of contamination. Fine-grained, organic-rich sediments are likely to become resuspended and transported to distant locations and are also efficient at scavenging pollutants. Thus, silty sediments high in TOC are potential sources of contamination. Conversely, organic-rich particles bind some toxicants so strongly that the threat to organisms can be greatly reduced. The NCA collected sediment samples, measured the concentrations of chemical constituents and percent TOC in the sediments, and evaluated sediment toxicity by measuring the survival of the marine amphipod *Ampelisca abdita* following a 10-day exposure to the sediments under laboratory conditions. The results of these evaluations may be used to identify the most-polluted areas and provide clues regarding the sources of contamination.

The physical and chemical characteristics of surface sediments are the result of interacting forces controlling chemical input and particle dynamics at any particular site. When assessing coastal condition, researchers measure the potential for sediments to affect bottom-dwelling organisms. The sediment quality index is based on measurements of three component indicators of sediment condition: sediment toxicity, sediment contaminants, and sediment TOC.

Some researchers and managers would prefer that the sediment triad (sediment chemistry, sediment toxicity, and benthic communities) be used to assess sediment condition (poor condition would require all three elements to be poor), or that poor sediment condition be determined based on the joint occurrence of elevated sediment contaminant concentrations and high sediment toxicity (see text box, *Alternative Views for a Sediment Quality Index*). However, benthic community attributes are included in this assessment of coastal condition as an independent variable rather than as a component of sediment quality.

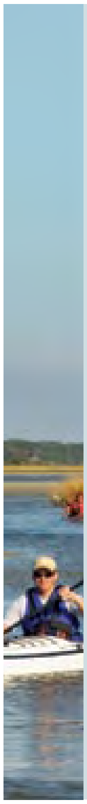


Guidelines for Assessing Sediment Contamination (Long et al., 1995)

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.

In this report, the focus of the sediment quality index is on sediment condition, not just sediment toxicity. Attributes of sediments other than toxicity can result in unacceptable changes in biotic communities. For example, organic enrichment through wastewater disposal can have an undesired effect on biota, and elevated contaminant levels can have undesirable ecological effects (e.g., changes in benthic community structure) that are not directly related to acute toxicity (as measured by the *Ampelisca* test). For these reasons, the sediment quality index in this report uses the combination of sediment toxicity, sediment contaminants, and sediment TOC to assess sediment condition. Sediment condition is assessed as poor (i.e., high potential for exposure effects on biota) at a site if any one of the component indicators is categorized as poor; assessed as fair if the sediment contaminants indicator is rated fair; and assessed as good if all three component indicators are at levels that would be unlikely to result in adverse biological effects due to sediment quality.



Alternative Views for a Sediment Quality Index

Some resource managers object to using ERM and ERL values to calculate the sediment quality index because the index is also based on actual measurements of toxicity. Because ERMs are defined as the concentration at which 50% of samples will exhibit toxicity, these managers believe that the same weight should not be given to a non-toxic sample with an ERM exceedance as is given to a sample that is actually toxic. O'Connor et al. (1998), using a 1,508-sample EPA and NOAA database, found that 38% of ERM exceedances coincided with amphipod toxicity (i.e., were toxic), 13% of the ERL exceedances (no ERM exceedance) were toxic; and only 5% of the samples that did not exceed ERL values were toxic. O'Connor and Paul (2000) expanded the 1,508-sample data set to 2,475 samples, and the results remained relatively unchanged (41% of the ERM exceedances were toxic, and only 5% of the non-exceedances were toxic). In a database generated in the EPA National Sediment Quality Survey (U.S. EPA, 2001d), 2,761 samples were evaluated with matching sediment chemistry and 10-day amphipod toxicity. Of the 762 samples with at least one ERM exceedance, 48% were toxic, and of the 919 samples without any ERLs exceedances, only 8% were toxic (Ingersoll et al., 2005). These data also showed a consistent pattern of increasing incidence of toxicity as the numbers of ERMs that were exceeded increased. Although, these analyses are consistent with the narrative intent of ERMs to indicate an incidence of toxicity of about 50% and ERLs to indicate an incidence of toxicity of about 10%, some researchers and managers believe that the sediment quality index used in this report should not result in a poor rating if sediment contaminant criteria are exceeded, but the sediment is not shown to be toxic in bioassays.

Sediment Toxicity

Researchers applied a standard direct test of toxicity at thousands of sites to measure the survival of amphipods (commonly found, shrimp-like benthic crustaceans) exposed to sediments for 10 days under laboratory conditions (U.S. EPA, 1995a). As in all tests of toxicity, survival was measured relative to that of amphipods exposed to uncontaminated reference sediment. The criteria for rating sediment toxicity based on amphipod survival for each sampling site are shown in Table 1-9. Table 1-10 shows how these site data were used to evaluate sediment toxicity by region. It should be noted that for this component indicator, unlike the others outlined in this report, only a good or poor rating is possible—there is no fair rating.

Table 1-9. Criteria for Assessing Sediment Toxicity by Site

Rating		Criteria
Good	🟩	The amphipod survival rate is greater than or equal to 80%.
Poor	🟥	The amphipod survival rate is less than 80%.

Table 1-10. Criteria for Assessing Sediment Toxicity by Region

Rating		Criteria
Good	🟩	Less than 5% of the coastal area is in poor condition.
Poor	🟥	5% or more of the coastal area is in poor condition.

Sediment Contaminants

There are no absolute chemical concentrations that correspond to sediment toxicity, but ERL and ERM values (Long et al., 1995) are used as guidelines in assessing sediment contamination (Table 1-11). ERM is the median concentration (50th percentile) of a contaminant observed to have adverse biological effects in the literature studies examined. A more protective indicator of contaminant concentration is the ERL criterion, which is the 10th percentile concentration of a contaminant represented by studies demonstrating adverse biological effects in the literature. Ecological effects are not likely to occur at contaminant concentrations below the ERL criterion. The criteria for rating sediment contaminants at individual sampling sites are shown in Table 1-12, and Table 1-13 shows how these data were used to create regional ratings for the sediment contaminants component indicator.

Table 1-11. ERM and ERL Guidelines for Sediment (Long et al., 1995)

Metal*	ERL	ERM
Arsenic	8.2	70
Cadmium	1.2	9.6
Chromium	81	370
Copper	34	270
Lead	46.7	218
Mercury	0.15	0.71
Nickel	20.9	51.6
Silver	1	3.7
Zinc	150	410
Analyte**	**ERL**	**ERM**
Acenaphthene	16	500
Acenaphthylene	44	640
Anthracene	85.3	1,100
Flourene	19	540
2-Methylnaphthalene	70	670
Naphthalene	160	2,100
Phenanthrene	240	1,500
Benz(a)anthracene	261	1,600
Benzo(a)pyrene	430	1,600
Chrysene	384	2,800
Dibenzo(a,h)anthracene	63.4	260
Fluoranthene	600	5,100
Pyrene	665	2,600
Low molecular-weight PAH	552	3,160
High molecular-weight PAH	1,700	9,600
Total PAHs	4,020	44,800
4,4'-DDE	2.2	27
Total DDT	1.6	46.1
Total PCBs	22.7	180

*units are μg/g dry sediment, equivalent to ppm
**units are ng/g dry sediment, equivalent to ppb

Table 1-12. Criteria for Assessing Sediment Contaminants by Site

Rating	Criteria
Good	No ERM concentrations are exceeded, and less than five ERL concentrations are exceeded.
Fair	No ERM concentrations are exceeded, and five or more ERL concentrations are exceeded.
Poor	An ERM concentration is exceeded for one or more contaminants.

Table 1-13. Criteria for Assessing Sediment Contaminants by Region

Rating	Criteria
Good	Less than 5% of the coastal area is in poor condition.
Fair	5% to 15% of the coastal area is in poor condition.
Poor	More than 15% of the coastal area is in poor condition.

Sediment TOC

Sediment contaminant availability or organic enrichment can be altered in areas where there is considerable deposition of organic matter. Although TOC exists naturally in coastal sediments and is the result of the degradation of autochthonous and allochthonous organic materials (e.g., phytoplankton, leaves, twigs, dead organisms), anthropogenic sources (e.g., organic industrial wastes, untreated or only primary-treated sewage) can significantly elevate the level of TOC in sediments. TOC in coastal sediments is often a source of food for some benthic organisms, and high levels of TOC in coastal sediments can result in significant changes in benthic community structure and in the predominance of pollution-tolerant species. Increased levels of sediment TOC can also reduce the general availability of organic contaminants (e.g., PAHs, PCBs, pesticides); however, increases in temperature or decreases in dissolved oxygen levels can sometimes result in the release of these TOC-bound and unavailable contaminants. Sediment toxicity from organic matter is assessed by measuring TOC. Regions of high TOC content are also likely to be depositional sites for fine sediments. If there are pollution sources nearby, these depositional sites are likely to be hot spots for contaminated sediments. The criteria for rating TOC at individual sampling sites are shown in Table 1-14, and Table 1-15 shows how these data were used to create a regional ranking.

Table 1-14. Criteria for Assessing TOC by Site (concentrations on a dry-weight basis)

Rating	Criteria
Good	The TOC concentration is less than 2%.
Fair	The TOC concentration is between 2% and 5%.
Poor	The TOC concentration is greater than 5%.

Table 1-15. Criteria for Assessing TOC by Region

Rating	Criteria
Good	Less than 20% of the coastal area is in poor condition.
Fair	20% to 30% of the coastal area is in poor condition.
Poor	More than 30% of the coastal area is in poor condition.

Courtesy of Andrew D. Stahl

Calculating the Sediment Quality Index

Once all three sediment quality component indicators (sediment toxicity, sediment contaminants, and sediment TOC) are assessed for a given site, a sediment quality index rating is calculated for the site. The sediment quality index was rated good, fair, or poor for each site using the criteria shown in Table 1-16. The sediment quality index was then calculated for each region using the criteria shown in Table 1-17.

Table 1-16. Criteria for Determining the Sediment Quality Index by Site

Rating	Criteria
Good	None of the individual component indicators is rated poor, and the sediment contaminants indicator is rated good.
Fair	None of the component indicators is rated poor, and the sediment contaminants indicator is rated fair.
Poor	One or more of the component indicators is rated poor.

Table 1-17. Criteria for Determining the Sediment Quality Index by Region

Rating	Criteria
Good	Less than 5% of the coastal area is in poor condition, and more than 50% of the coastal area is in good condition.
Fair	5% to 15% of the coastal area is in poor condition, or more than 50% of the coastal area is in combined poor and fair condition.
Poor	More than 15% of the coastal area is in poor condition.

Benthic Index

The worms, clams, crustaceans, and other invertebrates that inhabit the bottom substrates of coastal waters are collectively called benthic macroinvertebrates, or benthos. These organisms play a vital role in maintaining sediment and water quality and are an important food source for bottom-feeding fish, shrimp, ducks, and marsh birds. Benthos are often used as indicators of disturbance in coastal environments because they are not very mobile and thus cannot avoid environmental problems. Benthic population and community characteristics are sensitive to chemical-contaminant and dissolved-oxygen stresses, salinity fluctuations, and sediment disturbance and serve as reliable indicators of coastal environmental quality. To distinguish degraded benthic habitats from undegraded benthic habitats, EMAP and NCA have developed regional (Southeast, Northeast, and Gulf coasts) benthic indices of environmental condition (Engle et al., 1994; Weisberg et al., 1997; Engle and Summers, 1999; Van Dolah et al., 1999; Hale and Heltshe, 2008). These indices reflect changes in benthic community diversity and the abundance of pollution-tolerant and pollution-sensitive species. A high benthic index rating for benthos means that sediment samples taken from a waterbody contain a wide variety of benthic species, as well as a low proportion of pollution-tolerant species and a high proportion of pollution-sensitive species. A low benthic index rating indicates that the benthic communities are less diverse than expected, are populated by more pollution-tolerant species than expected, and contain fewer pollution-sensitive species than expected. The benthic condition data presented throughout this report were collected by the NCA unless otherwise noted. Indices vary by region because species assemblages depend on prevailing temperatures, salinities, and the silt-clay content of sediments. The benthic index was rated poor at a site when the index values for the Northeast, Southeast, and Gulf coasts' diversity or species richness, abundance of pollution-sensitive species, and abundance of pollution-tolerant species fell below a certain threshold.

Not all regions included in this report have developed benthic indices. Indices for the West Coast, Puerto Rico, Alaska, and Hawaii are under development and were unavailable for reporting at this time. In these regions, benthic community diversity or species richness were determined for each site as surrogates for the benthic index. Values for diversity or richness were compared with salinity regionally to determine if a significant relationship existed. This relationship was not significant for Southcentral Alaska and Hawaii, and no surrogate benthic index was developed; therefore, benthic community condition was not assessed for these regions. For the West Coast estuaries, there was a significant relationship between species richness and salinity ($r^2 = 0.43$, $p < 0.01$). A surrogate benthic index was calculated by determining the expected species richness from the statistical relationship to salinity and then calculating the ratio of observed to expected species richness. Poor condition was defined as less than 75% of the expected benthic species richness at a particular salinity. As in Southcentral Alaska and Hawaii, the data from Puerto Rico showed no significant relationship between benthic diversity or species richness and salinity; however, a different approach was used to assess benthic condition in this region. Benthic diversity (H') was used as a surrogate for a benthic index for Puerto Rico by determining the mean and 95% confidence limits for diversity in unstressed benthic habitats (i.e., sites with no sediment contaminants, low TOC, and absence of hypoxia). Poor benthic condition was then defined as observed diversity less than 75% of the lower 95% confidence limit of mean diversity for unstressed habitats in Puerto Rico. Table 1-18 shows the good, fair, and poor rating criteria for the different regions of the country, which were used to calculate an overall benthic condition rating for each region.

Table 1-18. Criteria for Assessing Benthic Index

Area	Good	Fair	Poor
Northeast Coast sites			
Acadian Province	Benthic index score is greater than or equal to 5.0.	Benthic index score is greater than or equal to 4.0 and less than 5.0.	Benthic index score is less than 4.0.
Virginian Province	Benthic index score is greater than 0.0.	NA*	Benthic index score is less than 0.0.
Southeast Coast sites	Benthic index score is greater than 2.5.	Benthic index score is between 2.0 and 2.5.	Benthic index score is less than 2.0.
Gulf Coast sites	Benthic index score is greater than 5.0.	Benthic index score is between 3.0 and 5.0.	Benthic index score is less than 3.0.
West Coast sites (compared to expected diversity)	Benthic index score is more than 90% of the lower limit (lower 95% confidence interval) of expected mean diversity for a specific salinity.	Benthic index score is between 75% and 90% of the lower limit of expected mean diversity for a specific salinity.	Benthic index score is less than 75% of the lower limit of expected mean diversity for a specific salinity.
Southcentral Alaska and Hawaii sites	NA**	NA**	NA**
Puerto Rico sites (compared to upper 95% confidence interval for mean regional benthic diversity)	Benthic index score is more than 90% of the lower limit (lower 95% confidence interval) of mean diversity in unstressed habitats.	Benthic index score is between 75% and 90% of the lower limit of mean diversity in unstressed habitats.	Benthic index score is less than 75% of the lower limit of mean diversity in unstressed habitats.
Regions	Less than 10% of the coastal area is in poor condition, and more than 50% of the coastal area is in good condition.	10% to 20% of the coastal area is in poor condition, or more than 50% of the coastal area is in combined poor and fair condition.	More than 20% of the coastal area is in poor condition.

* By design, this index discriminates between good and poor conditions only.
**Benthic condition was not assessed in these regions.

Coastal Habitat Index

Coastal wetlands are the vegetated interface between the aquatic and terrestrial components of coastal ecosystems and serve many purposes. Wetlands are beneficial because they can filter and process residential, agricultural, and industrial wastes, thereby improving surface water quality. Wetlands buffer coastal areas against storm and wave damage. Wetland habitats are critical to the life cycles of fish, shellfish, migratory birds, and other wildlife. Many species of commercial and sport fish spend a portion of their life cycles in coastal wetland and estuarine habitats. Adult stocks of commercially harvested shrimp, blue crabs, oysters, and other species throughout the United States are directly related to wetland quality and quantity (Turner and Boesch, 1988).

Wetlands throughout the United States have been and are being rapidly destroyed by human activities (e.g., flood control, agriculture, waste disposal, real estate development, shipping, commercial fishing, oil/gas exploration and production) and natural processes (e.g., sea-level rise, sediment compaction, droughts, hurricanes, floods). In the late 1970s and early 1980s, the country was losing wetlands at an estimated rate of 300,000 acres per year. The Clean Water Act, state wetland protection programs, and programs such as Swampbuster (USDA) have helped decrease wetland losses to an estimated 70,000 to 90,000 acres per year. Strong wetland protection is important nationally; otherwise, fisheries that support more than a million jobs and contribute billions of dollars to the national economy are at risk (Turner and Boesch, 1988; Stedman and Hanson, 2000), as are the ecological functions provided by wetlands (e.g., nursery areas, flood control, and water quality improvement).

Coastal wetlands, as defined here, include only estuarine and marine intertidal wetlands (e.g., salt and brackish marshes; mangroves and other shrub-scrub habitats; intertidal oyster reefs; and tidal flats, such as macroalgal flats, shoals, spits, and bars). This index does not include subtidal SAV, coral reefs, subtidal oyster reefs, worm reefs, artificial reefs, or freshwater/palustrine wetlands. It should be noted that the NWI data used in this assessment do not distinguish between the natural and created wetlands and that most created wetlands do not have all the functions of natural wetlands (NAS, 2001). For more information about wetlands, refer to EPA's wetlands Web site at http://www.epa.gov/owow/wetlands.

Because no new information on U.S. wetlands was available from the NWI, the assessment of coastal habitat from the NCCR II is used in this report. The NWI (Dahl, 2002) contains data on estuarine-emergent and tidal flat wetland acreage from 1990 and 2000 for all coastal states, except Hawaii and Puerto Rico. Data for Hawaii and Puerto Rico are only available for 1980 and 1990. The proportional change in regional coastal wetlands over the 10-year time period was determined for each region and combined with the long-term decadal loss rates for the period 1780 to 1990. The average of these two loss rates (historic and present) multiplied by 100 is the regional value of the coastal habitat index. The national value of the coastal habitat index is a weighted mean that reflects the extent of wetlands existing in each region (different than the distribution of the extent of coastal area). Table 1-19 shows the rating criteria used for the coastal habitat index.

Table 1-19. Criteria for Determining the Coastal Habitat Index

Rating		Criteria
Good	🟩	The index value is less than 1.0.
Fair	🟨	The index value is between 1.0 and 1.25.
Poor	🟥	The index value is greater than 1.25.

Coastal wetlands provide critical habitat for a variety of wildlife (courtesy of John Theilgard).

Highlight

An Index of Benthic Condition for the Coastal Acadian Biogeographic Province

Indices that combine several benthic community variables have been used by monitoring programs to measure the spatial extent of environmental problems, locate problem areas for further study, assess the effectiveness of remediation programs, and determine whether conditions are improving or deteriorating. For the NCCR II, the NCA used the Shannon-Wiener H' index, a measure of biodiversity, to evaluate the condition of benthic communities in the Acadian Province (Gulf of Maine). The Virginian Province Benthic Index (Paul et al., 2001) did not work well in this area, and at the time, there were not yet sufficient data to develop an index unique to the Acadian Province. Compared with the Virginian Province (the area from south of Cape Cod to Virginia), the Gulf of Maine is colder, deeper, better oxygenated, and more strongly flushed by tides. For the current report, NCA has used the 2000 and 2001 data to develop a specific Acadian Province Benthic Index (Hale and Heltshe, 2008).

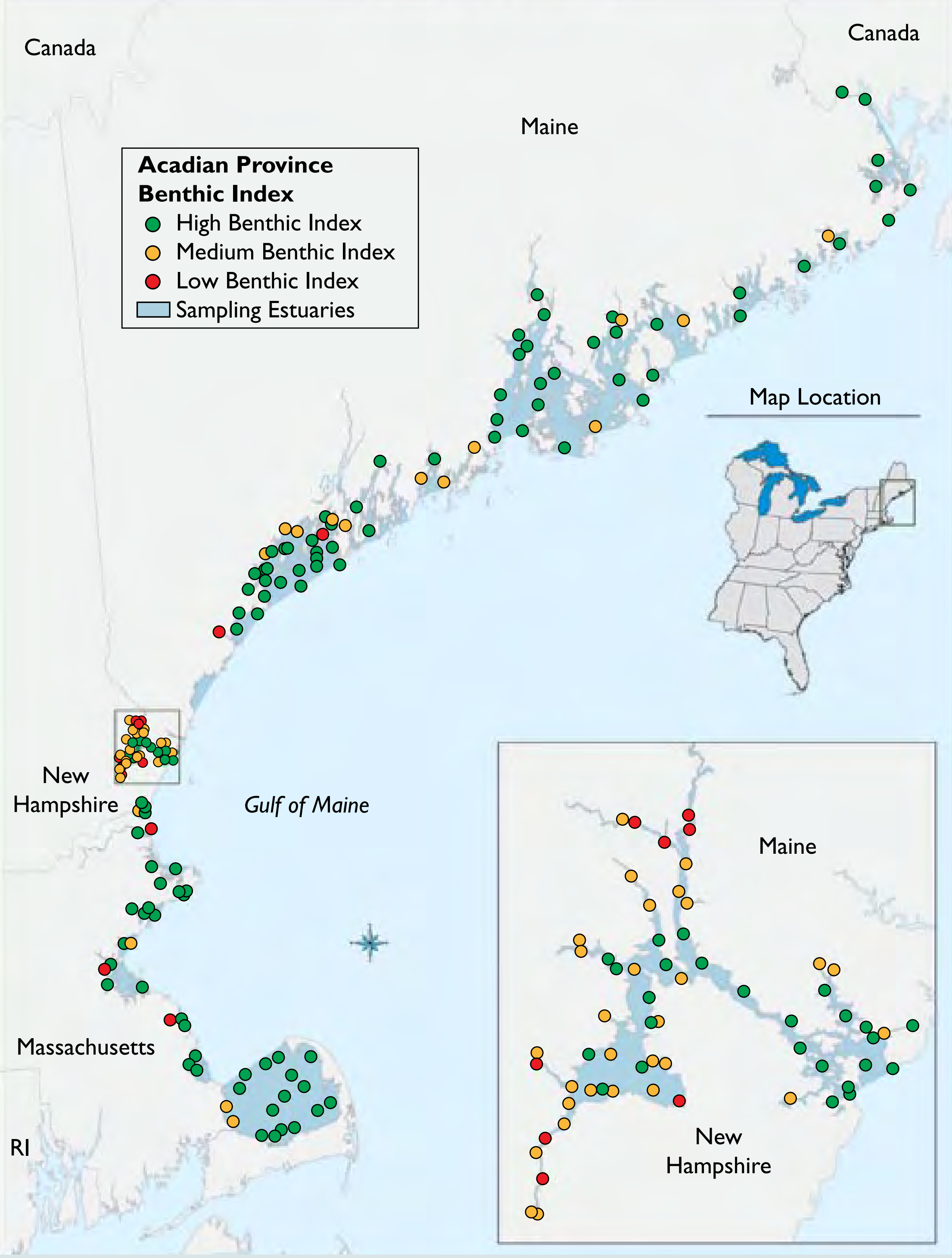
During the spring of 2004, the NCA held a workshop in Portsmouth, NH, with Gulf of Maine benthic ecologists to review candidate metrics, discuss preliminary indices, and learn about other available benthic data sets. First, the NCA identified the stations with the highest and lowest benthic environmental quality (BEQ). BEQ was defined as a function of nonbiological components, including sediment contaminant concentrations, sediment TOC levels, sediment toxicity, and concentrations of dissolved oxygen in bottom water. The aim was to use information from the benthic assemblage data to build an index that could discriminate stations with high and low BEQ. Using the scientific literature, the NCA developed a list of 40 possible candidates for benthic metrics that might be useful. These metrics included diversity measures and relative proportions of pollution-tolerant or pollution-sensitive taxa. The NCA used discriminant analysis with the candidate benthic metrics to identify those that had discriminatory power. These metrics were used to build discriminant functions. The discriminant functions that correctly classified at least 80% of the stations in the calibration data set became candidate benthic indices. Three independent data sets were used to validate the candidate indices and to select the best index. These data sets are the Massachusetts Water Resources Authority (MWRA) study of Boston Harbor and Massachusetts Bay (Williams et al., 2002), a study in Casco Bay (Larsen et al., 1983), and the NCA 2002 and 2003 data.

The discriminant function chosen as the Acadian Province Benthic Index for this report (see box) correctly classified 87.6% of the calibration data set and about three-quarters of the stations in the validation data sets. The map presents the classifications resulting from the application of this index at sampling sites within the Gulf of Maine in three categories: high, medium, and low. It should be noted that the NCA sampled few low- or intermediate-level saline estuaries in the Acadian Province, so the applicability of the current index in low-salinity areas is unknown. This index provides environmental managers with a way to assess the health of Gulf of Maine coastal benthic communities, both spatially and temporally. Further refinements and validations will be made as more NCA data become available.

$$\text{Acadian Province Benthic Index} = 0.494 \times \text{Shannon} + 0.670 \times \text{MN\_ES50}_{0.5} - 0.034 \times \text{PctCapitellidae}$$

where

Shannon = Shannon-Wiener H' diversity index
$\mathit{MN\_ES50}_{.05}$ = Station mean of species tolerance values (Rosenberg et al., 2004)
PctCapitellidae = Percent abundance of capitellid polychaetes



Benthic index scores at monitoring sites from the validation data sets (U.S. EPA).

The NWI estimates represent regional assessments and do not apply to individual sites or individual wetlands. Before individual wetland sites can be assessed, rigorous methodologies for estimating the quantity and the quality of wetlands must be developed. Until these methods are available and implemented, only regional assessments of quantity losses can be made. Although a 1% loss rate per decade may seem small (or even acceptable), continued wetland losses at this rate cannot be sustained indefinitely and still leave enough wetlands to maintain their present ecological functions.

Fish Tissue Contaminants Index

Chemical contaminants may enter a marine organism in several ways: direct uptake from contaminated water, consumption of contaminated sediment, or consumption of previously contaminated organisms. Once these contaminants enter an organism, they tend to remain in the animal's tissues and may build up with subsequent feedings. When fish consume contaminated organisms, they may "inherit" the levels of contaminants in the organisms they consume. The same inheritance of contaminants occurs when humans consume fish with contaminated tissues. Contaminant residues can be examined in the fillets, whole-body portions, or specific organs of target fish and shellfish species and compared with risk-based EPA Advisory Guidance values (U.S. EPA, 2000c) for use in establishing fish advisories. EPA has also developed an Ambient Water Quality Criterion (AWQC) for methylmercury in fish and shellfish tissue (U.S. EPA, 2001e) and prepared draft guidance for implementing this AWQC (U.S. EPA, 2006a).

For the NCA surveys, both juvenile and adult target fish species were collected from all monitoring stations where fish were available, and whole-body contaminant burdens were determined. The target species typically included demersal (bottom-dwelling) and slower-moving pelagic (water column-dwelling) species that are representative of each of the geographic regions (Northeast Coast, Southeast Coast, Gulf Coast, West Coast, and Southcentral Alaska). These intermediate trophic-level (position in the food web) species are prey for larger predatory fish of commercial value (Harvey et al., 2008). Where available, 4 to 10 individual fish from each target species at each sampling site were analyzed by compositing fish tissues.

Although the EPA risk-based fish advisory recommendations were developed to evaluate the health risks of consuming market-sized fish fillets, they also may be used to assess the risk of whole-body contaminants in fish as a basis for estimating advisory determinations—an approach currently used by many state fish advisory programs (U.S. EPA, 2000c). These advisory values may also be used (as NCA uses them) as surrogate benchmark values to examine contaminants in non-commercial, juvenile and adult fish to compare levels of pollutant contamination across geographic regions and provide a national baseline assessment. The NCA compared whole-body contaminant concentrations in fish to the EPA-recommended values used by states as a basis for setting fish advisories for recreational fishers (Table 1-20) (U.S. EPA 2000c). The AWQC for methylmercury (U.S. EPA, 2001e) was not used in this assessment. Although EPA fish consumption recommendations are generally based on fillet tissue samples, they are also appropriate to compare to data from whole-fish or organ-specific body burdens that are used by many states for those fish consumers whose culinary practices include consumption of fish tissues other than the fillets. The whole-fish contaminant information collected by NCA for U.S. coastal waters was compared with risk-based threshold values based on a 154-pound adult human's consumption of four 8-ounce meals per month for selected contaminants (the approach used by most state fish advisory programs) and assessed for non-cancer and cancer health endpoints (U.S. EPA, 2000c). Table 1-21 shows the rating criteria for the fish tissue contaminants index for each station sampled, and Table 1-22 shows how these ratings were used to create a regional index rating.

Summary of Rating Criteria

The rating criteria used in this report are summarized in Table 1-23 (primary indices) and Tables 1-24 and 1-25 (component indicators).

Table 1-20. Risk-based EPA Advisory Guidance Values for Recreational Fishers (U.S. EPA, 2000c)

Contaminant	EPA Advisory Guidelines Concentration Range (ppm)[a]	Health Endpoint
Arsenic (inorganic)[b]	0.35–0.70	non-cancer
Cadmium	1.2–2.3	non-cancer
Mercury (methylmercury)[c]	0.12–0.23	non-cancer
Selenium	5.9–12.0	non-cancer
Chlordane	0.59–1.2	non-cancer
DDT	0.59–1.2	non-cancer
Dieldrin	0.059–0.12	non-cancer
Endosulfan	7.0–14.0	non-cancer
Endrin	0.35–0.70	non-cancer
Heptachlor epoxide	0.015–0.031	non-cancer
Hexachlorobenzene	0.94–1.9	non-cancer
Lindane	0.35–0.70	non-cancer
Mirex	0.23–0.47	non-cancer
Toxaphene	0.29–0.59	non-cancer
PAHs (benzo(a)pyrene)	0.0016–0.0032	cancer[d]
PCB	0.023–0.04	non-cancer

[a] Range of concentrations associated with non-cancer and cancer health endpoint risk for consumption of four 8-ounce meals per month.

[b] Inorganic arsenic concentrations were estimated to be 2% of the measured total arsenic concentrations (U.S. EPA, 2000a).

[c] The conservative assumption was made that all mercury is present as methylmercury because most mercury in fish and shellfish is present primarily as methylmercury and because analysis for total mercury is less expensive than analysis for methylmercury (U.S. EPA, 2000a).

[d] A non-cancer concentration range for PAHs does not exist.

Table 1-21. Criteria for Determining the Fish Tissue Contaminants Index by Station

Rating		Criteria
Good	🟩	For all chemical contaminants listed in Table 1-20, the measured concentrations in fish tissue fall below the range of the EPA Advisory Guidance* values for risk-based consumption associated with four 8-ounce meals per month.
Fair	🟨	For at least one chemical contaminant listed in Table 1-20, the measured concentration in fish tissue falls within the range of the EPA Advisory Guidance values for risk-based consumption associated with four 8-ounce meals per month.
Poor	🟥	For at least one chemical contaminant listed in Table 1-20, the measured concentrations in fish tissue exceeds the maximum value in the range of the EPA Advisory Guidance values for risk-based consumption associated with four 8-ounce meals per month.

*The EPA Advisory Guidance concentration is based on the non-cancer ranges for all contaminants except the concentration for PAHs (benzo(a)pyrene), which is based on a cancer range because a non-cancer range for PAHs does not exist (see Table 1-20).

Table 1-22. Criteria for Determining the Fish Tissue Contaminants Index by Region

Rating		Criteria
Good	🟩	Less than 10% of the fish samples analyzed (Northeast Coast region) or the monitoring stations where fish were caught (all other regions) are in poor condition, and more than 50% of the fish samples analyzed (Northeast Coast region) or the monitoring stations where fish were caught (all other regions) are in good condition.
Fair	🟨	10% to 20% of the fish samples analyzed (Northeast Coast region) or monitoring stations where fish were caught (all other regions) are in poor condition, or more than 50% of the fish samples analyzed (Northeast Coast region) or the monitoring stations where fish were caught (all other regions) are in combined poor and fair condition.
Poor	🟥	More than 20% of the fish samples analyzed (Northeast Coast region) or the monitoring stations where fish were caught (all other regions) are in poor condition.

Table 1-23. NCA Indices Used to Assess Coastal Condition

Icon	Index	**Ecological Condition by Site**	**Ranking by Region**
Water Quality Index	**Water Quality Index** – This index is based on measurements of five water quality component indicators (DIN, DIP, chlorophyll *a*, water clarity, and dissolved oxygen).	**Good**: No component indicators are rated poor, and a maximum of one is rated fair. **Fair**: One component indicator is rated poor, or two or more component indicators are rated fair. **Poor**: Two or more component indicators are rated poor.	**Good**: Less than 10% of the coastal area is in poor condition, and more than 50% of the coastal area is in good condition. **Fair**: Between 10% and 20% of the coastal area is in poor condition, or more than 50% of the coastal area is in combined fair and poor condition. **Poor**: More than 20% of the coastal area is in poor condition.
Sediment Quality Index	**Sediment Quality Index** – This index is based on measurements of three sediment quality component indicators (sediment toxicity, sediment contaminants, and sediment TOC).	**Good**: No component indicators are rated poor, and the sediment contaminants indicator is rated good. **Fair**: No component indicators are rated poor, and the sediment contaminants indicator is rated fair. **Poor**: One or more component indicators are rated poor.	**Good**: Less than 5% of the coastal area is in poor condition, and more than 50% of the coastal area is in good condition. **Fair**: Between 5% and 15% of the coastal area is in poor condition, or more than 50% of the coastal area is in combined poor and fair condition. **Poor**: More than 15% of the coastal area is in poor condition.
Benthic Index	**Benthic Index** (or a surrogate measure) – This index indicates the condition of the benthic community (organisms living in coastal sediments) and can include measures of benthic community diversity, the presence and abundance of pollution-tolerant species, and the presence and abundance of pollution-sensitive species.	**Good**, **fair**, and **poor** were determined using regionally dependent benthic index scores (see Table 1-18).	**Good**: Less than 10% of the coastal area is in poor condition, and more than 50% of the coastal area is in good condition. **Fair**: Between 10% and 20% of the coastal area is in poor condition, or more than 50% of the coastal area is in combined poor and fair condition. **Poor**: More than 20% of the coastal area is in poor condition.
Coastal Habitat Index	**Coastal Habitat Index** – This index is evaluated using the data from the NWI (Dahl, 2002), which contains data on estuarine-emergent and tidal flat acreage for all coastal states (except Hawaii and Puerto Rico) for 1780 through 2000.	The average of the mean long-term, decadal wetland loss rate (1780–1990) and the present decadal wetland loss rate (1990–2000) was determined for each region of the United States and multiplied by 100 to create a coastal habitat index value.	**Good**: The coastal habitat index value is less than 1.0. **Fair**: The coastal habitat index value is between 1.0 and 1.25. **Poor**: The coastal habitat index value is greater than 1.25.
Fish Tissue Contaminants Index	**Fish Tissue Contaminants Index** – This index indicates the level of chemical contamination in target fish/shellfish species.	**Good**: For all chemical contaminants listed in Table 1-20, the measured concentrations in tissue fall below the range of the EPA Advisory Guidance* values for risk-based consumption associated with four 8-ounce meals per month. **Fair**: For at least one chemical contaminant listed in Table 1-20, the measured concentration in tissue falls within the range of the EPA Advisory Guidance values for risk-based consumption associated with four 8-ounce meals per month. **Poor**: For at least one chemical contaminant listed in Table 1-20, the measured concentration in tissue exceeds the maximum value in the range of the EPA Advisory Guidance values for risk-based consumption associated with four 8-ounce meals per month.	**Good**: Less than 10% of the fish samples analyzed (Northeast Coast region) or the monitoring stations where fish were caught (all other regions) are in poor condition, and more than 50% of the fish samples analyzed (Northeast Coast region) or the monitoring stations where fish were caught (all other regions) are in good condition. **Fair**: 10% to 20% of the fish samples analyzed (Northeast Coast region) or the monitoring stations where fish were caught (all other regions) are in poor condition, or more than 50% of the fish samples analyzed (Northeast Coast region) or the monitoring stations where fish were caught (all other regions) are in combined poor and fair condition. **Poor**: More than 20% of the fish samples analyzed (Northeast Coast region) or the monitoring stations where fish were caught (all other regions) are in poor condition.

*The EPA Advisory Guidance concentration is based on the non-cancer ranges for all contaminants except for PAHs (benzo(a)pyrene), which is based on a cancer range because a non-cancer range for PAHs does not exist (see Table 1-20).

Table 1-24. NCA Criteria for the Five Component Indicators Used in the Water Quality Index to Assess Coastal Condition

Dissolved Inorganic Nitrogen (DIN)

Ecological Condition by Site	Ranking by Region
Good: Surface concentrations are less than 0.1 mg/L (Northeast, Southeast, Gulf), 0.5 mg/L (West, Alaska), or 0.05 mg/L (tropical*).	**Good**: Less than 10% of the coastal area is in poor condition, and more than 50% of the coastal area is in good condition.
Fair: Surface concentrations are 0.1–0.5 mg/L (Northeast, Southeast, Gulf), 0.5–1.0 mg/L (West, Alaska), or 0.05–0.1 mg/L (tropical).	**Fair**: 10% to 25% of the coastal area is in poor condition, or more than 50% of the coastal area is in combined fair and poor condition.
Poor: Surface concentrations are greater than 0.5 mg/L (Northeast, Southeast, Gulf), 1.0 mg/L (West, Alaska), or 0.1 mg/L (tropical).	**Poor**: More than 25% of the coastal area is in poor condition.

Dissolved Inorganic Phosphorus (DIP)

Ecological Condition by Site	Ranking by Region
Good: Surface concentrations are less than 0.01 mg/L (Northeast, Southeast, Gulf), 0.01 mg/L (West, Alaska), or 0.005 mg/L (tropical).	**Good**: Less than 10% of the coastal area is in poor condition, and more than 50% of the coastal area is in good condition.
Fair: Surface concentrations are 0.01–0.05 mg/L (Northeast, Southeast, Gulf), 0.01–0.1 mg/L (West, Alaska), or 0.005–0.01 mg/L (tropical).	**Fair**: 10% to 25% of the coastal area is in poor condition, or more than 50% of the coastal area is in combined fair and poor condition.
Poor: Surface concentrations are greater than 0.05 mg/L (Northeast, Southeast, Gulf), 0.1 mg/L (West, Alaska), or 0.01 mg/L (tropical).	**Poor**: More than 25% of the coastal area is in poor condition.

Chlorophyll *a*

Ecological Condition by Site	Ranking by Region
Good: Surface concentrations are less than 5 μg/L (less than 0.5 μg/L for tropical ecosystems).	**Good**: Less than 10% of the coastal area is in poor condition, and more than 50% of the coastal area is in good condition.
Fair: Surface concentrations are between 5 μg/L and 20 μg/L (between 0.5 μg/L and 1 μg/L for tropical ecosystems).	**Fair**: 10% to 20% of the coastal area is in poor condition, or more than 50% of the coastal area is in combined fair and poor condition.
Poor: Surface concentrations are greater than 20 μg/L (greater than 1 μg/L for tropical ecosystems).	**Poor**: More than 20% of the coastal area is in poor condition.

Water Clarity

Ecological Condition by Site	Ranking by Region
Good: Amount of light at 1 meter is greater than 10% (coastal waters with high turbidity), 20% (coastal waters with normal turbidity), or 40% (coastal waters that support SAV) of surface illumination.	**Good**: Less than 10% of the coastal area is in poor condition, and more than 50% of the coastal area is in good condition.
Fair: Amount of light at 1 meter is 5–10% (coastal waters with high turbidity), 10–20% (coastal waters with normal turbidity), or 20–40% (coastal waters that support SAV) of surface illumination.	**Fair**: 10% to 25% of the coastal area is in poor condition, or more than 50% of the coastal area is in combined fair and poor condition.
Poor: Amount of light at 1 meter is less than 5% (coastal waters with high turbidity), 10% (coastal waters with normal turbidity), or 20% (coastal waters that support SAV) of surface illumination.	**Poor**: More than 25% of the coastal area is in poor condition.

Dissolved Oxygen

Ecological Condition by Site	Ranking by Region
Good: Bottom-water concentrations are greater than 5 mg/L.	**Good**: Less than 5% of the coastal area is in poor condition, and more than 50% of the coastal area is in good condition.
Fair: Bottom-water concentrations are between 2 mg/L and 5 mg/L.	**Fair**: 5% to 15% of the coastal area is in poor condition, or more than 50% of the coastal area is in combined fair and poor condition.
Poor: Bottom-water concentrations are less than 2 mg/L.	**Poor**: More than 15% of the coastal area is in poor condition.

*Tropical ecosystems include Hawaii, Puerto Rico, and Florida Bay sites.

Table 1-25. NCA Criteria for the Three Component Indicators Used in the Sediment Quality Index to Assess Coastal Condition

Sediment Toxicity is evaluated as part of the sediment quality index using a 10-day static toxicity test with the organism *Ampelisca abdita*.

Ecological Condition by Site	Ranking by Region
Good: Mortality* is less than or equal to 20%.	**Good**: Less than 5% of the coastal area is in poor condition.
Poor: Mortality is greater than 20%.	**Poor**: 5% or more of the coastal area is in poor condition.

Sediment Contamination is evaluated as part of the sediment quality index using ERM and ERL values.

Ecological Condition by Site	Ranking by Region
Good: No ERM values are exceeded, and fewer than five ERL values are exceeded.	**Good**: Less than 5% of the coastal area is in poor condition.
Fair: No ERM values are exceeded, and five or more ERL values are exceeded.	**Fair**: 5% to 15% of the coastal area is in poor condition.
Poor: One or more ERM values are exceeded.	**Poor**: More than 15% of the coastal area is in poor condition.

Sediment Total Organic Carbon (TOC)

Ecological Condition by Site	Ranking by Region
Good: The TOC concentration is less than 2%.	**Good**: Less than 20% of the coastal area is in poor condition.
Fair: The TOC concentration is between 2% and 5%.	**Fair**: 20% to 30% of the coastal area is in poor condition.
Poor: The TOC concentration is greater than 5%.	**Poor**: More than 30% of the coastal area is in poor condition.

*Test mortality is adjusted for control mortality.

How the Indices Are Summarized

Overall condition for each region was calculated by summing the scores for the available indices and dividing by the number of available indices (i.e., equally weighted), where good = 5; good to fair = 4; fair = 3; fair to poor = 2; and poor = 1. In calculating the overall condition score for a region, the indices are weighted equally because of the lack of a defendable, more-than-conceptual rationale for uneven weighting. The Southeast Coast region, for example, received the following scores:

Indices	Score
Water Quality Index	3
Sediment Quality Index	3
Benthic Index	5
Coastal Habitat Index	3
Fish Tissue Contaminants Index	4
Total Score Divided by 5 = Overall Score	18/5 = 3.6

The overall condition and index scores for the nation are calculated based on a weighted average of the regional scores for each index. The national ratings for overall condition and each index are then assigned based on these calculated scores, rather than on the percentage of area in good, fair, or poor condition. The indices were weighted based on the coastal area contributed by each geographic area. For example, the weighted average for the water quality index was calculated by summing the products of the regional water quality index scores and the area contributed by each region (Figure 1-4). These weighting factors were used for all indices except the coastal habitat index, which used the geographic distribution of total area of coastal wetlands (Figure 1-5). The national overall condition score was then calculated by summing each national index score and dividing by five. Additional discussion of this process is presented in Appendix A.

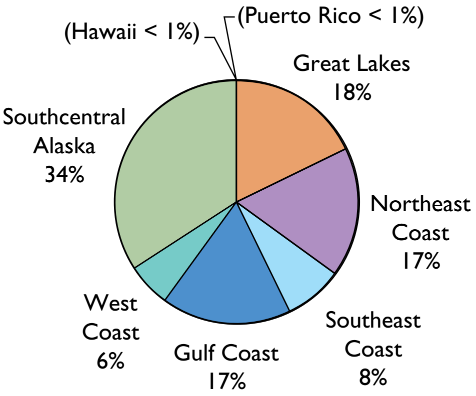


Figure 1-4. Percentage of coastal area contributed by each geographic region assessed in this report (U.S. EPA/NCA).

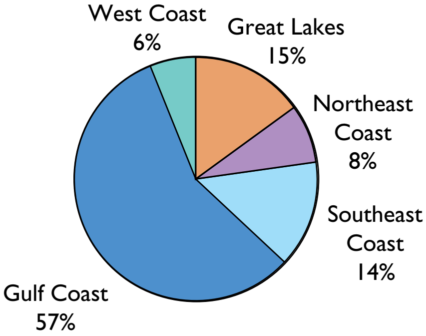


Figure 1-5. Percentage of coastal wetland area contributed by each geographic region assessed in this report (U.S. EPA/NCA).

The snowy grouper (*Epinephelus niveatus*) commercial fishery is managed by the South Atlantic Fishery Management Council (SAFMC) and is subject to limited-access permit requirements and gear restriction (courtesy of Andrew Davis, NOAA, and Lance Horn, University of North Carolina Wilmington).

Large Marine Ecosystem Fisheries Data

In addition to coastal monitoring data, a second type of data used to assess coastal condition in this report is LME fisheries data from the NMFS. LMEs are areas of ocean characterized by distinct bathymetry, hydrography, productivity, and trophic relationships. LMEs extend from river basins and estuaries to the seaward boundaries of continental shelves and the outer margins of major current systems. Within these waters, ocean pollution, fishery overexploitation, and coastal habitat alteration are most likely to occur. Sixty-four LMEs surround the continents and most large islands and island chains worldwide and produce 95% of the world's annual marine fishery yields; 10 of these LMEs are found in waters adjacent to the conterminous United States, Alaska, Hawaii, Puerto Rico, and U.S. island territories (NOAA, 1988; 2007g).

The NMFS fisheries data were organized by LME to allow readers to more easily consider fisheries and coastal condition data together. These data are more comparable using LMEs for several reasons. Geographically, LMEs contain both the coastal waters assessed by NCA and the U.S. Exclusive Economic Zone (EEZ) waters containing the fisheries assessed by NMFS. In addition, the borders of the LMEs coincide roughly with the borders of the NCA regions. When considered together, these two data sets provide insight into the condition of U.S. marine waters, especially considering how closely the areas covered by these data sets are related.

This report presents the offshore fisheries data by LME through 2004. This index period was limited to 2004 because this timeframe is more consistent with the coastal condition and advisory data presented in this report. This temporal consistency allows the reader to consider all three types of data together to get a clearer "snapshot" of conditions in U.S. coastal waters.

Interactions Between Fisheries and Coastal Condition

Freshwater and saltwater coastal areas are constantly changing as a result of both human and natural forces, which make these areas both resilient and fragile in nature (National Safety Council, 1998). The ecosystems in these areas are interconnected, and stressors on one of these systems can affect the other systems. For example, water quality in freshwater streams and rivers is vital to providing a healthy environment, particularly for anadromous (migratory) fish species such as salmon that are born in freshwater streams, migrate to the ocean as juveniles, utilize the ocean environment as they mature into adults, and return to the streams of their birth to spawn and ultimately die. Good water quality in the spawning areas is required to ensure development of the young. Good water quality is also important for the species that are spawned and develop as juveniles in estuaries, where fresh and salt waters mingle, interact, and are refreshed with the tidal change. When water quality in these upstream freshwater areas is negatively impacted, the survival of juvenile fish in the estuarine nursery areas may decrease, ultimately affecting the offshore fishery stocks of adults for these species.

The coastal and offshore waters, as well as the resources they contain, face many stressors. For example, land-based stressors include increasing coastal population growth coupled with inadequate land-use planning and increasing inputs of pollutants from the development of urban areas and from agricultural and industrial activities. Pollutant inputs to our freshwater, estuarine, and near-coastal waters include excessive amounts of nutrients from land runoff; toxic chemical contaminants discharged from point sources; nonpoint-source runoff; accidental spills; and deposition from the atmosphere. Degradation or loss of habitat (e.g., loss of wetland acreage), episodes of hypoxia, and pressures from overfishing by both recreational and commercial fisherman

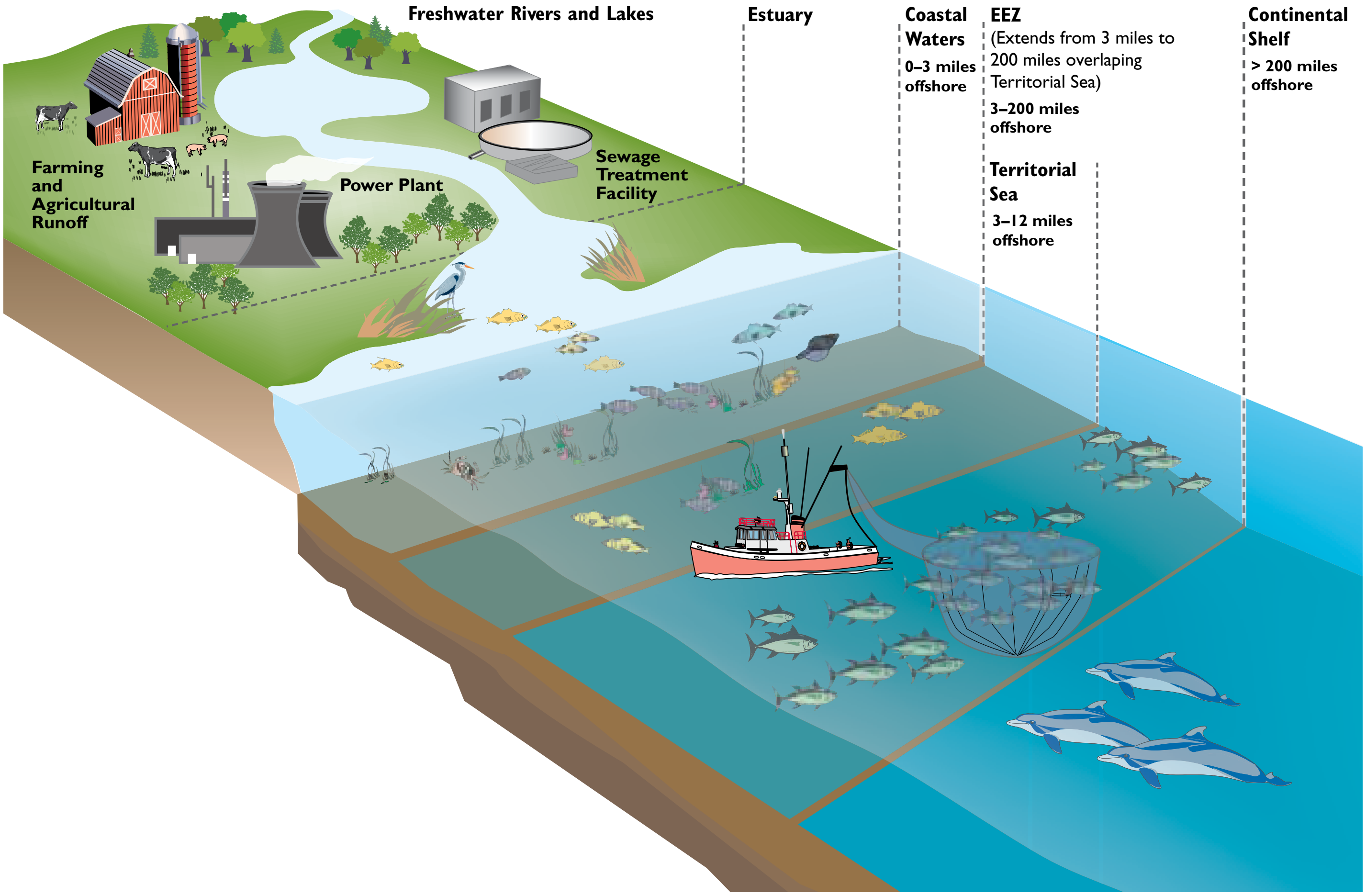


Figure 1-6. Linkages between the stressors in freshwater systems, estuaries, and the coastal ocean (U.S. EPA/NCA).

also impact these coastal ecosystems and the species they nurture. Offshore in the EEZ, stressors come from oil spills, overexploitation of fishery stock resources, and/or habitat loss associated with damage to benthic communities (e.g., macroalgal forests and coral reefs) from fishing activities or development of mineral and energy resources.

The linkage between the stressors in the freshwater rivers and estuaries and the coastal ocean is shown in Figure 1-6. Aquatic and estuarine fisheries resource managers direct their efforts to preserving water quality conditions; maintaining important spawning and nursery areas associated with wetlands, marshes, and SAV beds; and regulating fishing pressure by recreational and commercial fishermen. In contrast, offshore fisheries managers direct their efforts to managing the exploitation of commercial fishery resources of the adult stocks. Outside the EEZ, fisheries managers have less control over the fishery stocks unless established by international treaties. These combined efforts to reduce pollution, maintain habitat quality, and manage fisheries help to ensure that healthy fishery stocks can be maintained for many years into the future.

Fishery Management and Assessment

Ultimately, the Secretary of Commerce has management responsibility for most marine life in U.S. waters and has entrusted the management of these resources to NOAA's NMFS. Most of the NMFS's management and conservation responsibilities are derived from the following acts of Congress:

- Magnuson-Stevens Fishery Conservation and Management Act regulates fisheries within the EEZ
- Endangered Species Act (ESA) protects species that are in danger of extinction or likely to become an endangered species
- Marine Mammal Protection Act regulates the taking of marine mammals
- Fish and Wildlife Coordination Act authorizes the collection of fisheries data and coordination with other agencies for environmental decisions affecting fisheries management regions
- Federal Power Act provides concurrent responsibilities with the FWS on protecting aquatic habitat (NMFS, In press).

The NMFS regulates fisheries in the waters located 3 to 200 nautical miles offshore of the United States in an area known as the EEZ. The waters located landward of the EEZ (0–3 nautical miles offshore) are managed by coastal states and multistate fisheries commissions. Fishery resources in the EEZ are managed largely through fishery management plans (FMPs). FMPs may be developed by the NMFS or by fishery management councils (e.g., Pacific Fishery Management Council, New England Fishery Management Council, Gulf of Mexico Fishery Management Council) through extensive consultation with state and federal agencies, affected industry sectors, public interest groups, and, in some cases, international science and management organizations (NMFS, In press).

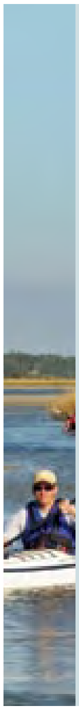
Various data sources are used to assess fishery stocks in the EEZ. Catch-at-age fisheries data are reported to the NMFS by commercial and recreational fisheries on the quantity of fish caught, the individual sizes of fish and their basic biological characteristics (e.g., age, sex, maturity), the ratio of fish caught to time spent fishing (i.e., catch per unit effort [CPUE]), and other factors. The NMFS also conducts direct resource surveys using specialized fishery research vessels to calculate the abundance index (i.e., estimated population size) for some species. The NMFS analyzes these data using several metrics to gain an understanding of the status and trends in U.S. fishery stocks. These metrics include

- **Landings/Catch**—*Landings* are the number or pounds of fish unloaded at a dock by commercial fishermen or brought to shore by recreational fishermen for personal use. Landings are reported at the points where fish are brought to shore. *Catch* is the total number or pounds of fish captured from an area over some period of time. This measure includes fish that are caught, but released or discarded. The catch may take place in an area different from where the fish are landed.
- **Fishing Mortality Rate**—The *fishing mortality rate* is the rate at which members of the population perish due to fishing activities.

- **Yields (various)**—The *maximum sustainable yield* is the largest average catch or yield that can continuously be taken from a stock under existing environmental conditions. The *recent average yield* is the average reported fishery landings for a recent timeframe. The *long-term potential yield* is the maximum long-term average yield that can be achieved through conscientious stewardship. The *near-optimum yield* is based on the maximum sustainable yield as modified by economic, social, or ecological factors to provide the greatest overall benefit to the nation with particular consideration for food production and recreational opportunities.
- **Overfishing/Overfished**—According to the Magnuson-Stevens Fishery Conservation and Management Act of 1996, a fishery is considered *overfished* if the stock size is below a minimum threshold, and *overfishing* is occurring if a stock's fishing mortality rate is above a maximum level. These thresholds and levels are associated with maximum sustainable yield-based reference points and vary between individual stocks, stock complexes, and species of fish.
- **Utilization**—The degree of *utilization* is determined by comparing the present levels of fishing effort and stock abundance to those levels necessary to achieve the long-term potential yield. A fishery can be classified as underutilized, fully utilized, overutilized, or unknown (NMFS, In press).

Once the status of a fishery is assessed, resource managers may employ various management tools to regulate where, when, and how people fish, thus protecting and sustaining our nation's fishery resources so that marine resources continue as functioning components of marine ecosystems, afford economic opportunities, and enhance the quality of life for U.S. citizens (NOAA, 2007c). When deemed necessary, fishery resource managers can employ a variety of different tools to regulate harvest depending on the fish or shellfish species involved. These fishery management tools include the following:

- **Daily bag or trip catch limits** that reduce or increase the number of fish caught per day or per trip, respectively
- **Size limits** that impose minimum fish lengths that limit harvest to adults, thereby protecting immature or juvenile fish
- **Seasonal closures** that prohibit commercial and/or recreational harvesting of specific fish or shellfish stocks during the spawning period
- **Limited access programs** that prevent increased fishing participation by reducing the number of fishing vessels through vessel buy-out programs, placing a moratorium on new vessel entrants into a fishery, or establishing a permitting system for commercial fishermen
- **Gear restrictions** that limit the use of certain types of equipment or mandate increases in regulated mesh size, thereby protecting the habitat from damage or excluding juveniles from harvesting through the use of larger mesh sizes, respectively
- **Time and area closures** that prohibit harvesting of specific fish stocks in specific fishing grounds or limit the allowable number of days at sea for fishing for certain types of vessels (e.g., trawl or gill-net) to protect habitat of juveniles or spawning species or to reduce total catch



Marine Fisheries Fuel the U.S. Economy

More than one-fifth of the world's most productive marine waters lie within the LMEs of the EEZ. The value of both commercial and recreational fishing is significant to the U.S. economy, thousands of private firms, and individuals, families, and communities. In 2004

- U.S. commercial fishermen landed 9.6 billion pounds of fish and shellfish, valued at $3.7 billion (Figure 1-7).
- The commercial marine fishing industry contributed an estimated $31.6 billion (in value added) to the nation's GNP.
- U.S. consumers spent an estimated $61.9 billion for fishery products (NMFS, 2005c).

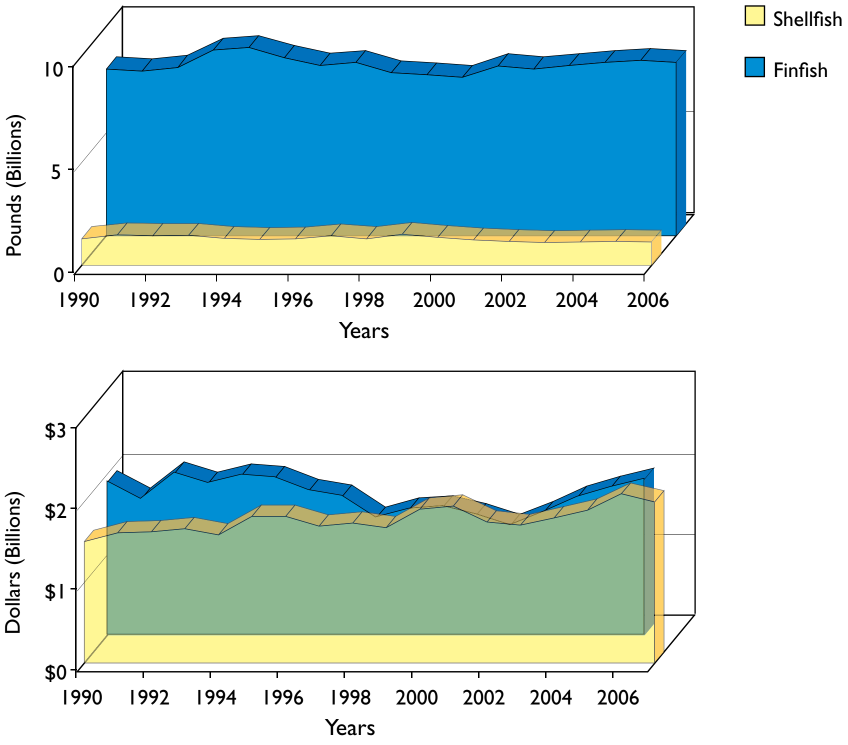


Figure 1-7. Volume and value of commercial fisheries landings, 1990–2006 (NMFS, 2007).

- **Harvest quotas** that limit the number of fish of a particular species that can be harvested annually from a particular region, thereby preventing overfishing
- **Establishment of Marine Protected Areas** within which the harvest of all species is prohibited.

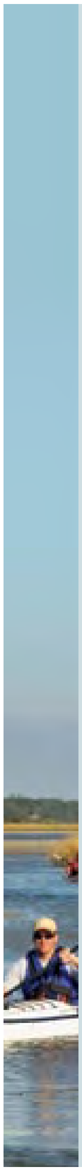
Through the use of these fishery management tools, the NMFS makes stewardship decisions and provides support for rebuilding stocks through science-based conservation and resources management to ensure that marine fishery resources continue as healthy, sustainable, and functioning components of marine ecosystems (NOAA, 2007c). Unless otherwise noted, the information provided for this report on living marine resources within U.S. LMEs was compiled from the NMFS productivity data and the report *Our Living Oceans* (NMFS, In press), which is issued periodically by the NMFS and covers most living marine resources of interest for commercial, recreational, subsistence, and aesthetic or intrinsic reasons to the United States.

Assessment and Advisory Data

Assessment and advisory data provided by states or other regulatory agencies are the third set of data used in this report to assess coastal condition. Several EPA programs, including the Clean Water Act Section 305(b) Assessment Program, the National Listing of Fish Advisories (NLFA) Program, and the Beaches Environmental Assessment, Closure, and Health (BEACH) Program, maintain databases that are repositories for information about how well coastal waters support their designated or desired uses. These uses are important factors in the public's perception of coastal condition and also address the condition of the coast as it relates to public health. The data for these programs are collected by multiple state agencies and reported to EPA, and data collection and reporting methods differ among states. In addition, advisories are precautionary and may not reflect regional condition. Because of these inconsistencies, data generated by these programs are not included in and are not comparable to the regional estimates of coastal condition.

Clean Water Act Section 305(b) Assessments

States report water quality assessment information and water quality impairments under Section 305(b) of the Clean Water Act. States and tribes rate water quality by comparing measured values to their state and tribal water quality standards. The 305(b) assessment ratings (submitted by the states in 2002) are stored in EPA's National Assessment Database (NAD) and are useful for evaluating the success of state water quality improvement efforts; however, it should be emphasized that each state monitors water quality parameters differently, so it is difficult to make generalized statements about the condition of the nation's coastal waters based on these data alone. For the 2002 reporting cycle, several states and island territories with estuarine and coastal marine waters did not submit 305(b) assessment information to EPA. For the states of North Carolina and Washington, as well as the island territories of American Samoa, Guam, and the Northern Mariana Islands, no data were available for the 2002 reporting cycle in the NAD. Because the reporting of 305(b) information was not complete for all coastal states and territories, it was decided that this information would not be summarized for inclusion in the NCCR III. For this report, only data from EPA's NLFA database and the BEACH PRogram tracking, beach Advisories, Water quality standards, and Nutrients (PRAWN) database are presented for calendar year 2003.

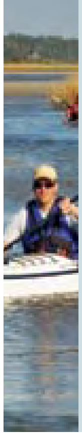


How the NCA fish tissue contaminants index differs from the state fish advisory data

The results of the NCA fish tissue contaminants index provide a different picture of chemical contamination in fish than the results obtained from the state fish consumption advisory programs. The main difference between these two programs is that the NCA is designed to be a nationally consistent *ecological* assessment of contaminant concentrations in fish tissue in a variety of *ecologically* important target species. In contrast, the state fish advisory programs are designed to identify fish tissue contaminant concentrations in fish species that are locally consumed by recreational fishers that may be harmful to *human health* and warrant issuance of a fish advisory. These programs differ in several other ways, including the contaminants analyzed, type of fish samples analyzed, and health benchmarks used in the assessment. These differences are discussed in greater detail below and are summarized in the table.

- The NCA analyzes each fish sample for a uniform suite of contaminants in all estuaries nationally. In contrast, individual states monitor for specific contaminants, but each state selects the contaminants of concern for a particular waterbody based on land-use practices in the watershed, identified sources of pollution, and available state resources. Therefore, some states may monitor for mercury and pesticides, while other states monitor for select heavy metals and PCBs.
- The NCA analyzes both juvenile and adult fish, most often as whole specimens, because this is the way fish would typically be consumed by predator species. This approach is appropriate for an ecological assessment. In contrast, most state programs assess the risk of contaminant exposure to human populations and, therefore, analyze primarily the fillet tissue (portion most commonly consumed by the general population). States may also conduct chemical analyses of whole fish or species organs in areas where certain populations such as Native Americans, Southeast Asians, or other ethnic groups consume whole fish or other fish tissues. The use of whole-fish samples can result in higher concentrations of those contaminants (e.g., DDT, PCBs, dioxins and other chlorinated pesticides) that are stored in fatty tissues and lower concentrations of contaminants (e.g., mercury) that accumulate primarily in the muscle tissue. In contrast, the states' practice of typically analyzing fillet samples can result in higher concentrations of those contaminants that tend to concentrate in the muscle tissue and lower concentrations of those contaminants that are typically stored in fatty tissues, which are not included in a fillet sample.

(continued)



How the NCA fish tissue contaminants index differs from the fish advisory data (continued)

- The NCA analyzes fish from a variety of species from intermediate trophic levels found in estuaries and coastal marine waters; these species are often prey species for many commercially valuable predator species. In addition, the NCA analyzes both juvenile and adult fish. In contrast, state programs typically analyze only the larger marketable-sized specimens (adults) of the fish or shellfish species that are consumed by members of the local population for making fish advisory determinations. These fish species are often predators (e.g., bluefish, striped bass, king mackerel) at the top of the estuarine or coastal food web and are more likely to have bioaccumulated higher concentrations of contaminants than some of the target species sought by the NCA program.

Summary of Differences Between State Fish Consumption Advisory Programs and NCA Fish Sampling Approach

Elements	State Fish Advisory Programs	NCA
Fish species and sizes sampled	Sample marketable-sized adult fish with a focus on those species consumed by the local fish-eating population.	Samples target species (unique to each geographic region) that includes demersal or slow-moving pelagic species from intermediate trophic levels, including all sizes and ages (juveniles and adults) of fish in an ecosystem.
Type of fish samples analyzed	Analyze primarily fillet tissue samples (edible portion) to assess human health concerns. Analysis of whole-body fish or other tissue types is conducted when the local consumer's culinary preference is to eat whole fish or body parts other than the fillet sample.	Analyzes primarily whole-body samples to assess the health of the ecosystem. Some fish fillet sampling has been conducted and will be conducted in future assessments.
Number and sample types analyzed	Analyze chemical contaminant residues in both individual fish and composite samples of varying numbers of adult fish. The number of fish used per composite is set by the state conducting the analyses.	Typically analyzes chemical contaminant residues in composite samples of fish of the same species. Composite samples may contain 4 to 10 juvenile and adult fish.
Contaminants analyzed in tissues	Individual states monitor for any contaminant or suite of contaminants that are of concern to human health in a particular waterbody in their jurisdiction. The extent of analyses is often dependent on available state resources.	Monitors for a specific suite of contaminants at all sites nationally including the following: 23 PAH compounds, 21 PCB congeners, 6 DDT derivatives and metabolites, 14 chlorinated pesticides (other than DDT), and 3 metals (including mercury).
Health benchmark values used	Use EPA-recommended fish consumption advisory values to identify fish species of human health concern and to develop fish advisories.	Uses EPA-recommended fish consumption advisory values as surrogate values to assess health of the ecosystem.

National Listing of Fish Advisories

States, U.S. territories, and tribes have primary responsibility for protecting their residents from the health risks of consuming contaminated, non-commercially caught fish and shellfish. Resource managers at the state, territory, or tribal level protect residents by issuing consumption advisories for the general population, including recreational and subsistence fishers, as well as for sensitive groups (e.g., pregnant women, nursing mothers, children, and individuals with compromised immune systems). These advisories inform the public that high concentrations of chemical contaminants (e.g., mercury or PCBs) have been found in local fish and shellfish. The advisories include recommendations to limit or avoid consumption of certain fish and shellfish species from specific waterbodies or, in some cases, from specific waterbody types (e.g., all coastal waters within a state).

The 2003 NLFA is a database—available from EPA and searchable on the Internet at http://www.epa.gov/waterscience/fish—that contains fish advisory information provided to EPA by the states and tribes. The NLFA database can generate national, regional, and state maps that illustrate any combination of advisory parameters.

Beach Advisories and Closures

There is growing concern in the United States about public health risks posed by polluted bathing beaches. Scientific evidence documenting the rise of infectious diseases caused by microbial organisms in recreational waters continues to grow; however, not enough information is currently available to define the extent of beach pollution throughout the country. EPA's BEACH Program, established in 1997, is working with state and local governments to compile information on beach pollution that will help define the national extent of the problem.

From 1997 through 2002, beach monitoring data were collected and submitted to EPA on a voluntary basis. During this time, sampled areas included coastal, Great Lakes, and some inland waters. Beginning with the 2003 season, the BEACH Act required that states submit data to EPA for beaches that are in coastal and Great Lakes waters and for all other beaches, as available. Due to these new reporting requirements, the 2003 and 2004 data cannot easily be compared to data gathered from 1997 through 2002, and long-term patterns are difficult to analyze.

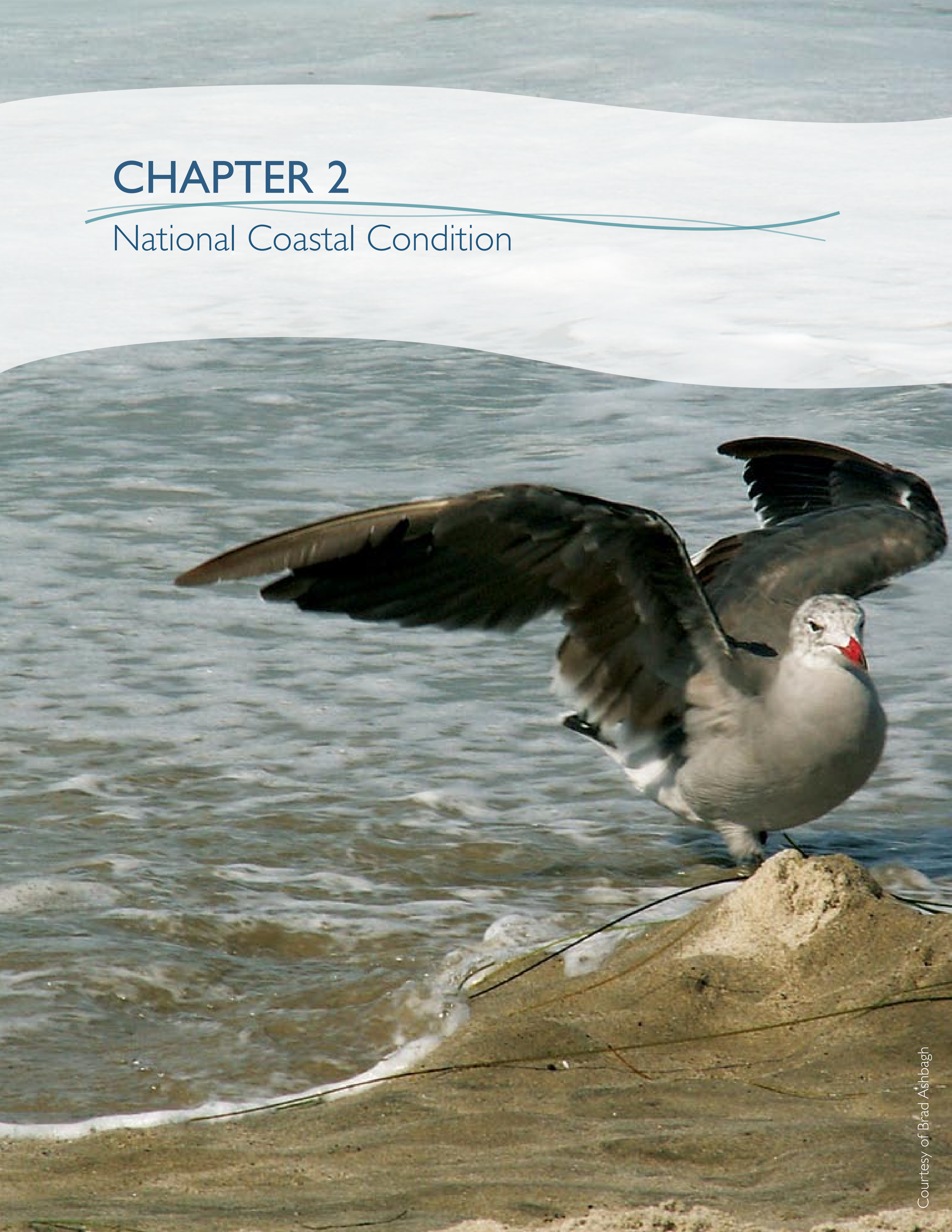
A few states have comprehensive beach monitoring programs to test the safety of water for swimming. Many other states have only limited beach monitoring programs, and some states have no monitoring programs linked directly to water safety at swimmable beaches. The number of beach closings and swimming advisories that continue to be issued annually, however, indicate that beach pollution is a persistent problem. In 2003, there were 839 beaches with at least one closure or advisory in coastal and Great Lakes waters (U.S. EPA, 2006c).

Connections with Human Uses

The first eight chapters of this report address the condition of the nation's coastal waters in terms of how well these waters meet ecological criteria. A related, but separate consideration is how well coasts are meeting human expectations in terms of the services they provide for transportation, development, fishing, recreation, and other uses. Human use does not necessarily compromise ecological condition, but there are inherent conflicts between human activities that alter the natural state of the coast (e.g., marine transportation) and activities (e.g., fishing) that rely on the bounty of nature. In Chapter 9 of this report, the emphasis is on the human uses of a particular estuary—Narragansett Bay in Rhode Island and Massachusetts—and how well these uses are met. Because this approach relies on local information, it can be pursued only at the level of an individual estuary. The corresponding chapter in the NCCR II centered on Galveston Bay, TX. The choice of Narragansett Bay is to a large extent dictated by the availability of long-term data on the abundance of commercial and recreational fish for this estuary. Fishing is not the only human use of an estuary, but it is an important use thought to be strongly connected with ecological indicators.

CHAPTER 2

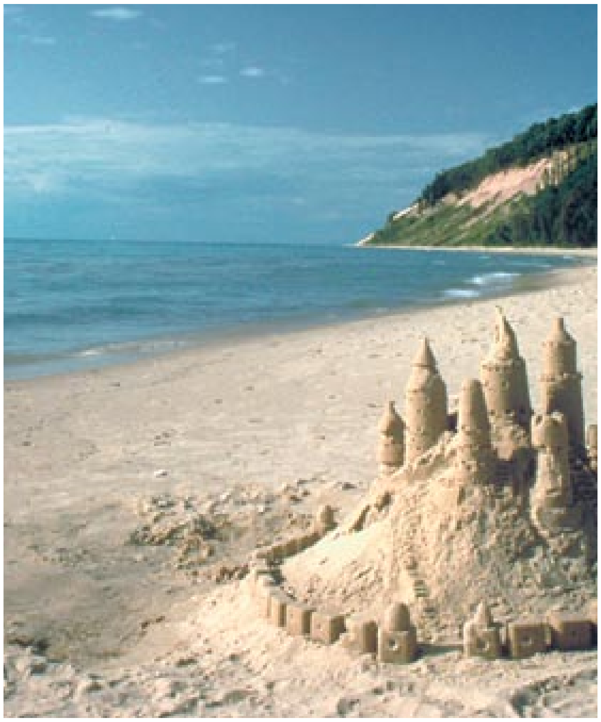
National Coastal Condition



Courtesy of Brad Ashbagh

National Coastal Condition

As shown in Figure 2-1, the overall condition of the nation's coastal waters is rated fair; the water quality index is rated good to fair; the sediment quality and fish tissue contaminants indices are rated fair; the benthic index is rated fair to poor; and the coastal habitat index is rated poor. Figure 2-2 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 between 1998 and 2002 from 2,424 sites in the coastal waters of the 24 coastal states of the conterminous United States; Hawaii; Puerto Rico; and Southcentral Alaska (Figure 2-3). About 85% of these data were collected in 2001 and 2002. Please refer to Chapter 1 for information about how these assessments were made, the criteria used to develop the rating for each index and component indicator, and the limitations of the available data.



Our nation's coastal waters are important for ecological, recreational, and economic reasons (courtesy of U.S. EPA GLNPO).

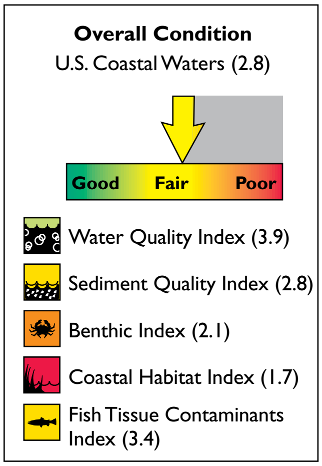


Figure 2-1. The overall condition of U.S. coastal waters is rated fair (U.S. EPA/NCA).

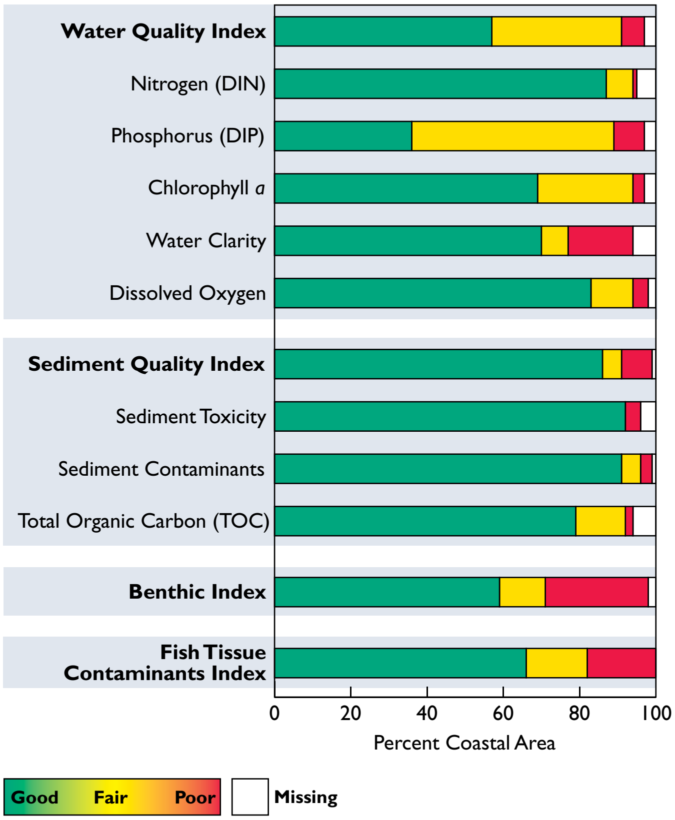


Figure 2-2. Percentage of coastal area achieving each ranking for all indices and component indicators—United States (U.S. EPA/NCA).

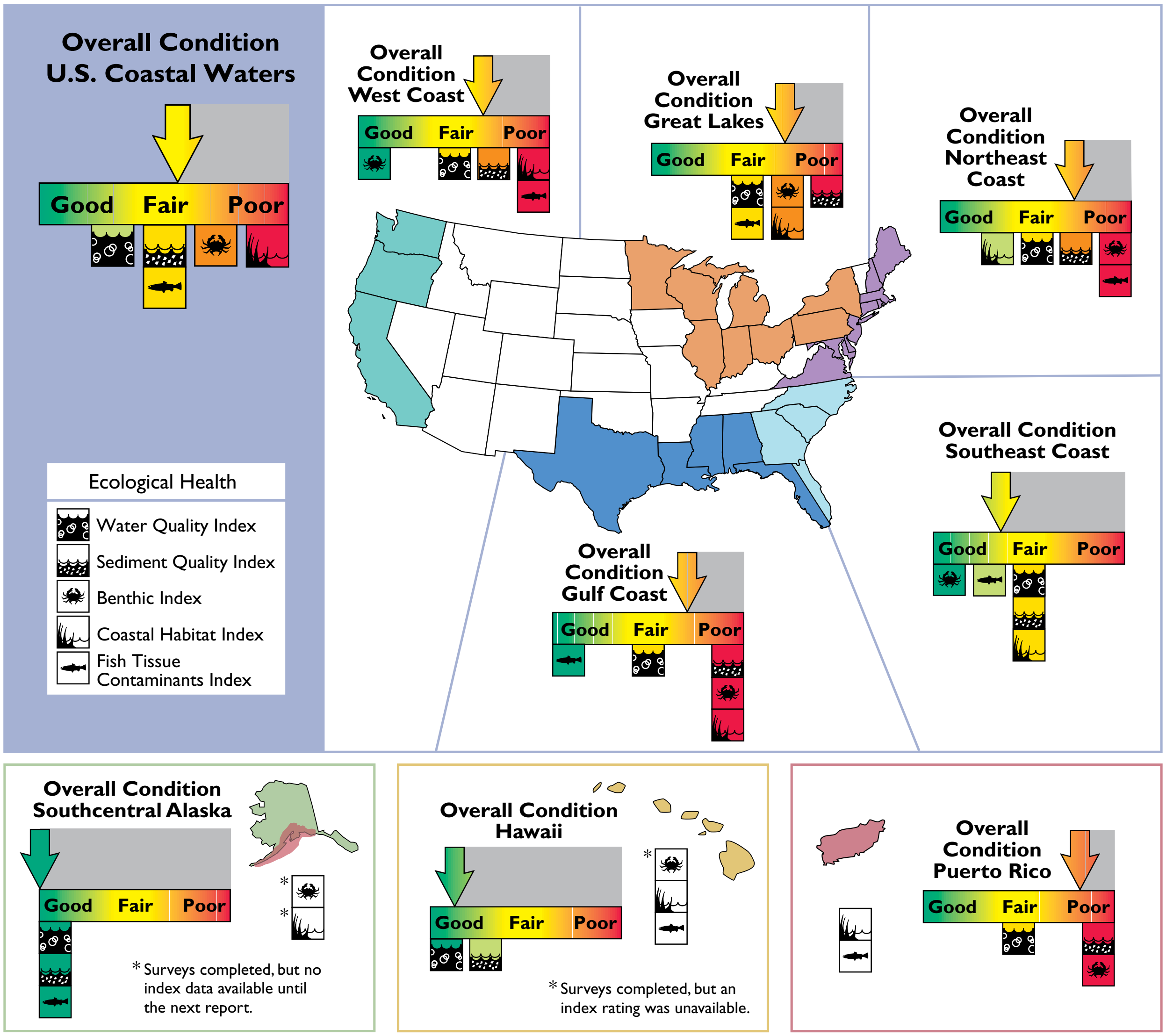
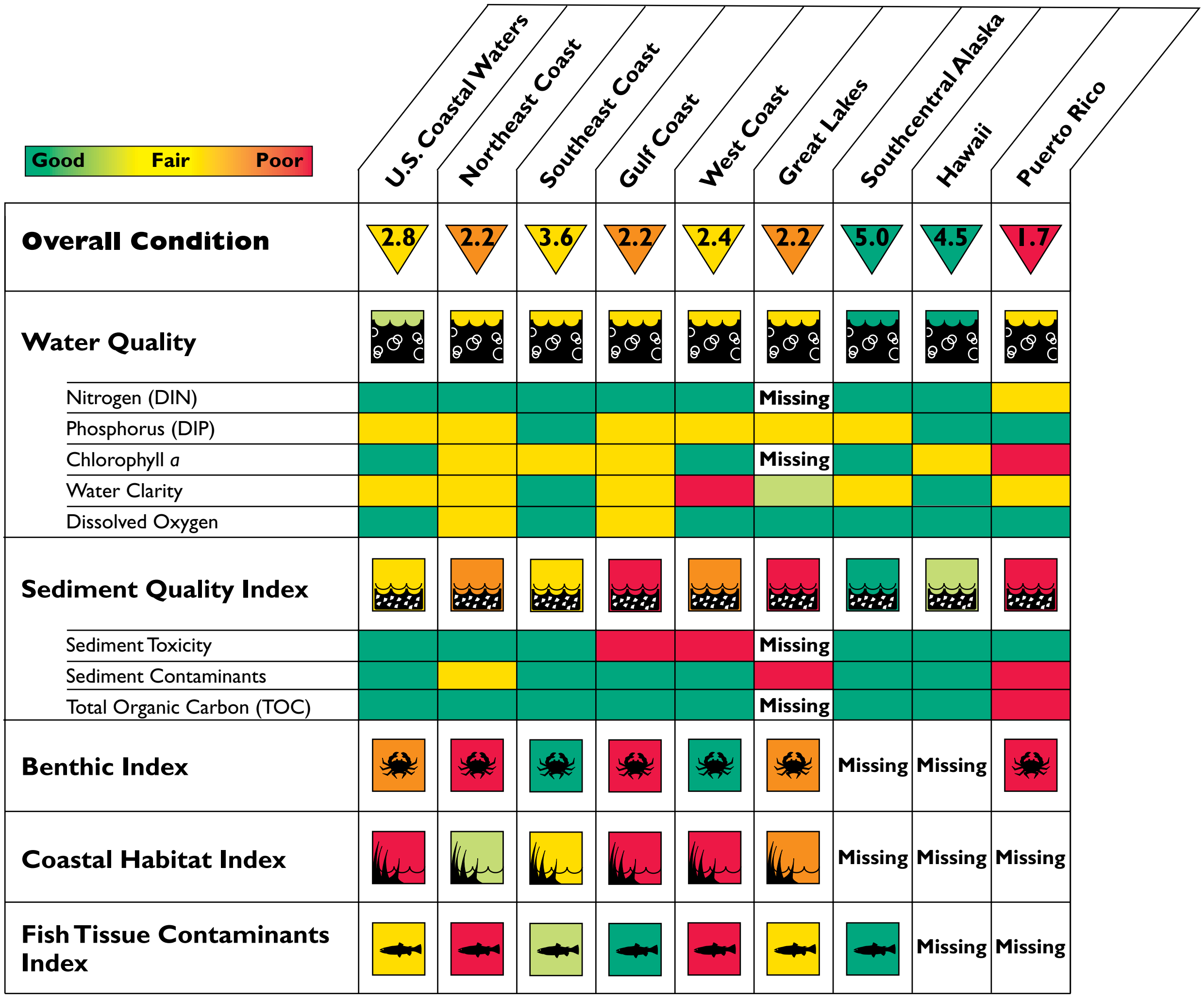


Figure 2-3. Overall national and regional coastal condition based on data collected primarily in 2001 and 2002 (U.S. EPA/NCA).

The condition of U.S. coastal waters was determined for this report by combining assessments from the Northeast Coast, Southeast Coast, Gulf Coast, Great Lakes, and West Coast regions of the conterminous United States with those from Hawaii, Puerto Rico, and Southcentral Alaska (Figure 2-3). It should be noted that the overall condition and index scores for the nation are determined using a weighted average of the regional scores, rather than the percent area rated good, fair, and poor. Southcentral Alaska and Hawaii were not included in the national assessment presented in the NCCR II (U.S. EPA, 2004a) because data were unavailable for the coastal areas of those states. A comparison of coastal condition in 2001 and 2002 based on the inclusion of data for Southcentral Alaska and Hawaii versus coastal condition with these data excluded is provided later in this chapter.



Good Fair Poor

	U.S. Coastal Waters	Northeast Coast	Southeast Coast	Gulf Coast	West Coast	Great Lakes	Southcentral Alaska	Hawaii	Puerto Rico
Overall Condition	🟨 2.8	🟧 2.2	🟨 3.6	🟧 2.2	🟨 2.4	🟧 2.2	🟩 5.0	🟩 4.5	🟥 1.7
Water Quality	🟩/🟨	🟨	🟨	🟨	🟨	🟨	🟩	🟩	🟨
Nitrogen (DIN)	🟩	🟩	🟩	🟩	🟩	Missing	🟩	🟩	🟨
Phosphorus (DIP)	🟨	🟨	🟩	🟨	🟨	🟨	🟨	🟩	🟩
Chlorophyll *a*	🟩	🟨	🟨	🟨	🟩	Missing	🟩	🟨	🟥
Water Clarity	🟨	🟨	🟩	🟨	🟥	🟩/🟨	🟨	🟩	🟨
Dissolved Oxygen	🟩	🟨	🟩	🟨	🟩	🟩	🟩	🟩	🟩
Sediment Quality Index	🟨	🟧	🟨	🟥	🟧	🟥	🟩	🟩/🟨	🟥
Sediment Toxicity	🟩	🟩	🟩	🟥	🟥	Missing	🟩	🟩	🟩
Sediment Contaminants	🟩	🟨	🟩	🟩	🟩	🟥	🟩	🟩	🟥
Total Organic Carbon (TOC)	🟩	🟩	🟩	🟩	🟩	Missing	🟩	🟩	🟥
Benthic Index	🟧	🟥	🟩	🟥	🟩	🟧	Missing	Missing	🟥
Coastal Habitat Index	🟥	🟩/🟨	🟨	🟥	🟥	🟧	Missing	Missing	Missing
Fish Tissue Contaminants Index	🟨	🟥	🟩/🟨	🟩	🟥	🟨	🟩	Missing	Missing

Figure 2-4. Overall national and regional coastal condition, 2001–2002 (U.S. EPA/NCA).

Figure 2-4 summarizes the national (including Hawaii and Southcentral Alaska) and regional condition of the nation's coastal waters. The water quality index is rated fair or good for regions throughout the nation, although the coastal waters of the West Coast region are rated poor for water clarity and the coastal waters of Puerto Rico are rated poor for chlorophyll *a*. The sediment quality index is rated poor for the Gulf Coast, Puerto Rico, and Great Lakes regions; fair to poor for the Northeast Coast and West Coast regions; fair for the Southeast Coast region; good to fair for Hawaii; and good for Southcentral Alaska. The benthic index shows that biological conditions are rated poor in the coastal waters of the Northeast Coast, Gulf Coast, and Puerto Rico regions; fair to poor in the coastal waters of the Great Lakes region; and good in the coastal waters of the West Coast and Southeast Coast regions. The fish tissue contaminants index is rated poor for the coastal waters of the Northeast Coast and West Coast regions; fair for the Great Lakes region; good to fair for the Southeast Coast region; and good for the Gulf Coast and Southcentral Alaska regions.

The population of the nation's collective coastal counties increased by 33 million people between 1980 and 2003 (Figure 2-5), constituting a 28% growth rate (Crossett et al., 2004). This growth rate matched that of the nation's total population, which increased by 63.3 million people during the same time period (U.S. Census Bureau, 2006b); however, because the land area of the nation's coasts comprises roughly 17% of the U.S. total land area, coastal population increases are frequently accompanied by larger population density increases and greater demands for limited resources (Crossett et al., 2004). Figure 2-6 shows the distribution of the U.S. coastal population in 2003.

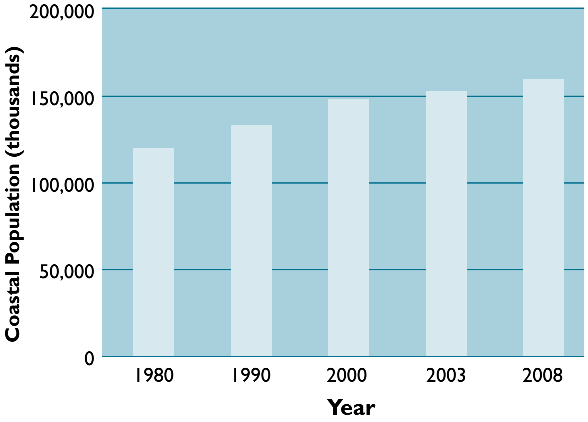


Figure 2-5. Actual and estimated population of U.S. coastal counties, 1980–2008 (Crossett et al., 2004).

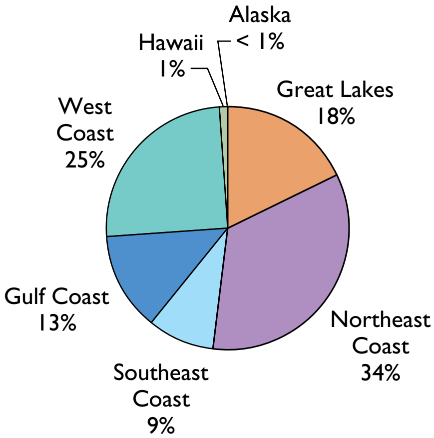


Figure 2-6. Regional distribution of the nation's coastal population in 2003 (Crossett et al., 2004).

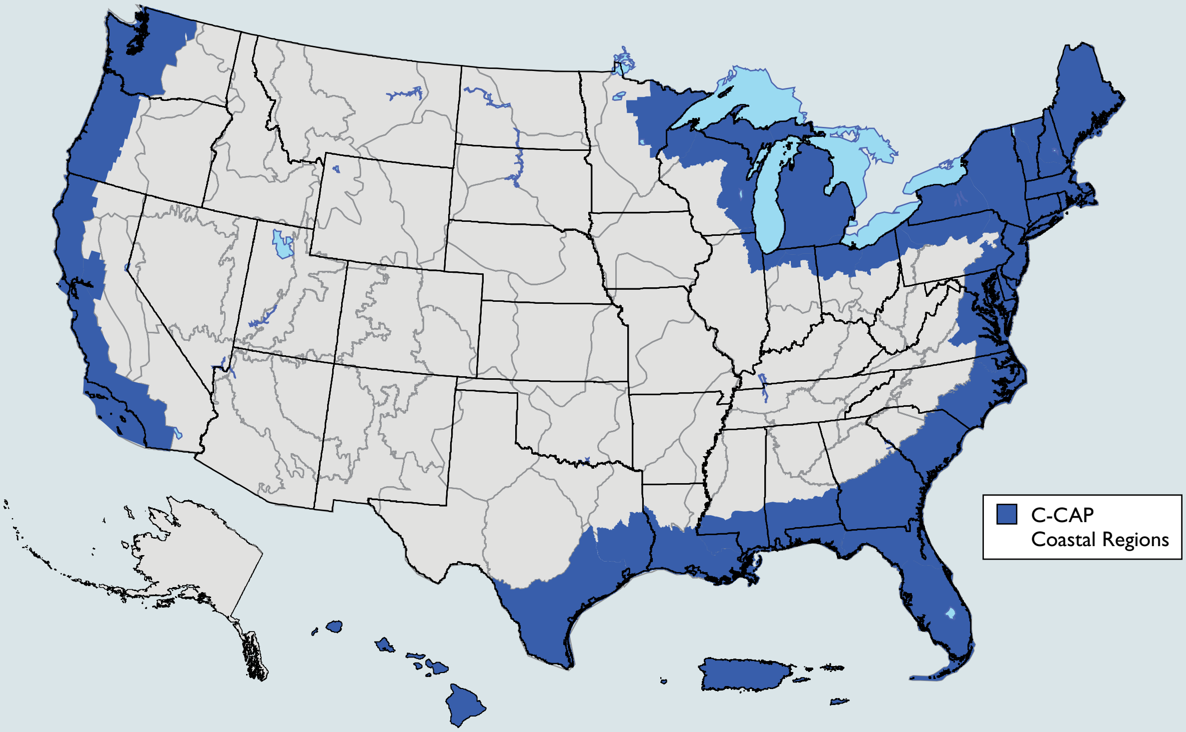
Camden Harbor, ME (courtesy of Patricia A. Cunningham).

Highlight

Monitoring Coastal Land Cover Change

Land cover information helps users gauge current conditions and plays an important role when crafting policies that direct future land-use decisions. Land cover maps document how much of a region is covered by forests, wetlands, agriculture, impervious surfaces, and other land and water types. By comparing maps from various years, users can see how the land surface has changed over time. Instead of viewing changes from the ground, parcel by parcel, users can get the entire view at once and access the information needed to assess current conditions and understand how the community or region is changing.

The National Land Cover Database (NLCD) is an example of a land-coverage data set that is used to generate land-coverage maps on different geographic scales. NLCD 2001 is a second-generation, land-coverage data set that was produced from satellite imagery by the Multi-Resolution Land Characteristics (MRLC) Consortium. The MRLC Consortium was originally created to meet the needs of several federal agencies and became a major provider of land cover information by successfully mapping the conterminous United States based upon early- to mid-1990s Landsat Thematic Mapper imagery. The continuing need for current, accurate, satellite-based information resulted in an expanded MRLC Consortium effort to produce the NLCD 2001 (Homer et al., 2004; MRLC Consortium, 2007).

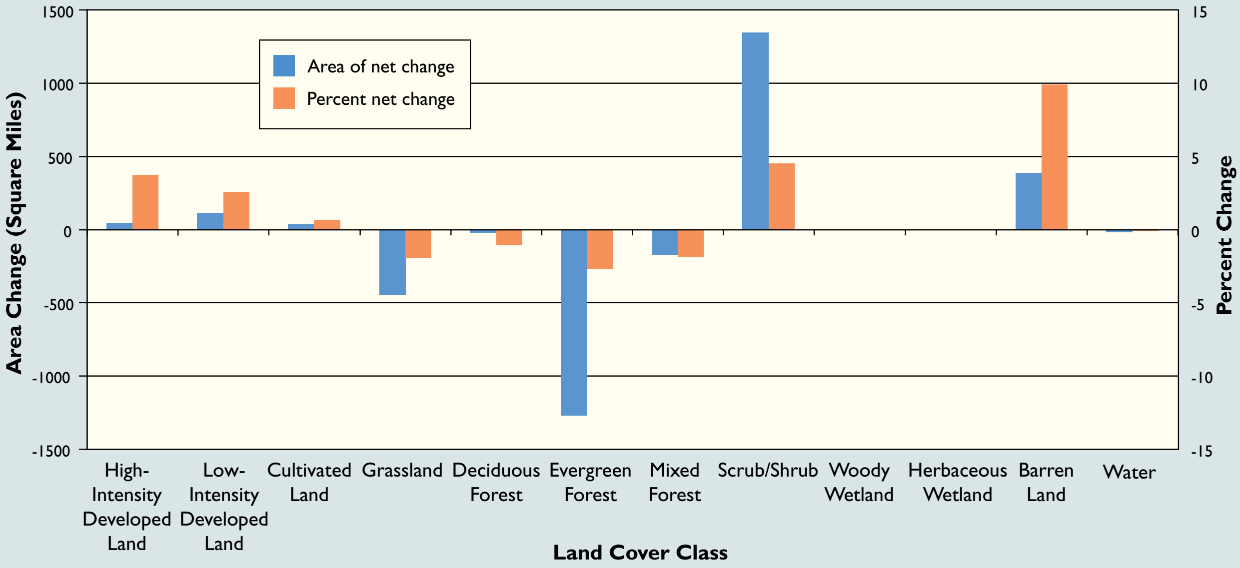


NOAA's Coastal Change Analysis Program (C-CAP) contributes land cover information for coastal regions of the United States (courtesy of NOAA).

NOAA's Coastal Change Analysis Program (C-CAP) contributes to the nationally standardized, moderate-resolution NCLD 2001 database by creating land cover information for the coastal regions of the United States (see map). C-CAP land cover products inventory coastal intertidal areas, wetlands, and adjacent uplands, with the goal of monitoring changes in these habitats on a 1- to 5-year cycle (NOAA, 1995). The program categorizes coastal lands into 29 land cover classes. Recent efforts have led to completed NLCD and C-CAP products for all of the conterminous United States and Hawaii. Additional imagery is being used to track land cover class changes in these areas through time.

For example, the figure shows how West Coast land cover has shifted among 12 land cover classes between 1996 and 2001. In terms of percentage and total area, the largest changes are associated with increases in barren land and scrub/shrub, as well as decreases in evergreen forest cover and grasslands. These changes are largely due to the forest management practices common in the Pacific Northwest and the resulting cycle of harvest and reforestation. During these practices, forests are cut for their timber, and the barren ground is colonized by grasses. The grassland subsequently develops into scrubland and eventually returns to mature forest. Between 1996 and 2001, the net loss in area of evergreen forest along the West Coast exceeded 1,000 mi^2 (NOAA, 2003b).

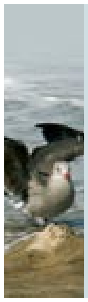
Consistent land cover information at a national scale provides data for a wide variety of analyses and applications. For example, trend information collected as part of this effort provides valuable feedback to managers on the success of policies and programs and helps users gain a better understanding of natural and human-induced changes.



Shifts in West Coast land cover classes, 1996–2001 (NOAA, 2003b).

Coastal Monitoring Data—Status of Coastal Condition

This section presents the monitoring data used to rate the five indices of coastal condition assessed in this report. These calculations do not include proportional-area and location data for the Great Lakes because, due to sampling design differences in the data sets, areal estimates for the Great Lakes cannot be determined. Although these two types of Great Lakes data are not presented in this section, the Great Lakes regional index and component indicator scores are included in the national scores. Chapter 7 provides further details of the Great Lakes monitoring data.



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

Water Quality Index

The water quality index for the nation's coastal waters is rated good to fair, with 6% of the coastal area rated poor and 34% rated fair for water quality condition (Figure 2-7). The water quality index was determined based on measurements of five component indicators: DIN, DIP, chlorophyll *a*, water clarity, and dissolved oxygen. Based on the NCA results, 40% of the nation's coastal waters experience a moderate-to-high degree of water quality degradation. Fair condition is generally characterized by degradation in water quality response variables (e.g., increased chlorophyll *a* concentrations or decreased dissolved oxygen concentrations). Although poor condition is characterized by some degradation in response variables, it is more likely to be characterized by degradation due to environmental stressors (e.g., increased nutrient concentrations or reduced water clarity). Although none of the regions outlined in this report are rated poor for water quality, the Gulf Coast region has the highest proportion of coastal area rated poor for this index (14%), followed by the Northeast Coast (13%) and Puerto Rico (9%) regions. The West Coast region has the lowest proportion of coastal area (23%) rated good for water quality.

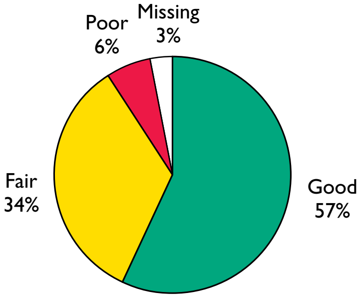


Figure 2-7. Water quality index data for the nation's coastal waters (U.S. EPA/NCA).

Nutrients: Nitrogen and Phosphorus

The nation's coastal waters are rated good for DIN concentrations, with only 1% of the coastal area rated poor. The highest percentage of coastal area rated poor for DIN concentrations occurred in the Northeast Coast (5%) region and Hawaii (5%). U.S. coastal waters are rated fair for DIP concentrations, with 8% of the coastal area rated poor for this component indicator and 53% of the area rated fair. Elevated DIP concentrations were most often observed in the coastal waters of the Gulf Coast region (22%).

Chlorophyll a

The nation's coastal waters are rated good for chlorophyll *a* concentrations, with 3% of the coastal area rated poor and 25% of the area rated fair for this component indicator. Puerto Rico was the only region of the country rated poor for chlorophyll *a* concentrations, with 71% of the region's coastal area rated fair and poor (combined) for this component indicator. Other regions with significant percentages of area rated fair and poor (combined) for chlorophyll *a* concentrations were the Southeast Coast (59%) and Gulf Coast (52%) regions. With the exception of Puerto Rico, none of the regions experienced large expanses of poor condition for chlorophyll *a* concentrations (Hawaii = 13%, Northeast Coast = 9%, Southeast Coast = 9%, and Gulf Coast = 7%).

Criteria for a Poor Rating (Percentage of Ambient Surface Light That Reaches a Depth of 1 Meter)	Coastal Areas
< 5%	Areas having high natural levels of suspended solids in the water (e.g., Louisiana, Delaware Bay, Mobile Bay, Mississippi) or extensive wetlands (e.g., South Carolina, Georgia).
< 20%	Areas having extensive SAV beds (e.g., Florida Bay, Indian River Lagoon, Laguna Madre) or desiring to reestablish SAV (e.g., Tampa Bay).
< 10%	The remainder of the country.

Water Clarity

The nation's coastal waters are rated fair for water clarity, with 17% of the U.S. coastal area rated poor for this component indicator. Sites with poor water clarity are distributed throughout the country, but the regions with the greatest proportion of total coastal area rated poor are the West Coast (36%), Gulf Coast (22%), Northeast Coast (20%), and Puerto Rico (20%) regions. Three different reference conditions were established for measuring water clarity conditions in U.S. coastal waters (see Chapter 1 for additional information). The box above shows the criteria for rating a site in poor condition for water clarity in estuary systems with differing levels of natural turbidity.

Dissolved Oxygen

Dissolved oxygen conditions in the nation's coastal waters are rated good, with 4% of the coastal area rated poor and 11% rated fair for this component indicator. The Northeast Coast region showed the greatest proportion of coastal area (9%) experiencing low dissolved oxygen concentrations.

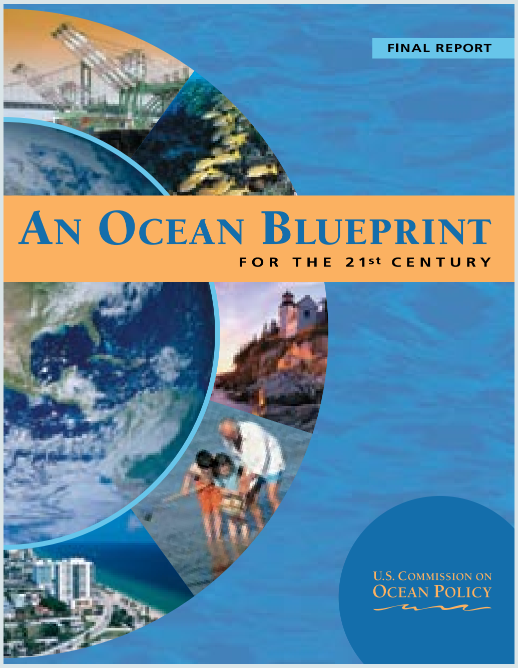
The NCA measures dissolved oxygen conditions only in nearshore coastal waters and does not include observations of dissolved oxygen concentrations in offshore coastal shelf waters. The Gulf of Mexico hypoxic zone is the largest zone of anthropogenic coastal hypoxia in the Western Hemisphere (CAST, 1999), and the occurrence of hypoxia in Gulf of Mexico shelf waters is a well-known and documented phenomenon. Between 1989 and 1999, the mid-summer hypoxic zone in Gulf of Mexico bottom waters steadily increased in area to include nearly 8,000 mi^2. In 2000, the hypoxic zone decreased in area to less than 1,800 mi^2; however, the zone returned to about 8,000 mi^2 in area in 2001 and 2002 (the years covered by NCA surveys in this report). The reduction in the size of the hypoxic zone in 2000 corresponds to severe drought conditions in the Mississippi River watershed and, presumably, to decreased flow and loading to the Gulf of Mexico from the river mouth. The long-term (1985–2005) average area of the Gulf of Mexico hypoxic zone is 4,800 mi^2. A more complete discussion of the Gulf of Mexico hypoxic zone is provided in Chapter 5 of this report, *Gulf Coast Coastal Condition*.

Interpretation of Instantaneous Dissolved Oxygen Information

Although the NCA results do not suggest that dissolved oxygen concentrations are a pervasive problem, the instantaneous measurements on which these results are based may have underestimated the magnitude and duration of low dissolved oxygen events at any given site. Longer-term observations by other investigators have revealed increasing trends in the frequency and areal extent of low-oxygen events in some coastal areas. For example, extensive year-round or seasonal monitoring data over multiple years in such places as North Carolina's Neuse and Pamlico rivers and Rhode Island's Narragansett Bay have shown a much higher incidence of hypoxia than is depicted in the present NCA data (Paerl et al., 1998; Bergondo et al., 2005; Deacutis et al., 2006). These data show that while hypoxic conditions do not exist continuously, they can occur occasionally to frequently for generally short durations of time (hours).

Highlight

A National Water Quality Monitoring Network for U.S. Coastal Waters and Their Tributaries



The annual cost of water quality monitoring in U.S. coastal waters and their tributaries is hundreds of millions of dollars. Yet, in recent years, numerous reports have indicated that water quality monitoring has been and remains insufficient and lacks coordination to provide comprehensive information about U.S. water resources. In 2004, the U.S. Commission on Ocean Policy recommended a national monitoring network to improve management of coastal resources (U.S. Commission on Ocean Policy, 2004a). In response, the Administration produced a *U.S. Ocean Action Plan* (CEQ, 2004), which included a proposal for the creation of a National Water Quality Monitoring Network as a key element for advancing our understanding of the oceans, coasts, and the Great Lakes. The network was designed by the National Water Quality Monitoring Council on behalf of the Advisory Committee on Water Information and in response to a request from the Council on Environmental Quality and two subcommittees of the National Science and Technology Council (NWQMC, 2006). Pilot-scale demonstrations of the proposed network are currently underway in select areas of the country (USGS, 2006a).

The proposed national water quality monitoring network for U.S. coastal waters and their tributaries (the “Network”) shares many attributes with ongoing monitoring efforts, but is unique in that it uses a multidisciplinary approach to address a broad range of resource components, from upland watersheds to offshore waters. Specifically, the proposed Network has several key design features, including the following:

- Clear objectives linked to important management questions
- Linkage with the IOOS
- Integration of water resource components from uplands to the coast, including physical, chemical, and biological characteristics of water resources
- Flexibility in design over time
- Importance of metadata, QA procedures, comparable methodology, and data management that allow readily accessible data storage and retrieval.

This initial design of the proposed Network focuses on U.S. coastal waters and estuaries. Of the 149 estuaries included in the proposed Network design, 138 are in the conterminous United States and represent more than 90% of the total surface area of conterminous U.S. estuaries and over 90% of the total freshwater inflow. The sampling scheme for these estuaries includes the following:

(1) probability-based sampling of estuaries in each IOOS region (see map) to determine the environmental condition of individual estuaries, (2) targeted and flexible sampling to address estuary-specific resource management issues and to determine temporal trends of selected parameters, and (3) selection of sampling sites to determine short-term variability in parameters of interest, using moored, automated sensors. For nearshore waters and the Great Lakes, the proposed Network design calls for probability-based sampling supplemented with additional observations from shipboard surveys, satellite-mounted and aerial sensors, shore-based sensors, and autonomous underwater vehicles. Shipboard sampling and remote sensing will help to monitor the oceanic regime (NWQMC, 2006).

River monitoring is focused on sampling rivers that (1) represent 90% of the outflow of major inland watersheds, (2) flow directly into Network estuaries, and (3) flow directly into the Great Lakes and drain watersheds greater than 250 mi^2 in area. Network river monitoring will allow calculation of seasonal and annual fluxes of freshwater and loads of constituents from the uplands to coastal marine waters and the Great Lakes (NWQMC, 2006).

Physical, chemical, and biological constituents are to be monitored throughout the Network. Information about specific constituents to be monitored for each resource type; recommended monitoring frequencies; data management, comparability, storage, and access; metadata standards; and quality assurance/quality control (QA/QC) considerations are discussed in the Network report (NWQMC, 2006). The Network report and appendices are available at http://acwi.gov/monitoring/network/design.

Integrated Ocean Observing System geographic regions (Ocean. US, 2005b).

Sediment Quality Index

The sediment quality index for the nation's coastal waters is rated fair, with approximately 8% of the coastal area rated poor for sediment quality condition (Figure 2-8). The sediment quality index is based on measurements of three component indicators: sediment toxicity, sediment contaminants, and sediment TOC. The region showing the largest proportional area with poor sediment quality was Puerto Rico (61%), followed by the Gulf Coast (18%), West Coast (14%), and Northeast Coast (13%) regions. Although there are no areal estimates for poor sediment condition in the Great Lakes region (see Chapter 7 for more information), local, non-probabilistic surveys of that region resulted in a sediment quality index rating of poor. Hawaii and Southcentral Alaska were the only regions that were rated good or good to fair for sediment quality condition.

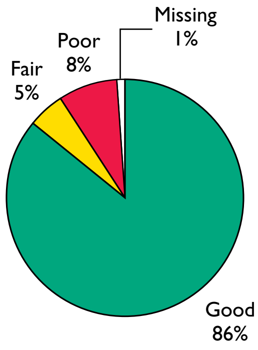


Figure 2-8. Sediment quality index data for the nation's coastal waters (U.S. EPA/NCA).

Sediment Toxicity

The sediment toxicity component indicator for the nation's coastal waters is rated good, with 4% of the U.S. coastal area rated poor for this component indicator. Sediment toxicity was observed most often in sediments of the West Coast (17%) and Gulf Coast (13%) regions.

Sediment Contaminants

The sediment contaminants component indicator for the nation's coastal waters is rated good. Poor sediment contaminant condition was observed in 3% of the coastal area, and fair condition was observed in an additional 5% of the coastal area. The highest proportion of area rated poor for sediment contaminants occurred in Puerto Rico (23%), followed by the Northeast Coast (9%) region. Although there are no areal estimates for poor sediment contaminant condition in the Great Lakes region, local, non-probabilistic surveys of that region produced results indicating a poor rating for this component indicator.

Sediment TOC

The nation's coastal waters are rated good for sediment TOC concentrations, with only 2% of the U.S. coastal area rated poor for this component indicator. The only region rated poor for this component indicator was Puerto Rico, where coastal sediments showed high levels of TOC in 44% of the coastal area.

Benthic Index

The benthic index for the nation's coastal waters is rated fair to poor, with 27% of the nation's coastal area rated poor for benthic condition (i.e., the benthic communities have lower-than-expected diversity, are populated by greater-than-expected pollution-tolerant species, or contain fewer-than-expected pollution-sensitive species, as measured by multi-metric benthic indices) (Figure 2-9). The regions with the greatest proportion of coastal area in poor benthic condition were the Gulf Coast (45%), Puerto Rico (35%), and Northeast Coast (27%) regions. The Southeast Coast and West Coast are the only regions where benthic condition was rated good. Data were unavailable to assess the integrity of benthic communities in Southcentral Alaska and Hawaii.

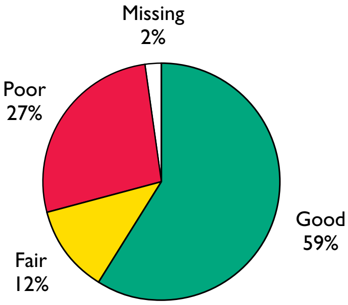
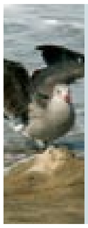


Figure 2-9. Benthic index data for the nation's coastal waters (U.S. EPA/NCA).



The coastal habitat index value is the average of the mean long-term, decadal loss rate of coastal wetlands (1780–1990) and the present decadal loss rate of coastal wetlands (1990–2000).

Coastal Habitat Index

The coastal habitat index ratings outlined in this report are the same as those reported in the NCCR II because more recent data on coastal habitat conditions were unavailable for this report. Although the loss of wetland habitats in the United States has been significant over the past 200 years, only small losses of coastal wetlands were documented from 1990 to 2000. Table 2-1 shows the change in wetland acreage from 1990 to 2000; the mean long-term, decadal loss rate of coastal wetlands from 1780 to 1990; and the coastal habitat index value for each region and the nation (including and excluding Alaska). It should be noted that coastal wetland acreages for Puerto Rico and Hawaii were unavailable in 2000, and the Great Lakes region was assessed using different methods. Also, the coastal wetland data presented in Table 2-1 for Alaska were for the entire state. Data for Southcentral Alaska were unavailable as a separate data set; therefore, a coastal habitat index score and rating for Southcentral Alaska could not be determined. In order to be consistent with the national coastal condition ratings for the other indices, the national coastal habitat rating is based on data for the conterminous United States and excludes the data from Alaska, Hawaii, Puerto Rico, and the Great Lakes region.

Table 2-1. Changes in Marine and Estuarine Wetlands, 1780–1990 and 1990–2000 (Dahl, 1990; 2003)

Coastline or Area	Area 1990 (acres)	Area 2000 (acres)	Change 1990–2000 (acres) (%)	Mean Decadal Loss Rate 1780–1990	Index Value
Northeast Coast	452,310	451,660	-650 (0.14%)	1.86%	1.00
Southeast Coast	1,107,370	1,105,170	-2,200 (0.20%)	1.91%	1.06
Gulf Coast	3,777,120	3,769,370	-7,750 (0.21%)	2.39%	1.30
West Coast	320,220	318,510	-1,710 (0.53%)	3.26%	1.90
Conterminous U.S. Coast (excluding Great Lakes region)	**5,657,020**	**5,644,710**	**-12,310 (0.22%)**	**2.30%**	**1.26**
Alaska	2,132,900	2,132,000	-900 (0.04%)	0.05%	0.05
Hawaii	31,150	No data	—	0.06%	—
Puerto Rico	17,300	No data	—	—	—
U.S. Coast (conterminous United States and Alaska)	**7,838,370**	**7,825,160**	**-13,210 (0.17%)**	**1.25%**	**0.71**

Highlight

Science-based Coastal Habitat Restoration

Restoration is the process of reestablishing a self-sustaining habitat that, in time, can evolve to closely resemble a natural condition in terms of structure and function (Turner and Steever, 2002). The five key elements necessary for successful restoration include the following:

- Reinstatement of ecological processes
- Integration with the surrounding environment
- Development of a sustainable, resilient system
- Re-creation of the historic type of physical habitat that may not always result in the historic biological community structure
- Development of a planning process with specific project goals and performance standards for measuring achievement of restoration goals (Society of Wetland Scientists, 2000).

SCIENCE FOR SOLUTIONS

NOAA COASTAL OCEAN PROGRAM
Decision Analysis Series No. 23, Volume 2

SCIENCE-BASED RESTORATION MONITORING OF COASTAL HABITATS

Volume Two: Tools for Monitoring Coastal Habitats

Gordon W. Thayer
Teresa A. McTigue
Ronald J. Salz
David H. Merkey
Felicity M. Burrows
Perry F. Gayaldo

April 2005

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL OCEAN SERVICE
NATIONAL CENTERS FOR COASTAL OCEAN SCIENCE
CENTER FOR SPONSORED COASTAL OCEAN RESEARCH

Researchers observe the progress at a restoration site in Palmetta Estuary, Manatee County, FL (courtesy of Mark Sramek, NOAA).

Habitat restoration is a relatively new science. Early restoration efforts frequently took a shotgun approach, with limited planning and limited or no monitoring of project results. Unfortunately, these efforts had limited success. The philosophy seemed to be that if a project was completed, nature would ensure that the newly reestablished habitat would persist, all the component parts would reappear independently, and the habitat would be wholly functional again. However, in recent years, there have been many advances in the design of restoration projects, the setting of project goals, and the scientific approach to research and monitoring of these projects (Thayer and Kentula, 2005). Stakeholder involvement, appropriate goal setting, and science-based monitoring are critical to the success of both small- and large-scale restoration projects. Restoration monitoring contributes to our understanding of complex ecological systems. Monitoring is also essential in documenting restoration performance and adapting project designs based on performance, which should lead to more effective restoration project results (Thayer et al., 2003; 2005).

The book *Science-Based Restoration Monitoring of Coastal Habitats* (Thayer et al., 2003) lays out the steps for a scientifically based restoration monitoring plan that includes the following:

- Identification of project goals
- Collection of information on similar restoration projects to aide in maximizing efficiency of approaches
- Identification and description of the habitats within the area
- Identification of the basic structural and functional characteristics for those habitat types
- Consultation with experts (e.g., hydrologists, soils experts, botanists, ecologists)
- Development of hypotheses regarding the trajectories of restoration development and recovery
- Collection of historical data for the area
- Selection of reference sites that can be used to evaluate restoration progress
- Agreement on the length of time the project will be monitored
- Selection of monitoring techniques to be used
- Design of a monitoring review and revision process
- Development of a cost estimate for implementation of the monitoring plan.

The incorporation of a scientific approach into the design of the restoration monitoring plan will provide for more successful habitat restoration (Turner and Steever, 2002) and incorporate the five elements considered essential by the Society of Wetland Scientists (2000).

Understanding of the value of restoring degraded and damaged habitats has increased in the past decade, and the U.S. Congress recognized this growing interest through the Estuary Restoration Act, Title 1 of the Estuaries and Clean Waters Act of 2000. Over time, better techniques have been developed, results of restoration have been more successful, and statistical rigor has been applied to both restoration and monitoring activity. Additionally, it has become increasingly evident that decisions regarding habitat restoration cannot be made entirely by using ecological parameters alone, but must involve consideration of the effects on and benefits to humans (Thayer et al., 2005).

A soil conservation technician examines sea oats recently planted to stabilize erosion during hurricanes and severe storms (courtesy of Bob Nichols, Natural Resources and Conservation Service [NRCS]).

From 1990 to 2000, the conterminous United States lost approximately 12,310 acres of coastal wetlands (exclusive of the Great Lakes region), resulting in a loss rate of about 0.2%. Averaging this recent rate of decadal wetland loss with the mean long-term decadal loss rate (2.3%) results in a coastal habitat index value of 1.26 and a rating of poor for the nation's coastal waters. The largest index values were seen in the West Coast (1.90) and Gulf Coast (1.30) regions, which are both rated poor. Because Gulf Coast wetlands constitute two-thirds of the coastal wetlands of the conterminous United States, and the Gulf Coast coastal habitat index value is high, the overall national rating for the coastal habitat index is poor (index value of 1.26). For the Great Lakes region, researchers used other measurement approaches to assess wetland losses and rated this region as fair to poor for coastal habitat condition. Figure 2-10 compares the national and regional percentages of wetlands lost.

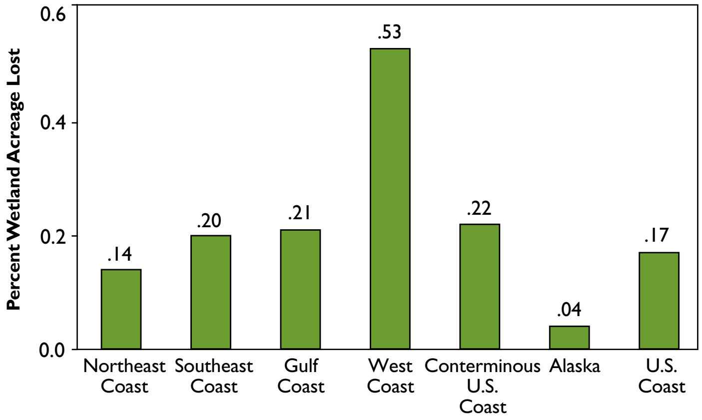


Figure 2-10. Percentage of wetland area loss, 1990–2000 (Dahl, 2003).

Fish Tissue Contaminants Index

The fish tissue contaminants index for the nation's coastal waters is rated fair. Figure 2-11 shows that 18% of all stations where fish were caught demonstrated contaminant concentrations in fish tissues above EPA Advisory Guidance values and were rated poor. The NCA examined whole-body composite samples (typically 4 to 10 fish of a target species per station) for specific contaminants from 1,277 stations throughout the coastal waters of the United States (excluding Hawaii and Puerto Rico). To standardize sampling methods across the United States and to coordinate the fish sampling when other NCA coastal samples were collected each year and across sampling years, the fish and shellfish that were collected were typically demersal (bottom-dwelling) and slower-moving pelagic (water-column-dwelling) species, usually smaller, younger juveniles. While the fish caught and analyzed may not exhibit commercial-grade consumable qualities, they do represent intermediate trophic-level (position in the food web) species that serve as prey for larger fish that may be of commercial size and value. Fish and shellfish analyzed included Atlantic croaker, white perch, catfish, flounder, scup, blue crab, lobster, shrimp, whiffs, mullet, tomcod, spot, weakfish, halibut, soles, sculpins, sanddabs, bass, and sturgeon. Stations in poor and fair condition were dominated by samples with elevated concentrations of total PCBs, total DDT, total PAHs, and mercury. In the Northeast Coast region, 31% of the fish samples analyzed were rated poor for fish tissue contaminant levels and 28% were rated fair (the Northeast Coast showed poor or fair condition for more than 50% of the fish samples analyzed). Southcentral Alaska and the Gulf Coast region were the only regions that received good ratings for the fish tissue contaminants index.

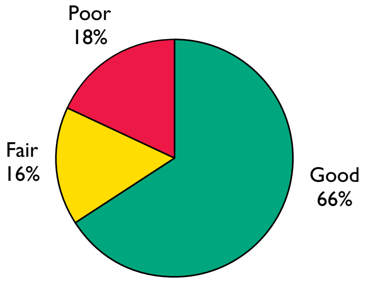


Figure 2-11. Fish tissue contaminants index data for the nation's coastal waters (U.S. EPA/NCA).

National Coastal Condition, Excluding Alaska and Hawaii

A sampling survey of the ecological condition of Alaska's coastal resources in the southcentral region of the state was completed in 2002, the results of which are included in this report. The southcentral region of Alaska is referred to as the Alaskan Province and includes Prince William Sound and Cook Inlet. This portion of Alaska encompasses 21,562 mi^2, or 35% of the total U.S. coastal area surveyed for this report. The national coastal condition scores and ratings represent areally weighted averages of the regional scores; because they encompass 35% of the total coastal area, the condition of Southcentral Alaska's coastal waters has a major influence on the nation's overall condition and index scores. In contrast, the area of Hawaii's estuaries and coastal embayments is 98 mi^2, or less than 1% of the total coastal area of the United States; therefore, estimates of the condition of Hawaii's coastal waters have little influence on the national scores.

For this report, the condition of U.S. coastal waters was determined by combining regional assessments, including assessments of Hawaii, Southcentral Alaska, and Puerto Rico. The NCCR II did not include Alaska or Hawaii in its national assessment because data were not available for the coastal waters of those states. The following assessment provides a comparison of the overall condition and index scores for the nation from 2001 to 2002, including data for Southcentral Alaska and Hawaii, to scores based only on data for the conterminous United States and Puerto Rico.

California beach (courtesy of Brad Ashbaugh).

Highlight

Assessing Coastal Watershed Conditions in the National Parks

The National Park System includes more than 5,100 miles of coast, including coral reefs, barrier islands, kelp forests, estuaries, and other resources in over three million acres of ocean and Great Lakes waters. Recognized for their beauty and national significance, these parks provide recreational opportunities, havens for ocean wildlife, and economic benefits to local communities. The National Park Service (NPS) is charged with conserving the natural and cultural resources within parks that are unimpaired for the enjoyment of current and future generations. To achieve its mission, the NPS must increase its scientific understanding of coastal park conditions, evaluate threats, and pursue solutions to known resource problems. The NPS Coastal Watershed Condition Assessment (CWCA) Program is providing scientific assessments of resource conditions in the coastal parks to address these needs.

Status of CWCA Program assessments as of June 2007 (courtesy of NPS).

Example Stressor Matrix Table Showing the Potential for the Degradation of Natural Resources in Kaloko Honokohau National Historical Park, HI (Hoover and Gold, 2005).

Stressor	Anchialine Pools	Kaloko Pond	Wetlands	Intertidal	Coastal Waters
Nutrients	PP*	PP	OK*	OK*	OK*
Fecal bacteria	OK*	OK*	OK*	OK*	OK*
Dissolved oxygen	OK	OK*	OK*	OK*	OK*
Metals	OK*	OK*	OK*	OK*	PP*
Toxic compounds	PP*	PP*	PP*	OK*	OK*
Increased temperature	OK	OK	OK*	OK*	PP*
Reduced GW flux	PP*	PP*	PP*	OK*	OK*
Fish/shellfish harvest	PP*	OK*	OK*	PP	OK*
Invasive species	EP*	EP*	EP	PP*	PP*
Physical impacts	OK	OK	OK	OK	OK*
Sea-level rise	PP	OK	OK	PP	OK
Sound pollution	OK*	OK*	PP*	PP*	PP*
Light pollution	PP*	OK*	OK*	OK*	PP*

EP – existing problem, PP – potential problem, OK – not currently or expected to be a problem
*Limited data.

NPS works closely with scientists from universities to review and synthesize existing information to determine the status of coastal park resources and condition indicators, including water quality, habitat condition, invasive and feral species, extractive uses, physical impacts from resource use and coastal development, and other issues affecting water resource health. Beginning in 2006, the assessments for the remaining parks were expanded to evaluate the condition of upland natural resources within coastal park boundaries. The NPS Water Resources Division (WRD) plans to complete assessments of 55 ocean and Great Lakes parks, utilizing expertise in physical and biological sciences, including oceanography, water quality, marine and estuarine sciences, and geographic information systems (GIS).

As of 2007, WRD has completed assessments of 23 ocean and Great Lakes parks (see map) characterizing the relative health or status of natural resources, revealing factors that may cause impairment, clarifying needs for field studies, and identifying the information gaps that hinder efforts to address resource problems or more fully evaluate conditions. These assessments include the development of stressor matrix tables, which are being included in each report (see table). These tables are useful summaries of known and potential stressors and will be used to provide a regional summary of the condition of the NPS coastal units by cross-walking with the EPA NCA regional scorecards.

WRD is providing the CWCA reports to help guide resource management planning and support the development of Vital Signs Monitoring Plans. These reports could be used to guide more intensive efforts aimed at further explaining known park problems, identifying pollution sources or other resource stressors, and developing restoration or cooperative watershed management strategies in parks and across the nation. The NPS plans to work collaboratively with programs such as the NCA, as well as with federal, state, and local agencies; watershed councils; landowners; and other community stakeholders, to address issues cooperatively on a local watershed or regional oceanographic scale. Copies of completed coastal watershed condition assessments may be found at http://www.nature.nps.gov/water/watershed_reports/WSCondRpts.htm. For more information, contact Kristen Keteles by phone at (303) 969-2342 or via email at Kristen_Keteles@partner.nps.gov.

The overall condition of U.S. coastal waters is rated fair whether or not data for Southcentral Alaska and Hawaii are included in the assessment; however, excluding data for Southcentral Alaska and Hawaii reduces the nation's overall condition score from 2.8 to 2.3, as shown in Figure 2-12. Figure 2-13 provides a summary of the percentage of conterminous U.S. coastal area in good, fair, poor, or missing categories for each index and component indicator. Removing Southcentral Alaska and Hawaii from the national score calculations primarily affects the assessments for the water quality and sediment quality indices. The water quality index score is 3.9 (rated fair to good) for U.S. coastal waters when data for Southcentral Alaska and Hawaii are included, but this score decreases to 3.3 (rated fair) if data for Southcentral Alaska and Hawaii are excluded. The sediment quality index score is 2.8 (rated fair) for U.S. coastal waters when data for Southcentral Alaska and Hawaii are included, but this score decreases to 1.6 (rated poor) when these data are excluded. Benthic and coastal habitat indices were unavailable for Southcentral Alaska and Hawaii, so these scores do not change. Fish tissue contaminant data were available for Southcentral Alaska, but not for Hawaii. The condition rating for the fish tissue contaminants index is fair regardless of whether Southcentral Alaska data were included, but the actual score changed from 3.4 (including Southcentral Alaska data) to 2.9 (excluding Southcentral Alaska data).

The estuaries and coastal embayments of Hawaii represent less than 1% of the nation's coastal area (courtesy of James P. McVey, NOAA).

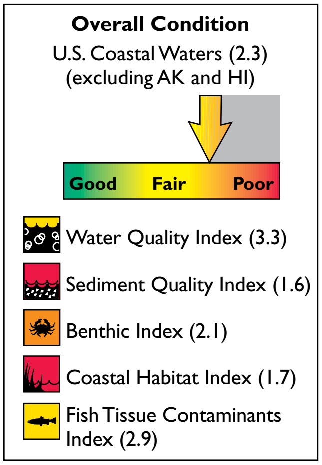


Figure 2-12. The overall condition of U.S. coastal waters (excluding Southcentral Alaska and Hawaii) is fair (U.S. EPA/NCA).

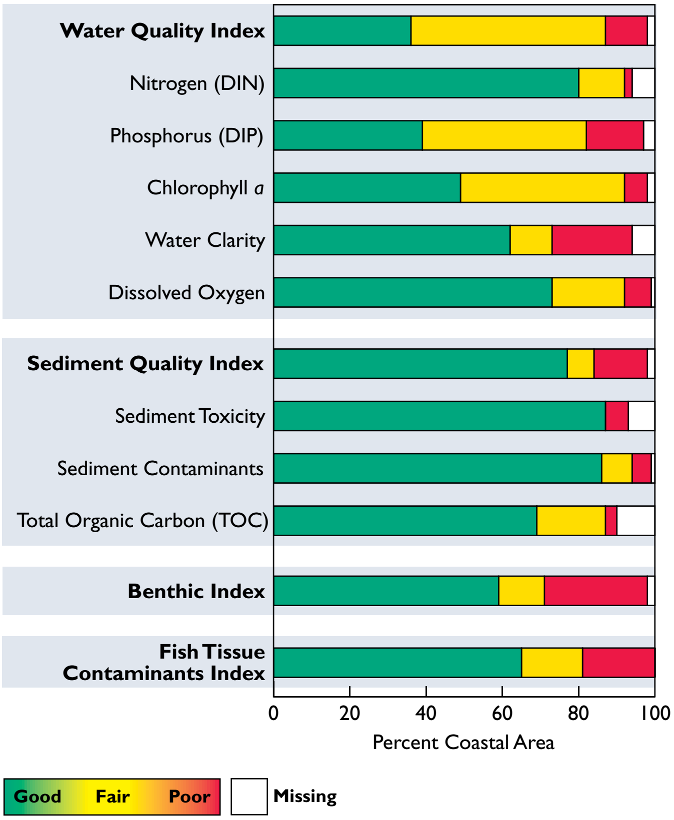


Figure 2-13. Percentage of estuarine area receiving each ranking for all indices and component indicators—United States (excluding Southcentral Alaska and Hawaii) (U.S. EPA/NCA).

Trends of Coastal Monitoring Data—United States

Coastal condition for the United States has been estimated since 1991, when both the Virginian and Louisianian provinces (Figure 2-14) were first surveyed concurrently. Annual surveys of coastal condition were conducted in the Virginian Province from 1990 through 1993 and 1997 through 1998; in the Louisianian Province from 1991 through 1994; in the Carolinian Province from 1995 through 1997; and in the West Indian Province in 1995. Beginning in 2000, the coastal waters of all regions of the United States (exclusive of Alaska, Hawaii, and the Island Territories) have been surveyed and assessed annually. In 2001, the NCCR I was produced and included information for the period 1990 through 1996 from the Virginian, Carolinian, West Indian, and Louisianian provinces (the Acadian, Californian, and Columbian provinces; Island Territories; Alaska; and Hawaii were largely excluded from this report). In 2004, the NCCR II included an assessment of all of the coastal ecosystems in the conterminous United States and Puerto Rico for the period 1997 through 2000. This NCCR III provides an assessment of the entire continental United States, Southcentral Alaska, Hawaii, and Puerto Rico for the years 2001 and 2002.

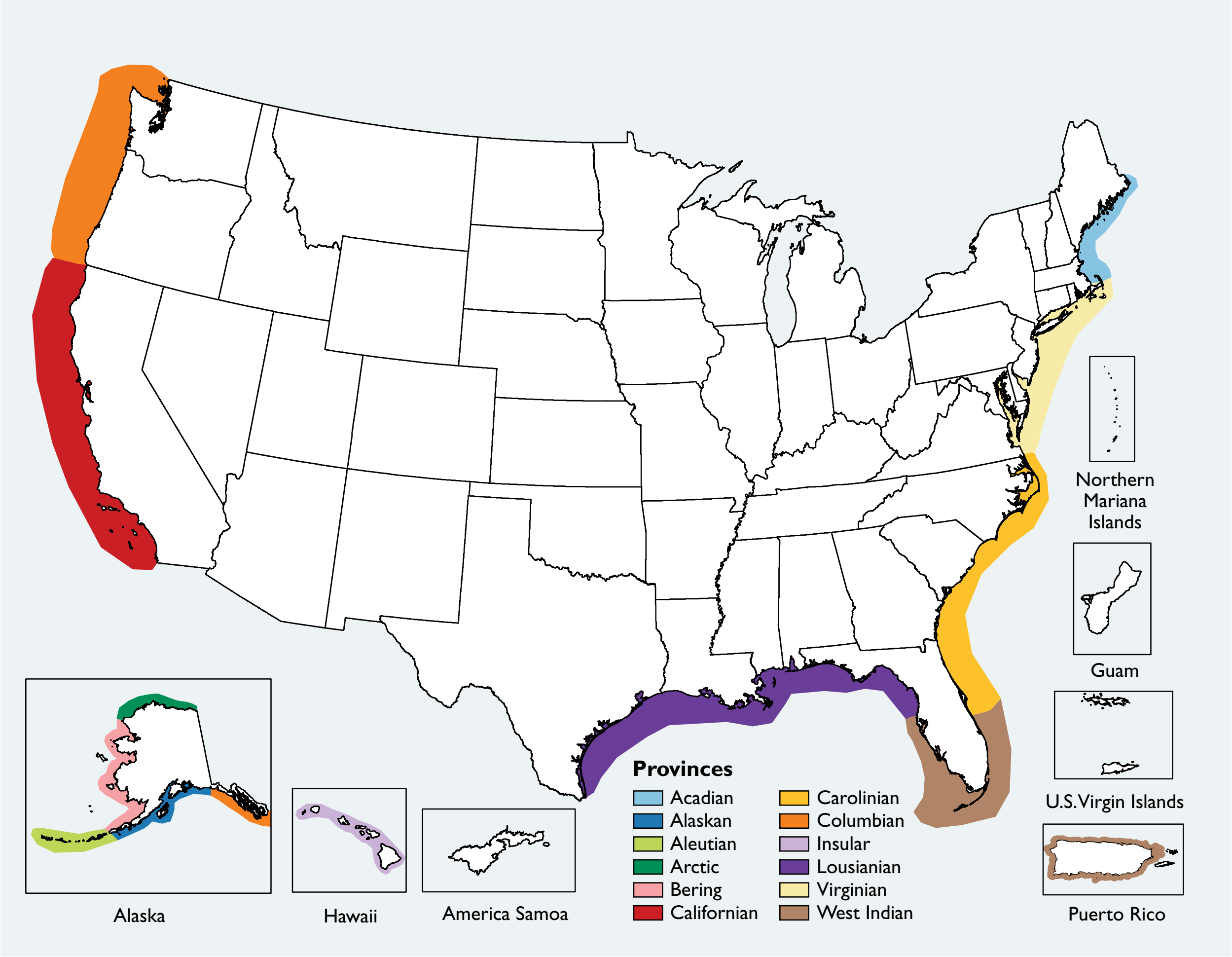
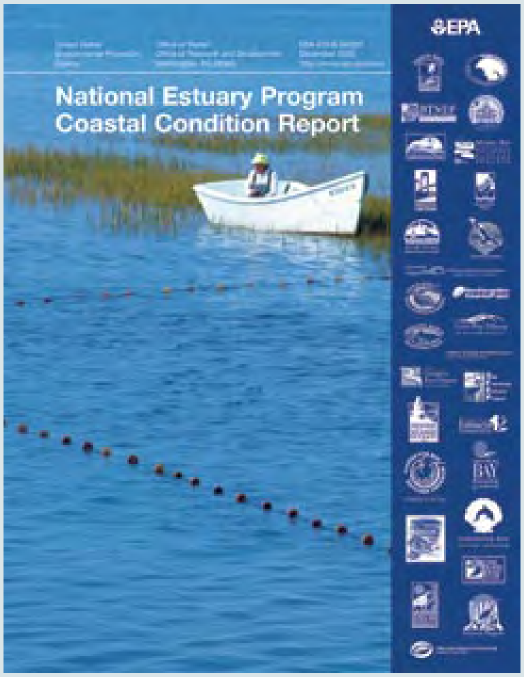


Figure 2-14. EMAP coastal provinces (U.S. EPA).

Highlight

Conditions in U.S. National Estuary Program Estuaries



EPA

National Estuary Program Coastal Condition Report

Our nation's estuaries encompass a wide variety of coastal habitats, including wetlands, salt marshes, coral reefs, mangrove and kelp forests, seagrass meadows, tidal mud flats, and upwelling areas. These estuarine habitats include cold temperate waters, as well as subtropical and tropical ecosystems. Estuaries provide spawning grounds, nurseries, shelter, and food for fish, shellfish, and other wildlife species, as well as nesting, resting, feeding, and breeding habitat for 75% of waterfowl and other migratory birds (U.S. EPA, 1998b). Estuaries are also a vital part of our national economy, providing areas used for recreation, tourism, commercial fishing, and port facilities for domestic and international trade.

The major objective of the *National Estuary Program Coastal Condition Report* (NEP CCR) is to document the condition of the nation's 28 National Estuary Program (NEP) estuaries—a subset of the nation's estuaries that have been designated as Estuaries of National Significance. NEP estuaries were nominated for inclusion in the NEP because they were deemed threatened by pollution, human development, or overuse. The Clean Water Act requires that the EPA report periodically on the condition of the nation's estuarine waters. As part of the 1987 amendments to the Clean Water Act, the Section 320 NEP promotes comprehensive planning efforts to help protect these nationally significant estuaries through their individual estuarine-specific programs.

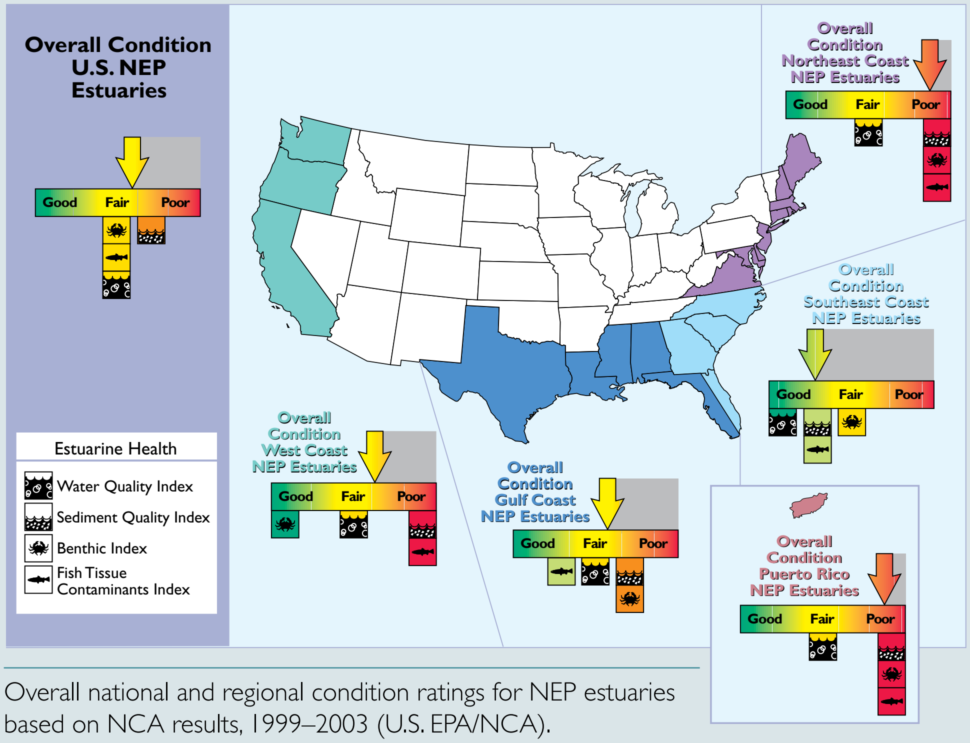
Data collected from 1999 to 2003 by EPA's NCA were used to rate the NEP estuaries individually, regionally, and nationally using four primary indices of estuarine condition (water quality, sediment quality, benthic condition, and fish tissue contaminant concentrations). The coastal habitat index was not evaluated for this report because the NWI data were not available on the estuary level. The NEP CCR presents the following two major types of data for each NEP estuary: (1) estuarine monitoring data collected as part of the NCA, and (2) estuarine monitoring data collected by the individual NEPs and/or NEP partners, which may include state agencies, universities, and volunteer monitoring groups.

The estuarine condition ratings developed in the NEP CCR are based solely on NCA estuarine monitoring data because these data are the most comprehensive and nationally consistent data available related to estuarine condition. The report uses these data in assessing estuarine condition by evaluating the four selected indices of estuarine condition in each region of the United States (Northeast Coast, Southeast Coast, Gulf Coast, West Coast, and Puerto Rico). The resulting ratings for each index are then used to calculate an overall NEP estuary rating, an overall NEP regional rating, and an overall NEP national rating of estuarine condition. This national assessment applies to the 28 individual NEP-designated estuaries located in 17 coastal states and the island territory of Puerto Rico (see figure). With the NEP CCR, the collaborating agencies and the individual NEPs strive to provide a benchmark of estuarine condition that paints a comprehensive picture of the nation's NEP estuaries.

The major findings of the NEP CCR include the following:

- Ecological assessment of NCA data shows that the nation's NEP estuaries are generally in fair condition nationally, but that regionally, the NEP estuaries are rated poor in Puerto Rico (San Juan Bay) and the Northeast Coast region, fair in the Gulf Coast and West Coast regions, and fair to good in the Southeast Coast region.
- The indices that show the poorest conditions throughout the United States are the sediment quality index, followed by the fish tissue contaminants index and benthic index. The index that generally shows the best condition is the water quality index.
- Nationally, 37% of NEP estuarine area is in poor condition. Regionally, roughly 100% of Puerto Rico's NEP estuarine area is in poor condition, and 46% of the Northeast Coast, 46% of the Gulf Coast, 36% of the West Coast, and 23% of the Southeast Coast NEP estuarine area is in poor condition (U.S. EPA, 2006b).

This report also provides individual NEP profiles of the nation's 28 nationally significant estuaries, including a map, background information on the NEP estuary, environmental concerns of most importance to the NEP and its stakeholders, population pressures affecting the individual NEPs, and environmental indicators used by the NEP to assess estuarine health. This information, together with data from the NCA monitoring program, provides a picture of the overall condition of the coastal resources of the nation's NEP estuaries.



Overall national and regional condition ratings for NEP estuaries based on NCA results, 1999–2003 (U.S. EPA/NCA).

A traditional trend analysis cannot be performed on the data presented in the *National Coastal Condition Report* series because the underlying population (i.e., the coastal resources included in the survey) has changed for each assessment; however, estimates have been made for the overall condition of U.S. coastal waters in each assessment. If we assume that the condition of any unsampled waterbodies has a similar distribution to the condition of those sampled, then the report provides estimates for all the coastal waters of the United States. Table 2-2 shows the primary index and overall condition scores from the three reports for each region and for the nation (including and excluding Southcentral Alaska and Hawaii).

Table 2-3 shows the percent of the nation's coastal area rated poor for overall condition and the associated overall condition scores from the three national assessments. An increase in a score and/or a decrease in the percent area in

Table 2-2. Rating Scores by Index[a] and Region Comparing the NCCR I, NCCR II, and NCCR III[b]

Region		Index					Overall Condition
		Water Quality	Sediment Quality	Coastal Habitat	Benthic	Fish Tissue Contaminants	
Gulf Coast	v1	1	3	1	1	3	**1.8**
	v2	3	3	1	2	3	**2.4**
	v3	3	1	1	1	5	**2.2**
Southeast Coast	v1	4	4	2	3	5	**3.6**
	v2	4	4	3	3	5	**3.8**
	v3	3	3	3	5	4	**3.6**
Northeast Coast	v1	1	2	3	1	2	**1.8**
	v2	2	1	4	1	1	**1.8**
	v3	3	2	4	1	1	**2.2**
Southcentral Alaska	v1	–	–	–	–	–	**–**
	v2	–	–	–	–	–	**–**
	v3	5	5	–	–	5	**5.0**[d]
Hawaii	v1	–	–	–	–	–	**–**
	v2	–	–	–	–	–	**–**
	v3	5	4	–	–	–	**4.5**[d]
West Coast[c]	v1	1	2	1	3	3	**2.0**
	v2	3	2	1	3	1	**2.0**
	v3	3	2	1	5	1	**2.4**
Great Lakes[c]	v1	1	1	1	1	3	**1.4**
	v2	3	1	2	2	3	**2.2**
	v3	3	1	2	2	3	**2.2**
Puerto Rico[c]	v1	–	–	–	–	–	**–**
	v2	3	1	–	1	–	**1.7**
	v3	3	1	–	1	–	**1.7**
United States[e]	v1	1.5	2.3	1.6	1.5	3.1	**2.0**
	v2	3.2	2.1	1.7	2.0	2.7	**2.3**
	v3[f]	3.3	1.6	1.7	2.1	2.9	**2.3**
	v3[g]	3.9	2.8	1.7	2.1	3.4	**2.8**

[a] Rating scores are based on a 5-point system, where a score of less than 2.0 is rated poor; 2.0 to less than 2.3 is rated fair to poor; greater than 2.3 to 3.7 is rated fair; greater than 3.7 to 4.0 is rated good to fair; and greater than 4.0 is rated good.

[b] AK and HI were not reported in the NCCR I or NCCR II. The NCCR I assessment of the Northeast Coast region did not include the Acadian Province. The West Coast ratings in the NCCR I were complied using data from many different programs.

[c] West Coast, Great Lakes, and Puerto Rico scores for the NCCR III are the same as NCCR II (no new data for the NCCR III except for the West Coast benthic index).

[d] Overall condition scores for Southcentral Alaska and Hawaii were based on 2–3 of the 5 NCA indices.

[e] U.S. score is based on an areally weighted mean of regional scores.

[f] U.S. score excluding Southcentral Alaska and Hawaii.

[g] U.S. score including Southcentral Alaska and Hawaii.

v1 = NCCR (adjusted scores from Table C-1 in NCCR II); v2 = NCCR II; v3 = NCCR III poor condition reflects improving condition for a particular index or for overall condition. In principle, a positive change in a score should correspond to a negative change in percent area in poor condition. In general, this is the case shown in Table 2-3; however, some inconsistencies exist due to several reasons, including (1) the scores represent ranges of condition, whereas the percent area in poor condition is an exact number; (2) the interpretation of values has changed as the assessments have become more sophisticated; (3) some index elements were measured only after 2000; and (4) in one case, the elements of an index reversed in importance. Although some of these inconsistencies can be adjusted through a recalculation of the percent of area or the score to "correct" differences to a common baseline for reason 2 (see Appendix C in the NCCR II), no adjustment can be made for reasons 1, 3, or 4. Figure 2-15 depicts the concurrent percent area in poor condition for each index.

From the NCCR I to NCCR III, the water quality index score for U.S. coastal waters increased from 1.5 (rated poor) to 3.3 (rated fair), with a corresponding decrease in percent area rated poor from 40% to 11%. Although water quality has likely improved during this time, the dramatic change in the water quality assessment from the NCCR I to the NCCR III is largely due to the reliance on professional judgment for eutrophication information in the NCCR I, rather than on direct measurements from surveys used for subsequent reports of the *National Coastal Condition Report* series (NCCR II, NCCR III). Nitrogen and phosphorus measurements were not used in the NCCR I assessment; instead, a survey of professional judgment conducted by NOAA was used to assess the eutrophication status of estuaries. These judgments were based on other measures (e.g., macroalgal abundance, SAV loss, HABs) (Bricker et al., 1999). The NCCR I reported that 40% of the nation's coastal area was rated poor for water quality (rating score of 1.5). In the NCCR II, water quality in the nation's collective coastal waters improved, with a reduction in percent area rated poor (11%) and an increase in the water quality index score to 3.2 (rated fair); however, this apparent improvement in the water quality index score and the percent area in poor condition is likely not as dramatic as the assessment suggests. In the current assessment (NCCR III), 11% of the U.S. coastal area is rated poor, and the water quality index score is 3.3 (rated fair). This assessment demonstrates

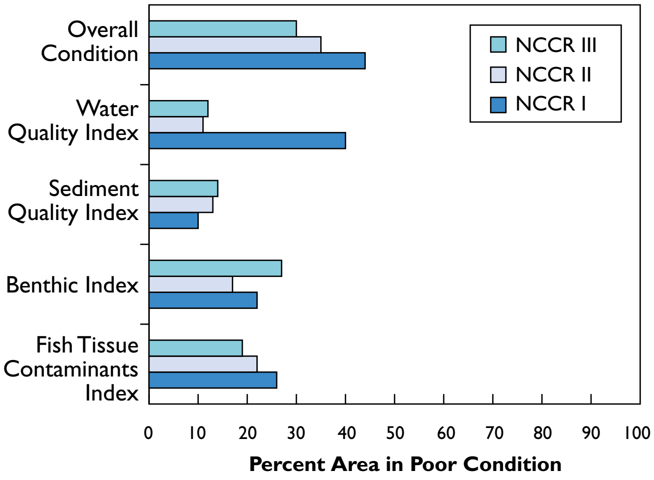


Figure 2-15. Comparison of percentage area in poor condition for the three *National Coastal Condition Report* assessments (U.S.EPA/NCA).

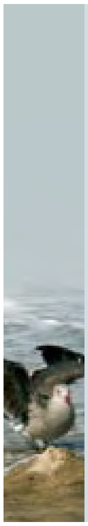
Table 2-3. Percentage of U.S. Coastal Area in Poor Condition and Corresponding Rating Score for the NCCR I (1990–1995), NCCR II (1996–2000), and NCCR III* (2001–2002) National Ecological Condition Assessments

Category	% Area in Poor Condition			Score		
	NCCR I	NCCR II	NCCR III	NCCR I	NCCR II	NCCR III
Water Quality Index	40	11	11	1.5	3.2	3.3
Sediment Quality Index	10	13	14	2.3	2.1	1.6
Benthic Index	22	17	27	1.5	2.0	2.1
Fish Tissue Contaminants Index	26	22	19	3.1	2.7	2.9
Overall Condition	44	35	30	2.0	2.3	2.3

*NCCR III assessment is for coastal waters in the conterminous United States (excluding Hawaii and Southcentral Alaska).

no significant change in the water quality of U.S. coastal waters since the publication of the NCCR II.

Although the percent area in poor condition changed very little (from 10% to 14%) between the NCCR I and the NCCR III, the sediment quality index score decreased from 2.3 (rated fair) to 1.6 (rated poor), respectively, between the two reports. Initially, this temporal pattern seems inconsistent because a significant decrease in the sediment quality index score should logically correspond to a significant increase in percent area in poor condition. This apparent inconsistency results from the inclusion of a sediment quality index score of 1.0 (rated poor) for the Great Lakes region in determining the sediment quality index score for the nation's coastal waters (Great Lakes were not included in calculations of percent area). Although the change in the nation's sediment quality index score between the two reports appears to be more significant than the change in the percent of coastal area rated poor, the NCCR III rating would only change from poor to fair to poor if it were based solely on percent area in poor condition. According to the regional assessment criteria, a region is rated poor if more than 15% of a region's coastal area is rated poor, and a region is rated fair if between 5% and 15% of the coastal area is rated poor. Based on the regional criteria outlined in Chapter 1 and the percent of national coastal area rated poor (14%), the sediment quality index score for the NCCR III would be 2.0 (rated fair to poor); however, when the national sediment quality index score is calculated based on the weighted average of the regional scores (including the Great Lakes sediment quality score of 1.0), the national score is reduced to 1.6 (rated poor). Similar comparisons can be made for the subsequent assessments.



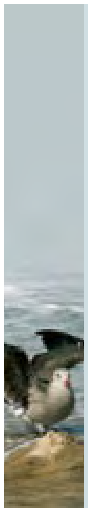
The approach used by NCA does not provide any estimate of "resiliency" for a given estuarine system. An area rated poor may, in fact, be relatively healthy and have the capacity to "bounce back" from the measured poor condition at the single point in time when sampling occurred; meanwhile, some of the areas rated good may be quite vulnerable over the longer term. These phenomena should be evaluated in concert with the trend data before any decisive environmental action is taken.

The coastal habitat index assessment has not changed from the NCCR II to the NCCR III. No new information is available to assess coastal habitat changes for the NCCR III, and the scores presented in this report are identical to those presented in the NCCR II. Although some regional improvements in the coastal habitat index rating occurred in the Northeast Coast region between the NCCR I (rated fair) and the NCCR II (rated good to fair), the regions with most of the wetland acreage in the United States (Gulf Coast, Southeast Coast, and Great Lakes) showed little or no change in their index ratings. The Gulf Coast and Southeast Coast regions showed a continuing loss of wetlands at about the same rate of approximately 0.2% of available acreage between 1990 and 2000.

The benthic index, although consistent in concept, is calculated differently for each region of the United States; therefore, the assumption that unsampled regions reflect the same distribution pattern of poor conditions as those sampled is not supported. The percent of coastal area with poor

Courtesy of Andrew D. Stahl

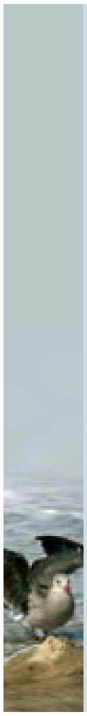
benthic condition in the West Coast region and Acadian Province of the Northeast Coast region is consistently lower than in the Gulf Coast region and the Virginian Province of the Northeast Coast region. As a result, the U.S. benthic index score of 1.5 (rated poor) in the NCCR I corresponds to the 22% of coastal area in poor condition in the Gulf Coast region, Southeast Coast region, and Virginian Province of the Northeast Coast region. When the West Coast region and Acadian Province of the Northeast Coast region were included in the NCCR II assessment, the percent of coastal area with poor benthic condition decreased to 17% (within the uncertainty estimates for the NCCR I) and the benthic index score increased to 2.0 (rated fair to poor). However, for the NCCR III, the percent area with poor benthic condition increased to 27% (an increase of 10%), and the benthic index score increased from 2.0 to 2.1 (rated fair to poor). The percent area with poor benthic condition in the Gulf Coast region increased to 45% in the NCCR III. Although this increase in the Gulf Coast region accounts for the sizeable increase in the percent of U.S. coastal area in poor condition, it has little affect on the national benthic index score because, based on the criteria described in Chapter 1, the regional rating would be poor in both cases. This change in the Gulf Coast region—coupled with small improvements in benthic condition in the Southeast Coast and West Coast regions—results in the apparent inconsistency of a significant increase (degradation) in percent coastal area with poor benthic condition in the United States (+10%) coupled with a minimal increase in overall benthic score (+0.1).



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.



Please note that some of the percentages discussed in this report differ from those published in the NCCR I or NCCR II. In some cases, data were reassessed to make the results comparable across reports. For example, the NCCR I reported that 35% percent of the national coastal area was rated poor for sediment quality. This assessment was based on criteria that included both ERM exceedances and five ERL exceedances in its estimate of percent area rated poor. These criteria changed in the NCCR II and NCCR III to reflect only ERM exceedances when calculating percent area rated poor. When the NCCR I data are reassessed using the updated criteria, the percent area rated poor is reduced to 10%.

The fish tissue contaminants index shows a consistent improvement from the NCCR I to the NCCR III. The percent of stations rated poor decreased from 26% of stations where fish were caught (NCCR I) to 19% (NCCR III). This reduction corresponds with an improvement of the fish tissue contaminants index score from the NCCR II (2.7) to the NCCR III (2.9), but is inconsistent with the reduction of the score from the NCCR I (3.1) to the NCCR II (2.7). This inconsistency is the result of comparing different methodologies. In the NCCR I, fish tissue contaminant concentrations were measured in edible fillets, whereas in both the NCCR II and NCCR III, whole-fish concentrations were measured. Currently, it is not possible to "adjust" the NCCR I assessments (fillets) to whole-fish concentrations and scores; however, research completed from 2003 through 2004, where both fillet and whole-fish concentrations were determined, will likely provide the information necessary to make that adjustment. At present, the best interpretation seems to be that there is little change in contaminant levels in fish tissue in U.S. coastal waters, with the national fish tissue contaminant index rated fair for all three reports.

Large Marine Ecosystem Fisheries

Ten LMEs are found in the waters bordering U.S. states and island territories around the world (Figure 2-16). The climates of these LMEs vary from subarctic to tropical, and their productivities range from low to high based on global estimates of primary production (phytoplankton). Some of these LMEs (i.e., the Northeast U.S. Continental Shelf, Caribbean Sea, Gulf of Mexico, California Current, Gulf of Alaska, Chukchi Sea, and Beaufort Sea LMEs) border multiple countries, such as the United States and Russia. As a result, information about fishery stocks in the Caribbean Sea, Chukchi Sea, and Beaufort Sea LMEs is unavailable. In addition, several of the U.S. island territories in the Pacific Ocean are not located within an LME. The fisheries in the waters surrounding these territories are managed on a regional level with the Insular Pacific-Hawaiian LME as the NMFS Western Pacific Region (NOAA, 2007g).

As of 2004, many marine fish stocks in U.S. LMEs were healthy, and other stocks were rebuilt. Despite this progress, a number of the nation's most significant fisheries still face serious challenges, including the California Current and Gulf of Alaska LME demersal fish, Southeast U.S. Continental Shelf LME snapper-grouper complex, and Northeast U.S. Continental Shelf LME mixed-species stocks (NMFS, In press).

In 2004, NOAA's Office of Sustainable Fisheries reported on the status of 688 marine fish and shellfish stocks with respect to their overfished and overfishing condition (NMFS, 2005c). According

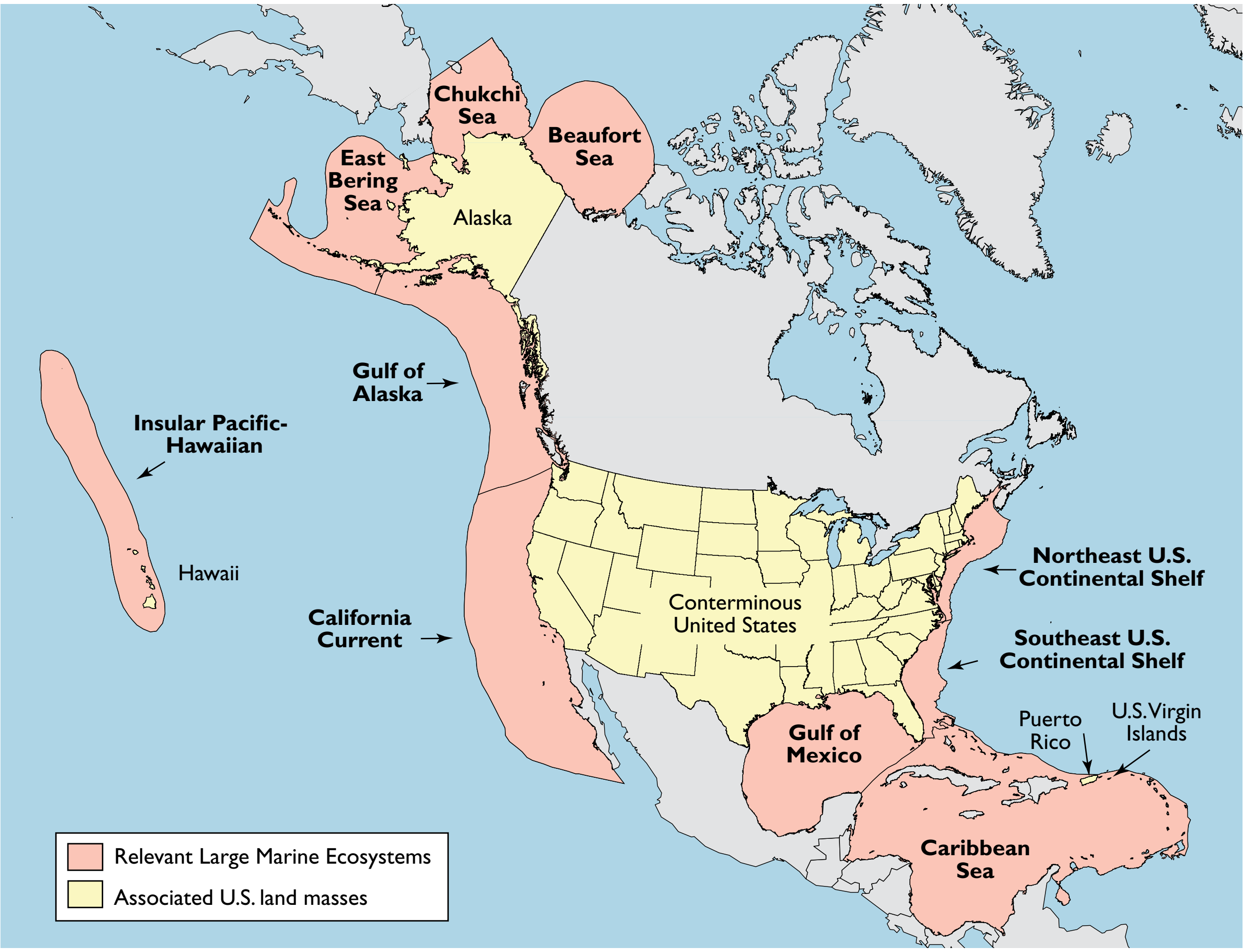


Figure 2-16. U.S. states and island territories are bordered by 10 LMEs (NOAA, 2007g).

to the Magnuson-Stevens Fishery Conservation and Management Act of 1996 (and reauthorized in 2006), a fishery is considered overfished if the stock size is below a minimum threshold, and overfishing is occurring if a stock's fishing mortality rate is above a maximum level. These thresholds and levels are associated with maximum sustainable yield-based reference points and vary between individual stocks, stock complexes, and species of fish. Of the 200 fish stocks whose status with respect to overfished condition is known, 144 were not overfished and 56 stocks or stock complexes were overfished (NMFS, 2002; 2005c). The overfishing status of 236 stocks is known, of which 44 stocks or stock complexes (19%) have a fishing mortality rate that exceeds the overfishing threshold. The NMFS has approved rebuilding plans for the majority of overfished stocks. Five FMP amendments were approved in 2004 to implement final rebuilding plans for 23 stocks in the Northeast U.S. Continental Shelf, Southeast U.S. Continental Shelf, Gulf of Alaska, and East Bering Sea LMEs.

The number of stocks considered to be overfished has decreased from 92 in 2000 and 81 in 2001 to 56 in 2004. Some of the stocks whose status has changed are located in the Gulf of Alaska, California Current, Northeast U.S. Continental Shelf, and Gulf of Mexico LMEs. The Pacific whiting (a demersal fish) stock of the Gulf of Alaska and California Current LMEs has been fully rebuilt, and overfishing is no longer occurring. Northeast U.S. Continental Shelf LME black sea bass stock is also no longer overfished. Three more stocks—lingcod, Pacific ocean perch (Gulf of Alaska and California Current LMEs), and king mackerel (Gulf of Mexico LME)—have increased in abundance to the point they also are no longer overfished. Rebuilding measures for all these stocks will continue until each stock has been fully rebuilt to a level that provides the maximum sustainable yield (NMFS, 2005a).

Commercial landings of fish can be measured by pounds of fish landed and by the value (in dollars) that those fish bring to the economy (Table 2-4). In 2004, Alaska led all states in pounds of fish landed (5.4 billion) and in the value of fisheries landings ($1.2 billion) (NMFS, 2005a). Alaska pollock, described as the largest food fish resource in the world, has been ranked first nationally (in pounds harvested) of the major U.S. domestic commercial species landed from 2001 through 2004. Menhaden (e.g., fatback, bugfish, munnawhatteaug), an industrial species used as bait and for fish meal and oil, is one of the most important fisheries on the Atlantic coast, with the majority of fish caught from estuaries and nearshore coastal waters. Nationally, the menhaden fishery ranked second by mass from 2000 through 2004, whereas the Pacific salmon fishery ranked third from 2001 through 2004, and the cod fishery (Atlantic and Pacific combined) has consistently ranked fourth. The shrimp fishery was ranked first by value in 2001 and 2002, then second in 2003 and 2004—the reverse of the crab fishery, which was ranked second in monetary value for the first 2 years and then first for the later 2 years (2003 and 2004). The American lobster fishery was consistently ranked third by value throughout this timeframe, Alaska pollock ranked fourth in 2001 and 2002, and flatfish and scallops ranked fourth in 2003 and 2004, respectively (NMFS, 2002; 2003; 2004; 2005c).

Table 2-4. Top 10 Commercial Species Landed in 2004 (NMFS, 2005c)

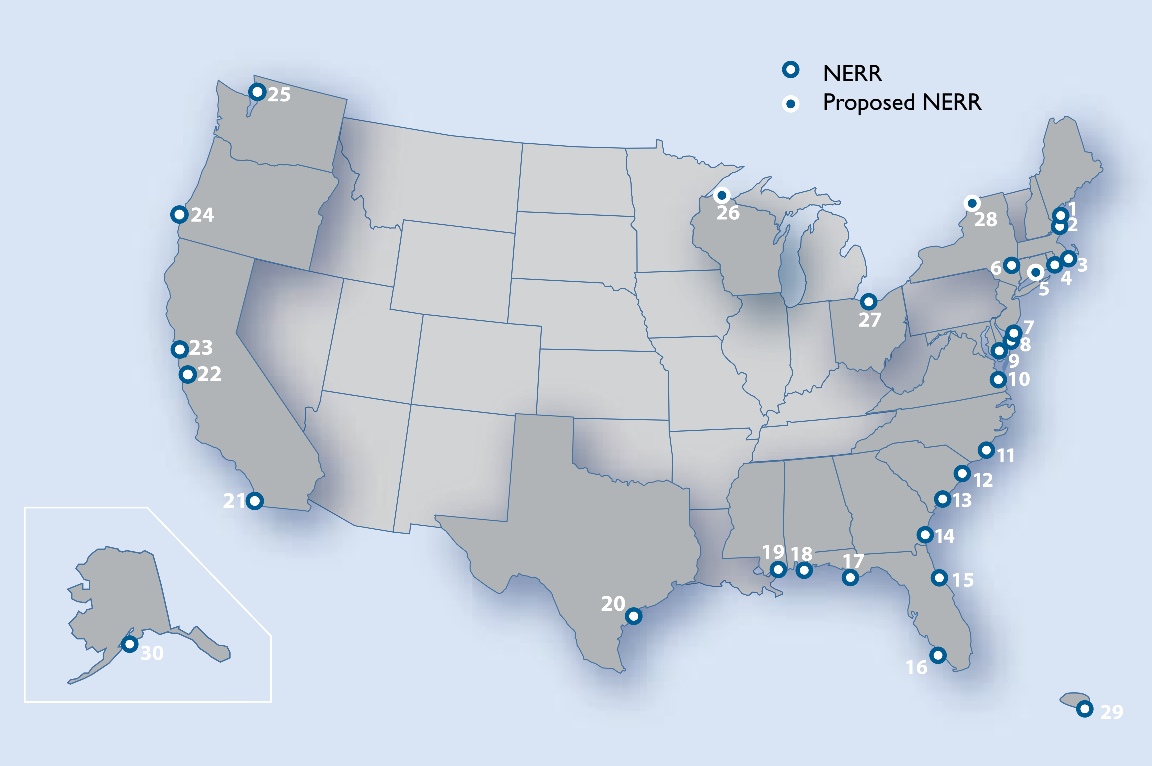
	Top 10 by Quantity		Top 10 by Value	
Rank	Species	Pounds (thousands)	Species	Dollars (thousands)
1	Pollock	3,361,989	Crabs	$447,978
2	Menhaden	1,497,610	Shrimp	$425,605
3	Salmon	737,935	Lobsters	$344,070
4	Cod	602,732	Scallops	$322,098
5	Hakes	502,502	Flatfish	$300,896
6	Flounders	440,699	Pollock	$277,029
7	Crabs	314,428	Salmon	$272,730
8	Shrimp	308,275	Cod	$169,647
9	Herring (sea)	255,931	Clams	$158,782
10	Sardines	199,613	Oysters	$111,125

Highlight

Integrating Science and Technology to Support Coastal Management Needs: The National Estuarine Research Reserve System-wide Monitoring Program

There are 27 National Estuarine Research Reserves (NERRs) covering more than 1 million acres of estuarine waters and adjoining lands across the continental United States, Alaska, and Puerto Rico (see map) (NERRS, 2003). NOAA's National Estuarine Research Reserve System (NERRS) was established by the Coastal Zone Management Act of 1972, which created reserves to protect estuarine areas, provide education opportunities, promote and conduct estuarine research and monitoring, and transfer critical information to coastal managers. In 1995, the NERRS established a System-wide Monitoring Program (SWMP) to collect data on estuarine biodiversity and water and weather conditions, as well as to classify watershed habitats and land-use changes. The SWMP was designed to track short-term variability and long-term changes in estuarine ecosystems and to understand and forecast how human activities and natural events can affect these ecosystems.

In 2005, the NERRS celebrated the SWMP's 10th anniversary. The long-term data sets of the SWMP make it possible to establish baseline conditions, examine both intra-annual (seasonal) and interannual patterns in estuarine systems, and study the effects of large-scale (e.g., El Niño and La Niña climatic conditions, sea-level rise, hurricanes, Nor'easters) and localized (e.g., floods, drought, contaminant spills) episodic events.



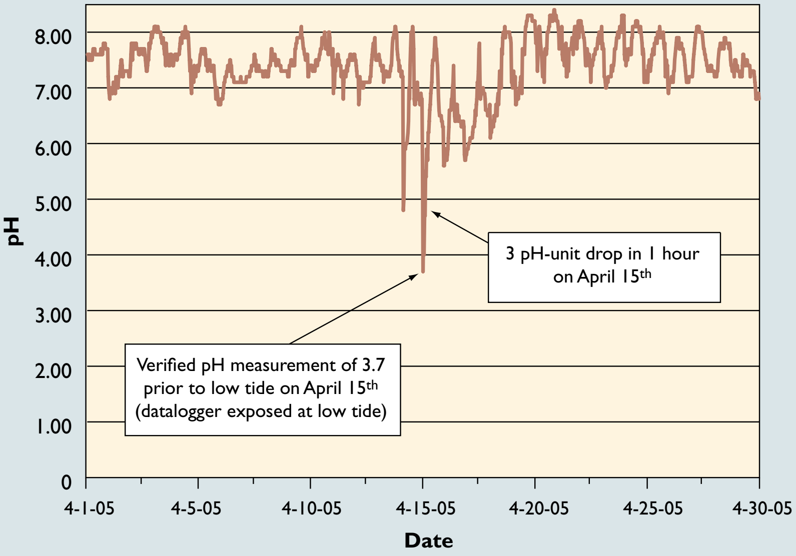
Estuaries of the NERRS are found on coastlines across the United States (NERRS, 2003).

The NERRS has compiled a subset of examples from across the 27 sites that demonstrate the application of water and weather monitoring data to local, regional, and national coastal management needs. One such example is the Grand Bay Reserve in Mississippi.

Grand Bay Reserve, MS—SWMP Data Used to Track Effects of a Phosphate Spill

The western border of the Grand Bay Reserve in southeastern Mississippi is lined with industrial plants. Grand Bay Reserve staff rely on SWMP data to monitor baseline water quality conditions and identify anomalies resulting from contaminant spills or other pollution episodes. One such incident occurred on April 14, 2005, when levees surrounding containment ponds at a fertilizer manufacturing plant collapsed after two weeks of record-breaking rain. A large volume of effluent water from the plant entered an adjacent tidal lake that lies within the Grand Bay Reserve's boundaries, resulting in an abrupt drop in pH levels. An SWMP datalogger located in the center of the lake recorded that the water's pH level fell from 7.5 to 3.7 within an hour (see figure). Eleven days later, phosphorus levels in the lake were ~5,000 times greater than before the spill and chlorophyll *a* concentrations had fallen to zero, indicating that primary productivity had ceased. Continual SWMP monitoring at Grand Bay Reserve captured the effects of this spill and will, in conjunction with additional monitoring, document the full recovery of this vital ecosystem. Following this incident, Grand Bay Reserve staff presented the SWMP data to the Mississippi Commission on Marine Resources and worked with the Mississippi Department of Environmental Quality staff to recommend corrective actions and restoration measures for the spill site (Owen and White, 2005).

More information about the NERRS program is available on NOAA's NERRS Web site at http://www.nerrs.noaa.gov. Monitoring data for each national reserve are available from the NERR's Centralized Data Management Office at http://cdmo.baruch.sc.edu.



NERRS' SWMP measurements showing the effect of an April 14, 2005, phosphate spill on pH in Bangs Lake, MS (Owen and White, 2005).

Assessment and Advisory Data

Fish Consumption Advisories

A total of 90 fish consumption advisories were in effect for the estuarine and coastal marine waters of the United States in 2003, including about 77% of the coastal waters of the conterminous 48 states (Figure 2-17). In addition, 30 fish consumption advisories were in effect for the Great Lakes and their connecting waters. An advisory may represent one waterbody or one type of waterbody within a state's jurisdiction and may cover one or more species of fish. Some advisories are issued as a single statewide advisory for all estuarine or marine waters within a state (Table 2-5). Although the statewide coastal advisories have placed a large proportion of the nation's coastal waters under advisory, these advisories are often issued for the larger-size classes of predatory species (e.g., bluefish, king mackerel) because larger, older individuals have had more time to be exposed to and accumulate one or more chemical contaminants in their tissues than younger individuals (U.S. EPA, 2004b).

The number and geographic extent of advisories can serve as indicators of the level of contamination in estuarine and marine fish and shellfish, but a number of other factors must also be taken into account. For example, the methods and intensity of sampling and the contaminant levels at which advisories are issued often differ among the states. In the states with statewide coastal advisories, one advisory may cover many thousands of square miles of coastal waters and many hundreds of miles of shoreline waters. Although advisories in U.S. estuarine, Great Lakes, and coastal marine waters have been issued for a total of 23 individual chemical contaminants, most advisories issued have resulted from four primary contaminants: PCBs,

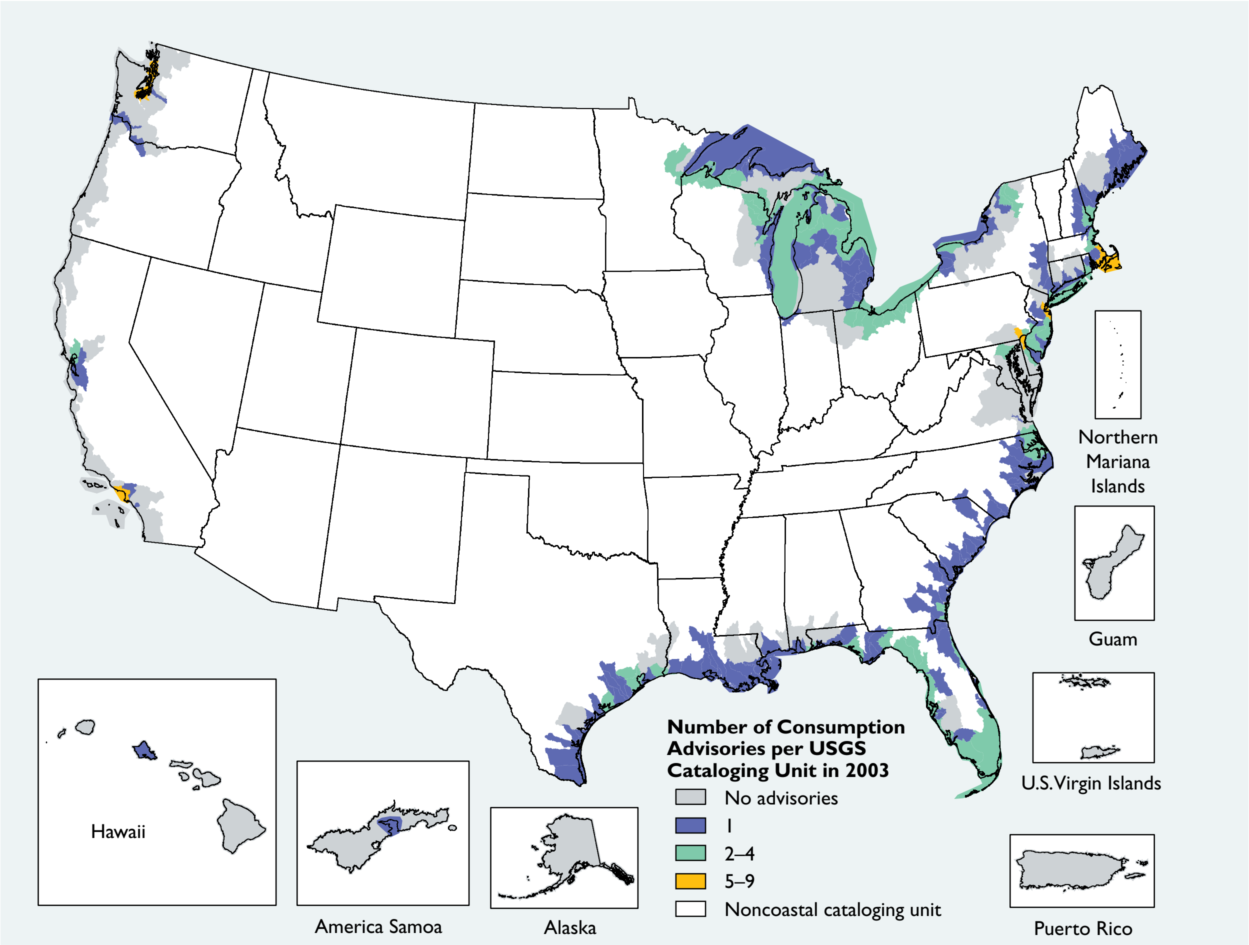


Figure 2-17. The number of fish consumption advisories active in 2003 for U.S. coastal waters (U.S. EPA, 2004b).

mercury, DDT and its degradation products (DDD and DDE), and dioxins/furans. These four chemical contaminant groups were responsible, at least in part, for 92% of all fish consumption advisories in effect in U.S. estuarine and coastal marine waters in 2003 (Figure 2-18; Tables 2-6 and 2-7). These chemical contaminants are biologically accumulated (bioaccumulated) in the tissues of aquatic organisms to concentrations many times higher than concentrations in seawater (Figure 2-19). In addition, concentrations of these contaminants in the tissues of aquatic organisms may be increased at each successive level of the food web. As a result, top predators in a food web may have concentrations of these chemicals in their tissues that can be a million times higher than the concentrations in seawater. A direct comparison of fish advisory contaminants and sediment contaminants is not possible because states often issue advisories for groups of chemicals; however, 4 of the top 10 contaminants associated with fish advisories (PCBs, dioxins, DDT, and dieldrin) are among the contaminants most often responsible for a Tier 1 National Sediment Inventory classification (i.e., associated adverse effects to aquatic life or human health are probable) of waterbodies based on potential human health effects (U.S. EPA, 2004b; 2004c).

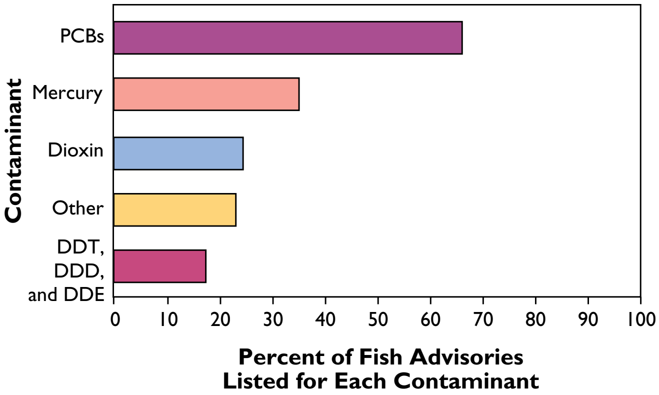


Figure 2-18. Pollutants responsible for fish consumption advisories in U.S. coastal waters. An advisory can be issued for more than one contaminant, so percentages may add up to more than 100 (U.S. EPA, 2004b).

Table 2-5. Summary of States* with Statewide Fish Advisories for Coastal and Estuarine Waters (U.S. EPA, 2004b)

State	Pollutants	Species under Advisory
Alabama	Mercury	King mackerel
Connecticut	PCBs	Bluefish Lobster (tomalley) Striped bass
Florida	Mercury	Bluefish Cobia Greater amberjack Jack crevalle King mackerel Little tunny Shark Spotted sea trout
Georgia	Mercury	King mackerel
Louisiana	Mercury	King mackerel
Maine	Dioxins Mercury PCBs	Bluefish King mackerel Lobster (tomalley) Shark Shellfish Striped bass Swordfish Tilefish All other fish
Massachusetts	Mercury PCBs	King mackerel Lobster (tomalley) Shark Swordfish Tilefish Tuna
Mississippi	Mercury	King mackerel
New Hampshire	PCBs	Bluefish Lobster (tomalley) Striped bass
New Jersey	PCBs Dioxins	American eel Bluefish Striped bass Lobster (tomalley)
New York	Cadmium Dioxins	American eel Blue crab Bluefish Lobster (tomalley) Striped bass
North Carolina	Mercury	King mackerel Shark Swordfish Tilefish
Rhode Island	PCBs Mercury	Bluefish Shark Striped bass Swordfish
South Carolina	Mercury	King mackerel
Texas	Mercury	King mackerel

*Hawaii has a statewide mercury advisory for several species of marine fish.

Table 2-6. The Four Bioaccumulative Contaminants Responsible, at Least in Part, for 92% of Fish Consumption Advisories in Estuarine and Coastal Waters in 2003—U.S. Coastal Waters (marine) (U.S. EPA, 2004b)

Contaminant	Number of Advisories	Comments
PCBs	60	Seven northeastern states (CT, MA, ME, NH, NJ, NY, RI) had statewide advisories.
Mercury	31	Twelve states (AL, FL, GA, LA, MA, ME, MS, NC, NJ, RI, SC, TX) had statewide advisories in their coastal marine waters; eleven of these states also had statewide advisories for estuarine waters. Seven states and the Territory of American Samoa had advisories for specific portions of their coastal waters.
DDT, DDD, and DDE	15	All DDT advisories in effect were in California (12), Delaware (1), Oregon (1), or the Territory of American Samoa (1).
Dioxins and furans	22	Statewide dioxin advisories were in effect in three states (ME, NJ, NY). Six states had dioxin advisories for specific portions of their coastal waters.

Table 2-7. The Four Bioaccumulative Contaminants Responsible, at Least in Part, for 92% of Fish Consumption Advisories in Estuarine and Coastal Waters in 2003—U.S. Great Lakes Waters (U.S. EPA, 2004b)

Contaminant	Number of Advisories	Comments
PCBs	30	Eight states (IL, IN, MI, MN, NY, OH, PA, WI) had PCB advisories for all five Great Lakes and several connecting waters.
Mercury	11	Three states (IN, MI, PA) had mercury advisories in their Great Lakes waters for Lakes Erie, Huron, Michigan, and Superior, as well as for several connecting waters.
DDT, DDD, and DDE	1	One state (MI) had a DDT advisory in effect for Lake Michigan.
Dioxins	15	Dioxin advisories were in effect in three states (MI, NY, WI) for all five Great Lakes and several connecting waters.

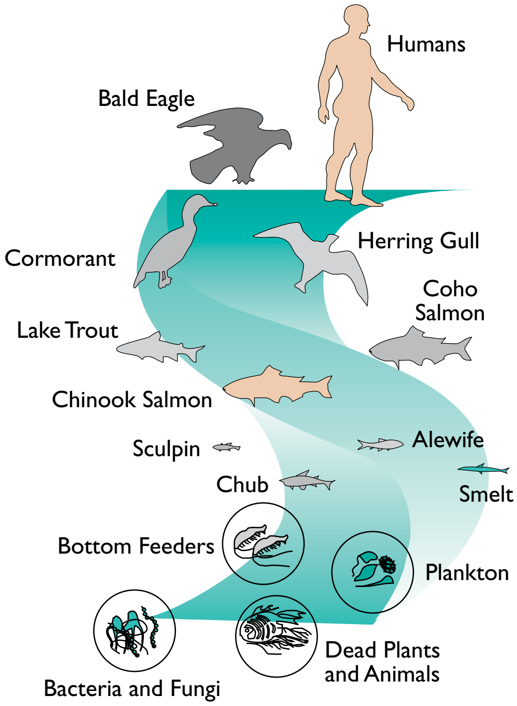


Figure 2-19. Bioaccumulation process (U.S. EPA, 1995b).

Boats rigged for commercial fisheries in Chincoteague Bay, MD (courtesy of Tim Carruthers, IAN Network).

Beach Advisories and Closures

For the 2003 swimming season, EPA gathered information on 4,080 beaches monitored nationwide (both inland and coastal) through the use of a survey. The survey respondents were state and local government agencies from coastal counties, cities, or towns bordering the Atlantic Ocean, Gulf of Mexico, Pacific Ocean, and the Great Lakes, and included agencies in Hawaii, Puerto Rico, the U.S. Virgin Islands, Guam, and the Northern Mariana Islands. A few of the respondents were regional (multiple-county) districts. Data are available only for those beaches for which officials participated in the survey. EPA conducts the survey each year and displays the results on the BEACH Watch Web site at http://www.epa.gov/OST/beaches. All data cited in this report were derived from data collected by the EPA's BEACH Watch Program during the 2003 swimming season (U.S. EPA, 2006c).

EPA's review of coastal beaches (e.g., U.S. coastal areas, the Great Lakes, and the coastal areas of Hawaii, Alaska, and the U.S. territories) showed that, of the 4,080 beaches reported in the survey responses, 4,070 were marine or Great Lakes' beaches. Of the coastal beaches monitored and reported, 839 (or 20.5%) had an advisory or closing in effect at least once during the 2003 swimming season (Figure 2-20). Beach advisories or closings were issued for a number of different reasons, including elevated bacterial levels in the water, preemptive reasons associated with rainfall events or sewage spills, and other reasons (Figure 2-21). Figure 2-22 shows that some of the major causes of public notifications for beach advisories and closures were stormwater runoff, wildlife, sewer line problems, and in many cases, unknown sources (U.S. EPA, 2006c).

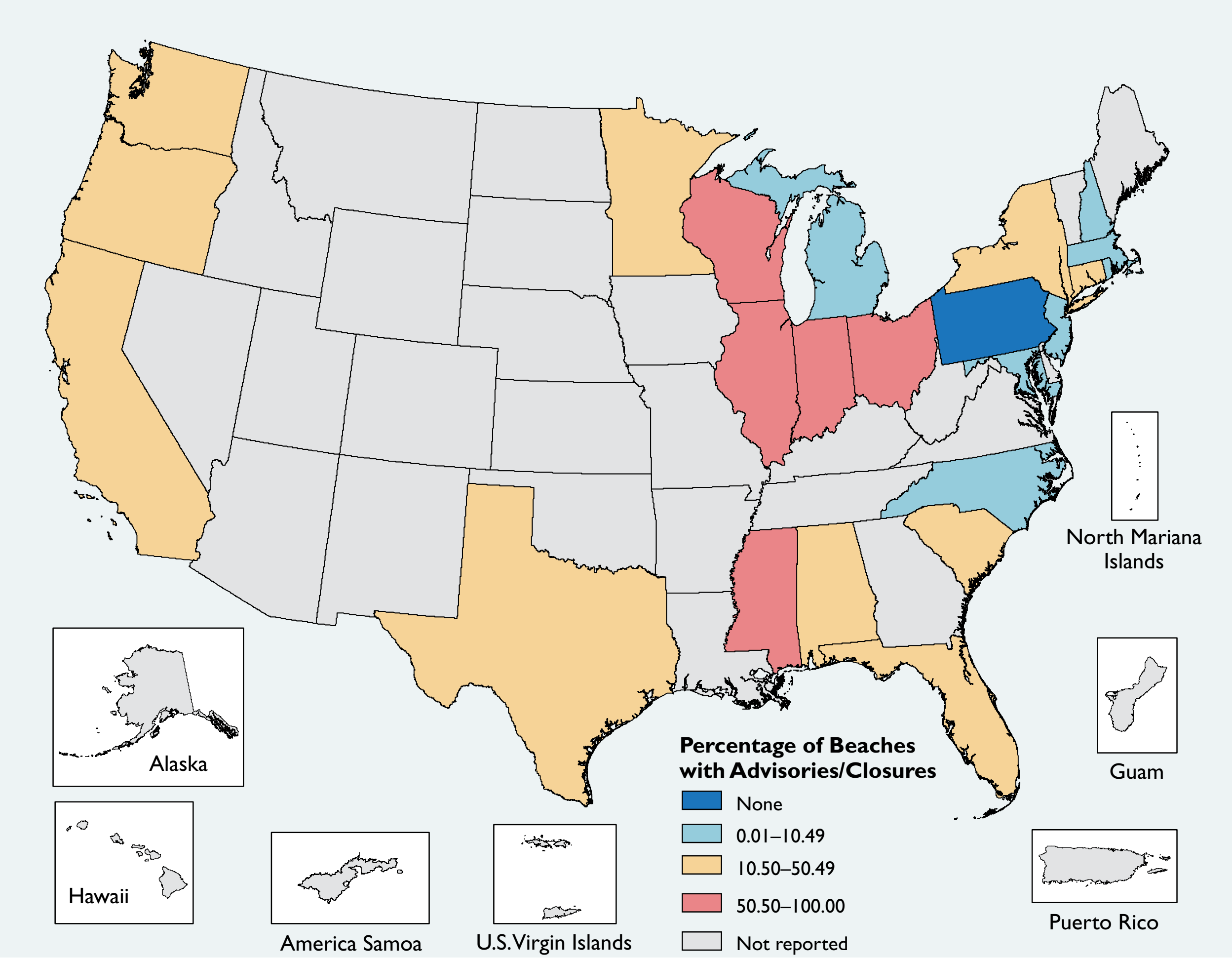


Figure 2-20. Percentages of monitored beaches with advisories/closures by coastal state in 2003. Percentages are based on the number of beaches that were reported for each state, not the total number of beaches (U.S. EPA, 2006c).

Highlight

Recovery of Endangered and Threatened Species

The primary purpose of the ESA of 1973, as amended, is the conservation of endangered and threatened species and the ecosystems on which they depend. Conservation efforts aim to recover populations of endangered species to a point where protection under the ESA is no longer necessary. NOAA's NMFS shares responsibility for implementing the ESA with the FWS.

The green turtle (*Chelonia mydas*) is one of 60 endangered or threatened species whose recovery is being addressed by NMFS (courtesy of David Burdick, NOAA).

In 2004, the NMFS had jurisdiction over a total of 60 species, comprised of 52 domestic and 8 foreign (found outside U.S. waters) species of salmon, sturgeon, sawfish, sea grass, corals, mollusks, sea turtles, and marine mammals. Of the 52 domestic species, 24 were listed as endangered and 28 were listed as threatened. Between 2002 and 2004, the status of 48% of the domestic endangered or threatened species listed under the ESA was stable or improving. These numbers are encouraging, especially given the large number of highly imperiled species listed in the past decade (NMFS, 2005b).

The recovery of threatened and endangered species is a long-term challenge. To organize and guide the recovery process, the ESA requires the development of recovery plans for listed endangered and threatened species. The ESA also requires that a report be sent to Congress every 2 years on the status of efforts to develop and implement recovery plans and on the status of all species for which recovery plans have been developed. In 2005, the NMFS published the *Biennial Report to Congress on the Recovery Program for Threatened and Endangered Species October 1, 2002–September 30, 2004* (NMFS, 2005b), which details recovery efforts for ESA-listed species and includes information on species status, current threats and impacts, the conservation actions undertaken, and the priority actions needed for recovery.

Of the 52 domestic species listed in 2004, 16 had recovery plans, and the recovery plans for 6 species (i.e., Hawaiian monk seal; eastern and western distinct population segments of Steller sea lion; the North Atlantic right whale; loggerhead sea turtle; Kemp's ridley sea turtle) were being updated. In addition, 32 recovery plans were in the draft stage, including those for 26 Evolutionarily Significant Units of Pacific salmon. There are active recovery teams for the white abalone, smalltooth sawfish, Kemp's ridley and loggerhead sea turtles, Hawaiian monk seal, and Steller sea lion. Additionally, take-reduction teams exist to curb the harassment, harming, pursuit, hunting, shooting, wounding, killing, trapping, capturing, or collection of specific species on the ESA list or the attempt to engage in any such conduct. Two active take-reduction teams, formed in accordance with the Marine Mammal Protection Act, assist in the population recovery of ESA-listed species. These are the Atlantic Large Whale Take Reduction Team for humpback, North Atlantic right, and fin whales and the Pacific Offshore Cetacean Take Reduction Team for humpback and sperm whales (NMFS, 2005b).

Species-recovery strategies are active for all ESA-listed species. Among ongoing conservation and research activities, the following two efforts for sea turtles and the North American right whale are especially noteworthy:

- One cause of sea turtle population decline occurs when turtles are caught as bycatch (marine animals caught inadvertently in commercial fishing operations) and die. The Strategy for Sea Turtle Conservation and Recovery is a comprehensive fishing-gear-based approach to reducing sea turtle bycatch in the state and federal waters of the Atlantic Ocean and Gulf of Mexico. The strategy will result in bycatch-reduction measures across jurisdictional boundaries and various fisheries by targeting gear types that have the greatest affect on sea turtle populations. These actions will ultimately help reduce sea turtle deaths and encourage population recovery (NMFS, 2005b).
- The North Atlantic right whale is one of the most severely endangered whale species; as a result, there are two facets to North Atlantic right whale population recovery efforts. The Atlantic Large Whale Take Reduction Plan uses modifications to fishing gear and fishing practices to reduce serious injury and death due to entanglement in commercial fishing gear. In addition, the NMFS has developed a draft Right Whale Ship Strike Reduction Strategy to minimize right whale deaths resulting from collisions with ships. This strategy includes mariner education and outreach programs, interagency consultations, and consideration of modifications to ships' operations to reduce ship strikes (NMFS, 2005b).

The NMFS is working to meet the challenge of recovery for ESA-listed species and to encourage stakeholder involvement in both recovery planning and implementation. All NMFS's active recovery teams either have stakeholder representation on their teams or hold stakeholder meetings to keep the public informed of their progress and to obtain public comment. Stakeholders include federal, state, and local government agencies; affected industries; conservation or other nongovernmental organizations; or affected individuals. In some cases, recovery boards were appointed by a state's Governor and recovery plans were written by local sub-basin recovery teams (e.g., Pacific salmon recovery efforts in Washington). The NMFS helps support and actively participates on these teams and is adopting the teams' plans as draft recovery plans to be published for public comment. Experience has shown that true stakeholder involvement in the planning process results in buy-in to the recovery plan, both during and after the planning process. Stakeholder involvement is also emphasized in the NMFS's *Interim Endangered and Threatened Species Recovery Planning Guidance* (NMFS, 2006), which is now being field-tested in regional and field offices.

For further information on marine species protected by NOAA under the ESA, please visit the NMFS Office of Protected Resources Web site at http://www.nmfs.noaa.gov/pr. Recovery plans for domestic ESA-listed species under the NMFS's jurisdiction are also available at http://www.nmfs.noaa.gov/pr/recovery/plans.htm.

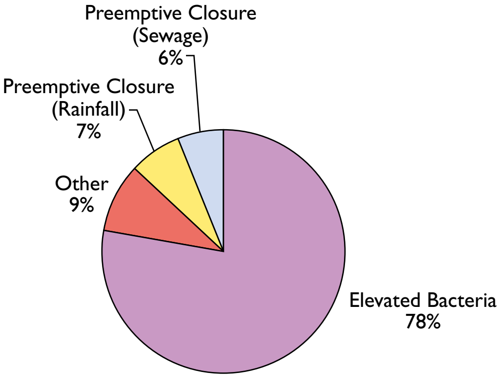


Figure 2-21. Reasons for beach advisories or closures for the nation (U.S. EPA, 2006c).

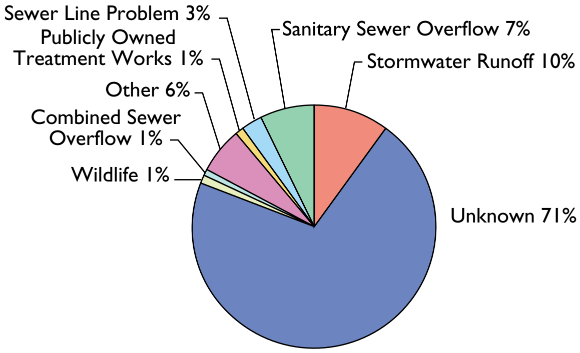


Figure 2-22. Sources of beach contamination resulting in beach advisories or closures for the nation (U.S. EPA, 2006c).

Flamenco Beach in Puerto Rico on a stormy morning (courtesy of Oliver Zena).

CHAPTER 3

Northeast Coast Coastal Condition

Courtesy of Patricia A. Cunningham

Northeast Coast Coastal Condition

As shown in Figure 3-1, the overall condition of the collective coastal waters of the Northeast Coast region is rated fair to poor, with an overall condition score of 2.2. The water quality index for the region is rated fair, the sediment quality index is rated fair to poor, the coastal habitat index is rated good to fair, and the benthic and fish tissue contaminants indices are rated poor. Figure 3-2 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 data collected from 723 water-, 507 sediment-, and 890 benthic-monitoring locations throughout the Northeast Coast coastal waters. Please refer to Chapter 1 for information about how these assessments were made, the criteria used to develop the rating for each index and component indicator, and any limitations of the available data.

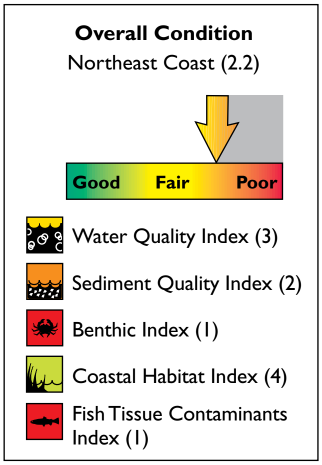


Figure 3-1. The overall condition of Northeast Coast coastal waters is rated fair to poor (U.S. EPA/NCA).

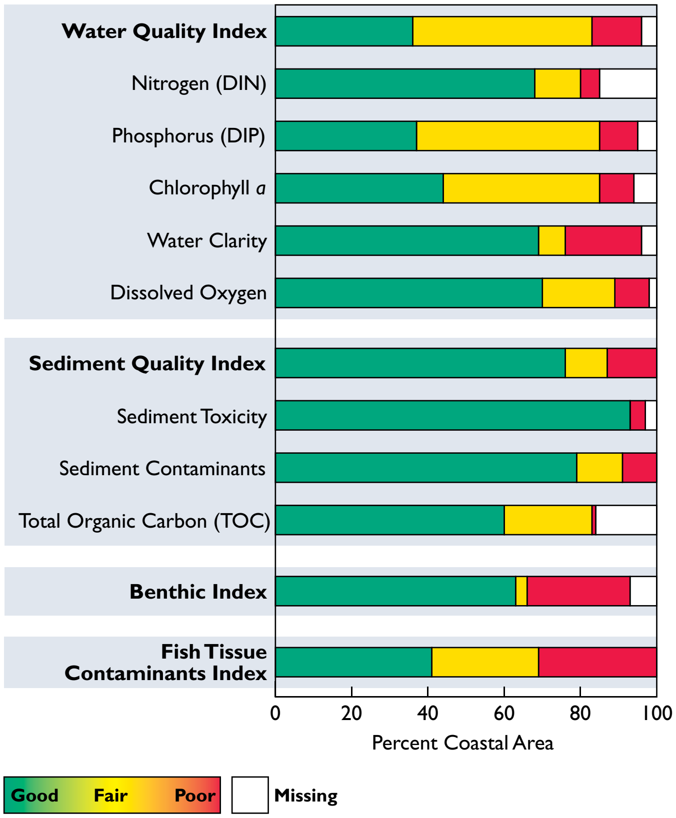
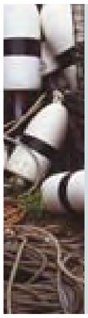


Figure 3-2. Percentage of coastal area achieving each ranking for all indices and component indicators—Northeast Coast region (U.S. EPA/NCA).

The Northeast Coast region contains diverse landscapes, ranging from the mountains, forests, and rocky coastal headlands of Maine to the coastal plain systems of the Mid-Atlantic states. The ratio of watershed drainage area to the area of estuary water in the Northeast Coast region is relatively small compared to the ratios in the Southeast Coast and Gulf Coast regions. Cape Cod, MA, represents a major biogeographic transition area for the region's coastal area, dividing the more arctic waters to the north of Cape Cod (Acadian Province) from the warmer, temperate waters to the south of Cape Cod (Virginian Province). The relatively larger average tidal ranges of 7 to 13 feet in the Acadian Province contribute to greater tidal mixing and flushing, in contrast to the tidal ranges of 7 feet or less in the coastal waters of the Virginian Province. The region's Chesapeake Bay, the largest estuary in the United States, is considered microtidal in character, having average tidal ranges of less than 3 feet (Monbet, 1992; Hammar-Klose and Thieler, 2001). The total area of Chesapeake Bay is 4,404 mi^2, representing 59% of the coastal area of the Northeast Coast region. The large size and volume of the Bay and the relatively small tidal range contribute to a freshwater residence time of 7.6 months, much longer than that of other estuaries in the Northeast Coast region (Nixon et al., 1996). In contrast, Delaware Bay, Narragansett Bay, and Boston Harbor have freshwater residence times of 3.3, 0.85, and 0.33 months, respectively (Dettmann, 2001). Because of the size of Chesapeake Bay, conditions in this estuary heavily influence area-weighted statistical summaries of Northeast Coast conditions.

The Northeast Coast region, which includes the coastal waters and watersheds of Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont, and Virginia, is the most densely populated coastal region in the United States (Figure 3-3). In 2003, the coastal population of the Northeast Coast region was the largest in the country, with 52.6 million people, representing 34% of the nation's total coastal population. Although coastal counties along the Northeast Coast showed the slowest rate of population increase (58%) between 1980 and 2003, the region gained the second-largest number of people (almost 8 million) of all U.S. regions during this time. Figure 3-4 presents population data for Northeast Coast coastal counties since 1980 (Crossett et al., 2004).

Although the data presented in this chapter are summarized on a regional level, they are publicly accessible and can be used to summarize conditions by biogeographic province, state, and—where sufficient data are available—by waterbody. The NEP CCR (U.S. EPA, 2006b) is an example of how these data may be assessed at a finer scale.



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 in late summer. Data were not collected during other time periods.

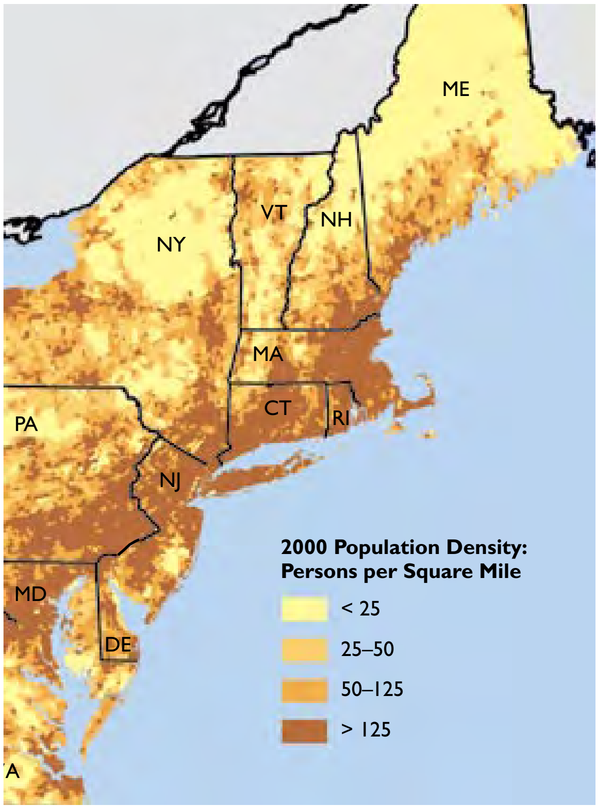


Figure 3-3. Human population density by county for watersheds that drain to the Northeast Coast (U.S. Census Bureau, 2001).

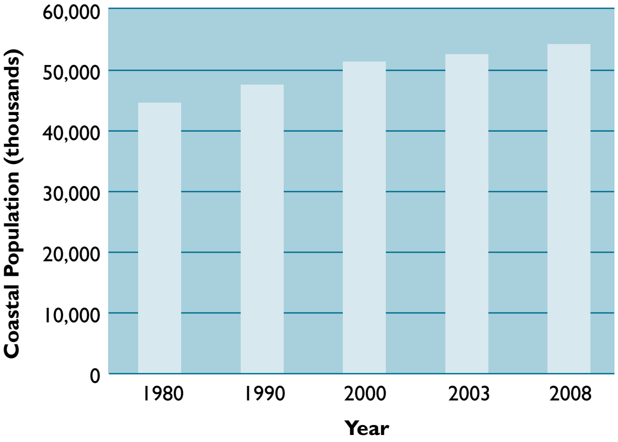


Figure 3-4. Actual and estimated population of coastal counties in Northeast Coast states, 1980–2008 (Crossett et al., 2004).

Coastal Monitoring Data—Status of Coastal Condition

All sampling sites that contributed data for this report were selected at random according to probabilistic sampling designs and were generally sampled during the summer months of 2001 and 2002 by states participating in the NCA; however, there were some exceptions to this scheme. Several areas, including parts of Maine, Massachusetts, Rhode Island, Connecticut, and New York (in the case of water quality assessment), contributed data only in 2001, either because of planned non-participation in 2002 or because of concerns regarding data quality. Chesapeake Bay was not sampled as part of the NCA survey in 2001 or 2002; therefore, the most recent representative data available from other programs were used for the assessment of this waterbody. Specifically, water quality conditions and benthic community data from 2001 and 2002 were provided by the Chesapeake Bay Program (CBP), and sediment quality data for the Bay were collected during NOAA's sediment triad cruises from 1998 through 2001.

Conditions for the Northeast Coast region were calculated and expressed in terms of the percentage of coastal area rated good, fair, or poor, or for which data were missing. For the areas not sampled in the 2002 survey, the 2001 station-area weights were doubled to ensure approximately equivalent representation on a per-area basis throughout the Northeast Coast region. An exception to this method of areal weighting was the fish tissue contaminants index, for which survey results were unweighted and reported as the percentage of fish samples analyzed in good, fair, or poor condition. Data from the 2002 survey were not included in the trend analysis discussed later in this chapter.

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.

Water Quality Index

The water quality index for the coastal waters of the Northeast Coast region is rated fair, with 13% of the coastal area rated poor and 47% of the area rated fair for water quality condition (Figure 3-5). The water quality index was based on measurements of five component indicators: DIN, DIP, chlorophyll *a*, water clarity, and dissolved oxygen.

Most of the Northeast Coast sites rated poor for water quality were concentrated in a few estuarine systems, in particular New York/New Jersey Harbor; some tributaries of Delaware Bay; the Delaware River; and the western and northern tributaries of Chesapeake Bay. Although signs of degraded water quality impacts are evident throughout the Northeast Coast region, the water

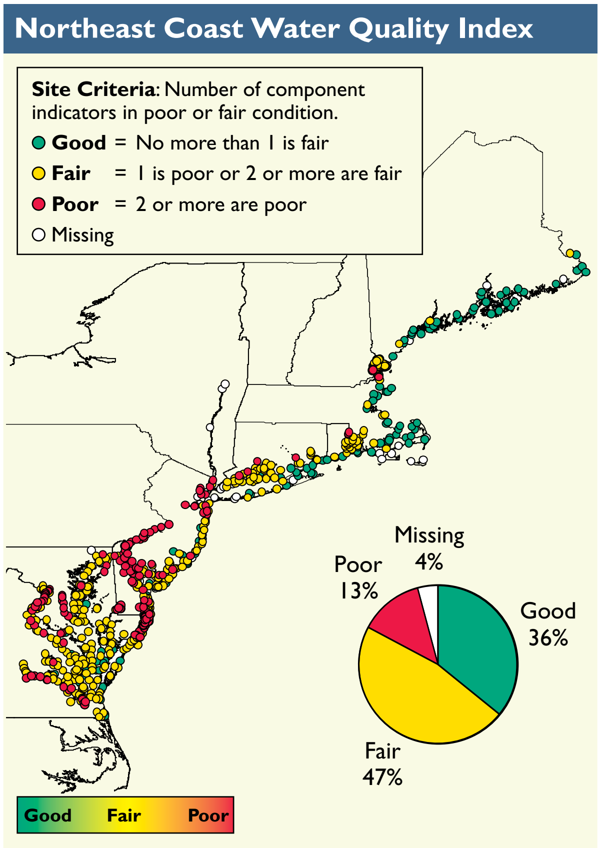


Figure 3-5. Water quality index data for Northeast Coast coastal waters (U.S. EPA/NCA).

quality index indicates that the degradation was more evident in the coastal waters of the Virginian Province than in the coastal waters of the Acadian Province. Generally, the relatively open rocky coasts; cold, salty waters; and high tidal ranges of the Acadian Province favor well-mixed conditions. In contrast, the historically unglaciated parts of the Virginian Province have extensive watersheds that funnel nutrients, sediment, and organic material into secluded, poorly flushed estuaries that are much more susceptible to eutrophication. The pattern of water quality degradation in the Northeast Coast region is also influenced by the distribution of population density (see Figure 3-3).

Nutrients: Nitrogen and Phosphorus

The Northeast Coast region is rated good for DIN concentrations, with only 5% of the coastal area rated poor for this component indicator. Poor DIN concentrations (DIN concentrations greater than 0.5 mg/L) were largely confined to stations in New York/New Jersey Harbor; the western tributaries of Chesapeake Bay; the Delaware River; and the Delaware Inland Bays.

The Northeast Coast region is rated fair for DIP concentrations, with 58% of the coastal area rated fair or poor for this component indicator. The highest DIP concentrations were most evident at stations in parts of the New York/New Jersey Harbor and Delaware River and were found to a lesser extent in Narragansett Bay, Long Island Sound, and the western tributaries of Chesapeake Bay. Good conditions (low DIP concentrations) were notable in Cape Cod Bay, coastal Rhode Island waters, and the mainstem of Chesapeake Bay.

Chlorophyll *a*

The Northeast Coast region is rated fair for chlorophyll *a* concentrations, with roughly 9% of the coastal area rated poor and another 41% of the area rated fair for this component indicator. Generally, the broad pattern of chlorophyll *a* concentrations is similar to that of nutrients, with chlorophyll *a* levels much higher to the south of Cape Cod (Virginian Province) than to the north (Acadian Province). Chlorophyll *a* concentrations mirror nutrient levels in the Maryland Coastal Bays, Chesapeake Bay tributaries, and much of the Northeast Coast coastal waters; however, there is little apparent spatial correlation between chlorophyll *a* and nutrient concentrations in the Chesapeake Bay mainstem, Delaware Bay, or New York/New Jersey Harbor areas. Spatial patterns in nutrient and chlorophyll *a* concentrations differ for a number of reasons. Algae may not be able to use nutrients effectively in very turbid water or in regions with high flushing rates; dissolved nutrient concentrations may be low due to nutrient uptake by phytoplankton blooms; or locations of peak nutrient and biomass concentrations may not coincide in space or time.

Water Clarity

The Northeast Coast region is rated fair for water clarity, with 20% of the coastal area rated poor for this component indicator. Water clarity reference levels varied across the Northeast Coast region (see Chapter 1 for additional information). The box below shows the criteria for rating a site in poor condition for water clarity in estuarine systems that have differing levels of natural turbidity.

Coastal Areas	Criteria for a Poor Rating (Percentage of Ambient Light that Reaches 1 Meter in Depth)
Chesapeake Bay Estuarine System	< 20%
Delaware River/Bay Estuarine System	< 5%
All remaining Northeast Coast coastal waters	< 10%

Dissolved Oxygen

Dissolved oxygen is rated fair for the Northeast Coast region, with 9% of the coastal area rated poor for this component indicator. Based on the NCA and CBP data collected in 2001 and 2002, the stations rated poor were primarily located in Long Island Sound and the isolated, deep channels of the Chesapeake Bay mainstem and western tributaries. Although not reflected by the data collected for this assessment, other areas of the Northeast Coast may experience low dissolved oxygen levels on a diel basis or due to prevailing wind events. Fair dissolved oxygen conditions were measured in another 19% of the coastal area, notably at stations in Chesapeake Bay, Long Island Sound, and Narragansett Bay. Dissolved oxygen levels were rated good in more than two-thirds of the Northeast Coast coastal area. A recent review of factors affecting the extent of hypoxic bottom water in Chesapeake Bay can be found in Hagy (2002), Hagy et al. (2004), and Kemp et al. (2005). In addition, more intensive and complementary monitoring programs in upper Narragansett Bay documented episodic dissolved oxygen depletion events (dissolved oxygen < 2 mg/L) during short time periods (Deacutis et al., 2006).

Sediment Quality Index

The sediment quality index for the coastal waters of the Northeast Coast region is rated fair to poor, with 13% of the coastal area rated poor for sediment quality condition (Figure 3-6). Data were missing for less than 1% of the coastal area. This index is based on measurements of three component indicators: sediment toxicity, sediment contaminants, and sediment TOC. Hot spots of poor sediment quality were evident at stations in Narragansett Bay, western Long Island Sound, New York/New Jersey Harbor, and the upper portions of the Chesapeake Bay and Potomac River. To a large extent, the pattern of the sediment quality index for the Northeast Coast region mirrors the pattern of sediment contamination, a component indicator of this index.

Sediment Toxicity

The Northeast Coast region is rated good for sediment toxicity, with about 4% of the coastal area rated poor for this component indicator. Sites rated poor for sediment toxicity were located predominantly in parts of Cape Cod Bay, western Long Island Sound, New York/New Jersey Harbor, and the tidal-fresh water parts of Delaware Bay. In a previous report (U.S. EPA, 2004a), a generally weak statistical relationship between sediment contamination and amphipod survival was found and may reflect, in part, the strict criterion of mortality used to characterize toxicity in the amphipod assay. This weak relationship also highlights the need for a more complete analysis of the bioavailability of the toxicants, i.e., an analysis that considers the effect of equilibrium partitioning and the mitigating effects of sequestering toxicants with sulfides or organic carbon (DiToro et al., 1991; U.S. EPA, 1993; Daskalakis and O'Conner, 1994).

Sediment Contaminants

The Northeast Coast region is rated fair for sediment contaminant concentrations, with 9% of coastal area rated poor and 12% of the area rated fair for this component indicator. Stations rated poor for sediment contaminants were clustered in areas neighboring major urban centers. These areas included Narragansett Bay, New York/New Jersey Harbor, western Long Island Sound, upper Chesapeake Bay, and the upper Potomac River. Elevated levels of metals (e.g., arsenic, chromium, mercury, nickel, silver, and zinc), PCBs, and DDT were primarily responsible for the poor sediment contaminant ratings.

Sediment TOC

The Northeast Coast region is rated good for sediment TOC because only 1% of the coastal area

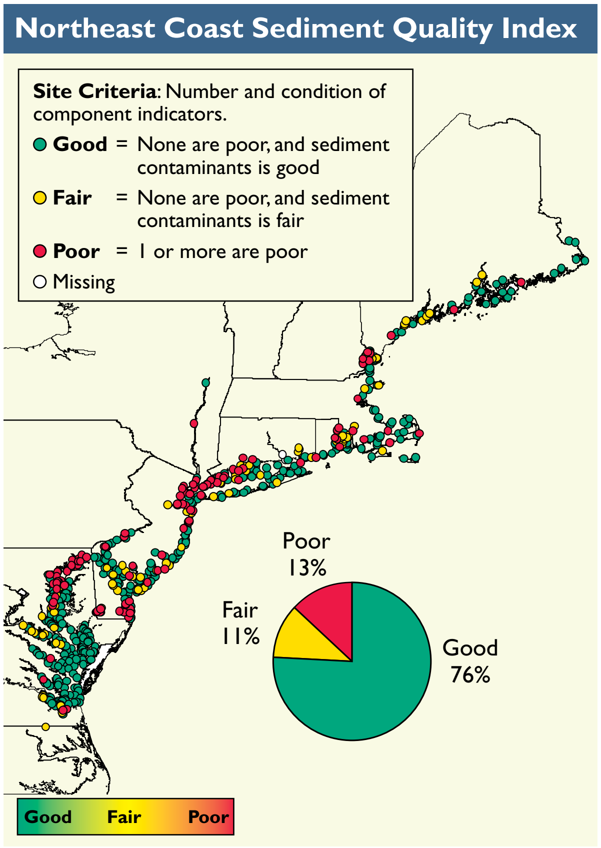


Figure 3-6. Sediment quality index data for Northeast Coast coastal waters (U.S. EPA/NCA).

was rated poor. In addition, 23% of the coastal area was rated fair, and 60% was rated good for this component indicator. Generally, elevated TOC levels were found at stations in the same locations as contaminated sediments. The high percentage of missing data (16%) for this component indicator reflects concerns about the quality of the TOC data analyzed for Connecticut's coastal waters.

Benthic Index

The benthic index for the coastal waters of the Northeast Coast region is rated poor, with 27% of the coastal area rated poor for benthic condition (Figure 3-7). The Northeast Coast region features two distinct biogeographic provinces: the Acadian Province (north of Cape Cod) and the Virginian Province (south of Cape Cod). Two separate benthic indices were developed to evaluate the unique benthic communities of these provinces: the Acadian Province Benthic Index (Hale and Heltshe, 2008) and the Virginian Province Benthic Index (Paul et al., 2001). Because of the way the indices were developed, the Acadian Province Benthic Index has three rating categories (good, fair, and poor), whereas the Virginian Province Benthic Index has only two rating categories (good and poor).

The benthic condition of the Acadian Province is very different from the benthic condition of the Virginian Province. Coastal conditions in the Acadian Province are more oceanic and have higher bottom-water salinity than those in the Virginian Province. In the northern waters (Acadian Province), benthic communities were sampled at sites with an average depth of 57 feet, 36 feet deeper than the average depth of stations sampled in the Mid-Atlantic coastal waters in the southern portion of the Virginian Province. Poor benthic condition is evident at stations in many sections of the Virginian Province, including Chesapeake Bay; portions of Delaware Bay; New York/New Jersey Harbor; western Long Island Sound; and upper Narragansett Bay. In contrast, most sampling stations in the Acadian Province show good or fair benthic condition. The differences by province reflect exposure to different stress levels by the benthic communities.

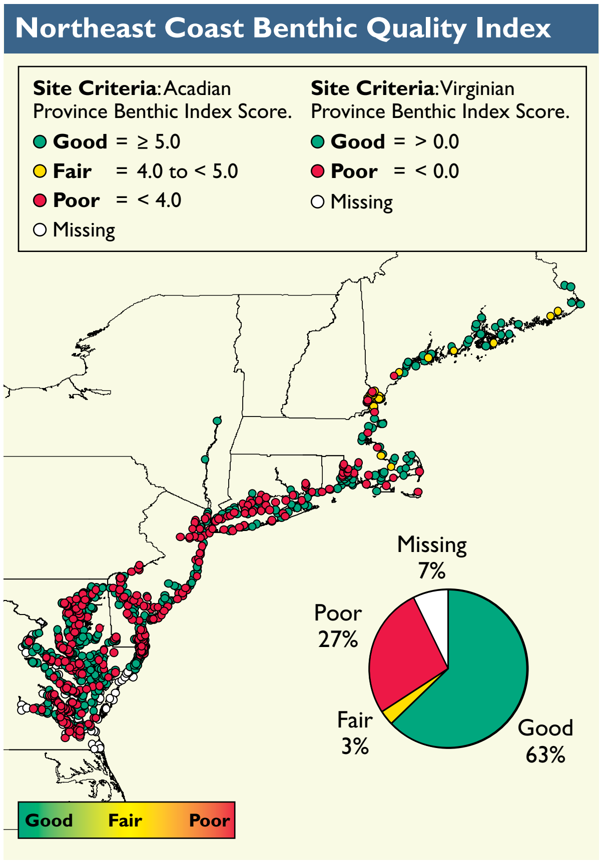


Figure 3-7. Benthic index data for Northeast Coast coastal waters (U.S. EPA/NCA).

Coastal Habitat Index

Wetlands are threatened by many human activities, including loss and destruction due to land development, eutrophication, and the introduction of toxic chemicals. Losses can also result from land subsidence, sea-level rise, and the introduction and spread of exotic species (e.g., nutria). Ecologists estimate that more than one-half of the coastal wetlands of the Northeast Coast region have been lost since pre-colonial times. Although modern legislation has greatly slowed the rate of habitat loss, the Northeast Coast region lost 650 acres between 1990 and 2000, which amounts to a loss of 0.14% over 10 years. The rate of wetland loss for this time period was the lowest percent loss for all regions of the conterminous United States. Based on the calculated coastal habitat index value, the coastal habitat index for the Northeast Coast is rated good to fair.

Highlight

Comparing Two Benthic Indices Applied to Monitoring Data from NY/NJ Harbor

Scientists and managers have worked diligently to answer the question "Is this place relatively clean, or is it stressed?" Evaluating a site can involve analyzing the levels of chemical and physical stress on bottom-dwelling communities by directly measuring sediment chemical concentrations, relative toxicity, and grain size. In addition, characterizing the salinity of the overlying water and the structure and composition of the benthic community reflects exposures to chemical and physical stresses in the environment. Indices of benthic condition have been developed to examine the complex conditions that exist in the sediments, quantifying those conditions as a single numeric value. To help evaluate the condition of the New York/New Jersey (NY/NJ) Harbor, two different, independently developed benthic indices were applied to Regional Environmental Monitoring and Assessment Program (REMAP) monitoring data from 1998 (Adams and Benyi, 2003). The resulting index ratings were compared to evaluate the similarities and differences between classifications developed by applying different benthic indices to the same set of data.

The two benthic indices used in this assessment were the Virginian Province Benthic Index and the Benthic Index of Biotic Integrity (B-IBI). The Virginian Province Benthic Index (Paul et al., 2001) was developed in the EMAP-Virginian Province (VP) for use in the waters along the East Coast of the United States from Cape Cod to the mouth of the Chesapeake Bay and has been used to assess NCA data for the Virginian Province in this NCCR III. The B-IBI (Adams et al., 1998) was developed specifically for evaluating the benthic communities of the NY/NJ region. The approaches used in developing the two indices were quite different. The Virginian Province Benthic Index uses statistical techniques to evaluate appropriate metrics, whereas the B-IBI uses a method that was developed for freshwater systems and involves applying values to select metrics based on established criteria derived from reference stations (see box). Validation of the NY/NJ Harbor B-IBI using independent data from 72 sites in the Harbor showed that the index was 93% effective at distinguishing anthropogenically stressed sites from reference sites (Adams et al., 1998).

Virginian Province Benthic Index, developed using discriminant analysis, is characterized by the following three metrics:

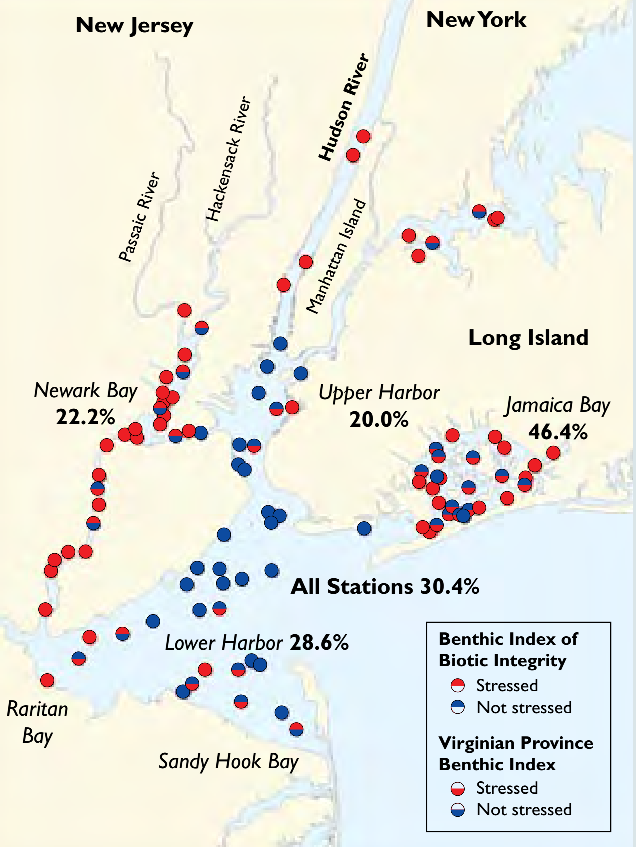
1) Gleason's Diversity Index, adjusted for salinity
2) Expected number of tubificids, adjusted for salinity
3) Abundance of spionid polychaetes (Strobel et al., 1995).

Gleason's Diversity Index measures the variety of invertebrates in the sediment. Tubificids are a type of worm found, but not exclusively, in enriched areas, and salinity adjustment makes the presence of tubificids of great importance in low-saline areas, but not of high importance in estuarine areas. Spionid polychaetes are also a type of worm.

Benthic Index of Biotic Integrity (B-IBI), developed by testing the classification efficiency of candidate measures, is characterized by the following five metrics:

1) Number of species
2) Abundance of species
3) Biomass
4) Percent of total abundance indicative of pollution
5) Percent of total abundance sensitive to pollution.

The B-IBI is similar to the Index of Biotic Integrity developed for freshwater benthic communities by Karr (Kerans and Karr, 1994). Threshold values for these metrics were defined for two salinity ranges (polyhaline and euryhaline) and two sediment types (mud and sand). The B-IBI was calculated by scoring each selected metric based on whether its threshold value approximated (5), deviated slightly (3), or deviated greatly (1) from conditions at the best reference sites. Those metrics were then averaged.



Benthic index classifications and percent disagreement between B-IBI and the Virginian Province Benthic Index classifications for REMAP sampling stations in the NY/NJ Harbor area (U.S. EPA).

The REMAP sampling stations were selected using a design common in EMAP programs (probabilistic, stratified-random design), with 28 stations located in each of the four subbasins. Benthic macroinvertebrate data from two replicate samples were averaged, and the benthic index results were calculated for each station. Overall, disagreement in the classifications resulting from analyses using the Virginian Province Benthic Index and B-IBI occurred at only 30% of the stations overall. In the map, a filled circle represents each station, with the top half representing the B-IBI classification and the bottom half representing the Virginian Province Benthic Index classification. When the halves of the circle are colored differently, they disagree. The percentage of disagreement between the results obtained using the two indices is included on the map for each subbasin.

Within the four subbasins, the percentage of stressed sites ranged from a low of 8% to a high of 93% using the B-IBI, and from 32% to 93% using the Virginian Province Benthic Index. In most subbasins, the percent of stations stressed was similar. For example, in the Upper Harbor, both indices identified 55% of stations in the subbasin as stressed, and the two indices had the strongest agreement by station. In contrast, the percent of stressed stations in Jamaica Bay was 46% for the B-IBI and 93% for the Virginian Province Benthic Index. In this subbasin, the Virginian Province Benthic Index classified two times as many stations as stressed as did the B-IBI (26 and 13 out of 28, respectively). In addition, the highest percentage of disagreement between the results obtained using the two indices (46%) occurred in this subbasin.

The Virginian Province Benthic Index and B-IBI use different metrics to come to an understanding of a station's ecological health status. Although there might appear to be a fair amount of disagreement between the classifications of stations, the overall agreement for the entire harbor was 70%. In areas where there was disagreement, it is worth examining the reasons for the differences. At stations where the B-IBI indicated stress and the Virginian Province Benthic Index did not, the primary metrics driving the B-IBI classification were biomass and the abundances of pollution-sensitive and pollution-indicative species; none of these metrics are measured in the Virginian Province Benthic Index. Since these two indices are used as indicators of stress, it would be valuable to examine other metrics, such as chemical concentrations of metals and organics in the sediment, to determine whether chemical stresses are occurring.

Fish Tissue Contaminants Index

The fish tissue contaminants index for the Northeast Coast region is rated poor based on concentrations of chemical contaminants found in composites of whole-body fish and lobster specimens. Thirty-one percent of the fish samples analyzed were rated poor, and 28% were rated fair (Figure 3-8). Although this figure gives an accurate indication of where fish or lobster specimens with appreciable contaminant levels were collected, several associated factors should be carefully considered before relating these findings to human risk or to the evaluation of coastal condition. For example, one factor that should be considered is the species of fish analyzed because different tissue types have different affinities for specific contaminants and these differences are likely to be species dependent. Currently, detailed information regarding these affinities is sparse. To improve understanding, NCA sampling and analysis protocols were altered in subsequent years to analyze "split samples" (i.e., samples of edible portions of fish and lobster are analyzed separately from inedible portions, and lobster hepatopancreas [tomalley] is also analyzed separately from the other tissues). In addition, it is helpful to consider the habits of the fish species collected when interpreting results. For instance, knowing the migration patterns of a fish species may help researchers determine the source of the contaminants measured in fish tissue.

Elevated concentrations of PCBs were responsible for the fair or poor ratings for a large majority of specimens, although other contaminants, such as DDT or mercury, were also implicated. Based on preliminary information from the split-sample study mentioned above, only those contaminants (e.g., mercury) that have an affinity for muscle tissue are likely to have significantly higher concentrations in fillets than in whole fish; concentrations for many other contaminants will be lower in fillets than in whole-fish samples. NCA data suggest that there may be a pronounced gradient increasing from north to south in the incidence of contamination; however, distinct differences also existed in the types of organisms caught and analyzed across the region (e.g., primarily lobster in Maine versus fish such as white perch and summer flounder farther south). It may be the case that cadmium was preferentially accumulated in lobster, although not to concentrations that exceeded Guidance levels. PCBs and DDT were the contaminants most frequently exceeding Guidance levels, with the highest concentrations measured in white perch and summer flounder. Further research is needed to understand the relative importance of the species and tissue affinity for contaminants versus the availability of the contaminants.

Northeast Coast Fish Tissue Contaminants Index

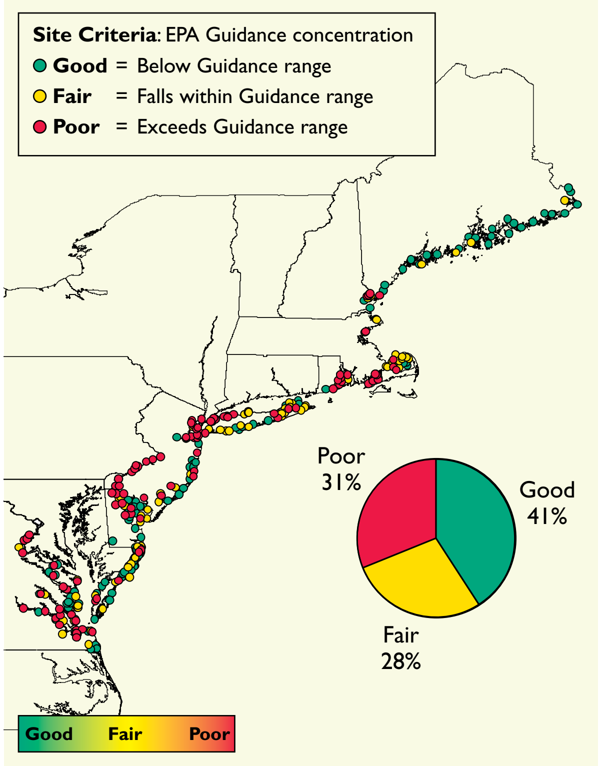


Figure 3-8. Fish tissue contaminants index data for Northeast Coast coastal waters (U.S. EPA/NCA).

Trends of Coastal Monitoring Data—Northeast Coast Region/Virginian Province Subset

Temporal Change in Ecological Condition

Beginning in the early 1990s, EPA and its partners conducted a series of monitoring programs to assess the ecological condition of the nation's coastal waters. A hallmark of the various programs was consistency, both in the probabilistic nature of the sampling designs (sites were selected at random to represent all coastal waters) and in the fact that all programs used a core set of parameters that were measured with equivalent protocols and QA/QC procedures. This consistency eases the task of tracking changes over time. The following sections analyze these data to answer two trend-related questions for the Northeast Coast region: what is the year-to-year variability evident in the proportions of the region's coastal area rated in good, fair, and poor condition, and are there significant changes in the area classified as poor during the period from 1990 to 2001?

Several monitoring programs have assessed portions of the Northeast Coast region since the early 1990s, including the Environmental Montoring and Assessment Program-Virginian Province (EMAP-VP), Mid-Atlantic Integrated Assessment (MAIA), Maryland Coastal Bays Program, and NCA. Details regarding these assessments are described in the following text box. Only common regions, indices, and component indicators measured by these programs over two time periods were considered. The trend analysis for the coastal waters north of Chesapeake Bay, through and including southern Cape Cod, compares conditions measured in 1990–1993 with those assessed a decade later in 2000–2001. The trend analysis is based on EMAP and NCA probability survey data restricted to the Virginian Province, exclusive of Chesapeake Bay. Core parameters measured consistently in these studies include dissolved oxygen, water clarity, sediment contaminants, sediment toxicity, sediment TOC, and benthic condition. Results for both periods were expressed as the percentage of coastal area rated good, fair, or poor based on the parameters assessed. Standard errors for these estimates were calculated according to methods listed on the EMAP Aquatic Resource Monitoring Web site (http://www.epa.gov/nheerl/arm). The reference values and guidelines outlined in Chapter 1 were used to determine good, fair, or poor condition for each indicator from both time periods.

The trend analysis results discussed in this section are restricted to a subset of the Virginian Province monitoring results from probability surveys. More detailed trend analyses can be done in estuaries with established long-term monitoring programs (e.g., in relation to hypoxia in Chesapeake Bay, reported on by Hagy et al. [2004]).

In this analysis, water quality is represented by two parameters: water clarity and bottom-water dissolved oxygen concentrations. Figure 3-9 indicates that poor water clarity was evident in 3% of the Northeast Coast coastal area in the early 1990s and was evident in 4% of the coastal area in 2000 and 2001. There were no persistent year-to-year trends of improvement or degradation, and there was no significant difference between the 1990–1993 and 2000–2001 averages.

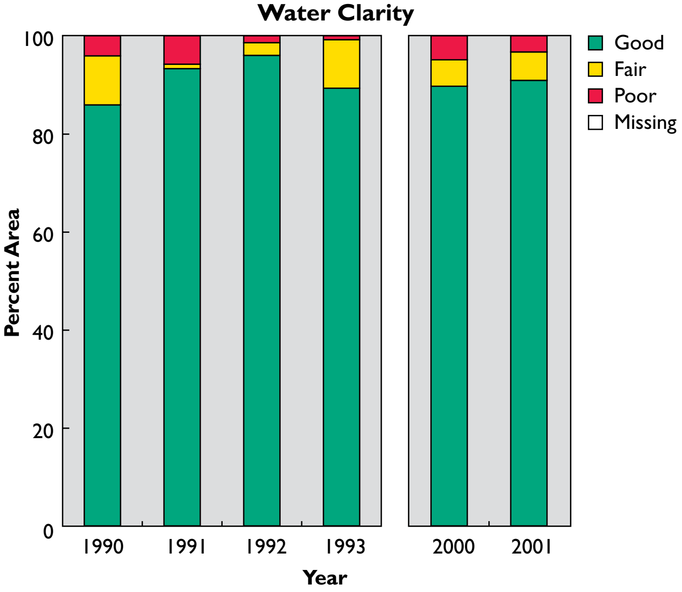


Figure 3-9. Percent area of Northeast Coast coastal waters in good, fair, poor, or missing categories for water clarity measured over two time periods, 1990–1993 and 2000–2001 (U.S. EPA/NCA).

Programs, Parameters, and Time Periods Considered in the Northeast Coast Trend Analysis

Since the early 1990s, four monitoring programs have assessed portions of Northeast Coast coastal waters using similar sampling designs and measurement protocols. For reasons outlined below, data from only two of these programs were used in analyzing trends in the Northeast Coast region over time. The contributing programs are the EMAP-VP (1990–1993) and the NCA (2000–2001). Interannual variability in a variety of parameters common to both EMAP-VP and NCA are summarized and used to help identify changes between these two time periods.

In the Northeast Coast region, the EMAP-VP project measured conditions in the Virginian Province (Cape Cod through Chesapeake Bay) each summer from 1990 through 1993. Core parameters measured included dissolved oxygen, water clarity, sediment contaminants, sediment toxicity, sediment TOC, and benthic condition. No other water quality indicators, such as chlorophyll *a* or nutrient concentrations, were measured. Results of the EMAP-VP survey were reported by Paul et al. (1999) and in the NCCR I (U.S. EPA, 2001c).

The Delaware and Maryland Coastal Bays were assessed in the summer of 1993 using EMAP methods, and the results were reported in *Assessment of the Ecological Condition of the Delaware and Maryland Coastal Bays* (Chaillou et al., 1996). These data were not included in this trend analysis because they represent a small fraction of the Northeast Coast region, and these bays were assessed independently in the EMAP-VP study.

The MAIA evaluated the coastal waters from Delaware Bay south through Albemarle-Pamlico Estuarine System during the summers of 1997 and 1998. All core indicators listed above were measured, along with several additional water quality parameters. Results were presented in the report *Condition of Mid-Atlantic Estuaries* (U.S. EPA, 1998a) and were also included in the NCCR I. Because of the limited overlap of the MAIA study area and Northeast Coast region considered here, MAIA data were not included in the trend analysis.

The NCA sampled all waters in the Northeast Coast region (Maine through the Delmarva Peninsula, with the exception of Block Island and Nantucket sounds) during the summers of 2000 and 2001, and portions of the region in 2002 and later. Conditions were evaluated using the EMAP core indicators listed above, as well as additional water quality parameters, such as chlorophyll *a* and nutrient concentrations. Assessment of the data collected in 2000 was reported in the NCCR II (U.S. EPA, 2004a), and data from 2001 and 2002 are assessed in this current report (NCCR III). It should be noted that NCA data from 2002 were excluded from the trend analysis because they were only collected from portions of the Northeast Coast region.

Only portions of Chesapeake Bay were monitored by the NCA survey in 2000 and 2001. The assessment of 2000 data, reported in NCCR II, utilized data from the CBP (http://www.chesapeakebay.net) to evaluate water quality and benthic quality, and MAIA 1997–1998 data were used to assess sediment quality for the Bay. A similar approach is used in the current report (NCCR III), which includes water quality and benthic community data sampled in 2001 and 2002 from the CBP, along with 1998–2001 sediment quality data from NOAA. Because of the different sampling designs and time periods for documenting Chesapeake Bay conditions, Chesapeake Bay was excluded from the trend analysis.

In summary, the data considered in the trend analysis for the Northeast Coast region were limited to estuaries and coastal embayments from southern Cape Cod through the Delmarva Peninsula that were sampled using data from consistent sampling designs for two time periods: 1990–1993 and 2000–2001. Indicators measured consistently in these studies include dissolved oxygen, water clarity, sediment toxicity, sediment contaminants, sediment TOC, and benthic condition.

Figure 3-10 shows the percentage of the Northeast Coast coastal area rated good, fair, or poor for dissolved oxygen during the periods 1990–1993 and 2000–2001. On average, 83% of the region's coastal area had adequate dissolved oxygen levels in the early 1990s, and less than 1% of the area was rated poor for this component indicator. In the 2000–2001 time period, dissolved oxygen levels were rated good in 73% of the coastal area and poor in 4% of the area. The year-to-year variation in dissolved oxygen concentrations is large, and the differences between the two time periods are not significant.

For the Virginian Province data subset being used in this trend analysis, the condition of coastal sediments was evaluated using three component indicators: sediment toxicity, sediment contaminants, and sediment TOC; however, the overall sediment quality index was not compared. Approximately 9% of the coastal area was rated poor for sediment toxicity during each time period (Figure 3-11). Figure 3-12 indicates that the proportion of coastal area rated fair or poor for sediment contaminants is variable and showed no significant trends. For example, 7% of the coastal area was rated poor and 18% was rated fair in 1990–1993 as compared to 12% rated poor and 17% rated fair in 2000–2001. Figure 3-13 shows that less than 2% of the Northeast Coast region's coastal area had excessive concentrations of TOC in sediments, and comparable areas were classified as fair for this indicator.

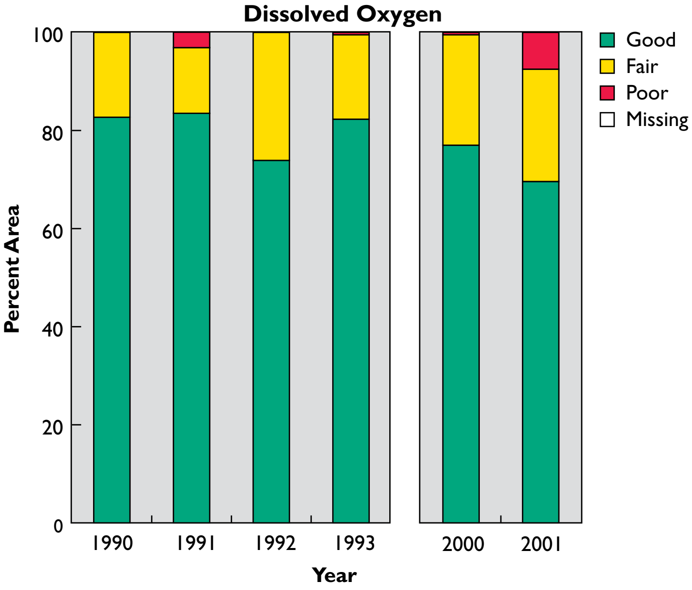


Figure 3-10. Percent area of Northeast Coast coastal waters in good, fair, poor, or missing categories for bottom-water dissolved oxygen concentrations measured over two time periods, 1990–1993 and 2000–2001 (U.S. EPA/NCA).

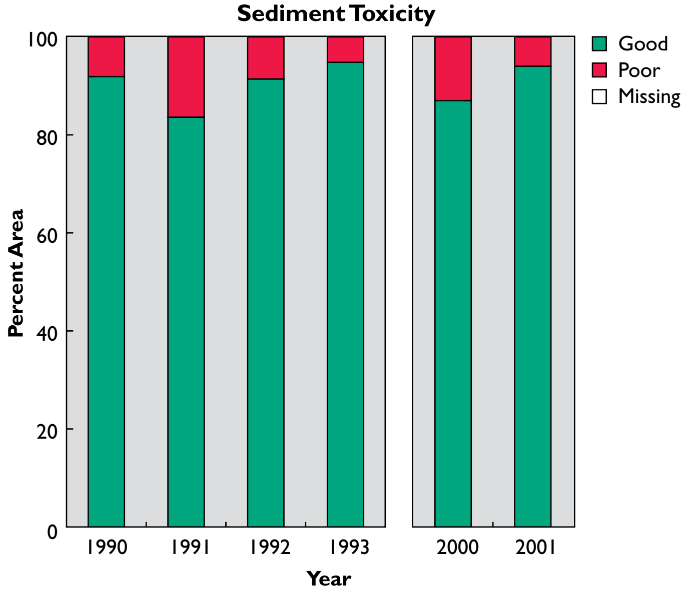


Figure 3-11. Percent area of Northeast Coast coastal waters in good, poor, or missing categories for sediment toxicity measured over two time periods, 1990–1993 and 2000–2001 (U.S. EPA/NCA).

Sediment quality can affect the health and abundances of bottom-dwelling invertebrates (courtesy of NPS).

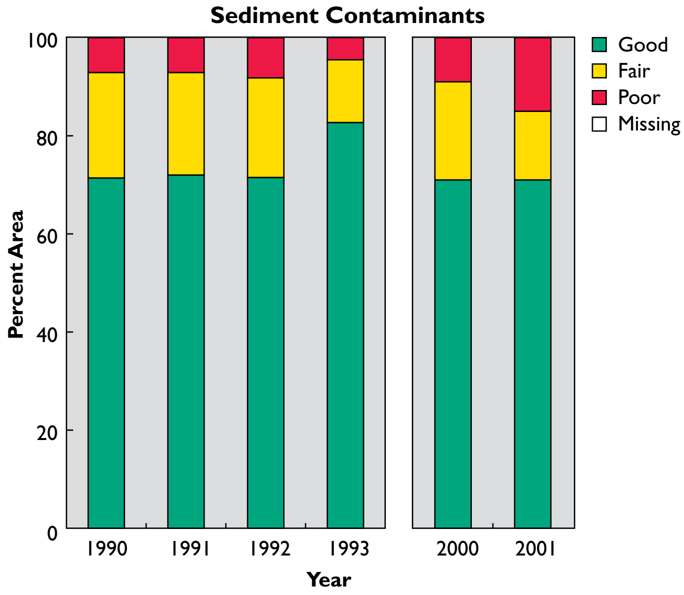


Figure 3-12. Percent area of Northeast Coast coastal waters in good, fair, poor, or missing categories for sediment contaminants measured over two time periods, 1990–1993 and 2000–2001 (U.S. EPA/NCA).

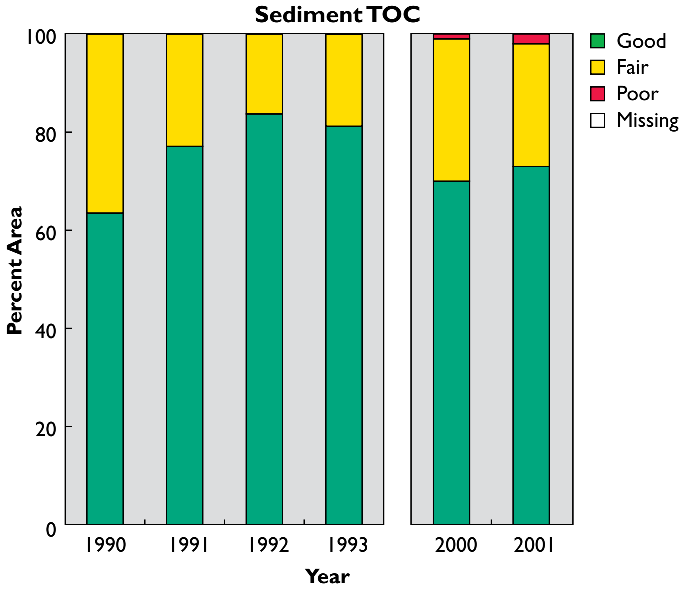


Figure 3-13. Percent area of Northeast Coast coastal waters in good, fair, poor, or missing categories for sediment TOC measured over two time periods, 1990–1993 and 2000–2001 (U.S. EPA/NCA).

The benthic index for the Northeast Coast coastal area is a multi-metric indicator of the biological condition of benthic macroinvertebrate communities. This index measures the habitability of sediments for benthic communities of high biological integrity and serves as an overall indicator of water and sediment conditions. Figure 3-14 shows a lack of detectable trend in the percent of Northeast Coast coastal area that was rated poor for the benthic index. On average, 26% of the coastal area was rated poor in 1990–1993 and 34% of the area was rated poor in 2000–2001, although the difference is not significant.

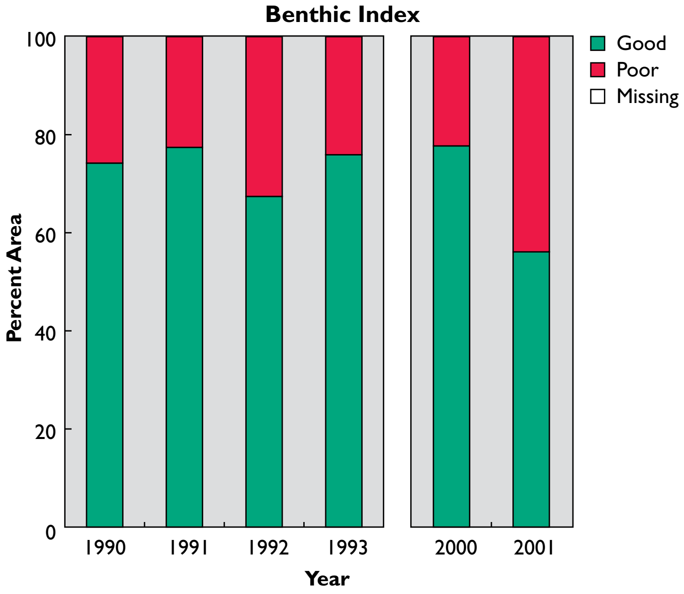


Figure 3-14. Percent area of Northeast Coast coastal waters in good, poor, or missing categories for the benthic index measured over two time periods, 1990–1993 and 2000–2001 (U.S. EPA/NCA).

Figure 3-15 summarizes changes in the percent area classified as poor in the Northeast Coast coastal area for the six common indicators measured over two time periods: 1990–1993 and 2000–2001. The error bars shown are 95% confidence intervals calculated as described at the EMAP Aquatic Resource Monitoring Web site (http://www.epa.gov/nheerl/arm). Note that for all indicators, a slightly greater percentage of coastal area is rated poor in the later time interval; however, none of the differences are significant (based on a jackknifed analysis of variance that considers variable station weighting).

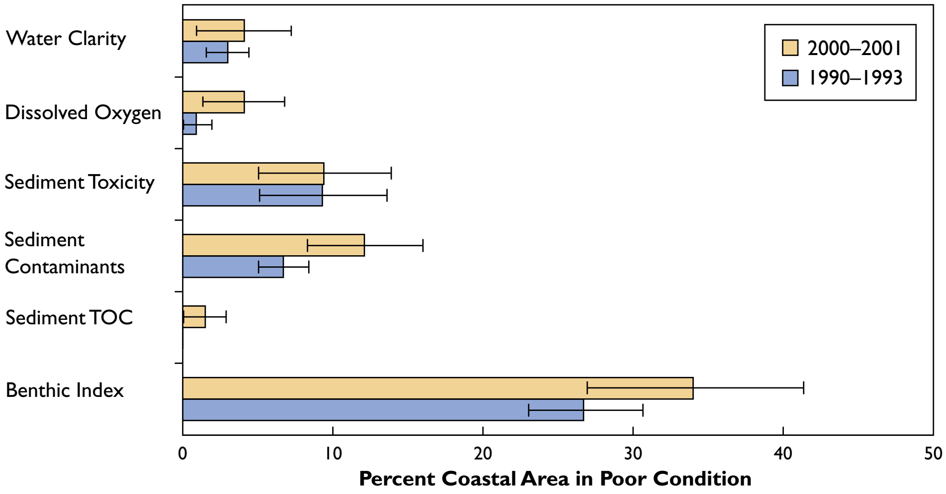


Figure 3-15. Comparison of percent area of Northeast Coast coastal waters rated poor for ecological indicators between two time periods, 1990–1993 and 2000–2001. Error bars are 95% confidence intervals (U.S. EPA/NCA).

Although data processing was performed to compare areas where sampling overlapped geographically during the 1990–1993 and 2000–2001 time periods, comparison of other properties indicated that there were some differences between the samples from the two time periods. The cumulative distribution function (CDF) for depth indicates that similar water depths were measured by the EMAP-VP (with Block Island and Nantucket Sound samples excluded) and NCA studies; however, Figure 3-16 shows the NCA depth CDF slightly above the EMAP-VP CDF over the range of 20–30 meters, indicating a slightly higher NCA sampling frequency in this depth range. There were much larger differences in the time of year sampled for the two studies. EMAP-VP sampling started slightly later in the year, but finished earlier than the NCA sampling. In addition, there were significant differences in surface water temperature and salinity at the time of sampling. Significantly warmer temperatures were measured by the NCA than by the EMAP-VP, likely due to a higher sampling frequency later in the summer for the NCA than the EMAP-VP. The percent of the coastal area with salinities below 25 ppt was the same in both time periods; however, when the areas with salinities above 25 ppt were compared, the NCA samples exhibited slightly lower salinities.

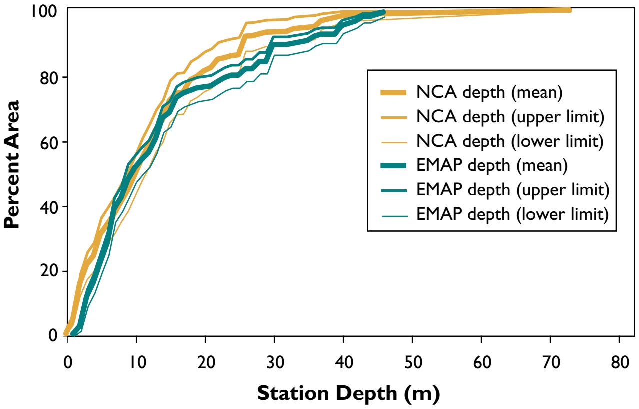


Figure 3-16. Cumulative distribution functions of station depths measured in EMAP-VP and NCA studies. Upper and lower limits are 95% confidence limits (U.S. EPA/NCA).

Bowers Beach, DE, is located on the Delaware Bay (courtesy of NOAA).

Highlight

Implementing System-Wide Monitoring in the NOAA National Marine Sanctuaries


Whale watching is a popular activity in Stellwagen Bank NMS (courtesy of NOAA).

In 2004, the NOAA National Marine Sanctuary (NMS) Program launched a System-Wide Monitoring Program (SWiM) for the nation's 14 marine sanctuaries. The goal of SWiM is to provide a consistent approach to the design, implementation, and reporting of environmental condition assessments in sanctuaries, while allowing for tailored monitoring at individual sanctuary sites. The information collected by this program will contribute to and benefit from other monitoring programs, such as IOOS. Assessment reports will be developed for each sanctuary at the local level following a consistent model. The reports will serve as building blocks for the system-wide monitoring approach and allow for regional and national reports on environmental conditions at larger scales (NOAA, 2007h).

Implementation of SWiM began with the development of a guidance document (NOAA, 2004b) and a pilot assessment report (NOAA, 2007d) for one site, the Stellwagen Bank NMS, located off the Massachusetts coast. The Stellwagen Bank NMS is located 3 miles north of Cape Cod and 3 miles southeast of Cape Ann, entirely within federal waters. The pilot assessment report will serve as a model for the remaining 13 sanctuary assessments and as a means by which to answer questions about the condition of sanctuary resources. These determinations will be key to tracking the condition of marine ecosystems on the scale of individual sanctuaries, groups of sanctuaries, and system wide.

The Stellwagen Bank NMS assessment includes sections that describe sanctuary resources, pressures that threaten the integrity of the marine environment (e.g., human activities), the current state of resources, trends, and management responses to the pressures. The primary purpose of the document is to report on the status and trends of water, habitat, living resources, and archaeological resources, as well as on the human activities that affect them. Resource status is rated on a scale from poor to good, and the timelines used for comparison vary from topic to topic. Trends are generally based on observed status changes over the past 5 years and are reported as improving, declining, or not changing. Reports summarizing resource status and trends will be prepared for each marine sanctuary once every 5 years and, when possible, will coincide with the review of sanctuary management plans.

Development of the assessment report card relies on appraisal of the condition of the marine environment, using 15 questions as a guide (see figure). The questions are widely applicable across the system of marine sanctuaries and were derived from both a generalized ecosystem framework and the NMS Program mission. The role of this national framework is not to encourage the same monitoring at all sanctuaries; rather, its primary function is to apply a set of design, implementation, and reporting principles for all monitoring within the NMS Program. Completion of the process will result in a status and trends "report card" for sanctuaries at the local level that can be compiled to provide a snapshot of system-wide conditions. As report cards are updated, time series data will be developed to provide information on changes in the condition of the marine environments over time (NOAA, 2007d). For additional information about SWiM, please visit the NMS Program Web page at http://sanctuaries.noaa.gov/science/monitoring/welcome.html.

National Marine Sanctuary Assessment Report Card Format (NOAA, 2007d)

Status:

Good	Good/Fair	Fair	Fair/Poor	Poor
🟩	🟩	🟨	🟧	🟥

Trends:

▲ Improving — Not Changing ▼ Declining

#	Questions/Resources	Explanation	Trends
Water			
1	Are specific or multiple stressors, including changing oceanographic and atmospheric conditions, affecting water quality?	Captures shifts in conditions arising from changing natural processes and human-induced inputs.	
2	What is the eutrophic condition of sanctuary waters, and how is it changing?	Potential overgrowth and other competitive interactions that can lead to shifts in dominance in assemblages and food webs.	
3	Do sanctuary waters pose risks to human health?	Human health concerns aroused by evidence of contamination in bathing waters or fish intended for consumption, reports of respiratory distress, and other disorders attributable to an increase in HABs.	
4	What are the levels of human activities that may influence water quality, and how are they changing?	Human activities that affect water quality, including direct discharges, nonpoint-source discharges, airborne chemicals, and results of dredging and trawling.	
Habitat			
5	What is the abundance and distribution of major habitat types, and how are they changing?	These key attributes compared with what would be expected without human impacts, such as pollution, trawling, pipelines, fish traps, and dredging.	*Each item is assigned a status color and trend symbol.*
6	What is the condition of biologically structured habitats, and how is it changing?	Places where organisms form structures (habitats) on which other organisms depend, including coral reefs, kelp beds, and intertidal assemblages.	
7	What are the contaminant concentrations in sanctuary habitats, and how are they changing?	Risks posed by contaminants within benthic formations, including soft sediments, hard bottoms, and biogenic organisms.	
8	What are the levels of human activities that may influence habitat quality, and how are they changing?	Human activities that degrade habitat quality by affecting structural, biological, oceanographic, or chemical characteristics.	
Living Resources			
9	What is the status of biodiversity, and how is it changing?	The condition of living resources based on expected biodiversity levels and the interactions between species.	
10	What is the status of environmentally sustainable fishing, and how is it changing?	Whether harvesting is occurring at ecologically sustainable levels. Important to know extraction levels and the impacts of removal.	
11	What is the status of nonindigenous species, and how is it changing?	The potential threat posed by nonindigenous species; in some cases, by presence, in others, by measurable impacts.	
12	What is the status of key species, and how is it changing?	(1) Keystone species on which the persistence of a large number of other species in the ecosystem depend, and (2) other key species, including those that are indicators of ecosystem condition or change, those targeted for special protection efforts, or charismatic species associated with certain areas or ecosystems.	
13	What is the condition or health of key species, and how is it changing?	Measures of condition of key species that are important to determining the likelihood that the species will persist and continue to contribute to a vital ecosystem.	
14	What are the levels of human activities that may influence living resource quality, and how are they changing?	Human activities that degrade living resource quality by causing a loss or reduction in species, disrupting critical life stages, impairing various physiological processes, or promoting the introduction of nonindigenous species or pathogens.	
Maritime Archaeological Resources			
15	What is the integrity of maritime archaeological resources, and how is it changing?	The apparent levels of site integrity, previous disturbance, condition of natural deterioration, and prospects for scientific investigation.	
16	Do maritime archaeological resources pose an environmental hazard, and is this threat changing?	Environmental hazards, including leakage of contents/contaminants, such as oil, in aging wrecks.	
17	What are the levels of human activities that may influence maritime archaeological resource quality, and how are they changing?	Human impacts with the potential to affect the quality of resources include looting by divers, damage caused by scuba divers, improperly conducted archaeology that does not fully document site disturbance, anchoring, groundings, and commercial and recreational fishing activities.	

Large Marine Ecosystem Fisheries—Northeast U.S. Continental Shelf LME

The Northeast U.S. Continental Shelf LME extends from the Bay of Fundy, Canada, to Cape Hatteras, NC, along the Atlantic Ocean (Figure 3-17) and is structurally very complex, with marked temperature and climate changes, winds, river runoff, estuarine exchanges, tides, and complex circulation regimes. In this temperate ecosystem, intensive fishing is the primary driving force for changes in the pounds of fish harvested, with climate as the secondary driving force. This LME has an oceanographic regime marked by a recurring pattern of interannual variability, but showing no evidence of temperature shifts of the magnitude described for other North Atlantic LMEs, such as the Scotian Shelf LME to the north (Zwanenburg et al., 2002). The Northeast U.S. Continental Shelf LME is one of the world's most productive ecosystems and has been characterized by robust average annual primary productivity (phytoplankton) and relatively stable zooplankton biomass for the past 30 years (Sherman et al., 2002). The most visible natural resource capital of the Northeast U.S. Continental Shelf LME is its rich biodiversity of fish, plankton, crustacean, mollusk, bird, and mammal species. The coastal states from Maine to North Carolina currently receive $1 billion in economic benefits annually from the fisheries of this LME (NMFS, In press).

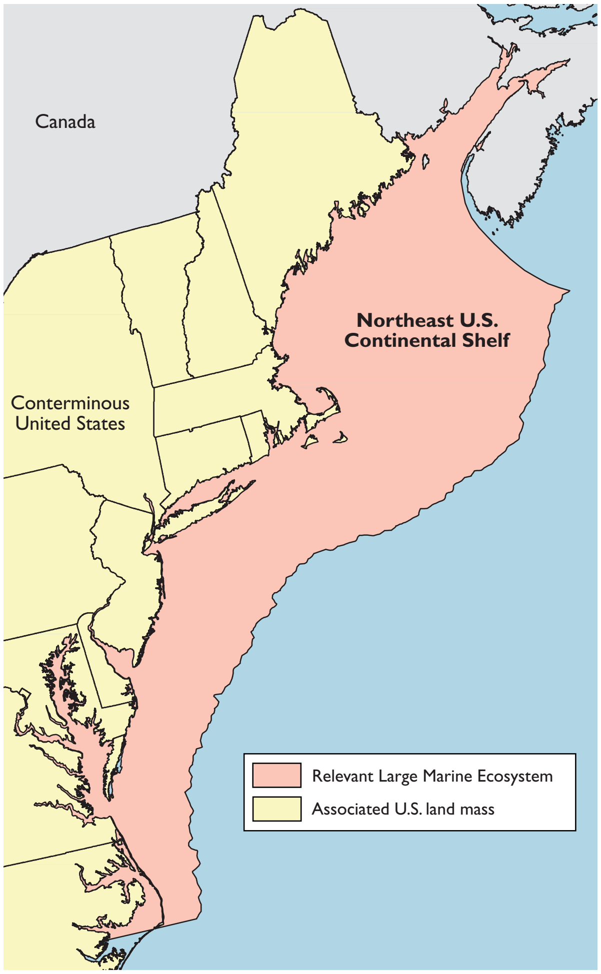


Figure 3-17. Northeast U.S. Continental Shelf LME (NOAA, 2007g).

In the late 1960s and early 1970s, intense foreign fishing within the Northeast U.S. Continental Shelf LME led to a precipitous decline in the biomass of fish stocks (NMFS, 1999). The catch of demersal (bottom-dwelling) fish stocks declined from 750,000 t in 1965 to less than 100,000 t in 1995. Significant biomass changes occurred among dominant species. For example, dogfish and skates increased in abundance in the 1970s, whereas demersal fish and flounders declined. The departure of foreign fleets in the mid-to-late 1970s was related to the 1976 Magnuson Fishing Management Act that established the 200-mile EEZ and extended U.S. jurisdiction over marine fish and fisheries. This departure, combined with management actions that reduced fishing effort in this LME, has contributed to a recovery of depleted herring and mackerel stocks and the start of a recovery of depleted yellowtail flounder and haddock stocks (Sherman et al., 2003). Long-term monitoring data on the principal prey of the pelagic fish (fish living within the water column) component of the LME shows prey biomass (total weight of prey) levels at or above a 32-year average (1972–2004) for the past 5 years (NMFS, In press).

The evidence that shows species biomass recovery following significant reduction in fishing effort through mandated actions is encouraging. Additional management efforts are underway to rebuild the depleted condition of cod, haddock, flounder, and other fish stocks to recover the economic potential of these species. With appropriate management practices, the ecosystem should provide the necessary capital in natural productivity for full recovery of depleted fish stocks (NMFS, In press).

Demersal Fish Fisheries

Northeast U.S. Continental Shelf LME demersal fish fisheries include about 35 species and stocks in waters off New England and the Mid-Atlantic states. In the New England subsystem, the demersal fish complex is dominated by members of the cod family (e.g., cod, haddock, hakes, pollock), flounders, goosefish, dogfish sharks, and skates. In the Mid-Atlantic subsystem, demersal fish fisheries include mainly summer flounder, scup, goosefish, and black sea bass (NMFS, In press).

Demersal fish resources of the Northeast U.S. Continental Shelf LME occur in mixed-species aggregations, resulting in significant bycatch interactions among fisheries directed to particular target species or species groups. Management is complex because of these interactions. This complexity is reflected, for example, in the use of different fishing gear, mesh size, minimum landing sizes, and seasonal closure regulations set by the various management bodies in the region (i.e., New England Fishery Management Council [NEFMC], Mid-Atlantic Fishery Management Council, Atlantic States Marine Fisheries Commission [ASMFC], individual states, and the Canadian government). Demersal fish fisheries in New England were traditionally managed primarily using indirect methods, such as regulating the mesh sizes of fishing gear, imposing minimum fish lengths, and closing some areas. The principal regulatory measures currently in place for the major New England demersal fish stocks are limits on the number of allowable days at sea for fishing, along with closure of certain fishing areas, trip catch limits (for cod and haddock), and targets for total allowable catch that correspond to target fishing mortality rates (NMFS, In press).

Extensive historical data for the Northeast U.S. Continental Shelf LME demersal fish fisheries have been derived from both fishery-dependent (i.e., catch and effort monitoring) and fishery-independent (e.g., NOAA research vessel surveys) sampling programs since 1963. The boundaries of the Northeast U.S. Continental Shelf LME and its subareas are depicted in Figure 3-18. Since 1989, a sea-sampling program has been conducted aboard commercial fishing vessels to document vessel discard rates and to collect high-quality, high-resolution data on their catch. Despite the past management record, some of the Northeast U.S. Continental Shelf LME demersal fish stocks (e.g., cod, yellowtail flounder, haddock, American plaice, summer flounder) are among the best understood and assessed fishery resources in the country (NMFS, In press).

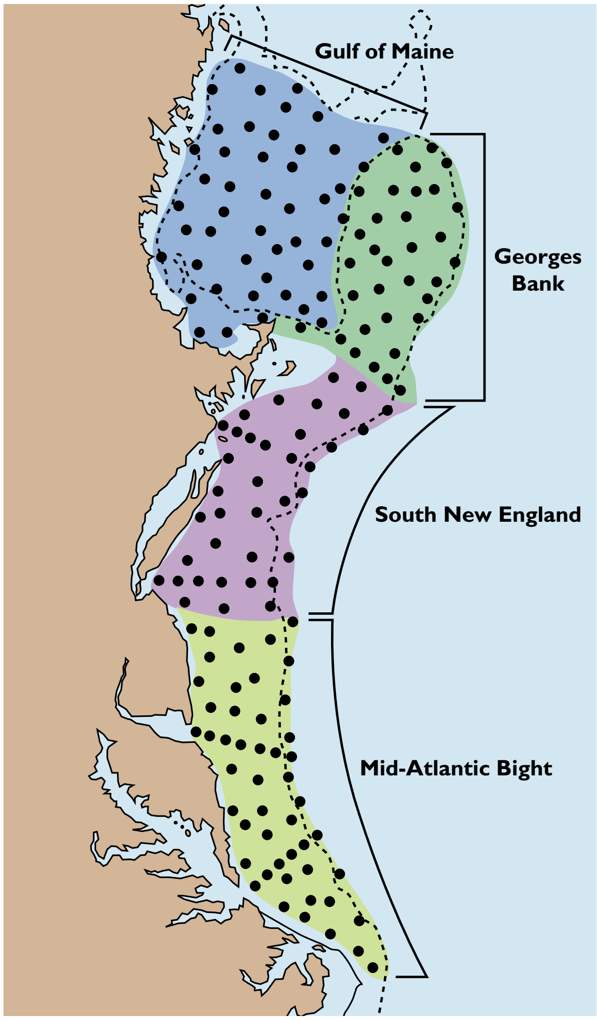


Figure 3-18. Northeast U.S. Continental Shelf LME subareas and sampling locations (Sherman et al., 2002).

In the Northeast U.S. Continental Shelf LME, fishing pressure is the primary driving force for changes in the pounds of fish harvested (courtesy of Patricia A. Cunningham).

Principal Demersal Fish Group

The principal demersal fish group of the Northeast U.S. Continental Shelf LME includes important species of cod (e.g., Atlantic cod, haddock, silver hake, red hake, white hake, pollock), flounders (e.g., yellowtail, winter, witch, windowpane, Atlantic halibut, American plaice), ocean pout, and redfish. Recent yield of these 14 species (representing 19 stocks) in this LME has averaged 81,000 t, of which 74% were U.S. commercial, 16% were Canadian, and 10% were U.S. recreational. The recent average yield is less than the combined maximum sustainable yield of about 222,000 t for these species (Figure 3-19) because many of these stocks are considered overfished and are currently rebuilding. Total ex-vessel revenue (amount the commercial fishermen receive from the quantity of fish landed) from the principal demersal fish group in 2003 was $123 million, compared to $121 million in 2000 and $109 million in 1997 (NMFS, In press). Northeast U.S. Continental Shelf LME demersal fish stocks also support important recreational fisheries for summer flounder, Atlantic cod, winter flounder, and pollock.

The research vessel survey abundance index for the principal demersal fish group has fluctuated over time and declined by almost 70% between 1963 and 1974 (Figure 3-19). This decline reflects substantial increases in exploitation associated with the advent of foreign distant-water fleets, which operate for extended periods of time in waters far from the ship's port of origin. Many stocks in this group declined sharply during that period, notably the Georges Bank haddock stock and most silver and red hake and flatfish stocks. The abundance index for the principal demersal fish group partially recovered during the mid-to-late 1970s because of the reduced fishing effort associated with increasingly restrictive management. The cod and haddock abundance indices increased markedly, pollock stock biomass increased more or less continually, and recruitment (addition of new generations of young fish) and the abundance index also increased for several flatfish stocks. The principal demersal fish group abundance index peaked in 1978, but subsequently declined and fell to new lows in 1987 and 1988. After reaching a 30-year low in 1992, this index has more than tripled due to stock-rebuilding efforts (NMFS, In press). The most recent changes in the principal demersal fish group abundance index are strongly influenced by the substantial biomass increases observed for redfish since 1996 in the Gulf of Maine subarea; however, the increased biomass of haddock and yellowtail flounder in the Georges Bank subarea and of cod in the Gulf of Maine has also influenced the principal demersal fish group abundance index (NEFSC, 2001; 2002).

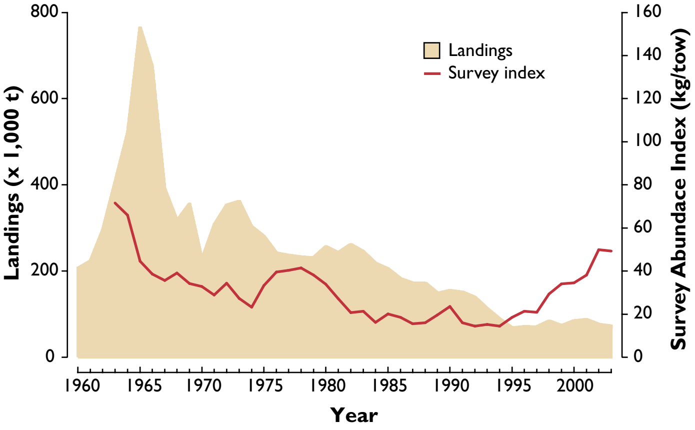


Figure 3-19. Landings in metric tons (t) and research vessel survey abundance index (kg/tow) of the principal demersal fish group, 1960–2003 (NMFS, In press).

Landings of most individual groundfish stocks declined substantially during the mid-1990s. Because of generally poor recruitment, landings of many demersal fish stocks continue to remain relatively low despite continued restrictions on days at sea; low trip limits; and additional area closures in the Gulf of Maine (NMFS, In press). However, improved stock conditions were observed for some stocks, including Georges Bank yellowtail flounder and haddock stocks. Increased landings of these two stocks have been reported since 2000 due to sharp reductions in fishing mortality combined with strong cohorts (generations of young fish from the same year) appearing in 1997 for the yellowtail flounder stock and in 1998, 2000, and 2003 for the haddock stock (NMFS, In press; NEFSC, 2002). Summer flounder spawning stock biomass in this LME has increased eight-fold over the past decade and is regulated by fishing quotas. When these quotas are attained, the fishery is shut down. Indications are that the biomasses of the scup and black sea bass stocks have also increased (NMFS, In press).

Management Concerns for Demersal Fish

During most of the 1980s and early 1990s, Northeast U.S. Continental Shelf LME demersal fish harvests were regulated by indirect controls on fishing mortality. These controls included some fishing area closures and mesh- and fish-size restrictions. These controls have been more stringent and focused since March 1994, which marked the beginning of an effort-reduction program to address the requirement to eliminate the overfished condition of cod, haddock, and yellowtail flounder stocks in this LME. The regulatory-management package included a moratorium on new vessel entrants, a schedule to reduce the number of days at sea for trawl and gill-net vessels, increases in regulated mesh size, and the expansion of closed areas to protect haddock. Since December 1994, three large areas—Closed Areas I and II on Georges Bank and the Nantucket Lightship Closed Area—have also been closed for all fishing to protect the regulated demersal fish (NMFS, In press).

A demersal fish vessel-buyout program was initiated in 1995, first as a pilot project and later as a comprehensive fishing capacity-reduction project. The program was designed to provide economic assistance to fishermen who were adversely affected by the collapse of the demersal fish fishery and who voluntarily chose to remove their vessels permanently from the fishery. This reduction in the number of vessels helped fish stocks recover to a sustainable level by reducing the excess fishing capacity in the Northeast U.S. Continental Shelf LME. The vessel-buyout program, which concluded in 1998, removed 79 fishing vessels at a cost of nearly $25 million and resulted in an approximate 20% reduction in the fishing effort in the Northeast U.S. Continental Shelf LME demersal fish fishery (NMFS, In press).

In 2004, the NEFMC increased stock-rebuilding efforts and implemented a new days-at-sea baseline that allowed only 60% of one's days at sea to be directed at regulated species in 2004 and 2005, with further reductions scheduled through 2009. The remaining 40% of days can only be used in Special Access Programs that minimize the catch of overfished stocks or in directed fishing where it can be demonstrated that bycatch of overfished stocks is minimal (NMFS, In press).

Pelagic Fisheries

The Northeast U.S. Continental Shelf LME pelagic fisheries are dominated by four species: Atlantic mackerel, Atlantic herring, bluefish, and butterfish. The abundance indices for mackerel and herring are presently above average, whereas the index for bluefish is near average and the index for butterfish is below average. During the early 1970s, the LME's two principal pelagic species (Atlantic mackerel and Atlantic herring) were exploited heavily by foreign fleets, resulting in declines in stocks and fishery yields to record-low levels by the late 1970s. Due to the exclusion of foreign fleets, the abundance indices and recruitment levels for these species have increased, leading to stock sizes that are currently at historically high levels (NMFS, In press).

The long-term trends in the abundance indices for mackerel and herring have fluctuated considerably during the past 25 years (Figure 3-20). The combined abundance index for these two species reached minimal levels in the mid-to-late 1970s, reflecting pronounced declines in stocks of both species and a collapse of the Georges Bank herring stock; however, the index subsequently increased steadily and peaked in 2001. Bottom-trawl survey abundance indices for both species have increased dramatically, with more than a ten-fold increase between the late 1970s and the late 1990s. Stock biomass of herring increased to more than 2.5 t by 1997 (NMFS, In press).

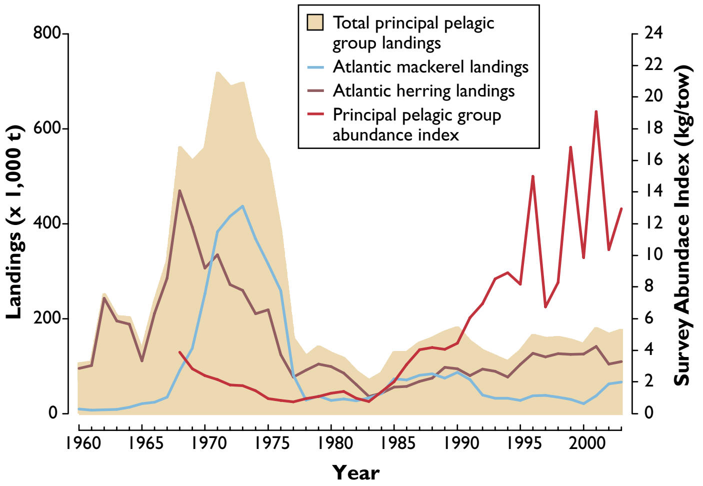


Figure 3-20. Landings in metric tons (t) and abundance indices (kg/tow) for principal pelagic stocks, 1960–2003 (NMFS, In press).

Studies of primary productivity (phytoplankton) and zooplankton biomass suggest that there are ample food resources for stocks of mackerel and herring. The zooplankton component of the Northeast U.S. Continental Shelf LME is in robust condition (Figure 3-21), with biomass levels at or above the levels of the long-term median values of the past two decades. This zooplankton community provides a suitable prey base for supporting a large biomass of pelagic fish (herring and mackerel), while also providing sufficient zooplankton prey to support strong cohorts of recovering haddock and yellowtail flounder stocks. No evidence has been found in the fish, zooplankton, temperature, or chlorophyll components to indicate any large-scale oceanographic regime shifts of the magnitude reported for the North Pacific or Northeast Atlantic ocean areas.

Although historical catch data are generally adequate for assessment purposes (except perhaps for bluefish), stock assessments for the Northeast U.S. Continental Shelf LME pelagic resources are relatively imprecise, owing to the highly variable bottom-trawl survey abundance indices used for calibrating cohort analysis models; the short life span of butterfish; and the currently low exploitation rates of mackerel and herring. The development of more precise assessments would require the use of hydroacoustic and mid-water trawl surveys to estimate herring and mackerel abundance, as well as alternative types of sampling surveys to estimate bluefish abundance. In the autumn of 1997, hydroacoustic surveys were implemented to improve stock assessments for Atlantic herring by indexing spawning concentrations. Research is underway to estimate the size of herring spawning groups directly from these survey data and to combine these estimates with data from traditional catch-at-age methods.

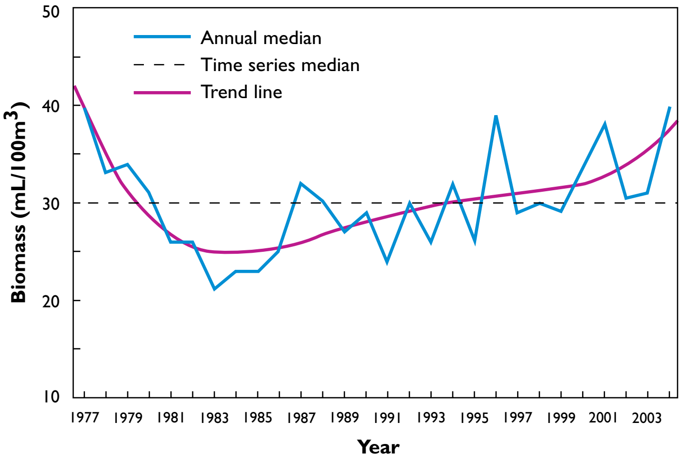


Figure 3-21. Zooplankton biomass in the Northeast U.S. Continental Shelf LME, 1977–2004 (NOAA/NMFS).

Invertebrate Fisheries

Offshore fisheries for crustacean and molluscan invertebrates are the most valuable fisheries of the Northeast U.S. Continental Shelf LME, with average ex-vessel revenues of $605 million per year during 2001–2003. The American lobster fishery ranked first in value, with average annual ex-vessel revenues of $287 million during 2000–2002 and $326 million during 2003–2004, and the Atlantic sea scallop fishery ranked second, with average annual revenues of $226 million during 2001–2003. Landings of all other offshore invertebrates (e.g., ocean quahogs, surf clams, blue mussels, squid) contributed roughly $92 million in additional revenue annually (NMFS, In press).

American Lobster

A recent assessment of American lobster stocks (ASMFC, 2000) indicated that fishing mortality rates for lobster in Gulf of Maine waters were double the overfishing level. For the inshore resource distributed from southern Cape Cod through Long Island Sound and for the offshore stock in the Georges Bank subarea, fishing mortality rates substantially exceeded the overfishing level. Throughout its range, the lobster fishery has become increasingly dependent on newly recruited animals, and commercial catch rates have markedly declined in heavily fished nearshore areas. In some locations, more than 90% of the lobsters landed are new recruits to the fishery, almost all of which are juveniles (i.e., not yet sexually mature). Fishing mortality rates for both inshore and offshore stocks presently far exceed the levels needed to produce maximum sustainable yields. Lobster landings during 1998–2000 averaged 38,100 t (with a record-high catch of 39,700 t in 1999), and during 2000–2002, landings averaged about 36,600 t. Although high fishing mortality is a persistent problem in lobster fisheries in the Northeast U.S. Continental Shelf LME, recent landings (1997–2002) are the highest observed in the period since 1940 (Figure 3-22) (NMFS, In press).

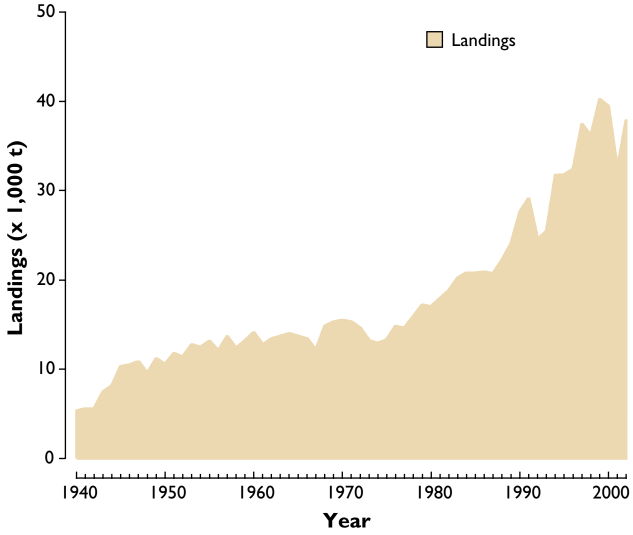


Figure 3-22. American lobster landings in metric tons (t), 1940–2002 (NMFS, In press).

Atlantic Sea Scallop

In the United States, Atlantic sea scallops are harvested in the Northeast U.S. Continental Shelf LME from Cape Hatteras, NC, to the U.S./Canadian border on Georges Bank and in the Gulf of Maine. Dredges are the principal harvesting gear, although bottom trawls take a small proportion of the landings (Serchuk and Murawski, 1997).

Management of the Atlantic sea scallop fishery changed markedly in 1994, when measures affecting the number of days at sea, vessel crew size, and dredge-ring size were implemented to address concerns about overfishing. Since December 1994, the harvesting of sea scallops in the three areas that were closed to protect demersal fish stocks has been prohibited, except under highly controlled, limited area-access provisions. In April 1998, two areas in the Mid-Atlantic Bight subarea were also closed to scallop fishing for 3 years to protect large numbers of juvenile scallops (NMFS, In press).

A recent stock assessment (NEFSC, 2001) indicated that sea scallop biomass in these closed areas increased dramatically between 1994 and 2000. Small, but substantial, increases also occurred in areas open to fishing as a result of reduced fishing effort and good reproductive success. Increases in stock biomass generated large increases in U.S. scallop landings collected in this LME (Figure 3-23) and associated revenues. Annual landings from the Northeast U.S. Continental Shelf LME averaged 25,100 t during 2001–2003 and were 29,374 t in 2004 (NMFS, In press).

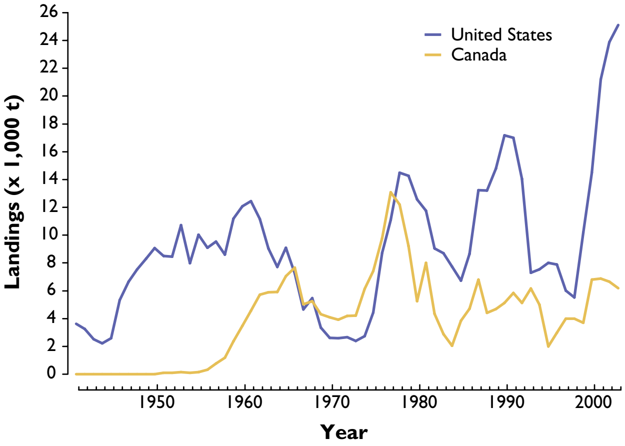


Figure 3-23. U.S. and Canadian landings in metric tons (t) of Atlantic sea scallop caught in the Northeast U.S. Continental Shelf LME, 1941–2003 (NMFS, In press).

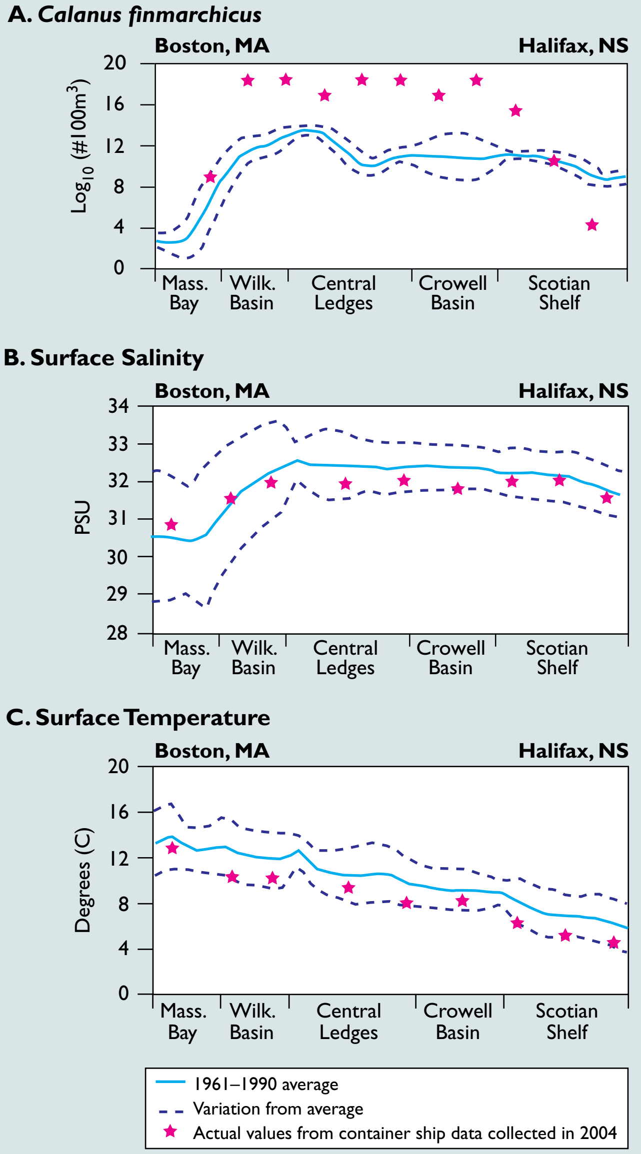
Highlight

Zooplankton Boost in the Northeast U.S. Continental Shelf LME

In 2004, NOAA scientists reported a 14-fold increase in the abundance of a key zooplankton species for waters of the Northeast U.S. Continental Shelf LME. This zooplankton species was the copepod, *Calanus finmarchicus*, which serves as prey for haddock and cod in the early stages of development, as well as for endangered right whales, which inhabit the waters of the Northeast U.S. Continental Shelf LME. Phytoplankton, which can be measured as concentrations of chlorophyll *a*, constitute a large part of the diet of *Calanus finmarchicus*, and when food is abundant, populations will increase. The boost in zooplankton abundance was linked to a drop in surface temperatures and a subsequent increase in chlorophyll *a* concentrations in the area. NOAA scientists have been employing various scientific techniques to study the relationships between surface temperatures, chlorophyll *a* concentrations, and zooplankton abundances (NOAA, 2004c).

Since 1960, scientists have employed commercial vessels to simultaneously collect data on zooplankton abundance and sea water conditions in the Northeast U.S. Continental Shelf LME. The commercial container vessels collect zooplankton population data using continuous plankton recorders (CPRs) on monthly transects between Boston, MA, and Halifax, Nova Scotia (NOAA, 2004c). Comparisons of the 2004 CPR data with the 30-year spring average (1961–1990) showed increased zooplankton populations, decreased salinity, and decreased surface water temperatures in 2004 (see figure).

Recently, scientists have paired CPR data with data obtained by NOAA's satellite-borne Advanced Very High Resolution Radiometer (AVHRR) temperature sensor and NASA's



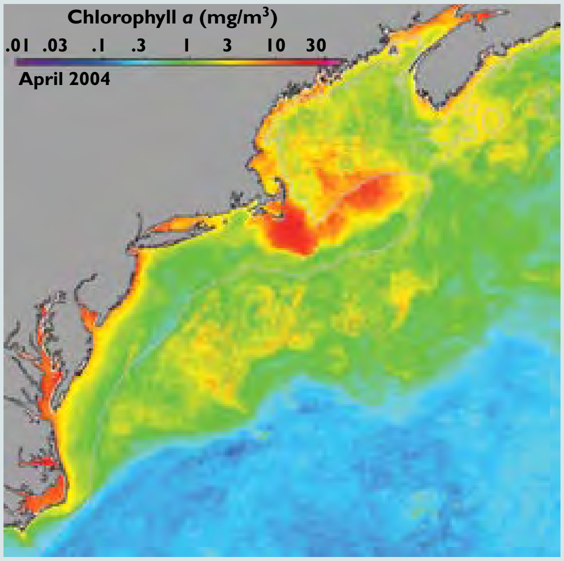
Calanus concentrations, sea surface salinity, and sea surface temperatures collected by commercial vessels traveling across the northern Northeast U.S. Continental Shelf LME (J. Jossi, NOAA/NMFS, Narragansett, RI). (A) Above average abundance of the zooplankton copepod *Calanus finmarchicus*. (B) Below average salinity. (C) Below average temperature.

Sea-viewing Wide Field-of-view Sensor (SeaWiFS) for chlorophyll to create a more robust analysis of Northeast U.S. Continental Shelf LME conditions. This combined analysis indicated that the boost in *Calanus* abundance was related to an incursion of a cold water mass into the waters of the Northeast U.S. Continental Shelf LME from the waters of the Labrador coast. The spring 2004 satellite-derived images show broad-scale chlorophyll increases and lower sea surface temperatures over the northern area of the ecosystem (see maps).

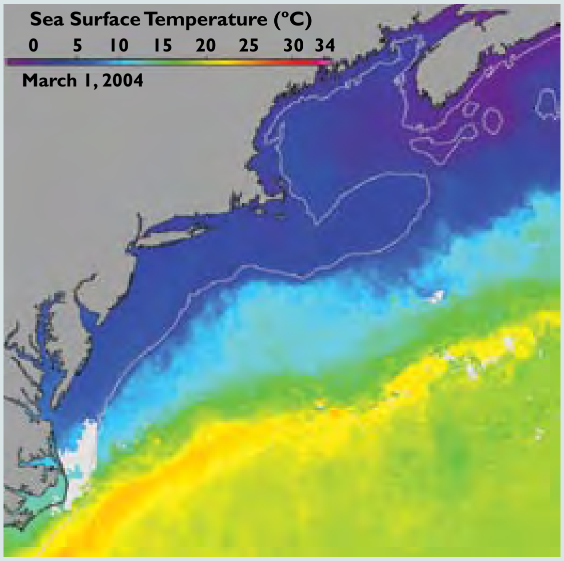
In addition, longer time-series data sets from the multi-decadal Marine Resources Monitoring, Assessment, and Prediction (MARMAP) Program provided a wider view of the path of the cold water mass. Analysis of the MARMAP database indicated that the 2004 incursion of Labrador water into the northern half of the Northeast U.S. Continental Shelf LME was related to events that occurred further north. Canadian scientists reported that the Scotian Shelf and Newfoundland-Labrador Shelf LMEs, which are located north of the Northeast U.S. Continental Shelf LME, are also under the influence of increasing incursions of cooler water from the north. These incursions may be the result of warming Arctic waters and increasing volumes of cooler, lower salinity ice-melt waters being carried southwestward into the Newfoundland-Labrador and Scotian Shelf LMEs (NOAA, 2004c).

Events such as the 2004 plankton boost provide opportunities for scientists to collect data on ecosystem variables, define potential correlations, and possibly predict future events. Marine scientists in Canada and the United States are closely monitoring the extent and volume of Labrador water incursions into the LMEs of the northwest Atlantic in an effort to better understand the impacts of cooler water on the Northeast U.S. Continental Shelf LME.

For more information, contact Kenneth Sherman at Kenneth.Sherman@noaa.gov.



Spring 2004 satellite imagery from SeaWiFS showing above average chlorophyll levels in the northern Northeast U.S. Continental Shelf LME (J. O'Reilly, NOAA/NMFS, Narragansett, RI).



Spring 2004 satellite imagery from AVHRR showing cooler than average sea surface temperatures in the northern Northeast U.S. Continental Shelf LME (J. O'Reilly, G. Wood, NOAA/NMFS, Narragansett, RI).

Assessment and Advisory Data

Fish Consumption Advisories

In 2003, 7 of the 10 Northeast Coast states had statewide consumption advisories for fish in coastal waters, placing nearly all of their coastal and estuarine areas under advisory. The states were Connecticut, Maine, Massachusetts, New Hampshire, New Jersey, New York, and Rhode Island. Due in large part to these statewide advisories, an estimated 81% of the coastal miles of the Northeast Coast and 56% of the region's estuarine area was under fish consumption advisories (Figure 3-24) in 2003, with a total of 37 different advisories active for the estuarine and coastal waters of the Northeast Coast during that year. These advisories were in effect for 10 different pollutants (Figure 3-25). Most of the fish advisory listings (97%) were, at least in part, caused by PCBs. Boston Harbor was listed for multiple pollutants (U.S. EPA, 2004b).

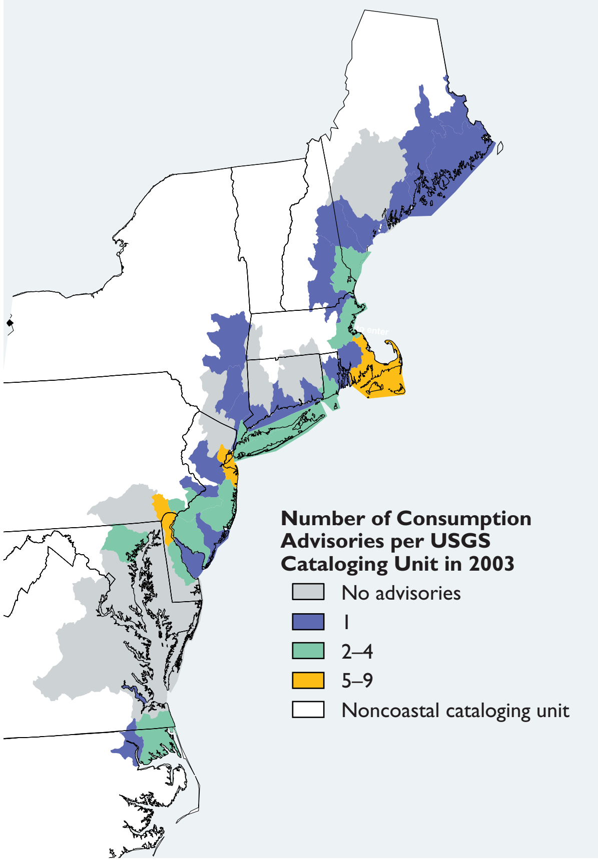


Figure 3-24. The number of fish consumption advisories active in 2003 for the Northeast Coast coastal waters (U.S. EPA, 2004b).

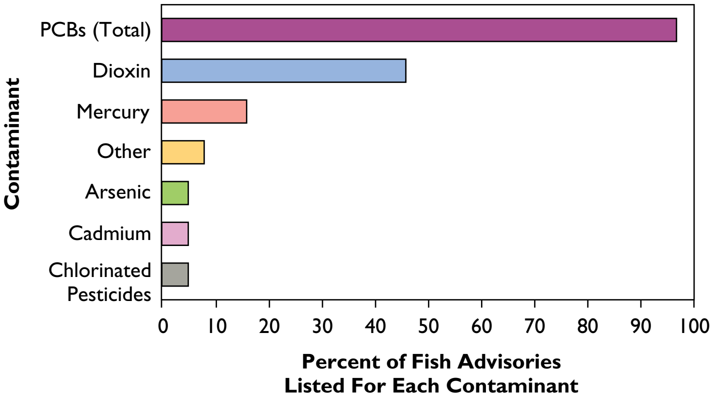


Figure 3-25. Pollutants responsible for fish consumption advisories in Northeast Coast coastal waters. An advisory can be issued for more than one contaminant, so percentages may add up to more than 100 (U.S. EPA, 2004b).

Species and/or groups under fish consumption advisory in 2003 for at least some part of the coastal waters of the Northeast Coast region:

American eel
Atlantic needlefish
Bivalves
Bluefish
Blue crab
 (whole and hepatopancreas)
Brown bullhead
Common carp
Channel catfish
Flounder
King mackerel
Largemouth bass
Lobster (whole and tomalley)
Northern hogsucker
Rainbow smelt
Scup
Shark
Shellfish
Smallmouth bass
Striped bass
Swordfish
Tautog
Tilefish
Tuna
Walleye
White catfish
White perch

Source: U.S. EPA, 2004b

Beach Advisories and Closures

Of the 1,684 Northeast Coast beaches that were reported to EPA in 2003, about 13.4% (226 beaches) were closed or under advisory for some period of time during that year. The states with the highest percentage of beaches with advisories/closures were Connecticut and New York, where 43.3% and 37% beaches, respectively, were closed or under advisory at least once in 2003. Table 3-1 presents the number of beaches monitored and under advisories/closures for each state. Figure 3-26 shows the percentage of monitored beaches in each county with at least one beach advisory or closure in 2003. Maine and Delaware did not report for the 2003 cycle, and Virginia only reported the number of beaches monitored (U.S. EPA, 2006c).

Table 3-1. Number of Beaches Monitored and With Advisories/Closures in 2003 for Northeast Coastal States (U.S. EPA, 2006c)

State	No. of Beaches Monitored	No. of Beaches with Advisories/ Closures	Percentage of Beaches Affected by Advisories/ Closures
Maine	NR	NR	NR
New Hampshire	12	1	8.3
Massachusetts	736	73	9.9
Rhode Island	208	19	9.1
Connecticut	67	29	43.3
New York	211	78	37
New Jersey	324	24	7.4
Delaware	NR	NR	NR
Maryland	88	2	2.3
Virginia	40	NR	NR
TOTAL	**1,686**	**226**	**13.4**

NR = Not Reported

The primary reasons for beach advisories and closures implemented at Northeast Coast beaches were elevated bacteria levels or preemptive closures associated with rainfall events or sewage-related problems (Figure 3-27). Most beaches had multiple sources of waterborne bacteria that resulted in advisories or closures. Figure 3-28 shows stormwater runoff and sanitary sewer overflows were most frequently identified as sources, and unknown sources accounted for 45% of the responses (U.S. EPA, 2006c).

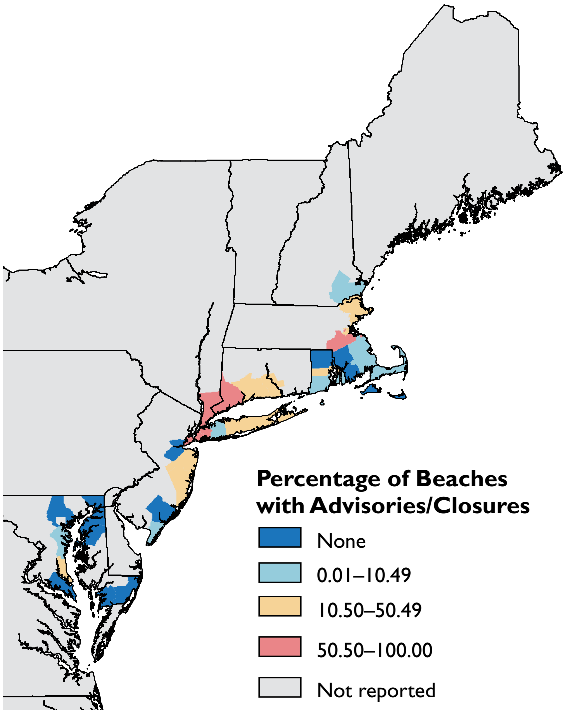


Figure 3-26. Percentage of monitored beaches with advisories or closures, by county, for the Northeast Coast region (U.S. EPA, 2006c).

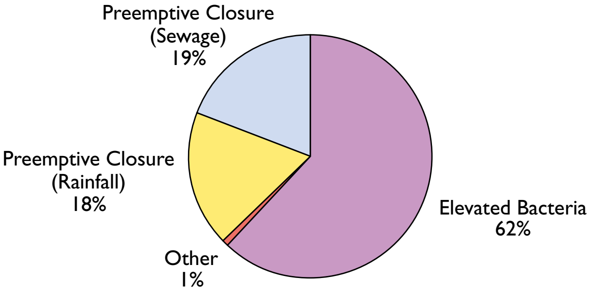


Figure 3-27. Reasons for beach advisories or closures in the Northeast Coast region (U.S. EPA, 2006c).

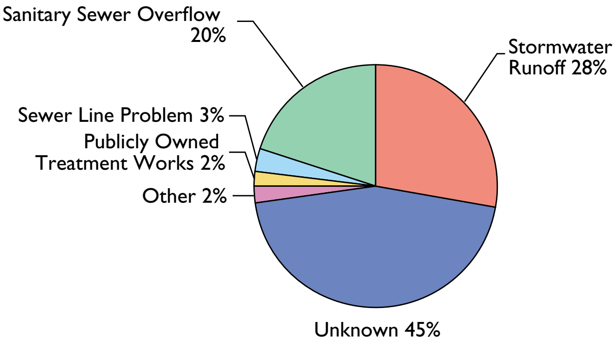


Figure 3-28. Sources of contamination resulting in beach advisories or closures for the Northeast Coast region (U.S. EPA, 2006c).

Highlight

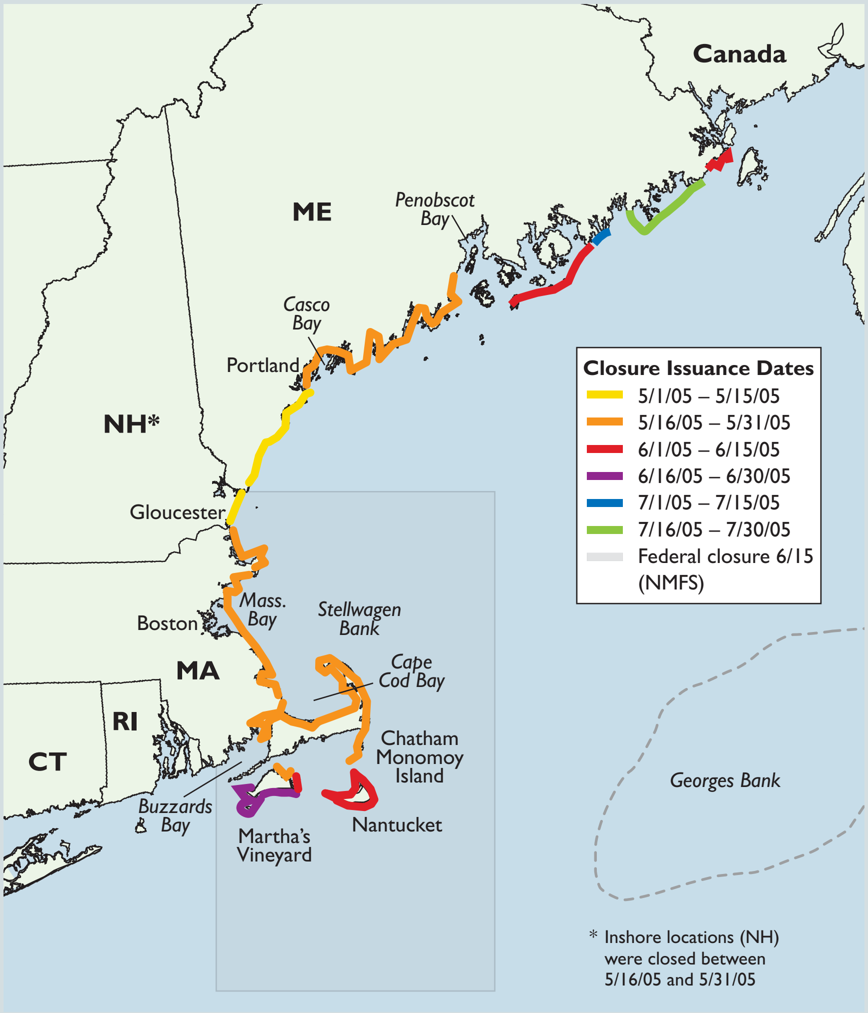
Spring 2005 Brings the Most Harmful Algal Bloom to New England in over Three Decades

Alexandrium fundyense is a naturally occurring algal species that periodically forms HABs in the Gulf of Maine. This algal species also produces potent neurotoxins that can accumulate in filter-feeding shellfish. When humans or other higher trophic-level organisms, such as marine mammals, consume shellfish contaminated with the neurotoxins, severe illness or death can result due to a syndrome called paralytic shellfish poisoning (PSP). In most years, normal wind and water current patterns prevent bloom transport to southern New England's nearshore waters; however, in the spring of 2005, the most severe bloom of this toxic dinoflagellate (type of algae) occurred since 1972 and spread from Maine to Massachusetts, reaching as far south as Martha's Vineyard, MA. This exceptionally expansive bloom may have been a result of elevated rainfall and snowmelt in the spring, followed by two unusually late nor'easters in May. Scientists hypothesize that strong winds pushed *Alexandrium* blooms down the coast, while nutrients supplied by increased runoff fueled their growth (Anderson et al., 2005; NOAA, 2007j).

States in the Northeast Coast region maintain rigorous shellfish monitoring programs to protect humans from PSP. During the 2005 bloom event, the findings of these programs resulted in extensive—and in some locations unprecedented—closures of shellfish harvesting areas (see map). State closures along the New England coast began as early as mid-May, disrupting shellfish sales during the busiest period of the tourist season. In addition to the state closures, NOAA instituted a closure of approximately 15,000 mi^2 of federal waters at the request of the U.S. Food and Drug Administration (FDA) and declared a commercial fisheries failure, which allowed for the mitigation of financial impacts on commercial shellfishermen in the region (Anderson et al., 2005).

NOAA and the National Science Foundation (NSF), through the interagency Ecology and Oceanography of Harmful Algal Blooms (ECOHAB) Program, have funded a decade of research on *Alexandrium* in the Gulf of Maine to advance understanding of *Alexandrium* bloom ecology. Combined with additional research funded through the Monitoring and Event Response for Harmful Algal Blooms Program, the ECOHAB research has also enhanced event response, forecasting, and mitigation capabilities for coastal managers. For example, new methods based on molecular biology are used for the rapid detection and mapping of *Alexandrium*, providing coastal managers with early warnings of shellfish toxicity (Anderson et al., 2005). These data, combined with oceanographic and meteorological data from ships and moorings, have been used in recently developed, coupled biological and physical models to forecast bloom movement and to understand the factors leading to this unusual event (NOAA, 2007k).

During the bloom event, emergency support from NOAA funded expanded monitoring, assessment, and prediction of the bloom extent and movement. *Alexandrium* abundance data allowed managers to focus toxin sampling efforts on newly exposed areas, as well as on areas that could possibly be reopened for shellfish harvesting. Researchers were also able to collect fish and zooplankton samples for an investigation into the potential relationship between the food-web transfer of toxins and whale mortalities in the region. Organizations involved in the emergency response to this HAB event included the Woods Hole Oceanographic Institution (WHOI), Massachusetts Division of Marine Fisheries, Massachusetts Water Resources Authority (MWRA), University of Massachusetts Dartmouth Center for Coastal Studies in Provincetown, and Cooperative Institute for Climate and Ocean Research. Ancillary data from moorings were provided by the Gulf



Map of shellfish closure areas and area of temporary federal closure of offshore waters with closure issuance dates during the 2005 *Alexandrium fundyense* bloom in Maine, New Hampshire, and Massachusetts (Anderson et al., 2005).

of Maine Ocean Observing System and the USGS's instrumented mooring near the MWRA outfall (NOAA, 2007j).

NOAA awarded additional funds to WHOI to sustain monitoring throughout the bloom period and to support post-bloom research. The goals of this research were to improve bloom forecasting, to enhance the efficiency of future monitoring and regulation, and to understand this particular event by "hindcasting" its causative factors. In addition, because future forecasts will be influenced by the "footprint" of dinoflagellate cysts (or seeds) left by this expansive bloom, scientists have developed new cyst maps and will incorporate these into predictive models to aid bloom forecasting in future years. Researchers will also monitor these new areas to see if *Alexandrium* cells originate from the newly deposited cysts (NOAA, 2007j).

]

Summary

Based on data from NCA, CBP, and NOAA, the overall condition of Northeast Coast coastal waters is rated fair to poor. Problems associated with excess nutrients and low levels of dissolved oxygen are much less prevalent in the Gulf of Maine than in the waters south of Cape Cod. Clean sediments with low levels of chemical contamination, an absence of acute toxicity, and moderate-to-low levels of sediment TOC are found in 76% of the Northeast Coast region's coastal area. Benthic conditions are considered to be poor in 27% of the coastal area, often in the vicinity of high human population density. Fish tissue contamination is also a concern in this region, with 31% of the samples rated poor. When EMAP-VP and NCA data on water clarity, dissolved oxygen sediment toxicity, sediment contaminants, sediment TOC, and benthic communities from 1990–1993 and 2000–2001 were compared, a slightly greater percentage of coastal area was rated poor in the later time interval; however, none of these differences are statistically significant.

NOAA's NMFS manages several fisheries in the Northeast U.S. Continental Shelf LME, including principal demersal fish (e.g, cod, flounder, ocean pout, redfish), pelagic fish (e.g, Atlantic mackerel, Atlantic herring, bluefish, butterfish), and invertebrates (e.g, American lobster, Atlantic sea scallop). Many stocks of principal demersal fish in this LME are considered overfished and currently rebuilding. The abundance indices for mackerel and herring are presently above average, whereas the abundance index for bluefish is near average and for butterfish is below average. The fishing mortality rates of the region's American lobster are substantially above the overfishing level. There have been substantial increases in scallop biomass in the Northeast U.S. Continental Shelf LME since changes were made to the Atlantic scallop fishery management measures in 1994.

Contamination in the coastal waters of the Northeast Coast region has affected human uses of these waters. In 2003, there were 37 fish consumption advisories in effect along the Northeast Coast, most of which (> 90%) were issued for PCB contamination alone or in combination with one or more other contaminants. In addition, approximately 13% of the region's monitored beaches were closed or under advisory for some period of time during 2003. Elevated bacteria levels in the region's coastal waters were primarily responsible for the beach closures and advisories.

CHAPTER 4

Southeast Coast Coastal Condition

Courtesy of Brad Ashbaugh

Southeast Coast Coastal Condition

As shown in Figure 4-1, the overall coastal condition of the Southeast Coast region is rated fair, with an overall condition score of 3.6. The water quality, sediment quality, and coastal habitat indices for the region are rated fair; the benthic index is rated good; and the fish tissue contaminants index is rated good to fair. Figure 4-2 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 the NCA, in collaboration with state resource agencies, from 294 locations throughout Southeast Coast coastal waters using comparable methods and techniques. Please refer to Chapter 1 for information about how these assessments were made, the criteria used to develop the rating for each index and component indicator, and the limitations of the available data.

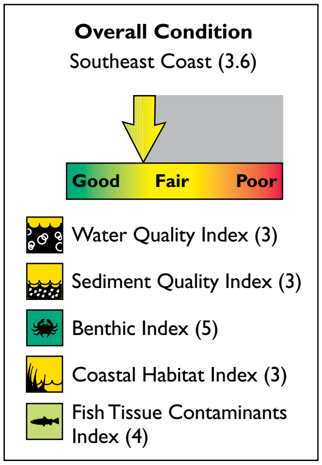


Figure 4-1. The overall condition of Southeast Coast coastal waters is rated fair (U.S. EPA/NCA).

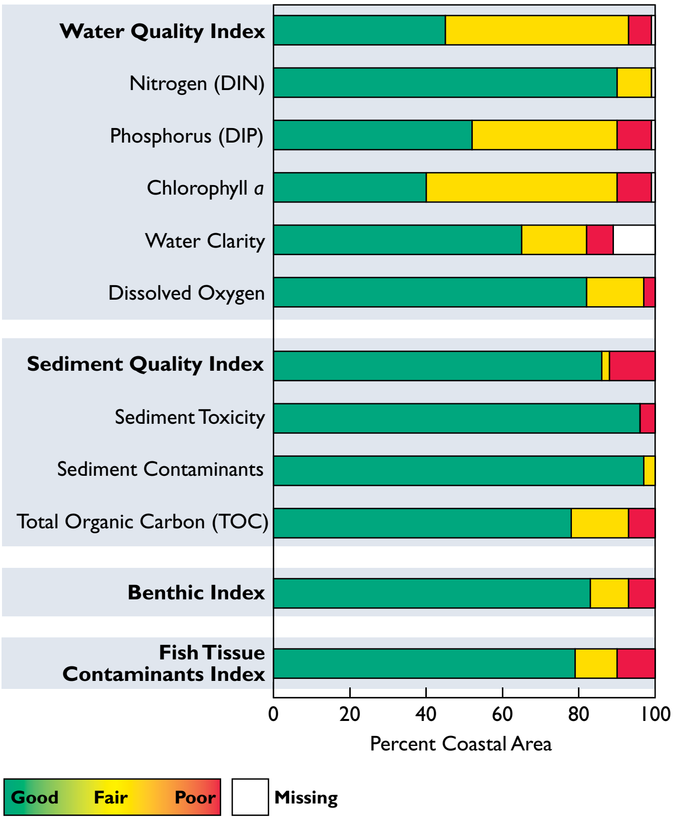


Figure 4-2. Percentage of coastal area achieving each ranking for all indices and component indicators—Southeast Coast region (U.S. EPA/NCA).

The Southeast Coast region contains a wealth of resources, including barrier islands such as North Carolina's Outer Banks; busy shipping ports in Miami and Jacksonville, FL, Savannah, GA, and Charleston, SC; quiet coastal wetlands that provide a habitat for migratory birds and other animals; and important commercial and recreational fishery resources. The coastal resources of this region are diverse and extensive, covering an estimated 4,487 mi^2. The provinces of this region include the Carolinian Province, which extends from Cape Henry, VA, through the southern end of the Indian River Lagoon, as well as part of the West Indian Province along the east coast of Florida from the Indian River Lagoon through Biscayne Bay. The borders of the Southeast Coast region roughly coincide with the borders of the Southeast U.S. Continental Shelf LME. Also included in the Southeast Coast region is North Carolina's Albemarle-Pamlico Estuarine System, one of the largest and most productive aquatic systems in North America. The Albemarle-Pamlico system represents North Carolina's key resource base for commercial fishing, recreational fishing, and tourism. Similarly, the coastal resources of other Southeast Coast states provide the resource base

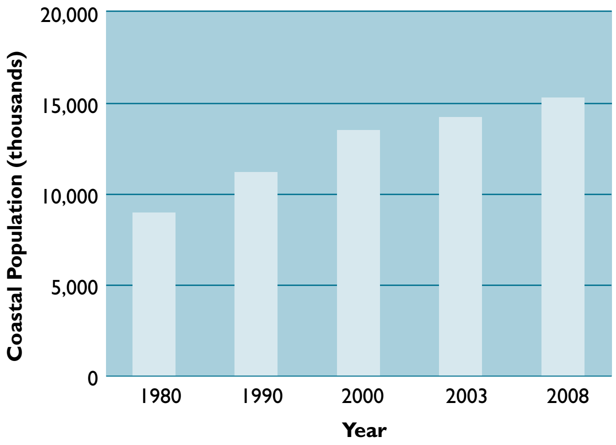


Figure 4-3. Actual and estimated population of coastal counties in Southeast Coast states, 1980–2008 (Crossett et al., 2004).

for fishing and tourism industries and generate vast amounts of sales tax income for those states.

Between 1980 and 2003, coastal counties of the Southeast Coast region showed the largest rate of population increase (58%) of any coastal region in the conterminous United States. Florida was largely responsible for this growth, with a population increase of 7.1 million people, or 75%, during this time period. Figure 4-3 presents population data for the Southeast Coast region's coastal counties and shows that these populations have increased significantly since 1980 (Crossett et al., 2004). There is evidence of human-induced stress in some areas of the Southeast Coast region. Given the influx of people and businesses to southeastern coastal states and the ensuing pressures on the coastal zones of this region, there is an increased need for effective management of the region's resources.

Coastal Monitoring Data—Status of Coastal Condition

Several programs have monitored the coastal waters of the Southeast Coast region, including NOAA's NS&T and EPA's EMAP Carolinian Province. EPA's NCA began partnerships with coastal states in this region in 1999 (South Carolina), 2000 (Georgia, Florida), and 2001 (North Carolina). Sampling sites were chosen randomly to represent larger spatial scales. Participating state partners sampled waters during the summer, when conditions were expected to be most stressful (i.e., experiencing low dissolved oxygen levels). This probabilistic sampling approach enabled comparison within and across state boundaries and allowed for the presentation of data in terms of percentages of coastal area rated good, fair, and poor.

Water Quality Index

The water quality index for the coastal waters of the Southeast Coast region is rated fair, with only 6% of the coastal area rated poor and 48% of the area rated fair for water quality condition (Figure 4-4). The water quality index was developed based on measurements of five component indicators: DIN, DIP, chlorophyll *a*, water clarity, and dissolved oxygen.

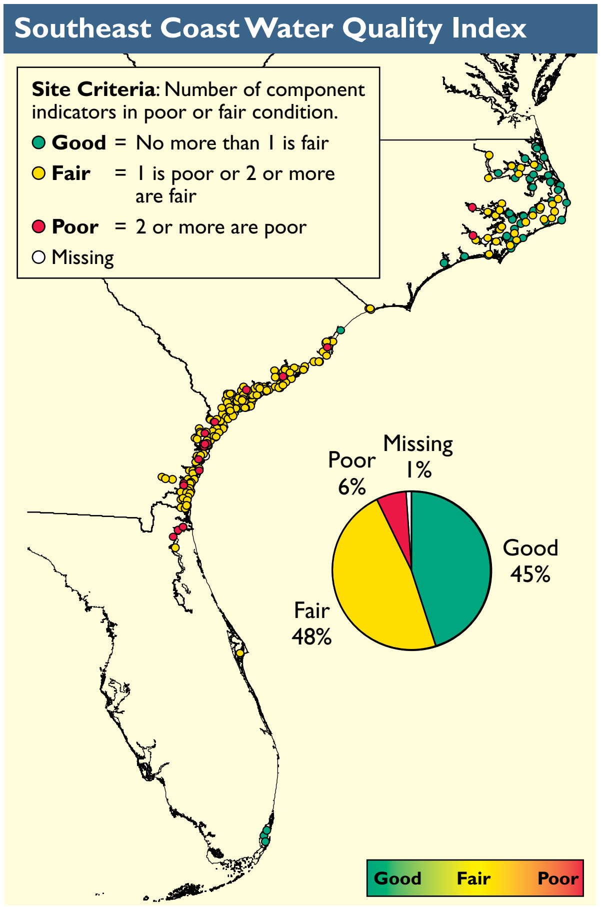
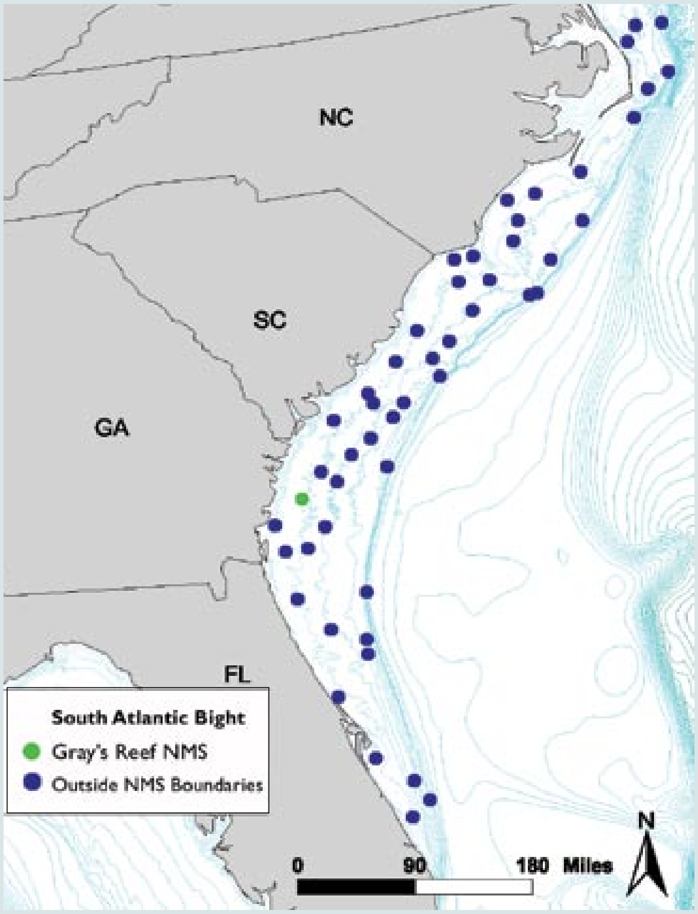


Figure 4-4. Water quality index data for the Southeast Coast coastal waters (U.S. EPA/NCA).

Highlight

EPA, NOAA, and Southeastern States Assess Ecological Condition in Near-Coastal Shelf Waters of the South Atlantic Bight



South Atlantic Bight sampling sites (Cooksey, 2004).

A study is under way by EPA, NOAA, and partnering southeastern states to assess the condition of aquatic resources throughout near-coastal shelf waters of the South Atlantic Bight (SAB). This SAB study may be regarded as an extension of previous EMAP efforts in estuaries and inland waters to these offshore areas, where such information has been limited in the past. A similar effort is also under way in shelf waters along the western coast of the United States (see Chapter 6, *West Coast Coastal Condition*). The SAB sampling effort applies EMAP's probabilistic sampling approach to support statistical estimation of the spatial extent of conditions with respect to various measured ecological indicators. The results of this study are intended to serve as a baseline for monitoring potential changes in these indicators over time due to either human or natural factors.

Sampling was conducted in April 2004 at 50 random stations (see map) from Nags Head, NC, to West Palm Beach, FL, at depths of about 32.8–328 feet (roughly from just offshore to the outer edge of the continental shelf). Data from these 50 stations will allow the assessment of conditions for the SAB offshore region and contribute to broader estimates of conditions at the national level. In addition, a station was included within the Gray's Reef NMS located off the coast of Georgia (Cooksey, 2004). NOAA also has conducted recent site-intensive surveys of condition at multiple stations within the boundaries of the Gray's Reef NMS, using the same protocols as in the present SAB-wide survey (Cooksey et al., 2004; Hyland et al., 2006). Thus, results of these companion surveys (the first conducted in 2000, and the second conducted in 2005) can be integrated with the present regional survey to assess the condition of sanctuary resources within the context of the broader SAB ecosystem.

As in other EMAP efforts (including the present NCCR III), multiple indicators were measured synoptically at each station to support weight-of-evidence assessments of condition and the examination of associations between biological characteristics and potential environmental controlling factors (U.S. EPA, 2002). Condition was assessed using indicators of (1) habitat condition, (2) general water quality, (3) biological condition with a focus on benthic infauna and demersal (bottom-dwelling) fish pathology, and (4) exposure to stressors. The table lists the specific indicators assessed during this study.

The consistent and systematic sampling of the different biological and environmental variables across such a large pool of stations provides a tremendous opportunity for learning more about the spatial patterns of these near-coastal aquatic resources and the processes controlling their distributions, including potential associations between the presence of stressors and biological responses. For example, a key environmental concern that the program will address with these data is the extent to which pollutants and other materials are being transported out of major rivers located along the developed areas of the coast. Another concern is how these pollutants may affect biological resources.

The study also demonstrates the benefits of performing science through partnerships that bring together complementary capabilities and resources from a variety of federal, state, and academic institutions. The project is principally funded by the EPA Office of Research and Development. NOAA also is a major partner in the effort, working with EPA to provide overall management and interpretive support, in addition to contributing ship time on the NOAA Ship *Nancy Foster*. State and academic partners include the North Carolina Department of Environment and Natural Resources, South Carolina Department of Natural Resources (DNR), Georgia DNR, Florida Department of Fish and Wildlife, and the College of Charleston.

A final report is expected by March 2009. It is anticipated that the resulting information on the condition of ecological resources in these deeper near-coastal waters will make a valuable contribution to future NCCRs.

Environmental Indicators Used in the SAB Study (Cooksey, 2004)
Habitat Condition Indicators
Salinity
Water depth
Dissolved oxygen
pH
Water temperature
Total suspended solids
Transmittance
Sediment grain size
Sediment percent total organic carbon (TOC)
Sediment color/odor
Presence of trash/marine debris
Water Quality Indicators
Chlorophyll *a* concentrations
Nutrient concentrations (nitrates, nitrites, ammonia, phosphate)
Biological Condition Indicators
Benthic species composition
Benthic abundance
Benthic species richness and diversity
External indicators of disease in fish
Presence of nonindigenous species
Exposure Indicators
Chemical contaminants in sediment
Chemical contaminants in fish tissues
Low dissolved oxygen condition
Organic over-enrichment

The sampling conducted in the EPA NCA survey has been designed to estimate the percent of estuarine area (nationally or in a region or state) 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.

Nutrients: Nitrogen and Phosphorus

The Southeast Coast region is rated good for DIN concentrations because less than 1% of the region's coastal area was rated poor and 9% of the area was rated fair for this component indicator. The Southeast Coast region is also rated good for DIP concentrations, with only 9% of the coastal area rated poor and 38% of the area rated fair for this component indicator.

Chlorophyll *a*

The Southeast Coast region is rated fair for chlorophyll *a* because 59% of the coastal area was rated fair and poor, combined, for this component indicator.

Water Clarity

Water clarity in the Southeast Coast region is rated good, with 17% of the coastal area rated fair and 7% of the area rated poor for this component indicator. The criteria used to assign water clarity ratings varied across Southeast Coast coastal waters, based on natural variations in turbidity levels and local waterbody management goals (see Chapter 1 for additional information). The box shows the criteria for rating a site in poor condition for water clarity in estuarine systems with differing levels of natural turbidity.

Coastal Areas	Criteria for a Poor Rating (Percentage of Ambient Light that Reaches 1 Meter in Depth)
Indian River Lagoon Estuarine System	< 20%
Albemarle-Pamlico and Biscayne Bay estuarine systems	< 10%
All Remaining Southeast Coast estuarine systems	< 5%

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 in late summer. Data were not collected during other time periods.

Dissolved Oxygen

The Southeast Coast region is rated good for dissolved oxygen concentrations, with 15% of the coastal area rated fair and 3% of the area rated poor for this component indicator.

Sediment Quality Index

The sediment quality index for the coastal waters of the Southeast Coast region is rated fair, with 2% of the coastal area rated fair and 12% of the area rated poor for sediment quality condition (Figure 4-5). The sediment quality index was calculated based on measurements of three component indicators: sediment toxicity, sediment contaminants, and sediment TOC.

Sediment Toxicity

The Southeast Coast region is rated good for sediment toxicity, with 96% of the area rated good and approximately 4% of the coastal area rated poor for this component indicator.

Sediment Contaminants

The Southeast Coast region is rated good for sediment contaminant concentrations, with approximately 3% of the coastal area rated fair and less than 1% of the area rated poor for this component indicator.

Sediment TOC

The Southeast Coast region is rated good for sediment TOC concentrations, with 15% of the coastal area rated fair and only 7% of the area rated poor for this component indicator.

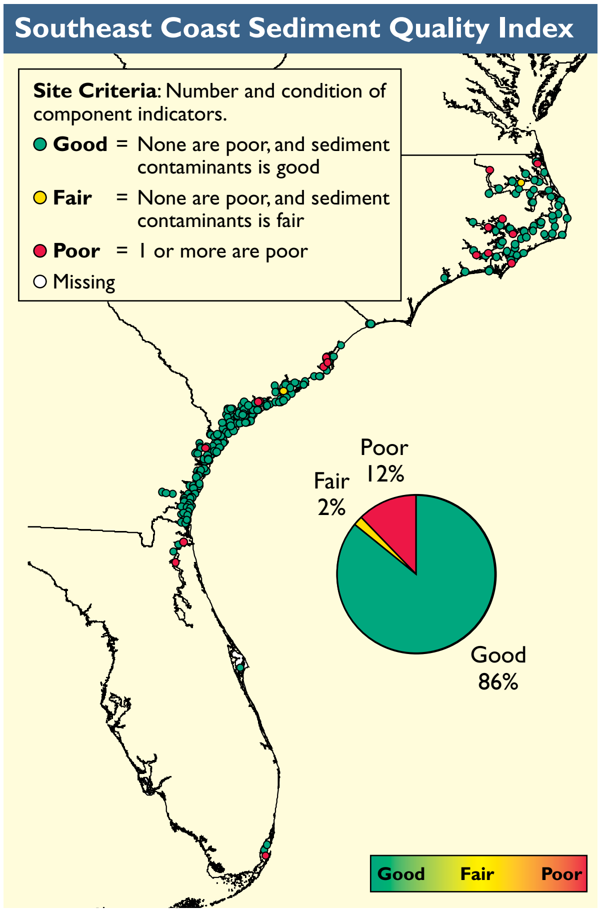


Figure 4-5. Sediment quality index data for Southeast Coast coastal waters (U.S. EPA/NCA).

Benthic Index

The biological condition of the coastal waters of the Southeast Coast region, as measured by the Southeast Coast Benthic Index, is rated good. Van Dolah et al. (1999) developed the benthic index based on several measures of benthic community condition, including the total number of species and integrated measures of species dominance, species abundance, and abundance of pollution-sensitive taxa. The index shows that 83% of the Southeast Coast region's coastal area was rated good for benthic condition, 10% of the area was rated fair, and 7% of the area was rated poor (Figure 4-6). Stations rated poor were located in portions of the Neuse River in North Carolina and Medway River in Georgia.

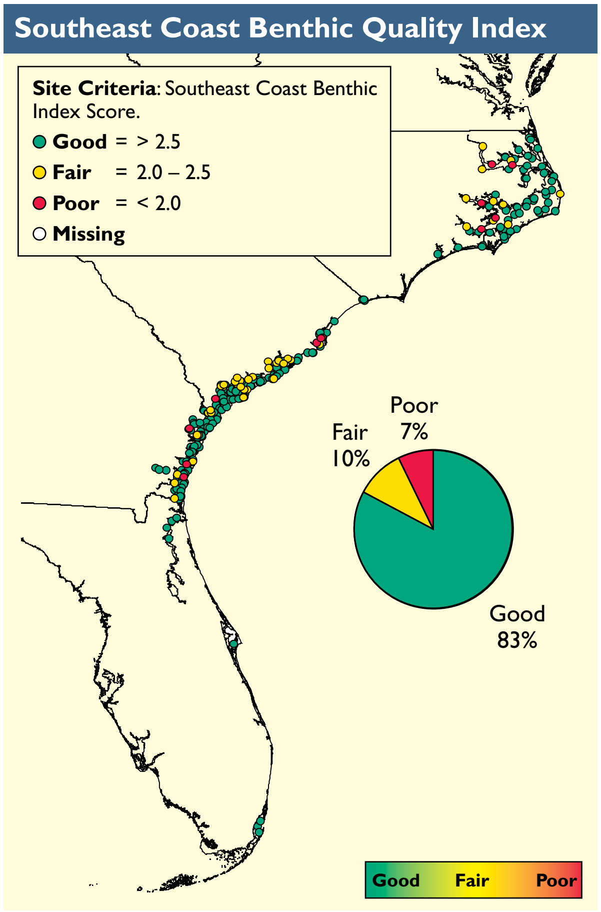


Figure 4-6. Benthic index data for Southeast Coast coastal waters (U.S. EPA/NCA).

Highlight

Georgia's Marsh Dieback

In March 2002, areas of dying coastal salt marshes were reported to the Georgia DNR Coastal Resource Division (CRD), who confirmed that dying marsh grasses (*Spartina alterniflora* and *Juncus roemerianus*) were resulting in open mudflats. The affected areas initially reported to the CRD were located in Liberty County and included several miles of creekside marsh die-off, as well as acres of receding marsh along the Jericho River. Since 2002, areas of dead and dying marsh have been reported in all six of Georgia's coastal counties, from the St. Mary's River in Camden County to Tybee Island in Chatham County. The CRD has consulted with other states that have experienced similar marsh epidemics (e.g., South Carolina, Louisiana), but the causes of the die-off in Georgia have not yet been determined. An estimated 1,000 acres of marsh have been affected, with the vast majority of this acreage located in Liberty County (Georgia DNR, 2003).

The CRD has collaborated with scientists from Savannah State University, the Sapelo Island NERR, the Gray's Reef NMS, Georgia Sea Grant, the U.S. Army Corps of Engineers (USACE), the University of Georgia Marine Extension Service, the University of Georgia Marine Institute, and the Skidaway Institute of Oceanography to collect data from the dying marsh sites via the Georgia Coastal Research Council (GCRC). Quarterly field sampling has been conducted using a standardized methodology developed by CRD and GCRC scientists. These marsh samples were analyzed for soil and interstitial salinities, the presence of fungi and/or abnormal bacteria, and pH. Although higher-than-normal salinities were detected, these levels were not high enough to denude the amount of marsh that has been lost. No other abnormal readings have been detected. Researchers are continuing field sampling to monitor and evaluate changes in salinities and vegetation (Georgia DNR, 2003).

In addition, Savannah State University has established a working laboratory for testing vegetation samples. Greenhouse trials were conducted to determine the effects of fresh water and examine the variation in soils. Initial results of these trials have shown no difference between the *Spartina* plants that were grown in soils from the die-off areas and those grown in healthy marsh soils. *Spartina* leaves revealed no abnormal species counts; however, root and rhizome analyses are ongoing (Georgia DNR, 2003).

In response to the marsh die-off, the CRD has coordinated outreach and research activities. Outreach activities included responding to concerned citizen reports and developing press releases for local media. The CRD is also cataloging all reports of dying marshes through aerial and on-the-ground photographic documentation and using GIS software to map and estimate the affected acreage. In collaboration with GIS specialists from the University of Georgia Marine Extension Service, the CRD is planning and implementing GIS classifications to delineate and track die-off areas. Scientists from the GCRC have applied for various grants to address certain aspects of the marsh die-off, including monitoring, transplant experiments, and plant tissue analysis studies (Georgia DNR, 2003).

The marsh die-off affects a vital coastal area of Georgia and has implications for wildlife, fisheries, water quality, navigation, and flood control. Under the Georgia Coastal Marshlands Protection Act (O.C.G.A. 12-5-280 et seq.), the State of Georgia recognizes that "the coastal marshlands of Georgia comprise a vital natural resource system. The estuarine area…is the habitat of many species of marine life and wildlife and, without the food supplied by the marshlands, such marine life and wildlife cannot survive. The estuarine marshlands of coastal Georgia are among the richest providers of nutrients in the world. Such marshlands provide a nursery for commercially and recreationally important species of shellfish and other wildlife, provide a great buffer against flooding and erosion, and help control and disseminate pollutants. The coastal marshlands provide a natural recreation resource, which has become vitally linked to the economy of Georgia's coastal zone and to that of the entire state. This…system is costly, if not impossible, to reconstruct or rehabilitate once adversely affected." The results of these investigations into the dead marsh issue have long-term implications for the preservation of Georgia's estuaries and the health of Georgia's coastal economy (Georgia DNR, 2003).

Updates regarding the progress made on the marsh die-off issue can be found at the GCRC Web site at http://www.gcrc.uga.edu or accessed through the CRD Web site at http://crd.dnr.state.ga.us.

Aerial survey of marsh dieback, Jerico River, GA (courtesy of Matt Ogburn, GCRC).

Coastal Habitat Index

The coastal habitat index for the coastal waters of the Southeast Coast region is rated fair. As reported in the NCCR II (U.S. EPA, 2004a), wetlands in the Southeast Coast region diminished from 1,107,370 acres in 1990 to 1,105,170 acres in 2000, representing a loss of 2,200 acres or 0.2%.

Fish Tissue Contaminants Index

The fish tissue contaminants index for the coastal waters of the Southeast Coast region is rated good to fair. Fish tissue samples were collected at 218 of the 294 NCA sampling sites (74%) in the Southeast Coast region. Figure 4-7 shows that 10% of all sites sampled where fish were caught were rated poor using whole-fish contaminant concentrations and EPA Advisory Guidance values. Total PAHs and total PCBs were the only contaminants with elevated concentrations in fish tissues collected from Southeast Coast coastal waters.

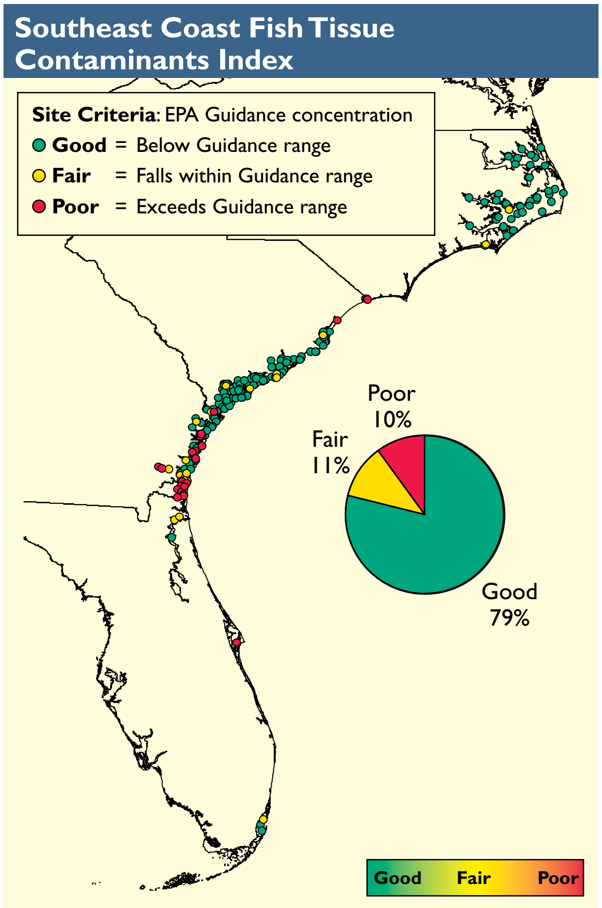


Figure 4-7. Fish tissue contaminants index data for Southeast Coast coastal waters (U.S. EPA/NCA).

Intracoastal Waterway, Onslow County, NC (courtesy of Kimberly Matthews).

Trends of Coastal Monitoring Data—Southeast Coast Region

Temporal Change in Ecological Condition

EMAP-Estuaries conducted annual surveys of estuarine condition in the Carolinian Province from 1994 to 1997, the results of which were reported in the NCCR I (U.S. EPA, 2001c). In 2000, EMAP-NCA initiated annual surveys of coastal condition in the Southeast Coast region, which includes the Carolinian Province and part of the West Indian Province. The assessment of 2000 data was reported in the NCCR II, and data from 2001 and 2002 are assessed in this current report (NCCR III). These seven years of monitoring data from Southeast Coast coastal waters provide an ideal opportunity to investigate temporal changes in ecological condition indicators. The data can be analyzed to answer two basic types of trend questions based on assessments of ecological indicators in Southeast Coast coastal waters: what is the interannual variability in the percentages of area rated good, fair, or poor, and is there a significant change in the percentage of area rated poor from the mid-1990s to the present?

This comparison was conducted using data for the same indicators, collected using similar methods over the same geographic area. The ecological parameters that can be compared between these time periods include water clarity, dissolved oxygen concentrations, sediment toxicity, sediment contaminants, sediment TOC, and benthic condition. Data supporting these parameters were collected using similar protocols and QA/QC methods. Fish tissue contaminants data were also collected by both surveys during both time periods; however, these data were excluded from this trend analysis because the sample preparation methods were not comparable. The available water quality data on chlorophyll *a* and nutrients from the EMAP-NCA survey (2000) were also excluded because these parameters were not evaluated during the EMAP-Estuaries surveys (1994–1997). In addition, the spatial extent of the EMAP-NCA Southeast Coast regional data was reduced to match that of the Carolinian Province surveyed during the EMAP-Estuaries study. The Carolinian Province extends from the Virginia–North Carolina state border to the Indian River Lagoon on the east coast of Florida.

Both programs (EMAP-Estuaries and EMAP-NCA) implemented probability-based surveys that support estimations of the percentage of coastal area rated in good, fair, or poor condition based on the indices and component indicators assessed. Standard errors for these estimates were calculated according to methods listed on the EMAP Aquatic Resource Monitoring Web site (http://www.epa.gov/nheerl/arm). The reference values and guidelines listed in Chapter 1 were used to determine good, fair, or poor condition for each index and component indicator from both time periods.

None of the indices or component indicators assessed showed any significant linear trends over time in the percent of coastal area rated poor (Figures 4-8 through 4-13); however, when the time periods were compared, some differences were observed (Figure 4-14). The percentage of coastal area rated poor for sediment toxicity was significantly greater for the time period from 1994 to 1997 than for 2000 to 2002 ($z = 3.67$; $p < 0.05$).

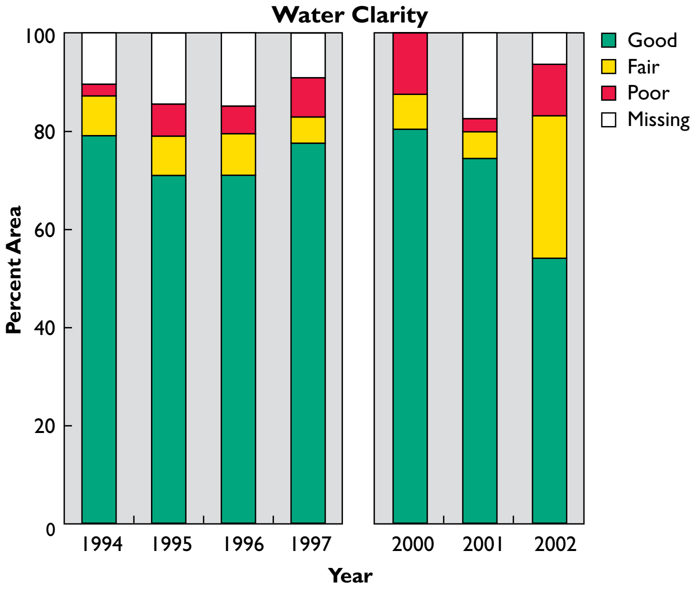


Figure 4-8. Percent area of Southeast Coast coastal waters in good, fair, poor, or missing categories for water clarity measured over two time periods, 1994–1997 and 2000–2002 (U.S. EPA/NCA).

Similarly, significantly greater percentage of the coastal area was rated poor for sediment contaminants from 1994 to 1997 than from 2000 to 2002 ($z = 2.028$; $p < 0.05$). In addition, the percentage of coastal area rated poor was greater (although not significantly) for the time period 1994–1997 than for 2000–2002 for all of the other indicators measured, with the exception of sediment TOC. Sediment TOC increased slightly from 5.5% to 7.2%, although this increase was not significant ($p < 0.05$). It should be noted that sediment toxicity samples were not collected in 1996, and these data were considered to be missing for 100% of the coastal area in 1996.

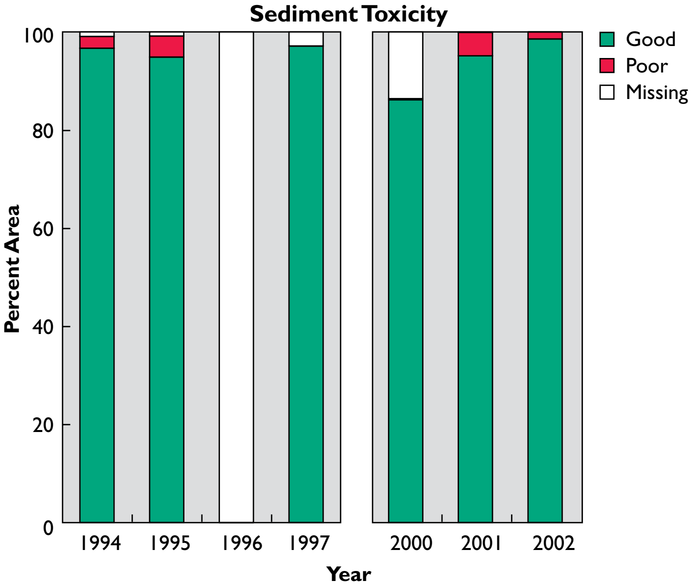


Figure 4-10. Percent area of Southeast Coast coastal waters in good, poor, or missing categories for sediment toxicity measured over two time periods, 1994–1997 and 2000–2002. No data were collected in 1996 (U.S. EPA/NCA).

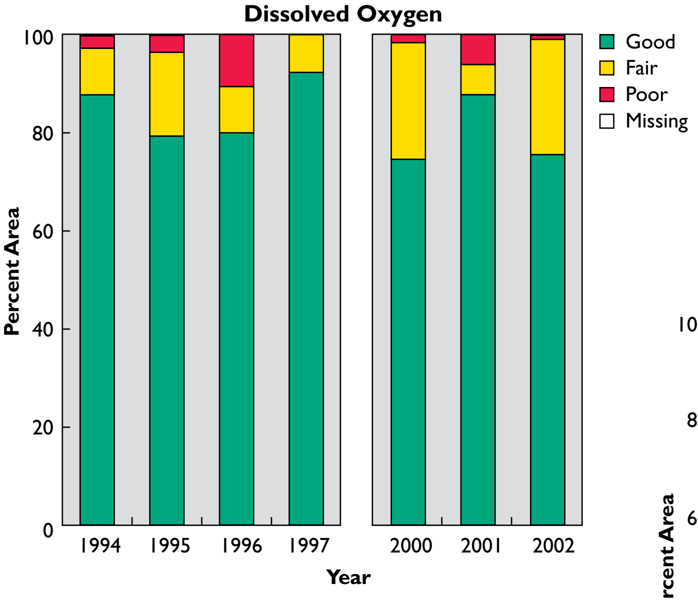


Figure 4-9. Percent area of Southeast Coast coastal waters in good, fair, poor, or missing categories for bottom-water dissolved oxygen concentrations measured over two time periods, 1994–1997 and 2000–2002 (U.S. EPA/NCA).

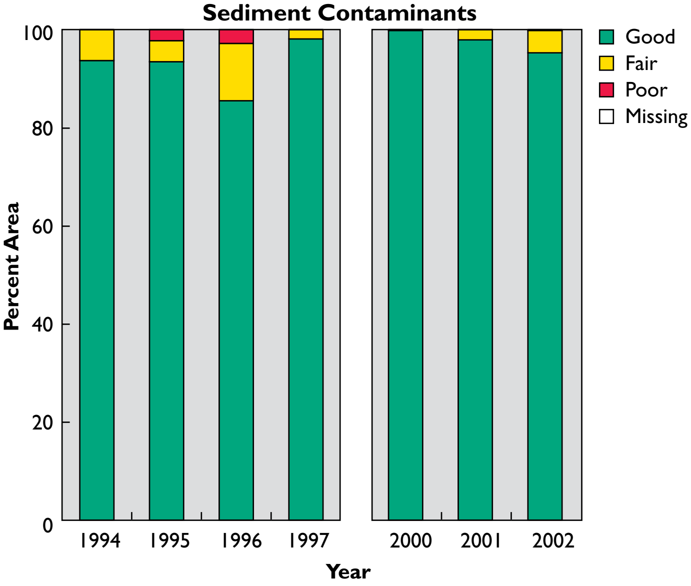


Figure 4-11. Percent area of Southeast Coast coastal waters in good, fair, poor, or missing categories for sediment contaminants measured over two time periods, 1994–1997 and 2000–2002 (U.S. EPA/NCA).

Porty spider crabs are bottom-dwelling scavengers found in estuarine waters from Nova Scotia to the Gulf of Mexico (courtesy of Andrew David, NMFS, and Lance Horn, University of North Carolina at Wilmington).

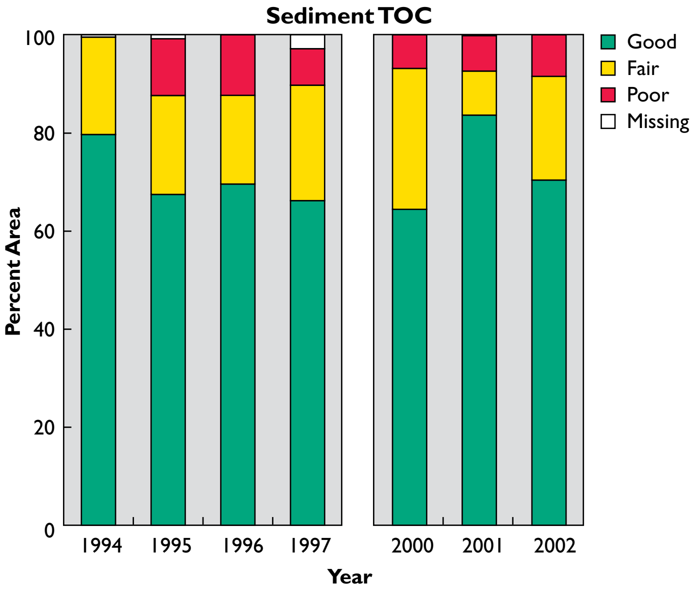


Figure 4-12. Percent area of Southeast Coast coastal waters in good, fair, poor, or missing categories for sediment TOC measured over two time periods, 1994–1997 and 2000–2002 (U.S. EPA/NCA).

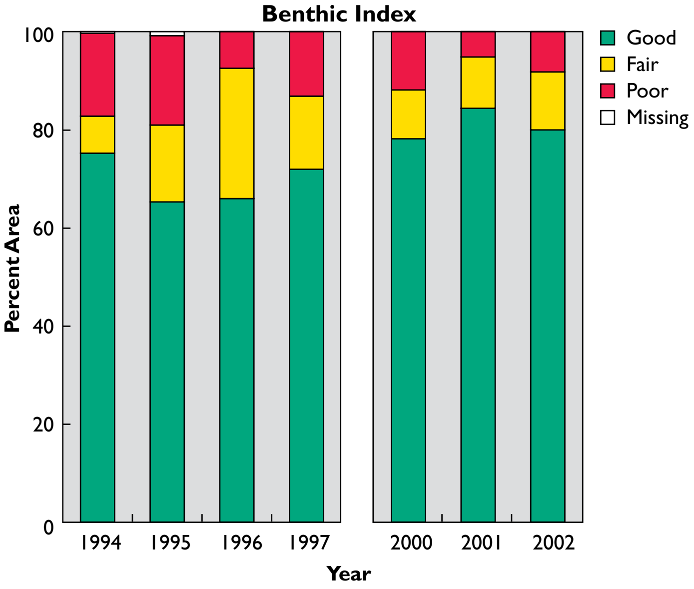


Figure 4-13. Percent area of Southeast Coast coastal waters in good, fair, poor, or missing categories for the benthic index measured over two time periods, 1994–1997 and 2000–2002 (U.S. EPA/NCA).

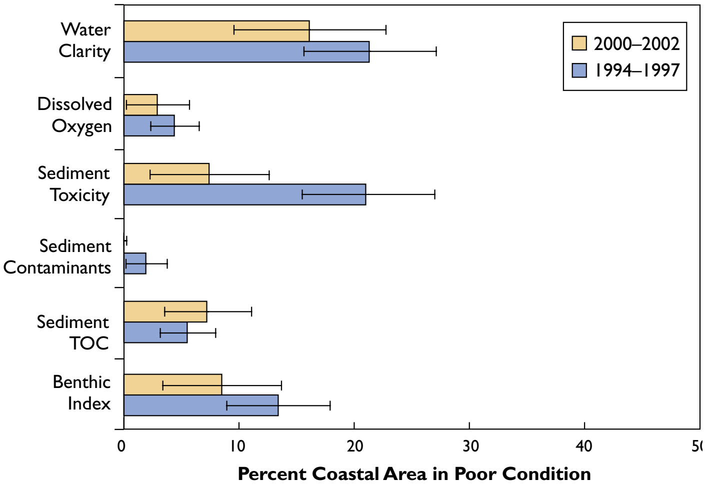
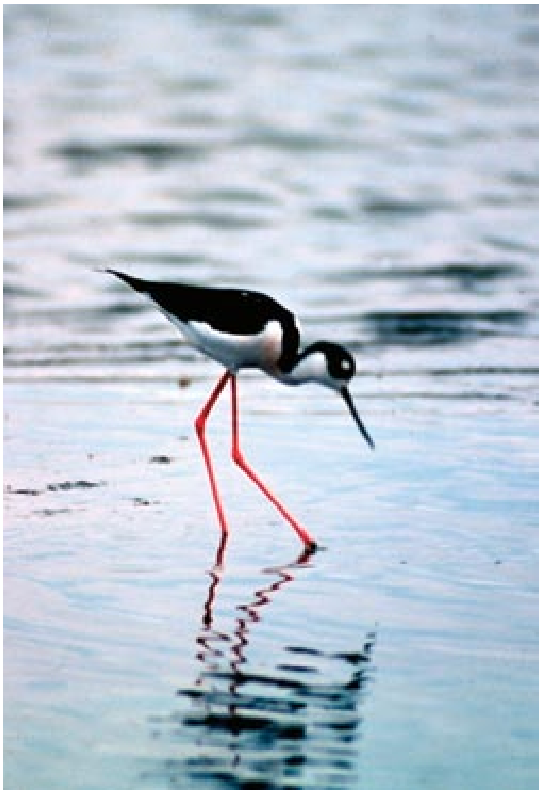


Figure 4-14. Comparison of percent area of Southeast Coast coastal waters rated poor for ecological indicators between two time periods, 1994–1997 and 2000–2002. Error bars are 95% confidence intervals (U.S. EPA/NCA).



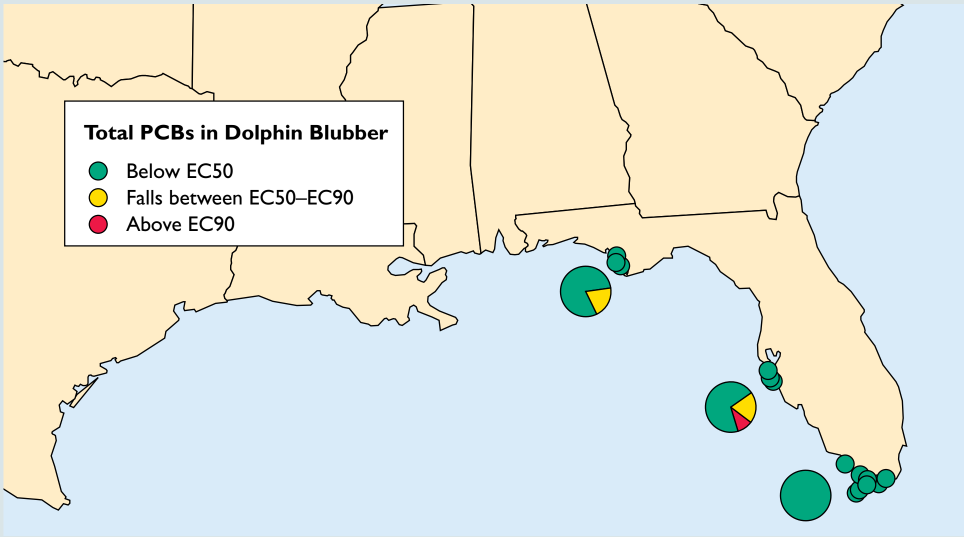
Black-necked stilts are found along edges of shallow waters, such as the ACE Basin NERR (courtesy of NOAA).

Bottlenose Dolphin Tissue Contaminants

Bottlenose dolphins are apex predators in estuarine and nearshore waters along the Atlantic coast from Long Island, NY, south to Florida and along the coast of the Gulf of Mexico. In many estuaries, bottlenose dolphins are year-round residents, showing a high degree of site fidelity. As such, dolphins can be good indicators of ecosystem contamination, particularly for very persistent pollutants such as PCBs. Total PCB concentrations were measured in blubber from live dolphins sampled along the Atlantic coast between 2000 and 2004 (Hansen et al., 2003). In the Gulf of Mexico, total PCB concentrations were measured in blubber from live dolphins in Sarasota Bay, FL, in 2000–2001 (Wells et al., 2005) and Florida Bay in 2002 (NOAA, 2003a), as well as from stranded bottlenose dolphins near St. Joseph Bay, FL, during an unusual mortality event (UME) in 2004 (NIST, 2004). Researchers have also examined concentrations of other organic compounds, including polyfluoroalkyl compounds (PFAs), in dolphin blubber and blood.

Female dolphins transfer a majority of their PCB contaminant load to their offspring during lactation, and it is difficult to interpret PCB concentrations from the blubber of a female dolphin without knowledge of the dolphin's reproductive history. For this reason, this analysis used total PCB concentrations analyzed in samples collected from male dolphins. The measured total PCB concentrations were compared to estimated risk values proposed by Schwacke et al. (2002). These risk values correspond with PCB concentrations that are estimated to cause reproductive failure (e.g., stillbirths, calf mortality) in dolphins. Measured total PCB levels of 33 µg/g lipid are considered to be the effective concentration required to induce 50% reproductive failure (EC50). Levels of 51.2 µg/g lipid are considered to be the effective concentration required to induce 90% reproductive failure (EC90).

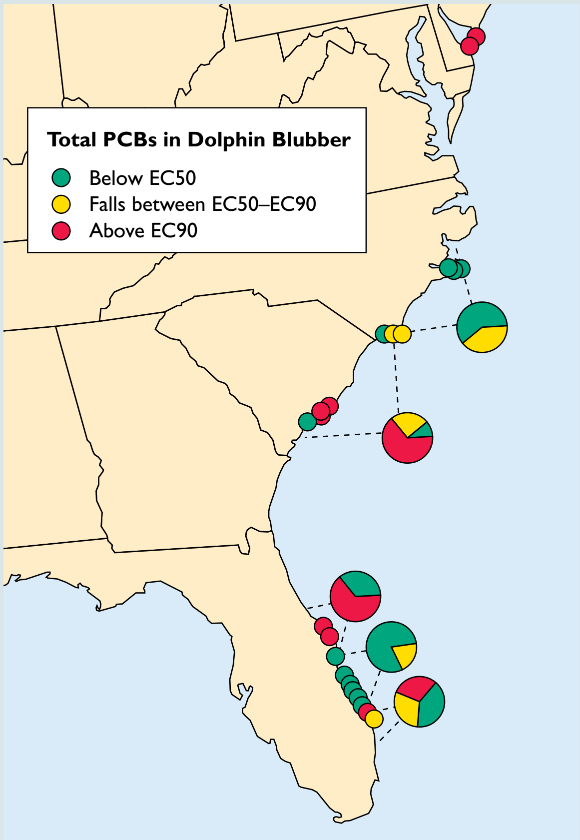
The results of these studies along the Gulf and Atlantic coasts are shown in the maps. For sites where many dolphins were sampled (≥ 5), data are summarized as a pie chart showing the proportion of the samples falling into each category. All of the dolphins sampled from Florida Bay and most of the UME dolphins from St. Joseph Bay showed total PCB concentrations below the EC50. In Sarasota Bay, 27% of dolphins had total PCB concentrations in their tissues above the EC50, but



Total PCB concentrations measured from the blubber of male dolphins sampled along the U.S. Gulf of Mexico coast, 2000–2004 (Wells et al., 2005; NOAA, 2003a; NIST, 2004).

only 9% measured concentrations above the EC90. In the Atlantic Coast estuaries around Charleston, SC, and in Florida's Mosquito Lagoon and the northern portion of the Indian River Lagoon, more than 60% of the male dolphins sampled showed total PCB values above the EC90. In addition, all tissue samples from the New Jersey coast measured PCB concentrations above the EC90, but only a few samples (n=4) were available. Dolphins sampled from estuaries and coastal regions of North Carolina and within the middle portion of the Indian River Lagoon fared better, with no individuals showing PCB concentrations above the EC90. Concentrations of total PCBs were higher than concentrations of other measured organic compounds at all of the sampled sites, and results of analyses of inorganic contaminants (e.g., metals) in dolphin tissues are not yet available.

Recently, scientists have identified other emerging chemical contaminants of concern, including PFAs, in the environment. PFA concentrations were measured in dolphin blood during capture-and-release studies in Sarasota Bay, FL, and at three Atlantic Coast sites (Houde et al., 2005). Differences in PFA levels were observed between sampling sites, but little is known about the potential health effects of these compounds in dolphins. The mean summed PFA concentration (900 ppb wet weight) measured in dolphins from Sarasota, FL, was similar to that measured in dolphins from Indian River Lagoon, FL (800 ppb wet weight) and less than that measured in dolphins from Charleston, SC (1800 ppb wet weight), and Delaware Bay, DE (1600 ppb wet weight). Additional research is needed to determine whether these levels of PFAs put dolphins at increased health risk.



Total PCB concentrations measured from the blubber of live male dolphins sampled along the U.S. Atlantic Coast between 2000 and 2004. Data sources: Charleston, SC; Indian River Lagoon, FL; and Beaufort, NC, data from Hansen et al. (2003) and from the NOAA Center for Coastal Environmental Health and Biomolecular Research (unpublished) and Harbor Branch Oceanographic Institute (unpublished); data for other sites from National Institute for Standards and Technology (unpublished) and NMFS (unpublished).

Large Marine Ecosystem Fisheries—Southeast U.S. Continental Shelf LME

The Southeast U.S. Continental Shelf LME extends from Cape Hatteras, NC, to the Straits of Florida (Figure 4-15) and is characterized by its temperate climate. This LME is considered to be moderately productive based on primary production (phytoplankton) estimates, and upwelling along the Gulf Stream front and intrusions from the Gulf Stream can cause short-lived plankton blooms. The Southeast U.S. Continental LME is distinguished by a very high percentage of commercially important crustacean catches. The valuable coastal shrimp fishery accounts for 10% of the total tonnage landed from this LME. Reef fishes, sciaenid species, menhaden, and mackerel are also important fisheries. The fisheries in this LME are managed by NMFS and the South Atlantic Fishery Management Council (SAFMC) (NOAA, 2007g).

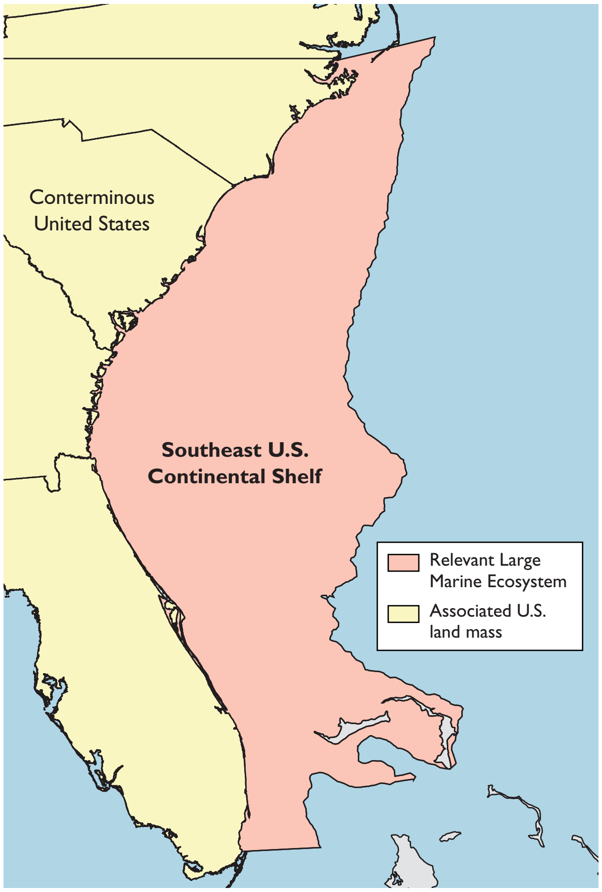


Figure 4-15. Southeast U.S. Continental Shelf LME (NOAA, 2007g).

The portion of the Atlantic coast of the United States that borders the Southeast U.S. Continental Shelf LME includes diverse habitats ranging in salinity, flora, and fauna. The coastal area includes freshwater and estuarine habitats, nearshore and barrier islands, and oceanic communities. Watersheds that drain the lower Appalachian Mountains, Piedmont, and Coastal Plains empty into the ecosystem along the coastlines of North Carolina, South Carolina, Georgia, and eastern Florida. The flow of fresh water mixes along the coast with prevailing oceanic waters to create diverse wetlands, marsh, and mangrove habitats that transition gradually from freshwater to brackish-water to saltwater areas. From an ecosystem perspective, this thin fringe of estuaries is dynamic, varying constantly with tidal fluctuations and levels of runoff, and serves as important habitat for invertebrates, fish, reptiles, waterfowl, mammals, and a diverse array of plants. These estuaries also act as a natural filter to remove pollutants and trap sediments from upland regions. The Southeast U.S. Continental Shelf LME coastal area supports diverse aquatic organisms and complex food webs in an irreplaceable nursery system. This system promotes the recruitment (addition of a new generation of young fish) and development of juvenile fish and invertebrate species that are important to recreational, commercial, and ecological interests.

Reef Fish Resources

Reef fish are generally found in reef or reef-like, hard-bottom habitats. Dominant reef fish species in the Southeast U.S. Continental Shelf LME include red, yellowtail, vermilion, and mutton snappers; red and gag grouper; black sea bass; and greater amberjack. In the Southeast U.S. Continental Shelf LME, the fishery for reef fishes has historically been conducted within waters that are less than 600-feet deep or within the area that approximates the outer edge of the continental slope. Reef fish fisheries are extremely diverse, have many users (commercial and recreational), and vary greatly by location and species (NMFS, In press).

Combined commercial and recreational landings of reef fish from the Southeast U.S. Continental Shelf LME have fluctuated since 1976, showing a slightly decreasing trend over time (Figure 4-16).

The recent average yield of reef fish species (2001–2003) was 6,407 t. Meanwhile, fishing pressure has increased significantly, with many stocks currently considered overfished. Regulations pertaining to the management of reef fish include prohibitions on the use of fish traps (except pots for black sea bass) and trawl gear, minimum-size limits, permitting systems for commercial fishermen, bag limits, quotas, seasonal closures, Special Management Zones, and the establishment of Marine Protected Areas prohibiting the harvest of any species. Reef fish are part of a complex, diverse multi-species ecosystem. The long-term effects of harvesting on reefs are not well understood, requiring cautious management controls of targeted fisheries (NMFS, In press).

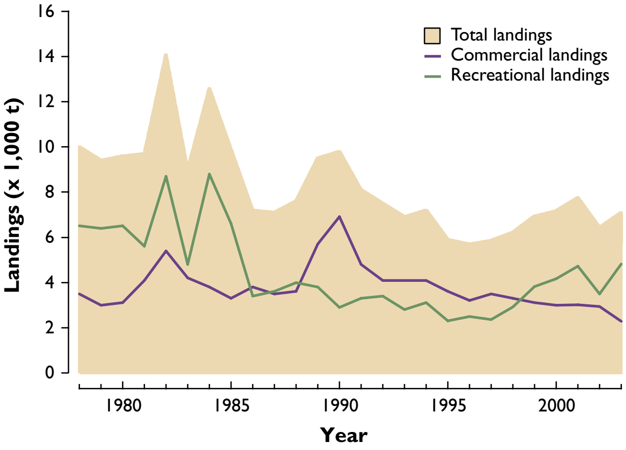


Figure 4-16. Reef fish landings from the Southeast U.S. Continental Shelf LME, 1978–2003, in metric tons (t) (NMFS, In press).

Sciaenids Fisheries

Fish of the family *Sciaenidae* include 22 species in the Southeast U.S. Continental Shelf LME. Some of the more notable members of this family of fish are red drum (*Sciaenops ocellatus*), black drum (*Pogonias cromis*), Atlantic croaker (*Micropogonias undulatus*), weakfish (*Cynoscion regalis*), spotted seatrout (*Cynoscion nebulosus*), kingfish (*Menticirrhus spp.*), and spot (*Leiostomus xanthurus*). Sciaenids have constituted an important fishery resource along the Atlantic coast since the late 1800s. Currently, these fish species support substantial harvests for both commercial and recreational fisheries and are captured with almost every type of gear used to fish the coastal waters of the Atlantic Ocean (NMFS, In press).

Of the sciaenid species for which an FMP has been developed, red drum is currently classified as overfished; weakfish is classified as recovered; and there is not enough information available to adequately determine the stock status of the remaining species. Commercial landings of red drum increased rapidly in the mid-1980s when market demand grew suddenly for blackened redfish, a gourmet seafood dish. In addition, large numbers of sciaenids (e.g., small Atlantic croaker, spot, and seatrout) are caught and killed as an incidental catch in Southeast U.S. Continental Shelf LME shrimp fisheries. Because much of this bycatch consists of juveniles, fishing mortality from incidental catches may slow the recovery of overfished stocks. Shrimp management regulations require the use of bycatch-reduction devices, which shrimpers in the Southeast U.S. Continental Shelf LME currently use. Use of these devices has contributed to the rebound of some overfished stocks, such as weakfish. Recent declines in the spotted seatrout abundance index in Southeast U.S. Continental Shelf LME waters have been attributed to increased coastal development leading to habitat loss and heavy fishing pressure. Regulations for sciaenid fishes in the Atlantic Ocean vary by state and range from no restrictions to complicated restrictions based on fish size and daily bag limits. The populations of several species of sciaenids, most notably Atlantic croaker and spotted seatrout, appear to be closely linked to environmental conditions, resulting in large annual population fluctuations (NMFS, In press).

Menhaden Fishery

The geographical range of the Atlantic menhaden extends from West Palm Beach, FL, to Nova Scotia, Canada. Menhaden are prey for many fish, marine mammals, and sea birds and form an important component of both the Southeast and Northeast U.S. Continental Shelf LMEs. Menhaden landings from these LMEs are reported by the Southeast Fisheries Science Center.

Landings and participation in the menhaden fishery (23 factories and more than 100 vessels on the Atlantic coast) increased rapidly after World War II, reaching peak harvests between 1953 and 1962, with record landings of 712,100 t in 1956

(Figure 4-17). Sharp declines in landings thereafter resulted in plant closings and vessel reductions. Stock rebuilding occurred during the 1970s and 1980s, and menhaden landings climbed to 418,600 t in 1983. During the late 1980s and 1990s, the fishery consolidated, primarily because of low product prices. In 2003, only 2 reduction plants and 12 vessels remained in operation on the Atlantic coast. The Virginia portion of Chesapeake Bay is currently the center of the modern menhaden fishery. In addition, an active baitfish fishery along the coast operates primarily in Virginia and New Jersey and harvests about 15% to 20% of the medhaden landed by the industrial fishery. The resource is almost fully utilized, with a maximum sustainable yield of 408,999 t per year and a recent average yield of 228,000 t annually for the 2001–2003 time period (NMFS, In press).

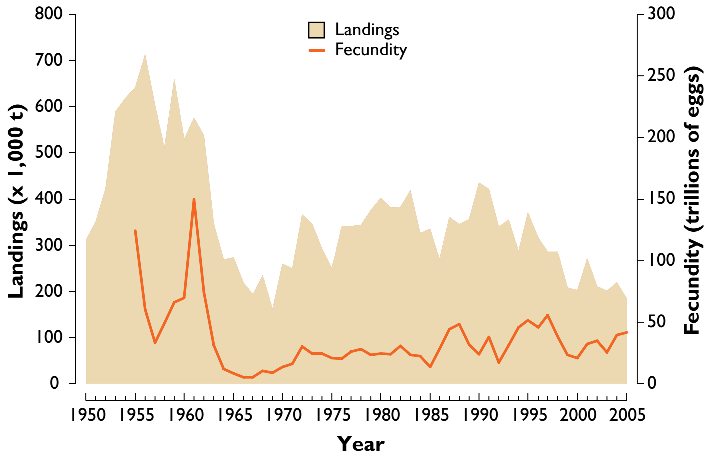


Figure 4-17. Landings in metric tons (t) and fecundity (potential reproductive capacity) in trillions of eggs of Atlantic menhaden, 1950–2002 (NMFS, In press).

Declining fishing effort in recent years has likely reduced the rate at which older menhaden are removed from the population, allowing time for the recruitment of new generations of young fish. In the past, relatively low survival to the age of 1 year has been a major concern for the Atlantic menhaden stock. The last dominant cohort (the generation of new fish from the same year that are the most prevalent in the population) occurred in 1988, and subsequent cohorts (generations of fish from the same year) have generally been poor to mediocre. Recruitment appears to be hindered largely by environmental conditions (centered in the Chesapeake Bay area), rather than by a lack of spawning stock. If recruitment continues to decline, erosion of the spawning stock may follow. Currently, several studies are examining the role of menhaden in the food web, with the goal of managing forage and predator fish species at a multi-species level (NMFS, In press).

Menhaden are most commonly used for fertilizer and pet food (courtesy of Bob Williams, NOAA).

Mackerel Fisheries

King and Spanish mackerel are two coastal pelagic (dwelling in the water column) fish species inhabiting the Southeast U.S. Continental Shelf LME. Coastal pelagics are fast swimmers that school and feed voraciously, grow rapidly, mature early, and spawn over many months. U.S. and Mexican commercial fishermen have harvested Spanish mackerel since the 1850s and king mackerel since the 1880s.

The total catch of Southeast U.S. Continental Shelf LME king mackerel averaged 3,345 t per fishing year from 1981 to 2001, with a maximum of 4,365 t in 1985 and a minimum of 2,570 t in 1999. The total catch was 2,748 t in 2001, and the recent average yield was 2,665 t for the 2000–2001 and 2002–2003 time periods. In 2003, the maximum sustainable yield was estimated at 2,680 t for king mackerel stock in this LME. On average, landings of king mackerel are larger for the recreational sector (66%) than for the commercial sector (34%), and landings have been below the total allowable catch limits since 1986. According to the 1998 and 2003 stock assessments, the stock is not overfished, nor is overfishing occurring, although it is near its estimated long-term potential yield. Currently, there are restrictions for the commercial fishing industry sector, including annual total allocated catch restrictions, minimum-size restrictions, gear restrictions, and catch trip limits. For the recreational sector, restrictions include bag limits, minimum-size limits, and annual quota allocations. Current issues affecting the Southeast U.S. Continental Shelf LME king mackerel stock concern the bycatch of juveniles in the shrimp trawl fishery and the allocation of landings within the mixing zone between Southeast U.S. Continental and Gulf of Mexico LME stocks (NMFS, In press).

The total catch of Southeast U.S. Continental Shelf LME Spanish mackerel averaged 2,307 t per fishing year from 1984 to 2001, with a maximum of 3,188 t in 1991 and a minimum of 1,406 t in 1995. In 2001, the total catch was 2,305 t, and the recent average yield was 2,716 t for the 2000–2001 to 2002–2003 time periods. For this LME, Spanish mackerel landings have also been below the total allowable catch limits, at least since 1991. The 1998 and 2003 stock assessments concluded that the Spanish mackerel stock in this LME was not overfished and that overfishing was not occurring, although current estimates indicate that the stock is exploited at its near-optimum, long-term yield (which is based on the maximum sustainable yield modified to account for economic, social, or ecological factors). At present, management restrictions for the commercial fishery of the Southeast U.S. Continental Shelf LME Spanish mackerel include minimum-size restrictions, gear restrictions, trip limits, and quota allocations. A major recreational fishery exists for Spanish mackerel throughout its range, and the percentage of landings by recreational anglers has increased since the mid-1990s to about 50% of all landings of the Southeast U.S. Continental Shelf LME stock. For the recreational fishery, there are minimum-size restrictions, bag limits, and charter-vessel permit requirements. Current issues affecting this stock include bycatch from the shrimp trawl fishery and the allocation of landings within the mixing zone between Southeast U.S. Continental Shelf and Gulf of Mexico LME stocks (NMFS, In press).

Shrimp Fisheries

The trend in commercial landings of the major shrimp species over the past 40 years has remained stable, while fishing pressure has increased. The shrimp stocks in the Southeast U.S. Continental Shelf LME appear to be more affected by environmental conditions than by fishing pressure. Both pink and white shrimp populations are affected by cold weather. The young of these species over-winter in estuaries and can potentially “freeze out” if water temperatures drop to lethal levels. The lower temperatures do not affect brown and rock shrimp populations because juveniles of these species are not found in the estuaries during cold seasons. Annual variations in white and pink shrimp populations due to fluctuating environmental conditions are a natural phenomenon that will likely continue to occur despite management activities; however, the recovery of the affected stocks can be mediated by management practices (NMFS, In press).

The current shrimp FMP (SAFMC, 2005) uses the mean total shrimp landings as a reasonable proxy for maximum sustainable yield. The harvest of shrimp in the Southeast U.S. Continental Shelf LME has fluctuated around stable levels for several years. This trend in landings has been maintained even though an increase in vessels has been observed; therefore, it seems these stocks are fully exploited. The recent average yield of brown, pink, rock, and white shrimp from the Southeast U.S. Continental Shelf LME was 10,984 t for the 2001–2003 time period (NMFS, In press).

NMFS catch statistics indicate that commercial shrimp species are being harvested at maximum levels; therefore, an increase in fishing effort is not likely to lead to an increase in catch. Although fishing mortality may affect future shrimp stocks in years experiencing harsh environmental conditions, the greatest threat to shrimp populations is the loss or destruction of habitat. Pollution or physical alteration of the salt marsh and inshore seagrass habitats results in changes to habitats that are critical nursery areas for juvenile shrimp (NMFS, In press).

Highlight

South Carolina Oyster Restoration and Enhancement (SCORE) Program


Natural South Carolina intertidal reef adjacent to fringing salt marsh (courtesy of South Carolina DNR).

Oysters are important because they not only provide a resource to harvest and enjoy, but also provide a number of ecosystem services. These services include filtering vast quantities of water, serving as an important habitat for numerous commercially and ecologically important estuarine species, and protecting marsh shorelines from erosion. Populations of the native eastern oyster, *Crassostrea virginica*, are declining throughout its range extending from Canada to South America, with populations in some areas, such as the Chesapeake Bay, at less than 1% of the historic abundance. In South Carolina, there are adequate breeding stocks of oysters, but recruitment (settling of oyster larvae out of the water column) is limited by the amount of substrate available for attachment (South Carolina DNR, 2007b).

The South Carolina DNR is responsible for managing the state's oyster resource habitats. In order to increase oyster reef habitat at a minimum cost to taxpayers, South Carolina DNR has initiated the South Carolina Oyster Restoration and Enhancement Program (SCORE) to increase the amount of substrate available for oyster recruitment in the state's waters. Community-based restoration and related monitoring are key components of SCORE. The program restores and enhances oyster resources and habitat by planting recycled oyster shells into the intertidal environment. Volunteers from across the state are helping to strategically place recycled oyster shells, thereby creating new oyster shell habitats for natural recruitment in areas with little or no natural oysters or substrate for recruitment (South Carolina DNR, 2007b).

SCORE also serves other uses beneficial to the state agencies and residents. The South Carolina DNR uses SCORE's small oyster shell reefs (hundreds of bushels of shells) to evaluate approaches for the department's larger oyster-planting program, which has involved placing tens of thousands of bushels of recycled shells onto acres of formerly barren, intertidal habitat on public grounds. In addition, the community-based aspect of SCORE helps to educate the public about the significant ecological and economic role of oysters in South Carolina. It is important for the community to understand that oysters are much more than a seafood treat and to learn about oysters' biology and the human activities that can influence their well-being (South Carolina DNR, 2007b).

Appropriate management of oyster resources includes the planting of appropriate shell material (cultch) to provide substrate for larval oyster recruitment onto the permanent substrate where they will reside as adults. The best cultch material is fresh oyster shells, but this material is getting scarce. There is a nationwide shortage of oyster shells to be used as cultch because many oyster shells go to landfills or are used for decorative purposes (tabby walls) or road bed coverage. Some volunteer groups recycle their own shells, but most use shells from the South Carolina DNR's larger Shell Recycling Program, which encourages the public to recycle oyster shells at one of the more than 16 designated recycling centers located along the South Carolina coast. The recycled shells generated in this fashion are used for restoration and enhancement of shellfish resources, reducing the costs of these activities (South Carolina DNR, 2007a). Less than 10% of the oysters harvested in South Carolina are returned to the South Carolina DNR for restoration projects (South Carolina DNR, 2007b). Additional shells may be recovered if volunteer groups recycle shells as a service project or if the shell material from restaurants, caterers, and resorts were recovered before going to a landfill.

Volunteers collect oyster shells before bagging them for use in oyster habitat restoration projects (courtesy of South Carolina DNR).

South Carolina DNR's largest completed reef at Mt. Pleasant, SC (courtesy of South Carolina DNR).

Since May 2001, SCORE has used more than 13,000 bags (over 275 tons) of oyster shells to complete over 120 reefs at 29 reef sites along the South Carolina coast. As these shell-bag reefs begin to recruit new oysters and attract other inhabitants of the estuary, they are also being used as living classrooms and South Carolina DNR research platforms. Volunteer support is critical to monitoring the new reefs throughout the year to increase understanding of how best to restore oyster habitats. Support to date has come from state and federal agencies, foundations, and volunteers, more than 2,000 of whom have been involved in one or more aspects of the program (South Carolina DNR, 2007b).

By working together, community members and South Carolina DNR biologists are restoring oyster populations while also enhancing habitat for fish, shellfish, mammals, and birds; improving water quality and the clarity of estuarine areas; and informing and educating children, industry, and the general public. More information on SCORE and other oyster-related links are available on SCORE's Web site at http://score.dnr.sc.gov. Information about the Shell Recycling Program is available at the Web page http://saltwaterfishing.sc.gov/oyster.html.

Assessment and Advisory Data

Fish Consumption Advisories

Ten fish consumption advisories were active in the coastal waters of the Southeast Coast region in 2003 (Figure 4-18). All four coastal states of this region—North Carolina, South Carolina, Georgia, and Florida—had statewide advisories covering all coastal waters to warn citizens against consuming large quantities of king mackerel because of potential mercury contamination. Florida and South Carolina also had statewide advisories for other species of fish. Because of these statewide advisories, 100% of the total coastline miles of the Southeast Coast region were under advisory in 2003. Most (91%) fish consumption advisories for the Southeast Coast region were issued, at least in part, because of mercury contamination (Figure 4-19), with separate advisories issued for only two other pollutants: PCBs and dioxins. All of the fish advisories for PCBs covered parts of Georgia, and the one fish advisory for dioxin was in North Carolina's Albemarle-Pamlico Estuarine System (U.S. EPA, 2004b).

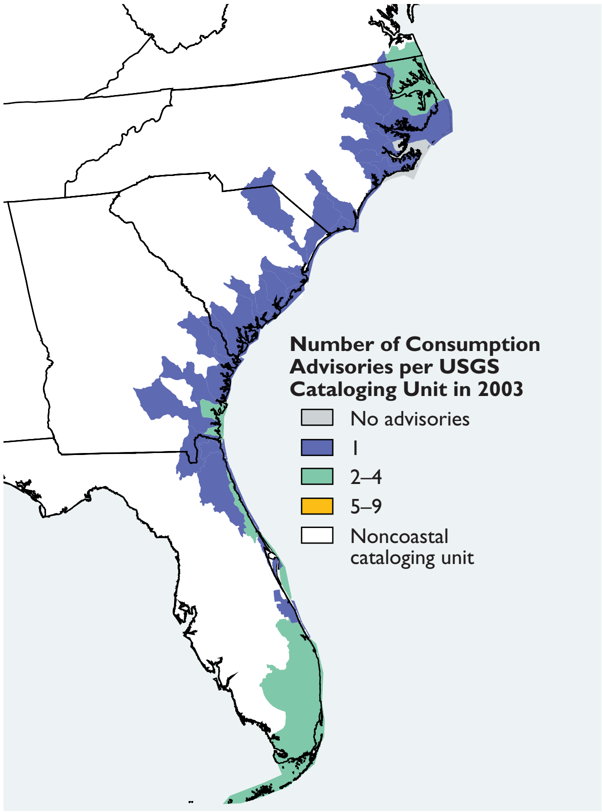


Figure 4-18. The number of fish consumption advisories in effect in 2003 for the Southeast Coast coastal waters (U.S. EPA, 2004b).

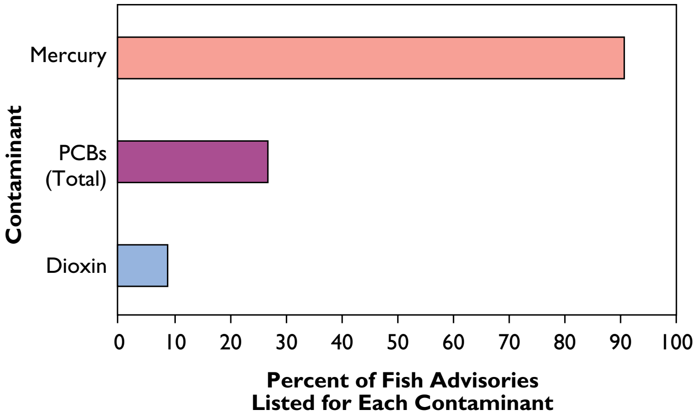


Figure 4-19. Pollutants responsible for fish consumption advisories in Southeast Coast coastal waters. An advisory can be issued for more than one contaminant, so percentages may add up to more than 100 (U.S. EPA, 2004b).

Species and/or groups under fish consumption advisory in 2003 for at least some part of the coastal waters of the Southeast Coast region

- Almaco jack
- Atlantic croaker
- Black drum
- Blackfin tuna
- Blue crab
- Bluefish
- Bowfin
- Carp
- Catfish
- Clams
- Cobia
- Crevalle jack
- Flounder
- Greater amberjack
- King mackerel
- Ladyfish
- Largemouth bass
- Little tunny
- Mussels
- Oysters
- Red drum
- Shark
- Silver perch
- Snowy grouper
- Spotted seatrout
- Swordfish
- Tilefish

Source: U.S. EPA, 2004b

Beach Advisories and Closures

Of the 487 Southeast Coast beaches reported to EPA in 2003, only 12% (59 beaches) were closed or under an advisory for any period of time during that year. Table 4-1 presents the number of beaches monitored and the number of beaches under closures or advisories reported for each state. Figure 4-20 presents advisory and closure percentages for each county within each state (U.S. EPA, 2006c).

Table 4-1. Number of Beaches Monitored and With Advisories/Closures in 2003 for Southeast Coast States (U.S. EPA, 2006c)

State	No. of Beaches Monitored	No. of Beaches With Advisories/ Closures	Percentage of Beaches Affected by Advisories/ Closures
North Carolina	222	21	9.5
South Carolina	7	2	28.6
Georgia	37	NR	NR
Florida (East Coast)	226	36	15.9
TOTAL	**492**	**59**	**12.0**

NR = Not Reported.

Most beach advisories and closures were implemented at beaches along the Southeast Coast because of elevated bacteria levels (Figure 4-21). Although stormwater runoff was identified as a source of beach contamination in the Southeast Coast region, unknown sources accounted for 97% of the survey responses (Figure 4-22, U.S. EPA, 2006c).

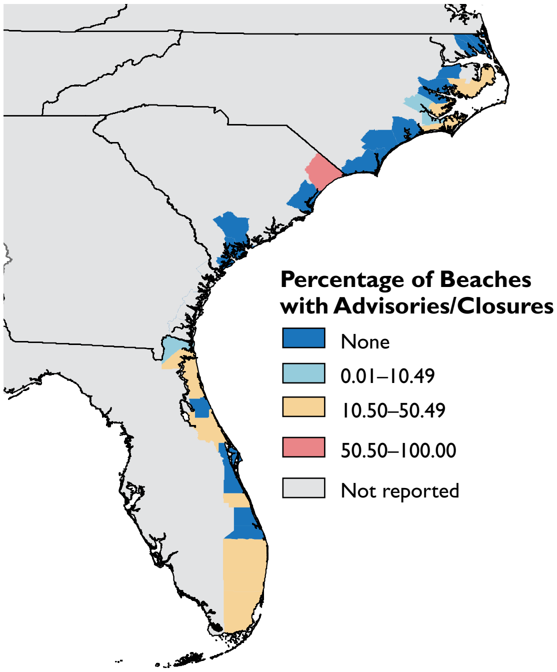


Figure 4-20. Percentage of monitored beaches with advisories or closures, by county, for the Southeast Coast region (U.S. EPA, 2006c).

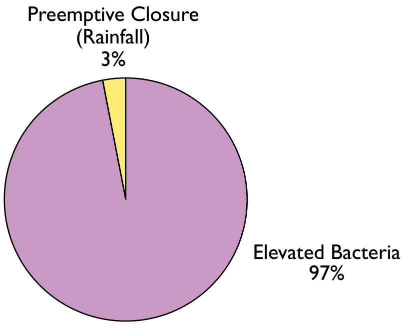


Figure 4-21. Reasons for beach advisories or closures in the Southeast Coast region (U.S. EPA, 2006c).

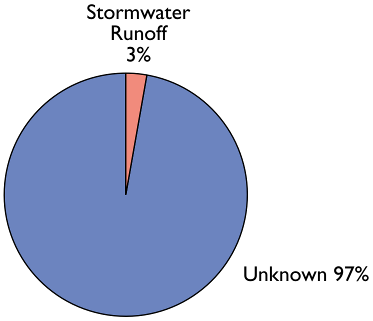


Figure 4-22. Sources of contamination resulting in beach advisories or closures in the Southeast Coast region (U.S. EPA, 2006c).

Leatherback sea turtles nest occasionally on the beach at Canaveral National Seashore. The leatherback is an endangered species of sea turtle and is one of the largest in the world. It can grow to be over 6 feet long and weigh over 1,000 pounds (courtesy of NPS).

Highlight

Responding to Sea-Level Rise

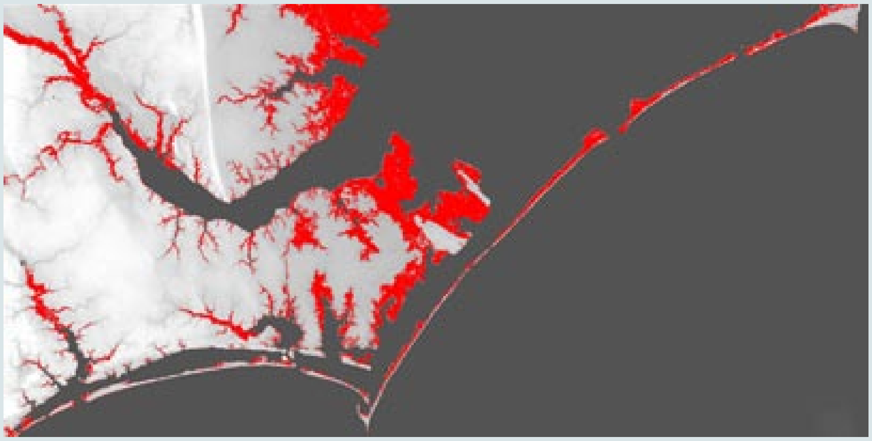
Sea level is expected to rise an average of 20 inches in the 21st century; about two to four times the rate observed over the 20th century (Houghton et al., 2001). A 20-inch rise in sea level will result in a substantial loss of coastal land and be associated with a host of other problems in coastal regions. These problems include the following:

- Higher and more frequent flooding of wetlands and low-lying coastal land
- Transformation of one ecosystem class to another
- Alteration of the function of the coastal area
- Increased flooding during severe storms
- Increased wave energy in nearshore areas
- Saltwater intrusion into coastal freshwater aquifers
- Breaching of coastal barrier islands
- Damage to coastal infrastructure
- Negative impacts to coastal economies
- Coastal erosion and coastal retreat, including dune and cliff erosion.

Sea-level rise is of special concern along the Southeast and Gulf coasts of the United States. The USGS evaluated vulnerability to sea-level rise by dividing the U.S. coastline into five categories based on geomorphology, coastal slope, relative sea-level change, shoreline erosion rate, tidal range, and mean wave height. The U.S. Southeast and Gulf coasts were determined to be the most vulnerable of the nation's coasts because of their low lying and gently sloping shorelines. In addition, the land in these regions is subsiding, while sea level is rising (Thieler and Hammar-Klos, 1999).

The prediction of shoreline retreat and land-loss rates is critical to the planning of future coastal zone management strategies, as well as to assessing biological impacts due to habitat changes and loss. To assist natural resource managers in mitigating the loss of coastal ecosystems resulting from the existing and predicted acceleration in the rate of sea-level rise, NOAA is developing digital coastal elevation maps with a vertical resolution of 8 inches, coastal flooding models that show the spatial extent of inundation for any projected rate of sea-level rise, and models of ecological response to inundation. NOAA has initiated the mapping and coastal flooding portions of this project for sections of the North Carolina coast. These sections include vulnerable areas and areas whose topography has been mapped by state agencies using light detection and ranging (LIDAR) technology, which is used to quantify coastal change with a rapidity of acquisition and very high data density. The digital elevation maps, hydrological models, and ecological models will ultimately be combined to produce forecasts of coastal change as a function of sea-level rise. One very important use of the forecasts for coastal planners is predicting the coastal response to specific proposals for coastal development.

In North Carolina, sea-level rise has occurred over the past several decades and has already had a major impact on the state's coastlines. Based on NOAA tide gauge measurements, the state's rate of relative sea-level rise ranges from 0.07 to 0.17 inches/year, with rates increasing from south to north (Zervas, 2004). As sea-level rises, the shoreline receeds and one ecosystem class may be transformed into another, significantly altering the function of coastal areas. Rates of shoreline



Areas in red along North Carolina Outer Banks, Bogue Sound, Pamlico Sound, and the Neuse River are projected to be inundated by a 40-inch rise in sea level (Zervas, 2004).

recession vary dramatically along the shore and are a function of shoreline type, geometry, and composition; geographic location; size and shape of the associated coastal waterbody; coastal vegetation; water level; and storm frequency and intensity. In North Carolina, the coastal plain has low topographic slopes, and the majority of the coastal zone is within several feet of current sea level. As a result, North Carolina has lost almost 50 mi^2 of coastal area along the shoreline from 1975 to 2000 and as much as 60% of wetlands in the northeastern portion of the state (Riggs, 2001).

The coastal flooding model combined a hydrodynamic tide model of Pamlico, Albemarle, Core, and Bogue sounds and adjacent estuarine and coastal waters with the high-resolution, topographic/bathymetric digital elevation map based on the LIDAR topographic and bathymetric data (Zervas, 2004). The model forecasted the extent of inundation in Pamlico and Bogue sounds and the Neuse River as a function of a 40-inch sea-level rise (see map).

In 2005, NOAA initiated development of ecological models for the area of North Carolina covered by the coastal flooding model. A GIS-based database of shoreline variables (e.g., fetch, offshore bottom character, shoreline geometry, height and composition of sediment banks, fringing vegetation, boat wake, soil series, marsh zone width, land form type and location, elevation) will help forecast estuarine shore-zone modification driven by sea-level rise. One type of ecological model will predict the effects of present sea-level rise, increased storm surge intensity, bulkheads, and breakwaters on net primary and secondary production within five types of habitat: subtidal un-vegetated, SAV, intertidal flat, oyster reef, and marsh. Another model will predict the spatial distribution of biomass and sediment accretion on salt marsh platforms based on vegetation responses to changes in mean sea level.

The results of the ecological models will allow researchers to examine and evaluate the connections between different habitats and how these connections will be affected by sea-level rise in coastal areas. For example, forecasts of the effects of sea-level rise on forests and forested wetlands will allow researchers to link surface soil salinity to estuarine salinity using soil type maps and information about vegetation/land cover and elevation. Forecasts will be used to determine feedback and transition processes between marshes and forests and between marshes and subtidal environments, as well as evaluate which specific thresholds are needed to initiate state changes from one zone to another due to salinity, inundation regime, or episodic events. In addition, the ecological models will be integrated with landscape models to assess the impact of land use activities on natural and cultural resources and will be used to project the loss/alteration of habitat and resulting impact on biodiversity.

Summary

Based on data from the NCA, the overall condition of the coastal waters of the Southeast Coast region is rated fair. The NCA monitoring conducted by coastal states in 2001 and 2002 showed that DIN, DIP, and bottom-water dissolved oxygen concentrations; water clarity; sediment toxicity; sediment contamination; TOC levels; and benthic condition are rated good for Southeast Coast coastal waters. Indices of concern include the water quality index (54% of the coastal area is rated fair or poor, combined) and coastal habitat index (rated fair). Although no significant linear trends were observed in the available EMAP and NCA data (1994–2001), increasing population growth in this region could contribute to increased susceptibility for water quality degradation in the future.

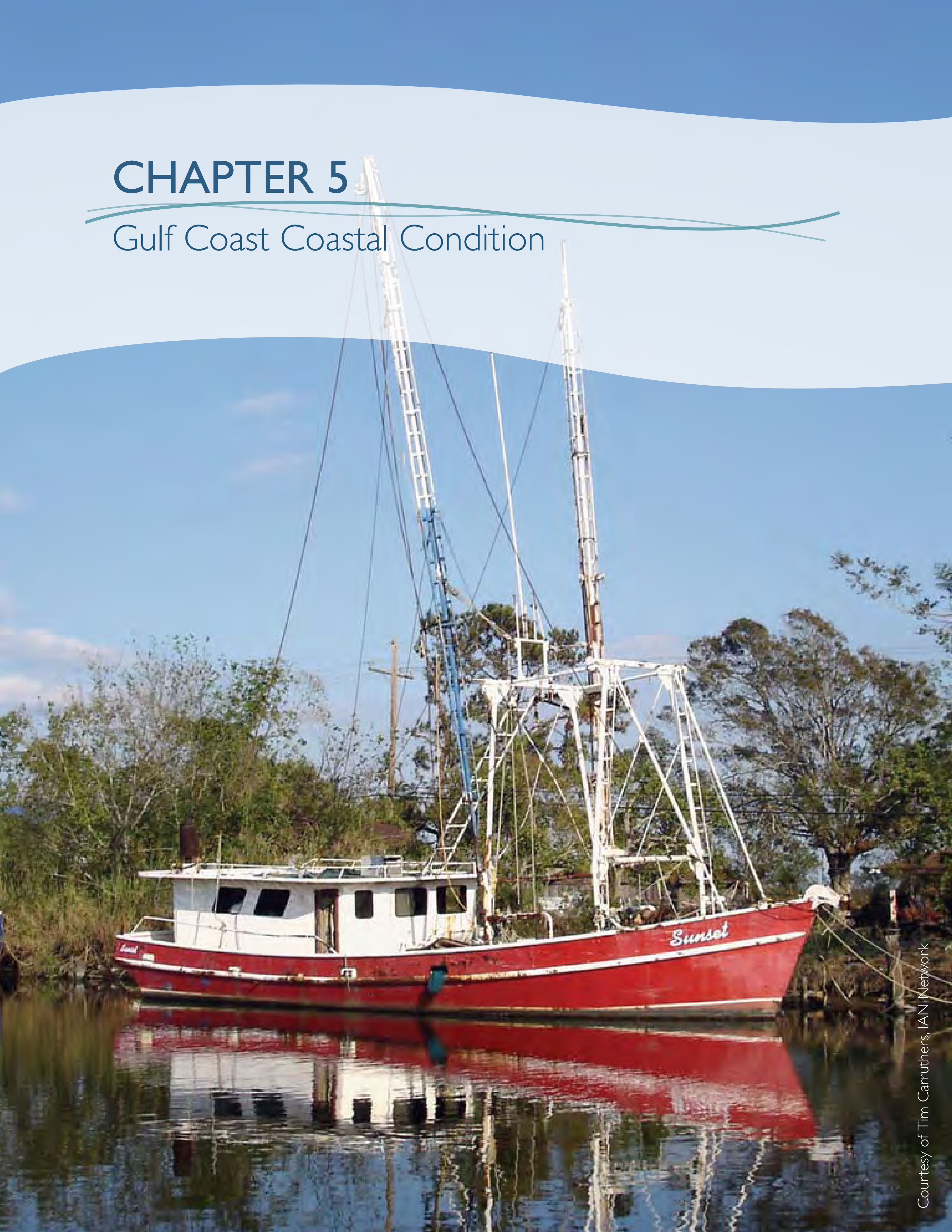
NOAA's NMFS manages several fisheries in the Southeast U.S. Continental Shelf LME, including reef fish, sciaenids, menhaden, mackerel, and shrimp. Landings of reef fish have fluctuated, but are decreasing slightly over time. Fish in the *Sciaenidae* family generally support substantial harvests in the Southeast U.S. Continental Shelf LME, but one member, red drum, is currently classified as overfished. The fishing effort for menhaden in this LME has decreased since the 1950s, but NMFS considers this resource to be almost fully utilized. Neither the king nor Spanish mackerel stocks are considered overfished, but these stocks are at or near their long-term potential and optimum long-term yields, respectively. Although fishing pressure has increased, the Southeast U.S. Continental Shelf LME shrimp fishery has exhibited a 40-year stable trend in catch levels.

Contamination in Southeast Coast coastal waters has affected human uses of these waters. In 2003, 10 fish consumption advisories, most of which were issued for mercury contamination, were in effect for the Southeast Coast region. In addition, 12% of the region's monitored beaches were closed or under advisory for some period of time during 2003. Elevated bacteria levels in the region's coastal waters were primarily responsible for the beach closures and advisories.

Although the overall condition of Southeast Coast coastal waters is rated fair for the 2001–2002 time period, the promotion of a vigilant attitude and the continuation of environmental education would help to protect and preserve this resource, as well as to provide a measure of success for management actions.

CHAPTER 5

Gulf Coast Coastal Condition



Courtesy of Tim Carruthers, IAN Network

Gulf Coast Coastal Condition

As shown in Figure 5-1, the overall condition of the coastal waters of the Gulf Coast region is rated fair to poor, with an overall condition score of 2.2. The water quality index for the region's coastal waters is rated fair; the sediment quality, benthic, and coastal habitat indices are rated poor; and the fish tissue contaminants index is rated good. Figure 5-2 provides a summary of the percentage of the region's coastal area rated good, fair, poor, or missing for each index and component indicator. This assessment is based on environmental stressor and response data collected by the states of Florida, Alabama, Mississippi, Louisiana, and Texas from 487 locations, ranging from Florida Bay, FL, to Laguna Madre, TX, in 2001 and 2002. Please refer to Chapter 1 for information about how these assessments were made, the criteria used to develop the rating for each index and component indicator, and the limitations of the available data.

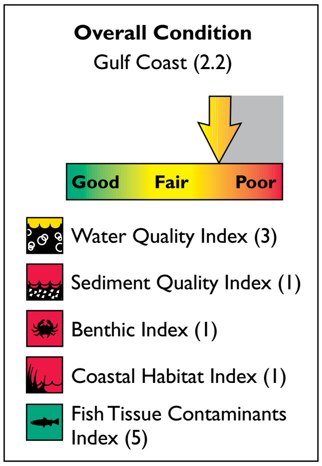


Figure 5-1. The overall condition of Gulf Coast coastal waters is rated fair to poor (U.S. EPA/NCA).

The Gulf Coast coastal area comprises more than 750 estuaries, bays, and sub-estuary systems that are associated with larger estuaries. The total area of the Gulf Coast estuaries, bays, and sub-estuaries is 10,643 mi^2. Gulf Coast estuaries and wetlands provide critical feeding, spawning, and nursery habitat for a rich assemblage of fish and wildlife, including essential habitat for shorebirds, colonial nesting birds, and migratory waterfowl. The Gulf Coast is also home to an incredible array of indigenous flora and fauna, including endangered or threatened species such as the Kemp's ridley sea turtle, Gulf sturgeon, Perdido Key beach mouse, West Indian manatee, telephus spurge, and piping plover. This region's coastal waters also support vegetated habitats that stabilize shorelines from erosion, reduce nonpoint-source loadings, and improve water clarity.

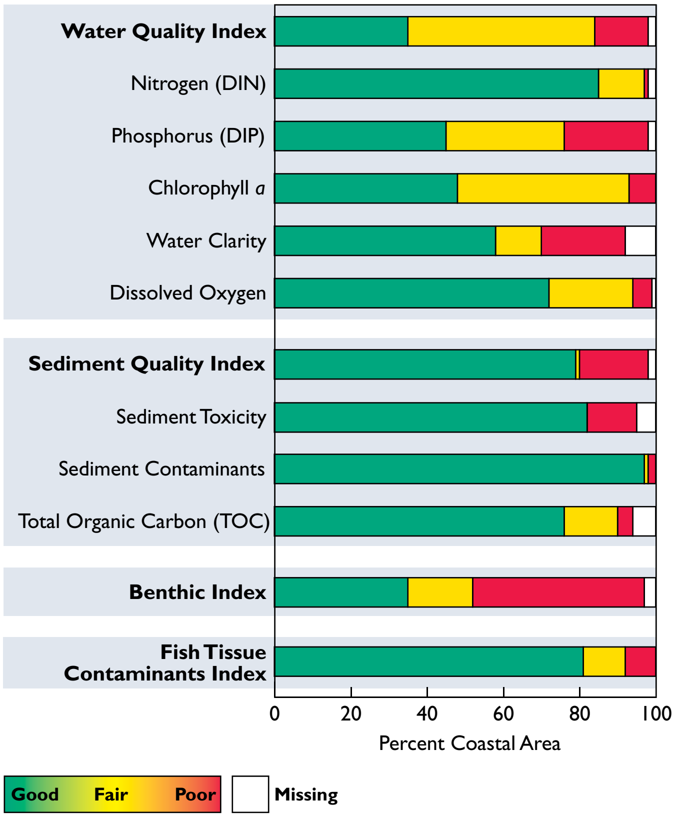


Figure 5-2. Percentage of coastal area achieving each ranking for all indices and components indicators—Gulf Coast region (U.S. EPA/NCA).

The coastal waters of the Gulf Coast region are among the most productive natural systems, and the region is second only to Alaska for domestic landings of commercial fish and shellfish. In 2001 and 2002, commercial fish and shellfish landings from Gulf Coast waters totaled 1.5 million t and were valued at $1.5 billion (NMFS, 2003). The

Gulf Coast led the United States as the source of commercial shrimp landings in 2004 with 115,566 t, which accounted for 83% of the total U.S. shrimp landings that year (NMFS, 2005c).

Gulf Coast coastal waters are located in two biogeographical provinces: the Louisianian Province and the West Indian Province. The Louisianian Province extends from the Texas–Mexico border east to Anclote Key, FL. The West Indian Province extends from Tampa Bay, FL, on the Gulf Coast to the Indian River Lagoon, FL, on the Atlantic Coast; the portion of this province included in the Gulf Coast region extends from Tampa Bay to Florida Bay. The borders of the Gulf Coast region roughly coincide with the borders of the Gulf of Mexico LME. The estuaries and embayments sampled by NCA in the Gulf Coast region range in size from 0.00946 mi^2 (Bayou Chico, FL) to 1,196 mi^2 (Florida Bay, FL).

The population of coastal counties in the Gulf Coast region increased 45% between 1980 and 2003. Coastal counties in Texas and Florida are leading the region in population change. Figure 5-3 presents population data for Gulf Coast coastal counties and shows the increase in population of these coastal counties since 1980 (Crossett et al., 2004).

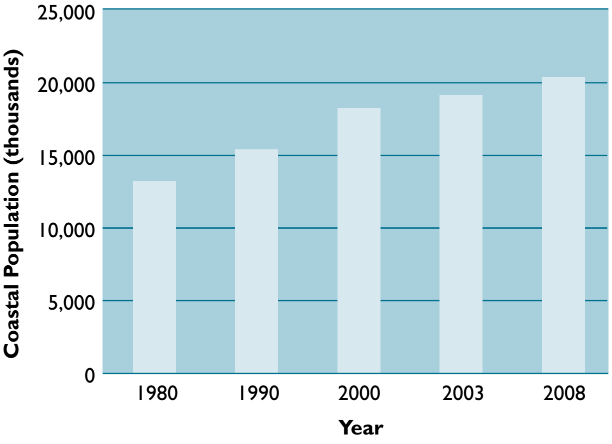
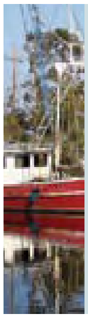


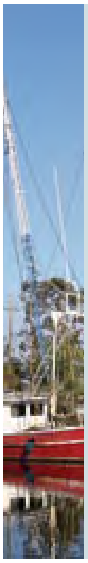
Figure 5-3. Actual and estimated population of coastal counties in Gulf Coast states from 1980 to 2008 (Crossett et al., 2004).



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 in late summer. Data were not collected during other time periods.

Coastal Monitoring Data—Status of Coastal Condition

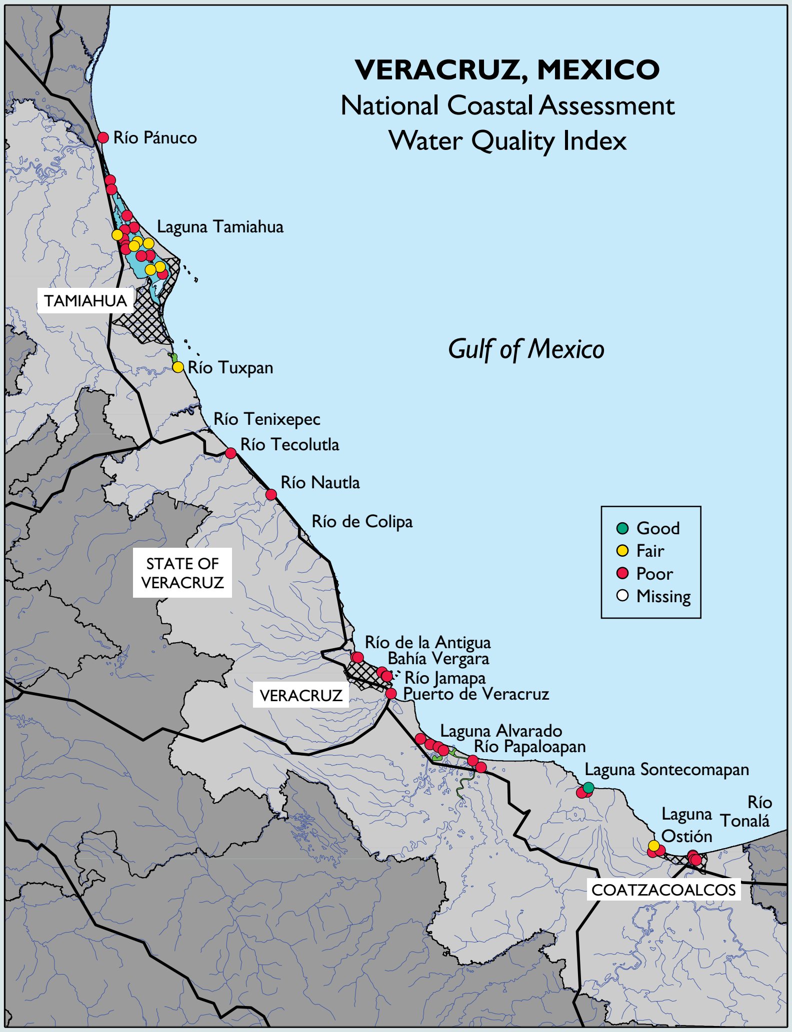
A variety of programs have monitored the coastal waters of the Gulf Coast region since 1991. EMAP focused its coastal monitoring efforts on Gulf Coast coastal waters from 1991 to 1995 (Macauley et al., 1999; U.S. EPA, 1999). The Joint Gulf States Comprehensive Monitoring Program (GMP) began an assessment in 2000, in conjunction with EPA's Coastal 2000 Program (U.S. EPA, 2000b). This partnership has continued as part of the NCA, with coastal monitoring being conducted by the five Gulf Coast states through 2004. In addition, NOAA's NS&T Program has collected contaminant bioavailability and sediment toxicity data from several Gulf Coast sites since the late 1980s (Long et al., 1996). Data from the NS&T Program Bioeffects Project are available at http://www.nos.noaa.gov/cit/nsandt/download/bi_download.aspx.



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.

Highlight

Assessing the Ecological Condition of the Coastal Waters of Veracruz, Mexico

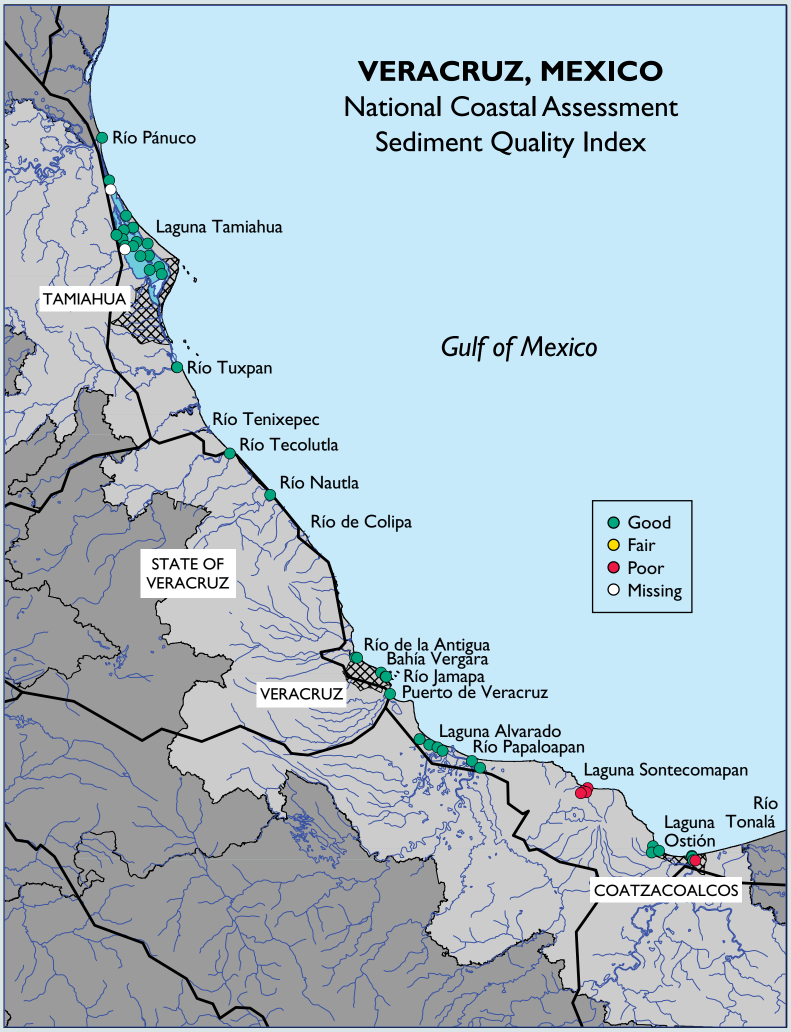


Water quality index data for Gulf of Mexico coastal waters of Veracruz, Mexico (U.S. EPA/NCA).

The influence of stressors, either natural or anthropogenic, on the coastal waters of the Gulf of Mexico does not abate across political boundaries. To fully understand the ecological condition of Gulf of Mexico coastal waters, the entire coastline needs to be assessed, including waters in both the United States and Mexico. In May 2002, the EPA undertook an international technology transfer activity with the Mexican State of Veracruz to transfer information about the NCA survey methodologies and to assist the State in collecting information to assess the condition of its Gulf of Mexico coastal waters. During the summer of 2002, representatives from EPA trained and assisted Mexican biologists in the application and implementation of the NCA probability-based survey design. Data were collected to support some of the same indices and component indicators as those collected by NCA for the U.S. Gulf Coast region so that comparisons between the ecological indicators of these two areas could be made. The joint U.S./Mexico team sampled 50 probability-based stations over a 3-week period. The samples were split between EPA and the Officina de Subsecrataria de Medio Ambiente Gobierno del Estado de Veracruz. The water quality and sediment quality indices were calculated using the data collected during the survey (Macauley et al., 2007).

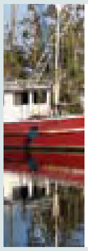
The water quality index was rated poor for 75% of the coastal area sampled in Veracruz, rated fair for 24%, and good for 1% (see map). Poor water clarity, high levels of chlorophyll *a*, and elevated concentrations of DIP and DIN contributed to the poor water quality ratings. Poor water quality was spread uniformly throughout the coastal waters. Inadequate treatment of sewage and municipal runoff are the candidate sources for these elevated levels (Macauley et al., 2007).

In contrast to the water quality index, only 1% of the Veracruz coastal area had poor sediment quality, primarily as a result of sediment contamination (see map). Sampled sediments were rated poor primarily due to exceedances of the ERL level for a variety of chemical contaminants, including PAHs, mercury, cadmium, chromium, copper, arsenic, silver, and zinc. The sediment toxicity and sediment TOC component indicators made only minor contributions to the poor rating of the sediment quality. Industry is concentrated around ports in the southern portion of Veracruz. The elevated concentrations of PAHs and metals contributing to poor sediment quality were detected only in southern ports, such as Laguna Sontecomapan and Laguna Ostión, which support petrochemical and pharmaceutical industries (Macauley et al., 2007).



Sediment quality index data for Gulf of Mexico coastal waters of Veracruz, Mexico (U.S. EPA/NCA).

The inclusion of the Mexican State of Veracruz in the assessment of coastal waters represents a significant step towards assessing coastal condition throughout the Gulf of Mexico. Discussions are underway with the Mexican government to include other Gulf Coast Mexican states in this ecological monitoring program (Macauley et al., 2007).



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.

Water Quality Index

Based on the 2001 and 2002 NCA survey results, the water quality index for the coastal waters of the Gulf Coast region is rated fair, with 14% of the coastal area rated poor and 49% of the area rated fair for water quality condition (Figure 5-4). The water quality index was developed based on measurements of five component indicators: DIN, DIP, chlorophyll *a*, water clarity, and dissolved oxygen. Estuaries with poor water quality conditions were found in all five states, but the contributing factors differed among states. At stations in Texas, Louisiana, and Mississippi, poor water clarity and high DIP concentrations contributed to poor water quality ratings, whereas poor conditions at stations in several Texas bays were also due to high chlorophyll *a* concentrations. Only three sites in Louisiana had high concentrations of both DIN and DIP. Many of the stations rated poor or fair for the various component indicators did not overlap, resulting in a lower percentage of Gulf Coast coastal area rated good for the water quality index than for any of its component indicators (see Chapter 1 for more information). This water quality index can be compared to the results of NOAA's Estuarine Eutrophication Survey (Brickler et al., 1999), which rated the Gulf Coast as poor for eutrophic condition, with an estimated 38% of the coastal area having a high expression of eutrophication.

Nutrients: Nitrogen and Phosphorus

The Gulf Coast region is rated good for DIN concentrations, but rated fair for DIP concentrations. It should be noted that different criteria for DIN and DIP concentrations were applied in Florida Bay than in other areas of the Gulf Coast region because Florida Bay is considered a tropical estuary. DIN concentrations were rated poor in 1% of the Gulf Coast coastal area, representing three sites in Louisiana's East Bay, Atchafalaya Bay, and the Intracoastal Waterway between Houma and New Orleans, LA. Elevated DIN concentrations are not expected to occur during the summer in Gulf Coast waters because freshwater input is usually lower and dissolved nutrients are used more rapidly by phytoplankton during this season. DIP concentrations were rated poor in 22% of the Gulf Coast coastal area, which included sites in Tampa Bay and Charlotte Harbor, FL, where high DIP concentrations occur naturally due to geological formations of phosphate rock in the watersheds and artificially due to significant anthropogenic sources of DIP.

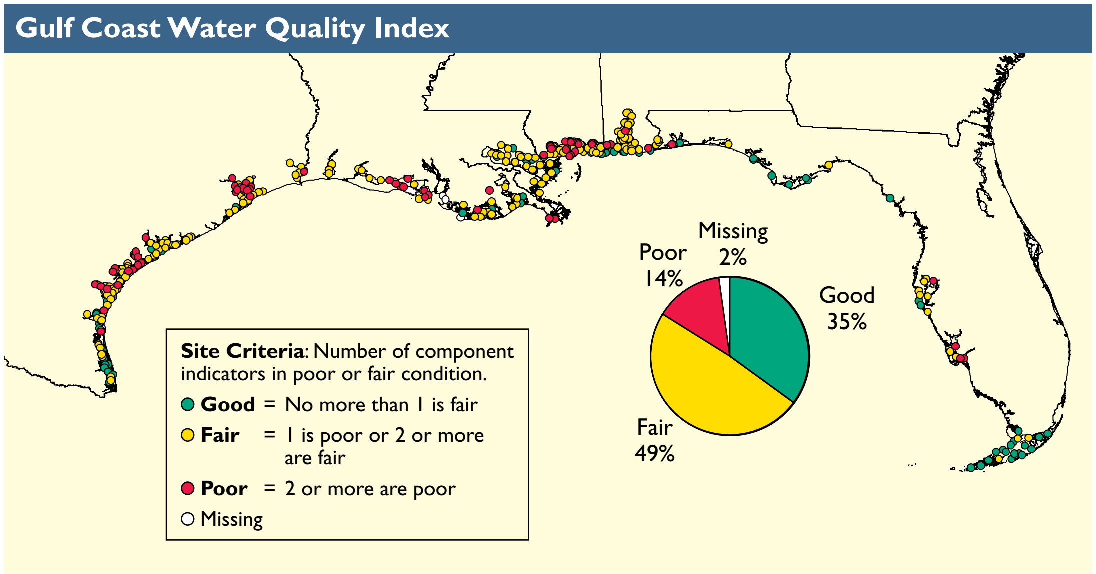
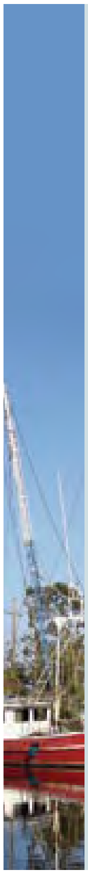


Figure 5-4. Water quality index data for Gulf Coast coastal waters (U.S. EPA/NCA).



Potential for Misinterpretation of Conditions for States with Smaller Coastlines

Alabama and Mississippi resource agencies are concerned that the figures presented in the Coastal Monitoring Data section of this chapter could potentially represent their estuaries unfairly. Both states have at least fifty locations that were sampled in the NCA 2001–2002 survey; however, because of the high density of these sites and the small area of estuarine resources of these states, even one or two sites rated poor (red circles) give the appearance of poor condition dominating a large portion of the entire coast of these states. Although showing the entire Gulf Coast region in a single graphic is consistent with the goals of this report, these displays do not provide a detailed view of all data, particularly for Alabama, Mississippi, and eastern Louisiana.

Chlorophyll a

The Gulf Coast region is rated fair for chlorophyll *a* concentrations, with 7% of the coastal area rated poor and 45% of the area rated fair for this component indicator. It should be noted that chlorophyll *a* concentrations were rated differently in Florida Bay than in other areas of the region because Florida Bay is considered a tropical estuary. High concentrations of chlorophyll *a* occurred in the coastal areas of all five Gulf Coast states.

Water Clarity

Water clarity in the Gulf Coast region is rated fair, with 22% of the coastal area rated poor for this component indicator. Lower-than-expected water clarity occurred throughout the Gulf Coast region, with poor conditions concentrated at stations in Mississippi, the Coastal Bend region of Texas, and Louisiana. The criteria used to assign water clarity ratings varied across Gulf Coast coastal waters (Figure 5-5) based on natural variations in turbidity levels, regional expectations for light penetration related to SAV distribution, and local waterbody management goals (see text box).

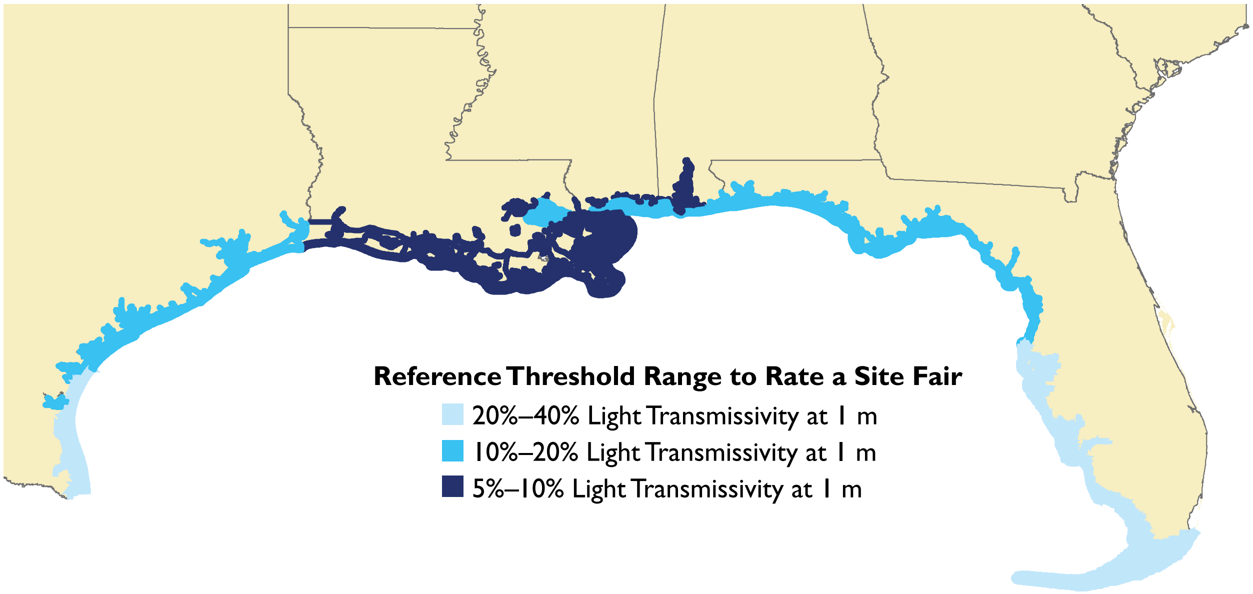
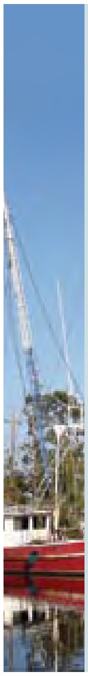


Figure 5-5. Map of water clarity criteria used in Gulf Coast coastal waters to rate a site fair (U.S. EPA/NCA).



Although the current NCA approach used to assess water clarity is an improvement over the previous effort, it still may reach inappropriate conclusions regarding water clarity for parts of the Gulf Coast region. Many of the areas of the Gulf Coast region have naturally high silt and suspended sediment loads. To modify the water clarity approach for this natural condition, researchers adjusted the approach by the "expected" water clarity levels to lower levels for much of the Gulf Coast region. Although this adjustment appears to have been successful for much of the Florida, Alabama, Mississippi, and Louisiana coasts, further adjustments may be necessary for Mississippi Sound and the Texas coast.

Dissolved Oxygen

The Gulf Coast region is rated fair for dissolved oxygen concentrations, with 5% of the coastal area rated poor for this component indicator. Hypoxia in Gulf Coast waters generally results from stratification, eutrophication, or a combination of these two conditions. Mobile Bay, AL, experiences regular hypoxic events during the summer that often culminate in "jubilees" (i.e., when fish and crabs try to escape hypoxia by migrating to the edges of a waterbody); however, the occurrence of jubilees in Mobile Bay has been recorded since colonial times, and these occurrences are most likely natural events for this waterbody (May, 1973).

Although hypoxia is a relatively local occurrence in Gulf Coast coastal waters, the occurrence of hypoxia in the Gulf Coast shelf waters is much more significant. The Gulf of Mexico hypoxic zone is the second-largest area of oxygen-depleted waters in the world (Rabalais et al., 2002). This zone, which occurs in waters on the Louisiana shelf to the west of the Mississippi River Delta, was not assessed by the NCA survey. From 1985 to 1992, the areal extent of bottom-water hypoxia in the zone during mid-summer averaged 3,000 mi^2, and the average area doubled to 6,500 mi^2 between 1993 and 1997 (Rabalais et al., 1999). In the summer of 2000, the area of the Gulf of Mexico hypoxic zone was reduced to 1,700 mi^2, following severe drought conditions in the Mississippi River watershed; however, by 2002, the hypoxic zone had again increased in size to 8,500 mi^2 (Figure 5-6). Current hypotheses speculate that the hypoxic zone results from water column stratification that is driven by weather and river flow, as well as from the decomposition of organic matter in bottom waters (Rabalais et al., 2002). River-borne organic matter, along with nutrients that fuel phytoplankton growth in the Gulf waters, enter the Gulf of Mexico from the Mississippi River. Annual variability in the area of the hypoxic zone has been related to the flows of the Mississippi and Atchafalaya rivers and, by

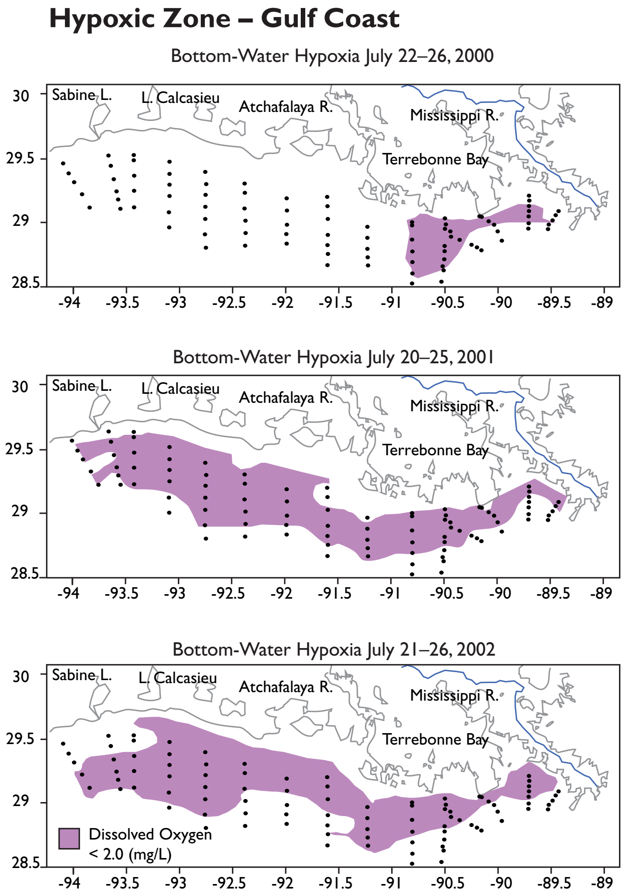
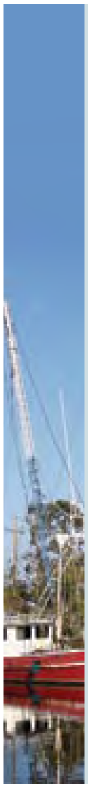


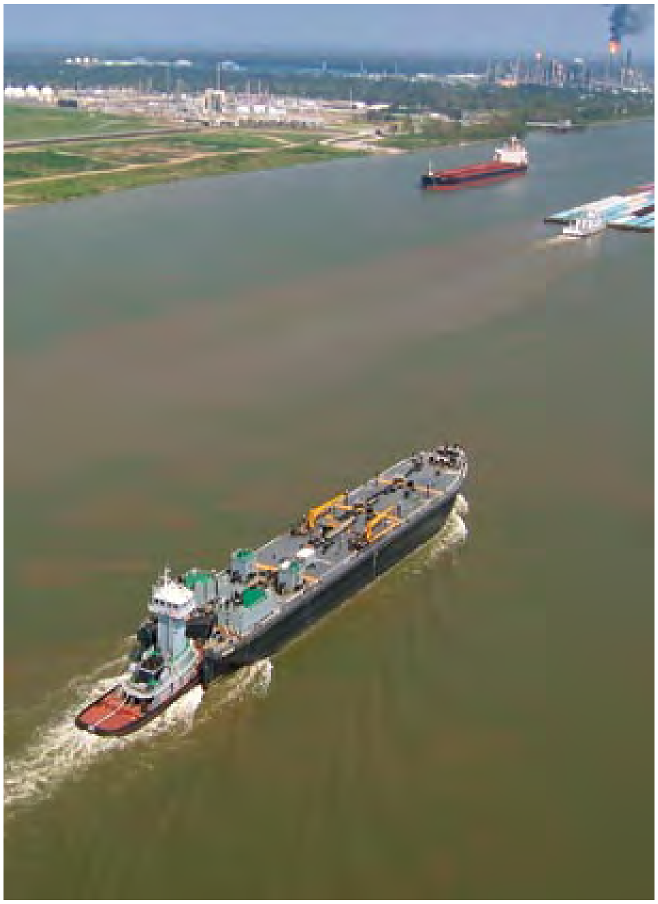
Figure 5-6. Spatial extent of the Gulf Coast hypoxic zone during July 2000, 2001, and 2002 (U.S. EPA/NCA, based on data provided by N. Rabalais, 2003).



The guideline used in the NCA analysis for poor dissolved oxygen condition is a value below 2 mg/L in bottom waters. The majority of coastal states either use a different criterion, ranging from an average of 4 to 5 mg/L throughout the water column to a specific concentration (usually 4 or 5 mg/L) at mid-water, or include a frequency or duration of time that the low dissolved oxygen concentration must occur (e.g., 20% of observed values). The NCA chose to use 2 mg/L in bottom waters because this level is clearly indicative of potential harm to estuarine organisms. Because so many state agencies use higher concentrations, the NCA evaluated the proportion of waters that have dissolved oxygen concentrations between 5 and 2 mg/L in bottom waters as being in fair condition (i.e., threatened).

extension, to the precipitation levels that influence these flows. Sediment cores from the hypoxic zone show that algal production in the Gulf of Mexico shelf was significantly lower during the first half of the twentieth century, suggesting that anthropogenic changes to the basin and its discharges have resulted in the increased hypoxia (CENR, 2000).

Between 1980 and 1996, the Mississippi-Atchafalaya River Basin discharged an annual average of 952,700 t of nitrogen as nitrate and 41,770 t of phosphorus as orthophosphate to the Gulf of Mexico (Goolsby et al., 1999). The nitrate load, which constitutes the bulk of the total nitrogen load from the Mississippi River basin to the Gulf of Mexico, has increased 300% since 1970 (Goolsby et al., 2001). Non-point sources, particularly from the agricultural areas north of the confluence of the Ohio and Mississippi rivers, contribute most of the nitrogen and phosphorus loads to the Gulf of Mexico (Goolsby et al.,1999). The potential importance of phosphorus limitation in the eastern portion of the hypoxic zone has led EPA to call for reductions in both nitrogen and phosphorus loads from the Mississippi-Atchafalaya River Basin.



Freshwater flows and nutrient loads from the Mississippi River are related to the extent of the hypoxic zone Gulf Coast shelf waters (courtesy of Lieut. Commander Mark Moran, NOAA).

Estimates of hypoxia for the Gulf of Mexico shelf have not been included in the NCA estimates of hypoxia for Gulf Coast coastal waters; consequently, the good rating for dissolved oxygen concentrations in the Gulf Coast region provided in this report should not be considered indicative of offshore conditions.

Sediment Quality Index

The sediment quality index for the coastal waters of the Gulf Coast region is rated poor, with 18% of the coastal area rated poor for sediment quality condition (Figure 5-7). The sediment quality index was calculated based on measurements of three component indicators: sediment toxicity, sediment contaminants, and sediment TOC.

Sediment Toxicity

The Gulf Coast region is rated poor for sediment toxicity, with 13% of the coastal area rated poor for this component indicator. Previous bioeffects surveys by NOAA (Long et al., 1996) and the results reported in the NCCR II (U.S. EPA, 2004a) showed less than 1% toxicity in large estuaries of the Gulf Coast region. Sediment toxicity is commonly associated with high concentrations of metals or organic chemicals with known toxic effects on benthic organisms; however, nine sites in Florida Bay were rated poor for sediment toxicity in the absence of high contaminant concentrations. The toxicity at these sites may have been caused by naturally high levels of hydrogen sulfide in the Bay's organic carbonate sediments, rather than by anthropogenic contamination (G. McRae, Florida Fish & Wildlife Research Institute, personal communication, 2006).

Sediment Contaminants

The sediment contaminants component indicator for the Gulf Coast region is rated good, with 2% of the coastal area rated poor for this component indicator. In addition, 1% of the coastal area was rated fair, primarily due to sites located in Alabama and in Pensacola Bay, FL. The sediment contaminants measured in Gulf Coast waters included elevated levels of metals, pesticides, PCB, and, occasionally, PAHs.

Sediment TOC

The Gulf Coast region is rated good for sediment TOC, with 14% of the coastal area rated fair for this component indicator and only 4% of the area rated poor.

Benthic Index

The condition of benthic communities in Gulf Coast coastal waters is rated poor, with 45% of the coastal area rated poor for benthic condition (Figure 5-8). This assessment is based on the Gulf Coast Benthic Index (Engle and Summers, 1999), which integrates measures of diversity and populations of indicator species to distinguish between degraded and reference benthic communities. Most Gulf Coast estuaries showed some level of benthic degradation.

Coastal Habitat Index

The coastal habitat index for the coastal waters of the Gulf Coast region is rated poor. The Gulf Coast region experienced a loss of 7,750 acres of coastal wetlands from 1990 to 2000, and the long-term,

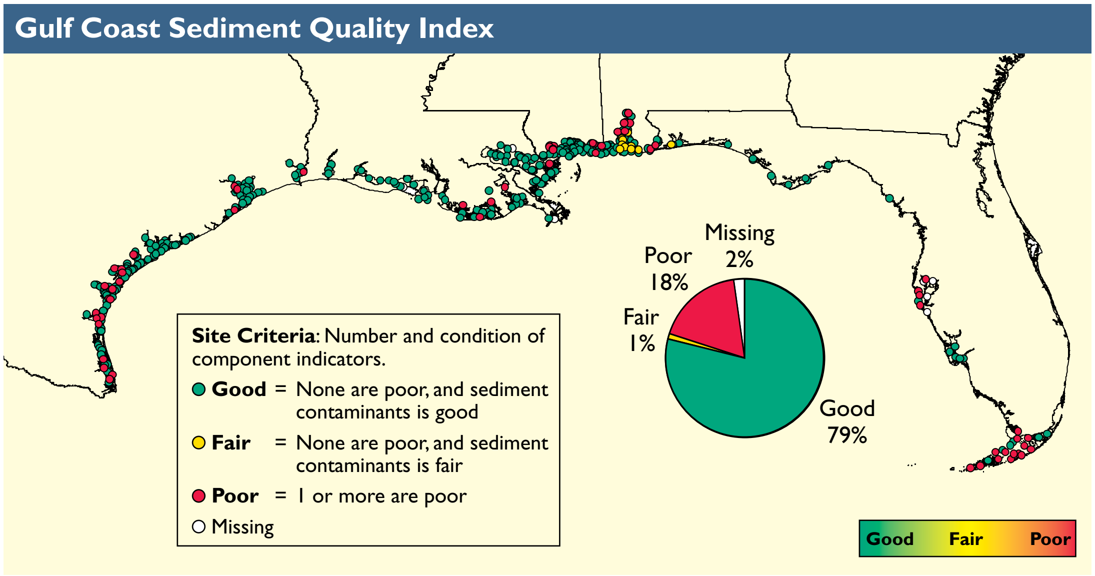


Figure 5-7. Sediment quality index data for Gulf Coast coastal waters (U.S. EPA/NCA).

average decadal coastal wetlands loss rate is 0.21%. Coastal wetlands in the Gulf Coast region constitute 66% of the total estuarine wetland acreage in the conterminous 48 states (Dahl, 2003). Although the Gulf Coast region sustained the largest net loss of coastal wetland acreage during the past decade compared with other regions of the country, the region also has the greatest total acreage of coastal wetlands (3,769,370 acres). Coastal development, sea-level rise, subsidence, and interference with normal erosional/depositional processes contribute to wetland losses along the Gulf Coast.

Fish Tissue Contaminants Index

The fish tissue contaminants index for the coastal waters of the Gulf Coast region is rated good, with 8% of all sites sampled where fish were caught rated poor for fish tissue contaminant concentrations (Figure 5-9). Contaminant concentrations exceeding EPA Advisory Guidance values in Gulf Coast samples were observed primarily in Atlantic croaker, catfish, and pinfish. Commonly observed contaminants included total PAHs, PCBs, DDT, mercury, and arsenic.

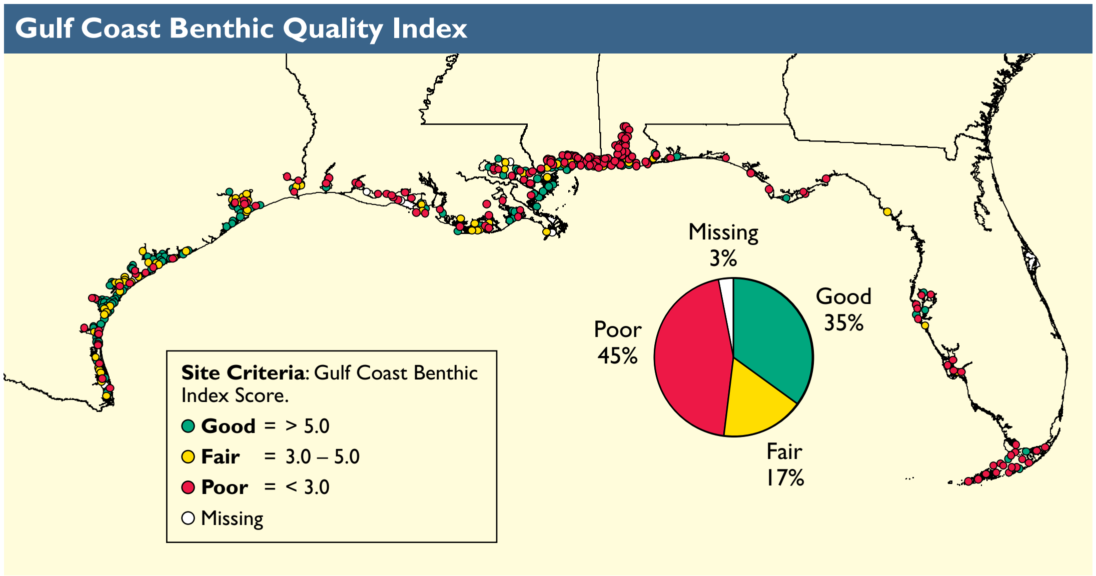


Figure 5-8. Benthic index data for Gulf Coast coastal waters (U.S. EPA/NCA).

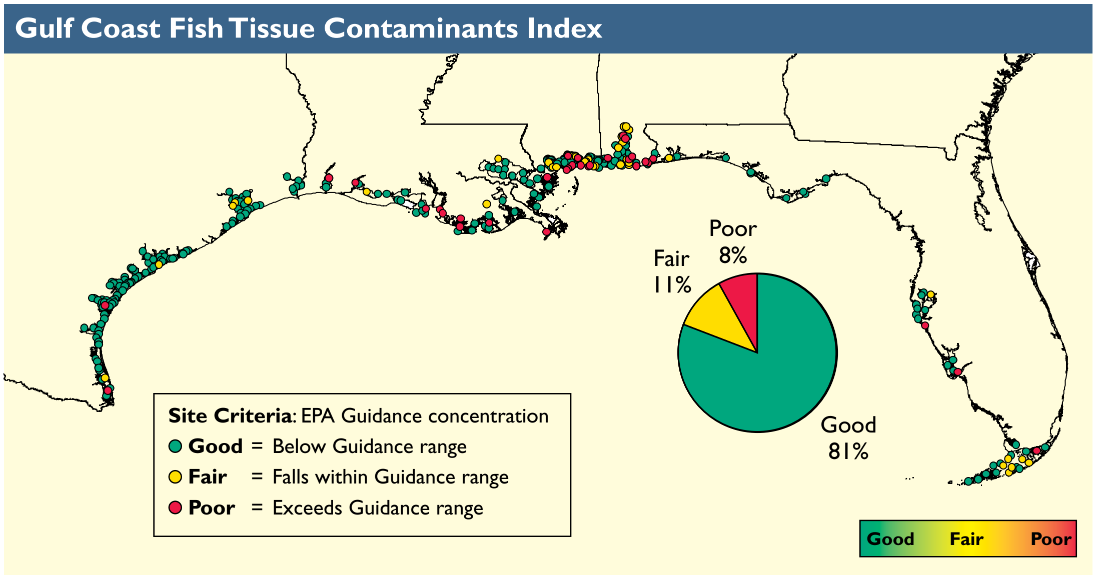


Figure 5-9. Fish tissue contaminants index data for Gulf Coast coastal waters (U.S. EPA/NCA).

Highlight

Project GreenShores Shoreline Restoration Project

The shoreline along Bayfront Parkway on Pensacola Bay in Florida has been subjected to pressures from human activities since as early as the 19th century. At that time, this portion of the bay was filled with wharfs and teeming with ships transporting timber cut from the forests of northwest Florida. Much of the bayfront and adjacent marsh areas were filled in, and the shorelines were hardened. In fact, privately and city-owned plots with streets are delineated into the bay. As is the case in many historic coastal communities, stormwater treatment is lacking in this older part of town, with stormwater directly entering the bay.

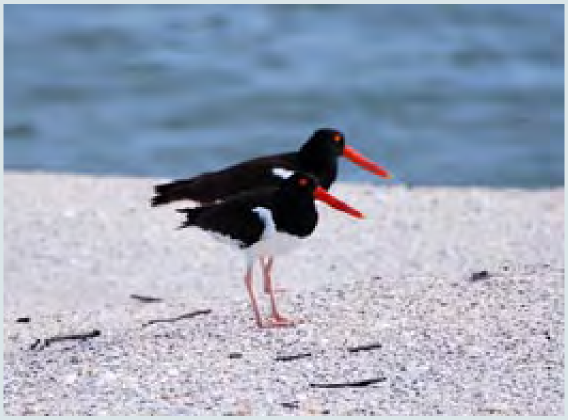
Although the shoreline has been significantly altered over time, the project area supported some SAV until the 1950s (Gulf of Mexico Foundation, 2007); therefore, there seemed to be enormous potential for a successful habitat restoration and enhancement project that would increase public awareness of the native species and habitats within the Pensacola Bay System. Project GreenShores Sites 1 and 2 focus on the highly visible area of Bayfront Parkway (at the north end of the Pensacola Bay Bridge) as the stage for a large-scale multi-habitat restoration project. Approximately 15 acres of subtidal and intertidal zones at Site 1 have been restored with oyster reefs, SAV, and emergent vegetation (Gulf of Mexico Foundation, 2007). As of August 2005, Site 2 had been designed and partially funded, and the project had entered the final permitting stages. Site 2 will continue the shoreline restoration project to the west along Bayfront Parkway and will add an additional 38 acres of emergent vegetation, oyster reefs, tidal channels, and SAV.

Project Greenshores, Site 1 (courtesy of Amy Baldwin, Florida Department of Environmental Protection).

Monitoring at Site 1 has shown an expanding oyster population and an increasing abundance and diversity of fish and birds. The reef has become populated with many typical reef species, including blennies and gobies, stone crabs, blue crabs, anemones, and shrimp. Juvenile stone crabs have been observed, and oyster spat are readily apparent. Schools of baitfish, gray snapper, mullet, sheepshead, flounder, redfish, and speckled trout have all been documented around the reef and in the marsh. In addition, recreational use of the area has increased, with more fishermen, canoers/kayakers, and bird watchers taking advantage of the newly created habitat and the productivity in the area (Florida DEP, 2007).

Education has been a key focus of the restoration project. Local television and newspapers have featured the project as it has progressed, providing an opportunity to reach members of the public beyond the thousands who drive by it every day. A grant-funded educational cruise aboard the *American Star* has hosted more than 4,000 students and civic group members. These cruises provide participants with a visit to the site, an opportunity to "seed-the-reef" with oyster shell, and worksheets for teachers to use as follow-up lessons to reinforce the learning experience.

A unique component of this habitat restoration project has been the community partnership support that has developed as the project progressed. More than 60 partners have contributed to the Project GreenShores restoration effort, including local businesses, state and local government, federal/state/local granting organizations, citizen groups, and individuals (Florida DEP, 2007). Contributions have ranged from volunteer time and expertise, to no- or low-cost supplies and equipment, to financial support. These cooperative and volunteer activities have resulted in a project that has provided many members of the community with a sense of ownership in Project GreenShores and are a focal point for teaching students and community members about environmental issues.



The American oystercatcher (*Haematopus palliatus*) is one of the more than 65 species of birds that have been spotted at Project Greenshores, Site I (courtesy of Kevin T. Edwards, IAN Network).

Trends of Coastal Monitoring Data—Gulf Coast Region

Temporal Change in Ecological Condition

The coastal condition of the Gulf Coast region has been assessed since 1991. EMAP-Estuaries conducted annual surveys of estuarine condition in the Louisianian Province from 1991 to 1994; this province extends from the Texas-Mexico border to just north of Tampa Bay, FL. The results of these surveys were reported in the NCCR I (U.S. EPA, 2001c). EMAP-NCA initiated annual surveys of coastal condition in the Gulf of Mexico in 2000, and these data were reported in the NCCR II. Data from 2001 and 2002 are assessed in the current report (NCCR III). Seven years of monitoring data from Gulf Coast coastal waters provide an ideal opportunity to investigate temporal changes in ecological condition indicators. These data can be analyzed to answer two basic types of trend questions based on assessments of ecological indicators in Gulf Coast coastal waters: what is the interannual variability in proportions of area rated good, fair, or poor, and is there a significant change in the proportion of poor area from the early 1990s to the present?

The parameters that can be compared between the two time periods include the dissolved oxygen, water clarity, sediment contaminants, sediment toxicity, and sediment TOC component indicators, as well as the benthic index. Data supporting these parameters were collected using similar protocols and QA/QC methods. Although EMAP-NCA also evaluated chlorophyll *a* and nutrients as part of its assessment of water quality, these component indicators were not collected during the EMAP-Estuaries surveys from 1991 to 1994. Both programs implemented probability-based surveys that support estimations of the percent of coastal area in good, fair, or poor condition based on the indicators. Standard errors for these estimates were calculated according to methods listed on the EMAP Aquatic Resource Monitoring Web site (http://www.epa.gov/nheerl/arm). The reference values and guidelines listed in Chapter 1 were used to determine good, fair, or poor condition for each index and component indicator from both time periods.

In order to compare indices and component indicators across years from the same geographic area, the spatial extent of the EMAP-NCA Gulf Coast data was reduced to match that of the Louisianian Province monitored by EMAP-Estuaries. Therefore, EMAP-NCA data collected in Florida between Tampa Bay and Florida Bay were excluded from this temporal comparison. In addition, no data were collected from the entire region between 1995 and 1999.

Only water clarity and dissolved oxygen data were available for the comparison of water quality conditions from 1991 to 2002. Neither of these component indicators showed a significant linear trend over time in the percent area rated in poor condition (Figures 5-10 and 5-11). However, when the two time periods were compared, significantly more of the coastal area was rated poor for water clarity in the 2000–2002 time period than in the 1991–1994 time period ($z = 4.252$; $p < 0.05$).

Water quality indicators are more likely to be influenced by interannual variation in climate than by long-term trends. To examine the potential

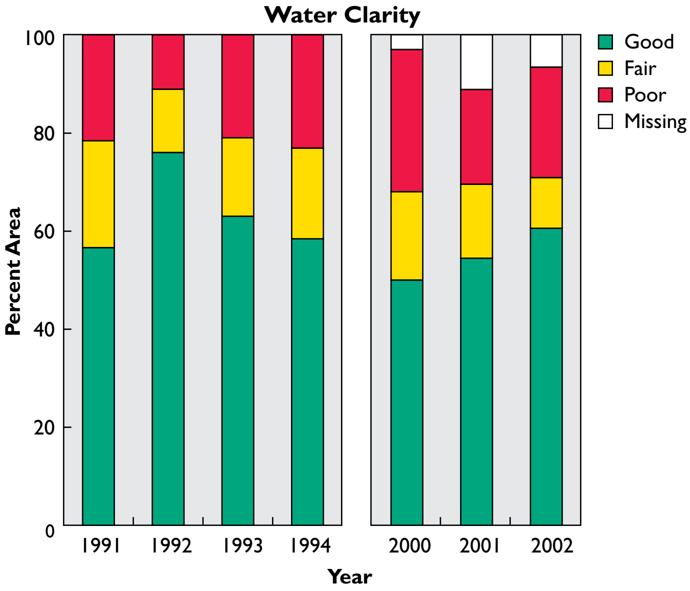


Figure 5-10. Percent area of Gulf Coast coastal waters in good, fair, poor, or missing categories for water clarity measured over two time periods, 1991–1994 and 2000–2002 (U.S. EPA/NCA).

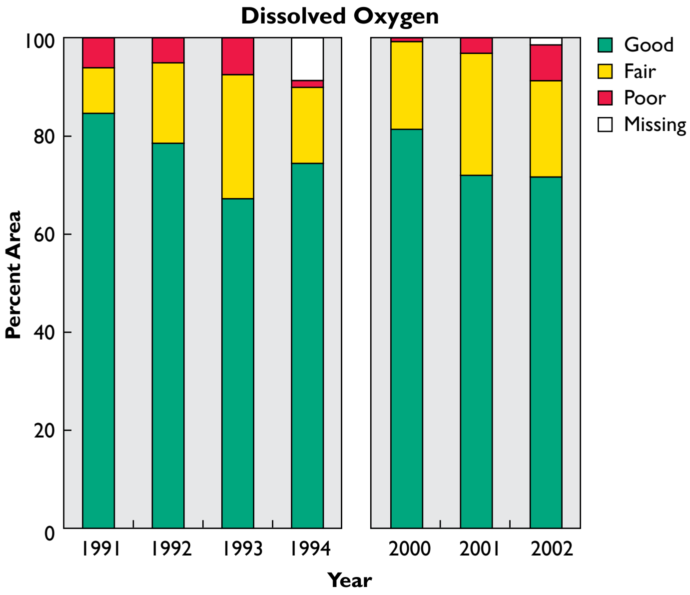


Figure 5-11. Percent area of Gulf Coast coastal waters in good, fair, poor, or missing categories for bottom-water dissolved oxygen measured over two time periods, 1991–1994 and 2000–2002 (U.S. EPA/NCA).

effects of interannual variation in climate on dissolved oxygen, the relationship between annual rainfall and the percent area in good condition for dissolved oxygen was examined. The estimated annual rainfall for the Gulf Coast was calculated as the sum of annual estimates for five states (Texas, Louisiana, Mississippi, Alabama, and Florida) using precipitation data available from NOAA (NOAA, 2007i). Linear regression resulted in a significant relationship between the percent coastal area in good condition for dissolved oxygen and annual rainfall estimates ($R^2 = 0.225$; $p < 0.05$). This linear relationship was used to predict the percent coastal area rated good for dissolved oxygen from 1995 to 1999, when data were not collected (Figure 5-12).

Shrimp trawlers and cactus—a seemingly incongruous but normal sight in south Texas (courtesy of William B. Folsom, NMFS).

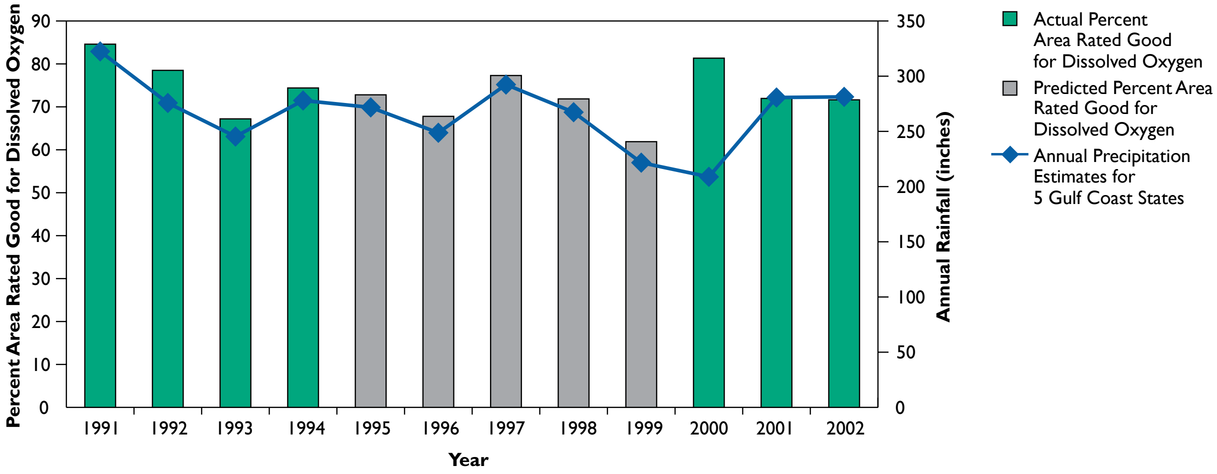


Figure 5-12. Percent area of Gulf Coast coastal waters with bottom-water dissolved oxygen concentrations > 5 mg/L (rated good) compared to annual precipitation estimates for the five Gulf Coast states from 1991 to 2002. Predicted dissolved oxygen levels from 1995 to 1999 are based on the significant linear relationship between percent area with good dissolved oxygen and rainfall (U.S. EPA/NCA).

The sediment quality component indicators available for comparison were sediment contaminants, sediment toxicity, and sediment TOC. None of these indicators showed a significant linear trend in the percent coastal area rated in poor condition from 1991–2002 (Figures 5-13, 5-14, and 5-15). There was also no significant difference in the percent area rated poor for these component indicators between the 1991–1994 and 2000–2002 time frames; however, the percent area rated good for sediment contaminant concentrations significantly increased ($R^2 = 0.77$; $p < 0.05$) from 1992–2002, as shown in Figure 5-13. Although the percent area rated poor remained stable, the sediment contaminants component indicator has improved in Gulf Coast coastal waters, as indicated by a significant decrease ($z = 3.96$; $p < 0.05$) in the total percent area rated poor and fair, combined, from 16.4% in 1991–1994 to 5.9% in 2000–2002.

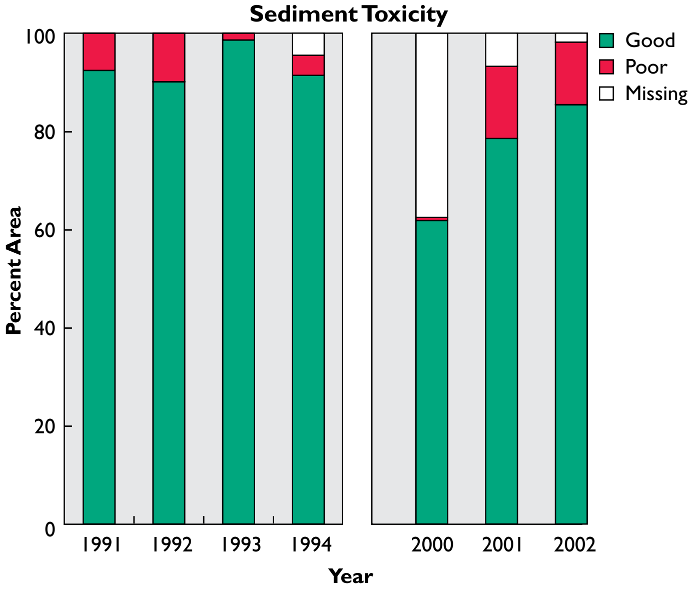


Figure 5-13. Percent area of Gulf Coast coastal waters in good, poor, or missing categories for sediment toxicity measured over two time periods, 1991–1994 and 2000–2002 (U.S. EPA/NCA)

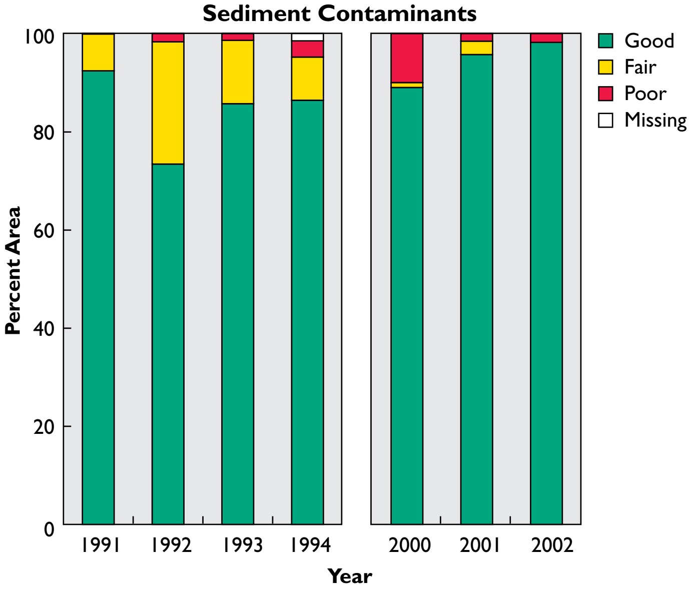


Figure 5-14. Percent area of Gulf Coast coastal waters in good, fair, poor, or missing categories for sediment contaminants measured over two time periods, 1991–1994 and 2000–2002 (U.S. EPA/NCA).

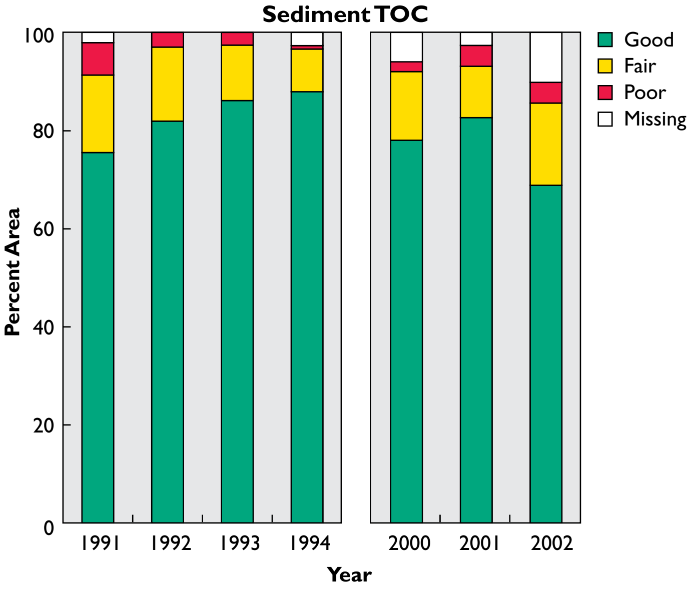


Figure 5-15. Percent area of Gulf Coast coastal waters in good, fair, poor, or missing categories for sediment TOC measured over two time periods, 1991–1994 and 2000–2002 (U.S. EPA/NCA).

The benthic index for Gulf Coast coastal waters is a multimetric indicator of the biological condition of benthic macroinvertebrate communities. Biological condition indicators integrate the response of aquatic organisms to changes in water quality and sediment quality over time. Benthic condition degraded from 1991 to 2002, as indicated by a significant increase in the percent area rated poor from 1991–1994 to 2000–2002 ($z = 4.68$; $p < 0.05$) and a significant negative trend in the percent area rated good ($R^2 = 0.61$; $p < 0.05$) (Figure 5-16).

In summary, sediment quality in Gulf Coast coastal waters improved between the time periods 1991–1994 and 2000–2002, whereas both water clarity and benthic community condition worsened over these same time periods (Figure 5-17).

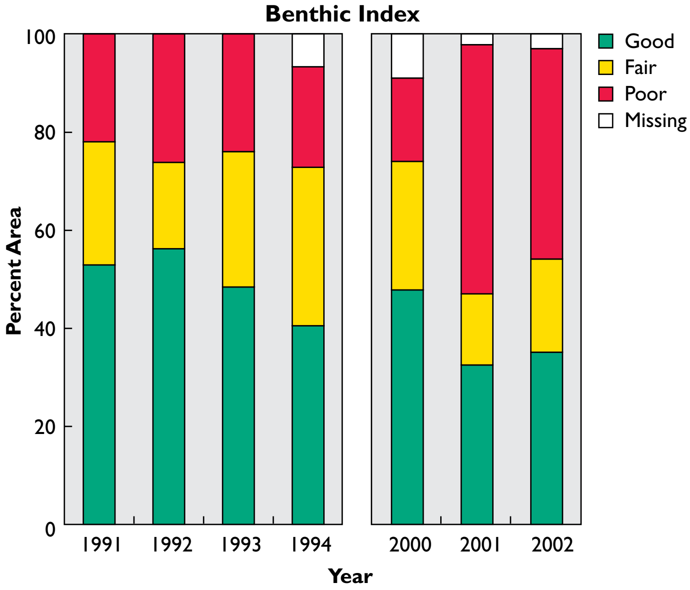


Figure 5-16. Percent area of Gulf Coast coastal waters in good, fair, poor, or missing categories for the benthic index measured over two time periods, 1991–1994 and 2000–2002 (U.S. EPA/NCA).

Little blue herons, such as this one resting in Charlotte County, FL, breed in estuarine and freshwater habitats in the Gulf Coast and Southeast Coast regions (courtesy of Kevin T. Edwards, IAN Network).

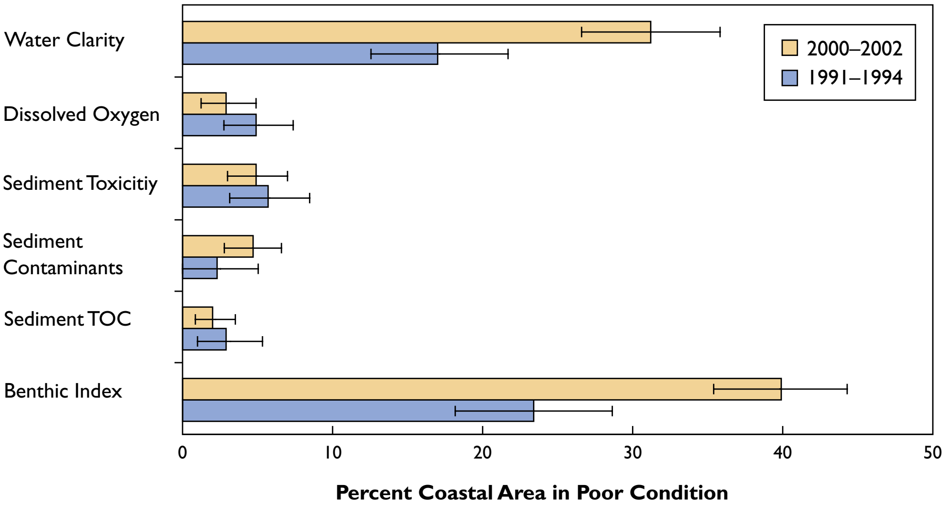
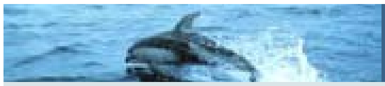


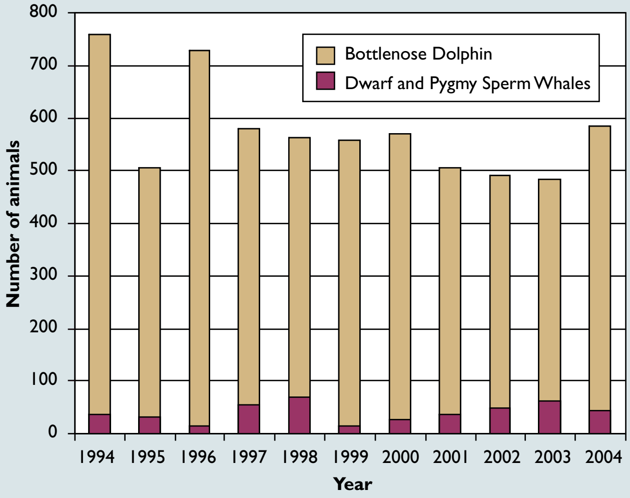
Figure 5-17. Comparison of percent area of Gulf Coast coastal waters rated poor for ecological indicators between two time periods, 1991–1994 and 2000–2002. Error bars are 95% confidence intervals (U.S. EPA/NCA).



Summary of Marine Mammal Strandings along the Gulf and Southeast Coasts

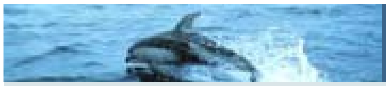
Strandings of marine mammals are a common event along the U.S. coast between North Carolina and Texas. These events involve both live and dead cetaceans (a type of marine mammal) and can include strandings of individual animals, mass strandings (where a large group of animals strand at the same time), and UMEs, which can be extended, large-scale events with elevated stranding rates. Data on marine mammal strandings in the Southeast and Gulf Coast regions are collected by the Southeast Region Marine Mammal Stranding Network, which is a diverse group of non-profit organizations, academic institutions, private research institutions, and state and local agencies that volunteer time to respond to and collect data from stranded marine mammals. Each organization, institution, or agency in the network has a regional area of primary responsibility, but resources are often shared, particularly when responding to mass strandings or UMEs. The network's activities are coordinated through the NMFS Southeast Fisheries Science Center and the Southeast Regional Office, with the support of the National Marine Mammal Health and Stranding Response program at NMFS headquarters.

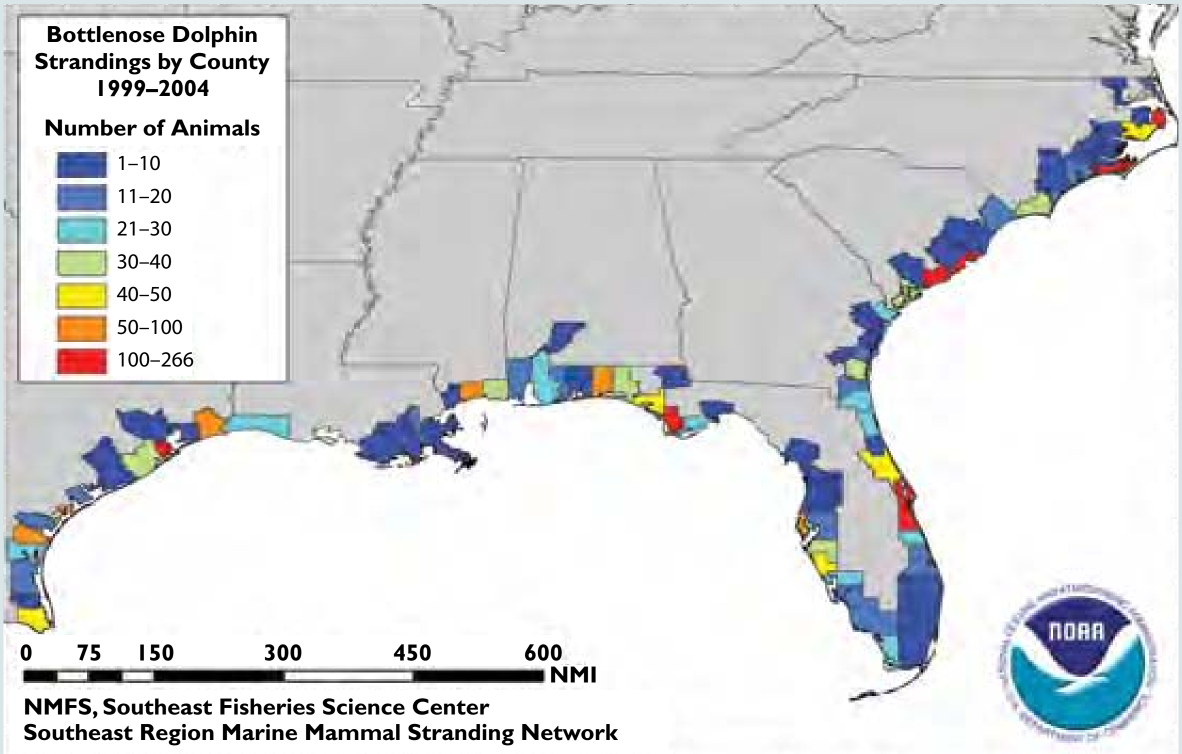
The most commonly stranded species are the bottlenose dolphin (*Tursiops truncatus*) and the dwarf and pygmy sperm whales (*Kogia sp.*). Together, these species have accounted for 73% of the stranded animals, on average, over the past decade. Members of many other cetacean species are stranded throughout the region, including offshore delphinids, sperm whales, and baleen whales. An average of 575 bottlenose dolphins and 40 dwarf and pygmy sperm whales have stranded each year in the Southeast and Gulf Coast regions over the past decade, and the number of animals stranding each year has remained relatively constant throughout that time period (see graph). Geographically, the strandings are not distributed evenly and include several "hot spots," where the number of animals stranding each year is relatively high. Notable hot spot areas include the Indian River Lagoon system along the central Atlantic coast of Florida; the area around Charleston, SC; and along the entire coastline and estuarine areas of North Carolina (see map). It should be noted that the observed spatial patterns also reflect variations in the ability to detect stranded animals. Along the Gulf Coast of the United States, the complexity of the coastline (including expansive marsh areas) and a generally lower level of local coverage by the stranding network results in notable gaps along the Florida panhandle and the central Louisiana coast (NOAA, 2006c).



The number of bottlenose dolphins and dwarf and pygmy sperm whale strandings in the Southeast and Gulf Coast regions between 1994–2004. These data include only individual stranding events and do not reflect either mass strandings or UMEs (courtesy of Southeast Region Marine Mammal Health and Stranding Response Network).

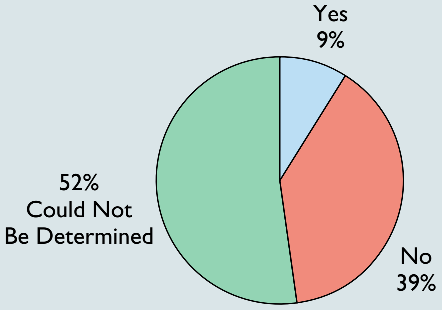
One of the primary goals of the stranding network is to assess the underlying causes for stranding events. Extensive data-collection protocols and training efforts exist to allow network members to record observations on each stranded animal, collect tissue samples, and conduct autopsies to provide information on the





Individual bottlenose dolphin strandings by county in the Southeast and Gulf Coast regions between 1999 and 2004. The number of events recorded in each county reflects both the rate of strandings and the ability of the local network to detect stranding events (courtesy of Southeast Region Marine Mammal Health and Stranding Response Network).

health and physiological condition of animals, where possible. In addition, carcasses are examined to determine if human interactions (primarily with fishery activities) resulted in mortality. For 52% of stranded bottlenose dolphins, it was not possible to determine if human interaction contributed to the stranding because of the advanced state of carcass decomposition. Evidence of human interactions was documented for 9% of the total number of animals stranded between 1999 and 2004 (see figure). Other causes for marine mammal strandings may include predation, disease, exposure to environmental toxins or pollutants, and juvenile and neonate morality. Directly identifying the cause of an event is often difficult, and evaluating the correlations between strandings and environmental conditions, human activities, habitat quality, exposure to pollutants, and other factors is a major research effort within NMFS (NOAA, 2006c).



Individual bottlenose dolphin strandings between 1999 and 2004, categorized by whether human interaction resulted in mortality (courtesy of Southeast Region Marine Mammal Health and Stranding Response Network).

Large Marine Ecosystem Fisheries—Gulf of Mexico LME

The Gulf of Mexico LME extends from the Yucatan Peninsula, Mexico, to the Straits of Florida, FL, and is bordered by the United States and Mexico (Figure 5-18). In this tropical LME, intensive fishing is the primary driving force, with climate as the secondary driving force. The Gulf of Mexico is considered a moderately productive LME based on global estimates of primary production (phytoplankton); however, the productivity of this LME is complex and influenced by a variety of factors of different scales. These factors include wave effects, tides, river flow, and seasonal variations in atmospheric conditions (NOAA, 2007g).

The Gulf of Mexico is partially isolated from the Atlantic Ocean, and the portion of the Gulf of Mexico LME located beyond the continental shelf is a semi-enclosed oceanic basin connected to the Caribbean Sea by the Yucatan Channel and to the Atlantic Ocean by the Straits of Florida. Through the narrow, deep Yucatan Channel, a warm current of water flows northward, penetrating the Gulf of Mexico LME and looping around or turning east before leaving the Gulf through the Straits of Florida. This current of tropical Caribbean water is known as the Loop Current, and, along its boundary, numerous eddies, meanders, and intrusions are produced and affect much of the hydrography and biology of the Gulf. A diversity of fish eggs and larvae are transported in the Loop Current, which tends to concentrate and transport early life stages of fish toward estuarine nursery areas, where the young can reside, feed, and develop to maturity (NMFS, In press).

Reef Fish Resources

Reef fishes include a variety of species (e.g., grouper, amberjack, snapper, tilefish, rock and speckled hind, hogfish, perch) that live on coral reefs, artificial structures, or other hard-bottom areas. Reef fish fisheries are associated closely with fisheries for other reef animals, including spiny lobster, conch, stone crab, corals and living rock, and ornamental aquarium species. Reef fish share many long life-history characteristics and are vulnerable to overfishing due to slow growth and maturity, ease of capture, large body size, and delayed reproduction. Currently, about 100 species in the Southeast U.S. Continental Shelf, Gulf of Mexico, and Caribbean Sea LMEs are managed as a unit by the South Atlantic, Gulf of Mexico, and Caribbean Fishery Management councils. Combined commercial and recreational landings of reef fish from the Gulf of Mexico LME have fluctuated since 1976 and show a slightly increasing trend over time. Meanwhile, fishing pressure in this

Figure 5-18. Gulf of Mexico LME (NOAA, 2007g).

region has increased significantly. Of the dominant reef fish within the U.S. waters of the Gulf of Mexico LME, the red snapper and red grouper stocks are currently overfished, and the gag grouper and greater amberjack stocks are approaching an overfished condition (NMFS, In press).

NOAA prohibits the use of fish traps, roller trawls, and power heads on spear guns within the inshore, stressed area; places a 15-inch total length minimum-size limit on red snapper; and imposes data-reporting requirements. The red snapper fishery has been under stringent management since the late 1990s (NMFS, In press). A stock-rebuilding plan (GMFMC, 2004a) proposed in 2001 provides for bag limits, size limits, and commercial and recreational seasons. This plan is expected to provide stability and predictability in this important fishery for both industry and consumers. Other regulations pertaining to the management of reef fish within the Gulf of Mexico LME include minimum size limits for certain species; permitting systems for commercial fishermen; bag limits; quotas; seasonal closures; and the establishment of Marine Protected Areas that prohibit the harvest of any species at two ecological reserves near the Dry Tortugas off south Florida and the Madison-Swanson and Steamboat Lumps off west-central Florida (NMFS, In press).

The regulatory measures and stock-rebuilding plans currently under way are designed to reduce fishing mortality and to continue or begin rebuilding all these stocks. Reef species form a complex, diverse, multi-species system. The long-term harvesting effects on reef fish are not well understood and require cautious management controls of targeted fisheries and the bycatch from other fisheries within the U.S. waters of the Gulf of Mexico LME.

Menhaden Fishery

Gulf menhaden are found from Mexico's Yucatan Peninsula to Tampa Bay, FL. This species forms large surface schools that appear in nearshore Gulf of Mexico LME waters from April to November. Although no extensive coast-wide migrations are known, some evidence suggests that older fish move toward the Mississippi River Delta. Gulf menhaden may live to an age of 5 years, but most specimens landed are 1 to 2 years old. Landing records for the Gulf of Mexico LME menhaden fishery date back to the late 1800s; however, the data up to World War II are incomplete. During the 1950s through the 1970s, the commercial fishery grew in terms of the number of reduction plants and vessels, and landings generally increased with considerable annual fluctuations (Figure 5-19). Record landings of 982,800 t occurred in 1984 and subsequently declined to a 20-year low of 421,400 t in 1992. This decline was primarily due to low product prices, consolidation within the menhaden industry, and concurrent decreases in the commercial fishing effort in the northern Gulf of Mexico LME and in the number of vessels and fish factories dedicated to this fishery. Landings in recent years (1998–2002) are less variable, ranging between 486,200 and 684,300 t, with 574,500 t landed in 2002. Average landings from 2001–2003 were 564,000 t. Historically, the geographical extent of Gulf of Mexico LME menhaden fishing ranged from the Florida Panhandle to eastern Texas, and the current extent of the fishery ranges from western Alabama to eastern Texas, with about 90% of the harvest occurring in Louisiana waters (NMFS, In press).

The 1999 stock assessment indicates that the menhaden stock is healthy and that catches are generally below long-term maximum sustainable yield estimates of 717,000 to 753,000 t (NMFS, In press). A comparison of recent fishing mortality estimates to biological reference points does not suggest that overfishing is occurring.

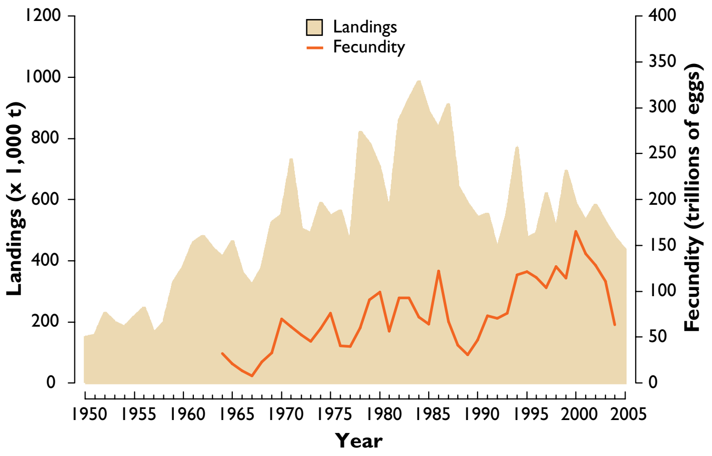


Figure 5-19. Menhaden landings in metric tons (t) and fecundity (trillions of eggs), 1950–2002, Gulf of Mexico LME (NMFS, In press).

Highlight

Gulf of Mexico Harmful Algal Blooms

Karenia brevis, often called the Florida red tide, is a phytoplanktonic organism that has been implicated in the formation of HABs throughout the Gulf of Mexico. In U.S. waters, the blooms occur almost annually during the fall in the waters along the West Florida shelf and less frequently in the waters of the Florida Panhandle, Alabama, and Texas. Only once has a bloom occurred in Mississippi or Louisiana. In addition to discoloring the water, *Karenia brevis* produces brevetoxins, which are potent neurotoxins that can contaminate shellfish and cause neurotoxic shellfish poisoning in humans (FWRI, 2007). Also, *Karenia brevis* can form aerosols along beaches that cause human respiratory problems and can kill fish, marine mammals, turtles, and birds. As a result, these blooms have major impacts on human health, tourism, shellfish industries, and ecosystems.

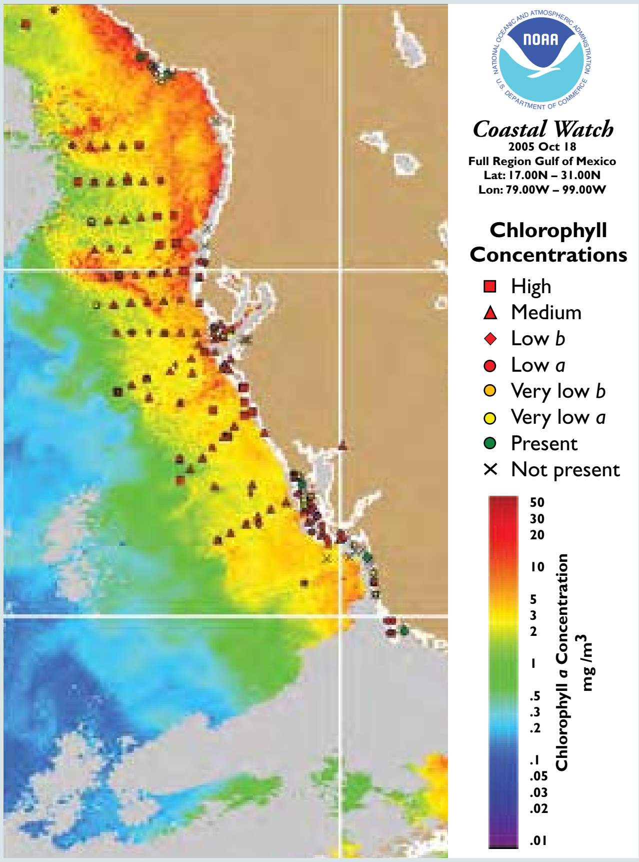
In January 2005, an unusually early and large bloom of *Karenia brevis* began on the West Florida shelf, resulting in fish kills and respiratory irritation in beachgoers. In 2005, 81 of the 396 manatee deaths (about 20%) in Florida were confirmed positive for brevetoxins (FWRI, 2006). This mortality event, following similar events in previous years, is casting doubt on the sustainability of the southwest Florida manatee subpopulation. In early summer 2005, the bloom receded to a small area in southern Tampa Bay, but then a unique set of oceanographic conditions led to the bloom expanding offshore and being trapped near the bottom. The toxins produced by the algae killed fish and bottom-dwelling organisms, and the dead organisms decayed, using up bottom-water dissolved oxygen. A large area of anoxic and hypoxic bottom water was created, resulting in additional animal mortalities in an area of more than 2,162 mi^2 located west of central Florida. The last time a similar event occurred was in 1971. In 2005, dissolved oxygen levels returned to normal after Hurricane Katrina re-aerated the water in late August, but the *Karenia brevis* bloom persisted (NOAA, 2005b). Unusually high marine turtle mortalities were reported in July and continued into September. At about the same time, a *Karenia brevis* bloom occurred in the Florida Panhandle, closing shellfish harvesting areas for an extended period of time. In September, *Karenia brevis* blooms were also reported along the south Texas coast.

Many agencies and institutions are involved in addressing this HAB problem. NOAA, EPA, and the State of Florida, in partnership with academic institutions, local governments, and business organizations, have undertaken major initiatives to understand and predict the occurrence of *Karenia brevis* blooms, improve monitoring and early warning identification of bloom events, investigate the effects on threatened species, and test newly developed control strategies. The U.S. Navy Office of Naval Research and the DOI Minerals Management Service (MMS) have also contributed to studies of optics, physical oceanography, and modeling. The NSF and National Institute of Environmental Health Studies (NIEHS) have funded studies related to the nutrient sources for blooms and the effects of brevetoxins on human health.

In the past few years, there have been many advances in our understanding of *Karenia brevis*. In 1999, NOAA, with ground-truthing data provided by the HAB monitoring program conducted by the Florida Fish and Wildlife Conservation Commission's Fish and Wildlife Research Institute, began developing a system that utilizes satellite imagery to help detect and monitor blooms. By 2004, this effort had significantly expanded and included models for projecting transport of the HABs using improved analysis of satellite data and meteorological conditions to predict likely impacts of the HABs. In October 2004, the forecast effort in Florida became operational as NOAA's Gulf of Mexico

Harmful Algal Bloom Forecasting System. The system produces an HAB Forecasting System Bulletin, which is now provided twice a week on an operational basis to federal, state, and local officials. The bulletin contains a written summary and analysis of bloom's levels and extent, which are also illustrated in maps (see figure). The bulletin is a resource used to guide sampling efforts, assist in management decisions, and provide information to the public (NOAA, 2007e). As of September 2005, more than 70 bulletins were provided to state and local managers during the 2005 HAB event, with more than 90% of the bulletins being used (Fisher et al., 2006).

The recently completed NOAA- and EPA-funded regional Florida project studied the occurrence and causes of *Karenia brevis* blooms for 5 years and developed a coupled physical/biological model to better understand environmental factors controlling blooms. Although the physiological and optical properties, bloom maintenance, termination, and transport of *Karenia brevis* are better understood, the nutrient sources supporting blooms and the trophic transfer and affects of brevetoxins on higher trophic levels require further study.



Map from Gulf of Mexico HAB Bulletin for October 20, 2005, showing data from September 30, 2005 (NOAA, 2005c).

Other efforts related to *Karenia brevis* HABs are also underway. Several agencies have supported the development of an optical sensor that can discriminate between *Karenia brevis* and most other phytoplankton (NOAA, 2005b). The sensor can be deployed on ships and Autonomous Underwater Vehicles for mapping and on moorings for continuous, real-time monitoring. NOAA is supporting the use of these new optical sensors as part of a networked system of autonomous sampling platforms, incorporating physical/chemical-sensor and bio-sensor packages to provide data for predictive models and to guide statewide adaptive field sampling. An effort is planned by NOAA to implement these as part of the dataset for the HAB Forecasting System Bulletin. In addition, after a series of laboratory feasibility studies, a recent field pilot project was conducted to test the efficacy of spraying a clay slurry on a *Karenia brevis* bloom to make the cells fall to the bottom without releasing their toxin. Although similar methods have been used in Asia, this was the first time a control method was tested under field conditions in the United States.

Mackerel Fisheries

King and Spanish mackerel are two coastal pelagic (water-column-dwelling) fish species that inhabit the Gulf of Mexico LME. Coastal pelagic fish are fast swimmers that school and feed voraciously, grow rapidly, mature early, and spawn over many months. U.S. and Mexican commercial fishermen have harvested Spanish mackerel since the 1850s and king mackerel since the 1880s.

The total catch of king mackerel from the Gulf of Mexico LME averaged 3,467 t per fishing year from 1981 to 2000, with maximum landings of 5,599 t in 1982 and minimum landings of 1,368 t in 1987. In 2001, the total catch was 3,649 t, with the recreational sector accounting for an average 62% of the total catch. From 1986 to 1996, landings were consistently above the total allocated catch, and by 1997, the Gulf of Mexico Fishery Management Council had increased the total allocated catch to 4,812 t. Until recently, the Gulf of Mexico LME king mackerel stock was considered overfished because of previous overexploitation of the fishery, and since 1985, the stock has been managed under rigid rebuilding schedules. In 2003, the maximum sustainable yield for the king mackerel stock in the Gulf of Mexico LME was estimated at 5,175 t. Results from the 2004 stock assessment suggest that the stock is not overfished and that overfishing is not occurring. At present, the commercial fishery for Gulf of Mexico LME king mackerel has restrictions on minimum size, regional quota allocations, trip catch limits, and gear restrictions. Although controlling the harvest of recreational fisheries is complex and the degree of compliance is not clear, the recreational fishery is regulated with restrictions on minimum size and bag limits (NMFS, In press).


Recreational anglers account for a significant portion of the landings of king and Spanish mackerel from the Gulf of Mexico LME (courtesy of NOAA).

The U.S. and Mexican commercial fishery for Spanish mackerel began in the waters off of New York and New Jersey, but has shifted southward over time to southern U.S. Atlantic and Gulf of Mexico waters. A major recreational fishery also exists for Spanish mackerel throughout its range, and the percent of landings by recreational anglers has increased to account for about 80% of Gulf of Mexico LME landings for the stock. The total catch of Spanish mackerel in the Gulf of Mexico LME averaged 2,081 t per fishing year from 1984 to 2001, with maximum landings of 4,586 t in 1987 and minimum landings of 995 t in 1996. Catches dropped substantially (about 50%) in 1995–1996 because of a gill-net ban in Florida waters, where a major portion of the commercial catch took place. In 2001, the total catch was 1,737 t. Since 1989, the landings of Spanish mackerel from this LME have been consistently below the total allocated catch, and total landings have been about 50% of the total allocated catch since 1995. The 2003 stock assessment indicated that the stock is currently exploited at the optimum long-term yield level (similar to the long-term potential yield, but modified for economic, social, or ecological factors), but not overfished. At present, management restrictions for the commercial fishery of Spanish mackerel in the Gulf of Mexico LME include minimum-size restrictions and quota allocation, as well as gear restrictions in state waters. Minimum size and daily bag restrictions are in place for the recreational fishery. Current issues affecting this stock involve mainly the bycatch of juveniles in the shrimp trawl fishery (NMFS, In press).

Shrimp Fisheries

In the Gulf of Mexico LME, shrimp have been fished commercially since the late 1800s. Brown, white, and pink shrimp are found in all U.S. Gulf of Mexico LME waters shallower than 395 feet. Most of the offshore brown shrimp catch is taken at depths of about 130 to 260 feet; white shrimp in waters 66 feet deep or less; and pink shrimp in waters approximately 130 to 200 feet deep. Brown shrimp are most abundant in the waters off the coast between Texas and Louisiana, and the greatest concentration of pink shrimp is in the waters off the coast of southwestern Florida (NMFS, In press).

Landings of brown, white, and pink shrimp in the Gulf of Mexico LME have varied over the years (Figure 5-20). Gulf of Mexico LME brown and white shrimp landings increased significantly from the late 1950s to around 1990, but landing levels during most of the 1990s were below these maximum values. In 2000, landing levels were extremely good for both species, with near-record levels reported. Landings in 2001–2003 were below these record catch levels, but were still well above average for both species. Pink shrimp landings remained stable until about 1985 and then declined to an all-time low in 1990. During the mid-1990s, landings increased to above-average levels, but have again shown a moderate declining trend in recent years. The numbers of young brown, white, and pink shrimp entering the fisheries (level of recruitment) have generally reflected the level of catch for each species (NMFS, In press).

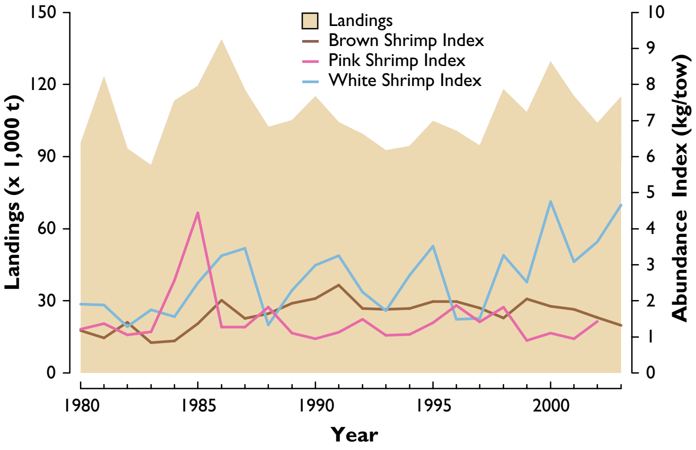


Figure 5-20. Shrimp landings in thousands of metric tons (t) and abundance index in kg/tow from the U.S. waters of the Gulf of Mexico LME, 1980–2003 (NMFS, In press).

Recruitment overfishing has not been evident in the Gulf of Mexico LME for any of the shrimp stocks. The number of young brown shrimp produced per parent increased significantly until about 1991 and has remained near or slightly below that level during most years. White and pink shrimp recruitment levels have not shown any general trend. Although pink shrimp stocks rebounded from the low values experienced in the early 1990s, they have started to decline again in recent years. The increase in brown shrimp recruitment appears related to marsh habitat alterations due to coastal subsidence and sea-level rise in the northwestern portion of this LME. These alterations cause the intertidal marshes to be inundated with water for longer periods of time, allowing the shrimp to feed for longer periods within the marsh area. Both factors have also expanded estuarine areas, created more marsh edges, and provided more protection from predators. As a result, the nursery function of these marshes has been greatly magnified, and brown shrimp production has expanded. However, continued subsidence or additional sea-level rise will lead to marsh deterioration, an ultimate loss of supporting wetlands, and the decline of currently high fishery yields (NMFS, In press).

Catch rates for both brown and white shrimp were at high levels for the 2001 harvesting season. Landings in 2004 were up 1% from the 2003 landings of 115,566 t, and U.S. landings of 116,519 t from the Gulf of Mexico LME were the nation's largest, representing 83% of the national total. All three of the commercial shrimp species are being harvested at maximum levels. Maintenance of shrimp stocks above the overfishing index levels should prevent overfishing of these populations (NMFS, In press). Regulations in the FMP for shrimp (GMFMC, 2004b) restrict shrimping through the closure of two shrimping grounds. There is a seasonal closure of fishing grounds off Texas for brown shrimp and a closure off Florida for pink shrimp. Size limits also exist for white shrimp caught in federal waters and landed in Louisiana. Because it has been shown that environmental factors determine production, negative effects on habitat have the potential to cause future reductions in shrimp catch. The loss of habitat, such as the destruction of wetland nurseries and the expansion of the hypoxic zone in Louisiana waters, may cause future declines in the shrimp harvest (NMFS, In press).

Highlight

Mobile Bay National Estuary Program Habitat Strategic Assessment for Coastal Alabama

River delta wetland habitat (courtesy of Mobile Bay NEP).

The Mobile Bay NEP led a strategic assessment process to examine habitat needs and deficiencies in coastal Alabama. The goal was to identify, examine, and prioritize sites of particular sensitivity, rarity, or value for potential acquisition and/or restoration using a multi-species approach. This assessment resulted in the identification of 17 priority sites for acquisition (or other conservation/protection options) and more than 30 other sites/habitat types where restoration and/or enhancement are considered necessary (Yeager, 2006). Identification of sites for acquisition or where restoration was considered necessary was based in part on data developed in Efroymson Coastal Alabama Conservation workshops held in December 2003 and March 2004 in a partnership between the Mobile Bay NEP and The Nature Conservancy. This assessment can be used by the state and other government organizations to more effectively guide resource management activities in coastal Alabama. Indeed, some state and local agencies and organizations have already acquired or are working to acquire certain sites on the priority site list (Yeager, 2006). Similarly, restoration activities are underway or are being planned in a number of the identified areas.

The need for such an assessment arose from the lack of coordination and communication among the many organizations and government agencies actively pursuing habitat acquisition, preservation restoration, and management activities in the Mobile Bay area. Through the strategic assessment process, the contributions of existing preservation and management programs and the capabilities of all agencies and organizations involved in these programs are coordinated and maximized.

The process was organized by the Mobile Bay NEP to carry out habitat action plans contained in its *Comprehensive Conservation and Management Plan* (Mobile Bay NEP, 2002) and was funded by the EPA's Gulf of Mexico Program (U.S. EPA, 2007a). The assessment involved an active partnership with The Nature Conservancy in hosting a workshop to examine possible conservation strategies and conservation targets for topics such as ecological systems and species, stresses, and threats. The findings of this workshop provided critical background information to assist attendees of subsequent workshops in the discussion of possible sites for acquisition, protection, and restoration, as well as the development of strategies for accomplishing these activities. Other participants in this strategic assessment covered a wide spectrum of federal, state, and public- and private-interest groups, including the USACE, FWS, the USDA's Natural Resources and Conservation Service (NRCS), the Mississippi–Alabama Sea Grant Consortium, the Alabama Department of Conservation and Natural Resources, the Alabama Forest Resources Council, the Weeks Bay NERR, the Mobile and Baldwin county governments, the Mobile Bay Audubon Society, the Dauphin Island Bird Sanctuary, the Alabama Coastal Foundation, the Alabama Power Company, and other local conservationists and realtors.

Dune habitat (courtesy of Mobile Bay NEP).

Although long-term success will be judged on the degree to which identified sites are protected or restored, short-term results are promising. For example, sites identified in the habitat strategic assessment have also been included as priorities for acquisition in recent state planning documents in response to the Coastal and Estuarine Land Protection Program (Yeager, 2006). Furthermore, efforts to create a coastal habitat restoration database are in progress. The Mississippi–Alabama Sea Grant Consortium initiated this database and funded its development to track ongoing restoration projects. The Mobile Bay NEP will be responsible for managing and maintaining the database as part of its data management system (Mississippi–Alabama Sea Grant Consortium and Mobile Bay NEP, 2007). Finally, a steering committee called the Coastal Habitats Coordinating Team has been created to promote a continuing focus on habitat needs. The Mobile Bay NEP will work to develop the public–private partnerships necessary to effectively conserve critical habitats throughout coastal Alabama.

Coastal marsh habitat (courtesy of Mobile Bay NEP).

Habitat conservation, protection, and restoration are very much a community concern in coastal Alabama. The development of effective partnerships and tools, such as the strategic assessment process, has helped the Mobile Bay NEP better utilize and target existing capabilities, resources, and funding for achieving habitat goals and assist in coordinating and maximizing various individual organization efforts.

Impact of Hurricanes Katrina and Rita

Since mid-September 2005, NOAA/NMFS has undertaken surveys of the northern Gulf of Mexico LME in areas affected by Hurricanes Katrina and Rita to assess the quality of marine resources used in seafood products and to determine if these events resulted in changes in the abundance or distribution of important shrimp, crab, and finfish species. NMFS will re-survey the northern Gulf of Mexico LME area periodically to determine the abundance of species and examine the potential for nursery area disruptions caused by habitat damage in coastal wetlands. Data obtained from the Gulf of Mexico LME abundance survey conducted in October and November 2005 provide a baseline from which to evaluate short-term storm impacts and long-term recovery actions. NMFS evaluated wetland restoration projects underway in the Louisiana wetlands and barrier islands after the hurricanes. Eight of nine projects functioned as intended to protect and begin to restore degraded habitats; however, approximately 100 mi^2 of wetlands in the southeastern Louisiana marshes were lost because of Hurricane Katrina. Studies are underway to evaluate the effect of Hurricane Katrina on the fishery value of shallow wetland nurseries (NMFS, In press).

NOAA announced in January 2006 that Hurricanes Katrina and Rita did not cause a reduction in fish and shrimp populations in the offshore areas of the Gulf of Mexico LME. The annual survey of shrimp and demersal (bottom-dwelling) fish completed in November 2005 showed that some species, such as the commercially valuable and overfished red snapper, had a higher abundance index in 2005 than the average calculated for the period of 1972 to 2004. The survey also showed that the abundance index for Atlantic croaker doubled. The overall abundance indices of shrimp and demersal fish increased by about 30% from 2004 levels, largely due to increases in Atlantic croaker, white shrimp, and red snapper populations. The reduction in fishing activities in the Gulf of Mexico LME since the hurricanes could be a factor contributing to the abundance index increases for some of the shorter-lived species (NOAA, 2006b).

Hurricane Katrina interrupted fishing activities in the Gulf of Mexico LME by destroying fishery infrastructure, such as the shrimp boats and barges shown here in Venice, LA (courtesy of Lieut. Commander Mark Moran, NOAA).

Assessment and Advisory Data

Fish Consumption Advisories

In 2003, 14 fish consumption advisories were in effect for the estuarine and marine waters of the Gulf Coast. Most of the advisories (12) were issued for mercury, and each of the five Gulf Coast states had one statewide coastal advisory in effect for mercury levels in king mackerel. The statewide king mackerel advisories covered all coastal and estuarine waters in Florida, Mississippi, Louisiana, and Alabama, but covered only the coastal shoreline waters in Texas. As a result of the statewide advisories, 100% of the coastal miles of the Gulf Coast and 23% of the estuarine square miles were under advisory in 2003 (Figure 5-21).

Species and/or groups under fish consumption advisory in 2003 for at least some part of the coastal waters of the Gulf Coast region

Barracuda	King mackerel
Blue crab	Ladyfish
Bluefish	Little tunny
Catfish	Permit
Crab	Red drum
Cobia	Shark
Gafftopsail catfish	Snook
Gag grouper	Spanish mackerel
Greater amberjack	Spotted seatrout
Crevalle jack	Wahoo

Source: U.S. EPA, 2004b

South Padre Island, TX (courtesy of Alisa Schwab).

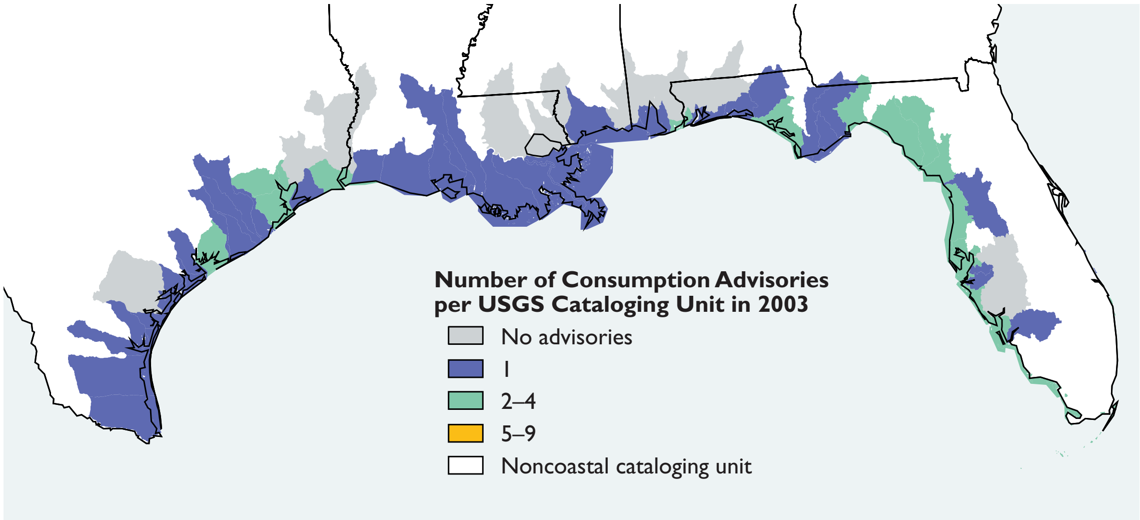


Figure 5-21. The number of fish consumption advisories active in 2003 for the Gulf Coast coastal waters (U.S. EPA, 2004b).

Fish consumption advisories placed on specific waterbodies included additional fish species. Florida had six mercury advisories in effect for a variety of fish, in addition to the statewide coastal advisory. In Texas, the Houston Ship Channel was under advisory for all fish species because of the risk of contamination by chlorinated pesticides and PCBs. Potential dioxin contamination in catfish and blue crabs resulted in additional advisories for the Houston Ship Channel. Figure 5-22 shows the number of advisories issued along the Gulf Coast for each contaminant (U.S. EPA, 2004b).

Beach Advisories and Closures

Of the 619 coastal beaches in the Gulf Coast region reported to EPA, 23.3% (144 beaches) were closed or under an advisory for some period of time in 2003. Table 5-1 presents the numbers of beaches monitored and under advisory or closure for each state. As shown in the table, Florida's west coast had the most beaches with advisories or closures, and Louisiana did not report any data for EPA's 2003 survey. Figure 5-23 presents advisory and closure percentages for each county within each state (U.S. EPA, 2006c).

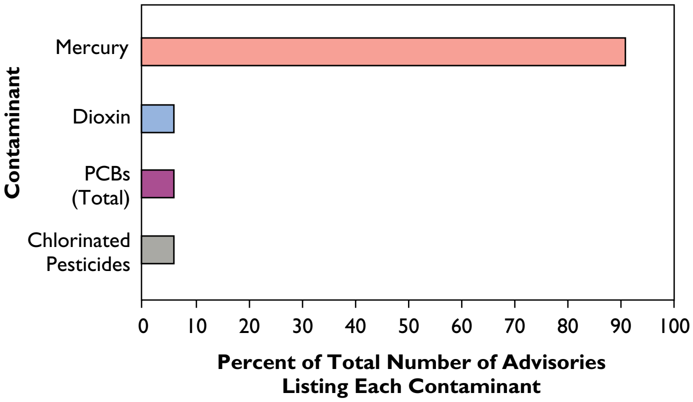


Figure 5-22. Pollutants responsible for fish consumption advisories in Gulf Coast coastal waters. An advisory can be issued for more than one contaminant, so percentages may add up to more than 100 (U.S. EPA, 2004b).

Table 5-1. Number of Beaches Monitored and With Advisories/Closures in 2003 for Gulf Coast States (U.S. EPA, 2006c)

State	No. of Beaches Monitored	No. of Beaches With Advisories/ Closures	Percentage of Beaches Affected by Advisories/ Closures
Florida (Gulf Coast)	407	103	25.3
Alabama	25	10	40.0
Mississippi	21	11	52.3
Louisiana	NR	NR	NR
Texas	166	20	12.3
TOTAL	**619**	**144**	**23.3**

NR = Not Reported.

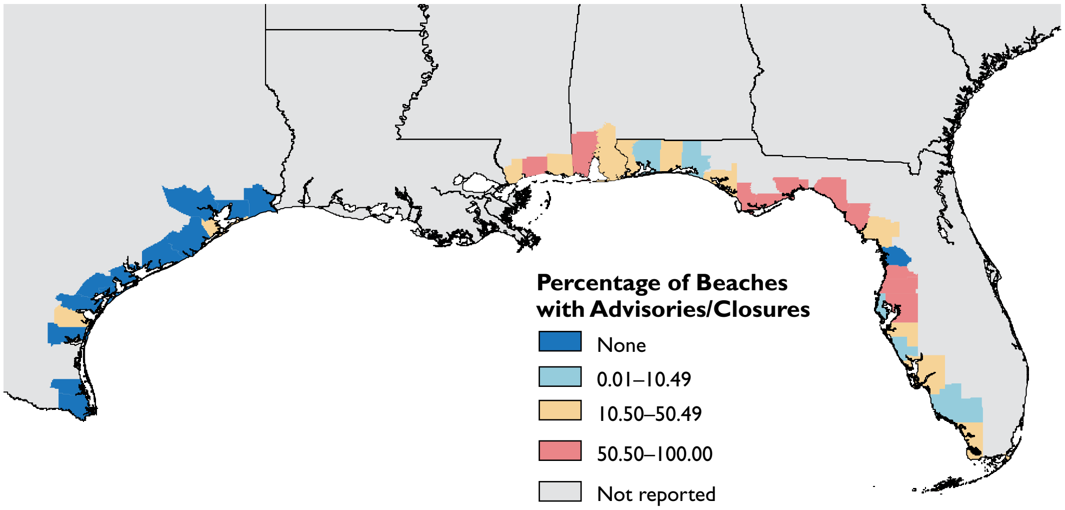


Figure 5-23. Percentage of monitored beaches with advisories or closures, by county, for the Gulf Coast region (U.S. EPA, 2006c).

Most beach advisories and closings were implemented at coastal beaches along the Gulf Coast because of elevated bacteria levels (Figure 5-24). Figure 5-25 shows that unknown sources accounted for 99% of the responses (U.S. EPA, 2006c).

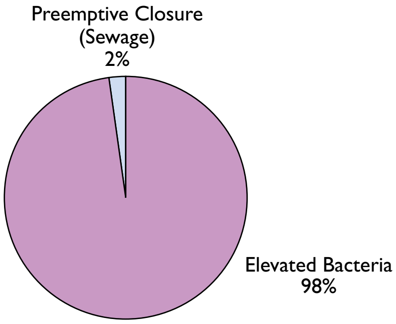


Figure 5-24. Reasons for beach advisories or closures for the Gulf Coast region (U.S. EPA, 2006c).

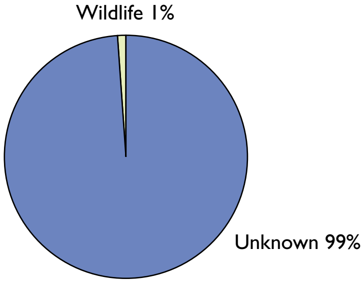


Figure 5-25. Sources of beach contamination resulting in beach advisories or closures for the Gulf Coast region (U.S. EPA, 2006c).

Galveston, TX (courtesy of Oscar Boleman).

Summary

Based on the indicators used in this report, the overall condition of Gulf Coast coastal waters is rated fair to poor. Coastal wetland loss, sediment quality, and benthic condition are rated poor in Gulf Coast coastal waters for 2001–2002, and water quality was also of concern (rated fair). Benthic index values were lower than expected in 45% of the Gulf Coast coastal area. Although elevated sediment contaminant concentrations were found in only 2% of the coastal area, sediments were toxic in 13% of the coastal area. Decreased water clarity and elevated DIP concentrations were observed in more than 22% of the coastal area, and elevated levels of chlorophyll *a* were observed in 7% of the area. DIN and dissolved oxygen concentrations rarely exceeded guidelines. The overall condition rating of 2.2 in this report represents only a slight decrease from the rating of 2.4 observed in the previous report (NCCR II), but still represents an improvement in overall condition since the early 1990s. Increasing population pressures in the Gulf Coast region warrant additional monitoring programs and increased environmental awareness to correct existing problems and to ensure that indicators that appear to be in fair condition do not worsen.

NOAA's NMFS manages several fisheries in the Gulf of Mexico LME, including reef fishes, menhaden, mackerel, and shrimp. Of the dominant reef fishes, red snapper and red grouper are currently overfished, and the gag grouper and greater amberjack are approaching an overfished condition. These issues are being addressed with regulatory measures and stock-rebuilding plans. The menhaden stock in this LME is healthy, and catches are generally below long-term maximum sustainable yield estimates. The Gulf of Mexico LME king and Spanish mackerel are currently not overfished, but the Spanish mackerel stock is exploited at its optimum long-term yield. Recruitment overfishing is not evident in any of the Gulf shrimp stocks; however, all three of the commercial shrimp species are being harvested at maximum levels. Loss of habitat has the potential to cause future reductions in shrimp catch.

Contamination in Gulf Coast coastal waters has affected human uses of these waters. In 2003, there were 14 fish consumption advisories in effect along the Gulf Coast, most of which were issued for mercury contamination. In addition, approximately 23% of the region's monitored beaches were closed or under advisory for some period of time during 2003. Elevated bacteria levels in the region's coastal waters were primarily responsible for the beach closures and advisories.

CHAPTER 6

West Coast Coastal Condition

Courtesy of Brad Ashbaugh

West Coast Coastal Condition

As shown in Figure 6-1, the overall condition of the coastal waters of the West Coast region is rated fair. The water quality index is rated fair; the sediment quality index is rated fair to poor; the benthic index is rated good; and the coastal habitat and fish tissue contaminants indices are rated poor. These ratings were primarily driven by NCA survey results for the Puget Sound and San Francisco Bay estuarine systems, which together represent a large percentage of the total coastal area of the West Coast region. The watersheds surrounding these two systems, together with coastal watersheds in southern California, also have the highest population densities in the West Coast region. In contrast, the majority of smaller estuarine systems along the West Coast were estimated to be in better condition. 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 of West Coast coastal waters is based on environmental stressor and response data collected by NCA from 210 sites in 1999 and 171 sites in 2000 as part of a pilot project. Data on sediment contaminants for 41 of the 71 Puget Sound sites 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. Please refer to Chapter 1 for information about how these assessments were made, the criteria used to develop the rating for each index and component indicator, and limitations of the available data.

Although the majority of the data discussed in this chapter were also presented in the NCCR II (U.S. EPA, 2004a), this report presents slightly different rating results for the West Coast region. During the interval between the publication of the NCCR II and the NCCR III, benthic community data collected in 2000 from San Francisco Bay became available, and all benthic community data collected from coastal waters during 2000 (Puget Sound, Columbia River, San Francisco Bay) were included in this NCCR III assessment. As a result of the inclusion of these new data, the

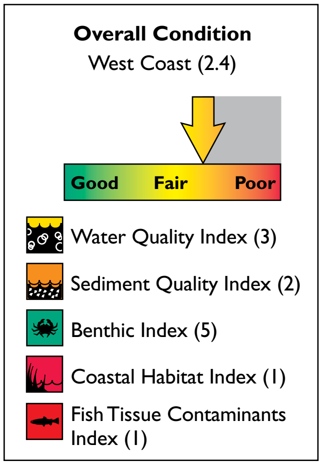


Figure 6-1. The overall condition of West Coast coastal waters is rated fair (U.S. EPA/NCA).

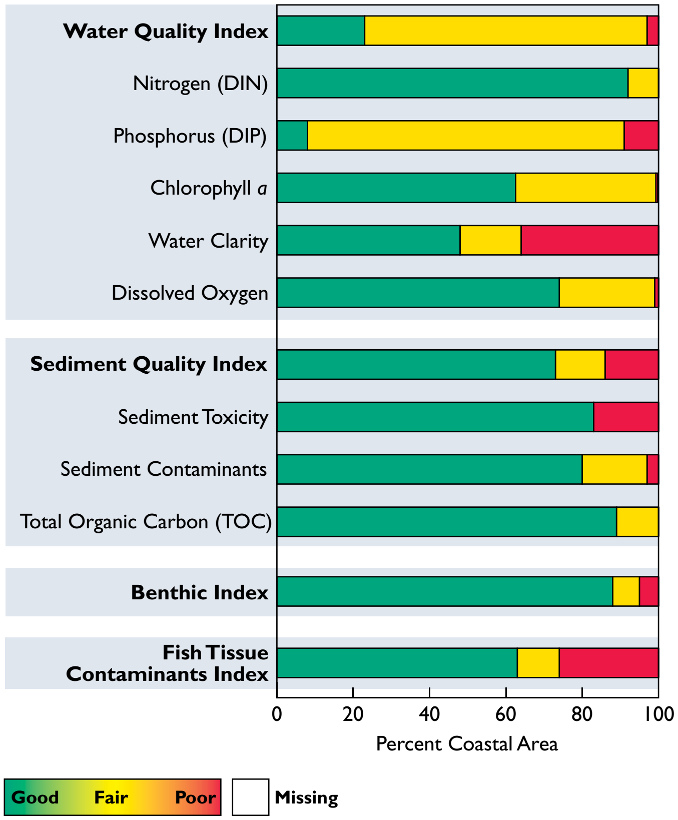
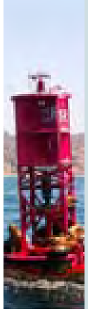


Figure 6-2. Percentage of coastal area achieving each ranking for all indices and component indicators—West Coast region (U.S. EPA/NCA).



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

overall condition rating for the coastal waters of the West Coast region changed from a rating of fair to poor, with an overall condition score of 2.2 (NCCR II), to the current rating of fair, with an overall condition score of 2.4. The benthic index rating for the region also changed from a rating of fair (NCCR II) to the current rating of good. In addition, water column means, rather than surface sample results, were inadvertently used in the NCCR II assessment of the DIN, DIP, and chlorophyll *a* data collected during 1999 and 2000. Although the reassessment of these data resulted in changes to the percent of coastal area rated good, fair, and poor for these component indicators and for the water quality index, the ratings for the water quality index and component indicators remain unchanged from those presented in the NCCR II. Data QC and refinement since the NCCR II also caused some slight differences in the percent area rated good, fair, or poor for the other indices and component indicators assessed in this report.

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 0.0237 mi^2 (Yachats River, OR) to 2,551 mi^2 (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 mi^2, 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 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. The coastal population of the West Coast region increased 47% between 1980 and 2003 to a total of 37.5 million (Figure 6-3), and 2003–2008 population growth rates for the counties bordering the San Diego, San Francisco, and Puget Sound estuaries are projected to be more than 40% (Crossett et al., 2004). These growth rates suggest that human pressures on West Coast coastal resources will increase substantially in future years.

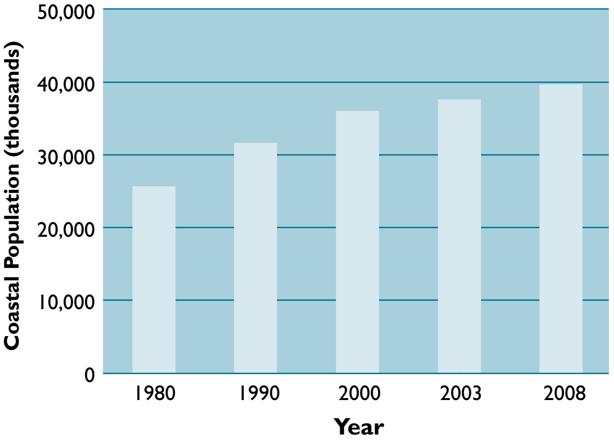
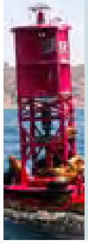


Figure 6-3. Actual and estimated population of coastal counties in West Coast states from 1980 to 2008 (Crossett et al., 2004).



The sampling conducted in the EPA NCA survey has been 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.

Coastal Monitoring Data—Status of Coastal Condition

Relatively few national programs monitor the coastal waters of the West Coast region. NOAA's Estuarine Eutrophication Survey (NOAA, 1998) examined a number of eutrophication variables for West Coast coastal waters through the use of a survey questionnaire. In addition, NOAA's NS&T Program collects data for several locations along the West Coast (Long et al., 2000), but these sites are not representative of all West Coast coastal waters. EMAP-like surveys have also been completed in the Southern California Bight (SCB) (SCCWRP, 1998). In comparison with these geographically focused studies, 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. A reassessment of coastal condition along the West Coast was conducted in 2004 for the NCA. Unfortunately, most of these data are not yet available for use in this report; therefore, this section focuses only on the assessment of data collected in small and large West Coast coastal waterbodies from 1999 to 2000.

Water Quality Index

The water quality index for the coastal waters of the West Coast region is rated fair, with 74% of the coastal area rated fair and 3% rated poor for water quality condition (Figure 6-4). The water quality index was developed based on measurements of five component indicators: DIN, DIP, chlorophyll *a*, water clarity, and dissolved oxygen. The sites rated poor for water quality condition were found primarily in California. The only sampling site outside California with poor water quality was located in southern Hood Canal, WA. Low ratings for the water quality index were driven primarily by high DIP concentrations and poor water clarity.

Nutrients: Nitrogen and Phosphorus

The West Coast region is rated good for DIN concentrations, with 8% of the coastal area rated

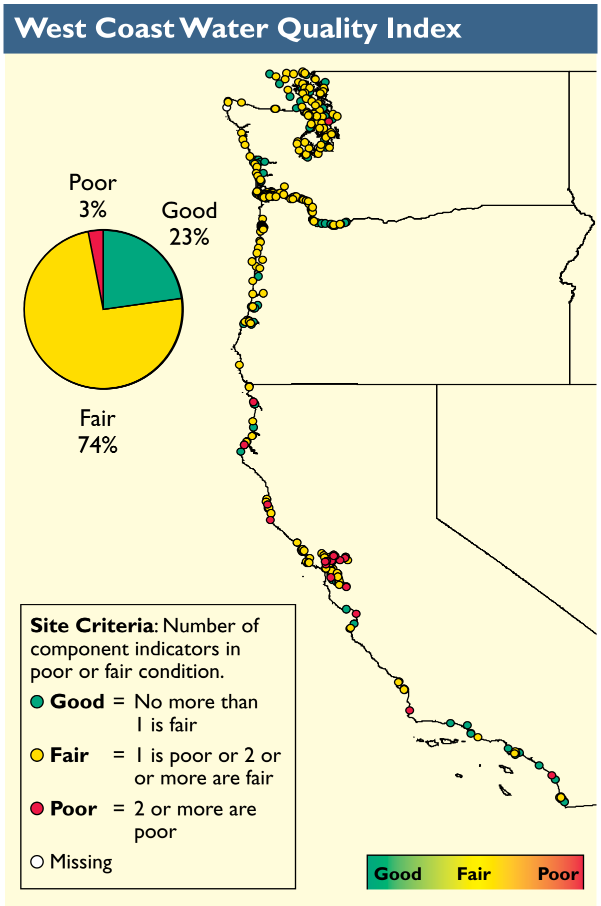


Figure 6-4. Water quality index data for West Coast coastal waters (U.S. EPA/NCA).

fair and less than 1% of the area rated poor for this component indicator. The West Coast region is rated fair for DIP concentrations, with 83% of the coastal area rated fair and 9% rated poor for this component indicator. Upwelling may be an important contributing factor to the DIN and DIP concentrations measured in the coastal waters of the West Coast region during the summer season.

Chlorophyll a

The West Coast region is rated good for chlorophyll *a* concentrations, with 37% of the coastal area rated fair for this component indicator. Less than 1% of the area was rated poor for chlorophyll *a* concentrations, with the sites rated poor located in California and Washington (southern Hood Canal).

Water Clarity

Water clarity is rated poor for the West Coast region, with 16% of the area rated fair and approximately 36% of the coastal area rated poor for this component indicator. The same criteria 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. The results of the 2000–2001 NCA assessment are consistent with those made by the NOAA Estuarine Eutrophication Survey (NOAA, 1998), which reported high turbidity in 20 of the 38 West Coast estuaries surveyed.

Dissolved Oxygen

The West Coast region is rated good for dissolved oxygen concentrations, with 25% of the coastal area rated fair for this component indicator. Approximately 1% of the coastal area was rated poor for dissolved oxygen concentrations, with the sites rated poor located in some sub-estuaries of Puget Sound (Dabob Bay and southern Hood Canal). Puget Sound is a deeper, fjord-like system and may often have low dissolved oxygen concentrations in the bottom waters of its more restricted arms.

Sediment Quality Index

The sediment quality index for the coastal waters of the West Coast region is rated fair to poor, with 14% of the coastal area rated poor for sediment quality condition (Figure 6-5). The sediment quality index was developed based on measurements of three component indicators: sediment toxicity, sediment contaminants, and sediment TOC. Elevated metal concentrations at stations in San Francisco Bay and high metal and organic compound concentrations at stations in the harbors and bays of the Puget Sound system (e.g., Duwamish River, Commencement Bay) impacted the region's sediment quality index rating. Toxic sediments collected at sites within Puget Sound, the Columbia River, and Willapa Bay were the second-most important contributor to

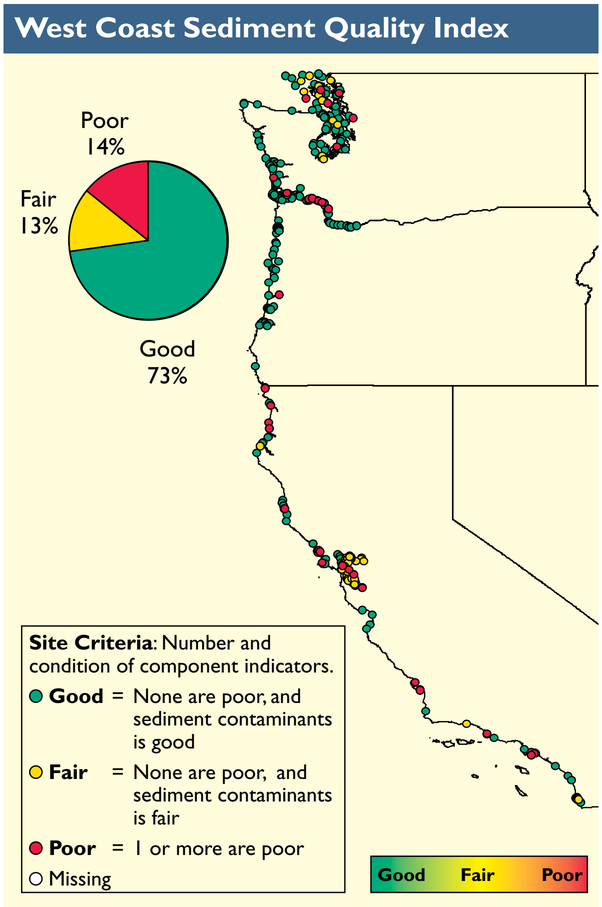

West Coast Sediment Quality Index

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

the areal estimate of poor condition for the West Coast region. In addition, sites in several other areas had either elevated sediment contaminant concentrations or high sediment toxicity (e.g., Smith River in northern California, Los Angeles Harbor), but these sites constituted a relatively small percentage of the West Coast coastal area.

Sediment Toxicity

The West Coast region is rated poor for sediment toxicity, with 17% of the coastal area rated poor for this component indicator.

Sediment Contaminants

The West Coast region is rated good for the sediment contaminants component indicator, with 17% of the coastal area rated fair and 3% rated poor for this component indicator. Elevated levels of DDT; chromium, mercury, copper, or other metals; PAHs; or PCBs were primarily responsible for poor ratings at West Coast sampling sites.

Sediment TOC

The West Coast region is rated good for sediment TOC, with 11% of the coastal area rated fair and none of the area rated poor for this component indicator.

Tide pools form along the West Coast's rocky shoreline (courtesy of Brad Ashbaugh).

Benthic Index

Benthic condition in West Coast coastal waters is rated good, with 7% of the coastal area rated fair and 5% rated poor (Figure 6-6). Although several efforts are underway and indices of benthic community condition have been developed for sections of the West Coast (e.g., Smith et al., 2001), there is currently no single benthic community index applicable for the entire West Coast region. In lieu of a 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. This approach requires that species richness be predicted from salinity. A significant linear regression between log species richness and salinity was found for the region, although it was not strong ($R^2 = 0.43$; $p < 0.01$).

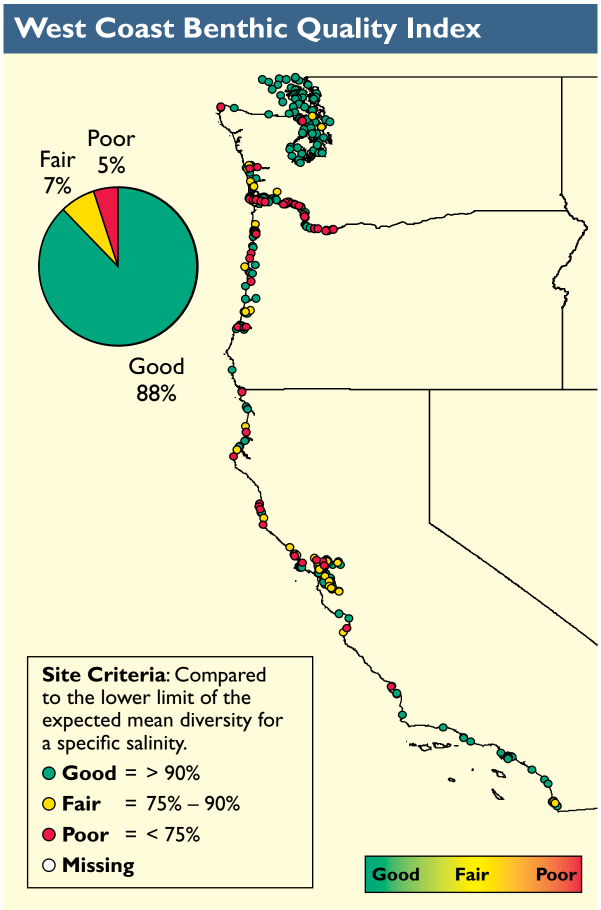


Figure 6-6. Benthic index data for West Coast coastal waters (U.S. EPA/NCA).

Coastal Habitat Index

The coastal habitat index for the coastal waters of the West Coast region is rated poor. From 1990 to 2000, the West Coast experienced a loss of 1,720 acres (0.53%) of the region's wetlands (Dahl, T., FWS, personal communication, 2002). The long-term, average decadal loss rate of West Coast wetlands is 3.4%. Although the number of 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 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 for the coastal waters of the West Coast region is rated poor. Based on whole-fish contaminant concentrations and EPA Advisory Guidance values, 11% of all stations sampled where fish were caught were rated fair and 26% of stations were rated poor (Figure 6-7). The contaminants found most often in fish tissue samples included total PCBs and DDTs, although elevated mercury levels were occasionally detected.

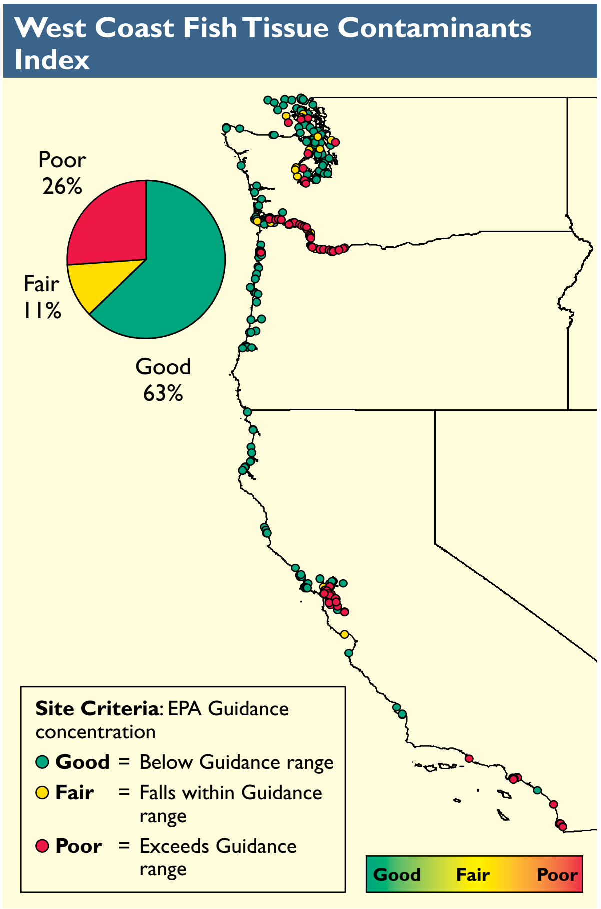


Figure 6-7. Fish tissue contaminants index data for West Coast coastal waters (U.S. EPA/NCA).

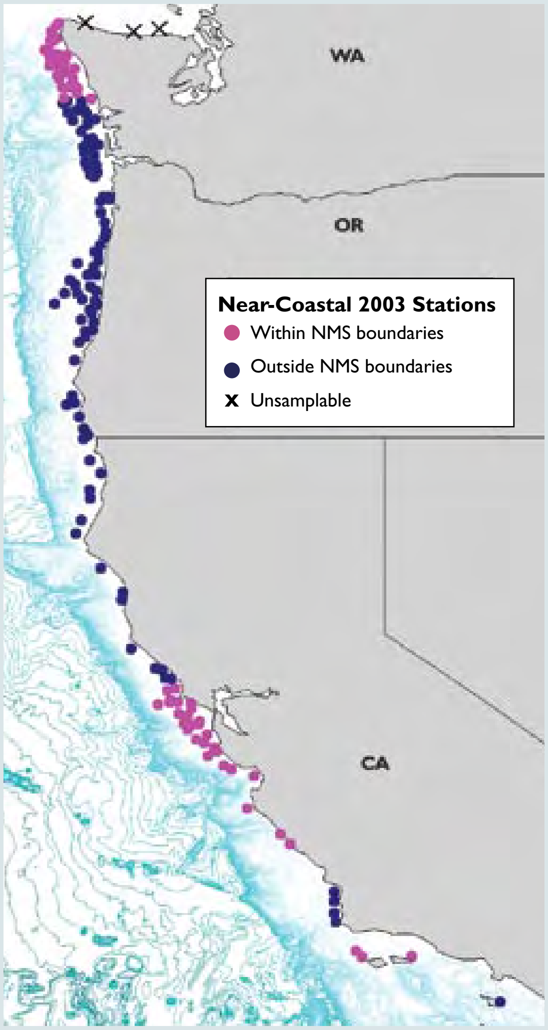
Coastal wetlands provide critical habitat for migratory birds (courtesy of San Francisco Estuary Project).

Highlight

EPA, NOAA, and West Coast States Assess Ecological Condition of Near-Coastal Waters Along the Western U.S. Continental Shelf

An effort is underway by the EPA, NOAA, and West Coast states to assess the condition of aquatic resources in near-coastal waters along the western U.S. continental shelf. The study is based largely on the protocols of EPA's EMAP and thus may be regarded as an extension of previous EMAP efforts in estuaries and inland waters to these offshore areas, where such information has been limited in the past. This near-coastal monitoring effort included EMAP's probabilistic-sampling approach to support statistical estimation of the spatial extent of condition with respect to various measured ecological indicators (U.S. EPA, 2002). Results are intended to serve as a baseline for monitoring potential changes in these indicators over time due to either human or natural factors.

Sampling was conducted successfully in the summer of 2003 at 150 stations (see map) located between the Straits of Juan de Fuca, WA, and Channel Islands, CA, at depths ranging from 100–395 feet (Cooksey et al., 2003). A stratified-random sampling design positioned 50 stations off each West Coast state (Washington, Oregon, and California). In addition, 60 of the 150 stations were located within NOAA NMSs, with 30 of these stations located within the Olympic Coast NMS off the coast of Washington and the remaining 30 stations distributed among the four other West Coast NMSs (Gulf of the Farallones, Cordell Bank, Monterey Bay, and Channel Islands), which are located off the California coast. Thus, the design allows for comparison of condition in NMSs to surrounding, nonsanctuary areas of the shelf (Cooksey et al., 2003).



Western U.S. Continental Shelf sampling sites (NOAA, 2007b).

As in EMAP efforts (including the present NCCR III), multiple indicators were measured synoptically at each station to support the weight of evidence assessments of condition and the examination of associations between biological characteristics and potential environmental controlling factors (U.S. EPA, 2002). Condition was assessed using indicators of (1) habitat condition, (2) general water quality, (3) biological condition with a focus on benthic infauna and demersal fish pathology, and (4) exposure to stressors. The table lists the specific indicators assessed during this study.

The consistent sampling of these variables across such a large number of stations provides a tremendous opportunity for learning more about the spatial patterns of near-coastal resources and the processes controlling their distributions, including potential associations between the presence of stressors and biological responses. For example, a key environmental concern that the program will address with these data is the extent to which pollutants and other materials are being transported out of major rivers, such as the Columbia River, located along the developed areas of the coast. Another concern is how these pollutants may affect biological resources.

The study also demonstrates the benefits of performing science through partnerships that bring together complementary capabilities and resources from a variety of federal, state, and academic institutions. The project is principally funded by the EPA Office of Research and Development. NOAA is also a major partner in the effort, working with EPA to provide overall management and interpretive support, in addition to contributing ship time on the NOAA Ship *McARTHUR II*. NOAA's Northwest Fisheries Science Center also provided field support and analysis of fish pathologies for the June 2003 survey and supplied fish for contaminant analysis from samples collected through the NOAA West Coast Slope Survey fisheries assessment program. State and academic partners include the Washington State Department of Ecology (WDOE), Oregon Department of Environmental Quality, Moss Landing Marine Laboratories, and the Southern California Coastal Water Resources Project (SCCWRP). A separate companion survey led by the SCCWRP was also conducted to assess condition in shelf waters of the SCB using similar methods and indicators. Data from the two surveys will be integrated to provide a comprehensive assessment of ecological condition of near-coastal waters along the majority of the U.S. western continental shelf between the Canadian and Mexican borders. A final report is expected by September 2008. It is anticipated that the resulting information on the condition of ecological resources in these deeper near-coastal waters will make valuable contributions to future reports in the NCCR series.

Environmental Indicators Used in the SAB Study (Cooksey, 2004)
Habitat Condition Indicators
Salinity
Water depth
Dissolved oxygen
pH
Water temperature
Total suspended solids
Transmittance
Sediment grain size
Sediment percent total organic carbon (TOC)
Sediment color/odor
Presence of trash/marine debris
Water Quality Indicators
Chlorophyll *a* concentrations
Nutrient concentrations (nitrates, nitrites, ammonia, phosphate)
Biological Condition Indicators
Benthic species composition
Benthic abundance
Benthic species richness and diversity
External indicators of disease in fish
Presence of nonindigenous species
Exposure Indicators
Chemical contaminants in sediment
Chemical contaminants in fish tissues
Low dissolved oxygen condition
Organic over-enrichment

Trends of Coastal Monitoring Data—West Coast Region

Temporal Change in Ecological Condition

As a pilot project, the NCA survey of the West Coast region was initially designed to develop trends in condition. The region was reassessed in 2004–2006 to determine trends, but these data were unavailable for inclusion in this report; therefore, a regional assessment of trends for West Coast coastal condition is not possible at this time.

Three local monitoring programs have sampled significant percentages of the coastal area of the West Coast region for periods up to nearly 35 years, and these programs measure many of the same parameters (e.g., sediment contaminants) as the NCA. The Puget Sound Ambient Monitoring Program (PSAMP) conducted annual assessments of sediment contamination, sediment properties, and benthic community composition at 10 fixed sites from 1989 through 2000. The principal agency conducting the sediment assessment is the WDOE, which was also the lead agency for the 1999–2000 NCA survey in Washington. Within San Francisco Bay, the Regional Monitoring Program for Trace Substances (RMP) has monitored chemical contaminant levels in water, sediments, and biota since 1993. The longest-running monitoring study in the region has been conducted primarily by the Los Angeles County Sanitation Districts (LACSD) to assess the condition of sediment and benthic and fish communities, as well as the levels of chemical contaminants in fish, for a series of sites on the Palos Verdes Shelf within the SCB. Although these long-term monitoring data have been collected from fixed stations, probability-based assessments within the SCB have also been conducted.

Changes and Trends in Puget Sound Sediments: Results of the Puget Sound Ambient Monitoring Program, 1989–2000

As part of the PSAMP, the WDOE sampled sediments at 10 fixed sites that were chosen from a variety of habitats and geographic locations in Puget Sound (Figure 6-8). Sediments from each site were analyzed for particle size, organic carbon content, and sediment contaminant concentrations, as well as for the types and abundances of benthic organisms present. Samples were collected each spring between 1989 and 2000; however, samples collected between 1997 and 1999 were not analyzed for sediment contaminant concentrations. Changes in sediment condition over the 1989–2000 time period provide evidence for both human-driven and naturally occurring influences on the marine ecosystem (Partridge et al., 2005).

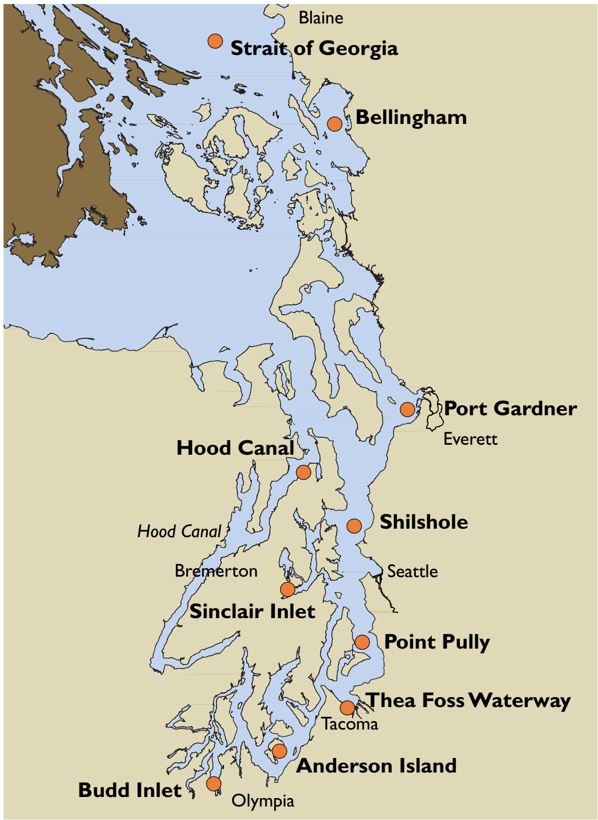


Figure 6-8. Locations of the 10 long-term PSAMP sediment monitoring stations in Puget Sound (courtesy of WDOE).

Human-Driven Changes

The PSAMP analyzed sediment samples for more than 120 contaminants, such as metals (i.e., priority pollutant and ancillary) and organic compounds (e.g., PAHs, chlorinated pesticides, PCBs). The most notable changes in sediment chemistry were in metal and PAH concentrations.

The concentrations of most metals did not change significantly over the study period; however, those that did change generally decreased. Significant decreases were observed in copper levels across all stations and in metal concentrations, in general, at stations in Port Gardner and Budd Inlet (Partridge et al., 2005). Freshwater and estuary sediment metal concentrations have exhibited similar declines nationwide since the mid-1970s. These trends may reflect decreases in emissions to air and water from municipal and industrial sources following the implementation of federal clean water and air regulations; however, despite these improvements, metal concentrations remain above sediment quality guidelines in many urban bays of Puget Sound, emphasizing the need for continued monitoring and cleanup (Lefkovitz et al., 1997; Mahler et al., 2004).

Port Townsend, WA (courtesy of Gary Wilson, NRCS).

The concentrations of most PAH compounds in sediment did not change significantly during the PSAMP study period; however, most of those that did change increased in concentration. Significant increases in benzofluoranthene levels were observed throughout the study area, and increases in PAH concentrations were observed at sites in Bellingham Bay, Port Gardner, and Anderson Island. In contrast, there was a significant decrease in PAH concentrations at the Point Pully site (Partridge et al., 2005). These results are consistent with nationwide trends. After peaking between the mid-1940s and the 1960s, nationwide PAH levels in sediment core samples decreased through the 1980s and have more recently increased. It is believed that the early declines in PAH concentrations can be attributed to the switch from coal to oil and natural gas for home heating, improvements in industrial emissions controls, and increases in the efficiency of power plants, whereas more recent increases have been linked to increasing urban sprawl and vehicle traffic in urban and suburban areas (Lefkovitz et al., 1997; Van Metre et al., 2000; Van Metre and Mahler, 2005). Recent studies by the USGS have also measured high PAH concentrations in stormwater runoff from parking lots sealed with coal-tar-based asphalt sealants (Mahler et al., 2005).

Naturally Occurring Changes

From 1989 through 1995, the amount of fine-grained sediment (percent silt) at the Strait of Georgia site varied between 25% and 50%. Between 1995 and 1997, the percent silt in the sediment rose to approximately 90%, then declined to about 50% between 1998 and 2000. During the PSAMP study, the benthic community in the Strait of Georgia changed from one characterized by multiple annelid worm species (i.e., *Prionospio*, *Pholoe*, and *Cossura*) to one consisting primarily of *Cossura*, a mobile burrower that tolerates living in a wide range of sediment grain sizes, and finally to one dominated by the bivalve mollusks *Macoma* and *Yoldia*, which are also active burrowers (Figure 6-9) (Partridge et al., 2005).

Examination of the flow and discharge plume of British Columbia's Fraser River, which can carry heavy sediment loads into the Strait of Georgia, suggested a possible cause for the observed changes.

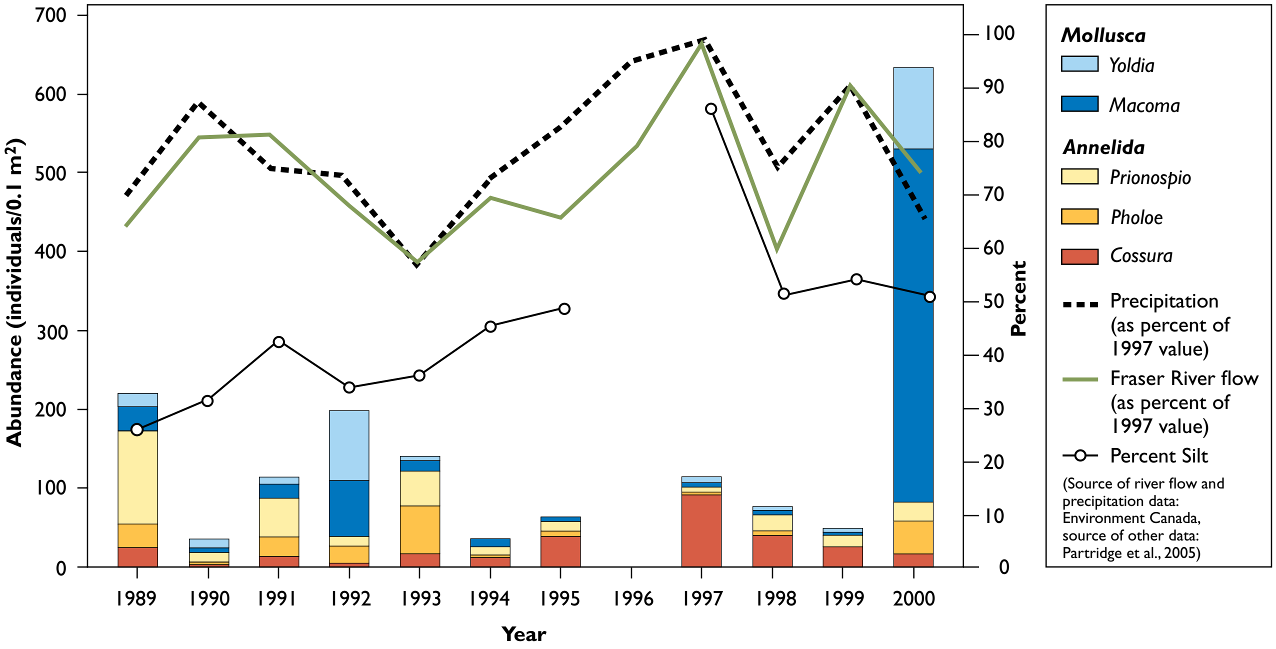


Figure 6-9. Changes in percent silt and abundance of dominant annelids and mollusks at the Strait of Georgia station, along with patterns in Fraser River flow and precipitation at the Vancouver International Airport. River flow and precipitation displayed as percent of highest value (courtesy of WDOE).

Annual rainfall, Fraser River flow volumes, and the percent silt at the Strait of Georgia site all exhibit similar temporal patterns. It is hypothesized that the changes in the sediment community observed in the Strait of Georgia were driven by above-average precipitation in 1996–1997, which increased the flow in the Fraser River and resulted in increased deposition of fine sediments in northern Puget Sound. Changes in grain size are known to influence community structure (Partridge et al., 2005).

Changes in the Strait of Georgia's sediment community in response to naturally occurring variations in rainfall and river flow clearly show the value of long-term monitoring for understanding the effects of stressors on the Puget Sound ecosystem. Understanding these processes at a local scale can help with assessments of similar changes in other regions. For example, the sediment-community changes observed in the Strait of Georgia may hold the key to understanding recent declines in San Juan Island eelgrass populations.

Acting on the results of the PSAMP sediment monitoring program, investigators from the University of Washington and the USGS are conducting sediment surveys to determine if the decline in eelgrass abundance can also be linked to the deposition of fine-grained sediments from the Fraser River (Partridge et al., 2005).

The PSAMP's long-term monitoring provides a vital record of sediment conditions in Puget Sound and gives insight into the effects of both natural and human-driven stressors on the estuary. The fixed "sentinel" stations monitored in this program can raise red flags, highlighting important environmental changes that affect Puget Sound. These results are critical for guiding the policy and regulatory decisions needed to effectively manage and maintain the environmental health of Puget Sound. General information and data generated from this survey can be accessed from WDOE's Marine Sediment Monitoring Web site: http://www.ecy.wa.gov/programs/eap/mar_sed/msm_intr.html.

Trends in Environmental Condition in San Francisco Bay

San Francisco Bay (Figure 6-10) has had the benefit of several long-term monitoring programs, including the RMP, sampling and analysis by the USGS, and the Interagency Ecological Program (IEP). The RMP has investigated chemical contamination in the water, sediments, and biota of the Bay since 1993 and provides data on spatial patterns and long-term trends for use in management of the estuary (SFEI, 2003). The USGS has 35 years of water quality data, including data on parameters such as chlorophyll, nutrients (phosphorus and nitrogen), suspended sediments, and dissolved oxygen. These data provide a record of biological and chemical changes in the Bay, such as improvements in dissolved oxygen concentrations in the South Bay and changes in phytoplankton production in Suisun Bay (USGS, 2006b). The IEP has monitored fisheries and the effects of freshwater diversions on the biota of the Bay and the Sacramento-San Joaquin Delta since 1971 (IEP, 2006). Recent IEP data have shown drastic declines in important Delta fish species, such as striped bass, delta smelt, and longfin smelt (Hieb et al., 2005). Other local, state, and national programs, such as the Bay Protection and Toxic Cleanup Program, state Mussel Watch Program, Coastal Intensive Sites Network (CISNet), EMAP, and NOAA's NS&T Program, have also provided data on the water, sediments, and biota of San Francisco Bay.

Figure 6-10. Map of San Francisco Bay (courtesy of San Francisco Estuary Institute).

Current and historical activities have contributed PCBs, pesticides, and mercury and other heavy metals (e.g., silver, copper) to the sediments of San Francisco Bay. Although many of these contaminants have been banned, they are persistent in the environment, biomagnify through the food web, and bioaccumulate in fish and wildlife. The highest concentrations of sediment contaminants are most often found at the urbanized edges of the Bay, and the distribution of contaminants is primarily driven by two factors: inputs from industrial and military sources near San Jose and the South San Francisco, Oakland, and East Bay shorelines and the distribution of fine particles to which these contaminants are sorbed. Many of the areas with high concentrations of PCBs, DDT, and/or chlordane in sediment correspond to areas of the estuary (i.e., South San Francisco Bay, San Pablo Bay, and along the East Bay shorelines) with high percentages of fine sediments (Connor et al., 2004).

Mercury contamination in San Francisco Bay dates back to 19th-century mining practices, and sediment cores from the South Bay reflect historic changes in concentrations over time (SFEI, 2004). Pre-mining concentrations were about four to five times lower than today's concentrations (Conaway et al., 2003). A peak in mercury concentrations occurred during the early to mid-20th century, coinciding with the height of mining activities at the New Almaden Mercury Mine. This mine was the richest mercury mine in the state and is located on the Guadalupe River, which drains into the South Bay.

Contaminant levels in fish and wildlife have been the main concerns of the TMDLs being developed by the San Francisco Bay Regional Water Quality Board. For example, 25 years after the ban on the use of PCBs in California, concentrations in some Bay sport fish remain 10 times higher than

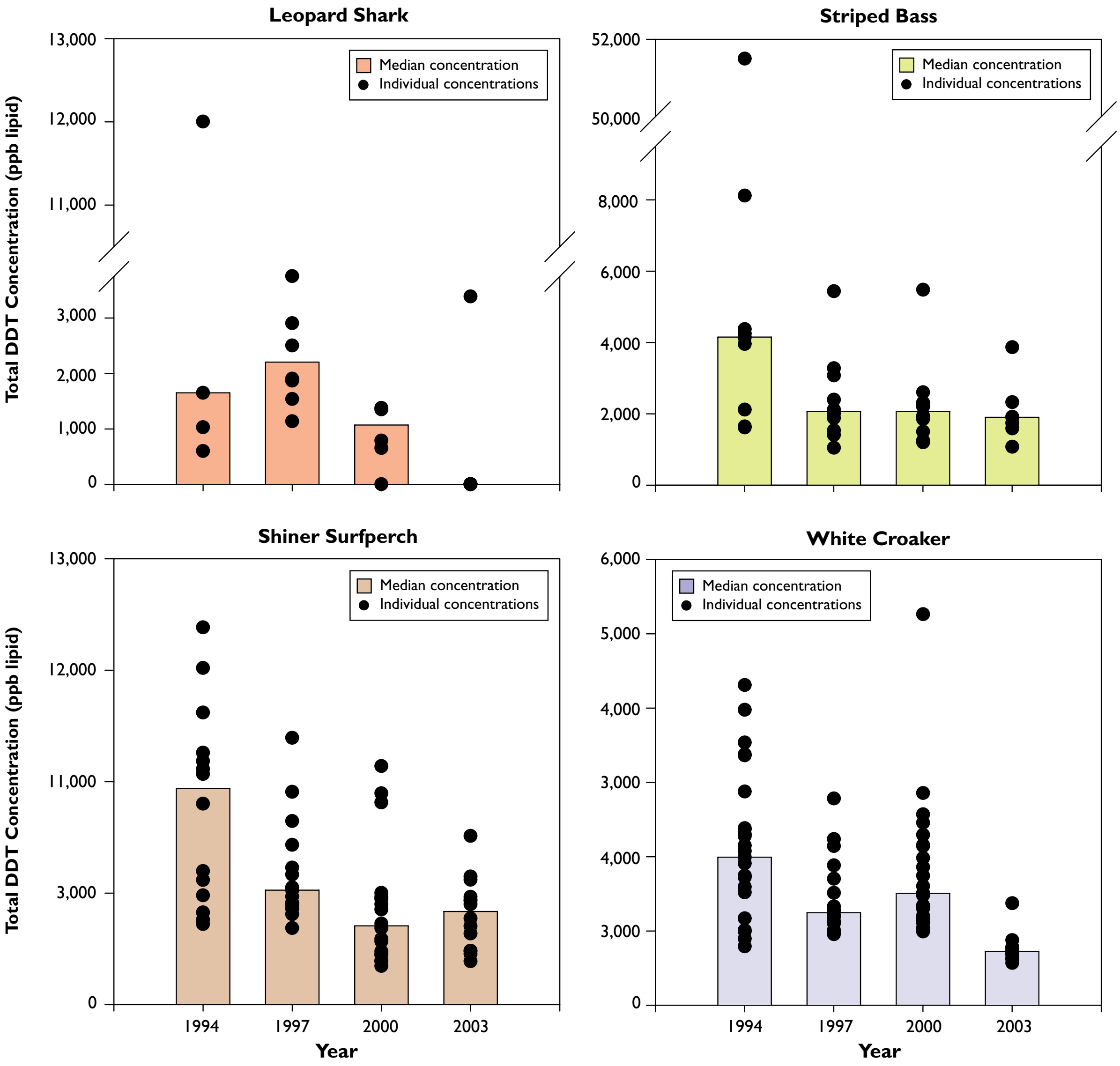


Figure 6-11. Total DDT concentrations in leopard shark, shiner surfperch, striped bass, and white croaker in ppb lipid weight, 1994–2003 (courtesy of San Francisco Estuary Institute).

human health consumption guidelines (Davis et al., 2006). Fish contaminants data have also been analyzed to determine whether there have been long-term changes in contaminant levels. Over the long term, concentrations of lipid-normalized DDTs in leopard shark, shiner, and white croaker suggest statistically significant declines in concentrations from 1994 to 2003 (Figure 6-11) (Connor et al., 2004). No long-term trends have been detected in lipid-normalized PCB data. PCB levels in leopard shark, white croaker, and striped bass were higher in 1994 compared to other years, but interannual variation since 1994 has fluctuated without a clear decline. Mercury concentrations in striped bass have shown no decline during the period from 1970–2003 (Figure 6-12) (Greenfield et al., 2005).

Declining concentrations of PCBs in transplanted mussels have suggested that water quality has improved in the Bay. Linear regression analyses have shown exponential declines in PCB concentrations in mussels at most transplant locations from 1980 to 2003. Similar declines in concentrations of legacy pesticides have also been seen in Bay transplanted mussels (Davis et al., 2006).

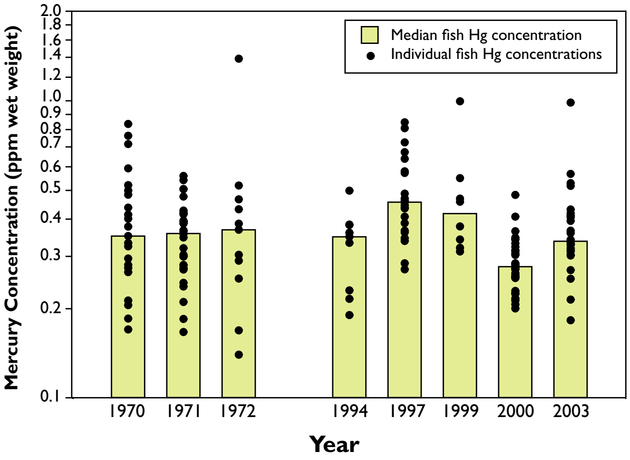


Figure 6-12. Mercury concentrations in ppm wet weight in striped bass from 1970–2003. Concentrations expressed as an average for a 55 cm fish (courtesy of San Francisco Estuary Institute).

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

Primary production in San Francisco Bay has historically been light-limited because of this waterbody's turbidity (SEFI, 2004). In recent years, chlorophyll levels in the southern reaches of the Bay have increased (Figure 6-13), which may be due to increased light penetration (SFEI, 2006). A South Bay suspended-sediment model, developed by USGS, predicts that increases in wetland area (as proposed under the South Bay Salt Pond Project) could result in increased sediment deposition onto wetlands and a subsequent decrease in suspended sediments in the water column (Shellenbarger et al., 2004). The resulting increase in light penetration could cause higher phytoplankton productivity. In the northern reaches of the estuary, chlorophyll concentrations have dramatically decreased in Suisun Bay sites (Figure 6-14) since the invasion of the freshwater clam *Corbula amurensis* in 1986. The high abundance of this filter-feeding clam has resulted in declines in chlorophyll in Suisun Bay, from an average of 9.8 mg/L (pre-invasion) to 2.1 mg/L (post-invasion) (SFEI, 2003).

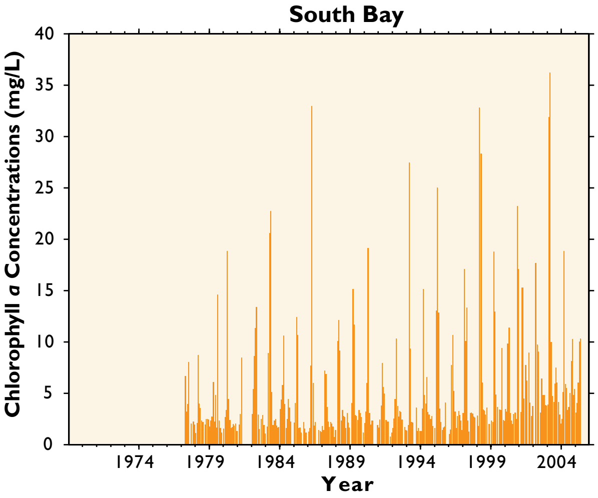


Figure 6-13. Chlorophyll *a* concentrations (mg/L) in South Bay, 1977–2004 (based on USGS data, courtesy of San Francisco Estuary Institute).

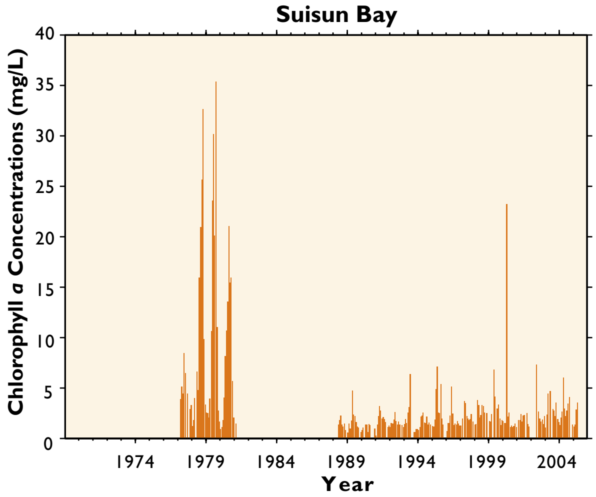


Figure 6-14. Chlorophyll *a* concentrations (mg/L) in Suisun Bay, 1977–2004 (based on USGS data, courtesy of San Francisco Estuary Institute).

Highlight

Development of Sediment Quality Objectives in California

An often overlooked benefit of the partnership between the EPA NCA and the states is the development of assessment tools. The California State Water Resources Control Board is required by the State of California's Porter-Cologne Water Quality Control Act (California Water Code, Division 7. Water Quality, Section 13393) to develop sediment quality objectives (SQOs) as part of a comprehensive program to protect existing and future beneficial uses within California's enclosed bays and estuaries. The process of developing SQOs has proven to be difficult both for EPA on a national basis and for many states on an individual basis. California is making progress toward developing direct-effects SQOs, in large part because of the data generated through probability-based, regional monitoring efforts supported by EMAP, the EMAP Western Pilot Project, and NCA beginning in 1999 (SWRCB, 2006).

Direct-effects SQOs are established to protect those organisms that are directly exposed to pollutants in sediments and to determine if sediment quality is negatively impacting those organisms. Reference condition is used to determine protected or optimal conditions. The State of California has proposed using a multiple-lines-of-evidence approach to SQOs, based upon a measure of exposure and two measures of biological condition. The three indicators that are being proposed are sediment contaminant concentrations, sediment toxicity, and benthic community condition. These indicators were selected to provide greater confidence in the decision-making process because benthic invertebrates are the focus of direct-effects SQOs. NCA data from bays and estuaries on the West Coast have provided an unbiased, synoptic data set to test various approaches. These data have been merged with other high-quality, site-specific data sets, such as the data for San Francisco Bay from the RMP. Approximately half of the data are being used to evaluate the utility of various measures of exposure, toxicity, and benthic community structure to assess sediment condition. The other half of the data set will be used to validate the approach for statewide application (SWRCB, 2006).

A summary of the process for developing and ultimately for implementing these SQOs can be found on California Environmental Protection Agency State Water Resources Control Board's Web site: http://www.swrcb.ca.gov/bptcp/sediment.html. For more information, contact Chris Beegan at (916) 341-5577.

Courtesy of Brad Ashbaugh

Direct-Effects Sediment Quality Objectives

Because the benthic invertebrates are the focus of direct-effects SQOs, sediment contaminant concentrations, sediment toxicity, and benthic comminity condition will be applied to provide greater confidence in the decision-making process. The steps involved in setting and implementing SQOs are described below.

1. **Set a Direct Effects SQO:** An example of a direct-effects narrative objective is “Sediment quality shall be maintained at a level that protects benthic invertebrates from degradation caused by bio-available pollutants in sediments.”
2. **Implement the Narrative Direct-Effects SQO:** A narrative objective must be linked to a methodology that describes how the narrative objective is implemented. Multiple thresholds will be developed for each indicator and used to assess a response at a particular station (see table).
3. **Assess Each Station Using Three Lines of Evidence and the Tool-Specific Thresholds:** Finally, a method to integrate the three results will be developed to describe sediment quality at the station level.

Sediment Toxicity		Sediment Contaminant Concentrations		Benthic Community Condition	
Response	Threshold	Response	Threshold	Response	Threshold
	T^0 tox		T^0 chem		T^0 ben
	T^1 tox	x	T^1 chem		T^1 ben
x	T^2 tox		T^2 chem		T^2 ben
	T^3 tox		T^3 chem	x	T^3 ben
	T^4 tox		T^4 chem		T^4 ben

Notes: The implementation tools cannot be used to identify the cause of impairment. This is the fundamental limitation with these current tools. Before any mitigation or restoration can begin, the stressor must be identified.

Although bulk chemistry data can quantify which pollutants are present, these data do not provide any information on bio-availibility. Many pollutants are bound by organics or anions in the sediment that prevent the pollutant from causing toxicity.

The implementation of the narrative SQO is based solely on the application of multiple lines of evidence. No single line of evidence should be used in any application because of the limitations associated with the tool used to quantify the condition or response of the indicator or the limitations associated with the indicator itself.

Trends in Coastal Sediment Condition in the Southern California Bight: A Clean Water Act Success Story

The SCB is the most densely populated coastal region in the nation, and its municipalities rely upon coastal waters for the disposal of treated wastewater. Nineteen publicly owned treatment works (POTWs) discharge 1,200 million gallons per day to the SCB. Of these POTWs, the LACSD's Joint Water Pollution Control Plant (JWPCP), which discharges to the Palos Verdes Shelf, is one of the largest in volume and industrialization.

Prior to the Clean Water Act of 1972, the primary goal for treatment systems was public health protection. Following the Clean Water Act, treatment processes and outfall designs were upgraded with the goal of also protecting aquatic life in the ambient environment. During the next 30 years, mass emission rates of effluent-suspended solids and contaminants were reduced as industrial waste source-control measures and treatment plant upgrades were implemented. In addition, receiving-water monitoring programs were instituted to assess the effects of discharge on the condition of the nearshore environment. The monitoring program established along the Palos Verdes Shelf area near the outfall of the JWPCP has the longest consistent record of monitoring receiving waters in the SCB, allowing assessment of the environmental response to effluent quality improvements (LACSD, 2006). This monitoring has been conducted primarily by the LACSD. The location of the outfall and receiving water monitoring sites discussed below are shown in Figure 6-15.

By 1970, the historic discharge had contaminated the seafloor of the Palos Verdes shelf with organic matter and chemicals (e.g., metals and chlorinated hydrocarbons). Organic matter loading resulted in sediment hypoxia and hydrogen sulfide in surface sediment pore waters. Potentially toxic metals and synthetic organic compounds, notably DDT and PCBs, were present in the sediments at levels well above those typically associated with biological effects. These alterations were severe enough to sharply degrade the benthic communities over the entire shelf (Stull, 1995).

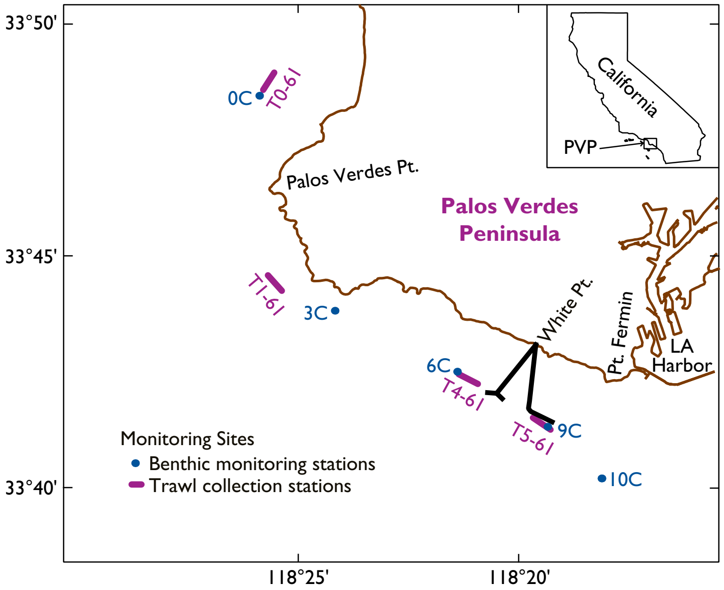


Figure 6-15. JWPCP outfall system and monitoring sites within the SCB. Stations indicated with C in the station ID are benthic monitoring stations, whereas those with T in the station ID are trawl collection stations (courtesy of SCCWRP based on data from LACSD).

As effluent contaminant emissions decreased from 1970 onward, so did the levels of organic matter, metals, chlorinated hydrocarbons, and other contaminants in the upper layers of seafloor sediments. Examples of sediment quality trends are shown in Figure 6-16. Similar reductions have been observed for other contaminants, including numerous metals and other chlorinated hydrocarbons (LACSD, 2006).

The unfavorable sediment conditions that developed over decades degraded benthic communities in much of the Palos Verdes shelf. Impacts were greatest near the outfall, where pollution-tolerant species dominated. Species richness was extremely low, crustaceans and echinoderms were rare, and many benthic species common to reference areas were conspicuously absent. Over time, the severity of biological effects lessened as sediment conditions improved (LACSD, 2006). This pattern of response is summarized by the Benthic Response Index (BRI) (Smith et al., 2001), which is a regional assessment tool calculated as the abundance of pollution-tolerant species within a sample. Whereas loss in community function, and even loss of the community altogether, was apparent at all sampling stations in the 1970s, even the sites closest to the outfall had only minor deviation from reference condition by the mid-2000s (LACSD, 2006).

As with the benthic communities, the demersal (bottom-dwelling) fish communities on the Palos Verdes shelf exhibited evidence of community-level impacts in the 1970s. Near-outfall sites were characterized by smaller populations, lower biomass, fewer species, and less diversity than sites distant from the discharge. Many species that were rare in the 1970s have become more abundant and widespread in the past two decades. Previously abundant pollution-tolerant species that had been associated with the discharge have declined in population (LACSD, 2006). These trends are summarized by an index of demersal fish biointegrity, the Fish Response Index (FRI) (Allen et al., 2001), with index values below 45 indicating reference biointegrity. The FRI has fallen over time (Figure 6-17), with all sites near the outfall currently within reference condition (LACSD, 2006).

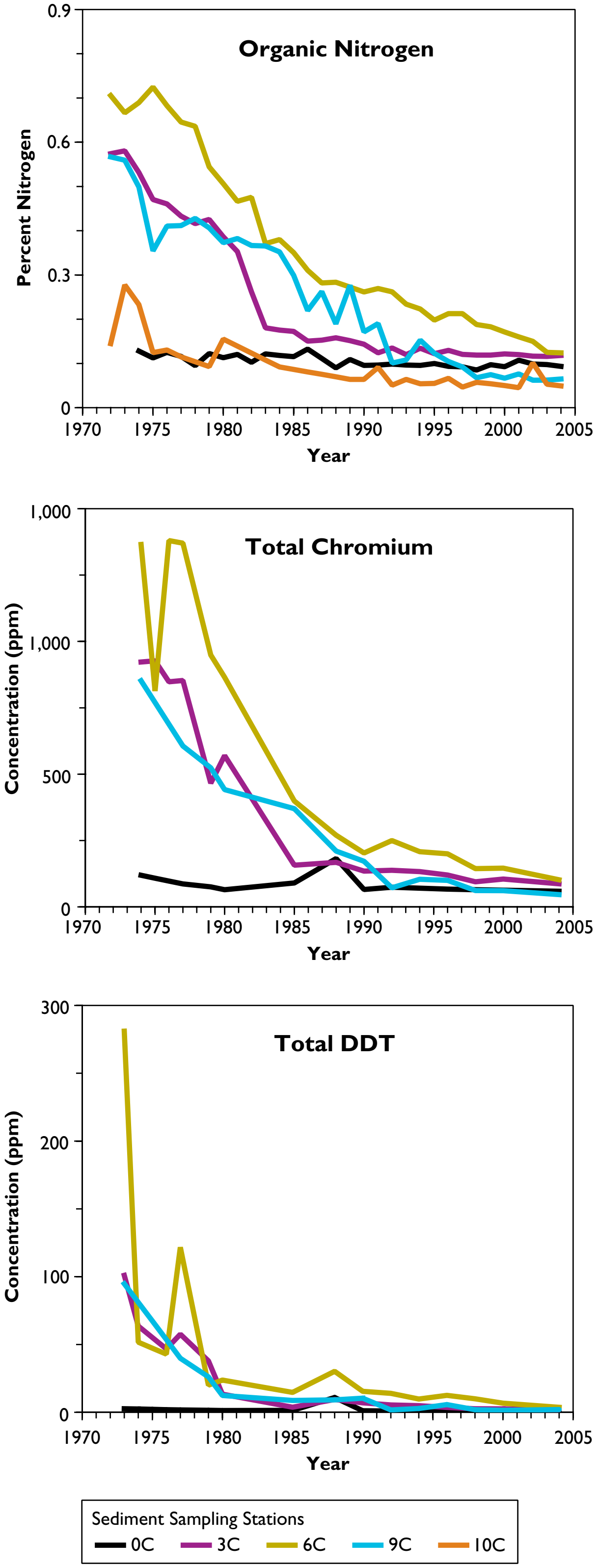


Figure 6-16. Trends in sediment quality represented by changes in concentrations of organic nitrogen, total chromium, and total DDT in sediment samples in the SCB, 1972–2004 (based on data from LACSD, courtesy of SCCWRP).

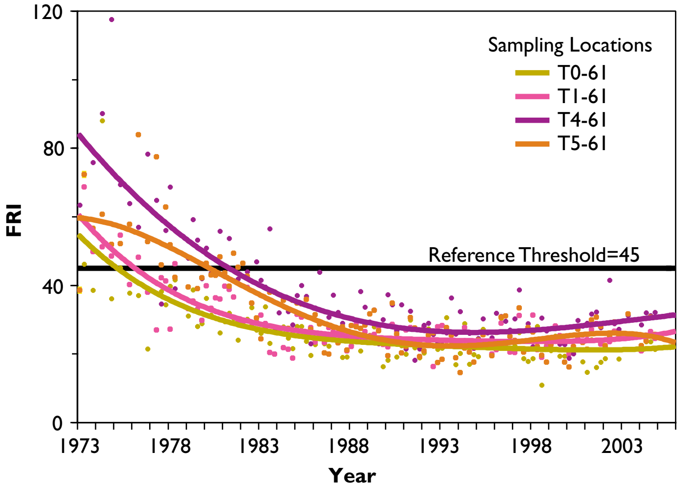


Figure 6-17. Trends in the condition of the demersal fish community in the SCB, 1972–2004, as represented by the Fish Response Index (based on data from LACSD, courtesy of SCCWRP).

Another indicator of pollution-related impacts within demersal fish communities is fin erosion. This disease manifests as the degeneration of fins and is thought to result from a complex set of causes, including contact with contaminated sediments, low dissolved oxygen environments, and secondary bacterial infections. In the past, fin erosion was commonly observed among demersal fish off Palos Verdes. Thirty-one of 69 species collected off the Palos Verdes Peninsula during 1969–1972 trawl surveys exhibited fin erosion, with Dover sole showing the highest incidence. This flatfish species prefers muddy bottoms, where it feeds on benthic organisms. Fin erosion was most commonly found on specimens from near-outfall sampling sites and was rare in specimens from the most distant sampling site. Fin erosion virtually disappeared from Dover sole and all other species of demersal fish collected off Palos Verdes by 1988 (LACSD, 2006).

In the SCB, DDT and PCBs are the persistent synthetic chlorinated hydrocarbons of greatest concern. DDT inputs to the JWPCP sewer system ended in 1971, and other sources of this chlorinated hydrocarbon have been eliminated. Use of PCBs was prohibited in 1979, and this compound has been virtually undetected in effluent since 1986 (Steinberger and Stein, 2004). However, the persistence of these legacy pollutants in the buried reservoir of historically contaminated sediments results in their continued appearance in the food web and tissues of local sea life. Although tissue burdens in local fish have fallen over time (Figure 6-18), levels in some species are still sufficiently high to justify consumption advisories (LACSD, 2006).

The long-term monitoring results on the Palos Verdes shelf cumulatively provide evidence of the effectiveness of the Clean Water Act. There is clear linkage between reductions in discharge from the POTW and improvements in sediment quality, which in turn has led to improvements in the biological integrity of the system. Although the example provided was for a single facility, similar patterns have been observed at each of the other southern California POTWs that maintain monitoring programs. The JWPCP typifies the successful response by POTWs in the SCB to the challenges presented by the Clean Water Act. Population in the coastal plain is expected to increase substantially over the next 30 years, and pressure on the local marine environment may increase. The requirements of the Clean Water Act will continue to assure that the gains of the past 30 years are sustained, and the monitoring programs associated with those facilities will provide a means of assessing that success.

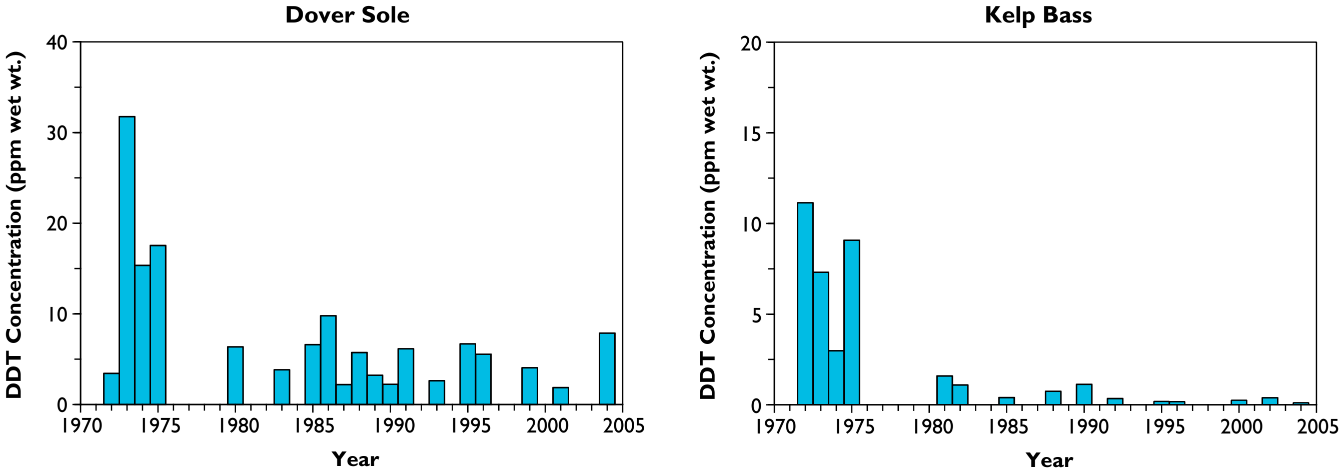


Figure 6-18. Trends in the median concentration of DDT (ppm wet wt.) in muscle tissue of Dover sole and kelp bass in the SCB, 1972–2004 (based on data from LACSD, courtesy of SCCWRP).

Overall Trends

Monitoring of fixed stations over an 11-year period in Puget Sound has shown that the general trend for metals in the sediments has been to decrease over time. Among the 10 priority pollutant metals sampled at 10 stations, a total of 39 cases (single metal at a single location) exhibited statistically significant differences over time. Of these 39 cases, 4 exhibited significant increases, and the rest were significantly decreasing. The Puget Sound PAH data demonstrate that different types of pollutants may have differing temporal trajectories. In contrast to metals, of the 45 cases where a significant temporal trend in PAH concentrations was detected, 41 instances were increases. The Puget Sound benthic monitoring data also strongly suggest that natural environmental variability can have impacts on certain environmental indicators, such as sediment grain size and benthic community composition. Separation of such natural sources of variation from anthropogenic changes remains a significant challenge for the interpretation of long-term monitoring data.

The data from the long-term monitoring programs within San Francisco Bay present a mixed picture of changes over time. As was the case in Puget Sound, sediment copper concentrations have generally declined. PCBs have shown declines in mussel tissue used in a monitoring program since the 1970s, but have shown no decline in the decade since 1994 in samples of various fish tissues. In contrast, DDT and chlordane pesticides have declined in the same fish species over the same time period. Of continued concern in San Francisco Bay is the fact that there is no indication of decreases of mercury over a 30-year period. In contrast, some stations in Puget Sound had significant decreases in sediment concentrations of mercury over only a decade.

The long-term data from the monitoring of fixed stations in the SCB was more focused on the evaluation of system responses near point sources of pollutants from POTWs, in contrast to the more regional assessments reported from Puget Sound and San Francisco Bay; therefore, the trends described tended to be much clearer. Reductions in effluent contaminant levels from the early 1970s onward have reduced the amount of organic matter, metals, and organic contaminants, such as DDT, in the surface sediments. The demersal fish and benthic communities have both responded favorably to these reductions in pollutant loads. As was the case in San Francisco Bay, the levels of synthetic organic contaminants (e.g., DDT, PCBs) in fish tissues have decreased over time, but in both regions, there is a highly persistent legacy of these pollutants in the sediments that continue to accumulate in fish at levels sufficient to require consumption advisories.

The temporal trends in benthic pollutants within these three large coastal areas of the West Coast demonstrate a number of significant reductions over periods of monitoring, ranging from one to three decades. The increasing trend for PAH concentration with time in Puget Sound is potentially a result of the large increases in human population in the region. Observation of increasing trends for pollutants indicates that there is still a major need for programs that address existing problems, as well as for programs to prevent environmental conditions from getting worse over time.

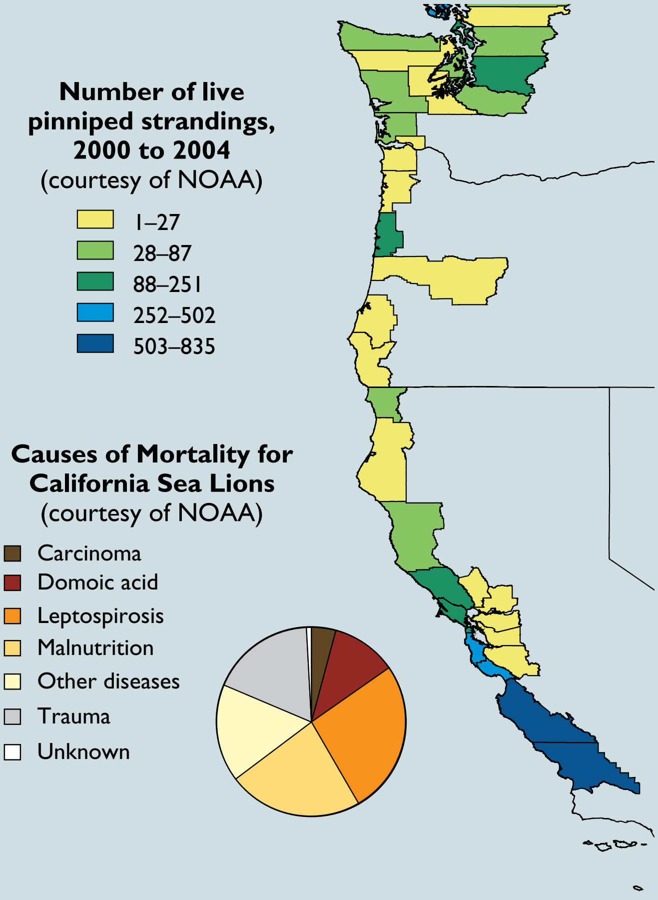
The sunflower sea star, *Pycnopodia helianthoides*, is found on a variety of subtidal bottoms and in extremely low intertidal zones from Unalaska Island, AK, to Baja California, Mexico (courtesy of NOAA).

Marine Mammal Strandings Along the West Coast

Seals and sea lions live and breed along the Pacific coasts of Washington, Oregon, and California (King, 1983). These marine mammals share their habitat with humans and consume many of the same fish species. California sea lions (*Zalophus californianus*), Pacific harbor seals (*Phoca vitulina richardsii*), and northern elephant seals (*Mirounga angustirostris*) are the pinniped species that commonly come ashore or "strand" on West Coast beaches when they are ill or in distress. Members of the Southwest and Northwest regions of the National Marine Mammal Health and Stranding Network respond to these strandings when they occur along the California and Oregon–Washington coasts, respectively. The network was formalized by the 1992 Amendments to the Marine Mammal Protection Act and is managed by the NMFS. Live stranded animals are admitted for care to rehabilitation centers, and investigations into cause of death are conducted for animals that die.

From 2000 to 2004, a total of 4,804 live pinnipeds were stranded along the West Coast. The map shows that the majority of animals were stranded along the California coast (64%), compared to Oregon (7%) and Washington (29%). The highest proportion of animals was stranded in central California, and these animals were most commonly sea lions (75%), followed by elephant seals (18%) and harbor seals (7%).

Major causes of mortality for California sea lions (see pie chart) included the bacterial disease leptospirosis (26%), malnutrition (23%), trauma (18%), domoic acid toxicity (11%), and carcinoma (1%). Domoic acid is a biotoxin produced by some marine algae, especially during HABs. This acid binds to receptors in the brain and is responsible for amnesic shellfish poisoning in humans (Teitelbaum et al., 1990). The first UME associated with domoic acid toxicity was documented along the coast of California in 1998 (Scholin et al., 2000). During that year, approximately 400 sea lions died with clinical signs of domoic acid toxicosis. Since 1998, recurrent toxin-producing events have occurred on a regular basis and have affected hundreds of animals. California sea lions are high-level predators that feed on some of the same species (e.g., anchovies, sardines, hake, rockfish, salmon, market squid) that often enter the human seafood market, and the detection of domoic acid in California sea lions dying along California's coast is helping to raise public awareness of the presence of this biotoxin in a variety of seafood species. These concerns are exacerbated by increasing reports of HABs that threaten both human and marine life safety (U.S. Commission on Ocean Policy, 2004b).



Number of live pinniped strandings, 2000 to 2004
(courtesy of NOAA)

Causes of Mortality for California Sea Lions
(courtesy of NOAA)

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 6-19). Puget Sound and a portion of Washington's northwestern coastline are part of the Gulf of Alaska LME, which is discussed in Chapter 8. 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 fish species are Pacific salmon, pelagic (water-column-dwelling) fishes (e.g., Pacific sardine, northern anchovy, jack mackerel, chub Pacific mackerel, Pacific herring) and demersal fish (e.g., Pacific halibut, Dover sole, shortspine thornyhead, longspine thornyhead, sablefish). Shrimp, crab, clam, and abalone have high commercial value (NOAA, 2007g).

Coastal upwelling, El Niño, and the El Niño-Southern Oscillation result in strong interannual variability in the productivity and, consequently, the landings of different species and groups in the California Current LME (NOAA, 2007g). There are major fluctuations in the LME's total landings, ranging from about 100,000 t in 1952 to an historic high of almost 800,000 t in 2000, with decreases in 1984 and 1992 (University of British Columbia, 2007). These forces are believed to be resulting in long-term shifts in abundance levels of both sardines and anchovies. Long-term monitoring data from 1956 to 1980 on zooplankton biomass show evidence of a decline in zooplankton abundance, which is a possible indication of a major oceanic regime shift. There is speculation about the causes of these fluctuations and a need for a better understanding of the climate's role, of seasonal change in the regulation of populations and communities, and of the feedback loops that determine community structure and regulate energy flow and population dynamics (NOAA, 2007g).

Figure 6-19. California Current LME (NOAA, 2007g).

Salmon Fisheries

Pacific salmon in the California Current LME include five species: Chinook, coho, sockeye, pink, and chum salmon. Chinook and coho salmon are harvested recreationally and commercially in the Pacific Ocean, Puget Sound, and freshwater rivers on their spawning migrations. All species are also harvested by Native American tribes for subsistence and ceremonial purposes. From 1995 through 1997, the average annual commercial salmon landings were 13,100 t, providing revenues averaging almost $22 million at dockside. From 2001 through 2003, the annual commercial salmon landings increased to average 19,000 t and provided revenues averaging approximately $26 million at dockside. If recreationally caught fish were valued at a conservative $20/fish, the

2001–2003 average landings of 1.2 million fish would have been worth about $24 million annually. Figure 6-20 demonstrates the changes over time in the landings of Chinook salmon from this LME. For all species, there is excess fishing power on this resource and overcapitalization of the fishing fleets. Although harvest rates in recent years have been held near or below levels that would produce the maximum sustainable yield, environmental conditions in the 1980s and 1990s resulted in generally poor ocean survival rates for Chinook and coho salmon stocks, as well as some individual stocks of the other species (NMFS, In press).

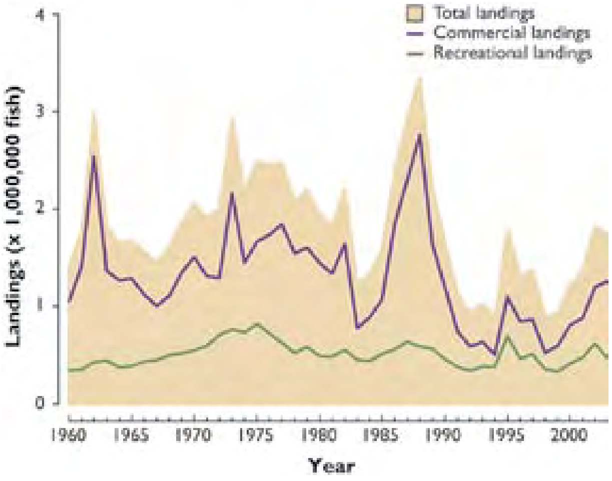


Figure 6-20. Chinook salmon landings in millions of individual fish, 1960–2003 (NMFS, In press).

Following coast-wide status reviews for all species of salmon and anadromous trout, numerous evolutionarily significant units (i.e., population or group of populations that is substantially reproductively isolated and represents an important component in the evolutionary legacy of the species) of all species except pink salmon have been listed as threatened or endangered under the ESA. The management of this resource is complex, involving many stocks originating from various rivers and jurisdictions. Ocean fisheries are managed primarily by gear restrictions, minimum-size limits, and time and area closures, although harvest quotas and cumulative impact quotas have also been placed on individual fisheries in recent years. Pacific salmon in the California Current LME depend on freshwater habitat for the spawning and rearing of juveniles. The quality of freshwater habitat is largely a function of land management practices; therefore, salmon production is heavily influenced by entities not directly involved in the management of fisheries. Salmon management involves the cooperation of the DOI Bureau of Land Management, FWS's Bureau of Reclamation, USACE, EPA, Bonneville Power Administration, state resource agencies, Native American tribes, municipal utility districts, agricultural water districts, private timber companies, and landowners (NMFS, In press).

Ecosystem Considerations

The coho salmon abundance index reached a peak in 1976 and suffered a dramatic decline through the late 1990s. The Chinook salmon abundance index has also generally declined since the mid-1970s, although there was a brief increase in the index during the late 1980s. These declines affected both hatchery and natural stocks and appeared to indicate a period of declining ocean survival. These declines were also coincident with a change in the oceanographic regime off the West Coast that occurred around 1978. Since then, the coastal waters off California, Oregon, and Washington, where many Chinook and coho salmon stocks mature, have been warmer and less productive than they were during the period from 1950 to 1978. The decline in ocean productivity off the Pacific Coast appears to be linked to increased productivity in the Gulf of Alaska LME. The abundance indices of sockeye, pink, and chum salmon, which migrate further offshore than Chinook and coho salmon, were relatively stable or increasing during the same period that Chinook and coho salmon populations declined. For sockeye salmon, Fraser River runs were strong through the mid-1990s, but ocean conditions have caused a large proportion of the fish to migrate north of Vancouver Island, where they are unavailable to U.S. fisheries. In addition, the late run of sockeye salmon has been entering the river as much as six weeks earlier in the year than runs occurring prior to 1996, and early river entry has been associated with high pre-spawning mortality. This phenomenon has concerned fishery managers and resulted in severe restrictions on harvest in sockeye fisheries (NMFS, In press).

Within the past few years, marine conditions again became favorable for Chinook and coho salmon. In 1999, water temperatures were lower

Red sockeye salmon (courtesy of Greg A. Syverson, FWS).

than normal off the coasts of California, Oregon, and Washington. In 2000, the marine plankton assemblages in the Pacific Northwest area shifted from species characteristic of temperate regions to species more characteristic of sub-arctic regions, and baitfish became abundant. Until 2005, marine conditions remained favorable for the growth and survival of all salmon species in the Pacific Northwest; however, California Current LME coho and Chinook salmon landings from the June 2005 surveys were lower than in June 1998, during El Niño (NMFS, In press).

Pacific salmon are particularly vulnerable to habitat degradation because of their dependence on freshwater habitat for spawning and juvenile rearing. 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 compete with salmon for the freshwater on which they depend. As the human population in the western United States continues to increase, so will the pressures on salmon habitat. The continued existence of salmon in harvestable quantities is a tribute to the resilience of these fish (NMFS, In press).

Pelagic Fisheries

Several stocks of small pelagic fish species support fisheries along the California Current LME. The major species are Pacific sardine, northern anchovy, jack mackerel, chub (Pacific) mackerel, and Pacific herring. Sardine, anchovy, and the two mackerels are primarily concentrated and harvested off California and Baja California. Pacific herring are harvested along the West Coast from California to Washington. Populations of these small pelagic fish tend to fluctuate widely (NMFS, In press).

Commercial fishing for small pelagic fish species has a long history in the California Current LME, and sardine and anchovy are the most prominent of these fisheries from an historical perspective. California sardines supported the largest fishery in the western hemisphere during the 1930s and early 1940s, when total landings averaged 500,000 t. The sardine abundance index and landings declined after World War II, and the stock finally collapsed in the late 1950s. In the mid-1940s, U.S. processors began canning anchovy as a substitute for sardine; however, consumer demand for canned anchovy was low, and landings from the mid-1940s to mid-1950s averaged only 20,000 t per year. Landings declined and remained low before starting to increase in 1965 after the sardine collapse. Together with landings from Mexico, the total landings from this LME increased to 250,000 t per year during 1975–1980, but declined thereafter due to significant price reductions for fishmeal. The biomass trend for the anchovy resource hit a peak of 1.6 million t in 1973 and declined steadily to 392,000 t by 1994. Northern anchovy landings in California have fluctuated more in response to market conditions than to stock abundance, and low prices and market problems continue to prevent a significant U.S. reduction fishery (i.e., fishery that reduces the fish caught to meal, oil, and soluble protein) for anchovy. Landings by the United States have varied and have been used mostly for live bait and other non-reduction uses. The current yield for the Unites States is 25,000 t or 30% of the maximum sustainable yield, although recent landings have been much lower (about 8,500 t) due to a lack of commercial markets (NMFS, In press).

All these pelagic fishery resources are currently under management. The well being of ecologically related species in the California Current LME is important in the management of these resources. For example, the endangered brown pelican depends on anchovy as a critical food source, and so to protect the ecological balance, the FMP (PFMC, 1998) has specified a threshold for determining optimum yield that prevents depletion of the anchovy stock and provides adequate forage for marine fishes, mammals, and birds.

Demersal Fish Fisheries

The demersal fish fishery of the California Current LME is conducted along the entire extent of the coastlines of Washington, Oregon, and California and includes a diverse range of habitats and species. The fishery has four sectors: commercial limited entry, commercial open access, recreational, and tribal (NMFS, In press).

In recent years, a number of dramatic changes have occurred in the California Current LME demersal fish fishery. Between 1999 and 2002, nine stocks were declared overfished, and the implementation of rebuilding plans for these stocks have sharply curtailed fishing opportunities for these species and for associated species throughout nearly all sectors of the fishery. As a result, allowable harvests and landings are at or near historical lows for many species. Two of the overfished stocks (Pacific hake and lingcod) have since been declared rebuilt, but rebuilding for many of the other stocks is expected to take decades. In addition to rebuilding plans for the recovery of overfished stocks, many strides have been made to improve management of the demersal fish fishery. These include the completion of a trawl permit buy-back to reduce fishing capacity, implementation of a coast-wide observer program to monitor bycatch, and expansion of demersal fish resource surveys (NMFS, In press; NWFSC, 2006; PFMC, 2006).

In 2003, U.S. commercial landings of California Current LME demersal fish totaled 168,987 t, generating $60.2 million in ex-vessel revenue (amount the commercial fishermen receive from the quantity of fish landed). Pacific hake landings dominate the California Current LME demersal fish landings, accounting for 84% of the fishery's total landed weight in 2003; however, with its low unit value, Pacific hake revenue composed only 29% of the demersal fish fishery's revenue in this LME. The demersal fish fishery's most valuable component is the "Dover sole-shortspine thornyhead-longspine thornyhead-sablefish" complex, which accounted for nearly $29 million, or 48%, of all demersal fish revenue from this LME in 2003. The trawl fleet (including those aimed at Pacific hake) comprises the largest gear component of the fishery, generating 72% of the ex-vessel revenue (NMFS, In press).

Although traditional management measures such as annual catch quotas have been in place for up to 20 years, some demersal fish stocks have declined during that period to less than 25% of their estimated unfished levels. At least three primary factors have contributed to these declines. First, during the 1980s and into the 1990s, little information was available on the life history and productivity of many demersal fish species, and target harvest rates were based upon knowledge of the productivity of other species. This was a reasonable approach in light of the absence of species-specific information, but it turned out that harvest rates were overly optimistic for most of the long-lived, slow-growing rockfishes. Additionally, resource survey information was insufficient to estimate stock abundance indices with adequate precision, and with no observer program in place, there was no way to verify that the total catch, including bycatch, did not exceed the intended level. Finally, a decline in the basic productivity of the California Current LME from 1977 until the late 1990s (including evidence of the decline in zooplankton abundance mentioned earlier and of ocean warming during the late 1970s) coincided with increases in demersal fish harvests in the late 1970s. This decline in productivity likely contributed to the decline in the overall abundance index and recruitment (addition of new generation of young fish) of demersal fish species (NMFS, In press).

Vermilion rockfish, *Sebastes miniatus*, are caught in West Coast waters and have not been singled out for species management (courtesy of Wayne Davis, U.S. EPA Biological Indicators of Watershed Health Photo Library, http://www.epa.gov/bioindicators).

Assessment and Advisory Data

Fish Consumption Advisories

In 2003, 25 fish consumption advisories were in effect for the estuarine and coastal waters of the West Coast region (Figure 6-21). A total of 31% of the estuarine square miles on the West Coast were under advisory in 2003, and all of the estuarine area under advisory was located within the San Francisco Bay/Delta region or within Puget Sound. Only 10% 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 2003 (U.S. EPA, 2004b).

Seventeen different contaminants or groups of contaminants were responsible for West Coast fish advisories in 2003, and 13 of those contaminants were listed only in the waters of Puget Sound and the bays emptying into the Sound. These contaminants were arsenic, chlorinated pesticides, creosote, dioxin, industrial and municipal discharge, metals, multiple contaminants, PAHs, pentachlorophenol, pesticides, tetrachloroethylene (PCE), vinyl chloride, and volatile organic compounds (VOCs). In California, Orgeon, and Washington, PCBs were partly responsible for 71% of advisories (Figure 6-22). DDT was partly responsible for 12 advisories issued in California. Although there were only two advisories issued for mercury on the West Coast, the entire San Francisco Bay was covered by one of these advisories (U.S. EPA, 2004b).

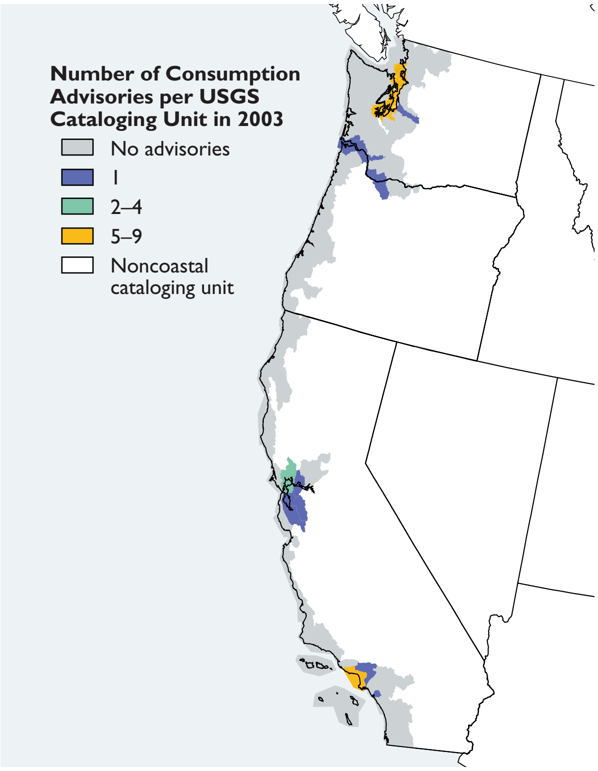


Figure 6-21. The number of fish consumption advisories active in 2003 for the West Coast coastal waters (U.S. EPA, 2004b).

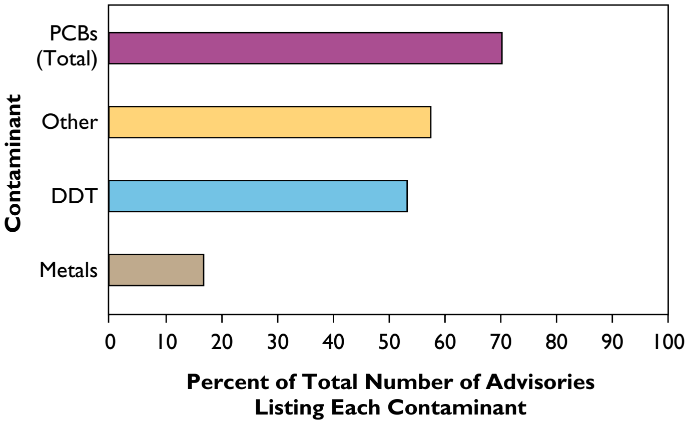


Figure 6-22. Pollutants responsible for fish consumption advisories in West Coast coastal waters. An advisory can be issued for more than one contaminant, so percentages may add up to more than 100 (U.S. EPA, 2004b).

Species and/or groups under fish consumption advisory in 2003 for at least some part of the coastal waters of the West Coast region

All fish
Black croaker
Bivalves
Bullhead
Clams
Corbina
Common carp
Crabs
Gobies
Kelp bass
Largescale sucker
Peamouth chub
Queenfish
Rockfish
Sculpin
Shark
Shellfish
Striped bass
Surfperch
White croaker

Source: U.S. EPA, 2004b

Beach Advisories and Closures

Of the 499 monitored coastal beaches in the West Coast region reported to EPA for 2003, 33.5% (167 beaches) were closed or under an advisory for some period of time during that year. Table 6-1 presents the number of beaches monitored and under advisories or closures for each state. California reported the greatest number of monitored beaches to the EPA survey (430), as well as the most beaches with at least one advisory or closure in 2003 (156). It should be noted that the total number of beaches with advisories and closures may not be indicative of increased health risks to swimmers, but is generally indicative of more intensive bacterial sampling efforts conducted at the surveyed beaches (U.S. EPA, 2006c). Figure 6-23 presents advisory and closure percentages for each county within each state.

Table 6-1. Number of Beaches Monitored and With Advisories/Closures in 2003 for the West Coast States (U.S. EPA, 2006c)

State	No. of Beaches Monitored	No. of Beaches With Advisories/ Closures	Percentage of Beaches Affected by Advisories/ Closures
California	430	156	36.3
Oregon	58	7	12.1
Washington	*11	4	36.4
TOTAL	**499**	**167**	**33.5**

* Washington did not report number of beaches for 2003; therefore, the number of beaches monitored in Washington during 2004 is presented here (U.S. EPA, 2005a).

Most of the advisories implemented on the West Coast were reported as due to elevated bacteria (53%), although many (42%) of the advisories were due to other reasons (Figure 6-24). Most beaches had multiple sources of waterborne bacteria that resulted in advisories or closures. Figure 6-25 shows that unknown sources accounted for 66% of the responses from West Coast beaches (U.S. EPA, 2006c).

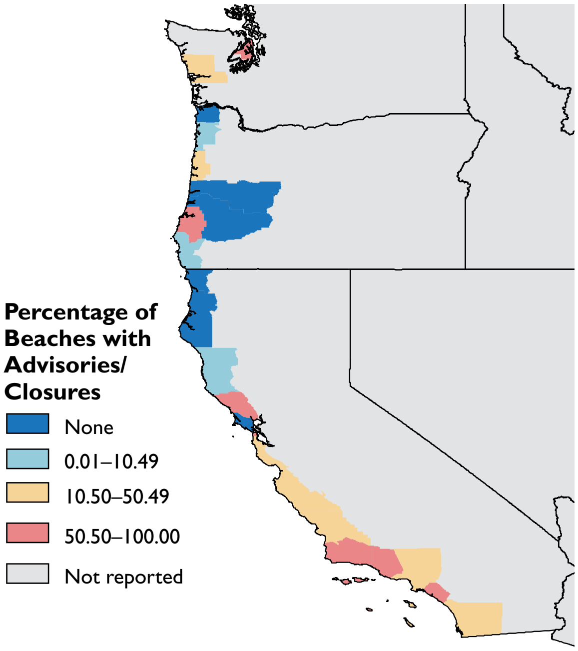


Figure 6-23. Percentage of monitored beaches with advisories or closures, by county, for the West Coast region (U.S. EPA, 2006c).

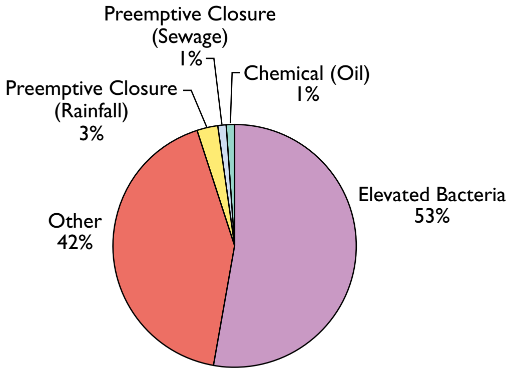


Figure 6-24. Reasons for beach advisories or closures for the West Coast region (U.S. EPA, 2006c).

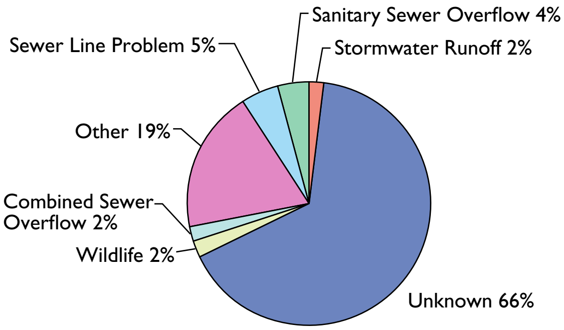


Figure 6-25. Sources of beach contamination resulting in beach advisories or closures for the West Coast region (U.S. EPA, 2006c).

Summary

Based on data from the NCA, the overall condition of West Coast coastal waters is rated fair. Additional benthic community data have become available since the NCCR II and were included in the analysis for this report; other data have been refined. As a result, the overall condition score and the benthic index rating for the West Coast region have changed since the NCCR II, and the percent of coastal area rated good, fair, or poor has been refined for several indices and component indicators.

Currently, NCA data for the West Coast region are only available for 1999 and 2000, and long-term trends in coastal condition cannot be evaluated; however, local monitoring programs have been used to examine long-term trends for several areas of the region. As measured by the PSAMP, no significant changes in the concentrations of most metals and PAHs in the sediments of Puget Sound occurred over time; however, where significant changes were observed, metal concentrations decreased and PAH levels increased. The PSAMP also observed changes in the percent silt over time, and these changes affected Puget Sound's benthic community composition. In San Francisco Bay, levels of DDT in some finfish species have declined over time due to natural environmental variation, although no trends have been observed for PCB or mercury concentrations in finfish. PCB levels in transplanted mussels have decreased in the Bay, and copper concentrations have decreased in water, clams, and sediment. Chlorophyll *a* levels have shown increasing trends in the northern reaches of San Francisco Bay and decreasing trends in the Bay's southern reaches. Since 1970, conditions in the SCB have improved, and levels of organic matter, metals, chlorinated hydrocarbons, and other contaminants have decreased in sediments. Demersal fish and benthic communities have also improved in the region, and DDT and PCB concentrations in fish have decreased.

NOAA's NMFS manages several fisheries in the California Current LME, including salmon, pelagic fish, and demersal fish. Landings of the five species of Pacific salmon within the California Current LME are near or below the maximum sustainable yield, and most of these species are listed as threatened or endangered. Pacific salmon are particularly vulnerable to habitat degradation due to human-induced pressures, such as construction, logging, and urbanization. Ocean conditions in the 1980s and 1990s resulted in decreased abundances of Chinook and coho salmon in this LME. During the same time period, abundances of sockeye, pink, and chum salmon were either stable or increasing. Populations of the small pelagic fish in this LME tend to fluctuate widely, and both anchovy and sardine landings are low due to market constraints. Nine stocks of California Current LME demersal fish were declared overfished between 1999 and 2002, and only two of these stocks are considered rebuilt.

Summary

Contamination in West Coast coastal waters has affected human uses of these waters. In 2003, there were 24 fish consumption advisories in effect along the West Coast, most of which were issued for PCBs contamination. In addition, 33.5% of the region's monitored beaches were closed or under advisory for some period of time during 2003. Elevated bacteria levels in the region's coastal waters were primarily responsible for the beach closures and advisories.

CHAPTER 7

Great Lakes Coastal Condition

Courtesy of Don Breneman, U.S. EPA GLNPO

Great Lakes Coastal Condition

As shown in Figure 7-1, the overall condition of the coastal waters of the Great Lakes region between 2001 and 2002 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 sediment quality index is rated poor, and the coastal habitat and benthic indices are rated fair to 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 2003* (Environment Canada and U.S. EPA, 2003). This report is the fifth biennial report issued jointly by the governments of Canada and the United States. No additional assessment data for the Great Lakes were collected for the 2001–2002 time period since the results presented in NCCR II (U.S. EPA, 2004a); therefore, the condition estimates presented in this chapter remain unchanged from that report. The next *National Coastal Condition Report* (NCCR IV) will present and discuss data presented in the report *State of the Great Lakes 2005* (Environment Canada and U.S. EPA, 2005) to generate updated condition estimates.

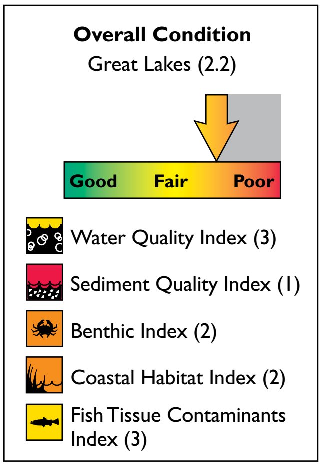


Figure 7-1. The overall condition of Great Lakes coastal waters is rated fair to poor (based on data from Environment Canada and U.S. EPA, 2003).

The 158 coastal counties of the Great Lakes region support a third of the region's population and represent the third-largest coastal population in the nation. The population of Great Lakes coastal counties increased by 6% (1.5 million people) between 1980 and 2003 (Figure 7-2) (Crossett et al., 2004).

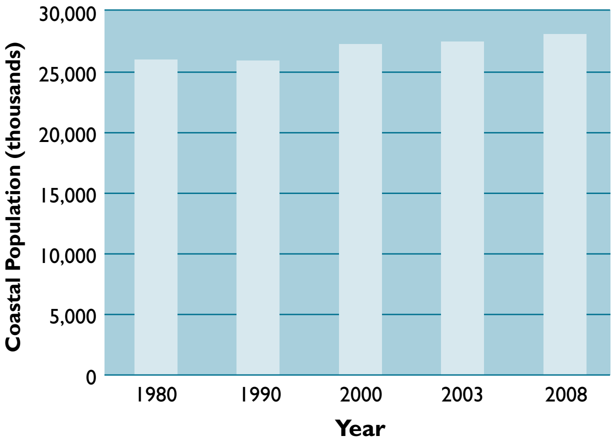


Figure 7-2. Actual and estimated population of coastal counties in the Great Lakes region from 1980 to 2008 (Crossett et al., 2004).

Lake Superior is the largest (in volume), deepest, and coldest of North America's five Great Lakes (courtesy of U.S. EPA GLNPO).

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 (see Appendix A). 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 were used to quantify and categorize NCA indices and component indicators for the Great Lakes in the NCCR II 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.

Water Quality Index

The NCCR II assessment combined several SOLEC indicators (e.g., eutrophic condition, water clarity, dissolved oxygen levels, phosphorus concentrations) into a water quality index to allow for comparison of water quality condition estimates for the Great Lakes with the NCA water quality index for U.S. marine coastal waters. The NCCR II rated the Great Lakes water quality as fair. Of the four SOLEC indicators used to develop the water quality index, eutrophic condition was rated fair to poor, phosphorus concentrations were rated fair, water clarity was rated good to fair, and dissolved oxygen concentrations were 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.

The Great Lakes region hosts the third-largest coastal population in the nation (courtesy of U.S. EPA GLNPO).

Highlight

International Field Years on Lake Erie (IFYLE) Program

One of NOAA's long-term goals is to provide enhanced ecosystem forecasts that predict patterns of biological, physical, and chemical variables in response to natural- and human-induced changes to the system across a variety of spatial and temporal scales. These changes may include extreme natural events, climate change, land and resource use, pollution, invasive species, and fisheries impacts. Ecosystem forecasts ultimately should benefit coastal communities, including those along the Great Lakes, by providing the foundation for the following:

- Improved decision-making for resource stewardship
- Mitigation of potentially hazardous human activities
- Reduced impacts of natural hazards
- Enhanced communication between scientists and managers
- More effective prioritization of science.

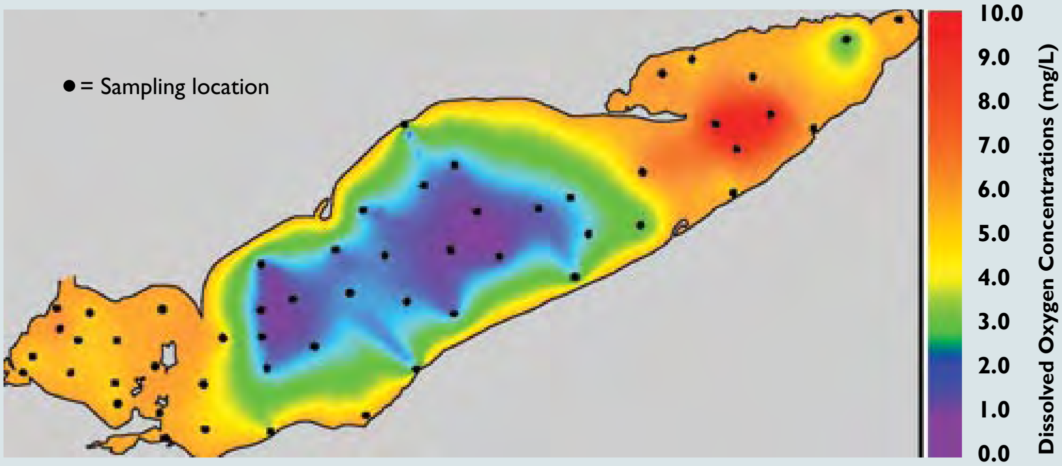
Some of the water quality and ecosystem health issues that persist within the Great Lakes are of concern to the user community and researchers and remain a challenge to Great Lakes resource management. These issues include, but are not limited to, HABs, reduced oxygen availability (hypoxia/anoxia), and the introduction of exotic species. All of these issues have the potential to negatively influence food web dynamics, native biodiversity, and biological production (e.g., fisheries yield). The development of tools to provide reliable forecasts of the Great Lakes ecosystem and its chemical, biological, and physical subsystems would help resource agencies choose among potential management options (NOAA, 2006a).

To improve the ability to provide reliable ecosystem forecasts in the Great Lakes, the NOAA Great Lakes Environmental Research Laboratory (GLERL) has been working toward development of an integrated (multi-agency), multidisciplinary research program for Lake Erie to deal with these important management issues. Lake Erie is an ideal candidate for a pilot ecosystem-forecasting framework development effort. It is small in size relative to coastal marine systems and the other Great Lakes; therefore, cost-effective field sampling can be performed to test hypotheses over the entire lake. A wealth of historical monitoring and research data has been compiled for this system and is available to use for model parameterization/calibration, validation, and ecological scenario testing. In addition, several predictive physical models (e.g., watershed-hydrology models, hydrodynamics models) already exist for Lake Erie. Finally, a large research and policy infrastructure (e.g., Lake Erie Millennium Network, Lake Erie Lakewide Management Plan) already exists and will facilitate efforts to develop truly integrative, multidisciplinary programs aimed at conducting the needed research for ecosystem forecasting (NOAA, 2006a).

This effort to develop a large-scale, integrative research program on Lake Erie began in 2005 with ship support from NOAA and the initiation of the International Field Years on Lake Erie (IFYLE) Program (NOAA, 2007f). This program is based largely on the research hypotheses, ideas, and needs that were generated at a large, international Lake Erie Science Planning Workshop that was hosted by NOAA–GLERL on March 4–5, 2004 (NOAA, 2004a). The three primary objectives of the IFYLE program are the following:

- To quantify the spatial extent of hypoxia across the lake and gather information that can help forecast its timing, duration, and extent

- To assess the ecological consequences of hypoxia to the Lake Erie food web, including the impacts on bacteria, phytoplankton, microzooplankton, mesozooplankton, and fish
- To identify factors that control the timing, extent, and duration of HABs (including toxin formation) in Lake Erie, as well as enhance our ability to use remote sensing as a tool to rapidly map HAB distributions in the lake (NOAA, 2007f).



Preliminary estimation of dissolved oxygen concentrations (mg/L) in Lake Erie bottom waters during September 2005 (courtesy of GLERL, NOAA).

The IFYLE program has become one of the largest international, multidisciplinary research efforts of its kind in Lake Erie's history, costing approximately $5 million and involving about 40 scientists from NOAA, academia, and private institutions throughout North America, Canada, and Europe (NOAA, 2007f). This program can truly be considered integrative, given involvement by numerous U.S. and Canadian universities and federal, state, and provincial agencies. The IFYLE serves as an example of how NOAA and other federal agencies are fulfilling the Presidential Executive Order 13340 (Bush, 2004) to execute the Great Lakes Regional Collaboration among agencies, including NOAA's ship support, EPA GLNPO, NOAA GLERL, the National Sea Grant College Program, the Ohio and New York Sea Grant College programs, Environment Canada, USACE, Ohio DNR, New York State Department of Environmental Conservation (DEC), Michigan DNR, Pennsylvania Fish and Boat Commission, and the Ontario Ministry of Natural Resources (NOAA, 2006a).

The 2005 field program centered on determining the factors regulating the distribution of oxygen concentrations in Lake Erie (see map) and the consequences of low oxygen on the abundance, distribution, and condition of fish and their prey. The remainder of 2005 and all of 2006 were devoted to sample processing, data analysis, testing and refining hypotheses, and building models that can be used for both understanding and forecasting purposes. During 2007, another intensive field season with more focused sampling objectives was conducted (NOAA, 2006a).

For additional information on the IFYLE program, see http://www.glerl.noaa.gov/ifyle or contact Dr. Stuart A. Ludsin (Stuart.Ludsin@noaa.gov) and Dr. Stephen B. Brandt (Stephen.B.Brandt@noaa.gov), co-coordinators of the IFYLE program, Ann Arbor, MI.

Sediment Quality Index

The NCCR II assessment 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 is rated poor, with sediment contamination contributing to the poor condition assessed in many harbors and tributaries and affecting the beneficial uses at all 31 of the U.S. and binational Great Lakes Areas of Concern (AOCs) throughout the region (Figure 7-3). 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-resuspension activities (Environment Canada and U.S. EPA, 2003).

Benthic Index

The benthic condition of the Great Lakes, as measured by benthic community health, was rated fair to poor in the NCCR II. 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 heath because of their importance at the base of the Great Lakes food web (Figure 7-4).

Coastal Habitat Index

More than one-half of the Great Lakes coastal wetlands were lost between 1780 and 1980, with the largest losses in Ohio (90%) and the smallest in Minnesota (42%) (Figure 7-5). The coastal habitat index used to assess the condition of Great Lakes wetland condition in the NCCR II was based on amphibian abundance and diversity, wetland-dependant bird diversity and abundance, the areal extent of coastal wetlands by type, and the effects of water level fluctuations. Based on these measures, the coastal habitat index for the Great Lakes region is rated fair to poor.

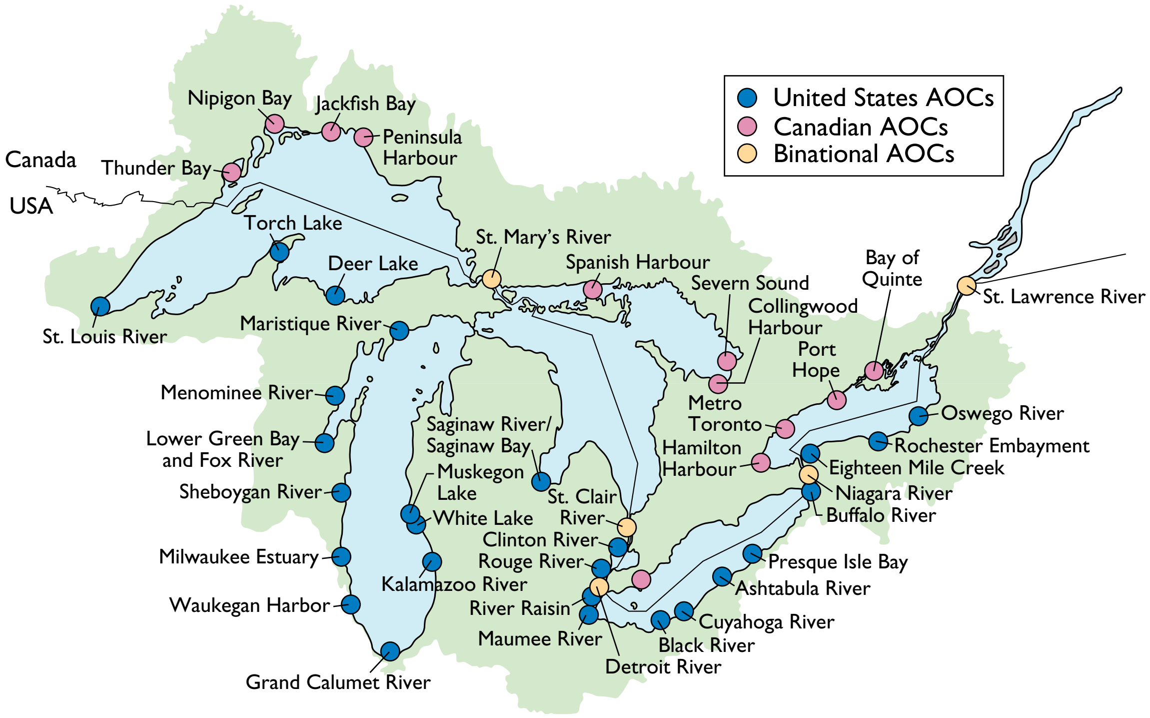


Figure 7-3. Great Lakes Areas of Concern (AOCs) (U.S. EPA, 2007c).

Highlight

Residual Ballast Water and Sediments Pose Aquatic Nuisance Species Threats to the Great Lakes Ecosystem

A 3-year, multi-institutional study (Johengen et al., 2005) completed in 2005 characterized a previously overlooked threat of nonindigenous aquatic species introductions by foreign commercial shipping into the Great Lakes ecosystem. The study was funded by the Great Lakes Protection Fund, NOAA, EPA, and the U.S. Coast Guard. The study examined both types of ballast-related threats to the Great Lakes: the regulated discharge of ballast water from vessels entering the Great Lakes from foreign ports, and the unregulated discharge from vessels that enter the Great Lakes with no ballast on board (NOBOB). The project team included scientists from NOAA, the University of Michigan, the University of Windsor (Canada), Old Dominion University, and the Smithsonian Institution, as well as a ship-operations expert (Philip T. Jenkins and Associates, Ltd.) from Canada.

During the study (Johengen et al., 2005), researchers found small bivalves, including zebra mussels such as those shown above, in the residual ballast sediment from several ships; however, the frequency and abundance of these bivalves was generally low overall (courtesy of the University of Michigan, Center for Great Lakes and Aquatic Sciences and the U.S. EPA GLNPO).

NOBOB vessels are ships loaded to capacity with cargo and therefore carry no declarable ballast on board; however, these empty ballast tanks may hold residual water and sediment containing live organisms, their resting stages, and microorganisms, including human pathogens. Once in the lakes, NOBOB vessels have to ballast with Great Lakes water as they offload cargo, allowing the water to mix with the foreign residuals in the ballast tanks. As outbound cargo is subsequently loaded onto these ships, the mixed ballast water containing the foreign residuals will be discharged. Ballast operations often occur at multiple ports within the Lakes during any single overseas ship transit, providing several opportunities for foreign organisms to be discharged. On average, about 90% of ocean-going ships entering the Great Lakes are NOBOBs (Transport Canada, 2007) and are thus not covered by the ballast water exchange regulations implemented in 1993 by the U.S. Coast Guard (58 FR 18330). These regulations require that pumpable ballast water from foreign sources must be exchanged with open-ocean water and have a salinity exceeding 30 ppt.

The results of three ballast water exchange experiments conducted within this study demonstrated that exchange can be highly effective in reducing the concentration of organisms entrained with coastal ballast water. Comparison across target taxa indicates that, in most cases, ballast water exchange efficacy was > 90%. Results of experiments to determine the additional benefits of "salinity shock" (i.e., replacing low salinity or freshwater ballast taken on in-port with open-ocean seawater) were highly variable, depending on taxa and the form in which they are found in ballast tanks, and should be regarded with caution. The study concluded that ballast water exchange is an imperfect, but generally beneficial management practice in the absence of more effective and consistent treatment options (Johengen et al., 2005).

Ballast sampling includes collection of water and sediment samples to examine the diverse collection of phytoplankton and other invertebrate fauna (courtesy of NOAA Great Lakes NOBOB Assessment Program).

In another study, the team surveyed 103 NOBOB vessels about their ballast management practices and boarded 42 of those vessels to enter and sample residual water and sediment in 82 ballast tanks (see photo). About one-third of the 103 surveyed vessels entered the Great Lakes with freshwater residual ballast. Ships in this condition present the most serious threat of inoculation of new freshwater organisms into the Great Lakes ecosystem. The survey found the total amount of residuals (water plus sediment) per ship ranged from negligible to 200 t, with sediment accumulation generally averaging between 10–15 t (Johengen et al., 2005).

Microbial pathogens and a diverse assemblage of phytoplanton and invertebrate biota, including several species not indigenous to the Great Lakes, were found in the residual ballast water and sediments sampled. The presence of one or more microbial pathogens was detected in 26 of the 42 ships sampled, but the research method only determined presence, not absolute concentrations, so the study cannot definitively assign a human health risk. More than 80% of the samples produced significant phytoplankton growth when inoculated in freshwater media. From these grow-out experiments, 41 nonindigenous taxa were reported, although concentrations tended to be < 5% of the total in most trials. The density of invertebrate resting stages in ship sediments was also examined. Seventy-six distinct taxa were hatched and identified from resting eggs separated from sediment residuals, including 21 nonindigenous species (Johengen et al., 2005).

The study concluded that results of the microbial, phytoplankton, and invertebrate analyses confirm that NOBOB vessels are vectors for the introduction of nonindigenous species to the Great Lakes Basin. Several lines of evidence indicated a decrease in organism abundance in ballast residuals with increasing salinity of residual water and/or flushing with open-ocean water. In addition, tanks that were regularly flushed with small amounts of open-ocean water had, in general, accumulated or retained less sediment. These findings suggest that regular flushing of the tanks with seawater may reduce (but not eliminate) the invasion risk associated with residual ballast material in NOBOB ballast tanks (Johengen et al., 2005). In 2005, the U.S. Coast Guard issued a new policy asking NOBOB vessels entering the Great Lakes to take steps as appropriate to increase the salinity of their residual ballast water to > 30 ppt by saltwater flushing, if not by ballast water exchange (70 FR 51831). In 2006, Canada began enforcing new regulations that all water in ballast tanks of ships arriving from overseas (including the residual water in NOBOBs) must have a salinity > 20 ppt, achieved by ballast water exchange or saltwater flushing, in order for those ships to discharge their ballast water in the Great Lakes (SOR/2006-129 pursuant to section 657.1 of the Canada Shipping Act).

Although the study provided a more comprehensive scientific basis for developing new policies and for identifying possible preventive measures and treatments, the authors recognized that managing the risk posed by NOBOB vessels is a complex problem, and they suggested that such policies and solutions are best developed by participation and cooperation among all involved constituencies, including regulatory agencies, the scientific community, the shipping industry, and the public. New regulations must be carefully considered and constructed to be practicable, enforceable, and verifiable, or they are likely to be ineffective (Johengen et al., 2005).

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 current report; therefore, the analysis of trends in environmental condition estimates for the Great Lakes cannot be made at this time.

Assessment and 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, the 8 states bordering the Great Lakes had a total of 30 fish consumption advisories in effect during 2003 for the waters and connecting waters of the Great Lakes. During 2003, every Great Lake had at least one advisory, and advisories covered 100% of the Great Lakes shoreline that year (Figure 7-6). Michigan, which borders four of the five Great Lakes and encompasses four of the six connecting waterbodies, issued the largest number of fish consumption advisories (13) (U.S. EPA, 2004b).

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 (50%) also listed dioxins (Figure 7-7). Lake Superior, Lake Michigan, and Lake Huron were under advisory for at least four pollutants each in 2003 (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, 2004b).

Fishing from shore (courtesy of U.S. EPA GLNPO).

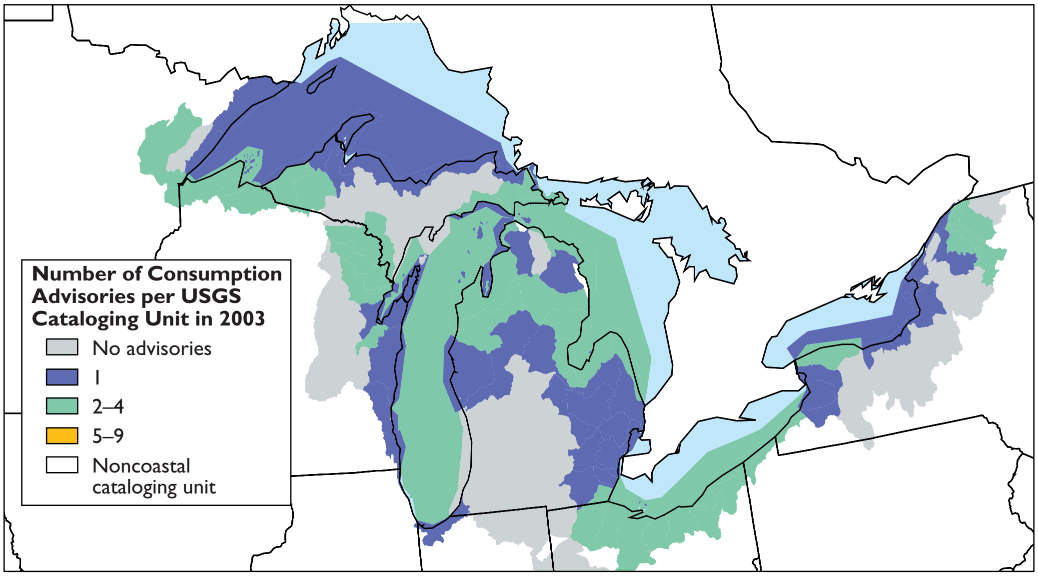


Figure 7-6. The number of fish consumption advisories in effect in 2003 for the U.S. Great Lakes waters (U.S. EPA, 2004b).

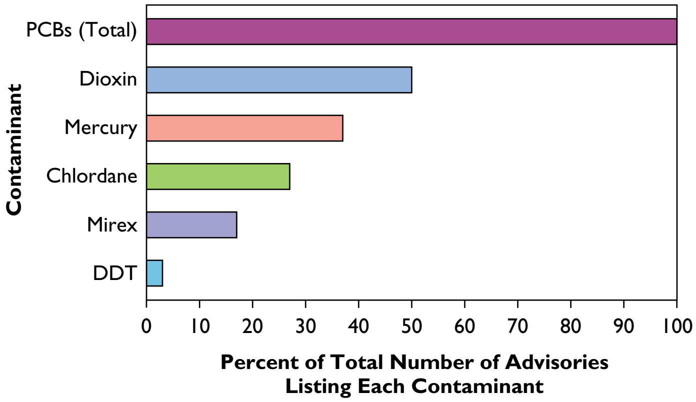


Figure 7-7. Pollutants responsible for fish consumption advisories in Great Lakes waters. An advisory can be issued for more than one contaminant, so percentages may add up to more than 100 (U.S. EPA, 2004b).

The Great Lakes have a long history of fishing activity, as shown by this 130-year old commercial fishing village in Leland, MI (courtesy of the Michigan Travel Bureau and U.S. EPA GLNPO).

Table 7-1. Fish Advisories Issued for Contaminants in Each of the Great Lakes (U.S. EPA, 2004b)

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

Species and/or groups under fish consumption advisory in 2003 for at least one of the Great Lakes or their connecting waters:

American eel
Black crappie
Bloater
Blue catfish
Bluegill sunfish
Bowfin
Brook trout
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 hogsucker
Northern pike
Pink salmon
Quillback carpsucker
Rainbow trout
Rock bass
Round goby
Silver redhorse
Siscowet trout
Smallmouth bass
Smelt
Splake trout
Steelhead trout
Walleye
White bass
White perch
White sucker
Yellow perch

Source: U.S. EPA, 2004b.

Beach Advisories and Closures

Of the 533 Great Lakes coastal beaches reported to EPA, about 33.6% (179 beaches) were closed or under an advisory for some period of time in 2003. Table 7-2 presents the number of beaches monitored and the number of beaches that were closed or under advisory for each state.

The highest percentage of beaches closed or under advisory occurred in Ohio, with 100% of monitored beaches reporting at least one public beach notification in 2003. Pennsylvania did not report the number beaches monitored or advisories/closures issued in 2003. Figure 7-8 presents advisory and closure percentages for each county within each state (U.S. EPA, 2006c).

Table 7-2. Number of Beaches Monitored and Beaches With Advisories/Closures in 2003 for Great Lakes Coastal States (U.S. EPA, 2006c)

State	No. of Beaches Monitored	No. of Beaches With Advisories/Closures	Percentage of Beaches Affected by Advisories/Closures
Minnesota	27	5	18.5
Wisconsin	111	76	68.5
Illinois	46	33	71.7
Indiana	25	18	72.0
Michigan	276	10	3.6
Ohio	20	20	100
Pennsylvania	Not reported	Not reported	Not reported
New York	28	17	60.7
TOTALS	**533**	**179**	**33.6**

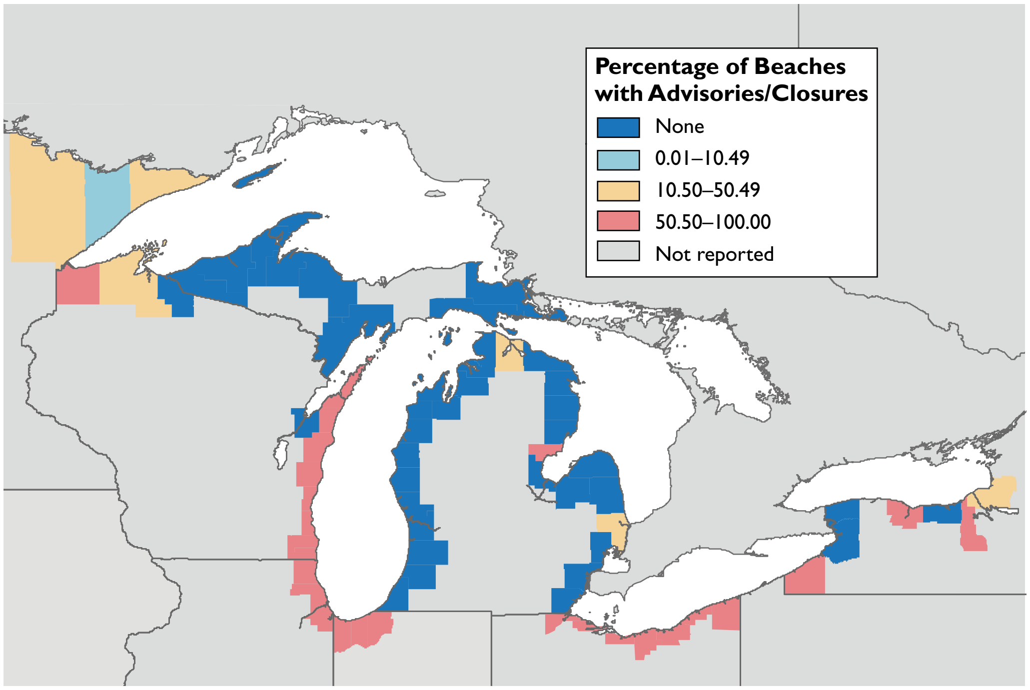


Figure 7-8. Percentage of monitored beaches with advisories or closures, by county, for the Great Lakes region (U.S. EPA, 2006c).

Most beach advisories and closures were implemented at coastal beaches along the Great Lakes because of elevated bacteria levels (Figure 7-9). Some beaches had multiple sources of waterborne bacteria that resulted in advisories or closures. Figure 7-10 shows that unknown sources accounted for 89% of the responses (U.S. EPA, 2006c).

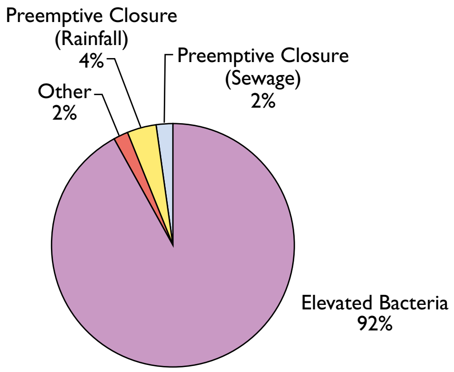


Figure 7-9. Reasons for beach advisories or closures for the Great Lakes region (U.S. EPA, 2006c).

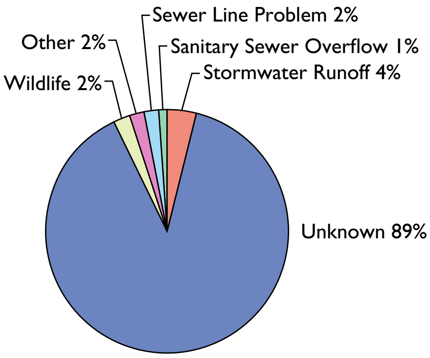


Figure 7-10. Sources of beach contamination resulting in beach advisories or closures for the Great Lakes region (U.S. EPA, 2006c).

Lake Michigan beach near Elberta, MI (courtesy of the Michigan Travel Bureau and U.S. EPA GLNPO).

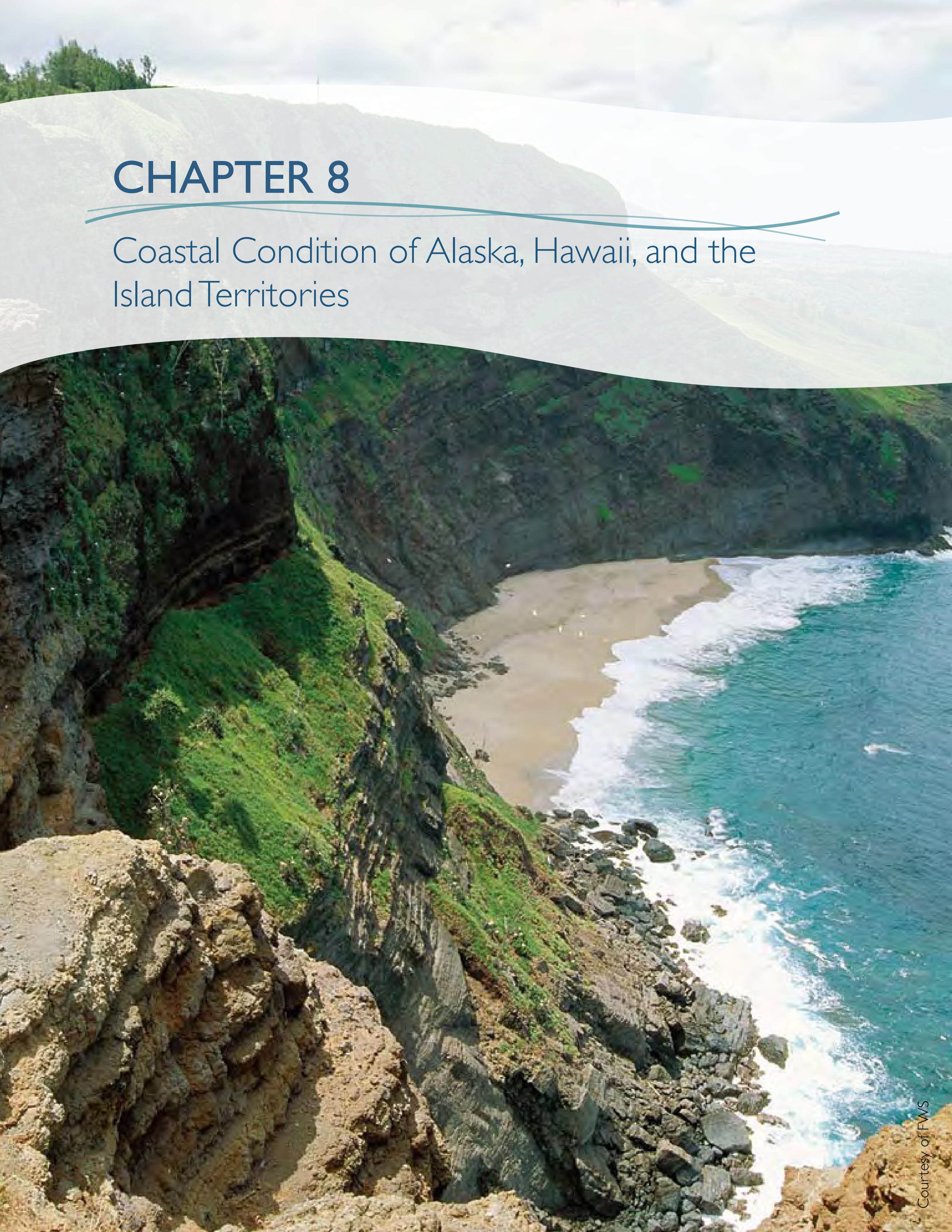
Summary

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, 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 reports in the NCCR series will use the NCCR I and subsequent reports 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.

Contamination in the Great Lakes has affected human uses of these waters. In 2003, there were 30 fish consumption advisories covering 100% of the shoreline of the Great Lakes. All of these advisories were issued for PCB contamination (alone or in conjunction with other contaminants). In addition, 33.6% of the region's monitored beaches were closed or under advisory for some period of time during 2003. Elevated bacteria levels in the region's coastal waters were primarily responsible for the beach closures and advisories.

CHAPTER 8

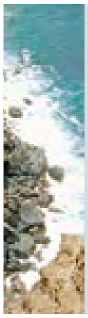
Coastal Condition of Alaska, Hawaii, and the Island Territories



Courtesy of FWS

Coastal Condition of Alaska, Hawaii, and the Island Territories

Currently, very little routine monitoring of coastal resources occurs in Alaska, Hawaii, and the island territories of the Pacific or Caribbean regions. EPA Regions 2 (Puerto Rico and U.S. Virgin Islands), 9 (Hawaii, Guam, the Northern Mariana Islands, and American Samoa), and 10 (Alaska), as well as the attendant state natural resource agencies, conduct some water quality monitoring, but it is often irregular and focused on specific locations or site-specific pollution problems. No consistent monitoring programs cover all of the coastal resources in these states, territories, and commonwealths. Efforts conducted through EPA's NCA are starting to fill this void for Alaska (ongoing), Hawaii, Puerto Rico, the U.S. Virgin Islands, Guam, and American Samoa; however, no plans are currently in place to survey conditions associated with the Northern Mariana Islands. This chapter briefly describes the surveys and presents the assessment findings from monitoring conducted in Southcentral Alaska and Hawaii during 2002. The southeastern region of Alaska was surveyed in 2004, and an assessment of the vast Aleutian Islands region of Alaska began in the summer of 2006, with field work completed during the summer of 2007. Puerto Rico, the U.S. Virgin Islands, Guam, and American Samoa were assessed in 2004–2005, and Hawaii was resurveyed in 2006; however, the results of these assessments were not available for inclusion in this report.



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

Alaska

The overall condition of Southcentral Alaska's coastal waters is rated good, based on three of the indices assessed by the NCA (Figure 8-1). The water quality, sediment quality, and fish tissue contaminants indices for Southcentral Alaska are each rated good, and the NCA was unable to evaluate the benthic and coastal habitat indices for this region. Figure 8-2 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 from 55 locations along Southcentral Alaska's coastline in 2002. Please refer to Chapter 1 for information about how these assessments were made, the criteria used to develop the rating for each index and component indicator, and limitations of the available data.

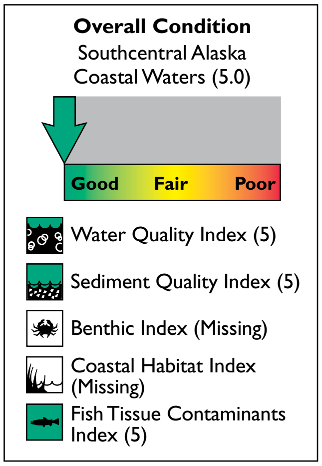


Figure 8-1. The overall condition of Southcentral Alaska's coastal waters is rated good (U.S. EPA/NCA).

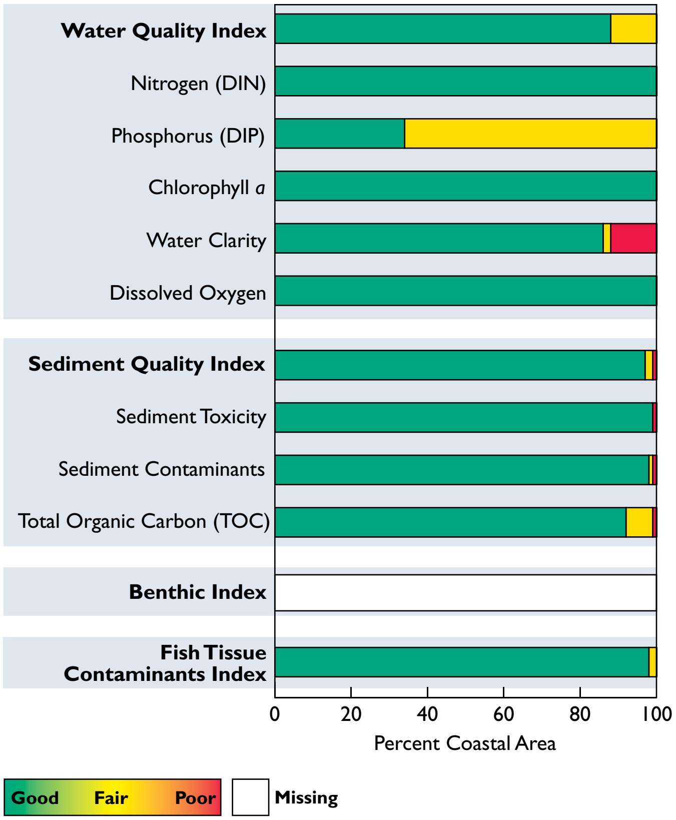


Figure 8-2. Percentage of coastal area achieving each ranking for all indices and component indicators–Southcentral Alaska (U.S. EPA/NCA).

Alaska has a marine shoreline length of approximately 45,000 miles, constituting more than 50% of total U.S. coastline miles. The surface area of coastal bays and estuaries in Alaska is 33,211 mi^2. Much of the southeast and southcentral coast of Alaska is very convoluted, and contains of hundreds of bays, estuaries, coves, fjords, and other coastal features. In addition, most of Alaska's extensive coastline is inaccessible by road, which makes a statewide coastal monitoring program both extremely difficult and expensive.

Alaska's coastal resources are often thought to be in pristine or near-pristine condition due to Alaska's low population density, the distance between most of its coastline and major urban or industrial areas, and the state's limited agriculture activities. Some contaminant concentrations have indeed been measured as having levels significantly lower than those in the rest of the coastal United States. For example, recent sampling of both commercial and subsistence fish for contaminants by the Alaska Department of Environmental Conservation (DEC) showed that organochlorine levels are very low (Alaska DEC, 2007). However, contaminants such as persistent organic pollutants (POPs) and mercury have been observed accumulating in the Alaska marine food web, raising ecological and human health concerns (AMAP, 2004a; 2004b). In a recent report, POPs were identified as a particular concern in Alaska, in part because of the subsistence lifestyle of many Native Alaskan communities (Chary, 2000).

Although localized pollution sources exist in Alaska, long-range atmospheric and oceanic transport from more-developed population and industrial centers are believed to be responsible for the majority of the contaminants deposited in Alaska. In addition, the state's coastal environment may represent long-term sinks for POPs and mercury due to the processes of cold condensation and the polar solar sunrise effect (AMAP, 2004a; 2004b). For example, even though this region has a low human population density, Steller sea lions and sea otters in the Aleutian Islands exhibit high levels of POPs and methylmercury than do specimens from other regions, such as California and southeastern Alaska (Bacon et al., 1999; Barron et al., 2003). Overall, the Arctic, including Alaska's coastal arctic region, is now seen as a potential sink for significant amounts of bioavailable mercury (Ebinghaus et al., 2004). Rapid economic development in Asia coupled with the long-range atmospheric transport of contaminants suggests the potential for increasing levels of some contaminants in Alaska (Wright et al., 2000; AMAP, 2004a; 2004b).

Prince William Sound, AK (courtesy of Commander John Bortniak, NOAA).

Between 1980 and 2003, coastal counties along the Alaskan Coast showed the largest rate of population increase (63%) of any coastal region in the entire United States. In addition, the population of Matanuska-Susitna County grew by more than 200%, which was the third-largest population change in the nation over that period of time. Figure 8-3 presents population data for Alaskan coastal counties since 1980 (Crossett et al., 2004).

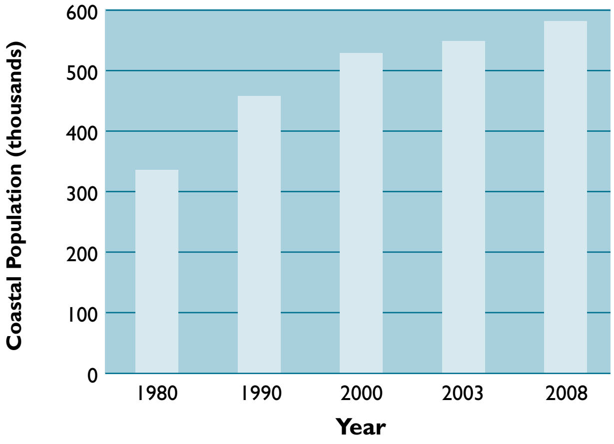


Figure 8-3. Actual and estimated population of coastal counties in Alaska from 1980 to 2008 (Crossett et al., 2004).

Coastal Monitoring Data—Status of Coastal Condition

In 2001, the NCA developed a sampling design in conjunction with the Alaska DEC and EPA Region 10 to assess all of the coastal resources in Alaska by monitoring 250 sites spread throughout the state. Because of the geographic expanse of Alaska, the reduced sampling window in Arctic regions, and the unique fiscal and logistical challenges of sampling the state's coastal resources, it was not feasible to survey the entire state at a single point in time. The NCA, EPA Region 10, Alaska DEC, and other state natural resource agencies determined that the sampling design for Alaska would be executed in five phases—Southcentral Alaska, Southeastern Alaska, the Aleutian Islands, the Bering Sea, and the Beaufort Sea (Figure 8-4). Each sampling phase surveys one of these five areas, and the target schedule for the completion of statewide surveys is 5 to 10 years. Before this collaboration between Alaska's resource agencies and EPA, the Alaska DEC routinely assessed only about 1% of the state's coastal resources, focusing its efforts on waterbodies known or suspected to be impaired (Alaska DEC, 1999). In June 2005, the Alaska DEC released its *Water Quality Monitoring*

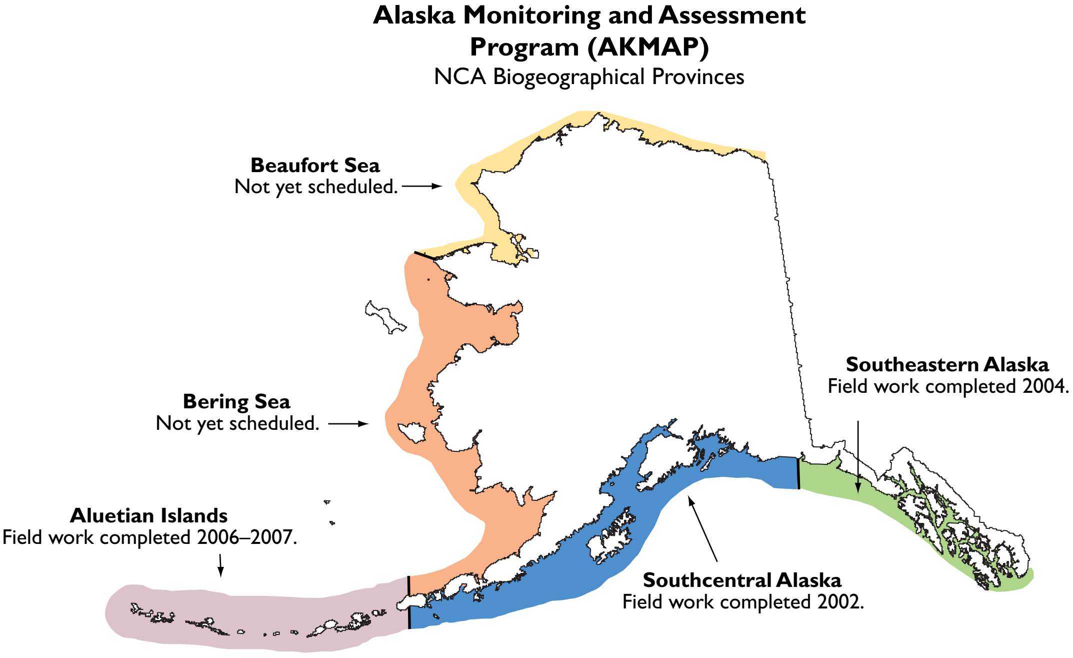
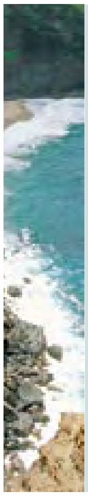


Figure 8-4. Five Alaskan provinces used in the NCA sampling design (Alaska DEC, Division of Water).

and Assessment Strategy and *Environmental Monitoring & Assessment Program Implementation Strategy* to guide its stewardship of Alaska's marine and freshwater resources (Alaska DEC, 2005b; 2005a).

In 2002, Alaska's southcentral coast (Alaskan Province) was selected as the first portion of the state to be assessed by the NCA because of the importance of this area's major estuarine resources (Prince William Sound and Cook Inlet) to aquatic living resources and to local and state economies. Due to the long distances between sites (even in this reduced area), the surveys were conducted using a large (100-foot), ocean-going research vessel equipped with a powered skiff for shallow-water work. The survey collected data at sites with approximate depths ranging from 13 to 1,155 feet. Many of the shallowest stations occurred in nearshore areas of Cook Inlet, which is known for wide intertidal depth fluctuations and extensive sediment depositional zones. The deepest stations were located in Prince William Sound. A report on the 2002 sampling effort in southcentral Alaska was produced by Alaska DEC (Saupe et al., 2005).

The environmental index and component indicator data collected during the survey of the southcentral region correspond to the parameters that will be collected in future surveys of the other regions. Alaska's southeastern coast (Juneau and the island passage area) was assessed by NCA in 2004, and a draft report on the results of this survey will be produced in 2008.



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.

Water Quality Index

The water quality index for the coastal waters of Southcentral 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 (88%) of the coastal area was rated good for water quality condition, with the remainder of the area rated fair (Figure 8-5). Fair conditions were largely due to elevated DIP concentrations or low water clarity measurements, both of which are likely the result of naturally occurring conditions and not human influences.

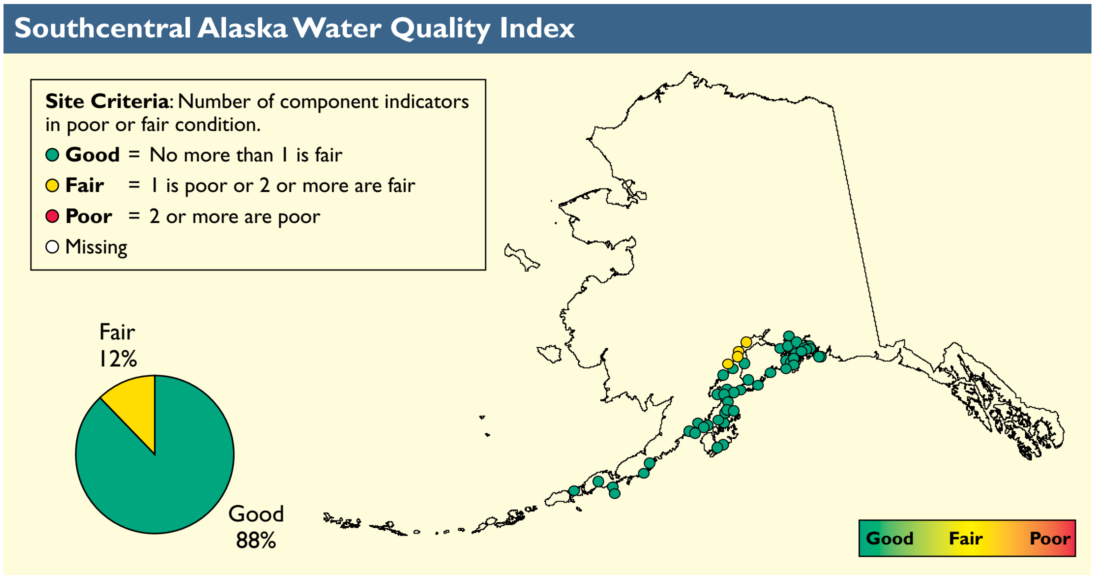


Figure 8-5. Water quality index data for Southcentral Alaska's coastal waters (U.S. EPA/NCA).

Nutrients: Nitrogen and Phosphorus

DIN concentrations in the coastal waters of Southcentral Alaska are rated good, with 100% of the coastal area rated good for this component indicator. DIP concentrations are rated fair for Southcentral Alaska's coastal waters, with 66% of the coastal area rated fair. The DIP levels may be of natural origin, based on historic data that suggest that seasonal upwelling brings in deeper, DIP-rich Gulf of Alaska waters into the lower waters of Cook Inlet. This seasonal supply of nutrients may account for the high productivity rates measured in late summer, which result in some of the most productive high-latitude shelf waters in the world (Larrance et al., 1977; Sambrotto and Lorenzen, 1986).

Chlorophyll a

Chlorophyll *a* concentrations in Southcentral Alaska's coastal waters are rated good, with 100% of the coastal area rated good for this component indicator. Although no areas of Southcentral Alaska showed high concentrations of water column chlorophyll *a*, this may not indicate low, land-based loadings of nitrogen and phosphorus. Many Alaskan waters have large intertidal areas, so nutrient utilization by benthic algae may be of greater importance than nutrient uptake by phytoplankton; however, data are not currently available to address this issue.

Water Clarity

Water clarity in the coastal waters of Southcentral Alaska is rated fair, with 12% of the coastal area rated 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. The coastal area rated poor represents only four sites, which were located in the Upper Cook Inlet area. At these sites, very high loadings of glacial river sediments occur during the summer peak-flow period. Three of the area's primary glacial rivers (the Knik, Matanuska, and Susitna rivers) have a combined peak discharge of about 24 million gallons/second in July and August and contribute, on average, more than 250,000 pounds of suspended sediment per day to Upper Cook Inlet (MMS, 1995). These waters then mix with the more saline waters in Cook Inlet and flow along the western edge of the Inlet to the Shelikof Strait. Thus, the low levels of light penetration observed at the four sampling sites are indicative of naturally occurring conditions representing summer high-flow inputs of suspended sediments at the time of sampling. During the period of low flow in the winter, glacial river inputs and suspended sediment loadings significantly decrease. In addition, the large tidal amplitude occurring along the Southcentral Alaska coast may contribute to the re-suspension of deposited glacial river sediments.

Dissolved Oxygen

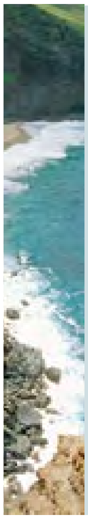
Dissolved oxygen conditions in the coastal waters of Southcentral Alaska are rated good, with 100% of the coastal area rated good for this component indicator. Although conditions in the Southcentral Alaska region appear to be generally good for dissolved oxygen, measured values reflect daytime conditions, and it is possible that some areas may still experience hypoxic conditions at night.

Sediment Quality Index

The sediment quality index for the coastal waters of Southcentral Alaska is rated good, with only 1% of the coastal area rated poor (Figure 8-6). The sediment quality index was calculated based on measurements of three component indicators: sediment toxicity, sediment contaminants, and sediment TOC. There were very few instances where any of the component indicators were rated either fair or poor.

Sediment Toxicity

Sediment toxicity for Southcentral Alaska's coastal waters is rated good, with only 1% 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 Southcentral Alaska. The State of Alaska has yet to select specific benthic species for use in sediment toxicity studies, but considers the EMAP work important in supporting future efforts to develop a sediment toxicity test for Alaska. One of the sites rated poor for sediment toxicity also had the highest chromium and nickel concentrations of any of the sites sampled in Southcentral Alaska during this survey. These trace metals are likely elevated due to the historic chromium-mining operations in the vicinity of this site. The other site rated poor for sediment toxicity exhibited the highest percent TOC measurement (6.43%) of any NCA site sampled in Southcentral Alaska. These elevated TOC measurements were influenced by the large amount of decomposing eelgrass mixed in with this sediment sample. Elevated trace metal and TOC levels have been shown to be detrimental to some benthic organisms.



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 Southcentral Alaska are rated good for sediment contaminant concentrations, with 1% of the coastal area rated poor and 2% of the area rated fair for this component indicator. 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 Southcentral 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. The site rated poor was located in Chrome Bay and exhibited elevated levels of chromium. The site rated fair was located in Prince William Sound, where elevated levels of metals (chromium, copper, zinc) and individual PAHs were detected.

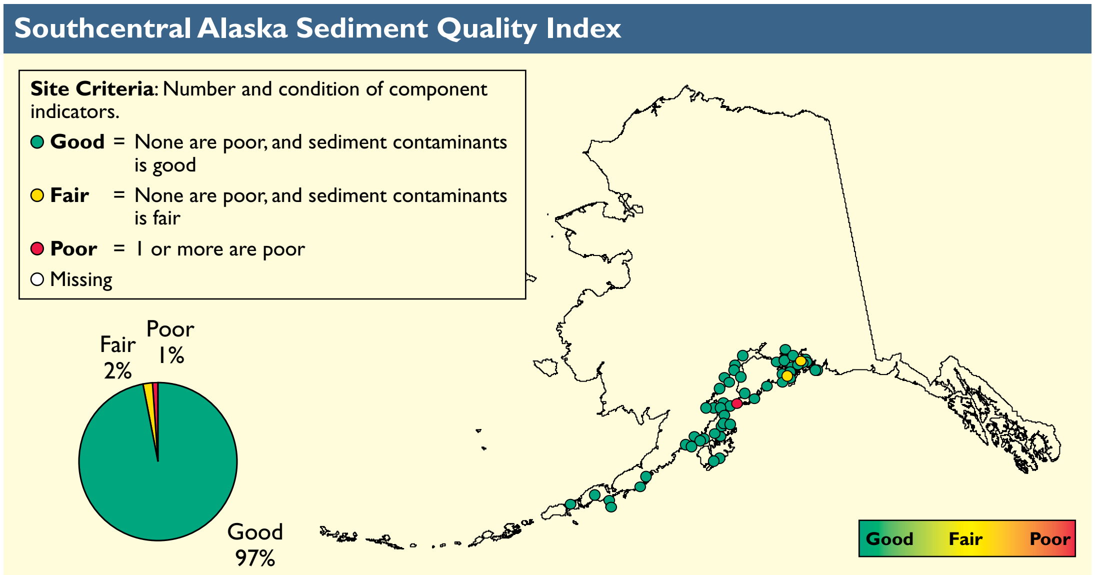


Figure 8-6. Sediment quality index data for Southcentral Alaska's coastal waters (U.S. EPA/NCA).

Highlight

The NCA Survey of the Aleutian Islands, Alaska, 2006–2007

Within the region known as the “Cradle of Storms,” the Aleutian Islands stretch over a 1,180-mile span of ocean, jutting westward from the Alaska Peninsula to form an arc that separates the North Pacific Ocean from the Bering Sea. The Aleutian Islands are the exposed peaks of a submerged mountain range. Along the southern edge of the island arc is a curving submarine trench, which has depths as great as 24,930 feet and extends across the North Pacific for 1,990 miles from the Gulf of Alaska to Kamchatka Peninsula. The Aleutian Islands rose from the volcanic activity caused by the convergence of the Pacific and North American tectonic plates. Today, this region is one of the most seismically and volcanically active regions in the world, and new islands are still being created.

The marine environment around the Aleutian Islands consists of highly productive, biologically diverse marine ecosystems. Significant upwelling occurs in this region, bringing nutrients to the surface and creating a green belt of high levels of primary and secondary production along the Aleutian Arc. As a consequence, numerous species of fish, mollusks, crustaceans, birds, and marine mammals live in this region. Fisheries harvests in this region provide more than 50% of the nation’s total harvest and around 10% of the global marine harvest of fish and shellfish (Alaska DCED, 2003). The Aleutian Islands are also within the major migratory pathways of many of the food species (e.g., fish, marine mammals) used for subsistence by the Aleut Natives.

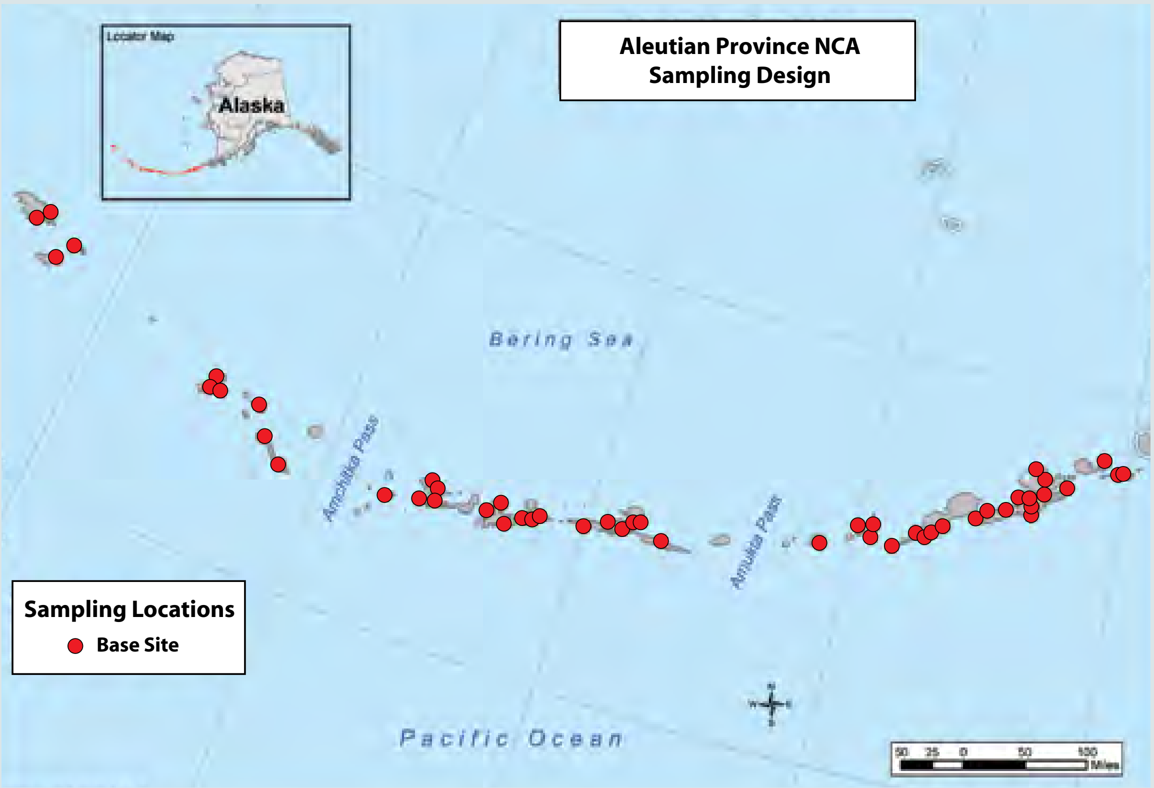
Although the Aleutians may seem remote, numerous portions of the islands have been contaminated with petroleum products, as well as with PCBs and several heavy metals. Many contaminated sites originated with World War II and subsequent Cold War activities. For example, Amchitka Island, which is located mid-way along the Aleutian Arc, was the site the United States’ largest underground nuclear tests, and leakage of radionuclides from this nuclear testing into the marine environment remains a long-term concern. International shipping activities may also contribute contaminants to the environment. In 2004, the *M/V Selendang Ayu* lost an estimated 321,052 gallons of intermediate fuel oil and 14,680 gallons of marine diesel fuel, in addition to its cargo of approximately 60,000 tons of soybeans, into the marine environment (Alaska DEC, 2006). Hundreds of ships a year travel along a major Pacific shipping route between the West Coast and Asia through the Aleutian Island chain. As the Arctic ice pack recedes due to climate change, a major increase in shipping through this region is expected to occur

The Aleutian Islands host the largest nesting population of seabirds in North America (courtesy of FWS).

as the northern sea routes open up for longer periods. Increased shipping traffic has the potential for increasing environmental impacts. In addition, pollutants from Pacific Rim countries are delivered to the Aleutians by the wind and ocean currents and pose potential threats to the marine ecosystem.

To complete the NCA survey of the Aleutian Islands personnel from the Alaska DEC served in the lead role, and support was provided from personnel from the University of Alaska Fairbanks and other state and federal agencies. The Aleutian component of the NCA survey is based on a combination of the procedures and methods of the NCA coupled with specialized methods for sampling hard- bottom habitats. The specialized methods were first developed for the 2002 NCA assessment in Hawaii (Nelson et al., 2007). A total of 50 randomly selected sites (see map) between the 0 and 60-foot depth contours sampled during the summers of 2006 and 2007 (25 sites per year). The 2-year duration period for the sampling effort was dictated by the long cruising distances between sampling stations and the difficult logistics of sampling in the Aleutian Islands.

The extent and effects of numerous anthropogenic stressors, ranging from impacts of commercial fisheries to invasive species, need to be understood if resource managers are to preserve and protect the ecological diversity of this coastal resource. The NCA survey in the Aleutian Islands will provide the Alaska DEC with the ability to assess the current ecological status and, as future assessments are completed, to assess trends in contaminant levels and ecosystem changes in the region.



Sampling locations for the 2006–2007 NCA survey of the Aleutian Islands (U.S. EPA/NCA).

Sediment TOC

The coastal waters of Southcentral Alaska are rated good for the sediment TOC component indicator. One site, representing about 1% of the area of the Southcentral Alaska's coastal waters, was rated poor. The poor rating at this site was influenced by the large amount of decomposing eelgrass present in this sediment sample. Another 7% of the coastal area was rated fair. These sites are spatially separated, span a range of depths, and presumably contain elevated levels of organic matter deposited from natural rather than anthropogenic sources.

Benthic Index

The benthic index for the coastal waters of Southcentral 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 Southcentral Alaska. In lieu of a benthic index for Southcentral 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 Southcentral Alaska survey data, the regression was not significant.

Coastal Habitat Index

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; therefore, a coastal habitat index could not be calculated for the coastal waters of Southcentral Alaska.

Fish Tissue Contaminants Index

The fish tissue contaminants index for the coastal waters of Southcentral Alaska is rated good. Two percent of the stations where fish were caught were rated fair due to mercury concentrations within the range of concern (Figure 8-7). This percentage represented one composite sample made up of three fish from one sampling station.

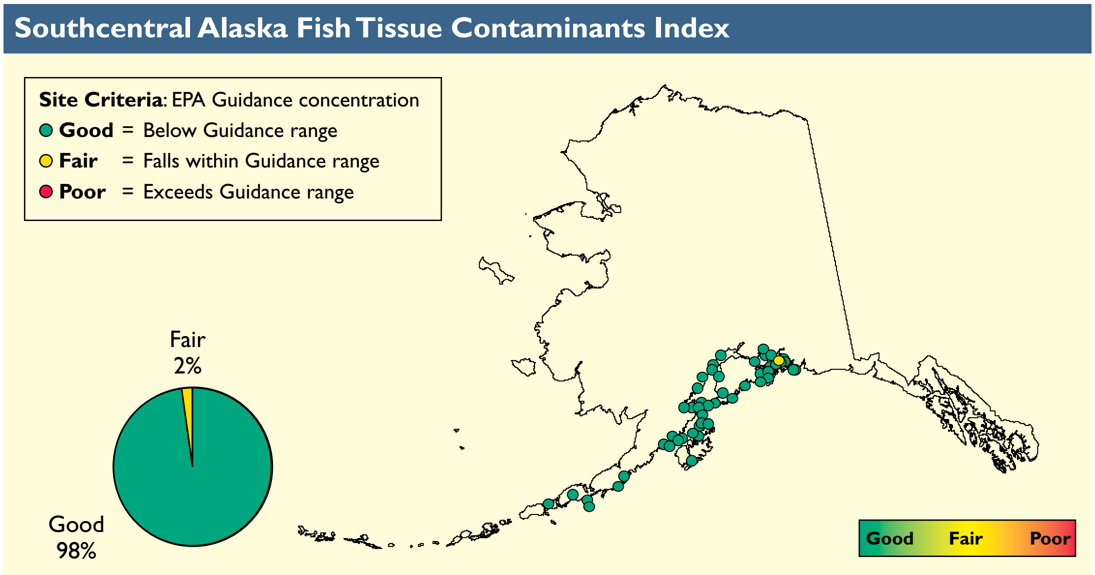


Figure 8-7. Fish tissue contaminants index data for Southcentral Alaska's coastal waters (U.S. EPA/NCA).

Snow-covered mountains meet the sea near Girdwood, AK (courtesy of Dave LaForest).

Trends of Coastal Monitoring Data—Southcentral Alaska

The 2002 NCA survey of Southcentral Alaska coastal waters was the first probabilistic survey of its kind in the state. Historically, coastal assessments have focused on areas of known or suspected impairment to examine the impacts of natural resource extraction activities, such as mining or oil exploration and production. One large-scale assessment occurring before resource development was the Alaska Outer Continental Shelf Environmental Assessment Program, conducted by NOAA in the 1970s. A large amount of physical, chemical, and biological data were collected through this program. Although much of these data remain difficult to locate, a summary may be found in Hood and Zimmerman (1986). Numerous assessments have also been conducted along the portion of Alaska's coastline affected by the Exxon Valdez oil spill in 1989, and this area continues to be monitored. In addition, several programs have provided an assessment of contaminants in Alaska as part of larger national assessments. For example, NOAA's NS&T Program analyzed contaminants in sediments and demersal (bottom-dwelling) fish at several sites along Alaska's coast as part of its Benthic Surveillance Program and measured contaminants in intertidal mussels and sediments as part of its Mussel Watch Program. Due to a lack of comparable data in the region, trends could not be evaluated for Southcentral Alaska's coastal waters at this time.

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

Alaska is surrounded by 4 sub-arctic LMEs (Figure 8-8). The Beaufort Sea LME is located off the northern coast of Alaska and stretches eastward into Canadian waters. West of the Beaufort Sea LME is the Chukchi Sea LME, which is located off the northwest coast of Alaska and extends westward to the northeast coast of Siberia in Russia. The East Bering Sea LME, which is located off the west coast of Alaska, extends from the Bering Strait, through the Bering Sea, and southward into the Pacific Ocean. Alaska's southern coast is bordered by the Gulf of Alaska LME, which extends along the coastline from the Alaska Peninsula southward through Canada to the northwestern coast of Washington (NOAA, 2007g). Only the fisheries in the East Bering Sea and Gulf of Alaska LMEs will be discussed in this chapter.

The East Bering Sea LME is considered to have moderately high productivity based on estimates of primary production (phytoplankton). The LME is characterized by a wide shelf and has historically had seasonal ice cover of up to 80% in March (NOAA, 2007g). More recent winter temperatures have been above the freezing point, indicating little or no sea ice in the southeastern East Bering Sea LME between 2000 and 2004 (NOAA, 2007a). Accompanying this change is a shift in the trophic structure of the ecosystem, with walrus population centers moving northward with the ice and an eastward extension in the movement of Alaska pollock (Overland and Stabeno, 2004).

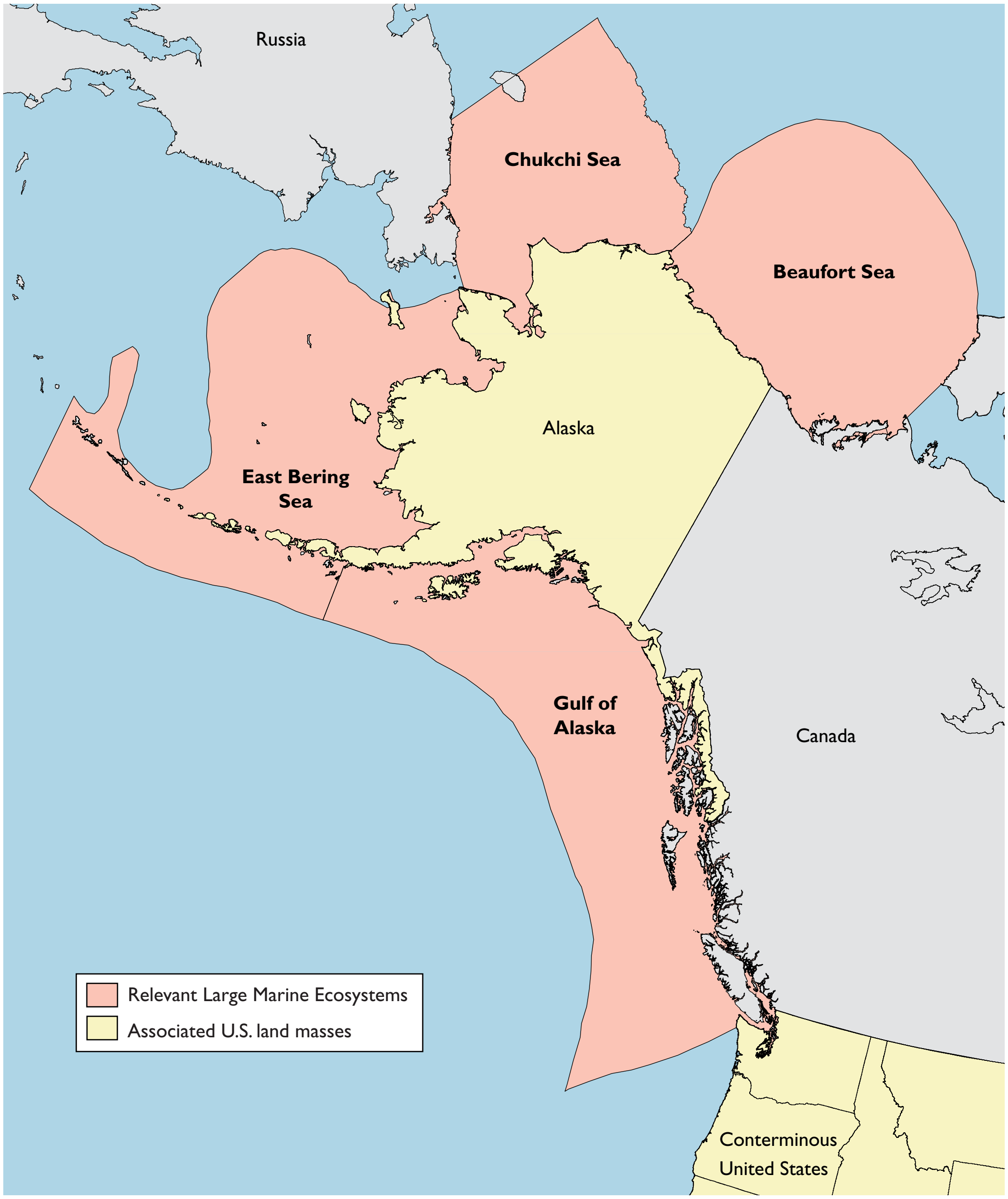


Figure 8-8. Alaska is surrounded by 4 LMEs (NOAA, 2007g).

Recruitment responses of many East Bering Sea LME fish and crabs are linked to decadal-scale patterns of climate variability. Decadal-scale changes in the recruitment of some flatfish species in the East Bering Sea LME appear to be related to patterns seen in atmospheric forcing. The Arctic Oscillation and Aleutian Low are two examples of atmospheric forcing in this LME. The Arctic Oscillation tracks the variability in atmospheric pressure at the polar region and mid-latitudes and tends to vary between negative and positive phases on a decadal scale. The negative phase brings higher-than-normal pressure over the polar region, and the positive phase does the opposite, steering ocean storms farther north. In winter, these patterns in atmospheric condition may influence surface wind patterns that transport fish larvae on or off the continental shelf. The recruitment (addition of a new generation of young fish) of some species (e.g., Bering Sea herring, walleye pollock, and Pacific cod) shows interannual variability that appears more related to climate variability. Years of strong onshore transport, typical of warm years and the negative phase of the Arctic Oscillation in this LME, correspond with strong recruitment of walleye pollock, possibly due to separation of young fish from cannibalistic adults. Alaskan salmon also exhibit decadal-scale patterns in production, and these patterns are inversely related to salmon production patterns in the California Current LME (discussed in Chapter 6). An Aleutian Low is a low-pressure cell located near the Aleutian Islands, and strength variations in this cell can affect wind directions and larvae transportation patterns. For example, periods of strong Aleutian Lows are associated with weak recruitment for some East Bering Sea LME crab species and are unrelated to recruitment of others, depending on species-specific life-history traits. Winds from the northeast favor retention of crab larvae in offshore mud habitats that serve as suitable nursery areas for young Tanner crabs to burrow in sediment for protection (Livingston and Wilderbuer, 2007). Winds from the opposite direction promote the inshore transport of crab larvae to coarse, shallow-water habitats in inner Bristol Bay, which serve as nursery areas for red king crabs to find refuge among biogenic structures (Rosenkranz et al., 1998; 2001; Livingston and Wilderbuer, 2007). The timing and composition of the plankton blooms may also be important because red king crab larvae prefer to consume diatoms (phytoplankton), whereas Tanner crab larvae prefer copepod nauplii (zooplankton) (Livingston and Wilderbuer, 2007).

Similar to the East Bering Sea LME, the Gulf of Alaska LME is sensitive to climate variations on time scales ranging from interannual to interdecadal. 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 presents a significant upwelling phenomenon linked to the Alaska Current and is considered a highly productive ecosystem based on primary productivity estimates. Changes in zooplankton biomass have been observed in both the Gulf of Alaska LME and the California Current LME directly to the south. These biomass changes appear to be inversely related to each other (NOAA, 2007g).

Salmon Fisheries

The abundance index for Pacific salmon is currently high in the Gulf of Alaska LME. The contributing factors to the high abundance index include (1) habitats with minimal impacts from extensive development, (2) favorable ocean conditions that promote high survival rates of juveniles, (3) improved management of the fisheries by state and federal agencies, (4) elimination of high-seas drift net fisheries by foreign nations, (5) hatchery production, and (6) reduction of bycatch in fisheries for other finfish species. Quality spawning and nursery habitat, favorable oceanic conditions, and sufficient numbers of spawning fish are most likely the paramount factors affecting current abundance levels. Alaska salmon management continues to focus on maintaining pristine habitats and ensuring adequate escapements; however, ocean conditions that favored high marine survival rates in recent years can fluctuate due to interdecadal climate oscillations. Recent evidence indicates that a change in the ocean conditions of the northern Pacific Ocean and the Gulf of Alaska LME may be underway, possibly reflecting the downturn in the abundance index for Alaska salmon runs observed in 1996 and 1997. Historic commercial landings show a distinct cyclic pattern of alternating high and low harvests, often lasting decades. Much of this fluctuation is now believed to be due to interdecadal climate oscillations in the ocean environment that affect the marine survival of juveniles. A pattern associated

Chinook salmon (courtesy of USGS).

with Alaska's cyclic salmon harvest appears to be inversely related to abundance patterns for California Current LME salmon (NMFS, In press).

All five species of Alaska salmon (pink, sockeye, chum, coho, and Chinook) are fully utilized, and stocks in most regions of the Gulf of Alaska and East Bering Sea LMEs have rebuilt to near or beyond previous high levels. Although there has been a high abundance index for salmon in these LMEs, there are issues of serious concern for salmon stocks, especially for some species and regions. For example, stocks in western Alaska, especially Chinook and chum salmon, have generally been at depressed levels since the mid-1990s. Some of the same issues implicated in the declines of California Current LME salmon stocks are also of concern in certain areas of Alaska. These issues include overfishing, incidental take of salmon as bycatch in other fisheries, and loss of freshwater spawning and rearing habitats (NMFS, In press).

Alaska commercial salmon harvests generally have increased during the past three decades. After reaching record-low catch levels in the 1970s, most populations rebounded, and fisheries in recent years have been at or near all-time peak levels in many regions of the Gulf of Alaska and East Bering Sea LMEs. The record-high commercial landings of 218 million salmon in 1995 were 17% higher than the previous record of 196 million salmon in 1994. Throughout the mid-to-late 1990s, recreational and subsistence fishermen harvested between 2 and 3 million salmon annually (NMFS, In press).

Beach seining for juvenile pink and chum salmon (courtesy of NOAA, Auke Bay Laboratories).

Pelagic Fisheries

Pacific herring is the major pelagic (water-column-dwelling) species harvested in the Gulf of Alaska and East Bering Sea LMEs. These fisheries occur in specific inshore spawning areas. In the Gulf of Alaska LME, spawning fish concentrate mainly off of southeast Alaska in Prince William Sound and around the Kodiak Island-Cook Inlet area. In the East Bering Sea LME, the centers of abundance are in northern Bristol Bay and Norton Sound.

The Gulf of Alaska LME herring industry began as early as 1878, when 30,000 pounds were marketed for human consumption. The fishery expanded rapidly in the late 1800s and early 1900s, with markets shifting from salt-cured herring to reduction products for fishmeal and oil. By 1934, the catch from the Gulf of Alaska LME alone had reached a record 140,000 t. The East Bering Sea LME fishery began in the late 1920s, initially with a small salt-cure plant in Dutch Harbor. A large, foreign offshore fishery developed in the 1950s. Catches in this LME peaked in 1970 at over 145,000 t and then fell off sharply to 16,000 t in 1975. Since 1977, East Bering Sea LME herring have been harvested primarily in inshore sac roe fisheries, and catches have risen slowly, but steadily, since that time. A portion of the East Bering Sea LME harvest is taken as bycatch in the offshore federally managed demersal fish fishery. Retention of herring in these fisheries is prohibited, with regulations limiting herring bycatch to no more than about 1,000 t annually (NMFS, In press).

Currently, the herring stocks in both LMEs remain at moderate levels and are in relatively stable condition, with the exception of populations in the Prince William Sound and Cook Inlet areas. Populations of Prince William Sound herring continue to be depressed from a disease outbreak in 1993. In more recent years, Alaska herring harvests have averaged about 35,000 t, with a value of around $10 million (NMFS, In press).

Demersal Fish Fisheries

The demersal fish complex is the most abundant of all fishery resources in the Gulf of Alaska and the East Bering Sea LMEs, with an estimated biomass of more than 26.4 million t. From 1999 to 2001, demersal fish catches from these LMEs averaged 1.8 million t. Prior to 1976, the only demersal fish species of significant commercial value to domestic fisheries was Pacific halibut, with foreign fisheries harvesting most other targeted commercial species. The Magnuson-Stevens Fishery Conservation and Management Act extended federal fisheries management jurisdiction to 200 nautical miles offshore and stimulated the growth of a domestic Alaskan demersal fish fishery that rapidly replaced the foreign fisheries. Much of the demersal fish catches are exported, particularly to Asia, and such trade contributes prominently as a major source of revenue for U.S. fishermen (NMFS, In press).

Demersal fish biomass in the East Bering Sea LME has been maintained at relatively high levels since implementation of the Magnuson-Stevens Act. Walleye pollock produce the largest catch of any single species inhabiting the EEZ. The recent average yield for East Bering Sea LME (including the Aleutian Islands) demersal fish from 2001–2003 was just over 1.9 million t, compared to the 1997 catch of 1.74 million t. The dominant species harvested were walleye pollock (76%), Pacific cod (10%), yellowfin sole (4%), Atka mackerel (3%), and rock sole (2%). The Eastern Bering Sea LME stock can be considered to be slightly underutilized because its catch quota has been reduced from the full current yield to reduce the risk of overfishing and to mitigate the food competition with species that prey on pollock, including marine birds and the threatened and endangered Steller sea lion populations (NMFS, In press).

The demersal fish abundance index for the Gulf of Alaska LME has increased since 1977, peaking at an estimated biomass of 5.3 million t in 1982 and 1988, and most recently, at 5.49 million t in 1997. Since then, the estimated biomass has remained relatively stable, fluctuating between about 4 and 5 million t. The recent average yield for Gulf of Alaska LME demersal fish was nearly 200,000 t for 2001–2003. Gulf of Alaska LME demersal fish catches have ranged from a low of 129,640 t in 1978 to a high of 352,800 t in 1984. Demersal fish catches are dominated by walleye pollock, followed by Pacific cod, flatfish, and rockfish. Since 1989, demersal fish catches have fluctuated around 200,000 t. The pollock abundance index increased dramatically during the 1970s, peaked in the mid-1980s, and subsequently declined. The current abundance index is similar to stock size in the early 1970s. Current evidence suggests that extreme variation in the pollock abundance index is primarily a result of environmental forcing. Pollock are carefully managed due to concerns about fishery impacts on the endangered and threatened populations of Steller sea lions because pollock is a major prey item of Steller sea lions in the Gulf of Alaska LME. Sea lion protection measures include closed areas around rookeries and "haul outs" (areas where sea lions rest onshore); division of the western-central Gulf of Alaska LME pollock total allowable catch over 3 years and four seasons; and use of a more conservative harvest policy to determine the acceptable biological catch. The pollock stock in this area is considered fully utilized, and Pacific cod stocks are considered healthy and fully utilized. In general, flatfish stocks are abundant, largely due to great increases in arrowtooth flounder biomass, and underutilized due to halibut bycatch considerations. Rockfish (e.g., slope rockfish, pelagic shelf rockfish, thornyhead rockfish, demersal shelf rockfish) are conservatively managed due to their long life spans and consequent sensitivity to over-exploitation (NMFS, In press).

Yelloweye rockfish, *Sebastes ruberrimus*, are the target of a commercial longline fishery in Southeastern Alaska (courtesy of NOAA, National Undersea Research Program and the Alaska Department of Fish and Game).

Shellfish Fisheries

Major shellfish fisheries were developed during the 1960s in the Gulf of Alaska LME and subsequently expanded to the East Bering Sea LME. Shellfish landings in 2003 generated an estimated ex-vessel value of $181.6 million, compared with the ex-vessel value of $151 million in for 1997; king and snow crabs account for a majority of this value ($161 million) (NMFS, In press).

Three king crab species (red, blue, and golden or brown) and two Tanner crab species (Tanner crab and snow crab) have traditionally been harvested commercially in these two major LMEs of Alaska. Alaska crab resources are fully utilized, and quotas, seasons, and size and sex limits restrict catches to protect the crab resource and maintain product quality. Landings are limited to large male crabs, and seasonal closures are set to avoid fishing during times when crabs are molting or mating, as well as during soft-shell periods. In 2004, two Alaska crab stocks (the St. Matthew Island blue king crab stock and the Eastern Bering Sea Tanner crab stock) were determined to be overfished (NMFS, In press). There are rebuilding plans for these stocks (NPFMC, 2000a; 2000b), and fishing of these species is not allowed. Since 1999, exploratory fisheries on new deep-water stocks of scarlet king crab, grooved Tanner crab, and triangle Tanner crab have begun; however, they have produced only minor landings to date (NMFS, In press).

The northern pink shrimp is the most important of the five species that comprise Alaska shrimp landings. The domestic shrimp fishery in western Gulf of Alaska LME waters is currently at a low level, and shrimp abundance is too low in the Bering Sea to support a commercial fishery. The western Gulf of Alaska LME has been the main area of operation for Alaska's shrimp fishery, with shrimp landings indicating that catches in this area rose steadily to about 58,000 t in 1976 and then declined precipitously. As with crabs, the potential yields of shrimp stocks in both LMEs are not well understood (NMFS, In press).

Assessment and Advisory Data

Fish Consumption Advisories

In 2003, no consumption advisories were in effect for chemical contaminants in fish and shellfish species harvested in Alaskan waters (U.S. EPA, 2004b).

Beach Advisories and Closures

Alaska did not report monitoring, advisory, or closing information for any beaches in 2003 (U.S. EPA, 2006c).

Kazakof Bay, AK (courtesy of Poppy Benson, FWS).

Hawaii

The overall condition of Hawaii's coastal waters is rated good based on two of the indices assessed by NCA (Figure 8-9). The water quality index is rated good, and the sediment quality index is rated good to fair. The NCA was unable to evaluate the benthic, coastal habitat, or fish tissue contaminants indices for Hawaii's coastal waters. Figure 8-10 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 the NCA, in conjunction with state agencies, EPA Region 9, and the University of Hawaii, from 79 locations along the islands of the Hawaiian chain in 2002. Please refer to Chapter 1 for information about how these assessments were made, the criteria used to develop the rating for each index and component indicator, and limitations of the available data.

The Hawaiian Islands are the most isolated archipelago in the world. Hawaii's isolation has resulted in the highest percentage of endemic flora and fauna species anywhere in the world. However, this singular distinction has a downside: Hawaii has suffered the greatest number of known extinctions of fauna and flora during the past 200 years due to the development and westernization of the islands (Loope, 1998).

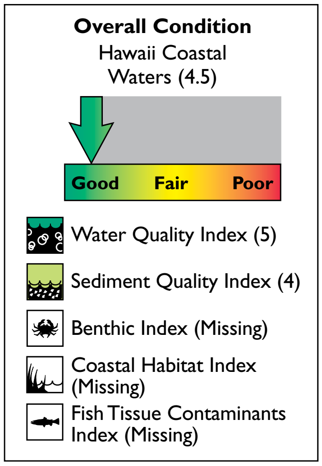


Figure 8-9. The overall condition of Hawaii's coastal waters is rated good (U.S. EPA/ NCA).

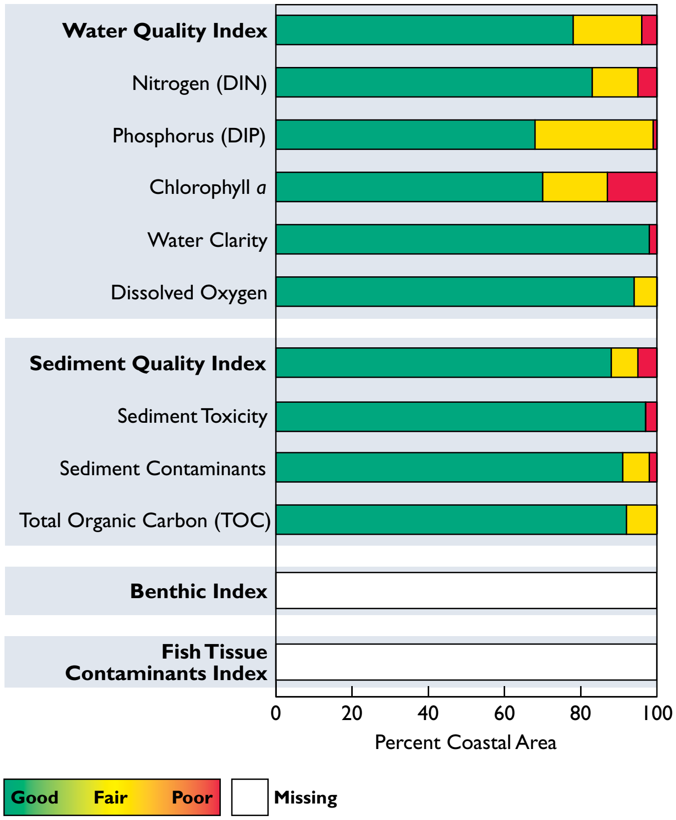


Figure 8-10. Percentage of coastal area achieving each ranking for all indices and components indicators—Hawaii (U.S. EPA/NCA).

Hawaiian monk seals are an endangered species that is native to Hawaii (courtesy of James Watt, DOI).

The human population of the Hawaiian Islands has fluctuated over time. Following contact with the West, disease took its toll on the islands' native population, and there were less than 60,000 individuals remaining on the islands by the 1870s. By 1900, the total population had grown to 154,000 people, primarily through the importation of labor for agriculture. Figure 8-11 shows that the population of Hawaiian coastal counties increased by 0.3 million people (30%) between 1980 and 2003 (Crossett et al., 2004). As of 2004, Hawaii's population exceeded 1.2 million people, and more than 90% of residents lived in urban centers (U.S. Census Bureau, 2006a).

Human development, increases in population, and economic growth have all exacerbated the impacts to native ecosystems because of the relatively small land area of the Hawaiian Islands. Sedimentation problems associated with land-use changes may be especially acute in the coastal areas of Hawaii because of the combination of steeply sloped coastal watersheds, high seasonal rainfall, and agricultural and other land development (Cox and Gordon, 1970; Meier et al., 1993). Human population growth in Hawaii is a principal driver for many ecological stressors (e.g., habitat loss, pollution, nutrient enhancement), which may alter coastal ecosystems and affect the sustainability of coastal ecological resources. Increased globalization of the economy is a major driver influencing the introduction of exotic species into Hawaiian ports and harbors.

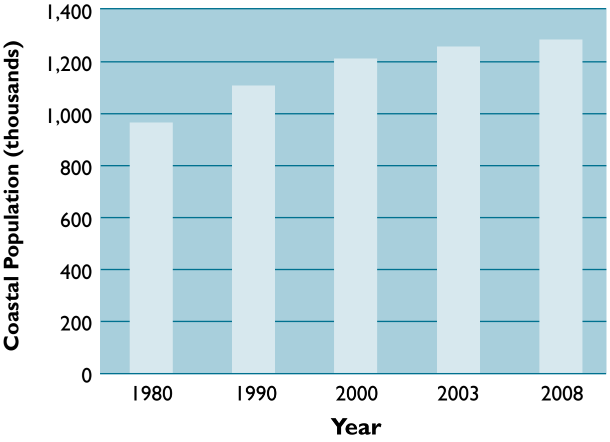


Figure 8-11. Actual and estimated population of the Hawaiian Islands from 1980–2008 (Crossett et al., 2004).

Compared to other regions considered in the NCCR III, estuaries and coastal embayments 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, which is the largest remaining Hawaiian estuary, has a water surface area of approximately 22 mi^2 and is one of the country's largest naval ports. However, most of Hawaii's estuaries and coastal embayments are small, occupying less than half a square mile. Historically, these coastal waters were more significant than they are today. 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).

Estuaries and coastal embayments serve as important nursery habitat for a number of commercial and recreational Hawaiian fishery resources. These aquatic features also act as natural biological filters by sequestering sediments and pollutants adsorbed to particulate materials, thus lessening the impact of stormwater runoff on adjacent coral reefs. The development of the hinterland surrounding most of Hawaii's largest estuaries, combined with concurrent pollution and alien species introductions, have resulted in tremendous changes to the abundance and species composition of important coastal communities. Causal mechanisms responsible for these changes have not been quantitatively defined, and the rate of these changes has not been measured.

Coastal Monitoring Data—Status of Coastal Condition

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. These coastal systems are highly altered and surrounded by a high-density, urban setting. The rest of the Hawaiian Islands have a much lower population density. Although one might presume that the magnitude of anthropogenic impacts would be highest in the urbanized estuaries of Oahu, this hypothesis needs to be rigorously tested.

Hawaii does not yet have a comprehensive coastal monitoring program. Some monitoring occurs in Oahu and is planned for adjacent coral reef ecosystems; however, 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 to examine WWTP outfalls from Oahu into the Bay. This sampling showed that the discharge areas were not statistically different from reference areas; however, data were lacking to interpret these findings in a statewide or regional context (Swartz et al., 2002). In 2002, the NCA, in conjunction with state agencies, EPA Region 9, and the University of Hawaii, conducted the first comprehensive survey of the coastal condition of Hawaii. The survey sampled 50 stations spread across the main islands and 29 stations concentrated along the south shore of Oahu within the urbanized estuaries, including Pearl Harbor and Honolulu Harbor. For this assessment, the coastal area assessed included semi-enclosed coastal embayments and true estuaries.

Water Quality Index

The water quality index for Hawaii's coastal waters is rated good. This index was developed based on measurements of five component indicators: DIN, DIP, chlorophyll *a,* water clarity, and dissolved oxygen. Most (78%) of the coastal area was rated good for water quality condition, 18% of the area was rated fair, and 4% of the area was rated poor (Figure 8-12). Most cases of fair condition were driven by elevated concentrations of DIP and chlorophyll *a*. The finding that 22% of the area has either poor or fair water quality should be considered preliminary. As described below, water clarity measurements were not obtained at many stations. Determination of an acceptable level for DIP concentrations may also require further consideration.

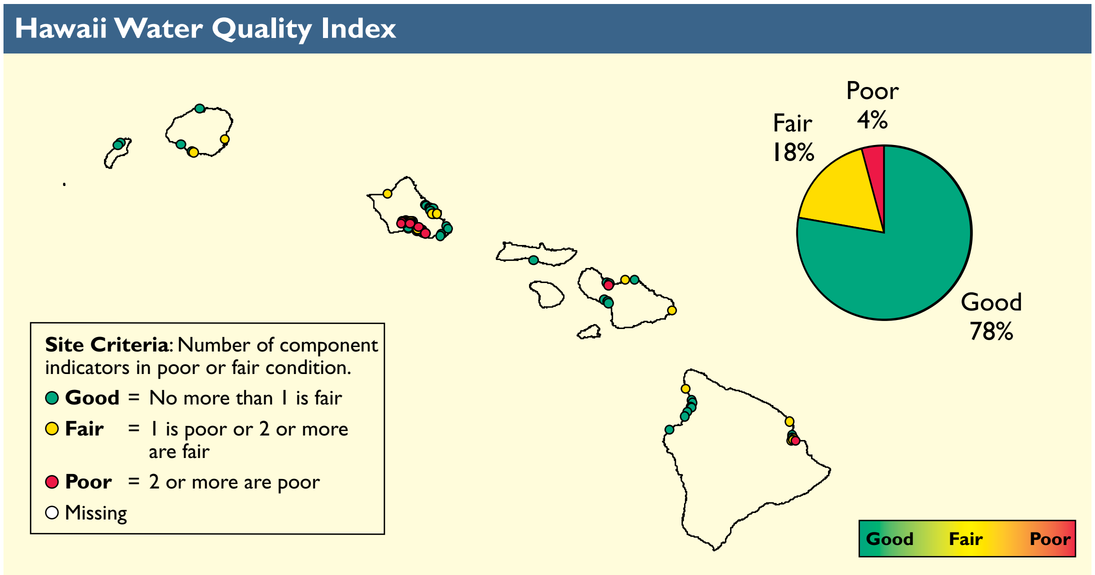


Figure 8-12. Water quality index data for Hawaii's coastal waters (U.S. EPA/NCA).

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.

Nutrients: Nitrogen and Phosphorus

Hawaii's coastal waters are rated good for DIN concentrations, with only 5% of the coastal area rated poor and 12% rated fair for this component indicator. Sites with high nitrogen levels tended to be located in harbors or urban estuaries. For example, sites in the Ala Wai Canal in downtown Honolulu, Kahalui Harbor, and Hilo Bay exhibited elevated DIN concentrations.

Hawaii's coastal waters are also rated good for DIP concentrations, with 31% of the coastal area rated fair for this component indicator. Only 1% of the coastal area, representing one site in Pearl Harbor, received a poor rating for DIP concentrations.

Chlorophyll *a*

Hawaii's coastal waters are rated fair for chlorophyll *a* concentrations, with 13% of the coastal area rated poor and 17% rated fair for this component indicator. Approximately two-thirds of sites rated poor for chlorophyll *a* concentrations were located within the urbanized estuaries of Honolulu on the island of Oahu.

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 for this component indicator, and 98% of the area was rated good. In Hawaii, estimates of water clarity were obtained using a Secchi disk. At more than half of the stations, the Secchi disk was still visible at the bottom, and a valid reading of Secchi depth for estimating water clarity could not be obtained; therefore, these estimates of water clarity have a high degree of uncertainty and should be considered preliminary. Given the situation of having the Secchi disk visible at the bottom, it is likely that the estimate of good condition for water clarity in these waters is conservative.

Dissolved Oxygen

Dissolved oxygen conditions in Hawaii's coastal waters are rated good, 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 located in Pearl Harbor (2 sites) and Keechi Lagoon. At each of these stations, the dissolved oxygen concentrations were 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.

Garden of Eden, Maui, HI (courtesy of Ben Fertig, IAN Network).

Sediment Quality Index

The sediment quality index for Hawaii's coastal waters is rated good to fair, with 7% of the coastal area rated fair and 5% of the area rated poor for sediment quality condition (Figure 8-13). The sediment quality index was calculated based on measurements of three component indicators: sediment toxicity, sediment contaminants, and sediment TOC. Poor sediment quality ratings were primarily a result of metal and organic contaminant concentrations in the urbanized estuaries on the south shore of Oahu. Amphipod toxicity at two sites (one on Oahu and one on Kauai) was the second-most important contributing factor to the areal estimate of poor condition. Sites rated fair for sediment condition were almost exclusively associated with elevated levels of sediment contaminants, primarily metals and individual PAHs, within the ports, harbors, and canals of Honolulu on Oahu.

Sediment Toxicity

Hawaii's coastal waters are rated good for sediment toxicity, with 97% of the coastal area rated good and 3% of the area rated poor for this component indicator. Toxic sediments were found at only two sites (Wahiawa Bay, Kauai, and Kaneohe Bay, Oahu), and sediment samples from these sites also exhibited elevated levels of arsenic and DDT, respectively. Since no other sediment contaminant concentrations were elevated at these sites, it is unclear whether the sediment toxicity was directly caused by the contamination.

Small sea anemone on volcanic rock (courtesy of NOAA, National Undersea Research Program).

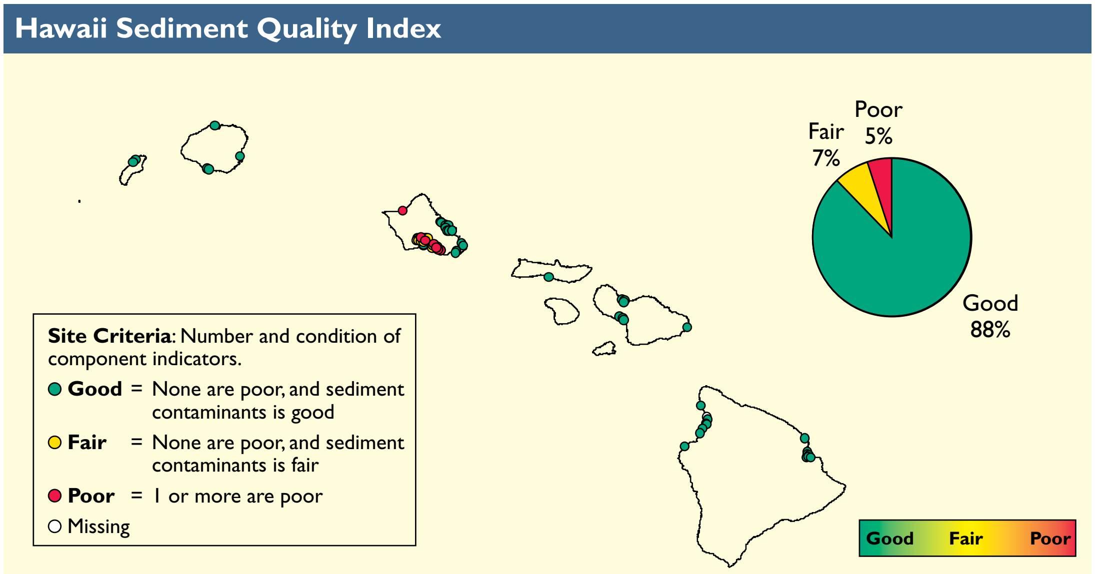


Figure 8-13. Sediment quality index data for Hawaii's coastal waters (U.S. EPA/NCA).

Sediment Contaminants

Hawaii's coastal waters are rated good for sediment contaminant concentrations, with 7% of the coastal area rated fair and 2% of the area rated poor for this component indicator. Six of the 7 sites rated poor were located in the urbanized estuaries of Oahu, and the remaining site was located in Paukaulia Stream on the north shore of Oahu. Primarily, these sites exhibited elevated levels of copper and mercury; however, high concentrations of chromium and PAHs were found in sediments collected from Paukaulia Stream and Honolulu Harbor, respectively. All of the sites rated fair were located in the urbanized estuaries of Oahu and were primarily rated fair due to elevated concentrations of metals (e.g., chromium, copper, lead, mercury, silver, zinc) and some individual PAHs.

It should be noted that nickel was excluded from this evaluation of sediment contamination in Hawaii's coastal waters 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, although no conclusive evidence is available to support this suggestion; therefore, mercury data were not excluded from this assessment. In addition, it should be noted that 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 Hawaii are rated good for sediment TOC. A total of 8% of the coastal area was rated fair, and none of the area was rated poor. The majority of sites that were rated fair for sediment TOC were located within Pearl Harbor, which is both extensively modified and has a restricted connection to the ocean. Sites in Reeds Bay and Hilo Bay on the island of Hawaii were also rated fair.

Benthic Index

Benthic condition in Hawaii's coastal waters as measured by a benthic index could not be evaluated. As was the case for Alaska, a benthic condition index for Hawaii is not currently available. In lieu of a benthic index for Hawaii, the deviation 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 Hawaii survey data, the regression was not significant.

Coastal Habitat Index

Estimates of coastal habitat loss are not available for Hawaii; therefore, a coastal habitat index could not be calculated. It is clear that there have been major alterations and losses of coastal wetlands in Hawaii. Modification of coastal wetlands prior to western contact was probably generally limited to the conversion of these marshes into taro cultivation ponds. Later, agricultural activities (e.g., cattle ranching, sugarcane/pineapple production) in the islands modified or eliminated many coastal wetlands. Commercial and military navigation projects also resulted in losses of wetlands on Kauai, Maui, Oahu, and Hawaii; however, perhaps the most extensive loss of coastal wetlands occurred as the result of housing and resort construction following World War II, heavily impacting wetlands on Oahu (Meier et al., 1993).

Fish Tissue Contaminants Index

The NCA survey of Hawaii did not produce estimates of contaminant levels in fish. Instead, a preliminary feasibility study was conducted to determine whether sea cucumbers could be utilized to assess tissue body burdens. Samples of two species of sea cucumbers were analyzed for tissue contaminant levels in the pilot method-development effort. Some heavy metals (e.g., mercury, cadmium, silver) were undetected in sea cucumber tissue samples. PCBs and DDT were detected at low levels in some tissue samples, whereas PAHs and other pesticides were not detected. These results have a high degree of uncertainty because the total sample size was small and analytical issues were present with the tissue matrix. As a result, a fish tissue contaminants index could not be calculated for Hawaii.

Large Marine Ecosystem Fisheries—Insular Pacific-Hawaiian LME

The Insular Pacific-Hawaiian LME surrounds the Main Hawaiian Islands (MHI) of Hawaii, Maui, Lanai, Molokai, Oahu, Kauai, and Niihau, as well as the Northwestern Hawaiian Islands (NWHI) (Figure 8-14). This tropical LME is influenced by equatorial currents and predominantly northeasterly trade winds. The Insular Pacific-Hawaiian LME is classified as a low-productivity ecosystem based on estimates of primary productivity (phytoplankton). The waters of this LME have high levels of marine diversity and support a variety of fisheries; however, maximum sustainable yields are relatively low due to limited ocean currents. The NMFS manages this LME as part of its Western Pacific Region, which includes the fisheries of American Samoa, Guam, the Commonwealth of the Northern Mariana Islands, and other U.S. Pacific island possessions (NOAA, 2007g).

In 2006, the NWHI were designated as a U.S. Marine National Monument. The islands extend from 160 miles northwest of Kauai into the Pacific Ocean approximately 1,200 miles, cover nearly 140,000 mi^2 of ocean, and include 70% of the tropical, shallow-water coral reefs in U.S. waters. Commercial and recreational harvest of precious coral, crustaceans, and coral reef species are prohibited in monument waters, and commercial fishing is being phased out over a 5-year period. Commercial activities within the state waters of the NWHI were banned in 2005. Additional information about the Marine National Monument is available at: http://www.hawaiireef.noaa.gov.

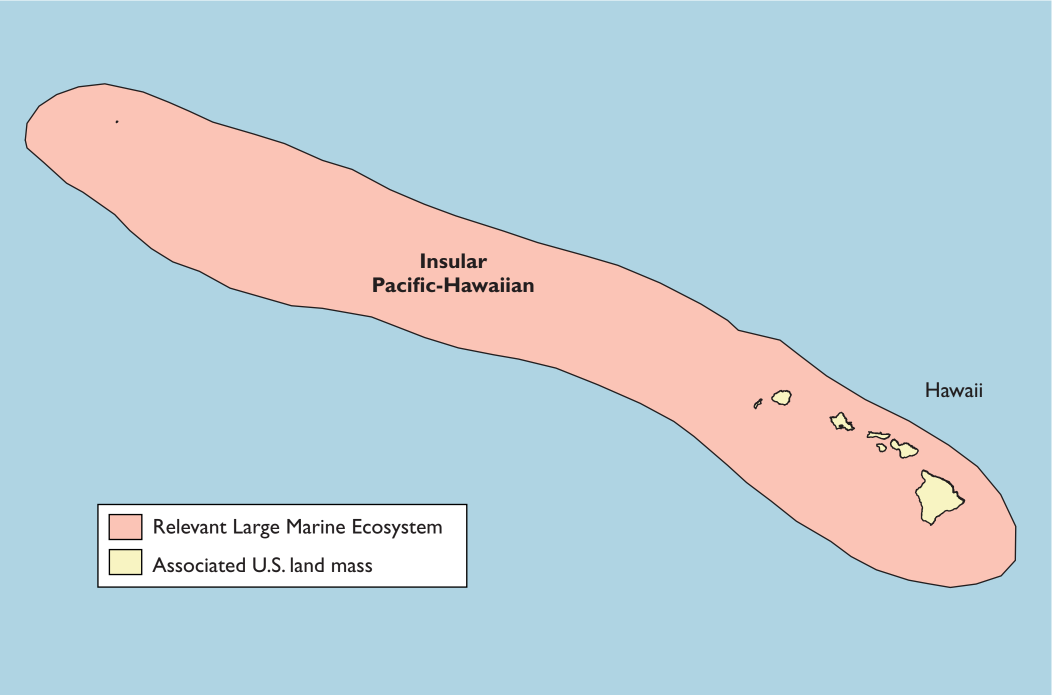


Figure 8-14. Insular Pacific-Hawaiian LME (NOAA, 2007g).

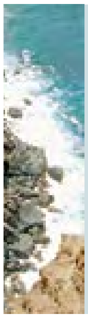
Invertebrate Fisheries

The dominant invertebrate species fished in the state, territorial, commonwealth, and remote island waters of the NMFS Western Pacific Region include lobsters, shrimp, squid, octopus, and precious corals. Most of these fisheries operate on a small scale and are regulated solely by local island fisheries agencies. The NWHI lobster fishery and the Hawaii precious coral fishery are the only invertebrate fisheries managed by NMFS in this area. Although the NWHI lobster trap fishery is the major commercial marine invertebrate fishery in this region, small-scale, primarily recreational fisheries for different species of lobster exist in the MHI, American Samoa, Guam, and the Northern Mariana Islands. A resource of deep-water precious coral (gold, bamboo, and pink corals) and shallow-water coral (black) exists in Hawaii and possibly other western Pacific areas. A short-lived, domestic precious coral fishery operated in Hawaii from 1974 to 1979, but there was no significant precious coral harvest for 20 years until 1999 through 2001. A deep-water shrimp resource is found throughout the Western Pacific Region, but currently is relatively unexploited (NMFS, In press).

Northwestern Hawaiian Islands Lobster

A commercial lobster trap fishery operated in the NWHI from the mid-1970s through 1999. Although this multi-species fishery primarily targeted the Hawaiian spiny lobster and slipper lobster, three other species (green spiny lobster, ridgeback slipper lobster, and Chinese slipper lobster) were caught in small numbers. Historically, traps set at deeper depths caught slipper lobster, while the shallower sets caught spiny lobster. In later years, slipper lobsters (particularly at Maro Reef) have been caught at shallow depths; this shift was presumably caused in part by the fishing pressure on spiny lobsters and the availability of suitable habitat formerly occupied by spiny lobster (NMFS, In press).

The estimated populations of spiny and slipper lobsters declined dramatically from the mid-1980s through the mid-1990s. Much of this decline has been attributed to a shift in oceanographic conditions that affected recruitment in the mid-1980s. Although oceanographic conditions have returned to a more typical long-term state and the fishery has been closed since 2000, recent NMFS research surveys have not indicated any increase in spiny lobster populations at Necker Island or Maro Reef. Variability in oceanographic conditions may have contributed to the decline of NWHI spiny lobster; however, improvements in our understanding of the spatial structure of the NWHI spiny lobster population, the dynamics of larval transport, and commercial fishery data suggest that spiny lobster populations in the NWHI constitute a metapopulation and that a suite of factors (both anthropogenic and biotic) contributed to the observed decline (NMFS, In press).



A metapopulation is a group of populations inhabiting discrete patches of suitable habitat that are connected by the dispersal of individuals between patches; the degree of isolation for local populations may vary depending on the distance between habitat patches.

Precious Coral

The waters of the MHI host commercial fisheries for deep-water and shallow-water corals. For the first time since the mid-1970s, deep-water precious corals (pink, gold, and bamboo corals) were harvested commercially in Hawaii from 1999 to 2001. A single company collected corals at the established coral-harvesting bed of Makapu'u, Oahu, and in an exploratory coral harvesting bed off Keahole, Hawaii. The allowable harvest quotas were not filled in either location. Although the fishery remains open, the company has suspended harvesting activities due to the high cost of operating submarines and the low bid price for coral. The only shallow-water coral species that are currently harvested are black corals. Black corals are collected by three independent divers working at depths less than 260 ft; all within the Au'au Channel, Maui (NMFS, In press).

In 2000 and 2001, scientists surveyed all known deep-water and shallow-water precious coral beds in the Hawaiian Archipelago using submersibles that belong to the Hawaii Undersea

Research Laboratory. These surveys provided the first real insight into the relative abundance of precious corals across the archipelago. Post-harvest inspections of the deep-water coral beds at Makapu'u and Keahole found numerous live colonies and little evidence of damage associated with commercial coral-harvesting activities. The 2001 survey of the Makapu'u bed will be compared with pre-harvest survey data collected at Makapu'u in 1997 to evaluate possible harvesting impacts. Both divers and submersibles were used to survey the black coral bed of the Au'au Channel in 2000 and 2001. At depths shallower than 260 feet, divers surveyed the size structure of black coral trees and their associated fish assemblages. The submersible surveys conducted at depths below 260 feet observed an invasive species of soft coral (*Carijoa riisei*) overgrowing black coral trees. A follow-up survey of coral size and structure was conducted in 2004 and will be used to revisit the harvesting regulations presently in place (NMFS, In press).

Deep-sea coral on seamount in Northwest Hawaiian Islands (courtesy of NOAA Office of Ocean Exploration).

Monitoring the activities related to the precious coral fishery in Hawaii is important because these activities and their effects could possibly interfere with the feeding habits of endangered Hawaiian monk seal populations. Studies of monk seal foraging patterns using seal-mounted satellite tags documented a small number of seals visiting sites with deep-water precious coral beds (Parrish et al., 2002). Another study recorded seals visiting black coral beds on successive nights to feed on eels hiding amongst the corals. These and other studies of seal diving and foraging behavior have spurred concern that coral harvesting might impact the seals' use of the deep-water fish community. In 2003, a seal was observed by a submersible at a depth of about 1,750 feet near precious coral, further strengthening the link between seals and precious coral beds (NMFS, In press).

Demersal Fish and Armorhead Fisheries

The Western Pacific Region hosts fisheries for demersal fish and pelagic armorhead. The demersal fish fishery geographically encompasses the Insular Pacific-Hawaiian LME, Guam, the Commonwealth of the Northern Mariana Islands, and American Samoa. In contrast, pelagic armorhead are harvested in this region from the summits and upper slopes of a series of submerged seamounts along the southern Emperor-northern Hawaiian Ridge. This chain of seamounts is located just west of the International Date Line and extends into the northernmost portion of the NWHI.

Demersal Fish

The Guam, Commonwealth of the Northern Mariana Islands, American Samoa, and MHI demersal fish fisheries employ relatively small vessels on one-day trips close to port; either part-time or sport fishermen take much of the catch. In contrast, demersal fish in the NWHI are fished by full-time fishermen on relatively large vessels that range far from port on trips of up to 10 days. Fishermen use the hand-lining technique in which a single weighted line with several baited hooks is raised and lowered with a powered reel. The demersal fish fisheries are managed jointly by the Western Pacific Fishery Management Council and territorial, commonwealth, or state authorities (NMFS, In press).

In Hawaii, the demersal fish species fished include several snappers (ehu, onaga, opakapaka, and uku), jacks (ulua and butaguchi), and a grouper (hapu'upu'u). In the more tropical waters of Guam, the Commonwealth of the Northern Mariana Islands, and American Samoa, the fisheries include a more diverse assortment of species within the same families as in Hawaii, as well as several species of emperors. These species are found on rock and coral bottoms at depths of 170 to 1,350 feet. Catch weight, size, and fishing effort data are collected for each species in the five areas (i.e., MHI, NWHI, Guam, Commonwealth of the Northern Mariana Islands, American Samoa); however, the sampling programs vary in scope between these areas. About 90% of the total landings are taken in Hawaii, with the majority of the landings taken in the MHI. Although somewhat limited, stock assessment indicate that the spawning stocks of several important MHI species (ehu, hapu'upu'u, onaga, opakapaka, and uku) are at only 5% to 30% of unfished levels. Onaga and ehu presently appear to be the most stressed among MHI demersal fish species (NMFS, In press).

Pelagic Armorhead

The seamount demersal fish fishery has targeted just one species—the pelagic armorhead. The commercial seamount fishery for pelagic armorhead was started by bottom-trawl vessels of the former Soviet Union in 1968. During 1969, Japanese trawlers entered this fishery, and by 1972, CPUE (based on Japanese data) peaked at 54 t per hour. The United States has never been a participant in this fishery. By the end of 1975, the two foreign fleets had harvested a combined cumulative total of 1,000,000 t of pelagic armorhead. Facing a steady decline in CPUE beginning in 1972, the former Soviet fleet left the fishery after 1975. The combined catch index for all seamounts has remained depressed since the late 1970s. In 1977, the southermost seamounts (Hancock Seamounts) were included in the EEZ, and subsequently, a small portion of the fishery was managed in a limited way. A preliminary FMP was developed that year and provided for limited foreign harvesting at the Hancock Seamounts under a permit system between 1978 and 1984 (NMFS, In press). However, catches remained low, and all fishing in this area ceased after 1984. Under the FMP for this region's demersal fish fisheries (WPRFMC, 1986), a 6-year fishing moratorium was imposed on the Hancock Seamounts in 1986. The moratorium was extended for three additional 6-year periods, the latest starting in 2004 and ending in 2010 (NMFS, In press).

Since 1976, Japanese trawlers have conducted this fishery almost exclusively around the seamounts in international waters beyond the Hancock Seamounts. The fishing grounds of the Hancock Seamounts represent less than 5% of the total fishing grounds for the pelagic armorhead. The maximum sustainable yield is 2,123 t, but recovery to the fishery's former levels has not yet occurred. Standardized stock assessments were conducted between 1985 and 1993. Research cruises focused on Southeast Hancock Seamount, and the armorhead stock was sampled with bottom long lines and calibrated against Japanese trawling effort. Catch rates varied, but have not shown the increases expected after the fishing moratorium was implemented. Furthermore, the increase in the 1992 seamount-wide CPUE caused by high recruitment was apparently short lived because CPUE declined appreciably in 1993 and thereafter. Closure of only the small EEZ portion of the pelagic armorhead's demersal habitat may not be sufficient to allow population recovery because these seamounts remain the only part of the fishery currently under management. The primary issue for the armorhead seamount fishery is how to implement some form of management on an international basis to provide conditions conducive to stock recovery (NMFS, In press).

Kona coast (courtesy of Calbear22).

Assessment and 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 8-15). In addition to the existing estuarine advisory, a statewide advisory took effect in 2003. The new 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, 2004b).

Beach Advisories and Closures

Hawaii did not report monitoring, advisory, or closing information for any beaches in 2003 (U.S. EPA, 2006c).

Freshwater pools leading to the ocean in Haleakala National Park on the southeastern coast of Maui (courtesy of NPS).

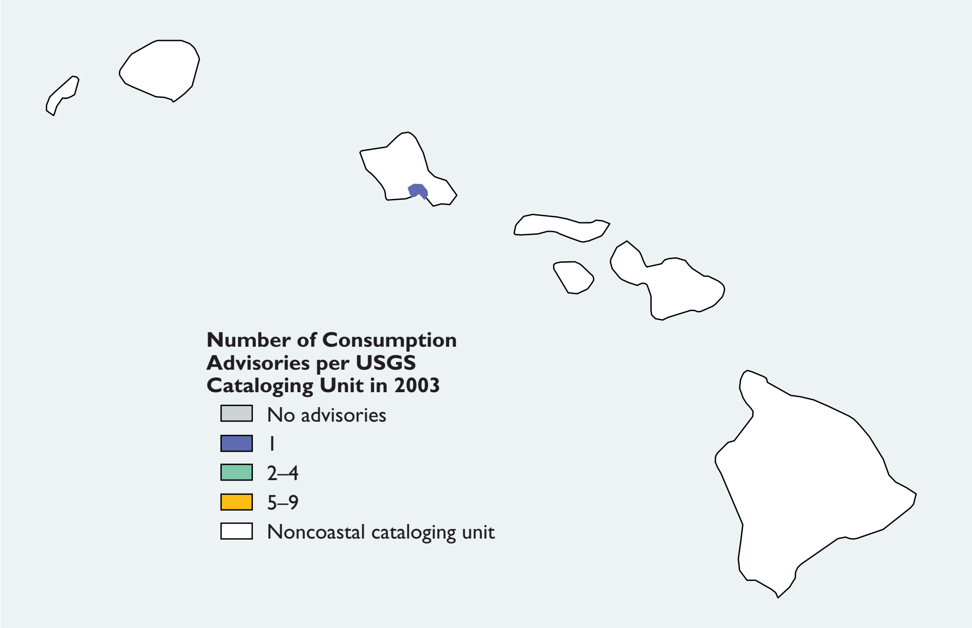


Figure 8-15. Fish consumption advisory for Hawaii, location approximate. Hawaii also has a statewide advisory for marine fish consumption by sensitive populations, although this is not mapped (U.S. EPA, 2004b).

Puerto Rico

Coastal Monitoring Data—Status of Coastal Condition

The overall condition for Puerto Rico's coastal waters presented in the NCCR II (U.S. EPA, 2004a) was poor based on three of the indices used by NCA (Figure 8-16). The water quality index is rated fair, and the sediment quality and benthic indices are rated poor. NCA was unable to evaluate the coastal habitat or fish tissue contaminants indices for Puerto Rico. Figure 8-17 provides a summary of the percentage of coastal area in good, fair, poor, or missing categories for each index and component indicator. This assessment was based on the results of sampling conducted at 50 sites in 2000. Please refer to Chapter 1 for information about how these assessments were made, the criteria used to develop the rating for each index and component indicator, and limitations of the available data.

In Puerto Rico, manatees are most abundant along the south and east coasts of the island (courtesy of USGS).

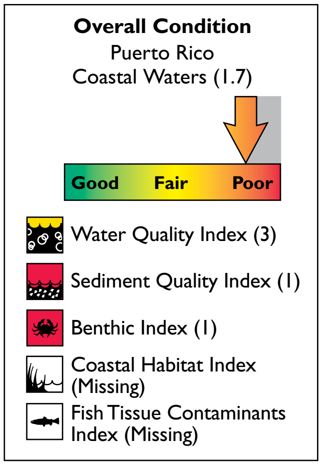


Figure 8-16. The overall condition of Puerto Rico's coastal area is rated poor (U.S. EPA/NCA).

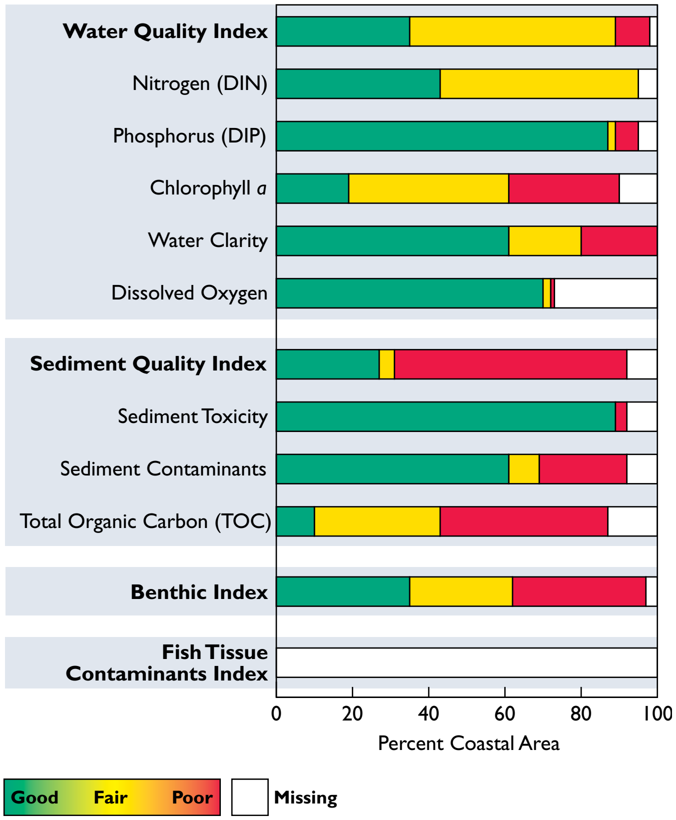


Figure 8-17. Percentage of area receiving each ranking for all indices and component indicators – Puerto Rico (U.S. EPA/NCA).

Although another NCA sampling event for Puerto Rico occurred in 2004, these results are not yet available for publication and will be presented in the NCCR IV. This section of the NCCR III summarizes the results that were presented in NCCR II. The NCCR II assessment indicated that, for the indices and component indicators measured, the primary problems in Puerto Rico's coastal waters are degraded sediment quality, degraded benthos, 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 Harbor, the Caño Boquerón, Laguna del Condado, and Laguna San José.

Water Quality Index

As described in the NCCR II, the water quality index for Puerto Rico's coastal waters is rated fair. This water quality index was developed using five water quality indicators: DIN, DIP, chlorophyll *a*, water clarity, and dissolved oxygen. Although only 9% of the coastal area was rated poor, 63% of the area was rated poor and fair, combined (Figure 8-18). Nutrient levels were rated fair and good for DIN and DIP, respectively. Low scores for chlorophyll *a* (poor) and water clarity (fair) contributed to the overall rating. Dissolved oxygen concentrations in Puerto Rico coastal waters were rated good. Estimates showed that only 1% of bottom waters have hypoxic conditions (< 2 mg/L) on a continuing basis in late summer; however, dissolved oxygen data were missing for 27% of the coastal area.

Limestone cliffs near Los Morillos Lighthouse, Cabo Rojo, PR (courtesy of Smylere Snape).

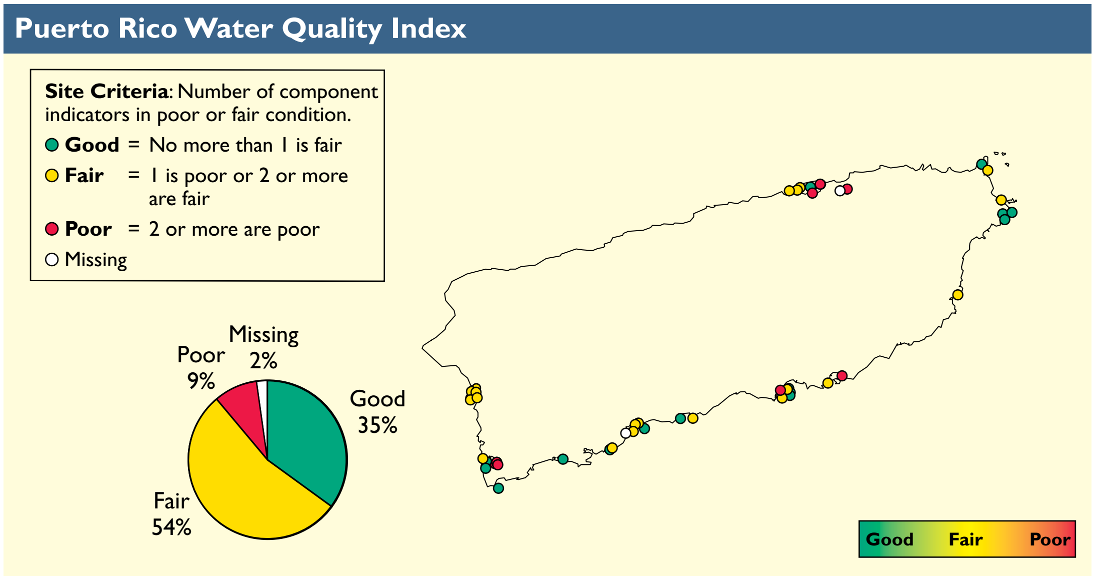


Figure 8-18. Water quality index data for the coastal waters of Puerto Rico (U.S. EPA/NCA).

Highlight

The Condition of Coral Reefs in Puerto Rico and the U.S. Virgin Islands

The current condition of coral reef ecosystems in Puerto Rico and the U.S. Virgin Islands, which constitute the U.S. Caribbean, was summarized recently in the report *The State of Coral Reef Ecosystems of the United States and Pacific Freely Associated States: 2005* (Waddell, 2005). This report contains quantitative results of assessment and monitoring activities conducted in shallow-water coral reef ecosystems by federal, state, territory, commonwealth, non-government, private, and academic partners. Additionally, it is based primarily on recent, quantitative monitoring data collected *in situ* in each of 14 jurisdictions, including the U.S. Virgin Islands, Puerto Rico, Florida, Navassa Island, Flower Garden Banks, and other banks in the Gulf of Mexico, MHI, NWHI, U.S. Pacific Remote Island Areas, American Samoa, Commonwealth of the Northern Mariana Islands, Guam, and the Freely Associated States of the Republic of the Marshall Islands, the Federated States of Micronesia, and the Republic of Palau.

Coral reef ecosystems in the U.S. Caribbean comprise a mosaic of habitats that host a large diversity of marine organisms, including coral and other hard-bottom areas, seagrass beds, and mangroves. These biologically rich ecosystems provide important services to coastal areas (e.g., shoreline protection) and support valuable socio-economic activities (e.g., fishing, tourism); however, coral reefs are also affected directly and indirectly by these activities. Coral reefs generally form three types of reef structures: fringing reefs, patch reefs, or spur and groove reefs. These structures are distributed around the islands (Adey, 1975; Hubbard et al., 1993; Garcia-Sais et al., 2003). Recent estimates of the spatial extent of coral reef ecosystems from Landsat satellite imagery indicate that coral reef ecosystems in Puerto Rico and the U.S. Virgin Islands potentially cover about 1,022 mi^2 within the 60-ft depth contour or 2,945 mi^2 within the 600-ft depth contour (Rohmann et al., 2005).

Coral reef ecosystems in the U.S. Caribbean face several threats, including climate change, disease, tropical storms, coastal development and runoff, coastal pollution, tourism and recreation, fishing, and ships, boats, and groundings. Point and non-point source discharges into the marine environment remain a major concern and may be contributing to an increase in the abundance and incidence of coral diseases, such as black band disease. Where they exist, rivers represent the main sources of pollutants and sediments to coastal waters (CH2M Hill, Inc., 1979; Anderson and MacDonald, 1998; IRF, 1999).

In Puerto Rico, the highest cover of live corals generally occurs on reefs located on the leeward side of the islands (e.g., Desecheo, Mona); at offshore islands (e.g., Vieques, Culebra, Cayo Diablo); and along the south and west coast of the main island (e.g., La Boya Vieja, Tourmaline). Boulder star coral (*Montastrea annularis*) is the dominant coral species on reefs with relatively high coral cover, whereas the great star coral (*Montastrea cavernosa*), massive starlet coral (*Siderastrea spp.*), and finger coral (*Porites astreoides*) constitute the main coral assemblage of degraded reefs. Coral reefs with high live coral cover generally exhibit relatively a high abundance and diverse assemblage of zooplanktivorous fishes (such as *Chromis spp*., *Clepticus spp*., and *Stegastes partitus* that feed on zooplankton), whereas coral reefs with low live coral cover are dominated numerically by a single species, the dusky damselfish (*Stegastes dorsopunicans*) (Garcia-Sais et al., 2005).

Large flower corals in coral reefs communities in the Jobos Bay NERR (NOAA).

In the U.S. Virgin Islands, current assessments indicate that marine water quality is good, but declining because of increases in point and non-point sources of pollution. Generally, coral cover on reefs is low relative to the abundance of macro- and filamentous algae, which indicate a possible phase-shift from coral-dominated reefs to algal-dominated reefs. Additionally, the dense stands of elkhorn coral (*Acropora palmata*) that were once the dominant shallow-water species of coral in some areas four decades ago have not recovered (Jeffrey et al., 2005).

Several management actions have been taken to conserve coral reef ecosystems in the U.S. Caribbean. Marine-protected areas have been established or expanded throughout Puerto Rico and the U.S. Virgin Islands to provide varying levels of protection for resources and to serve as fishery management tools. Puerto Rico's Department of Natural and Environmental Resources recently revised fisheries laws to halt major declines in recreational and commercial catches, which have fallen as much as 70% between 1979 and 1990 (Garcia-Sais et al., 2005). In the U.S. Virgin Islands, 3,250 mooring buoys have been installed to reduce ship groundings and protect benthic habitats from anchor damage caused by commercial and recreational boat usage. Recent monitoring data from marine protected areas in both Puerto Rico and the U.S. Virgin Islands suggest that commercially important reef fishes such as red hind grouper (*Epinephelus guttatus*) are increasing in size and abundance within reserve boundaries (Jeffrey et al., 2005; Nemeth, 2005).

Although these management actions have had some success in protecting coral reef ecosystems, they could be more effective with greater enforcement. Current coral reef ecosystem conditions would improve further with

- Reductions in the number and intensity of the major threats affecting coral reefs
- Greater enforcement of existing marine protected areas and regulations that govern resource use and extraction
- Increased environmental education and awareness among island residents and visitors.

Additionally, coral reef ecosystems in the U.S. Caribbean would benefit substantially from stronger coordination and collaboration among the federal, territorial, and non-governmental agencies and organizations that have an interest in marine conservation in these islands.

Sediment Quality Index

Overall, sediment quality in Puerto Rico's coastal waters is rated poor. A sediment quality index was developed for Puerto Rico coastal waters using three sediment quality component indicators: sediment toxicity, sediment contaminants, and sediment TOC. More than 60% of Puerto Rico's coastal area was rated poor for one or more of the component indicators (Figure 8-19). Puerto Rico's sediment toxicity was rated good because only 3% of the coastal area contained sediments that were toxic to the test organism. The sediment contaminants component indicator was rated poor in 23% of the coastal area. Puerto Rico sediments were also rated poor with respect to sediment TOC. In this area, elevated sediment TOC values are often associated with contributions to a waterbody's organic loads from untreated wastewater, agricultural runoff, and industrial discharges; however, occasionally, these levels are associated with natural processes in mangrove estuaries. Although it is difficult to discern whether the high levels of TOC in Puerto Rico are due to anthropogenic sources or natural mangrove habitat, many of the areas rated poor for TOC are also relatively devoid of mangrove systems and are known to have high levels of poorly treated sewage discharge.

Benthic Index

The benthic index for Puerto Rico's coastal waters is rated poor, with 35% of the coastal area rated poor (Figure 8-20). Currently, no benthic community index has been developed for Puerto Rico. As a surrogate for benthic condition, the benthic samples were evaluated using standard ecological community indicators: biological diversity, species richness, and abundance. Biological diversity and species richness are measurements that contribute to all of the benthic indices developed by the NCA in the Northeast Coast, Southeast Coast, and Gulf Coast regions. Biological diversity is directly affected by natural gradients in salinity and silt-clay content. Analyses using Puerto Rico data showed no significant relationships between benthic diversity and either salinity or silt-clay content; therefore, benthic diversity was used to directly evaluate benthic condition.

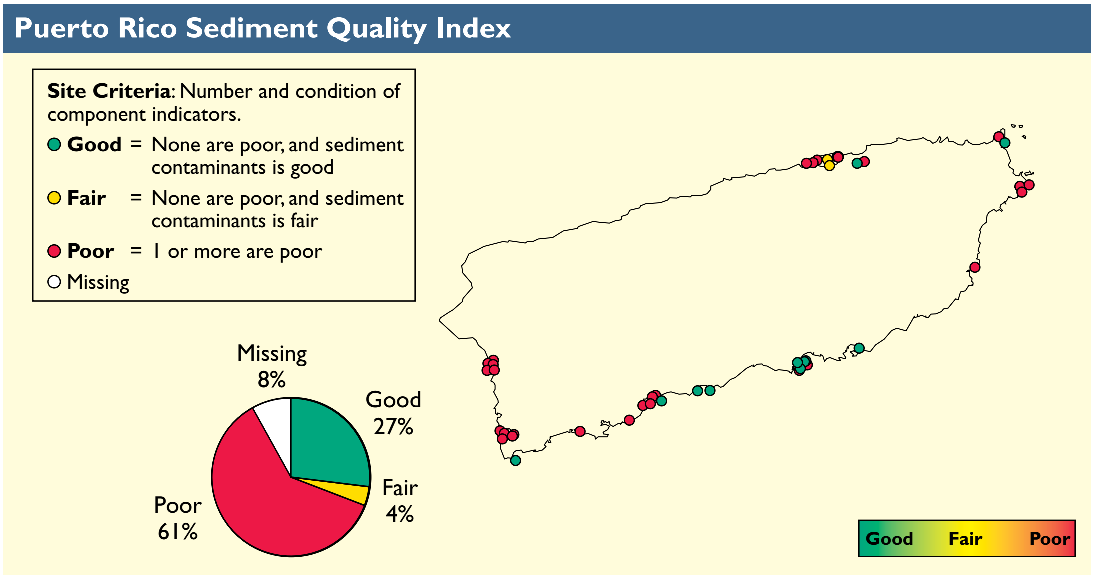


Figure 8-19. Sediment quality index data for the coastal waters of Puerto Rico (U.S. EPA/NCA).

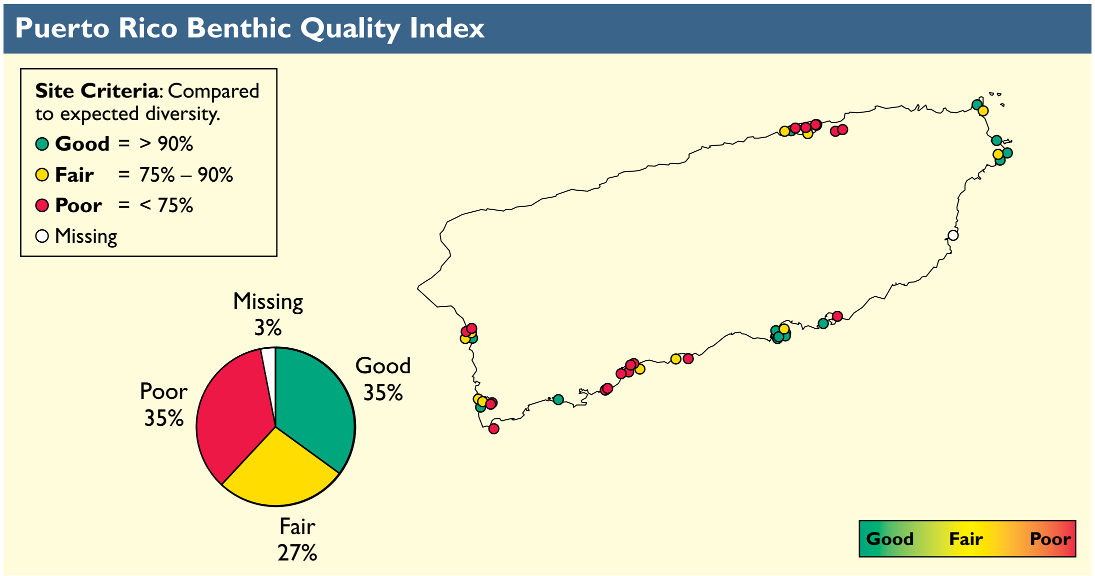


Figure 8-20. Benthic index data for the coastal waters of Puerto Rico (U.S. EPA/NCA).

Coastal Habitat Index

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

Fish Tissue Contaminants Index

Estimates of fish tissue contaminants are not available for Puerto Rico; therefore, the fish tissue contaminants index could not be calculated. In conjunction with the San Juan Bay Estuary Partnership, fish tissue sampling was conducted in the San Jose Lagoon, and the results are available in the NEP CCR (U.S. EPA, 2006b).

Castillo de San Felipe del Morro, also known as El Morro, in San Juan, PR (courtesy of Tony Santana, USACE).

Large Marine Ecosystem Fisheries—Caribbean Sea LME

Puerto Rico is located within the Caribbean Sea LME (Figure 8-21). This semi-enclosed LME is bounded by the Southeast U.S. Continental Shelf and Gulf of Mexico LMEs to the north, Central America to the west, South America to the south, and the Atlantic Ocean to the east. The Caribbean Sea LME is considered a low-productivity ecosystem with localized areas of higher productivity along the coast of South America. This LME is bordered by 38 countries and dependencies and lacks a coordinated effort to monitor and manage the ecosystem (NOAA, 2007g). There is no information available for the fisheries of this LME.

Assessment and Advisory Data

Fish Consumption Advisories

Puerto Rico did not report fish consumption advisory information to EPA in 2003 (U.S. EPA, 2004b).

Beach Advisories and Closures

Puerto Rico did not report monitoring, advisory, or closing information for any beaches in 2003 (U.S. EPA, 2006c).

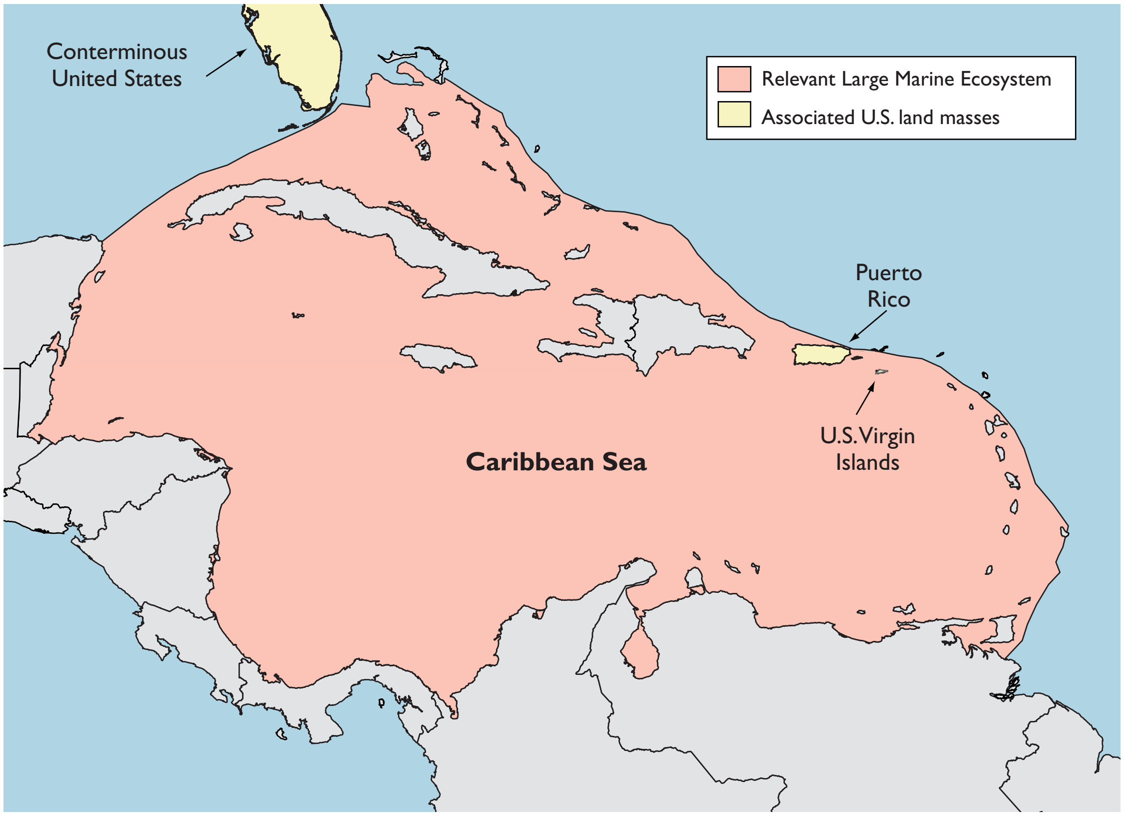


Figure 8-21. Caribbean Sea LME (NOAA, 2007g).

American Samoa, Guam, Northern Mariana Islands, U.S. Virgin Islands

Coastal Monitoring Data—Status of Coastal Condition

American Samoa, Guam, the Northern Mariana Islands, and the U.S. Virgin Islands were not assessed by NCA in 2001 or 2002. American Samoa, Guam, and the Northern Mariana Islands are located in the Pacific Ocean (Figure 8-22), and the U.S. Virgin Islands are found in the Caribbean Sea (Figure 8-21).

Large Marine Ecosystem Fisheries

Guam, the Northern Mariana Islands, and American Samoa are not located within an LME. The NMFS Western Pacific Region manages the fisheries in these waters in conjunction with those of the Insular Pacific-Hawaiian LME. These fisheries were discussed in the Hawaii section of this chapter. The U.S. Virgin Islands are located within the Caribbean Sea LME, which is discussed in the Puerto Rico section of this chapter.

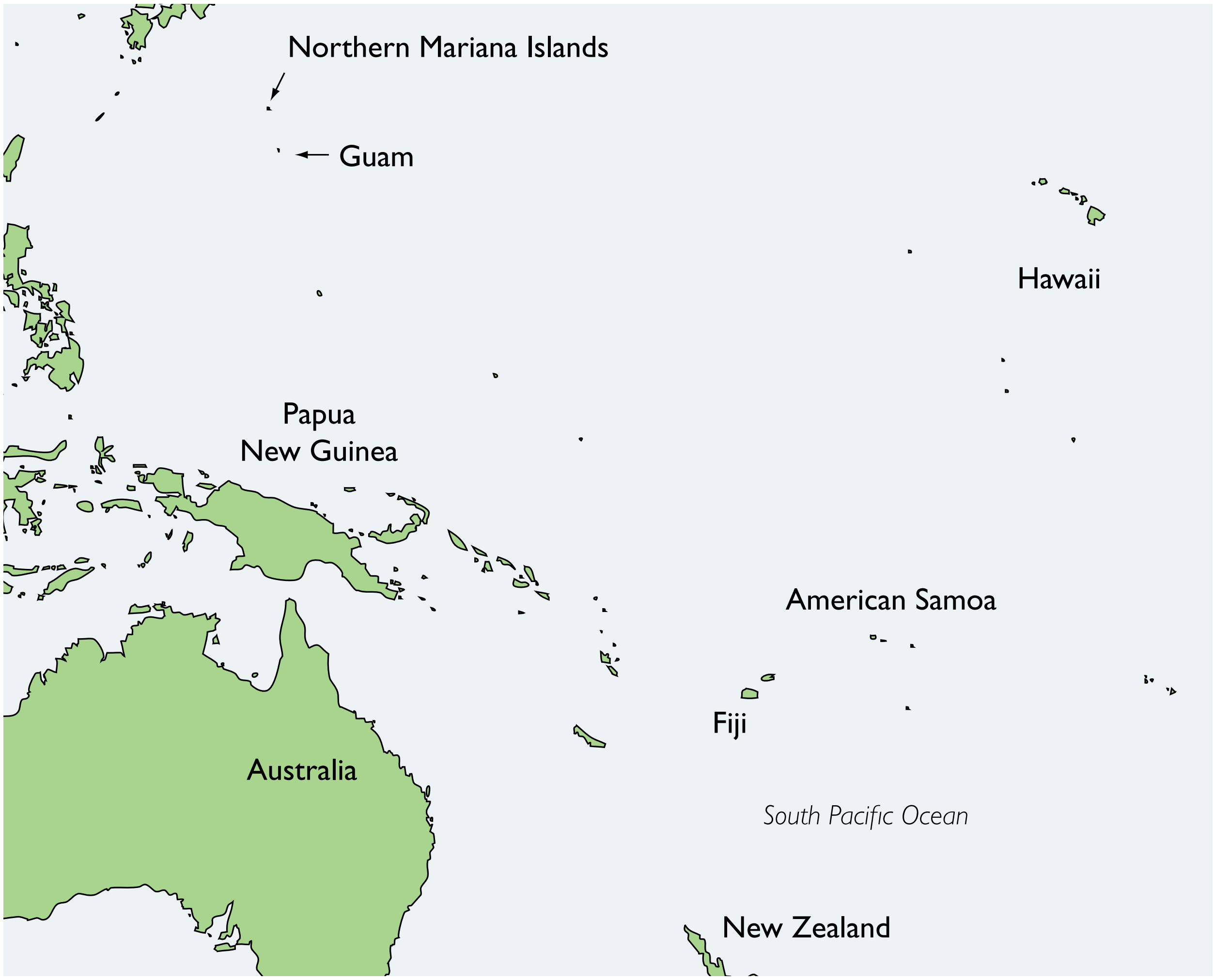


Figure 8-22. Locations of the U.S. Pacific island territories (U.S. EPA/NCA).

Highlight

The NCA Survey of Guam, 2004

The island of Guam is a 212-mi^2, unincorporated territory of the United States, with a population of approximately 166,000 residents. The entire island of Guam is classified as a coastal zone. Practically all residences are served by public/military community water supply systems, with a large number of single-family dwellings using individual septic tank/leaching field systems. Approximately 1 million tourists visit Guam annually, largely drawn by the island's tropical climate and clean, recreational, fresh and marine waters. The Guam Environmental Protection Agency currently monitors some indicators of the physical and chemical condition of marine receiving waters; however, the lack of quantitative baseline information for water, sediment, and tissue pollutant concentrations limits the ability to provide a comprehensive assessment of receiving waterbodies. The establishment of long-term comprehensive monitoring programs is needed as a first step toward developing any program of pollution abatement and habitat restoration. As a first step in this process, the Guam Environmental Protection Agency has participated in the NCA survey (Guam Environmental Protection Agency, 2006).

The Guam component of the NCA survey is based on a combination of the procedures and methods of the NCA coupled with specialized methods for sampling hard-bottom habitats such as coral reefs (Guam Environmental Protection Agency, 2006). These specialized methods were first developed and used by the 2002 NCA assessment for Hawaii (Nelson et al., 2007). Thus, the Guam assessment is consistent with the broader NCA, while taking into account modifications that have been developed for tropical coral reef island environments.

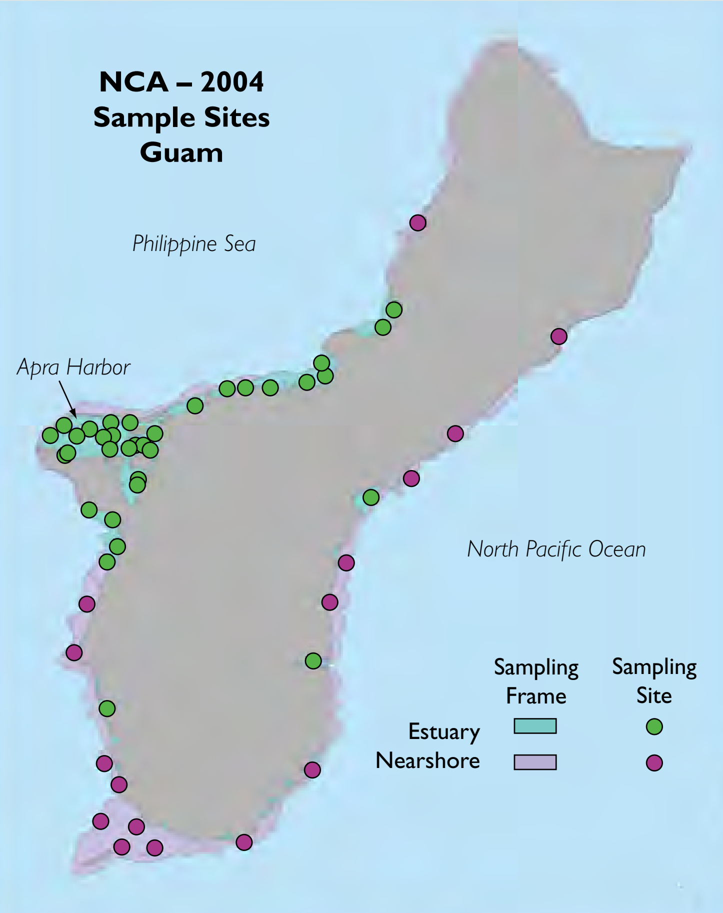
The Guam NCA survey used some of the same indices and indicators as the NCA surveys of other regions, but some indices/indicators were added or modified. The Guam assessment included such standard NCA indices as the fish tissue contaminants index and the benthic index, as well as component indicators such as water-column nutrient levels, bottom-water dissolved oxygen concentrations, water clarity, and sediment contaminant concentrations. Coral disease identification is under consideration as an indicator for use in future monitoring efforts. The major modifications to the NCA index/indicator list and protocols include the following:

- Replacement of fish trawls, which are very destructive to coral reef communities, with visual census protocols in conjunction with reef and pelagic fish standing stock estimates for fish community assessments
- Use of sea cucumber or crab samples rather than fish samples for the fish tissue contaminants index
- Addition of storm wave-impact estimates
- Addition of water-column analyses for microbial contamination
- Addition of hard-bottom benthic habitat monitoring using transect and quadrat measurements of the percent cover of macroinvertebrate and algal composition on rock outcrops and coral substrates (Guam Environmental Protection Agency, 2006).

The coastal resource definition for the NCA in Guam encompasses all waters with salinity greater than 0.5 psu and a depth between mean low water and the 60-ft depth contour. Within this depth contour, two sampling strata were created. The estuary stratum consisted of estuaries and more protected embayments, whereas the nearshore stratum consisted of the more open coastlines of the island. There was one exception to the depth criterion. NCA sampling was conducted in Apra

Harbor, which was designated as a special study area where water depth often exceeds 60 feet. At stations located within Apra Harbor and with depths greater than 60 feet, a modified sampling procedure was utilized to sample only for water-column parameters, sediment contaminants, and benthos. The Guam assessment is designed to be conducted during the island's wet season, July through December, during even numbered years. To conduct the sampling, fisheries experts from the staff of the Government of Guam Department of Agriculture's Division of Aquatic and Wildlife Resources collaborated with staff scientists from the Monitoring Program of the Guam Environmental Protection Agency.

The field sampling for the Guam NCA was initiated in November 2004 and completed in August 2005. High seas proved to be a major challenge to conducting field work in the near-coastal area of Guam because tropical typhoons in the region frequently generated rough weather. Additional difficulties were encountered in the deepest areas of Apra Harbor. In spite of an attempt to use grab samplers in this area, five stations could not be sampled with the vessel available due to excessive depth and strong currents; alternate stations were added as replacements. All of the dropped stations were at depths greater than 120 feet. During the NCA in 2004, 50 stations were successfully sampled (see map). Samples collected during the study period are still undergoing analyses.



Estuarine and nearshore sampling stations used in the 2004 NCA survey of the island of Guam (U.S. EPA/NCA).

The Guam NCA represents a major effort on the part of the Guam Environmental Protection Agency to improve its approach to monitoring the coastal resources of the island. The effort would not have been possible without the collaboration and support of scientists from EPA NCA and the EMAP, the staff of EPA Region 9 Pacific Islands Office, and the dedicated personnel from multiple agencies of the Government of Guam.

Assessment and 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 8-23). This estuarine 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 waters under advisory. 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. Guam, the Northern Mariana Islands, and the U.S. Virgin Islands did not report fish consumption advisory information to EPA in 2003 (U.S. EPA, 2004b).

Beach Advisories and Closures

American Samoa, Guam, the Northern Mariana Islands, and the U.S. Virgin Islands did not report monitoring, advisory, or closing information for any beaches in 2003 (U.S. EPA, 2006c).

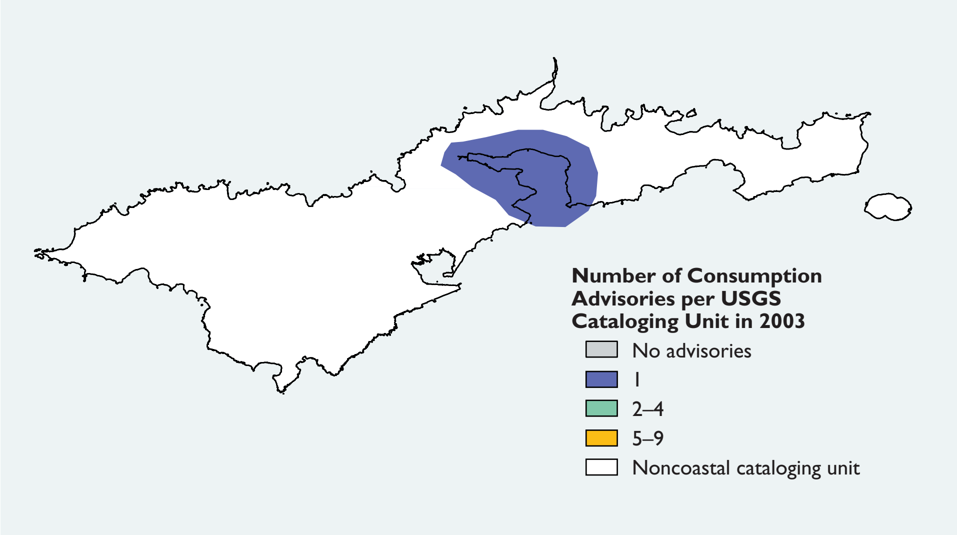


Figure 8-23. Fish consumption advisory for American Samoa, location approximate (U.S. EPA, 2004b).

Pago Pago Harbor, American Samoa (courtesy of NPS).

Summary

During 2002, NCA conducted sampling in the coastal waters of Southcentral Alaska and in Hawaii. Puerto Rico was assessed by NCA in 2000, and those results were presented in the NCCR II and are summarized here. Sampling was conducted in Guam, American Samoa, and the U.S. Virgin Islands in 2004–2005; however, these results are not included in this NCCR III. Currently, no plans have been made to assess the Northern Mariana Islands.

Based on the NCA data, overall condition is rated good for Southcentral Alaska's coastal waters, good in Hawaii's coastal waters, and poor in the coastal waters of Puerto Rico. The water quality, sediment quality, and fish tissue contaminants indices are rated good for Southcentral Alaska. All of the component indicators, except for DIP and water clarity, are also rated good for Southcentral Alaska, and DIP and water clarity are rated fair. The coastal habitat and benthic indices were not assessed for Southcentral Alaska's coastal waters. In Hawaii, the water quality index is rated good and the sediment quality index is rated fair to good. Chlorophyll *a* is the only component indicator rated fair for Hawaii; the rest of the indicators are rated good. The coastal habitat, benthic, and fish tissue contaminants indices were not assessed in Hawaii during 2002. As reported in the NCCR II, Puerto Rico's water quality index is rated fair, and the sediment quality and benthic indices are rated poor. The coastal habitat and fish tissue contaminants indices were not assessed in Puerto Rico. Trends in NCA data could not be evaluated for Alaska, Hawaii, or Puerto Rico.

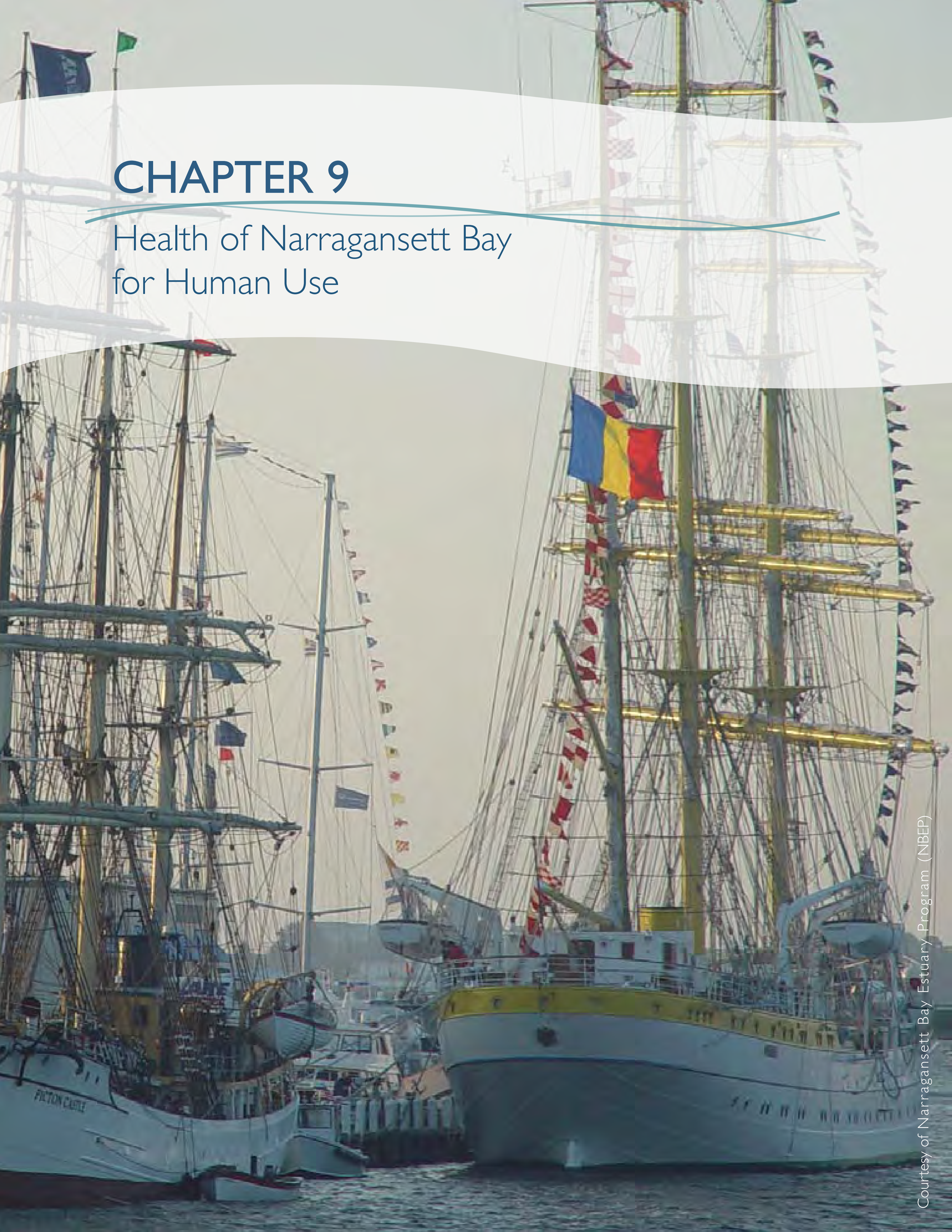
NOAA's NMFS manages several fisheries in the LMEs bordering Alaska and Hawaii, as well as those in the waters surrounding Guam, the Northern Mariana Islands, and American Samoa. No information is available for the fisheries of LME surrounding the U.S. Virgin Islands and Puerto Rico. The East Bering Sea LME and the Gulf of Alaska LME are two of the LMEs that surround Alaska, and NMFS manages the salmon, herring, demersal fish, and shellfish fisheries in these waters. In general, salmon and crab resources are fully utilized; East Bering Sea LME demersal fish stocks are slightly underutilized; herring and Gulf of Alaska LME demersal fish stocks are relatively stable; and shrimp stocks are low. The Insular Pacific-Hawaiian LME consists of the waters around Hawaii and is managed by the NMFS Western Pacific Region in conjunction with the waters surrounding Guam, the Northern Mariana Islands, and American Samoa. The fisheries managed in these waters include invertebrate, demersal fish, and pelagic armorhead fisheries. The lobster and pelagic armorhead fisheries are closed or under a fishing moratorium; the coral fishery is open, but only shallow-water, black coral is being harvested. Limited stock assessments indicate that MHI spawning stocks of demersal fish are at 5% to 30% of unfished levels.

Summary

Contamination in the coastal waters of Hawaii and American Samoa has affected human uses of these waters. In 2003, there was one fish consumption advisory in effect for Pearl Harbor, HI, and one in effect for Inner Pago Pago Harbor, American Samoa. Hawaii's advisory was for PCBs, and American Samoa's advisory was for chromium, copper, DDT, lead, mercury, zinc, and PCBs. Alaska, Puerto Rico, Guam, the Northern Mariana Islands, and the U.S. Virgin Islands did not report fish consumption advisory information to EPA in 2003. None of these areas reported beach monitoring, advisory, or closure information to EPA for 2003.

CHAPTER 9

Health of Narragansett Bay for Human Use



Courtesy of Narragansett Bay Estuary Program (NBEP)

Health of Narragansett Bay for Human Use

The previous chapters of this report address the condition of the nation's coasts in terms of how well they meet ecological criteria. A related, but separate consideration is how well coasts are meeting human expectations in terms of the goods and services they provide for transportation, development, fishing, recreation, and other uses. Human use does not necessarily compromise ecological condition, but there are inherent conflicts between human activities (e.g., marine transportation) that alter the natural state of the coasts and activities (e.g., fishing) that rely on the bounty of nature. The emphasis of this chapter is on human uses and how well they are met. For uses that are not being fully met, the question arises as to how the shortfall is related to coastal condition as described by ecological indicators.

Because determining the effect of human uses on an estuary is specific to an estuary's surrounding area and relies on local information, such an assessment can be pursued only at the level of individual estuaries. The corresponding chapter in the NCCR II centered on Galveston Bay, TX, for this assessment; in this report, the chosen estuary is Narragansett Bay in Rhode Island and Massachusetts. To a large extent, this choice is dictated by the availability of data, and Narragansett Bay is an estuary for which high-quality, long-term data exist on the abundance of commercial and recreational fishes. Although fishing is not the only human use of an estuary, it is an important use that is thought to be strongly connected with ecological indicators.

Wickford Harbor on the west shore of Narragansett Bay (courtesy of NBEP).

Overview of Narragansett Bay

Narragansett Bay (Figure 9-1), which includes the Providence and Seekonk rivers, is approximately 48 miles long, 37 miles wide, and 132 mi^2 in area (Ely, 2002). Although the Bay lies almost entirely within Rhode Island, a small portion of northeastern Mount Hope Bay is located within Massachusetts. The Bay's watershed includes parts of all five Rhode Island counties (Bristol, Kent, Newport, Providence, and Washington) and five counties (Worcester, Middlesex, Norfolk, Bristol, and Plymouth) in Massachusetts. The total area of the watershed is 1,820 mi^2, and approximately 40% of this area is located in Rhode Island (Ries, 1990; Crawley et al., 2000). The three main rivers that drain into Narragansett Bay are the Pawtuxet, Blackstone, and Taunton rivers.

This chapter will examine the human uses of the Bay (bounded at its seaward end by a line running southwest from Sakonnet Point to Point Judith) and its watershed. Data associated with Block Island and the coast of mainland Rhode Island running along Block Island Sound from Point Judith to the Connecticut state line will not be included in this assessment.

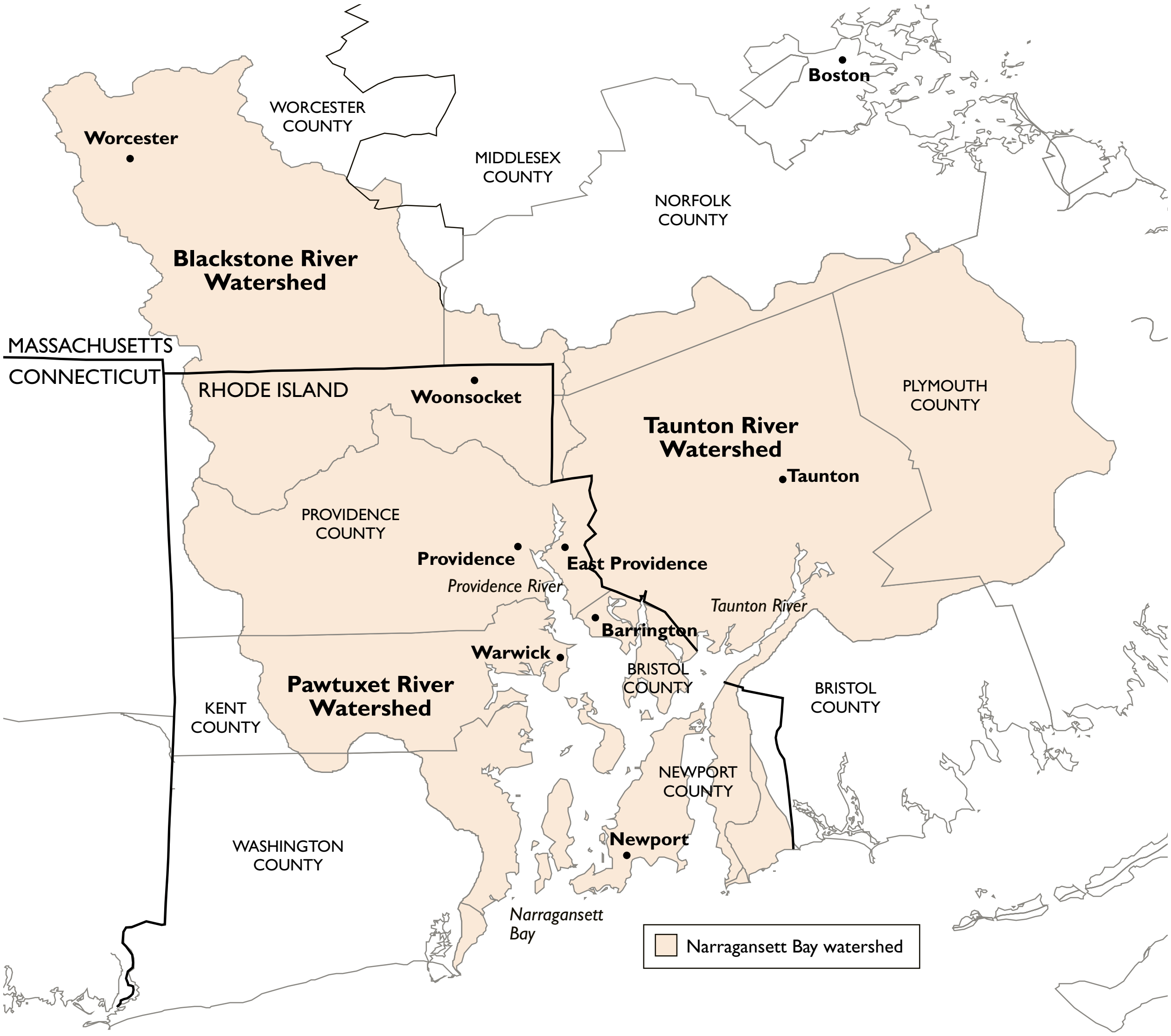


Figure 9-1. The Narragansett Bay watershed and surrounding counties (U.S. EPA/NCA).

Development Uses of Narragansett Bay

Development uses are human activities that alter the natural state of Narragansett Bay and its watershed. Some of the most important of these activities are land use changes and development in the Bay's watershed; marine transportation; and point-source discharges of cooling water and wastewater to the Bay.

Land Use Changes and Development

By the 18th century, a merchant economy had developed to replace agriculture as the primary economic force in Rhode Island. The deep, sheltered harbors and availability of fresh water helped to spur the transformation of Newport into one of the premier centers for maritime trade and shipbuilding. By the middle of the 19th century, another transformation had occurred: the rivers draining into Narragansett Bay were being used to provide both power and transportation for a rapidly developing industrial economy. Textile mills, metalworking operations, and jewelry manufacturing plants lined many of the watershed's rivers (Crawley et al., 2000); however, by the 20th century, industrial production had declined, in part due to the migration of textile industries to the south. Currently, land use in the Narragansett

Bay watershed is divided among a number of categories (Table 9-1). The largest categories of developed land are residential and agricultural.

Throughout the 20th century, the counties in the Narragansett Bay watershed have been a popular place to live (Figure 9-2). The human population in the watershed doubled between 1900 and 1980. The population of the watershed has moved from urban areas to the more suburban and rural parts of the watershed since 1980 due to the advent of better transportation and changing lifestyles, resulting in a population decline in several cities, including East Providence, Warwick, Newport, Barrington, and Woonsocket in Rhode Island, and Worcester and Taunton in Massachusetts (Burroughs, 2000; Crawley et al., 2000). Although the rate of population growth in Rhode Island has been slow since 1980, residential development, particularly single-family homes, has increased markedly (Rhode Island Department of Administration, 2000). Currently, the watershed's population is estimated at approximately 1.8 million people, and residential land accounts for more than 20% of the area, representing the largest area of any developed land use category in the watershed (Crawley et al., 2000; Save the Bay, Inc., 2006).

Table 9-1. Land Use in the Narragansett Bay Watershed (Crawley et al., 2000)

Land Use	Area (mi^2)	Percent
Residential	216.6	20.1
Agricultural	76.7	7.1
Commercial	20.7	1.9
Recreational	19.4	1.8
Institutional	16.7	1.5
Industrial	13.4	1.2
Transportation and Utilities	10.7	1.0
Roads	10.2	0.9
Commercial/Industrial Mix	2.3	0.2
Urban Vacant	6.9	0.6
Gravel Pits and Quarries	8.4	0.8
Waste Disposal	4.4	0.4
Wetlands, Water, Barren	203.3	18.8
Forest	470.4	43.6

The approximately 77 mi^2 of farmland in the Narragansett Bay watershed represent approximately 7% of the total land area (Crawley et al., 2000). Major agricultural crops in Rhode Island and Massachusetts include corn and turf. Although Newport County, RI, has the highest percentage (15%) of agricultural area in the watershed, Worcester County, MA, has the greatest number of acres (104,000 acres) dedicated to agriculture (USDA, 2004a; 2004b). It should be noted that these data are presented on a county level and may include agricultural area located within the county, but outside of the Narragansett Bay watershed.

Although the economy of Rhode Island has moved towards a mix of service industries, specialized businesses, and tourism and recreation since World War II, industrial operations remain in the area. Land used for industrial operations accounts for a little over 1% of the land area in the Narragansett Bay watershed (Crawley et al., 2000). According to the Economic Census, the manufacturing industry in Rhode Island produced $10.5 billion in sales and employed more than 75,000 people in 1997 (U.S. Census Bureau, 2000b). The computer manufacturing and electronics, fabricated metal, electrical equipment and appliances, and textile industry sectors offered the major employment opportunities in the

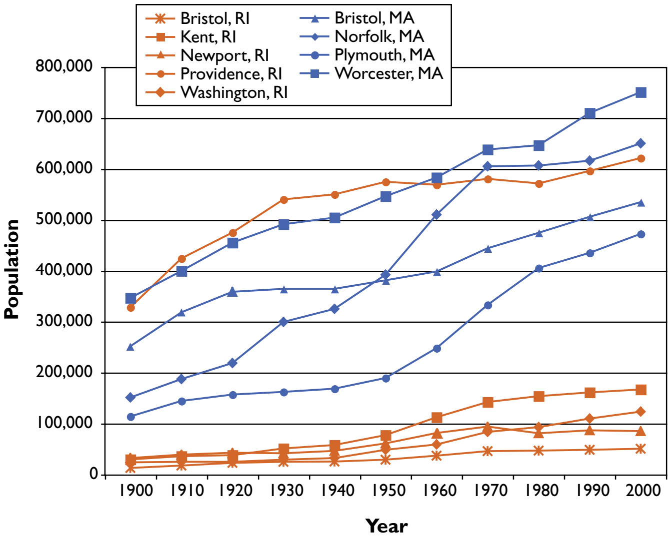


Figure 9-2. Population trends by county in the Narragansett Bay watershed (U.S. Census Bureau, 2001).

Industrial production in the Narragansett Bay watershed developed in the middle of the 19th century (courtesy of Marcbela).

region (U.S. Census Bureau, 2000a; 2000b). For example, manufacturing in Worcester County, MA, accounts for $11.3 billion annually and employs 61,000 people, primarily in computer, metal fabrication, and chemical manufacturing. In Bristol County, MA, computer, electronics, and primary metal manufacturing activities accounted for $7.7 billion in 1997 and employed more than 49,000 people (U.S. Census Bureau, 2000a).

Marine Transportation

Marine transportation is integral to the economy of Narragansett Bay. There are two main shipping channels (Providence River and Quonset/Davisville) and three public ports (Providence, Fall River, and Quonset/Davisville). The majority of commercial marine vessels entering Narragansett Bay carry petroleum products. In 1997, 86% of the 8.78 million t of cargo entering Narragansett Bay were petroleum products, primarily fuel oil and gasoline carried on barges. Cruise ships and ferries are also an important part of the economy of Narragansett Bay, and the number of cruise ships heading to Newport, RI, has increased since 1994 (Anderson et al., 2000).

Recently, the citizens of Rhode Island were faced with three marine transportation issues. Since last dredged in 1971, the Providence Ship Channel had become so shallow and narrow that the U.S. Coast Guard restricted the passage of two-way ship traffic and deep-draft vessels in the upper portion of the Channel located within the Providence River. As a result of these restrictions, petroleum products had to be transferred from tankers onto barges before delivery to Providence Harbor. Dredging was required to return the Channel to its authorized 40-ft depth and to increase the efficiency of marine transportation to the Harbor. After some debate, dredging operations began in April 2003 and were completed in January 2005, resulting in the removal of 6 million cubic yards of sediment (USACE, 2001; 2005). A second issue concerned the development of a container ship terminal at the former U.S. Naval facility at Quonset Point in North Kingstown (Ardito, 2002). The project was dropped in 2003, and other plans are being developed for the area. Finally, there have been a number of proposals to develop liquid natural gas (LNG) terminals at various locations in Narragansett Bay. Safety, security, and environmental concerns have been raised over the transport and storage of LNG.

Point-Source Discharges

Narragansett Bay is also used to receive point-source discharges of cooling water, industrial wastewater, and municipal wastewater. EPA reports that there are more than 40 major point-source dischargers in the Narragansett Bay watershed (Figure 9-3) (U.S. EPA, 2005c). The largest of these dischargers is the Brayton Point power plant in Somerset, MA. Brayton Point is the largest fossil-fuel power plant in New England and produces approximately 6% of the region's electricity (Ardito, 2002). This plant uses approximately 800 million gallons of water from the Bay per day as cooling water; after the water is used, warm water is discharged to the Bay. Studies have shown that the discharge of heated water from the Brayton Point facility to the Bay has contributed to the collapse of the Mount Hope Bay winter flounder fishery. In recognition of this possible conflict between competing human uses, renewal of the plant's discharge permit contains provisions to decrease water withdrawals from the Bay by 94% and reduce the annual heat discharge by 96% (U.S. EPA, 2003). The next-largest point-source facility in the watershed is the Dominion Energy power plant in Providence, RI, with a discharge flow of approximately 260 million gallons per day (U.S. EPA, 2005c).

Wastewater from industrial and municipal sources is also discharged from point sources located within the Narragansett Bay watershed. A number of paint/pigment manufacturers, seafood processors, and petroleum bulk stations and terminals operate in Rhode Island and discharge industrial wastewater to the Bay and its watershed. The majority of the other large point-source dischargers are WWTPs. There are ten major WWTPs in the watershed, with design capacities of more than 10 million gallons per day; three plants are located in Massachusetts (Worcester, Brockton, and Fall River), and seven are located in Rhode Island (Field's Point [Providence], Bucklin's Point [East Providence], East Providence, Cranston, West Warwick, Woonsocket, and Newport) (U.S. EPA, 2005c). Although the total population of the watershed has continued to increase, the number of area residents using these WWTPs has remained steady over the past 30 years (Nixon et al., 2005).

Industrial and municipal wastewater can contribute heavy metals to the Bay. In the context of detailing metal inputs to Narragansett Bay, Nixon (1995) described the history of development and industrialization in Rhode Island from colonial times to the present. Metal inputs began to decline remarkably after about 1960. Some of this decrease can be attributed to the state's changing economic base, but increasing controls on metal releases from a variety of sources, upgrades to STPs, and the cessation of sewage sludge dumping in the Bay has also contributed to the decline (Nixon, 1995).

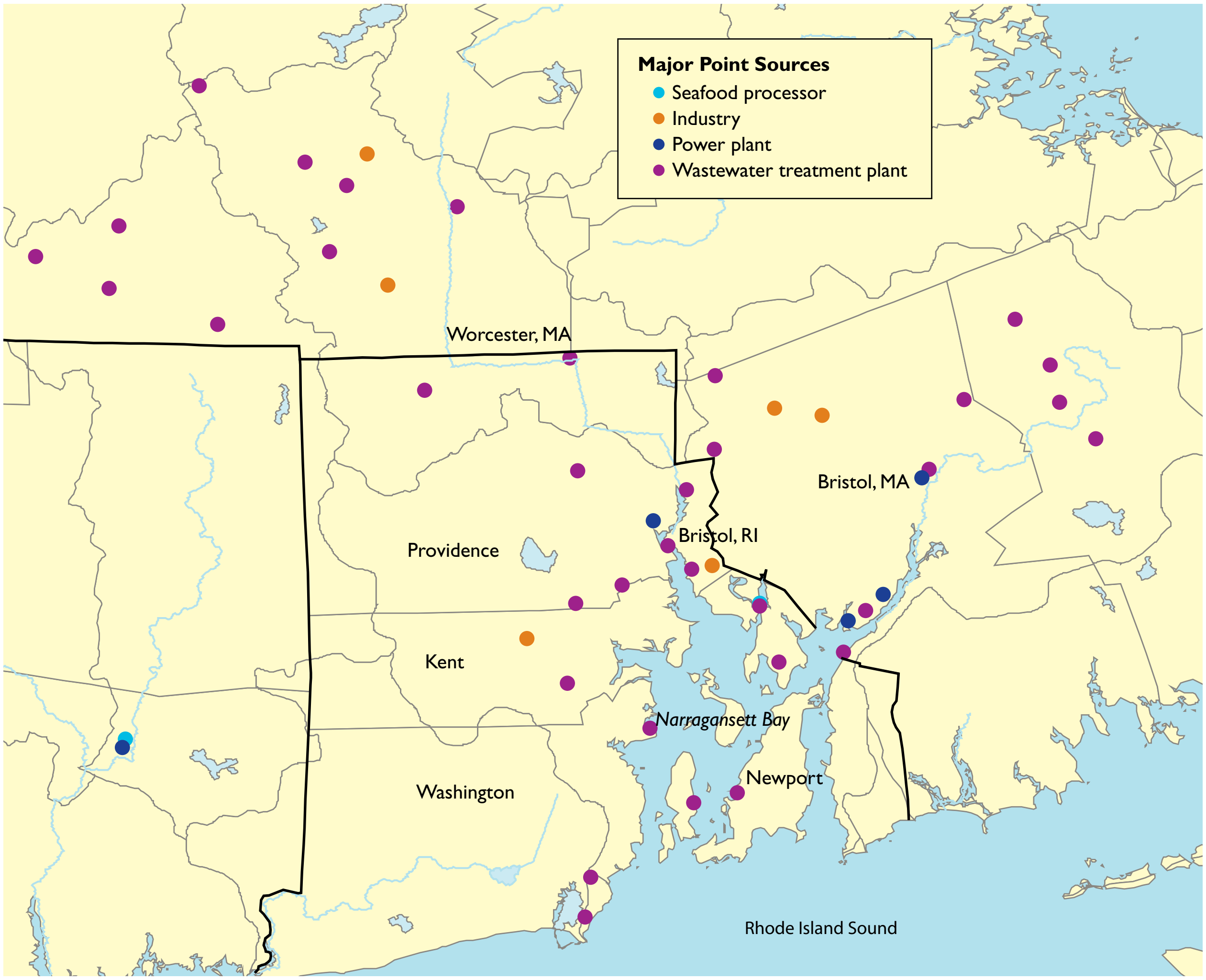


Figure 9-3. Major point sources in the Narragansett Bay watershed (U.S. EPA, 2005c).

Nitrogen and phosphorus are other pollutants that can enter the Bay through point-source discharges of industrial and municipal wastewater. Nixon et al. (2005) examined nitrogen and phosphorus inputs to the Bay from the direct discharge of municipal wastewater, as well as inputs from the some of the Bay's tributaries, which can provide insight into contributions from upstream point and non-point sources of nitrogen and phosphorus (including WWTPs). Overall, nitrogen inputs to the Bay have not increased in recent decades, and phosphorus inputs have decreased. The study also concluded that these tributaries contributed 1.5 times more nitrogen and 2.7 times more phosphorus than the combined discharges from the area's three largest WWTPs (Nixon et al., 2005); however, a large portion of the nutrient load to these tributaries comes from other municipal WWTPs.

Nutrients, including nitrogen and phosphorus, support vegetative growth and are essential to marine life; however, high levels of nutrients can lead to excessive vegetative growth. The subsequent decay of this plant matter consumes oxygen and lowers dissolved oxygen concentrations in the waterbody. Bergondo et al. (2005) and Deacutis et al. (2006) found that summer oxygen measurements in both deep and shallow waters in certain areas of upper Narragansett Bay can drop below 2 mg/L (a level that is intolerably low to some organisms even when maintained over short periods [hours]). These hypoxic conditions are due to nutrient-induced algal growth coupled with the lower mixing rates that occur during neap tides, which are periods of low wind and strong stratification that isolate deep water from surface waters. Bergondo et al. (2005) also reviewed dissolved oxygen measurements collected since 1959 during summertime neap tides in the deep waters of upper Narragansett Bay. Low dissolved oxygen concentrations (< 3 mg/L) were only observed in 18% of the measurements, indicating that the presently observed conditions are likely a relatively new feature of Narragansett Bay. Further information on dissolved oxygen levels in Narragansett Bay is available at http://www.geo.brown.edu/georesearch/insomniacs. In recognition of the low oxygen levels in the upper Bay and their connection with nutrient levels, the Rhode Island Department of Environmental Management (RIDEM) has initiated a program to reduce nitrogen concentrations in effluent from WWTPs (RIDEM, 2005b).

The Rose Island Lighthouse is located in the southern portion of the Narragansett Bay, near Newport, RI (courtesy of NBEP).

Highlight

Summer Dead Zone Kills Billions of Narragansett Bay Mussels

During the summer of 2001, low dissolved oxygen levels (hypoxia) caused fish kills, foul odors, and closed beaches throughout Narragansett Bay (Lawton, 2006). At the same time, scientists discovered a massive die-off of blue mussels (*Mytilus edulis*), which are a foundation species and vital to the health of the Bay. Oxygen depletion in bottom waters suffocates sea life, particularly sedentary bottom dwellers that are unable to leave the area, such as the blue mussels. These species are frequently keystones of coastal ecosystems, providing water filtration and circulation, as well as habitat for other species (Altieri and Witman, 2006). As they filter the water, these sedentary bottom dwellers consume phytoplankton or algae, and the declines in bivalve populations may result in the inability to avoid future hypoxic events caused by algal blooms.

Increased nutrient levels from sources such as fertilizer applications, sewage spills, or septic tanks can initiate hypoxic events in estuarine waters. Paired with warm summer temperatures and a lack of water circulation, nutrient pulses to the estuary create ideal conditions for exponential increases in phytoplankton populations, resulting in massive algal blooms. As the algae from the blooms die and sink to the bottom, bacteria consume them along with dissolved oxygen, creating hypoxic areas or “dead zones” in estuarine bottom waters (Lawton, 2006).

By consuming phytoplankton, suspension feeders such as bivalve mollusks (e.g., blue mussels) have the potential to help control the eutrophication that ultimately fuels the development of hypoxic events (Officer et al., 1982); however, bivalves are frequently the casualties of hypoxia due to their sedentary nature. When hypoxia reduces bivalve populations, the bivalves filter less water and consume less phytoplankton. A decreased filtration capacity may lead to increased occurrences of hypoxia and further mortality of these suspension feeders; therefore, these catastrophic hypoxic events and their resulting localized extinctions may trigger a downward spiral, with coastal zones less able to cope with environmental degradation (Altieri and Witman, 2006).

One month before the 2001 hypoxia event occurred, surveys of nine mussel reefs in Narragansett Bay revealed healthy, densely packed mussels covering the sea floor. As the summer progressed, researchers noted the greatest reductions in mussel densities on reefs where bottom-water dissolved oxygen concentrations were lowest. One of the nine reefs studied experienced complete mussel extinction, and seven more were severely depleted. Approximately 4.5 billion mussels, about 80% of the reefs’ populations, died that summer. In the fall of 2002, one year after the die-off event, the mussel population on only one of the nine reefs was recovering (Altieri and Witman, 2006).

In order to help assess the effects of the die-off on the Bay, Altieri and Witman (2006) calculated the filtering capacity of mussels on the reefs. Before the 2001 hypoxic event, healthy mussel populations took approximately 20 days to filter the equivalent of the entire water volume of Narragansett Bay. During the summer of 2001, the filtering capacity of the nine mussel reefs studied declined by more than 75%, increasing the number of days needed to filter the volume of the Bay to approximately 79 days (Altieri and Witman, 2006). With the mussel population and its filtering capacity severely depleted, Narragansett Bay may lose the ability to prevent future dead zones from forming. Dead zones have occurred in Southeast Coast estuaries as a result of the near extinction of oysters (*Crassostrea virginica*), which in turn contributed to further hypoxia and failure of oyster populations to recover (Ulanowicz and Tuttle, 1992; Lenihan and Peterson, 1998).

The loss of a foundation species such as the blue mussel, which filters water and provides food and habitat for other estuarine organisms, can have a significant, long-lasting effect on the local Narragansett Bay ecosystem; however, it is not an isolated incident. According to a 2004 United Nations Environment Programme report (UNEP, 2004), the number of coastal areas affected by hypoxia worldwide has doubled since 1990. Dead zones similar to those experienced in Narragansett Bay can also be found along the East Coast of the United States, in European coastal waters, and off the coasts of Australia, Brazil, and Japan. One of the largest dead zones occurs annually in the Gulf of Mexico near the mouth of the Mississippi River Delta, where the hypoxic zone has been know to extend along the coastline covering up to 8,500 mi^2, an area the size of New Jersey (Rabalais et al., 2002).

When excess nutrients are introduced to poorly flushed waters, massive algal blooms, such as this dense green macroalgal bloom near Warwick, RI, can occur. These blooms can initiate hypoxic events in estuarine waters (courtesy of Giancarlo Cichetti, IAN Network).

Amenity-Based Uses of Narragansett Bay

Amenity-based uses depend on the natural resources of Narragansett Bay and include accessing the shoreline, swimming, boating, and commercial and recreational fishing. Over time, many of these uses have been impacted by human activities and population pressures in the watershed.

Amenity-based uses contribute economic and recreational value to the area's residents. For example, more than 12 million people visit the Bay area each year, contributing to the area's major tourism industry (Save the Bay, Inc., 2006). In 1998, this industry was second only to health services in terms of total wages for the area, and 30% of tourism was associated with amenity-based uses of Narragansett Bay (Colt et al., 2000). Colt et al. (2000) estimate that the great economic value of the Bay's tourism industry is probably far exceeded by its recreational value to area residents.

Public Access

The Rhode Island Constitution (Article I, Section 17) states that "The people shall continue to enjoy and freely exercise all rights of fishery, and privileges of the shore, to which they have been heretofore entitled under the charter and usages of the state… 'Privileges of the shore' include 'fishing from the shore, the gathering of seaweed, leaving the shore to swim in the sea, and passage along the shore.'" Nonetheless, Bay access is limited because most of the area landward of high tide is privately owned. Although there are 16 miles of public beaches, most of the Bay's 256-mile shoreline is not publicly accessible (Colt et al., 2000; Ely, 2002; Allard Cox, 2004). Of the 80 licensed beaches along Narragansett Bay, 10 are operated by the state or a town and 70 are privately owned (RIDOH, 2005). Some of the private and town-owned beaches are open to the public for a fee. In 1978, the Rhode Island Coastal Resources Management Council (CRMC) began to establish public rights-of-way to the coast. Of the 252 locations described in the guidebook *Public Access to the Rhode Island Coast* (Allard Cox, 2004), 191 access rights-of-way routes established by the CRMC cross otherwise private lands to areas where, depending on the particular right-of-way, the public can reach areas for viewing nature; fishing; swimming; or launching a boat.

Beaches

Bacterial contamination in Narragansett Bay has resulted in periodic closures of licensed private and public beaches. These closures are due to exceedances of bacterial standards and are generally associated with stormwater runoff after rainstorms in the northern, more populated part of the Bay. For example, episodic closures occur near Providence due to overflows from combined storm and sanitary sewers. In other areas, periodic closures occur due to spills. Table 9-2 lists the number of licensed beaches in each county and the number of closings/advisories issued for 2001 to 2004. The Rhode Island Department of Health maintains a Web site (http://www.ribeaches.org/closures.cfm) listing current beach closures. In addition, a general advisory has been issued to discourage swimming and other full-body contact activities in the Providence River portion of upper Narragansett Bay because "These waters are directly affected by pollution inputs due to heavy rains and discharges from area wastewater treatment facilities. Water contact should be avoided for a minimum of 3 days after heavy rainfall" (RIDOH, 2005). A combined sewer overflow (CSO) project is underway in Providence to create a tunnel that will divert up to 62 million gallons of storm water for later treatment rather than allowing it to flow directly into the Bay (Samons, 2002).

Boating is a popular pastime, but the number of slips and moorings in Narragansett Bay has not risen in proportion to boat registrations (courtesy of Chris Deacutis).

Table 9-2. Total Number of Licensed Beaches and Closure/Advisory Days (NRDC, 2005)

County	Number of Beaches	Closure/Advisory Days			
		2001	2002	2003	2004
Providence	1	15	6	0	38
Bristol	4	4	9	132	16
Kent	4	26	67	55	3
Newport	18	13	21	39	192
Washington*	44	4	0	79	2
Total	**71**	**62**	**103**	**305**	**251**

*Washington County beaches include those along Rhode Island Sound.

Boating

The number of registered boats in Rhode Island increased from about 29,000 in 1993 to 41,000 in 2002 (NBEP, 2002), and it is probably fair to assume that most are used in Narragansett Bay. In 1988, there were 13,500 slips and moorings in Narragansett Bay (Colt et al., 2002). New docks and marinas are disallowed along 70% of the statewide Rhode Island shoreline, and the number of slips and moorings has not risen in proportion to boat registrations (Rhode Island CRMC, 1996; Liberman, 2005). As a result, most boaters in Narragansett Bay must tow boats to one of the 32 public or 12 private boat ramps, many of which have no or limited space for parking cars and trailers (Allard Cox, 2004; RIDEM, 2005c).

Fishing

Fishing is a popular and rewarding recreational and commercial activity in Narragansett Bay. Although the Bay supports commercial and recreational fishing, the species sought and landed have changed over time.

Commercial Fishing

In 1880, Narragansett Bay supported a variety of commercial fisheries, including alewife, tautog, scup, lobster, and winter flounder. As time passed, however, the Bay's commercial fisheries grew smaller as offshore fishing increased. By the 1960s, Narragansett Bay no longer supported a large commercial finfish fishery (Oviatt et al., 2003). Currently, the annual commercial fish catch for Rhode Island fetches more than $70 million (RIDEM, 2005a). The great bulk of these commercial landings consists of fish caught in Rhode Island Sound or further offshore; however, Narragansett Bay remains commercially important for shellfish. An estimated 10–20% of Rhode Island's total lobster landings are caught in the Bay (Ely, 2002). In addition, the state's quahog fishery is contained mostly within the Bay, with average landings of 1.5 million pounds for the period 1990–2004 and a value of $7.5 million (NOAA, 2005a).

Although the causes for many of the declines in the Narragansett Bay fisheries are unknown, some of them can be traced to changes in environmental conditions (Ardito, 2003; Oviatt et al., 2003). For example, habitat loss can play a key role in fisheries decline. Eelgrass beds are critical habitat for bay scallops. Narragansett Bay once supported a large, commercial bay scallop fishery. In 1880, more than 300,000 bushels of bay scallops were harvested from Narragansett Bay, a quantity that would be worth more than $33 million on today's wholesale market; however, in 2003, the bay scallop landings from the Bay were nonexistent. The loss of this fishery can be traced to the loss of the scallop's habitat—eelgrass beds (Ardito, 2003). Eelgrass beds were widespread in Narragansett Bay as late as the 1860s, and historical accounts record eelgrass beds at the head of the Bay in the lower Providence River. During the 1930s, wasting disease—a widespread infection partly attributed to the slime mold *Labryinthula zosterae*—decimated Atlantic coast eelgrass populations, including those in Narragansett Bay (Short et al., 1987). The Bay's eelgrass beds continued to shrink throughout the 20th century, due largely to decreased light penetration from nutrient pollution and algal growth (Ardito, 2003; Lipsky, 2003). Approximately 100 acres of eelgrass remain in Narragansett Bay today (Save the Bay, Inc., 2006). Many former scallop-harvesting areas of the Bay now support the quahog fishery (Ardito, 2003).

Recreational Fishing

About 300,000 sport anglers seek finfish and shellfish in Rhode Island's marine waters (RIDEM, 2005a). Since 1981, the NMFS has maintained a database (NOAA, 2005d) containing information gathered from a survey on recreational catches. It should be noted that this database shows data on a statewide level and combines catches in the Bay with those reported in Rhode Island's sounds. In the 24-year period from 1981 to 2004, the NMFS recreational survey showed that the total number of fish caught annually fluctuated with no overall trend (Figure 9-4). The median recreational catch since 1981 has been 2 million fish, and nine species have been among the five most commonly reported recreationally caught fish in any given year (Table 9-3) (NOAA, 2005d). On the basis of information from the RIDEM, an estimated one-third to one-half of the state's recreational catch is taken from within the Bay as opposed to Rhode Island Sound, Block Island Sound, or areas further offshore (Ely, 2002). Narragansett Bay's recreational fishery is estimated at more than $300 million per year (NBEP, 2006).

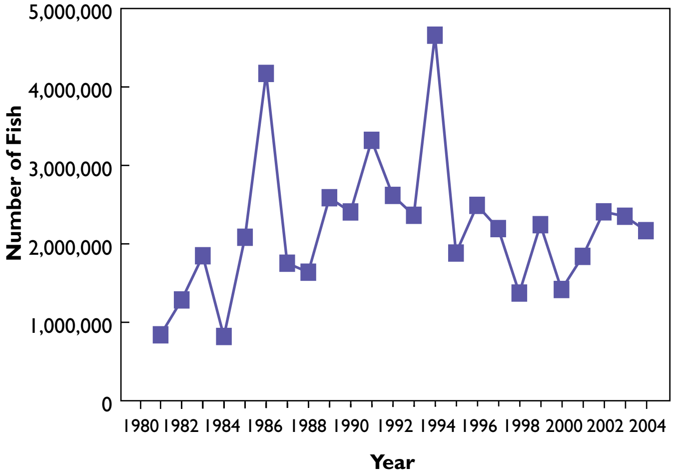


Figure 9-4. Recreational fish catches in Rhode Island by year (NOAA 2005d).

Table 9-3. The Most Commonly Reported Recreationally Caught Fish in Rhode Island Between 1981 and 2004 (NOAA, 2005d)

Fish Species	Number of Years Listed in the Top 5
Bluefish	24
Scup	24
Winter flounder	11
Striped bass	10
Summer flounder	10
Tautog	10
Herrings	6
Cunner	7
Atlantic mackerel	5

Estimates of Fish and Shellfish Abundance

Data from systematic trawls and estimates of recreational fish landings have been used to monitor shifts in species abundance in Narragansett Bay. The University of Rhode Island (URI) has maintained a weekly fish trawl at Fox Island since the 1960s (Oviatt et al., 2003). RIDEM has also conducted fishery-independent estimates of fish abundances in the Bay using biannual (spring and fall) systematic trawling of Narragansett Bay, Rhode Island Sound, and Block Island Sound. Starting in 1990, the Narragansett Bay biannual trawling was augmented with monthly trawling at 12 stations randomly selected from a pre-set grid (Lynch, 2005). The NMFS recreational survey database (NOAA, 2005d) supplies information on recreation landings in Rhode Island, and these data are used in conjunction with trawl data to provide additional insight into shifts in species abundance.

The species that dominated the URI weekly fish trawl at Fox Island in the 1960s and 1970s were sea robins, winter flounder, and windowpane flounder. These species comprised a much smaller portion of the catch in the 1980s and a very small portion in the 1990s. The opposite trend was observed for crabs and lobsters, which were a very small part of the total in the 1960s, but grew to dominate the Fox Island catch in the 1990s (Oviatt et al., 2003).

Figure 9-5 and Table 9-4 combine data on annual numbers of fish taken in RIDEM biannual trawl surveys with the recreational catch numbers from the NMFS database. It should be noted that these two sets of data were collected over different geographic regions. The RIDEM data used in this analysis were collected in Narragansett Bay, whereas the NMFS data set includes recreational landings from Rhode Island coastal sounds. This comparison is not ideal, but is necessary because NMFS does not segregate their data to distinguish landings in Narraggansett Bay from those outside of the Bay.

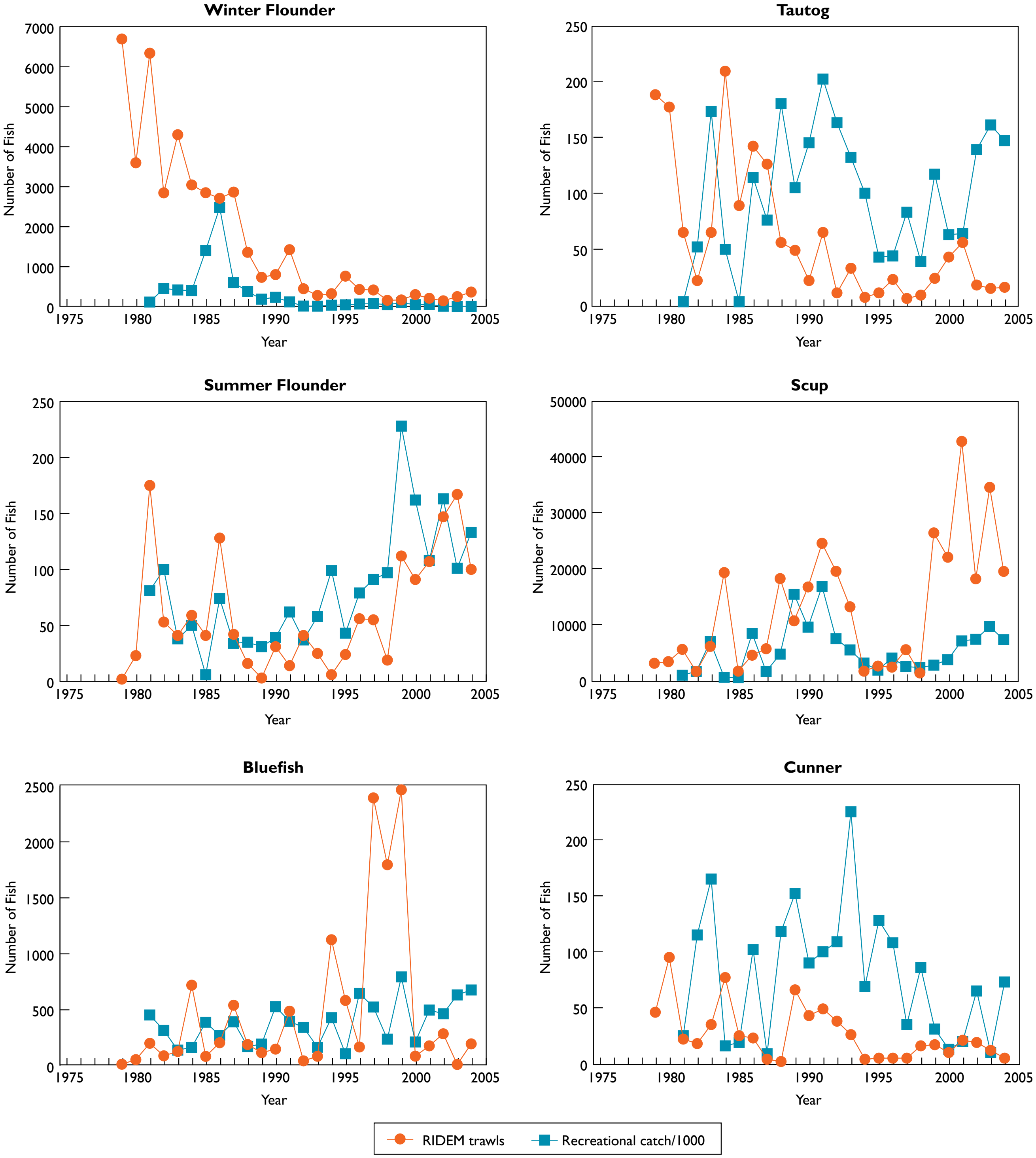


Figure 9-5. Number of fish of six species annually taken in RIDEM trawls in Narragansett Bay and number reported by recreational anglers to NMFS in Narragansett Bay and the Rhode Island coastal sounds (based on data from Lynch, 2005 and NOAA, 2005d).

Table 9-4. Comparison of the Most Commonly Harvested Fish Species during RIDEM Trawls Conducted from 1979–2004 in Narragansett Bay, and Recreational Fishing Efforts Reported to NMFS from 1981–2004 in Narragansett Bay and the Rhode Island Coastal Sounds (Lynch, 2005; NOAA, 2005d)

Species	RIDEM Median (number of fish)	RIDEM Trend[b]	Recreational[a] Median (number of fish)	Recreational[a] Trend[b]
Bay anchovy	31,000	—	none	—
Scup	8,400	—	440,000	—
Longfin squid	3,800	—	none	—
Butterfish	2,600	I	none	—
Winter flounder	750	D	89,000	D
Weakfish	470	—	1,700	D
Atlantic herring	440	I	70,000	I
American lobster	350	—	none	—
Bluefish	180	—	39,000	—
Skates	190	—	13,000	—
Windowpane flounder	120	D	none	—
Alewife	80	I	none	—
Atlantic moonfish	72	I	none	—
Blueback herring	60	—	**[c]	—
Red hake	56	D	none	—
Summer flounder	42	—	77,000	I
Tautog	38	D	100,000	—
Spotted hake	26	—	none	—
Cunner	20	D	79,000	—
Striped searobin	20	—	16,000	—
Striped bass	0	I	85,000	I
Atlantic mackerel	0	—	29,000	—

[a] Recreational landings included fish caught in Rhode Island and Block Island sounds.

[b] Trends are indicated as increasing (I) or decreasing (D) if Spearman rank correlation coefficient between numbers of fish and year was greater than 0.5 or less than -0.5, respectively.

[c] Blueback herring are probably included in the recreational landings for "herring."

The graphs in Figure 9-5 plot the annual numbers of six species commonly caught by the RIDEM trawls and the landings by recreational anglers from the NMFS database. These graphs reflect the large year-to-year variability in annual catch data, which is characteristic of many species, and provide the opportunity to evaluate the different results obtained using the two sampling methods: trawls (RIDEM) vs. recreational hook-and-line fishing (NMFS). Table 9-4 displays data for the 20 species with the highest median annual RIDEM trawl catch numbers over the 1979–2004 time period and for the 12 species that were most commonly taken by recreational anglers between 1981 and 2004. Some of the commonly trawled species are not taken by recreational anglers, and the median NMFS recreational catch numbers for these species are listed as "none" in the table. Conversely, two of the species commonly taken by anglers (striped bass and Atlantic mackerel) are often absent in RIDEM trawls (medians of zero indicate that no fish of that species were collected during more than half of the years). Table 9-4 also shows whether trawl catch or recreational landing numbers exhibited an increasing (I) or decreasing (D) trend over the time period. Although this correlation was an objective definition of trends, similar conclusions can be made by simply looking at the time series in Figure 9-5 for several of the species (i.e., winter flounder, tautog, and cunner catches are decreasing, whereas summer flounder are increasing). It should be noted that the species and data listed in Table 9-4 are based on long-term data sets; therefore, species exhibiting large catch numbers over the short term were excluded. For example, menhaden were present at high numbers (median of 9,800 fish) in RIDEM trawls collected between 1999 and 2004; however, this species does not appear in Table 9-4 because the median number of fish collected in trawls over the long-term (1979–2004) is only 18. Furthermore, although long-term data may show decreasing trends, some individual species (e.g., tautog, winter flounder) may be increasing over shorter time scales (i.e., 2001 to 2006) (personal communication, Lynch, 2006).

All of the fish species caught in Narragansett Bay forage in the Bay, and some of these species also spawn in the Bay; however, most species spawn offshore and move into the Bay as part of their annual migration. The species that spawn in Narragansett Bay would seem to be most sensitive to environmental quality in the Bay. Two of the species that spawn in the Bay (i.e., tautog and winter flounder) are recreationally important and have exhibited decreasing abundances. In addition to fishing pressure, tautog and winter flounder population declines are possibly related to the summertime hypoxia reported in the upper portions of the Bay (Bergondo et al., 2005; Deacutis, In press), but these declines could also be related to large-scale environmental changes unrelated to any human use of Narragansett Bay. For example, species shifts in parts of North America and Europe have been correlated with cyclic climate changes induced by the North Atlantic Oscillation (Drinkwater et al., 2003). In addition, a steady rise in sea surface water temperature has been observed since the mid-1960s in the coastal waters of the northeastern United States (Nixon et al., 2004). If these temperature patterns are representative of the water column as a whole, winter flounder populations could be impacted. Under experimental conditions, warmer water decreased the survival rates of winter flounder eggs. These results were attributed to increased predation on the eggs by sand shrimp (Keller and Klein-MacPhee, 2000; Taylor and Danila, 2005).

Newport Bridge, RI (courtesy of NBEP).

Fishery Restrictions

Regardless of the cause for decreasing abundance of any species, removal of fishing pressure should benefit the population. The abundance of winter flounder is so low in Narragansett Bay that recreational or commercial harvest of this species is prohibited in parts of the Bay (RIDEM, 2005a). Because high concentrations of bacteria indicative of mammalian fecal material were found in water and in mollusks that are often eaten raw, 34% of the Bay was permanently closed to shellfishing in 2005 and another 16% was closed for some period after rainfall events (RIDEM, 2005a). In the absence of these closures, the quahog landings may have been greater.

Narragansett Bay encompasses estuarine and coastal areas in both Rhode Island and Massachusetts. Although no waterbody-specific fish advisories are in effect for Narragansett Bay, both of these states have issued fish consumption advisories for all estuarine and coastal waters within their respective jurisdictions, including the waters of Narragansett Bay (U.S. EPA, 2005b). Table 9-5 summarizes the fish consumption advisories covering Narragansett Bay and includes information on the contaminants for which the advisories have been issued, the fish and shellfish species covered in the advisory, and the population (general population or sensitive subpopulation) for whom the advisory has been issued.

Fish consumption advisories are issued based on the level of chemical contaminants detected in the fish tissue. The PCB advisories have been in effect since 1993 (Rhode Island) and 1994 (Massachusetts), whereas the mercury advisories were first issued in 2001 (Massachusetts) and 2002 (Rhode Island). For two popular recreational species, striped bass and bluefish, the states advise sensitive populations against consuming any of these fish because of the levels of mercury and total PCB concentrations in their tissues (Rhode Island) or because of PCBs in their tissues (Massachusetts). In addition, the State of Massachusetts advises all members of the general population against consuming the heptatopancreas tissue (tomalley) of lobster because of elevated concentrations of PCBs in this tissue. The State of Rhode Island also recommends that members of the general population limit consumption to one meal per month of striped bass because of the PCB levels in this fish tissue (U.S. EPA, 2005b). In addition, a commercial fishing ban was in effect for all striped

Table 9-5. Fish Consumption Advisories in Effect for Narragansett Bay in 2004 (U.S. EPA, 2005b)

State	Chemical Contaminant	Populations Targeted by the Advisory	Fish Species Under Advisory
Massachusetts—all estuarine and coastal marine waters	Mercury	NCSP	King mackerel Shark Swordfish Tilefish Tuna (steaks)
	PCBs	NCSP	Bluefish
		NCGP	Lobster (tomalley)
Rhode Island—all estuarine and coastal marine waters	Mercury	NCSP	Striped bass Bluefish Shark Swordfish
	PCBs	NCSP	Striped bass Bluefish
		RGP	Striped bass
		CFB	Striped bass 26–37" in length*

NCSP=No-consumption recommended for sensitive populations (pregnant and nursing women and children)
NCGP=No-consumption recommended for the general population
RGP=Restricted consumption for the general population to one meal/month
CFB=Commercial fishing ban
*This ban has since been lifted (personal communication, Deacutis, 2006)

bass from 26–37 inches in length (U.S. EPA, 2005b); however, this ban has since been lifted (personal communication, Deacutis, 2006).

It is important to note that fish advisories are issued by state governments; therefore, some differences between state advisories may occur in estuarine areas that span state borders. It should also be understood that many species of fish, such as striped bass and bluefish, are highly migratory in nature. The mercury and PCB concentrations bioaccumulated in the tissues of these species are not solely derived from chemical contamination in Narragansett Bay, but have been accumulated from exposure to contamination along the species' migratory routes, which include many of the estuaries and coastal areas of the Northeast.

Are Human Uses Being Met by Narragansett Bay?

Human uses are being met by Narragansett Bay; however, as with most any other estuary, there are some limitations. Development uses are presently met, but there is controversy. Earlier plans to build a container ship terminal at Quonset Point have been dropped, but plans are being pursued to develop LNG terminals at various locations in Narragansett Bay. In order to decrease the frequency and spatial extent of summertime hypoxia in the deep waters of the upper Bay, nitrogen inputs are being reduced by increasing the level of treatment required at WWTPs from secondary to tertiary treatment.

Rhode Islanders and tourists relish the Bay's natural amenities. The shoreline is public in Rhode Island, and while ready access to most of it is enjoyed by property owners, an increasing number of public access points are being established. Boat registrations indicate that the popularity of boating is on the rise; however, participants in this activity would benefit from improved access points. The availability of slips and mooring space has not kept pace with the rise in boat registrations, and many of the shore access points do not have parking space for boat trailers.

Bacterial contamination causes periodic beach closures and is the basis of a permanent advisory against recreational water contact in the Providence River. Closures generally occur after storm events carry runoff into the Bay. In Providence, a CSO project is proceeding to capture storm water before it enters the Bay. The successful completion of this project may lead to the removal of a permanent advisory against recreational water contact in some areas. Bacteria are also the cause of permanent shellfish bed closures in over 34% of Bay waters, with an additional 16% of the area closed after storms. These closures are effectively removing some predation on quahogs in the closed areas, and these populations may be serving as the seed stock to sustain the quahog fishery in the rest of the Bay (Oviatt et al., 2003).

The Rhode Island commercial fishery has moved offshore during the past 50 years. With the exception of the quahog and small lobster fisheries, the Bay no longer supports a major commercial fishery; however, the recreational fishery attracts over 300,000 anglers each year and is a major part of Rhode Island's tourist industry. Although winter flounder dominated the recreational catch in the early 1980s, the abundance of this species has been decreasing since the late 1980s, and there is a current ban on harvesting winter flounder in most of the Bay. The total annual number of all fish species harvested recreationally has been relatively constant (no positive or negative trend), and the decrease in the catch of demersal fish (e.g., winter flounder, tautog) has been countered by the increase in catch of summer flounder and pelagic fish (e.g., bluefish, striped bass). Because the total recreational catch has remained relatively constant, winter flounder population declines have not decreased the overall value of Narragansett Bay to recreational anglers.

Although recreational catches remain relatively constant in the Bay, fish advisories first issued for PCBs in the 1990s and for mercury in the early 2000s remain in effect. These advisories recommend that sensitive populations (e.g.,pregnant and nursing women, young children) not consume any of the listed species from the Bay. In addition, advisories in effect for the general population recommend no consumption of lobster tomalley (Massachusetts) and restricted consumption of striped bass (Rhode Island). These advisories restrict uses of Narragansett Bay's fishery resources.

Human Uses and NCA Environmental Indicators

As reported in the NEP CCR (U.S. EPA, 2006b), the overall condition of Narragansett Bay is rated poor based on the four NCA indices of estuarine condition (Figure 9-6). The water quality index for Narragansett Bay is rated fair, the benthic index is rated fair to poor, and the sediment quality and fish tissue contaminants indices are both rated poor. Figure 9-7 provides a summary of the percentage of estuarine area in good, fair, poor, or missing categories for each parameter considered. Please refer to Chapter 1 for a summary of the criteria used to develop the rating for each index and component indicator. This environmental assessment is based on data from 56 NCA sites sampled in the Narragansett Bay estuarine area in 2000 and 2001.

In general, the water quality, sediment quality, and benthic index data demonstrate a north-to-south gradient, with poorer conditions found in the northern, more populated portion of the estuary. These findings are consistent with the human uses being compromised in the same portion of the Bay. The fish tissue contaminants index was rated poor for 91% of the fish and shellfish samples collected from the Bay, and all whole-fish samples surveyed contained quantities of PCBs that exceeded or fell within EPA's Advisory Guidance values for fish consumption. These results were consistent with the fish advisories issued for the Bay. It should be noted that migratory fish species can bioaccumulate contaminants across a wide geographic range; therefore, high contaminant concentrations measured in fish collected in Narragansett Bay are not necessarily indicative of high levels of pollution in the Bay. This index is best examined in context with other environmental indicators.

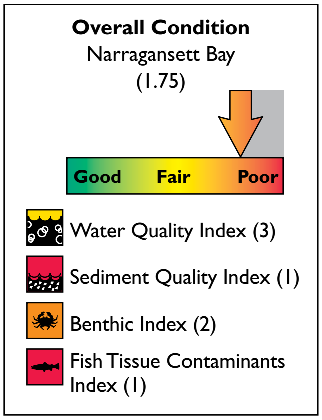


Figure 9-6. The overall condition of the Narragansett Bay estuarine area is poor (U.S. EPA/NCA).

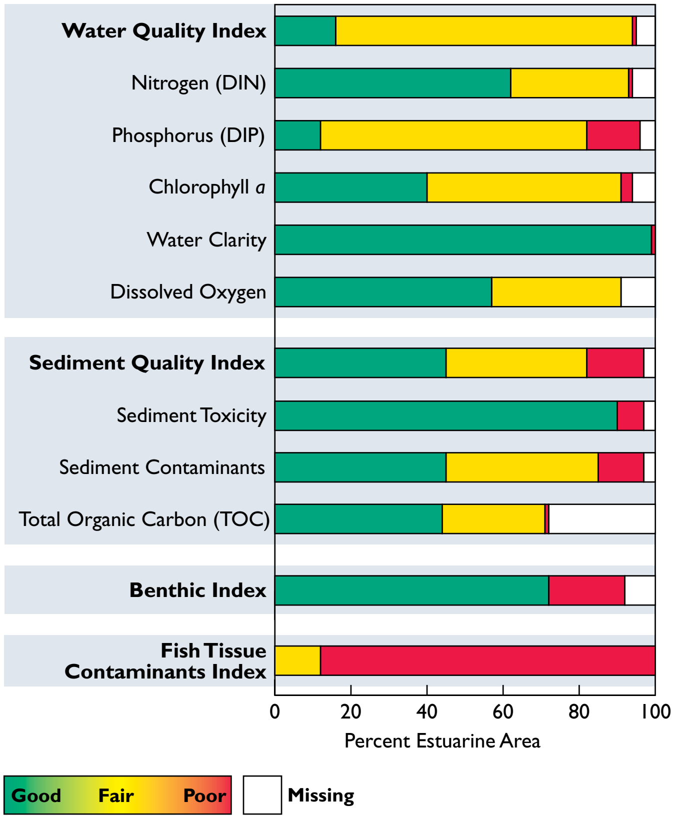


Figure 9-7. Percentage of estuarine area achieving each rating for all indices and component indicators—Narragansett Bay (U.S. EPA/NCA).

APPENDIX A

Quality Assurance

Courtesy of Brad Ashbaugh

Quality Assurance

The primary purpose of this appendix is to provide information regarding the sample collection, data quality, and data analysis methods used in this report. This appendix provides additional specific detail and explanation on the analysis of uncertainty (i.e., error estimates) and the assignment of ratings and calculation of scores used in the regional and national assessments. An important programmatic goal is to provide researchers with a large, robust database of coastal environmental information of known data quality. The National Coastal Assessment (NCA) partners have already written many peer-reviewed journal articles using these data. It is our hope that other researchers will recognize the utility of this large database and add to the body of knowledge on coastal monitoring and assessment.

Analysis of Uncertainty

Background

As one of the largest and most comprehensive state partnership programs, the NCA allows assessment of ecological condition at state, regional, and national scales. The program partners use the NCA Quality Assurance (QA) Program to monitor and assess the quality of the data collected through NCA activities. The NCA QA Program is conducted under the guidance of the National Health and Environmental Effects Research Laboratory (NHEERL) Director of Quality Assurance. The NCA QA team consists of the following team members:

- **National QA Coordinator**—Assures that a QA program is in place and being followed and that the known quality of the data sets developed by the national contract laboratories is properly documented.
- **Four regional QA coordinators**—Assure that the QA program is being followed and develop the documentation supporting the known quality of the data collected in the NCA.
- **Twenty-four state QA coordinators**—Responsible for reviewing and qualifying all data sets sent to the program from their respective states.

A detailed Quality Assurance Project Plan (QAPP) was developed by the NCA (U.S. EPA, 2001b) and provided to all participants in the program. Compliance with the QAPP is assessed through extensive field training exercises, site visits, reviews, and audits. The QAPP addresses multiple levels of the program, ranging from the collection and laboratory processing of field samples to the review of data sets compiled from the field and laboratory activities. The NCA QA team is responsible for performing assessments of the adequacy of these activities.

Sample Collection

Approximately 2,200 water quality sites were sampled in both the 1999–2000 and 2001–2002 time frames. This count includes Chesapeake Bay water quality sites, Puerto Rico 2000 sites, and sites in Southcentral Alaska and Hawaii. The number of sites varied slightly among the media sampled based on the acceptance/rejection criteria detailed in the field sampling manual and the QAPP; however, more than 2,000 sites were sampled for each media (except fish tissue, see below) in each of the *National Coastal Condition Report* (NCCR) time periods. To ensure the comparability of data between states, NCA conducted a 4- to 5-day training workshop for all state partners participating in the program. The workshop included training on the application of the probability-based design to state monitoring activities and implementation of the standardized methods required for sample collection. Each state field crew was evaluated on their ability to apply the protocols and received certification after the training based on a field trial. As outlined in the *National Coastal Assessment Field Operations Manual* (U.S. EPA, 2001a), field crews were audited throughout the duration of the program to ensure comparable sampling methods were used. Each field crew is visited once at the beginning of each sampling season and reviewed for adherence to the protocols in the QAPP.

Data Quality

Before the sampling event began in 2000, NCA convened a diverse panel of environmental scientists to help formulate a list of core indicators to ensure that the NCA collected the appropriate types of data to support its mission. These indicators and the application of these indicators are reviewed prior to NCA data analysis and the publication of each NCCR. In order to ensure that the data collected were of appropriate quality to generate sound estimates on environmental condition, the NCA utilized the U.S. Environmental Protection Agency's (EPA's) concept of data quality objectives (DQOs) to set the overall level of data quality required by management to make informed decisions. In other words, how much error can be tolerated within the measurement process before the data are deemed unacceptable?

NCA developed an a priori, program-level DQO for estimates of condition: "For the cumulative distribution function (CDF) of each index and component indicator of condition, estimate the portion of the resource in degraded condition within ±10% for the overall system and ±10% for subregions, with 90% confidence based on a completed sampling regime." Table A-1 shows that this requirement was met by the estimates of condition in this report for the indices and component indicators in all regions, with the exception of Puerto Rico and the Great Lakes. It should be noted that the uncertainty associated with areal estimates of ecological condition in the Great Lakes cannot be determined because areal estimates of condition were not available for the Great Lakes. Also, the fish tissue contaminants index is expressed as a percentage of fish samples analyzed (Northeast Coast region) or stations where fish were caught (all other regions); therefore, the uncertainty associated with areal estimates of ecological condition cannot be determined.

Data Assessment Methods

In general, all data assessments for this report followed the methods outlined in the *National Coastal Condition Report II* (NCCR II) (U.S. EPA, 2004a). For most of the regions, the data used in the assessments of condition were collected in 2001 and 2002 (some exceptions exist; see Table A-2). In the Gulf Coast, Southeast Coast, and Northeast Coast regions, these data were compared to similar survey data collected in the 1990s and 2000 to conduct an initial estimate of trends in estuarine condition.

Table A-1. Levels of Uncertainty Associated with the Estimate of Proportion of Area in Poor Condition (2001–2002, except West Coast 1999–2000, and Puerto Rico 2000)

Index/Indicator	Northeast Coast	Southeast Coast	Gulf Coast	West Coast	Great Lakes	Puerto Rico	United States (without AK & HI)	South-central Alaska	Hawaii
Water Quality Index	4%	6%	4%	4%	NA	15%	4%	12%	6%
Nitrogen	5%	2%	2%	3%	NA	14%	3%	14%	11%
Phosphorus	4%	6%	4%	3%	NA	8%	4%	11%	8%
Chlorophyll *a*	4%	6%	3%	4%	NA	14%	3%	12%	8%
Water Clarity	3%	9%	5%	3%	NA	15%	5%	12%	19%
Dissolved Oxygen	3%	3%	3%	4%	NA	8%	3%	12%	11%
Sediment Quality Index	3%	7%	4%	4%	NA	15%	2%	2%	2%
Sediment Toxicity	3%	3%	3%	4%	NA	10%	1%	11%	11%
Sediment Contaminants	3%	2%	2%	5%	NA	10%	2%	2%	6%
Sediment TOC*	6%	5%	3%	4%	NA	16%	2%	11%	10%
Coastal Habitat Index	<.1%	<.1%	<.1%	<.1%	NA	NA	<.1%	NA	NA
Benthic Index	4%	7%	4%	4%	NA	15%	3%	NA	NA
Fish Tissue Contaminants Index	NA	NA	NA	NA	NA	NA	NA	NA	NA

* total organic carbon (TOC)

Table A-2. Years Assessed for NCCR III Condition Estimates and for Trends in Condition

Region	Years Assessed for NCCR III	Years Assessed for Trends
Northeast Coast	2000–2002	1990–1993, 2000–2001
Southeast Coast	2001–2002	1994–1997, 2000–2002
Gulf Coast	2001–2002	1991–1994, 2000–2002
West Coast	1999–2000	NA
Great Lakes	2001–2002	NA
Southcentral Alaska and Hawaii	2002	NA
Puerto Rico	2000	NA

Assignment of Ratings and Calculation of Scores

Determining Rating Scores for Indices

The data analysis methods that were used to determine rating scores for the regional and national condition indices and component indicators were similar to those used in the NCCR II. These methods are outlined below and summarized in a series of tables showing the ranges of values used for the indices, component indicators, and rating scores.

The data analysis process includes several steps, which are outlined in Chapter 1. Briefly, each site receives a rating of "good," "fair," or "poor" for each index and component indicator (see Tables 1-23, 1-24, and 1-25 in Chapter 1), depending on the value of that index or component indicator. The range of values for these indicators was determined from literature, best professional judgment, or expert opinion (Table A-3). In some cases, different value ranges were determined for different regions based on comments from peer reviewers and consultations with state water quality managers. These ranges are reevaluated for each NCCR by groups of experts including academic scientists, government scientists, and others. For the component indicators and the benthic and fish tissue contaminants indices, the rating at each station (or fish samples analyzed for the fish tissue contaminants index in the Northeast Coast region) is then translated to scores (good = 5, fair = 3, poor = 1). The water quality and sediment quality index, which are the two indices with component indicators, ratings for each station are calculated based on how many component indicators received a poor rating.

Table A-3. Sources of Information to Establish Ranges of Indicator Values for Good, Fair, or Poor Ratings

Index or Component Indicator	Source
Water Quality Index	Best professional judgment; consultations with experts and selected state water quality managers
Dissolved Inorganic Nitrogen (DIN) Dissolved Inorganic Phosphorus (DIP) Chlorophyll *a*	Bricker et al., 1999; selected state criteria for chlorophyll a in coastal waters
Water Clarity	Smith et al., 2006; best professional judgment; consultations with selected state water quality managers
Dissolved Oxygen	Diaz and Rosenberg, 1995; U.S. EPA, 2000a; selected state criteria for dissolved oxygen in coastal waters
Sediment Quality Index	Best professional judgment; consultations with experts and selected state water quality managers
Sediment Toxicity	U.S. EPA, 1994
Sediment Contaminants	Long et al., 1995; consultations with experts
Sediment TOC	Best professional judgment; consultations with experts and selected state water quality managers
Benthic Index	Engle et al., 1994; Weisberg et al., 1997; Engle and Summers, 1999; Van Dolah et al., 1999; Hale and Heltsche, 2008
Benthic Diversity (in lieu of benthic index)	Best professional judgment; consultations with experts
Fish Tissue Contaminants Index	U.S. EPA, 2000c; consultations with experts

To determine the regional ratings, an areally weighted CDF is then calculated for each index and component indicator (except for the fish tissue contaminants index) for the distribution of sites in each region to show what percentage of the area in each region has scores of 1 (poor), 3 (fair), and 5 (good). The CDF also calculates error estimates and 95% confidence intervals. The region is then rated overall as good, fair, or poor for each index or component indicator based on the percent area that is rated poor and fair for each index or indicator. The regional rating for the fish tissue contaminants index is based on the percentage of fish samples analyzed (Northeast Coast region) or monitoring stations where fish were caught (all other regions) in poor or fair condition. For the all of the indices of condition, the "fair" rating can have a score of 2, 3, or 4. This distinction was based on best professional judgment and was used to determine when final scores were "fair to poor" or "good to fair" rather than just fair. The specific ranges in percent area with poor ratings that result in scores of 2, 3, or 4 are shown in Table A-4. If a region has < 50% of its coastal area (or for the fish tissue contaminants index, fish samples analyzed [Northeast Coast region] or stations where fish were caught [all other regions]) rated good, then the score is 3 and the region is rated fair. The regional rating for the coastal habitat index is determined based on the average rate of wetland loss as indicated by data from the NWI (Dahl, 2002).

Additional steps are required to calculate the "overall condition" score for each region. The overall condition score for a region is an average of the final scores for each index. In this calculation, the "fair" rating can also have a score of 2, 3, or 4.

To create the national index scores, an areally weighted average was calculated from the regional index scores. Each regional index score was areally weighted by the percentage of total area of U.S. estuaries and coastal embayments in each region. For example, the weighted average for the national water quality index was calculated by summing the products of the regional water quality index scores and the coastal area contributed by each region (Table A-5). The national overall condition score was then calculated by summing each national index score and dividing by five.

Table A-4. Ranges of Percent Area Rated Poor that Result in Scores of 1 – 5

Index	Poor (1)	Fair to Poor (2)	Fair (3)	Good to Fair (4)	Good (5)
Water Quality Index	> 20%	18–20%	13–17%	10–12%	< 10%
Sediment Quality Index	> 15%	13–15%	8–12%	5–7%	< 5%
Benthic Index	> 20%	18–20%	13–17%	10–12%	< 10%
Fish Tissue Contaminants Index (% of sites)	> 20%	18–20%	13–17%	10–12%	< 10%

Table A-5. Calculation of the National Water Quality Index Score

Region	Water Quality Index Score (A)	Proportion of U.S. Estuarine Area (B)	Product (A x B)	National Water Quality Index Score
Northeast Coast	3	0.167	0.501	Sum (A x B) = 3.701
Southeast Coast	3	0.075	0.225	
Gulf Coast	3	0.171	0.513	
West Coast	3	0.063	0.189	
Southcentral Alaska	5	0.347	1.735	
Hawaii	5	0.002	0.010	
Great Lakes	3	0.175	0.525	
Puerto Rico	3	0.001	0.003	

Fish Tissue Contaminant Assessments in NCCR III

There is currently no EPA guidance available for evaluating the ecological risk of whole-body contaminant burdens in fish. EPA's *Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories: Volume 2: Risk Assessment and Fish Consumption Limits* (U.S. EPA, 2000c) provides guidance for estimating the contaminant risk that non-commercial fish and shellfish pose to consumers. This guidance is intended to be used by the local, state, regional, and tribal environmental health officials responsible for issuing fish consumption advisories. To that end, the assessments of fish tissue contaminants in the NCCR II and the *National Coastal Condition Report III* (i.e., NCCR III) relied on the suggested human health "benchmarks" provided in this guidance document. In essence, if concentrations of contaminants found in the fish tissue met or exceeded a human health consumption endpoint, then best professional judgment determined that the fish were likely exposed to an environmentally available contaminant.

The methodology recommended in the EPA fish advisory guidance document (U.S. EPA, 2000c) and cited in the two previous NCCR documents was used as a surrogate method for establishing an "ecological threshold value" for fish and shellfish. The EPA guidance document was designed to provide a method for assessing the health risks to consumers of eating chemical-contaminated fish and shellfish that are harvested from local waterbodies by recreational or subsistence fishers (those who rely on fish as a primary source of protein). The guidance provides a methodology for developing fish consumption limits for 25 high-priority chemical contaminants (i.e., target analytes). These target analytes were selected by EPA's Office of Water as significant contaminants based on their documented occurrence in fish and shellfish, persistence in the environment, potential for bioaccumulation in aquatic food webs, and oral toxicity to humans. The fish advisory threshold values used in the NCCR reports (see Table 1-20) are based on values for adults in the general population who fish recreationally and consume their catch. The EPA guidance also provides information on input values for use in calculating fish advisory threshold values so that they are applicable to more vulnerable populations (e.g., pregnant and nursing women, or young children) as well as to subsistence fishers who typically consume larger quantities of fish from local waterbodies than the general population. The NCA analyzed fish tissues for 81 chemical analytes, 16 of which matched the target analyte list provided in the fish advisory guidance document (U.S. EPA, 2000c). These 16 analytes were the only chemical contaminants monitored by the NCA for which quantifiable surrogate "ecological threshold values" could be calculated to evaluate fish tissue contaminant concentrations. For each analyte, a concentration range was calculated that provided for safe consumption of four 8-oz fish meals per month by a 154-pound adult. For example, the risk-based EPA Avisory Guidance values for mercury ranged from 0.12 to 0.23 ppm of mercury in fish tissue. If the NCA measured a concentration in fish that was less than 0.12 ppm of mercury, then the fish sample analyzed (in the Northeast Coast region) or the monitoring station where fish were caught (in all other regions) was rated good. If the contaminant concentration measured in fish tissue was within the EPA Advisory guidance value range, then the fish sample analyzed or monitoring station where fish were caught was rated fair; and if the mercury concentration exceeded 0.23 ppm, then the fish sample analyzed or monitoring station where fish were caught was rated poor.

REFERENCES

Courtesy of Paul Goetz

References

Adams, D.A., and S. Benyi. 2003. *Sediment Quality of the NY/NJ Harbor System: A 5-year Revisit. An Investigation under the Regional Environmental Monitoring and Assessment Program (REMAP)*. EPA/902-R-03-002. U.S. Environmental Protection Agency, Region 2, Division of Environmental Science and Assessment, Edison, NJ.

Adams, D.A., J.S. O'Connor, and S.B. Weisberg. 1998. *Final Report: Sediment Quality of the NY/NJ Harbor System—An Investigation under the Regional Environmental Monitoring and Assessment Program (REMAP)*. EPA/902-R-98-001. U.S. Environmental Protection Agency, Region 2, Division of Environmental Science and Assessment, Edison, NJ.

Adey, W.H. 1975. The algal ridges and coral reefs of St. Croix: Their structure and Holocene development. *Atoll Research Bulletin 187*:1–67.

Alaska DCED (Department of Community and Economic Development). 2003. *Alaska Economic Performance Report 2003*. Alaska Department of Community and Economic Development, Division of Community Advocacy, Juneau, AK.

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 DEC (Department of Environmental Conservation). 2006. *Current Situation Report for* M/V Selendang Ayu *Grounding*. Situation Report #111 and Final. Alaska Department of Environmental Conservation, Division of Spill Prevention and Response, Prevention and Emergency Response Program, Juneau, AK.

Alaska DEC (Department of Environmental Conservation). 2007. *Fish Monitoring Program*. Alaska Department of Environmental Conservation online information. Alaska Department of Environmental Conservation, Division of Environmental Health, State Veterinarian, Anchorage, AK. Available at: http://www.dec.state.ak.us/eh/vet/fish.htm (Accessed September 2007).

Allard Cox, M. (ed.). 2004. *Public Access to the Rhode Island Coast*. Rhode Island Sea Grant, Narragansett, RI.

Allen, M.J., R.W. Smith, and V. Raco-Rands. 2001. *Development of Biointegrity Indices for Marine Demersal Fish and Mega Invertebrate Assemblages of Southern California*. Southern California Coastal Water Research Project, Westminster, CA.

Altieri, A.H., and J.D. Witman. 2006. Local extinction of a foundation species in a hypoxic estuary: Integrating individuals to ecosystem. *Ecology 87*(3):717–730.

AMAP (Arctic Monitoring and Assessment Programme). 2004a. *AMAP Assessment 2002: Persistent Organic Pollutants in the Arctic*. Arctic Monitoring and Assessment Programme, Oslo, Norway.

AMAP (Arctic Monitoring and Assessment Programme). 2004b. *Arctic Pollution: Persistent Organic Pollutants; Heavy Metals; Radioactivity; Human Health; and Changing Pathways: 2002*. Arctic Monitoring and Assessment Programme, Oslo, Norway.

Anderson, D.M., and L.H. MacDonald. 1998. Modeling road surface sediment production using a vector geographic information system. *Earth Surface Processes and Landforms 23*:95–107.

Anderson, R.W., D.A. Carey, Y.T. Chang, T. Grigalunas, M. Luo, B. Marti, P.A. Popko, J.B. Torgan, H. Twichell, W.R. Webster, and S. Whitehouse. 2000. *Commercial Marine Transportation on Narragansett Bay: Status, Trends and Issues*. White paper prepared for Narragansett Bay Summit 2000. Narragansett Bay Estuary Program, Providence, RI.

Anderson, D.A., B.A. Keafer, D.J. McGillicuddy, M.J. Mickelson, K.E. Keay, P.S. Libby, J.P. Manning, C.A. Mayo, D.K. Whittaker, J.M. Hicky, R. He, D.R. Lynch, and K.W. Smith. 2005. Initial observations of the 2005 *Alexandrium fundyense* bloom in southern New England: General patterns and mechanisms. *Deep-Sea Research II 52*:2856–2876.

Aquatic Sciences, Inc. 1996. *Examination of Aquatic Nuisance Species Introductions to the Great Lakes through Commercial Shipping Ballast Water and Assessment of Control Options, Phase 1 and Phase 2*. Final Report, Project E9225/E9285. Aquatic Science, Inc., St. Catherines, ON.

Ardito, T. 2002. Issues to reckon with: Brayton Point is one of several Bay controversies. *Narragansett Bay Journal 1*(2):1,6–9.

Ardito, T. 2003. Can we restore the Bay? *Narragansett Bay Journal 6*(Fall):1,16–17.

ASMFC (Atlantic States Marine Fisheries Commission). 2000. *American Lobster Stock Assessment for Peer Review*. Stock Assessment Report No. 00-01 (Supplement). Atlantic States Marine Fisheries Commission Special Report 61. Atlantic States Marine Fisheries Commission, Washington, DC.

Bacon, C.E., W.M. Jarman, J.A. Estes, M. Simon, and R.J. Norstrom. 1999. Comparison of organochlorine contaminants among sea otter (*Enhdyra lutris*) populations in California and southeast Alaska. *Environmental Toxicology and Chemistry 18*(3):452–458.

Barron, M.G., R. Heintz, and M.M. Krahn. 2003. Contaminant exposure and effects in pinniped: Implications for Steller sea lion declines in Alaska. *Science of the Total Environment 311*(1–3): 11–33.

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.

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.

Burroughs, R. 2000. *Narragansett Bay Ecosystem Management: Goals, Trends, and Issues*. White paper prepared for Narragansett Bay Summit 2000. Narragansett Bay Estuary Program, Providence, RI.

Bush, G.W. 2004. Executive Order 13340—Establishment of Great Lakes Interagency Task Force and Promotion of a Regional Collaboration of National Significance for the Great Lakes—May 18, 2004. In: *The American Presidency Project*. J. Woolley and G. Peters, 2007. University of California, Santa Barbara online information. University of California, Santa Barbara, CA. Available at: http://www.presidency.ucsb.edu/ws/?pid=61434 (Accessed May 2007).

CAST (Council for Agricultural Science and Technology). 1999. *Gulf of Mexico Hypoxia: Land and Sea Interactions*. Task Force Report No. 134. Council for Agricultural Science and Technology, Ames, IA.

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.

CEQ (Council on Environmental Quality). 2004. *U.S. Ocean Action Plan: The Bush Administration's Response to the U.S. Commission on Ocean Policy*. Council on Environmental Quality, Committee on Ocean Policy, Washington, DC.

CH2M Hill, Inc. 1979. *A Sediment Reduction Program*. Prepared for the Government of the Virgin Islands of the United States, Department of Conservation and Cultural Affairs, St. Thomas, VI.

Chaillou, J.C., S.B. Weisberg, F.W. Kutz, T.E. DeMoss, L. Mangiaracina, R. Magnien, R. Eskin, J. Maxted, K. Price, and J.K. Summers. 1996. *Assessment of the Ecological Condition of the Delaware and Maryland Coastal Bays*. EPA/620/R-96/004. U.S. Environmental Protection Agency, Office of Research and Development, Washington, DC.

Chary, L.K. 2000. *Persistent Organic Pollutants (POPs) in Alaska: What Does the Science Tell Us?* Circumpolar Conservation Union, Washington, DC.

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.

Colt, A.B., T. Tyrrell, and V. Lee. 2000. *Marine Recreation and Tourism in Narragansett Bay: Critical Values and Concerns*. White paper prepared for Narragansett Bay Summit 2000. Narragansett Bay Estuary Program, Providence, RI.

Conaway, C.H., E.B. Watson, J.R. Flanders, and A.R. Flegal. 2003. *Report on Mercury Deposition in a Tidal Marsh Downstream of the Historic New Almaden Mining District, California*. Submitted to San Francisco Bay Regional Water Quality Control Board, Oakland, CA.

Connor, M., J.A Davis, J. Leatherbarrow, and C. Werme. 2004. *Legacy Pesticides in San Francisco Bay: Conceptual Model/Impairment Assessment*. SFEI Contribution #313. Prepared by the San Francisco Estuary Institute, Oakland, CA, for the Clean Estuary Partnership, Oakland, CA.

Cooksey, C. 2004. *NOAA Ship* Nancy Foster *NF-04-08-CL (March 30–April 11, 2004): Spring 2004 Survey of Ecological Conditions of the U.S. South Atlantic Bight*. Cruise Report. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service, Center for Coastal Environmental Health and Biomolecular Research, Charleston, SC.

Cooksey, C., R. Fairey, and S. Wilson. 2003. *NOAA Ship* McArthur II *Cruise AR-03-01-NC (June 1–26, 2003): EMAP Summer '03 Survey of Ecological Conditions of the Western U.S. Continental Shelf*. Cruise Report. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service, Center for Coastal Environmental Health and Biomolecular Research, Charleston, SC.

Cooksey, C., J. Hyland, W.L. Balthis, M. Fulton, G. Scott, and D. Bearden. 2004. *Soft-bottom Benthic Assemblages and Levels of Contaminants in Sediments and Biota at Gray's Reef National Marine Sanctuary and Nearby Shelf Waters Off the Coast of Georgia (2000 and 2001)*. NOAA Tech. Memo. NOS NCCOS 6. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service, National Center for Coastal Environmental Health and Biomolecular Research, Charleston, SC.

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.

Crawley, K., M. Pryor, R. Ribb, S. Kaplan, A. Langhauser, and M. Peck. 2000. *Land Use and Transportation in the Narragansett Bay Watershed: Issues and Challenges*. White paper prepared for Narragansett Bay Summit 2000. Narragansett Bay Estuary Program, Providence, RI.

Crossett, K.M., T.J. Culliton, P.C. Wiley, and T.R. Goodspeed. 2004. *Population Trends along the Coastal United States: 1980 – 2008*. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service, Management and Budget Office, 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. 2002. *Results of the 2000 Wetlands Inventory*. Personal communication from Tom Dahl, U.S. Fish and Wildlife Service, National Wetland Inventory, Madison, WI.

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.

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.

Davis, J.A., F. Hetzel, and J.J. Oram. 2006. Polychlorinated biphenyls (PCBs) in San Francisco Bay. Pp. 40–52. In: *The Pulse of the Estuary: Monitoring and Managing Water Quality in the San Francisco Estuary*. San Francisco Estuary Institute, Oakland, CA.

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

Deacutis, C.F. In press. Evidence of ecological impacts from excess nutrients in upper Narragansett Bay. In: *Ecosystem-Based Management of a Southern New England Estuary: A Case Study of Narragansett Bay*. Rhode Island Sea Grant, Narragansett, RI.

Deacutis, C.F., D. Murray, W. Prell, E. Saarman, and L. Korhun. 2006. Hypoxia in the upper half of Narragansett Bay, RI, during August 2001 and 2002, in natural and anthropogenic influences on the Mount Hope Bay Ecosystem. *Northeastern Naturalist 13*(Special Issue 4):173–198.

Dettmann, E.H. 2001. Effect of water residence time on annual export and denitrification of nitrogen in estuaries: A model analysis. *Estuaries 24*:481–490.

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-Ramos, S., D.L. Stevens, Jr., and A.R. Olsen. 1996. *EMAP Statistical Methods Manual*. EPA/620/R-96/002. U.S. Environmental Protection Agency, Office of Research and Development, 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.

Drinkwater, K.F., A. Belgrano, A. Borja, A. Conversi, M. Edwards, C.H. Greene, G. Ottersen, A.J. Pershing, and H. Walker. 2003. The response of marine ecosystems to climate variability associated with the North Atlantic oscillation. Pp. 211–234. In: *The North Atlantic Oscillation: Climate Significance and Environmental Impact*. Geophysical Monograph 134. American Geophysical Union, Washington, DC.

Ebinghaus, R., C. Temme, S.E. Lindberg, and K.J. Scott. 2004. Springtime accumulation of atmospheric mercury in polar ecosystems. *Journal de Physique IV 121*:195–208.

Ely, E. 2002. *An Overview of Narragansett Bay*. Rhode Island Sea Grant, Narragansett, RI.

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, V.D., 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). 2003. *State of the Great Lakes 2003*. EPA/905-R-03-004. Prepared by 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). 2005. *State of the Great Lakes 2005*. EPA/905-R-06-001. Prepared by Environment Canada, Federal Great Lakes Program, Gatineau, Quebec, and the U.S. Environmental Protection Agency, Great Lakes National Program Office, Chicago, IL.

Fisher, K.M., A.L. Allen, H.M. Keller, Z.E. Bronder, L.E. Fenstermacher, and M.S. Vincent. 2006. *Annual Report of the Gulf of Mexico Harmful Algal Bloom Operational Forecast System (GOM HAB-OFS): October 1, 2004 to September 30, 2005*. NOAA Tech. Rep. NOS CO-OPS 047. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service, Center for Operational Oceanographic Products and Services, Silver Spring, MD.

Florida DEP (Department of Environmental Protection). 2007. *Northwest District–Project GreenShores*. State of Florida online information. Florida Department of Environmental Protection, Northwest District, Tallahassee, FL. Available at: http://www.dep.state.fl.us/northwest/ecosys/section/greenshores.htm (Accessed April 2007).

FWRI (Fish and Wildlife Research Institute). 2006. *FWC Biologists Preliminary 2005 Manatee Mortality Data – Red Tide Contributes to Second-Highest Mortality Year on Record*. Press Release. Florida Fish and Wildlife Conservation Commission, Fish and Wildlife Research Institute, St. Petersburg, FL.

FWRI (Fish and Wildlife Research Institute). 2007. *Features*. Florida Fish and Wildlife Conservation Commission online information. Florida Fish and Wildlife Conservation Commission, Fish and Wildlife Research Institute, St. Petersburg, FL. Available at: http://www.floridamarine.org/features/default.asp?id=1018 (Accessed February 2007).

García-Sais, J., J. Morelock, R. Castro, C. Goenaga, and E. Hernández-Delgado, 2003. Puertorican reefs: Research síntesis, present tretas and management perspectives. Pp. 111–130. In: *Latin American Coral Reefs*. J. Cortéz (ed.). Elsevier Science B.V.

García-Sais, J., R. Appeldoorn, A. Bruckner, C. Caldow, J.D. Christensen, C. Lilyestrom, M.E. Monaco, J. Sabater, E. Williams, and E. Diaz. 2005. The state of coral reef ecosystems of Puerto Rico. Pp. 91–134. In: *The State of Coral Reef Ecosystems of the United States and Pacific Freely Associated States: 2005*. J. Waddell (ed.). NOAA Technical Memorandum NOS NCCOS 11. National Oceanic Atmospheric Administration, National Centers for Coastal Ocean Science, Center for Coastal Monitoring and Assessment's Biogeography Team, Silver Spring, MD.

Georgia DNR (Department of Natural Resources). 2003. *Georgia's Marsh Dieback*. Online information. Georgia Department of Natural Resources, Coastal Resources Division, Brunswick, GA. Available at: http://crd.dnr.state.ga.us/content/displaycontent.asp?txtDocument=436 (Accessed April 2007).

GMFMC (Gulf of Mexico Fishery Management Council). 2004a. *Final Amendment 22 to the Reef Fish Fishery Management Plan to Set Red Snapper Sustainable Fisheries Act Targets and Thresholds, Set a Rebuilding Plan, and Establish Bycatch Reporting Methodologies for the Reef Fish Fishery*. Gulf of Mexico Fishery Management Council, Tampa, FL.

GMFMC (Gulf of Mexico Fishery Management Council). 2004b. *Final Amendment Number 13 to the Fishery Management Plan for the Shrimp Fishery of the Gulf of Mexico, U.S. Waters with Environmental Assessment Regulatory Impact Review and Regulatory Flexibility Act Analysis*. Gulf of Mexico Fishery Management Council, Tampa, FL.

Goolsby, D.A., W.A. Battaglin, G.B. Lawrence, R.S. Artz, B.T. Aulenbach, R.P. Hooper, D.R. Keeney, and G.J. Stensland. 1999. *Flux and Sources of Nutrients in the Mississippi-Atchafalaya River Basin: Topic 3 Report for the Integrated Assessment on Hypoxia in the Gulf of Mexico*. Decision Analysis Series No. 17. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service, Coastal Ocean Program, Silver Spring, MD.

Goolsby, D.A., W.A. Battaglin, B.T. Aulenbach, and R.P. Hooper. 2001. Nitrogen input to the Gulf of Mexico. *Journal of Environmental Quality 30*:329–336.

Greenfield, B.K., J.A. Davis, R. Fairey, C. Roberts, D. Crane, and G. Ichikawa. 2005. Seasonal, interannual, and long-term variation in sport fish contamination, San Francisco Bay. *Science of the Total Environment 336*(1):25-43.

Guam Environmental Protection Agency. 2006. *2006 Integrated Report*. Guam Environmental Protection Agency, Barrigada, GU.

Gulf of Mexico Foundation. 2007. *Year 2005 Restoration Projects – NOAA CRP Restoration Projects – Project #4002: GreenShores Site 2, Pensacola, FL*. Gulf of Mexico Foundation online information. Gulf of Mexico Foundation, Corpus Christi, TX. Available at: http://www.gulfmex.org/crp4002.html (Accessed April 2007).

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.

Hammar-Klose, E.S., and E.R. Thieler. 2001. *Coastal Vulnerability to Sea-Level Rise: A Preliminary Database for the U.S. Atlantic, Pacific, and Gulf of Mexico Coasts*. Digital Data Series DDS-68. U.S. Department of the Interior, U.S. Geological Survey, Woods Hole, MA.

Hansen, L.J., L.H. Schwacke, G.B. Mitchum, A.A. Hohn, R.S. Wells, E.S. Zolman, P.E. Rosel, and P.A. Fair. 2003. Geographic variation in polychlorinated biphenyl and organochlorine pesticide concentrations in the blubber of bottlenose dolphin from the U.S. Atlantic Coast. *Science of the Total Environment 319*:147–72.

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.

Hieb, K., M. Bryant, M. Dege, T. Greiner, S. Slater, and K. Souza. 2005. Fishes in the San Francisco Estuary, 2004 status and trends. *IEP Newsletter 18*(2):19–36.

Homer, C., C. Huang, L. Yang, B. Wylie, and M. Coan. 2004. Development of a 2001 national land-cover database for the United States. *Photogrammetric Engineering and Remote Sensing 70*(7): 829-840.

Hood, D.W., and S. Zimmerman (ed.). 1986. T*he Gulf of Alaska: Physical Environment and Biological Resources*. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Washington, DC.

Hoover, D., and C. Gold. 2005. *Assessment of Coastal Water Resources and Watershed Conditions at Kaloko-Honokohau National Historical Park, Hawaii*. Technical Report NPS/NRWRD/NRTR-2005/344. U.S. Department of the Interior, National Park Service, Water Resources Division, Fort Collins, CO.

Houde, M., R. Wells, P. Fair, G. Bossart, A. Hohn, T. Rowles, J. Sweeney, K. Solomon, and D. Muir. 2005. Polyfluoroalkyl compounds in free-ranging bottlenose dolphins (*Tursiops truncatus*) from the Gulf of Mexico and the Atlantic Ocean. *Environmental Science and Technology 39*: 6591–6598.

Houghton, J.T., Y. Ding, D.J. Griggs, M. Noguer, P.J. van der Linden, X. Dai, K. Maskell, and C.A. Johnson (eds.). 2001. *Climate Change 2001: The Scientific Basis*. Prepared by Contribution of Working Group 1 to the 3rd Assignment Report of the Intergovernmental Panel on Climate Change. Published by Cambridge University Press, Cambridge, UK, and New York, NY.

Hubbard, D.K., E.H. Gladfelter, and J.C. Bythell. 1993. Comparison of biological and geological perspectives of coral-reef community structure at Buck Island, U.S. Virgin Islands. Pp. C13–C19. In: *Proceedings of the Colloquium on Global Aspects of Coral Reefs: Health Hazards and History, 1993*. Rosentiel School of Marine and Atmospheric Sciences, University of Miami.

Hyland, J., C. Cooksey, W.L. Balthis, M. Fulton, D. Bearden, G. McFall, and M. Kendall. 2006. The soft-bottom macrobenthos of Gray's Reef National Marine Sanctuary and nearby shelf waters off the coast of Georgia, USA. *Journal of Experimental Marine Biology and Ecology 330*:307–326.

IEP (Interagency Ecological Program). 2006. *CA Department of Water Resources Interagency Ecological Program (I.E.P.)*. California Department of Water Resources online information. California Department of Water Resources, Interagency Ecological Program, Sacramento, CA. Available at: http://www.iep.ca.gov/ (Accessed June 2006).

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.

IRF (Island Resource Foundation). 1999. *Abbreviated 1998 Water Quality Assessment of the United States Virgin Islands*. Submitted to the U.S. Environmental Protection Agency, Washington, DC, by the Government of the Virgin Islands of the United States, Department of Planning and Natural Resources, Division of Environmental Protection, St. Thomas, VI.

Jeffrey, C.F.G., U. Anlauf, J. Beets, S. Caseau, W. Coles, A. Friedlander, S. Herzlieb, Z. Hillis-Starr, M. Kendall, V. Mayor, J. Miller, R. Nemeth, C. Rogers, and W. Toller. 2005. The state of coral reef ecosystems in the U.S. Virgin Islands. Pp. 45–90. In: *The State of Coral Reef Ecosystems of the United States and Pacific Freely Associated States: 2005*. J. Waddell (ed.). NOAA Technical Memorandum NOS NCCOS 11. National Oceanic Atmospheric Administration, National Centers for Coastal Ocean Science, Center for Coastal Monitoring and Assessment's Biogeography Team, Silver Spring, MD.

Johengen, T., D.F. Reid, G.L. Fahnenstiel, H.J. MacIssac, F.C. Dobbs, M. Doblin, G. Ruiz, and P.T. Jenkins. 2005. *A Final Report for the Project "Assessment of Transoceanic NOBOB Vessels and Low-Salinity Ballast Water as Vectors for Non-indigenous Species Introductions to the Great Lakes."* U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Great Lakes Environmental Research Laboratory, Ann Arbor, MI, and the University of Michigan, Cooperative Institute for Limnology and Ecosystems Research, Ann Arbor, MI.

Keller, A.A., and G. Klein-MacPhee. 2000. Impact of elevated temperature on the growth, survival, and trophic dynamics of winter flounder larvae: A mesocosm study. *Canadian Journal of Fisheries and Aquatic Sciences 57*(12):2382–2392.

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.

Kerans, B.L., and J.R. Karr. 1994. A benthic index of biotic integrity (B-IBI) for rivers of the Tennessee Valley. *Ecological Applications 4*:768–785.

King, J.E. 1983. Northern phocids. Pp. 79–85. In: *Seals of the World*, 2nd edition. British Museum (Natural History) London, Cornell University Press, Ithaca, NY.

LACSD (Los Angeles County Sanitation Districts). 2006. *Palos Verdes Ocean Monitoring Annual Report*, 2005. Los Angeles County Sanitation Districts, Whittier, CA.

Larrance, J.D., D.A. Tennant, A.J. Chester, and P.A. Ruffino. 1977. Phytoplankton and primary productivity in the northeast Gulf of Alaska and Lower Cook Inlet final report. *National Oceanic and Atmospheric Administration/Environmental Assessment of the Alaskan Continental Shelf Annual Reports of Principal Investigators 10*(1977):1–136.

Larsen, P.F., A.C. Johnson, and L.F. Doggett. 1983. *Environmental Benchmark Studies in Casco Bay–Portland Harbor, Maine, April 1980*. NOAA Technical Memorandum NMFS-F/NEC-19. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Northeast Fisheries Center, Woods Hole, MA.

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.

Lawton, W. 2006. *Marine Ecology: "Dead Zone" Summer Killed Billions of Ocean State Mussels*. Brown University online information. Brown University, Office of Media Relations, Providence, RI. April 11, 2006. Available at: http://www.brown.edu/Administration/News_Bureau/2005-06/05-108.html (Accessed 2006).

Leeworthy, V.R. 2000. *Preliminary Estimates from Versions 1–6: Coastal Recreation Participation, National Survey on Recreation and the Environment (NSRE)*. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Oceans and Coasts, Special Projects Office, Silver Spring, MD.

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.

Lefkovitz, L.F., V.I. Cullinan, and E.A. Crecelius. 1997. *Historical Trends in the Accumulation of Chemicals in Puget Sound*. NOAA Tech. Memo. NOS ORCA 111. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service, Silver Spring, MD.

Lenihan, H.S., and C.H. Peterson. 1998. How habitat degradation through fishery disturbance enhances impacts of hypoxia on oyster reefs. *Ecological Applications 8*:128–140.

Liberman, E. 2005. Give 'em the slip. *Rhode Island Monthly* May:25–26

Lipsky, A. 2003. From shucking houses to seeding machines, restoring the bay's eelgrass. *Narragansett Bay Journal 6*(Fall):8.

Livingston, P.A., and T.K. Wilderbuer. 2007. *What is the Impact of the Ecosystem on Fishery Resources in the Bering Sea?* National Oceanic and Atmospheric Administration online information. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Fisheries-Oceanography Investigations Program, Seattle WA. Available at: http://www.beringclimate.noaa.gov/essays_livingston.html (Accessed May 2007).

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.

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., J. Hameedi, A. Robertson, M. Dutch, S. Aasen, K. Welch, S. Magoon, R. Carr, T. Johnson, J. Biedenbach, K. Scott, C. Mueller, and J. Anderson. 2000. *Sediment Quality in Puget Sound: Year 2, Central Puget Sound*. NOS NCCOS CCMA Technical Memo No. 147 and Ecology Publication No. 00-03-055. National Oceanic and Atmospheric Administration, National Ocean Service, Silver Spring, MD; and Washington State Department of Ecology, Olympia, WA.

Loope, L.L. 1998. Hawaii and Pacific Islands. In: *Status and Trends of the Nation's Biological Resources*. M.J. Mac, P.A. Opler, C.E. Puckett Haecker, and P.D. Doran (eds.). U.S. Department of the Interior, U.S. Geological Survey, Reston, VA.

Lynch, T.R. 2005. *Assessment of Recreationally Important Finfish Stocks in Rhode Island Waters – Coastal Fishery Resource Assessment – Trawl Survey 1979 to Present*. Database output. Rhode Island Department of Environmental Management, Division of Fish & Wildlife, Marine Fisheries, Jamestown, RI.

Lynch, T.R. 2006. Personal communication from Timothy R. Lynch, Rhode Island Department of Environmental Management, to David Whitall, NOAA. December.

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.

Macauley, J.M., L.C. Harwell, and H.V. Alafita. 2007. The ecological condition of Veracruz, Mexico estuaries. *Environmental Monitoring and Assessment 133*(1–3):177–85.

Mahler, B., P. Van Metre, and E. Callender. 2004. *National-Scale Trends in Metals in Urban and Reference Lake Sediment Cores, 1975 to Present*. Abstract and oral presentation at The Society of Environmental Toxicology and Chemistry, 25th Annual Meeting in North America.

Mahler, B.J., P.C. Van Metre, T.J. Bashara, J.T. Wilson, and D. A. Johns. 2005. Parking lot sealcoat: An unrecognized source of urban polycyclic aromatic hydrocarbons. *Environmental Science & Technology 39*(15):5560–5566.

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

McRae, G. 2006. Personal communications from G. McRae, Florida Fish & Wildlife Research Institute, to Virginia Engle, U.S. EPA/ORD via phone and e-mail. May 2006.

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

Mississippi-Alabama Sea Grant Consortium and Mobile Bay NEP (National Estuary Program). 2007. *Mississippi–Alabama Habitat Database*. Mobile Bay National Estuary Program online information. Mobile Bay National Estuary Program, Mobile, AL. Available at: http://restoration.disl.org/www/ (Accessed April 2007).

MMS (Minerals Management Service). 1995. *Cook Inlet Planning Area Oil and Gas Lease Sale 149: Final Environmental Impact Statement*. MMS 95-0066. U.S. Department of the Interior, Minerals Management Service, Alaska Outer Continental Shelf Region, Anchorage, AK.

Mobile Bay NEP (National Estuary Program). 2002. *Comprehensive Conservation and Management Plan, Volume I – A Call to Action*. Mobile Bay National Estuary Program, Mobile, AL.

Monbet, Y. 1992. Control of phytoplankton biomass in estuaries: A comparative analysis of microtidal and macrotidal estuaries. *Estuaries 15*(4):563–571.

MRLC (Multi-resolution Land Characteristics) Consortium. 2007. *MRLC Consortium*. Online information. U.S. Department of the Interior, U.S. Geological Survey, Multi-resolution Land Characteristics Consortium, Sioux Falls, SD. Available at: http://www.mrlc.gov/index.asp (Accessed March 2007).

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.

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

NBEP (Narragansett Bay Estuary Program). 2002. More boats in R.I. *Narragansett Bay Journal 1*(2):9.

NBEP (Narragansett Bay Estuary Program). 2006. *Narragansett Bay Estuary Program*. Narragansett Bay Estuary Program online information. Narragansett Bay Estuary Program, Providence, RI. Available at: http://www.nbep.org/ (Accessed November 2006).

NEFSC (Northeast Fisheries Science Center). 2001. *TRAC Advisory Report on Stock Status – A report of the Fourth Meeting of the Transboundary Resources Assessment Committee (TRAC), St. Andrews Biological Station, St. Andrews, New Brunswick, April 17–20, 2001*. Northeast Fisheries Science Center Ref. doc. 01-08. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Northeast Fisheries Science Center, Woods Hole, MA.

NEFSC (Northeast Fisheries Science Center). 2002. *Assessment of 20 Northeast Groundfish Stocks through 2001 – A Report of the Groundfish Assessment Review Meeting (GARM), Northeast Fisheries Science Center, Woods Hole, Massachusetts, October 8–11, 2002*. Northeast Fisheries Science Center Reference Document 02-16. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Northeast Fisheries Science Center, Woods Hole, MA.

Nelson, W.G., R. Brock, H. Lee, J.O. Lamberson, and F. Cole. 2007. *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, Washington, DC.

Nemeth, R. 2005. Population characteristics of a recovering U.S. Virgin Island red hind spawning aggregation following protection. *Marine Ecology Progress Series 286*:81–97.

NERRS (National Estuarine Research Reserve System). 2003. *National Estuarine Research Reserve System Strategic Plan 2003–2008*. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Office of Ocean and Coastal Resource Management, Silver Springs, MD.

NIST (National Institute of Standards and Technology). 2004. *Data on PCB concentrations in dolphins measured during an unusual mortality event in St. Joseph Bay, Florida in 2004*. Unpublished. National Institute of Standards and Technology, National Marine Analytical Quality Assurance Program, Charleston, SC.

Nixon, S.W. 1995. *Metal Inputs to Narragansett Bay: A History and Assessment of Recent Conditions*. Rhode Island Sea Grant, Narragansett, RI.

Nixon, S.W., J.W. Ammerman, L.P. Atkinson, V.M. Berounsky, G. Billen, W.C. Boicourt, W.R. Boynton, T.M. Church, D.M. DiToro, R. Elmgren, J.H. Garber, A.E. Giblin, R.A. Jahnke, N.J.P. Owens, M.E.Q. Pilson, and S.P. Seitzinger. 1996. The fate of nitrogen and phosphorus at the land-sea margin of the North Atlantic Ocean. *Biogeochemistry 35*:141–180.

Nixon, S.W., S. Granger, B.A. Buckley, M.L. Lamont, and B. Rowell. 2004. A one hundred and seventeen year coastal water temperature record from Woods Hole, Massachusetts. *Estuaries 27*(3):397–404.

Nixon, S., B. Buckley, S. Granger, L. Harris, A. Oczkowski, L. Cole, and R. Fulweiler. 2005. *Anthropogenic Nutrient Inputs to Narragansett Bay: A Twenty-five Year Perspective*. Prepared by University of Rhode Island, Graduate School of Oceanography. Prepared for Narragansett Bay Commission, Providence, RI, and Rhode Island Sea Grant, Narragansett, RI.

NMFS (National Marine Fisheries Service). 1999. *Our Living Oceans: Report on the Status of U.S. Living Marine Resources, 1999*. NOAA Tech. Memo. NMFS-F/SPO-41. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Silver Spring, MD.

NMFS (National Marine Fisheries Service). 2002. *Fisheries of the United States 2001*. Current Fishery Statistics, No. 2001. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Silver Spring, MD.

NMFS (National Marine Fisheries Service). 2003. *Fisheries of the United States 2002*. Current Fishery Statistics, No. 2002. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Silver Spring, MD.

NMFS (National Marine Fisheries Service). 2004. *Fisheries of the United States 2003*. Current Fishery Statistics, No. 2003. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Silver Spring, MD.

NMFS (National Marine Fisheries Service). 2005a. *2004 Report to Congress: The Status of U.S. Fisheries*. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Office of Sustainable Fisheries, Silver Spring, MD.

NMFS (National Marine Fisheries Service). 2005b. *Biennial Report to Congress on the Recovery Program for Threatened and Endangered Species: October 1, 2002–September 30, 2004*. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Office of Protected Resources, Silver Springs, MD.

NMFS (National Marine Fisheries Service). 2005c. *Fisheries of the United States 2004*. Current Fishery Statistics, No. 2004. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Silver Spring, MD.

NMFS (National Marine Fisheries Service). 2006. *Interim Endangered and Threatened Species Recovery Planning Guidance*. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Silver Springs, MD.

NMFS (National Marine Fisheries Service). 2007. *Fisheries of the United States 2006*. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Silver Spring, MD.

NMFS (National Marine Fisheries Service). In press. *Our Living Oceans: Report on the Status of U.S. Living Marine Resources*. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Silver Spring, MD.

NOAA (National Oceanic and Atmospheric Administration). 1988. Fishery resource assessment programs and Large Marine Ecosystems, Folio Map No. 7. In: *A National Atlas: Health and Use of Coastal Waters, United States of America*. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service, Office of Oceanography and Marine Assessment, Rockville, MD.

NOAA (National Oceanic and Atmospheric Administration). 1995. *NOAA Coastal Change Analysis Program (C-CAP): Guidance for Regional Implementation*. NOAA Technical Report NMFS 123. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Washington, DC.

NOAA (National Oceanic and Atmospheric Administration). 1998. *NOAA's Estuarine Eutrophication Survey—Volume 5: Pacific Coast Region*. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service, Office of Ocean Resources Conservation and Assessment, Silver Springs, MD.

NOAA (National Oceanic and Atmospheric Administration). 2003a. *Final Report: Assessment of Contaminant Concentrations in Tissues of Bottlenose Dolphins* (Tursiops truncatus) *in Florida Bay*. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service, Center for Coastal Environmental Health and Biomolecular Research, Charleston, SC.

NOAA (National Oceanic and Atmospheric Administration). 2003b. *Pacific Coast Land Cover 2000-ERA Land Cover/Land Use*. Data set. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Coastal Services Center, Charleston, SC.

NOAA (National Oceanic and Atmospheric Administration). 2004a. *Lake Erie Research Planning Workshop, March 4–5, 2004, GLERL/NOAA Ann Arbor, MI*. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Great Lakes Environmental Research Laboratory, Ann Arbor, MI.

NOAA (National Oceanic and Atmospheric Administration). 2004b. *National Marine Sanctuaries: A Monitoring Framework for the National Marine Sanctuary System*. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service, National Marine Sanctuary Program, Silver Spring, MD.

NOAA (National Oceanic and Atmospheric Administration). 2004c. *News- Plankton Boost Detected in Northern Ocean Water off the U.S.* Press Release. U.S. Department of Commerce, National Oceanographic and Atmospheric Administration, National Marine Fisheries Service, Northeast Fisheries Science Center, Woods Hole, MA. October 5.

NOAA (National Oceanic and Atmospheric Administration). 2005a. *Commercial Fishery Landings Database*. National Oceanic and Atmospheric Administration online information. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Office of Science and Technology, National Marine Fisheries Service, Fisheries Statistics Division, Silver Spring, MD. Available at: http://www.st.nmfs.gov/st1/commercial (Accessed December 2005).

NOAA (National Oceanic and Atmospheric Administration). 2005b. *CSCOR Sponsored Research Cruise Documents Low Oxygen and Animal Mortalities Associated with Florida Toxic Algal Bloom*. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Center for Sponsored Coastal Ocean Research, Silver Spring, MD.

NOAA (National Oceanic and Atmospheric Administration). 2005c. *Gulf of Mexico Harmful Algal Bloom Bulletin—20 October 2005*. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service, National Environmental Satellite, Data, and Information Service, Silver Spring, MD.

NOAA (National Oceanic and Atmospheric Administration). 2005d. *Marine Recreational Fishery Statistics Survey Database*. National Oceanic and Atmospheric Administration online information. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Office of Science and Technology, National Marine Fisheries Service, Fisheries Statistics Division, Silver Spring, MD. Available at: http://www.st.nmfs.gov/st1/recreational (Accessed December 2005).

NOAA (National Oceanic and Atmospheric Administration). 2006a. *International Field Years on Lake Erie*. Fact Sheet. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Great Lakes Environmental Research Laboratory, Ann Arbor, MI.

NOAA (National Oceanic and Atmospheric Administration). 2006b. *Latest Tests of NOAA Gulf Fish Surveys Show No Negative Impact on Seafood Quality*. Press Release. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Silver Spring, MD. January.

NOAA (National Oceanic and Atmospheric Administration). 2006c. *NOAA Fisheries: Office of Protected Resources*. National Oceanic and Atmospheric Administration online information. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Office of Protected Resources, Silver Spring, MD. Available at: http://www.nmfs.noaa.gov/pr/contact.htm (Accessed July 2006).

NOAA (National Oceanic and Atmospheric Administration). 2007a. *Bering Climate—A Current View of the Bering Sea Ecosystem and Climate*. National Oceanic and Atmospheric Administration online information. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Fisheries-Oceanography Investigations Program, Seattle, WA. Available at: http://www.beringclimate.noaa.gov/ (Accessed May 2007).

NOAA (National Oceanic and Atmospheric Administration). 2007b. *CEP Project #02E0052*. National Oceanic and Atmospheric Administration online information. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service, National Centers for Coastal Ocean Science, Center for Coastal Environmental Health and Biomolecular Research, Charleston, SC. Available at: http://www.chbr.noaa.gov/default.aspx?category=cep&pageName=project%2002E00052 (Accessed September 2007).

NOAA (National Oceanic and Atmospheric Administration). 2007c. *Fisheries Management: Building a Sustainable Future for America's Fisheries*. National Oceanic and Atmospheric Administration 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). 2007d. *Gerry E. Studds Stellwagen Bank National Marine Sactuary Condition Report 2007*. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Sanctuary Program, Silver Spring, MD.

NOAA (National Oceanic and Atmospheric Administration). 2007e. *Harmful Algal Bloom Forecasting System*. National Oceanic and Atmospheric Administration online information. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service, National Environmental Satellite, Data, and Information Service, Silver Spring, MD. Available at: http://www.csc.noaa.gov/crs/habf (Accessed February 2007).

NOAA (National Oceanic and Atmospheric Administration). 2007f. *International Field Years on Lake Erie (IFYLE)*. National Oceanic and Atmospheric Administration online information. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Great Lakes Environmental Research Laboratory, Ann Arbor, MI. Available at: http://www.glerl.noaa.gov/ifyle/ (Accessed May 2007).

NOAA (National Oceanic and Atmospheric Administration). 2007g. *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://woodsmoke.edc.uri.edu/Portal/ptk (Accessed May 2007).

NOAA (National Oceanic and Atmospheric Administration). 2007h. *National Marine Sanctuaries Monitoring*. National Oceanic and Atmospheric Administration online information. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Sanctuary Program, Silver Spring, MD. Available at: http://sanctuaries.noaa.gov/science/monitoring/welcome.html (Accessed March 2007).

NOAA (National Oceanic and Atmospheric Administration). 2007i. *U.S. Climate at a Glance*. National Oceanic and Atmospheric Administration online information. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Satellite and Information Service, National Environmental Satellite, Data, and Information Service, National Climatic Data Center, Asheville, NC. Available at: http://www.ncdc.noaa.gov/oa/climate/research/cag3/cag3.html (Accessed April 2007).

NOAA (National Oceanic and Atmospheric Administration). 2007j. *Worst New England Harmful Algal Bloom in 30 Years*. National Oceanic and Atmospheric Administration online information. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Center for Sponsored Coastal Ocean Research, Silver Spring, MD. Available at: http://www.cop.noaa.gov/news/fs/ne_hab_200505.html (Accessed March 2007).

Nowlin, W.D. 2001. *Developing the U.S. Sustained and Integrated Ocean Observing System*. Ocean.US, Arlington, VA.

NPFMC (North Pacific Fishery Management Council). 2000a. *Amendment 11 to the Fishery Management Plan for Bering Sea/Aleutian Islands King and Tanner Crabs*. Prepared by the North Pacific Fishery Management Council, Anchorage, AK, for the U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Alaska Region, Sustainable Fisheries Division, Juneau, AK.

NPFMC (North Pacific Fishery Management Council). 2000b. *Amendment 15 to the Fishery Management Plan for Bering Sea/Aleutian Islands King and Tanner Crabs*. Prepared by the North Pacific Fishery Management Council, Anchorage, AK, for the U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Alaska Region, Sustainable Fisheries Division, Juneau, AK.

NRDC (National Resources Defense Council). 2005. *Testing the Waters: A Guide to Water Quality at Vacation Beaches*. National Resources Defense Council, New York, NY.

NWFSC (Northwest Fisheries Science Center). 2006. *West Coast Groundfish Observer Manual*. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Northwest Fisheries Science Center, Seattle, WA.

NWQMC (National Water Quality Monitoring Council). 2006. *A National Water Quality Monitoring Network for U.S. Coastal Waters and Their Tributaries*. U.S. Department of the Interior, U.S. Geological Survey, Advisory Committee on Water Information, National Water Quality Monitoring Council, Providence, RI.

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.

Ocean.US. 2002. *An Integrated and Sustained Ocean Observing System (IOOS) For the United States: Design and Implementation*. Ocean.US, Arlington, VA.

Ocean.US. 2005a. *Data Management and Communications Plan for Research and Operational Integrated Ocean Observing Systems*. Ocean.US. Publication No. 6. Ocean.US, Arlington, VA.

Ocean.US. 2005b. *National Office for Integrated and Sustained Ocean Observations: Ocean.US*. Ocean.US online information. Ocean.US, Arlington, VA. Available at: http://www.ocean.us (Accessed January 2006).

Ocean.US. 2006. *The First U.S. Integrated Ocean Observing System (IOOS) Development Plan: A Report of the National Ocean Research Leadership Council and the Interagency Committee on Ocean Science and Resource Management Integration*. Ocean.US Publication No. 9. Ocean.US, Arlington, VA.

Officer, C.B., T.J. Smayda, and R. Mann. 1982. Benthic filter-feeding: A natural eutrophication control. *Marine Ecology Progress Series 9*:203–210.

Olsen, A.R., J. Sedransk, D. Edwards, C.A. Gotway, W. Liggett, S. Rathburn, K.H. Reckhow, and L.J. Yyoung. 1999. Statistical issues for monitoring ecological and natural resources in the United States. *Environmental Monitoring and Assessment 54*:1–45.

Overland, J.E., and P.J. Stabeno. 2004. Is the climate of the Bering Sea warming and affecting the ecosystem? *Eos, Transactions, American Geophysical Union 85*(33):309–316.

Oviatt, C., S. Olsen, M. Andrews, J. Collie, T. Lynch, and K. Raposa. 2003. A century of fishing and fish fluctuations in Narragansett Bay. *Reviews of Fisheries Science 11*(3):221–242.

Owen, B., and S. White (eds.). 2005. *National Estuarine Research Reserve System 10th Anniversary Report on the System-wide Monitoring Program (SWMP) Data Applications: 1995–2005*. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Office of Ocean and Coastal Resource Management, Silver Springs, MD.

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.

Parrish, F.A., K. Abernathy, G.J. Marshal, and B.M. Buhleier. 2002. Hawaiian monk seals (*Monachus schauinslandi*) foraging in deep-water coral beds. *Marine Mammal Science 18*(1).

Partridge, V., K. Welch, S. Aasen, and M. Dutch. 2005. *Temporal Monitoring of Puget Sound Sediments: Results of the Puget Sound Ambient Monitoring Program, 1989–2000*. Ecology Publication No. 05-03-016. Washington State Department of Ecology, Olympia, WA.

Paul, J.F., J.H. Gentile, K.J. Scott, S.C. Schimmel, D.E. Campbell, and R.W. Latimer. 1999. *EMAP-Virginian Province Four-Year Assessment (1990–93)*. EPA/620-R-99-004. U.S. Environmental Protection Agency, Office of Research and Development, Washington, DC.

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.

PFMC (Pacific Fishery Management Council). 1998. *Amendment 8 to the Northern Anchovy Fishery Management Plan Incorporating a Name Change to The Coastal Pelagic Species Fishery Management Plan*. Pacific Fishery Management Council, Portland, OR.

PFMC (Pacific Fishery Management Council). 2006. *Pacific Coast Groundfish Management Plan for the California, Oregon, and Washington Groundfish Fishery – As Amended Through Amendment 19 (Including Amendment 16-4)*. Pacific Fishery Management Council, Portland, OR.

Rabalais, N.N., R.E. Turner, D. Justiç, Q. Dortch, and W.J. Wiseman, Jr. 1999. *Characterization of Hypoxia: Topic 1 Report for the Integrated Assessment on Hypoxia in the Gulf of Mexico*. Decision Analysis Series No. 15. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service, Coastal Ocean Program, Silver Spring, MD.

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

Rhode Island CRMC (Coastal Resources Management Council). 1996. *Coastal Resources Management Program, As Amended (a.k.a. the "Red Book")*. Rhode Island Coastal Resources Management Council, Wakefield, RI.

Rhode Island Department of Administration. 2000. *Rhode Island Land Use Trends and Analysis (Including Land Use Surveys for the Period 1970–1995)*. Technical Paper 149. Rhode Island Department of Administration, Division of Planning, Statewide Planning Program, Providence, RI.

RIDEM (Rhode Island Department of Environmental Management). 2005a. *Bay Assessment & Response Team (BART)—Fishing in Narragansett Bay, Providence, RI*. Rhode Island Department of Environmental Management online information. Rhode Island Department of Environmental Management, Bay Assessment & Response Team, Providence, RI. Available at: http://www.dem.ri.gov/bart/fishing.htm (Accessed December 2005).

RIDEM (Rhode Island Department of Environmental Management). 2005b. *Plan for Managing Nutrient Loadings to Rhode Island Waters*. Rhode Island Department of Environmental Management, Providence, RI.

RIDEM (Rhode Island Department of Environmental Management). 2005c. *Rhode Island Public Boat Launching Sites*. Rhode Island Department of Environmental Management online information. Rhode Island Department of Environmental Management, Division of Fish and Wildlife, Providence, RI. Available at: http://www.dem.ri.gov/programs/bnatres/fishwild/boatlnch.htm (Accessed December 2005).

RIDOH (Rhode Island Department of Health). 2005. *Beach Water Quality Monitoring*. Rhode Island Department of Health online information. Rhode Island Department of Health, Bathing Beaches Monitoring Program, Providence, RI. Available at: http://www.ribeaches.org (Accessed December 2005).

Ries, K.G., III. 1990. *Estimating Surface-Water Runoff to Narragansett Bay, Rhode Island and Massachusetts*. Water Resources Investigation Report 89-4164. U.S. Department of the Interior, U.S. Geological Survey, Providence, RI.

Riggs, S.R. 2001. *Shoreline Erosion in North Carolina Estuaries*. North Carolina Sea Grant Publication UNC-SG-1-11. North Carolina Sea Grant, Raleigh, NC.

Rohmann, S.O., J.J. Hayes, R.C. Newhall, M.E. Monaco, and R.W. Grigg. 2005. The area of potential shallow-water tropical and subtropical coral ecosystems in the United States. *Coral Reefs 24*(3):370–383.

Rosenberg, R., M. Blomqvist, H.C. Nilsson, H. Cederwall, and A. Dimming. 2004. Marine quality assessment by use of benthic species-abundance distributions: A proposed new protocol with in the European Union Water Framework Directive. *Marine Pollution Bulletin 49*:728–739.

Rosenkranz, G.E., A.V. Tyler, G.H. Kruse, and H.J. Niebauer. 1998. Relationship between wind and year-class strength of Tanner crabs in Southeastern Bering Sea. *Fishery Research Bulletin 5*(11):18–24.

Rosenkranz, G.E., A.V. Tyler, and G.H. Kruse. 2001. Effects of water temperature and wind on year-class success of Tanner crabs in Bristol Bay, Alaska. *Fisheries Oceanography 10*(1):1–12.

SAFMC (South Atlantic Fishery Management Council). 2005. *Final Amendment 6 to the Fishery Management Plan for the Shrimp Fishery of the South Atlantic Region*. South Atlantic Fishery Management Council, Charleston, SC.

Sambrotto, R.N., and C.J. Lorenzen. 1986. Phytoplankton and primary production. Chapter 9, pp. 249–284. In: *The Gulf of Alaska: Physical Environment and Biological Resources*. D.W. Hood and S.T. Simmerman (eds.). University of Washington Press, Seattle, WA.

Samons, J. 2002. Cleaner waters in pipeline, $550 million project launched. *Narragansett Bay Journal 1*(1):1, 4.

Saupe, S., J. Gendron, and D. Dasher. 2005. *AKMAP—Alaska Monitoring and Assessment Program: The condition of Southcentral Alaska's Bays and Estuaries Technical Report and Statistical Summary*. Alaska Department of Environmental Conservation, Fairbanks, AK.

Save the Bay, Inc. 2006. *Save The Bay—Narragansett Bay*. Save the Bay, Inc., online information. Save the Bay, Inc., Providence, RI. Available at: http://www.savebay.org/ (Accessed April 2006).

SCCWRP (Southern California Coastal Water Research Project). 1998. *Southern California Bight 1994 Pilot Project*. Volumes I–V. Southern California Coastal Water Research Project, Westminster, CA.

Scholin, C.A., F. Gulland, G.J. Doucette, S. Benson, M. Busman, F.P. Chavez, J. Cordaro, R.D. DeLong, A. Vogelaere, J. Harvey, M. Haulena, K. Lefebvre, T. Lipscomb, S. Loscutoff, L.J. Lowenstine, R. Marin, III, P.E. Miller, W.A. McLellan, P.D.R. Moeller, C.L. Powell, T. Rowles, P. Silvagni, M. Silver, T. Spraker, V. Trainer, and F.M.Van Dolah. 2000. Mortality of sea lions along the central California coast linked to a toxic diatom bloom. *Nature 403*:80–84.

Schwacke, L.H., E.O. Voit, L.J. Hansen, R.S. Wells, G.B. Mitchum, A.A. Hohn, and P.A. Fair. 2002. Probabilistic risk assessment of reproductive effects of polychorinated biphenyls on bottlenose dolphins (*Tursiops truncatus*) from the southeast United States coast. *Environmental Toxicology and Chemistry 21*:2752–64.

Serchuk, F.M., and S.A. Murawski. 1997. The offshore molluscan resources of the Northeastern Coast of the United States: Surfclams, ocean quahogs, and sea scallops. Pp. 45–62. In: *The History, Present Condition, and Future of the Molluscan Fisheries of North and Central America and Europe, Vol. 1, Atlantic and Gulf Coasts*. C.L. MacKenzie, Jr., V.G. Burrell, Jr., A. Rosenfield, and W.L. Hobart (eds.). NOAA Tech. Rep. 127. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Silver Spring, MD.

SFEI (San Francisco Estuary Institute). 2003. *The Pulse of the Estuary: Monitoring and Managing Contamination in the San Francisco Estuary*. SFEI contribution 74. San Francisco Estuary Institute, Oakland, CA.

SFEI (San Francisco Estuary Institute). 2004. *The Pulse of the Estuary: Monitoring and Managing Water Quality in the San Francisco Estuary*. SFEI contribution 78. San Francisco Estuary Institute, Oakland, CA.

SFEI (San Francisco Estuary Institute). 2006. *Pulse of the Estuary: Monitoring and Managing Water Quality in the San Francisco Estuary*. San Francisco Estuary Institute, Oakland, CA.

Sharma, G.D. 1979. *The Alaska Shelf—Hydrographic, Sedimentary, and Geochemical Environment*. Springer-Verlag, NY.

Shellenbarger, G.G., D.H. Schoellhamer, and M.A. Lionberger. 2004. *A South San Francisco Bay Sediment Budget: Wetland Restoration and Potential Effects on Phytoplankton Blooms.* Proceedings of the 2004 Ocean Research Conference, Honolulu, HI, February 15–20.

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.

Sherman, K., J. O'Reilly, and J. Kane. 2003. Assessment and sustainability of the U.S. Northeast Shelf Ecosystem. Pp. 93–120. In: *Large Marine Ecosystems of the World: Trends in Exploitation, Protection, and Research*. G. Hempel and K. Sherman (eds.). Elsevier, Amsterdam.

Short, F.T., L.K. Muehlstein, and D. Porter. 1987. Eelgrass wasting disease: Cause and recurrence of a marine epidemic. *Biological Bulletin 173*:557–562.

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.

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, 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.

Society of Wetland Scientists. 2000. *Position Paper on the Definition of Wetland Restoration*. Society of Wetland Scientists, McLean, VA.

South Carolina DNR (Department of Natural Resources). 2007a. *Oyster Recycling and Restoration Program*. South Carolina Department of National Resources online information. South Carolina Department of Natural Resources, Marine Resources Division, Charleston, SC. Available at: http://saltwaterfishing.sc.gov/oyster.html (Accessed April 2007).

South Carolina DNR (Department of Natural Resources). 2007b. *South Carolina Oyster Restoration and Enhancement*. South Carolina Department of National Resources online information. South Carolina Department of Natural Resources, Marine Resources Division, Charleston, SC. Available at http://score.dnr.sc.gov/index.php (Accessed April 2007).

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.

Steinberger, A., and E.D. Stein. 2004. Effluent discharges to the Southern California Bight from large municipal wastewater treatment facilities in 2001 and 2002. Pp. 2–15. In: *Southern California Coastal Water Research Project 2003–2004 Biennial Report*. S.B. Weisberg and D. Elmore (eds.). Southern California Coastal Water Research Project, Westminster, CA.

Strobel, C.J., H.W. Buffum, S.J. Benyi, E.A. Petrocelli, D.R. Reifsteck, and D.J. Keith. 1995. *Statistical Summary: EMAP-Estuaries Virginian Province—1990 to 1993*. EPA/620-R-94-026. U.S. Environmental Protection Agency, National Health and Environmental Effects Research Laboratory-Atlantic Ecology Division, Narragansett, RI.

Stull, J. 1995. Two decades of biological monitoring, Palos Verdes, California, 1972 to 1992. *Bulletin of the Southern California Academy of Sciences 94*:21–45.

Summers, J.K., J.F. Paul, and A. Robertson. 1995. Monitoring the ecological condition of estuaries in the United States. *Toxicological and Environmental Chemistry 49*:93–108.

Swartz, R.C., J.H. Bailey-Brock, W.J. Cooke, and E.A. Kay. 2002. *Regional Monitoring of Benthic Fauna in Mamala Bay, O'ahu, Hawai'i, August 2001*. Project Report PR-2002-07. University of Hawai'i at Manoa, Water Resources Research Center, Honolulu, HI.

SWRCB (State Water Resources Control Board). 2006. *Development of Sediment Quality Objectives for Enclosed Bays and Estuaries*. CEQA Scoping Meeting Information Document. State Water Resources Control Board, Division of Water Quality, Sacramento, CA.

Taylor, D.L., and D.J. Danila. 2005. Predation on winter flounder (*Pseudopleuronectes americanus*) eggs by the sand shrimp (*Cragnon septemspinosa*). *Canadian Journal of Fisheries and Aquatic Sciences 62*(7):1611–1625.

Teitelbaum, J.S., R.J. Zatorre, S. Carpenter, D. Gendron, A.C. Evans, A. Gjedde, and N.R. Cashman. 1990. Neurologic sequelae of domoic acid intoxication due to the ingestion of contaminated mussels. *New England Journal of Medicine 322*:1781–1787.

Thayer, G.W., and M.E. Kentula. 2005. Coastal restoration: Where have we been, where are we now, and where should we be going? *Journal of Coastal Research Special Issue 40*:1–5.

Thayer, G.W., T.A. McTigue, R.J. Bellmer, F.M. Burrows, D.H. Merkey, A.D. Nickens, S.J. Lorenzo, P.J. Gayaldo, P.J. Polmateer, and P.T. Pinit. 2003. *Science-Based Restoration Monitoring of Coastal Habitats Volume 1: A Framework for Monitoring Plans Under the Estuaries and Clean Water Act of 2000 (Public Law 160-457)*. NOAA Coastal Ocean Program Decision Analysis Series No. 23, Volume 1. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service, National Centers for Coastal Ocean Science, Center for Sponsored Coastal Ocean Research, Silver Spring, MD.

Thayer, G.W., T.A. McTigue, R.J. Salz, D.H. Merkey, F.M. Burrows, and P.F. Gayaldo (eds.). 2005. *Science-Based Restoration Monitoring of Coastal Habitats Volume 2: Tools for Monitoring Coastal Habitats*. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service, National Centers for Coastal Ocean Science, Center for Sponsored Coastal Ocean Research, Silver Spring, MD.

Thieler, E.R., and E.S. Hammar-Klose. 1999. *National Assessment of Coastal Vulnerability to Sea-Level Rise: Preliminary Results for the U.S. Atlantic Coast*. USGS Open-file Report 99-593. U.S. Department of the Interior, U.S. Geological Survey, Woods Hole, MA.

Transport Canada. 2007. *The Canadian Ballast Water Program*. Transport Canada online information. Transport Canada, Marine Safety, Ottawa, ON. Available at: http://www.tc.gc.ca/marinesafety/oep/environment/ballastwater/management.htm (Accessed May 2007).

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.

Turner, R.E., and B. Steever. 2002. *Approaches to Coastal Wetland Restoration: Northern Gulf of Mexico*. SPB Academic Publishing, The Hague, The Netherlands.

U.S. Census Bureau. 2000a. *1997 Economic Census, Manufacturing, Geographic Area Series—Massachusetts*. EC97M31A-MA. U.S. Department of Commerce, U.S. Census Bureau, Washington, DC.

U.S. Census Bureau. 2000b. *1997 Economic Census, Manufacturing, Geographic Area Series—Rhode Island*. EC97M31A-RI. U.S. Department of Commerce, U.S. Census Bureau, Washington, DC.

U.S. Census Bureau. 2001. *Your Gateway to Census 2000*. U.S. Census Bureau online information. U.S. Department of Commerce, U.S. Census Bureau, Washington, DC. Available at: http://www.census.gov/main/www/cen2000.html (Accessed November 2006).

U.S. Census Bureau. 2006a. *State and County Quickfacts*. U.S. Census Bureau online information. U.S. Department of Commerce, U.S. Census Bureau, Washington, DC. Available at: http://quickfacts.census.gov/qfd/index.html (Accessed August 2006).

U.S. Census Bureau. 2006b. *Statistical Abstract of the United States: 2006*. U.S. Department of Commerce, U.S. Census Bureau, Washington, DC.

U.S. Commission on Ocean Policy. 2004a. *An Ocean Blueprint for the 21st Century*. Final Report. U.S. Commission on Ocean Policy, Washington, DC.

U.S. Commission on Ocean Policy. 2004b. *Preliminary Report of the U.S. Commission on Ocean Policy*. Governors' Draft. U.S. Commission on Ocean Policy, 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). 1994. *Methods for Assessing the Toxicity of Sediment-Associated Contaminants with Estuarine and Marine Amphipods.* EPA/600/R-94/025. U.S. Environmental Protection Agency, Office of Research and Development, 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). 1995b. *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). 1998a. *Condition of the Mid-Atlantic Estuaries*. EPA/600-R-98-147. U.S. Environmental Protection Agency, Office of Research and Development, 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. *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). 2000b. *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). 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 Field Operations Manual*. EPA/620-R-01-003. U.S. Environmental Protection Agency, Office of Research and Development, Washington, DC.

U.S. EPA (Environmental Protection Agency). 2001b. *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). 2001c. *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). 2001d. *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). 2001e. *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). 2002. *Research Strategy, Environmental Monitoring and Assessment Program*. EPA/620-R-02-002. U.S. Environmental Protection Agency, Office of Research and Development, National Health and Environmental Effects Research Laboratory, Research Triangle Park, NC.

U.S. EPA (Environmental Protection Agency). 2003. *Brayton Point Station, Somerset, MA: Final National Pollutant Discharge Elimination System (NPDES) Permit*. Fact Sheet. U.S. Environmental Protection Agency, Region 1, Boston, MA.

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. *National Listing of Fish and Wildlife Database—2003*. 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). 2004c. *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). 2005a. *EPA's BEACH Program: 2004 Swimming Season Update*. EPA/823-F-05-006. 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). 2005b. *National Listing of Fish Advisories Database*. U.S. Environmental Protection Agency online information. U.S. Environmental Protection Agency, Office of Water, Washington, DC. Available at: http://epa.gov/waterscience/fish/advisories/ (Accessed December 2005).

U.S. EPA (Environmental Protection Agency). 2005c. *Water Discharge Permits-Permit Compliance System (PCS) Database*. U.S. Environmental Protection Agency online information. U.S. Environmental Protection Agency, Office of Ground Water and Drinking Water, Washington, DC. Available at: http://www.epa.gov/enviro/html/pcs/index.html (Accessed December 2005).

U.S. EPA (Environmental Protection Agency). 2006a. *Draft Guidance for Implementing the January 2001 Methylmercury Water Quality Criterion*. EPA/823-B-04-001. U.S. Environmental Protection Agency, Office of Water, Washington, DC.

U.S. EPA (Environmental Protection Agency). 2006b. *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). 2006c. *PRAWN Database (September 11, 2006)*. U.S. Environmental Protection Agency, Office of Water, Washington, DC.

U.S. EPA (Environmental Protection Agency). 2007a. *Alabama Habitat Strategic Assessment Workshop, Project # MX964002*. U.S. Environmental Protection Agency online information. U.S. Environmental Protection Agency, Gulf of Mexico Program, Stennis Space Center, MS. Available at: http://www.epa.gov/gmpo/projects/ala-habitat_intro.html (Accessed April 2007).

U.S. EPA (Environmental Protection Agency). 2007b. *Aquatic Resources Monitoring*. U.S. Environmental Protection Agency 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). 2007c. *Areas of Concern (AoCs) On-line*. U.S. Environmental Protection Agency 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 May 2007).

U.S. EPA (Environmental Protection Agency). 2007d. *Benthic Community Health*. U.S. Environmental Protection Agency online information. U.S. Environmental Protection Agency, Great Lakes National Program Office, Chicago, IL. Available at http://www.epa.gov/glnpo/glindicators/biology/benthica.html (Accessed May 2007).

U.S. Senate. 2003. *Coastal and Estuarine Land Protection Act. (to accompany S. 861)* (S. Rpt. 108–158). Committee on Commerce, Science and Transportation. Government Printing Office, Washington, DC.

Ulanowicz, R.E., and J.H. Tuttle. 1992. The trophic consequences of oyster stock rehabilitation in Chesapeake Bay. *Estuaries 15*:298–306.

UNEP (United Nations Environment Programme). 2004. *GEO Year Book 2003*. United Nations Environmental Program, Division of Early Warning and Assessment, Global Environment Outlook Team, Nairobi, Kenya.

University of British Columbia. 2007. *Sea Around Us Project—Web Products: Large Marine Ecosystems*. University of British Columbia online information. University of British Columbia, Aquatic Ecosystems Research Laboratory, Fisheries Centre, Vancouver, BC, Canada. Available at: http://www.seaaroundus.org/LME/lme.aspx# (Accessed May 2007).

USACE (U.S. Army Corps of Engineers). 2001. *Providence River and Harbor Maintenance Dredging Project, Final Environmental Impact Statement*. U.S. Army Corps of Engineers, New England District, Concord, MA.

USACE (U.S. Army Corps of Engineers). 2005. *Rhode Island, Corps to Mark Completion of Providence River and Harbor Maintenance Dredging Project*. News Release RI 2005-04. U.S. Army Corps of Engineers, New England District, Concord, MA. January 10.

USDA (U.S. Department of Agriculture). 2004a. *2002 Census of Agriculture, Volume 1, Geographic Area Series, Part 21—Massachusetts State and County Data*. AC-02-A21. U.S. Department of Agriculture, National Agricultural Statistics Service, Washington, DC.

USDA (U.S. Department of Agriculture). 2004b. *2002 Census of Agriculture, Volume 1, Geographic Area Series, Part 39—Rhode Island State and County Data*. AC-02-A39. U.S. Department of Agriculture, National Agricultural Statistics Service, Washington, DC.

USGS (U.S. Geological Survey). 2006a. *National Water Quality Network Pilot Underway*. News Release. U.S. Department of the Interior, U.S. Geological Survey, Reston, VA.

USGS (U.S. Geological Survey). 2006b. *Water Quality of San Francisco Bay: A Long-term Program of the U.S. Geological Survey*. U.S. Geological Survey online information. U.S. Department of the Interior, U.S. Geological Survey, Menlo Park, CA. Available at: http://sfbay.wr.usgs.gov/access/wqdata/ (Accessed June 2006).

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.

Van Metre, P.C., and B.J. Mahler. 2005. Trends in hydrophobic organic contaminants in urban and reference lake sediments across the United States, 1970–2001. *Environmental Science and Technology 39*:5567–5574.

Van Metre, P.C., B.J. Mahler, and E.T. Furlong. 2000. Urban sprawl leaves its PAH signature. *Environmental Science and Technology 34*:4064–4070.

Waddell, J.E. (ed.). 2005. *The State of Coral Reef Ecosystems of the United States and Pacific Freely Associated States: 2005*. NOAA Technical Memorandum NOC NCCOS 11. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service, National Centers for Coastal Ocean Science, Center for Coastal Monitoring and Assessment, Biogeography Team, Silver Spring, MD.

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.

Wells, R.V., V. Tornero, A. Borrell, A. Aguilar, T.K. Rowles, H.L. Rhinehart, S. Hofmann, W.M. Jarman, A.A. Hohn, and J.C. Sweeney. 2005. Integrating life-history and reproductive success data to examine potential relationships with organochlorine compounds for bottlenose dolphins (*Tursiops truncatus*) in Sarasota Bay, Florida. *Science of the Total Environment 349*:106–19.

Williams, I.P., N.J. Maciolek, J.D. Boyle, D.T. Dahlen, and E. Baptiste Carpenter. 2002. *Combined Work/Quality Assurance Plan for Benthic Monitoring: 2002–2005*. MWRA Miscellaneous Report Number ms-076. Massachusetts Water Resources Authority, Environmental Quality Department, Boston, MA.

WPRFMC (Western Pacific Region Fishery Management Council). 1986. *Combined Fishery Management Plan, Environmental Assessment and Regulatory Impact Review for the Bottomfish and Seamount Groundfish Fisheries of the Western Pacific Region*. Western Pacific Region Fishery Management Council, Honolulu, HI.

Wright, B.A., J.W. Short, T.J. Weingartner, and P.J. Anderson. 2000. The Gulf of Alaska, Chapter 20, pp. 373–384. In: *Seas at the Millennium: An Environmental Evaluation. Volume I—Regional Chapters: Europe, The Americas and West Africa*. C.R.C. Sheppard (ed.). Pergamon, Amsterdam.

Yeager, D.W. 2006. Estuary reflections. *Alabama Current Connection 1*(1):5.

Zervas, C. 2004. *North Carolina Bathymetry/Topography Sea Level Rise Project: Determination of Sea Level Trends*. NOAA Technical Report NOS CO-OPS 041. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service, Center for Operational Oceanographic Products and Services, Silver Spring, MD.

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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Protection Agency
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