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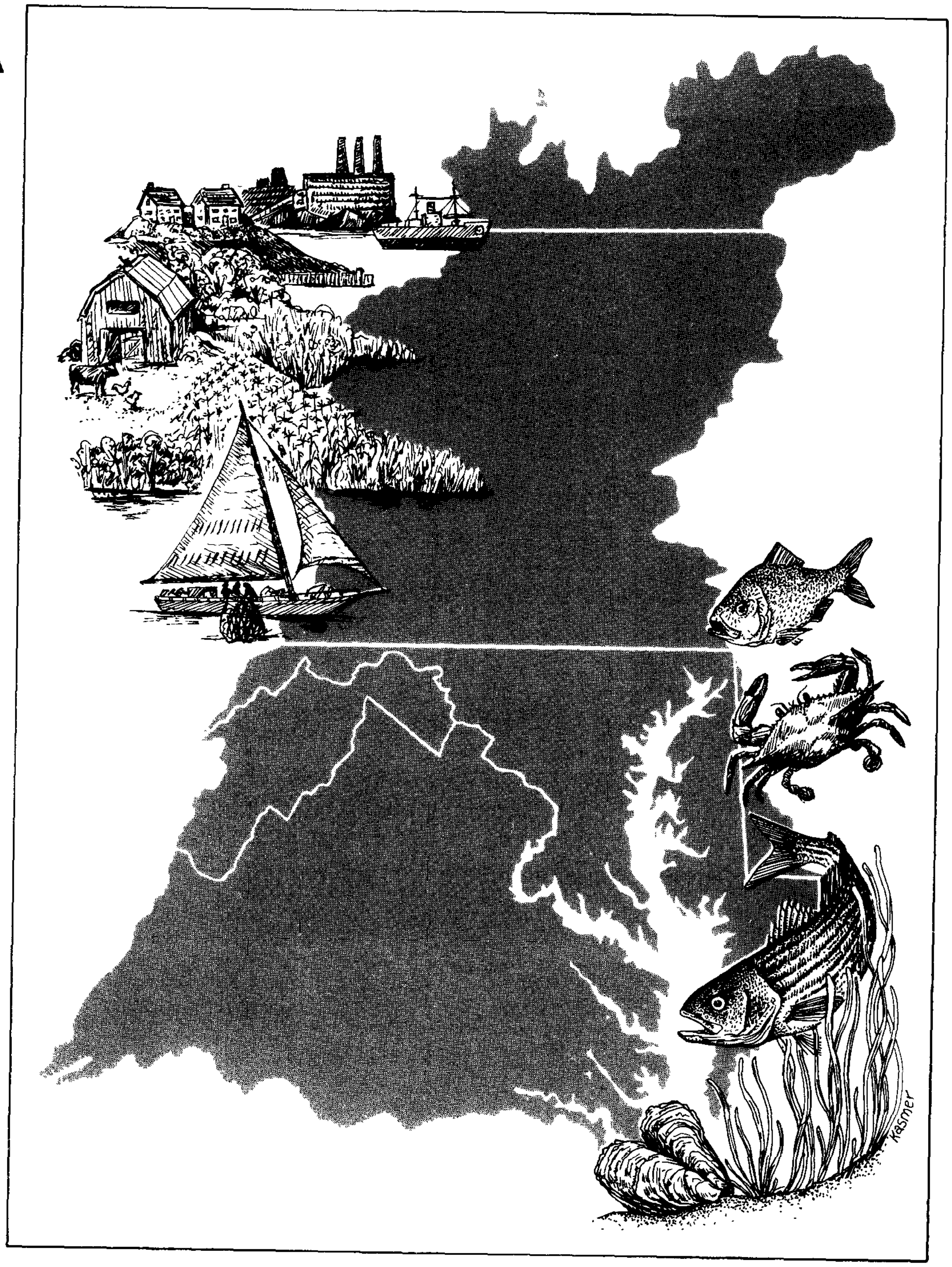
CHESAPEAKE BAY PROGRAM: FINDINGS AND RECOMMENDATIONS

EPA



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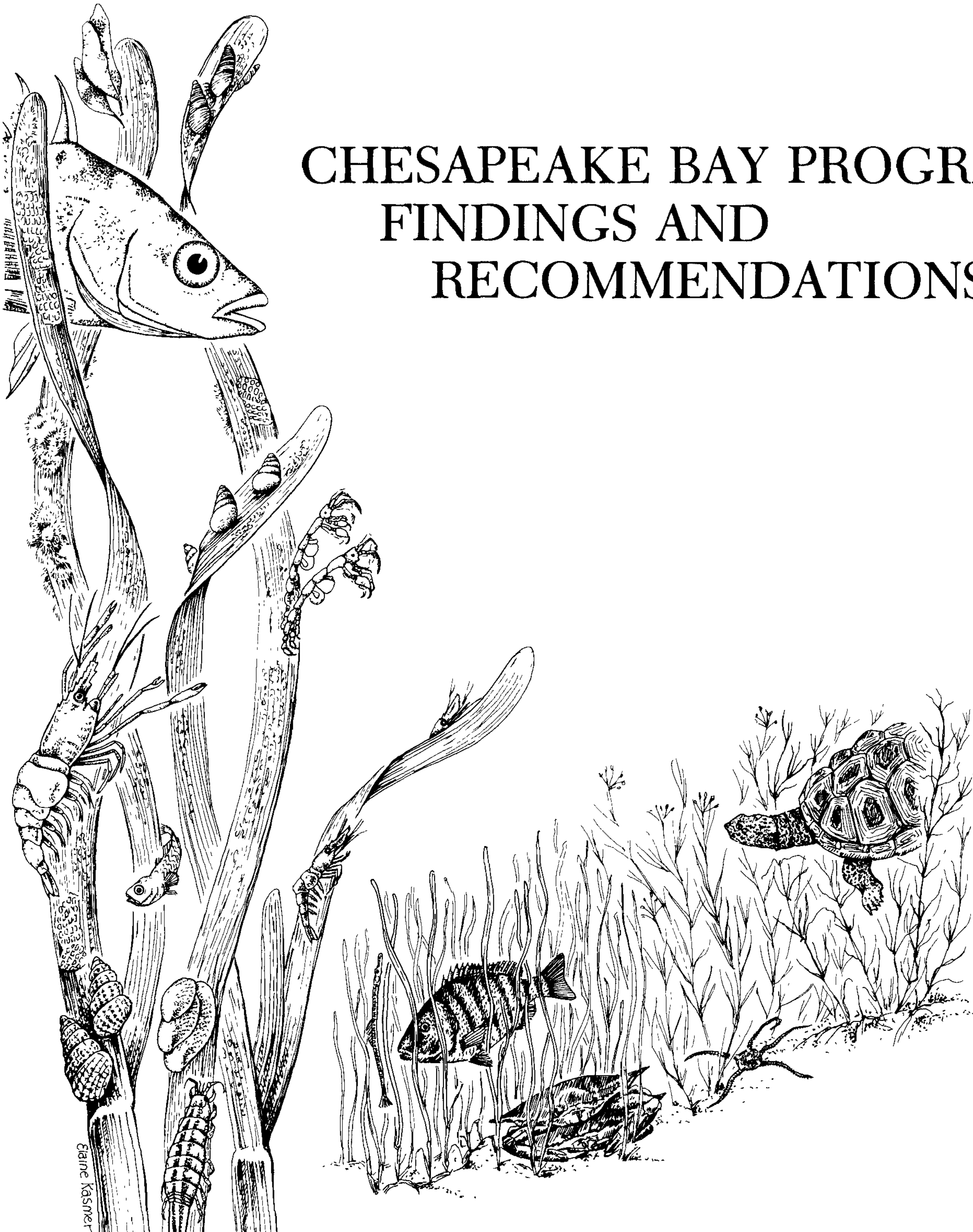

ACKNOWLEDGEMENTS

Many individuals and institutions have been involved in the Chesapeake Bay Program effort. It would be virtually impossible to acknowledge all of them and their unique contributions. However, the following institutions are gratefully acknowledged for their cooperation, active support, and sustained interest in the Chesapeake Bay Program:

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Maryland Department of Natural Resources
Pennsylvania Department of Environmental Resources
Susquehanna River Basin Commission
Virginia Council on the Environment
Virginia State Water Control Board

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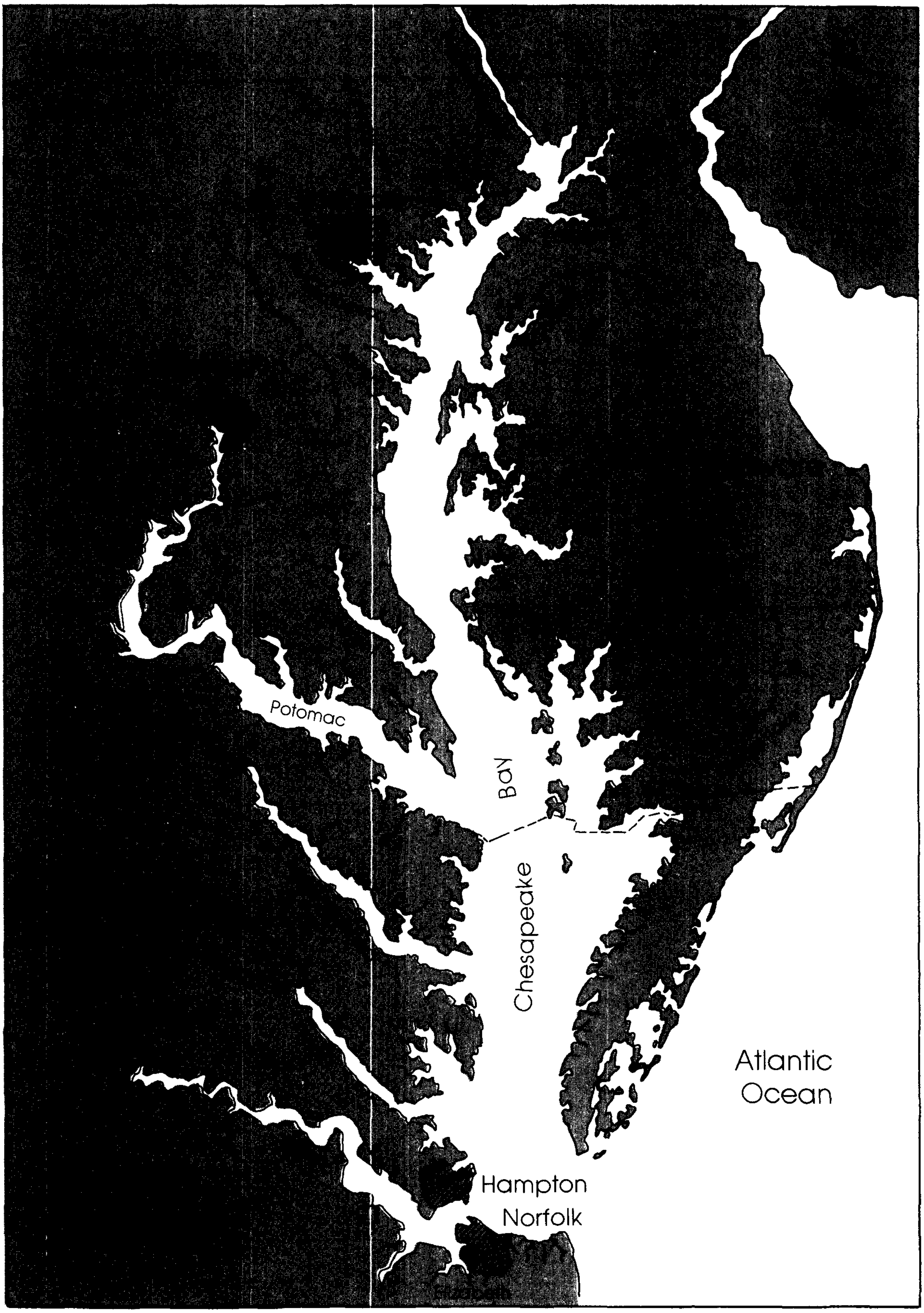
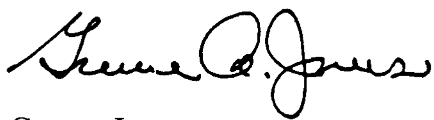

Potomac
Bay
Chesapeake
Atlantic
Ocean
Hampton
Norfolk

FOREWORD

The water and related land resources of Chesapeake Bay serve over 12 million people in five states. The beauty and richness of the region have been well known since the area was first settled by the Susquehannock and other Indians. Although Chesapeake Bay is still enjoyed today, 400 years later, the estuary and its resources are pressured from growth and development. The future will bring additional stresses as population continues to grow and the region seeks the expanded economic base needed to provide a decent standard of living for all of its citizens. It is hoped that the needs of the future will be met and the quality of the Bay preserved. But first, the Bay ecosystem must be understood; then patterns of growth must respect the capabilities of the Bay's system to assimilate human pressures and, finally, areas and resources which are particularly vulnerable must be ardently protected through controlling pollution.

This report provides an overview of the major research findings and range of pollution controls recommended by the Environmental Protection Agency's Chesapeake Bay Program (CBP), in accordance with P.L. 94-116 passed by the 94th Congress on October 17, 1975. The report summarizes three main phases of the program: research on nutrient enrichment, toxic substances, and submerged aquatic vegetation; a characterization of the Bay's water quality and resources; and a management framework for ameliorating current pollution problems and preserving the future quality of Chesapeake Bay. Chapter 1 of the report provides a brief education on the ecological processes governing the Bay and the complex ways that animals, plants, and humans make use of the ecosystem. In the second chapter, the state of the ecosystem and the sources of pollutants are described. The final chapter recommends and specifies actions or approaches which appear to be most necessary and effective to improve and maintain the well-being of this ecosystem.

While the Chesapeake Bay Program significantly advanced the technical understanding of the nation's largest and most productive estuary, it also promoted a unique regional management ethic. This ethic was encouraged by the Chesapeake Bay Program Management Committee which guided the Program's efforts over the years. The committee, representing the EPA, the state governments, and the citizens of the area, has been a unique example of regional cooperation. The Chesapeake Bay Program hopes that the findings and recommendations presented in this report will encourage a continued commitment by both the governments and the people of the Chesapeake Bay region.



Greene Jones
Chairman,
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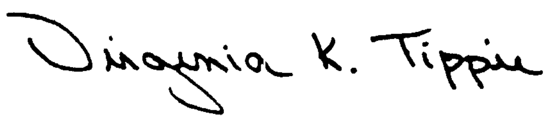
Management Committee



Virginia K. Tippie
Director,
Chesapeake Bay Program

INTRODUCTION

HISTORY OF THE BAY PROGRAM

Concern for the well-being of Chesapeake Bay and its tributaries prompted Congress to direct the U.S. Environmental Protection Agency to conduct a five-year study of the Bay's water quality and resources, and to develop management strategies to preserve the Bay's quality (P.L. 94-116). A technical program was set up in 1976 to identify and study the major environmental problems in Chesapeake Bay. Concurrently, a study on environmental management was established to determine available management mechanisms on the Bay and develop alternative controls. In 1981, the technical program ended, and during 1982 and 1983 the CBP analyzed and integrated their findings, leading to conclusions and recommendations for actions needed to preserve the environmental quality of the Bay.

THE RESEARCH PHASE

Numerous studies existed in 1976 documenting the negative effects of pollution. However, an absence of scientific documentation and analysis existed on several serious problems which were disturbing leaders and citizens throughout the Bay region—namely, a trend of disappearing Bay grasses (submerged aquatic vegetation) and of declining fish landings among certain species. Arguments centered on questions of whether the losses of fish and Bay grasses were cyclic or permanent occurrences, and due to natural or human causes.

State personnel from Maryland and Virginia, the scientific community, and citizens from around the Bay identified 10 primary water quality problems of the Bay, and suggested methods needed to investigate them. These 10 problems were:

- Wetlands alteration
- Shoreline erosion

- Effects of boating and shipping on water quality
- Hydrologic modification
- Fisheries modification
- Sellfish bed closures
- Accumulation of toxic substances
- Dredging and dredged material disposal
- Nutrient enrichment
- Decline of submerged aquatic vegetation

Three critical areas were chosen from the 10 for intensive investigation—nutrient enrichment, toxic substances, and the decline of submerged aquatic vegetation (SAV).

State and CBP staffs, together with EPA personnel, wrote plans of action and asked interested scientists to respond with suggestions and proposals for researching the three problem areas. Nearly 40 research projects, grants, and cooperative agreements were funded. Many of the studies were conducted by major scientific research institutions in the Chesapeake Bay region. These investigations have greatly increased the understanding of sources of pollutants, their transport and fate within the estuary, as well as impacts on a major ecosystem component, SAV.

Products

Approximately 40 final research and survey reports present the methodology, findings, and recommendations of the CBP's scientific studies; these are available through the Nationai Technical Information Service and in the libraries of the management agencies and principal research institutions of the region. In addition, the CBP has produced several major summary documents: *Chesapeake Bay: Introduction to an Ecosystem* explains some of the important components and interactions within the Bay ecosystem; *Chesapeake Bay Program Technical Studies: A Synthesis* pulls together all available research from the three study areas in one volume which is structured to address the questions pertinent to managers. These research findings contributed to the second phase of the program, the characterization effort.

CHARACTERIZING THE BAY

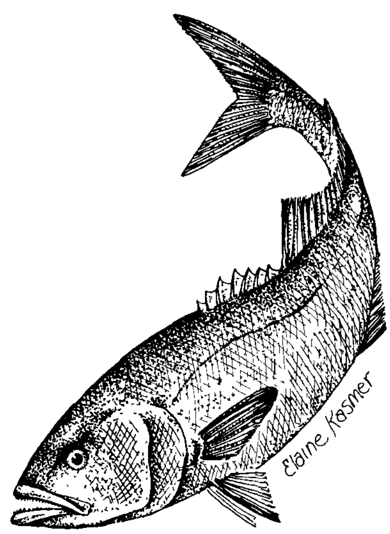
The second phase of the CBP concentrated on determining trends in the Bay's water quality and the health of its resources. The goal of this phase was to provide an information base for evaluating human impacts on the ecosystem and a framework for guiding management options.

As in the research phase, a diverse group of people, from scientists to citizens, helped the CBP formulate an approach for this characterization. For ease of comparison and organization, the Bay was divided into segments based on natural factors such as circulation patterns and salinity. To characterize how water quality has changed over time, the CBP looked at levels of nutrients, dissolved oxygen, organic compounds, and heavy metals in those segments over the past 30 years. Available data was assessed for phytoplankton, submerged aquatic vegetation, benthic animals (including shellfish), and finfish. In some areas, it was possible to analyze both water quality and resource trends over a hundred years. For nearly two years, CBP staff collected present and historical data from institutions and agencies throughout the Bay region. The Program's data base is one of the largest on any single estuary.

After trends were established for most segments of the Bay, potential relationships between water and sediment quality, and resources were examined. Several positive correlations were found, indicating that there may be cause-and-effect relationships between certain trends in water quality and the abundance of resources. These relationships point to specific management needs, such as pollution controls in particularly sensitive areas, and to future monitoring strategies.

Products

The major product of the second phase is *Chesapeake Bay: A Profile of Environmental Change*. This report presents the current state of the Bay and trends in its water quality and resources. It also suggests possible causes of some of the changes observed and thereby provides a useful management tool. An important non-technical product of this characterization effort is the public concern for the Bay that it has generated.



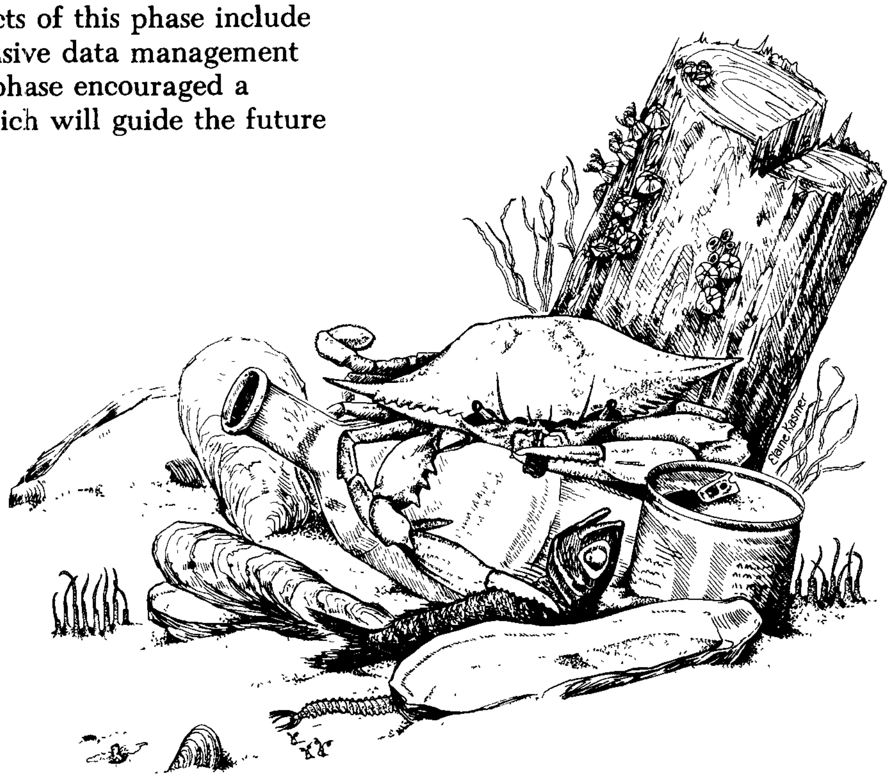
MANAGING THE BAY

The technical studies and Bay-wide characterization provided a foundation for determining appropriate management strategies, the third and final phase of the CBP. Several steps were involved in developing management options for Chesapeake Bay. One was to examine the effectiveness of current control programs for present and future situations. To this end, predictive models were developed to evaluate the effectiveness of various pollution controls. Another step in the management phase involved setting up monitoring strategies. These strategies can enhance the ability to distinguish natural from human-influenced events, provide a framework for future research, and fill in the gaps in the present base of knowledge. In a final step in the management process, the CBP recommended institutional arrangements for implementing results of the Program and directing future management of Chesapeake Bay.

Developing and implementing a comprehensive management plan for Chesapeake Bay is a public choice process. Therefore, the CBP, together with the Citizen's Program for the Chesapeake Bay (CPCB), established a Resource User's Management Team comprised of users of the Bay, and a Water Quality Management Team comprised of state managers who influence Bay activities. Throughout the management process, the Citizen's Program and these teams have reviewed findings and conclusions and have been involved in developing strategies. These teams were an invaluable component of the CBP, particularly in guiding the Program's third phase. Their help exemplifies the kind of participation and cooperation necessary for effective implementation of any environmental management plan.

Products

The major product from the third Program phase is *Chesapeake Bay: A Framework for Action.* This report presents a framework for the actions that need to be taken by users to restore and maintain the ecological integrity of Chesapeake Bay. Additional products of this phase include predictive models and a comprehensive data management system. Lastly, the third program phase encouraged a regional management approach which will guide the future of the Bay.



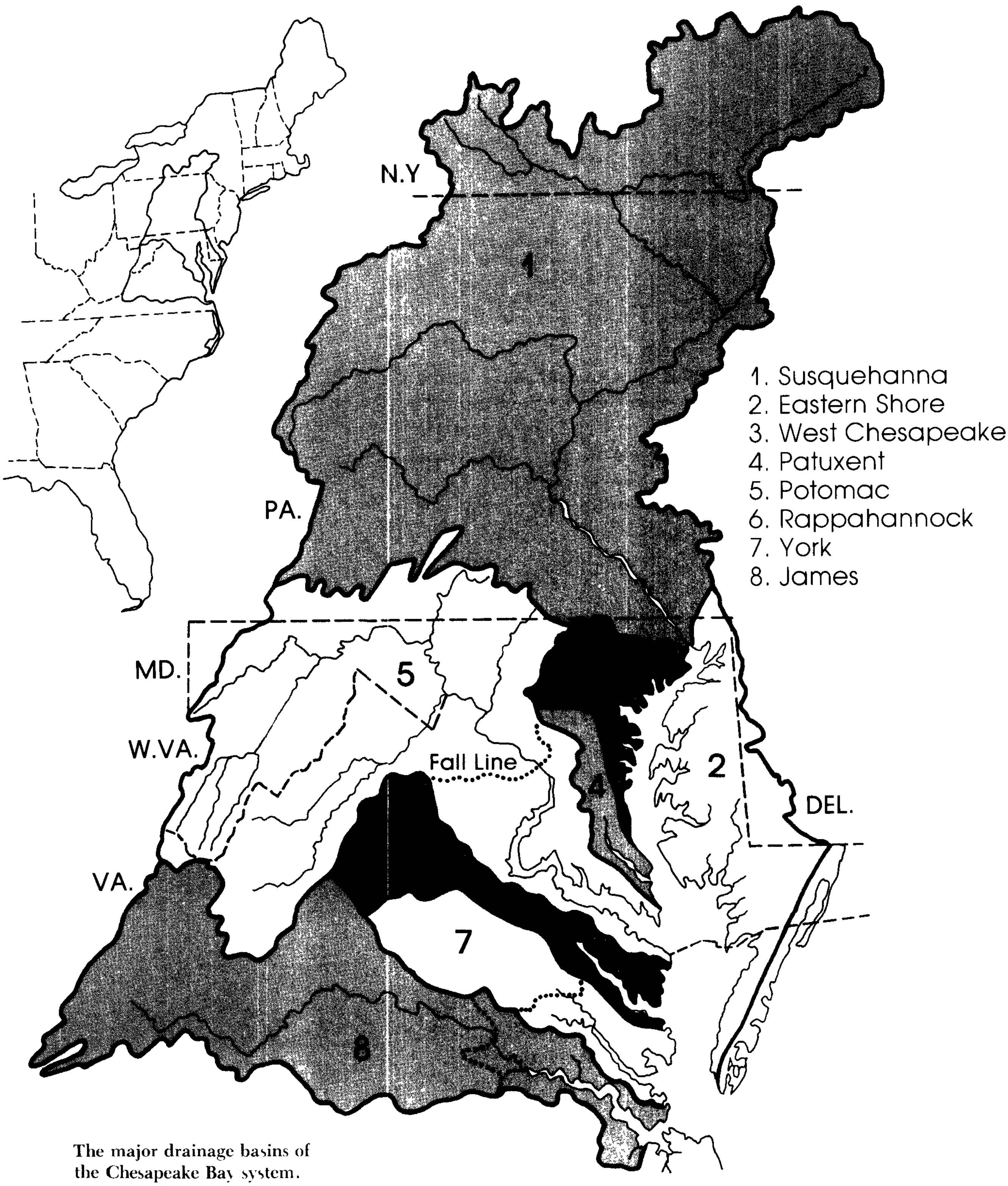
THE CHESAPEAKE BAY SYSTEM

GENERAL DESCRIPTION

Chesapeake Bay is the largest estuary in the United States and biologically, one of the most productive systems in the world. It is part of an interconnected system which includes a portion of the Atlantic Ocean and rivers draining parts of New York, Pennsylvania, West Virginia, Maryland, Delaware, and Virginia. The main Bay and all of its tidal tributaries compose the Chesapeake Bay system as that term is employed in this document.

The Bay proper is approximately 200 miles long and ranges in width from about four miles near Annapolis, Maryland to 30 miles at its widest point near the mouth of the Potomac. The water surface of the Bay proper encompasses more than 2,500 square miles. That figure nearly doubles when its tributaries are included. However, the Bay is a relatively shallow body of water, averaging 28 feet in depth, making it very sensitive to temperature and wind.

The Bay draws from an enormous 64,000 square-mile drainage basin. Of the more than 150 rivers, creeks, and streams flowing through portions of six states and the District of Columbia, and contributing freshwater to the Bay, 50 are considered major tributaries. Eight of these fifty rivers contribute about 90 percent of the freshwater contained in the Bay main-stem: they are the Susquehanna, Patuxent, Potomac, Rappahannock, York, James, Choptank Rivers and the West Chesapeake Drainage Area. The Susquehanna is by far the largest river in the basin, discharging approximately 50 percent of the freshwater that reaches the Bay. In addition, it has the highest freshwater discharge rate of any river on the East Coast of the United States—a mean annual rate of 40,000 cubic feet per second. These eight major tributaries and the ocean shape the circulation and salinity characteristics of the estuary. Thus, the way in which land is used and managed within each of the river basins largely determines the volume and chemical properties of the freshwater discharged to the Bay.



The major drainage basins of the Chesapeake Bay system.

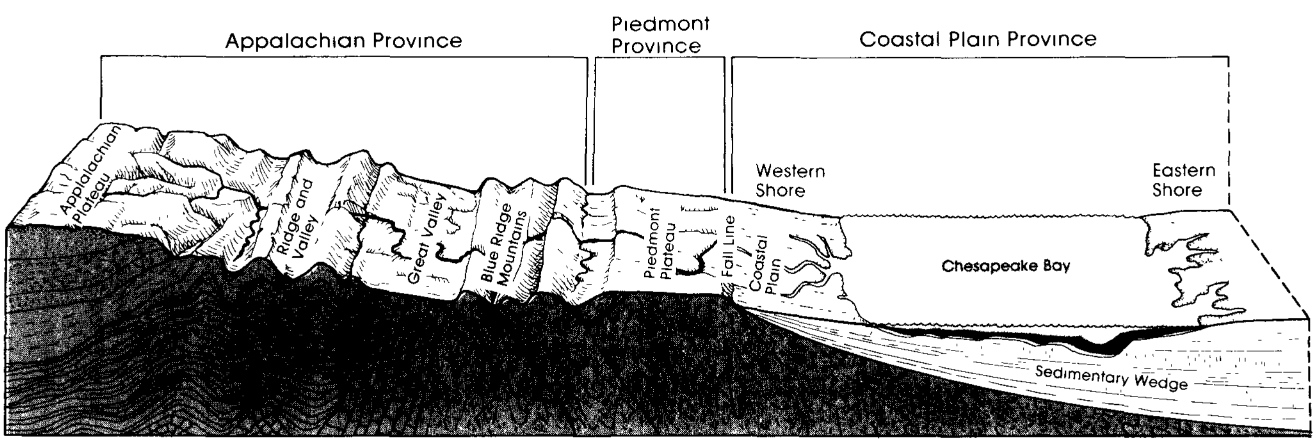
THE BAY'S ECOLOGICAL PROCESSES

Natural processes have subjected the Chesapeake ecosystem to unending modifications. In the Chesapeake's long history, beginning when sea level changes started to form it about 15,000 years ago, humans have only recently emerged as leading actors in this reshaping process. Following is a brief overview of the Bay ecological processes and characteristics. This information helps to show how natural and human actions continuously initiate chains of events that can alter the condition of the Bay's environment. This description is divided into four major areas: geological composition; water and sediments; key biological communities; and food production and consumption.

Geological Composition

In geological terms, the Chesapeake is very young. If the entire geological calendar from the earliest fossil formations were equated to one year, the Bay would be less than one minute old. The birth of Chesapeake Bay followed the most recent retreat of glaciers that once covered the North American continent during the final part of the Pleistocene epoch (which began one million years ago). The melting glacial ice resulted in a corresponding rise in sea level that submerged coastal areas, including the Susquehanna River Valley and many of the river's tributaries. The complex of drowned river-beds now forms the basin of Chesapeake Bay and its tributaries.

The Bay proper lies within the Atlantic Coastal Plain, a relatively flat, low land area with a maximum present elevation of about 300 feet above sea level. The Coastal Plain extends from the edge of the continental shelf on the east to a fall line that ranges from 15 to 90 miles west of



the Bay. The fall line forms the boundary between the Piedmont Plateau and the coastal plain. Waterfalls and rapids clearly mark this line where the elevation sharply increases because of erosion of the soft sediments of the coastal plain. Cities such as Fredericksburg and Richmond, Virginia; Baltimore, Maryland; and Washington, D.C. have developed along this fall line for reasons that include the limits of navigability, the abundance of freshwater, and the water power potential of the falls and rapids.

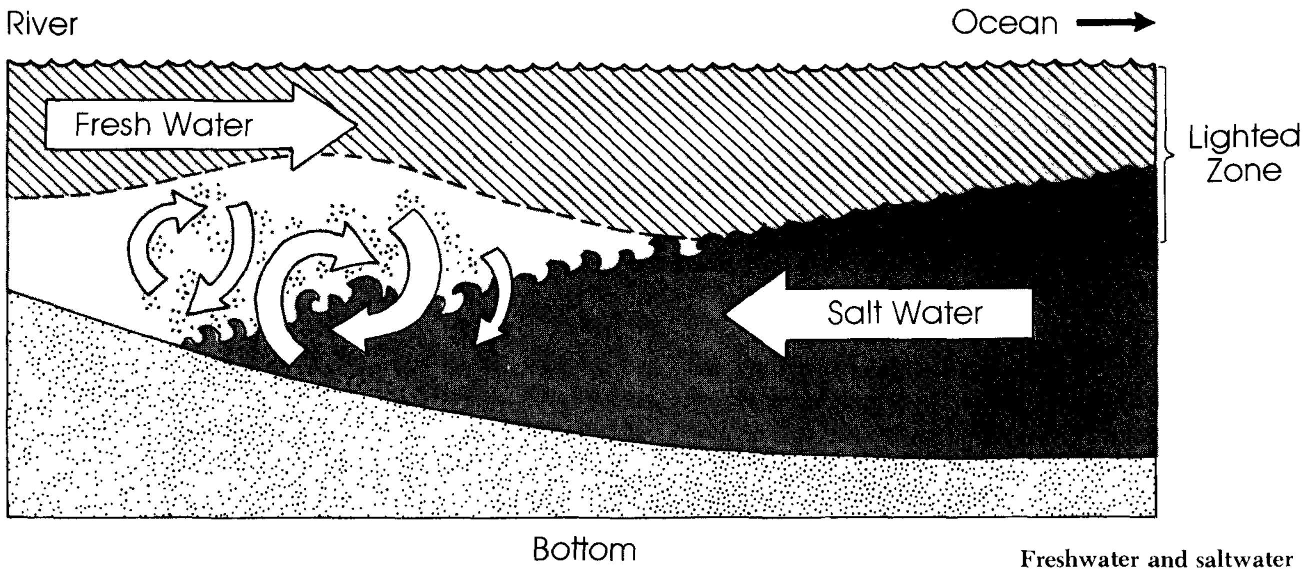
The Chesapeake's shoreline has undergone constant modification by erosion, and by the transport and deposition of sediments. Areas of strong relief, like peninsulas and headlands, are eroded and smoothed by currents, tides, and storms, and the materials are deposited in other areas of the Bay. Sediments carried by a river are left on the floor of the Bay and major tributaries, depositing mud and silt. Grasses and other plants colonize and stabilize the sediments, developing marshes. Build-up of land in the marshes causes the area to eventually become part of the shoreline.

The forces of erosion and sedimentation are continually reshaping the Bay. For example, erosion caused a historically swift submersion of Sharp's Island which was, in colonial times, a rich plantation of six hundred acres situated off the Eastern Shore. Mooring piles for sailing ships are visible at Joppatowne, Maryland, more than a mile from open water today, demonstrating the rapidity with which sediments can fill an estuary like the Gunpowder River.

Water and Sediments

Of all bodies of water, estuarine systems offer the greatest diversity in water composition. Freshwater mixing with salt water creates unique chemical and physical environments, each of which supports different communities of organisms particularly suited to that type of water.

Temperature, salinity, and circulation are three very important physical characteristics which affect the location and stability of Bay environments. Fluctuations in water temperature affect the rates of chemical and biochemical reactions within the water, which in turn influence processes such as phytoplankton growth. Salinity refers to the concentration of dissolved salts in the water. Because sea water enters the Bay through its mouth, the salinity is highest at that point and gradually diminishes toward the northern end of the estuary. Salinity levels are also graduated vertically and horizontally; that is, deeper water and the waters on the eastern side of the estuary are saltier. This characteristic distribution is due to differences in the density of fresh and salt water, and the effects of circula-



Freshwater and saltwater mix in the Bay creating a unique environment.

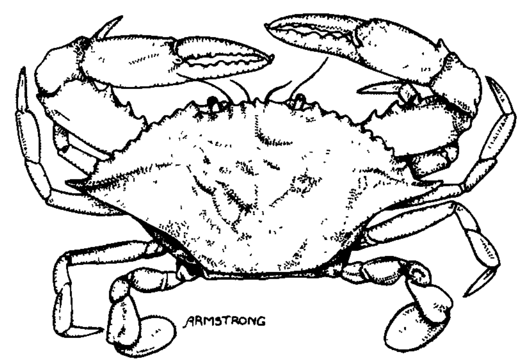
tion and fresh-water inflow. These salinity gradations and the water circulation play enormously important roles in the distribution and well-being of various organisms living in the Bay. The movement of water transports plankton, eggs and juveniles of fishes, shellfish larvae, sediments, minerals, nutrients, and other chemicals.

The waters of the Chesapeake are a complex chemical mixture, containing dissolved organic and inorganic materials, including dissolved gases, nutrients, and a variety of other chemicals.

Dissolved Oxygen—Among the chemical constituents most important to the Bay is dissolved oxygen which is essential for animals inhabiting the Bay. Oxygen is transferred from the atmosphere into the surface waters by the aerating action of the wind and by adsorption. It is also added at or near the surface as a by-product of plant photosynthesis. As a result, floating and rooted aquatic plants increase dissolved oxygen levels. Because the existence of plants also depends on the availability of light, the oxygen-producing processes occur only near the surface or in shallow waters. Due to the natural variations in temperature and salinity throughout the year, the concentration of dissolved oxygen tends to diminish in deeper areas of the Bay and tributaries in the summer and then increase in the fall.

Nitrogen and Phosphorus—The plant nutrients, nitrogen and phosphorus, are also key constituents in the Bay's system. In addition to being supplied by natural processes, they enter the Bay in significant quantities through discharges from sewage treatment plants, food processing industries, and in runoff from agricultural land, urban areas, and forests. Nitrogen plays a principal role in producing plant and animal tissue. Phosphorus is essential to cellular growth and the reproduction of phytoplankton and bacteria. Just as fertilizer aids the growth of agricultural crops, both nitrogen and phosphorus are vital to the growth of plants within the Bay. Too much nutrients, however, can lead to an over-abundance of phytoplankton, creating dense populations, or blooms, of plant cells. These blooms become a nuisance because oxygen is used up as they decompose. This can lead to anoxic conditions, meaning that the affected water area becomes devoid of oxygen and, therefore, of life.

Sediments — Suspended in the waters of the Chesapeake are huge quantities of particulate matter composed of both organic and inorganic materials, including detritus, living plankton, and suspended sediments. Individual sediment particles have a large surface area, and many molecules easily adsorb, or attach, to them. As a result, suspended sediments act as chemical sweeps by adsorbing metals, nutrients, oils, organic chemicals, and other potentially toxic compounds. For this reason, areas of high sediment deposition can possess high concentrations of long-lasting toxicants. Accumulation of sediments can cause other undesirable consequences. Settling of sediments on the bottom can fill in channels and other waterways; bottom dwelling plants and animals (benthos) can be smothered; and, when the sediments are suspended, the water becomes turbid and thus decreases the amount of light available for plant growth.



Key Biological Communities

The Chesapeake provides critical types of habitat for various stages of animal and plant life and serves as a supplier of seafood to humans. More than 2,700 species of plants and animals inhabit the Chesapeake and its shoreline. All depend on the Bay and their fellow inhabitants for food and shelter. Each, in turn, contributes to the continued life of the entire Chesapeake ecosystem. Five major communities that interact closely are the marshes, submerged aquatic vegetation communities, bottom residents (benthos), the floaters (plankton), and swimmers (nekton). Each community makes use of particular habitats within the Bay.

Marshes — Marshes, or wetlands, form a natural boundary between land and water. Most wetlands consist of moist vegetated areas kept wet by runoff, ground-water seepage, adjacent streams, and the Bay's tides. These types of wetlands usually have bountiful supplies of nutrients and are among the most productive areas known for plant growth. The abundance of food and shelter offered by the marsh plants results in valuable habitat for other members of the Bay community. A host of invertebrates, for example, feed on decomposed plant material and, in turn, provide food for many species of higher animals. Many game birds, animals, and furbearers depend on wetlands for food and shelter, as do the young of commercially important fish and shellfish.

Submerged Aquatic Vegetation – Ten major species of Bay grasses are found in the Chesapeake Bay. They are collectively termed submerged aquatic vegetation (SAV). Most cannot withstand excessive drying and must live with their leaves at or below the surface of the water. They are also found only in shallow waters where light reaches the bottom. Like the marsh grasses, the different species are generally distributed according to salinity. These submerged grasses are important links in the Bay's food chain. They serve as protective cover and food to a diverse community of organisms. For example, many species of invertebrates feed on decaying grasses and then, in turn, provide food for small blue crabs, striped bass, perch, and other small inhabitants of the Bay. Wading birds such as herons often feed on small fish which shelter in the SAV beds. Another important ecological function of the Bay grasses is their ability to slow down water velocities, causing particulate matter to settle at the base of their stems; this makes water clearer in the SAV zones. Finally, like marsh grasses, Bay grasses act as nutrient buffers, taking up nitrogen and phosphorus and releasing them later in the season when the plants decay.

Benthic organisms – The organisms that live on and in the bottom of the Bay outside of the marshes and grass beds form a complex assemblage of communities, primarily composed of invertebrate animals. Commonly termed benthos, they are usually described in terms of the animal components, although plant and bacterial groups are crucial parts of the ecosystem as well. Again, salinity and sediment type help dictate the distribution and specific kinds of benthos residing in the Bay.

Some benthic organisms are commercially important, such as clams, oysters, and blue crabs, and are widely distributed. Salinity determines the locale of hard-shell and soft-shell clams, the former requiring highly saline waters and the latter being able to thrive in lower salinity. Certain benthic predators, diseases, and parasites of oysters are unable to tolerate lower salinities so they are far less a problem in upper Bay areas than they are in the lower Bay.

Plankton – The tiny organisms that float and drift with the water's movements are the plankton of the Bay. This community includes phytoplankton, zooplankton, bacteria, and jellyfish. Phytoplankton are microscopic, one-celled plants which often occur in colonies known as algae. Zooplankton, are the microscopic animals of the Bay. The bacteria are essentially the undertakers or decomposers— they break down dead matter, particularly plants. The jellyfish include sea nettles, and comb jellies.

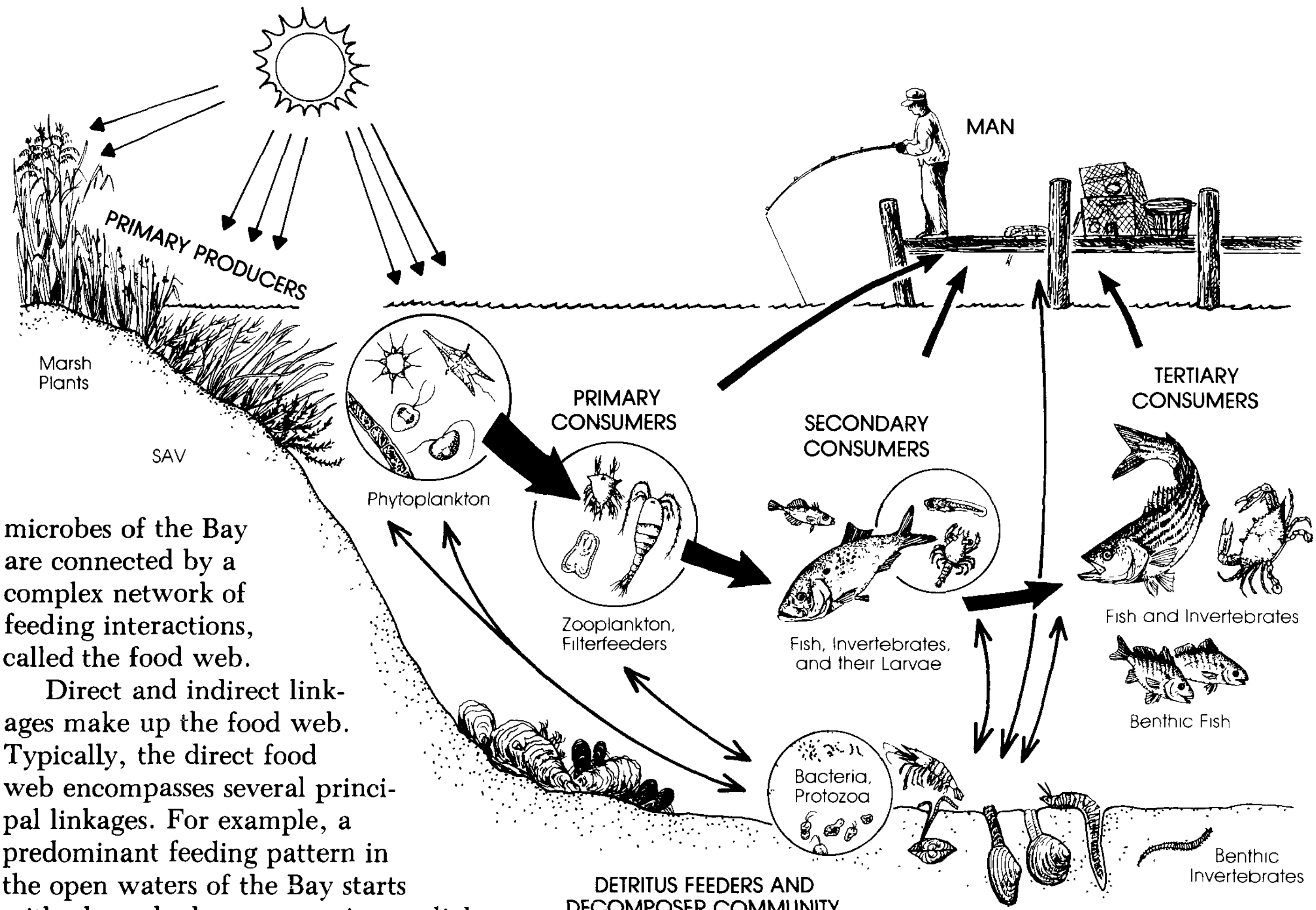
In general, the phytoplankton and zooplankton of the Bay provide the major food source for the larger organisms of the Bay. Like all plants, the phytoplankton require light and, therefore, are found near the surface. They include diatoms, dinoflagellates, golden algae, green algae, and blue-green algae. Most of the zooplankton are copepods, a particular type of crustacean that is only about a millimeter long. Also, the tiny larvae of benthic animals and fish are considered to be zooplankton. The zooplankton feed on the phytoplankton and, in turn, they may be consumed by larger organisms.

Nekton—Nekton, including fish, certain crustaceans, squid, and other invertebrates, are the swimmers of the Bay. The approximately 200 species of fish living in the Bay are classified as either permanent residents or migratory. The residents tend to be smaller in size, and are therefore less capable of negotiating the distances often covered by the larger migratory species. The resident fish include killifishes, anchovies, and silversides.

The migratory fish fall into two categories: those who spawn in the Bay or its tributaries, and those who spawn on the ocean shelf. The members of the Bay-spawning category migrate varying distances to spawn in freshwater. For example, yellow and white perch travel quite short distances from their residence areas in the slightly salty (brackish) water of the Bay to freshwater areas in the upper parts. Striped bass also spawn in low salinity areas. On the other hand, shad and herring fit the definition of anadromous fish more completely; they travel from the ocean to freshwater to spawn, and return to the ocean to feed. Other migratory fish use the Bay strictly for feeding and they spawn in the lower Bay or on the ocean shelf. Croakers, drum, menhaden, weakfish, bluefish, and spot fall into this group. Menhaden, which feed on plankton, occupy the Bay and nearby coastal waters in particularly great abundance and, in fact, support a major commercial fishery.

Food Production and Consumption

The Food Web—The production of the Chesapeake's important species of fish and plants depends on the production of plant biomass in the Bay. The animals, plants, and



Simplified food web for Chesapeake Bay, illustrating important communities and pathways.

microbes of the Bay are connected by a complex network of feeding interactions, called the food web.

Direct and indirect linkages make up the food web. Typically, the direct food web encompasses several principal linkages. For example, a predominant feeding pattern in the open waters of the Bay starts with phytoplankton converting sunlight and nutrients into living tissue. They, in turn, are eaten by copepods, members of the zoo-plankton community. The copepods are then swallowed by anchovies or other small fish, which are later eaten by bluefish. The indirect (detritus) pathway leads from dead organic matter to benthic animals or decomposers such as bacteria, and then to higher animals. Food webs dependent on marsh and Bay-grass production are largely dominated by this pathway.

Several important ecological processes characterize these food-web patterns. For one, energy flows through an ecosystem via the food web. In the process of photosynthesis, energy from the sun is used by plants to produce organic matter. Phytoplankton, SAV, and marsh plants are thus the primary producers of the Bay's food web, and constitute the lowest trophic level. Energy and materials are then transferred from plants to consumers at higher trophic levels. Because energy is lost at each transfer, relatively few animals are supportable at the highest trophic level. For instance, massive amounts of plant production are required to support the various trophic levels that eventually support the top carnivores such as the striped bass or bluefish. Carnivores consume many times their weight in food during their lifetime. If this food contains a toxic chemical, even in small amounts, the fish or animal may be exposed over time to large amounts of the chemical. Heavy metals and organic chemicals can be concentrated and stored in tissues of the animal. As a result, the body may contain a much higher concentration of the chemical than did its food. This phenomenon is called biological magnification. It can have serious implications when the animal is used as food by humans.

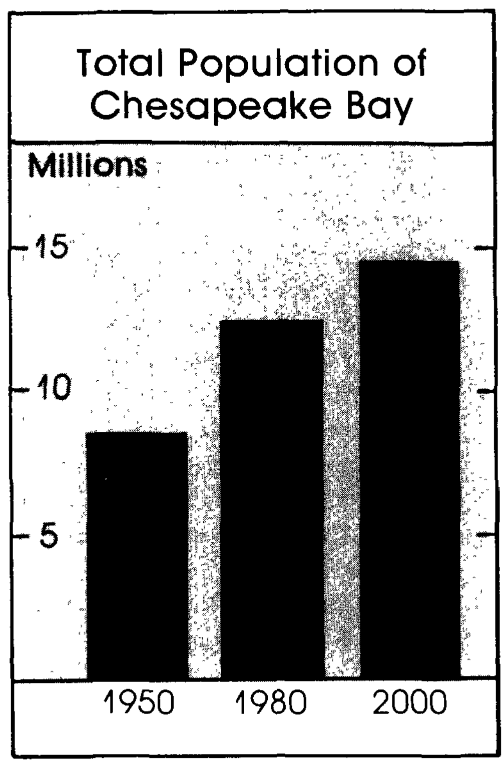
POPULATION AND LAND-USE TRENDS

For over 300 years the Bay region has been used to support a number of regional requirements and economic needs. Its beauty, richness, and other values have attracted people since the early colonial days. Today over 12.7 million people live in the region, and virtually every type of economic activity and land usage is found within the basin. Forestry uses occupy large areas of the Piedmont. Agriculture dominates many portions of the soil-rich coastal plain. Poultry, seafood, and vegetable processing are important industries on the Eastern Shore, while animal husbandry and agricultural processing activities take place throughout the Chesapeake Bay basin area. Industrial facilities for steelmaking and shipbuilding, leather tanning, plastics and resin manufacturing, paper manufacturing, and chemical production are located on the major tributaries. As the population continues to increase, the land-use patterns and the economic activities of the region will change.

Population Trends

Basin-wide, the population grew by 4.2 million between 1950 and 1980 and is expected to grow an additional 1.9 million, to a total of 14.6 million by 2000. Although the largest increases in population (1.4 million) will occur in the three largest basins, the Susquehanna, Potomac, and James Rivers, the highest rates of increase between 1980 and 2000 are expected in the York (43 percent), Rappahannock (40 percent), and Patuxent (27 percent) River basins. More people living in the drainage basin could place additional stress on the Chesapeake because of increasing freshwater withdrawal and larger amounts of wastes (sewage, urban runoff, construction activity, intensified agricultural activities, additional industrial activity, etc.) which the Bay will have to assimilate unless necessary actions are taken.

Population growth in the Chesapeake Bay drainage basin, 1950–2000 (projected).



Increased Urbanization

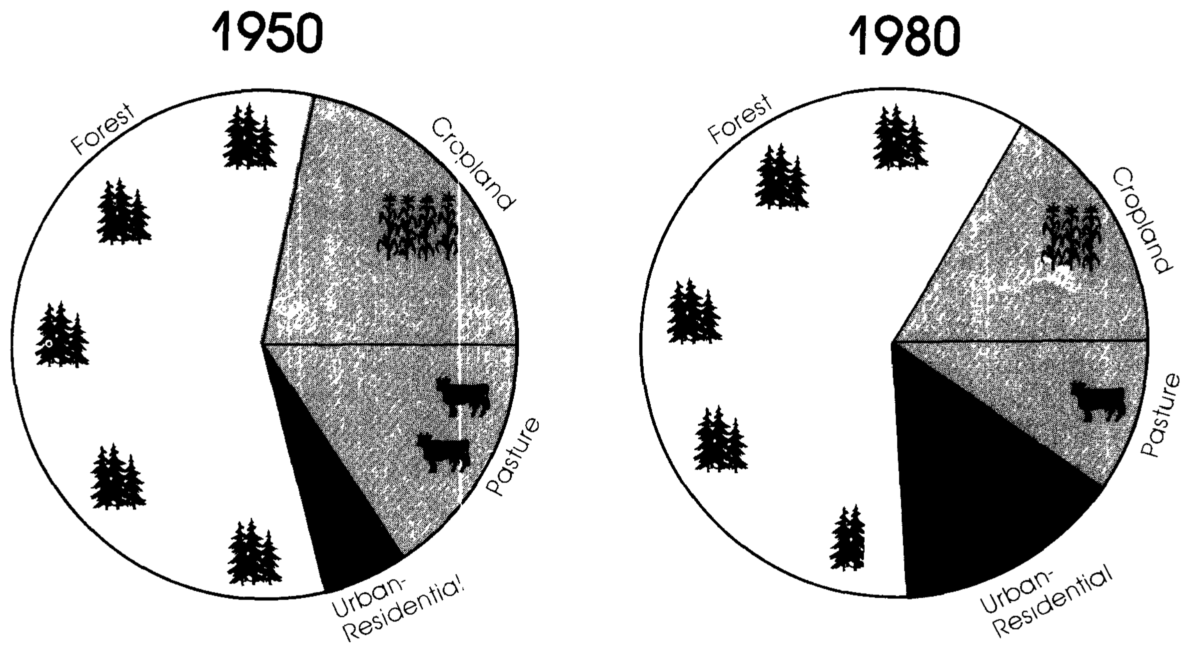
The steady trend of population growth in the Bay region has had major impacts on the land use. During the last thirty years, conversion to residential, urban, and suburban areas has taken place at an increasingly rapid rate. Although less than 15 percent of the land in the watershed is utilized for these purposes, it represents an increase of 182 percent since 1950. The conversion of land to residential areas has been concentrated in areas surrounding existing development. In particular, the West Chesapeake and Patuxent River basins have had dramatic increases in urban and residential development, losing cropland, pasture, and forest area, and gaining rapidly rising populations between 1950 and 1980. For example, in the Patuxent River basin, the percent of developed land has risen from approximately three percent in 1950 to over 35 percent in 1980. These physical changes in the uses of land, coupled with changing perceptions of the Bay, have had a significant impact on the system and the ways humans have tried to manage it.

Changes in Agricultural Activities

In the eight major basins, cropland has decreased by an average of 24 percent over the last 30 years. At the same time, agriculture in the watershed has shifted from a labor-intensive to a capital-intensive activity. More specifically, three major changes in agricultural activity have increasingly emerged in the region over the past thirty years: a growing number of farmers have adopted low tillage or conservation practices; agricultural land is being farmed more intensively; and the size of the average farm has increased due to a steady consolidation of land. These changing practices are affecting the Bay.

Conversion to Conservation-Tillage Practices— Conservation-tillage is economically advantageous to the farmer for it decreases energy consumption and therefore, costs. However, it can increase the use of herbicides and pesticides. Conservation-tillage also reduces soil erosion and, therefore, decreases the runoff of sediments and nutrients.

Intensification of Agricultural Activity—The intensification of agricultural activity requires the use of increased fertilizer, pesticide, and herbicide inputs. In addition, newer technologies used to increase the efficiency and speed of soil preparation, crop maintenance, and harvesting have led to abandonment of many of the basic conservation techniques.



Land-use patterns in the Chesapeake Bay drainage basin, 1950 and 1980.

Consolidation of Agricultural Land — Consolidation of agricultural land refers to a pattern of fewer and larger farms and more absentee owners, including corporations, who lease the land to tenants. Tenants have few incentives to reduce soil erosion and chemical loss, especially when there are high initial costs and slow pay-backs.

Loss of Wetlands

Today, Chesapeake Bay is edged by 498,000 acres of wetlands. Although statistics vary widely regarding the trends of wetlands loss, research indicates, for example, that several thousand acres of Bay wetlands were destroyed each year during the 1960's. Increased Federal, state, and local regulation, as well as public and private conservancy efforts, seem to have slowed down the loss of tidal wetlands to approximately 50 acres per year. However, important non-tidal wetlands still have relatively little protection. Losses are attributable to various forms of wetlands modification. For example, agriculture drainage is a principal cause of wetlands loss in Maryland; channelization projects (particularly for agriculture) play a dominant role in destroying wetlands in Virginia. In addition, residential development, industrial projects, expansion and development of marinas, and dredge-and-fill activities have also caused the continuing decrease in wetlands in the Bay area.

SUMMARY

The physical and ecological processes of the Bay make it a complex support system for many forms of life. Diverse habitats are sustained, exchanging materials and complementing one another's resources. The existence of the two major food webs—direct (plankton-based) and indirect (detritus-based)—promotes overall stability. If one pathway falters, resources can be used from the other. Some organisms are even able to switch food sources. However, while complex food webs provide a degree of resiliency, they, alone, cannot restore and maintain high levels of desirable biological productivity in the Bay.

It is also evident that the population growth and changes in land use within the drainage basin are stressing the Bay's ecological health. Population growth and urban development have caused increases in municipal wastewater discharges and concentrations of industrial processes and their effluents in certain areas. Changes in agricultural practices and other human activities also contribute to the problems of the Bay. Forecasts predict that the increase in population will continue. Because the Bay's ecological "performance" is highly subject to the intervention of humans as well as to natural forces, the manner in which human activities are managed in the upcoming years will determine to a great extent the degree to which the Bay's environment can be maintained or improved.

The chapter that follows gives an account of the ways in which the Bay is degrading and describes the sources and loadings that are contributing to its problems.

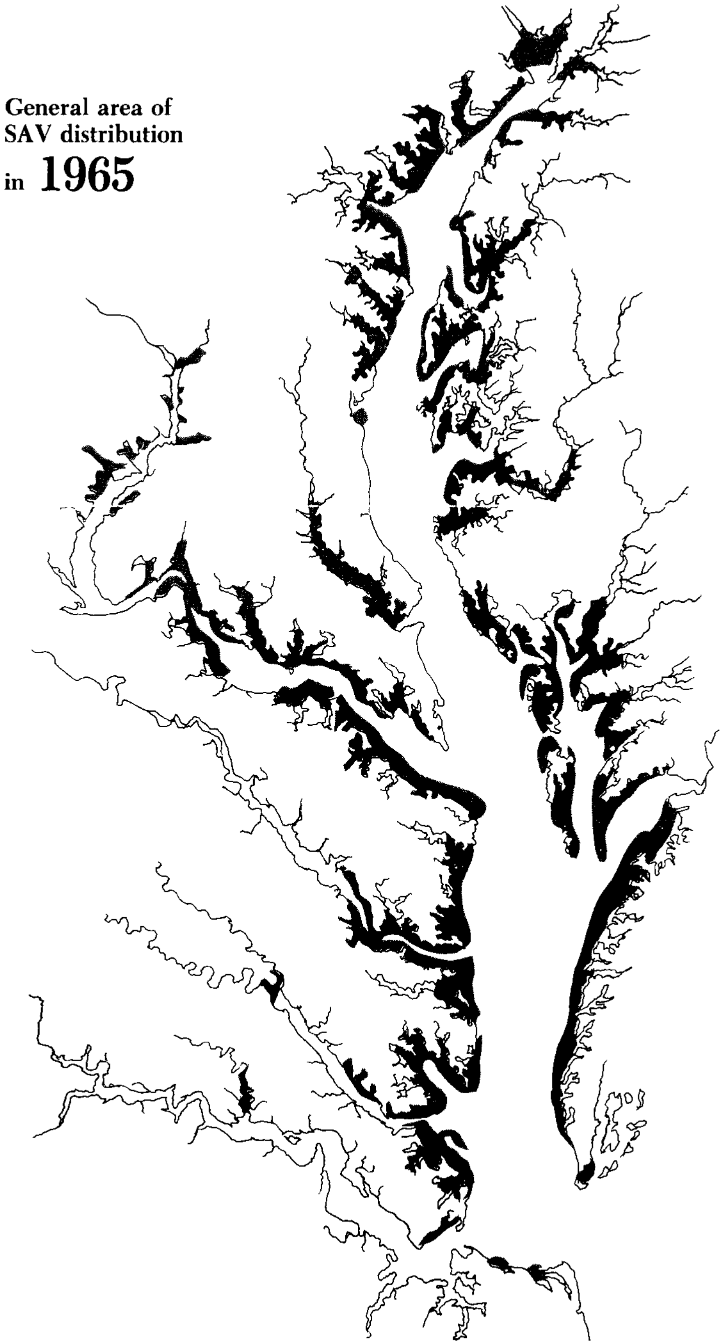
THE STATE OF THE BAY

INTRODUCTION

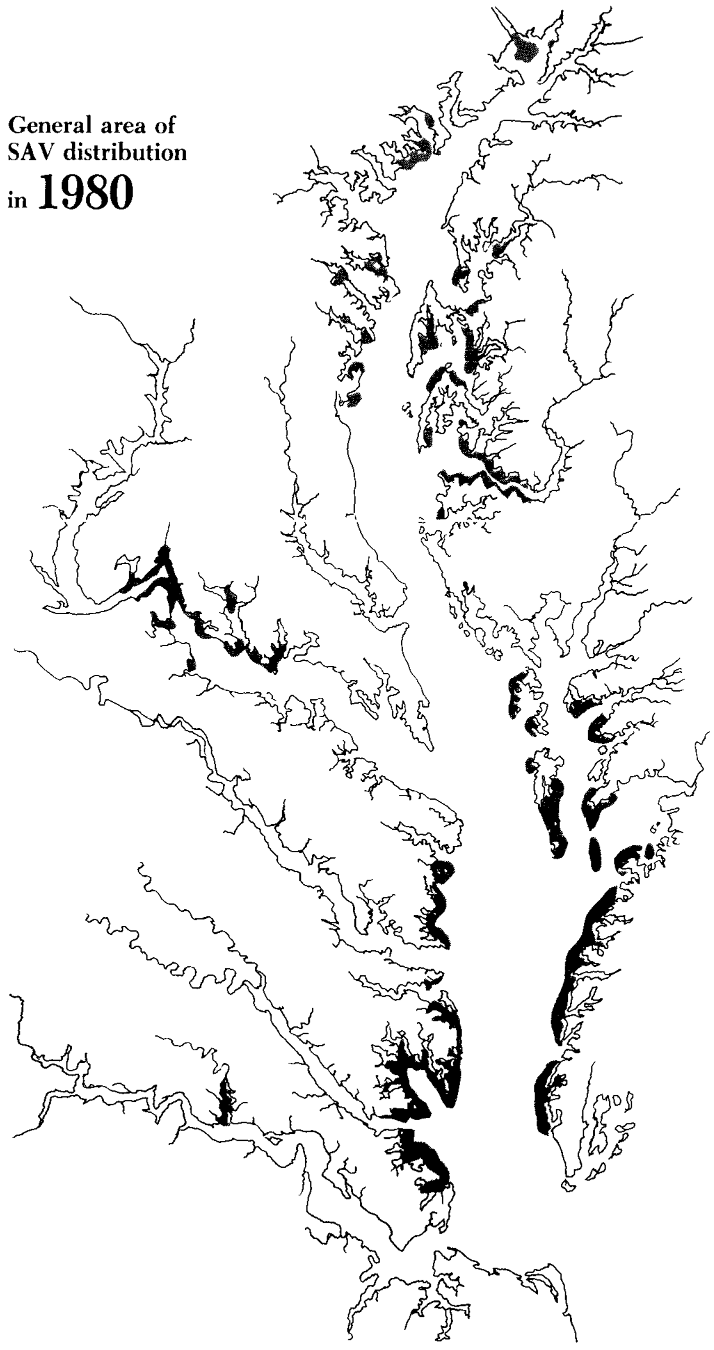
> *"The Bay is an organic whole. If one part is damaged, all parts are affected. It is of little use to study one link in an environmental chain without relating it to the whole. If the Chesapeake Bay is to survive, it must be addressed as an entity, as a total system without duplication and without omission."*
>
> *Charles McC. Mathias*
> *United States Senator,*
> *Maryland*

The Chesapeake Bay Program utilized all available scientific analyses to assess the Bay as an 'organic whole.' Research findings were integrated on a continuous basis to further the understanding of the Bay as a total system. The Program's scientific investigations, in conjunction with other studies, essentially documented that the Bay has dramatically changed in the last century; this change has accelerated in the last thirty years. Increasing population growth over time has resulted in major land-use changes, large increases of municipal waste water, and other outcomes which, in turn, have caused substantial increases in the amounts of pollutant loads entering the Bay. For many years, these activities had a relatively minor impact on the Bay's aesthetic beauty and productivity. Understandably, many people believed that the Bay had an unlimited capacity to assimilate human wastes. This belief was only questioned when dramatic changes in resources were observed and concerned citizenry asked why. As a result of CBP research, it is now known that contaminants entering the Bay are not readily flushed out into the ocean but, because of the unique circulation pattern in the Bay, they accumulate within the estuary. Over time, this process has gradually changed the nature of the Bay.

General area of
SAV distribution
in **1965**



General area of
SAV distribution
in **1980**

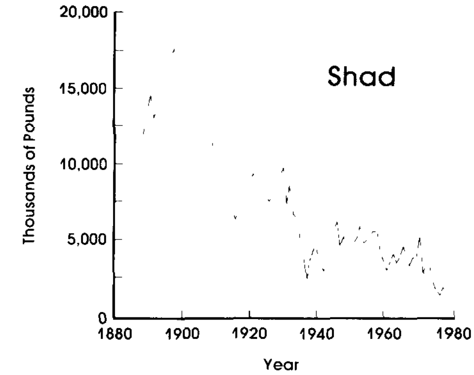


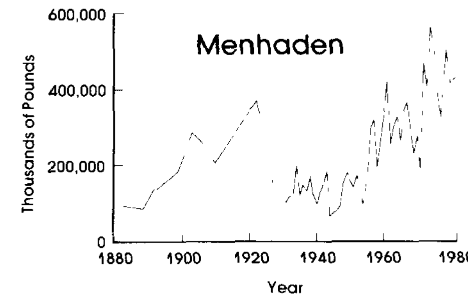
SUMMARY OF SCIENTIFIC FINDINGS

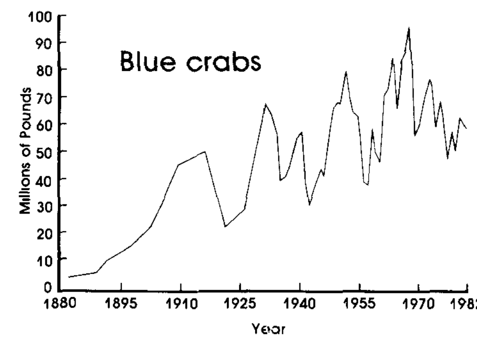
Trends in Living Resources

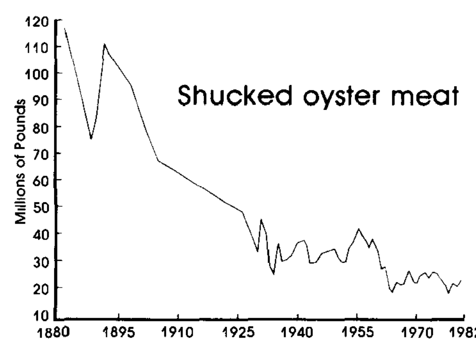
The major changes documented by the Bay Program follow:

- In the upper Bay, an increasing number of blue-green algal or dinoflagellate blooms has been observed in recent years. In fact, cell counts have increased approximately 250-fold since the 1950's. In contrast, the algal populations in the upper Potomac River have recently become more diverse, with the massive blue-green algal blooms generally disappearing since nutrient controls were imposed in the 1960's and early 1970's in this segment of the Bay watershed.
- Since the late 1960's, submerged aquatic vegetation has declined in abundance and diversity throughout the Bay. The decline is most dramatic in the upper Bay and western shore tributaries. An analysis over time indicates that the loss has moved progressively down-stream, and that present populations are mostly limited to the lower estuary.
- Landings of freshwater-spawning fish such as shad and alewife have decreased. Striped bass landings, after increasing through the 1930's and 1940's, have also decreased, especially since 1973. Harvests of marine-spawning fish such as menhaden and bluefish have generally remained stable or increased. The increased yield of marine spawners and decreased yield of freshwater spawners represent a major shift in the Bay's fishery. Over the 100 year period from 1880 to 1980, marine spawners accounted for 75 percent of the fishery; during the interval from 1971 to 1980, they accounted for 96 percent.
- Oyster harvests have also decreased Bay-wide. Oyster spat set has declined significantly in the past 10 years as compared to previous years, particularly in the upper Bay and western shore tributaries and some Eastern Shore tributaries such as the Chester River. The decline in oyster harvest has been somewhat offset by recent increases in the harvest of blue crabs which may be due to increased fishing effort. As a result, the Bay-wide landings of shellfish have not changed greatly over the last twenty years. However, overall shellfish harvest for the western shore has decreased significantly during this period.



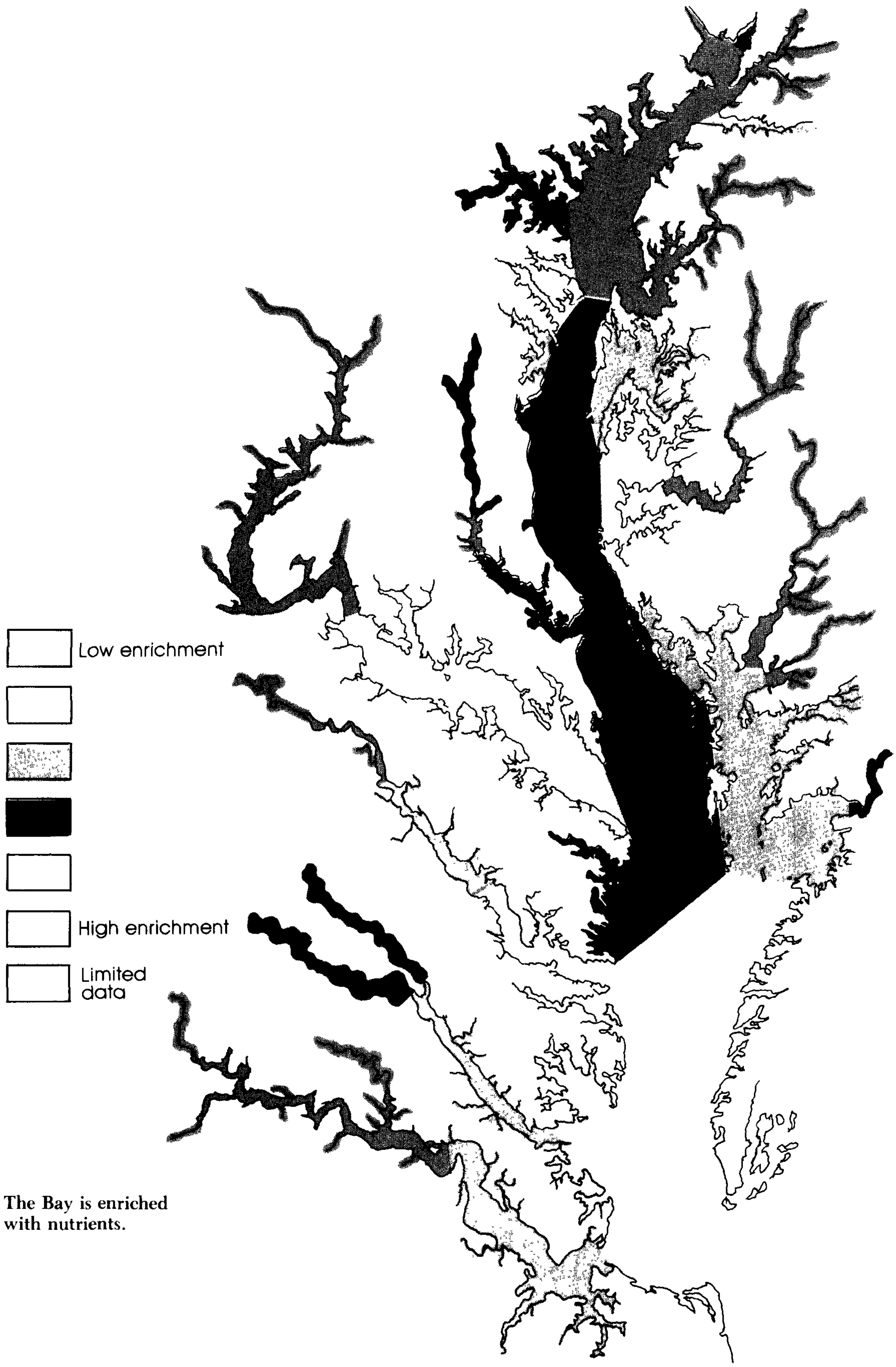






Water and Sediment Quality Trends

- Increasing levels of nutrients are entering many parts of the Bay: the upper reaches of almost all the tributaries are highly enriched with nutrients; lower portions of the tributaries and eastern embayments have moderate concentrations of nutrients; and the lower Bay does not appear to be enriched. Data covering 1950 to 1980 indicate that, in most areas, water quality is degrading, partially because increasing levels of nutrients are entering the waters. Only in the Patapsco, Potomac, and James Rivers (and some smaller areas) is there improvement in water quality; this is evidently largely due to pollution control efforts in those areas.
- The amount of water in the main part of the Bay which has low or no dissolved oxygen has increased about fifteen-fold between 1950 and 1980. Currently, from May through September in an area reaching from the Annapolis Bay Bridge to the Rappahannock River, much of the water deeper than 40 feet has no oxygen and, therefore, is devoid of life. The dissolved oxygen levels in the Bay have been affected by nutrient enrichment. The excessive loads of nutrients which enter the Bay stimulate the growth of undesirable large algal blooms. As the algae die and settle to the bottom, they decay and consume the oxygen that is crucial for Bay organisms such as crabs, oysters, and finfish. Although these processes occur naturally in an estuarine system, they appear to have become far more severe in the Bay in recent years as nutrient inputs have increased.
- High concentrations of toxic organic compounds are in the bottom sediments of the main Bay near known sources such as industrial facilities, river mouths, and areas of maximum turbidity. Highest concentrations were found in the Patapsco and Elizabeth Rivers where several sediment samples contained concentrations exceeding 100 parts per million. These general patterns suggest that many of these toxic substances adsorb to suspended sediment and then accumulate in areas dominated by fine-grained sediments. Benthic organisms located in such areas tend to accumulate the organic compounds in their tissues.
- Many areas of the Bay have metal concentrations in the water column and sediment that are significantly higher than natural (background) levels. In fact, many violations of water quality criteria were noted. Also, Bay sediments in the upper Potomac, upper James, small sections of the Rappahannock and York



The Bay is enriched with nutrients.

Rivers, and the upper mid-Bay had high levels of metal contamination. The most contaminated sediments—with concentrations greater than 100 times natural background levels—are in the industrialized Patapsco and Elizabeth Rivers.

Relationships between Living Resources and Water Sediment Quality

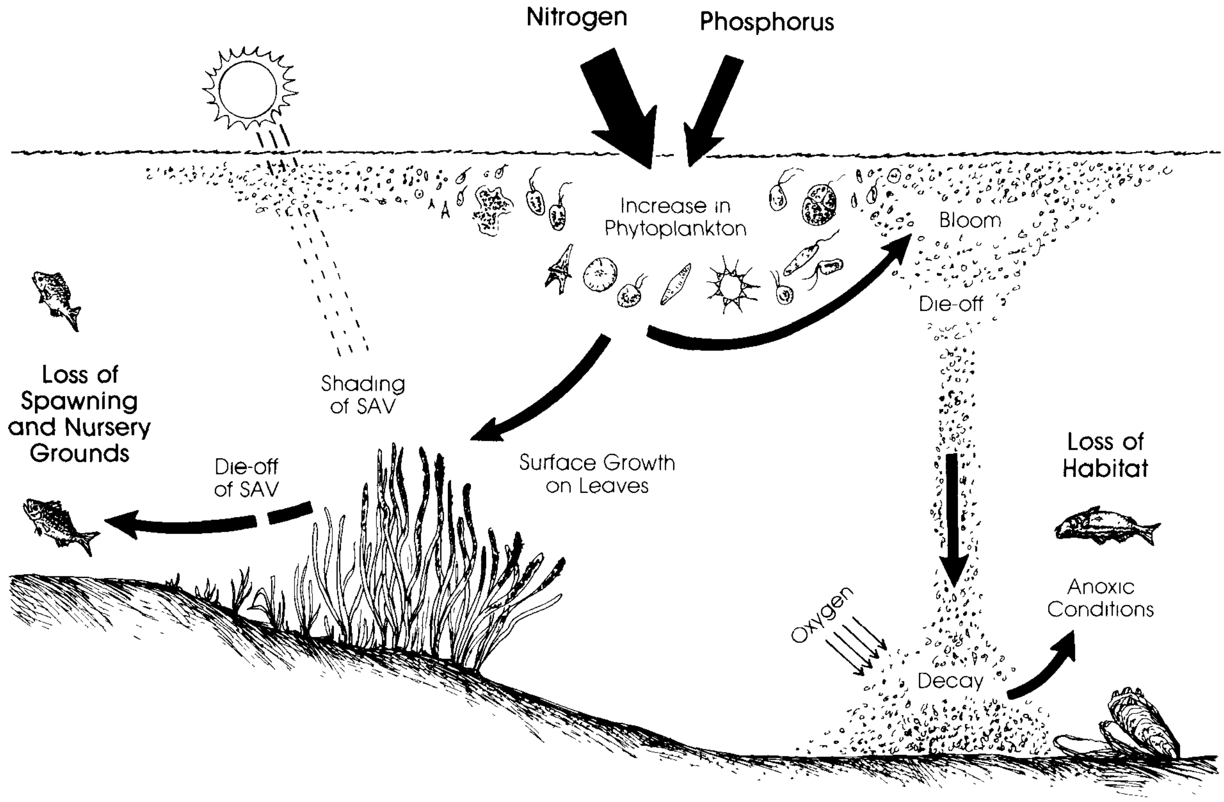
In summary, valued resources of the Bay are declining. This trend parallels an increase in nutrients and toxicants throughout the Bay. A geographic characterization and analysis of segments of the Bay suggests a relationship between the resources, and the water and sediment quality. In areas of the Bay afflicted by high concentrations of nutrients and toxicants such as Baltimore Harbor and the Elizabeth River, there is no submerged aquatic vegetation. In fact, only a few hardy organisms can survive in this hostile environment. On the other hand, in certain areas of the Eastern Shore where the nutrient and toxicant concentrations are still fairly low, submerged aquatic vegetation still grows, and crabs, oysters, and finfish are plentiful.

Although the circumstantial evidence appears to be compelling, the CBP cannot definitively link the trends seen in the resources to the Bay's deteriorating water quality. There are other factors affecting the abundance of the grasses and fish, including over-fishing, climatic trends, and physical alterations of the Bay associated with dredging and filling. It is quite probable that there is no 'single bullet,' but rather a myriad of ecological stresses. However, it is clearly estalished that nutrient loadings have substantially increased, that massive quantities of toxicants have entered this sytem, and that the unchecked increases of these pollutants threatens important resources.

NUTRIENTS

Nutrients and the Living Resources

The increase in nutrients and the corresponding decrease in dissolved oxygen are affecting the living resources of the Bay. Conceptually, one would expect to see a positive relationship between nutrients and Bay productivity. As these nutrients (which are essentially fertilizer) increase, one would expect to see an increase in plant production and, as a result, an increase in fish harvests. However, if too many nutrients are added, the excessive growth of undesirable weed-like plants such as blue-green



Nutrients affect the ecology of the Bay in many ways.

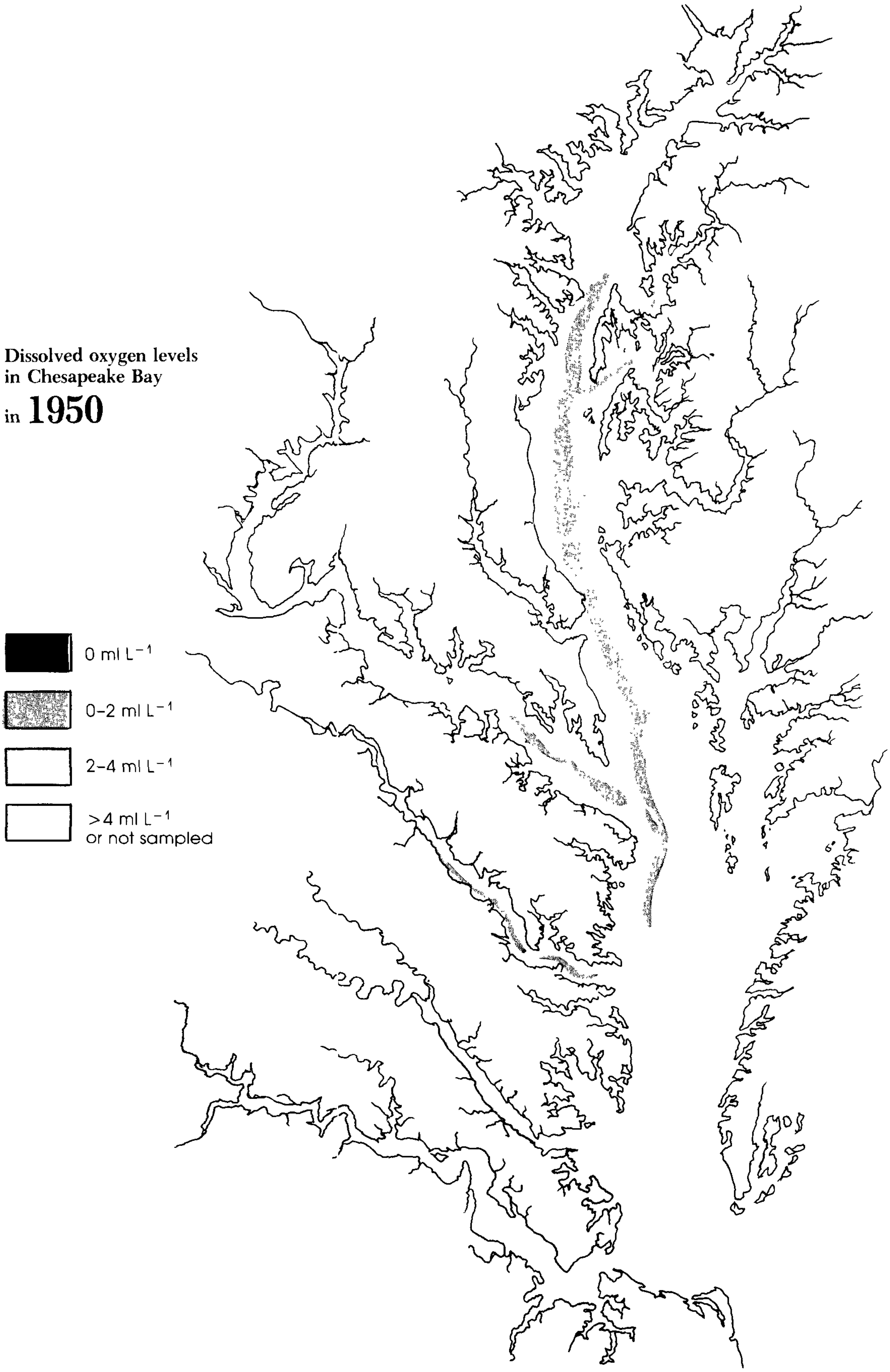
algae is encouraged. This prevents the growth of desirable plants such as submerged aquatic vegetation. Chesapeake Bay Program findings suggest that this situation is occurring in the Bay. Areas of the Bay that have relatively low nutrient concentrations, such as the eastern embayments, have abundant submerged aquatic vegetation; however, areas of the Bay that have high nutrient concentrations, such as the upper Bay, have very little vegetation.

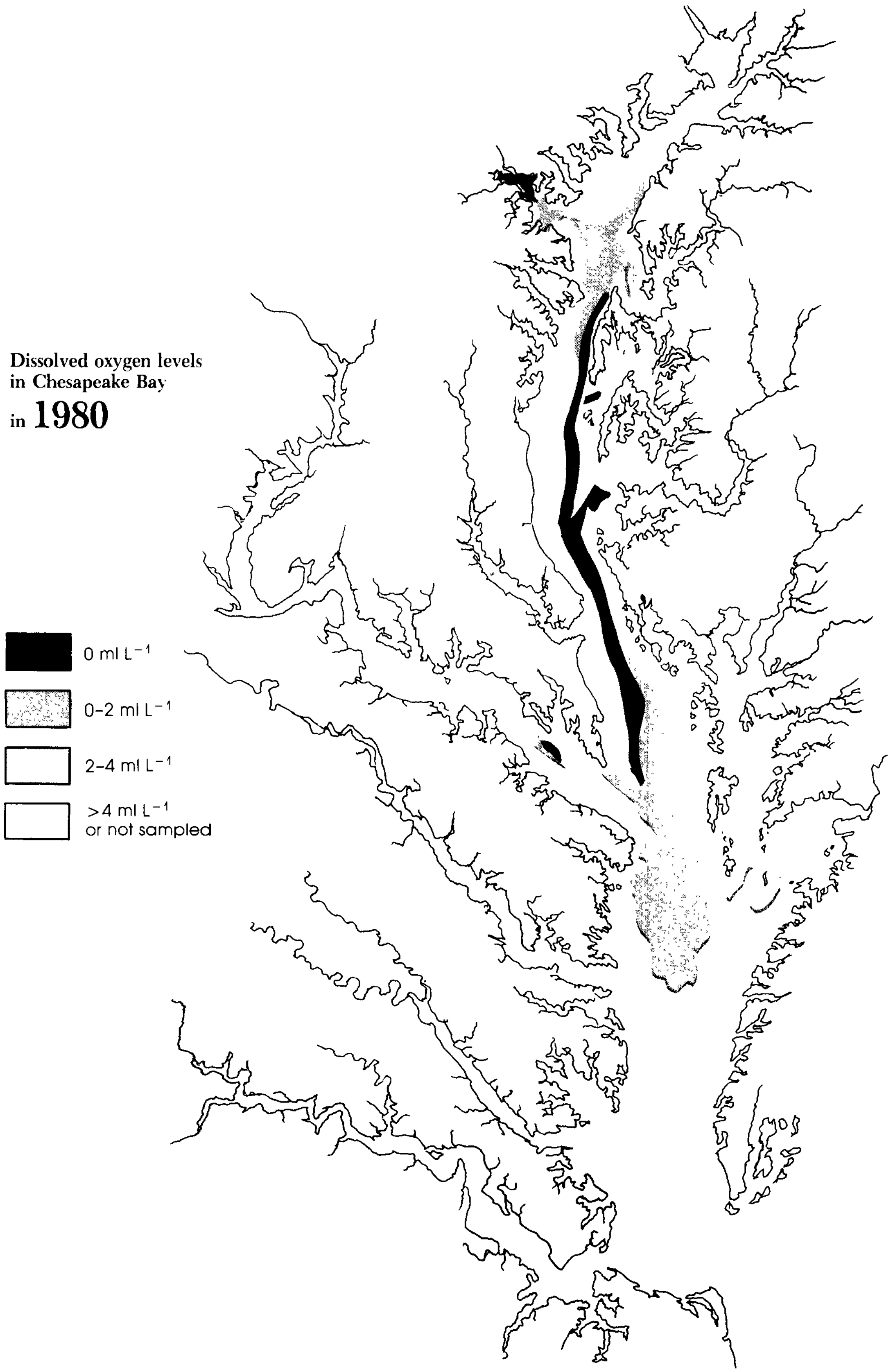
There is also a similar, but not as precise, relationship between nutrients and Bay fisheries. Fish that spawn in the freshwater, nutrient-enriched upper sections of the tributaries are decreasing. Also, oysters and other commercial shellfish that live all their life on the Bay bottom are reduced in abundance, possibly in part due to the elimination of their habitat by low dissolved oxygen. Although the decline in desirable resources cannot be definitively linked to the increase in nutrients, there is sufficient evidence to recommend corrective actions in controlling nutrient discharges to the Bay.

Sources of Nutrients

The Bay Program examined in detail the sources of nutrients entering the Bay, and the relative contributions of different types of sources. In addition, an assessment was

Dissolved oxygen levels
in Chesapeake Bay
in **1950**

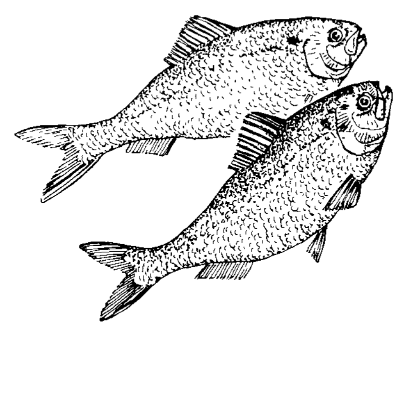



Dissolved oxygen levels
in Chesapeake Bay
in 1980
0 ml L⁻¹
0-2 ml L⁻¹
2-4 ml L⁻¹
>4 ml L⁻¹
or not sampled

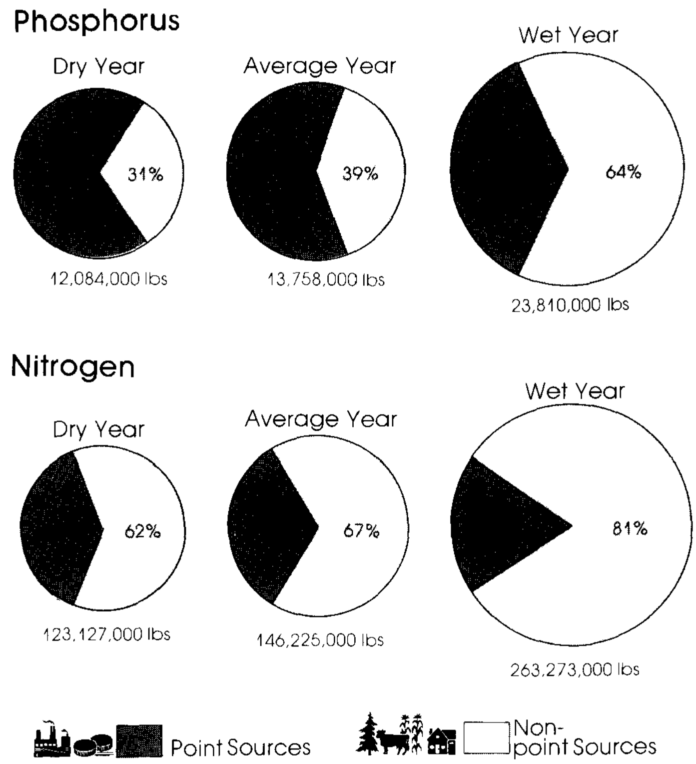
made of changing land-use activities, such as the intensification of agricultural activities and urbanization, which have strong implications for the levels of pollutants going into the Bay. For example, as the population continues to increase in and around the metropolitan areas of the Bay, the volume of municipal effluent will also increase proportionately. If current projections prove true, and, if present treatment practices continue, the volume of municipal effluent generated and discharged is expected to increase 36 percent by the year 2000.

Special attention was also given to assessing the relative importance of point versus nonpoint sources in various sections of the Bay watershed as a basis for targetting management and control strategies. For example, the nutrient input from the Susquehanna River basin is principally from nonpoint sources, particularly from agricultural lands; in contrast the input into the West Chesapeake Bay basin (which is composed of several rivers, including the Patapsco, Back, and Gunpowder basins) is dominated by point sources, particularly municipal sewage treatment plants. A strategy for nutrient reduction in each of these basins would logically focus on controlling the dominant sources. Below is a more detailed summary of the variations in the sources of nutrients entering the Bay.

Point Sources—Point sources are concentrated waste streams discharged to a water-body through a discrete pipe or ditch. Although there may be daily or seasonal fluctuations in flow, they are essentially continuous, daily discharges which occur throughout the year. The significance of point sources increases during the summer and other periods of low rainfall because the dilution of effluent by receiving water is reduced. Conversely, their relative significance decreases during periods of wet weather when rainfall, runoff, and nonpoint loadings increase. Examples of point sources include discharges from industrial production facilities and discharges from publicly owned treatment works (POTWs). The CBP data base contains an inventory of over 5,000 industrial and municipal point sources located within the Chesapeake Bay drainage area.



Nonpoint Sources—Nonpoint sources of nutrients include runoff from forests, farmland, residential and commercially developed lands, ground-water flow, and atmospheric deposition on land and water. Within the major river basins discharging to Chesapeake Bay, changes in population, land use, and land management are occurring which alter storm-water runoff quality and the rate of discharge. These changes affect the size and nature of nonpoint source loadings to the Bay. The diffuse nature of nonpoint sources render them difficult both to quantify and control. In addition, nonpoint source loads are largely determined by unpredictable rainfall patterns. In wet



Relative contribution of point and non-point sources of nutrients in wet, dry and average years.

years, nonpoint source loads are generally very high and in dry years, low. The nonpoint source runoff from cropland contributes the largest share of the nonpoint source nutrient load to the Bay. Although a minor contributor to the Bay-wide nutrient load, urban runoff causes localized water quality problems.

Nutrient Loadings

The Chesapeake Bay Program estimated present (1980) and future (2000) nutrient loadings delivered to the Bay from throughout its drainage basin. The fractions of nutrient loadings originating from point sources and nonpoint sources (agricultural and urban runoff) were also determined. In general, the nitrogen entering Bay waters is contributed primarily by nonpoint sources which are dominated by cropland runoff loadings. Point sources, on the other hand, and especially sewage treatment plants, are the major source of phosphorus to Chesapeake Bay. It is important to note again that point source nutrient discharges tend to be more dominant in dry years than in wet years. In contrast, nonpoint sources which enter waterways primarily in stormwater runoff contribute a greater share of total nutrient loadings during wet years.

Basin-wide Nutrient Loadings—Basin-wide, point sources contribute about 33 percent of the total nitrogen load to the Bay. However, point sources contribute a larger share of the phosphorus load, averaging 61 percent. Nonpoint sources contribute the difference in the nitrogen and phosphorus loads, making up 67 and 39 percent of the total loads, respectively. Most of the nitrogen entering Chesapeake Bay waters has been transported from watersheds throughout the Bay basin; phosphorus loadings originate mostly from sources adjacent to the Bay (below the fall line).

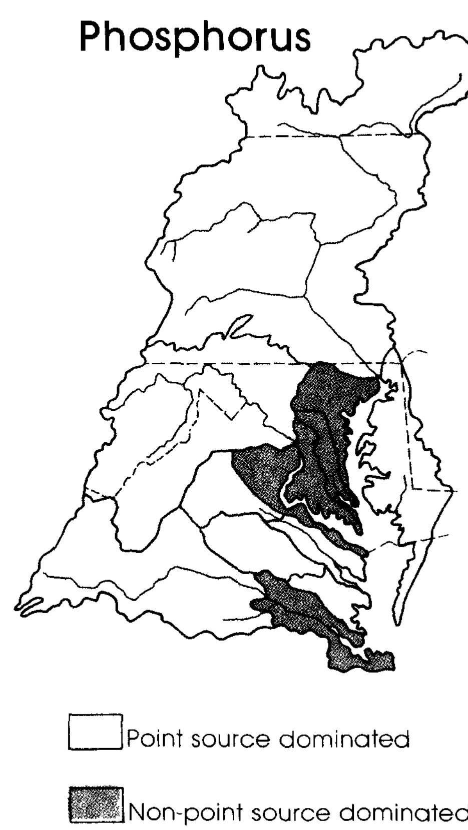
The three largest tributaries of the Bay, the Susquehanna, Potomac, and James Rivers, carry most of the nitrogen (78 percent) and phosphorus (70 percent) loads that enter the tidal waters of Chesapeake Bay. Although the West Chesapeake basin, centered near Baltimore, is not a large land area compared to other basins, it contributes significant amounts of nutrients to the Bay. The Eastern Shore, and the Patuxent, Rappahannock, and York River basins contribute the smallest portion of the Bay-wide nutrient loads.

Nutrient Loadings by Major River Basin—To link loadings of nutrients with specific areas where nutrient and dissolved oxygen concentrations potentially limit aquatic resources, it is necessary to understand the relative contributions of point and nonpoint sources by major river basin. It is also necessary to determine inputs in dry, average, and wet years. Only then can decisions be made on the best course of action to reduce nutrients contributing to a certain problem.

Analysis by a computerized model demonstrates that point source loads of phosphorus exceed the nonpoint source loads from the Potomac and James River basins in almost all rainfall conditions. In contrast, the nonpoint sources contribute most of the phosphorus from the Susquehanna River basin under all conditions. This finding reflects the fact that the James and Potomac River basins contain major population centers which contribute large point source loadings to tidal waters, unlike the more rural Susquehanna basin. It is not surprising that in the urbanized Patuxent and West Chesapeake basins, the phosphorus loadings from point sources exceed those from nonpoint sources, and in the largely rural Eastern Shore, and Rappahannock and York River basins, nonpoint contributions are always the dominant source of phosphorus.

Nitrogen loadings from the major river basins are more often dominated by nonpoint sources than are phosphorus loadings. In the Susquehanna, nonpoint sources provide most of the nitrogen under all conditions. In the Potomac River basin the nonpoint sources of nitrogen dominate under all hydrologic conditions. Most of the nitrogen load in the James River comes from point sources, however, nonpoint sources become important in a wet year. Point

Importance of point or non-point sources for phosphorus in the major drainage basins.



source loads of nitrogen always exceed nonpoint sources in the West Chesapeake; however, in the Patuxent River basin, point sources of nitrogen are only dominant under dry conditions. Loadings of nitrogen from the Eastern Shore, and the Rappahannock and York River basins originate primarily from nonpoint sources, as do those of phosphorus.

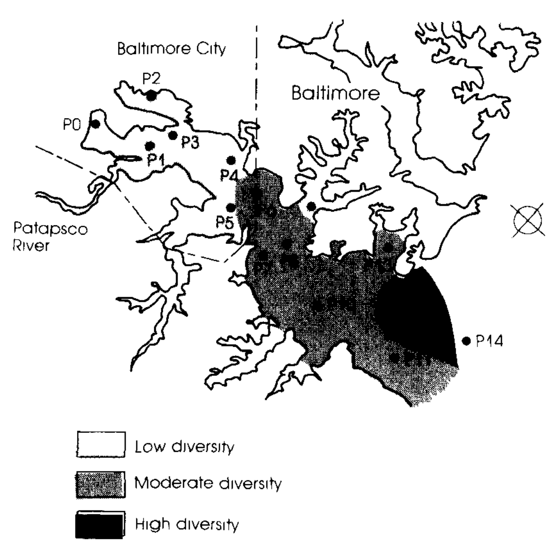
TOXIC COMPOUNDS

Toxic Compounds and Living Resources

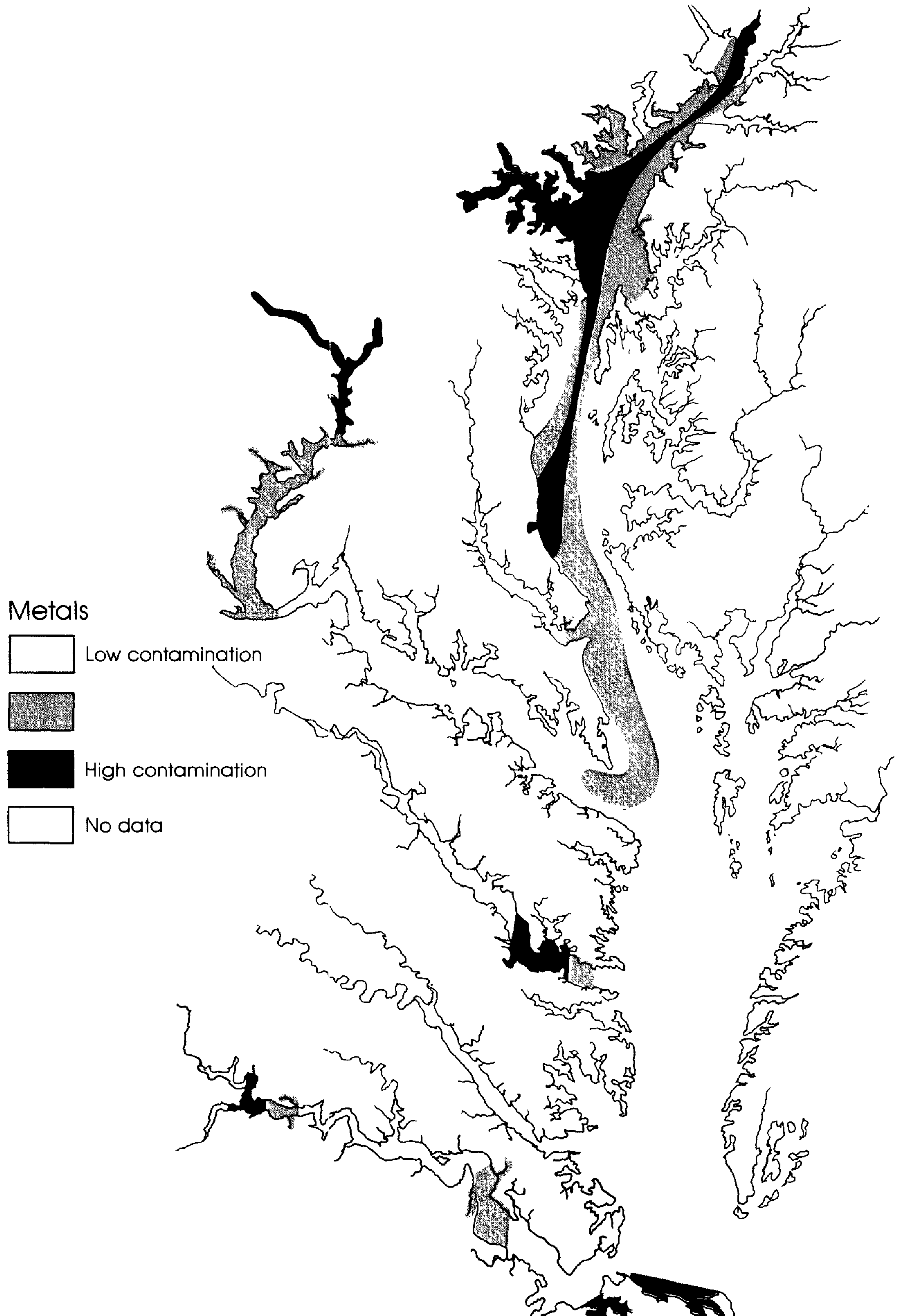
Toxic compounds are affecting the Bay's resources especially in urbanized areas. These compounds include metals such as cadmium, copper, and lead; organic chemicals such as PCBs, Kepone, and DDT; and other chemicals like chlorine. Low concentrations of these toxic compounds have little effect on organisms. However, increasingly higher concentrations of toxic compounds can cause reduced hatching and survival, gross effects such as lesions or fin erosion in fish, and eventually the mortality of an entire population. Toxicants can affect the ecosystem by eliminating sensitive species, and producing communities dominated by a few pollution-tolerant forms. In localized areas of the Bay, the CBP has found evidence of such toxic stress.

Chesapeake Bay Program research has shown a relationship between the levels of toxic compounds found in the sediments in certain areas, and the survival of individual organisms and the resulting health of the ecosystem. Bioassay studies of a small amphipod that lives in the bottom sediments of the Bay indicate that its chance of survival significantly decreases when it is exposed to polluted Bay sediments. When the amphipods were exposed to "uncontaminated" Bay sediment that had natural levels of metals and organic substances, they all survived. However, when the amphipods were exposed to highly contaminated sediments from the inner harbors of the Patapsco and Elizabeth Rivers, they all died. Moderately contaminated sediments produced intermediate levels of mortality.

Reduction of diversity of benthic communities along a gradient of toxic pollutants in Baltimore Harbor.



The fact that this particular organism could not live in these highly contaminated sediments suggests that other organisms cannot live in such conditions. Studies of these areas confirm this theory. Those areas of the Patapsco River that have highly toxic sediments support only a few types of organisms—primarily worms (low diversity); areas that are not as contaminated have many different organisms, including crabs, clams, oysters, and amphipods. These findings reinforce the need for careful control of toxic compounds.



Sediments contaminated with toxic compounds are found in many areas of the Bay.

Sources of Toxic Compounds

Toxic materials enter the Bay from a variety of sources, including industrial effluents and other point sources, runoff from urban areas and agricultural lands, atmospheric inputs, and disposal of contaminated dredge spoil. Except for long-range atmospheric deposition, the primary sources are located within the basin.

Point Sources—Industrial facilities and sewage treatment plants discharge a variety of metals and synthetic organic compounds. Chlorine and chlorinated organics are also common constituents of effluent from industries, POTWs, and power plants. The CBP analyzed the effluent from 20 industries and eight POTWs; over 75 percent of the facilities had toxic substances in the effluent. Point sources of toxics appear to be most significant in industrialized areas such as Baltimore and Norfolk.

Nonpoint Sources—The three major tributaries to Chesapeake Bay, the Susquehanna, Potomac, and James Rivers, deliver metals and organic compounds from urban and agricultural lands. In addition, deposits of air pollution are delivered directly to Bay waters and also indirectly through urban runoff. One example is automobiles which contribute large amounts of lead from gasoline. Another important nonpoint source is shore erosion which contributes significant amounts of iron and other metals to the Bay. Also, maritime ships and leisure and work boats occasionally leak or spill petroleum and are regularly treated with copper-based anti-fouling paints. The toxicants associated with maritime activities reach their highest levels in harbors and marinas where these activities are most concentrated and natural flushing is low.

Loadings of Toxic Compounds

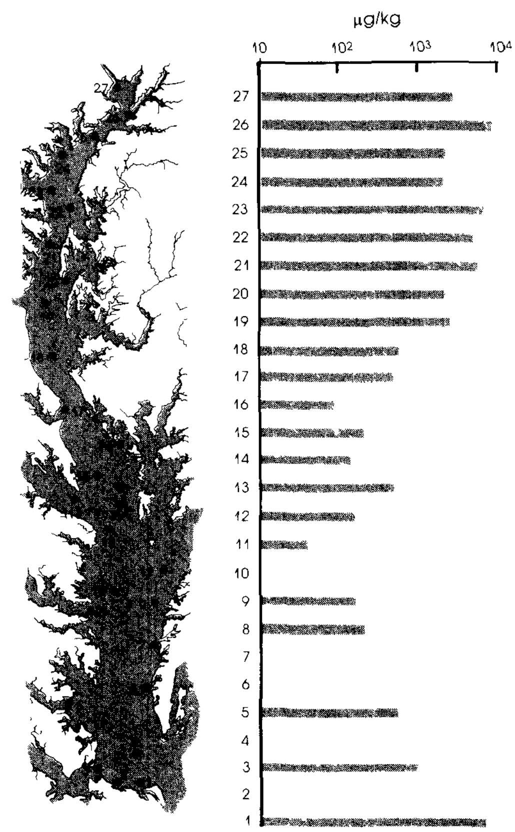
The Chesapeake Bay Program estimated metal loadings delivered to the Bay from the entire drainage basin. Although the CBP was unable to quantify the loadings of organic compounds to the Bay, it is probable that the relative contribution of different sources would be similar to that estimated for metals. In general, the Susquehanna, Potomac, and James Rivers are major sources of toxicants entering the tidal Bay. Effluent from industries and sewage treatment plants located directly on the Bay are also important. In urbanized areas such as Baltimore; Washington, D.C.; and Hampton Roads, urban runoff can contribute significant loadings of toxicants.

Organic Compounds—The CBP detected over 300 organic compounds in the water and sediments of the Bay; up to 480 organic compounds were detected in Baltimore Harbor. Most of the compounds identified were toxic. The mean concentrations of all organic compounds detected were typically in hundreds of parts per million. Priority pollutants were detected in all areas sampled and about half were found in concentrations greater than 50 parts per billion. In general, the compounds observed showed a trend of high concentrations adjacent to urbanized areas such as Baltimore and Hampton Roads. High concentrations are also found in the Susquehanna Flats. In the southern Bay, high concentrations exist near river mouths.

Although the CBP is unable to quantify the loadings of organic compounds, the fact that high concentrations of many of these compounds were detected in analyses of effluents from industries and sewage treatment plants suggests that the major source of toxic loadings is point sources. Furthermore, in several instances, the CBP was able to link the compounds with specific industrial sources. It is essential that the release of such compounds be substantially reduced and that Bay sediments and point source effluents be thoroughly monitored.

Metals—The James, Potomac, and Susquehanna River systems are by far the major transport mechanisms for each metal examined by the CBP. Collectively, they account for 69 percent of the cadmium, 72 percent of the chromium, 69 percent of the copper, 80 percent of the iron, 51 percent of the lead, and 54 percent of the zinc discharged to the Bay system. The other principal source of each metal is: for cadmium, industry (13 percent); for chromium and iron, shore erosion (13 percent and 18 percent, respectively); for copper, industrial and municipal point sources (21 percent); for lead, urban runoff (19 percent); and for zinc, atmospheric deposition (31 percent).

High levels of toxic organic compounds are found near industrialized areas of the Bay.



SUMMARY

The Chesapeake Bay Program's research has documented the serious impact of the nutrients and toxic chemicals released from point and nonpoint sources on the Bay's water and sediment quality and on the vitality and abundance of its living resouces. Moreover, forecasts indicate that the sources of these pollutants will continue to grow in number and change in nature, resulting in corresponding increases in the levels of the pollutants entering the Bay. The present state of the Bay and the forecast for the future provide the basis for the recommendations set forth in the following chapter. It is essential that we act now to control and alter human activities and practices on land if we are to halt the deterioration of the Bay and the subsequent losses of animal and plant life they produce.

A FRAMEWORK FOR ACTION

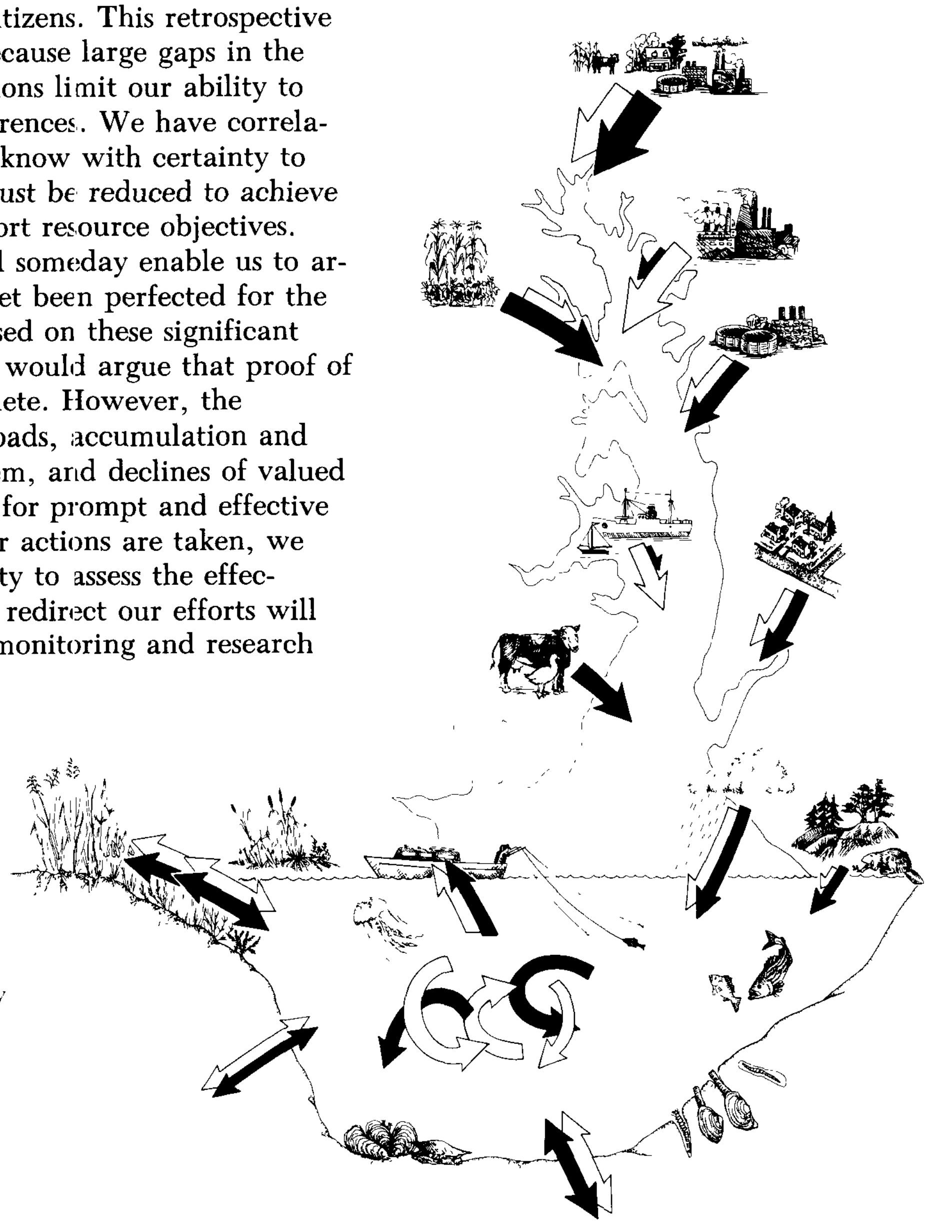
INTRODUCTION

Chesapeake Bay Program findings clearly indicate that the Bay is an ecosystem with increasing pollution burdens and declines in desired resources. It is also evident that actions throughout the Bay's watershed affect the water quality of the rivers flowing into the Bay. Degradation of the Bay's water and sediment quality can, in turn, affect the living resources. Thus, effective management of the Chesapeake Bay must be based on an understanding of, and an ability to control both point and nonpoint sources of pollution throughout the Chesapeake Bay basin. To achieve this objective, it is essential that the states and Federal government work closely together to develop specific management plans to reduce the flow of pollutants into the Bay, and to restore and maintain the Bay's ecological integrity. In the text that follows, specific recommendations are outlined for monitoring and research, control of nutrients, reduction in toxic compounds, and management of the environmental quality of the Bay system.

MONITORING AND RESEARCH

The relationships observed between the water quality and resource trends enabled the CBP to begin to identify cause-and-effect. For example, Bay-wide, the areas experiencing significant losses of SAV had high concentrations of nutrients in the water column. The high levels of nutrients evidently enhance phytoplankton growth and epiphytic fouling of plants, thus reducing the light reaching SAV to below critical levels. However, it is also probable that high levels of sediment-induced turbidity and herbicides contributed to the SAV problem in localized areas. In another analysis, the reduced diversity and abundance of benthic organisms in urbanized areas was related to toxic contamination of the sediments. Low dissolved oxygen in the summertime also appears to be a major factor limiting the benthic population, particularly in the upper and mid-Bay. The increase in the volume of water with low dissolved oxygen is attributed to increased algal production and decay triggered by nutrient enrichment. Lastly, nutrient enrichment and increased levels of toxicants occurred in major spawning and nursery areas for anadromous fish, as well as in areas experiencing reduced oyster spat. This information was utilized to develop a preliminary Environmental Quality Classification Scheme (EQCS) that related water quality criteria to resource-use attainability.

The characterization of the Bay, and the attempt to link water quality trends to living resource trends, has made science useful to managers and citizens. This retrospective approach is imperfect though, because large gaps in the data base and necessary assumptions limit our ability to make strong scientific causal inferences. We have correlations, not proof. We also do not know with certainty to what extent levels of pollution must be reduced to achieve a quality of water that can support resource objectives. Mathematical models, which will someday enable us to arrive at these answers, have not yet been perfected for the complex Chesapeake estuary. Based on these significant gaps in our understanding, some would argue that proof of the urgency for action is incomplete. However, the evidence of increased pollution loads, accumulation and retention of toxicants in the system, and declines of valued resources are compelling reasons for prompt and effective correction. Nonetheless, whatever actions are taken, we must bear in mind that our ability to assess the effectiveness of control programs and redirect our efforts will depend on the adequacy of our monitoring and research efforts.



Pollutants enter the Bay from many sources.

MONITORING AND RESEARCH RECOMMENDATIONS

OBJECTIVE:

TO ACQUIRE INFORMATION TO REFINE THE CBP ENVIRONMENTAL QUALITY CLASSIFICATION SCHEME AND TO DEVELOP STATE WATER QUALITY STANDARDS BASED ON RESOURCE-USE ATTAINABILITY.

The states and Federal governments, through the Management Committee, should design and implement a coordinated program of Bay-wide monitoring and research by July 1, 1984.

This program should include the following components:

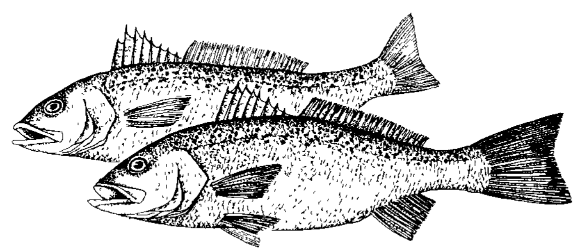
- A baseline (descriptive and analytical) long-term monitoring program;
- A coordinated and sustained, interpretive program of monitoring and research to improve the understanding of relationships between water and sediment quality, and living resources; and
- A research effort to identify important resource habitats and guide their preservation and restoration.

NUTRIENTS

Nutrients enter the Bay from point sources, such as sewage treatment plants, and from nonpoint sources, such as agricultural and urban runoff. In general, the nitrogen entering Bay waters is contributed primarily by nonpoint sources, which are dominated by cropland runoff loadings. Point sources on the other hand, and especially sewage treatment plants, are the major source of phosphorus to Chesapeake Bay. It is important to note that in dry years, point source nutrient discharges tend to be more dominant than in wet years. In contrast, nonpoint sources, which enter waterways primarily in stormwater runoff, contribute a greater share of total nutrient loadings during wet years. Also, different river basins tend to be dominated by different sources and, therefore, require different control strategies. For example, nutrient loadings in the Susquehanna River are primarily associated with nonpoint sources, although nutrient loadings to the James River are primarily attributed to point sources. The major findings and information regarding nutrient sources, loadings, and control programs are summarized below:

- The Susquehanna, Potomac, and James Rivers are major sources of nutrients to the Bay. They contribute, respectively, 40, 24, and 14 percent of the nitrogen and 21, 21, and 28 percent of the phosphorus in an average year.

- Runoff from cropland and other nonpoint sources are the major sources of nitrogen to the nutrient enriched areas in the Bay. Nonpoint sources contribute 67 percent, whereas point sources contribute 33 percent, of the total nitrogen load to the Bay in an average year.
- Point sources, such as sewage treatment plants, are the dominant source of phosphorus to the nutrient-enriched areas of the Bay. Point sources contribute 61 percent, whereas nonpoint sources contribute 39 percent, of the total phosphorus load to the Bay in an average year.
- Agricultural runoff control strategies, such as conservation tillage, best management practices, and animal manure waste management, can effectively reduce nutrient loadings from areas dominated by agricultural nonpoint sources (e.g., the Susquehanna River basin).
- Urban runoff control efforts have been shown to be effective in reducing nutrient loadings to small tributaries located in the Baltimore, D.C., and Hampton Roads areas.
- Point source controls, such as restrictions on nutrient discharges from municipal sewage treatment plants or limitations on phosphate in detergents, can effectively reduce nutrient loadings to those areas where point sources are significant (e.g., the James and Patuxent River basins).
- Point and nonpoint source controls in combination achieve consistent reductions in pollutant loadings during varying rainfall conditions in all basins.



The Federal government and the states have a variety of control programs for point and nonpoint sources to reduce loadings to the Bay. However, CBP research has shown that many areas of the Bay are over-enriched with nutrients and that the Bay acts as a sink, essentially trapping and recycling nutrients through the system. Additional actions designed to reduce the nutrient loads to the Bay will ultimately be beneficial. In response to these findings, the states are already taking bold new initiatives, as well as providing additional funding for proven old ideas. For example, Maryland is attempting to provide state dollars to pay for phosphorus and nitrogen removal at selected sewage treatment plants which are not eligible for Federal funding. Virginia has already established an innovative new incentive program for farmers, paying them from the state coffers for removing from production buffer strips along waterways. Pennsylvania is initiating a pilot manure management program that may decrease nutrient loadings to the lower Susquehanna. These are vigorous first steps toward achievement of sustained improvement, still, there is much more that needs to be done.

BAY-WIDE NUTRIENT RECOMMENDATIONS

OBJECTIVE:

TO REDUCE POINT AND NONPOINT SOURCE NUTRIENT LOADINGS TO ATTAIN NUTRIENT AND DISSOLVED OXYGEN CONCENTRATIONS NECESSARY TO SUPPORT THE LIVING RESOURCES OF THE BAY.

General Recommendations

1. *The states* and the EPA, through the Management Committee, should utilize the existing water quality management process to develop a basin-wide plan by July 1, 1984 that includes implementation schedules, to control nutrients from point and nonpoint sources.*

2. *The states and the EPA, through the Management Committee, should continue the development of a Bay-wide water quality model to refine the ability to assess potential water quality benefits of simulated nutrient control alternatives. This model should be continuously updated with new information on point source discharges, land use activities, water quality, etc.*

Point Source Recommendations

3. *The States and the EPA should consider CBP findings when updating or issuing NPDES permits for all point sources discharging directly to Chesapeake Bay and its tributaries. Furthermore, the States should enforce NPDES permit limitations.*

4. *Technical data from CBP findings should be considered when evaluating funding proposals for POTWs under the EPA's Advanced Treatment Policy.*

5. *The States of Maryland, Virginia, and the District of Columbia should consider by July 1, 1984, as one of several control alternatives, a policy to limit phosphate in detergents to 0.5 percent by weight, in light of the immediate phosphorus reductions which would be achieved.*

6. *The following administrative procedures should be reviewed for action by January 1, 1985, by the States, counties, and/or municipalities:*
   - *To increase POTW efficiency, improve operator*

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*The states refers to those states within the Chesapeake Bay drainage basin.

training programs, and provide or encourage incentives for better job performance, such as increased salaries, promotions, bonuses, job recognition, etc.

- *The states should consider CBP findings when ranking construction grant projects.*
- *Accelerate the development and administration of state and local pre-treatment programs.*
- *Continue to evaluate and utilize innovative and alternative nutrient removal approaches.*
- *Improve sampling and inspection of point source discharges.*
- *Develop plans to ensure long-term operation and maintenance of small, privately-owned sewage treatment facilities.*
- *Institute educational campaigns to conserve water to reduce the need for POTW expansion as population in the Chesapeake Bay basin increases.*

Nonpoint Source Recommendations

7. *The states and the EPA, through the Management Committee, should develop a detailed nonpoint source control implementation program, by July 1, 1984, as part of the proposed basin-wide water quality management plan.*

Initial efforts should concentrate on establishing strategies to accelerate the application of best management practices in priority sub-basins to reduce existing nonpoint source nutrient loadings. Long-term strategies should seek to maintain or further reduce nutrient loads from other sub-basins to help restore Chesapeake Bay water quality.

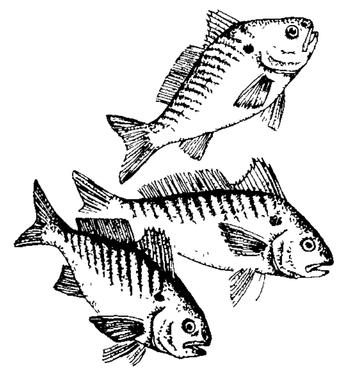
The implementation program should not be limited to traditional approaches toward soil and water conservation; an intensified commitment of resources for educational, technical, and financial assistance is warranted and may require innovative administration of available resources. Long-term funding must be assured at the outset of the implementation program, and a detailed plan to track accomplishments, including water quality improvement, should be developed by the states through the Management Committee. The framework for this program should include the following stages:

Stage 1 –

A program that emphasizes increased education, technical assistance, and cost-sharing, as well as other financial incentives, should be in place by July 1, 1985 in priority sub-basins (i.e., those determined through nonpoint source modeling to be significant contributors of nutrients to identified problem areas of the Bay). Full implementation of the stage 1 abatement program should occur by July 1, 1988.

Stage 2 –

The Stage 1 program should be expanded to intermediate priority sub-basins based on additional basin-wide nonpoint source modeling and Bay-wide water quality modeling assessments that should determine both the need for additional nonpoint source nutrient reductions and the additional sub-basins to be targetted for nonpoint source control.



Stage 3 –

Provide the necessary educational, technical, and financial assistance to maintain or improve the level of soil and water resource protection throughout the Chesapeake Bay basin. Soil conservation districts should establish annual conservation goals and report annually on accomplishments and technical, financial, educational, and research needs.

Concurrently with stages 1 through 3, the states and the EPA, through the Management Committee and the agricultural research community, should initiate research to evaluate the effectiveness of BMPs in reducing the loss of soluble nutrients from farmland, to improve soil-testing procedures to refine recommended fertilizer application rates (especially with respect to nitrogen), and to explore a range of financial incentives, disincentives, or other measures that would accelerate the BMP-adoption process. Regulatory alternatives should be evaluated and, where necessary, implemented if the above approaches do not achieve the needed nutrient reductions.

8. *The USDA and the EPA, in consultation with the Management Committee, should strengthen and coordinate their efforts to reduce agricultural nonpoint source pollution to improve water quality in Chesapeake Bay.*

Specifically, an agreement that establishes a cooperative commitment to work toward the goal of improved water quality in Chesapeake Bay and its tributaries should be developed. The agreement should outline ways that programs could be targetted to reduce loadings of a) nutrients (from soil, fertilizer, and animal wastes), b) sediment, c) agricultural chemicals, and d) bacteria from animal wastes. Also, the agreement should encourage the targetting of EPA and USDA technical assistance and computer modeling personnel to Chesapeake Bay priority sub-basins.

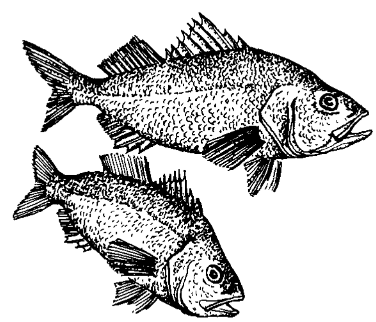
9. *Federal agencies, states, and counties should develop incentive policies by July 1, 1984 that encourage farmers to implement BMPs.*

Policies that could be considered include: incentives to maintain sensitive or marginal farmland out of production, such as the USDA Payment-in-Kind Program or other similar state or local efforts; cross-compliance; changes in the Internal Revenue Code, or state and local tax structures that will encourage landowner investment in BMPs or discourage the lack of adequate BMPs; the establishment of Federal, state, or local agricultural conservation trust funds for additional cost-share, education, or technical assistance resources; user fees; dedicated taxes; or expanded implementation funding.

10. *The states, counties, and municipalities located in subbasins adjacent to tidal-fresh and estuarine segments of Chesapeake Bay and its tributaries should implement fully and enforce existing urban stormwater runoff control programs.*

Although nonpoint source loadings of nutrients from urban land were not found to contribute to overall nutrient loads, unnecessary loadings of nutrients. sediment, heavy metals, and other pollutants from urbanized or developing watersheds should be avoided because of their potential impact on living resources in isolated or sensitive reaches of the Bay. In addition, stormwater management programs should place equal emphasis on control techniques for runoff quality and runoff quantity; they should also either establish owner-developer responsibility for long-term maintenance of urban stormwater BMPs or else include innovative finance mechanisms to pay for long-term BMP maintenance.

11. *The States of Maryland and Virginia and local governments should consider strengthening wetland protection laws to include non-tidal wetlands because of their value as nutrient buffers and living resource habitat.*



TOXIC COMPOUNDS

Toxic compounds enter the Bay from point sources, such as industrial facilities and sewage treatment plants, and from nonpoint sources such as urban runoff, dredged material disposal, and atmospheric deposition. The three major tributaries to the Chesapeake, the Susquehanna, Potomac, and James Rivers, are the major sources of metals and organic compounds to the Bay. Industrial facilities and sewage treatment plants discharging directly to the Bay are signficant sources of cadmium, copper and organic compounds. Urban runoff is an important source of lead, and atmospheric deposition is an important source of zinc to the Bay. The toxic problem is most severe in industrialized areas such as Baltimore and Norfolk, where the water and sediments have high metal concentrations and many organic compounds. The major findings regarding the toxic compound sources and controls are summarized below:

- The James, Potomac, and Susquehanna Rivers are the major sources of metals to the Bay. Collectively, they account for 69 percent of the cadmium, 72 percent of the chromium, 69 percent of the copper, 80 percent of the iron, 51 percent of the lead, and 54 percent of the zinc discharged to the Bay system.
- Over 300 organic compounds were detected in the water and sediments of the Bay; up to 480 organic compounds were detected in Baltimore Harbor. Most of the compounds detected are toxic and many are priority pollutants.
- An analysis of effluent from 20 industries and 8 publicly owned treatment works revealed that over 75 percent of the facilities had toxic substances in the effluent, principally metals, chlorine, and chlorinated organic compounds.
- Point source control programs resulted in significant reductions in metal loadings between 1970 and 1980 to areas such as Baltimore Harbor. However, these programs focus only on the 129 EPA priority pollutants. Large quantities of metals and organic pollutants continue to enter the Bay system.
- Nonpoint source control efforts, such as urban runoff controls, integrated pest management, and the regulation of dredge spoil disposal, have probably resulted in reduced loadings of toxic compounds to the Bay.
- Toxic pollution control tools, and information developed by the CBP, such as the toxicity index, the toxicity testing protocol, and the effluent and sediment fingerprinting procedure, will help managers address the toxic substance problem.

The Federal government and the states have made significant advances in the control of toxic substances. However, alarmingly high levels of toxic compounds are still found in certain "hot spot" areas of the Bay. It is also disconcerting that present regulatory monitoring efforts would not detect an illegally discharged or dumped bioaccumulative compound which exceeded chronic toxicity levels. This would suggest that a Kepone-type incident as occurred in the James River in 1975 could easily occur again. Such a possibility is frightening in light of the fact that toxic materials tend to adsorb to sediment and remain trapped in the Bay. They are often recycled throughout the system, causing repeated damage, until they are eventually buried by the accumulation of clean sediment. These findings suggest that current permitting, monitoring, and enforcement programs do not sufficiently control toxic loadings to the Bay.

BAY-WIDE TOXICANT RECOMMENDATIONS

OBJECTIVE:

CONTROL AND MONITOR POINT AND NONPOINT SOURCES OF TOXIC MATERIALS TO MITIGATE THE POTENTIAL OR DEMONSTRATED IMPACT OF TOXICANTS ON THE LIVING RESOURCES OF THE BAY

General Recommendations

1. *The States and the EPA, through the Management Committee, should utilize the existing water quality management process to develop a basin-wide plan, that includes implementation schedules, to control toxicants from point and nonpoint sources by July 1, 1984.*

Point Source Recommendations

2. *The States, through the NPDES permit and general enforcement authority program, should use biological and chemical analyses of industrial and municipal effluents to identify and control toxic discharges to the Bay and its tributaries.*

Biomonitoring and chemical analyses (GC/MS "fingerprint") of effluents can be used to identify toxic discharges and to assess potential impacts on receiving waters. Initial focus should be on all major discharges, facilities known or thought to be releasing priority pollutants, and POTWs receiving industrial wastes. In developing this protocol, the States should follow EPA policy and recommendations . Priority areas for implementation should be the Patapsco, Elizabeth, and James Rivers, to be expanded to other areas as appropriate. All effluent biological and chemical data will be stored in EPA's Permit Compliance System (PCS), as well as in the CBP data base. Monitoring of effluents should be coordinated with the Bay-wide monitoring plan; this includes analysis of toxicant levels in sediments, water column, and in tissues of finfish and shellfish.

3. *The states and the EPA, through the Management Committee, should utilize Chesapeake Bay Program*

findings in developing or revising water quality criteria and standards for toxicants.

Initial priority should be given to pollutants identified as highly toxic and prevalent in the Bay, specifically chlorine, cadmium, copper, zinc, nickel, chromium, lead and, in tributaries, atrazine and linuron. Numerical criteria should be developed when needed and incorporated into state water quality standards as soon as feasible. Site-specific criteria that are developed should be based on biological and chemical characteristics of individual receiving waters according to EPA guidelines and appropriate estuarine research.

4. *The states should base NPDES permits on the EPA effluent guidelines or revised state water quality standards, whichever are more stringent. Furthermore, the states should enforce all toxicant limitations in NPDES permits.*

The EPA should maintain its current schedule for promulgating best available technology (BAT) effluent guidelines. To facilitate the writing of permits, the EPA should continue to transfer knowledge and expertise developed during the effluent guideline process to the states. The states should also consider increasing the number of training programs for permit writers.

5. *Pre-treatment control programs should be strengthened where needed to reduce the discharge of hazardous and toxic materials.*

The pre-treatment program in various basins has contributed to reductions of toxicants in some municipal discharges, but the CBP has found that, as a group, treatment plants continue to be major contributors of heavy metals, organic compounds, and other toxicants, including chlorine. Current EPA regulations require pre-treatment programs to be developed by July 1, 1983. Municipal dischargers who have not submitted their program should do so as soon as possible. The EPA and the states should enforce these programs.

6. *Chlorine control strategies should be implemented (or continued, where now in place) in areas of critical resource importance. Strategies should focus on the reduction or elimination of chlorination, use of alternative biocides, and the reduction of the impact of effluents.*

Major areas of emphasis would include fresh or brackish fish spawning and nursery areas, and shellfish spawning areas. Maryland and Virginia have already begun to reduce chlorine residuals, evaluate site-specific effects of chlorine, and consider environmental effects in siting and permitting of dischargers.

Nonpoint Source Recommendations

7. *The EPA, the U.S. Army Corps of Engineers, and the States should utilize CBP program findings and other new information in developing permit conditions for dredge-and-fill and 404 permits*

Information developed (or assembled) by the Chesapeake Bay Program includes: a measure of the relative enrichment of sediments by six metals, concentrations of organic materials in surface sediments, shoaling and erosion patterns, distribution of sediment types, location of submerged aquatic vegetation beds, shellfish beds, fish spawning and nursery areas, and relationships between habitat quality and living resources.

8. *A Bay-wide effort should be made to ensure proper handling and application techniques of pesticides and herbicides, particularly in light of the potential increase in use of these materials in low-till farming practices.*

Innovative strategies, such as integrated pest management (IPM) and reduction and timing of application have proven to be successful in the Bay area. The States should encourage the use of these reduction strategies, support runoff and erosion control programs, demonstration projects, and monitor the fate and effects of those substances on the Bay's aquatic environment.

9. *Research, monitoring programs, and control strategies to reduce urban runoff should be continued and strengthened by the localities which are most directly affected.*

The states and urban areas should develop and implement plans which identify urban management strategies to protect water quality in those areas where urban runoff controls provide the most effective results.

10. *The States and the EPA should evaluate the magnitude and effects of other sources of toxicants, including atmospheric deposition, acid precipitation, contaminated ground-water, acid mine drainage, hazardous waste disposal and storage sites, accidental spills, and anti-fouling paints.*

As information becomes available, it should be factored into control and permit processes, etc. For example, models indicate that 30 to 40 percent of the atmospheric emissions generated within the Bay area are deposited there. The CBP has estimated potentially significant inputs of metals from acid mine drainage and anti-fouling paints, particularly in tributaries. Many of these toxicant sources are currently being investigated by Federal and state agencies.

BAY MANAGEMENT

To effectively manage the Bay, both its variability and its unity must be recognized. The Bay's water quality needs vary from region to region as do the controls necessary to support specific regional resource-use objectives. The industrialized Patapsco and Elizabeth Rivers have a very different water quality problem than do the Choptank or Rappahannock Rivers. Also, the desired and actual use of these areas varies significantly (i.e., industrial versus agriculture and fishing). It is apparent that our control strategies must be targetted by geographic area. The CBP report, *A Framework for Action* describes the different areas of the Bay and recommends actions to address their specific regional needs. The Bay is a complex interactive ecosystem and actions taken in any part of the watersehed may result in water quality degradation and impacts on aquatic resources downstream. For this reason, it is essential that a Bay-wide management mechanism with appropriate representation coordinate the respective activities of the Federal and state planning and regulatory agenices. Therefore, it is recommended that *the CBP Management Committee be maintained and expanded to provide a coordinating mechanism to ensure that actions are taken to reduce the flow of pollutants into the Bay, and to restore and maintain the Bay's ecological integrity.*

The Management Committee's specific responsibilities should include:

- Coordinating the implementation of the Chesapeake Bay Program's recommendations;
- Developing a comprehensive basin-wide water quality planning process in conjunction with ongoing planning efforts;
- Investigating new regional approaches to water quality management, including creative financing mechanisms;
- Resolving regional conflicts regarding water quality issues; and
- Reviewing related ongoing Bay research efforts and recommmending additional research needs.

It is hoped that the needs of the future can be met and the quality of the Bay preserved. It is apparent that some governmental change, long-term commitments, and money are necessary. There will be no quick-fix for the Chesapeake's problems. We will need to continue to study and to monitor, but while we do that, we will also need to focus concerted remedial action on some of the most severe problems in the system. Above all, we will need to continue the dialogue among the states and among the users of the Bay. The new spirit of cooperation and awareness generated by the Chesapeake Bay Program has brought us to the point of believing that we can manage the Bay for the benefit of all.