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Data Collection Methodology: The NWI produces periodic reports of changes in wetland area. The data, summarized in the aforementioned report, are derived from three separate analyses; one covering the 1950s to the 1970s; one covering the 1970s to 1980s, and one covering the 1980s to the 1990s. For this report, decadal estimates are presented as the midpoint of the decade. For example, "1980s" data are presented as "1985." Note that more detailed data are available from the NWI maps and accompanying digital data but that acreage summaries are not compiled for national or regional reporting.

NWI counts all wetlands, regardless of land ownership, but recognizes only wetlands that are at least 3 acres. To ensure adequate coverage of coastal wetlands, supplemental sampling along the Atlantic and Gulf coastal fringes was added.

The patchy distribution of Pacific coast estuarine wetlands precluded gathering statistically valid data on this wetland type. Therefore, consistent with past studies, NWI did not sample Pacific coast estuarine wetlands such as those in San Francisco Bay, California; Coos Bay, Oregon; or Puget Sound, Washington.

A permanent study design is used, based initially on stratification of the 48 conterminous states by state boundaries and 35 physiographic subdivisions. Within these subdivisions are located 4375 randomly selected, 4-square-mile (2560 acres) sample plots. These plots were examined with the use of aerial imagery, ranging in scale and type; most were 1:40,000 scale, color infrared, from the National Aerial Photography Program.

Data Quality/Caveats: Field verifications addressing questions on image interpretation, land use coding, attribution of wetland gains or losses, and plot delineations were made. For example, for the analyses in the 1980s to 1990s, 21% of the sample plots were verified.

Data Access: *The Status and Trend of Wetlands in the Conterminous United States 1986-1997* is available on the Web at http://wetlands.fws.gov/bha/SandT/SandTReport.html.

Coasts and Oceans

Coastal Living Habitats—Coral Reefs, Wetlands, Seagrasses, and Shellfish Beds

The Data: Coastal Wetlands

Data Source: The coastal wetland data came from the U.S. Fish and Wildlife Service's (FWS) National Wetlands Inventory (NWI; Dahl et al. 2000, p. 44). The data presented here include estuarine vegetated wetlands, which are approximately 87% of the total coastal wetlands included in the FWS report. Excluded types include estuarine non-vegetated and marine intertidal, neither of which fall into the category of "biologically structured habitat"—that is, they are not characterized by significant vegetation that is habitat for various animals and plants. Note that no estimate of "presettlement" coastal wetlands is included in this indicator. There are estimates of coastal wetlands prior to major development along the coastline that affected many wetlands. Gosselink and Baumann (1980) estimate that 10 million acres of coastal wetlands existed in 1923, which was prior to most of the coastal development.

The Data Gap: Coral Reefs

According to the federal interagency Coral Reef Task Force (CRTF; http://coralreef.gov), accurate geo-referenced information on the exact location of specific natural resources and habitat types is essential for effective management of coral reefs. Comprehensive maps and habitat assessments form the foundation for a variety of reef conservation measures, including creating accurate baselines for long-term monitoring. However, according to the CRTF, most coral reefs in U.S. waters, and particularly those in the Pacific Ocean, have not been accurately mapped with modern techniques and at a scale relevant to emerging conservation issues.

In March 2000, the CRTF released a plan of action (http://coralreef.gov/CRTFAxnPlan9.PDF) committing the agencies to produce comprehensive digital maps of all coral reefs in the United States and trust territories within 5 to 7 years. During this period, the ongoing mapping of the Caribbean region will be completed, and new efforts will begin in the Pacific where critical data gaps presently exist. This interagency effort will produce maps at both low and high resolutions that address locally identified conservation and management needs.

The Data Gap: Shellfish Beds

The National Shellfish Register of Classified Growing Waters has been produced every 5 years since 1966; the most recent is the

1995 Register, released in 1997 (http://spo.nos.noaa.gov/projects/95register/). The Register is a cooperative effort among the nation's shellfish-producing states, federal agencies such as the U.S. Food and Drug Administration and the National Oceanographic and Atmospheric Administration, and the Interstate Shellfish Sanitation Conference (ISSC).

The program's focus is on the number and area of shellfish beds that are classified according to sanitary guidelines administered by the ISSC. States have been encouraged to monitor as broad a range of shellfish beds within their waters as possible, in order to protect public health. However, the resulting increase in area monitored confounds reporting on trends in overall shellfish bed area, making it inappropriate simply to report the acreage trends contained within the 1995 Register.

Note that shellfish beds that are no longer living (i.e., relict beds) continue to provide valuable habitat to marine organisms; over time, these beds will slowly disappear as the shells are dissolved.

The Data Gap: Submerged Aquatic Vegetation

While many programs monitor the extent of submerged aquatic vegetation (seagrasses, kelp, and other similar underwater plants), we are aware of no effort to compile and assess national trends. However, the United Nation's Environment Program is actively gathering all available information on the worldwide distribution of seagrasses.

References

Dahl, T.E., et al. 2000. Status and trends of wetlands in the conterminous United States 1986-1997. Washington, DC: U.S. Department of the Interior, Fish and Wildlife Service.

Gosselink, J.G., and R.H. Baumann. 1980. Wetland inventories: Wetland loss along the United States coast. Z. Geomorph. N.F. Suppl. Bd. 34:173–187.

Shoreline Types

The Indicator

Total miles of shoreline are shown for the three regions grouped together, and the breakdown of different shoreline types is shown as a percentage of each region's total shoreline miles. As discussed below, there is some double counting of shoreline types (e.g., a stretch of shoreline may be both mud flat and wetland); this occurs for only about 10% of the shoreline miles. This double counting has two minor implications for the figures. First, a sum of the miles of different types in the left-hand graph would slightly exceed the actual miles along the shore for these three regions. Second, the values in the right-hand graph represent the percentage of total shoreline length for all the types in a given region, which is somewhat more than the actual miles along the shore because of the double counting.

The Data

Data Source: These data were provided by the National Oceanographic and Atmospheric Administration (NOAA), National Ocean Service, Office of Response and Restoration, Hazardous Materials Response Division. Data on Florida's shoreline were collected by the Florida Marine Institute and processed and interpreted by NOAA.

Data were extracted from Environmental Sensitivity Index (ESI) atlases, a product of NOAA's Office of Response and Restoration. The ESI method provides a standardized mapping approach for coastal geomorphology as well as biological and human use elements. More information is available at http://response.restoration.noaa.gov/esi/esiintro.html. Data from multiple atlases (1984–2001) were aggregated into the regions used in this report. For most of the regions, digital data were unavailable for parts of the coastline. The currency and the completeness of the coverage affect the quality of the shoreline summary. With regard to these issues, information specific to the three regions for which data are available is presented in the "Data Quality" section below. Complete metadata for each atlas, including collection methods and source information, can be viewed at http://response.restoration.noaa.gov/esi/metadata.html.

Data Collection Methodology: ESI shoreline types were classified using a combination of overflight information, aerial photography, local habitat maps, National Wetlands Inventory data, and ground truthing. For more detailed information specific to each atlas, see the individual atlas metadata, specifically sections 5.1—Detailed Description: ESI; and 2.5.1—Source Information: ESI.

Data Manipulation: This indicator presents a simplified summary of shoreline types, by region. It is a summary of the total length of land/water interface for the region, as well as the total length of each of the five shoreline types described below.

The first step in defining the indicator was to consolidate the shorelines from the various atlases for each region and reconcile older terminology with current ESI shoreline type classifications. The next step was to combine the ESI shoreline type classes into the five more general categories, based on substrate and slope, that are used in this report. The five categories and the ESI types that make them up, are as follows:

- *Steep sand, rock, or clay:* ESI categories 1 (unvegetated steep banks, cliffs, and seawalls), 1A (exposed rocky shores), 2A (exposed wave-cut platforms in bedrock, mud, or clay), 2B (exposed scarps and steep slopes in clay), 3B (scarps and steep slopes in sand), and 8A (sheltered rocky shores and sheltered scarps in bedrock, mud, or clay)
- *Mud or sand flats:* ESI categories 7 (exposed tidal flats) and 9A (sheltered tidal flats)
- *Beaches (sand or gravel):* ESI categories 3AF (fine- to medium-grained sand beaches), 4 (coarse-grained sand beaches), 5 (mixed sand and gravel beaches), and 6A (gravel beaches)
- *Wetlands, mangroves, etc.:* Includes grasslands, scrublands/shrublands, and marshes. ESI categories 8D (vegetated, steeply sloping bluffs), 9B (vegetated low banks), 10A (salt- and brackish-water marshes, 10B (freshwater marshes), 10C (swamps), and 10D (scrub–shrub wetlands)
- *Armored:* ESI categories 1B (exposed, solid manmade structures, 6B (riprap), 8B (sheltered, solid manmade structures), and 8C (sheltered riprap)

After the regional shoreline was characterized, tables were generated detailing the length of each shoreline segment and its associated ESI type. These data were input into a series of computer programs to sum the total shoreline length and that of each of the shoreline types. ESI shoreline data are quite complex, however, in that a single shoreline segment may contain up to three ESI classifications. For example, a segment may have a tidal flat on the

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water side backed by a sand beach, then a marsh on the landward side. If a segment has different shoreline types, that segment is counted multiple times. However, when the total length of land/water interface is calculated, each shoreline segment is counted only once, regardless of the number of shoreline types it contains. Thus, the sum of the lengths of all the shoreline types will be greater than the total shoreline length. This double counting occurs for about 10% of the coastlines characterized.

Data Quality/Caveats: ESI shoreline coverage of the three regions shown was complete; the Pacific Northwest region also included considerable area along the shore of the Columbia River. Some of the older atlases used for this region were compiled more than 15 years ago. Though the West Coast is generally not considered an overly dynamic coastline, some changes may have altered coastline shape or type for a small percentage of this region.

Data Access: The data reported here are the result of an analysis undertaken specifically for this project; however, some data are available at http://response.restoration.noaa.gov/esi/esiintro.html.

The Data Gap

Data are not currently available for the majority of coastal regions; however, the necessary analyses are under way at NOAA.

Areas with Depleted Oxygen

The Indicator

The percentage of brackish water exposed to a range of oxygen concentrations for at least 1 month will be reported as anoxic (no oxygen), hypoxic (>0 and <2 parts per million [ppm]), low (2–4 ppm), or sufficient (>4 ppm). Low oxygen levels for a brief period may do little to disrupt the marine ecosystem; however, when those levels persist, significant effects on the local ecosystem can be expected. The percentage of brackish waters that are hypoxic for at least 1 month will be reported by region. Note that bottom waters are the first to become hypoxic or anoxic because less light is available for the oxygen-producing algae to grow, excess organic matter generally sinks and is decomposed in bottom waters, and little exchange with the atmosphere occurs—a process that can introduce oxygen to surface waters.

Dissolved oxygen is an important habitat parameter for both aerobic and anaerobic organisms. In addition to directly affecting the distribution, abundance, and diversity of aerobic organisms (including commercial and sport fish), oxygen depletion (the development of hypoxia and anoxia) in bottom waters alters biogeochemical reactions involving biologically important elements such as carbon, nitrogen, phosphorus, sulfur, and iron.

The distribution of dissolved oxygen is an integrative measure of the dynamic balance between processes that produce, consume, transport, and exchange dissolved oxygen. Plants (dominated by microscopic algae called phytoplankton) generally produce more oxygen than they consume. The amount of dissolved oxygen in the water at any given time and place reflects the balance between this production and several ways that oxygen is lost from a given location: consumption by respiration, loss from surface waters to the atmosphere because of equilibrium processes (e.g., cold water can hold more oxygen than warmer water), and movement of water masses between regions of the world's ocean.

Anthropogenic nutrient loading is considered by many to be the primary cause of increasing trends in the duration and extent of hypoxia and anoxia. Influxes of nutrients stimulate phytoplankton production which can lead to more bacterial decomposition and rapid increases in biological and chemical oxygen demand when this production is not consumed by zooplankton, fish, or shellfish. Consequently, the occurrence of hypoxic and anoxic bottom waters is an important indicator of coastal eutrophication and of the effects of human activities on biogeochemical cycles. Long-term observations of the extent of oxygen depletion in brackish waters will reflect changes in land cover and land-use patterns in coastal watersheds, including the efficacy of efforts to control nutrient loading to coastal ecosystems (see the National Oceanographic and Atmospheric Administration study, Hypoxia in the Gulf of Mexico, at www.nos.noaa.gov/products/pubs_hypox.html).

The Data Gap

Dissolved oxygen should be measured with a precision of ±0.5 ppm. Measurements should be frequent enough (several times a month) to capture seasonal variability on the spatial scales appropriate to estuaries and coastal areas. In addition, the required data cannot be easily accessed because they reside in a variety of databases that are maintained on an ecosystem-by-ecosystem basis by county, state, and federal agencies and institutions.

Observations with sufficient resolution in time and space to calculate the extent of bottom water hypoxia with known certainty exist for some regions (e.g., the northern Gulf of Mexico, Gulf of Maine, Middle Atlantic Bight, South Atlantic Bight) and for many estuaries and bays (e.g., Long Island Sound, the lower Hudson River estuary, Chesapeake Bay, San Francisco Bay, Puget Sound). Although some of these data are available from the National Oceanographic Data Center (www.nodc.noaa.gov/), the National Estuary Program (http://www.epa.gov/owow/estuaries/), and the National Estuarine Research Reserve System (www.ocrm.nos.noaa.gov/nerr), much of the required data resides with state agencies and other federal programs; and sufficient data on both dissolved oxygen and salinity distributions are not available to calculate this index on regional to national scales.

Contamination in Bottom Sediments

The Indicator

This indicator provides information on the concentration, in coastal bottom sediments, of four major classes of contaminants that can harm fish and other aquatic organisms and can adversely affect human health if ingested while consuming fish or shellfish. Sediment concentration levels will be reported separately for estuaries and the coastal ocean out to 25 miles; currently only data for estuaries are available.

The sediment quality guidelines used in this indicator were developed by the National Oceanographic and Atmospheric Administration, through its National Status and Trends Program (see http://response.restoration.noaa.gov/cpr/sediment/SPQ.pdf). Before these guidelines, there were no national criteria or other widely applicable numerical guidelines for sediment quality. These quality guidelines were developed as informal, interpretive tools to estimate the possible toxicological significance of chemical concentrations in sediments. The guidelines have not been promulgated as regulatory criteria or standards, cleanup or remediation

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targets, discharge attainment targets, pass–fail criteria for dredged material disposal decisions, or for any other regulatory purpose. See http://response.restoration.noaa.gov/cpr/sediment/SQGs.html.

These guidelines were derived from examination of a large number of individual contamination studies, all in salt water. Data from each study were arranged in order of ascending concentrations. Study endpoints in which adverse effects were reported were identified. From the ascending data tables, the 10th percentile and the 50th percentile (median) of the effects database were identified for each substance. The 10th-percentile values were named the "Effects Range—Low" (ERL), indicative of concentrations below which adverse effects rarely occur. The 50th percentiles were designated the "Effects Range—Median" (ERM) values, representative of concentrations above which effects frequently occur. In this report, ERL is referred to as the "possible effects" guideline and ERM as the "probable effects" guideline.

The Data

For this indicator, The Enironmental Monitoring and Assessment Program for estuaries (EMAP-E) provided information assessing the contaminant levels in estuarine sediments and the condition of benthic organisms in those sediments. These information were collected from over 2000 sites from Cape Cod, Massachusetts, to Brownsville, Texas, and represent over 70% of the total estuarine acreage of the United States (excluding Alaska). These data and EMAP-E are described in more detail in the technical note for the national contaminants indicator, p. 210)

Coastal Erosion

The Indicator

The condition of the U.S. coastline—whether it is managed or natural, and whether it is eroding, accreting, or stable—has become a matter of great concern. Not only can a wide sandy beach or broad expanse of coastal marshland be aesthetically pleasing, but it can also protect coastal homes from hazards such as storms and high tides. An eroding shoreline can translate into hundreds of million of dollars in damage to coastal property and loss of tourism revenues.

Management responses to erosion are also problematic. Replacing sand ("beach nourishment") is costly and may have environmental impacts such as disturbance of fish and wildlife habitat and damage to dunes from heavy equipment. Construction of bulkheads and other structures ("armoring") is generally a longer-term approach, but has very significant effects on fish and wildlife that use the shoreline or beach. Neither nourishment nor armoring necessarily stops erosion; however, armoring typically lasts longer than nourishment.

An accurate assessment of how much of the U.S. shoreline is eroding and how much is accreting or stable is necessary to determine how many coastal homes may be in jeopardy (see The Heinz Center 2000). It will also allow planners and officials to take action to protect existing homes from damage and help them manage future development of the coastal zone. Such assessments are complicated by the fact that erosion is a natural and naturally varying phenomenon. Erosion changes on a seasonal and multi-year basis; there will always be some areas that are eroding and some that are accreting, and these areas will shift over time.

The Data Gap

As discussed in the indicator text, guidelines will be necessary for classifying stretches of coastline as "accreting" or "eroding." It is thought that the associated change in the horizontal movement of the shoreline will be in the range of one-half to several feet per year. In addition, the coastal management community will need to agree on impact to the shoreline of groins, which are erosion control structures typically built perpendicular to the shoreline. It is not a simple matter, as it would be for bulkheads, to assign a length of shoreline affected by a groin.

Most shoreline erosion and beach nourishment data are developed on a short-term, project-specific basis. Few long-term or regional studies have been carried out, and differences in data collection and analysis protocols make it difficult to compare site-specific reports and compile the data for either regional or national reporting. A study by Dolan et al. (1985) contains a compilation of erosion data from the 1960s, 1970s, and 1980s. This one-time study may be a model for future analyses.

Various methods have been used to determine whether shoreline locations are eroding, accreting, or stable. These include shoreline profiles, National Oceanographic and Atmospheric Administration's (NOAA) National Ocean Service Topographic Survey Sheets, and aerial photographs, which can be geo-referenced or orthorectified. In addition, Light Detection and Ranging (LIDAR) has been an effective tool for measuring erosion and has been used in at least two different programs. The Airborne LIDAR Assessment of Coastal Erosion (ALACE) project was a partnership between NOAA, the National Aeronautical and Space Administration (NASA), and the U.S. Geological Survey that utilized LIDAR collected via aircraft to map a good portion of the sandy beaches of the lower 48 states; NOAA continues to utilize LIDAR for site-specific analyses of shorelines rather than broad surveys of the U.S. coastline in its Topographic Change Mapping program. (For further information on ALACE or the Topographic Change Mapping program, see http://www.csc.noaa.gov/crs/tcm/.)

Depending on what methods are used, comparison of site-specific reports may or may not provide an accurate regional or national assessment. For example, shoreline profiles may not be dense enough to provide results that can be compared with those of aerial photography. Another consideration in comparing site-specific erosion studies is the time period over which the change in shoreline condition is measured. Reporting on the extent of erosion nationally will require establishing parameters for comparison between various datasets.

Beach nourishment may be undertaken to control erosion, or it may be the by-product of harbor or inlet construction or maintenance, when the excavated material is placed on an adjacent beach. Nourishment that occurs as a by-product is typically not well documented.

References

Dolan, R., F. Anders, and S. Kimball. 1985. Coastal erosion and accretion. National atlas of the United States of America, Department of Interior, U.S. Geological Survey.

The H. John Heinz III Center for Science, Economics and the Environment. 2000. Evaluation of erosion hazards. Washington, DC: The Heinz Center. (available at http://www.heinzctr.org/publications.htm)

Sea Surface Temperature (SST)

The Indicator

This indicator was calculated as follows: (1) the seasonal average sea surface temperature (SST) of near-shore water (shoreline out to 25 miles) was calculated for the warmest season in each region (termed the "seasonal mean maximum"), which typically occurred during summer or fall; (2) the long-term mean (during the warmest seasons) for the period of observation (1985–1998) was calculated; and (3) the long-term mean was then subtracted from the seasonal mean maxima. Thus, values greater than zero are positive "anomalies" (i.e., deviations from the long-term average), and those less than zero are negative anomalies.

Because of the large heat capacity of the ocean, changes in water temperature on the scales reported here are likely to reveal universal changes, such as those caused by global warming, sooner than will be apparent in air temperature (i.e., changes in water temperature are less susceptible to daily and seasonal variability). Changes in annual cycles of water temperature and the occurrence of interannual to decadal trends not only will affect the kinds of organisms that will thrive in a region, but are thought to be associated with the degradation of coral reefs (bleaching) and may be related to the development of harmful algal blooms and the growth of invasive species. On longer time scales (decades to centuries), such changes may be related to decreases in the supply of nutrients to surface waters from the deep sea and a cascade of effects from decreases in primary production to declines in fish production.

As discussed in the text, there is considerable evidence building that the surface waters of the oceans are warming gradually (e.g., Barry et al. 1995 and Levitus et al. 2000).

The Data

Data Source: Data from 1985 through 1998 were analyzed for The Heinz Center by the National Ocean Service of the National Oceanographic and Atmospheric Administration (NOAA). The NOAA/National Aeronautics and Space Administration (NASA) Oceans Pathfinder SST data were obtained using Advanced Very High Resolution Radiometers onboard several NOAA Polar Orbiting Environmental Satellites. Complete data are not available for 1996 and 1997, but are available for 1998. It is important to note that SST data are available back to 1979; however, these data are not yet comparable to the series beginning in 1985.

Data Manipulation: Data were acquired on a grid of square pixels nominally 10 km (about 6 miles) on a side. Both the day and nighttime data were processed to remove clouds (using an "erosion filter") and then averaged to produce monthly means, which were then averaged to produce seasonal means. See "The Indicator" section above for a description of the calculations necessary to generate the SST anomalies.

Data Quality: Systematic errors are rare in such an analysis, and the data are expected to be within 2°F of actual temperatures measured 3.3 ft below the surface.

Data Availability: Data are available for free on the Web from NASA at http://podaac.jpl.nasa.gov/sst/.

References

Barry, J.P., C.H. Baxter, R.D. Sagarin, and S.E. Gilman. 1995. Climate-related, long-term faunal changes in a California rocky intertidal community. Science 267:672–675.

Levitus, S., J.I. Antonov, T.P. Boyer, and C. Stephens. 2000. Warming of the world ocean. Science 287:2225–2229.

At-Risk Native Marine Species

There is no technical note for this indicator.

Non-native Species

Further refinement is required to produce an indicator that combines both number of species and the area they inhabit. However, even with such an indicator, assessment of the national situation would be impossible without a program of data collection and assessment. Monitoring activities will need to be conducted regularly in estuaries around the country. These activities must be supported by historical research to determine which species are native and which have been introduced.

Two definitions are appropriate for this indicator. "Invasive species" are defined in Executive Order 13112, "Invasive Species" (Feb. 3, 1999), as "alien species whose introduction does or is likely to cause economic or environmental harm or harm to human health" where "alien species" are, "with respect to a particular ecosystem, any species, including its seeds, eggs, spores or other biological material capable of propagating that species, that is not native to that ecosystem."

According to an Office of Technology Assessment study (U.S. Congress 1993), just 79 non-native species had cost the American public some $97 billion in damages to natural resources and lost industrial productivity during the 20th century. Pimentel et al. (2000) recently published a more comprehensive estimate; they found that more than $120 billion is spent every year in the United States to deal with the effects of some 50,000 non-native species. Although these figures are not limited to coastal non-natives, they illustrate the scope of the issue.

The discharge of ballast water by oceangoing vessels is a major source of such introductions in coastal waters. With the high speed of modern vessels, organisms taken in with ballast water at one location have little difficulty surviving the trip to a distant destination, where the ballast water and its associated organisms are discharged. Other mechanisms, such as the escape of fish from aquaculture facilities or the intentional introduction of non-native species of shellfish to supplement dwindling native populations, can also contribute to the introduction and spread of non-native species.

The number of successful new invasions appears to have increased dramatically during the 1970s and 1980s, perhaps as a consequence of nutrient enrichment and over-fishing in coastal ecosystems. The list of recent invaders includes several species of benthic algae, submerged aquatic vegetation, toxic dinoflagellates (e.g., *Alexandrium catenella* in Australia) , bivalves (e.g., the zebra mussel in the Great Lakes and the Chinese clam in San Francisco Bay), polychaetes, ctenophores, copepods, crabs, zooplankton, and fish. Such invasions can profoundly alter the population and trophic dynamics of coastal ecosystems. For example, the introduction of the ctenophore *Mnemiopsis leidyi* caused the collapse of the anchovy fishery in the Black Sea by preying on the

Table 1. Proposed Framework for Non-native Species Indicator

	% of Non-native Species		
% of area inhabited or % of total biomass	<25	25–75	75–100
<25	1 (low)	2 (low)	3 (medium)
25–75	2 (low)	3 (medium)	4 (high)
75–100	3 (medium)	4 (high)	5 (high)

Possible ranking system: 1, 2 = low; 3 = medium; 4, 5 = high

anchovy's preferred food, copepods; the introduction of the macrobenthic green algae, *Caulerpa taxifolia*, displaced a diverse community of sponges, gorgonians, and other seaweeds on more than 10,000 acres of sea floor in the northern Mediterranean.

The Indicator

The indicator will report the degree of influence (low to high) of non-native species in major U.S. estuaries. The proposed approach does not evaluate the significance of non-native species (also called non-indigenous, exotic, introduced, or invasive species) to economic or ecological condition, but rather focuses on the degree to which non-natives occupy the system. It would report an index created by combining the percentage of all species in a region that are non-native with the percentage of habitat they occupy (see Table 1). For purposes of this indicator, non-native species fall into at least five categories: fishes, mollusks, crustaceans, higher aquatic plants, and macroalgae. Non-estuarine areas can also have a significant non-native presence; however, the assumption of this indicator is that estuaries are generally more negatively affected.

Table 1 is a proposed framework for establishing the degree of significance of non-native species in a region. Both the number of species and the area they inhabit (or their biomass) are factors, so this measure proposes a combined ranking approach, in which both factors contribute to an overall score. The values presented in the table are arbitrary and are intended only to illustrate the utility of such a ranking system.

The basis for judging significance will vary somewhat among the different categories of organism—for higher aquatic plants, mollusks, and macroalgae, the percentage of the total potential area inhabited would be measured, while for fish and crabs, the percentage of biomass accounted for by non-native species would be measured. The non-native rankings for selected major estuaries should be calculated periodically.

The Data Gap

The number and distribution of native species—not to mention non-natives—are not well documented in most coastal ecosystems, especially when considering species of bacteria, microalgae, and protozoa.

Species lists for the five categories of organism will need to be developed and maintained for each major U.S. estuary. The lists will be based on existing knowledge of the species in the target groupings in each estuary and on ongoing surveys of biological resources that are conducted in these regions for a variety of purposes. These surveys will also provide the data required to assess the ecological significance of the non-native species found in an estuary.

Species lists, data on ecological significance, and some monitoring data on various species are available from surveys and compilations produced by a variety of sources, including state living resource and environmental protection agencies, environmental impact statements, and academic research projects. However, such data are not available in any consistent fashion for many of the major estuaries, and there is no nationwide compilation of data.

The National Aquatic Nuisance Species Task Force (http://www.anstaskforce.gov/), an interagency group, is working to bring together information and data that will undoubtedly be useful for this indicator in the future. Also, the Smithsonian's Environmental Research Center is actively creating databases on invasive species (see http://invasions.si.edu/).

References

Pimentel, D., L. Lach, R. Zuniga, and D. Morrison. 2000. Environmental and economic costs of nonindigenous species in the United States. BioScience 50:53–65.

U.S. Congress, Office of Technology Assessment. September 1993. Harmful non-indigenous species in the United States, OTA-F-565. Washington, DC: U.S. Government Printing Office.

Unusual Marine Mortalities

The Indicator

A deliberate choice was made to focus this indicator on unusual mortalities rather than all marine mortalities. The latter includes death from old age, predation, and human-related causes such as entanglement with fishing gear. Unusual mortalities were selected so that only extraordinary instances of animal deaths would be included; a death from old age is within normal functioning of an ecosystem and should not be treated as a signal of changing ecosystem status.

In response to a major dolphin die-off during 1987–88, the National Marine Fisheries Service (NMFS) established a Working Group on Unusual Marine Mammal Mortality Events (WGUMMME) to create criteria for determining when an unusual mortality event is occurring and then to direct responses to such events (see http://www.nmfs.noaa.gov/prot_res/PR2/Health_and_Stranding_Response_Program/WGUMMME.html). The Working Group consists of a multidisciplinary team that makes judgments based on the following: (1) there is an increased number of mortalities when compared with historical data; (2) animals are stranding at an unusual time of year; (3) strandings occur in a localized area, throughout the geographical range, or they spread geographically with time; (4) the species, age, or sex composition of the stranded animals is different from what is normally seen; (5) stranded animals exhibit similar or unusual pathological findings or general physical condition; (6) mortality is accompanied by abnormal behavior among living individuals in the wild; and (7) critically endangered species are dying.

The Data

Data Source: U.S. Department of Commerce, National Oceanographic and Atmospheric Administration (NOAA), NMFS, Office of Protected Resources, Marine Mammal Health and Stranding Response Program; and Dierauf and Gulland (2001).

Data Quality/Caveats: The data for 2001 are preliminary as these unusual mortality events (UMEs) have not been officially

closed and the total number of affected animals tallied. Also, there was a single UME for gray whales that spanned three years (1999–2001). A total of 678 animals were lost to a UME, with 273 in 1999. NOAA has not yet finalized the accounting for this event, so the remainder was simply split between 2000 and 2001. Given that there is no apparent trend to the data, this gross simplification should not distort the interpretation of this indicator.

Data Access: The 2001 data for two UMEs and the total number of gray whales lost in the 1999–2001 UME were obtained directly from NMFS. All other UME data were obtained from Dierauf and Gulland (2001).

The Data Gap

There is no program for sea birds, fish, and shellfish similar to that in place for marine mammals run under the auspices of the WGUMMME. It will be necessary to establish guidelines for what constitutes a UME for these animals, which typically perish in much larger numbers than mammals. For example, a guideline for fish may be that 1,000 deaths of members of two or three species would be necessary to qualify for a UME. This guideline may vary by species and by location and will certainly be different from the guidelines appropriate for shellfish and sea birds. Because these UMEs would all involve large numbers of animals, only the number of events will be reported. In addition, it is unclear if data exist on UMEs for sea turtles; however, these mortalities would be reported by the number of animals lost as is done for mammals.

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Harmful Algal Blooms

The Indicator

For the purposes of this analysis, harmful algal blooms (HABs) are defined as (1) an increase in the abundance of species that are known to produce toxins harmful to marine animals or humans (see Table 2); (2) the occurrence of lesions or mass mortalities of marine animals caused by HAB species; and (3) the occurrence of human pathologies caused by HAB species. A single event counts only once toward the relative intensity scale, even if it produces multiple impacts (e.g., an increase in the abundance of a HAB species that causes mass mortalities and an increased human health risk will be counted as a single event).

There are approximately 5000 species of microalgae in the world. Of these, about 100 are toxic. The scientific community refers to the phenomenon that cause these events as HABs, recognizing that HAB species represent a broad spectrum of taxa (e.g., dinoflagellates, diatoms, cyanobacteria) and trophic levels (e.g., autotrophic, heterotrophic, mixotrophic) and that many HAB species cause problems at low cell densities (i.e., a visible bloom is not necessarily required for a HAB event to occur). A second group of problematic algal blooms is recognized: those that cause problems such as oxygen depletion, habitat loss, starvation, or respiratory or reproductive failure in marine animals by virtue of their high abundance or biomass. These issues are addressed to some extent in other indicators.

Although definitive scientific evidence is lacking, HAB events appear to be increasing in number, extent, and severity (see *National Assessment of Harmful Algal Blooms in US Waters*, http://www.habhrca.noaa.gov/FinalHABreport.pdf). Rapid increases in the number of people living, working, and playing in the coastal zone have increased the input of nutrients to coastal waters, and HAB events may be occurring more frequently as a consequence. In addition, increases in shipping (and the inadvertent transport of non-native species of algae in ballast water) and the transport of shellfish between regions and continents may be increasing the frequency of HAB events by introducing new HAB species to U.S. coastal waters, or moving them to new locations within the United States. A growing human population also increases the demand for food from coastal waters in the form of wild and cultured fish and shellfish. The aquaculture industry is threatened by HAB events and may contribute to their increase.

The Data Gap

Most harmful algal events, such as fish kills, are typically identified after the event occurred or when it is well under way. Systematic monitoring programs that (1) quantify the abundance of harmful algal species, (2) quantify the concentrations of biotoxins or establish unequivocal causal relations between HAB

Table 2. Harmful Algal Species: By Region and Toxic Effect

Region	Effect	Species
Northeast	Paralytic Shellfish Poisoning (PSP)	*Alexandrium tamarense*
	Fish kills	*Gymnodinium mikimotoi*
	Shellfish mortality	*Aurococcus anophagefferens*
Southeast	Neurotoxic Shellfish Poisoning (NSP)	*Gymnodinium breve*
	Fish kills, Human health	*Pfiesteria piscicida*
Gulf of Mexico	Neurotoxic Shellfish Poisoning (NSP)	*Gymnodinium breve*
	Ciguatera Fish Poisoning (CFP)	*Gambierdiscus toxicus*
	Amnesic Shellfish Poisoning (ASP)	*Pseudo-nitzschia spp.*
West Coast	Paralytic Shellfish Poisoning (PSP)	*Alexandrium catenella*
	Amnesic Shellfish Poisoning (ASP)	*Pseudo-nitzschia spp.*
	Diarrhetic Shellfish Poisoning (DSP)	*Dinophysis spp.*

Note: PSP, NSP, CFP, ASP, and DSP all cause human health problems.

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species and mortality events, or (3) quantify increases in human health risks are rare. Consequently, the data required to calculate this index on regional or national scales do not exist.

Although efforts to monitor and report these events are increasing nationwide, there is no standard measure of HABs. This is largely because of the heterogeneous nature of HABs (in terms of taxonomy, nutrition, the conditions under which they become toxic, the kinds of toxins produced, and their effects) and the fact that some species cause problems when they bloom while others cause problems at low cell densities.

State, federal, and academic programs collect most existing data, such as those in the database maintained by the Florida Marine Research Institute, for specific purposes (e.g., research or mitigation) or for specific locations (e.g., the west coast of Florida) where HABs have caused problems in the past. Thus, there is little consistency among programs, and there is no mechanism in place to establish regional or national databases. Both the National Oceanographic and Atmospheric Administration (NOAA; http://www.nodc.noaa.gov/col/projects/habs/index.html) and the Environmental Protection Agency (EPA; http://es.epa.gov/ncer/rfa/02ecohab.html) have initiated efforts to address these problems, and the U.S. Global Ocean Observation System Program, in collaboration with the Southern Association of Marine Laboratories and the Gulf of Mexico Program, is developing a prototype system for the northern Gulf of Mexico (http://www.hpl.umces.edu/projects/HABSOS.pdf).

In addition, the Harmful Algal Bloom and Hypoxia Research and Control Act was enacted in 1998 (PL 105-383) in response to concerns that HABs and related environmental events (e.g., hypoxia, fish kills) are increasingly a threat to human and coastal ecosystem health. The act called for the establishment of an interagency task force on HABs and hypoxia; a national assessment of HABs and hypoxia; and an assessment plan for the Gulf of Mexico. A federal interagency task force released the *National Assessment of Harmful Algal Blooms in US Waters* in October 2000 (http://www.habhrca.noaa.gov/FinalHABreport.pdf).

Condition of Bottom-Dwelling Animals

The Indicator

The worms, clams, and crustaceans that inhabit the bottom substrates of estuaries are collectively called benthic macroinvertebrates. 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 disturbances in estuarine environments because they are not very mobile and thus cannot avoid environmental problems.

The Data

Data Source: The U.S. Environmental Protection Agency's (EPA) Environmental Monitoring and Assessment Program (EMAP) (http://www.epa.gov/emap/) collected these data. See the technical note for Contamination in Bottom Sediments for a description of the EMAP program. These data were collected as part of the EMAP for Estuaries (EMAP-E).

Data Collection Methodology: EMAP-E examined benthic samples from over 2000 sites from Cape Cod, Massachusetts, to Brownsville, Texas. All site selections were based on probabilistic designs that permit the extrapolation of the data to the entire area. Using a Young-modified Van Veen grab, three replicate grabs were collected from each site and forwarded for identification and quantification of species. Using an index developed by EMAP-E (Engle and Summers 1999, Engle et al. 1994, Van Dolah et al. 1999, Weisberg et al. 1997), the condition of the benthic community was determined for each replicate sample, each site, and the bottom surface area of U.S. estuaries. The index reflects changes in benthic community diversity and the abundance of pollution-tolerant and pollution-sensitive species. A low benthic index rating indicates that the benthic communities are less diverse than expected, are populated by more than expected pollution-tolerant species, and contain fewer than expected pollution-sensitive species. The data in this report reflect an assessment of benthic communities as "good" (high index score), "fair" (moderate index score), or "poor" (low index score). For this report, these classes were described using the terms "undegraded," "moderate," and "degraded." These terms were chosen to ensure a neutral description of the index information (i.e., whether a site's benthic community indicates that the site is degraded or not in relation to a reference site).

Data Quality/Caveats: The indices used in the three regions were developed independently and may not be comparable. Each has been demonstrated to be accurate in the region in which it was developed, but there is some question about whether they can be combined because of the different procedures used in their development.

The definition of undegraded and degraded areas also varied because the levels and types of stress differ from region to region. As a result, the indices in less disturbed areas, such as those being developed in southern California, are designed to detect smaller levels of perturbation than are indices developed for areas like the Chesapeake Bay, where hypoxia and resulting defaunation are prevalent.

Finally, some indices are closely identified with particular sampling methods, creating challenges for integration of results. For example, Gulf of Mexico and Atlantic coast indices are based on animals held on a 0.5-mm screen, while an index used in southern California is based on samples sieved through a 1.0-mm screen.

Data Access: The data presented here were obtained directly from EPA.

The Data Gap

Benthic infaunal data are available from most areas of the country, but the index tools necessary to conduct regional-scale assessments of benthic condition are available for estuaries in only three areas of the country: the Mid-Atlantic, the South Atlantic, and the Gulf of Mexico. Altogether, these indices cover less than half of the nation's estuarine waters. EPA has recently issued national guidance on index development (EPA 822-B-00-024), which should facilitate development efforts in the remaining areas. The guidance document is available on the Web at http://www.epa.gov/waterscience/biocriteria/States/estuaries/estuaries1.html. In addition, few data are available on benthic community condition in coastal ocean waters (out to 25 miles).

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Chlorophyll Concentrations

The Indicator

Coastal Ocean: For each year, the average chlorophyll-a (referred to here as chlorophyll) concentration (parts per billion, or ppb) for the season with the highest average is reported; this is referred to as the "seasonal mean maximum." Data are reported for each region in a band of coastal water extending 25 miles from the shoreline. This boundary was chosen so the index would be more sensitive to changes in nutrients input from terrestrial sources than influences from the deep sea.

Estuaries: It is proposed to report the percentage of U.S. estuary area that has seasonal mean maximum chlorophyll values below 5 ppb, from 5 to 20 ppb, and above 20 ppb.

The Data

Coastal Ocean: Data from the National Aeronautical and Space Administration's (NASA) Sea viewing Wide Field-of-view Sensor (SeaWiFS; see http://seawifs.gsfc.nasa.gov) were analyzed for the nine ocean regions by the National Ocean Service, National Oceanographic and Atmospheric Administration (NOAA). "Water leaving radiance" (reflectance, or light reflected from the sea surface) is used to estimate chlorophyll concentrations at the surface using a series of assumptions accepted by the scientific community. The data utilized for this analysis are termed "level 3." In all cases, seasonal maxima were determined for strips of water 25 miles wide along the coast. These strips were analyzed using square pixels 6 miles on a side. Note that earlier data from the Coastal Zone Color Scanner are available; however, they are not directly comparable to the SeaWiFS data.

The Data Gap

Coastal Ocean: Algorithms used to translate water leaving radiance into chlorophyll concentration currently provide only rough estimates of concentration in those waters where concentrations of suspended sediments and colored dissolved organic matter are high; for example, near-shore waters influenced by surface and groundwater discharges, coastal erosion, and sediment resuspension. A major research effort is currently under way to improve coastal algorithms. Spatial resolution is also a problem. The data presented here are based on a fairly coarse scale (6-mile resolution), but data with 10 times more resolution will soon be available. In order to provide more reliable estimates, satellite data need to be analyzed together with field (in situ measurements) data that typically are not available electronically and, therefore, not easily accessible. In addition, techniques for integrating the two types of data are needed. Currently, data showing relative changes in chlorophyll within a region can be trusted; however, data showing actual concentrations for any given region may be off by a factor of two. Thus, unless differences are large, meaningful comparisons between regions are not yet possible.

Estuaries: As discussed in the text, no regularly reported data are available for this portion of the indicator. Data from NOAA's National Estuarine Eutrophication Assessment (see http://spo.nos.noaa.gov/projects/cads/nees/Eutro_Report.pdf) suggest that 40 percent of the area of major estuaries has "high" chlorophyll levels (>20 ppb), with another 46 percent having "moderate levels" (5–20 ppb). At the extremes, the north and south Atlantic regions had mostly low-to-moderate levels, while three-quarters of the estuary area in the mid-Atlantic had high chlorophyll levels. These results are not based on quantitative data analysis but on the knowledge of scientists familiar with the estuaries in each region. Monitoring data do exist for some estuaries, but need to be assembled into a uniform, national database, and new programs would be required for the remaining estuaries. A combination of aircraft and satellite remote-sensing and in situ measurements will be required to determine the estuarine component of this indicator.

Commercial Fish and Shellfish Landings

The Data

Data Source: Data are from the U.S. Department of Commerce, National Oceanographic and Atmospheric Administration, National Marine Fisheries Service (NMFS), Office of Science and Technology, Fisheries Statistics and Economics Division. In addition, data on foreign and joint-venture landings for Alaska came from Kinoshita et al. (1993 and 1997) and NMFS "blend data" for June 2000 (for a description of "blend data," see http://www.fakr.noaa.gov/sustainablefisheries/blend.htm). The estimates for foreign catches that occurred prior to the establishment of the Fisheries Conservation Zone in 1976 (dotted line in the figure) came from Wise (1991) and are based on NMFS data; however, these data could not be verified.

Data Collection Methodology: Fish landings data for the Pacific Coast were collected by four state fishery agencies, and NMFS reported fish processed at sea by U.S. boats (fish processed by foreign boats and then exported are not reported). On the Atlantic and Gulf coasts, landings data were usually collected cooperatively by the 19 state fishery agencies and NMFS. Some data were also collected by marine fishery commissions.

Atlantic and Gulf commercial fishery data represent a census of landings and were principally reported using seafood dealer weighout slips, while data on the Pacific coast were principally reported using trip ticket reports and observer reports for at-sea processors. Since 1994, an increasing portion of the fishery catch and effort data for federally managed species has been collected using federally mandated logbooks. The use of Vessel Monitoring

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Systems and other electronic data collection and reporting methods is relatively recent and is limited to a small sector of U.S. fisheries.

Note that NMFS has historically included all commercial landings of mollusks in these data, in part because it is not provided with information that will allow it to separate wild-caught from cultured mollusks. In terms of finfish (simply termed "fish" here), those raised by aquaculture are not included with the exception of Alaska salmon, which are released at smolt size (2–4 inches in length) and are caught several years later when they return from the ocean to spawn.

Data Manipulation: All finfish landings have been transformed, when necessary, from landed weight (e.g., dressed, filleted) to round (live) weight equivalents. All mollusks have been standardized from the collected landing report format (e.g., bushels, totes, gallons, counts, and dozens) and reported as meat weight (i.e., without shell) landings. The collecting state and federal agencies themselves transform the landings data.

Data Quality/Caveats: The National Research Council conducted a review of NMFS fisheries data and published *Improving the Collection, Management, and Use of Marine Fisheries Data* in 2000. The report made several recommendations for strengthening fishery data collection, such as implementing a national set of standards and protocols under the umbrella of a Fisheries Information System, but no serious flaws in the existing data collection system were noted.

Data Access: Non-confidential commercial fisheries landings data for 1950–2000 are available at no cost from the NMFS Fisheries Statistics and Economics Division Web site (http://www.st.nmfs.gov/st1/commercial/index.html). The Web site allows users to summarize the data by year, region, state, species, fishing gear, pounds, and dollars.

References

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Wise, J.P. 1991. Federal conservation and management of marine fisheries in the United States. Washington, DC: Center for Marine Conservation.

Status of Commercially Important Fish Stocks

The Data

Data Source: The National Oceanographic and Atmospheric Administration's (NOAA) National Marine Fisheries Service (NMFS) Research Centers in Woods Hole, Massachusetts; Miami, Florida; La Jolla, California; and Seattle, Washington (two centers). Natural Resources Consultants, Inc., analyzed the data under contract for The Heinz Center.

Data Manipulations: As reported by NMFS in the recent publication *Our Living Oceans*, there are 203 stocks within federal jurisdiction. Excluded from these analyses are near-shore stocks, many of which are under state management jurisdiction, and anadromous salmon stocks from the Pacific Northwest.

For 158 of these stocks, data are adequate to consider reporting on their status; the remaining 45 stocks constitute a small fraction (2.5%) of recent landings. Analyses presented in this report were limited to those stocks for which at least 10 years of data were available over the 1981–1999 time period. Both spawning stock biomass and total exploitable stock biomass figures were used to track stock trends. This restriction (i.e., 10 years of data) meant that only 49 of the 158 stocks having status data could be used (these 49 stocks represent about 75% of the weight of fish caught in U.S. waters). It should be noted that requiring spawning stock biomass or total exploitable stock biomass figures certainly restricted the number of trackable stocks; other means exist (e.g., catch per unit effort, relative abundance, indices that combine several stocks) to track stocks that were not included in this analysis.

Biomass refers to the total weight of fish, and can change either because there are more or fewer fish or because, on average, fish are larger or smaller, although changes in biomass are generally described as changes in population size. Stock trends (i.e., "increasing," "decreasing" or "no trend") were determined by linear regression. Trends were determined for four overlapping 10-year periods (1981–1990, 1984–1993, 1987–1996, 1990–1999), which reduced the likelihood that normal year-to-year fluctuations would influence the results. (This is analogous to the effect of using a running average.) Two conditions were necessary for a trend to be reported: the regression line had to have a correlation coefficient (R) indicating at least 95% confidence that the slope was different than zero; and the regression line had to indicate a minimum 25% change over the 10-year period (increasing or decreasing). Trends for the following 49 stocks were studied:

- ***North/Mid-Atlantic:*** Atlantic menhaden, Georges Bank cod, Georges Bank haddock, Georges Bank yellowtail flounder, southern northeast yellowtail flounder, mid-Atlantic summer flounder, Gulf of Maine red fish, Gulf of Maine cod, Gulf of Maine–Georges Bank plaice, Gulf of Maine–Georges Bank witch, Georges Bank winter flounder, and southern New England winter flounder.
- ***Gulf of Mexico:*** Brown shrimp, white shrimp, and pink shrimp.
- ***Southern California:*** Mackerel and sardine.
- ***Pacific Northwest:*** Dark blotched rockfish, lingcod (northern), lingcod (southern), widow rockfish, yellowtail rockfish, bacaccio rockfish, canary rockfish, cow rockfish, Pacific hake, petrale sole, chilipepper rockfish, sablefish, Dover sale, and longspine thorny rockfish.
- ***Alaska Region:*** West & central Alaska pink salmon, west & central Alaska sockeye salmon, west & central chum salmon, west & central Alaska Chinook salmon, west & central Alaska Coho salmon, Bering Sea pollock, Bering Sea Pacific cod, Bering Sea yellow fin sole, Bering Sea rock sole, Bering Sea sablefish, Gulf of Alaska pollock, Gulf of Alaska sablefish, Pacific halibut, red king crab, blue king crab–Pribilofs, blue king crab–St. Matthews, Tanner crab, and snow crab.

Data Quality/The Remaining Data Gap: Currently, we are able to evaluate trends on only about 25% of the commercially important stocks found in U.S. waters.

Data Access: Stock biomass data are available by contacting the NMFS research centers noted above in "Data Source."

Selected Contaminants in Fish and Shellfish

The Indicator

Mercury, DDT, and polychlorinated biphenyls (PCBs) are the chemical contaminants of most concern with respect to the human health impacts of the consumption of seafood. Many fish consumption advisories have been issued for because of high concentrations of these compounds.

This indicator would report the concentration of DDT, PCBs, and mercury in the edible portion of fish and shellfish. The edible portion is preferred for this indicator because whole-body analyses can overstate the level of risk, as some contaminants concentrate in portions that are not eaten.

The Data Gap

The Food and Drug Administration (FDA), Environmental Protection Agency (EPA), and state governments have a variety of monitoring and reporting programs in place; however, these programs do not provide the basis for national reporting on contaminant concentrations.

The FDA has the power to conduct wharf examinations and collect and analyze fish and shellfish samples for a wide variety of defects including chemical contaminants, decomposition, radionuclides, various microbial pathogens, food and color additives, drugs, filth, and marine toxins such as paralytic shellfish poison and domoic acid. When necessary the FDA has the authority to detain or remove any imported or domestic product from interstate commerce that fails to meet standards. Though these powers are broad, they are not used in a manner that provides periodic national reporting on chemical contamination.

The FDA works with state regulators when commercial fish, caught and sold locally, are found to contain methyl mercury levels exceeding 1 part per million (ppm). The agency also checks imported fish at ports and refuses entry if methyl mercury levels exceed the FDA limit. There is no FDA reporting program based on these inspections, however.

With the cooperation of state, county, regional, and country officials, the FDA has a Pesticide Residue Monitoring program whose emphasis is on the raw agricultural product but also includes some seafood products. In its 1999 Total Diet Study (TDS; http://vm.cfsan.fda.gov/~comm/tds-toc.html), sometimes called the Market Basket Study, the FDA determined intake levels of various pesticide residues, contaminants, and nutrients in foods, in representative diets of specific age-sex groups in the United States. In the 1999 and subsequent studies, a total of 267 different foods were represented in the 26 market baskets analyzed. Of those 267 foods, only seven involved seafood. While this program might provide estimates of consumption of various contaminants in the American diet, it does not provide a consistent means of tracking contaminant concentrations in fish from U.S. waters.

EPA has provided a national guidance manual (www.epa.gov/ost/fish/guidance.html) to states for developing consumption advisories and contaminant monitoring programs, but does not directly conduct such monitoring. The manual, which is not binding upon states, was designed to promote consistency in sampling and analysis methods, risk assessment methods, decision-making procedures, and approaches for communicating risks to the public. In addition, both EPA and FDA have issued action levels for concentration of various contaminants, and states may choose between them when deciding whether to issue fish consumption advisories.

EPA maintains a Listing of Fish and Wildlife Advisories (http://fish.rti.org). This database describes state-, tribal-, and federally issued fish consumption advisories. Information in the database is provided voluntarily by the states and may not include the actual concentration data used to determine an advisory need. Since advisories may be based on different levels in different states; it is not even possible to use this database to determine how many cases exceeded a certain level.

From 1990 to 1995, EPA published the National Survey of Mercury Concentrations in Fish (www.epa.gov/ost/fish/mercurydata.html). In addition to the fact that this survey was discontinued, several factors contribute to the variability of the current database. States collect data for purposes other than mercury analyses, and not all sampling strategies are based on a random sample. For example, data collected for the purpose of annual water-quality monitoring may not produce the same results as a site-specific study of fish tissue mercury concentrations. States use different techniques to sample fish. The sampling techniques used by each state influence sample size, fish size, and fish type. States do not adhere to the same standards for assimilating a composite sample. The absence of a standardized method for grouping fish may result in grouping different species of fish into composites, which can affect both the representativeness of the sample and the results of analyses. States use various analytical procedures to measure the concentration of total mercury in fish. Variations among analytical equipment, use of different protocols and procedures, and different levels of laboratory staff experience can all bias the assessment of mercury concentrations in fish. In addition, mercury analyses reported on a wet weight basis cannot be directly compared to concentrations reported on a dry weight basis.

Recreational Water Quality

The Indicator

The most commonly used indicators of fecal contamination are total coliform bacteria, fecal coliform bacteria, *Escherichia coli*, and *Enterococcus* (the latter two are bacteria as well). Although indicator bacteria do not necessarily cause illness, they are abundant in human waste where pathogenic organisms, such as viruses and parasites, are also likely to exist. Bacterial indicators are currently measured instead of pathogenic organisms because the indicators occur in much larger numbers and can be measured with faster, less expensive methods than the pathogens of concern. However, with advances in biotechnology, it may soon be feasible to monitor pathogens using genetic tests.

This indicator focuses on *Enterococcus*, which was selected over other measures of bacteria because it has been shown to be the most closely correlated with human health effects. The U.S. Environmental Protection Agency (EPA) recommended the use of *Enterococcus* as the fecal-indicator bacteria for recreational water quality standards in 1986, but it is still not as widely used as the coliform measures. The reporting categories for this indicator correspond to the daily (104 cells per milliliter of water) and monthly (35 cells per milliliter) geometric mean thresholds suggested by EPA as national beach water quality standards. It should

be noted that the selection of *Enterococcus* is logical today based on EPA guidelines; however, it is possible that new recommendations from EPA and other sources may alter the organism(s) reported in this indicator (for a discussion of a multi-organism indicator, see http://www.healthebay.org/beachreportmethod.asp).

Because some events are short-term but extend over large areas and others are chronic closures in small areas (near a small local source, for example), the indicator is based on the number of beach-mile-days exceeding thresholds of concern, rather than on the number of exceedances or closures. These different scenarios would be weighted inappropriately if the measure were limited to the number of events or to the mileage of beaches that exceeded thresholds at any time during the year.

The indicator is also based on the underlying microbiological data rather than on the number of beach closures or advisories, as is done in EPA's national report (http://www.epa.gov/OST/beaches/); differences in procedures used by local governments in making closure decisions make such reporting less informative. Moreover, the amount of beach monitoring varies dramatically among states, and an indicator based on the number of closures may focus undue concern on states or beach areas that are the most vigilant.

The Data Gap

In 2000, the U.S. Congress passed the Beaches Environmental Assessment and Coastal Health (BEACH) Act. The Act authorizes EPA to award grants to local entities (states, tribes, and territories) to develop and implement monitoring programs at beaches along the coast, including along the Great Lakes. In response to recent legislation, the state of California is moving toward routine reporting of closures in beach-mile-days. Most other states do not summarize their data in this format.

Only one study has ever estimated the number of beach-mile-days exceeding bacteriological thresholds of concern, and that was a one-time research project (Noble et al. 2000).

There are several challenges to reporting this indicator at a national level. These involve, first, the adoption by states and municipalities of the use of *Enterococcus* as an indicator bacteria and adoption of the use of beach-mile-days as the unit of reporting. Second, national reporting will require obtaining the microbiological data from the numerous local governments that collect it. The indicator also requires an assessment of the extent of beach monitoring, which will require three additional types of information: an estimate of the number of miles of publicly accessible beach that is available for water-contact recreation, the spatial extent of beach associated with each water quality measurement (e.g., distance to the next measurement location or to the farthest location that would be closed based on results from that sample site), and the time between samples. This can be complex in practice because some programs measure bacteria sporadically based on events such as spills or citizen complaints, and defining how much beach is represented by a sample can be difficult. Most monitoring uses sampling sites a mile or more apart, while closure decisions typically apply to much smaller areas around any given sampling point.

In addition, many of the agencies and organizations that monitor water quality do not store their data electronically, and even those that do so do not use an agreed-upon storage format. There are also considerable differences in the number, frequency, and degree of coverage of sampling among states and even among beaches within individual states. More consistency among sampling efforts across the nation would enhance the value of the measure. EPA is working to solve the data management problem by collaborating with coastal states to produce an annual report on the national extent of beach closures. While this is a start, EPA's reporting effort focuses only on closures, rather than on the underlying water quality. Since the standards used to determine when a beach is too dirty for swimming vary from place to place, this information cannot provide a consistent picture of water quality nationwide.

References

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