United States Environmental Protection Agency

http://www.epa.gov/

The Great Waters Program

Introduction

Over the past 30 years, scientists have collected a large and convincing body of evidence demonstrating that toxic pollutants released to the air can be deposited at locations far from their original sources. Chemicals of human origin such as polychlorinated biphenyls (PCBs) and pesticides like DDT have been found thousands of miles from likely emission sources in the fatty tissues of polar bears and other Arctic animals. Fish from Siskiwit Lake, a small lake on an island in northern Lake Superior that is isolated from most human influences, are contaminated with PCBs and the pesticide toxaphene, which have no known sources on the island.

On November 15, 1990, in response to mounting evidence that air pollution contributes to water pollution, Congress amended the Clean Air Act and included provisions that established research and reporting requirements related to the deposition of hazardous air pollutants to the "Great Waters." The waterbodies designated by these provisions are the Great Lakes, Lake Champlain, and Chesapeake Bay and certain other coastal waters (identified by their designation as sites in the National Estuarine Research Reserve System or the National Estuary Program).

This atlas is written to provide basic information about the Great Waters, their water quality problems, and the issue of atmospheric deposition to aquatic ecosystems in general. For more detail, the Great Waters biennial Reports to Congress discuss current scientific understanding of atmospheric deposition and the health and environmental effects of toxic pollution, as well as EPA's programs to protect human health and the environment.

The Program

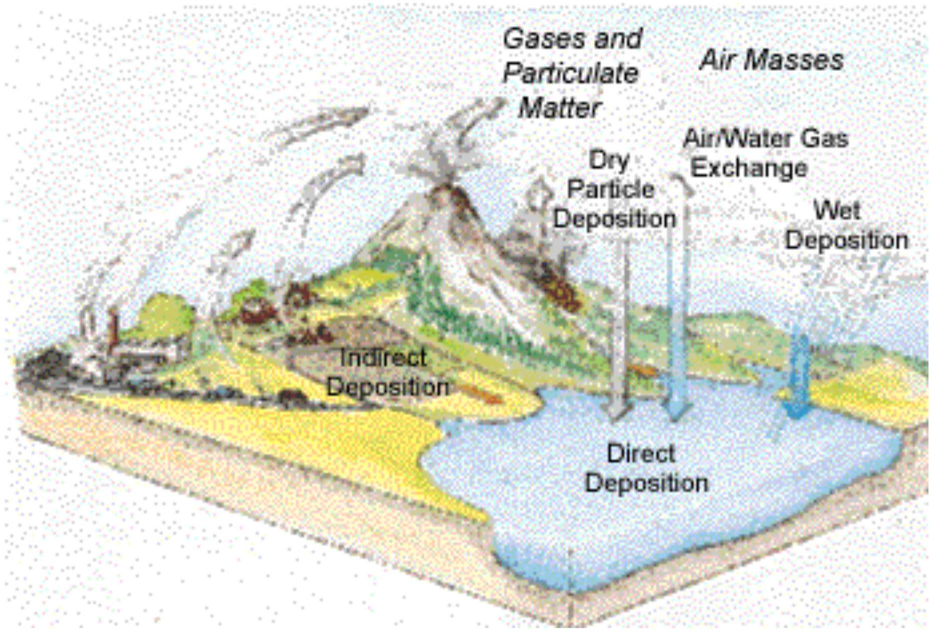
As part of the Great Waters Program, Congress requires EPA, in cooperation with the National Oceanic and Atmospheric Administration, to:

- monitor hazardous pollutants by establishing sampling networks
- investigate the deposition of these pollutants
- improve monitoring methods
- monitor for these hazardous pollutants in fish and wildlife
- determine the contribution of air pollution to total pollution in the Great Waters
- evaluate any adverse effects to public health and the environment
- determine sources of pollution
- provide a report to Congress in 1993 and every 2 years

Legend

Great Waters designated by Clean Air Act
EPA National Estuary Program Sites
NOAA NEERS Sites*
EPA and NOAA NEERS Sites
*NOAA - National Oceanic and Atmospheric Administration
NERRS - National Estuarine Research Reserve System

Atmospheric deposition can occur in three steps:

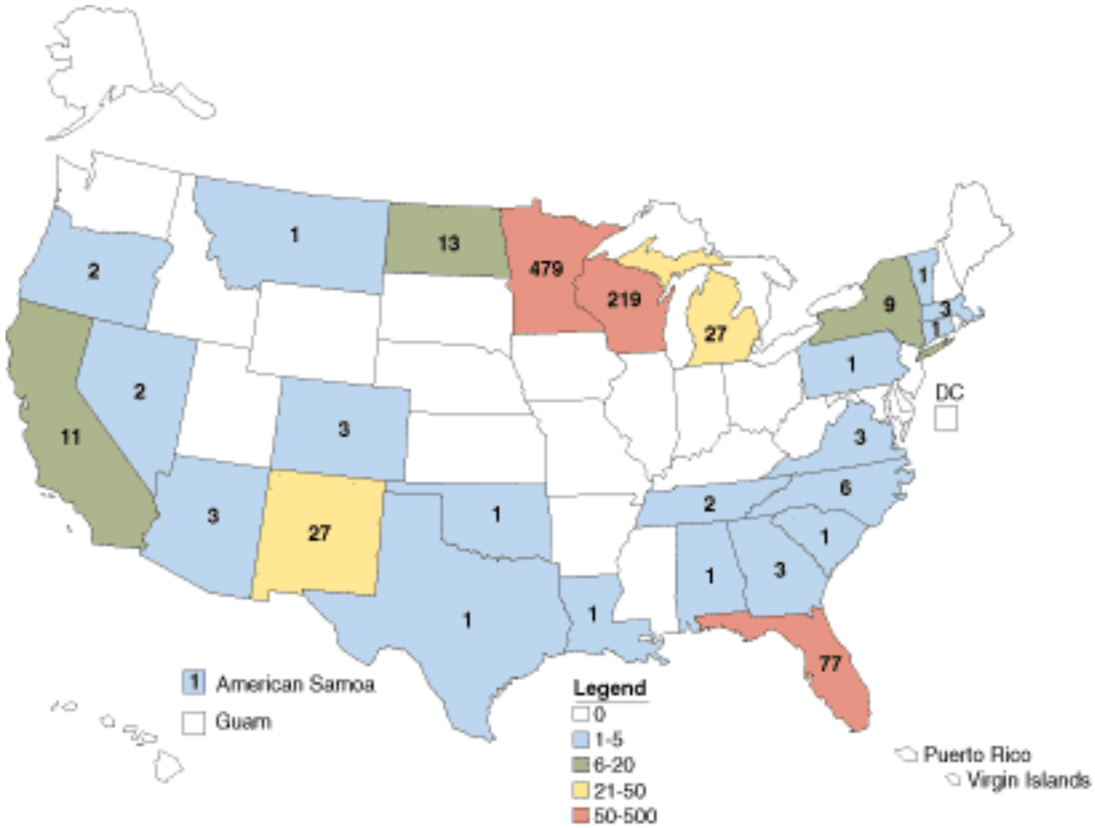


- Pollutants are released into the air from man-made or natural sources. Man-made sources include industrial stacks, municipal incinerators, pesticide applications, and vehicle exhaust. Natural sources can be volcanic eruptions, windblown gases spray.
- Pollutants released to the air are carried by continental wind patterns away from their areas of origin. Depending on weather conditions and the chemical and physical properties of the pollutants, they can be carried varying distances from their sources and can undergo physical and chemical changes as they travel.
- Air pollutants are deposited to the earth or directly to waterbodies by either wet or dry deposition. Wet deposition occurs when pollutants are removed from the air by falling rain or snow. Dry deposition occurs when particles settle out of the air by gravity or when gases are transferred directly from the air into water. Air pollutants that deposit on land can be carried into a waterbody by stormwater runoff.

The Clean Air Act requires the establishment of monitoring networks to collect data to help identify and track movement of air pollutants into Great Waters ecosystems and determine overall pollution loadings from the air. EPA must report the findings of the investigations in their biennial reports to Congress. These reports provide an information base that can be used to:

- establish whether air pollution is a significant contributor to water quality problems of the Great Waters
- determine whether there are significant adverse effects to humans or the environment
- evaluate the effectiveness of existing regulatory programs in addressing these problems
- determine whether additional regulatory actions are needed to reduce atmospheric deposition to the Great Waters.

Fish Consumption Warnings for Mercury



There is widespread evidence in the United States, Canada, and Europe of high concentrations of mercury, a toxic metal, in fish tissue that exceed local, national, or international public health guidelines. This contamination represents a serious human health concern as well as a significant economic threat to both the commercial and sportfishing industries.

Currently 27 states have consumption advisories for specific waterbodies warning consumers about mercury-contaminated fish and shellfish (see map). Many of these advisories, particularly in Minnesota, Wisconsin, and Florida, have been issued for relatively pristine waterbodies where atmospheric deposition is thought to be the main source of the mercury contamination.

Mercury comes from natural and man-made sources. Natural sources of atmospheric mercury include degassing of the earth's crust and forest fires. Major man-made sources of atmospheric mercury include combustion of coal and other fossil fuels, incineration of municipal refuse, and evaporation from surfaces painted with mercury-containing paints.

The Great Lakes

The Great Lakes-Superior, Michigan, Huron, Erie, and Ontario-are the largest system of fresh surface water on earth, by area. They contain approximately 18 percent of the world's fresh water supply. Together the lakes contain about 5,500 cubic miles of water covering a total area of 94,000 square miles. These vast inland freshwater seas (which span more than 750 miles from east to west) provide water for consumption, transportation, power production, recreation, and an array of other uses. The Great Lakes basin is currently home to one-tenth of the population of the United States and one-quarter of the population of Canada.

Physical Features

	Superior	**Michigan**	**Huron**	**Erie**	**Ontario**
Length (mi)	350	307	206	241	193
Width (MI)	160	118	183	57	53
Average depth (ft)	483	279	195	62	283
Maximum depth (ft)	1,330	923	750	210	802
Volume (mi3)	2,900	1,180	850	116	393
Surface area (mi2)	31,700	22,300	23,000	9,910	7,340
Land drainage area (mi2)	49,300	45,600	51,700	30,140	24,720
Shoreline (MI)	2,726	1,638	3,827	871	712
Retention time (yr)	173	62	21	2.7	7.5

Population:

United States (1990)	425,528	10,057,026	1,502,687	10,017,530	2,704,284
Canada (1991)	181,493		191,017	1,857,961	5,446,611

Fish Advisories

PCBs	*	*	*	*	*
Dioxins					*
Chlordane	*	*		*	
Mercury	*	*			

Despite their large size, the Great Lakes are sensitive to the effects of a broad range of environmental pollutants from agricultural and urban runoff, industrial and municipal facilities, spills, and hazardous waste sites. The large surface area of the lakes also makes them vulnerable to direct atmospheric pollutants that fall with snow or rain (wet deposition) and as dust particles (dry deposition) on the lake surface or within the extensive land drainage system.

Although part of a single freshwater system, each lake has different physical characteristics that influence pollutant impacts (see table at left). In volume, **Lake Superior** is the largest and also the deepest and coldest of the five lakes. Because most of Lake Superior's drainage basin is forested, supports little agriculture, and is sparsely populated, it is believed that relatively few pollutants enter the lake except through airborne transport.

Lake Michigan is the second largest of the lakes and is the only one that lies entirely within the borders of the United States. The drainage area is sparsely populated in the north except for the Green Bay area. Green Bay has one of the most productive fisheries in the Great Lakes region but receives wastes from a large number of pulp and paper facilities. The southern shoreline of Lake Michigan is among the most heavily urbanized of all the lakes; this region, which includes Milwaukee and Chicago, is home to 8 million people.

Huron is the third largest lake by volume. The northern shore surrounding the Georgian Bay is a recreational area for both Canadian and U.S. citizens. The Saginaw River basin is farmed intensively and contains the metropolitan areas of Flint and Saginaw Bay. Like Green Bay, Saginaw Bay contains a highly productive fishery.

Lake Erie is the smallest of the lakes by volume and yet is the most significantly stressed from both urbanization and agriculture. The lake receives agricultural runoff from southwest Ontario and portions of Ohio, Michigan, and Indiana. Seventeen urban areas, each with a population of more than 50,000, are within the drainage basin.

Although slightly smaller in area than Erie, Lake Ontario is much deeper. Major Canadian urban industrial areas include Toronto and Hamilton; however, the US shoreline is less urbanized and not intensively farmed except in the area adjacent to the lake shore. Development in the Great Lakes region has taken advantage of the many resources within the watershed:

- **Agriculture** - Grain, dairy and meats, and specialty crops such as fruits, vegetables, and tobacco are produced.
- **Urbanization and industrial growth** - The major industries in the Great Lakes basin produce steel, paper, chemicals, automobiles, and a wide array of manufactured goods. Urbanization, accompanied by industrial growth, brought an increase in the number of municipal water and sewage treatment facilities and industrial plants that discharge their effluents into the Lakes.
- **Shipping and transportation** - Commodities, primarily iron ore, coal, and grain, are shipped via an extensive navigational system that extends through the St. Lawrence Seaway to the Atlantic Ocean.
- **Commercial fishery** - Only pockets remain of a once large commercial fishery for lake trout, lake whitefish, coho and chinook salmon, and walleye. In the US waters, the commercial fishery is based primarily on lake whitefish, smelt, and perch and on the alewife for animal feed.
- **Sport fishery** - Today walleye, splake, and coho, Chinook, and pink salmon predominate the sport catch; however, with few exceptions, none of these predator species has been able to reproduce and the fishery has had to be restocked year after year.
- **Recreation** - The economy of many areas in the Great Lakes basin depends heavily on tourism and revenues from local recreation- al activities, including sport outfitters, marinas, boatbuilders, resorts, and restaurants.

Water Quality Issues

By the late 1960s, the most obvious problems affecting the Great Lakes were inputs of nutrientsand oxygen-demanding materials, largely from direct piped discharges from municipal wastewater treatment plants and industries. In particular, excess phosphorus led to algal blooms near the shorelines that interfered with recreational uses and caused taste and odor problems in drinking water. As mats of dead algae settled into bottom waters, oxygen levels plummeted, causing fish kills. Lake Erie was the most vulnerable to these problems due to its shallow depth, warm temperatures, and many wastewater discharges. To a lesser extent, Lake Ontario and natural embayments such as Green Bay and Saginaw Bay experienced similar problems.

Impacts from conventional water pollution were added to decades of cumulative effects from overharvesting of fisheries, the introduction of exotic species, dredging operations in harbors and shipping channels, and habitat alterations in shorelines and wetlands due to agricultural, urban, and industrial development. The harm from conventional pollutants was also made more severe by the widespread use of chemicals such as DDT that accumulate in fish tissues and magnify up the food chain.

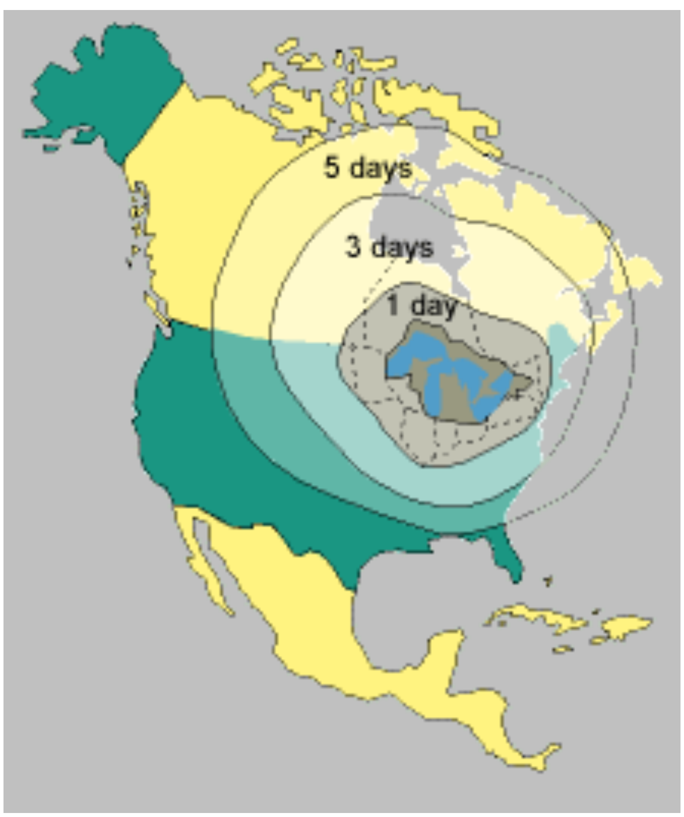
By the late 1970s, major investments in upgrading wastewater treatment facilities and the promotion of improved conservation practices in agriculture led to significant progress in controlling conventional waterborne pollutants. However, toxics levels in sediments and fish tissue are still a major issue today. The amounts of mercury and some pesticides in fish flesh have often reached levels serious enough for public health authorities to issue warnings about eating certain sizes and species of fish. In some instances, long-term exposure raises health concerns over cancer. Ongoing research suggests that there are other types of risks, ranging from birth defects to harmful physiological impacts to children. Similar toxicity concerns are also an issue for many types of wildlife.

Concerns over these toxics have encouraged a comprehensive approach to management initiatives in the Great Lakes. This approach starts with the realization that the natural environment cannot be viewed apart from the institutional ecology of human beings and their economic systems. While many management initiatives can best be implemented by focusing on subsystems such as particular Great Lakes or Areas of Concern, these geographically targeted activities must always take into account the fact that the entire Great Lakes basin is interconnected. Such a comprehensive perspective also requires an understanding of the movement of pollutants through air, surface water, sediment, and ground water.

Major Pollution Control Initiatives

In recent years, several major environmental laws have been amended to contain features relevant to Great Waters or specifically to the Great Lakes basin. The 1990 Clean Air Act contains provisions related to water and land ecosystem impacts from the deposition of air pollutants, with particular emphasis on toxics. Under the Superfund and Resource Conservation and Recovery Act (RCRA) programs, the Toxics Release Inventory improves the knowledge base for life-cycle tracking of wastes from industrial processes and encourages recycling and pollution prevention efforts. Ecological risk assessments of the threats posed by waste disposal facilities are becoming more sophisticated, and progress under the Assessment and Remediation of Contaminated Sediments (ARCS) program holds promise of reducing pollution impacts from toxic sediment. Cooperative efforts with other federal agencies such as the U.S. Department of Agriculture, the National Oceanic and Atmospheric Administration, the Fish and Wildlife Service, and the Corps of Engineers address issues as diverse as appropriate disposal of dredge materials, maintaining biodiversity, and protecting habitats for threatened or endangered wildlife species. Perhaps the most ambitious pollution control initiatives seek to implement provisions of the 1978 U.S.-Canada Water Quality Agreement.

Through a combination of treaty arrangements, federal and state laws, enhancements to existing regulations, and consensus-based approaches involving stakeholders from governments,industry groups, and environmental organizations, problems are tackled at several geographiclevels. Site-specific Remedial Action Plans (RAPs) are nearing completion for Areas of Concern,usually at river mouths or harbors where ongoing pollutant loads, combined with cumulative effects dating to the period before 1970, have created the most severe challenges for remediating toxic sediment problems.



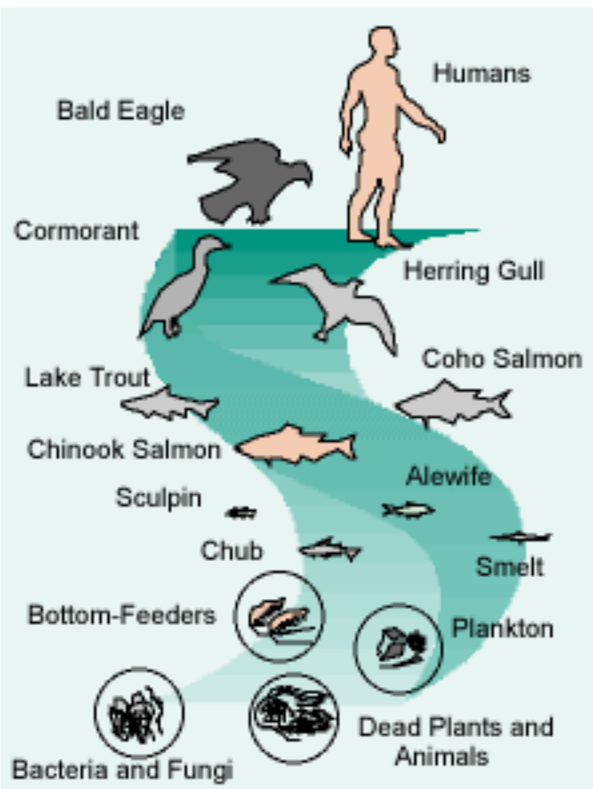
The Great Lakes "Airshed" Bands indicate the approximate number of days required for airborne contaminants to be transported to the Great Lakes basin.

At larger regional levels, each lake is scheduled for the development of a Lakewide Management Plan. Special issues facing each lake will be stressed. For instance, coordinated steps to reduce ongoing pollutant loadings will be a central focus of the plans for Lake Michigan or Lake Ontario. For Lake Superior, the largest and most nearly pristine of the Great Lakes, pollution prevention and the goal of virtual elimination of persistent toxic loadings will be a central theme.

To ensure that appropriate criteria are in place for planning and management activities, proposed Great Lakes Water Quality Guidance contains uniform water quality criteria for toxics in the Great Lakes basin. These criteria can then be incorporated into state water quality standards to guide the National Pollutant Discharge Elimination System permitting process (for point source or piped water discharges) and other programs. EPA and the states will seek to achieve water quality standards by the most efficient means by reducing releases from point sources, from nonpoint or diffuse sources, from atmospheric sources, and from contaminated sediments, spills, and waste sites, as appropriate. An effort is currently under way to address nonpoint sources releasing toxics in the basin, with an emphasis on bioaccumulative chemicals identified in the Great Lakes Water Quality Guidance.

Accumulation of PCBs in Great Lakes Food Chain

The nutrients necessary for plant growth (e.g., nitrogen and phosphorus) are found at very low concentrations in most surface waters. In the process of collecting these nutrients, phytoplankton also accumulate certain synthetic chemicals, such as PCBs and pesticides. These may be present in the water at concentrations so low they cannot be measured even by very sensitive instruments.



The chemicals, however, biologically accumulate (bioaccumulate) in the organism and become concentrated at levels that are much higher than in the surrounding water. Small fish and zooplankton consume vast quantities of phytoplankton. In doing so, any toxic chemicals accumulated by the phytoplankton are further concentrated in their bodies. These concentrations are increased at each level in the food chain. This process of increasing pollutant concentration through the food chain is called biomagnification. The top predators in a food chain, such as lake trout, coho and chinook salmon, and fish-eating gulls, herons, and bald eagles, may accumulate concentrations of a toxic chemical high enough to cause serious deformities or death or to impair their ability to reproduce. The concentration of some chemicals in the fatty tissues of top predators can be millions of times higher than the concentration in the surrounding water. Eggs of fish-eating birds often contain some of the highest concentrations of toxic chemicals. Thus, the first apparent effects of a toxic chemical in a lake may be unhatched eggs or dead or malformed chicks. Scientists monitor colonies of gulls and other aquatic birds because these effects can serve as early warning signs of a growing toxic chemical problem. Biomagnification of pollutants in the food chain is also a significant concern for human health. To protect their residents from these risks, all the Great Lakes states have issued fish consumption advisories or warnings about eating certain types of fish.

Chesapeake Bay

Chesapeake Bay, the largest estuarine system in the contiguous United States, has a watershed of almost 64,000 square miles. The total surface area of the Bay is 3,830 square miles. Of these, 153 square miles are tidal fresh waters, 3,562 square miles constitute the mixing zone, and 115 square miles are salt waters. This unique ecosystem also contains more than 1,500 square miles of wetlands that provide critical habitat for fish, shellfish, and wildlife; filter and process residential, agricultural, and industrial wastes; and buffer coastal areas against storm and wave damage.

Fish Advisories within the Shaded Area

		PCBs	Dioxin	Chlordane	Kepone
West Virginia	Potomac River		*		
Virginia	Jackson River		*		
	James River		*		*
Maryland	Back River			*	
	Baltimore Harbor			*	
District of Columbia	Anacostia River	*		*	
	Potomac River	*		*	

Chesapeake Bay's watershed stretches from New York State to Virginia and encompasses one-sixth of the Eastern Seaboard. The Bay accounts for almost half the fresh water entering estuaries in the Middle Atlantic Region. Five major tributary systems--the Potomac, Susquehanna, Rappahannock, York, and James Rivers--as well as dozens of smaller rivers supply fresh water to Chesapeake Bay. This freshwater inflow (85,800 cubic feet per second) significantly affects estuarine circulation and combines with tides to create complex circulation patterns that contribute to Chesapeake Bay's vitality.

Atlantic Coastal Plain estuaries such as the Chesapeake Bay are characteristically shallow and are subject to strong tidal circulation, creating ideal conditions for biological productivity. About 25 percent of all approved shellfish waters for oysters and clams in the United States are found in Chesapeake Bay.

In 1991 over 150 million pounds of fish and shellfish were harvested from this highly productive system. The Chesapeake Bay estuarine system is not only a major fishing area but also provides essential nursery areas for a wide variety of commercial and sport fish species. The Bay provides year-round habitat for white perch, bay anchovy, and several catfish species, including the channel catfish and white catfish, and attracts marine predators such as bluefish and Atlantic croaker. The Bay also serves as a nursery for early life stages of migratory species, such as Atlantic menhaden, American shad, American eel, weakfish, spotted sea trout, and striped bass.

Water Quality Issues

In 1975, Chesapeake Bay became the Nation's first estuary to be targeted for protection and restoration when Congress directed EPA's Office of Research and Development to initiate a study investigating the causes of the environmental declines observed in the Bay. The Clean Water Act Amendments of 1987 required the EPA Administrator to continue the ongoing Chesapeake Bay Program and maintain a Chesapeake Bay Program Office. This Program continues to collect and make available information about the Bay's environmental quality, to coordinate federal and state efforts to improve the Bay, and to determine the impact of natural and man-made environmental changes in the Bay, especially from sediment deposition, nutrients, chlorine, acid precipitation, low dissolved oxygen, and toxic pollutants.

Studies completed in the 1970s documented that increases in agricultural development, population growth, and sewage treatment plant discharges were causing the Bay to become nutrient enriched. Nitrogen and phosphorus are the two primary nutrients required to sustain aquatic biological productivity. Although phosphorus is the limiting nutrient in most freshwater systems, nitrogen is the limiting nutrient in most coastal estuarine and marine waters. As a result of elevated inputs, however, these nutrients are often present at concentrations in excess of basic nutrient requirements, causing excessive growth of phytoplankton and algae. This condition has two effects:

- In shallow areas, the excess algae block the sunlight that important submerged aquatic grasses need to grow. This degrades the habitat and causes the eventual loss of these grass beds.
- In deeper areas, the decomposition of dead algae uses up available oxygen in the water. During the warm summer months, oxygen in the bottom waters can only be replenished slowly because little mixing with the high-oxygen surface water occurs. Many bottom-dwelling organisms such as oysters, clams, and worms, which provide food for fish and crabs, cannot survive this prolonged period of low oxygen.

Nutrients in the Chesapeake Bay originate from point sources (e.g., municipal and industrial wastewater), nonpoint sources (e.g., cropland, animal wastes, urban and suburban runoff), and airborne contaminants, including inputs from states within the Bay watershed that are not signatories to the Chesapeake Bay Agreement (New York, West Virginia, and Delaware).

Water Quality Trends and Characterization

Bay water quality monitoring data confirm the significant progress made in reducing phosphorus from nonpoint sources and municipal point sources but indicate that further progress is needed toward reducing nitrogen loadings.

The Bay Program's highest priority is to restore the Bay's living resources. One way to do this is to improve water quality through nutrient reductions.

These reductions will increase dissolved oxygen, improve water clarity, and enhance conditions conducive to the growth of submerged aquatic vegetation that provides critical habitat for many of the Bay's organisms.

Point Source Nutrient Reduction

Municipal wastewater treatment plant discharges contribute the majority of point source loadings. Three elements of the Chesapeake Bay Program's point source control strategy are responsible for reductions in the nutrient loading:

- pollution prevention actions such as prohibiting the sale of detergents containing phosphorus
- upgrading wastewater treatment plants
- improving compliance with permit requirements.

Because the majority of municipal treatment plants discharge into fresh waters where phosphorus is the limiting nutrient, nitrogen concentrations received little attention until recent years. New technologies such as biological nutrient removal are being developed to increase removal of nitrogen from wastewaters, and these are being added to some existing treatment facilities. Upgrading of wastewater treatment plants has strengthened controls for nitrogen as well as for phosphorus.

Nonpoint Source Nutrient Reduction

Nonpoint sources of nutrients contribute about 60 percent of the nitrogen that reaches the Bay. The largest single source is agricultural runoff. Nitrogen loading results from application of chemical fertilizers, livestock manure, and sewage sludge on fields as well as from animal wastes that run off pastures and feedlots. Other nitrogen sources include atmospheric deposition to tidal surface waters, adjacent ocean waters, and the watershed, as well as runoff from urban and suburban lawns, roadways, and other developed areas to creeks and tributary rivers. The Chesapeake Bay Program's nonpoint source control program emphasizes reductions of controllable nonpoint sources including agriculture, paved surfaces, and construction in urban areas. The most important additional control measure is the practice of nutrient management in which animal wastes and fertilizers are applied to farmland in amounts carefully calculated to meet the needs of the crops. This practice reduces the runoff and leaching of nutrients that result from overuse of fertilizers.

Atmospheric Nitrogen Reduction

In addition to point and nonpoint sources of nitrogen loadings to Chesapeake Bay, concern is growing over the atmospheric deposition of nitrogen to the Bay. Atmospheric nitrogen is largely produced from the burning of fossil fuels; its two largest sources are automobiles and fossil fuel electric generating plants throughout the Chesapeake Bay airshed, which extends well beyond the watershed. Computer models indicate that about 10 percent of the Bay's nitrogen load is the result of airborne nitrogen, deposited directly on the surface of the Bay and the tidal portions of its tributaries. When the amount of atmospheric nitrogen deposited throughout the 64,000-square-mile watershed is considered, air pollution could account for nearly 40 percent of the Bay's total nitrogen load. The exact nitrogen load added from air pollution sources is uncertain because of the lack of monitoring data and questions about how and where nitrogen is transported. The EPA is developing a model that will provide a more definitive idea about air pollution sources that impact the Bay.

Reductions in atmospheric deposition are difficult to achieve because the sources of the pollutants, stationary and mobile, are not easily controlled and may be generated within the Chesapeake Bay region or transported a considerable distance to the Bay. To obtain the greatest reductions, the Bay states are considering enacting air pollution controls more stringent than those specifically mandated by the Clean Air Act Amendments, particularly for car emissions. The Governors of Maryland, Virginia, and Pennsylvania recently took a first step in that direction by endorsing a plan to require California-style emissions standards for cars sold after 1995.

Toxics Problem

In recent years, increased attention has been paid to the role that toxics may play in the problems facing Chesapeake Bay. Through a recent reevaluation of a 1989 basinwide toxic reduction strategy, the Bay Program has determined that toxics problems exist in some locations in the Bay. A few well-known areas have serious, localized problems, and some other regions that were previously thought to be uncontaminated have shown toxic effects. No evidence was found of severe, system-wide responses to toxics similar in magnitude to the effects observed throughout the Bay due to excessive nutrients. Widespread areas have measurable levels of toxic substances, below thresholds associated with adverse effects on the Bay's living resources. The long-term effects from these low levels remain unclear. Through efforts to develop a basinwide toxics loading and release inventory, estimates of direct atmospheric deposition to tidal surface waters have been made using data from a sampling network set up in 1990. Atmospheric deposition was found to be a significant source of metals, organics, and pesticides loadings to the Bay's tidal waters, although not the major source. Recent research and assessments of sediment contaminant patterns in Chesapeake Bay indicate that atmospheric deposition may be the major source of sediment contamination, particularly of polynuclear aromatic hydrocarbons resulting from incomplete combustion of fossil fuels.