Chapter 2: Purer Water

Indicators that were selected and included in this chapter were assigned to one of two categories:

- **Category 1** –The indicator has been peer reviewed and is supported by national level data coverage for more than one time period. The supporting data are comparable across the nation and are characterized by sound collection methodologies, data management systems, and quality assurance procedures.
- **Category 2** –The indicator has been peer reviewed, but the supporting data are available only for part of the nation (e.g., multi-state regions or ecoregions), or the indicator has not been measured for more than one time period, or not all the parameters of the indicator have been measured (e.g., data has been collected for birds, but not for plants or insects). The supporting data are comparable across the areas covered, and are characterized by sound collection methodologies, data management systems, and quality assurance procedures.

2.0 Introduction

Our nation's water resources have immeasurable value. Animals, plants, and ecosystems depend on clean and abundant water, without which they could not exist. Humans, too, need clean water to drink, to grow food, and to produce goods and services. Clean water generates billions of dollars for the economy each year. Water resources provide opportunities for families to swim and fish, and wetlands protect homes and property against floods. Rivers, lakes, wetlands, and coastal waters provide critical habitats for many species and serve as nurseries for many of the valued commercial and recreational fisheries. Water beneath the water table in fully saturated soils and geological formations, known as ground water, provides half the nation with drinking water.

An increasing tide of pressures has compromised the health of many waterbodies. In the early 20th century, industrial growth and an expanding population left behind a legacy of pollution. After the burning of Ohio's Cuyahoga River—so polluted with oil and debris that it caught fire—Congress passed the landmark Clean Water Act (CWA) and Safe Drinking Water Act (SDWA). These acts and other laws brought to bear strong regulatory and financial tools to clean up polluted surface waters and ensure that public water systems provide safe drinking water.

Thanks to these significant investments, pollutant discharges into our nation's waters have been substantially reduced and the safety of public water supplies has improved (EPA, OW, December 1999). Nevertheless, significant water pollution problems persist and threats to drinking water remain. Today, discharges from industry and sewage treatment plants, together with pollution from many other sources—including, agricultural lands, residential areas, city streets, forestry operations, and pollutants settling out of the air—continue to degrade our nation's waters. Other stresses also threaten water quality. These include landscape modification, introduction of invasive species, changes in flow patterns, and over-harvesting of fish and other aquatic organisms.

Adequately maintained water infrastructure will be essential to sustain the water quality gains of the past 30 years and to address challenges to water quality and delivery of safe drinking water in the coming years. By achieving a better understanding of the condition of our nation's waters, we will be able to make informed decisions about how to protect and preserve our water infrastructure.

This chapter summarizes what is generally understood about the current status and trends in water quality, the pressures affecting water quality, and information regarding associated human health and ecological effects. It poses fundamental questions about water quality, sources of pollution, and health and ecological effects, and it uses indicators drawn from well-reviewed data sources to help answer those questions. Exhibit 2-1 lists these questions and indicators, as well as the number of the chapter section where each indicator is presented.

The questions addressed in this chapter are divided into four categories:

- Waters and watersheds, discussed in Section 2.2.
- Drinking water, discussed in Section 2.3.
- Recreation in and on the water, discussed in Section 2.4.
- Consumption of fish and shellfish, discussed in Section 2.5.

Section 2.1 provides information on the extent and use of our nation's water resources. Section 2.6 reviews the challenges and data gaps that remain in assessing the condition of our nation's water resources.

The key sources of data used to support these indicators vary and are described in each section. Some of the primary data sources that contribute directly or indirectly to indicators throughout this chapter include data from EPA and other federal agencies. Predominant EPA programs or data sets supporting the indicators in this chapter include the Environmental Monitoring and Assessment Program (EMAP); the National Sediment Quality Inventory; the Toxics Release Inventory (TRI); the Safe Drinking Water Information System (SDWIS); the National Health Protection Survey of Beaches; and the National Listing of Fish and Wildlife Advisories (NLFWA). Other national programs that provide data for the indicators described in this chapter include the:

- *U.S. Geological Survey's* National Water Quality Assessment (NAWQA) program.
- *U.S. Fish and Wildlife Service's* (USFWS's) National Wetlands Inventory (NWI) studies of the status and trends of wetlands resources.
- *U.S. Department of Agriculture* (USDA) Natural Resources Conservation Service's (NRCS's) National Resources Inventory (NRI).
- *National Atmospheric Deposition Program* (NADP).
- *National Oceanic and Atmospheric Administration* (NOAA) programs.

Many of these data sets have been compiled and summarized in a report titled *The State of the Nation's Ecosystems*, developed by the H. John Heinz III Center for Science, Economics and the Environment (The Heinz Center, 2002). Gaps in the data exist that make it difficult or impossible to answer some of the questions posed about the condition of our nation's waters. Data gaps and limitations are described under each question and at the end of this chapter.

Exhibit 2-1: Water - Questions and Indicators

Waters and Watersheds

Question	Indicator Name	Category	Section
What is the condition of fresh surface waters and watersheds in the U.S.?	Altered fresh water ecosystems	2	2.2.1
	Lake Trophic State Index	2	2.2.1
What are the extent and condition of wetlands?	Wetland extent and change	1	2.2.2
	Sources of wetland change/loss	2	2.2.2
What is the condition of coastal waters?	Water clarity in coastal waters	2	2.2.3
	Dissolved oxygen in coastal waters	2	2.2.3
	Total organic carbon in sediments	2	2.2.3
	Chlorophyll concentrations	2	2.2.3
What are pressures to water quality?	General pressures		
	Percent urban land cover in riparian areas	2	2.2.4a
	Agricultural lands in riparian areas	2	2.2.4a
	Population density in coastal areas	2	2.2.4a
	Changing stream flows	1	2.2.4a
	Number/duration of dry stream flow periods in grassland/shrublands	2	2.2.4a
	Sedimentation index	2	2.2.4a
	Nutrient pressures		
	Atmospheric deposition of nitrogen	2	2.2.4b
	Nitrate in farmland, forested, and urban streams and ground water	2	2.2.4b
	Total nitrogen in coastal waters	2	2.2.4b
	Phosphorus in farmland, forested, and urban streams	2	2.2.4b
	Phosphorus in large rivers	2	2.2.4b
	Total phosphorus in coastal waters	2	2.2.4b
	Chemical Pressures		
	Atmospheric deposition of mercury	2	2.2.4c
	Chemical contamination in streams and ground water	2	2.2.4c
	Pesticides in farmland streams and ground water	2	2.2.4c
	Acid sensitivity in lakes and streams	2	2.2.4c
	Toxic releases to water of mercury, dioxin, lead, PCBs, and PBTs	2	2.2.4c
	Sediment contamination of inland waters	2	2.2.4c
	Sediment contamination of coastal waters	2	2.2.4c
	Sediment toxicity in estuaries	2	2.2.4c
What ecological effects are associated with impaired waters?	Fish Index of Biotic Integrity in streams Also see Ecological Condition chapter	2	2.2.5
	Macroinvertebrate Biotic Integrity index for streams Also see Ecological Condition chapter	2	2.2.5
	Benthic Community Index for coastal waters Also see Ecological Condition chapter	2	2.2.5

Drinking Water

Question	Indicator Name	Category	Section
What is the quality of drinking water?	Population served by community water systems that meets all health-based standards	1	2.3.1
What are sources of drinking water contamination?	No Category 1 or 2 indicators identified		2.3.2
What human health effects are associated with drinking contaminated water?	No Category 1 or 2 indicators identified Also see Human Health chapter		2.3.3

Recreation in and on the Water

Question	Indicator Name	Category	Section
What is the condition of waters supporting recreational use?	Number of beach days that beaches are closed or under advisory	2	2.4.1
What are sources of recreational water pollution?	No Category 1 or 2 indicators identified		2.4.2
What human health effects are associated with recreation in contaminated waters?	No Category 1 or 2 indicators identified Also see Human Health chapter		2.4.3

Consumption of Fish and Shellfish

Question	Indicator Name	Category	Section
What is the condition of waters that support consumption of fish and shellfish?	Percent of river miles and lake acres under fish consumption advisories	2	2.5.1
	Contaminants in fresh water fish	2	2.5.1
	Number of watersheds exceeding health-based national water quality criteria for mercury and PCBs in fish tissue	2	2.5.1
What are contaminants in fish and shellfish, and where do they originate?	No Category 1 or 2 indicators identified		2.5.2
What human health effects are associated with consuming contaminated fish and shellfish?	No Category 1 or 2 indicators identified Also see Human Health chapter		2.5.3

2.1 Extent and Use of Water Resources

Our nation's water resources, which consist of both surface waters and ground water, are critical to both human activities and the functioning of ecological systems:

- Surface waters, such as rivers, lakes, ponds, reservoirs, wetlands, riparian (river and stream) areas, and estuarine areas, are fundamental components of ecological systems described in this report. They are also important sources of fresh water for human use, including drinking water, recreation, wastewater treatment, industrial usage, livestock, and irrigation. Wetlands and riparian areas help provide clean water, reduce flooding, and support critical fish and wildlife habitat.
- Ground water, one of our nation's most important natural resources, provides about 40 percent of the U.S. public water supply and much of the rural water supply, which comes primarily from domestic wells. Ground water also is the source of much of the water used for irrigation, is the principal reserve of fresh water, and represents much of our nation's potential future water supply. Ground water may contribute as much as 40 percent of all stream flow in the eastern U.S. (Alley, et al., 1999).

Extent of Ground Water and Fresh Water Resources

Ground water comprises about 25 percent of all fresh water on Earth. By contrast, surface water and soil moisture constitute less than one percent of the world's fresh water (Alley, et al., 1999) (the remaining 75 percent is stored in polar ice and glaciers). The Great Lakes, which cover 60.2 million acres, hold about 18 percent of the globe's fresh surface water (Environment Canada and EPA, 1995).

The lower 48 states (conterminous U.S.) contain:

- About half of our nation's 41.6 million acres of lakes, ponds, and reservoirs.
- About 3.7 million miles of streams and rivers (EPA, OW, June 2000).
- An estimated 105.5 million acres of wetlands as of the mid-1990s (Dahl, 2000).

Alaska has an estimated 170 million acres of wetlands, which cover approximately 45 percent of the state. Hawaii has nearly 52,000 acres of wetlands (Dahl, 1990). U.S. coastal waters include 66,645 miles of coastline and 57.9 million acres of estuarine surface area (EPA, OW, June 2000).

Ground water and surface water are closely related and, in many areas, constitute a singe resource. Both are recharged through precipitation. The U.S. receives enough annual precipitation to cover the entire country to a depth of 30 inches (known as the U.S. water budget), though the eastern U.S. receives more rainfall than the western part of the country. Over two-thirds (21 inches) of this precipitation returns to the water cycle through evapotranspiration. The rest becomes surface water, ground water, or soil moisture.

Water use is an important dynamic that can impact both the quantity and quality of available fresh water resources. Accurate information about water use helps planners and managers make informed decisions about our nation's water resources. With this information, they can project future water demand and better assess the effectiveness of alternative water-management policies, regulations, and conservation activities.

States report their water use to the U.S. Geological Survey (USGS) in five mutually exclusive categories:

- *Public water supply use*—water withdrawn by public and private water suppliers and delivered to homes and businesses for drinking, commercial, and industrial uses.
- *Self-supplied water*—water for domestic use and for livestock that is not drawn from the public supply.
- *Irrigation*—this includes application to crops, pastures, and recreational lands such as parks and golf courses.
- *Thermoelectric use*—that is, water used for cooling during electric power generation.
- *Industrial use*—this includes self-supplied water for fabrication, processing, cooling, and washing (including commercial and mining uses).

The USGS coordinates the national water-use compilation effort and publishes the results every five years in the circular series *Estimated Use of Water in the U.S.* Withdrawals are reported in billions of gallons of water per day for the five use categories. Sources of information and accuracy of water-use data vary by state and by water-use category (The Heinz Center, 2002).

The USGS (Solley, et al., 1998) estimated that:

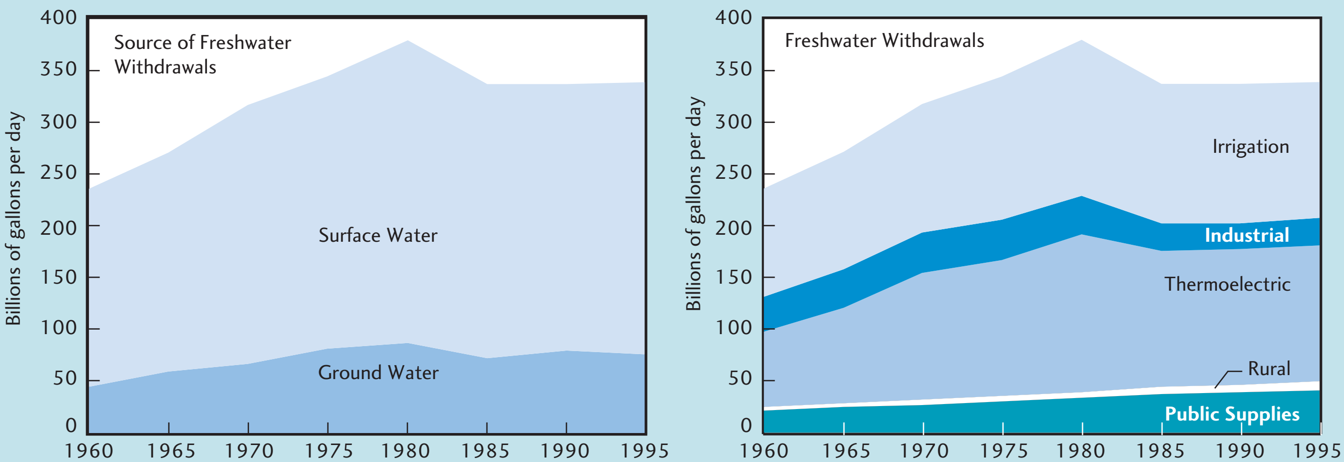
- Total withdrawals of fresh water and saline water during 1995 were 402,000 million gallons per day (Mgal/d) for all water-use categories (public supply, domestic, commercial, irrigation, livestock, industrial, mining, and thermoelectric power).
- Total fresh water withdrawals were an estimated 341,000 Mgal/d. About 100,000 Mgal/d (29.3 percent) of this was consumed, and the rest (241,000 Mgal/d, or 70.7 percent) was returned.

From 1960 to 1980, total water use, as well as the water use for each major use category, increased. However, from 1980 to 1995, total water use, as well as usage in several individual categories declined, though water used for public supply continued to grow (Exhibit 2-2). The two largest uses of water in the U.S.—irrigation and cooling (during electric power generation)—were responsible for much of the decline in total use between 1980 and 1995.

Decreases in withdrawals by self-supplied industrial users also contributed to the overall decline.

In many areas of the U.S., withdrawal of ground water has significantly depleted ground water reserves. Since ground water and surface water are closely related, this depletion can reduce river flows, lower lake levels, and reduce discharges to wetlands and springs. These reductions may, in turn, affect drinking water supplies, riparian areas, and critical aquatic habitats (Alley, et al., 1999). In the southwestern U.S., for example, the High Plains aquifer covers 174,000 square miles under eight states stretching from South Dakota to Texas. By 1999, an estimated 220 million acre-feet (270 cubic kilometers, or something over half the amount of water contained in Lake Erie) had been removed (USGS, 2002), primarily for irrigation.

Exhibit 2-2: Sources of fresh water withdrawals, 1960-1995



Coverage: all 50 states

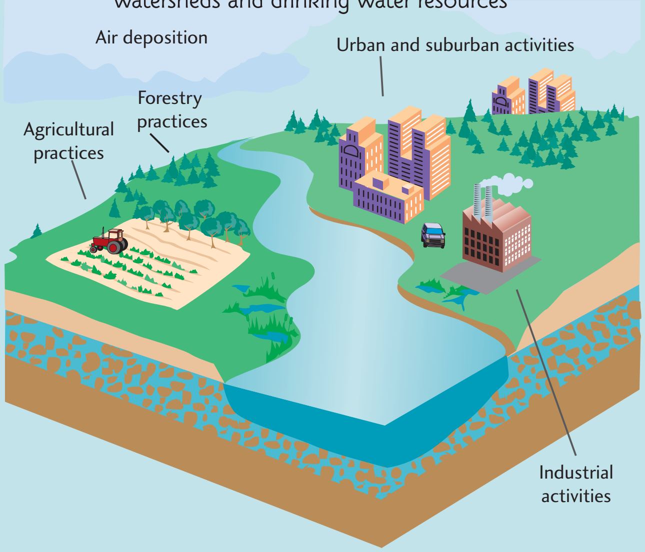
Source: Solley et al. *Estimated Use of Water in the United States in 1995*. 1998.

2.2 Waters and Watersheds

A watershed is the area that drains to a common waterway, such as a stream, lake, estuary, wetland, or ultimately the ocean. It is a land feature that is identified by tracing a line along the highest elevations (often a ridge) between two areas on a map. Watersheds come in all shapes and sizes, and smaller watersheds drain into larger watersheds which may cross county, state, and national boundaries. For example, a small stream running through a farmer's field in Pennsylvania may drain only a few acres within the larger Susquehanna River watershed, which in turn is a portion of the Chesapeake Bay watershed, which extends across six states and the District of Columbia. The watershed's natural processes (e.g., rainfall runoff, ground water recharge, sediment transport, plant succession) provide beneficial services when functioning properly, but may cause ecological and physical (flooding) disasters when misunderstood and disrupted. Watersheds are subject to many different pressures (or "stressors"), including pollution and human activities (see Exhibit 2-3).

Because of their many influences on water quality, watersheds are often the focus of efforts to manage water use and reduce pollution. Traditionally, managers have focused on reducing pollution from specific sources (such as sewage discharges) or within specific water resources (such as river segments or wetlands). This approach successfully reduces pollutant loads, but often does not adequately address the combined concentration of multiple sources that contribute to a watershed's decline. For example, pollution from a sewage treatment plant might be reduced significantly after a new technology is installed, and yet the local river may still suffer if other factors in the watershed, such as habitat destruction or non-point source pollution, are not addressed. Watershed management can offer a stronger foundation than more traditional segmented approaches for elucidating the many stressors that affect a watershed and for developing effective management strategies to protect water resources.

Exhibit 2-3: Selected activities affecting water, watersheds and drinking water resources



Section 2.2 addresses five questions about our nation's waters and watersheds:

- What is the condition of fresh surface waters and watersheds in the U.S.?
- What are the extent and condition of wetlands?
- What is the condition of coastal waters?
- What are pressures to water quality?
- What ecological affects are associated with impaired waters?

Loss of wetlands and the diversion of stream flows are important to understand and quantify condition. Condition, which is addressed in the first three questions, is a function of the quality, extent, and location of the water and how that water quality affects the condition of the biotic resources that depend on that water. To answer questions about condition, a watershed's extent, as well as its chemical, physical, and biological attributes, must be defined. Section 2.2 addresses extent and chemical and physical attributes. Chapter 5, Ecological Condition, describes the biotic condition of waters and watersheds.

2.2.1 What is the condition of fresh surface waters and watersheds in the U.S.?

Indicators

Altered fresh water ecosystems
Lake Trophic State Index

Because the components of condition vary naturally, condition is most often defined as a trend in concentrations or as concentrations relative to standards adopted by state agencies or set by EPA. Only a few programs collect information on the condition of waters at a national scale. One of the most widespread among these programs is EPA's state data collection and reporting program, mandated under Section 305(b) of the Clean Water Act (CWA), and the associated biennial National Water Quality Inventory (NWQI). At this time, however, these data cannot be used to produce a national indicator that can answer this question with sufficient confidence and scientific credibility because the programs vary greatly from state to state in the:

- Percentage of waters assessed.
- Monitoring approaches used.

- Water quality standards upon which the assessments are based.
- Water quality characteristics measured in those assessments.

The CWA vests responsibility in states, territories, and tribes to assess the health of their waters at least every two years. The purpose of these assessments is to determine if the water quality in different areas is supporting "designated uses," which are defined under state procedures and approved by EPA. Typical state designated uses include aquatic life protection, drinking water supplies, fish and shellfish consumption, recreation, and agricultural, industrial, and domestic uses. Because of the high cost of monitoring, states, territories, and tribes typically collect data and information for only a portion of their waterbodies. Their programs and sampling techniques differ. Compounding these differences is the fact that states also have the responsibility to set water quality standards, many of which differ between states. States monitor water quality to identify and address problems, and they often place a higher priority on immediate management concerns than on characterizing all their water resources. These issues limit the ability to use CWA-mandated state data to describe water quality conditions at the national level.

Two indicators, "altered fresh water ecosystems" and "lake trophic state," partially address the question of the quality of the nation's waters. These indicators are somewhat limited at this time, but they do show that 23 percent of fresh water resources have been altered physically to some degree and that 22 percent of northeastern U.S. lakes exhibit eutrophic conditions.

In addition to the CWA 305(b) reporting program, several other existing programs also contribute to our understanding of the condition of aquatic resources:

The U.S. Geological Survey's (USGS's) National Water Quality Assessment (NAWQA) program is a perennial program designed to provide consistent descriptions of the status and trends of some of the largest and most important streams and aquifer systems of the nation and to link the status and trends to the natural and human factors that affect water quality. The program involves physical, chemical, and biological assessments of 42 large hydrologic systems, which are conducted on staggered 10-year cycles. These assessments include targeted sampling designs to measure stream flow, habitat, water, sediment, and tissue chemistry, and to characterize algae, invertebrate, and fish communities. NAWQA studies cover watersheds and aquifers contributing a high percentage of the water used in the U.S. The NAWQA program has made valuable contributions in documenting the close relationship between land use, chemicals used in watersheds (e.g., for urban/industrial or agricultural activities), and the presence and concentrations of chemicals found in streams and ground water.

EPA's Environmental Monitoring and Assessment Program (EMAP) conducts representative sampling of estuarine and stream resources and incorporates biological measures in condition estimates. Geographic coverage for fresh water resources is limited to the mid-Atlantic region and the western states. Coverage of estuarine resources has been primarily limited to coastal areas on the East Coast south of Cape Cod, in the Gulf of Mexico, and in some western states. EMAP data on biological condition have been reported for fish and macroinvertebrates in Mid-Atlantic Highland streams and for macrobenthos in East Coast and Gulf of Mexico estuaries.

The National Oceanic and Atmospheric Administration's (NOAA's) National Status and Trends program (NS&T) collects information on the chemical contamination of sediments and organisms and potential biological effects in the nation's coastal areas. Sampling of sediments and bivalves was initiated in the mid-1980s from over 250 sites along the U.S. coast in areas not considered to be heavily polluted. On a national scale, the higher levels of contamination in sediments are clearly associated with the urbanized areas of the northeast states and with areas near San Diego, Los Angeles, and Seattle on the West Coast. Except at a few sites, higher levels of sediment contamination are relatively rare in the Southeast and along the Gulf of Mexico coast.

The Natural Resources Conservation Service's (NRCS's) National Resources Inventory (NRI) is a statistically-based sample of land use and natural resource conditions and trends on U.S. non-federal lands. NRI collects data on land cover and use, soil erosion, prime farmland soils, wetlands, habitat diversity, selected conservation practices, and related resource attributes. Many of the resource inventories have recognized relationships to water quality. The NRI provides comprehensive data on land use on the 1.5 billion acres of non-federal lands which are made up of roughly equal parts of rangeland (27 percent), forest land (27 percent), and cropland (25 percent).

The U.S. Fish and Wildlife Service's (USFWS's) National Wetlands Inventory (NWI) project produces information on the characteristics and extent of the nation's wetlands that is used by the USFWS to produce status and trends reports. The Emergency Wetlands Resources Act requires USFWS to update this information at 10-year intervals. Data collected from over 4,300 randomly selected sample plots provide important long-term trend information about specific changes in wetland extent, where those changes take place, and the overall status of wetlands in the U.S.. Data are produced by the USFWS National Wetlands Inventory, which has mapped 89 percent of the conterminous U.S. USFWS results are discussed further in Section 2.2.2 of this chapter.

These programs portray a general picture of widespread fresh water and coastal wetland loss, of water quality widely impacted by stream bank habitat loss, and of chemical contamination as urban land uses and agriculture encroach into riparian areas. They show that the abundance of nutrients from agriculture and atmospheric sources impacts coastal areas, with 40 percent of estuaries exhibiting eutrophic conditions (high nutrient concentrations and algae production), and some estuaries also experiencing hypoxia (insufficient oxygen levels to support marine life) and reduced water clarity.

Pesticides from agricultural and urban areas are found widely in surface waters, and residues from past chemical uses are found in sediments and fish tissue. Mercury and mercury compounds are foremost among pollutants contaminating fish. Bacterial contamination is found throughout surface waters used for drinking, although treatment of public water supplies is an effective barrier to protect human health. Contamination of swimming beaches by bacteria, however, continues to be a concern.

An improved ability to report on the condition of surface waters will require a collaboration of states, tribal authorities, and federal agencies. This may involve a nationally coordinated program. Under Section 305(b) of the Clean Water Act, states are required to report on the condition of their waterways. This requirement could serve as a platform upon which national condition estimates could be compiled using a consistent sample design approach and comparable data collection and analysis procedures.

EPA has long sought to increase the coverage of water quality assessments made and submitted biannually in conformance with Section 305(b) of the CWA. Historically, states have employed monitoring programs with sampling methods targeted to known problem areas that exhibit well-defined point and non-point pollution sources. While these approaches are effective in relating pollution sources to water quality conditions, they cannot accurately represent both the extent and condition of water quality problems and resources. EPA issued guidance on water quality assessments in 1997 (EPA, OW, September 1997), and produced a major supplement to this guidance in 2002 (EPA, OW, July 2002). These documents describe a comprehensive assessment as an evaluation of water resources that covers a complete geographic area or resource; provides information on the resource condition and spatial and temporal trends in the resource condition; and identifies the stressors (causes) and sources of pollution. The approach to these assessments is defined as either a complete survey (census), a judgmental or targeted design, or a statistical survey (probability-based) using randomly selected sample locations that allow researchers to make valid inferences about the condition of the water resource. The targeted approach is effective for relating specific pollution sources to water condition and is used in guiding pollution abatement, whereas the statistical/census survey approaches provide a complete or representative assessment of the entire resource.

In 2000, 14 states reported that they had monitored and assessed more than 95 percent of their lakes, and 10 states reported that they had assessed at least 98 percent of their rivers. Two years. later, in 2002, three states reported that they had made these assessments using a statistically valid sampling design. Several states are engaged in multi-year studies that are adding probabilistic surveys to their assessments. Examples of states that are collecting data from statistically-based monitoring networks are described in the sidebar.

Statistically-based water quality monitoring in states: Two examples

Indiana

In its 2002 State of the Environment Report, the Indiana Department of Environmental Management (IDEM) used a statistical survey to assess stream water quality by major watersheds. Historically, IDEM assessed 6,000 to 8,000 miles of stream every two years. Beginning in 1996, 20 percent of the state's streams were sampled each year in its watershed monitoring program and then assessed for the ability to support aquatic life. The results allowed IDEM to estimate the water quality within each major water basin in the state. IDEM reports its data with 95 percent confidence. Accuracy varies between basins, but is between 11 and 16 percent.

Of the 35,430 stream miles assessed over the past five years, approximately 64.5 percent were estimated to fully support the maintenance of well-balanced aquatic communities. Fish and benthic macroinvertebrate community assessments provided a measurement of adverse response to stressors. Some of the community responses included loss of sensitive species, lack of diversity, and increase in tolerant species. As a result, several hundred stream miles were classified as not fully supporting aquatic life based on the fish and macroinvertebrate community surveyed.

Maryland

The Maryland Biological Stream Survey (MBSS) uses a probability-based survey design to assess the status of biological resources in Maryland's non-tidal streams. The state intends to:

- Characterize biological resources and ecological conditions.
- Assess the condition of these resources.
- Identify the likely sources of degradation.

The state has developed an interim framework for applying biocriteria in the state's water quality inventory (305[b] report) and list of impaired waters (303[d] list). To date, the proposed biocriteria for wadeable, non-tidal (first- to fourth-order) streams rely on two biological indicators from the MBSS; the fish and benthic indices of biotic integrity (IBIs). The approach centers on identifying impaired waterbodies at the Maryland 8-digit watershed and 12-digit subwatershed levels.

A preliminary evaluation using MBSS 2000 data was conducted to identify watersheds failing to meet the requirements of the interim biocriteria framework. For a portion of the state, three 8-digit watersheds that were assessed passed, and six were inconclusive. Of the 123 watersheds sampled at the 12-digit subwatershed level, 69 failed, 32 passed, and 22 were inconclusive.

Indicator Altered fresh water ecosystems - Category 2

Physically altering a fresh waterbody can change its character and the benefits it provides local communities and land owners. Fresh waterbodies may be altered to increase some other benefit— for example, to control floods; improve navigation; reduce erosion; increase the available area for farming, livestock grazing, or development; and increase the amount of water available for drinking and industrial purposes. However, these alterations also change fish and wildlife habitat, disrupt patterns and timing of waterflows, serve as barriers to animal movement, and reduce or eliminate the natural filtering of sediment and pollutants. In addition, water usage, particularly in the arid West, but also in suburban areas that rely on wells, may deplete aquifers and thus cause permanent damage to the physical characteristics of surface water resources, including reduced base flows.

The altered fresh water ecosystems indicator reports the percentage of each of the major fresh water ecosystems (rivers and streams, riparian areas, wetlands, lakes, ponds, and reservoirs) that are altered. "Altered" is defined differently for each of these ecosystems:

- Streams and rivers (all flowing surface waters) are altered if they are leveed or channelized or impounded behind a dam.
- Riparian zones along rivers and streams are considered altered if they are used for urban or agricultural purposes.
- Lakes and reservoirs are considered altered if any portion of the area immediately adjacent to the shoreline is either urban or agricultural land. Since there is no agreed-upon proportion of shoreline that must be in these land use categories to classify an individual lake as "altered," this indicator simply reports the overall percentage of lake or reservoir shoreline with agricultural or urban land use in the shoreline zone. (Note that, at present, data for lakes and reservoirs are aggregated, even though a reservoir is a man-made structure or seriously altered habitat. If, in the future, natural lakes can be distinguished from reservoirs, these may be reported separately. In this case, the number or percent of natural lakes whose waterflow has been altered by damming would also be reported.)
- Wetlands are considered altered if they are excavated, impounded, diked, partially drained, or farmed (Cowardin, et al., 1979).

What the Data Show

Data reported for this indicator were produced using remote sensing imagery and the USGS stream/lake database (National Hydrography Data Set). These data characterize areas adjacent to a waterbody at a resolution of about 100 feet across. Thus, they present the general land cover surrounding a lake or stream, rather than a fine-scale picture of the exact composition of a shoreline or bank.

The available data indicate that 23 percent of the banks of both rivers and streams (riparian areas) and lakes and reservoirs have either croplands or urban development in the narrow area immediately adjacent to them. Data on the degree to which streams and rivers are channelized, leveed, or impounded are not available.

Dahl (2000) does provide some information on the extent to which wetlands are altered. For example, from 1986 to 1997:

- A total of 78,100 acres (31,600 hectares) of forested wetlands were converted to fresh water ponds.
- Human activities, such as creating new impoundments or raising the water levels on existing impoundments (thus killing the trees), created conversions to deep water lakes.
- Additionally, fresh water unconsolidated shores exhibited an 8 percent gain in acreage or about 32,000 acres (13,000 hectares). This was due, in part, to peat mining operations that removed the wetland vegetation and exposed the substrate. Because these areas were not drained, they remained wetland, but their classification was changed from "fresh water shrub bogs" to "fresh water unconsolidated shores."

Indicator Gaps and Limitations

There is no nationally aggregated database that records the number of impounded or leveed river miles. As noted above, there is also no method for calculating the extent of downstream effects of dams, other than by conducting site-specific investigations for each dam.

At present, there are no nationally aggregated databases that list whether natural lakes are dammed at their outlets. It is possible that existing databases on dam locations, such as those maintained by the U.S. Army Corps of Engineers, could be merged with other datasets, such as the National Hydrography Data Set (NHD), to derive this information.

Data on the alteration of rivers and streams are not collected in a manner that allows for aggregation to provide a national perspective.

Data Source

Data on altered wetlands are available only in paper form on a quad-sheet by quad-sheet basis. The data sources for this indicator were the:

- Multi-Resolution Land Characterization Consortium and U.S. Geological Survey National Hydrography Dataset, processed by

Indicator — Altered fresh water ecosystems - Category 2 (continued)

the EPA's Office of Research and Development (National Exposure Research Laboratory).

- Department of the Interior, U.S. Fish and Wildlife Service, National Wetlands Inventory (See Appendix B, page B-9, for more information.).

Indicator — Lake trophic state index - Category 2

Lakes can be divided into three categories based on trophic state: oligotrophic, mesotrophic, and eutrophic. These categories reflect a lake's nutrient and clarity levels.

- *Oligotrophic lakes* are generally clear, deep, and free of weeds or large algae blooms. They are low in nutrients and do not support large numbers of fish. Oligotrophic lakes often develop a food chain capable of sustaining a very desirable fishery of large game fish.
- *Eutrophic lakes* are high in nutrients and support a large biomass (all the plants and animals living in a lake). They are usually either weedy, or subject to frequent algae blooms, or both. Eutrophic lakes often support large fish populations, but are also susceptible to oxygen depletion. A subcategory, *hypertrophic lakes*, is used below to describe lakes that are extremely eutrophic (i.e., very nutrient-enriched), resulting in particularly high productivity (Peterson, et al., 1999).
- *Mesotrophic lakes* lie between the oligotrophic and eutrophic stages.

A natural aging process occurs in all lakes, causing them to change from oligotrophic to eutrophic over time. This process is accelerated by nutrient enrichment from agriculture, lawn fertilizers, streets, septic systems, and urban storm drains.

Various methods are used to calculate the trophic state of lakes. Common characteristics used to determine trophic state are: total phosphorus concentration (important for algae growth); concentration of chlorophyll *a* (a measure of the amount of algae present); and secchi disc readings (an indicator of water clarity).

No national data regarding the trophic state of lakes are available. However, regional patterns of lake trophic condition were assessed for a target population of 11,076 northeast lakes, which were sampled during the summers of 1991 to 1994 using a trophic state index based primarily on their nutrient or total phosphorus (TP) concentrations (Peterson, et al., 1999). A total of 344 lakes were sampled once.

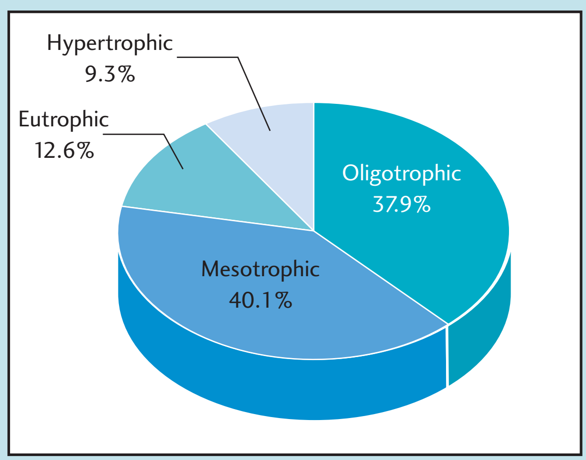
The following trophic state categories were established based on total phosphorus concentrations:

- *Oligotrophic* for nutrient poor (less than 10 parts per billion [ppb]).
- *Mesotrophic* to denote nutrient concentrations sufficient to support natural algal communities (from 10 to 30 ppb).
- *Eutrophic* for enriched nutrient conditions (from 30 to 60 ppb).
- *Hypertrophic* for very nutrient-enriched (greater than 60 ppb).

What the Data Show

The trophic state analysis (Exhibit 2-4) showed that 37.9 percent of the northeast lakes were oligotrophic, 40.1 percent were mesotrophic, 12.6 percent were eutrophic, and 9.3 percent were hypertrophic (Peterson, et al., 1999).

Exhibit 2-4: Trophic State Index for northeast lakes, 1991-1994



Source: Peterson S.A., et al. *Sample Representativeness: A Must for Reliable Regional Lake Condition Estimates.* 1999.

Indicator | Lake trophic state index - Category 2 (continued)

Indicator Gaps and Limitations

These data reflect a one-time sample of lakes in one region, the Northeast, and cannot be extrapolated to the national scale or provide trends data. Also, trophic status in and of itself does not necessarily imply that water quality problems exist (i.e., that oligotrophy is a common natural state).

Data Source

The data source for this indicator was the Environmental Monitoring and Assessment Program Lakes Data Set. (See Appendix B, page B-9, for more information.)

2.2.2 What are the extent and condition of wetlands?

Indicators

Wetland extent and change
Sources of wetland change/loss

When European settlers first arrived, wetland acreage in the area that would become the 48 states was more than 220 million acres, or about five percent of the total area of the conterminous U.S. More than one-half of the wetlands in the conterminous U.S. have been lost or converted to other uses since pre-colonial times. However, in as little as four recent decades, the rate of wetland loss has declined dramatically, from about 500,000 acres per year to less than 100,000 acres per year (Dahl, 2000). By 1997, total wetland acreage was estimated to be 105.5 million acres (Dahl, 2000). Almost 50 percent of wetland loss occurring in the 1990s was due to conversion to urban and suburban development.

Wetland ecosystems are areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support (and that under normal circumstances do support) a prevalence of vegetation typically adapted for life in saturated soil conditions. There are different types of wetlands, including: fresh water wetlands, inland wetlands, and coastal wetlands (see glossary for definitions). These habitats provide many benefits to humans and ecological systems. For example, wetland habitats are critical to the life cycles of many plants and fish, shellfish, migratory birds, and other wildlife. They provide essential breeding habitat for roughly one-quarter of all North American breeding bird species (Davis, 2000). In 1997, it was estimated that 81 percent (72 species) of the U.S. bird species on the Endangered Species List were dependent on or associated with wetlands (Day Boylan and MacLean, 1997).

An estimated 95 percent of commercial fish and 85 percent of sport fish spend a portion of their life cycles in coastal wetland and estuarine habitats. Adult stocks of commercially harvested shrimp, blue crab, oysters, and many other species throughout the U.S. (EPA, ORD, OW, September 2001) are directly related to wetland quality and quantity (EPA, OW, OWOW, March 2002). More than half of all U.S. adults (98 million people) hunt, fish, birdwatch, or photograph wildlife (USFWS, 2002). Many of these activities are associated with healthy wetlands.

Wetlands also filter residential, agricultural, and industrial wastes, thereby improving surface water quality. They buffer coastal areas against storm and wave damage. Wetlands function as natural sponges that trap and slowly release surface water, rain, snowmelt, ground water, and flood waters. Trees, root mats, and other wetland vegetation also slow the speed of flood waters and distribute them more slowly over the floodplain. This combined water storage and braking action lowers flood heights and reduces erosion. Wetlands within and downstream of urban areas are particularly valuable, counteracting the greatly increased rate and volume of surface water runoff from pavement and buildings. The holding capacity of wetlands helps control floods and prevents water logging of crops. Preserving and restoring wetlands can often provide the level of flood control otherwise provided by expensive dredge operations and levees. For example, the bottomland hardwood-riparian wetlands along the Mississippi River once stored at least 60 days of flood water. Now these wetlands store only 12 days of flood water because most have been filled or drained (EPA, OW, December 1995).

Wetlands are diverse. Inland wetlands are most common on floodplains along rivers and streams (riparian wetlands), in isolated depressions surrounded by dry land (e.g., playas, basins, and "potholes"), along the margins of lakes and ponds, and in other low-lying areas where the ground water intercepts the soil surface or where precipitation sufficiently saturates the soil (e.g., vernal pools and bogs). Inland wetlands include marshes and wet meadows dominated by herbaceous plants, swamps dominated by shrubs, and wooded swamps dominated by trees. Many wetlands are seasonal (i.e., they are dry one or more seasons every year). In fact, particularly in the arid and semiarid West, wetlands may be wet only periodically. The quantity of water present and the timing of its presence in part determine the functions of a wetland and its role in the environment. Even wetlands that appear dry at times for significant parts of the year, such as vernal pools, often provide critical habitat for wildlife adapted to breeding exclusively in these areas.

Coastal wetlands in the U.S. are found along the Atlantic, Pacific, Alaskan, and Gulf coasts. They are closely linked to our nation's estuaries, where sea water mixes with fresh water to form an environment of varying salinities. Certain grasses and grasslike plants that adapt to the saline conditions form the tidal salt marshes that are found along the Atlantic, Gulf, and Pacific coasts. Mangrove swamps, with salt-loving shrubs or trees, are common in tropical climates, such as in southern Florida and Puerto Rico. Some tidal fresh water wetlands form beyond the upper edges of tidal salt marshes where the influence of salt water ends.

An indicator related to wetland extent has been identified to address the question "What are the extent and condition of wetlands?" This indicator is discussed on the following pages. No indicators for the biological condition of wetlands are being implemented nationally or regionally at this time, and none were recommended for inclusion in this report. However, wetland extent can partially serve as a surrogate to address wetland condition. This is because the loss of wetlands in the landscape negatively impacts the condition of the remaining wetlands by decreasing both the connectivity among aquatic resources and the landscape heterogenity.

Indicators of wetland condition are being developed and implemented by some states, but not on a broad-scale basis. States have been developing assessment methods for a variety of organisms in multiple wetland types, including macroinvertebrates, algae, amphibians, and vegetation (Danielson, 1998). These indicators and an assessment process will be necessary to ensure that both wetland extent and condition can be properly described in the future.

Indicator Wetland extent and change - Category 1

Two programs, the USFWS NWI status and trends studies and the NRCS NRI, estimate wetland extent. The USFWS surveys all wetlands in the conterminous U.S. The NRI surveys wetlands on non-federal lands, which make up approximately 75 percent of the nation's land base. The methods employed differ, but the statistical results from the most recent survey period were not significantly different. USFWS data are used for the "wetland extent and change" indicator due to their broader coverage. This indicator is 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.

The USFWS counts all wetlands every 10 years, regardless of land ownership, but only recognizes wetlands that are at least three acres. 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 4,375 randomly selected, four-square-mile (2,560 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.

Field verification was conducted to address questions of image interpretation, land use coding, and attribution of wetland gains or losses; plot delineations were also completed. For example, for the 1980s to 1990s analysis, 21 percent of the sample plots were verified.

What the Data Show

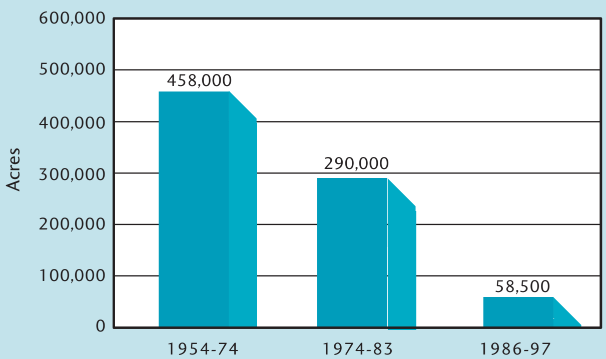
When European settlers first arrived, wetland acreage in the area that would become the 48 states was more than 220 million acres, or about five percent of the total area of the conterminous U.S. Since then, extensive losses have occurred, and over half of our original wetlands have been drained and filled. By 1997, total wetland acreage was estimated to be 105.5 million acres (Dahl, 2000). Of that total, nearly 95 percent or 100.2 million acres were fresh water and about five percent or 5.3 million acres were intertidal marine and estuarine. Between 1986 and 1997, 98 percent of all wetland losses in the conterminous U.S. were fresh water wetlands.

Rates of annual wetland losses have been decreasing from almost 500,000 acres a year three decades ago to less than 100,000 acres, averaged annually since 1986 (Exhibit 2-5). The USFWS estimated the annual rate of loss at 58,500 acres per year between 1986 and 1997. This represents an 80 percent reduction compared to the previous decade's rate of loss. The slower rate of wetland loss is due to several factors, including:

- Federal farm policies that discourage drainage and encourage restoration.
- More effective government regulation.
- Better land stewardship.
- Acquisition and protection of sensitive environmental areas.
- More state, tribal, and local involvement in wetland protection programs.

Indicator Wetland extent and change - Category 1 (continued)

Exhibit 2-5: Average annual wetland loss, 1954-1974, 1974-1983, 1986-1997



Coverage: Conterminous United States

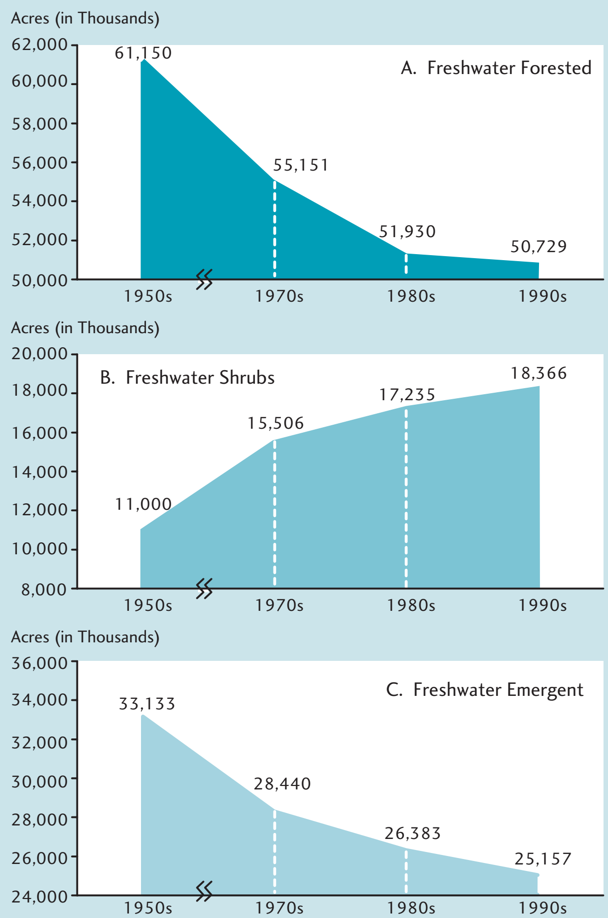
Source: Frayer et al. *Status and Trends of Wetlands and Deepwater Habitats in the Conterminous United States, 1950s to 1970s.* 1983; Dahl, T.E. and C. E. Johnson. *Wetlands Status and Trends in the Conterminous United States: 1970s to 1980s.* 1991; Dahl, T. E. *Status and Trends of Wetlands in the Conterminous United States 1986 to 1997.* 2000.

In addition to loss of wetland acreage, a major ecological impact has been the conversion of one wetland type to another, such as clearing trees from a forested wetland or excavating a shallow marsh to create an open water pond. Open water ponds have more than doubled in area since the 1950s and are not the ecological equivalent of fresh water emergent marshes. These types of conversions change habitat types and community structure in watersheds and impact the animal communities that depend on them.

Wetland types include fresh water forested, shrub, and emergent wetlands, plus open water ponds. Forested and emergent wetlands make up over 75 percent of all fresh water wetlands. Since the 1950s, fresh water emergent wetlands have declined by nearly 24 percent—more than any other fresh water wetland type. Fresh water forested wetlands have sustained the greatest overall losses—10.4 million acres since the 1950s (Exhibit 2-6).

Coastal wetlands are the vegetated interface between aquatic and terrestrial components of estuarine ecosystems. Estuarine emergent wetlands account for nearly 75 percent of coastal wetlands. The loss of coastal wetland habitats in the U.S. is significant (Exhibit 2-7). Since the 1950s, coastal and estuarine losses were about 1.4 million acres–a nearly 12 percent decline. Emergent and forested intertidal wetlands experienced the greatest absolute and proportional losses during this four-decade measurement period. Proportional losses along the West Coast have been the largest (68 percent), although the actual number of acres lost there is among the smallest. Absolute and proportional acreages lost in the Great Lakes and Gulf of Mexico are also high (about 50 percent of wetlands that existed in pre-colonial times). Even in more recent years (mid- to late 1990s), wetland losses in southeastern and Gulf of Mexico states continue at a high rate—more than one percent per year.

Exhibit 2-6: Long-term trends in selected freshwater wetlands, 1954-1997

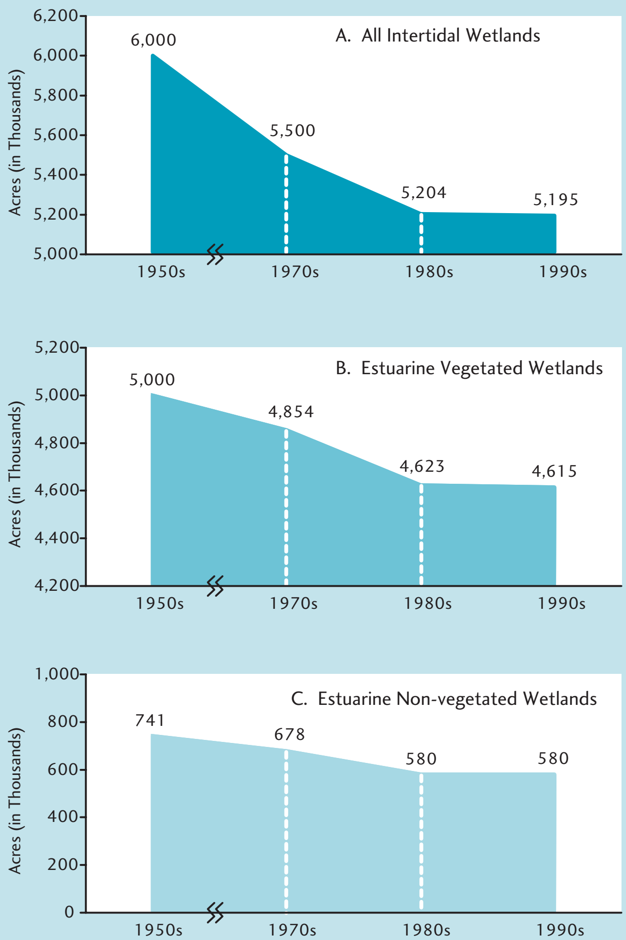


Coverage: Conterminous United States

Source: Frayer et al. *Status and Trends of Wetlands and Deepwater Habitats in the Conterminous United States, 1950s to 1970s.* 1983; Dahl, T.E. and C. E. Johnson. *Wetlands Status and Trends in the Conterminous United States: 1970s to 1980s.* 1991; Dahl, T. E. *Status and Trends of Wetlands in the Conterminous United States 1986 to 1997.* 2000.

Indicator Wetland extent and change - Category 1 (continued)

Exhibit 2-7: Long-term trends in selected estuarine wetlands, 1954-1997



Coverage: Conterminous United States

Source: Frayer et al. *Status and Trends of Wetlands and Deepwater Habitats in the Conterminous United States, 1950s to 1970s.* 1983; Dahl, T.E. and C. E. Johnson. *Wetlands Status and Trends in the Conterminous United States: 1970s to 1980s.* 1991; Dahl, T. E. *Status and Trends of Wetlands in the Conterminous United States 1986 to 1997.* 2000.

Indicator Gaps and Limitations

This indicator does not effectively address the question of wetland condition. While it is possible to inventory wetlands that have been lost, many wetlands have suffered degradation of condition and functions, which cannot be quantified nationally.

Different methods were used in some of the early classification schemes to classify wetland types. The currently used classification system was not applied to some of the earlier (1970s) maps. As methods and spatial resolution have improved over time, acreage data were adjusted, resulting in changes in the overall wetland base over time. Thus, the evaluation process is evolving, which contributes to reducing the accuracy of the trends observed.

Forested wetlands are difficult to photointerpret and are generally underestimated by the USFWS. Ephemeral wetlands and effectively drained palustrine wetlands observed in farm production are not recognized as a wetland type by the USFWS and, therefore, are not included. Also, USFWS does not survey wetlands under 3 acres in size; therefore, no record exists of the extent and change in these valuable resources. Pacific coast estuarine wetlands are not surveyed due to the discontinuity in their patch sizes. The temporal coverage of the coastal wetland loss indicator (length of record) is not consistent across the U.S.

Data Source

The data for this indicator are from the Department of the Interior, U.S. Fish and Wildlife Service, Status and Trends Report. (See Appendix B, page B-9 for more information.)

Indicator

Sources of wetland change/loss - Category 2

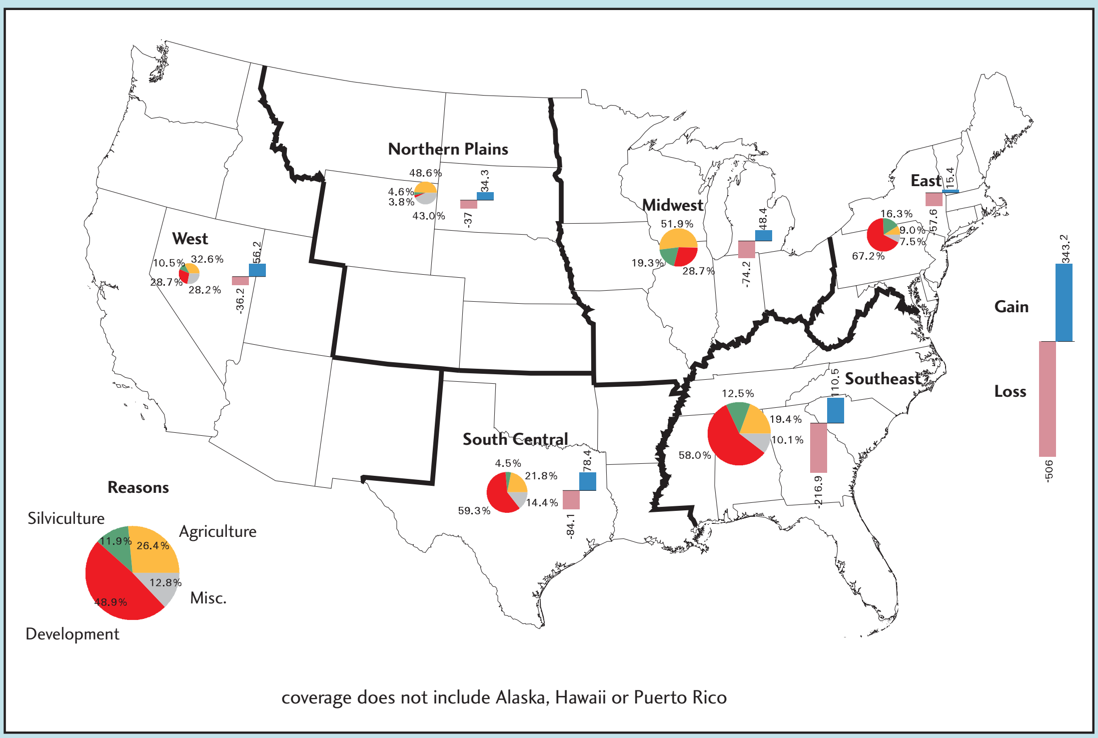
This indicator attempts to estimate the causes or sources of wetland losses. The extensive survey data collected in the NRI by the USDA's Natural Resources Conservation Service in cooperation with the Iowa State University Statistical Laboratory provides land use information that can be associated with estimates of wetland extent. This database is a compilation of natural resource information on non-federal land, which comprises nearly 75 percent of the nation's total land area. The 1997 NRI captures data on land cover and use, soil erosion, prime farmland soils, wetlands, habitat diversity, selected conservation practices, and related resource attributes at over 300,000 primary sample units (nominally 160 acres each) containing over 800,000 sample points.

Data used for the NRI were collected using a variety of imagery, field office records, historical records and data, ancillary materials, and a limited number of on-site visits. The data have been compiled, verified, and analyzed to provide a comprehensive look at the state of the nation's non-federal lands.

What the Data Show

According to the USDA Agricultural Research Service, between 1954 and 1974, agriculture accounted for 81 percent of all wetlands conversions. As a result of changing federal agricultural policies that emphasize wetlands conservation, agriculture accounted for only 20 percent of national wetlands conversion between 1982 and 1992 (USDA, 2000). In surveys conducted between 1992 and 1997, NRI determined that 506,000 acres of wetlands on non-federal lands were lost, while 343,000 were gained, for a net loss of 163,000 acres. Agriculture accounted for 26 percent of the net national wetlands loss for this survey period, although this varies by region. For example, in the Midwest and northern plains, about 50 percent of the losses were from agriculture (Exhibit 2-8). Since the mid–to late 1980s, urban, suburban, and commercial development have been the major contributors to net losses of wetland resources and were responsible for 49 percent of those losses. The East, Southeast, and South Central states had the highest percentages of wetland losses due to development. In the East, 67 percent of the wetland losses were a result of development (USDA, 2000). Timber harvesting practices and conversion of land to silvicultural uses

Exhibit 2-8: Non-Federal wetland losses and gains and reasons for conversion, 1992-1997



Source: *Summary Report: 1997 National Resources Inventory (Revised December 2000)*. 2000.

Indicator Sources of wetland change/loss - Category 2 (continued)

have also contributed to losses in wetland resources. The NRI analysis attributed 12 percent of the wetland losses between 1992 and 1997 to silviculture.

Using different methods, the USFWS reported a similar result from 1986 to 1997: 30 percent of wetland losses were attributed to urban development; 21 percent to rural development; 23 percent to silviculture; and 26 percent to agriculture (Dahl, 2000).

Indicator Gaps and Limitations

The differences in survey design between NRI and USFWS will continue to cause difficulties in assessing the effectiveness of current wetlands policies. The USFWS data are gathered from interpretation of aerial imagery and remotely sensed data, and are repeated every 10 years. The NRI data are based on statistical sampling, but do not include an adequate sample of coastal resources. They provide information at a coarse scale, summarized by state, and are useful for national reporting. The NRI does not collect data on federal lands or for the state of Alaska.

Data Source

Data for this indicator come from the U.S. Department of Agriculture, National Resources Inventory (2000).
(See Appendix B, page B-10, for more information.)

2.2.3 What is the condition of coastal waters?

Indicators

- Water clarity in coastal waters
- Dissolved oxygen in coastal waters
- Total organic carbon in sediments
- Chlorophyll concentrations

Coastal waters—the interface between the land and the sea—provide a wide range of habitats for animals and plants essential to global ecosystems, and they support the majority of commercial and recreational fisheries in the U.S. Coastal waters also contain significant energy and mineral reserves, travel lanes for shipping, and a base for outdoor recreation and tourism industries (EPA, ORD, OW, September 2001).

Coastal waters include estuaries—bodies of water that are balanced by fresh water and sediment influx from rivers and tidal action of the oceans. They provide a transition zone between fresh water and saline water. Estuaries are unique environments that support wildlife and fisheries and contribute substantially to the economy of coastal areas. These natural areas are under the most intense development pressure in the nation. This narrow fringe accounts for only 17 percent of the total conterminous U.S. land area, but is home to more than 53 percent of the population. Today, that proportion is growing faster than in any other area of the U.S. (NRC, 2000).

Four indicators have been selected to address the condition of coastal waters: water clarity, dissolved oxygen content, organic carbon content of sediments, and chlorophyll concentrations. The first three—water clarity, dissolved oxygen, and organic carbon content—are derived from EPA's EMAP, which samples estuaries using a probability- based design.

For water clarity and dissolved oxygen, estuaries in the East, West, and Gulf of Mexico coast are well represented. These two indicators, as reported in EPA's Coastal Condition Report (EPA, ORD, OW, September 2001), show that water clarity and oxygen conditions are good. Organic carbon data indicate that 16 percent of the area of mid-Atlantic estuaries have enriched carbon levels. About 33 percent of the mid-Atlantic estuarine area had chlorophyll concentrations exceeding the Chesapeake Bay restoration goal for survival of submerged aquatic vegetation. Coastal waters overall exhibited much lower chlorophyll concentrations. Chlorophyll concentrations were the most pronounced in the Gulf of Mexico.

Eutrophication is also an important parameter for understanding the condition of coastal waters; however, insufficient data were available to develop a scientifically robust indicator for this parameter at the national level. Eutrophication is discussed following the indicator descriptions.

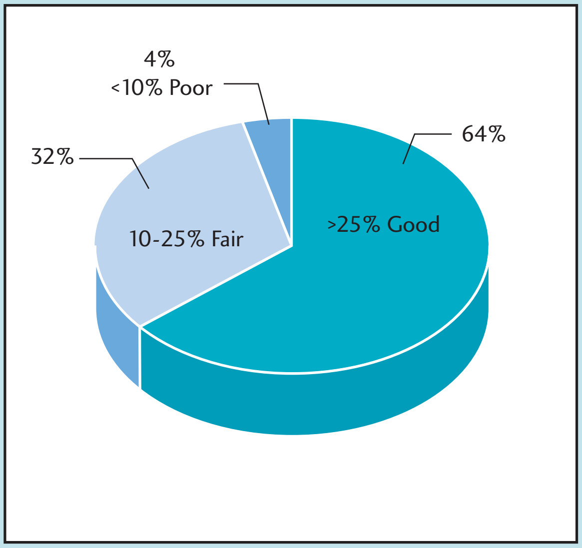
Indicator

Water clarity in coastal waters - Category 2

Light penetration is an important characteristic of many estuarine and coastal habitats. Reduced penetration is often associated with eutrophic conditions, algal blooms, and erosional events. Reduced clarity can impair the normal algal growth that contributes to oligotrophy and the extent and vitality of submerged aquatic vegetation. This is a critical habitat component for many aquatic animals.

For purposes of this indicator, water clarity is defined as a measure of light penetration (i.e., the amount and type of light reaching a one - meter water depth compared to the amount and type of light at the water's surface). Data were collected using a point-in-time measurement with a transmissometer, which estimates light transmission. Measurements were made at one meter below the water's surface. EPA in its Coastal Condition Report describes light penetration less than 10 percent of the amount of light incident at the surface is considered to represent poor conditions. Light penetration greater than 25 percent of that at the surface is deemed good.

Exhibit 2-9: Estuarine area with good (>25% of light incident at the surface), fair (between 25 and 10% of incident light), and poor (<10% of incident light) light penetration, 1990 – 1997



Coverage: United States east coast (excluding waters north of Cape Cod), west coast, and Gulf of Mexico

Source: EPA, Office of Research and Development and Office of Water. *National Coastal Condition Report.* September 2001.

What the Data Show

The overall water clarity of the nation's estuaries is rated as good (EPA, ORD, OW, September 2001). That is, 25 percent of light incident at the surface penetrates to a depth of one meter. That condition existed at 64 percent of the estuarine areas assessed. Poor light penetration is a problem in only about four percent of estuarine waters (Exhibit 2-9).

Indicator Gaps and Limitations

Sampling generally occurred during an EMAP-defined index period (summer months) as a point-in- time measure. While eutrophic stress is expected to be highest during warmer months, episodic algal blooms or runoff/erosional events would likely not occur during this timeframe.

Turbid waters are a natural characteristic of many estuaries (e.g., upper Chesapeake Bay, Albermarle-Pamlico Sound), and low light penetration conditions are not necessarily associated with impaired aquatic health. This indicator does not account for naturally turbid conditions and will rate those areas as "poor," reflecting degraded water quality.

Data Source

Water clarity data are from EPA's Environmental Monitoring and Assessment Program Estuaries database. (See Appendix B, page B-10, for more information.)

Indicator Dissolved oxygen in coastal waters - Category 2

Dissolved oxygen (DO) is a fundamental requirement for all estuarine life. Low levels of oxygen often accompany the onset of severe bacterial degradation, sometimes resulting in algal scums, fish kills, and noxious odors, as well as loss of habitat and aesthetic values. Often, low dissolved oxygen occurs as a result of the process of decay of large algal blooms whose remnants sink to the bottom. Concentrations of oxygen below about 2 parts per million are thought to be stressful to estuarine organisms (Diaz and Rosenberg, 1995; EPA, OW, October 2000).

Under EPA's EMAP, data were collected generally at one-meter above the bottom using electronic DO meters. In some cases, data were point-in-time measurements taken once during the summer months (e.g., in the Virginian Province), while in other cases data were predominantly collected by continuous readings over a multiple day/time period (e.g., in the Louisianian Province). Values of dissolved oxygen were classified into three condition categories:

- Poor: less than 2 parts per million (ppm)
- Fair: between 2 and 5 ppm
- Good: greater than 5 ppm

What the Data Show

Dissolved oxygen conditions in the nation's estuaries are reported by EPA, ORD, OW (September 2001) in its Coastal Condition Report as "good" because 80 percent of the estuarine waters assessed exhibited dissolved oxygen at concentrations greater than five ppm. Both EMAP and NOAA's National Eutrophication Assessment examined the extent of estuarine waters with low dissolved oxygen. EMAP estimates that only about four percent of bottom waters have low dissolved oxygen (Exhibit 2- 10). However, low dissolved oxygen is a problem in some individual estuarine systems like the Neuse River Estuary and parts of the Chesapeake Bay.

Hypoxia resulting from anthropogenic activities is a relatively local occurrence in Gulf of Mexico estuaries, accounting for about 4 percent of the total area, however, hypoxia in the shelf waters of the Gulf of Mexico is more significant. The Gulf of Mexico hypoxia zone is the largest anthropogenic coastal hypoxic area in the western hemisphere (CAST, 1999). Since 1993, mid-summer bottom water hypoxia in the northern Gulf of Mexico has been larger than 3,860 square miles (except in 2000). In 1999, it reached over 7, 700 square miles (CENR, 2000).

Indicator Gaps and Limitations

Coverage of the nation's coastline is limited. Probabilistic surveys like those in the Northeast, the Southeast, and the Gulf Coast do not exist for areas north of Cape Cod or for the Great Lakes. Similar probabilistic data do not exist for Puget Sound or San Francisco Bay.

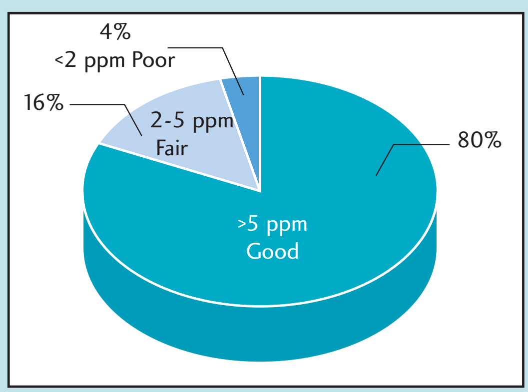
The relationship between threshold values and effects on aquatic life is neither well established nor expected to be consistent across all regions. For example, warm water environments would be naturally lower in DO. The criteria of two ppm might not be sufficiently protective in cold water environments. Much of the data apparently represent point-in-time measures. If so, the data contain limitations, and the length of time that dissolved oxygen concentrations were below two ppm would not have been considered.

The data set incorporates a mix of time series and point-in-time measures based on historical data sets collected. Where time series data are available and used, better estimates of oxygen conditions would be achieved. Point-in-time measures are weaker. Since only one season, the summer, was generally represented, oxygen stress in other seasons would be missed.

Data Source

Dissolved oxygen data used for this indicator are from the EPA's Environmental Monitoring and Assessment Program Estuaries database. (See Appendix B, page B-10, for more information.)

Exhibit 2-10: Estuarine area with poor (<2 ppm), fair (between 2 and 5 ppm), and good (>5 ppm) dissolved oxygen conditions, 2000



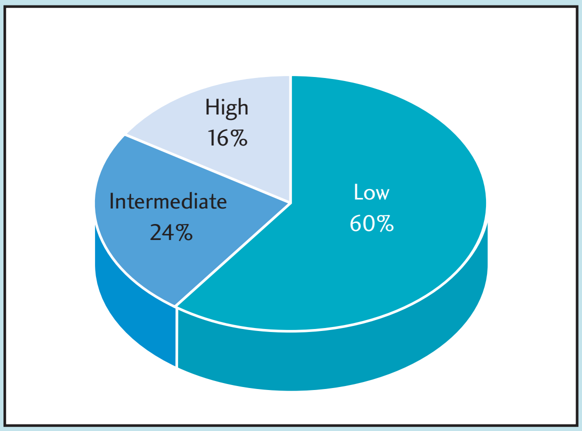
Coverage: United States east coast (excluding waters north of Cape Cod), west coast, and Gulf of Mexico

Source: EPA, Office of Research and Development and Office of Water. *National Coastal Condition Report.* September 2001.

Indicator Total organic carbon in sediments - Category 2

Total organic carbon (TOC) is a measure of the concentration of organic matter in sediments. It represents the long-term, average burial rate of organic matter in the sediments. High TOC values can arise from frequent algal blooms in the overlying waters or transport of sewage or high organic waste from point sources. TOC can also sequester or chelate organic compounds and some metals and make them less biologically available for uptake.

Exhibit 2-11: Percentages of Mid-Atlantic estuarine area with low, intermediate, and high total organic carbon content in sediments, 1997-1998



Note: High is > 3%; Intermediate is >1 to 3%; Low is ≤1%

Source: EPA, Office of Research and Development. *Mid-Atlantic Integrated Assessment, MAIA - Estuaries 1997-98, Summary Report.* May 2003.

TOC values are calculated as percent carbon in dried sediments. Assessment categories for the Mid-Atlantic estuaries were:

- Low: 1 percent
- Intermediate: >1 to 3 percent
- High: >3 percent

What the Data Show

Carbon values ranged from 0.02 to 13 percent throughout the mid-Atlantic estuaries (Paul, et al., 1999). For the mid-Atlantic region, about 60 percent of the estuarine sediments had low TOC values, about 24 percent had intermediate TOC values, and 16 percent had high TOC sediment values (EPA, ORD, May 2003); (Exhibit 2-11). Values ranged from Delaware Bay with about 95 percent of its sediments having low TOC values to the Chowan River in the Albemarle-Pamlico Estuary with 65 percent of its sediments having high TOC values (EPA, ORD, May 2003). The Chesapeake Bay mainstem had about 65 percent of its sediments with low TOC values and about 15 percent with high TOC values.

Indicator Gaps and Limitations

These data are from a survey of mid-Atlantic estuaries and cannot be extrapolated to national-scale estimates. Samples were collected during an EMAP-defined index period of summer months.

Data Source

The total organic carbon data for this indicator come from EPA's Environmental Monitoring and Assessment Program, Mid-Atlantic Integrated Assessment (MAIA) Estuaries Program. (See Appendix B, page B-10, for more information.)

Indicator Chlorophyll concentrations - Category 2

Chlorophyll concentrations are a measure of the abundance of phytoplankton. Phytoplankton account for most of the plant production in the ocean. Excessive growth of phytoplankton, as measured through chlorophyll concentrations, can lead to degraded water quality, such as noxious odors, decreased water clarity, oxygen depletion, and harmful algal blooms. Excess phytoplankton growth is usually associated with increased nutrient inputs (e.g., watershed or atmospheric transport, upwelling) or a decline in filtering organisms such as clams, mussels, or oysters (The Heinz Center, 2002).

Indicator Chlorophyll concentrations - Category 2 (continued)

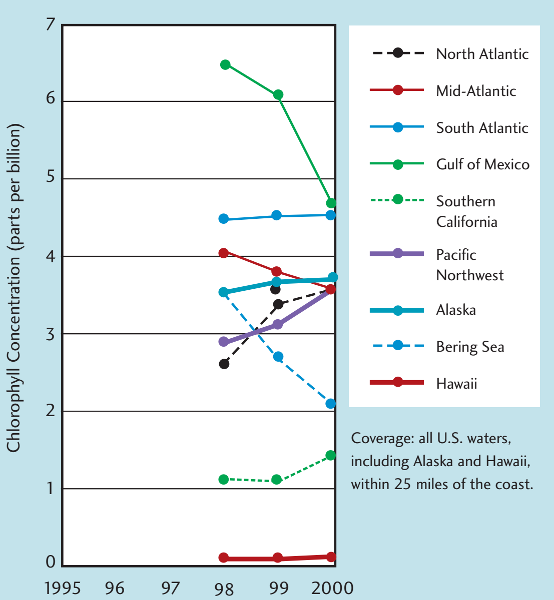
Chlorophyll concentrations were considered for both estuarine and ocean waters within 25 miles of the coast (The Heinz Center, 2002). Three categories of concentrations were established by EPA for mid-Atlantic estuaries:

- Good: 15 ppb
- Fair: 15-30 ppb
- Poor: > 30 ppb

The lower threshold of 15 ppb chlorophyll is equal to the restoration goal recommended for the survival of submerged aquatic vegetation (SAV) in Chesapeake Bay (Batiuk, et al., 2000).

For ocean waters, the indicator reports the average value for the season, displaying the highest concentrations for each region. Estuarine chlorophyll concentrations are not available for national reporting. Ocean data, based on surface reflectance, were inferred from National Aeronautics and Space Administration's (NASA's) Sea-viewing Wide Field-of-View-Sensor. Data were analyzed for nine ocean regions by NOAA's National Ocean Service. The estuarine chlorophyll concentrations were obtained from field measurements as part of the EPA EMAP Mid-Atlantic Estuaries Program.

Exhibit 2-12: Chlorophyll concentrations in U.S. coastal waters, 1998-2000



Source: Modified from The Heinz Center. *The State of the Nation's Ecosystems. 2002.* Data from National Oceanic and Atmospheric Administration, National Ocean Service.

What the Data Show

Analysis of the data showed that:

- Ocean chlorophyll concentrations ranged from average seasonal concentrations of 0.1 to 6.5 ppb (Exhibit 2-12) (The Heinz Center, 2002).
- The highest ocean chlorophyll concentrations (4.8 to 6.5 ppb) occurred in the Gulf of Mexico, with the lowest concentrations (0.1 ppb) in Hawaiian waters (Exhibit 2-12).
- Southern California had the next lowest chlorophyll concentrations—between 1.1 and 1.5 ppb (Exhibit 2-12).
- Other ocean waters (e.g, north, mid-, and south Atlantic, and the Pacific Northwest) had chlorophyll concentrations ranging from 2 to 4.5 ppb (Exhibit 2-12).
- Chlorophyll concentrations in the mid-Atlantic estuaries ranged from 0.7 to 95 ppb in 1997 and 1998 (EPA, ORD, May 2003).
- About 33 percent of the mid-Atlantic estuarine area had chlorophyll concentrations exceeding 15 ppb.
- The Delaware Estuary showed a wide range of chlorophyll concentrations, from a low (< 15 ppb) in the Delaware Bay, to intermediate (15-30 ppb) in the Delaware River, to very high (> 80 ppb) in the Salem river.
- The western tributaries to the Chesapeake Bay were consistently high in chlorophyll *a*, with more than 25 percent of the area showing > 30 ppb chlorophyll concentrations.
- Chlorophyll concentrations in the coastal bays were generally low (< 15 ppb), even though nutrients were elevated because of increased turbidity and low light penetration.

Indicator Gaps and Limitations

Algorithms used to translate spectral reflectance data into chlorophyll concentrations currently provide only rough estimates of concentrations in those waters where concentrations of suspended sediments and colored dissolved organic matter are high (e.g., near-shore waters influenced by surface and ground water discharges, coastal erosion, and sediment resuspension).

The data presented here are based on a fairly coarse scale (six-mile resolution). Currently, data showing relative changes in chlorophyll within a region can be reliable; however, data showing actual concentrations for any given region might vary by a factor of two. Thus, unless differences are large, meaningful comparisons between regions are not yet possible.

The mid-Atlantic estuary data are one-time estimates of chlorophyll content in mid-Atlantic estuaries only, so these data cannot be projected to the national scale or to different time periods. Samples were

Indicator Chlorophyll concentrations - Category 2 (continued)

collected during an EMAP-defined index period of summer months and do not represent conditions at different times.

Data Source

Ocean data are found in the National Aeronautics and Space Administration's Sea-Viewing Wide Field-of-View Sensor. Estuarine chlorophyll concentrations are found in the EPA's Environmental Monitoring and Assessment Program, Mid-Atlantic Integrated Assessment (MAIA) Estuaries Program. (See Appendix B, page B-11, for more information.)

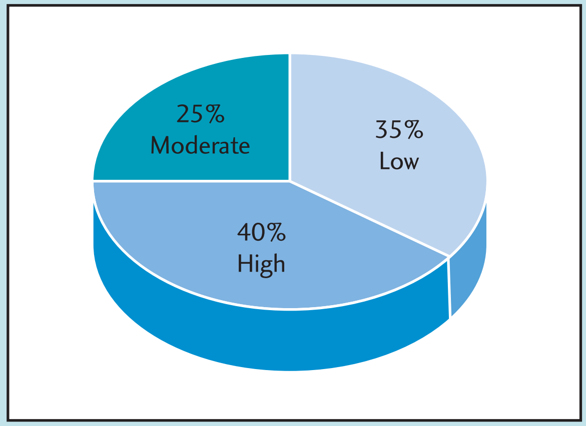
Additional Consideration: Eutrophication

Another key issue relevant to understanding the condition of coastal waters is eutrophication. Eutrophication is a natural process, through which there is "an increase in the rate of supply of organic matter" to a waterbody (Nixon, 1995). This process usually represents an increase in the rate of algal production. Under natural conditions, algal production is influenced by a gradual buildup of plant nutrients in ecosystems over long periods of time and generally leads to productive and healthy estuarine and marine environments. However, in recent years, human activities have substantially increased the rate of delivery of plant nutrients to many estuarine and marine areas (NRC, 2000; Peierls, et al., 1991; Turner and Rabalais, 1991). As a result, algal production in many estuaries has increased much faster than would occur under natural circumstances. This accelerated algal production is referred to as "cultural" or "anthropogenic" eutrophication and often results in a host of undesirable conditions in estuarine and marine environments.

These conditions, which include low dissolved oxygen concentrations, declining sea grasses, and harmful algal blooms, might impact the uses of estuarine and coastal resources by reducing the success of commercial and sport fisheries, fouling swimming beaches, and causing odor problems from the decay of excess amounts of algae (NRC, 2000; Duda, 1982). Despite much research, however, the link between coastal eutrophication and effects on living marine resources and fisheries is not well understood or quantified (NRC, 2000; Boesch, et al., 2001).

Between 1992 and 1998, NOAA conducted a survey and series of regional workshops to synthesize the best available information on eutrophication-related symptoms in 138 estuaries. Data from these surveys are presented in NOAA 's National Estuarine Eutrophication Assessment (Bricker, et al., 1999). They indicate that the nation's estuaries exhibit strong symptoms of eutrophication, which were reported by EPA to be "poor" (EPA, ORD, OW, September 2001). When data on the symptoms of eutrophication are combined, they suggest that 40 percent of the surface area of the nation's estuarine waters exhibit high levels of eutrophic condition (Exhibit 2-13).

Exhibit 2-13: Percent of estuaries with high, moderate, and low levels of eutrophic condition, 1998



Coverage: United States, excluding the Great Lakes

Source: Bricker *et al. National Estuarine Eutrophication Assessment: Effects of Nutrient Enrichment in the Nation's Estuaries*. 1999; EPA, Office of Research and Development and Office of Water. *National Coastal Condition Report*. September 2001.

Many of these waters are in the mid-Atlantic and gulf regions of the U.S. Moreover, based on expert opinion, eutrophic conditions are expected to worsen in 70 percent of U.S. estuaries by 2020 (Bricker, et al., 1999).

These eutrophication estimates are largely based upon best professional judgement. They do not adequately reflect regional differences that may occur naturally, so high scores may not be a true measure of eutrophication. Also, there are no strong scientific data to indicate that the thresholds used are indeed indicative of eutrophic conditions on a region-by-region basis. Use of SAV loss, macroalgae, and epiphytic growth is not appropriate for regions/areas where SAV beds or macroalgae are not present (e.g., South Carolina, Georgia). Standard methods do not appear to have been used among states. For all these reasons, these data were judged not to be sufficiently robust to qualify as an indicator for purposes of this report. Nevertheless, accelerated eutrophication can be an important symptom of environmental decline in estuarine and marine areas.

Therefore, eutrophication should be reconsidered as an indicator in the future if and when scientifically sound data become available.

2.2.4 What are pressures to water quality?

Indicators

Percent urban land cover in riparian areas
Agricultural lands in riparian areas
Population density in coastal areas
Changing stream flows
Number/duration of dry stream flow periods in grassland/shrublands
Sedimentation index
Atmospheric deposition of nitrogen
Nitrate in farmland, forested, and urban streams and ground water
Total nitrogen in coastal waters
Phosphorus in farmland, forested and urban streams
Phosphorus in large rivers
Total phosphorus in coastal waters
Atmospheric deposition of mercury
Chemical contamination in streams and ground water
Pesticides in farmland streams and ground water
Acid sensitivity in lakes and streams
Toxic releases to water of mercury, dioxin, lead, PCBs, and PBTs
Sediment contamination of inland waters
Sediment contamination of coastal waters
Sediment toxicity in estuaries

A complex suite of pressures weighs on surface water resources. EPA data on water quality provide some measure of the major stressors. Under the Clean Water Act, EPA requires states to define and list waters under their jurisdiction that are impaired, and to identify the causes of those impairments and develop a program to manage and control the causes. In 1998, more than 21,000 waterways were identified as impaired under the provisions of Section 303(d) of the CWA (EPA, OW, March 2003). The following top five causes of impairment accounted for 60 percent of the cases:

- Sediment/siltation
- Pathogens
- Metals
- Nutrients
- Organic enrichment/low dissolved oxygen

The next five causes account for additional 21 percent of impairment:

- Habitat alteration
- Thermal modifications
- Low or high pH
- Pesticides
- Fish consumption advisories

Twenty indicators have been identified to help answer the question "What are the pressures to water quality?" These indicators have been divided into three categories:

General pressures—Section 2.2.4.a presents six indicators of general pressures that relate in some way to habitat quality but do not fall into a specific stressor category.

Nutrient pressures—Section 2.2.4.b presents six indicators that relate specifically to nutrient enrichment.

Chemical contaminant pressures—Section 2.2.4.c discusses eight indicators that describe chemical contamination.

These indicators do not address sediment/siltation or pathogens (the two most important causes of water quality impairment as identified under Section 303[d] of the Clean Water Act), nor do they address another key concern—the impact of invasive species. Additional pressures to water quality are discussed in the Ecological Condition, Better Protected Land, and Cleaner Air chapters.

2.2.4.a General Pressures

General pressures that alter aquatic ecosystems and for which indicators are available include (1) the extent of urban land cover and agricultural lands in stream riparian areas, and (2) the extent of coastal development, as represented by population density. Additional indicators of pressures on streams relate to changes in stream flow and altered in-stream habitat. These six indicators, discussed in this section, address pressures directly on stream ecosystems and coastal areas, but they do not attempt to define pressures on lakes, ponds, reservoirs, or wetland resources, even though the pressures are likely comparable.

The difference in pressures related to urban development versus pressures from agricultural activities generally are a function of the location of, extent of, and change in urban and agricultural areas. Coastal development data, in the form of population density, suggest strong pressures on coastal systems today and in the future. Data on stream flow indicate that changes in minimum and maximum flow have increased slightly over the last three decades and that maximum flows in some areas have increased significantly. Zero (no) flow data for grassland and shrubland streams are consistent with these observations in that the percent of streams with no- flow periods has decreased.

Indicator: Percent urban land cover in riparian areas - Category 2

This indicator provides a snapshot in time of the potential stress to stream ecosystems across the nation due to urban development. Specifically, the indicator examines the extent of land cover within riparian zones, which are defined as the 30-meter buffer on each side of a stream or river. The indicator focuses on land cover along streams or rivers within watersheds categorized by the U.S. Geological Survey (USGS) as eight-digit HUCs under its hydrologic unit code (HUC) categorization system.

To calculate the extent of urban land cover, each of these buffer zones was divided into grid cells (of 15 minute latitude by 15 minute longitude dimensions). The extent of urban land cover was calculated as the percent of grid cells with land cover, divided by the total number of grid cells. To make this calculation:

- Stream map sets were derived from remote sensing techniques, generally aerial photography and satellite imagery.
- The land cover data sets were collected using remote sensing techniques, generally satellite imagery, with ground truth fieldwork.
- Stream extent and locations were defined as any line or polygon feature attributed as "stream/river." This is consistent with the definition in the USGS's National Hydrography Dataset (NHD), a key data source for this indicator.
- Urban land cover was defined as (1) the sum of low-intensity residential, high-intensity residential, and commercial/industrial/transportation land cover types in the National Land Cover Database (NLCD) and (2) the sum of both high-intensity and low-intensity developed land cover types in the Coastal Change Analysis Program (C-CAP).

What the Data Show

The analysis indicates that nearly 80 percent of the watersheds (8-digit HUCs) in the continental U.S. have less than 2 percent urban land uses within 30 meters of streams. Five percent of watersheds (8-digit HUCs) have urban land uses of greater than 8 percent within 30 meters of streams. Less than 1 percent of the nation's watersheds (8-digit HUCs) have more than 25 percent urban uses within stream riparian areas. Watersheds with streamside urban development tend to be concentrated in certain parts of the country (e.g., the Midwest, Southeast, and Northeast).

Indicator Gaps and Limitations

The streams data set is known to contain both systematic and random errors. Many of these errors, such as positional accuracy of stream segments due to digitizing accuracy, are minimized due to the scale of this analysis (i.e., at the 8-digit HUC level). But stream omission, the degree of which varies between different scale maps (i.e., 30- by 60-minute quadrangle maps), has a higher impact on potential error. In addition, the accuracy of whether or not a stream was perennial also varied between quadrangle maps, preventing a more accurate representation of riparian areas.

This indicator only examines urban land within 30 meters of streams and rivers, which means that more significant urban development at distances beyond 30 meters is not evaluated. The analysis is not a standardized ongoing assessment. Because the land cover data sets exists only for a single year, changes in the amount of urban land cover over time are not addressed by this indicator at present.

Data Source

Information is available from the specific program datasets (National Land Cover Database, Coastal Change Analysis Program, National Hydrography Dataset, and Hydrologic Unit Code). Data were summarized by the EPA. (See Appendix B, page B-11, for more information.)

Indicator Agricultural lands in riparian areas - Category 2

Agricultural land uses in riparian areas may have environmental effects, due to erosion and disturbance of riparian habitat. When land immediately adjacent to streams is used for agricultural purpose, this may affect water quality in a number of ways:

- Runoff from plowed fields can potentially become a source of stream sediment.
- Fertilizers and pesticides are often conveyed to streams by runoff or by drainage.
- Grazing animals may contaminate streams with coliform bacteria.

Results for this indicator are expressed in bank miles, calculated as the percent of agricultural land cover within the stream corridor, multiplied by the total length of stream bank within the 8- digit HUC. The data sets and analytical procedures are the same as those for the urban land in riparian areas indicator described above.

What the Data Show

The major areas of high agricultural activities in riparian areas of the U.S. are found in the Midwest, in the Southeast, east of the Cascade Mountains in Washington state, and in the inland valleys of California. The arid Southwest has very few stream miles in agriculture, due both to a low stream density and limited agriculture. Conversely, areas with the highest number of stream miles in agriculture are in watersheds that have extensive agriculture and high stream density. Only one percent of the watersheds (8-digit HUCs) in the conterminous U.S. have no stream miles in agriculture. Ten percent of the watersheds (8-digit HUCs) in the conterminous U.S. have more than 1,500 miles of streams in agriculture. About half of the watersheds (8-digit HUCs) in the conterminous U.S. have less than 250 miles of streams in agriculture.

Indicator Gaps and Limitations

The issues associated with this indicator are the same as those described for the previous indicator "percent urban land cover in riparian areas." Because the classified land cover data sets were only produced once, changes in the amount of agricultural land cover over time are not addressed by this indicator at present. Refer to the "Indicator Gaps and Limitations" section in the discussion of the previous indicator for details.

Data Source

EPA's Office of Research and Development analyzed and summarized data from the National Land Cover Database for stream miles with agricultural uses. Information is available from the specific program datasets (NLCD, C-CAP, NHD, and HUC). (See Appendix B, page B-11 for more information.)

Indicator Population density in coastal areas - Category 2

Land along the U.S. coastline is experiencing more acute pressure from population growth than other areas. Using primarily census data, NOAA has produced several reports on population distribution, density, and growth in coastal areas. These reports describe the pressure on coastal environments from land development.

What the Data Show

The NOAA reports find that coastal areas are the most developed in the nation. The narrow fringe of coastline, comprising 17 percent of our nation's total land area, contains 53 percent of the nation's population. The rate of population growth along the coast is faster than for the nation as a whole. At an average growth rate of 3,600 people per day, coastal population is expected to reach 165 million by 2015 (NOAA, 1998).

Indicator Gaps and Limitations

The NOAA estimates of coastal population and pressures are likely to be an overestimate, as data are aggregated by counties, which have extensive inland areas in addition to coastal shoreline.

Data Source

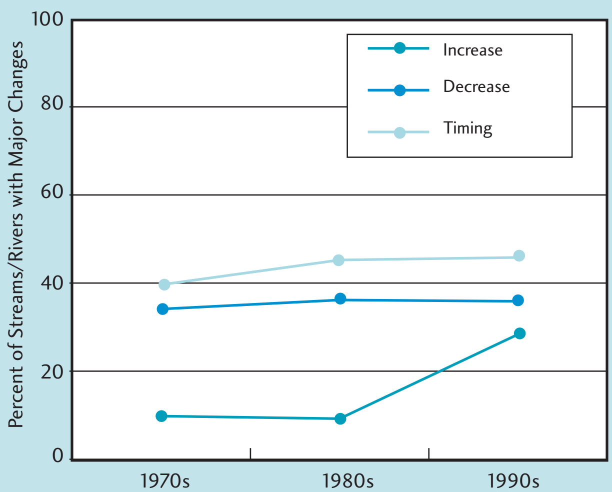
Data for this indicator are from a report on urban development in coastal areas by the U.S. Department of Commerce, National Oceanic and Atmospheric Administration. (See Appendix B, page B-11, for more information.)

Indicator Changing stream flows - Category I

Flow is a critical aspect of hydrology in streams. Low flows define the smallest area available to stream biota during the year; high flows shape the stream channel and clear silt and debris from the stream. Also, some fish depend on high flows for spawning (The Heinz Center, 2002). The timing of a stream's high and low flows can influence many ecological processes. Changes in flow can be caused by dams, water withdrawal, changes in land use, and climate trends. This indicator reports the percentage of streams or rivers with major changes in the magnitude or timing of their high or low flows over three decades (1970s, 1980s, 1990s) compared to a reference period from 1930 to 1949.

The USGS stream gauge database, which served as the data source for this indicator, contains 867 gauging sites with at least 20 years of discharge records within the target dates 1930 to 1949, and 10 years of records for the 1970s, 1980s, and 1990s. The measures were 7-day low flow and the corresponding Julian days and the average 1-day high flow and Julian day.

Exhibit 2-14: Percent of streams with changes in high flows (1970s-1990s) compared to baseline high flow data (1930-1949)



Coverage: lower 48 states

Note: Totals may add to more than 100%, because both the timing and magnitude may change in a single stream or river.

Source: The Heinz Center. *The State of the Nation's Ecosystems.* 2002. Data from the U.S. Geological Survey.

What the Data Show

The percentage of streams and rivers with major changes in their high or low flows or the timing of those flows (i.e., compared to the same data for those streams or rivers as recorded between 1930 and 1949) increased slightly from the 1970s to the 1990s (The Heinz Center, 2002). The number whose high flows were well above the flows in those same streams and rivers between 1930 and 1949 increased by approximately 30 percent in the 1990s (Exhibit 2-14). The baseline period of 1930 to 1949 included some droughts, which may partially explain the increase in high flows in subsequent decades. However, much of this baseline period also preceded widespread irrigation projects, which means that fewer high flows would be expected in subsequent decades.

Indicator Gaps and Limitations

Data from the period 1930 to 1949 are being used here as a practical baseline for historical comparison, even though many dams and other waterworks had already been constructed by this time, and even though this period was characterized by low rainfall in some parts of the country. For this reason, it may be more useful to compare changes in stream flows on a decade-by-decade basis rather than to the 1930 to 1949 baseline period selected here.

Although the sites analyzed here are spread widely throughout the U.S., gauge placement by the USGS is not a random process. Gauges are generally placed on larger, perennial streams and rivers, and changes seen in these larger systems may differ from those seen in smaller streams and rivers. In addition, the USGS gauge network does not represent the full set of operating stream flow gauges in the U.S. The U.S. Army Corps of Engineers, for example, operates gauges, and those data are not available through the USGS; they were not used in this analysis.

Data Source

Data for this indicator came from the U.S. Geological Survey gauging station network, compiled for The Heinz Center (2002). (See Appendix B, page B-12, for more information.)

Indicator Number/duration of dry stream flow periods in grassland/shrublands - Category 2

Many grassland/shrublands are located in arid climates where water availability is critical. The number and duration of dry periods in streams and rivers is used as a hydrology/geomorphology indicator in the Heinz report (The Heinz Center, 2002). Changes in the number and/or duration of no-flow periods can significantly stress aquatic plants and animals. These alterations can result from changes in agricultural management or irrigation practices, development, change in flow regulation below dams, or depletion of shallow ground water. Riparian condition is critical for grassland and shrubland streams. Because most of the streams are ephemeral, aquatic organisms have evolved to complete their life histories during periods when water is available (Fisher, 1995). Increasing the percentage of no-flow periods can significantly stress riparian and aquatic communities.

Gauging sites with at least 50 percent grassland/shrubland were identified for 4-digit HUC watersheds. The NLCD coverage was used to identify these areas as grassland/shrubland. The number of sites with at least one no-flow day in a year was determined for each year from 1950 to 1999. The corresponding percentage of area as grassland/shrubland for that year was also calculated. To analyze the duration of no-flow, only sites with at least one no-flow day in each decade between October 1, 1949, and September 30, 1999, were considered. This analysis considered whether there was an increase, decrease, or minimal change in the number of no-flow days, compared to the long-term (50-year) average for each stream.

What the Data Show

The percentage of no-flow periods has decreased in all grassland/shrubland regions of the West (The Heinz Center, 2002). The percentage of no-flow periods was similar in the 1950s and 1960s and then generally decreased in the 1970s, 1980s, and 1990s (Exhibit 2-15) (The Heinz Center, 2002). The 1980s was a relatively wet period, during which some of the smallest percentages of no-flow periods existed in a 50-year period of record (The Heinz Center, 2002). The duration of no-flow periods also decreased during the 1970s through the 1990s, compared to the 1950s and 1960s (The Heinz Center, 2002).

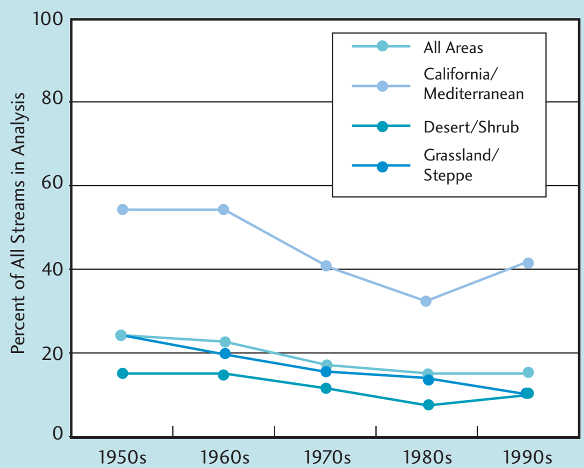
Indicator Gaps and Limitations

These data are from USGS gauging stations, which may be found on larger, perennial streams; thus, these data may not reflect conditions on very small streams. Data limitations, generally, are similar to those described for the "number/duration of dry stream flow periods in grasslands/shrublands" indicator described on the previous page.

Data Source

The data source for this indicator was the U.S. Geological Survey gauging stations, analyzed by Colorado State University for The Heinz Center. (See Appendix B, page B-12, for more information.)

Exhibit 2-15: Percent of streams that have zero-flow periods, 1950s-1990s



Coverage: grassland/shrubland regions in lower 48 states.

Source: The Heinz Center. *The State of the Nation's Ecosystems.* 2002. Data from the U.S. Geological Survey.

Indicator Sedimentation index - Category 2

Stream channels undergo a long-term adjustment to a region-specific rate of sediment supply that is delivered by erosion processes from natural disturbance. The size distribution of streambed particles is dependent upon the relationship between sediment supply and stream sediment transport capability. Under a natural disturbance regime, sediment supply in watersheds that are not altered by human disturbances may be roughly in long-term equilibrium with stream sediment transport. In watersheds that are relatively undisturbed by humans, the relationship between bed particle size and stream transport capability should tend toward a characteristic value that is typical to the region. Human activities may increase sediment input rates to streams, resulting in higher amounts of fine substrates in sediments than the predicted regional value.

Higher sedimentation rates can significantly alter instream habitat. These alterations are the greatest stressor to mid-Atlantic streams and many other streams throughout the U.S. For example, change in channel morphology can affect stream biota and ecological condition. Thrush, et al. (2000) provide 10 geomorphic attributes that are needed for suitable stream habitat, in addition to critical channel morphological indicators.

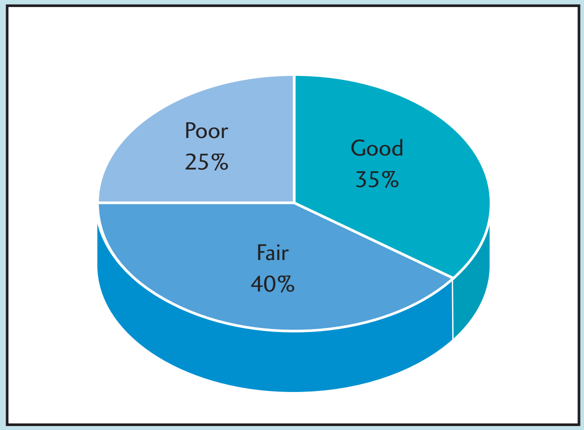
A sedimentation index was developed for Mid-Atlantic Highland streams to assess the quality of instream habitat to support aquatic communities (Kaufmann, et al., 1999). Stream sedimentation was defined as an increase or excess in the amount of fine substrate particles (smaller than 16-mm diameter) relative to an expected reference value that is based on the region and the sediment transport capability of each sample stream reach. Streams were given the following ratings with respect to sedimentation:

- "Good" when the proportion of fine particles was at least 10 percent below the predicted value.
- "Fair" when the population of fine particles ranged from 10 percent below to 20 percent above the predicted value.
- "Poor" when the proportion of fine particles was more than 20 percent above regional mean expectations.

What the Data Show

Based on the sedimentation index, about 35 percent of the Mid-Atlantic Highland stream miles had good instream habitat, 40 percent had fair instream habitat, and 25 percent of the stream miles had poor instream habitat (Exhibit 2-16) (EPA, ORD, Region 3, August 2000).

Exhibit 2-16: Percent of Mid-Atlantic highland streams exhibiting good, fair, and poor habitat condition based upon a sedimentation index, 1993-1994



Source: EPA Region 3 and the Office of Research and Development. *Mid-Atlantic Highlands Streams Assessment.* August 2000.

Indicator Gaps and Limitations

This sedimentation index has been applied only in the context of the mid-Atlantic region and cannot be used for a national assessment. The index itself may not apply equally to other regions of the nation.

Data Source

The data source for this indicator was EPA's Mid-Atlantic Highlands Streams Assessment, part of the Environmental Monitoring and Assessment Program. (See Appendix B, page B-12, for more information.)

2.2.4.b Nutrient Pressures

Nutrient enrichment by nitrogen and phosphorus is one of the leading causes of water quality impairment in the nation's rivers, lakes, and estuaries. In a 1998 water quality report to Congress, nutrients were listed as a leading cause of water pollution. About half of the nation's waters surveyed by states do not adequately support aquatic life because of excess nutrients. In 1998, states reported that excessive nutrients have degraded almost 2.5 million acres of lakes and reservoirs and over 84,000 miles of rivers and streams to the extent that they no longer meet basic uses such as supporting healthy aquatic life. Nutrients have also been associated with both the large hypoxic zone in the Gulf of Mexico, the hypoxia observed in several East Coast states, and *Pfisteria*-induced fish kills and human health problems in the coastal waters of several East Coast and Gulf states.

Many of the nutrients used in chemical fertilizers are water soluble. Consequently, one of the major potential environmental effects of fertilizer usage is the nitrogen or phosphorus that may find its way into water systems, affecting water quality and aquatic habitats. Another major source of nutrients from agricultural lands are those related to animal feed operations. Nutrients, particularly nitrogen and phosphorus, increase the levels of algae in receiving waterbodies.

Most of the streams that are enriched with nutrients lie in drainage areas for agricultural and/or urban land. Forested landscapes rarely contribute to heightened water concentrations of these nutrients. Ground water from more than half the sites sampled in a nationwide study contained nutrients at concentrations higher than natural background levels. Data presented in Chapter 3, Better Protected Land, describe a USGS risk analysis that evaluated the likelihood of ground water contamination from nitrate resulting from a combination of well-drained soils and a high proportion of cropland to woodland. The data illustrate a clear relationship between potential ground water contamination and predominantly agricultural areas of the country (see Chapter 3–Better Protected Land).

"Nitrogen export" is the annual quantity of total nitrogen produced by nitrogen sources in a watershed that leaves the watershed through a river or stream that connects to other watersheds downstream. Estimates of total nitrogen (TN) export were developed by Smith, et al. (1997) through analysis of data from monitoring stations in the USGS's National Stream Quality Accounting Network (NASQAN) SPARROW (SPAtially-Referenced Regressions On Watershed attributes). This model relates in-stream measurements of TN export to point and non-point sources of pollution, and to land-surface and stream-channel characteristics in the watersheds that contain the monitoring stations. This modeling was performed using data from approximately 400 long-term stream monitoring sites. Using these data, the model empirically estimated the delivery of nutrients to streams and the outlets of watersheds from point and non-point sources.

This section presents six indicators of pressures on water quality related to nutrient enrichment:

- Atmospheric deposition of nitrogen
- Nitrates in farmland, forested, and urban streams and ground water
- Total nitrogen in coastal waters
- Phosphorus in farmland, forested, and urban streams
- Phosphorus in large rivers
- Phosphorus in coastal waters

Chapter 3–Better Protected Land, discusses the potential for nutrient runoff from farmlands.

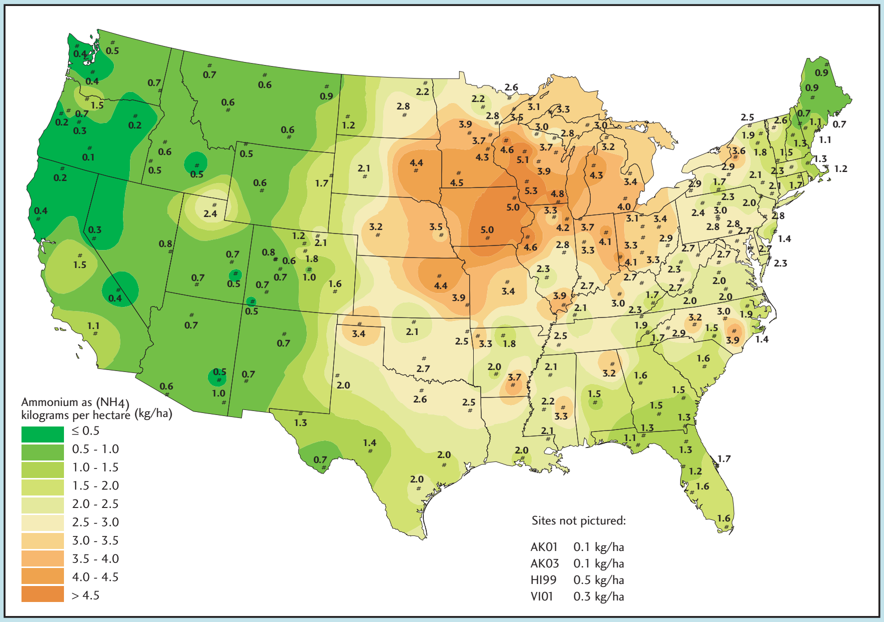
Indicator Atmospheric deposition of nitrogen - Category 2

Nitrogen, essential to life, is a component of proteins and nucleic acids. Natural and human processes convert nitrogen gas to a variety of usable forms, including nitrogen oxides, ammonia, and organic nitrogen. Natural sources of nitrogen oxides and ammonia include volcanic eruptions, lightning, forest fires, and certain microbial processes. Anthropogenic sources contribute about the same amount of nitrogen oxides and ammonia to the environment as do natural sources. The largest single source of nitrogen oxides to the atmosphere is the combustion of fossil fuels (such as coal, oil, and gas) by automobiles and electric power plants (Schlesinger, 1997). The largest sources of ammonia emissions are fertilizers and domesticated animals (such as hogs, chickens, and cows).

In some places, nitrogen deposited from the atmosphere is a large percentage of the total nitrogen load. For instance, Albemarle-Pamlico Sound in North Carolina receives 38 percent of its nitrogen from the atmosphere (EPA, OAQPS, June 2000). As human sources of nitrogen compounds to the atmosphere increase, the importance of atmospheric deposition of nitrogen to bodies of water will increase as well.

Indicator Atmospheric deposition of nitrogen - Category 2 (continued)

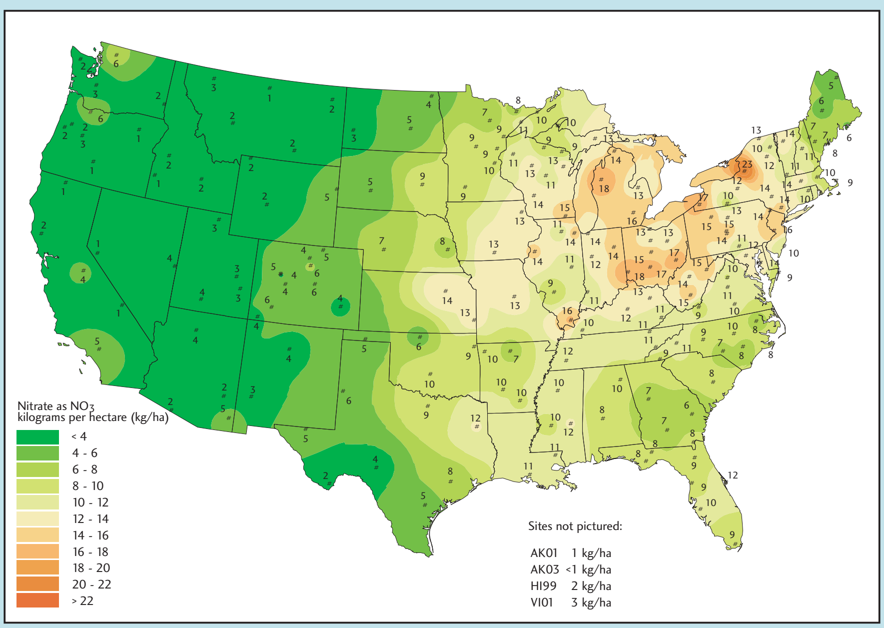
Exhibit 2-17: Ammonium wet deposition, 2001



Coverage: lower 48 states

Source: National Atmospheric Deposition Program, National Trends Network. 2001. (March 25, 2003; *http:..nadp.sws.uiuc.edu/isopleths/maps2001/nh4dep.pdf*).

Exhibit 2-18: Nitrate wet deposition, 2001



Coverage: lower 48 states

Source: National Atmospheric Deposition Program, National Trends Network. 2001. (March 25, 2003; *http://nadp.sws.uiuc.edu/isopleths/maps2001/no3dep.pdf*).

The deposition of nitrogen compounds on land or water can take several forms. Wet deposition occurs when air pollutants fall with rain, snow, or fog. Dry deposition is the deposition of pollutants as dry particles or gases. In either form, the pollutants can reach bodies of water as direct deposition falling directly into the water or as indirect deposition—falling onto land and passing into a body of water as runoff. In either case, atmospheric deposition is often one of the major sources of nitrogen in surface waters.

This indicator focuses on atmospheric deposition of inorganic nitrogen, as it is the most immediately available form of nitrogen in the environment. Its components, nitrate and ammonium, are presented using the National Atmospheric Deposition Program/National Trends Network (NADP/NTN) data collected in 2001.

What the Data Show

Ammonium deposition is lowest in the western states, where it is generally less than 1 kg/ha. Highest rates occur in the upper midwestern states in the upper Mississippi River watershed (Exhibit 2-17). Nitrate deposition also is low in the western states (< 4 kg/ha). Highest deposition rates occur in the upper Midwest and in the eastern states (Exhibit 2-18). High ammonium values are associated with wastes from animal agriculture, while nitrates are largely from fertilizers used in row crop agriculture.

Indicator Gaps and Limitations

This indicator measures wet deposition, not dry deposition. Total nitrogen deposition is not measured.

Indicator Atmospheric deposition of nitrogen - Category 2 (continued)

Additionally, the indicator estimates deposition only to the surface areas, not directly to the water, except where large waterbodies are present.

Data Source

The data source for this indicator was the interagency National Atmospheric Deposition Program. (See Appendix B, page B-12 for more information.)

Indicator Nitrate in farmland, forested, and urban streams and ground water - Category 2

Nitrogen is a critical plant nutrient, and most nitrogen is used and reused by plants within an ecosystem. Thus, in undisturbed ecosystems, minimal "leakage" occurs into either surface runoff or ground water, and concentrations are very low. However, when amounts of nitrate in streams and ground water are elevated, this generally indicates that inputs from human sources have increased or that plants in the system are under stress. Elevated nitrogen levels might come from fertilizer use, disposal of animal waste, onsite septic systems, sewage treatment plants, or rain and snowfall (in the form of atmospheric deposition).

This indicator reports on the concentration of nitrate in streams and ground water in farmland, forested, and urban areas. Specifically, the indicator reports the percent of streams with average nitrate concentrations in one of four ranges: less than two ppm; two-six ppm; six-10 ppm; and 10 ppm or more. The data, comprised of samples collected at over 100 stream sites in farmland areas, were collected and analyzed by the NAWQA program in 36 large watersheds across the U.S. during 1993 to1998. Thirty-six forested streams and 21 urban/suburban streams also were evaluated. Ground water samples were collected from 20 to 30 private wells in each of 36 agricultural study areas and 13 urban study areas.

What the Data Show

USGS data, compiled for The Heinz Center (2002), indicate that:

- Nitrate concentrations were above two ppm (mg/L) in about half of the stream sites and 55 percent of ground water wells sampled in areas where agriculture is the primary land use (Exhibit 2-19).
- Most nitrate concentrations in forested streams were less than 0.5 ppm (50 percent had concentrations of nitrate less than 0.1 ppm, 75 percent had concentrations of less than 0.5 ppm, and only one had a concentration of more than 1.0 ppm).
- Forty percent of urban/suburban streams had nitrate concentrations above 1.0 ppm (25 percent had concentrations below 0.5 ppm, and three percent had concentrations below 0.1 ppm).

About 20 percent of the ground water wells and about 10 percent of stream sites had concentrations that exceeded the federal drinking water standard (10 mg/L). Only three percent of urban ground water wells had nitrate concentrations exceeding the standard. Samples of ground water in agricultural areas have nitrate concentrations higher than ground waters of forested or urban areas.

In four of 33 major drinking water aquifers sampled, the federal drinking water standard for nitrate was exceeded in more than 15 percent of samples collected. In these aquifers, all of which underlie intensive agricultural areas, nitrate most often is elevated in karst (carbonate) areas or where soils and aquifers consist of sand and gravel. These natural features enable rapid infiltration and downward movement of water and chemicals. Some of the more vulnerable areas of the nation are the Central Valley of California, and parts of the Pacific Northwest, the Great Plains, and the Mid-Atlantic region. In contrast, contaminants are barely detectable in ground water underlying farmland in parts of the upper Midwest, despite similar high rates of chemical use. In these areas, ground water contamination may be limited, because of the relatively impermeable, poorly drained soils and glacial till that cover much of the region, and because tile drains provide quick pathways for runoff to streams (Gilliom, et al., 2002).

Nitrate contamination in shallow ground water (less than 100 feet below land surface) raises potential concerns for human health, Indicator Nitrate in farmland, forested, and urban streams and ground water - Category 2 (continued)

particularly in rural agricultural areas where shallow ground water is used for domestic water supply. Furthermore, high levels of nitrate in shallow ground water may serve as an early warning of possible future contamination of older underlying ground water, which is a common source for public water supplies (USGS, 1999).

Indicator Gaps and Limitations

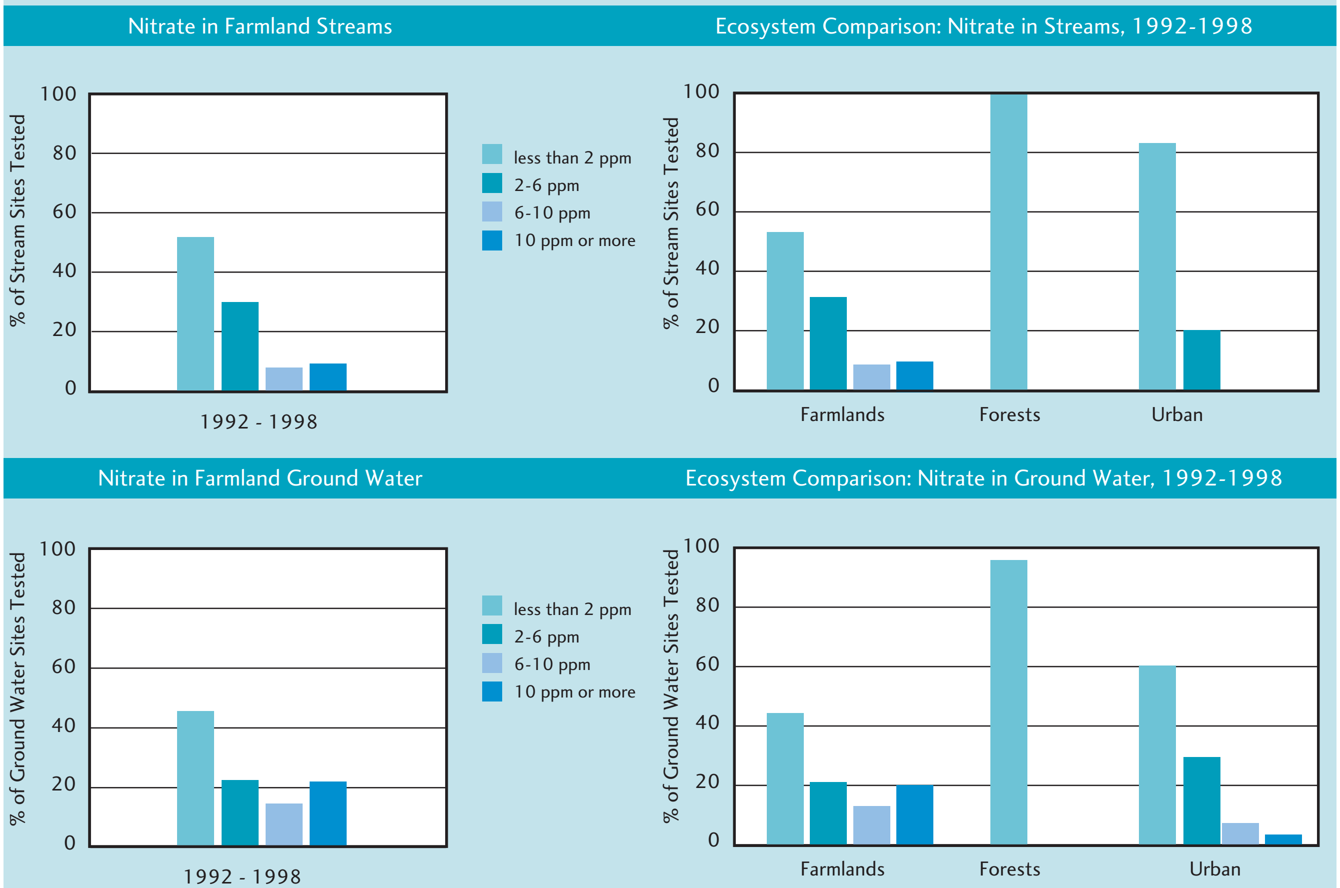
These data only represent conditions in the 36 major river basins and aquifers sampled by the NAWQA program. While they were subjectively chosen to be representative of watersheds across the U.S., they are the result of a targeted sample design.

The data also are highly aggregated and should only be interpreted as an indication of national patterns. For example, the definition of agricultural land included land use by cropland or pasture. The percentage of land used for agricultural purposes within specific watersheds varied from 10 to 99 percent of the land cover, so the characterization of lands as agricultural is subject to this degree of variation in land use.

Data Source

Data for this indicator were compiled for The Heinz Center (2002) from the U.S. Geological Survey's National Water Quality Assessment Program. (See Appendix B, page B-13 for more information.)

Exhibit 2-19: Nitrates in farmland streams and ground water, 1992-1998



Coverage: lower 48 states. Each sampling area was sampled intensively for approximately 2 years during 1992–1998.
Source: The Heinz Center. *The State of the Nation's Ecosystems. 2002.* Data from the U.S. Geological Survey.

Indicator Total nitrogen in coastal waters - Category 2

Nitrogen in estuaries is commonly regarded as the most important limiting nutrient. Nutrients can originate at either point sources (e.g., sewage treatment plants and industries) or non-point sources (e.g., farmlands, lawns, leaking septic systems, and the atmosphere). Excess nutrients can lead to eutrophication.

Total nitrogen (TN) in the mid-Atlantic estuaries was calculated by summing the concentrations of total dissolved nitrogen and particulate organic nitrogen (EPA, ORD, May 2003). Assessment categories were determined based on the 25th and 75th percentiles. The categories are (EPA, ORD, May 2003):

- Low: < 0.5 ppm nitrogen
- Intermediate: 0.5 to 1.0 ppm nitrogen
- High: > 1.0 ppm nitrogen

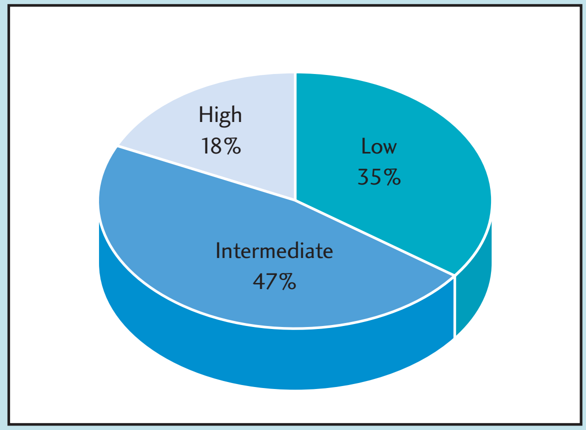
Currently there are no national-level water quality criteria for total nitrogen in estuaries, but states are in the process of determining nutrient criteria for their waters.

What the Data Show

This analysis yielded the following results:

- For the mid-Atlantic region, about 35 percent of the estuarine area had low TN concentrations, 47 percent had intermediate TN concentrations, and 18 percent had high TN concentrations (Exhibit 2-20).
- About 50 percent of the mainstem area of the Chesapeake Bay had low TN concentrations, with only about five percent having high TN concentrations.
- In contrast, about fives percent of coastal bays had low TN concentrations, and about 35 percent had high TN concentrations.
- The entire Delaware River estuary portion of Delaware Bay had high TN concentrations.

Exhibit 2-20: Extent of Mid-Atlantic estuaries with low, intermediate, and high total nitrogen concentrations, 1997-1998



Source: EPA, Office of Research and Development. *Mid-Atlantic Integrated Assessment, MAIA - Estuaries 1997-98, Summary Report.* May 2003.

Indicator Gaps and Limitations

These TN estimations for estuaries apply only to the mid-Atlantic region and cannot be used to make national estimates of nitrogen concentrations.

Data Source

The data source for this indicator was EPA's Mid-Atlantic Integrated Assessment (MAIA) Estuaries Program, part of EPA's Environmental Monitoring and Assessment Program. (See Appendix B, page B-13, for more information.)

Indicator

Phosphorus in farmland, forested, and urban streams - Category 2

Phosphorus, an essential nutrient for all life forms, occurs naturally in soils and aquatic systems. However, at high concentrations, phosphates, the most biologically active form of phosphorus, can cause significant water quality problems by overstimulating algae growth. This is both aesthetically unappealing and can contribute to the loss of oxygen needed by fish and other animals. Human activity can increase phosphorus levels through fertilizer use, disposal of animal waste, sewage treatment, and use of some detergents.

This indicator reports on the concentration of phosphorus in streams that drain watersheds comprised primarily of farmland, forested, or urban land use. Specifically, the indicator reports the percent of these streams that have average annual phosphorus concentrations in one of four ranges: less than 0.l ppm; 0.1 to 0.3 ppm; 0.3 to 0.5 ppm; and 0.5 ppm or more. Thirty-six forested streams and 21 urban/suburban streams also were evaluated.

What the Data Show

Data compiled by the USGS indicate that:

- About three-fourths of farmland stream sites had concentrations of phosphorus above 0.1 parts per million (mg/L) (Exhibit 2-21).
- About 15 percent of farmland stream sites had phosphorus concentrations greater than 0.5 ppm of phosphorus.
- Phosphorus concentrations in streams of agricultural lands were similar to but slightly higher than those in urban streams and much greater than those in forest streams.

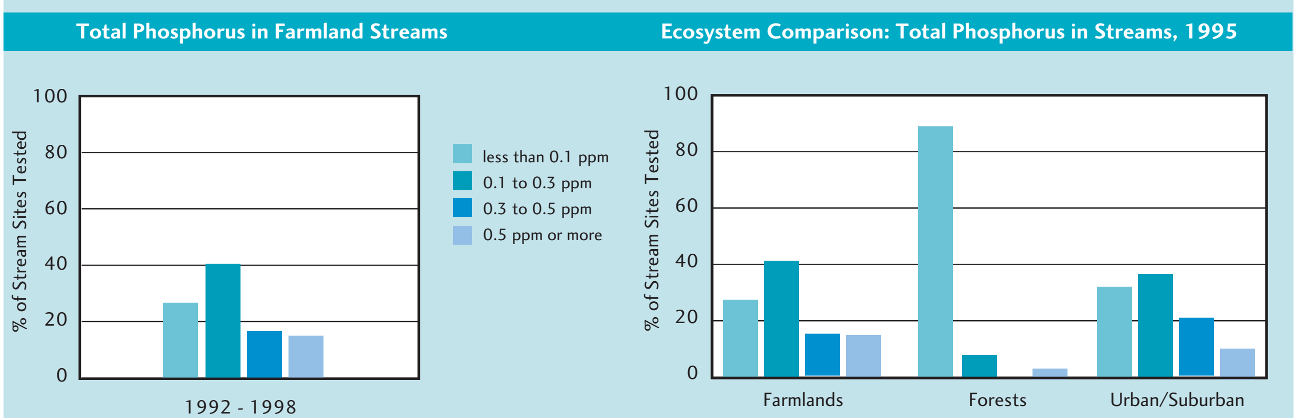
EPA has recently set new regional water quality criteria for phosphorus levels in streams in agricultural ecosystems. These criteria range from 0.023 to 0.076 ppm and vary according to differences in ecoregions, soil types, climate, and land use.

Compared to nitrogen, a smaller proportion of phosphorus (originating mostly from livestock wastes or fertilizers) was lost from watersheds to streams. The annual amounts of total phosphorus measured in agricultural streams were equivalent to less than 20 percent of the phosphorus that was applied annually to the land. This is consistent with the general tendency of phosphorus to attach to soil particles that move more slowly with runoff to surface water. Even though less phosphorus is transported from land than nitrogen, phosphorus is more likely to reach concentrations that can cause excessive aquatic plant growth. Nitrogen concentrations are rarely low enough to limit aquatic plant growth in fresh water, whereas phosphorus concentrations can be low enough to limit such growth. Thus, adding phosphorus to an aquatic system can have a greater impact than adding nitrogen. Hence, excessive aquatic plant growth and eutrophication in fresh water generally result from elevated phosphorus concentrations (typically greater than 0.1 ppm) (EPA, OW, June 1998). In contrast, nitrogen typically is the limiting nutrient for aquatic plant growth in saltwater and coastal waters.

Indicator Gaps and Limitations

These data only represent conditions in the 36 major river basins and aquifers sampled by NAWQA. While they were subjectively

Exhibit 2-21: Phosphorus in farmland streams and ground water, 1992-1998



Coverage: lower 48 states. Each sampling area was sampled intensively for approximately 2 years during 1992–1998.

Source: The Heinz Center. *The State of the Nation's Ecosystems.* 2002. Data from the U.S. Geological Survey.

Indicator Phosphorus in farmland, forested, and urban streams - Category 2 (continued)

chosen to represent watersheds across the U.S., they are the result of a targeted sample design.

The data also are highly aggregated and should only be interpreted as an indication of national patterns. For example, watersheds dominated by agricultural land included land use by cropland or pasture. The percentage of land used for these purposes varied from 10 to 99 percent, so the characterization of lands as agricultural is subject to this degree of variation in land use.

Data Source

Data used for this indicator were compiled for The Heinz Center (2002) from the U.S. Geological Survey's National Water Quality Assessment Program. (See Appendix B, page B-13, for more information.)

Indicator Phosphorus in large rivers - Category 2

Increased phosphorus in large rivers and other waterbodies leads to an increase in growth of algae. While small amounts of algae provide the critical base of the food chains in these waterbodies, larger amounts lead to eutrophication. As discussed in Section 2.2.3, eutrophication can lead to loss of oxygen, shifts in fish population, and "nuisance blooms" of algal species. Algal blooms generally degrade aesthetic and recreational values.

Data on phosphorus were collected from 140 sites in large rivers (i.e., rivers with flows exceeding 1,000 cubic feet per second) at least 30 times over a 2-year period between 1992 and 1998 by the USGS (The Heinz Center, 2002).

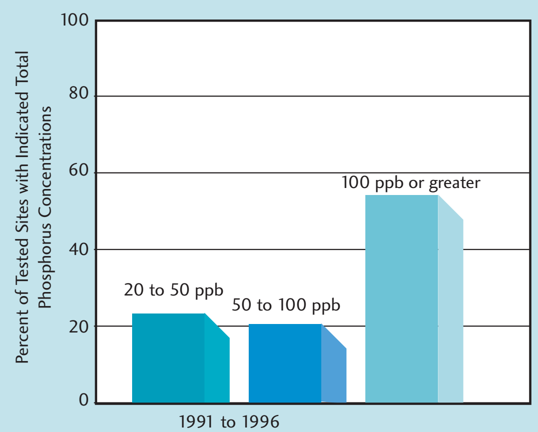
What the Data Show

Half of the rivers tested had total phosphorus concentrations equaling or exceeding 100 parts per billion (The Heinz Center, 2002) (Exhibit 2-22), which is EPA's recommended goal for preventing excess algal growth in streams that do not flow directly into lakes. None of the rivers had concentrations below 20 parts per billion, a level generally held to be free of negative effects (EPA, OW, November 1986).

Indicator Gaps and Limitations

Phosphorus measurements in rivers were restricted to those large rivers with flows exceeding 1,000 cubic feet per second. To ensure proper characterization of average values for each river, only sites that had at least 30 samples over the course of 2 years were included. Thus, only large rivers with adequate sampling are represented.

Exhibit 2-22: Distribution of phosphorus concentrations in large rivers, 1991-1996



Coverage: lower 48 states

Note: 140 sites were tested. (ppb = parts per billion)

Source: The Heinz Center. *The State of the Nation's Ecosystems.* 2002. Data from the U.S. Geological Survey.

The data used for this indicator are from larger rivers. Larger rivers typically have both larger discharge volumes and watersheds with more diverse land uses. These samples, therefore, represent the integrating influences of many different land uses. Also, they were the result of a targeted sample design, and may not be representative of large rivers across the U.S.

Data Source

The data used for this indicator were from the U.S. Geological Survey as compiled for The Heinz Center (2002). (See Appendix B, page B-14, for more information.)

Indicator Total phosphorus in coastal waters - Category 2

Phosphorus is an essential plant nutrient. It is derived from weathering and erosion of natural mineral deposits, runoff of fertilizers applied to agricultural and urban areas, and point source discharges of sewage, detergents, pharmaceuticals, and other phosphorus-containing products. Phosphorus is generally considered the limiting nutrient in fresh water systems (Schindler, 1977), but it can also become limiting in estuarine areas if total nitrogen becomes abundant (EPA, ORD, May 2003).

Total phosphorus data were collected in the mid-Atlantic estuaries (EPA, ORD, May 2003) during 1997 and 1998. TP assessment categories were based on the 25th and 75th percentile concentrations measured throughout the mid-Atlantic region. These categories are:

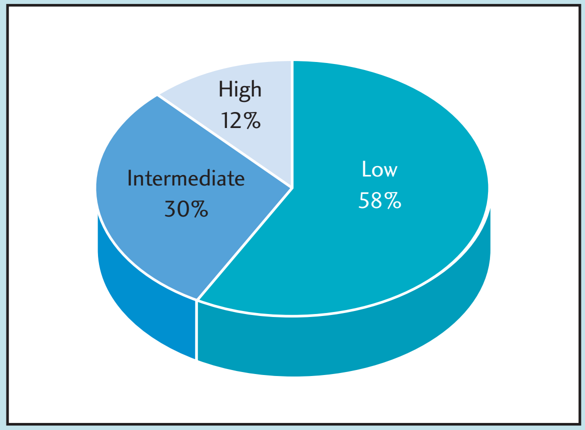
- Low: <0.05 to 0.1 ppm
- Intermediate: 0.05 to 0.1 ppm
- High: >0.1 ppm

What the Data Show

Analysis of the data showed that:

- TP concentrations in mid-Atlantic estuaries ranged from 0 to 0.34 ppm.
- For the mid-Atlantic region, about 58 percent of the estuarine area had low TP concentrations, 30 percent had intermediate TP concentrations, and 12 percent had high TP concentrations (Exhibit 2- 23).
- About 85 percent of the mainstem area of Chesapeake Bay had low TP concentration with no areas having high TP concentrations.
- The coastal bays, in contrast, had no areas with low TP concentrations and about 35 percent with high TP concentrations.
- The Delaware River estuary portion of Delaware Bay had 100 percent of its area with high TP concentrations.

Exhibit 2-23: Extent of Mid-Atlantic estuaries with low, intermediate, and high total phosphorus concentrations, 1997-1998



Source: EPA, Office of Research and Development. *Mid-Atlantic Integrated Assessment, MAIA - Estuaries 1997-98, Summary Report.* May 2003.

Indicator Gaps and Limitations

These TP estimations apply only to estuaries of the mid-Atlantic region and cannot be used to make national estimates of phosphorus concentrations.

Data Source

Data for this indicator came from EPA's Environmental Monitoring and Assessment Program, Mid-Atlantic Integrated Assessment (MAIA) Estuaries Program. (See Appendix B, page B-14, for more information.)

2.2.4.c Chemical Contaminant Pressures

The waters of our rivers, lakes, and oceans have been contaminated by pollutants. Some of these pollutants, such as the pesticide DDT and the industrial chemicals known as PCBs, were released into the environment long ago. The use of DDT and PCBs in the U.S. was banned in the 1970s, but these chemicals persist for many years. Other contaminants enter our waters every day. Some flow directly from industrial and municipal waste dischargers, while others come from non-point source pollution in urban and agricultural areas. Additionally, other contaminants are carried through the air and eventually are deposited on lands and in lakes and streams far from the facilities that produced them. When this happens, sediments in waterbodies may serve as a reservoir for these contaminants and, ultimately, as a source of contamination.

The USGS has compiled contaminant data for waterbodies as part of its National Water Quality Assessment Program. Gilliom, et al. (2002) summarized some of major NAWQA findings as follows:

- Detectable concentrations of pesticides were widespread in agricultural area streams. DDT was the most commonly detected organochlorine compound, followed by dieldrin and chlordane.
- Water in urban areas has a characteristic "signature" that is reflective of the chemicals used in the watersheds. Insecticides—such as diazinon, carbaryl, cholorpyrifos, and malathion—were detected more frequently and usually at higher concentrations in urban streams than in agricultural streams.
- Concentrations of selected trace elements, such as cadmium, lead, zinc, and mercury, are elevated above background levels in heavily populated urban settings.
- Volatile organic compounds (VOCs), which are used in plastics, cleaning solvents, gasoline, and industrial operations, are prevalent in shallow urban ground water.

Eight indicators have been chosen to describe chemical contaminant pressures on water resources:

- Atmospheric deposition of mercury.
- Chemical contamination in streams and ground water.
- Pesticides in farmland streams and ground water.
- Acid sensitivity in lakes and streams.
- Toxic releases to water of mercury, dioxin, lead, PCBs, and persistent bioaccumulative toxic chemicals (PBTs).
- Sediment contamination of inland waters.
- Sediment contamination of coastal waters.
- Sediment toxicity in estuaries.

Mercury contamination of waters and sediments is one of the leading causes of closed fisheries and fish consumption advisories in the U.S. (see Section 2.5). Atmospheric deposition in the Great Lakes and northeastern area of the U.S. is the primary source of this contaminant. Discharges to waterways as indicated by data from EPA's Toxics Release Inventory (TRI) are a relatively small source of mercury contamination.

The EPA National Sediment Inventory (NSI) has extensively reviewed sediment quality data collected predominantly from sampling programs targeted at sites of known contamination (see <*http://www.epa.gov/waterscience/basins/metadata/nsi.htm*>). NSI classifies these sites as demonstrating, by association or otherwise, probable biological effects related to the contamination. Not surprisingly, the most contaminated watersheds are found in the Great Lakes region and northeast corridor in areas of dense populations and industrial development. Data show that a small proportion (1 percent or less) of the sampled estuarine areas of the eastern U.S. and Gulf of Mexico coasts contain chemicals at concentrations high enough to be associated with biological effects.

Indicator — Atmospheric deposition of mercury - Category 2

The primary sources of mercury emissions on a national level are coal-fired power plants (33 percent), municipal waste incinerators (18 percent), and medical waste incinerators (10 percent) (EPA, OW, December 1997). Coal-fired power plants produce mercury by burning coal, which contains trace amounts of mercury that are released during combustion. Incinerators emit mercury when they burn wastes containing mercury. For medical waste incinerators, mercury waste comes from medical devices like thermometers and blood pressure cuffs. For municipal waste incinerators, mercury comes from discarded appliances, such as thermostats and fluorescent lights and lamps.

Mercury deposition was estimated from measurements made by the Mercury Deposition Network (MDN), which is part of the National Atmospheric Deposition Program. Precipitation samples were collected weekly and analyzed for total mercury and methylmercury. The MDN began a transition network of 13 sites in 1995 and, in the next year, became an official network in the NADP with 26 sites. During 2000, more than 50 sites were in operation.

Indicator **Atmospheric deposition of mercury - Category 2 (continued)**

What the Data Show

Estimates of annual mercury wet deposition in 2001 are presented in Exhibit 2-24. Mercury deposition ranges from a low of 2.4 micrograms per square meter (µg/m²) measured at a California site to over 14 µg/m² at sites in eastern Texas, south Florida, and eastern Wisconsin. The Great Lakes and southeastern states are those most greatly affected by mercury deposition.

Indicator Gaps and Limitations

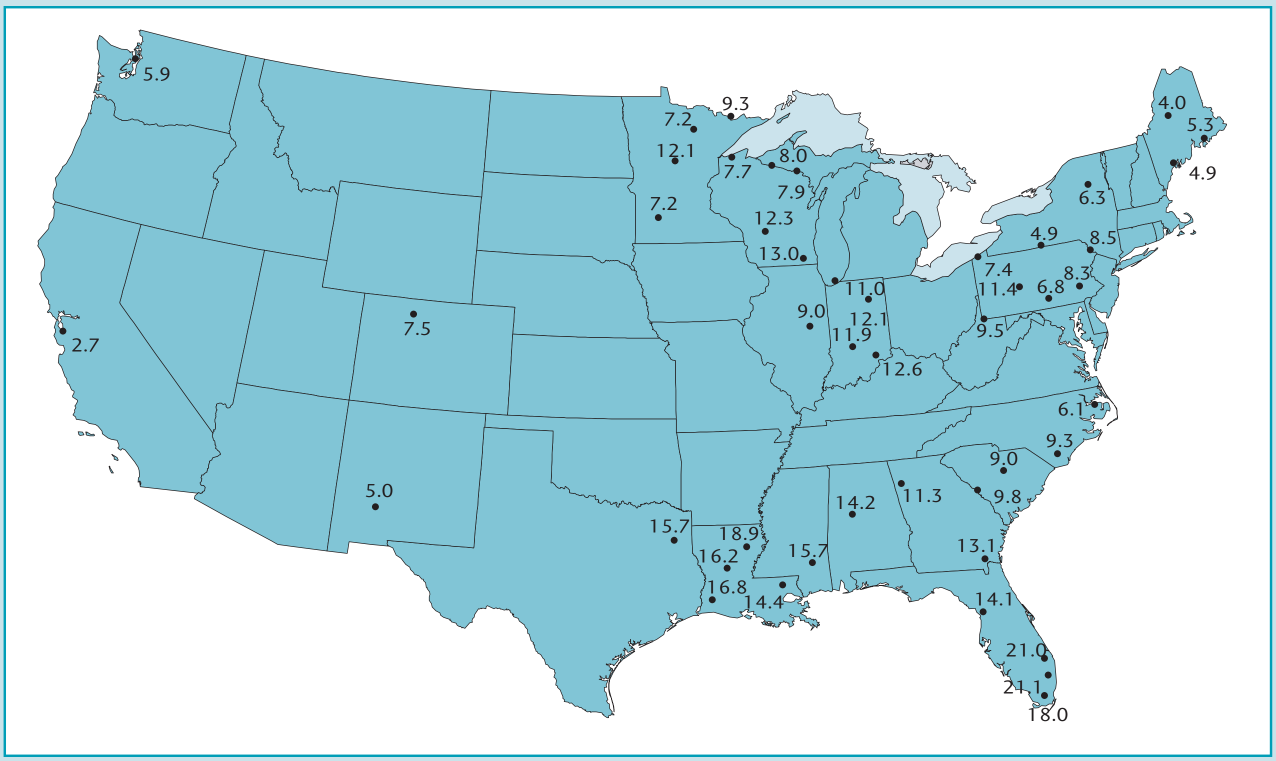
Limitations for this indicator include:

- The spatial coverage provided by the Mercury Deposition Network is somewhat limited, though the measurement sites have been distributed relative to major mercury emission sources.
- Only wet deposition of mercury was measured.

Data Source

The interagency National Atmospheric Deposition Program served as the data source for this indicator. (See Appendix B, page B-14, for more information.)

Exhibit 2-24: Annual mercury wet deposition in 2001 per square meter (µg/m²)



Note: Coverage does include Alaska, Hawaii, or Puerto Rico

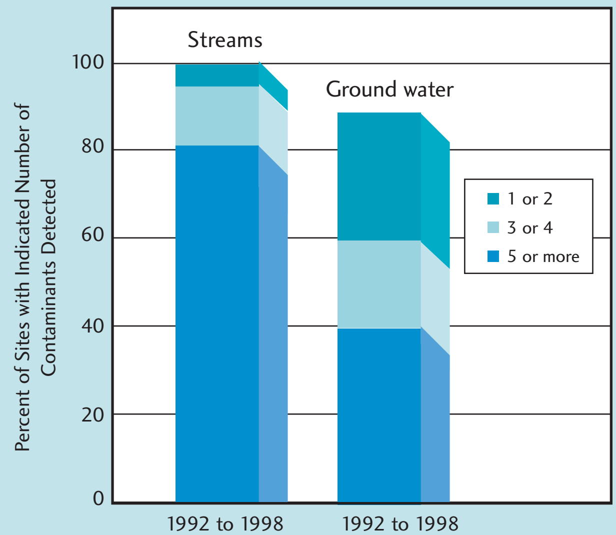
Source: National Atmospheric Deposition Program, Mercury Deposition Network. 2001. March 25, 2003; (*http://nadp.sws.uiuc.edu/mdn/maps/2001/01MDNdepo.pdf*).

Indicator Chemical contamination in streams and ground water - Category 2

The U.S. Geological Survey reported on contaminants in stream waters and streambed sediment for the entire U.S. (see The Heinz Center, 2002). The contaminants reported include many pesticides, selected pesticide degradation products, PCBs, polyaromatic hydrocarbons (PAHs), volatile organic compounds, other industrial contaminants, and trace elements. In sufficient concentrations, any of these chemicals can harm wildlife, but for many of these compounds, there are no standards or guidelines for acceptable levels in aquatic systems.

In the USGS analysis, water contaminant data were derived from 36 major river basins, which included 109 stream sites with data sufficient to calculate annual averages. Stream water samples generally were collected on 20 to 40 occasions over a one-year period (Gilliom, et al., 2002) during 1992 to 1998. Ground water data were collected from 3,549 wells in these major river basins and aquifers.

Exhibit 2-25: Occurrence of contaminants in streams and ground water, 1992-1998



Coverage: lower 48 states.

Source: The Heinz Center. *The State of the Nation's Ecosystems.* 2002. Data from the U.S. Geological Survey.

What the Data Show

All stream waters averaged one or more contaminants at detectable levels throughout the year. More than 80 percent averaged five or more (Exhibit 2-25). About 90 percent of ground water sites averaged one or more detectable contaminants. 40 percent contained five or more contaminants.

Indicator Gaps and Limitations

The sites sampled are representative of a wide range of stream sizes, types, and land uses broadly distributed across the U.S. (Gilliom, et al., 2002; The Heinz Center, 2002).

Data Source

Date for this indicator came from U.S. Geological Survey, as compiled for The Heinz Center (2002). (See Appendix B, page B-15, for more information.)

Indicator Pesticides in farmland streams and ground water - Category 2

Nearly one billion pounds of pesticides are used in the U.S. each year to control weeds, insects, and other organisms that threaten or undermine human activities such as agriculture. The vast majority of pesticides—about 80 percent—are used for agricultural purposes. Although pesticide use has resulted in increased crop production and other benefits, it has also raised concerns about potential adverse effects on the environment and human health. Pesticide contamination of streams, rivers, lakes, reservoirs, coastal areas, and ground water may cause unintended adverse effects. These water resources support aquatic life and related food chains and are used for recreation, drinking water, irrigation, and many other purposes. In addition, water is one of the primary pathways by which pesticides are transported from their application areas to other parts of the environment.

Indicator Pesticides in farmland streams and ground water - Category 2 (continued)

From 1992 to 1998, the USGS, under its National Water Quality Assessment Program, conducted the largest data collection effort ever performed for pesticides (including insecticides and herbicides) in ground and surface waters. This effort involved analysis for 76 pesticides and seven selected pesticide degradation products in 8,200 samples of ground water/surface water in 20 of the nation's major hydrologic basins. Sampling sites included streams and ground water in both agricultural areas and urban areas.

What the Data Show

In all streams, at least one pesticide was present at detectable levels throughout the year. Data were analyzed separately for agricultural and urban areas:

- *Agricultural areas.* About 75 percent of monitored farmland streams had an average of five or more pesticides at detectable levels, and over 80 percent had at least one pesticide that exceeded aquatic life guidelines. About 60 percent of ground water sites in agricultural areas had a least one detectable pesticide, and seven percent had an average of five or more compounds at detectable levels. A very small proportion (less than one percent) of ground water sites in farmland areas had one or more pesticides in concentrations that exceeded human health standards or guidelines (The Heinz Center, 2002). A relatively small number of these chemicals—specifically the herbicides atrazine (and its breakdown product desethylatrazine), metolachlor, cyanazine, and alachlor—accounted for most detections in ground water. The high detection frequency for these pesticides is related to their use. All are among the top five herbicides used in agriculture across the nation (Gilliom, et al., 2002).
- *Urban areas.* Water in urban areas has a characteristic "signature" that is reflective of the chemicals used in the watersheds serving those areas. Insecticides such as diazinon, carbaryl, chlorpyrifos, and malathion were detected more frequently, and usually at higher concentrations, in urban streams than in agricultural streams. Herbicides were detected in 99 percent of urban stream samples and in more than 50 percent of sampled wells. The most common herbicides in urban streams and ground water were simazine and prometon.

Frequency of detection, expressed as a percentage of pesticides in water samples, serves as a basic indicator (Exhibit 2-26):

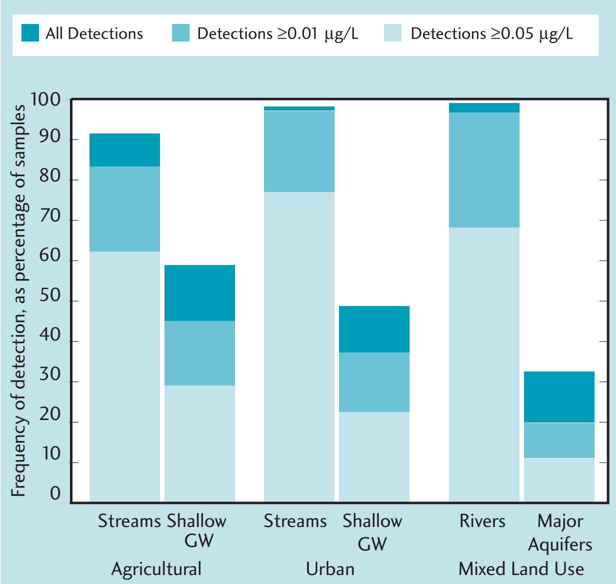
- *Streams*. The data suggest that pesticides are fairly ubiquitous in both farmland and urban streams and rivers. As noted above, at least one pesticide was present at detectable levels throughout the year in all monitored streams. Most pesticide detections were found in rivers associated with mixed land uses, followed by streams associated with urban land use, then streams associated with agricultural land uses.
- *Ground water*. Significantly fewer detections of pesticides were found in shallow ground water, and the least detections were found in major aquifers.

For the 21 most detected pesticides, data suggest that their occurrence, in both streams and ground water, closely mirrors their use. Surprisingly, pesticides were detected as frequently, or sometimes more frequently, in urban streams than in streams associated with agricultural lands. The NAWQA data indicate that, in urban and agricultural streams and shallow ground water, pesticides most often occur in mixtures (i.e., more than one compound is present in the sample). The human health and environmental impacts of pesticide contamination, particularly when the pesticides occur as mixtures, are not well understood.

Data Gaps and Limitations

Knowing how many pesticides are detected and at what concentrations provides basic information on the extent to which these compounds are found in streams and ground water. However, the presences of pesticides does not necessarily mean that the levels

Exhibit 2-26: Summary of detections of one or more pesticides in streams and ground water, 1992-1998



Coverage: lower 48 states

Source: Modified from The Heinz Center. *The State of the Nation's Ecosystems.* 2002. Data from the U.S. Geological Survey.

Indicator Pesticides in farmland streams and ground water - Category 2 (continued)

are high enough to cause problems. Comparison to standards and guidelines provides a useful reference to help judge the significance of contamination.

Drinking water standards or guidelines do not exist for 43 percent (33 of 76) of the pesticides analyzed, and aquatic life guidelines do not exist for 63 percent (48 of 76) of the pesticides analyzed. Current standards and guidelines do not account for mixtures of chemicals and seasonal pulses of high concentrations. In addition, potential effects on reproductive, nervous, and immune systems, as well as on chemically sensitive individuals, are not yet well understood.

Data Sources

The data sources for this indicator were The U.S. Geological Survey's National Water Quality Assessment Program, as compiled for The Heinz Center (2002), and The EPA's Office of Prevention, Pesticides, and Toxic Substances.(See Appendix B, page B-15, for more information.)

Indicator Acid sensitivity in lakes and streams - Category 2

Airborne nitrogen and sulfur gases (i.e., nitrogen oxides and sulfur oxides) are referred to as acid precursors because they react with water, oxygen, and other compounds to form sulfuric acid and nitric acid. For example:

- They combine with water vapor and oxygen in the atmosphere to form acids that fall to earth as a component of snow, fog, dry particles, gases, or acid rain.
- When they reach a waterbody through dry deposition, they combine with surface water to form nitric acid and sulfuric acid.
- Indirect deposition can occur when these precursors are deposited on land and then washed into a waterbody by storm water runoff. The effects of indirect deposition are particularly serious if the storm deposits acid rain.

Acidification is common in waterbodies in the eastern U.S., where weather patterns deposit acids made from air pollutants generated in the Midwest and points further west. Also, many eastern waterbodies are naturally acidic, making them more susceptible to the effects of acid deposition because their underlying soils and rock are not able to buffer incoming acids. This is particularly true for many lakes in the Adirondack Park, located in upstate New York.

Acidification affects ecosystems in many ways. For example:

- Aquatic organisms in acidified waters often suffer from calcium deficiencies that can weaken bones and exoskeletons and can cause eggs to be weak or brittle.
- It affects the permeability of fish membranes and, particularly, the ability of gills to take in oxygen from water.
- Increasing amounts of acid in a waterbody change the mobility of certain trace metals like aluminum, cadmium, manganese, iron, arsenic, and mercury. Species that are sensitive to these metals, particularly fish, can suffer as a result.

Acid sensitivity in lakes and streams is determined based on a suite of chemical measurements, including pH, conductivity, dissolved organic carbon (DOC), cations, anions, and acid-neutralizing capacity (ANC). Using data for these parameters, it is possible to distinguish, on a national scale, natural sources of acidity such as wetlands, from anthropogenic sources such as acid deposition and mine drainage (Baker, et al., 1991). For example, in low pH waters:

- High conductivity and high sulfate concentrations indicate acid-mine drainage.
- High DOC concentrations with low conductivity indicate acid contributions from wetlands.
- Low conductivity, moderate sulfate concentrations, and low DOC concentrations indicate acid deposition.

What the Data Show

EPA's 1984 to 1986 National Surface Water Survey (NSWS) estimated that, in acid-sensitive regions of the northern and eastern

Indicator Acid sensitivity in lakes and streams - Category 2 (continued)

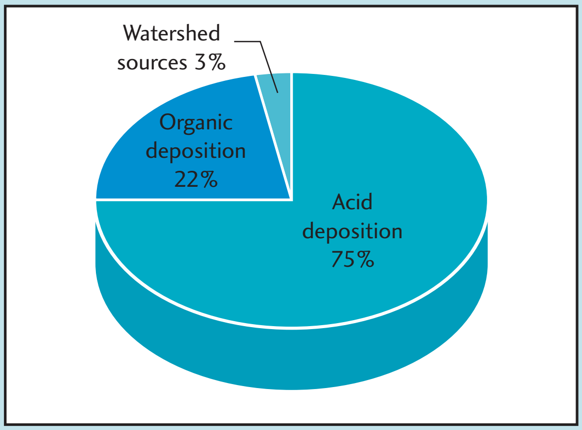
U.S., 4.2 percent of lakes and 2.7 percent of streams were acidic. Of those acidic lakes and streams, 75 percent were acidic due to acid deposition, 22 percent were acidic due to organic sources, and three percent were acidic due to acid-mine drainage (Exhibit 2-27).

These surveys have been repeated periodically for smaller probability samples of lakes in the Northeast, the Adirondacks and streams in the Appalachians (Stoddard, et al., 1996). More intensive monitoring also has been conducted on lakes in the Northeast, the Appalachians, and the Midwest, and on streams in the Appalachian Plateau and Blue Ridge to assess long-term acidification trends (Stoddard, et al., 1998). Based on these programs, EPA estimated that in three regions, one-quarter to one-third of lakes and streams previously affected by acid rain were no longer acidic, although they were still highly sensitive to future changes in deposition (EPA, ORD, January 2003). EPA has concluded that the decrease in acidity is a result of reduced sulfate emissions under its acid rain programs. Specifically:

- Eight percent of lakes in the Adirondacks are currently acidic, down from 13 percent in the early 1990s.
- Less than two percent of lakes in the upper Midwest are currently acidic, down from three percent in the early 1980s.
- Nine percent of the stream length in the northern Appalachian plateau region is currently acidic, down from 12 percent in the early 1990s.

Lakes in New England did not show decreases in acidity, and streams in the Ridge and Blue Ridge regions of Virginia were unchanged. Even though acid deposition has been decreasing in the Ridge and Blue Ridge regions, waterbodies in these areas are expected to show a lag time in their recovery due to the nature of the soils in those regions. Immediate responses to decreasing deposition were neither seen nor expected in these two regions.

Exhibit 2-27: Sources of acidity in acid-sensitive lakes and streams, 1984-1986



Coverage: Acid sensitive regions of the United States north and east, inclusive of the upper midwest, New England, Adirondack Mountains in New York, the northern Appalachian Plateau, and the Ridge and Blue Ridge Provinces of Virginia

Source: Baker et al. *Acid Lakes and Streams in the United States: The Role of Acidic Deposition.* (1991).

Indicator Gaps and Limitations

The NSWS has not been repeated nationwide since the mid-1980s, so there are no data to assess trends in surface water acidification in other sensitive areas of the country.

Data Source

The data source for this indicator was EPA's National Surface Water Survey. (See Appendix B, page B-15, for more information.)

Indicator: Toxic releases to water of mercury, dioxin, lead, PCBs, and PBTs - Category 2

The Toxics Release Inventory (TRI) contains information on toxic chemical releases and other waste management activities reported annually by certain industries as well as by federal facilities. This inventory was established under the Emergency Planning and Community Right-to-Know Act of 1986 (EPCRA), which requires facilities to use their best readily available data to calculate their releases and other waste management estimates. This indicator is based on reported TRI releases of mercury, dioxins, PCBs, sum of all persistent bioaccumulative toxic chemicals (PBTs), and lead to water in calendar year 2000 (EPA, OEI, May 2002).

PBT chemicals include dioxins, mercury, PCBs, PAHs, and pesticides (but not lead). PBT pollutants are chemicals that are toxic, persist in the environment, and bioaccumulate in food chains, thus posing risks to human health and ecosystems. They transfer easily across and among ecological systems.

Under EPCRA, most dischargers must report releases of toxic chemicals. Specifically, a facility must report to TRI if it meets all of the following criteria:

- Conducts manufacturing operations within Standard Industrial Classification (SIC) codes 20 through 39 or, beginning in the 1998 reporting year, is in one of the following industry categories: metal mining, coal mining, electric utilities that combust coal and/or oil, chemical wholesale distributors, petroleum terminals, bulk storage facilities, Resource Conservation and Recovery Act (RCRA) subtitle C hazardous waste treatment and disposal facilities, and solvent recovery services. Also, federal facilities must report to TRI regardless of their SIC code classification.
- Has 10 or more full-time employee equivalents.
- For all but certain PBT chemicals, manufacturers or processes more than 25,000 pounds or otherwise uses more than 10,000 pounds of any listed chemical during the calendar year.

What the Data Show

During 2000, facilities reporting to the TRI released over 7 billion pounds of chemicals (EPA, OEI, May 2002). Of that total, nearly 261 million pounds (3.7 percent) were discharged to water, including 21,318 pounds of PBTs, 29 pounds of PCBs, 5 pounds of dioxin compounds, and 2,302 pounds of mercury compounds. (Note that the total for PBTs includes all PBT compounds reported under TRI. Total releases for specific types of PBT compounds, such as PCBs and mercury compounds, are also aggregated and reported separately.)

Indicator Gaps and Limitations

The TRI data have several limitations:

- The TRI program only accounts for direct releases to water (i.e., it does not include releases from non-point sources). However, it does identify releases of metal and metal compounds from publicly owned treatment works (POTWs).
- It does not include releases below the reporting thresholds.
- Reporting is made by the releasing facilities, and no standard estimation procedure is employed (see Chapter 3–Better Protected Land).

Data Source

The data source for this indicator is EPA's Toxics Release Inventory program. (See Appendix B, page B-15, for more information.)

Indicator Sediment contamination of inland waters - Category 2

Contaminated sediments generally have localized impacts, with the severity of impact depending on the degree of chemical contamination. Contaminated sediments affect benthic organisms, such as worms, crustaceans, and insect larvae that inhabit the bottom of waterbodies. In some cases, toxic sediments kill these benthic organisms, reducing the food available to larger animals such as fish. Also, some contaminants in sediments may be taken up by benthic organisms and passed onto larger animals that feed on these contaminated organisms. In this way, toxins in sediment move up the food chain in increasing concentrations. As a result, fish and shellfish, waterfowl, and fresh water and marine animals, as well as benthic organisms, may be affected by contaminated sediments.

As part of EPA's National Sediment Inventory (described in the introduction to Section 2.2.4c), sediment chemical concentrations were evaluated in over 19,000 samples in the U.S. and categorized into three groups:

- Tier 1 (associated adverse effects on aquatic life or human health are probable).
- Tier 2 (associated adverse effects on aquatic life or human health are possible).
- Tier 3 (no indication of associated adverse effects on aquatic life or human health).

Tier 1 sampling stations were distinguished from Tier 2 sampling stations based on the magnitude of a contaminant concentration in sediment, or the degree of corroboration among the different types of sediment quality measures.

What the Data Show

Of the sampling stations evaluated, 8,348 stations (43 percent) were classified as Tier 1, 5,846 (30.1 percent) were classified as Tier 2, and 5,204 (26.8 percent) were classified as Tier 3. The sampling stations were located in 5,695 individual river reaches (or waterbody segments) across the conterminous U.S., which constitute approximately 8.8 percent of all river reaches in the country (based on EPA's River Reach File 1).

- Approximately 3.6 percent of all river reaches in the conterminous U.S. had at least one station categorized as Tier 1.
- Approximately 3 percent of reaches had at least one station categorized as Tier 2 (but none as Tier 1).
- In about 2.3 percent of reaches, all of the sampling stations were classified as Tier 3.

In the National Sediment Inventory, watersheds (8-digit HUC) containing areas of probable concern (APCs) for sediment contamination were defined as those that include at least 10 Tier 1 sampling stations and in which at least 75 percent of all sampling stations were classified as either Tier 1 or Tier 2. APC designation could result from extensive sampling throughout a watershed, or from intensive sampling at a single contaminated location or a few contaminated locations.

Analysis of survey data showed that:

- Ninety-six eight-digit HUC watersheds were identified as containing APCs (Exhibit 2-28).
- These watersheds represent about 4.2 percent of all eight-digit HUC watersheds in the U.S. (96 of 2,264).
- In many of these watersheds, contaminated areas may be concentrated in specific river reaches in the watershed. For example, within the 96 watersheds containing APCs across the country, 97 individual river reaches or waterbody segments have 10 or more Tier 1 sampling stations.
- Twenty-four percent of reaches in watersheds (eight-digit HUC) containing APCs have at least one Tier 1 sampling station and 18.3 percent have no Tier 1 sampling station but at least one Tier 2 sampling station.

The evaluation results indicate that sediment contamination associated with probable or possible adverse effects for both aquatic life and human health exists in a number of watersheds across the country.

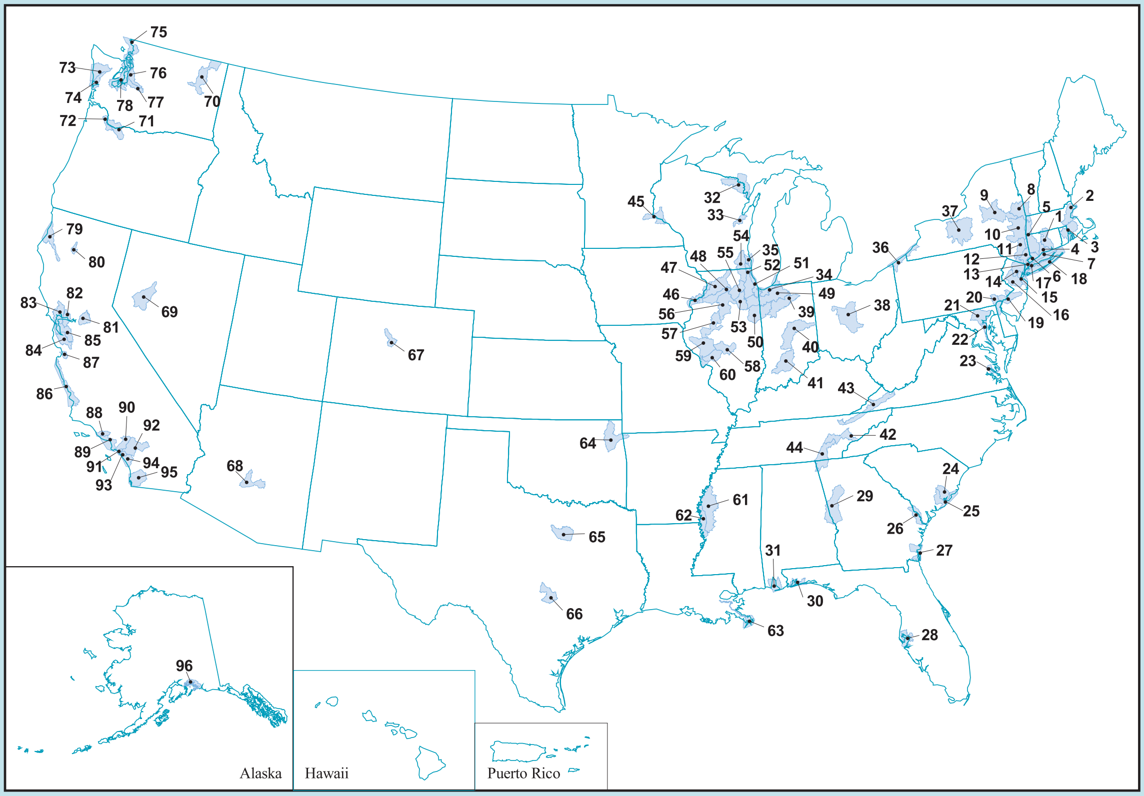
Indicator Gaps and Limitations

Two general types of limitations are associated with the National Sediment Inventory:

- *Limitations of the compiled data.* These limitations include the mixture of data sets derived from different sampling strategies, incomplete sampling coverage of geographic regions and monitored chemicals, the age and quality of the data, and the lack of measurements of important assessment parameters, such as TOC and acid volatile sulfide.
- *Limitations of the evaluation approach.* These include uncertainties in the interpretive tools used to assess the sediment quality, use of assumed exposure potential in screening-level quantitative risk assessment (e.g., fish consumption rates as a surrogate for human health risk), and the subsequent difficulties in interpreting assessment results. Also, because this analysis is based only on readily electronically formatted data, the survey does not include a vast amount of information available from sources such as local and state governments and published academic studies.

Indicator | Sediment contamination of inland waters - Category 2 (continued)

Exhibit 2-28: Watersheds in sediment quality inventory (1980-1999) identified as containing areas of particular concern (APCs)



Source: EPA, Office of Water. *The Incidence and Severity of Sediment Contamination in Surface Waters of the United States, National Sediment Quality Survey: Second Edition, Draft*. December, 2001.

Another key limitation is that most of the NSI data were compiled from monitoring programs that focus their sampling efforts on areas where contamination is known or suspected to occur. While this is important for meeting the stated objective of the NSI survey, which is to identify contaminated sediments, it means that the data cannot be used to accurately characterize the overall condition of the nation's sediment, because national sampling coverage is incomplete and because uncontaminated areas are most likely substantially under-represented. In addition, the data analyzed for this indicator were collected over a relatively long time period; therefore, they do not definitively assess the current condition of sediments, but can serve as a baseline for future assessments.

Data Source

The data are described in Appendix A of the draft report *The Incidence and Severity of Sediment Contamination in Surface Waters of the U.S., National Sediment Quality Survey;* second edition (EPA-822-R-01-01). A draft is available. The final report is expected to be released in 2003. Summary reports on the data are not available. (See Appendix B, page B-15, for more information).

Indicator Sediment contamination of coastal waters - Category 2

Estuaries are important habitats for migratory birds, and many species of fish and shellfish rely on the sheltered waters of estuaries as protected places to spawn. Contamination of sediments in estuaries can pose a threat to individual species and to estuarine ecosystems.

Contaminated sediments may harm benthic organisms that feed on these sediments, and they may accumulate up the food chain as larger organisms feed on smaller organisms, eventually posing a risk to human health. Additionally, contaminants in sediments may be resuspended into the water by dredging and boating activities.

One of the challenges of assessing sediment contamination is distinguishing among naturally occurring contaminants, such as certain organics and metals, from those created by human activities. PAHs and metals occur naturally in estuarine sediments, so a special approach must be used to determine how much of their concentrations in sediment are contributed by human sources (Windom, et al., 1989). On the other hand, pesticides and PCBs are relatively easy to evaluate, as they can only come from human activities.

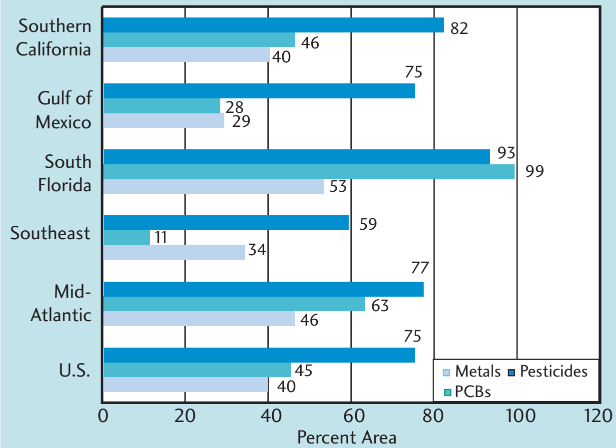
Under the EPA's Environmental Monitoring and Assessment Program (EMAP), contamination was measured for sediments from estuaries in the Virginian, Carolinian, and Louisianian Provinces of the eastern U.S. Chemical concentrations were identified as enriched by human sources if they exceeded values expected to occur naturally. Sediment chemical concentrations also were compared to NOAA-derived effects range low (ERL) values and effects range median (ERM) values. These values identify threshold concentrations that, if exceeded, are expected to produce ecological or biological effects 10 percent and 50 percent of the time, respectively. A site was considered contaminated if five or more chemical concentrations exceeded the ERL, or if one or more exceeded the ERM.

What the Data Show

Sediment contaminant concentrations indicate that 40 percent, 45 percent, and 75 percent of U.S. estuarine sediments that were sampled are enriched with metals from human sources, PCBs, and pesticides, respectively (Exhibit 2-29).

One to two percent of estuarine sediments show concentrations of contaminants (PAHs, PCBs, pesticides, and metals) that are above ERM values (Exhibit 2-30). Between 10 and 29 percent of sediments have contaminant concentrations between the ERM values and lower-level ERL values (Exhibit 2-30). Most of the locations exceeding the ERM guidelines are in the northeast coastal area, while the Gulf of Mexico coast contains many locations where concentrations of five or more contaminants exceed the ERL values. The highest contamination is found in the Northeast. Estuaries most affected are: Hudson River-New York, New Jersey Harbor system; eastern Long Island Sound; Delaware River; Potomac River; and upper Chesapeake Bay.

Exhibit 2-29: Regional sediment enrichment (1990-1997) due to human sources



Source: EPA, Office of Research and Development and Office of Water. *National Coastal Condition Report.* September 2001.

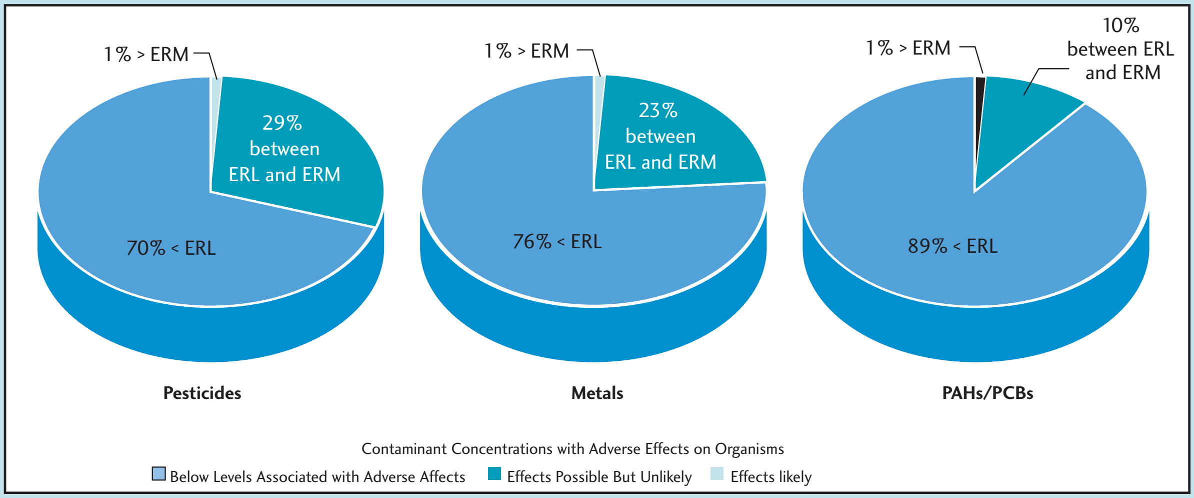
Indicator Gaps and Limitations

Several limitations are associated with this indicator:

- Assessment of contamination is limited to the three provinces noted above. Probabilistic assessments of coastal waters of the Great Lakes, West Coast, and northern New England do not exist, so this indicator does not include data for these regions.
- The sampling design did not proportionately represent shallow habitats (less than 3 meters), which may represent as much as 50 percent of the total estuarine area in the Southeast and Gulf of Mexico.
- While the data currently are adequate to address regional condition, they provide little information on gradients from major sources of contamination (e.g., large urban areas).
- Many factors control availability of contaminants in sediments, including organic content, acid volatile sulfides, pH, particle size and type, and the specific form of chemical (e.g., chromium). Therefore, sediment chemical concentrations, in and of themselves, do not directly estimate the biological availability of those contaminants.

Indicator Sediment contamination of coastal waters - Category 2 (continued)

Exhibit 2-30: Distribution of sediment contaminant concentrations in sampled estuarine sites, 1990 – 1997



Coverage: United States east coast (excluding waters north of Cape Cod) and Gulf of Mexico

Source: EPA, Office of Research and Development and Office of Water. *National Coastal Condition Report.* September 2001.

- The scientific basis for the ERL/ERM criteria may vary among estuaries, habitats, and regions depending upon the kinds and abundances of indigenous biota.
- Sediment contamination is not directly related to the biological availability of contaminants in sediments. Bioavailability of contaminants in sediments can be directly measured by sediment toxicity testing, which forms the basis for the next indicator discussed, "sediment toxicity in estuaries."

Data Source

Sediment contamination data are from the EPA's Environmental Monitoring and Assessment Program Estuaries dataset. (See Appendix B, page B-16, for more information.)

Indicator Sediment toxicity in estuaries - Category 2

Many factors control the biological availability of contaminants in sediments, including acid volatile sulfides, pH, particle size and type, organic content, resuspension potential, and specific species/form of contaminant (e.g., chromium). Sediment toxicity tests are the most direct current measure for determining the bioavailability of contaminants in sediments. These tests provide information that is independent of chemical characterization and ecological surveys (Chapman, et al., 1987). They improve upon the direct measure of contaminants in sediments (the basis for the previous indicator "sediment contamination of coastal waters"), because many contaminants are tightly bound to sediment particles or are chemically complex and are not biologically available. Thus, the presence of contaminants in sediments does not necessarily mean that the sediments are toxic.

To assess bioavailability of sediment contaminants in estuaries, the EPA's EMAP Estuaries Program, in conjunction with the NOAA Status and Trends Program, conducted sediment toxicity tests on estuarine sediments.

What the Data Show

The EPA's EMAP Estuaries Program found that about 10 percent of the sediments in estuaries in the Virginian, Carolinian, Louisianian, West Indian, and Californian Provinces were toxic to

Indicator Sediment toxicity in estuaries - Category 2 (continued)

the marine amphipod, *Ampelisca abdita,* over a 10-day period (EPA, ORD, OW, September 2001). The NOAA Status and Trends Program also used a sea urchin fertility test and a microbial test to evaluate chronic toxicity in selected estuaries, NOAA found that 43 to 62 percent of the sediment samples from these selected estuaries showed chronic toxicity.

Indicator Gaps and Limitations

Sediment toxicity tests are a useful tool to establish the potential availability of contaminants in sediments. That availability can, however, be affected by artifacts of laboratory procedures that may make contaminants more or less available. Also, natural sediment features such as particle size and the presence of ammonia and sulfides may cause toxicity that is not related to the presence of contaminants.

Data Sources

Data for this indicator came from EPA's Environmental Monitoring and Assessment Program, Estuaries Program to Estuaries Dataset, and the National Oceanic and Atmospheric Administration's Status and Trends Program. (See Appendix B, page B-16, for more information.)

2.2.5 What ecological effects are associated with impaired waters?

No single program examines the ecological condition of our nation's surface waters. However, a number of regional programs do track the biotic condition of aquatic organisms and attempt to relate degradations in their condition to observed pressures on aquatic systems. Biotic condition does not fully represent the breadth of ecological parameters that ideally would be needed to answer the question, "What are the ecological effects of impaired waters?" However, biological condition is widely acknowledged as a valuable indicator that contributes to an understanding of overall ecological condition.

There are several measures of biotic condition; three were selected for this report:

- Fish index of biotic integrity (IBI) in streams.
- Macroinvertebrate IBI for streams.
- Benthic community index (coastal waters).

These indicators are discussed in detail in Chapter 5, Ecological Condition. As they are relevant to water quality, they are briefly summarized below to demonstrate their effectiveness for future national assessments.

Fish and Macroinvertebrate Indices of Biotic Integrity

Consistent sampling methods and index development procedures were used to measure the biotic integrity of fish and benthos in streams in the Mid-Atlantic Highlands (EPA, ORD, Region 3, August 2000). The mid-Atlantic streams were assessed using both fish and benthic insect indicators. Of the stream miles assessed in the Mid-Atlantic Highlands, the fish IBI indicated that 17 percent of the streams were in good condition and 31 percent were in poor condition. The macroinvertebrate condition measures indicated that 17 percent of the Mid-Atlantic Highland streams were in good condition, while 26 percent were in poor condition. (See Chapter 5–Ecological Condition, for definitions of these categories.)

The assessment permits estimates of both the number and proportion of stream miles in good, fair, or poor condition, but it does not provide information about where these categories of streams are located. Associations of biological condition with specific stressors have not been completed. While the stressors found in the streams can be identified, it is not possible to determine which stressors are contributing to the observed biological condition.

Benthic Community Index (Coastal Waters)

Samples of bottom sediments were collected and benthic index scores were assessed for the northeast, southeast, and Gulf coastal areas. In these three areas, 56 percent of the coastal waters were assessed in good condition, 22 percent in fair condition, and 22 percent in poor condition. The work of associating biological condition with specific stressors has been completed for these coastal waters, so the stressors that co-occur with poor benthic condition can be evaluated. Of the 22 percent of the coastal areas with poor benthic condition, 62 percent also had sediment contamination, 11 percent had low dissolved oxygen concentration, seven percent had low light penetration, and two percent showed sediment toxicity (EPA, ORD, OW, September 2001).

2.3 Drinking Water

Drinking water comes from surface water and ground water. Large-scale water supply systems tend to rely on surface water resources (including rivers, lakes, and reservoirs), while smaller water systems tend to use ground water. Slightly more than half of our nation's population receives its drinking water from ground water by means of wells drilled into aquifers (USGS, 1998).

To protect human health, EPA, under the Safe Drinking Water Act (SDWA), sets health-based standards (called maximum contaminant levels, or MCLs) for contaminants in drinking water. These standards specify the maximum allowable level of each regulated contaminant in drinking water. The standards also prescribe protocols, frequencies, and locations that water suppliers must use to monitor for about 90 regulated contaminants. The SDWA standards and associated monitoring and treatment by water suppliers provide a critical barrier that serves to protect the quality of much of our nation's drinking water. Some 55,000 community water systems in the U.S. test and treat water to remove contaminants before distributing it to customers.

This section addresses three questions relevant to evaluating progress in drinking water protection:

- What is the quality of drinking water?
- What are sources of drinking water contamination?
- What human health effects are associated with drinking contaminated water?

An indicator has been developed to help answer the first of these questions (Section 2.3.1). The second and third questions are addressed in Sections 2.3.2 and 2.3.3, respectively; however, no indicators were identified to answer these questions.

2.3.1 What is the quality of drinking water?

Indicators

Population served by community water systems that meet all health-based standards

In 2002, state data reported to EPA showed that approximately 251 million people were served by community water systems that had no violations of health-based standards. This number represents 94 percent of the total population served by community water systems, up from 79 percent in 1993. Under-reporting and late reporting of violations data by states to EPA affect the accuracy of this data.

The drinking water standards set by EPA under the Safe Drinking Water Act apply to public water systems (PWSs). PWSs are systems that serve at least 25 people or 15 service connections for at least 60 days a year. They may be publicly or privately owned. PWSs include:

- *Community water systems (CWSs)*—systems that supply water to the same population year- round. There are some 55,000 community water systems in the U.S.
- *Non-transient non-community water systems*—systems that regularly supply water to at least 25 of the same people at least 6 months per year, but not year-round (e.g., schools, factories, office buildings, and hospitals that have their own water systems).
- *Transient non-community water systems*—systems that provide water in a place where people do not remain for long periods of time (e.g., a gas station or campground).

Under the 1996 Amendments to the SDWA, EPA must go through several steps to determine, first, whether setting a standard is appropriate for a particular contaminant, and if so, what the standard should be. To make these determinations, EPA considers many factors for each contaminant, including:

- Its occurrence in the environment.
- Human exposure and the risks of adverse health effects in the general population and sensitive subpopulations.
- Analytical methods of detection.
- Available technology.
- How the regulation would impact water systems and public health.

As of 2003, about 90 contaminants are regulated in drinking water under the SDWA.

Indicator Population served by community water systems that meet all health-based standards - Category 1

Under SDWA regulations, all public water systems must monitor the quality of their drinking water and report the monitoring results to their state. Using these results, states determine whether a maximum contaminant level has been violated and must report all violations of federal drinking water regulations to EPA quarterly. The indicator presents the total population across the nation that is served by community water systems that met all health-based drinking water standards.

What the Data Show

In 2002, community water systems (CWS) served 268 million people—just over 95 percent of the U.S. population as recorded in the 2000 census. Analysis of state-reported violations data shows that, in 2002, 94 percent of this population was served by systems that met all drinking water standards (i.e., did not report violations of health-based standards) for the entire year (Exhibit 2-31).

Indicator Gaps and Limitations

Under-reporting and late reporting of CWS violations data by states to EPA affect the ability to accurately report the quality of our nation's drinking water. EPA last quantified the quality of violations data in 1999. Based on this analysis, the agency estimated that states were not reporting 40 percent of all health-based violations to EPA. EPA is continuing to verify state-reported CWS data and expects to issue an updated estimate of data quality in 2003.

Data Source

The underlying database for this indicator is EPA's Safe Drinking Water Information System/Federal version. (See Appendix B, page B-16 for more information.)

Exhibit 2-31: Population served by community water systems (CWSs) with no reported violations of health-based standards, 1993-2002

Fiscal Year	Population served by CWSs that had no reported violations	Percent of CWS-served population that was served by systems with no reported violations
2002	250,596,287	94
2001	239,927,650	91
2000	239,299,701	91
1999	229,805,285	91
1998	224,808,251	89
1997	215,351,842	87
1996	213,109,672	86
1995	208,700,100	84
1994	202,626,433	83
1993	196,229,162	79

Coverage: all 50 states

Source: EPA, Office of Water. *Safe Drinking Water Information Systems/Federal version (SDWIS/FED)*. 2003.

2.3.2 What are sources of drinking water contamination?

Microbiological, chemical, and radiological contaminants can enter water supplies. These contaminants may be produced by human activity or occur naturally. For instance, chemicals can migrate from disposal sites or underground storage systems and contaminate sources of drinking water. Animal wastes, pesticides, and fertilizers may be carried to lakes and streams by rainfall runoff or snow melt. Nitrates from fertilizers can also be carried by runoff and percolate through soil to contaminate ground water. Arsenic and radon are examples of naturally occurring contaminants that may be released into ground water as it travels through rock and soil.

Human wastes from sewage and septic systems or wastes from animal feedlots and wildlife carrying microbial pathogens may get into waters ultimately used for drinking. Coliform bacteria from human and animal wastes may be found in drinking water if the water is not properly treated or disinfected. These bacteria are used as indicators that other harmful microbial pathogens, such as *Giardia, Cryptosporidium*, and *E. coli* O157:H7, might be in the water.

Disinfection of drinking water is a critical public health measure as it provides a barrier against harmful microbes. Under the SDWA, all surface water supplies, and ground water supplies with close hydrological connections to surface water must disinfect (and most must also filter) their water to remove pathogens. However, disinfectants such as chlorine react with naturally occurring organic matter in source water and in distributions systems to form chemical by-products (known as disinfection by-products) such as trihalomethanes and haloacetic acid compounds.

For systems that disinfect, water leaves the plant with a disinfectant residual. However, in some cases water could become contaminated if there is a breach in the distribution system.

2.3.3 What human health effects are associated with drinking contaminated water?

Effects of exposure to contaminants in drinking water will vary depending on many factors, including the type of contaminant, its concentration in drinking water, and how much contaminated water is consumed over what period of time.

- *Chemical contaminants.* Chemical contaminants found or expected to occur in drinking water can include metals, pesticides, and solvents. Most of these would be expected to cause no health effects at the levels found in treated drinking water, but they may cause a variety of biological responses at high doses. These could include cosmetic effects (such as skin discoloration) or unpleasant odors, as well as more severe health effects such as nervous system or organ damage, developmental or reproductive effects, or cancer. One well-studied consequence of drinking contaminated water is the formation of methemoglobin in infants drinking formula with more than 10 ppm nitrate. This altered hemoglobin does not carry oxygen efficiently; too much of it in the blood of very young children can be fatal (i.e., blue baby syndrome).
- *Pathogens.* The consequences of consuming water with pathogenic microbes can include gastrointestinal illnesses causing stomach pain, diarrhea, headache, vomiting, and fever. Waterborne pathogens can cause diseases that are less common in the U.S., such as typhoid fever and cholera, as well as more common waterborne diseases such as giardiasis or cryptosporidiosis. Pathogenic microbes can enter water from human and animal wastes. One of the largest outbreaks of disease from contaminated water occurred in Milwaukee in l993, when an estimated 400,000 people became ill from exposure to *Cryptosporidium,* a single-celled parasite that is found in the large intestines of a large number of animals, including cattle and humans. That outbreak killed more than 50 people, the vast majority of whom had seriously weakened immune systems (Hoxie, et al., 1997).

Drinking water disinfection is one of the great public health success stories of the 20th century. It has been a critical factor in reducing the incidence of waterborne diseases such as typhoid, cholera, and hepatitis, as well as gastrointestinal illness in the U.S. Though drinking water disinfection is a critical public health measure, the process does generate disinfection by-products, as mentioned earlier. These compounds have been associated with cancer, developmental, and reproductive risks, the extent of which is still uncertain (see Chapter 4–Human Health).

2.4 Recreation in and on the Water

Our nation's rivers, lakes, and oceans are used for recreation in many different ways, including swimming, fishing, and boating. Environmental programs implemented under the Clean Water Act (CWA) have significantly improved the quality of many of our nation's waters since the early 1970s. These programs help to maintain the quality of waters that have been specifically designated for recreational uses and ensure that they do not become degraded in the future. Despite this progress, recreational waters are threatened or affected by pollution at some times and in various locations. For example:

- During and following heavy rainfall, the sewer systems in some cities may become overloaded, resulting in the temporary discharge of raw sewage, wastewater, and storm water into rivers and coastal areas.
- Lakes and ponds may be affected by non-point source pollution, for example from septic tanks and agricultural sources, resulting in chemical contamination and elevated levels of nutrients.
- Industries are issued permits under the Clean Water Act that allow discharges of certain treated wastewaters to rivers and streams. These discharges compromise our ability to also use those waters for recreational purposes.

Perhaps the greatest human health concern associated with pollution of recreational waters is the potential for exposure to human pathogens. Many Americans risk illness from exposure to contaminated recreational waters. Epidemiology studies in the U.S. and abroad have consistently found an association between disease burden and contaminated waters. State and local officials monitor water quality at public beaches and close the beaches or issue advisories when monitoring indicates that pathogens in water may have exceeded thresholds for public safety. The fact that hundreds of beach advisories and closings are issued every year at recreational rivers, lakes, and coastal waters throughout the U.S. suggests that our recreational waters are significantly impacted by pollution. Three questions are posed with regard to recreational waters:

- What is the condition of waters supporting recreational use?
- What are sources of recreational water pollution?
- What human health effects are associated with recreation in contaminated waters?

An indicator has been developed to help answer the first of these three questions, at least with regard to pathogens in recreational waters. The second and third questions are addressed in Sections 2.4.2 and 2.4.3, respectively. No indicators were identified to answer these two questions. Note that concerns associated with consumption of fish and shellfish, including fish and shellfish caught through recreational activities, are discussed in Section 2.5.

2.4.1 What is the condition of waters supporting recreational use?

Indicators

Number of beach days that beaches are closed or under advisory

As described in Section 2.2.1, a number of programs collect information on the condition of waters at a national scale, including the conditions that support recreational uses of waters. However, for a variety of reasons described in Section 2.2.1, none of these programs (including the widespread CWA-mandated 305[b] state data collection and reporting program) produce data with sufficient confidence and scientific credibility to serve as a national indicator for water quality condition. Nevertheless, data from an entirely different source (state and local monitoring of water quality at beaches) can be used to help answer the question "What is the condition of surface waters that support recreational use?"—at least with respect to pathogen contamination.

When local and state officials monitor water quality at beaches, they generally test for indicator organisms, such as coliforms. Not all of these organisms are harmful themselves, but their presence generally suggests that disease-causing microorganisms are also likely to be present. When indicator organisms exceed certain thresholds, local or state officials will close the beach to the public. The number of days that beaches are closed or under advisory provides the basis for an indicator for recreational water quality with respect to pathogen contamination. This indicator reflects decisions made by state and local governments about whether pathogen levels are above their public health thresholds at beaches under their jurisdiction. Beach closure/advisory data predominantly represent coastal and Great Lakes areas. Data on inland waterways generally are not available or are not collected and reported. Thus, the question "What is the condition of surface waters that support recreational use?" can only be addressed for a portion of coastal and Great Lakes beaches on a national level at this time.

Indicator Number of beach days that beaches are closed or under advisory - Category 2

Data on beach closures are collected by EPA under the Beaches Environmental Assessment and Coastal Health (BEACH) Program. This program is authorized by Section 104 of the Clean Water Act and described in EPA's Action Plan for Beaches and Recreational Waters (EPA, ORD, OW, March 1999).

The BEACH program collects data for the National Health Protection Survey of Beaches by sending a questionnaire to managers (usually in health or environmental quality departments in states, counties, or cities) who are responsible for monitoring swimming beaches on the coasts or estuaries of the Atlantic Ocean, Pacific Ocean, and Gulf of Mexico, and the shoreline of the Great Lakes. Information on some other inland fresh water beaches has also been collected. Responses to these surveys are voluntary and have increased substantially from 159 local, state, and federal agencies reporting in 1997, to 237 agencies reporting on 2,445 beaches in 2001.

What the Data Show

Using the survey data, EPA compiles the number of days that beaches are closed or under advisory and compares that to the total number of "beach days"—i.e., days that the beaches would normally be open to the public. In 2001, survey respondents reported a total of approximately 320,000 beach days during the swimming season for the 2,445 beaches for which data were collected. These beaches were closed or under advisory on almost six percent (over 19,000) of those beach days.

Indicator Gaps and Limitations

This indicator has a number of limitations:

- Since reporting is voluntary, the data cannot be extrapolated to accurately determine the suitability on a national level of surface waters to support recreation.
- The indicator applies primarily at this time to coastal and Great Lakes beaches, as relatively few fresh water inland beaches are surveyed.
- The causes of closures vary greatly among states; therefore, linking beach closures to human health problems or stressors is difficult.
- Some reports are based upon infrequent monitoring. Infrequent monitoring could miss events that would cause closures.
- In interpreting the data, the assumption is made that the public was at minimal risk of exposure to waterborne illness on days the beach was open. However, this may not always be true.

Data Source

Data for this indicator came from EPA's National Health Protection Survey of Beaches. (See Appendix B, page B-17 for more information.)

2.4.2 What are sources of recreational water pollution?

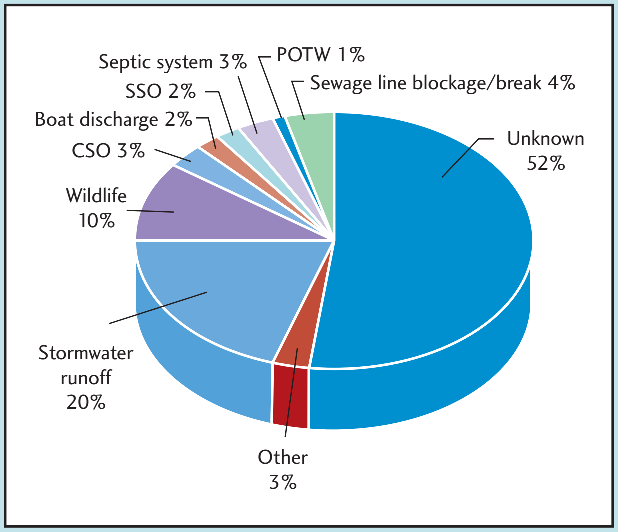
As mentioned earlier, beach advisories and closings in the U. S. are generally due to elevated levels of indicator organisms, such as coliforms, some of which do not themselves cause disease but may indicate the presence of disease-causing microorganisms. In the survey of beaches (see Section 2.4.1), respondents are asked to identify, based on best professional judgment, the sources of pollution (i.e., the indicator organisms and any associated pathogens) that caused a beach advisory or closing. Exhibit 2-32 presents the sources reported for the 2001 swimming season.

For just over half the cases, the sources were unknown. Storm water runoff was the reported cause for one-fifth (20 percent) of the beach closing or advisories. Rainfall, particularly heavy rain, creates runoff from farmland, city streets, construction sites, suburban lawns, roofs and driveways. This runoff contains harmful contaminants, including human and animal wastes, sediments, and excess nutrients. Runoff can enter waterbodies directly or via the storm water drainage system. Other reported causes of beach closings and advisories were: wildlife (10 percent), sewage line blockages and breaks (four percent), improperly functioning onsite wastewater facilities (i.e., septic systems—see Chapter 3–Better Protected Land) (three percent), combined sewer overflows (three percent), sanitary sewer overflows (two percent), boat discharges (two percent), and publicly owned treatment works (one percent). No indicators have been identified to answer the question "What are the sources of recreational water pollution?" at this time.

2.4.3 What human health effects are associated with recreation in contaminated waters?

The primary health concern associated with recreational waters is the risk of infection from waterborne pathogens. People may be at

Exhibit 2-32: Reported sources of pollution that resulted in beach closings or advisories, 2001



CSO - Combined Sewer Overflow
SSO - Sanitary Sewer Overflow
POTW - Publicly Owned Treatment Works

Source: EPA, Office of Water. *EPA's BEACH Watch Program: 2001 Swimming Season.* May 2002.

risk if they ingest or inhale contaminated water, or simply through general dermal contact with the water. Some people may be more vulnerable than others, either because they are more susceptible to infection or because they have greater exposure to the water. For example, children may be more vulnerable to environmental exposure due to their active behavior and developing immune systems. Elderly and immunosuppressed persons may also be more vulnerable.

The health effects of swimming in contaminated waters are usually minor—sore throats, ear infections, and diarrhea. In some instances, however, effects can be more serious and even fatal. Waterborne microbes can cause meningitis, encephalitis, and severe gastroenteritis (EPA, ORD, OW, March 1999). However, data on the effects and number of occurrences are limited. The number of occurrences are likely under-reported because individuals may not link common symptoms (e.g., gastrointestinal ailments, sore throats) to exposure to contaminated recreational waters. At this time, no indicators have been identified to quantify the health effects associated with recreation in contaminated waters. Additional research is needed to better understand the types and extent of health effects associated with swimming in contaminated water.

2.5 Consumption of Fish and Shellfish

Many coastal and fresh water environments are contaminated with a variety of toxic substances. Of particular concern are mercury, DDT, and PCBs because they persist in the environment and bioaccumulate in the food chain. Though PCBs and DDT are no longer manufactured or distributed in the U.S., they persist in historical deposits in watersheds and near-shore sediments. These deposits continue to provide an active source for contaminating fish and shellfish. Mercury can come from several sources, including industrial releases, abandoned mines, the burning of fossil fuels for electric power generation, and natural sources such as weathering of rock and volcanoes.

Persistent chemicals enter the food chain when they are ingested by bottom-dwelling (benthic) organisms. Benthic organisms are eaten by smaller fish, which in turn are eaten by larger fish, which may be consumed by humans or wildlife. Levels of PCBs and DDTs are a concern in bottom-feeding fish and shellfish, as well as in higher-level predators. Mercury is concentrated particularly in larger and longer-lived predators, such as large-mouth bass, tunas, swordfish, and some sharks. Concentrations of all these compounds, especially in larger fish, can reach levels that are harmful to humans. To protect human health, state and local officials monitor levels of these compounds in fish and shellfish, and issue advisories when tissue concentrations exceed threshold levels. Typically, a fish or shellfish advisory will suggest that intake of a particular species be limited, especially for those at higher risk of health effects such as children, pregnant women, and nursing mothers.

Three questions have been posed concerning consumption of fish and shellfish:

- What is the condition of waters that support consumption of fish and shellfish?
- What are contaminants in fish and shellfish, and where do they originate?
- What human health effects are associated with consuming contaminated fish and shellfish?

Sections 2.5.1, 2.5.2, and 2.5.3, respectively, discuss these questions and, where available, the indicators that are used to help answer these questions.

2.5.1 What is the condition of waters that support consumption of fish and shellfish?

Indicators

Percentage of river miles and lake acres with fish consumption advisories
Contaminants in fresh water fish
Number of watersheds exceeding health-based national water quality criteria for mercury and PCBs in fish tissue

Three indicators, presented on the following pages, are available to help answer this question:

- Percentage of river miles and lake acres with fish consumption advisories.
- Contaminants in fresh water fish.
- Number of watersheds exceeding health-based national water quality criteria for mercury and PCBs in fish tissue.

The first indicator describes the extent of fish advisories, such as closed fisheries and/or restricted fish consumption. Fish advisories are issued by state or local authorities when levels of contaminants in monitored fish exceed threshold levels. These advisories, which are widespread across the U.S., limit or restrict consumption of contaminated species. Mercury, dioxin, PCBs, DDT, and chlordane are responsible for many of these advisories (EPA, OW, May 2002a). Increases in the number of advisories over the years may reflect increased monitoring, increased contamination, and in some cases, more stringent health standards.

The second indicator examines the number of contaminants in fish tissue from samples across the nation. This indicator shows that more than 90 percent of sampled fish had at least one contaminant and more than half had at least five.

The third indicator compares average fish tissue concentrations of mercury and PCBs across watersheds to human-health based water quality criteria. This analysis showed that more than 30 percent of the watersheds for which there are data exceed mercury criteria. These watersheds are predominantly located in eastern coastal states, New England, and the lower portion of the Mississippi River watershed.

For all three indicators, data are based on fish tissue data collected by state or local government agencies, which tend to focus primarily on areas where these agencies believe there may be contaminated fish. This bias may result in inaccurate estimates of the extent of contamination.

Coastal Fish

For coastal fish, insufficient data on the edible portion of these fish are available to provide a national indicator. However, examination of fish tissue collected in coastal waters of the eastern U.S. and Gulf of Mexico shows that compounds of concern were present at levels above EPA's threshold for issuing an advisory.

Shellfish

No national indicators are available for shellfish. However, as discussed below, data are available on the extent of shellfish waters that were classified as harvest-limited or harvest-prohibited from 1966 to 1995. These data show a steady decrease over this time period in the extent of waters classified as harvest-limited or harvest-prohibited. Still, as of 1995, harvesting was limited in 31 percent of shellfish waters and prohibited in 13 percent (NOAA, 1997). The predominant causes of closures are both human and non-human coliform bacteria.

Data on shellfish waters come from the National Oceanic and Atmospheric Administration (NOAA), which records areas that are closed to shellfishing or are subjected to restricted or conditional harvesting. NOAA obtains its data from coastal states, which identify, survey, and classify shellfish-growing waters according to National Sanitary Survey Program (NSSP) guidelines (FDA, 1993). Classification status is based on sanitary surveys of water quality and shoreline surveys of pollution sources. Individual shellfish-growing areas are classified either as approved for harvest or as one of four harvest-limited categories: conditionally approved, restricted, conditionally restricted, and prohibited.

All identified shellfish-growing waters must be classified as prohibited unless sanitary surveys indicate that water quality meets specific NSSP standards for the other categories. Harvesting is permissible in approved areas year-round. The conditionally approved and conditionally restricted categories are for voluntary use by states when a predictable pollution event such as seasonal population, heavy rainfall, or fluctuating discharges from local sewage plants affects the suitability of an area for harvest. Most shellfish harvest restrictions are made based on the concentration of fecal coliform bacteria in shellfish. This organism is not directly harmful to humans, but typically is associated with human sewage and with organic wastes from livestock and wildlife.

The *National Shellfish Register* provides a record of the acreage of all classified shellfish-growing waters in the conterminous U.S. The Register was first published in 1966 to meet the need for summary information on the status and extent of the nation's commercial shellfish-growing areas. Since the publication of the first *Register*, the acreage of classified shellfish-growing waters has increased more than two-fold from 10 million acres to more than 21 million acres (Houser and Silva, 1966; FDA, 1971; EPA, OE, 1975; DOC and HHS, 1985; NOAA, 1991; NOAA,1997), primarily due to an expanding consumer demand for shellfish.

Since 1966, the percentage of all classified waters approved for harvest has decreased 10 percent. However, data compiled for the *1995 Register*, the last available compilation, suggest significant improvements. For example, the overall percent of harvest-limited waters decreased from a high of 42 percent in 1985 to 31 percent in 1995. The percent of prohibited waters also decreased from a high of 26 percent in 1974 to 13 percent in 1995—the lowest percentage recorded.

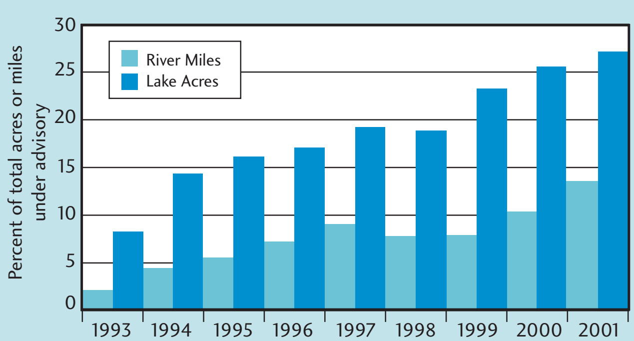
Indicator Percent of river miles and lake acres under fish consumption advisories - Category 2

State and local governments protect people from possible risks of eating contaminated fish by monitoring local waters and issuing fish advisories when contaminant levels are unsafe. A consumption advisory may recommend that people limit or avoid eating certain species of fish caught from certain lakes, rivers, or coastal waters. Advisories are often very specific. They may apply to specific water types (such as lakes), or they might include recommendations for specific groups (such as pregnant women or children). Advisories apply to locally caught fish or wildlife as well as fish purchased in stores and restaurants. EPA has compiled these advisory data into the National Listing of Fish and Wildlife Advisories (NLFWA) database, which lists, among other things, the species and size of fish or wildlife under advisory, the chemical contaminants covered by the advisory, the location and surface area of the waterbody under advisory, and the population subject to the advisory.

What the Data Show

Exhibit 2-33 shows the percent of the nation's river miles and lake acres under advisory for the years 1993 to 2001. Note that the Great Lakes and their connecting waters are considered separately from other waters and are not included in the calculations of total lake acres or river miles. Except for 1998, the percentage increased continuously during this 8-year period. Approximately 79,119 lakes (11,277,276 lake acres) and 485,205 river miles were under advisory in 2001, compared to 14,962 lakes and 74,505 river miles under advisory in 1993. Note that the increase in the total size of waters under advisory is due in part to increased monitoring for chemical contaminants in fish and wildlife tissue and the states' increasing use of statewide advisories. Currently, the 2,618 advisories in the national listing represent almost 28 percent of the nation's total lake acreage and 14 percent of the nation's total river miles.

Exhibit 2-33: Trends in percentage of river miles and lake acres under fish consumption advisory, 1993-2001



Coverage: all 50 states

Source: EPA, Office of Water. *Update: National Listing of Fish and Wildlife Advisories.* May 2002.

In addition to the NLFWA data, much information is available on the advisory status of our nation's waters. EPA and FDA issued a national mercury advisory in January 2001 recommending that women of childbearing age and young children limit their consumption of fish (<http://www.epa.gov/waterscience/fish>).

Many great waters of the U.S. are currently under fish advisories for a variety of pollutants. The great waters include the Great Lakes, Lake Champlain, the Chesapeake Bay, 20 National Estuary Program (NEP) sites, and 14 National Estuarine Research Reserve System (NERRS) sites.

- All of the Great Lakes and their connecting waters are under advisory.
- Lake Champlain is under advisory for PCBs and mercury.
- Although the Chesapeake Bay is not under any advisories, the Potomac, James, Back, and Anacostia Rivers, which connect to it, are all under PCB advisories.
- Baltimore Harbor, which also connects to the Chesapeake Bay, is under advisory for chlordane and PCB contamination in fish and blue crabs.
- Many of the major estuaries listed in the NEP and/or designated as NERRS sites are under fish and/or shellfish advisories for multiple chemical contaminants. Sixty-five percent of the total number of NEP, NERRS, and combined sites are under fish consumption advisories. Seventeen sites have no current fish consumption advisories.

Several states have issued fish advisories for all of their coastal waters. An estimated 71 percent of the coastline of the conterminous 48 states currently is under advisory. This includes 92 percent of the Atlantic coast and 100 percent of the gulf coast. The Atlantic coastal advisories have been issued for a wide variety of chemical contaminants, including mercury, PCBs, dioxins, and cadmium. All of the gulf coast advisories have been issued for mercury, although other contaminants may also be present. No Pacific coast state has issued a statewide advisory for any of its coastal waters, although several local areas along the Pacific coast are under advisory.

Indicator Gaps and Limitations

Currently, fish consumption advisories are being used as a way of informing the public of risks associated with eating contaminated

Indicator Percent of river miles and lake acres under fish consumption advisories - Category 2 (continued)

fish in certain waterbodies. Advisories are based on fish tissue monitoring data collected by states and are largely focused on areas where states know fishing occurs or suspect contamination. Criteria used to issue advisories vary among states, with some having more stringent criteria and more robust advisory programs than others.

Due to the large range in geographic size of lake acres and river miles affected by chemical contaminants that may be contained under a single advisory, the number of advisories is not as accurate a measure of the contamination as geographic extent. As a result, information is now provided on total lake acres and river miles where advisories are currently in effect. A large-scale fish tissue study is underway and will help identify waters that require further monitoring to determine whether advisories are necessary.

This indicator is based on fish tissue monitoring data collected by the states. It does not provide unbiased geographical coverage, and it is largely focused on areas where states know fishing occurs or suspect contamination problems. At present, 43 states issued risk-based advisories.

Data Source

Fish advisory indicator data are from the National Listing of Fish and Wildlife Advisories program. (See Appendix B, page B-17, for more information.)

Indicator Contaminants in fresh water fish - Category 2

From 1992 to 1998, fish samples were collected from 223 stream sites in the U.S. Geological Survey's (USGS) National Water Quality Assessment (NAWQA) program. Tissue composites from whole fish were analyzed for PCBs, organochlorine pesticides, and trace elements. These contaminants may harm organisms directly or by affecting their reproduction, and they may make fish unsuitable for consumption by humans. These data were compiled for the entire U.S.

What the Data Show

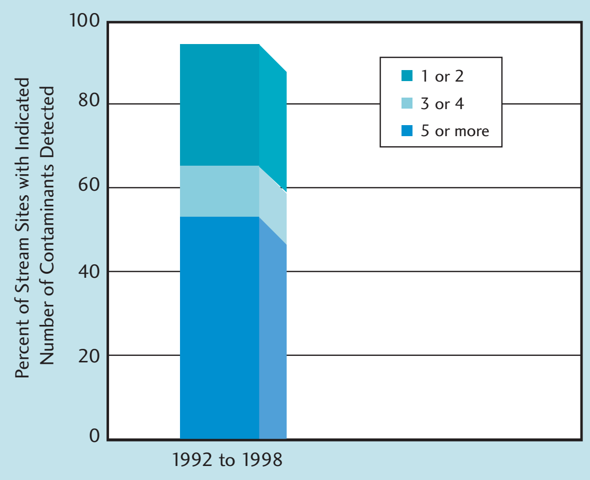
More than 90 percent of sampled fish had at least one contaminant detected and about half of the fish tested had at least five contaminants at detectable levels (Exhibit 2-34) (The Heinz Center, 2002). All fish tested from the Great Lakes had five or more detected contaminants.

Indicator Gaps and Limitations

The sites sampled are representative of a wide range of stream sizes, types, and land uses broadly distributed across the U.S., but they do not represent a probability sample, so confidence bounds on the estimates could not be calculated (Gilliom, et al., 2002; The Heinz Center, 2002).

Fish tissue concentration data are derived from composites of whole fish and not from edible portions alone. Thus it is not possible to compare tissue concentrations to aquatic or human health

Exhibit 2-34: Occurrence of contaminants in stream fish, 1992-1998



Coverage: lower 48 states.

Note: Partial indicator data: freshwater stream fish only,

Source: The Heinz Center. *The State of the Nation's Ecosystems.* 2002. Data from the U.S. Geological Survey.

Indicator Contaminants in fresh water fish - Category 2 (continued)

guidelines. These data do, however, indicate organism exposure to measured chemicals.

Data Source

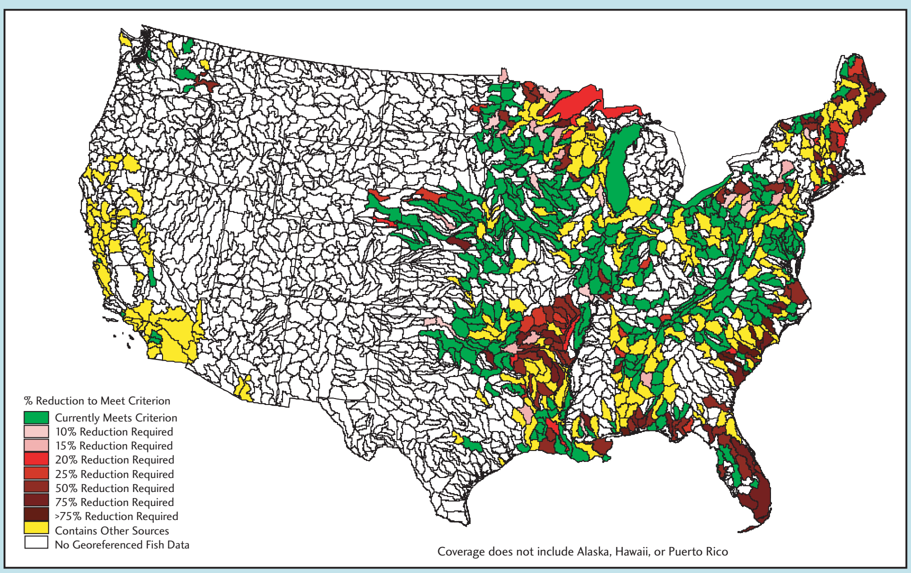
Data for this indicator came from the U.S. Geological Survey's National Water Quality Assessment Program as compiled for The Heinz Center (2002). (See Appendix B, page B-17, for more information.)

Indicator Number of watersheds exceeding health-based national water quality criteria for mercury and PCBs in fish tissue - Category 2

For this indicator, fish tissue concentrations of each chemical in the NLFWA database were averaged across 8-digit hydrologic unit code (HUC) watersheds. The average concentration was then compared to fish- tissue based criteria for mercury and PCBs. The average fish tissue concentration is for all monitored species, fillet samples only (whole fish samples were omitted from the analysis as these are not recommended for use in assessing human health impact). Thus, the average is meant to represent the potential exposure concentration for persons consuming fish from typically frequented local lakes, streams, and rivers.

The mercury criterion used in this comparison was the national fish-tissue-based criterion. The PCBs criterion was based on the fish tissue levels used to derive the current national health-based water concentration criteria. Criteria exceedances can be interpreted as meaning that the watershed, on average, is not meeting maximum tissue contaminant levels designed to be protective of human health.

Exhibit 2-35: Watersheds with fish tissue concentrations exceeding health-based national water quality criteria for mercury, 2001



States currently use water column concentration-based mercury water quality standards and would need to adopt fish tissue-based target levels in order to use this approach for mercury Total Maximum Daily Loads. Additional reductions would be required to meet EPA national and most state fish advisory levels, which are often set below the methyl-mercury criterion.

Note: Watersheds highlighted yellow have "significant" mercury sources other than deposition, defined as where the total estimated load from Publicly Owned Treatment Works (POTWs) and pulp and paper mills is greater than 5% of estimated waterbody delivered mercury at a typical air deposition load (10 g/km2/yr) and/or where mercury cell chlor-alkali facilities, mercury mines, or significant past producer gold mines are present

Source: EPA, Office of Water. *National Listing of Fish and Wildlife Advisories (NLFWA) Mercury Fish Tissue Database.* June 2001.

What the Data Show

The data for mercury are a fairly good representation of conditions in the eastern U.S. and California. Of the 696 8-digit HUC watersheds with available data, 225 exceeded the mercury criterion (Exhibit 2-35). These are predominantly located in eastern coastal states, New England, and the lower portion of the Mississippi River watershed. Data for PCB concentrations are less available; 114 of 153 watersheds where data were available contained tissue above the criterion level (Exhibit 2-36).

Indicator

Number of watersheds exceeding health-based national water quality criteria for mercury and PCBs in fish tissue - Category 2 (continued)

Indicator Gaps and Limitations

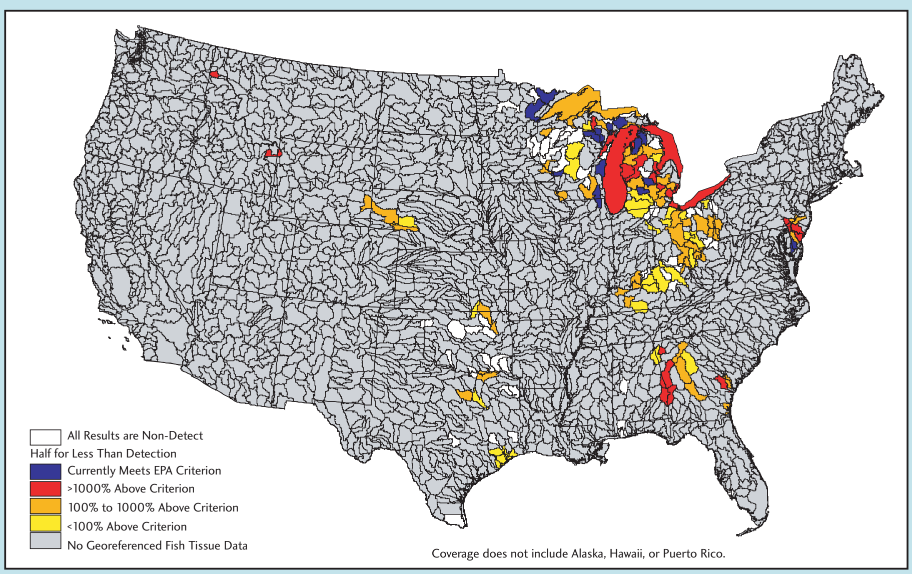
Several limitations should be noted for this indicator:

- The data were compiled based on voluntary contributions from individual states and have not undergone an independent quality assurance/quality control (QA/QC) review. Data quality is a function of the distinct programs for which the data were collected.
- Sampling by state agencies was not generally done on a statistical basis, but rather was targeted toward specific waterbodies and fish species. Some selection of sampling locations was based on fishing pressure and/or suspected elevated contaminant levels. For example, there appears to be a bias in the mercury data towards top predator or sport fish (of the top 10 most frequent species sampled, 83 percent are trophic level 4 species). This bias could potentially skew the average watershed concentration level to higher than actual exposure depending on real consumption patterns.
- Some states may not have reported tissue data when resultant concentrations were found to be below state fish advisory levels.
- Substantially more data are available for the years 1990 to 1995 than for more recent years.
- Spatial gaps in the data are readily apparent from the indicator maps. Since a large fraction (roughly two-thirds) of the database was not georeferenced (i.e., no latitude/longitude coordinates were created), those data could not included in the indicator. Bias imposed by these missing data was not examined. Latitude/longitude coordinates will be assigned in a database update in the near future and can be incorporated in future indicators.
- The human health-based criteria of 0.3 ppm methylmercury that was used for comparison is considerably higher than the more recent federal advisory of 0.18 ppm for consumption of mercury-contaminated fish. State consumption advisories are typically at levels closer to the 0.18 ppm than to the 0.3 ppm level.
- Sampling patterns of state agencies are largely being directed toward areas of higher fishing pressure or based on suspected elevated contaminant levels. Thus this indicator, which is based on generalizing from specific sampling locations to watershed averages, is expected to represent a somewhat conservative estimate of the average concentration in consumed fish in each respective area.

Data Sources

The fish tissue indicator data are from the National Listing of Fish and Wildlife Advisories program. (See Appendix B, page B-18, for more information.)

Exhibit 2-36: Watersheds with fish tissue concentrations exceeding health-based national water quality criteria for polychlorinated biphenyls (PCBs), 2001



Note: Graphic was created for this report in ArcView using NLFWA data.
Source: EPA, Office of Water. *National Listing of Fish and Wildlife Advisories (NLFWA)*. June 2001.

2.5.2 What are contaminants in fish and shellfish, and where do they originate?

Information is available to help answer this question in a general sense. Fish and shellfish can be contaminated by both chemical pollutants and pathogens. Chemical contaminants of greatest concern tend to be those that are toxic and persistent and that bioaccumulate. Contaminants with these properties that are common in fresh and coastal waters include:

- *DDT and PCBs*. The manufacture and use of these compounds have been banned in the U.S. However, deposits from past pollution persist in sediments and land-based sources, and these deposits continue to pollute watersheds. In addition, PCBs can be found in some products manufactured prior to the ban (e.g., electrical transformers).
- *Mercury*. This metal, a natural and highly toxic element, can now be detected (although in small amounts) in all waters. Sources of mercury include wastes from past mining practices and the burning of fossil fuels and wastes, which can create mercury emissions that settle on land and water. In water, bacteria convert mercury to methylmercury, a toxic compound that is absorbed by fish and accumulates in their tissue.

Biological threats to shellfish consumption include bacterial contamination from human and animal wastes and contamination from naturally occurring toxins that shellfish accumulate from consuming certain algae.

Some data are available on the sources of bacterial contamination. When state managers close or otherwise restrict a shellfish-growing area due to high levels of fecal coliform bacteria, they typically cite potential sources of that contamination. This information was collected for the 1990 and 1995 Shellfish Registers (NOAA, 1991; NOAA, 1997). In 1995, sources of shellfish contamination cited by reporting officials were (in decreasing order of frequency):

- Urban runoff (40 percent)
- Unidentified sources upstream of coastal watersheds (39 percent)
- Wildlife (38 percent)
- Individual wastewater treatment systems (e.g., septic tanks) (32 percent)
- Wastewater treatment plants (24 percent)
- Agricultural runoff (17 percent)
- Marinas (17 percent)
- Boating (13 percent)
- Industrial facilities (9 percent)
- Combined sewer overflows (7 percent)
- Direct discharges (4 percent)
- Feedlots (3 percent)

The 1990 Register reflects the same top five sources of pollution, although in slightly different order.

Marine biotoxins associated with "red tides" and other naturally occurring contaminants such as *Vibrio* species (a free-living marine and estuarine bacteria associated with stomach and intestinal disorders of varying intensity) can also cause temporary closures, although they are not usually regarded as a pollution source (Rippey, 1994; FDA, 1993).

At this time, insufficient data are available to develop national-level indicators about the type and origin of fish and shellfish contaminants.

2.5.3 What human health effects are associated with consuming contaminated fish and shellfish?

The health effects of consuming contaminated fish and shellfish depend on many factors, including the type of contaminant, its concentration in the organism, and how much contaminated fish or shellfish is consumed. Health effects include the following:

- Risk assessments show that exposure to sufficient levels of some contaminants in fish tissues may increase the risk of cancer
- Mercury, in sufficient quantities, is toxic—especially to the nervous system.
- Shellfish contaminated with fecal wastes can cause gastrointestinal illness and even death in individuals with compromised immune systems. Mollusks, mussels and whelks are the main shellfish that carry biotoxins causing common symptoms, such as irritation of the eyes, nose, throat, and tingling of the lips and tongue.

Advisories warn the public of these risks and suggest limits or outright bans on consuming some species in certain problem areas. Certain groups may be at higher risk for health effects from contaminated fish and shellfish. These include children, pregnant women, and nursing mothers, who may be more vulnerable to effects, and tribal, ethnic, and other populations that fish for subsistence and therefore consume more fish or shellfish.

At this time, insufficient data are available to develop indicators that can monitor, at the national level, the health effects of consuming contaminated fish and shellfish. Chapter 4, Human Health, provides more information on the human health impacts of contaminated fish.

2.6 Challenges and Data Gaps

Tremendous amounts of data are being collected on water resources. These data provide evidence of water quality condition at the national, regional, and state scales. Some of these data are sufficiently comprehensive in scope to serve as the basis for indicators of water quality at the national level. These indicators provide a starting point for describing our nation's water quality. However, as discussed below, they also have limitations that make it difficult to make confident statements about the condition of water resources at the national scale or to thoroughly describe the stressors that degrade that condition.

2.6.1 Water and Watersheds

Several indicators are available that provide information about the quality of our nation's waters and watersheds. For wetlands, for example, the relevant indicator shows that the rate of wetland loss has dropped dramatically in recent years. However, as discussed in Section 2.2.2, there currently are no indicators of wetland biological condition and none are being implemented at the national or regional scale. Without these indicators and an assessment process, ensuring that the net gain goal is sustaining not only wetland extent, but also wetland condition, will not be possible.

Drawing accurate conclusions about the condition of surface waters can be equally as challenging as for wetlands, but the indicators in this area do provide evidence of some success in reducing important stressors. In addition, data suggest that atmospheric deposition of sulfates has been reduced (EPA, ORD, January 2003), which will help improve the quality of acidic surface waters. Ongoing efforts by EPA (for example, through the National Pollutant Discharge Elimination System permit program), the U.S. Department of Agriculture, and individual states to reduce the amount of pollutants discharged to our nation's waters from both point and non- point sources will also help to improve water quality.

However, many challenges remain in monitoring water quality and taking steps to improve water quality. This is, in part, because significant environmental problems persist, despite environmental management activities to address these problems. Persistent hypoxia in the Gulf of Mexico and fish contaminated by toxic organics and mercury are examples.

To better address water quality problems in the future, more and better quality data on the condition of waters and watersheds will be needed. This will require a greater collaboration among the federal agencies that participate in monitoring and managing our nation's waters so that results and metadata can be provided in a common format. Data in a common format will be much more useful for developing or improving indicators and can also more easily be made available to the public. In addition, the relevant federal agencies should work with the states to design and implement cost-efficient water quality monitoring programs whose data will be useful not only to the state water quality programs, but also to national water quality characterizations. State resources often are limited for such key activities as characterizing waters, identifying sources of watershed stress, and monitoring the effects of implementing pollution controls. Therefore, it is critical to encourage the development, dissemination, and use of cost-effective monitoring and assessment tools, such as biological methods for water quality assessment and a new framework for design and data collection in water quality monitoring programs.

2.6.2 Drinking Water

The indicator for the quality of treated drinking water in the U.S. shows that quality of drinking water has improved from the early 1990s through 2002. This indicator is based on health standards violations by community water systems that are reported by states to EPA's Safe Drinking Water Information System (SDWIS). The systems that are monitored under SDWIS serve water to about 95 percent of the U.S. population. Compliance trends may change in the future as new regulations create new compliance challenges for public water systems.

The primary limitation of this indicator is under-reporting and late reporting of community water systems violations by states to EPA. This affects the accuracy of annual reports produced using SDWIS and thus the quality of the indicator. EPA last quantified data quality in 1999 and estimated that states were not reporting 40 percent of all health-based violations. EPA and states are taking steps to address identified deficiencies and to improve data quality. A survey of reporting completeness is underway. Another limitation of the indicator is that it does not cover the quality of water from private wells.

It is important to understand the condition of the raw waters (both ground water and surface waters) that serve as drinking water sources. For example:

- States are currently conducting assessments to delineate the extent of source waters and identify potential contaminant sources.
- Data provided by the U.S. Geological Survey under its National Water Quality Assessment program and occurrence data for unregulated contaminants collected by EPA under the Safe Drinking Water Act (SDWA) also provide information about raw water stressors, and are used by EPA to determine whether additional contaminants should be regulated under the SDWA.
- It is important that EPA assure that the frequency of sampling is adequate to characterize episodic events affecting source water quality.

The incidence of waterborne disease is another parameter that could be used to describe and track water quality at the national level. Additional efforts to obtain data could help provide a basis in the future for a national-level indicator in this area. This would, however, require significant new work, as the existing data likely reflect an unknown but probably very large degree of under-reporting. For example, there currently are no consistent national surveillance and reporting requirements for doctors or states with respect to incidence of diarrhea, except as associated with Hepatitis A, cholera, salmonellosis, or shigellosis. Doctors rarely order the tests that would identify these diseases, or tests that would identify other, more common diseases that can be caused by contaminants in drinking water.

2.6.3 Recreation in and on the Water

The quality of recreational waters is compromised when pollution increases the level of pathogens or (to a lesser extent) chemical contaminants in those waters past thresholds judged safe for human exposure. When this happens at a monitored beach, particularly for pathogens, local or state authorities close or issues advisories for beaches. Sufficient information is available to provide the basis for an indicator about the risks to public health from exposure to pathogens in recreational water at coastal and Great Lakes beaches. Although the indicator shows that the number of beaches with advisories or closures has increased in recent years, this trend simply represents the fact that more beaches are providing information. In fact, as the indicator shows, the percent of beaches under advisory or closure has been fairly constant over the last few years. Overall, relatively few days (six percent of the days beaches could be open) have been lost due to pathogen exposure. This indicator is limited by three considerations:

- The number of beach days closed or under advisory does not directly measure pathogens or contaminants in water.
- Reporting of beach days closed or under advisory is voluntary, thus the ability of this indicator to describe conditions nationwide is unknown.
- At this time, this indicator applies primarily to coastal and Great Lakes beaches, as most fresh water inland beaches are not surveyed.
- Improving the value of this indicator as a national measure of recreational water quality would entail an assessment of the presence of pathogens in all waters used for recreational activities. Chemical contaminants would need to be selectively measured in waters with known risk from contamination.

2.6.4 Consumption of Fish and Shellfish

Three indicators are available to help describe the condition of surface waters that support fish and shellfish consumption. For example, information about specific areas where contaminants in fish are above public health thresholds is available. One indicator suggests that the number of lake acres and river miles for which fish consumption advisories have been issued is increasing. This trend may represent an increase in monitoring, more stringent state health standards, or increased contamination. Other indicators show that the vast majority of sampled fish are contaminated to some degree and that contamination for particular pollutants (mercury and PCBs) tends to be concentrated in certain areas of the country. For all three indicators, it is important to note that sampling tends to focus on areas where states know fishing occurs or suspect there may be a contamination problem, so the data may over-report or under-report the degree and extent of contamination. Also, monitoring of fish and shellfish at the state level is very inconsistent, and different criteria are used to issue advisories.

A true national assessment of the safety of fish and shellfish for human consumption can only be accomplished through a comprehensive, representative survey of pathogens and chemical contaminants in edible fish tissue in all waters. A national survey of this type, involving 500 lakes and reservoirs, is underway. Initial data on 268 contaminants in the tissue of fresh water fish have been collected. These data are not presented in this report because they reflect only one year of a four-year study and, as such, are not ready for public release. However, they should be available for future use as a potential indicator.