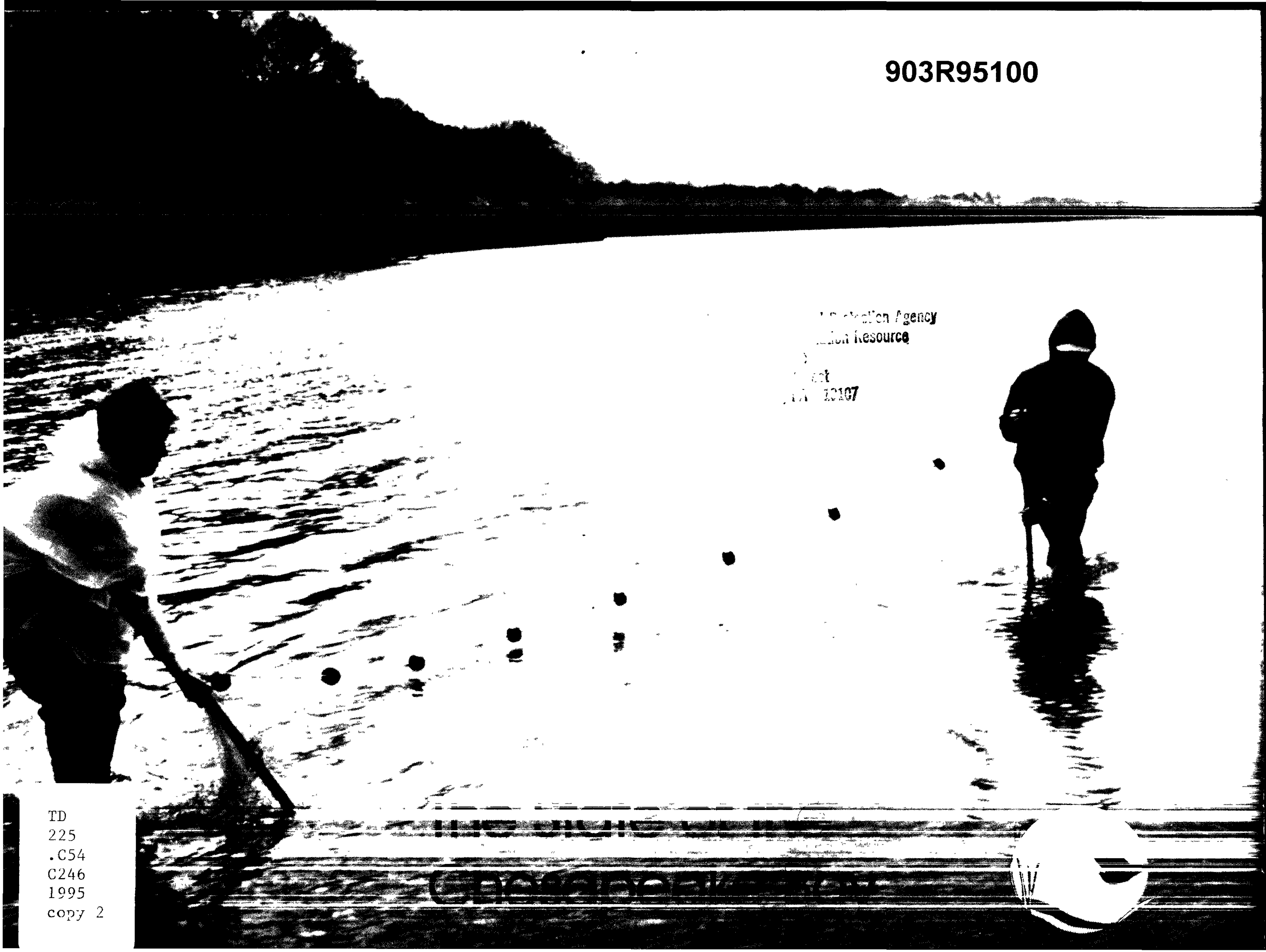
903R95100



ISBN 0-16-042627-8

For sale by the U S Government Printing Office
Superintendent of Documents, Mail Stop SSOP, Washington, DC 20402-9328
ISBN 0-16-042627-8

Foreword

THE CHESAPEAKE BAY PROGRAM

Now in its twelfth year, the Chesapeake Bay Program is the unique, regional, federal-state-local partnership which has directed and coordinated Chesapeake Bay restoration since the signing of the historic 1983 Chesapeake Bay Agreement. The Chesapeake Bay Program partners are the State of Maryland, the commonwealths of Pennsylvania and Virginia; the District of Columbia; the Chesapeake Bay Commission; the U.S. Environmental Protection Agency (EPA) representing the federal government; and participating advisory groups.

Considered a national and international model for estuarine restoration and protection programs, the Chesapeake Bay Program is still a "work in progress." Since 1983, milestones in the evolution of the program include the 1987 Chesapeake Bay Agreement, which set a goal of a 40 percent reduction of nutrients entering the Bay by the year 2000. In the 1992 amendments to the Chesapeake Bay Agreement, the partners agreed to maintain the 40 percent goal beyond the year 2000 and attack nutrients at their source — upstream in the Bay's tributaries. The agreements have also stressed management of the Bay as a whole ecosystem, using both habitat and living resources restoration as measures of progress.

Both agreements were signed by the policymaking body of the Bay Program — the Chesapeake Executive Council. This council, consisting of the governors of the Bay states, the mayor of the District of Columbia, the administrator of the U.S. EPA, and the chairperson of the Chesapeake Bay Commission, provides leadership for the Bay Program and is accountable to the public for progress made under these agreements.

Editors: Robert Magnien, Daniel Boward, and Steven Bieber
Designer/Graphic Artist: Torrie Hedge

On the cover: Volunteers at the Jug Bay Wetlands Sanctuary seine for fish on the Patuxent River. Photo by Carroll Hughes. Back cover photo by Kent Mountford.

Illustrations on pages 25, 27, 31, 33, 35, 37, and 40 by Alice J. Lippson.

Contributors:

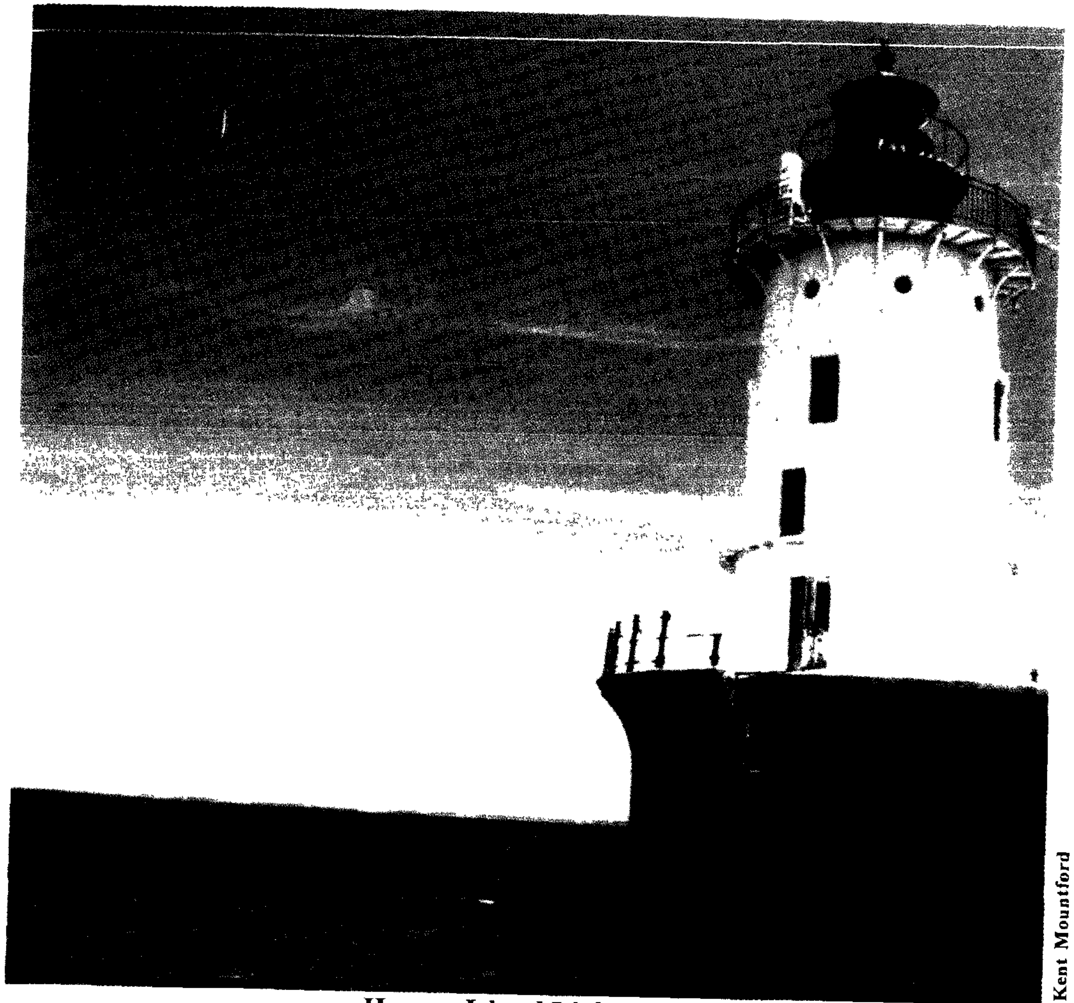
Daniel Boward	Kathleen Ellett	Joseph Macknis
Steven Bieber	Richard Eskin	Robert Orth
John Jacobs	Deborah Tan Everitt	Kathryn Rowland
Robert Magnien	Paul Foer	William Romano
Richard Batiuk	Douglas Forsell	Robert Summers
Donna Belval	Larry Haas	Lisa Thompson
Peter Bergstrom	Mike Haire	Elizabeth Weisengoff
Carin Bisland	Frederick Hoffman	
David A.C. Carroll	Jerry Hollowell	

This report was produced by the Chesapeake Bay and Watershed Management Administration, Maryland Department of the Environment. Production was conducted on behalf of the Monitoring Subcommittee, Paul Swartz, Chairperson, with funding support from the Chesapeake Bay Program.

This report acknowledges the outstanding contributions of Dr. Bruce Neilson to the development of the Chesapeake Bay monitoring program. Dr. Neilson helped in the initial design of the program in 1983 and over the last decade served as a member of the Chesapeake Bay Monitoring Subcommittee providing objective and insightful guidance in the program's implementation and in translating the data it provided into meaningful measures of the state of the Bay.

The Chesapeake Bay Program acknowledges assistance and cooperation from the following: Maryland Department of the Environment - Chesapeake Bay and Watershed Management Administration; Maryland Department of Natural Resources - Tidewater Administration; District of Columbia Environmental Regulation Administration; Pennsylvania Department of Environmental Resources; Pennsylvania Fish and Boat Commission; Virginia Department of Environmental Quality; Virginia Department of Game and Inland Fisheries; Virginia Department of Conservation and Recreation; Virginia Marine Resources Commission; U.S. Environmental Protection Agency - Chesapeake Bay Program Office; National Oceanographic and Atmospheric Administration - Chesapeake Bay Office; U.S. Army Corps of Engineers; U.S. Geological Survey; Susquehanna River Basin Commission; Interstate Commission on the Potomac River Basin; Metropolitan Washington Council of Governments; University of Maryland (CEES); Old Dominion University; Virginia Institute of Marine Sciences; The Academy of Natural Sciences; Chesapeake Research Consortium; Versar, Inc; and Coastal Environmental Services, Inc.

Table of Contents



Kent Mountford

Hooper Island Light

Printed by the U.S Environmental Protection Agency for the Chesapeake Bay Program

Recycled/Recyclable as Newsprint - Printed with Vegetable Oil Based Inks on 100% Recycled Paper (50% Postconsumer)

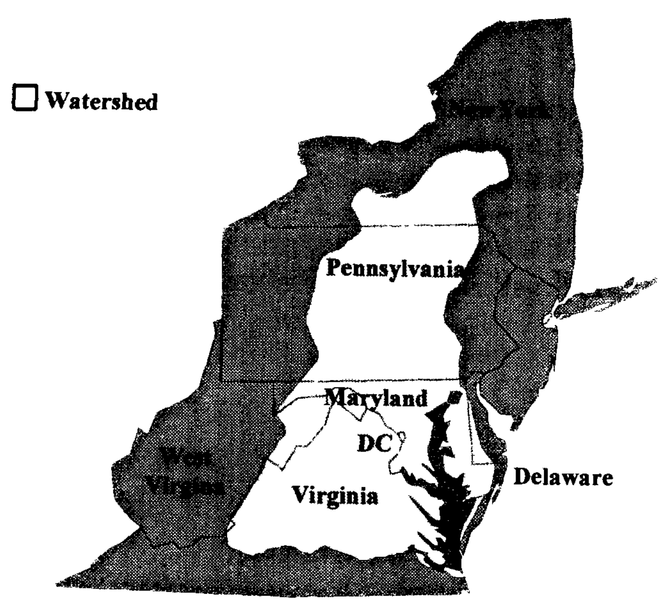
Introduction and Findings

1

The Chesapeake Bay is an expansive and dynamic system of water and living creatures. The fresher and saltier waters of the Bay are constantly being affected by, and intermingling with, the tributary rivers, ocean water, the shoreline and the air, all of which are likewise changing with the tides and seasons. While this natural brew of physical, chemical and biological interactions challenges our ability to understand and manage this great estuary, we are now in a better position than ever to assess the "state of the Bay".

If the health of the Bay could be likened to that of a hospital patient, the doctor would report that the patient's vital signs, such as living resources, habitat, and water quality, are stabilized and the patient is out of intensive care. Some vital signs, such as striped bass and Bay grasses have improved dramatically, while a few, such as oysters, are in decline. Other vital signs are mixed but stable. Nutrients are being reduced, with phosphorus levels down considerably more than nitrogen levels, and dissolved oxygen remains steady. Overall, the patient still suffers stress from an expanding population and changing land use, but it is on the road to recovery. Taken as a whole, the concentrated restoration and management effort begun ten years ago has produced tangible results -- a state of the Bay that is better today than when we started and that holds promise that the future will be brighter.

Chesapeake Bay Watershed



The 64,000 square mile Chesapeake Bay watershed extends from New York to Virginia, and from West Virginia to Delaware. A cooperative effort of all residents of the watershed is needed to restore the Bay and its tributaries.

In recent years, we have greatly improved our understanding of what ails the Bay and what treatments will be required to restore its vitality. Over the past decade we have also fortified our ability to measure the health of this vast system by establishing a network of sites at which we monitor key vital signs, or indicators, that reveal the successes and sometimes the failures of our restoration efforts. We must be willing, on a frequent basis, to examine the facts that we collect and feed them back into our management of the Bay. It is only through this periodic assessment and feedback that we will be able to efficiently and effectively fine-tune the treatments required to nurture this precious patient back to health.

OUR PERCEPTIONS

Before we dissect the state of the Bay, we must recognize that there are differing perceptions to be considered. Everyone who cares about the Bay has their own personal perspective on what is important based upon their livelihood, recreational pursuits, culinary tastes and knowledge about the Bay gleaned from various sources and experiences. Often these perceptions change through life as we learn more and are faced with the challenges of supporting ourselves and our families.

To the young child who visits one of the numerous harbors of the Bay, trash floating on the water's surface, invariably deposited by "someone else", may appear to be the most obvious sign of the Bay's health. As that child matures and learns more about the Bay, he or she may come to realize that the major pollution threat to the Bay is actually an overenrichment with nutrients and some concern for toxic compounds in localized areas. As an adolescent in the Bay region, he or she is exposed to many of the pleasures of the Bay such as steamed crabs, boating, fishing and birding to name just a few. These experiences further shape our perceptions of what is important about the state of the Bay.

As that adolescent matures into the workforce, new realities emerge. Many professions depend directly upon the Bay, such as the seafood industry or those that thrive from the numerous recreational pursuits afforded by a healthy Bay. Other professions, and the multitudes of people themselves, are actually perceived as threats to the Bay because of the forests that must be cleared for factories, farm fields and housing, and because of the chemicals that they spew into the environment. Before long it becomes obvious that we are all responsible in some ways for the Bay's problems and that we need to make tough choices to restore the health of what we perceive to be important components of the state of the Bay.

In the sequence of chapters in this report, an attempt is made to capture the major elements of the Bay's health that reflect the current perceptions of scientists, managers and citizens as to what constitutes the state of the Bay. It contains many of the traditional measures that have been used in the past such as the harvests of seafood, the quality of its waters and the amounts of pollution reaching the Bay. These are all critical measures that we must continue to monitor. But there are new or enhanced measures that reflect a broadening of approaches to restoring the Bay. In this report, there is more attention devoted to the state of the watershed where our activities affect the amounts of pollution reaching the Bay via its tributaries. There is also more information about the intermediate linkages between pollution or water quality and our very visible living resources such as fish, shellfish and waterfowl. These linkages include submerged aquatic vegetation, microscopic plankton and small organisms that dwell in the Bay's bottom muds. These biological communities form the base of the food web and must be healthy to support the more visible living resources that we wish to see in greater abundance.

We conclude this report with a chapter on citizen involvement in measuring the state of the Bay. Government agencies cannot afford to assess conditions everywhere in the Bay and its watershed; concerned citizens can provide the additional help needed to plug gaps in our geographic coverage. Involvement of citizens in assessing the Bay's health also serves to broaden participation in the Bay cleanup and increase awareness about what all of us can do to restore the Bay.

Undoubtedly, our perceptions of the Bay will continue to evolve in the future. The widening circle of influences impinging upon the Bay will probably make us look harder at the "airshed", that geographic region from which air pollutants reaching the Bay watershed are released. We may also be more concerned about the influence of ocean currents which can bring pollutants from throughout the eastern coast of our country into the Bay. The migratory nature of fish species which constitute important Bay resources also link our restoration efforts with those of other east coast states. And, within the Bay's watershed itself, we are likely to challenge ourselves over and over again concerning the degree to which we can restore the Bay, given the continuing increases in population and demands for its resources.

We cannot return the Bay to a pristine state, nor will we ever have the uninhabited expanses that many of our parents and grandparents knew. We will probably never go back to the days when we could harvest oysters by the tens of millions of bushels nor to the days when we could catch as many forty-pound rockfish as our boat could hold. Those days are gone forever. But, we can have relatively clean water and large, protected areas of marsh and shoreline. We can have viable fish and bird populations, although never the "limitless" stocks of fish for all to harvest. And we can have protections and institutions in place to ensure that a "clean" and "healthy" Bay will be here for our children and grandchildren.

THE FINDINGS

In the chapters that follow, you will learn, in some detail, about various parts of the Bay ecosystem that constitute the state of the Bay. The following is a preview of what you will find:

U.S. Geological Survey

Conowingo Dam near the mouth of the Susquehanna River.

• The Bay's watershed, radically changed by European settlement three centuries ago, continues to undergo changes that reflect how we use the land in this 64,000 square mile expanse. Urban, suburban and agricultural lands all leach more pollutants into the Bay than natural forests or wetlands. About 40 percent of the land is no longer in its natural state and we are losing wetlands at a rate of about 8 acres per day.

• An ever expanding population has resulted in higher wastewater flows to the Bay. Through increased wastewater treatment and bans of detergents containing the nutrient phosphorus, we have been able to reduce these point sources of phosphorus by 70 percent since a peak in the 1970s despite a 40 percent increase in flows. Nitrogen controls, just recently being implemented, are already starting to reduce the levels of this pollutant entering the Bay from point sources, such as industries and municipal sewage treatment plants.

• Inputs of nutrient and sediment pollution from the Bay's rivers show encouraging signs. Phosphorus and sediment concentrations reaching the Bay from rivers draining its two largest watersheds, the Susquehanna and Potomac, are declining. After many years of increasing nitrogen concentrations, most of the Bay's tributaries are showing a leveling off of this trend and some are actually showing declines. These results, which represent trends throughout most of the Bay's watershed, show that both point and nonpoint source pollution abatement programs are working.

- Nutrient levels in the waters of the Bay and its tributaries are responding to the trends seen in the inputs of nutrients from wastewater and the Bay's rivers. Many regions are showing declines in phosphorus levels. Nitrogen levels are no longer increasing in most areas. Despite these promising trends, oxygen levels are still low enough to cause severe impacts or stressful conditions in the mainstem of the Bay and several larger tributaries.

- Potentially toxic contaminants stored in the Bay's bottom sediments from years of pollution only reach levels of concern in a few localized areas that have intensive industrial activity and high population densities. The inputs of many of these pollutants have already been reduced but additional measures are being studied to reduce any possible toxic impacts.

- Submerged aquatic vegetation, a critical habitat for fish, crabs, waterfowl and their food, have increased 75 percent since 1978 in response to improving water quality. These increases bring us to about 64 percent of the initial restoration goal. Additional improvements in water quality will be needed to sustain the resurgence in SAV.

- Important biological communities in the Bay, such as plankton and bottom-dwelling organisms, reveal underlying concerns in the food web that sustain some of the more visible Bay species.

- Due to improved reproduction and better control of the harvest, striped bass, or rockfish, have made a remarkable recovery over the past decade.

- American shad, which spawn in the Bay's tributaries, have suffered huge population declines over the past century due to overharvesting, blockage of migration routes by dams and habitat degradation. Controls on the harvest and providing fish passages at numerous blockage points have led to modest increases in the numbers of fish returning to spawn. These management measures along with stocking and habitat restoration are expected to yield increases in the American shad and similar fish species.

- Prospects for the Bay's oyster populations remain poor. Overharvesting, habitat loss and diseases have all conspired over the years to severely deplete the stocks. New management efforts have been developed to improve this situation.

- The blue crab is currently the most important commercial and recreational fishery in the Bay. With increasing fishing pressures and relatively low harvests in recent years, there is growing concern for the health of the stocks. Both Maryland and Virginia have recently implemented new regulations on commercial and recreational crabbers to protect this important resource.

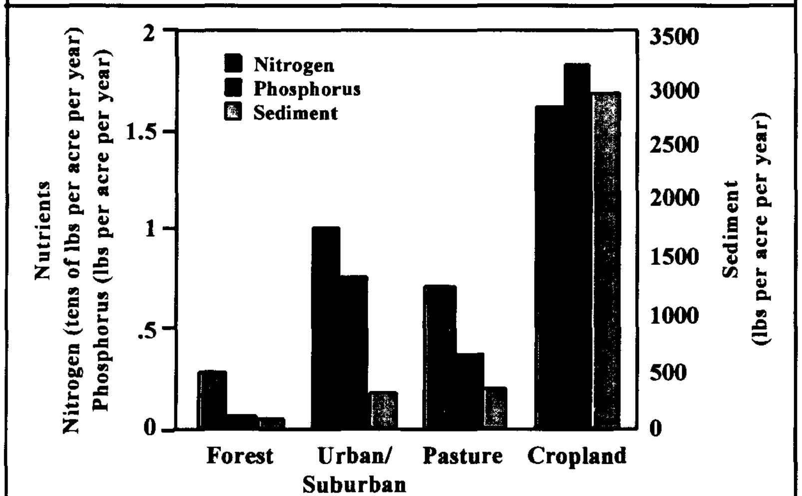
- The Bay's waterfowl consists of numerous species including some that are non-native. In general, the native species are undergoing a long-term decline in abundance. It is hoped that improvements in habitat, including submerged aquatic vegetation, will help to reverse this decline.

The findings contained within this report allow for much optimism but also warn that we are far from declaring victory in our fight to save the Bay. They show that the Bay is an interconnected system where activities on the land set off a chain of events that ultimately yields degraded conditions in the water and declines in living resources. They show that these conditions, which have resulted from almost 300 years of abuse, are reversible. The lessons we learn from these findings, and our willingness to act on them, will determine the state of the Bay that we leave to future generations.

Watershed Land Use

The Chesapeake Bay watershed covers about 64,000 square miles and portions of six different states and the District of Columbia. How the land is used in the watershed is a basic factor in the ecological "health" of the Bay. The trees filter sediment and nutrients from runoff and their roots stabilize the shoreline and reduce erosion. By shading the water, riparian forests also reduce summer water temperatures, increasing dissolved oxygen levels. Agricultural land use is mainly divided into two categories — pasture and cropland. Pasture land consists of grassy areas for feeding livestock. Cropland is cultivated to provide various food products. Urban and suburban lands provide space for homes, roads, and jobs, and increase the amount of impervious surface area and stormwater runoff. As a watershed becomes more developed, the amount of pollutants carried in the stormwater runoff increases, as does the amount of wastewater and solid waste requiring disposal.

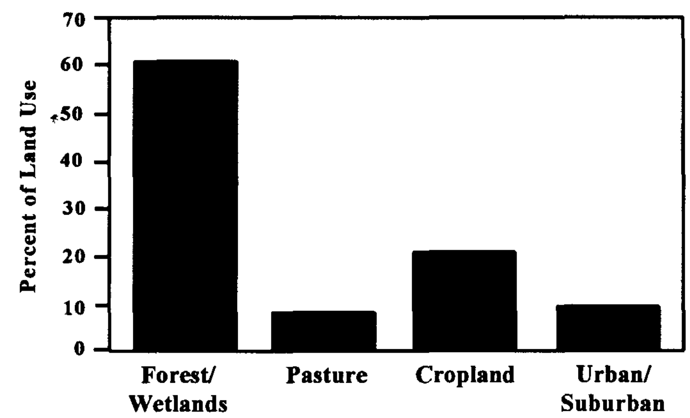
Nutrient and Sediment Pollution from Different Land Uses



Nonpoint source pollution is greatly dependent upon land use. Nutrient and sediment washed from forested lands, the most natural and undisturbed use, are very low compared to urban and agriculture. Sediment loads are greatest from cropland. This figure represents the overall year to year average of nonpoint source loads for the Chesapeake Watershed.

Sources: Nutrient Loads - CBP Watershed Model Base Case Scenario (1991); Sediment Loads - CBP Watershed Model Appendix C (1991)

Chesapeake Watershed Land Use



Recent (1985) data show that forest is the dominant land use within the Bay watershed, but much of these forests are in areas distant from the shores of the Bay. In some parts of the watershed, forests are rapidly being replaced by agricultural and urban lands. By the year 2000, the amount of urban or suburban land is expected to increase to 13 percent of the watershed.

Source: CBP Watershed Model, Appendix E (1992)

The connection between human activities on the land and Bay degradation is clear. Shifts from environmentally beneficial uses to less desirable uses increase pollutant loads and challenge water quality, habitat, and living resource restoration efforts. Nutrient and sediment loads from forest land are low compared to urban and agricultural land uses.

Data from 1985 show that forest is the dominant land use within the Bay watershed, comprising about 60 percent of the land, mostly in areas far removed from the Bay's shoreline. Agricultural land, including pasture and cropland, constitutes about 30 percent of the watershed. Urban and suburban lands are generally close to the Bay and its tidal tributaries and cover about 10 percent of the watershed. Based on projections of a steadily increasing population, the largest change in land use will be from forest and agriculture to urban and suburban. In 1985, about 4.0 million acres of the watershed were urban or suburban. This number is projected to increase to about 5.4 million acres by the year 2000, an increase of 35 percent over the 1985

Forests

6

When the colonists first arrived on the shores of the Chesapeake, they found a vast forest covering over 95% of the watershed. These forests served as a continuous living filter and regulator of the Bay's environment. As the land was settled, the pace of forest clearing accelerated. By the mid-1800s, over half of the forest land had been converted to other uses.

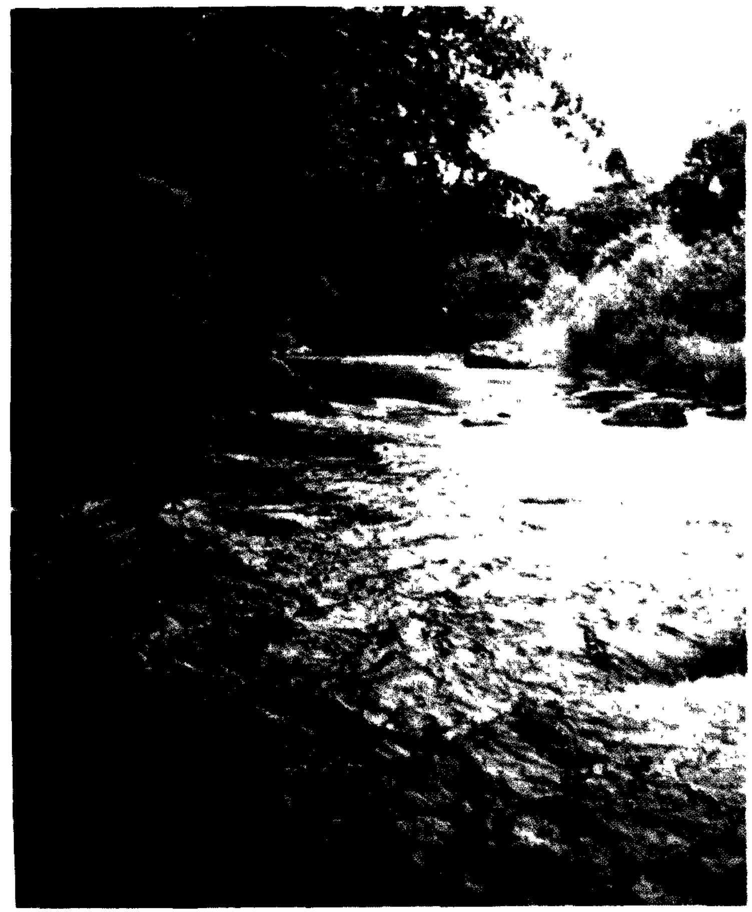
Forests have recovered somewhat from their historic lows, but only about 60% of the watershed is forested today. From 1980 to 1990, forests were lost at a rate as high as 300 acres per day.

As the natural land cover for most of the Bay's watershed, forests provide a physical and biological system that supports a clean and productive Bay. Scientific findings clearly show that forests are the most beneficial land cover for maintaining clean water. While it is difficult to predict exactly how much forest we can afford to lose without diminishing the watershed's role in maintaining the Bay's health, we are near or exceeding the threshold in many areas of the watershed.

Some tributary basins of the Bay have lost over 85% of their forests while others have experienced little or no loss. For example, while forest acreage is expected to decrease in Virginia and Maryland, forest land in the Pennsylvania portion of the watershed is projected to remain stable or increase slightly. The location and distribution of these forests, however, may be as critical as the total acreage. The fragmentation of forests into small isolated parcels is especially common in urban landscapes.

- **Filter nutrients and sediment**
- **Capture rainfall and regulate streamflow**
- **Moderate stream and air temperature**
- **Stabilize erodible soils**
- **Create and maintain fish and wildlife habitat**
- **Preserve biodiversity**

Thousands of miles of streams have been left unprotected by the stripping away of their natural riparian (streamside) forest. Riparian forests are critically important to the delicate balance and health of the Chesapeake Bay ecosystem. The trees filter sediments and nutrients from runoff and their roots stabilize the shoreline and reduce erosion. Lower nutrient levels minimize the incidence of algal blooms — large areas of dense phytoplankton which consume substantial quantities of life-supporting dissolved oxygen as they decompose. By shading the water, riparian forests also reduce summer water temperatures and increase dissolved oxygen levels. Riparian forests provide habitat and food for wildlife both on the land and in the water.



Tony Allred

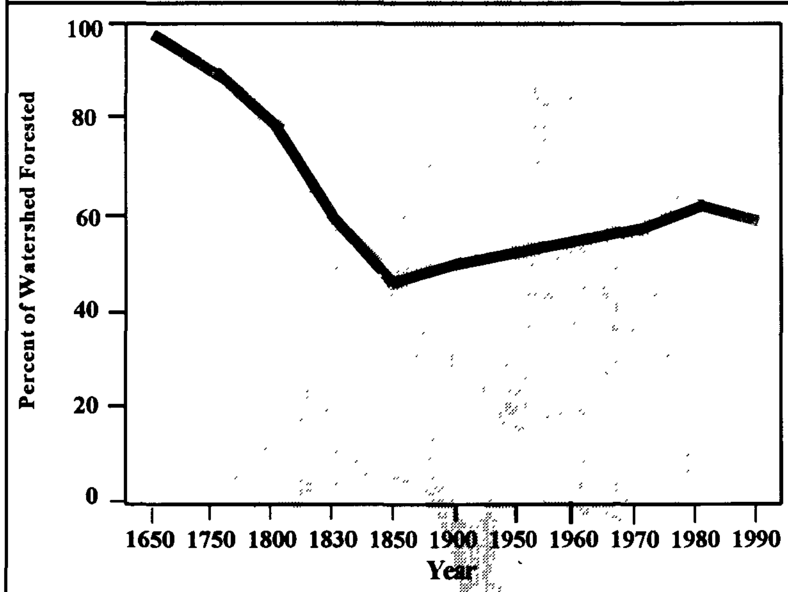
Through the Chesapeake Bay Program, unique partnerships have been formed among the Bay region's forestry agencies, forest managers, and interested citizen groups. Since 1990, the U.S. Forest Service has assigned a Forestry Program Coordinator to the Chesapeake Bay Program to assist both the EPA and Bay Program committees in developing strategies and projects which contribute to the restoration goals. A Forestry Work Group, formed under the Nonpoint Source Subcommittee, raises and addresses issues related to forests and the practice of forestry in the watershed.

In addition, state foresters and local governments have responded to the Chesapeake Bay Program with the development and implementation of numerous programs and projects aimed at the protection and restoration of forests. Forestry incentive programs in all of the Bay states have resulted in the planting of millions of trees, restoration of nearly 50 miles of riparian forest, development of forest stewardship plans, and forest enhancement projects on thousands of acres within the Bay watershed. Protecting existing forests and planting additional trees, where possible, is a significant element of a Baywide effort to reduce nutrient pollution — the Tributary Strategies.

The Chesapeake ecosystem has a tremendous ability to buffer and repair itself. Forests play an integral role in this resilience. Conserving and replanting forests are critical elements of our efforts to restore the Bay.

Forest Solutions

The Chesapeake Bay History of Forested Lands



When the colonists arrived, forests covered 95 percent of the Bay watershed. By the mid-1800s, over half of these natural woodlands had been converted to other uses. Reforestation projects, public awareness, and displacement of logging operations halted the rapid downward trend into the 1900s. Between 1980 and 1990 , however, forests have been lost to urbanization at the rate as high as 300 acres per day.

Source: U.S. Forest Service

- **Maryland's Forest Conservation Act requires consideration of forest conservation in land use planning.**
- **Virginia has a program aimed at improving implementation and effectiveness of best management practices in forest management.**
- **Riparian forest protection and reestablishment programs:**
  - **Maryland's Tree-mendous and Greenshores programs;**
  - **Pennsylvania's Stream Fencing (streambank protection) and Conodoguinet Watershed programs;**
  - **Virginia's Chesapeake Bay Preservation Act;**
  - **District of Columbia's Anacostia Watershed Projects.**

Wetlands

8

For years, wetlands were considered mosquito-infested wastelands best suited for dumping and filling. Wetland ecosystems, such as bogs, marshes and swamps, however, are now recognized as some of the most ecologically important areas in the world. A wetland is generally defined as an area where saturation of the soil with water is the dominant factor determining plant, animal, and soil composition. Typically, these lands are transitional areas between terrestrial and aquatic systems. Due to this relationship with both land and water, wetlands provide critical food and habitat for a wide variety of fish and wildlife. Many fish and shellfish rely on tidal wetlands at some point in their life cycle. Tidal wetlands also calm wave action and prevent shoreline erosion. Non-tidal wetlands, such as bogs, swamps, flooded forests, and riparian wetlands, provide habitat for wildlife and migrating waterfowl. They also provide a natural buffering capacity to watersheds by retaining stormwater runoff and capturing pollutants such as sediments, nutrients, and toxicants, all of which pose a serious threat to the health of the Chesapeake Bay.

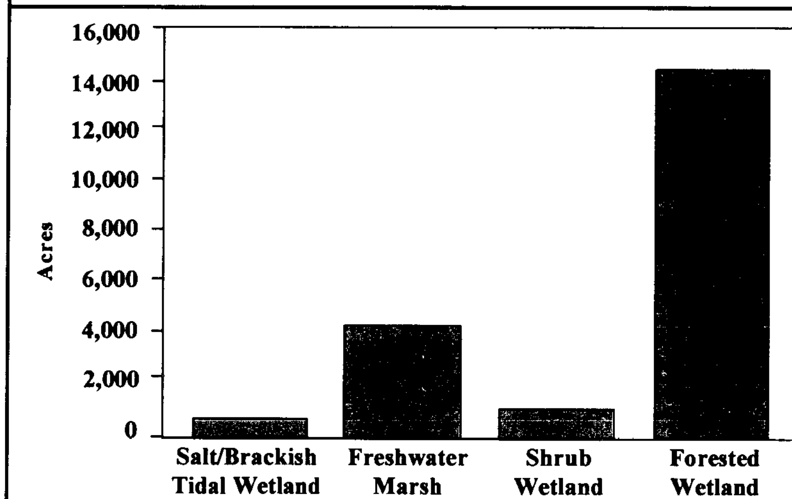
Between 1982 and 1989, wetlands in the Bay watershed were lost at a rate of about 8 acres per day.

Based on data collected by the U.S. Fish and Wildlife Service, the Bay's watershed lost about 2.5 percent of its wetlands between 1982 and 1989. Out of the approximately 1.7 million acres of wetlands surveyed in 1982, a net loss of about 20,000 acres occurred during the seven-year period, primarily through filling, draining or conversion to open water. This acreage equals about half the size of the District of Columbia. Pennsylvania, however, experienced a net gain in wetlands acreage.

Three basic changes in wetland acreage were observed during the study period. "Destroyed" refers to those areas previously classified as wetland that are no longer wetland, either due to filling to create upland or conversion to open water, such as a reservoir. "Created" refers to wetlands created from either an upland site or open water. "Transformed" wetlands are those that changed wetland type. For instance, a shrub wetland can change to a forest wetland through succession from smaller, younger trees to larger, more mature forests. This change would appear as a loss for shrub wetlands and a gain for forested wetlands. These changes are combined to obtain a net change of wetland acreage and type. For all wetland types, the losses were partially offset by gains in acreage due to the conversion or natural growth of other wetland types, but the data presented here illustrate net changes in acreage.

The four most common types of wetlands in the Bay watershed are salt and brackish tidal wetlands, freshwater marshes, nontidal shrub wetlands, and nontidal forested wetlands. Net losses of about 500 acres of salt and brackish tidal wetlands, 4,000 acres of freshwater marsh, and 1,000 acres of shrub wetlands occurred during the study period. Much of the salt and brackish tidal marsh loss occurred via

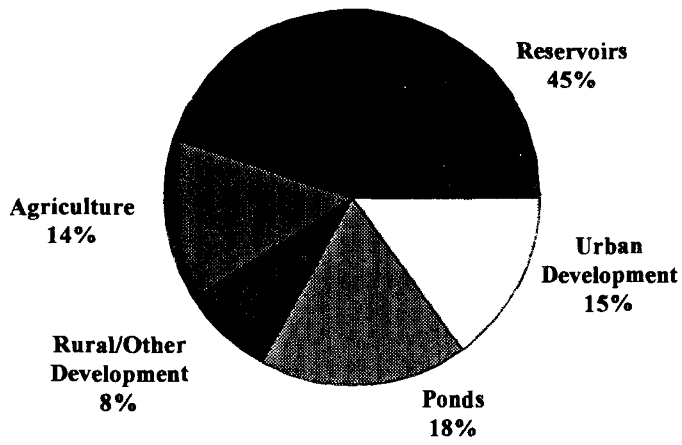
Net Wetland Loss in the Bay Watershed



A net loss of about 19,500 acres of wetlands occurred in the Bay watershed between 1982 and 1989. Although each wetland type gained and lost acreage, the net change for each type was a loss.

Source: Recent Wetland Status and Trends in the Chesapeake Watershed; 1982-1989 (U.S. Fish and Wildlife Service, 1994)

Freshwater Forested Wetland Destruction in the Bay Watershed



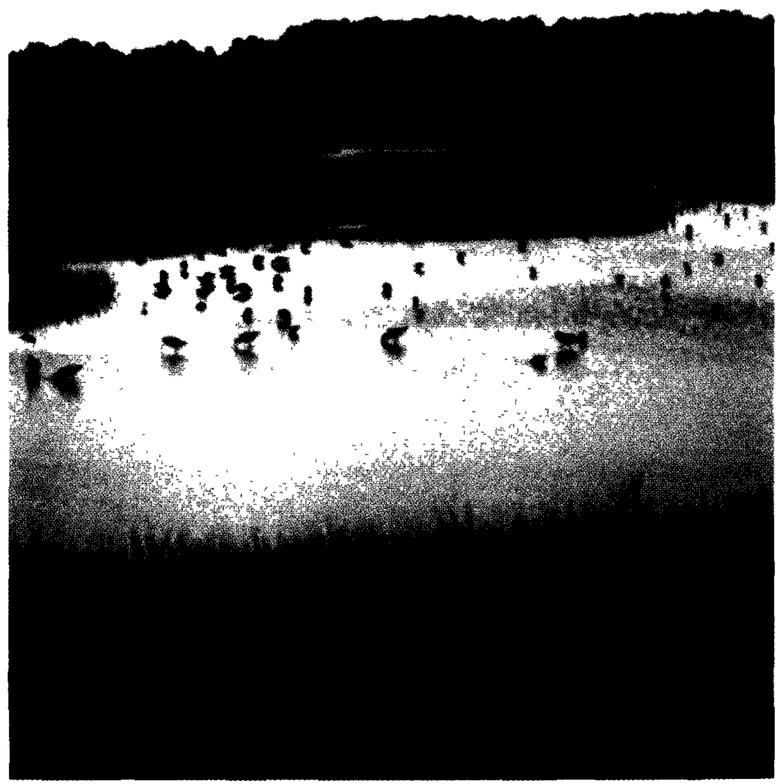
Forested wetlands sustained the greatest loss of any type in the Bay watershed. More than half were destroyed for reservoir and pond construction. Agriculture and urban development were also major factors. These numbers do not include wetlands harvested for timber.

Source: Recent Wetland Status and Trends in the Chesapeake Watershed; 1982-1989 (U.S. Fish and Wildlife Service, 1994)

draining and/or filling for upland areas, or conversion to ponds and lakes. Reservoir construction was responsible for most of the shrub wetlands destroyed during this period.

Forested wetlands sustained the greatest loss of any wetland type, with a net loss of over 14,000 acres during the study period. About 25,000 acres of these wetlands were transformed to other wetland types; 18,000 acres of the forested wetlands were harvested for timber. Forested wetlands managed for timber harvest are not considered destroyed; instead these wetlands are temporarily transformed to the emergent or shrub type, maintaining wetland functions such as wildlife habitat, and gradually returning to forest through natural succession. Conversely, 22,000 acres of other wetland types were transformed to forested wetlands, largely due to successional changes, and 3,000 acres were created from upland areas. Over 14,000 acres of forested wetlands, however, were considered destroyed because they were converted to open water, urban areas, and agricultural land.

Protection of our remaining wetlands is an essential step in restoring and enhancing the environmental quality of the Bay and its watershed. Identification of sensitive wetland areas before development encroaches is an important tool in wetland management. Protection of our remaining wetlands through a strong regulatory program — in some cases combined with a targeted acquisition program — is vital to the restoration and conservation of the Chesapeake Bay ecosystem.



U.S. Fish and Wildlife Service

Population Growth and Wastewater Discharges

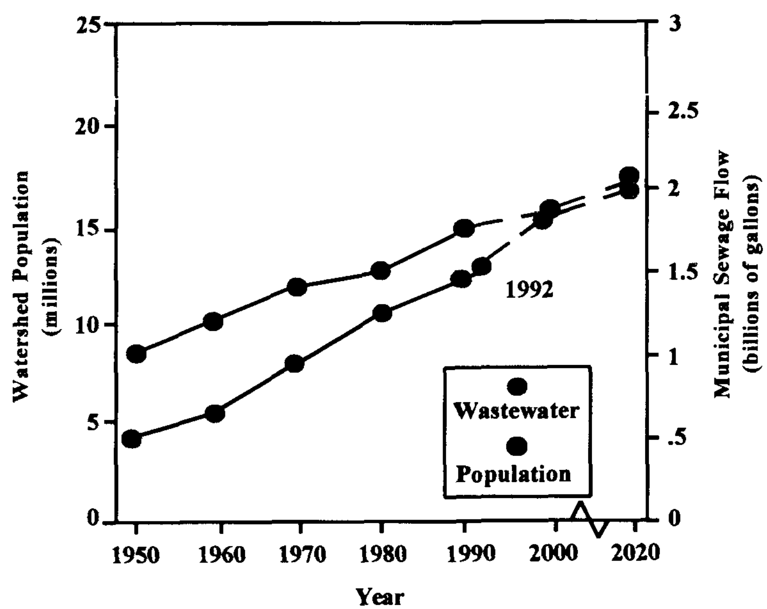
Population growth is the single most important factor underlying the various stresses on the Bay ecosystem. In 1950, the Bay's watershed contained 8.4 million residents. By 1990, this figure had grown to 14.7 million and, by 2020, there will be an estimated 17.4 million people living in the watershed. Most of the growth is taking place in Maryland and Virginia. An expanding population relies on highways and automobiles, increasing both the number of cars on the road and the miles driven. In Fairfax County, Virginia, for example, the population has risen 31 percent since 1975 and the autos required to transport these people to new employment centers increased 89 percent over the same period.

The growing population requires land for homes, transportation, shops, jobs, and recreation. Forests and other land of environmental significance are often converted to meet these needs. Without careful planning, growth causes adverse environmental impacts that will diminish the quality of life of the human population as well as the living resources of the Bay and its tributaries. Population growth also has the potential to negate any progress in Bay improvements, overwhelming past and current efforts. Consequently, growth should be managed in ways that will minimize its adverse environmental impacts.

Along with changes in land use, population growth also results in higher flows from wastewater treatment plants. The volume of discharge by wastewater treatment plants in the Bay watershed has increased with the general population trend. After the passage of the Clean Water Act of 1972, which established the Federal Construction Grants Program to build, expand, and upgrade wastewater treatment plants, each treatment plant was able to serve a larger population. With an increased number of conversions from septic systems to sewerage, the amount of wastewater discharged per facility also increased. Thus, the rate of increase in wastewater flow surpassed that of the population during the 1970s. Other factors which possibly contributed to increases in wastewater flow include rising industrial flows, water seeping from aging pipes, and an increase in per capita water use due to a rising standard of living.

These wastewaters contain the nutrients phosphorus and nitrogen. Excessive quantities of these nutrients are the primary pollution threat affecting Bay waters. The Federal Construction Grants Program provided improved treatment at municipal plants to remove phosphorus, resulting in a sharp decline in phosphorus discharges between 1970 and 1980. These reductions have continued since 1980 with additional treatment plant upgrades and the implementation of phosphorus bans which prohibit the use of this nutrient in

Watershed Population and Wastewater Flow



Between 1950 and 2020, population in the Bay watershed is expected to more than double. As population increases, the amount of municipal wastewater generated and discharged also increases. These wastewaters contain the nutrients phosphorus and nitrogen which fuel algal growth and result in lower dissolved oxygen levels. Increased funding for upgrading wastewater treatment plants in the 1970s, followed by a greater number of conversions from septic systems to sewerage, resulted in a higher rate of increase in wastewater flow than in population.
Source: Chesapeake Bay Program

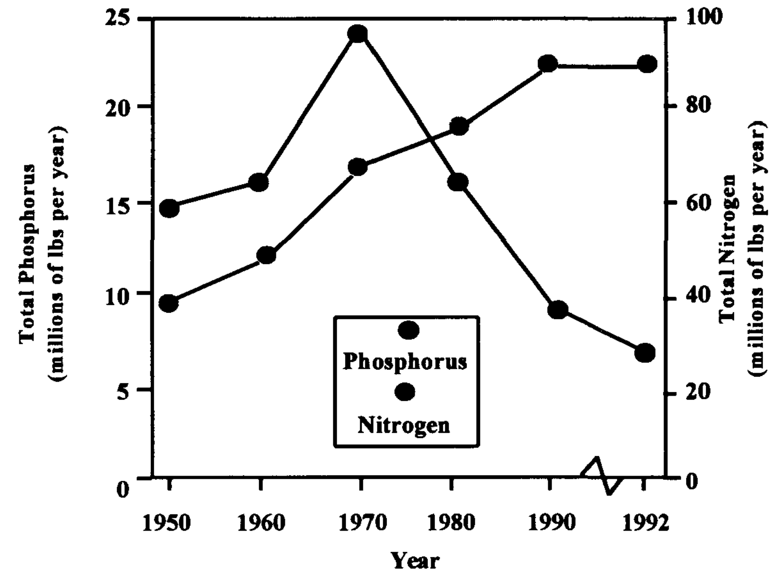
household detergents. Overall, phosphorus loads have declined by about 70 percent since the 1970s. Nitrogen discharges increased steadily between 1950 and 1985. Improved treatment at both industrial and municipal facilities is responsible for reductions in nitrogen discharges since 1985. Innovative technologies, such as biological nutrient removal (BNR), are being implemented for nutrient control. This technology provides better management of the sewage treatment process, resulting in lower nitrogen and phosphorus levels.

The signatories of the Chesapeake Bay Agreement have committed to develop and implement nutrient reduction strategies — the Tributary Strategies — that will reduce the 1985 combined point and nonpoint source loads by 40 percent by the year 2000. Great strides have been made in reducing point source phosphorus loads. Continued reductions are needed, especially in nitrogen, however, to offset flow increases in areas of rapid population growth.

Maryland Department of the Environment

Baltimore's Inner Harbor

Baywide Industrial and Municipal Nutrient Discharges



Trends in point source municipal and industrial discharges of phosphorus and nitrogen, as measured at the end of pipe, show dramatically different patterns. Total phosphorus discharges increased with population and municipal flows until the 1970s. The sharp decline in phosphorus discharges between 1970 and 1980 resulted from improved treatment at municipal plants. Improved treatment levels and implementation of the phosphorus bans in the 1980s resulted in continued reductions in point source phosphorus discharges. Nitrogen discharges kept pace with municipal flow from 1950 to 1985. Recent upgrades of municipal and industrial discharges have started to reverse this trend.

Source: Chesapeake Bay Program

Rivers and the Bay

The quality of river water entering the Chesapeake Bay from the surrounding non-tidal tributaries is an important factor in the water and habitat quality of the estuary. Point and nonpoint source pollution control measures have been, and will continue to be, applied in the basins discharging to the Bay. To evaluate the effectiveness of such measures, the River Input Monitoring Program was established as a cooperative effort by the U.S. Geological Survey, Maryland Department of the Environment, the Virginia Department of Environmental Quality, and the Washington Metropolitan Council of Governments. In Pennsylvania, additional data are supplied by the Susquehanna River Basin Commission's Surface Water Monitoring Program.

Nutrients, sediments, and flow are monitored as part of these programs during both base flow and storm flow conditions on the Bay's major rivers. Monitoring programs, designed to assess trends in pollutant concentrations and loads, began in 1984 in Maryland, 1985 in Pennsylvania, and 1988 in Virginia. Historic data, collected since 1970 and 1978 in Virginia and Maryland, respectively, were also used to interpret trends as part of these programs. The goal of the trend analyses is to establish a link between nutrient loadings at the monitoring stations and the nutrient reduction strategies. The most recent results are presented here for total nitrogen, total phosphorus, and suspended sediment concentrations in each of the rivers.

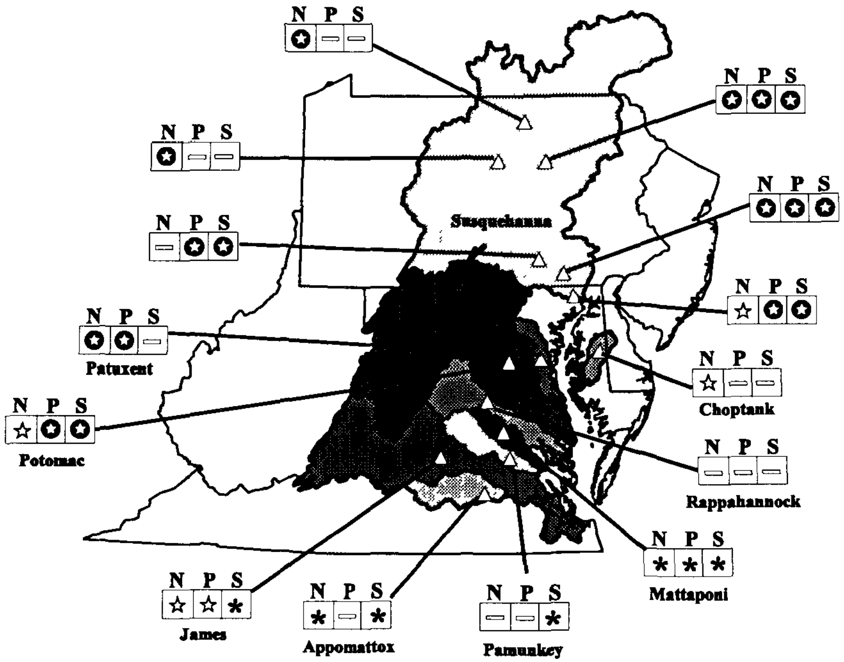
The Susquehanna River, which drains 27,100 square miles, is the Bay's largest tributary. It alone contributes 47 percent of the Bay's river flow and is monitored at its mouth in Maryland, and at five sites in Pennsylvania. The northernmost Susquehanna site captures the inflow from New York. Two mid-basin sites monitor the main stem and the River's West Branch. One lower basin site monitors contributions from upstream of the three major hydroelectric power pools, which act as major sediment sinks. The other lower basin site, the Conestoga River, is the largest contributor of nutrients and sediment to the Susquehanna River, per square mile of watershed.

Trends for the Susquehanna River watershed were analyzed between 1985 and 1993 in Pennsylvania and for the periods 1978 to 1993, and 1984 to 1993 at the site near the mouth in Maryland. In Pennsylvania, decreasing trends in total nitrogen were found in the northern to middle reaches of the Susquehanna and Conestoga rivers. Decreasing trends in total phosphorus and suspended sediment were observed in the lower Susquehanna River. At the mouth, total nitrogen concentrations showed an increasing trend over the entire 1978 to 1993 period, but the concentrations appeared to level off between 1984 and 1993. Total phosphorus and sediment concentrations decreased over the 16-year period.

In addition to the mouth of the Susquehanna, Maryland monitors three other rivers for their inputs to the Bay. The monitoring site on the Potomac, the second largest Bay tributary, covers the drainage coming from 11,800 square miles in Maryland, Virginia, Pennsylvania, West Virginia, and the District of Columbia, and contributes 16 percent of the total fresh water to the Bay. The Patuxent River drains only 348 square miles above the monitoring site. The watershed is rapidly becoming urbanized, however, and is the focus of a specific nutrient control strategy developed cooperatively by state and local governments. The Choptank River has the smallest of the four drainage areas, 113 square miles, and is typical of many basins on the Eastern Shore or eastern Coastal Plain Province.

Trend analysis was performed for the periods 1978 to 1993 and 1984 to 1993. The results of the analysis indicate some trends occur at each river for some constituents. Total nitrogen concentrations showed an increasing trend in the Potomac and Choptank rivers over the entire 1978 to 1993 period, but the concentrations appeared to level off between 1984 and 1993. The Patuxent River has shown a significant decline in nitrogen over both periods. Total phosphorus concentrations decreased in the Potomac and Patuxent over the 16-year period and these trends continued in the more recent period. The Potomac River showed decreases in suspended sediment over both periods, while the Patuxent showed decreases only since 1984.

Pollutant Trends in the Bay's Rivers



LEGEND

N	Nitrogen	☆	Increasing trend
P	Phosphorus	▭	No trend
S	Sediment	*	Insufficient data
✪	Decreasing trend	△	Sampling station

Nitrogen, phosphorus and suspended sediment are monitored near the head of tide in nine of the Bay's major rivers, and in the non-tidal portion of the Susquehanna River in Pennsylvania. These sites track changes in concentrations and loads of these pollutants to evaluate the success of point and nonpoint source management programs on a watershed-wide scale. Results are shown for trend analyses using the earliest reliable data collected since the 1970s and early 1980s, depending upon location.

Sources: Maryland Department of the Environment, Virginia Department of Environmental Quality, Susquehanna River Basin Commission, U.S. Geological Survey, Metropolitan Washington Council of Governments

The James River, which drains approximately 10,206 miles and contributes 12 percent of the total freshwater flow to the Bay, is the largest river monitored in Virginia. The Rappahannock River is the second largest contributor of flow to the Bay from Virginia, draining 2,848 square miles. Its watershed includes portions of the rapidly expanding District of Columbia suburbs. The Pamunkey and Mattaponi rivers converge to form the York River and drain 2,650 square miles. The fifth tributary monitored is the Appomattox River, with a drainage area of 1,344 square miles.

Trends at the fall line region of Virginia rivers were statistically analyzed from 1970 to 1989 and 1984 to 1989. Analyses of total nitrogen, total phosphorus, and suspended sediment were conducted where sufficient data were available. The James River was the only Virginia river exhibiting a trend. Total nitrogen concentrations increased from 1970 to 1989, however, no trend was detected during recent years (1984-1989). Total phosphorus increased in the James over both periods through 1989. Although total phosphorus data for the James between 1989 and 1994 have not been statistically examined, there appears to be a decreasing trend in phosphorus at the fall line of the James.

When taken as a whole, these results from the Bay's rivers, generally show very encouraging signs that the inputs of several important pollutants are either declining or leveling off after previously increasing trends. Point and nonpoint source controls of nutrients appear to be having an impact on the total phosphorus concentrations for a number of the rivers. The phosphate detergent bans enacted in Maryland, Virginia, Pennsylvania, and the District of Columbia during the mid 1980s have clearly contributed to the lowering of phosphorus inputs from the rivers. Even nitrogen, which has only recently been targeted for load reductions is showing declines in parts of the Susquehanna and Patuxent Rivers.

Overall Nutrient Sources and Reduction Goals

The nutrients nitrogen and phosphorus are the most significant and widespread pollution threat to the Chesapeake Bay. These nutrients fuel algal blooms which cloud the water and ultimately result in low levels of the oxygen required by all the Bay's living resources. Virtually all individuals and industries in the watershed, and some even beyond the watershed, contribute the nutrients that ultimately reach the Bay. Therefore, all of us must cooperate to reduce nutrient pollution.

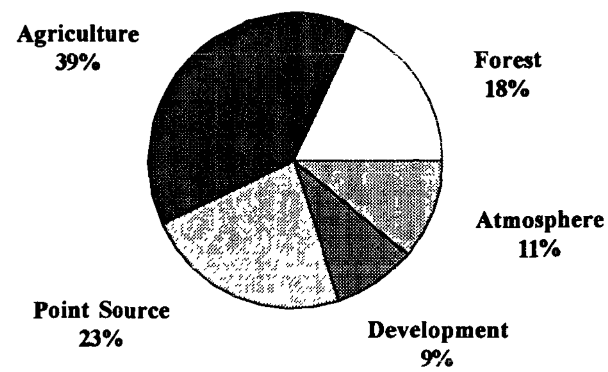
In 1987, the Chesapeake Bay Agreement was updated to include specific nutrient reduction goals and time lines for the implementation of nutrient control strategies. One of the key goals of this new agreement was a 40 percent reduction of nutrient pollution entering the Bay by the year 2000.

Using mathematical models, managers and scientists determined the expected range of dissolved oxygen concentrations in the Bay's bottom waters. At one extreme, without nutrient reductions, conditions would worsen considerably by the year 2000. At the other extreme, the dissolved oxygen levels present when John Smith first explored the Bay 350 years ago were much better than they are today. The managers and scientists determined that the 40 percent nutrient reduction goal would provide significant improvements in water and habitat quality and would also be close to the best achievable, given present population levels and available technology.

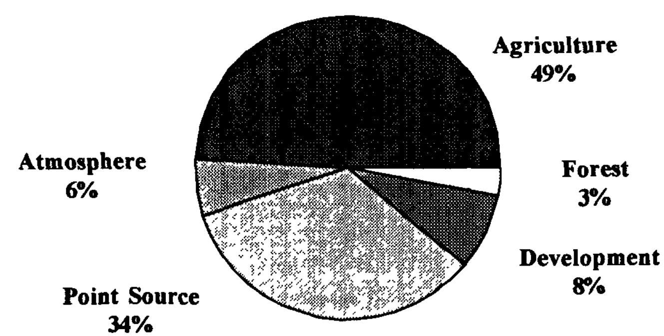
Mathematical modeling of the Chesapeake Bay system has also shown that the individual tributaries have varying impacts on the low dissolved oxygen problem of the main Bay. This modeling indicated that the Potomac River and the tributaries to the north dominate status of the main Bay's dissolved oxygen. The tributaries to the south of the Potomac, conversely, have a minimal impact on the main Bay dissolved oxygen. Consequently, the nutrient reduction goals for the lower Bay tributaries are regarded as "interim." Specific nutrient reduction goals for each of the lower tributaries are being developed to meet the requirements of the plants and animals in each tributary. Those lower tributary goals are being developed

Overall Watershed Nutrient Sources

NITROGEN



PHOSPHORUS



When accounting for all the nutrients that enter the Bay, the two largest contributors of both nitrogen and phosphorus are agriculture and point sources, based on 1985 estimates. Forests are a natural source of nutrients. Atmospheric nutrient pollution that falls directly on the water is displayed as a separate category and accounts for 11 percent of the total nitrogen load. Atmospheric nitrogen also falls on the land and accounts for an additional 16 percent of the total nitrogen load, but is included as part of the forest, agriculture, and developed land sources.

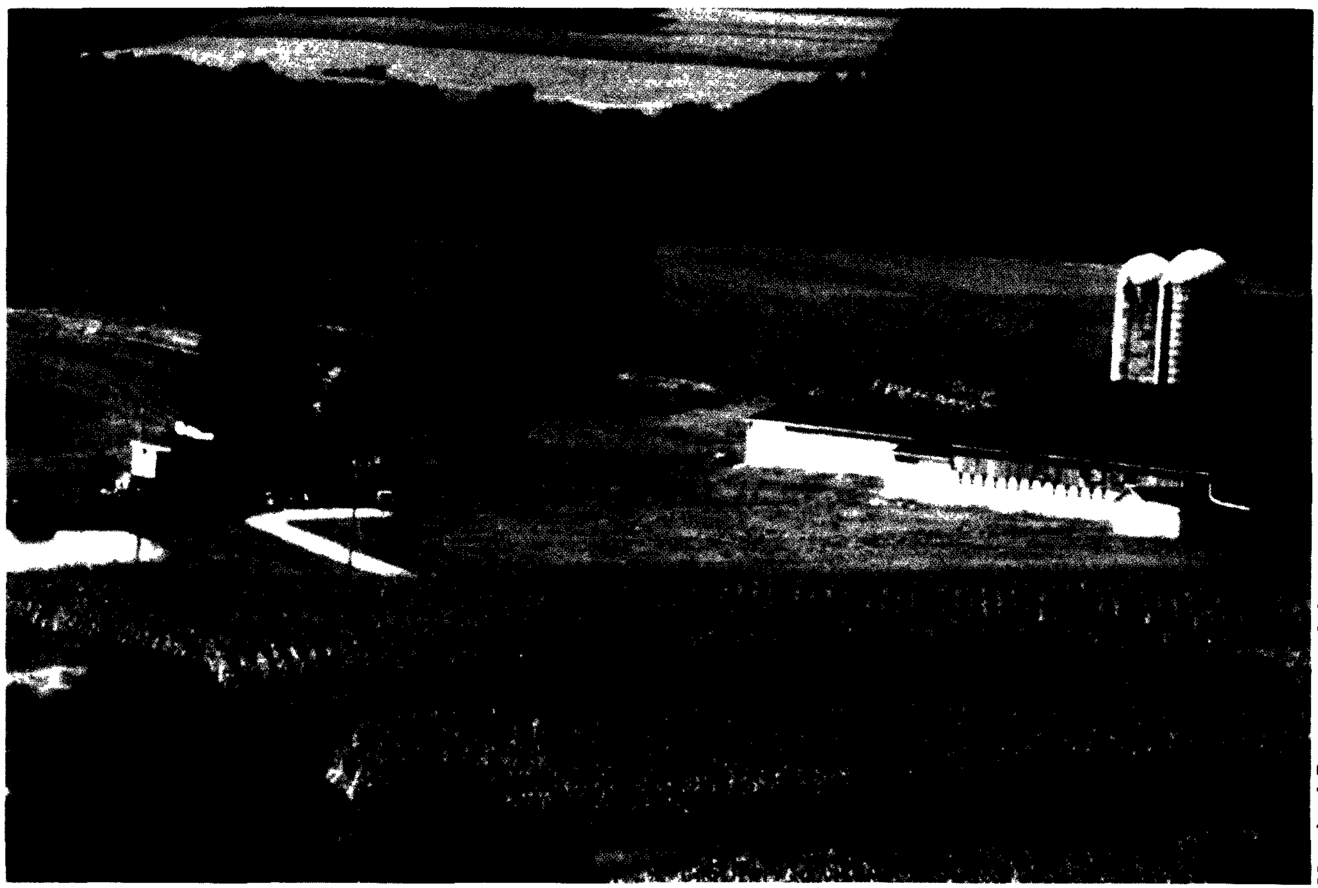
Source: Chesapeake Bay Program

through the expansion and refinement of the basic Chesapeake Bay water quality model with results expected in late 1997 or 1998.

As a result of the 1992 Amendments to the Chesapeake Bay Agreement, nutrient reduction targets were allocated among Maryland, Virginia, Pennsylvania, and the District of Columbia to achieve the greatest improvement in the Bay and its tributaries. The focus of the nutrient reduction effort also moved upstream — "Tributary Strategies" became the keyword for this restoration initiative.

The reduction targets use nutrient loads from 1985 — the baseline year for the 1987 Agreement. The loads remaining after the reductions are meant to be a cap to prevent backsliding in the future. As population grows, new and more efficient pollution control measures must be developed to allow us to "hold the line." The Bay amendments also spell out the importance of reducing atmospheric sources of nutrients and broadening regional interstate cooperation.

The challenge before us is to continue reducing excess nutrients entering the tributaries and ultimately the Bay. This challenge will be difficult to meet and may require changes in both attitude and lifestyle. Meeting this challenge, however, will pay large dividends. By reaching the 40 percent nutrient reduction goal, water quality will improve to a level that allows fish, crabs, waterfowl, Bay grasses and other living resources to increase in abundance.



Maryland Department of the Environment

Nutrient Enrichment and Habitat Quality

To many people, the phrase "cleaning up the Chesapeake Bay" means increasing the amount of good water in the Bay. Good water contains enough dissolved oxygen and is sufficiently clear to support the tremendous variety of aquatic life found in the Bay. In many areas of the Bay and for much of the year, however, the quality of the water is not sufficient to support the Bay's living resources.

In the warmer months, large portions of Chesapeake Bay contain little or no dissolved oxygen. Low oxygen conditions may cause the eggs and larvae of fish to die. The growth and reproduction of oysters, clams, and other bottom-dwelling animals are impaired. Adult fish find their habitat reduced and their feeding inhibited.

Many areas of the Bay also have cloudy water from an overgrowth of algae or too much sediment in the water. These turbid waters block the sunlight needed to support the growth and survival of Bay grasses, also known as submerged aquatic vegetation (SAV). Without SAV, critical habitat for fish and crabs is lost. Although there has been a resurgence of SAV in some areas of the Bay, most areas still do not support abundant populations as they once did.

The main causes of the Bay's poor water quality and aquatic habitat loss are elevated levels of two nutrients, nitrogen and phosphorus. Both are natural fertilizers found in animal wastes, soil, and even the atmosphere. These nutrients have always existed in the Bay, but not at the present excessive concentrations. When the Bay was surrounded primarily by forest and wetlands, very little nitrogen and phosphorus ran off the land into the water. Most of it was absorbed or held in place by the natural vegetation. Today, much of the forests and wetlands has been replaced by farms, cities, and suburbs.

As the use of the land has changed and the watershed's population has grown, the amount of nutrients entering the Bay's waters has increased tremendously. The excess phosphorus and nitrogen feed an abundant growth of algae which clouds the water and blocks the sunlight needed by Bay grasses. When the algae die, they sink and decompose, using up the dissolved oxygen in the water. As the water becomes depleted of oxygen, those species that can move must leave and compete for food and space in the remaining areas that can sustain them. Animals that can't move may die.

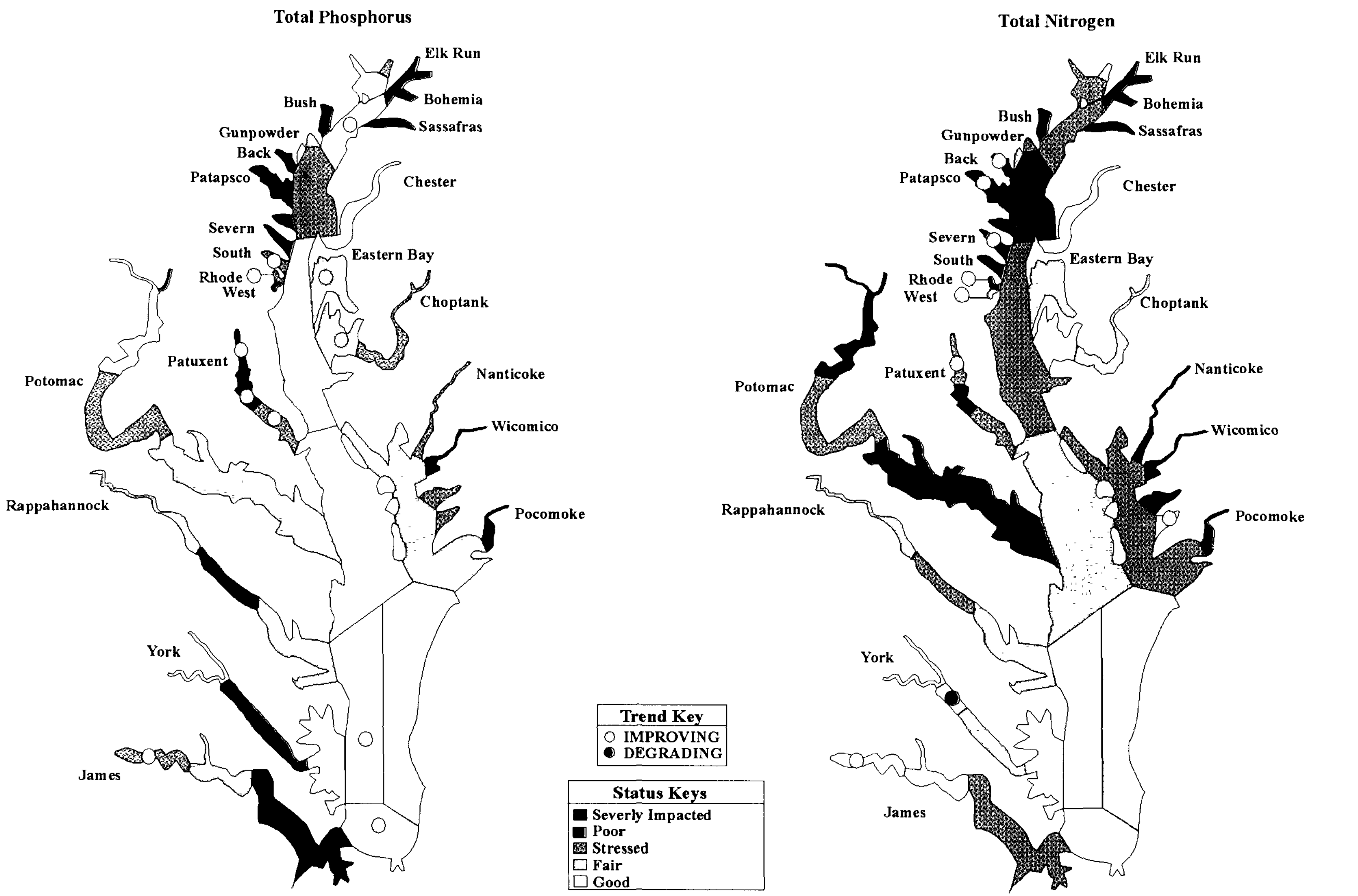
One of the main goals of the Chesapeake Bay restoration is to reduce the profound impacts of excess nutrients on the Bay. To this end, the Chesapeake Bay Program jurisdictions have agreed to reduce nitrogen and phosphorus pollution reaching the Bay in 1985 by 40 percent by the year 2000. A reduction goal of 40 percent was chosen because that level of nutrient reduction would result in significant improvements in the Bay's dissolved oxygen levels and in the habitat for SAV. It is also a realistic goal given present population levels and available nutrient reduction technologies.

Since the 40 percent nutrient reduction goal was established, significant progress has been made in lowering the amounts, or loads, of nutrients entering the Bay. Examples of this progress are provided in the previous sections on wastewater discharge and the inputs from the Bay's rivers. Much of the progress has been made in controlling phosphorus, especially from wastewater treatment plants. However, controls of nitrogen and nonpoint sources in general are also starting to yield results. As nutrient loads have changed, water quality in the Bay has responded.

For example, nitrogen concentrations in the water appear to be declining in some areas, especially Maryland's upper western shore, the Patuxent River, and the James River in Virginia. Many of these reductions have occurred in areas that, relative to other Bay waters, are severely impacted by nutrient overenrichment. The reductions in most areas are due to a combination of improved wastewater treatment and nonpoint source controls.

In all areas of the Bay and its tributaries, phosphorus concentrations are either declining or have remained stable since1984. Phosphate detergent bans in Pennsylvania, Virginia, Maryland, and the District of Columbia between 1986 and 1988, along with numerous wastewater treatment plant upgrades, have played a significant role in

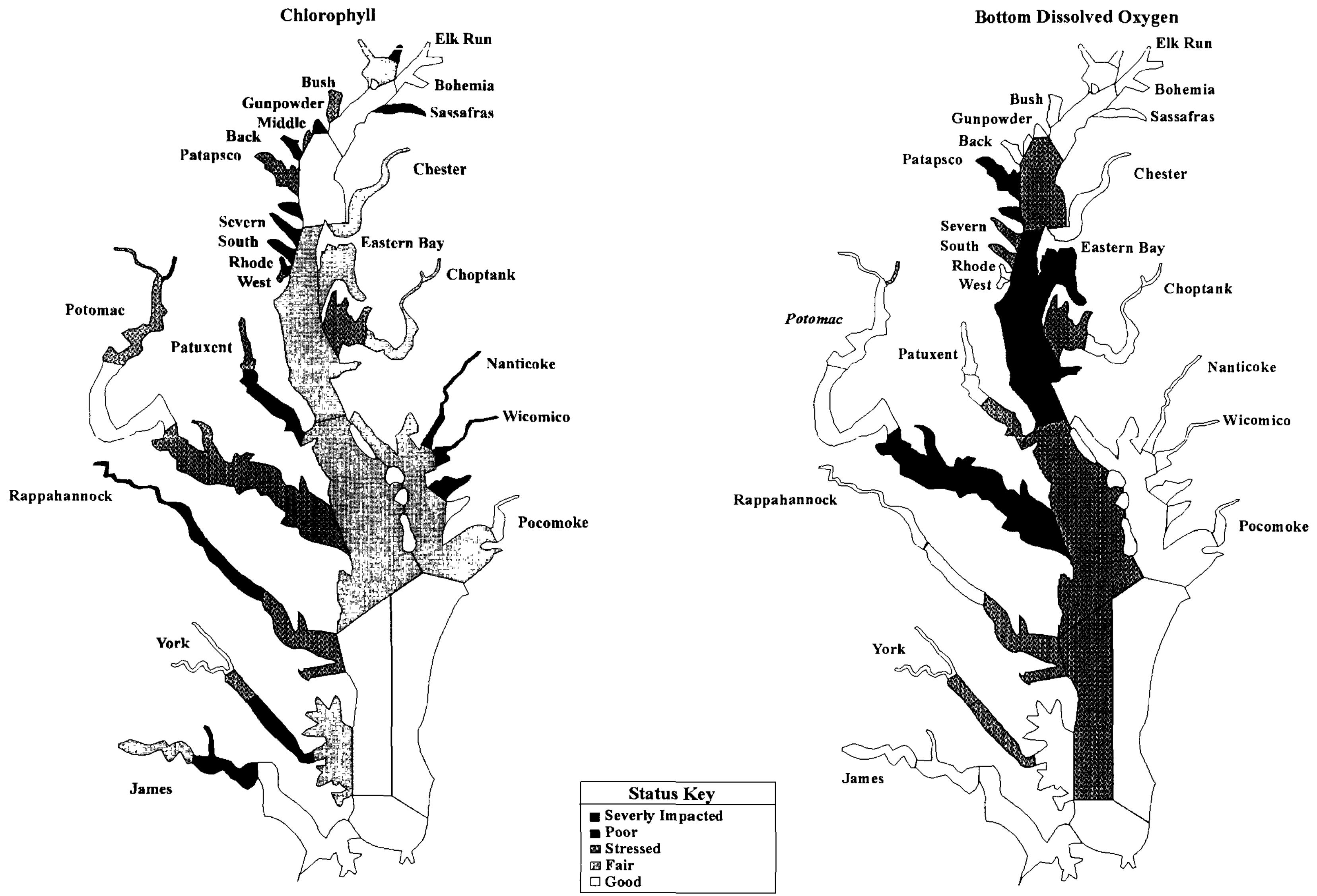
Nutrient Status and Trends



These maps show the conditions in Chesapeake Bay for total nitrogen and total phosphorus. Levels of these nutrients were evaluated by comparing areas of similar salinity. A five level scale was used with "GOOD" areas having the lowest nutrient concentrations and among the best water quality in the Bay. Areas shaded as "SEVERELY IMPACTED" have among the highest nutrient concentrations in the Bay and the worst water quality. Trends in nutrients for Maryland waters were assessed from 1985-1993 and in Virginia waters from 1985-1992. Improving trends indicate declining concentrations of nitrogen and phosphorus while degrading trends indicate increasing concentrations of these nutrients.

Sources: Maryland Department of the Environment, Virginia Department of Environmental Quality and District of Columbia Department of Consumer and Regulatory Affairs

Algae and Dissolved Oxygen Status



These maps show the conditions in Chesapeake Bay for algae (measured as chlorophyll) and dissolved oxygen. Algae levels were evaluated by comparing areas of similar salinity. A five level scale was used with "GOOD" areas having the lowest algae concentrations and best water quality. Areas shaded as "SEVERELY IMPACTED" have among the highest algae concentrations in the Bay and the worst water quality. Dissolved oxygen levels in bottom waters were evaluated relative to target concentrations required to support the growth, reproduction, and survival of the Bay's fish, shellfish, and bottom dwelling organisms. A three level scale was used with "GOOD" areas having among the highest bottom dissolved oxygen concentrations and "SEVERELY IMPACTED" areas having among the lowest dissolved oxygen concentrations.

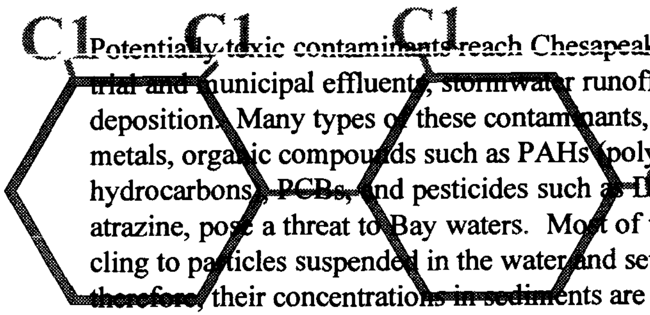
Sources: Maryland Department of the Environment, Virginia Department of Environmental Quality and District of Columbia Department of Consumer and Regulatory Affairs these reductions. Nonpoint source controls, which are often very effective at reducing runoff containing phosphorus-rich sediments, are also making a difference. In the Potomac River, improved wastewater treatment and phosphate detergent bans have lowered the total phosphorus load from major wastewater treatment plants from over 22,000 pounds per day in 1970 to less than 500 pounds per day in 1994. There have been significant improvementsts in phosphorus levels in the Potomac since the 1970's but these improvements are not shown on the accompying map which displays trends since 1985. As with many other areas of the Bay, water and habitat quality throughout the Potomac River have improved due to reduced phosphorus loads.

While reductions in nutrient loads and concentrations have been widespread throughout the Bay watershed, changes in the levels of dissolved oxygen and algae (measured as chlorophyll) are few and do not show any consistent pattern. Many areas of the Bay are so overenriched with nutrients that further reductions are needed to see improvements in algal and oxygen levels. In addition, the Bay's bottom sediments hold a reservoir of nutrients that has built up over the years and will, likewise, take years to become depleted after inputs have been reduced. Although substantial progress has been made toward meeting the 40 percent nutrient reduction goal, we still need to do more to achieve the water and habitat quality improvements that the Bay requires. Examples such as the Potomac, however, show that substantial nutrient reductions will result in habitat improvements and a resurgence in living resources with time.

Bob Gilbert, The Capital

Scientists monitor water quality in the Bay.

Sediment Contaminants



Potentially toxic contaminants reach Chesapeake Bay from industrial and municipal effluents, stormwater runoff, and atmospheric deposition. Many types of these contaminants, including trace metals, organic compounds such as PAHs (polycyclic aromatic hydrocarbons), PCBs, and pesticides such as DDT, chlordane, and atrazine, pose a threat to Bay waters. Most of these contaminants cling to particles suspended in the water and settle to the bottom; therefore, their concentrations in sediments are typically much higher than in the water. Monitoring toxic substances in the sediment is an efficient method of determining contamination levels in the Bay and identifying areas that may require further evaluation of potential contaminant problems.

Several monitoring programs have collected data on sediment concentrations of all the major types of potentially toxic contaminants in Chesapeake Bay. The risk to aquatic life posed by the sediment concentrations of two important classes of contaminants — trace metals and PAHs — is discussed below. For most areas of the Bay, these two classes of compounds are most likely to present significant risks to Bay life.

The concentration in the sediment at which a contaminant becomes toxic depends on the species and life stages of the organisms present, as well as the physical and chemical characteristics of the sediment and overlying waters. Due to the difficulties in determining toxic concentrations of trace metals and PAHs, no applicable state or federal regulatory criteria exist to determine "acceptable" sediment concentrations of these substances.

Informal guidelines based on many field and laboratory studies have been developed, however. These guidelines consist of estimates of the sediment concentration above which adverse effects to aquatic organisms are likely to occur for each contaminant. These critical concentrations are called Probable Effects Levels (PELs). Sediment concentrations of a contaminant that exceed its PEL pose a considerable risk of adverse effects to aquatic organisms, although such effects are not always observed.

While these sediment quality guidelines have many shortcomings, the PELs are probably the best benchmarks available, and were used to evaluate, in a general way, the significance of sediment concentrations of contaminants in different areas of the Chesapeake Bay. For each contaminant found at an average concentration above its PEL, two points were added to an area's score. One point was assigned for each contaminant found at an average concentration approaching the PEL (i.e., greater than 80 percent of the PEL). For each area, the scores for each contaminant were added, and areas with similar total scores were placed in the same category.

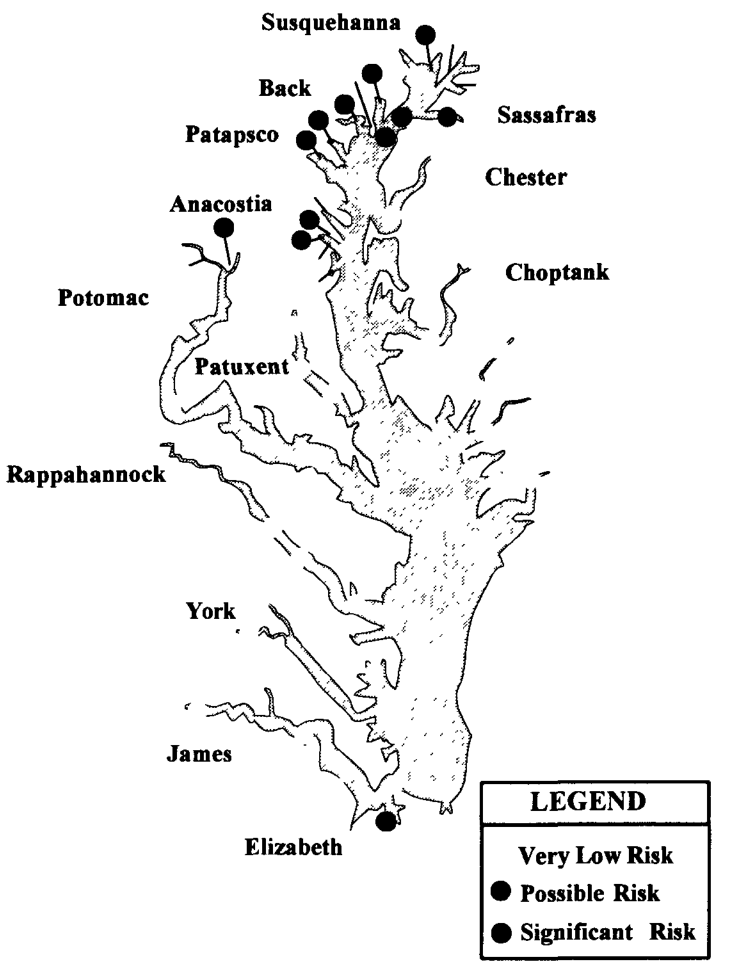
High levels of sediment contamination are restricted to the Elizabeth River, Baltimore Harbor area (Patapsco and Back rivers), and the Anacostia River. Sediment contaminant concentrations in these areas were generally much higher than those found elsewhere in the Bay. Each of these areas had several contaminants at concentrations above their PELs, thus, this contamination poses a significant risk to aquatic organisms in these areas. The Chesapeake Bay Program has designated the Baltimore Harbor, Elizabeth River, and Anacostia River as "Regions of Concern", and the District of Columbia, Maryland and Virginia are developing "Action Plans" to address toxic pollution problems in each location.

[redacted]

Trace metals such as arsenic, cadmium, and lead are naturally present in the earth's crust and their presence in the sediment does not necessarily indicate contamination from human activities. Many of these metals are essential to some organisms in minute quantities, but if present in sufficiently high concentrations, they become toxic.

Like PCBs and many pesticides, PAHs are organic compounds. They are released to the environment primarily through the burning of fossil fuels, although spills of petroleum compounds may also cause environmental contamination. Due to the widespread use of fossil fuels, PAHs are now ubiquitous in the environment. Many individual compounds in this class have been monitored in Chesapeake Bay.

Sediment Contamination and Risk to Aquatic Life



Since 1984, approximately 135 stations throughout the Bay and its tributaries have been sampled for sediment contaminants by various monitoring programs. A ranking of the risk to aquatic biota from sediment contamination was based on comparisons of the average sediment concentrations of seven trace metals and eight PAHs to sediment quality guidelines. Black circles indicate that sediment concentrations of one or more contaminants represent a significant risk of adverse effects to aquatic biota. Colored circles indicate sediment concentrations that represent a possible risk to aquatic biota. Open circles indicate that the sediment contaminant concentrations represent a low risk to aquatic biota.

Sources: Maryland Department of the Environment, Virginia Department of Environmental Quality, and Interstate Commission on the Potomac River Basin.

Several tributaries draining into the northern and upper western Bay, as well as a portion of the northern mainstem Bay, have intermediate levels of sediment contamination with no more than one contaminant in excess of the PEL and/or one or more contaminants at concentrations approaching its PEL. The level of sediment contamination in these areas could result in adverse effects to aquatic organisms, but such effects are unlikely.

Sediments in the vast majority of the monitored areas of the Bay and its tidal tributaries have low levels of contamination which are unlikely to have negative impacts on aquatic biota. In these areas, no contaminants were found at concentrations near or above their PELs.

Areas with highly contaminated sediments are near urban areas, that generally have a history of high levels of industrial activity. Moderate levels of contamination are generally associated with populous urban and suburban areas which lack a great deal of heavy industry. The lowest levels of contamination occur in less populated, rural areas.

Implementation of the 1972 Clean Water Act resulted in large reductions in the quantity of contaminants discharged through industrial wastewater outfalls or sent to municipal wastewater plants and ultimately to Chesapeake Bay. Generally, contaminant concentrations in the sediment have been substantially reduced in the past two decades. Subsequent revisions of the Clean Water Act and the Clean Air Act required additional measures to reduce the discharge of trace metal and organic contaminants and prevent toxic impacts.

The Chesapeake Bay Program is currently re-evaluating its toxic substances reduction strategy in order to determine if additional measures are needed to reduce the amount of toxic contaminants in the Bay watershed. One of the major initiatives that will be pursued is pollution prevention — the reduction of toxic contaminant production and usage — so that the possibilities for their release into the environment are also lessened.

Submerged Aquatic Vegetation

Over the last 30 to 40 years, many Chesapeake Bay plant and animal populations have been depleted by overharvesting, deterioration of water quality, habitat destruction, disease, and meteorological changes. One such valuable resource, submerged aquatic vegetation (SAV), historically covered vast areas of the Bay's shallow waters and nurtured a rich variety of Bay life. During the late 1960s and early 1970s, however, Bay SAV populations experienced a dramatic decline due to increased nutrient and sediment pollution from development of the surrounding watershed. This decline galvanized commitment to a Baywide policy and implementation plan that is used by managers and scientists in SAV assessment, protection, education, and research actions to ensure the restoration of these plants.

The strong link between water quality and SAV distribution and abundance makes SAV plant communities good barometers of Chesapeake Bay health. Significant progress has been made in defining water quality requirements for SAV in the Bay. Those requirements emphasize good water clarity and low levels of suspended sediment, nutrients, and algae. The Chesapeake Executive Council used this new information about SAV in 1993 to establish an SAV restoration goal of 114,000 acres Baywide. At current rates of recovery, this goal should be achieved by the year 2005. At a technical level, targets have also been proposed for SAV bed density and species diversity.

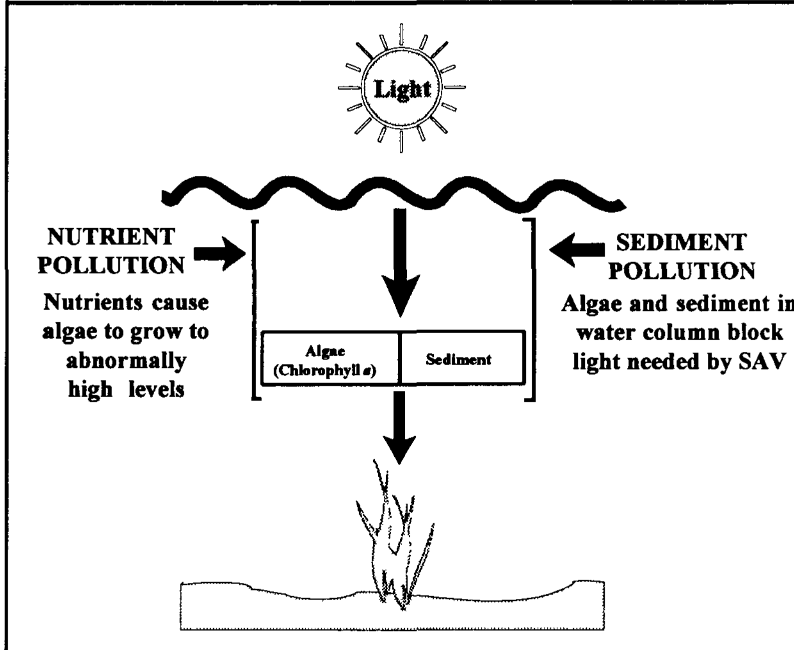
In Chesapeake Bay, SAV monitoring is necessary to evaluate the success of restoration and protection efforts. Since 1978, the Virginia Institute of Marine Science has monitored SAV using black and white aerial photography. The information derived from the aerial survey is confirmed using ground survey data collected by state, federal, and local agencies and organizations. From 1978 to 1993, the total abundance of SAV in the Bay and its tidal tributaries increased by 75 percent, from 41,748 acres to 73,092 acres. The most visible increases in SAV have been in the Susquehanna Flats, the Potomac River, Tangier Sound, the Virginia eastern and western shores, and Mobjack Bay.

Patterns of change in SAV populations throughout the Bay are complex, varying both in space and time. This complexity is due to the diversity of the Bay's major watersheds, varied water quality conditions, and differences in the biology of the SAV species in different regions of the Bay.

Between 1978 and 1993, the largest expansion of SAV occurred in the lower mainstem Bay, where SAV declines during the 1970s had been relatively small and where water quality conditions were good enough to allow healthy growth. The SAV beds remaining in these areas after the Baywide decline may have contributed to a pool of propagules (seeds or fragments of vegetation capable of forming new plants) that repopulated unvegetated areas.

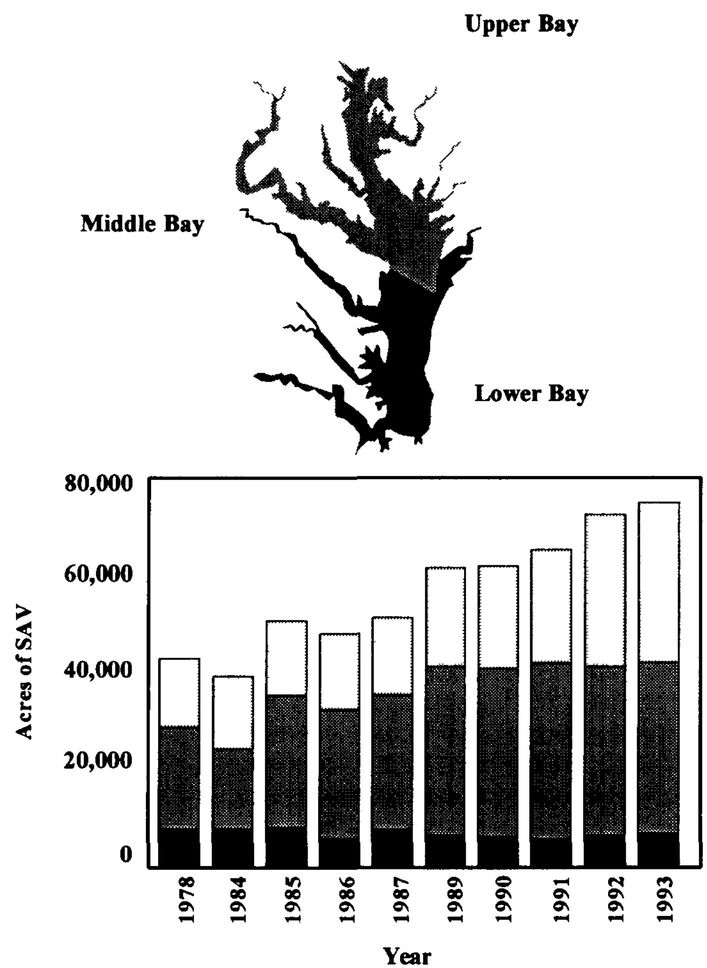
The rapid spread of SAV in the tidal fresh Potomac River, following major water quality improvements in the 1970s and 1980s, has resulted in the highest levels of abundance of SAV in the river since the early 1900s. The exotic species *Hydrilla* was the dominant plant contributing to this rapid spread. Many native species, however, also increased during this period.

The Water Quality/SAV Linkage



Clear water is a critical water quality requirement for SAV. Water clarity is diminished by particles such as algae and suspended sediments. Excessive amounts of nutrients contribute to an overabundance of algae in the water column and on SAV leaf surfaces, both of which prevent sunlight from reaching the vegetation.

Trends in Submerged Aquatic Vegetation



Since the first Baywide SAV survey in 1978, the total abundance of SAV in Chesapeake Bay and its tidal tributaries has increased by 75 percent from 41,748 acres in 1978 to 73,092 acres in 1993. Upper Bay increases occurred primarily in the Susquehanna Flats regions, with little or no changes in western shore tributaries. The Potomac River and the areas around Tangier Sound were responsible for most of the increasing trends in the middle Bay since 1984. The Virginia eastern and western shorelines and Mobjack Bay continued the increasing trend observed since the mid-1970s.

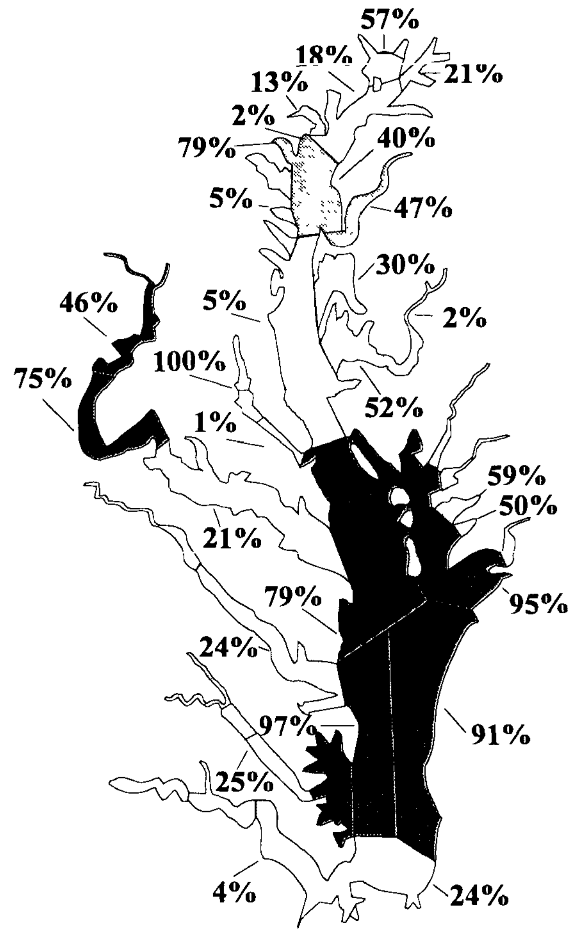
Source: Chesapeake Bay Program

In the 1980s, widgeon grass underwent a sudden and rapid expansion in the middle mainstem Bay, as well as in the lower Patuxent, Chester, Choptank, and Rappahannock rivers, with a subsequent decline in some areas. The areas where SAV declined were characterized by water quality conditions near the threshold that would permit healthy growth of SAV.

The increase in SAV acreage between 1984 and 1993 was accompanied by an increase in the density of many SAV beds. While 38 percent of mapped SAV was classified as dense (70 percent to 100 percent coverage) in 1984, by 1993 more than twice as many acres of SAV fit this category. Despite large gains in total SAV acreage and density, however, many sections of the Bay and its tidal tributaries remain unvegetated or have very sparse SAV populations. Areas typically lacking SAV include many northern, western, and eastern shore tributaries where water quality has not consistently met the SAV habitat requirements. Two major western shore tributaries, the James and Patuxent rivers, have almost no SAV throughout their lengths.

Submerged aquatic vegetation distribution patterns in the Bay and its tidal tributaries exhibit fairly sharp transitions between areas with SAV and those without. Such boundaries suggest that small changes in water quality can lead to rapid increases or decreases in SAV populations. Ground surveys have confirmed the presence of remnant SAV populations in small tidal creeks and tributaries adjacent to areas with little or no mapped SAV (e.g., the Patuxent River), suggesting that vegetative sources or seed banks in the river bottom could repopulate riverine areas with little or no mapped SAV if water quality conditions improve. Recent changes in Chesapeake Bay SAV populations suggest that most of these populations can rebound rapidly if water quality conditions are improved and maintained. Some areas may not become revegetated even after the return of suitable water quality conditions, however, due to a lack of SAV propagules either within or close to these areas.

Baywide SAV Status and Trends



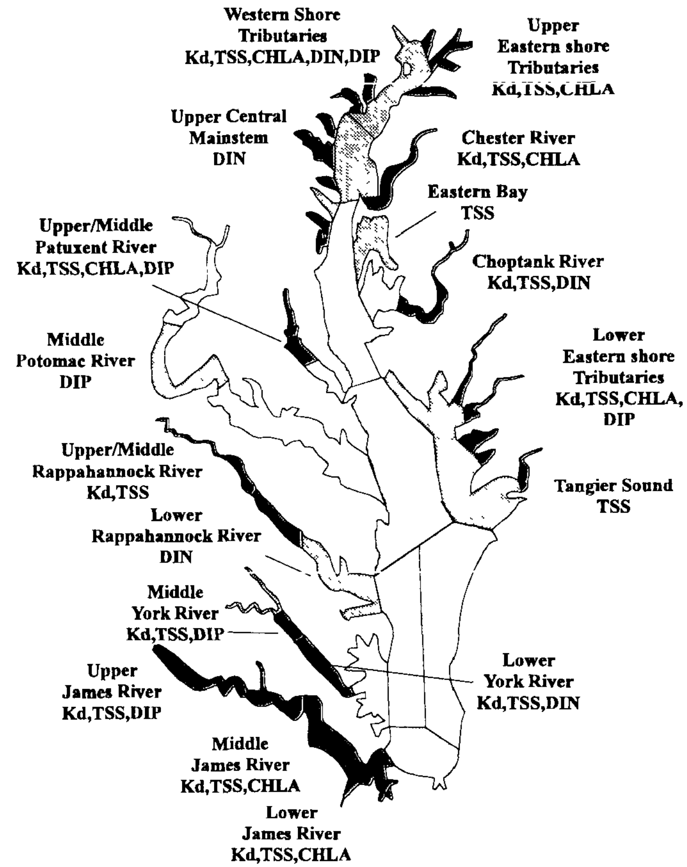
Trends in SAV
■ Increasing Trends
▨ Decreasing Trends
□ No Trend

Status in SAV
Percentages indicate progress toward initial restoration goal for each Bay segment. Baywide, 64% of the initial goal has been met.

Each segment of the Bay has been evaluated for its status and trends in SAV. This figure shows the 1993 percentage of the initial goal, which calls for restoring SAV to areas having vegetation at any time after 1970. Those segments with no percentages had little or no SAV and therefore had zero percent achievement of initial goal. Shading of each segment represents the SAV coverage trends since 1978.

Source: Chesapeake Bay Program

Achievement of Bay SAV Habitat Requirements



Legend
□ All habitat requirements achieved
▨ One habitat requirement not achieved
■ Two or more habitat requirements not achieved

Water Quality Habitat Requirements
Kd= light penetration
TSS= total suspended solids
CHLA= algae (chlorophyll *a*)
DIN= dissolved inorganic nitrogen
DIP= dissolved inorganic phosphorus

For any type of SAV to grow and survive, water quality must be within the environmental tolerances of that species. Five important water quality parameters, listed in the legend, are critical in defining acceptable SAV habitat conditions, and each has been assigned an acceptable threshold value. Chronically exceeding the value of one or more critical parameter can potentially lead to the loss of SAV in an area. The map depicts three levels of habitat quality and those water quality requirements that were not being met, in 1991.

Source: Chesapeake Bay Program

Phytoplankton

Phytoplankton — the community of floating, mostly microscopic plants or algae that inhabit aquatic environments — are the most plentiful plants in the Chesapeake Bay and its tributaries. One drop of water can contain thousands of phytoplankton cells, ranging in size from very tiny single-celled plants to large colonies of cells that form mats on the surface of the water. Phytoplankton are particularly important to the Bay ecosystem because they are primary producers, converting energy from sunlight into food for animals such as zooplankton, oysters, and fish. They also produce life-sustaining oxygen and are useful as indicators of the Bay's water quality, establishing an important link between efforts to clean the Bay's water and improve the abundance of valuable living resources.

The phytoplankton community in Chesapeake Bay is composed of a wide variety of species. The composition varies seasonally, usually with one species dominant in each season. A healthy aquatic system will contain a balance of several different organisms, forming an interconnecting system of food producing (i.e., phytoplankton) and consuming (e.g., zooplankton and fish) organisms. Although phytoplankton form the foundation of the food chain in the Bay, problems can occur if this community grows out of control due to excess nutrients.

When algal blooms occur in the Bay, decomposition of the algae contributes to the depletion of dissolved oxygen in the Bay's bottom waters during the warmer months. In the deepest parts of the Bay,

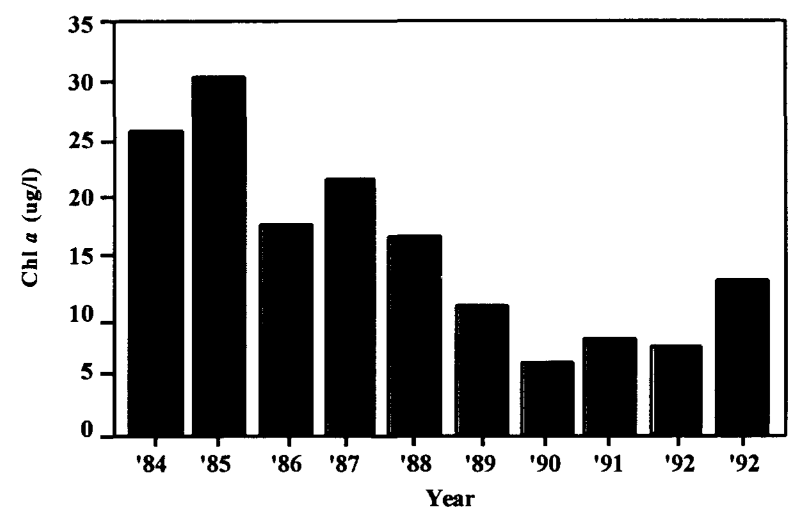
Phytoplankton in the Upper Potomac Estuary

One of the most commonly used estimators of the amount of phytoplankton is chlorophyll a, one of the chemicals in plants that converts sunlight to plant food. In the Potomac River Estuary, phytoplankton monitoring data provided an early indication that management actions to reduce nutrient pollution and improve the water quality of the river were paying off. In the 1960s and 1970s, large mats of blue-green algae were a common sight in the summer. Besides looking and smelling bad, these mats prevented light from penetrating the water, limiting the ability of underwater grasses to grow and survive. These mats were caused by large blooms of phytoplankton which, fueled by an excess of nutrients, could grow at abnormally high rates and cover the surface of the water.

Since the mid 1970s, aggressive nutrient controls have been put in place at the major wastewater treatment plants in the Potomac Estuary. These controls have targeted the nutrient phosphorus, reducing wastewater treatment plant phosphorus loadings from over 22,000 pounds per day in 1970 to less than 500 pounds per day in 1994. These nutrient loading reductions were followed by measurable responses in the phytoplankton community. Most notably, the large algal mats that were once common appear to be under control and no excessively large blooms of blue-green algae have occurred since 1988. As the nutrients and phytoplankton declined, an abundant and diverse community of underwater grasses reestablished itself in the Potomac Estuary.

Source: Maryland Department of the Environment

Summer Median Chlorophyll*a* Concentration



decomposition of algae from the annual spring bloom causes the bottom waters to become hypoxic (very low dissolved oxygen levels) or even anoxic (no dissolved oxygen) during the middle of the summer. Consequently, the amount of suitable habitat available to fish may be greatly reduced and bottom-dwelling organisms (benthos) that cannot move may die. Algal blooms can also shade the water, blocking the light needed by underwater grasses to grow and survive. One of the primary goals of the Chesapeake Bay restoration is to improve conditions in the Bay so that enough light reaches underwater Bay grasses and at least some dissolved oxygen is available in the deepest parts of the Bay throughout the year.

Because phytoplankton are a critical component of the Chesapeake Bay ecosystem and represent the first biological response to the Bay's nutrient enrichment problem, they are monitored as part of the Chesapeake Bay Water Quality Monitoring Program. Thirty-two stations, located in the mainstem Bay and its major tributaries, are monitored to provide managers and scientists with estimates of phytoplankton biomass, abundance, and community composition. Managers and scientists use this information to track changes in the Bay's water quality over time, test for the presence of exotic organisms or toxic algae, and develop environmental indices that reflect the relative "health" of different areas of the Bay. Results from the phytoplankton monitoring program have been used to show the success of Bay cleanup efforts, explain important linkages between water quality and living resources, and provide an early warning of potentially harmful exotic species.

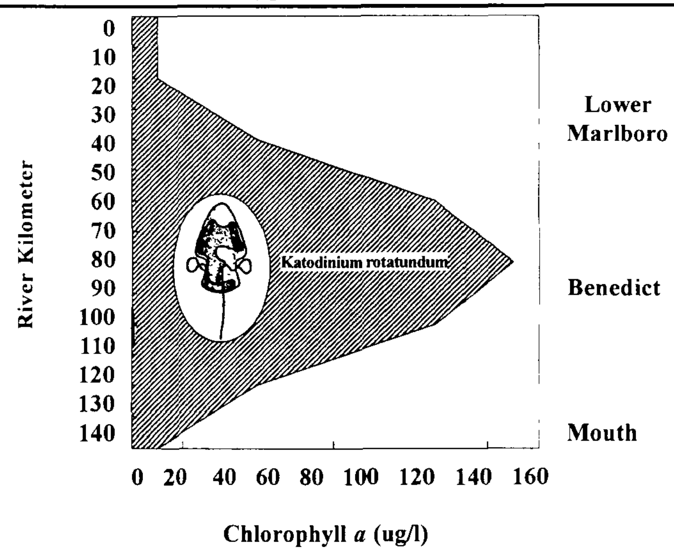
In the Chesapeake Bay and its tributaries, the winter and spring phytoplankton blooms are composed almost exclusively of non-toxic algal species and have no direct ill effects on people or aquatic life. However, certain species of dinoflagellates, which are uncommon in Chesapeake Bay but common along the East Coast, can be toxic to shellfish, fish, and even people. As a consequence, shellfish producing states such as Maryland and Virginia must monitor for the presence of these organisms and close any shellfish harvesting areas where dangerous levels are detected. In the Chesapeake Bay, no shellfish producing areas have ever been closed due to the threat of contamination by toxic algae.

Winter Phytoplankton Blooms in the Patuxent Estuary

Although the annual phytoplankton bloom is characteristically considered a spring phenomenon in the Bay's saltier water (hence the common phrase "spring bloom"), winter blooms also can contribute significant amounts of phytoplankton to the Chesapeake Bay system. This phenomenon is especially true in the Patuxent River Estuary, where large winter blooms of the dinoflagellate *Katodinium rotundatum* have been documented between December and March near Benedict, Maryland. The blooms, which are often called red or mahogany tides, can last for several months. During a bloom, the numbers of *Katodinium* can reach about one hundred million cells per liter - approximately 20,000 per drop of water. Unlike the nuisance algal blooms documented in the Upper Potomac River, blooms of *Katodinium* are a vast food source for microscopic animals called zooplankton, which in turn become food for various species of fish and fish larvae. Low winter water temperatures prevent oxygen poor conditions from developing during the decomposition of the bloom.

Source: Maryland Department of the Environment

Typical Winter Bloom



Zooplankton

The term "zooplankton" describes the community of floating, often microscopic animals that inhabit aquatic environments. Zooplankton are the most plentiful animals in the Chesapeake Bay and its tributaries. Being near the base of the food chain, they serve as food for larger animals, such as fish. One gallon of water can contain over 500,000 zooplankton, ranging in size from tiny single-celled Protozoa to large jellyfish such as sea nettles. The most common zooplankton are the Crustacea, which include animals such as crab and barnacle larvae.

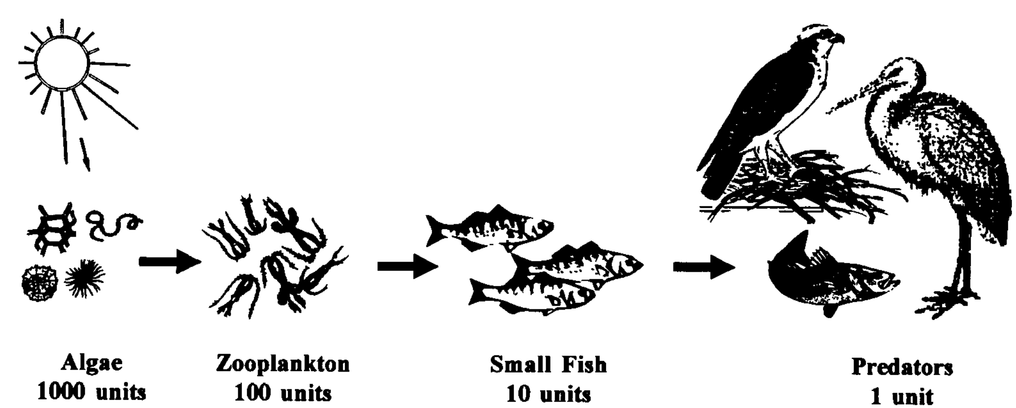
Because the zooplankton are a critical component of the Chesapeake Bay ecosystem, they are monitored monthly at 32 stations throughout the Bay and its tributaries. Using this information, it is possible to track changes in the habitat quality of the Bay over time, test for the presence of exotic organisms such as the zebra mussel, and develop environmental indices that reflect the relative "health" of different areas of the Bay. Zooplankton are proving to be good indicators of water quality conditions, habitat quality for living resources, and the effects of toxic contamination in the Bay.

An example of one zooplankton environmental index that is still under development is an index of the food availability for larval striped bass. Several studies have indicated that sufficient numbers of zooplankton during the critical life stages of larval striped bass are vitally important to their growth and survival. Although larval striped bass are able to survive several days without food, low densities of zooplankton diminish the likelihood of larval survival in a hostile environment where over 90% of larvae perish. While other factors are also important, larval striped bass are not likely to survive and produce a strong year class without sufficient amounts of food.

To develop the index, four distinct feeding categories were established based on the density of zooplankton per liter of water. These categories — optimal, minimum, below minimum, and poor — indicate the status of food availability during critical larval periods of striped bass. To apply the index, the spring (April to June) density of zooplankton was calculated for monitoring stations located in striped bass nursery areas.

Measures such as the food availability index demonstrate the use of zooplankton data in providing important information about the health

The Zooplankton Link in the Bay Food Chain



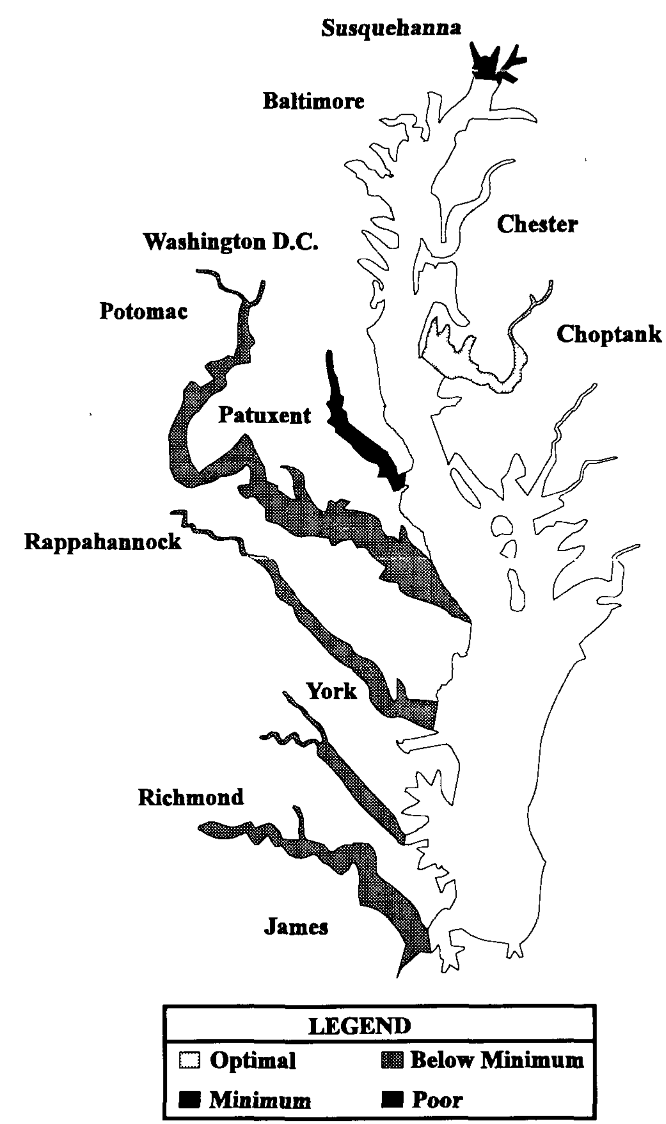
Zooplankton, such as copepods, are the most important food source for several species of adult and larval fish. As such, they provide a critical link between algae at the base of the food chain, and predators, such as striped bass, ospreys, and herons. Most zooplankton graze directly on algae. These zooplankton are then eaten by the larvae and juveniles of all fish species and adult forage fish such as anchovies. These smaller fish then become a meal for larger predators at the top of the food chain, the most visible signs of Bay life. The number of units at each level is the approximate amount of new biomass that can be produced by eating the amount shown at the next lower level.

of the Chesapeake Bay ecosystem. This index also illustrates how zooplankton act as a critical link between water quality and living resources. Additional zooplankton environmental indicators are currently under development for use in assessing the health of the Chesapeake Bay.

Maryland Department of the Environment

Sampling zooplankton on the Bay's mainstem

Zooplankton Food Availability Index



This map shows the overall food availability index for larval striped bass during spring where zooplankton are monitored. The results of the index suggest that overall densities of zooplankton are typically sub-optimal for normal larval striped bass growth and development in all spawning reaches except the Choptank River, where recent high striped bass spawning success has coincided with optimal zooplankton availability.
Sources: Maryland Department of the Environment, Virginia Department of Environmental Quality

Benthos

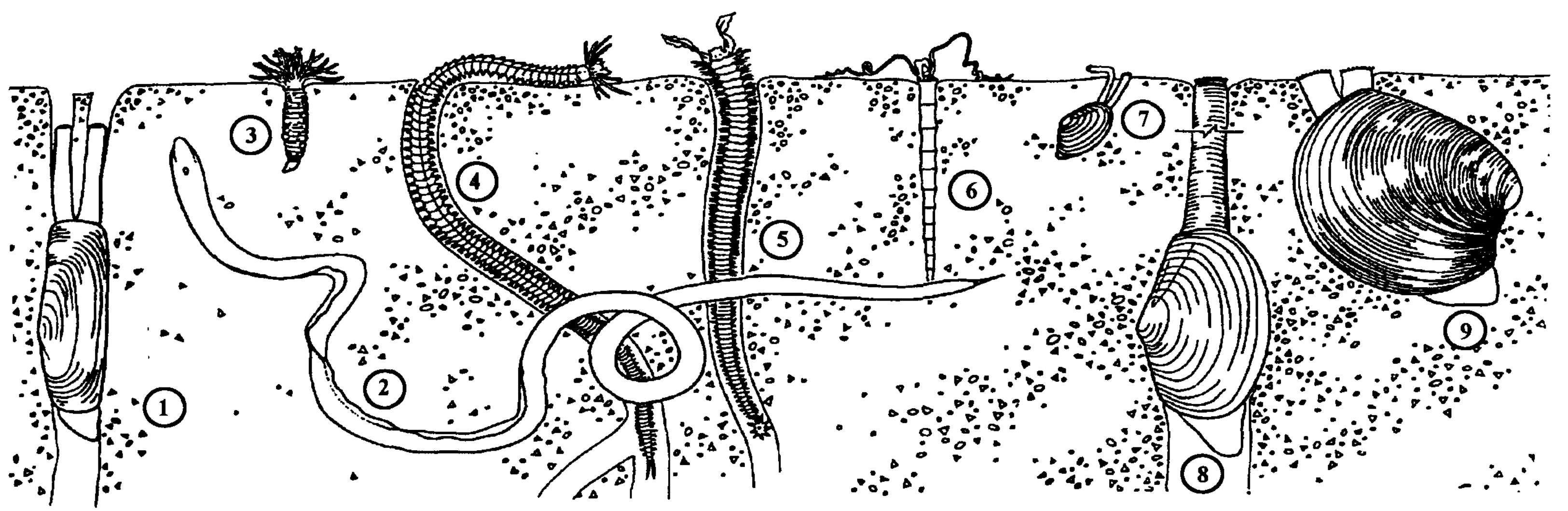
The "Benthos" describes the benthic invertebrate community, a group of organisms that live on or in the bottom sediments. This community includes a wide variety of organisms such as clams, oysters, and small crustaceans, in addition to the blood and clam worms commonly used as bait.

Benthic communities are particularly vulnerable to the stresses associated with toxic and organic pollution. Toxic contaminants frequently attach to silt and clay particles and, therefore, concentrate in deposited sediments. The low dissolved oxygen levels associated with nutrient and organic pollutants occur most frequently in the deeper layers of water overlying the sediment.

Because most benthic invertebrates have limited mobility and cannot avoid changes in habitat quality, they are often used as reliable and sensitive environmental indicators. The analysis of benthic communities is, therefore, a useful tool for Bay managers to assess status and trends in water and habitat quality and how they affect the Bay's living resources.

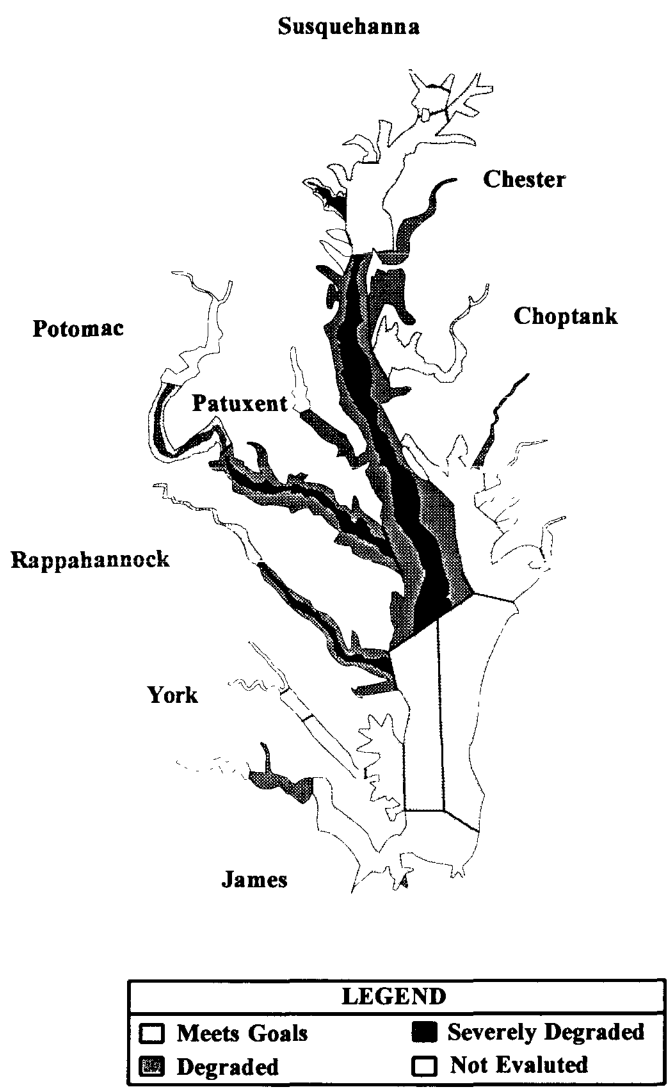
The condition of the benthic community is also important in its own right. Some benthic organisms are commercially important and all have important functions in the Bay ecosystem. They act as nutrient recyclers and important links in the Bay's food chain, feeding on microscopic plankton and serving as food for the bottom-feeding blue crab and fish such as spot and croaker.

Recently, an index has been developed to provide managers with an overall measure of the "health" of a benthic community. This Restoration Goal Index was developed by examining benthic communities from areas relatively free of pollution and comparing them with those in areas more affected by pollution. Scientists determined



This picture shows a typical "healthy" benthic community, including species characteristic of unstressed communities. In a polluted environment, these species would be replaced by species more tolerant of pollution. A "degraded" community would also tend to have fewer species, fewer large organisms deep in the sediment, and a lower total mass of organisms. The animals shown here are about one-half actual size. 1. Common jackknife clam 2. Red ribbon worm 3. Burrowing anemone 4. Common clam worm 5. Red-gilled mudworm 6. Glassy tube worm 7. Baltic *Macoma* clam 8. Soft-shelled clam 9. Hard clam. Oysters, mussels, sponges, and barnacles (not shown) are other examples of benthic organisms.

Benthic Community Condition



The condition of the benthic community varies in different regions of the Bay and the tidal portions of its tributaries. Ratings are based on average "Restoration Goals Index" scores for summer benthic community samples taken between 1984 and 1990. Data are aggregated by depth within segments of the Bay.

Sources: Maryland Department of the Environment and Maryland Department of Natural Resources; Virginia Department of Environmental Quality

how stressed and unstressed benthic communities differed in various attributes such as the number of species, the total number and mass of organisms, the presence of organisms in deeper layers of the sediment, and the relative abundance of species that are tolerant of pollution. A benthic community is assigned a score for each of these attributes, based on how much it differs from benthic communities typical of unpolluted areas. The scores for each of the attributes are averaged to give an overall rating of the community's condition.

The adjacent map shows the varying condition of the benthic community in different areas of the Bay and the tidal portion of its tributaries. The mid Bay, the Patapsco River, and the lower reaches of the Rappahannock and Potomac rivers are characterized by severely degraded benthic communities in their deeper waters and moderately degraded benthic communities in their shallower areas. Moderately degraded benthic communities are found in the Back, South, West, Rhode, and Patuxent rivers on the Bay's western shore and in the Chester and Nanticoke rivers and Eastern Bay on the Eastern Shore. The upper and lower portion of the mainstem, Tangier Sound on the Eastern Shore, the James and York rivers, and the upper portion of the Potomac and Patuxent rivers are all characterized by healthy benthic communities.

Most of the areas with severely or moderately degraded benthic communities are located in deeper tributary channels and the deep trench of the Bay and experience stress from low concentrations of dissolved oxygen. Sediment concentrations of toxic substances appear to have a secondary, but significant, influence on benthic community condition, primarily in industrialized areas such as the Elizabeth and Patapsco rivers.

The target of the Tributary Strategies is to improve areas with seasonally low dissolved oxygen by reducing nutrient pollution. The Bay Program Toxics Strategy, on the other hand, is addressing those areas in which contaminants in the sediment may be degrading the benthic community.

Striped Bass

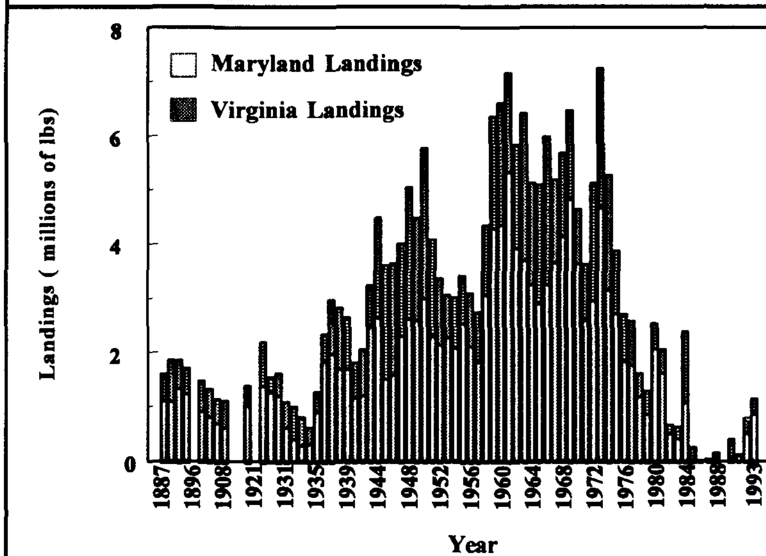
The increasing numbers of striped bass (*Morone saxatilis*), also known as rockfish, seen racing through Bay waters are a tribute to interagency cooperation in the management of an important Bay resource. Monitoring data show that significant progress has been made in rebuilding the population from the all-time lows of the 1980s. The increased abundance of striped bass is due largely to the implementation of coastwide fishing restrictions, including a fishing ban in Chesapeake Bay, allowing more fish to reach sexual maturity. Consequently, the percentage of females that are mature (those at least eight years old) in the Choptank, Potomac, and upper Bay spawning areas has increased from 10 percent in 1988 and 1989 to 50 percent in 1992. Thus, management efforts have concentrated on restoring the spawning stock to high levels.

Most striped bass spend much of their life cycle in coastal waters, migrating into tidal freshwater tributaries to spawn. Healthy spawning habitat and other environmental conditions are critical to the reproductive success of such anadromous species. Sudden drops in water temperature (generally below 55° F) or toxic conditions during the spawning period can severely limit the survival of eggs and larvae.

Juvenile indices calculated for Virginia and Maryland record the average number of juvenile striped bass captured per seine net haul at various locations. The Virginia Institute of Marine Science has analyzed all of the Chesapeake Bay juvenile index data to develop a relative representation of juvenile striped bass populations Bay-wide. In 1993, the Maryland and Virginia pooled juvenile striped bass index was the greatest ever recorded in the history of the surveys. The wet, cool spring of 1993 provided ideal spawning conditions for returning females. The record number of juveniles in 1993 indicates the potential for an excellent commercial and recreational season in 1996 and 1997 when these young stripers reach harvestable size.

The striped bass management program has been successful and is considered a model for future Bay fisheries plans. Improved stock assessments of resident and spawning populations and estimates of losses due to fishing have allowed biologists to measure changes in the fish population. Fishing restrictions (and to a lesser extent, restocking efforts) have been the means of the recovery for striped bass populations. The comprehensive conservation programs applied by the Atlantic states have restored an economically and culturally valuable species in the Chesapeake Bay.

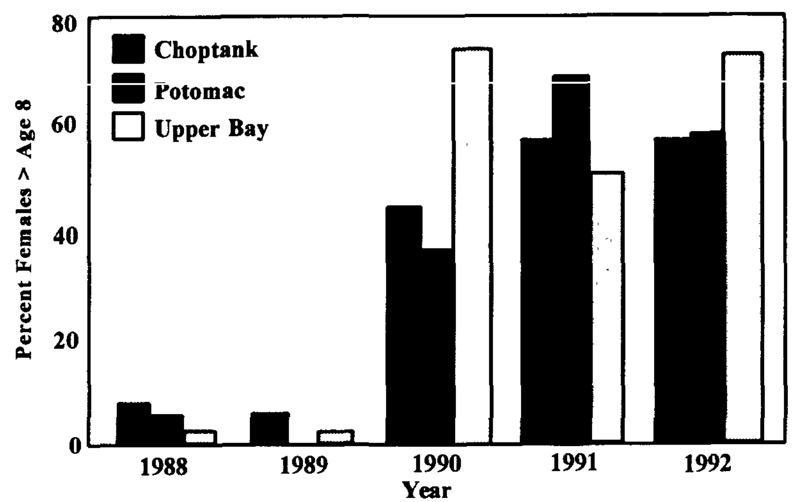
Striped Bass Commercial Landings



Data on the commercial landings of striped bass show a large harvest through the 1960s and early 1970s (data before 1952 include coastal landings). By the mid-1970s, a major decline in landings was underway. This decline prompted the Atlantic Striped Bass Conservation Act in 1984. Maryland and Delaware followed with fishing moratoria from 1985 to 1989. Virginia imposed a one-year moratorium in 1989. The fishery reopened in 1990 in response to three successful spawning years, but is still tightly restricted.

Source: National Marine Fisheries Service (1993 data are preliminary)

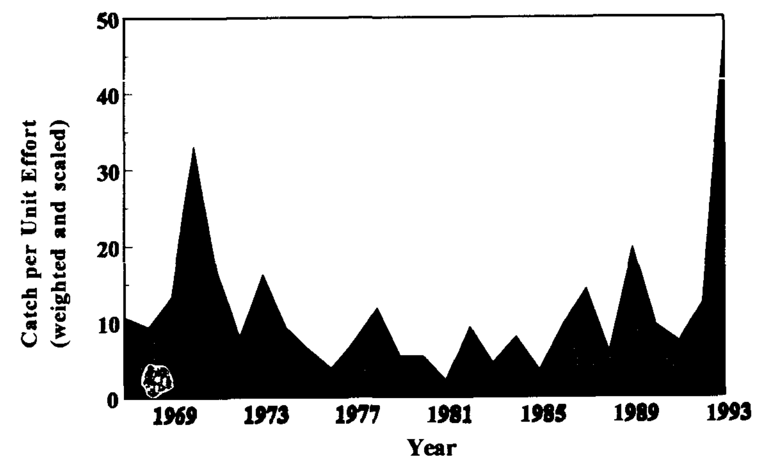
Percent Female Striped Bass Spawning Stock Greater Than Age 8



Three areas of the Chesapeake, the Choptank and Potomac rivers, and the upper Bay are sampled annually for striped bass spawning stock composition. These data show a remarkable increase in the percentage of females greater than age eight (generally 100 percent mature and contributing greatly to the total egg production) over the five-year period. Presumably, an increase in mature females will greatly increase spawning success.

Source: Maryland Department of Natural Resources

Baywide Striped Bass Juvenile Index



The striped bass juvenile index is a key management tool in monitoring the return of stripers to the Bay. Designed to obtain a relative measure of the young of the year, the index provides a general description of spawning success. The above figure is a combined index of Virginia and Maryland data. Higher values indicate good spawning success. The index of 1993 was the highest recorded in recent decades.

Source: Virginia Institute of Marine Science

History of Striped Bass Management in the Bay

Prompted by a long term decline in abundance of striped bass, Federal legislation was passed in 1979 authorizing the Emergency Striped Bass Research Study in order to gain a better understanding of the extent, magnitude and source of the problem. In the early 1980s, the Atlantic States Marine Fisheries Commission (ASMFC) prepared a coastwide management plan severely restricting striped bass harvest along most of the Atlantic Coast. As stocks continued to decline, the Atlantic Striped Bass Conservation Act was passed by Congress in 1984, enabling Federal imposition of striped bass fishing moratoria in states found out of compliance with ASMFC Plan. Subsequently, recreational and commercial fishing were suspended in Maryland, Delaware, Virginia and the Potomac River. The Chesapeake Bay Program developed a Striped Bass Management Plan in 1989 outlining the necessary steps to revive and maintain the population throughout the Bay. The Bay fishery was reopened in 1990 with limited seasons and is closely monitored by the ASMFC.

American Shad

Once one of the most commercially valuable species in the Chesapeake Bay, American shad (*Alosa sapidissima*) populations have declined to a shadow of their former abundance. Historical over-harvesting and habitat degradation, combined with stream impediments blocking miles of spawning and nursery grounds, have been cited as the main causes for this reduction.

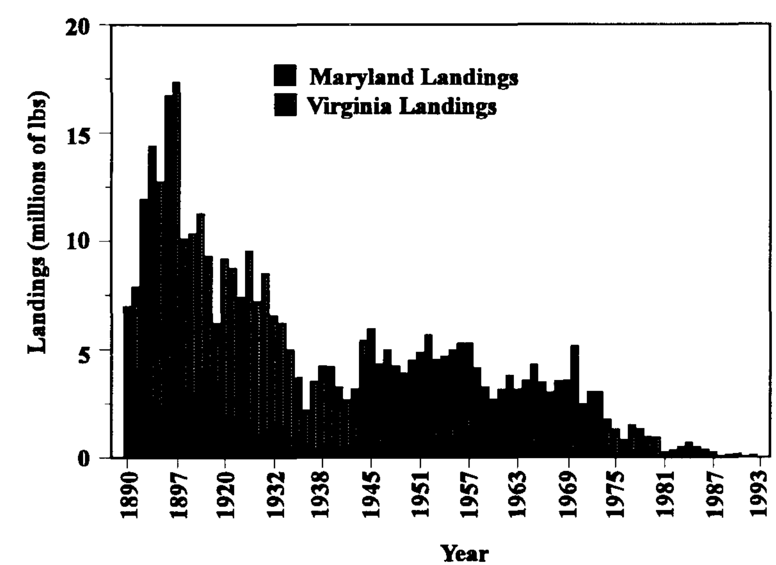
The American shad is an anadromous species, living at sea and returning to freshwater tributaries in the spring to spawn. Juveniles leave the estuary in the fall and do not return for 2 to 5 years. As with salmon, the majority of mature adults will return to their native stream. Excellent habitat and environmental conditions are necessary to ensure their successful reproduction. Blockage of spawning habitat by dams and culverts can therefore play a major role in inhibiting reproductive success.

To combat this problem, the Chesapeake Bay Program's Executive Council signed a directive in 1993 which set goals for providing fish passage on the major tributaries of the Bay watershed. One hundred and sixty miles of potential spawning habitat have already been made accessible through the Bay Program's fish passage efforts. In five years, 582 miles will be open and in ten years, 1,357 miles will once again be available to the Bay's anadromous fish populations. Efforts are also underway to remove impediments along secondary streams and rivers in the Bay watershed. Coupled with stream restoration work, the Bay Program's fish passage efforts will allow American shad and other anadromous fish to return to their historic spawning areas.

One method of estimating the number of shad returning to spawn in the upper Bay is to tag and recapture fish. By examining the ratio of tagged fish captured to all fish captured, biologists can estimate the total number of shad returning. Beginning in 1980, a slow but steady increase occurred until 1991. In 1993, this trend appeared to all but reverse with a meager 47,000 shad returning. Biologist are uncertain why such a major decline occurred coast-wide in 1993. Shad captured in the upper Bay in 1993 also tended to be smaller than normal. Those shad which did return, however, found excellent spawning conditions leading to a good spawning year. While wide fluctuations in abundance are normal in fish populations, biologists are concerned about dramatic declines in already depressed stocks. The 1994 estimate of 129,482 shad offers hope that the 1993 decline was short-lived.

Due to declining stocks, Maryland placed a moratorium on shad in 1980 prohibiting its sale, capture, or possession in the Chesapeake Bay. The District of Columbia also placed a moratorium on American and hickory shad in 1989 and Virginia imposed a moratorium in

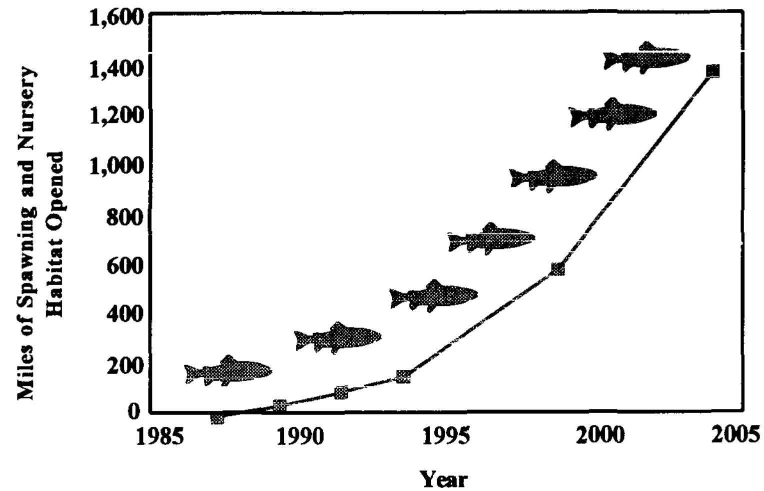
Baywide American Shad Landings



Historically, the American shad was one of the most sought after fish in the Bay. Intense fishing pressure around the turn of the century, as well as the creation of hydroelectric facilities and pollution, have severely reduced shad populations. In the wake of this decline, Maryland imposed a moratorium on the American shad in 1980 and widened it to cover the hickory shad in 1981. While there are slight signs of improvement, shad numbers remain at extremely low levels in the Bay. In 1994, Virginia joined Maryland by imposing a moratorium on the American shad (data before 1952 include coastal landings).

Source: National Marine Fisheries Service (1993 data are preliminary)

Fish Passage



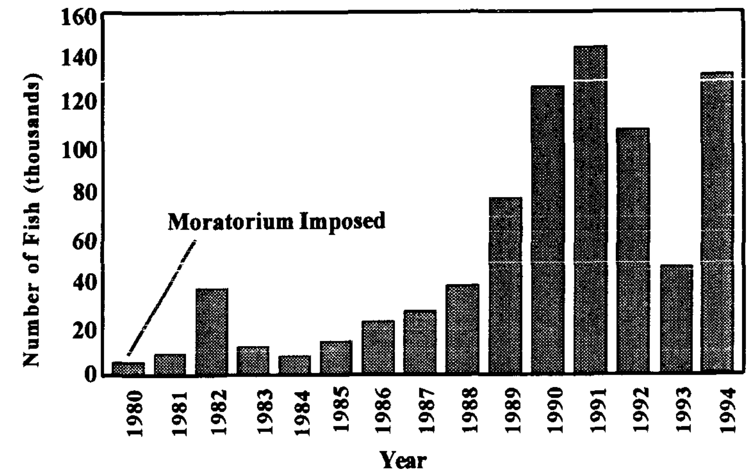
This figure shows the progress of the Chesapeake Bay Program's initiative to provide passage for anadromous species in major tributaries of the Bay. As of 1994, 160 river miles of nursery and spawning grounds have been reopened with a five-year goal of 582 total miles, and a ten-year goal of 1,357 miles.

Source: Chesapeake Bay Program

1994. None of these management decisions affect the coastal "intercept" fishery which continues to harvest the species all along the Atlantic coast, although Maryland has proposed to end the coastal fishery in 1995.

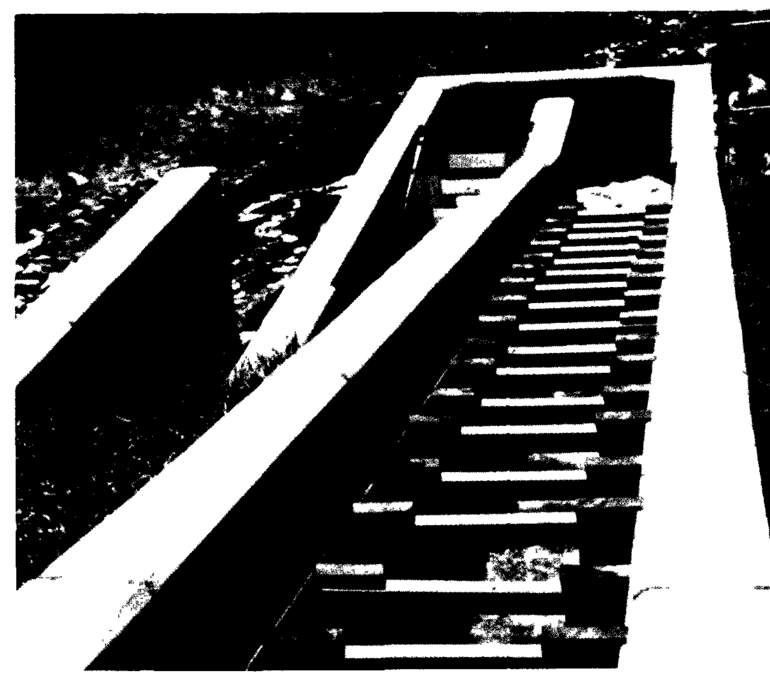
In 1989, the Chesapeake Bay Program established an Alosid Fisheries Management Plan to protect, restore, and enhance Bay-wide stocks of American shad, hickory shad, blueback herring, and alewife. Efforts have focused on habitat restoration, restocking, reduction of fishing effort, and stock assessment survey improvement. Through these efforts, managers and researchers hope to restore a once valuable species to its former abundance in the Bay.

American Shad Population Estimates for the Upper Bay



Shad captured, tagged and recaptured in the Upper Bay, allow fisheries managers to estimate the population of mature fish returning to spawn. A standard of a three-consecutive-year increase and a total of 500,000 fish *has been set to reopen the fishery for the species.*

Source: Maryland Department of Natural Resources



U.S. Fish and Wildlife Service

A Denil-style fish ladder, Herring Creek, Virginia.

Oyster

The oyster is extremely important economically and ecologically to the Chesapeake Bay. Oyster harvesting has been an integral part of the Bay region's economic development and cultural heritage. The filtering capabilities of the oyster enable it to remove large quantities of algae and sediment from the water column, while its shells provide habitat for a variety of benthic organisms and fish species. Some scientists feel that the restoration of this creature is an important key to improving water quality and the overall health of the Bay.

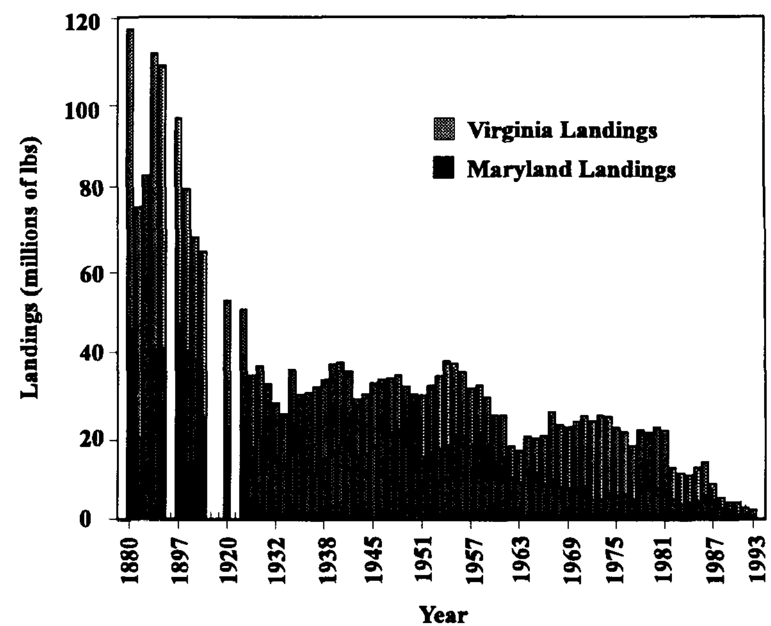
Harvestable oyster populations in the Chesapeake Bay, however, have dropped to their lowest level in history. During 1993, a scant 592,000 pounds were taken from Bay waters. Although the oyster (*Crassostrea virginica*) is an extremely resilient estuarine species, able to tolerate wide variations in salinity, temperature, and dissolved oxygen, it is not immune to the pressures of disease, overharvest, and pollution.

The initial cause of the oyster's decline was linked to overharvesting at the turn of the century, when oyster harvests far exceeded sustainable levels. Subsequent habitat loss has also been a significant problem. Since the mid 1980s, however, the oyster diseases MSX and Dermo have prevented oyster populations from rebounding, causing the precipitous decline in oyster harvests to continue.

The parasites MSX (*Haplosporidium nelsoni*) and Dermo (*Perkinsus marinus*) kill the majority of oysters before they reach harvestable size. MSX and Dermo were extremely prevalent Bay-wide in the late summer of 1992, with approximately 70 percent of Maryland's oyster beds and 90 percent of Virginia's beds infected. Little is known about MSX; it does, however, thrive in higher salinities and increases in prevalence during dry years. The ability of Dermo to tolerate lower salinities makes it more persistent and damaging to oyster populations than MSX. A major breakthrough in 1993 was the ability to culture and experiment with Dermo in a laboratory setting. Both parasites are harmless to humans but deadly to oysters.

MSX and Dermo have not severely affected the reproductive success of the oyster, but have significantly altered the size and age structure of the population. The parasites shorten the oyster's life span substantially, with the majority of mortalities occurring in the first two years. Mortality caused by disease, in combination with the continued harvest of older age classes, has left some areas with oyster populations consisting primarily of small, immature oysters. The oyster's reproductive success, however, is still in a healthy range. Although there was a decline in 1992 and 1993, the spatfall index of 1991 (the average number of young oysters found on a given amount of natural shell) was at its highest level in eight years.

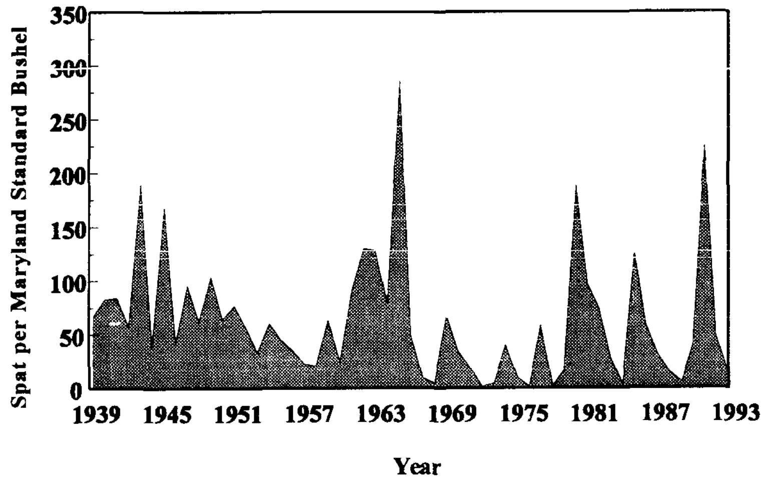
Baywide Oyster Landings

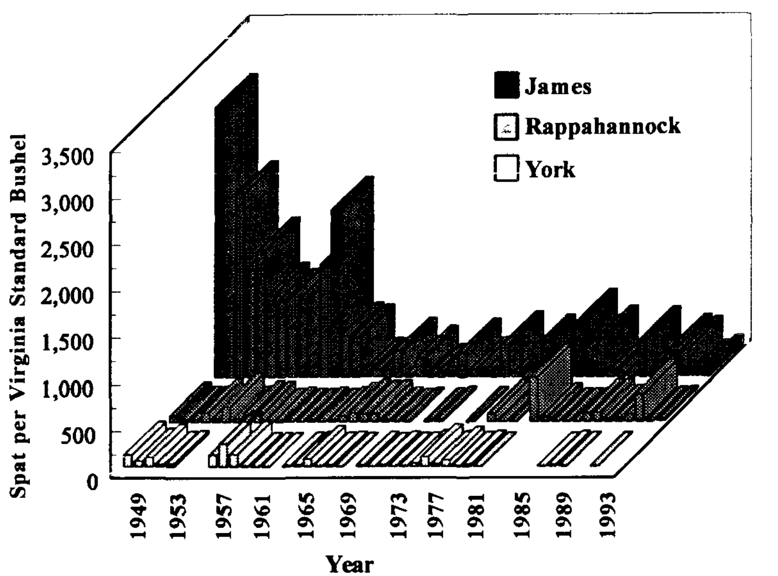


In 1993, a mere 592,000 pounds of oysters were harvested from Bay waters. This is less than one percent of peak harvests at the end of the last century. Although data prior to 1952 include coastal landings, this accounts for only a small portion of the total landings. Once the Bay's most valuable fishery, overharvest, disease, habitat loss, and predation have taken their toll.

Source: National Marine Fisheries Service (1993 data are preliminary)

Maryland and Virginia Oyster Spatfall Index





Numbers of spat, or immature oysters, are measured annually to gain insight into the relative spawning success of the oyster. Spat are counted and reported as the number per bushel of dredged material. The spatfall index of 1991 was considered healthy, however, 1992 and 1993 were poor. Due to inconsistencies in the Maryland and Virginia bushel size, the indices cannot be directly compared.

Sources: Maryland Department of Natural Resources and Virginia Institute of Marine Science

1993 Oyster Roundtable Recommendations

- **Monitor and research disease.**
- **Reduce the spread of disease.**
- **Restore oyster habitat.**
- **Increase hatchery production of seed and larval oysters: maintain replenishment program.**
- **Establish permitting process for aquaculture demonstration projects.**
- **Designate oyster recovery areas for the evaluation of rehabilitation methods and the ability of beds to recover under "quarantine".**

In 1989, the Chesapeake Bay Program established an oyster management plan with the goal of conserving oyster stocks while maintaining a viable fishery. To date, efforts include planting shell, moving oyster seed, investigating alternative reef materials, researching disease, and conducting stock assessment surveys. An aquatic reef restoration plan is also under development to guide the creation of new oyster bars and the restoration of existing oyster habitat.

In the latest effort to restore oyster stocks in Maryland, 40 representatives including watermen, academics, state officials, environmentalists, and aquaculturists joined in an Oyster Roundtable to address the oyster's dilemma. These discussions led to the signing of an "action plan" with several recommendations for aquaculture, research, and the designation of special "recovery areas." This management plan is the first of its kind to recognize the ecological importance of the oyster in addition to its commercial value.

Blue Crab

Presently, the blue crab (*Callinectes sapidus*) is the most important commercial and recreational fishery in Chesapeake Bay although the year-to-year variability in the reported harvest is relatively high. Since 1945, the maximum reported annual catch has been about two times the minimum annual catch. While it is estimated that approximately 75 percent of the adult stock is removed each year due to fishing, populations are considered healthy. With the decline of other species in the Bay and the resultant increase in crab harvesting pressure, however, concern about the future of this great resource is mounting.

Although the blue crab appears to be one of the more resilient Bay species, it is not immune to the effects of habitat loss, environmental degradation, and overharvest. The widespread disappearance of submerged aquatic vegetation (SAV) has resulted in a loss of important crab habitat, particularly for the juvenile and molting stages. Habitat loss caused by low oxygen levels in deep waters sometimes results in death and increases competition for food and shelter in the remaining areas of suitable habitat. In some parts of the Bay, low oxygen levels kill crabs captured in pots. The growing harvest of soft crabs for export to international markets is also of concern because it may lead to an increased harvest of immature females.

The density of the blue crab population is variable. Increasing fishing pressure could cause a population crash and prevent crab populations from recovering. In an effort to avoid such a problem, the states of Maryland and Virginia enacted licensing and gear restrictions on recreational and commercial crabbing. Maryland has a ceiling on the number of pots that an individual can deploy, commercial license restrictions, daily time limits, and other restrictions. Virginia has imposed a two year waiting period for commer-

U.S Fish and Wildlife Service

cial licenses and pot limits on recreational crabbers in 1994. Other restrictions involving the winter dredge fishery and time constraints are under consideration. With such actions, the states hope to reduce fishing pressure before the populations are severely stressed, avoiding the rapid declines seen in other Bay species.

A priority for improving management of the blue crab fishery is to enhance our understanding of crab population dynamics. Knowledge of both environmental and anthropogenic factors contributing to annual fluctuations in reproductive success and population levels is essential for effective fishery management.

Maryland and Virginia currently have summer trawl (a net towed behind a boat) and winter dredge surveys to provide information on recruitment, population size, mortality, migration, growth, and sex ratios. By examining the number of crabs caught per unit effort (i.e., per standardized sample), indices can be developed for yearly comparison. Such indices are not affected by changes in fishing pressure that influence commercial harvest data.

Virginia's Recruit Trawl Survey measures the number of recruits (1 to 4 inch long crabs) that enter into the crab population each year. This survey, which samples crabs between June and August, indicates that the population of recruit crabs is currently at a low point. In addition, the Virginia Institute of Marine Science has employed suction techniques to sample shallow seagrass beds. The high numbers of juveniles captured in the seagrass beds is indicative of their importance as nursery grounds. The Maryland Summer Trawl Survey collects crab population data from May to October. By reporting in three crab size classes, it is possible to project the number of small and large crabs for the following season.

The Winter Dredge Survey is also a valuable tool in the prediction of blue crab availability for the forthcoming fishery. This survey

Changes in Blue Crab Regulations

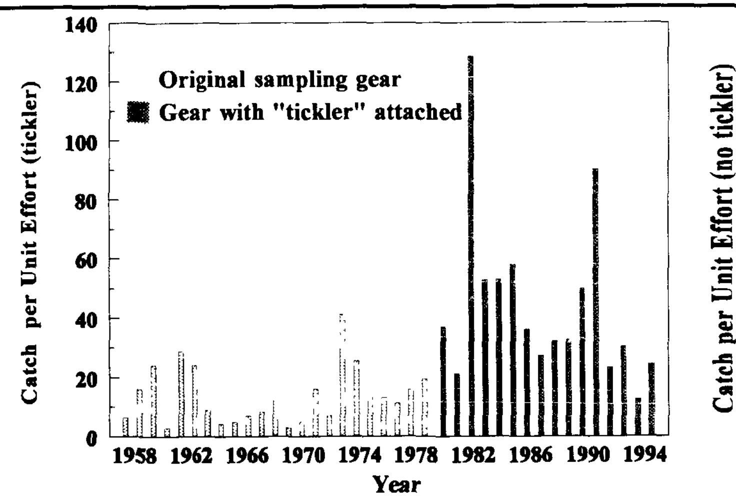
Maryland

- **Daily time limits - recreational and commercial.**
- **A cap on commercial fishing licenses.**
- **300 per license/ 900 per boat crab pot limit.**
- **Abolition of the non-commercial license.**
- **1 bushel per day/ 2 per boat sport crabber catch limit.**
- **Cull rings required in pots.**

Virginia

- **A sport crabbing license allowing the use of 5 crab pots.**
- **No license required for fishing two pots and taking one bushel per day.**
- **Limited entry into the winter dredge fishery after December 1. No new licenses issued until total number of licenses falls below 225.**
- **Daily catch limit cut from 25 to 20 barrels a day for winter dredge fishery.**
- **2 5/16 -inch cull ring in upper portion of each crab pot to allow smaller crabs to escape.**

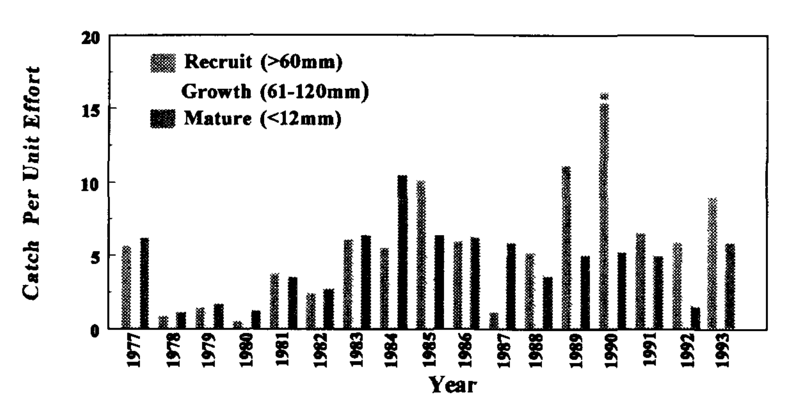
Virginia Blue Crab Recruit Trawl Survey Data



Virginia is measuring the number of "recruits" that enter the crab population each year. Recruits are defined as crabs with a shell (carapace) width between 1 and 4 inches. In 1980, a "tickler chain" was added to the trawl, greatly increasing catch and making a comparison between methods invalid. Data from samples collected between June and August indicate that recruit populations are highly variable and were at a low point in the early 1990s.

Source: Virginia Institute of Marine Science

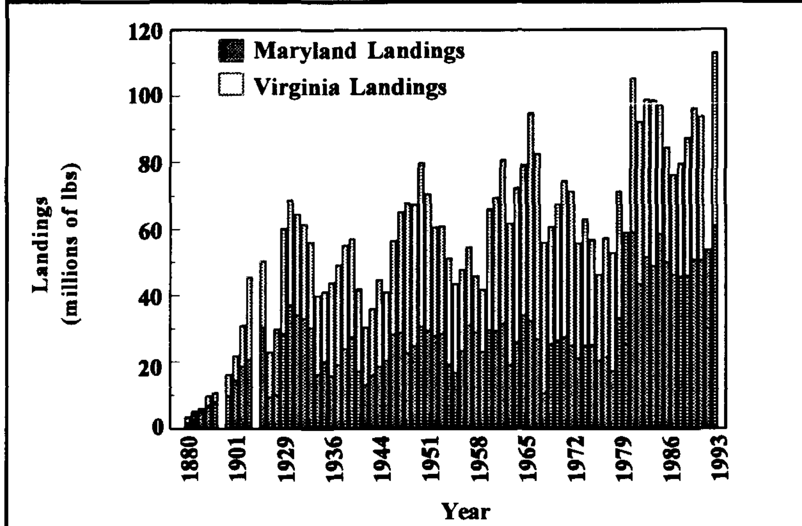
Maryland Summer Trawl Survey



The Maryland Summer Trawl Survey monitors 37 sites per month, collecting information from May to October. By reporting in three categories - recruits, growth stages, and mature - it is possible to assess the size distribution of the populations and predict the number of large and small crabs for the following season.

Source: Maryland Department of Natural Resources

Blue Crab Commercial Landings



Although 1992 was a poor year, crab harvests have remained at a fairly constant level since 1980 (Data before 1952 include coastal landings). In the early 1980s, Maryland changed its reporting system, resulting in a major increase in reported landings. Much concern has surrounded the fishery lately due to the decline of other commercially valuable species in the Bay.

Source: National Marine Fisheries Services (1993 data are preliminary)

takes advantage of the lack of movement in blue crabs during winter to assess their population status. When water temperatures drop below 10° Celsius (December to March), blue crabs quasi-hibernate in the sediment. In addition to the obvious advantages associated with sampling stationary organisms, fishing pressure is confined to a limited area at the mouth of the Bay for Virginia's dredge season and does not interfere substantially with the survey. The current survey consists of a single 100 meter tow of a six foot toothed dredge at nearly 1000 stations throughout the Bay. By using a 15 millimeter mesh bag, the winter dredge survey captures a wide range of size classes.

As with other Chesapeake Bay fisheries, a comprehensive approach to managing the blue crab is needed because biological, physical, economic, and social aspects of the fishery are shared among the Bay's jurisdictions. To provide such an approach, a Bay-wide blue crab fishery management plan was developed in 1989 to sustain the ecological and economic value of the blue crab stock. The plan has already resulted in the implementation of better fishery practices and more effective monitoring of the blue crab stock, as mentioned previously. A revised plan requiring further conservation measures will be completed in 1994.

Waterfowl

Historically, waterfowl were so abundant they seemed to blanket areas of the Bay. Today, their numbers are greatly reduced. Widespread deterioration of shallow water habitats and wetlands, coupled with increasing human disturbance, have reduced the ability of many Bay areas to support waterfowl.

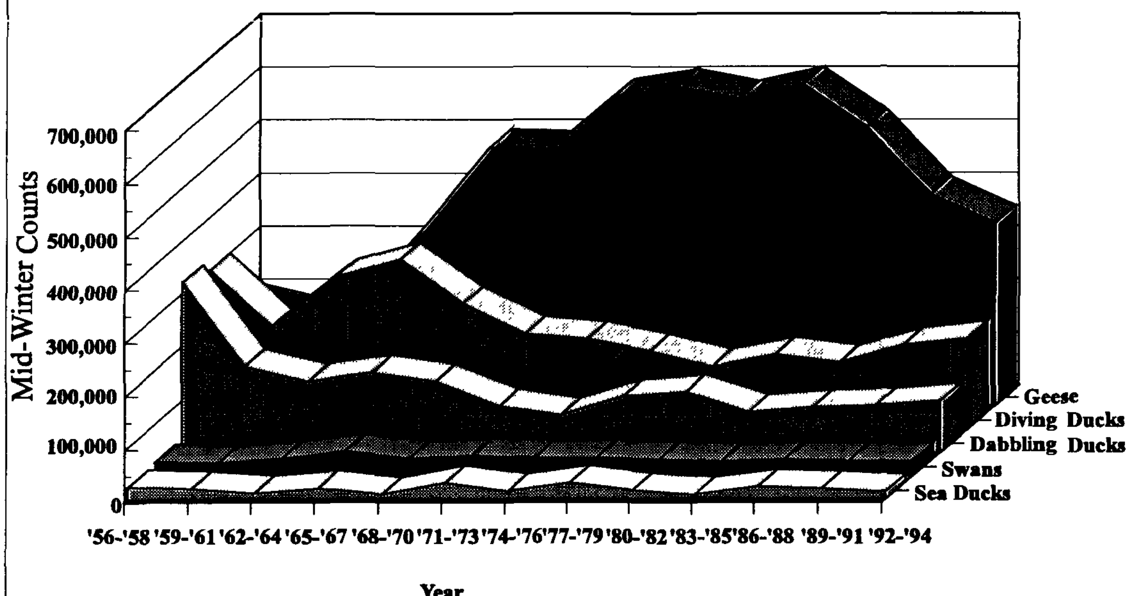
Currently, twenty-nine species of waterfowl use the Bay for wintering, breeding, or as a stopover during migration. Historically, only black ducks and wood ducks bred around the Bay. The major importance of Chesapeake Bay to waterfowl is the extensive wintering habitat it provides.

Gaining a clear picture of the status and trends of migratory birds is extremely difficult because these birds are so mobile and influenced by numerous environmental conditions. Although we focus on the Chesapeake region, Bay population levels of ducks, geese, and swans are influenced by environmental conditions outside the region. For example, canvasback numbers in any given year may decline in the Bay because of drought conditions in the prairie pothole region where the ducks breed. The following information considers the status and trends of certain species, with the understanding that conditions in the Bay may satisfy only a portion of a species' needs during an annual cycle.

Two species of swans, the tundra swan and the mute swan, are found on the Chesapeake Bay. Tundra swans are native to the Bay region, but rely on the Bay only for wintering habitat. Their populations have remained relatively stable. The mute swan, a common orange-billed swan found around the Bay in the summer, is not native to North America and is becoming a problem in Maryland. The mute swan destroys SAV beds, competes with native waterfowl, and destroys colonies of nesting terns by trampling the eggs and chicks. Control of mute swans is necessary to protect our native birds.

The Canada Goose is the most abundant species of waterfowl on the Bay. The most attractive areas to these geese are large, open grain fields close to water. The population of Canada geese started increasing in the late 1960s, providing good hunting

Trends in Bay Waterfowl



The annual Aerial Mid-winter Waterfowl Survey is used to calculate average counts of Chesapeake Bay waterfowl. Canada geese are most abundant, but have declined in recent years due to overharvesting and poor reproduction. Most large groups of similar species appear stable. Declines of individual species, however, are often masked by population changes of others in their group, as evidenced by the decline in black ducks and the increase in mallards, both dabbling ducks.

Source: U.S. Fish and Wildlife Service

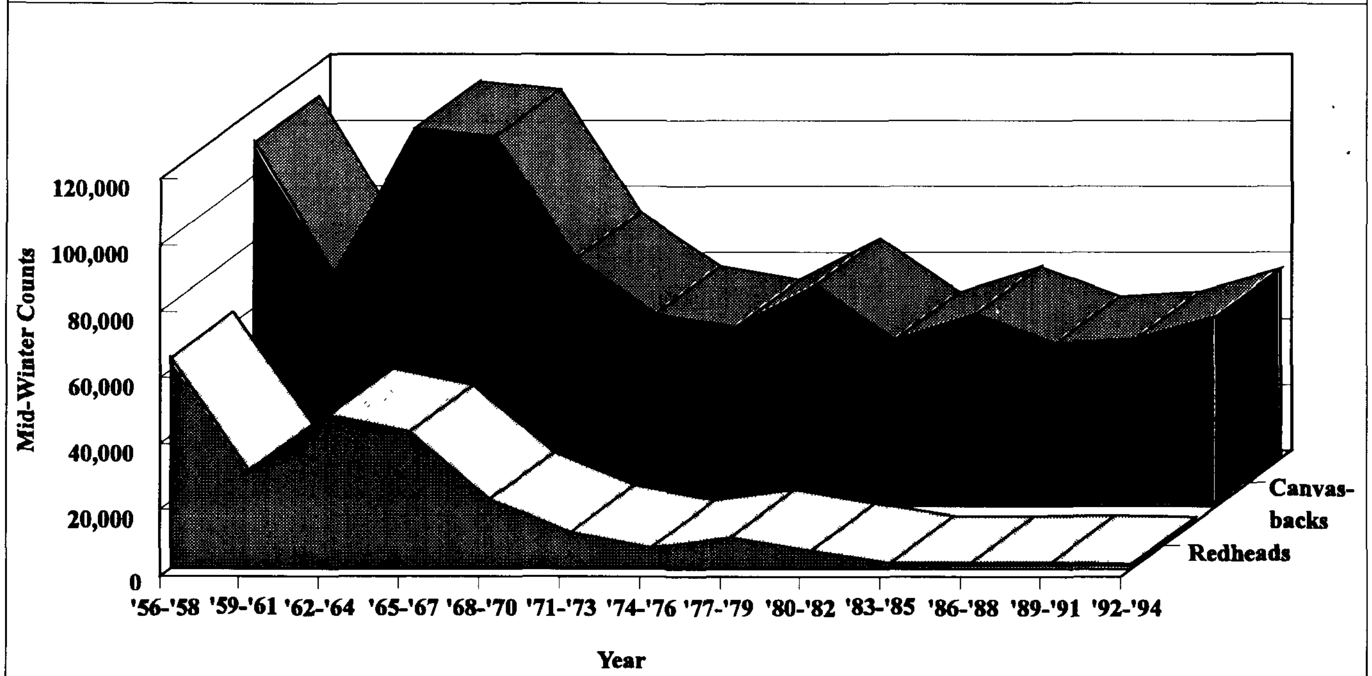
opportunities around the Bay. Poor breeding success over the past several years however, has caused a considerable decline in numbers, forcing managers to reduce bag limits and the length of the hunting season.

The black duck and mallard are the most abundant dabbling ducks in the Bay. Although the population of mallards is increasing, black ducks are declining. In Chesapeake Bay, uninhabited offshore islands and remote marshes are the best black duck production areas. Black ducks raise their broods in intertidal flats, emergent marshes, beaver ponds, beds of submerged aquatic vegetation, and alder-fringed streams. It is important that brood rearing habitat be close to the nesting habitat. Development throughout the watershed has limited the area where these two types of habitats co-occur. This limitation, coupled with the black duck's intolerance to human disturbance, are contributing to the decline in its numbers.

In the 1940s, the State of Maryland and private groups began releasing farm-reared mallards for recreational hunting. Mallards began breeding in the Bay in the 1960s The breeding population in Maryland has recently increased significantly, primarily from game farm stock. Nesting habitat preferences are similar for both the black duck and mallard, although the mallard will nest in close association with humans. The majority of resident Chesapeake Bay mallards are semi-domesticated and are often associated with housing, marinas, and other areas of intense human use. Resident mallards may adversely affect black duck populations by competing for nest sites and food resources or through hybridization with black ducks. Increasing mallard populations may be a sign of degradation of the Bay rather than improvement.

The canvasback is the most abundant diving duck on the Chesapeake. This bird now relies heavily on small clams for food, although in past years it fed extensively on wild celery, a type of SAV, when this plant was abundant. A decline in wild celery caused canvasbacks to shift their diet to clams. The redhead, a similar species, feeds almost exclusively on SAV. Because of drastic declines in SAV in certain areas of the Bay, and an apparent inability to switch to animal foods, only small numbers of redheads now use the Bay.

The Redhead and Canvasback Story



Redheads and canvasbacks are similar both in appearance and their traditional use of SAV as food. Redheads declined sharply due to poaching and the loss of SAV, their major food source. Canvasback populations are slowly increasing due to the ability to change their diet from SAV to small clams and a ban on hunting.

Source: U.S. Fish and Wildlife Service

Sea ducks in the Bay consist of all three species of scoters along with oldsquaw and red-breasted mergansers. These deep-diving ducks inhabit the offshore waters of the Bay and are often not visible from land. Because they live in the vast shallow water areas of the Bay, they are not fully accounted for by the Mid-winter Waterfowl Survey which covers only the shorelines. Recent surveys of the Bay's offshore waters indicate there are over 160,000 scoters, 90,000 oldsquaw, and 45,000 red-breasted mergansers. The surf scoter and oldsquaw are the most abundant sea ducks in the Bay. The scoters feed primarily on small clams, oldsquaw on a large variety of plants and invertebrates, and mergansers on small fish.

Overall, waterfowl are declining in the Bay, with the largest declines occurring in the Canada goose population. The black duck continues its gradual decline, as do scoters, oldsquaw, and goldeneye. Merganser, bufflehead, mallard, and the non-indigenous mute swan populations are increasing.

Waterfowl numbers rise with increases in food resources, such as SAV and shellfish. Stopping the loss and degradation of coastal marshes, reducing disturbance, and controlling competing exotic species will help stabilize these declining waterfowl populations.


U.S. Fish and Wildlife Service

Black Ducks

Citizen Monitoring

Several citizen monitoring groups run volunteer programs throughout the Bay watershed. The largest of these is a regional program coordinated by the Alliance for the Chesapeake Bay. The Chesapeake Bay Citizen Monitoring Program (CBCMP), begun in 1985, uses its volunteers to collect water quality data on Bay tributaries. The program was designed to involve local citizens with a stake in the Chesapeake Bay restoration effort and to compile a valuable long-term database of water quality indicators in the tributaries to the Bay.

Under this program, more than 150 individuals collect weekly water samples in Maryland, Virginia, and Pennsylvania. Monitors are typically highly motivated, caring individuals who enthusiastically pursue their projects. Through training, weekly monitoring, periodic group meetings and other hands-on watershed activities, volunteers increase their awareness and get first-hand experience of both natural and manmade changes to our land and waterways. The resultant education gives volunteers a greater understanding of natural resources and their role in protecting these valuable resources.

Citizen monitors routinely provide ground truthing for the annual SAV survey, assess achievement of living resources goals for SAV, monitor for the appearance of zebra mussels in Bay waters, and track water quality response to nutrient control efforts.

They also support such diverse activities such as participating in an atmospheric deposition study, planting trees in a forested buffer habitat restoration project, and reporting observations on backyard wildlife.

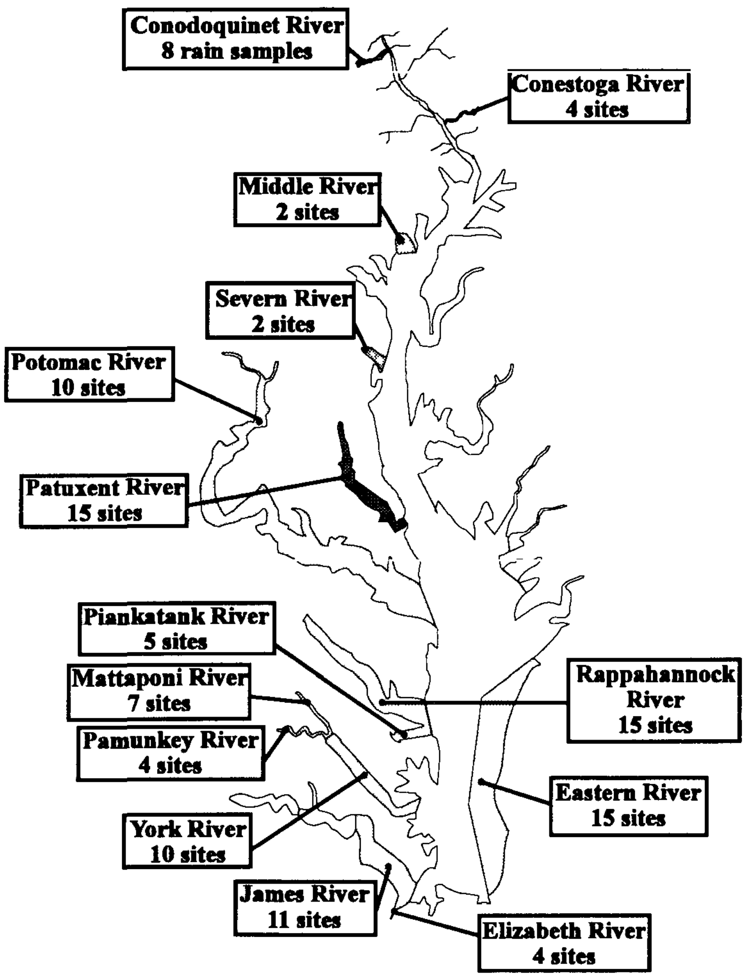
A variety of methods and equipment has been tested to find those that provide consistent and cost-effective data quality. From this experimentation, the Citizen Monitoring Program has developed standard protocols and produced a monitoring manual for use by volunteers.

Citizen monitors involved in CBCMP projects to date have collected quality-assured, long-term baseline data on several watersheds in the Bay basin. This network of highly trained and committed volunteers collect data at 110 stations. A core group has been sampling for eight years and stands ready to accept the new challenge of making a more direct link between water quality and living resources. All CBCMP's sites are in the shallow water of tributaries to the Bay — precisely where the efforts of the Bay program will focus in the immediate future.

Chesapeake Bay Citizen's Monitoring Program Data Usage

- **Assess achievement of SAV habitat goals (Piankatank River, Virginia, and Patuxent River, Maryland).**
- **Track water quality response to nutrient control efforts (Patuxent River, Maryland).**
- **Provide data to support Virginia's *State of the State's Waters* report to Congress.**
- **Provide nearshore nutrient data to confirm characterization of mid-channel data collected by the State (Patuxent River, Maryland).**
- **Measure nitrogen compounds to assess trends, and to evaluate effectiveness of various nutrient reduction programs (Conestoga River, Pennsylvania).**
- **Provide data to reevaluate the permit of the Hopewell Regional Sewage Treatment Plant (James River, Virginia).**

Parameters Measured by Volunteer Monitors



LEGEND

T Temperature	S Salinity	☐ N,H,P	■ T,D,C,P,L,S,N
D Dissolved Oxygen	N Nutrients	▩ N,T,D,C	☐ T,D,C,P,S,V
C Water Clarity	H Herbicides	■ T,D,C,P	
P pH	V SAV	■ T,D,C,P,L	

The Chesapeake Bay Citizen Monitoring Program maintains 110 sites throughout the Bay watershed that are monitored by about 150 volunteers. To make their data useful to managers, the Bay Program has paid particular attention to data quality assurance. Most samples are collected in the nearshore areas of Bay tributaries — where the efforts of the Bay Program will be focusing in the near future.

Source: Alliance for the Chesapeake Bay

Examples of Other Citizen Monitoring Programs in the Bay Watershed

Delaware
- Delaware Stream Watch (WQ/BIO)

District of Columbia
- Izaak Walton League of America (WQ/BIO)

Maryland
- Anne Arundel County Volunteer Monitoring Program (WQ)
- Audubon Naturalists Society (WQ/BIO)
- Chester River Association, Water Quality Monitoring Program (WQ)
- Jug Bay Marsh Monitoring Program (WQ/BIO)
- Maryland Save Our Streams (BIO)
- Sassafras River Community Council (WQ)
- Sawmill Creek Watershed Association (WQ)
- Upper Chesapeake Bay Volunteer Monitoring Program (WQ/TOX)

Pennsylvania
- Environmental Management Council (WQ)
- Alliance for Acid Rain Monitoring (ALLARM) (WQ/TOX)
- Bureau of State Parks Water Quality Monitoring (WQ/BIO)
- Codorus Monitoring Network (WQ/BIO)
- Environmental Management Council (WQ)
- Lackawanna River Watch (WQ/BIO/TOX)
- Zebra Mussel Network (BIO)

Virginia
- Chesapeake Bay National Estuarine Research Reserve System (WQ)
- Friends of the North Fork Shenandoah River (WQ/BIO)
- Friends of the Rappahannock (WQ)
- Izaak Walton League of America (WQ/BIO)

Parameters Measured

WQ - Water Quality
BIO - Biology
TOX - Toxicants

Glossary

Anadromous fish - fish that spend most of their life in salt water but migrate into freshwater tributaries to spawn.

Anoxic - a condition where no oxygen is present.

Anthropogenic - of human origin.

Baseflow - stream or river flows consisting entirely of groundwater contributions.

Benthos - a group of organisms, most often invertebrates, that live in or on the bottom in aquatic habitats.

Best Management Practices (BMP) - a practice or combination of practices that provide the most effective and practicable means of controlling point and nonpoint pollutants at levels compatible with environmental quality goals.

Biological Nutrient Removal (BNR) - a temperature dependent process in which the ammonia nitrogen present in raw wastewater is converted by bacteria first to nitrate nitrogen and then to nitrogen gas.

Biomass - the quantity of living matter, expressed as a concentration or weight per unit area.

Bog - a wetland that has poorly drained acidic peat-soil dominated by sedges and sphagnum moss.

Brackish - somewhat salty water, as in an estuary.

Diatoms - tiny, single-celled or colonial algae with skeletons made of silica that either drift with the motion of the water or are attached to surfaces.

Dinoflagellate - algae of the order Dinoflagellata.

Effluent - the discharge to a body of water from a defined source, generally consisting of a mixture of waste and water from industrial or municipal facilities.

Emergent Wetland - a wetland dominated by nonwoody, soft-stemmed plants.

Exotic Species - any introduced plant or animal species that is not native to the area and that may be considered a nuisance.

Fall Line - a line joining the waterfalls on several rivers that marks the point where each river descends from the upland to the lowland and marks the limit of navigability of each river.

Hypoxic - a condition where only very low levels of oxygen are present.

Marsh - an emergent wetland that is usually seasonally flooded or wet, and often dominated by one or a few plant species.

Nonpoint Source - a diffuse source of pollution that cannot be attributed to a clearly identifiable, specific physical location or a defined discharge channel.

Phytoplankton - microscopic plants (algae) suspended in the water column.

Point Source - a source of pollution that can be attributed to a specific physical location, as in a waste water treatment plant effluent pipe.

Polycyclic Aromatic Hydrocarbon (PAH) - a chemical compound composed of fused six-carbon rings.

Polychlorinated Biphenyl (PCB) - a chemical compound composed of a biphenyl group and chlorine atoms.

Primary Producers - organisms, such as algae, that convert solar energy to organic substances through the molecule, chlorophyll. Primary producers serve as a food source for higher organisms.

Probable Effects Level (PEL) - An estimate of the concentration of a potentially toxic substance in the sediment above which the substance is likely to cause adverse effects to aquatic organisms.

Propagule - seeds or fragments of vegetation capable of producing new plants.

Riparian - relating to or located on the bank of a natural watercourse, such as a river.

Submerged Aquatic Vegetation (SAV) - rooted vegetation that grows under water in shallow zones where light penetrates.

Storm Flow - rainfall runoff that reaches a stream channel during, or soon after a rainfall event that causes high rates of discharge.

Swamp - a wetland dominated by woody vegetation.

Trend Analysis - a formal statistical process that is used to determine the presence or absence of changes in measures of water quality over time or a geographic area.

Tributary - a body of water flowing into a larger body of water.

Watershed - a region bounded at the periphery by physical barriers that cause water to part and ultimately drain to a particular body of water.

Zooplankton - a community of floating, often microscopic animals that inhabit aquatic environments.