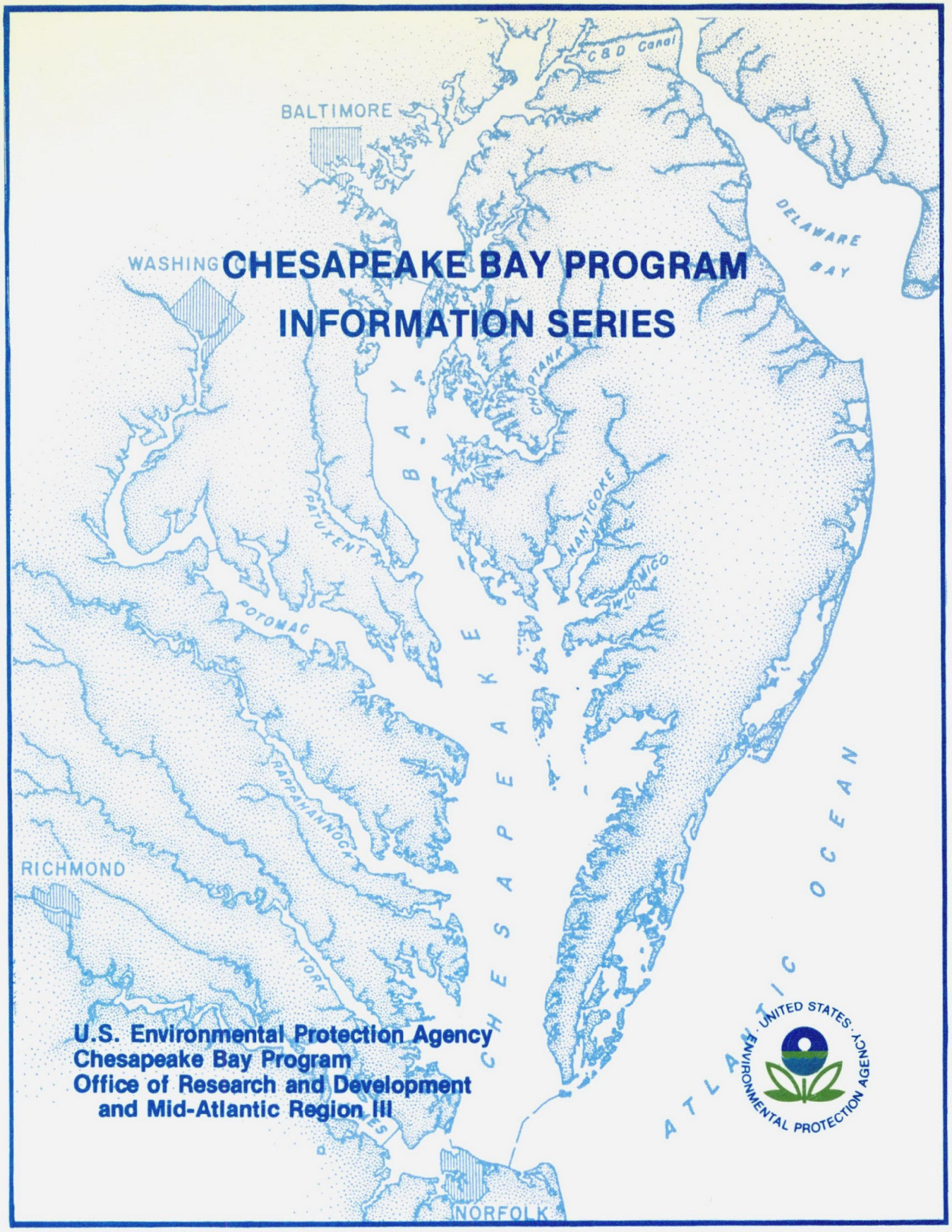
CHESAPEAKE BAY PROGRAM INFORMATION SERIES



U.S. Environmental Protection Agency
Chesapeake Bay Program
Office of Research and Development
and Mid-Atlantic Region III

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
Chesapeake Bay Program
2083 West Street -Suite 5G
Annapolis, Maryland 21401

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To All Interested Citizens, Legislators,
Administrators and Researchers:

Enclosed are the first three Brief-Summary Report packages of the Chesapeake Bay Program's Information Series, a set of publications describing findings, observations and management implications of research sponsored by the Chesapeake Bay Program.

The Briefs and Summaries cover the three areas in which the Chesapeake Bay Program sponsors research--Bay Grasses, Nutrients and Toxics. The headings on the reports are colored differently for each area--Green for Bay Grasses, Blue for Nutrients and Rust for Toxics. There will be several reports under each area; they are numbered at the top right hand corner of the reports. In this mailing, you have the first two reports under the Toxics area, and one in the Bay Grasses area. The notebook we have provided is for your use in storing the reports.

You will be receiving both the Briefs and Summaries throughout the remainder of the Chesapeake Bay Program. The Briefs are short, simplified descriptions of Chesapeake Bay Program research, designed to make the reader quickly aware of the general contents of that particular project. The Summaries go further, giving more detailed and technical explanations of the various projects. Through both types we hope to keep you informed of our research results and their importance to the health of the Chesapeake Bay.

If you have any comments regarding the Briefs and Summaries, please do not hesitate to contact Elizabeth Macalaster at the Chesapeake Bay Program in Annapolis. We want to communicate this material in the best way possible and appreciate any suggestions.

Sincerely,

Tudor T. Davies
Director,
Chesapeake Bay Program

TTD/jfl

brief 1

EPA Chesapeake Bay Program Information Series

SAV Distribution and Abundance

July 1980

In Search of Bay Grasses

Scientists refer to them collectively as submerged aquatic vegetation. SAV, for short.

Eight types of these grasses grow in the shallower waters of the Chesapeake Bay. To the casual observer, they may appear to be inconsequential, or even a nuisance. But, to fish, crabs, and waterfowl, they are food, shelter, and nursery--the essentials of life itself.

Since 1972, Bay grasses have been declining dramatically in distribution and number. And no one knows why.

One of the many objectives of the EPA's Chesapeake Bay Program Submerged Aquatic Vegetation Program is to find out what is causing this decline.

Two of Many Studies

To determine the distribution and abundance of these grasses, companion studies were started in 1978: one, covering the Maryland portion of the Bay, under Dr. Richard R. Anderson, of the American University, in Washington, D.C.; the other, covering the lower part of the Bay, under Dr. Robert J. Orth, of the Virginia Institute of Marine Science, Gloucester Point, Virginia.*

These are just two of thirty-nine studies involving hundreds of scientists engaged in research for the Chesapeake Bay Program.

Grass Roots Census

Both groups set out to determine what grasses are growing where, how abundant they are, and how their patterns of growth have changed.

Archival aerial photographs provided clues to the past.

To determine the present status of SAV distribution and abundance, teams of scientists took aerial photographs from all over the Bay and mapped their findings. They then analyzed the maps and compared them with historical photographs dating back to about 1940. As a result, there is now much more information concerning the distribution and abundance of these important grasses. This information is available to everyone concerned about the Bay and its future.

The greatest distribution and abundance of submerged grasses in Maryland occur in the area around the Chester River and Eastern Bay. Only marginal distributions of grasses were found on the Western Shore from Baltimore Harbor to Herring Bay, in the Choptank River system, and along the lower Eastern Shore. And almost no grasses were found in the Patuxent and lower Potomac Rivers or in the upper part of the Bay.

In Virginia, Bay grasses were found mainly at the mouths of the major rivers and along the eastern and western

*Two follow-up studies were conducted in the upper and lower Bay in 1979, but results are not yet available.

shorelines. In the tributaries, small grass beds were found along certain sections of the Potomac River and Chickahominy River.

Field studies also provided useful information on the diversity and density of Bay grasses, as well as associations of the various species, which were found to vary with the depth and salinity of the water.

Now What?

What does it all mean?

Already, copies of maps produced by these studies have been distributed to Maryland and Virginia resource management agencies, which will use them in reviewing applications for dredging and disposal permits. The purpose is to avoid disturbing established communities of grasses.

Beyond that, while it is clear from archival photographs that Bay grasses have been disappearing in almost all areas for at least ten years, it is not clear how long or to what extent this trend will continue. Nor are the reasons for the decline yet clear. By correlating the findings of these studies with those of others in the Chesapeake Bay Program, scientists hope to be able to predict patterns of change and recommend ways of preventing further damage to the delicate ecosystem we call the Chesapeake Bay.

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brief 1

EPA Chesapeake Bay Program Information Series

Nutrients Fall Line Nutrient Studies January 1981

Too Much of a Good Thing

Nutrients--phosphorus, nitrogen, carbon--are necessary for plants and animals to grow. In the Chesapeake Bay, nutrients exist naturally, but human-related activities, including agricultural and urban runoff, sewage discharge and septic tank leakage, are adding more and more of these elements. When too many nutrients enter the Bay they cause overenrichment of the water, becoming harmful, rather than nourishing to Bay life.

Over the Falls

To learn how nutrients are affecting the water quality of the Bay, the U.S. Environmental Protection Agency's Chesapeake Bay Program is calculating nutrient loadings, the total amounts of nutrients carried by water entering the tidal Bay. In one study conducted by the U.S. Geological Survey, scientists are looking at amounts of nutrients flowing past fall lines of the James, Potomac and Susquehanna Rivers. The fall lines of these rivers are areas where the Piedmont Province and Coastal Plain meet. Waterfalls often exist at fall lines, and the tide's effects end here.

The scientists picked these rivers because they are the Bay's largest tributaries and contribute over 85% of the estuary's freshwater. Thus, most of the nutrients entering the Bay from human-related sources come via these rivers.

Three River Sampling

The Geological Survey scientists collect water samples from the three rivers at sites shown in Figure 1.

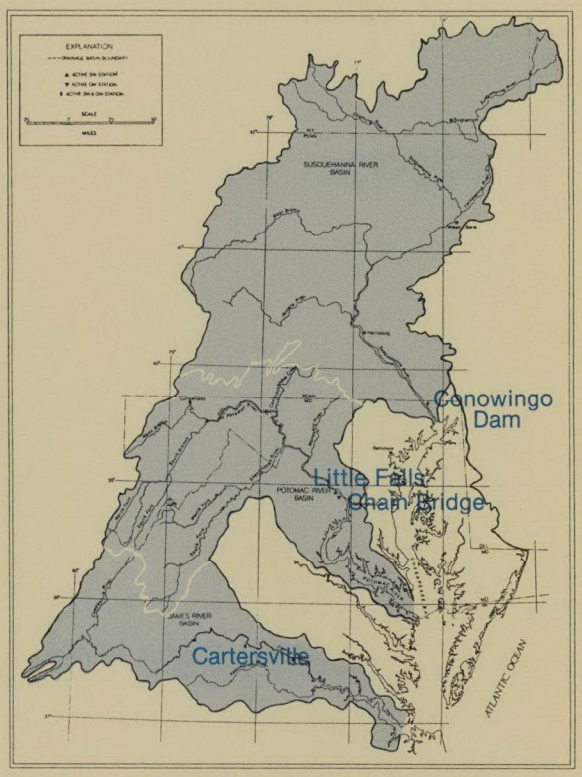

Figure 1. Fall Line Sampling Sites.

For deep-water samples, they use a torpedo-shaped container which faces the river current and continually

collects samples as it is lowered from the surface to the bottom and raised back to the surface again. For shallower and slow-flowing stream reaches, the scientists use a brass or steel, weighted bottle. Figure 2. shows a researcher collecting water samples from a bridge. The truck in the photograph is equipped with a small laboratory, allowing the scientists to process their samples on location.

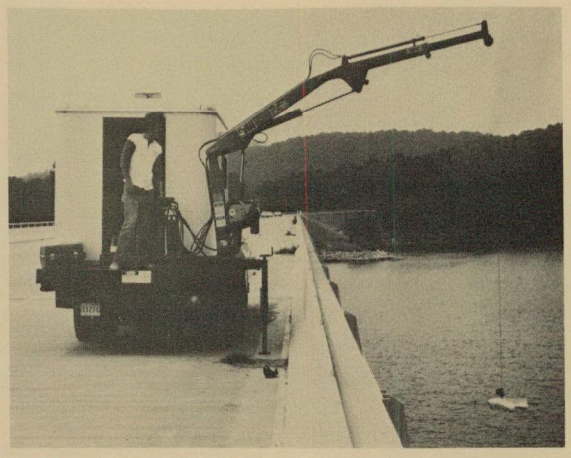

Figure 2. U.S. Geological Survey researcher samples from a bridge using a specially built crane.

Chemical analyses of water samples give the scientists concentrations of nutrients flowing past the river fall lines. This information together with measurements on flow rate give total amounts of the nutrients over a day or year.

The scientists have also devised a more cost-effective sampling method. Some nutrients the scientists measure correlate well with stream flow, suspended sediments or electrical conductivity. The ability to correlate a nutrient concentration, say of phosphorus, with a physical factor such as stream flow saves scientists time and money, because they need only measure stream flow to obtain a good estimate of the concentrations of phosphorus. Thus, they avoid the time and expense involved in analyzing their samples.

Good Nutrition

Results from the fall line research will provide information on sources, quantities and kinds of nutrients flowing to the Chesapeake Bay. The Susquehanna, Potomac and James Rivers are the major sources of freshwater to the Bay. Therefore, assessing nutrients coming from these tributaries will help scientists assess levels of enrichment in the Bay and how to control them. The Bay Program's mathematical models will, in turn, help managers determine how many nutrients should travel across the fall lines to maintain or improve certain water quality conditions. Thus, Bay life will be assured of receiving the right amounts of nourishment.

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brief 1

EPA Chesapeake Bay Program Information Series

Toxics Baseline Sediment Studies

July 1980

Sedimental Journeys

The Chesapeake Bay is gradually getting wider and shallower, largely because of erosion and the deposit of fine-grain sediments.

The characteristic combination of a net inward flow of water in the lower layer and a net outward or seaward flow near the surface makes this estuary a natural sediment trap.

Not so natural, however, is the addition of toxic chemicals. Their transport and deposition can be closely correlated with those of fine-grain sediments.

Traveling Companions

Toxics move with sediment. Track one, and you track the other, and thereby perhaps predict where toxics might threaten biological life in the Bay.

It was on that premise that baseline sediment studies were started in the Maryland and Virginia portions of the Bay, one headed by Randall T. Kerhin, of The Johns Hopkins University's Maryland Geological Survey, the other headed by John M. Ziegler, of the Virginia Institute of Marine Science.

Lost and Found

Tides, currents, wave action, and estuarine flow all influence the travels of sediments--and therefore toxics.

Samples of bottom sediments, from more than 6,500 sites, provided information about their physical characteristics--water content, grain size, and carbon and sulfur content.

Historic charts and shoreline maps from 1850 and from 1950 and later were studied to document sites of erosion and sediment deposits. Factors that alter depths, such as changes in sea level, changes in the continental crust, and tidal variations, were also taken into acccunt.

From this, a sediment "budget," a comparison between sediments entering the Bay and sediments leaving the Bay, was developed. Since the Bay is a sediment trap, the amount of sediment entering can be expected to outweigh the amount leaving. It has been estimated that since salt water first entered the Bay, about 45 billion cubic meters of sediment have been trapped.

Scientists sampling bottom sediments

Detailed maps are now being developed to outline the distribution of sediments by grain size, to show sites of erosion and sediment deposit and variations in the carbon, sulfur, and water content of the sediment.

Useful Information

Knowing more about sediments in the Bay means knowing more about erosion patterns, about the filling in of channels, and about places to dispose of dredge spoils.

Water-content data will help scientists determine how long it will take for dredged materials to dry out.

We now have clues to the paths toxics are likely to follow and where toxics are likely to accumulate.

We are better prepared to protect shellfish and to manage the development of new shellfish beds.

Information about sediment patterns will also be useful to Chesapeake Bay Program researchers investigating the recent decline in submerged aquatic vegetation.

An important by-product of the field sampling in the lower Bay is a refinement of the LORAN C navagational system used by air and sea pilots, resulting in better Bay navigation.

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brief 2

EPA Chesapeake Bay Program Information Series

NUTRIENTS

Circulation in the Chesapeake Bay April 1981

The Bay in Motion

Knowing the movement of the Bay's waters is basic to our understanding the Bay as an ecosystem. The Bay is dynamic, its waters constantly circulating in intricate patterns, picking up and depositing material sometimes miles from its origin. These patterns are commonly altered by seasonal fluctuations, weather changes and tides, forces that largely influence the movement of the whole system.

The Bay is used not only for transportation, but is itself a tireless transporter. Some of the many substances circulation moves are nutrients. Phosphorus, nitrogen, and calcium are among these important organic and inorganic chemicals which enter the Bay from decaying plant and animal matter, or from overland runoff and shoreline erosion.

Without nutrients the Bay's plants and animals would die; but too much can harm Bay life and diminish the water quality. Understanding how circulation transports pollutants such as excessive nutrients will help scientists and managers know what measures need to be taken to limit certain nutrient loadings and maintain the right amount of nourishment in the Bay.

The Layered Look

Freshwater inflow from rivers is one of the major forces affecting estuarine circulation (the Coriolis effect, wind, and tides are the others). Freshwater from the Bay's many tributaries flows seaward toward the mouth in the water's upper layers. Seawater from the open ocean also enters the Bay, but travels upward in the lower portion of the water column. These opposing flows form a unique, two-layered pattern in the upper Bay east of Baltimore and in parts of the Bay's major tributaries. Figure 1. illustrates this two-layered flow.

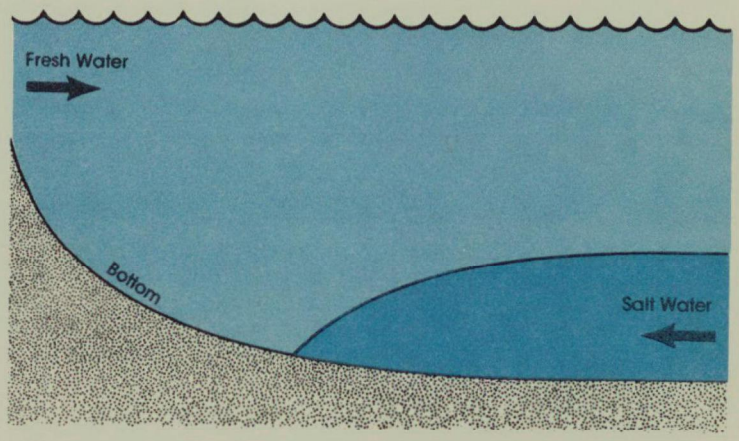

Figure 1. Two-layered flow pattern showing denser, heavier seawater (dark blue) flowing along the bottom of the Bay.

The meeting of fresh- and seawater in this two-layer pattern forms fronts, or saltwater intrusions, which move up and downstream in response to the amount of freshwater entering the tributaries and Bay. Many organisms use the upstream flow to move into and within the estuary. The young and larvae of ocean-spawning fish such as menhaden, croaker and eel use this means to reach their nursery grounds.

Sediment Traps

Where the saltwater fronts touch the bottom of the Bay, special zones are formed; fine sediments from the upper layers sink, and are trapped by heavy, incoming seawater. Here, the sediments are mixed around and because these areas are often clouded, or turbid, they are called zones of maximum turbidity. (See Figure 2.) Nutrients are also mixed here, causing the areas to be rich and productive. Plankton blooms often occur near these zones, and the availability of these tiny plants as food for fish larvae make these areas important spawning and nursery grounds.

Down Under

Although the two-layered flow forms the basic circulation pattern for a large part of the Bay, seasonal changes and other influences often alter it. When more freshwater enters, as is the case in the spring, the Bay becomes stratified, and the zone of saltwater intrusion is pushed downstream. In the autumn, the intrusions are pushed upstream.

Wind is another force that can alter the Bay's circulation pattern. If the wind blows in the same direction

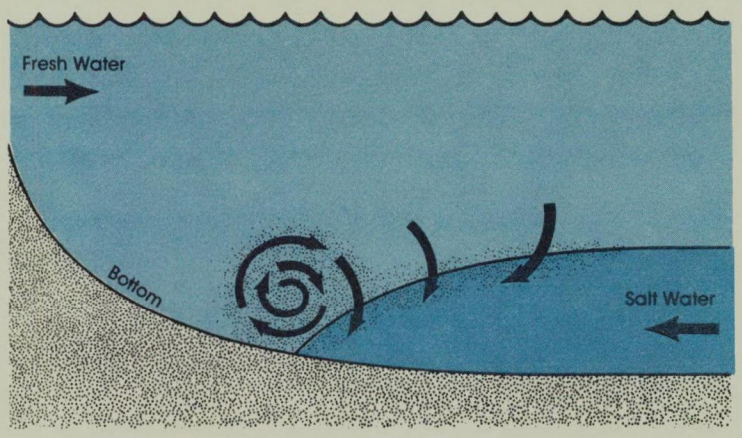

Figure 2. Zone of maximum turbidity. Area with arrows indicates where sediment is trapped and mixed.

as the surface water moves, it will enhance stratification. If the wind blows in the opposite direction of surface movement, stratification will break down. Wind is an important factor in mixing the Bay's waters.

Storms can drastically change the two-layered flow. In 1972 Hurricane Agnes poured so much freshwater and sediments into the Bay, that surface salinities were forced miles downstream producing a highly stratified system, and many habitats were changed. The rooted aquatic plants in the upper Bay were nearly wiped out.

Finding the Routes

Because circulation patterns in the Bay are important, yet complex, the Chesapeake Bay Program is developing a mathematical model to help scientists understand the Bay's movements. By pointing out some of the pathways pollutants can travel, the model will identify whether nutrient controls are needed and if so, where.

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Author: Elizabeth Macalaster, Editorial Assistant: Dottie Van Doren

brief 2

EPA Chesapeake Bay Program Information Series

SAV Biostratigraphy of the Chesapeake Bay September 1980

Time Machine

Biostratigraphy is a special tool, a time machine which takes geologists back through time to learn about the history of living things. By studying layers of Bay sediments which have built up over time, scientists can see how animal and plant communities have changed and what land activities may have contributed to those changes.

Telltale Fossils

In the layers of the Chesapeake Bay's sediments are trapped aquatic organisms. They lived and died and became buried under layers and layers of sediments, fossilized into permanent records of what once existed. As part of the Chesapeake Bay Program's Submerged Aquatic Vegetation (SAV) Program, scientists at the Johns Hopkins University are using biostratigraphy to study some of these fossils. Right now, their work is only exploratory and concentrates on a few sites in the Bay. At these locations, the scientists are particularly looking at fossils of pollen grains, diatoms (microscopic, one-celled, aquatic plants) and seeds of bay grasses to learn how land uses and natural disturbances have affected populations of these organisms over time.

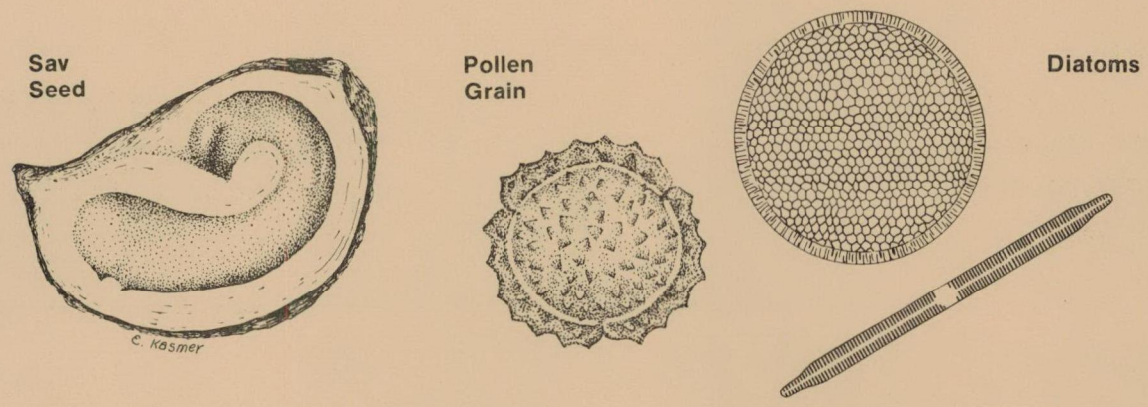
Scientists can tell a lot from pollen grains. From changes in pollen grain types, they can tell when land in a certain area was cleared of forest and when agriculture began. And, the amount of pollen in the sediment layers will show how quickly sediment was deposited.

Changes in diatom populations can also give scientists a measure of water quality, because these tiny plants respond very quickly to changes in nutrients, turbidity, trace metals and other water quality factors.

Because of the important role SAV plays in the Chesapeake Bay, the disappearance of these plants is a major concern to everyone. Studying how both human and natural activities, such as major storms, affected seed populations of SAV in the past may help scientists determine why bay grasses are declining now.

Following the Clues

The Johns Hopkins University scientists are sampling three areas in the Chesapeake Bay--the Patuxent River in Maryland, the Ware River in Virginia and the Upper Chesapeake



These are some of the kinds of fossils found in sediment layers of the Chesapeake Bay.

Bay. Sediment samples from each area provide the scientists with fossils from different layers, or time periods. By counting the numbers and kinds of fossil diatoms, pollen grains and SAV seeds, and then comparing this information with historical records, the researchers can estimate changes in land uses from pre-settlement times up to the present and can correlate those uses to changes in the fossil populations.

Studies from the Upper Chesapeake Bay have shown, among other things, that both amounts and kinds of SAV and diatoms have changed over time. The scientists relate the changes, in part, to the settlement of land in this region. Land clearance in the early 1800's, for example, caused an increase in siltation in the water, leaving less light for plants to use in photosynthesis. Thus, diatom populations declined drastically. Another obvious change was caused by Hurricane Agnes in 1972. Floodwaters from this storm destroyed SAV beds in the Upper Bay. The SAV populations still haven't recovered in this area.

Using the Past to Protect the Future

When these scientists finish their study, they will have reconstructed a chapter out of history, a special glimpse at how human and natural activities have affected some of the organisms in the Chesapeake Bay. Much can be learned from knowing how past changes in land use affected water quality. This unique look at some of the historical trends around the Chesapeake Bay region can help decision-makers make better choices for the Bay now and tomorrow.

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brief 2

EPA Chesapeake Bay Program Information Series

Toxics
Sediment-Animal Relationships

August 1980

Underwater Mix Masters

On the bottom of the Chesapeake Bay, there is a hidden world of tiny molluscs, crustaceans, bloodworms, mud shrimp, and other almost microscopic animals that burrow into Bay-floor sediments. These benthic, or bottom-dwelling, organisms are masters at mixing sediment deposits.

Unfortunately, sediments tend more and more to contain toxics, so these small creatures could be stirring up trouble.

Questions

When the EPA Chesapeake Bay Program was started in 1976, there were more questions than answers about the Bay. Among them were questions about the specific relationships between sediment and animal activities.

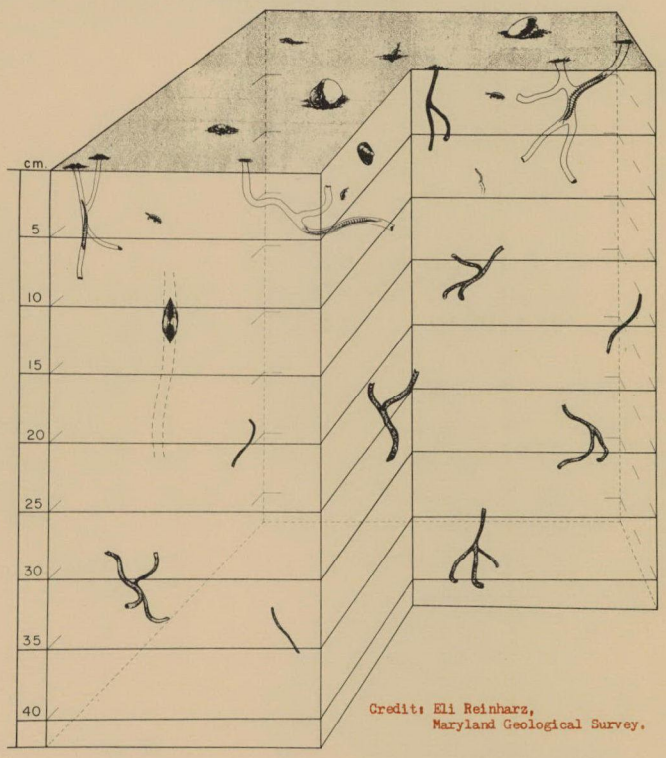
Where are the different kinds of benthic organisms found in the Bay? What kinds of burrow tubes and other structures do they create? How do they affect the exchange of toxic and other materials between the sediment and the water?

Answers

To answer these questions, companion studies for the upper and lower portions of the Bay are being conducted by Dr. Owen P. Bricker and Mr. Eli Reinharz, of the Maryland Geological Survey, and Dr. Donald F. Boesch, of the Virginia Institute of Marine Science.

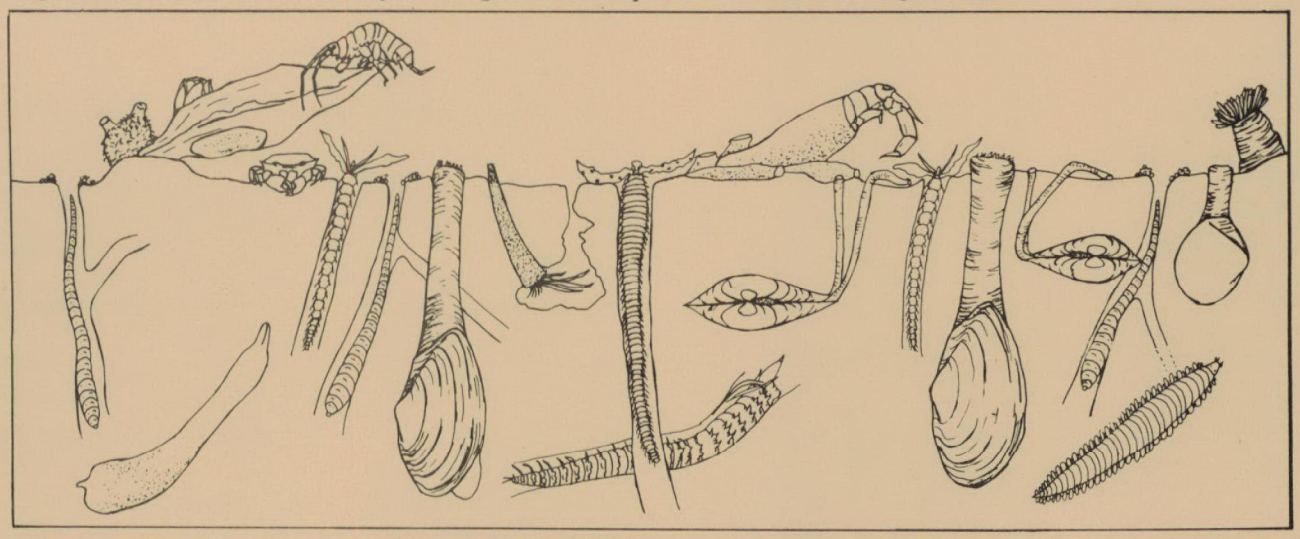
Using box-core samples, microscopic examination of sediment particles, and radiographic, or X-ray, analysis of the burrows and other structural changes, investigators have been able to construct three-dimensional drawings of the sediment community.

Figure 1. Three-dimensional diagram of a sediment community.



Credit: Eli Reinharz, Maryland Geological Survey.

Figure 2. A sediment community is composed of many kinds of benthic organisms.



Credit: Martha H. Heigel, Chesapeake Biological Laboratory, Solomons, Maryland.

They have also collected and collated data on depth distribution, which generally ranges to about 12 inches (30 cm). They know what types of feeding methods the various organisms favor. They know what types of sedimentary structures these animals "build." And they know which types of organisms prefer which types of sediment--sand, clay, mud, or, in some cases, almost anything.

Scientists also know that the more wave and current activity there is, the less building activity goes on. And, as salinity increases toward the mouth of the Bay, so does the number of types of organisms. Moreover, the more types of organisms and the more diverse the structures they create, the greater the rate of chemical exchange between sediment and water.

Management Tools

What good is it to know so much about creatures that are so small and, to the average observer, seemingly insignificant?

They may be an important key to managing some of the Bay's biggest future problems, those dealing with the increase of toxic materials in Bay waters. Knowing the distribution of benthic organisms and the extent of their mixing operations can help predict how long toxic substances will remain in the system. In addition, gathering information on the diversity and abundance of benthic animals will provide baseline data for comparisons between healthy communities and those that might be affected by toxics and other environmental hazards.

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brief 3

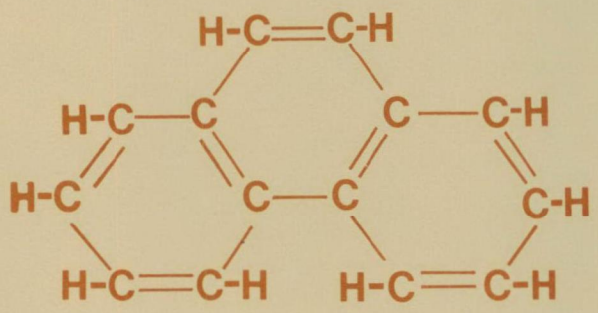
EPA Chesapeake Bay Program Information Series

Toxics
Investigation of Organic Pollutants

September 1980

Tied Up With Carbon

Organic compounds, the building blocks of life, contain carbon atoms linked one to another in long chains or rings. Most of these compounds come from living things, from plants and animals. But more recently, man has begun to make new chains and rings never before found in the environment. These new compounds, the synthetic organic compounds, are a great boon to modern society. These are our plastics, our pesticides and too often, our new pollutants.



Phenanthrene is a carbon compound with a ringed structure.

Choked Up With Organics

Because many of these compounds are new to Mother Nature, they do not break down easily in the environment. They are tough to digest, they persist. Some, in fact, relatively few, are toxic. But those few can cause reproductive failure, birth defects and cancer. The U.S. Environmental Protection Agency (E.P.A.) estimates that 40,000 to 60,000 synthetic organic compounds are in use in this country. And the problem is that no one knows much about the toxicity of most of these compounds.

To learn more about toxic substances and their effects on the Chesapeake Bay, E.P.A.'s Chesapeake Bay Program is conducting a series of studies on the sources of toxic substances, how they reach the Bay and where they settle in the estuary. In one study, scientists at the Virginia Institute of Marine Science (VIMS) are collecting and analyzing samples from water, sediment, oysters and clams to find out what kinds of organic compounds, and how much of each, exist in the Bay.

Untying the Carbon

To analyze the sediment and mollusc samples, scientists are using what seem to be rooms full of elaborate instruments. But all of these complicated tools serve important roles in identifying the organic compounds. At least four instruments are involved in the identification scheme. By isolating the compounds and their components, each instrument progressively uncovers a little more information. At the end of the identification process, the very structure of the carbon atoms for each compound is revealed.

The VIMS scientists have finished collecting data for their mollusc and sediment samples and have begun analysis.

Using a different method, the scientists test the water samples only for a certain kind of organic compound, a group called volatile halogenated compounds. These substances are formed when waste water already containing natural organic compounds is chlorinated. Bromoform and the common anesthetic, chloroform, are examples. So far, the VIMS scientists found low concentrations of halogenated compounds in water samples from the Bay.

Plot to Protect

The VIMS team has a shrewd plot in mind, one which should help protect the Chesapeake Bay from toxic synthetic organic compounds. Through their identification scheme, they can select and monitor for groups of chemicals with known toxicity, and also watch for the appearance of new, potentially harmful compounds. They've designed this system so that managers can do the monitoring themselves after the project is finished. By the end of the study, the scientists will also have produced a map showing where toxic compounds have been found in the Bay and where places which naturally trap pollutants may occur. With this knowledge, managers can monitor, and then if needed, place limits on harmful substances entering the Chesapeake Bay.

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brief 3

EPA Chesapeake Bay Program Information Series

SAV

Light and Decline of Bay Grasses August 1981

Linked to Light

For submerged aquatic vegetation (SAV) living in the Chesapeake Bay, light is life itself. The watery environment in which these aquatic plants live is full of bits of sediment, chemicals, nutrients, even tiny plants and seeds. These bits and pieces reflect or absorb light as it travels through the water, creating an obstacle course certain to prevent some of the light from reaching the grasses living just below the surface. In addition, only a small portion of the light actually reaching the plant is used in photosynthesis--the process in which plants use light energy to produce food.

Redhead grass, a native Bay grass, and Eurasian watermilfoil, an intruder, are two of the SAV species used in light experiments at the University of Maryland's Horn Point Laboratory.

Illustrations from: Summary of Available Information on Chesapeake Bay Submerged Vegetation, Maryland Department of Natural Resources, U. S. Environmental Protection Agency and Fish and Wildlife Service, U.S. Department of the Interior. FWS/OBS-78/66, August 1978, pgs. 3 & 16.

In the Shadows

Scientists believe that low light levels in the Bay's waters may be one cause of SAV's decline. Under the U.S. Environmental Protection Agency's Chesapeake Bay Program, researchers in both Maryland and Virginia are studying the relationship between SAV and light and what environmental changes may influence the amount of light reaching these grasses. In one kind of experiment, researchers are finding out just how sensitive SAV is to light. At the University of Maryland's Horn Point Laboratory, scientists are growing SAV populations in aquaria under artificial and natural light. Using special shading screens, they can allow either a little or a lot of light to reach the plants. To learn how well plants photosynthesize under the range of shading, they measure oxygen which plants release during photosynthesis. So far, researchers are finding that SAV is very sensitive to light, with small changes in amounts of light energy causing large changes in the amounts of oxygen produced.

Turbidity (which can be measured as concentration of sediment in water) is one environmental condition that scientists think may prevent light from reaching SAV. To test this theory they are experimenting with populations of eelgrass grown in

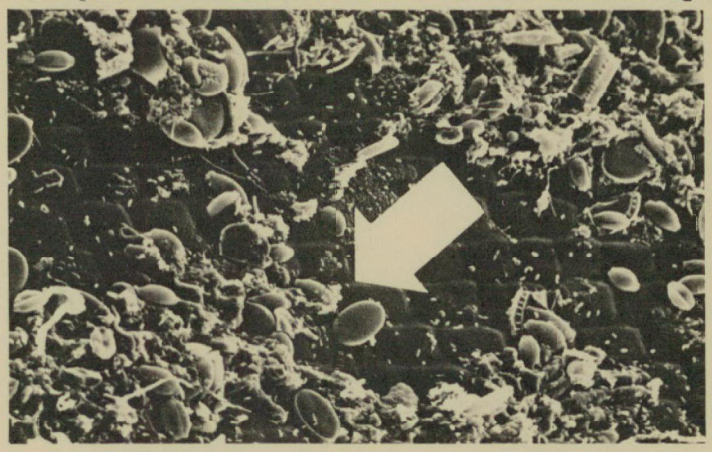
laboratory aquaria. The scientists dose some aquaria with high amounts of sediment, others with small amounts. The researchers then measure the amount of oxygen produced in the aquaria over time compared with undosed, or control colonies. In one set of experiments, scientists found that when turbidity is increased from a dose of 20 milligrams per liter (mg/L) to 100 mg/L, a five-fold increase, as much as a 50 percent reduction in photosynthesis occurs.

Blocking the Way

Another area being investigated is how the growth of plants and animals living on SAV affects the amount of light absorbed by the blades. Many kinds of small plants and animals live naturally on blades of SAV, but unnaturally large populations can grow when too many nutrients, coming perhaps from human sources, are present in the water. Either the encrusting plants and animals use the nutrients directly, or they feed on increased supplies of algae which have already consumed the nutrients. As more and more fouling organisms grow, less and less light can be absorbed by the SAV leaves, creating low light levels that scientists believe may be a cause of SAV's decline.

Increased growth of fouling plants on eelgrass may also be caused by a lack of natural predation. Scientists at the Virginia Institute of Marine Science (VIMS) are investigating the role of a small snail living on blades of eelgrass. By grazing on the fouling plants, this snail keeps the blades clean and free to absorb light. Eelgrass populations in the lower Bay have fewer of these snails now than in the past. Scientists speculate that absence of snails may cause eelgrass to foul to the extent that light is blocked from entering the blades. Researchers at VIMS are now studying the habits of this snail and what factors, such as temperature and salinity, might be responsible for reduced populations.

Arrow points out two kinds of diatoms which live on blades of eelgrass.



A scanning electron microscope took this photograph of part of an eelgrass blade. The cleared area where Bittium has grazed shows the underlying cellular structure of the leaf. Whole diatoms (one-celled plants), blue-green algae, bacteria and organic detritus form the crust on which Bittium feeds. Photo by: Jacques van Montfrans, Virginia Institute of Marine Science.

Out of the Darkness

Through these and other experiments, scientists are chipping away at the secret of the SAV decline. By learning first how SAV populations are altered by certain conditions such as low light levels, and then what causes those conditions, scientists and managers will know better how to manage SAV.

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EPA Chesapeake Bay Program Information Series

SAV Waterfowl and the Decline of SAV October 1981

A Winter Haven

The Bay, with its rich shoal waters, protected estuarine rivers and mild, usually ice-free winters, offers an ideal wintering spot for many of the continent's migratory waterfowl. A million and a half unswerving geese, swans and ducks spend the winter in the Bay area or rest while migrating farther south. These harbingers of a new season in the Chesapeake Bay have been favorites of both sportsmen and nature lovers ever since the area was settled.

Populations of the Bay's waterfowl can change from year to year depending on hunting regulations, diseases and environmental changes such as weather or water conditions on breeding grounds. Another recent ecological change in many parts of the Bay has been a decline in submerged aquatic vegetation (SAV), a food resource many species of waterfowl use. Scientists believe that the decline of this important vegetation may be one cause for the sharp reduction of some waterfowl species in the Bay.

Because of the economic and recreational importance of waterfowl to the Bay, the U.S. Environmental Protection Agency's Chesapeake Bay Program initiated projects to study the relationship between SAV and waterfowl. The study was done by Robert Munro and Matthew Perry at the Migratory Bird and Habitat Research Laboratory in Laurel, Maryland, covering the period from 1971 to 1979. Munro and Perry looked at waterfowl population surveys in Maryland, taken annually by the U.S. Fish and Wildlife Service and then at trends in the distribution and abundance of SAV beds in those areas.

Redheads Prefer Grass

The decline in SAV, according to Munro and Perry's study, caused some waterfowl species to leave the Bay area and others to change their feeding habits. During the 1971 to 1979 study period, many pintails and wigeons left the area. These ducks

This wigeon, a favorite of Bay sportsmen, is largely a vegetation eater. Scientists have linked its absence in the Bay area during winter months to a decline in SAV. (Photo by R.E. Munro)

are both dabblers, feeding in dense, vegetated areas. Apparently, they were still tied to SAV for a large part of their diet, unable to switch to more available animal food. The redhead, a diving duck, also did not change its diet and left for lusher habitats farther south. However, the canvasback, another diving duck, changed its food preference to clams and was thus able to stay. Scientists believe that the structure of some ducks' gullets and bills prevents them from changing feeding habits.

Whistling swans and Canada geese are two other types of waterfowl that have adapted their feeding habits and remained in the Bay area. These waterfowl have even expanded their populations, foraging on the rich grain fields around the Bay.

Signs of Change

The general decrease in kinds of waterfowl wintering in the Bay area during the 1970's reflects environmental changes occurring during this time. The absence of some waterfowl species shows that SAV and other parts of the Bay ecosystem are tightly tied together and that changes in one part can vastly affect another. To encourage the return of the Bay waterfowl and thus help ensure a healthy estuary, scientists will continue to study the cause of decline in SAV and how these changes affect other parts of the Bay.

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EPA Chesapeake Bay Program Information Series

Nutrients Fall Line Nutrient Studies January 1981

Importance

Nutrients are essential to the health of plants and animals living in the Chesapeake Bay. Carbon, phosphorus and nitrogen are three of the major nutrients needed by the simplest to the most complex living organisms in the Bay for maintenance, growth and reproduction.

However, these elements are nourishing only in the right quantities. In excess, nutrients can alter water quality and harm Bay life. Decaying plant and animal matter provide nutrients naturally to the Bay, but agricultural and urban runoff, sewage discharge and septic tank leakage add additional quantities. These human activities can produce a glut of nutrients, or overenrichment, leading to accelerated plant growth (algal blooms), noxious odors, decreases in oxygen supplies and even fish kills.

Because excesses of nutrients threaten to diminish the Bay's water quality, the U.S. Environmental Protection Agency's Chesapeake Bay Program is looking at present enrichment in the Bay and acceptable nutrient levels for the future. One of the Bay Program's projects in this area involves quantifying nutrient loadings (total amount of nutrients carried by the water) coming into the Bay from its three largest tributaries--the Susquehanna, James and Potomac Rivers. Together, these rivers contribute about 85% of the freshwater flowing into the Bay. Thus, measuring amounts of nutrients traveling past the fall lines (the upstream points of tidal influence) of these rivers is important in assessing the amounts of nutrients entering the Bay.

Data from this study will also be used for a mathematical model that will help identify current and future water quality problems in the Bay. Specifically, the model will relate nutrient loadings to existing and future land use, water use, and regional and economic development of the Chesapeake Bay area. The model will also evaluate the feasibility for controlling loads from land runoff. This information will help management agencies assess relative nutrient contributions to the Bay and determine sources of the greatest inputs. In turn, they will be able to make better decisions on ways of maintaining or improving the estuary's water quality.

The only other major effort to assess tributary input into the Chesapeake Bay was made by E.P.A. from 1969 to 1970. The U.S. Geological Survey team will compare these historical data and methods to their own findings and determine the existence of any trends for the ten year period (1969-1979). From the

trend information, scientists and managers will know how water quality factors might relate to certain natural and human-related events over time.

This summary, one of a series of publications describing Chesapeake Bay Program research, presents the most current findings of the fall line studies being conducted by David Lang and David Grason of the U.S. Geological Survey in Towson, Maryland.

Research

Sampling

The Susquehanna, Potomac and James River monitoring sites are located at Conowingo, Maryland, Chain Bridge at Washington, D.C., and Cartersville, Virginia, respectively (See Figure 1.). Along with major nutrients the scientists from the U.S. Geological Survey are measuring suspended sediment, which can transport nutrients, stream discharge (the volume of water passing a point along a stream in a given time) and specific conductance (a measure of dissolved ions, or how well the water sample conducts electricity).

To collect most of the water samples, the scientists use a depth-integrating sampler--a heavy, torpedo-shaped container. This device faces the river current and continually collects samples as it is lowered from the surface to the bottom and raised back to the surface again. For shallow and slower-flowing stream reaches, scientists use a dip bottle--a simple brass or steel, weighted bottle. A truck equipped with a power crane and a small laboratory allows the scientists to sample from bridges and prepare the samples on location. Figure 2. shows the sample system being used. All water samples are refrigerated or otherwise preserved, and sent to laboratories in Atlanta, Georgia or Harrisburg, Pennsylvania for analysis.

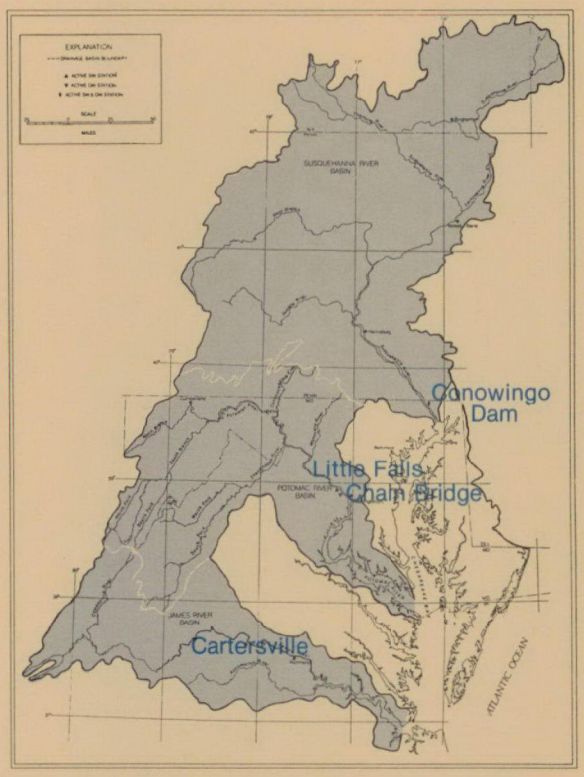

Figure 1. Fall Line Sampling Sites.

Figure 2. U.S. Geological Survey researcher samples from a bridge using a specially built crane.

Results

When the researchers want to look at these data, they can obtain computerized printouts of graphs with the required information already plotted. Figures 3. to 5. are actual plots (redrawn) obtained from data collected at Chain Bridge.

To calculate total amounts of nutrients flowing past the Chain Bridge fall line, the scientists first determine flow rates of water and concentrations of specific nutrients in the water. Figure 3., for example, shows the concentration of suspended sediments flowing across the fall line at the Chain Bridge station over a one-and a-half-year period. Figure 4. shows the stream flow during that same time. From these flow rate and concentration figures, scientists can calculate total sediment loads in pounds per day, shown in Figure 5. High peaks on the graphs result from storm conditions where both streamflow and concentrations of suspended sediments are high.

The U.S. Geological Survey team is also attempting to correlate nutrient concentrations with stream flow, suspended sediments, and

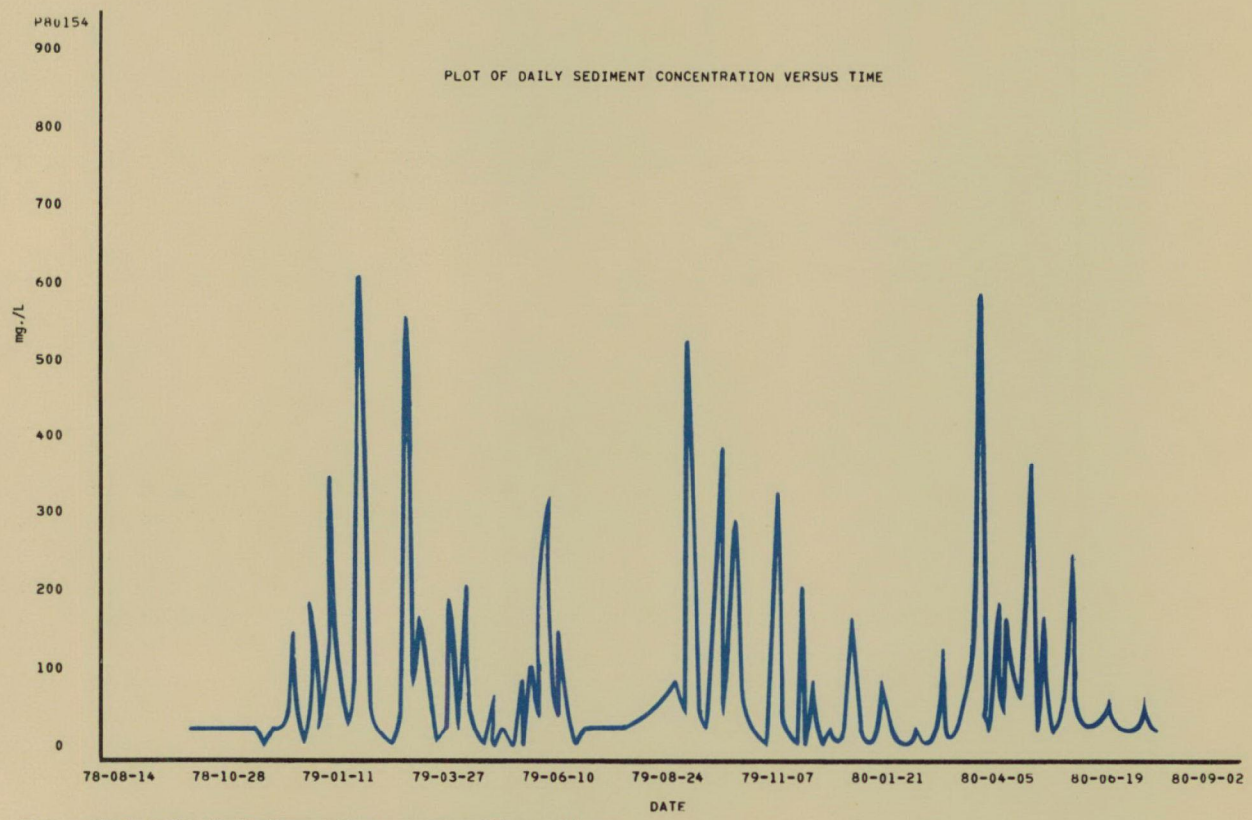

Figure 3. Plot of Daily Sediment Concentration Versus Time.

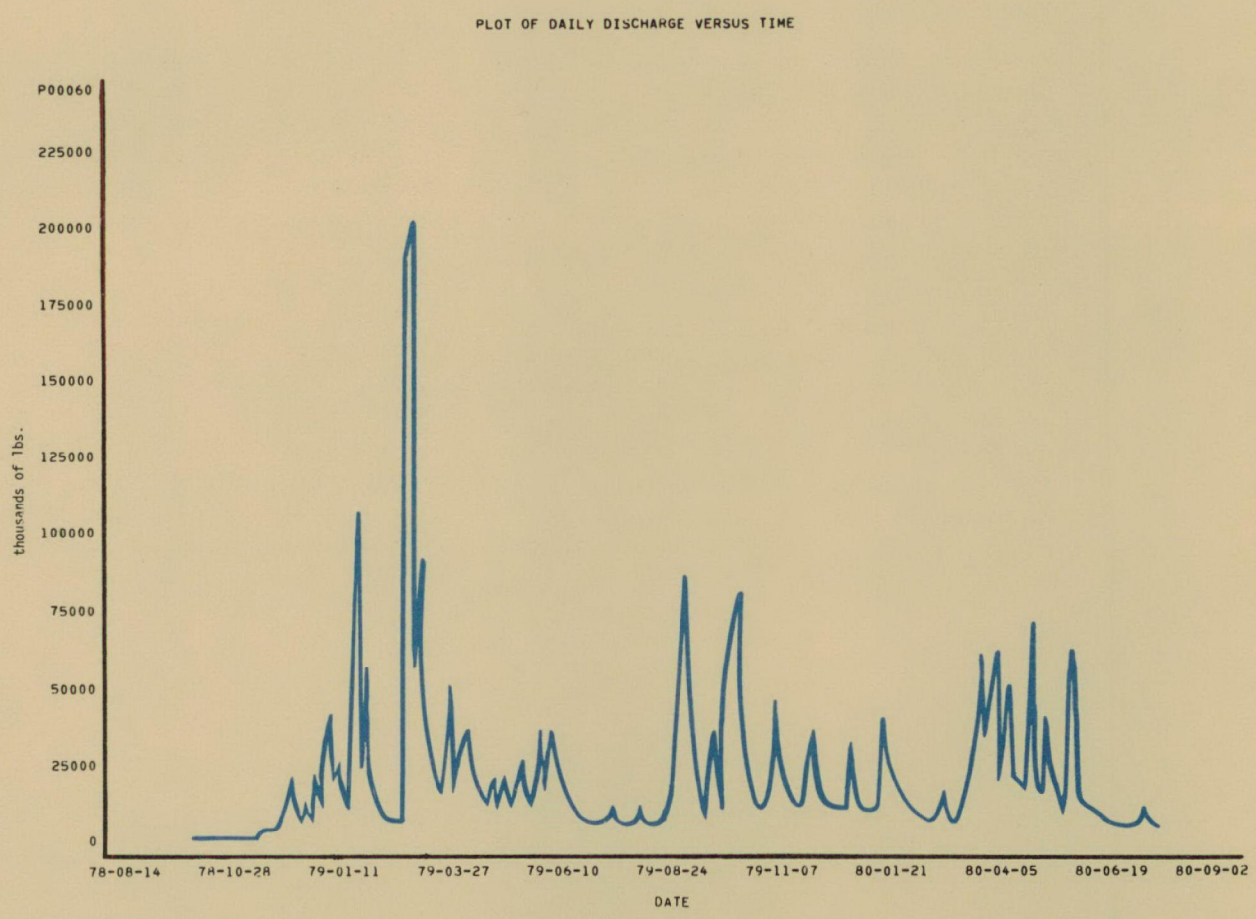

Figure 4. Plot of Daily Discharge Versus Time.

specific conductance. The scientists have found correlations of some significance with many of the nutrient parameters. Successful correlation means more economical sampling, because only physical parameters (water flow, suspended sediments) need to be measured. For example, phosphorus has a high correlation with suspended sediments. The Geological Survey scientists can, therefore, calculate good estimates of phosphorus without actually measuring the element.

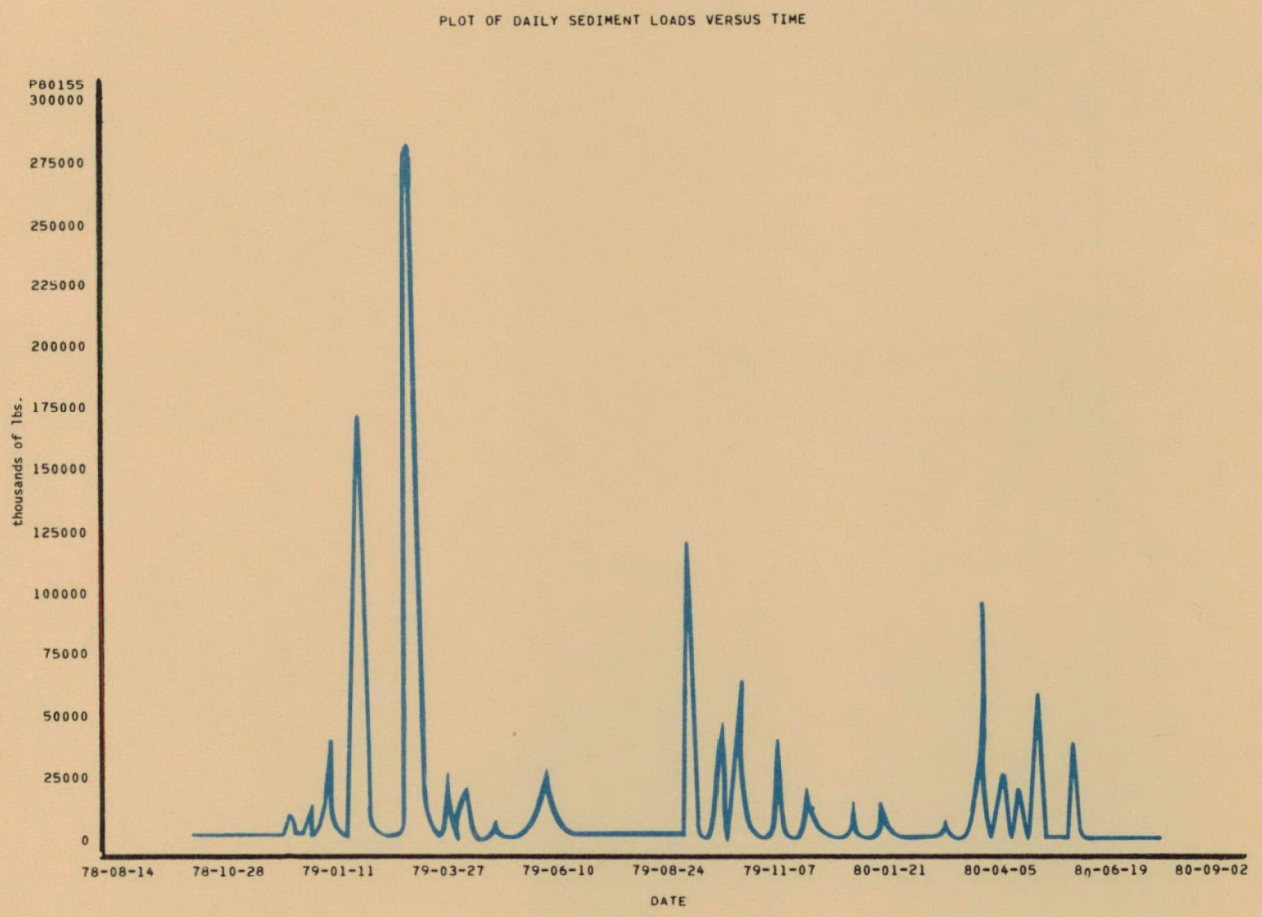

Figure 5. Plot of Daily Sediment Loads Versus Time.

This summary highlights the research findings from an ongoing project sponsored by the Chesapeake Bay Program: Water-Quality Monitoring of Three Major Tributaries To The Chesapeake Bay-Interim Data Report (Principal Investigators, David J. Lang and David Grason, U.S. Geological Survey) September 1980.

This is one of a series of briefs, reports, research summaries, and final project reports designed to make available the findings, observations, and management implications of the Chesapeake Bay Program, a project of the U.S. Environmental Protection Agency. It is based on conversations with the principal investigators and on the final reports covering these projects.

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summary 1

EPA Chesapeake Bay Program Information Series

SAV Distribution and Abundance

July 1980

Importance

Over the last ten years, Bay grass populations, which play an important role in the coastal Bay ecosystem, have declined.

Grasses growing along the shoreline regions of the Bay:

--Provide food and shelter to many animals, such as waterfowl, fish, and shellfish.

--Provide breeding and spawning grounds for many of these animals.

--Help stabilize the Bay bottom.

--Filter and provide oxygen to Bay waters.

--Recycle nutrients, such as phosphorus and nitrogen, which are required by many plants and animals.

--Act as a buffer and take up toxic substances.

The loss of Bay grasses may indicate changes in water quality of the Chesapeake Bay. Many factors, including excessive nutrients, chlorine, disease, dredging, boat traffic, weather, turbidity, herbicides, or a combination of several of these factors, are suspected causes of this decline. However, no one is sure whether the decline is part of a natural cycle or is caused by human activities.

A series of research projects is being conducted by the Chesapeake Bay Program to investigate the causes of this decline in Bay grasses. This research summary, which is one of a series of publications describing Chesapeake Bay Program research, presents the findings of the 1978 SAV distribution and abundance projects.

Research

Mapping of Grasses

Aerial photography was used to determine where grasses are found in the Chesapeake Bay. During the summer of 1978, photographs were taken of the Bay shoreline, where grasses are found. This shallow coastal region, less than three meters deep, is the area where light can penetrate, allowing the growth of rooted aquatic grasses.

The photographic information was transferred to U.S. Geological Survey maps, so that a complete inventory of the distribution of Bay grasses could be produced.

In Virginia, 31 maps were produced of areas where grass was observed. Of these, 27 cover the eastern and western shores of the Bay and show 207,480 acres of grasses. The other four maps, which cover Bay tributaries, show 338 acres of Bay grasses.

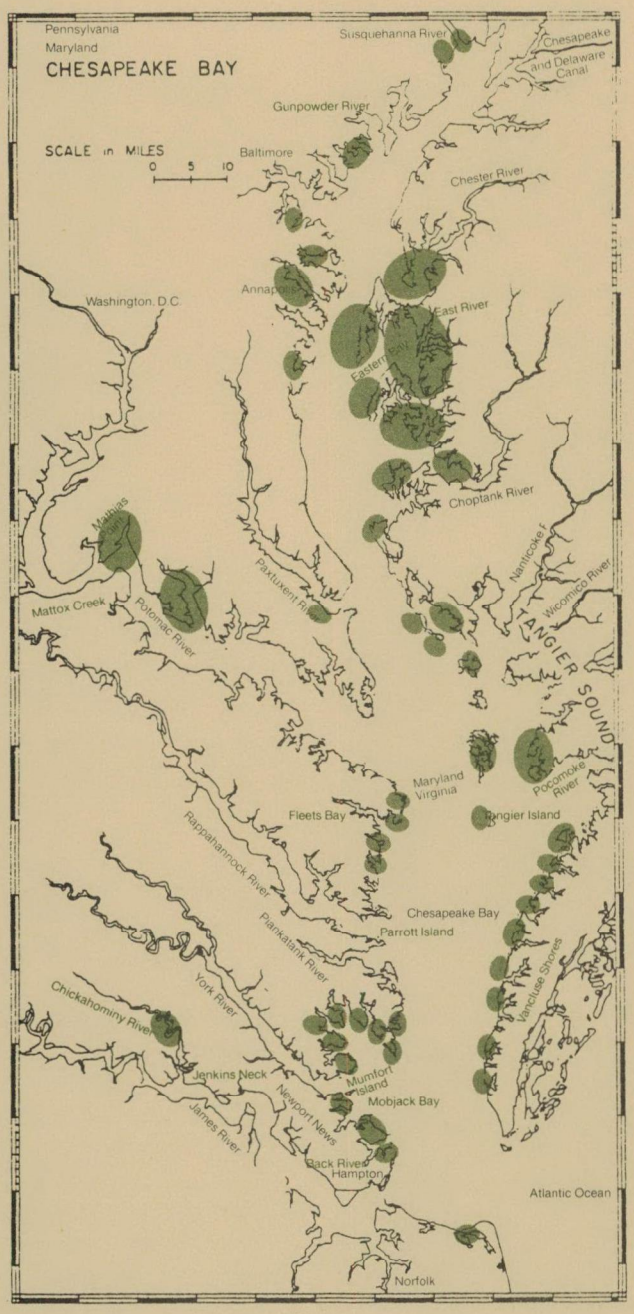


Figure 1. The Chesapeake Bay.

EPA Research Summary, Chesapeake Bay Office of Research and Development, May 1980.

(See Figure 1.)
In the Virginia region of the Bay, grasses were found mainly at the mouths of the major rivers and along the eastern and western shorelines.

The areas with the most grasses were:

--Along the western shoreline of the Bay between the Back and York Rivers.

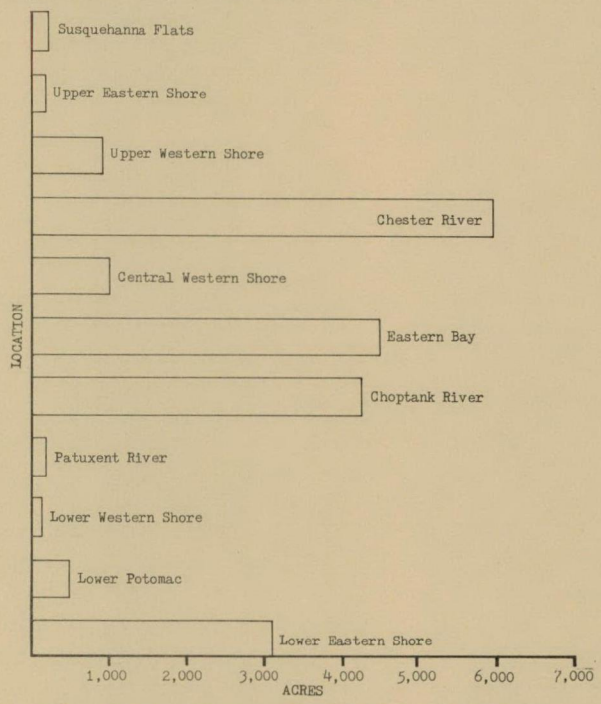
--Shoreline of Mobjack Bay.

--Shallow areas east of Tangier Island and other Bay islands.

In the Virginia tributaries, small grass beds were found along the Potomac River from Matox Creek to Mathias Neck Point and along the Chickahominy River, a tributary of the James River.

For the Maryland region of the Bay, 77 maps were produced. Of these, 17 covered areas showing no mappable vegetation, and 24 contained less than 25 acres of grasses. Figure 2 shows the acreage of Bay grasses found in Maryland waters.

Figure 2. Bay Grasses of Maryland.



As this figure shows, the Maryland mid-Bay sites, such as the Chester River, Eastern Bay, and Choptank River, have the greatest abundance of Bay grasses, as compared to the other Maryland Bay regions.

Field Study Results

Field studies were used to verify aerial photography information and to identify plant species.

Analysis showed that the kinds of grasses found in an area were related to the salinity of the water. Table 1 shows the relationship between species and salinity.

Table 1. Relationship Between Grass Species and Salinity.

Salinity	Major Species Found
Fresh Water	Coontail *Ceratophyllum demersum* Bushy pondweed *Najas guadalupensis* Waterweed *Elodea canadensis*
Intermediate	Wild celery *Valisneria americana*
Low	Horned pondweed *Zanichellia palustris* Redhead grass *Potamogeton perfolictus* Eurasian milfoil *Myriophyllum spicatum* Sago pondweed *Potamogeton pectinatus*
High	Eelgrass *Zostera marina* Widgeongrass *Ruppia maritima*

The two main species found in the lower Bay were eelgrass and widgeongrass. Widgeongrass is usually found in shallow, protected regions, whereas eelgrass is usually found in the deeper, more exposed areas, along the shore.

The field data for the Maryland study confirmed that the midportion of the Bay from the Magothy to the Choptank Rivers had the greatest diversity of species. This diversity declined to two or three species in the southern portion of the eastern shore, where horned ponweed and widgeongrass were usually found.

Historical Distribution of Bay Grasses

To determine how the dsitribution of grasses has changed over time, early aerial photographs were studied. This information showed that there has been a downward trend in grasses in the Chesapeake Bay over the last ten years.

In the Virginia region of the Bay, six areas had photography available for selected years between 1937 and 1978. These sites were Parrott Island, Fleets Bay, Mumfort Islands, Jenkins Neck, the East River, and Vancluse Shores. Of these areas, only Vancluse Shores did not show significant changes in the amount of grass present.

In general, the amount of vegetation observed in 1937 increased for about a 35-year period until a dramatic decline occurred in the 1970's. This decline continued through the 1978 inventory, which documented the lowest levels of vegetation seen over the last 40 years. Some researchers believe that, because the 1937 and 1973 data are similar, the factors responsible for the 1930's decline may also be active in the present decline.

In Virginia, the greatest decline occurred in the lower reaches of the major rivers. North of the York River on the western shore, significant declines were also noted. The maps in Figure 3 are part of a series of six that illustrate the changes in the grass population at the Fleets Bay site. Similar series exist for the other five sites and are contained in the full Virginia report.

Figure 3. Historical Distribution of Grasses at Fleets Bay, Virginia.

From Distribution and Abundance of Submerged Aquatic Vegetation in the Lower Chesapeake Bay. Virginia: Orth, R. S., K. A. Moore, and H. H. Gorden, Virginia Institute of Marine Science, Gloucester Point, VA, EPA Report No. 600/8-79-029/ SAV1, Sept. 1979.

In Maryland, the historical analysis was not as clear-cut. Three sites were selected: the Chester River, Eastern Bay, and the Gunpowder River. The Chester River site showed fluctuations in the amount of vegetation present. The Eastern Bay area showed a downward trend in acres of grasses found, although photographs were available only for three years. The third site, the Gunpowder River, which includes the Dundee, Saltpeter, and Seneca Creeks, was chosen because of its nearness to the C. P. Crane Generating Station, which discharges cooling water into Saltpeter Creek. The data before and after the plant opened in 1962 show no changes in grass populations, but this may not reflect a normal situation, since, during this period, there was a sudden increase in the abundance of Eurasian milfoil, an introduced species.

From all the historical data, it seems that the populations of rooted aquatic grasses have been declining in most areas of the Bay over the last ten years.

Management Implications

The maps developed in the two projects provide a basis for future comparisons of changes in the populations of Bay grasses. At present, the maps are being put to practical use. Copies have been distributed to Maryland and Virginia resource management agencies, for use in the review of permit applications for dredging and disposal and shoreline construction. The maps have already aided Virginia agencies in avoiding disturbance of established grass communities and are thereby helping to protect the Bay ecosystem.

This summary highlights the research findings from two projects sponsored by the Chesapeake Bay Program: Distribution and Abundance of the Submerged Aquatic Vegetation in the Lower Chesapeake Bay, Virginia--1978 (Principal Investigator, Robert J. Orth, Virginia Institute of Marine Science) and Distribution of Submerged Vascular Plants in the Chesapeake Bay, Maryland--1978 (Principal Investigator, Richard R. Anderson, American University).

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EPA Chesapeake Bay Program Information Series

Toxics Baseline Sediment Studies

July 1980

Importance

Many toxic substances are now being discharged directly or indirectly into the Chesapeake Bay. Since many of these toxic chemicals end up in the sediments of the Bay, deposition and erosion have significant effects upon the fate of these chemicals. Furthermore, interaction between toxic substances and benthic or bottom-dwelling organisms takes place in the sediments.

For these reasons, two organizations sponsored by the Chesapeake Bay Program (Toxics Program), the Virginia Institute of Marine Science and the Maryland Geological Survey, are conducting baseline sediment studies to:

--Determine the distribution and physical properties of Bay sediments.

--Identify sites of erosion and deposition in the Bay.

--Develop a total sediment budget for the Bay.

This research summary, which is one of a series of publications describing Chesapeake Bay Program research, presents the preliminary findings of these baseline sediment studies, which are being conducted at the Johns Hopkins University's Maryland Geological Survey and at the Virginia Institute of Marine Science.

Background

The modern Chesapeake Bay system was formed by the flooding of the ancestral Susquehanna and Virginia River valleys, beginning some 10,000 to 15,000 years ago.

In the river systems, strong currents carried sediment and other matter outward toward the ocean. But, with the change to an estuary, in which seawater flows into the Bay in the lower layers and fresh water flows outward in the upper layers, the total flow of fresh water became less. A decrease in the ability of the Bay's upper layers to hold material in suspension resulted, and now, only very fine-grain matter reaches the mouth of the Bay.

The rest settles to the bottom and is trapped within the zone of the turbidity maximum, an area in the northern section of the Bay about five miles long. Here is where the interfacing fresh and salt water touch the bottom. Heavier sediments sink through the interface, but are usually pushed back by the inward flow of seawater. Lighter particles are trapped and mixed around at this interface, often causing the area to become turbid.

Since the time of salt-water intrusion, the Chesapeake Bay has trapped approximately 45 billion cubic meters of sediment, coming primarily from land runoff, shore erosion, primary production, and the sea. Deposition of Bay sediments also results from erosion of islands and shorelines, and from the creation or expansion of channels and sand bars through shifting currents.

Research

Sediment Sampling and Analysis

The plan for the field sampling was based on a uniform grid system to ensure Bay-wide sampling. Sediment profiles (box-core and gravity-core samples) were collected at 4,500 sites in the Maryland region of the Bay and 2,018 locations in the Virginia portion. In the field, physical characteristics of the samples were noted, and laboratory analysis provided information on grain size and water, carbon, and sulfur content of the sediments.

Preliminary results have indicated that:

--Sands are generally found in the shallow areas and lower reaches of the Bay.

--Clayey silts and silty clays were found in the deeper Bay regions.

--Water and total carbon content increase as the mean grain size becomes finer.

The beach and near-shore sands are distributed primarily by wave action, whereas the sediments in the main channel are influenced mainly by estuarine processes. Between these two zones lies a region of sediment mixing that may result from combined tidal, current, and wave actions.

Exposed areas of geologically old coastal-plain sediments were discovered on the Bay floor on the eastern shore along Poplar Island. Along the Calvert County shoreline on the western shore, scientists found a similar outcrop.

Erosion and Deposition

Two methods are being used to document sites of erosion and deposition in the Chesapeake Bay:

--Comparison of historic bathymetric (water depth) charts.

--Assessment of shoreline erosion by reviewing historical shoreline maps.

Bathymetric data from the 1950 and later surveys and 1850 surveys were compared. However, other factors besides deposition and erosion alter depths, such as sea-level changes, continental-crust changes, and semi-annual and annual tidal variations. An equation incorporating these factors was used to compare the sets of bathymetric data. These comparisons resulted in the determination of average sedimentation rates for different Bay regions.

Researchers in Virginia noted an interesting pattern when they compared average sedimentation rates to water depths in three areas: Mobjack Bay, Pocomoke Sound, and the main stem of the Bay. Both the main stem of the Bay and Mobjack Bay show the following pattern of sedimentation rates:

Sedimentation Rate	Depth
High	0 - 6 ft. (0 - 1.8 m)
Low	6 - 12 ft. (1.8 - 3.7 m)
High	12 ft. (3.7 m)

A high sedimentation rate was found for the shallow and deep areas, and a low rate for the 6-to-12-foot depths. Pocomoke Sound was similar, except that it lacked the high rate for shallow depths.

The average deposit rate in the lower Bay has been found to be 22 inches (55 cm) per century. In general, the lower Bay is filling with sediments at a slightly faster rate than the relative sea-level rise.

In Maryland, similar results were found:

--Major deposition in the main channel is causing the Bay to become shallower.

--Erosion along the slopes of the channel is causing the Bay to become wider.

--Varying patterns of erosion and deposition occur along near-shore areas.

To assess shoreline erosion, the Maryland researchers used historical shoreline maps to designate all Maryland shorelines as areas of sediment loss or gain. Existing geological information is being used to calculate the sediment types (sand, silt, and clay) available to the Bay through shoreline erosion. The Virginia investigators have also undertaken a sampling program to permit quantitative estimates of the volumes of sand, silt, and clay derived from corresponding areas of shoreline erosion. They have estimated that between 1850 and 1950, some 95 million cubic yards of sediments have eroded from lower Bay shores.

Sediment Budget

A sediment budget is basically a comparison of sediments entering the Bay and sediments leaving the Bay, to determine net gain or loss. Since the Chesapeake Bay acts like a sediment trap (sink), most of the sediments sink to the Bay bottom, resulting in a net gain.

Formulation of a budget for the Bay requires an inventory of the principal sediment sources and sinks and rates of deposition. The principal sources of sediment are:

--The tributaries.

--Erosion of shorelines.

--Sediments from the continental shelf entering through the Bay mouth.

--Decaying organisms.

Sediment Maps

Using results from this research, detailed maps of the Chesapeake Bay are being compiled to outline:

--Distribution of sediments by grain size.

--Sites of erosion and deposition.

--Carbon and sulfur content of sediments.

--Water content of sediments.

Once completed, the research will provide three major products:

--Information concerning the recent history of the bottom sediments of the Chesapeake Bay.

--Maps detailing the present sediment distribution of the entire Bay.

--A sediment budget, or an account of the sediment volumes entering the Chesapeake Bay from specific sources and an account of the deposition of these sediments.

Management Implications

The results of this research will help define the relationship between sediments and toxic substances in the Bay. At present, little is known about the paths that toxic substances follow once they enter the Bay. It is known, however, that toxic substances tend to cling to clay and other fine-sediment particles. Potential toxic "hot spots," or areas of toxic-chemical accumulation, may be predicted using information on sediment characteristics.

Understanding the general role of sediments as the site of toxic-chemical deposition, transformation, or uptake by organisms is a prerequisite to managing toxics.

Species of submerged aquatic vegetation, or Bay grasses, live on sediments suited to their survival. The habitats of bottom-dwelling organisms like clams and worms are also limited by the nature of the sediments. These baseline sediment studies will provide the data required to establish the connection between sediment types and organisms that live there. In particular, the data will be very important for those studying the recent decline of submerged aquatic vegetation.

This research will be useful to managers when addressing such issues as loss of land by erosion, filling in of main shipping channels, or the choice of suitable sites for disposal of dredge material. For example, areas of high natural deposition may be appropriate for the disposal of dredged material. Reestablishment of the natural biota is more likely if the sediment characteristics of the dredging and disposal sites are similar.

Water-content data from these studies will help determine how long it will take for dredged materials to dry out, a major consideration for managers.

Information on sediment characteristics, especially their distribution, may help identify potential shellfish habitats and aid managers who designate areas for shellfish harvesting and for the development of new oyster bars.

From the surface samples, the researchers have identified sediment types, including potential areas for sand and gravel extraction. In the future, such construction-aggregate mining may become an important economic resource in the Chesapeake Bay.

Another by-product of the field sampling of the lower-Bay study was a refinement of the LORAN C theoretical values. LORAN C, Long Range Aid to Navigation, is a radio navigation device used by air and sea pilots. LORAN C is also used by scientists to accurately locate sampling stations in a body of water. The researchers studying sediment properties in the lower Bay developed bias correction factors for the LORAN C theoretical values at 2,018 locations. The tabulated locations will now give other Chesapeake Bay scientists the ability to collect additional data from the same locations more accurately. The corrected values will also assist boaters and pilots in navigating with greater precision.

This summary highlights the research findings from two ongoing projects sponsored by the Chesapeake Bay Program: Chesapeake Bay Earth Science Study Sedimentology of the Chesapeake Bay (Maryland), Principal Investigator, Randall T. Kerhin, Maryland Geological Survey, and Baseline Sediment Studies to Determine Distribution, Physical Properties, Sedimentation Budgets and Rates (Virginia), Principal Investigator, John M. Ziegler, Virginia Institute of Marine Science.

This is one of a series of briefs, reports, research summaries, and final project reports designed to make available the findings, observations, and management implications of the Chesapeake Bay Program, a project of the U. S. Environmental Protection Agency. It is based on conversations with the principal investigators and on the final reports covering these projects.

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summary 2

EPA Chesapeake Bay Program Information Series

SAV Biostratigraphy of the Chesapeake Bay September 1980

Importance

Biostratigraphy is a method geologists use to analyze sediment layers and their fossil remains. By counting the numbers and kinds of fossils in each layer, scientists can identify changes in populations of animals and plants over time.

Aquatic organisms such as diatoms (microscopic, one-celled plants), pollen, and seeds of terrestrial and aquatic plants, are trapped and preserved in the layers of the Bay's sediments. These fossil remains represent a portion of the estuarine biota at the time of deposition. By analyzing these fossils, scientists can evaluate changes in biology and chemistry of the Chesapeake Bay and its tributaries, and thus, identify historic changes and trends in uses of the river basins.

Variations in species composition and in numbers of terrestrial pollen grains over time indicate changes in watershed uses, as well as how quickly sediment was deposited. Each species of flowering plant produces a distinctive form of pollen, and scientists can examine a pollen grain microscopically to determine which species of plant produced it. In a watershed, changes from high percentages of oak to ragweed pollen, indicate that the land has been cleared of forest.

Low concentrations of pollen in the sediment generally indicate high rates of sediment deposition. Historical records can date when these changes occurred, and scientists can then use the dated sediment layers, or horizons, to calculate sedimentation rates. Determining how quickly sediment was deposited at different times will provide a measure of turbidity and siltation, important factors affecting water quality at those times.

Changes in amounts and composition of diatom populations indicate changes in water quality, because diatoms will quickly respond to changes in nutrients, levels of turbidity, temperature, trace metals and other factors. Characterizing diatom populations at different times provides a record of changing conditions, such as progressive eutrophication (excessive nutrients) in the Bay.

Researchers at the Johns Hopkins University are currently using biostratigraphy to study changes in submerged aquatic vegetation (SAV) populations, eutrophication, and sedimentation rates in the Chesapeake Bay over long periods of time. They will examine historical records for dates of human activity and meteorological events to determine if population changes of

SAV, diatoms, and pollen coincide with periods of major human activities or natural disturbances.

This summary will highlight research to date of a research project headed by Dr. Grace S. Brush at the Johns Hopkins University. It is one of a series of publications describing Chesapeake Bay Program research.

Research Sampling Sites

The Johns Hopkins University researchers sampled three areas in the Chesapeake Bay--the Patuxent River, the Ware River and the Upper Chesapeake Bay (see Figure 1). The Patuxent and Ware Rivers were chosen, because other Chesapeake Bay Program scientists and engineers are currently studying these watersheds. Also, the Patuxent represents an area of intensive development, while the Ware River is a more pristine watershed; biostratigraphic data from these two regions would, therefore, provide valuable comparisons between the impact on water quality of different land uses. The Susquehanna Flats-Furnace Bay area in the Upper Chesapeake Bay was chosen because historically, this watershed has been intensively used for both farmland and industrial development. In addition, large populations of SAV once grew there.

Several sediment cores were taken at each of the three regions using a piston corer 5.4 cm (about 2 inches) in diameter and ranging in length from one to two meters. This device extracts cores up to 180 cm (70.9 inches) long.

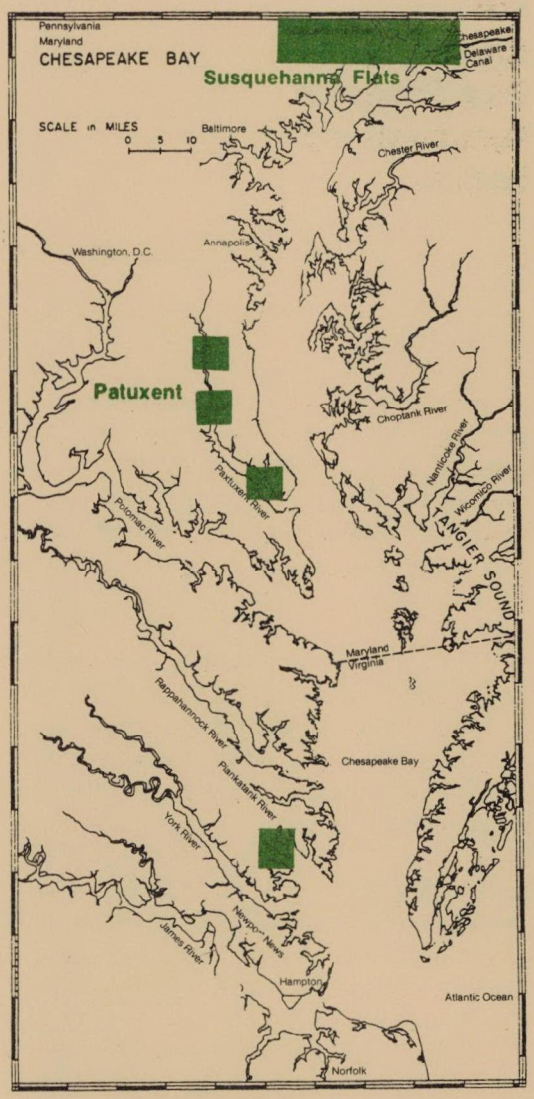


Figure 1. Sampling sites for sediment cores in the Chesapeake Bay.

Core Analysis

The scientists have completed their analysis of cores collected in the Furnace Bay region. They have nearly finished with the Patuxent cores and have just begun the Ware River sampling.

The core samples are analyzed in several steps. The core is split lengthwise; one side is for extracting seeds, the other for diatoms and pollen. The seed section is divided into small samples which are then soaked in dilute acid to break apart the sediment. The samples are then run through a series of sieves. The larger mesh sizes sort out the seeds, while the smaller-meshed sieves catch the residue. Scientists examine the residues to determine the coarseness of the sediment on which SAV grows.

The diatom/pollen sample is also divided into small sections, then weighed, dried and treated with chemicals. The chemicals break apart the sediment and isolate the pollen grains which are then counted and identified as to species. Generally, the fewer numbers of grains present, the greater the sedimentation rates in that area.

Scientists use a similar procedure to extract, count, and identify diatoms. An increase in numbers of diatoms usually indicates an increase in eutrophic conditions.

Figures 2, 3 and 4 illustrate the kinds of SAV seeds, pollen grains and diatoms found in the core samples.

Figure 2. Bay Grass Seed Fossils

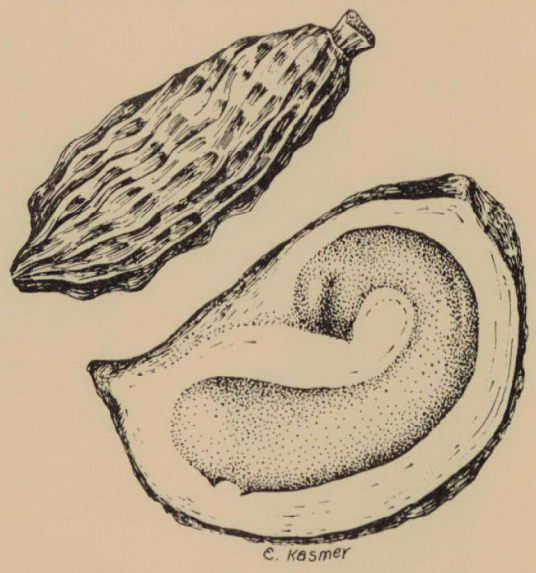


Figure 3. Pollen Grain Fossils

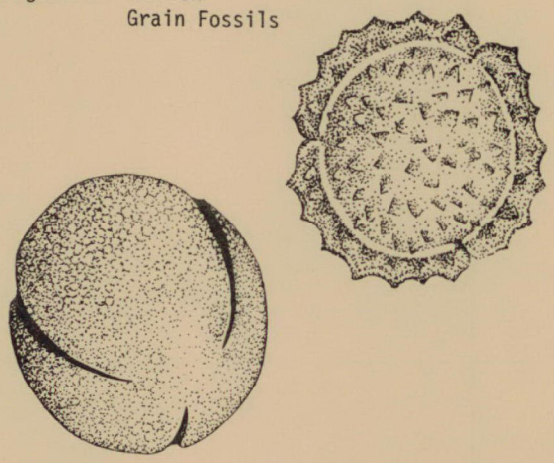
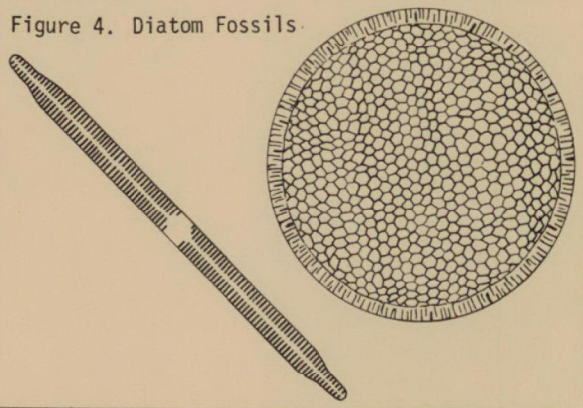


Figure 4. Diatom Fossils



Results

From analyses of the Furnace Bay cores, the Johns Hopkins team has constructed a graph (Figures 5-7) relating land uses from pre-settlement up to 1980, to populations of SAV and diatoms.

Figures 5-7 show that:

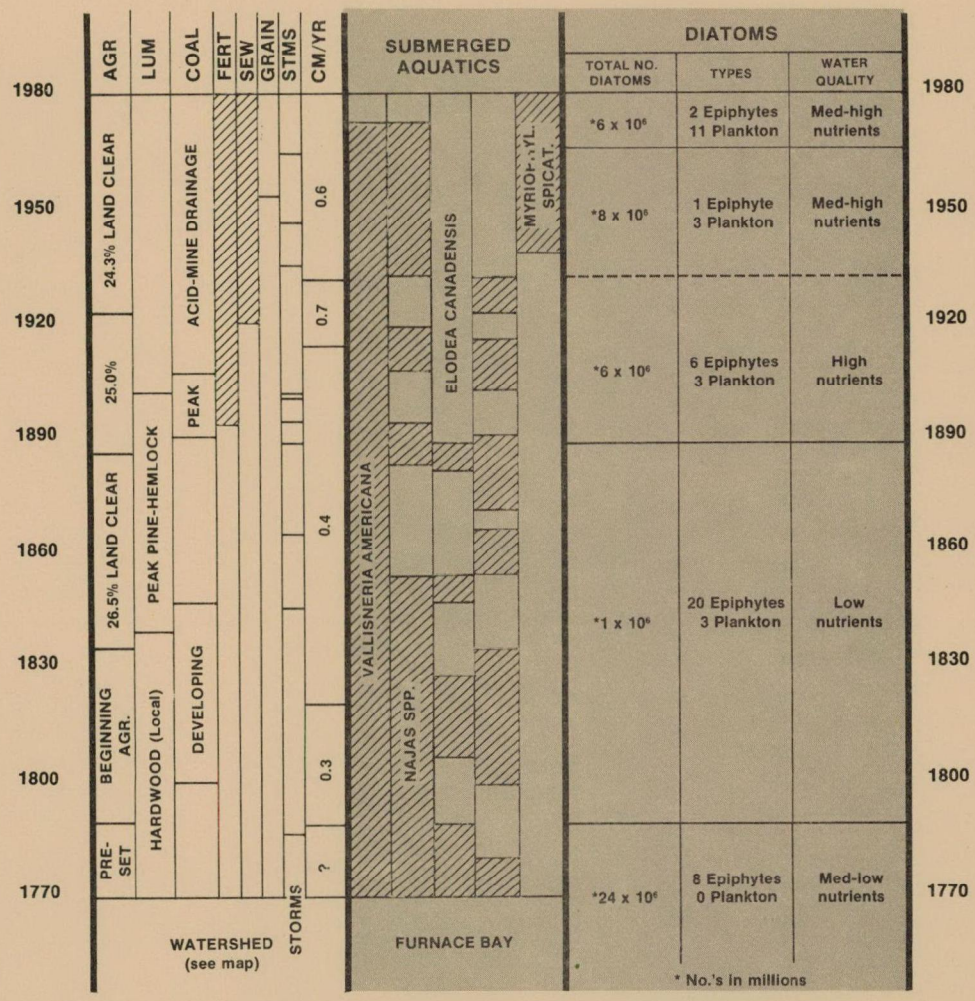


Figure 5. Furnace Bay: Effects of land use on SAV and diatom populations, showing watershed uses over time.

--SAV beds are continuous from before human settlement in the early 1800's up to the time of Hurricane Agnes in 1972.

--Some changes in SAV species accompanied settlement.

--SAV practically disappeared after Agnes

--Amounts of diatoms decreased 24 fold from before settlement to after settlement.

--The kinds of diatoms changed from those living attached to rocks or other plants (epiphytes) before settlement, to types living freely in the water (plankton).

--Diatom species changed from those preferring low nutrient levels to types preferring high nutrients by the early 20th Century.

Decreases in the amounts of both SAV and diatoms relates to the settlement of the land in the Upper

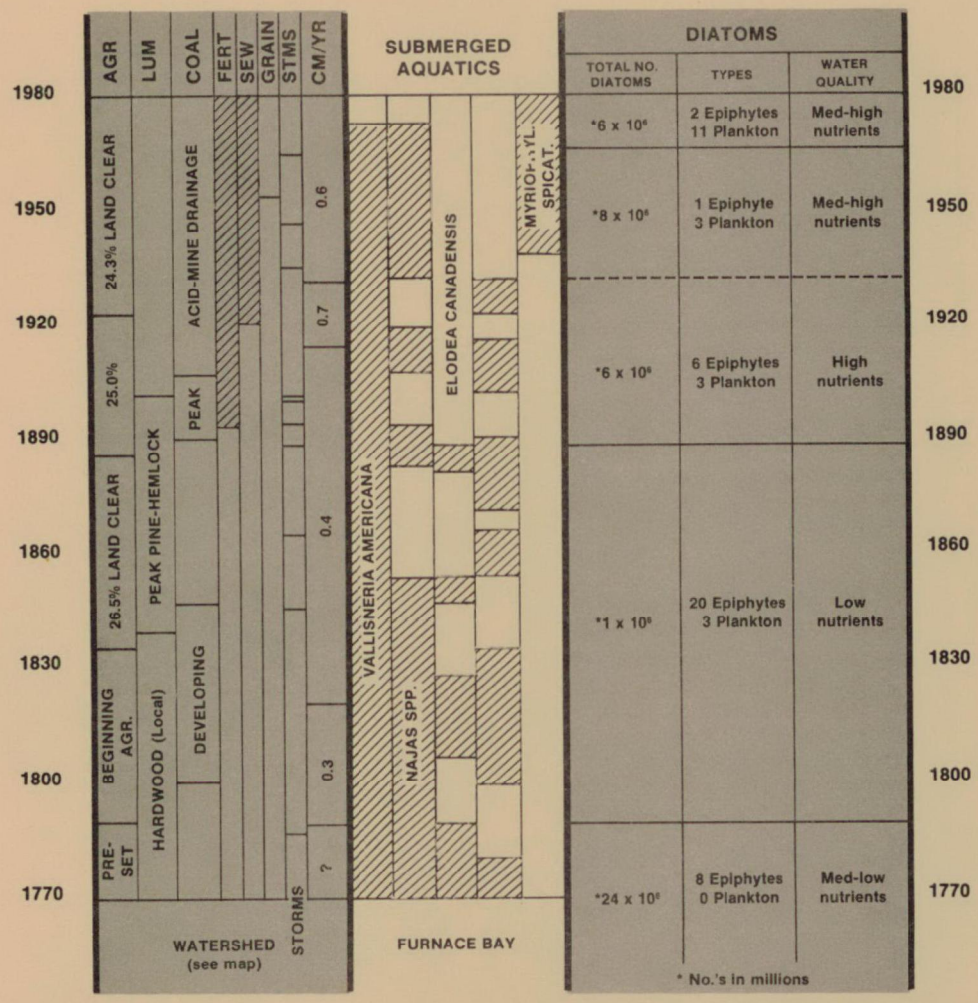


Figure 6. Furnace Bay: Effects of land use on SAV and diatom populations, showing changes in SAV populations over time.

Chesapeake Bay region. Land clearance in the early 1800's caused an increase in siltation in the water, resulting in less light available for plants to use in photosynthesis. This factor may have been the reason for the decline in numbers of diatoms after settlement, according to the Johns Hopkins researchers. Later, the numbers increased at about the time inorganic fertilizers were added to the watershed. The additional nutrients may have compensated for possible light-limiting conditions, thus allowing the populations to increase.

Hurricane Agnes caused the most disasterous change by wiping out SAV populations and causing a shift in the diatom populations to planktonic forms. The storm may have provided an avenue for toxics to reach the Bay or its plant life. Variations in the diatoms also suggest that the Upper Bay has become increasingly eutrophic with increased use of the watershed.

Management Implications

Continuous increased siltation, whether resulting from agriculture, lumbering or urbanization, can have

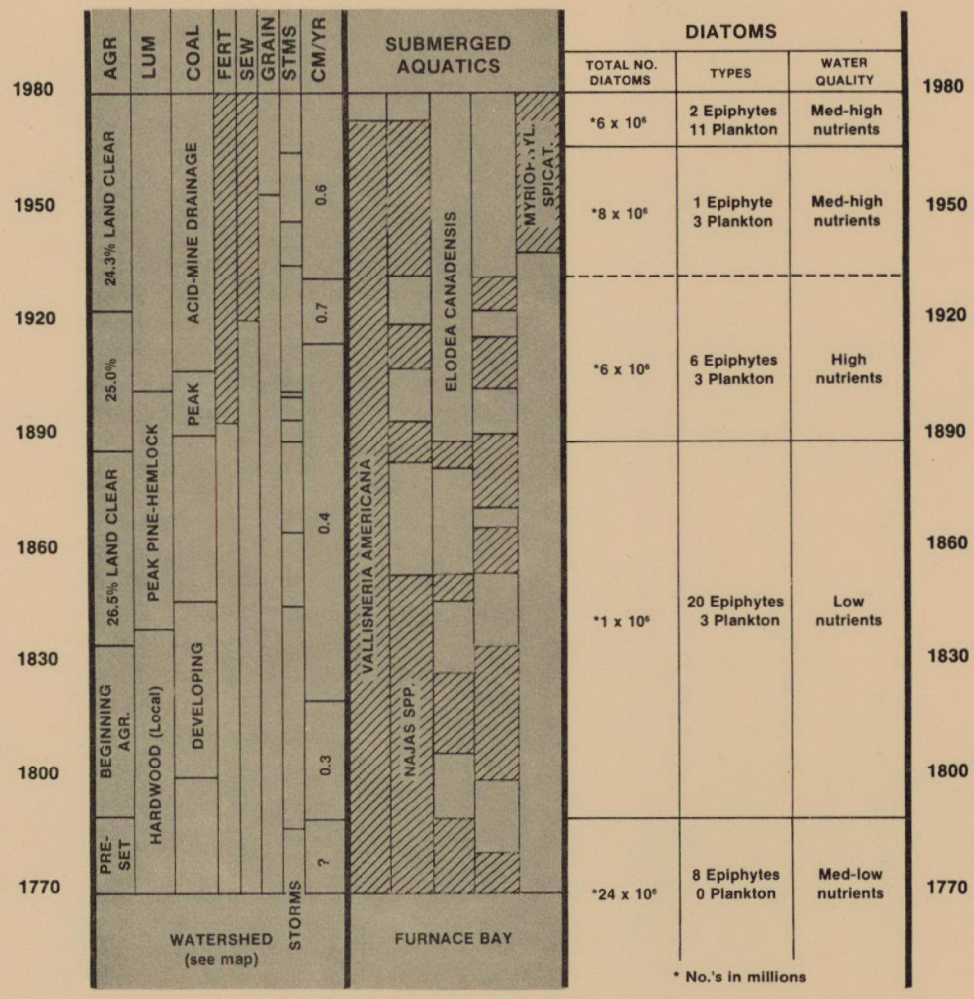


Figure 7. Furnace Bay: Effects of land use on SAV and diatom populations, showing changes in diatom populations over time.

profound (largely injurious) effects on water quality and biota. This research gives a unique, historical perspective on how water quality has been affected by human activity and natural disturbances in the past. Managers can use this information to suggest how future activities might affect the Bay's water quality.

Knowing the amounts of pollen and their distribution at certain times will not only indicate to managers what kinds of land uses can influence sediment transport, but will also help them estimate the rate and distance that sediment moves.

The changes in amounts and kinds of diatom populations in the Bay as they relate to past land uses indicate what conditions can contribute to increased eutrophication in the future.

This summary highlights the research findings from a project sponsored by the Chesapeake Bay Program; Biostratigraphy of the Chesapeake Bay and Its Tributaries, (Principal Investigator, Grace S. Brush, The Johns Hopkins University).

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summary 2

EPA Chesapeake Bay Program Information Series

NUTRIENTS

Circulation in the Chesapeake Bay April 1981

Importance

The addition of nutrients such as phosphorus, nitrogen, and calcium to water is a natural and healthful process. These organic and inorganic chemicals can enter the Bay from decaying plant and animal matter or from overland runoff and shoreline erosion. Living organisms in the Bay use nutrients for maintenance, growth and reproduction.

However, increased human activity can accelerate nutrient enrichment, turning lakes into swamps, stagnating bodies of water and harming organisms living there. The acceleration process is well understood in lakes, but has been little studied in estuarine systems.

Because nutrients largely affect the water quality of the Bay yet have been so little studied, EPA's Chesapeake Bay Program began a program to investigate nutrient enrichment in the Chesapeake Bay. One of the program's aims is to evaluate alternatives for controlling nutrient loading from the land. However, before control measures can be accurately assessed, the relationship between nutrients and water quality in an estuarine environment must be understood.

One important channel to understanding how nutrients affect water quality is to look at circulation in the Bay. Water circulation moves and distributes much material in this estuary, including nutrients. Patterns of water circulation control not only pathways of nutrients, but also the distribution of organisms relying on these chemicals. The quality of the Bay, in turn, can be measured in large part by the numbers and kinds of organisms living there.

Since circulation carries and distributes other constituents including pollutants and sediment, it has far greater implications for water quality than just nutrient enrichment. The Chesapeake Bay Program is developing a computerized model of circulation in the Bay. The model will simulate the circulation patterns described here, and thus, help discern some of the pollutant pathways in the Bay. Modeling water circulation and its implications for understanding water quality will be the subject of a future summary in the Chesapeake Bay Program's Information Series.

The Four Forces

Freshwater Inflow

One of the most powerful forces affecting circulation in estuaries is freshwater inflow. Most freshwater entering an estuary comes from precipitation that falls in the drain-

age basin. Fresh water reaches the tidal waters by streams and underground movement which run into rivers and eventually the estuary.

At the same time, saltwater from the mouth of the estuary flows along the bottom up toward the head, creating a characteristic gradient in salinity from the mouth (high salinity) to the head (low salinity). This flow pattern can be seen as a two-layered flow. The top layer contains less saline water which flows seaward; the bottom section is saltier, denser water with a tendency to flow up the Bay. The two layers are separated by an intermediate layer, the halocline, in which the increase in salinity is very abrupt (See Figure 1). This two-layered pattern forms saltwater fronts, or intrusions, which move up and downstream in response to river flow.

Zones of maximum turbidity are located where these fronts touch bottom (See Figure 2). In the upper Bay and upper tributaries the zones usually range from five to ten miles. These areas act as sediment traps where sediment particles washed in with freshwater settle into the lower layers and are then pushed back upstream by inward-flowing seawater. They are trapped and mixed around at the interface between fresh- and seawater, often causing the area to become turbid.

Because of the turbulent action, which brings rich bottom water up to surface layers, these zones can be very productive. Nutrients are mixed in these areas and become available to phytoplankton in the upper layers of the water. The turbulent action itself keeps phytoplankton suspended in the lighted zones of the water, allowing the tiny plants to use light in photosynthesis. Zones of maximum turbidity may, subsequently, represent important nursery grounds for many anadromous fish--striped bass,

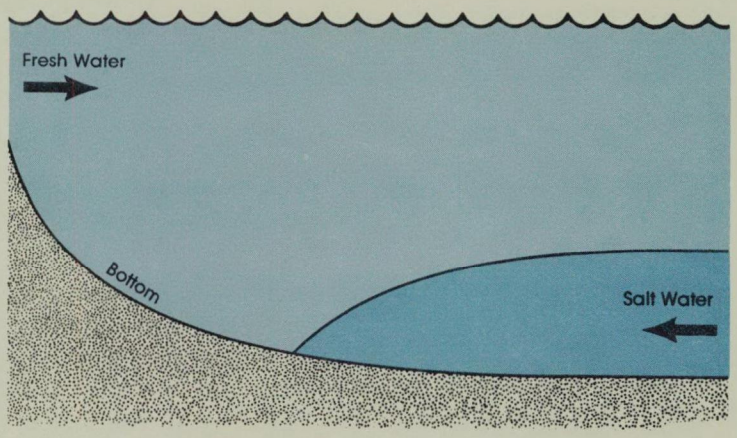

Figure 1. Two-layered flow pattern showing saltwater intrusion (dark blue area).

Figure 2. Zone of maximum turbidity. Area with arrows indicates where sediment is trapped and mixed.

herring and alewives, among others. If the location of these fronts is in some way altered by a change in freshwater inflow, the amounts of nutrients available, and hence the productivity of plankton, may be altered, possibly affecting the abundance and diversity of biota.

During the year, freshwater inflow fluctuates widely. The greatest inflow occurs in the spring from rainfall and melting snow. Stratification (layering) of an estuary is strongest at this time, while in the fall when inflow is weakest, no distinct layers may appear at all. A reduction in flow can change the two-layered circulation pattern by shifting the turbidity maximum zone upstream, thereby compressing spawn-

ing and nursery grounds. Stratification will also decrease resulting in greater mixing of salinity.

Inflow also varies within any season depending on rainfall or catastrophic events like storms. In 1972, Hurricane Agnes caused the Bay's tributaries to swell with floodwaters; over a third of the region received more than 12 inches of rain.[1] Most rivers crested at levels higher than previously noted in some 200 years of record, and flows in the Susquehanna alone averaged 15.5 times greater than normal.[2] Consequences on nutrient distribution and on other biota were drastic in the upper Bay, where Bay grasses all but disappeared.

Coriolis Effect

All things which move over the surface of the earth, whether birds, wind, rivers, bullets or rockets, slide from their appointed path to the right in the Northern Hemisphere, to the left in the Southern Hemisphere. This sidewise drifting is called the Coriolis Effect, named after the 19th century mathematician G.G. Coriolis, who made the first complete analysis of it. The effect is caused by the clockwise rotation of the earth.

In the Bay, the effect shows its power by moving salt water from tidal action slightly to the eastern side. Saltwater thus hugs the Eastern Shore, while freshwater flows seaward close to the Western Shore.

Figures 3 and 4 show how the Coriolis effect influences patterns of salinity in the Bay. This type of flow pattern has implications for the distribution of plants and animals which require different salinities in their habitats.

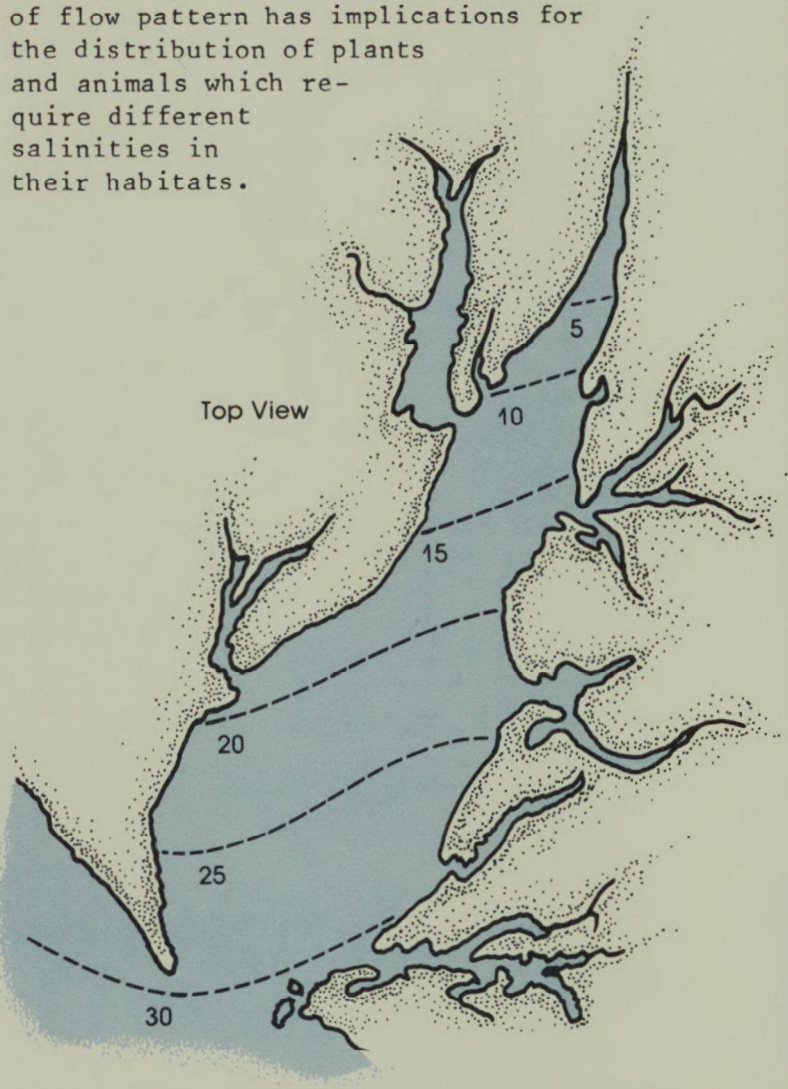

Figure 3. Salinity patterns in a shallow estuary altered by the Coriolis effect. The numbers correspond to concentration of salts in the water, expressed as parts of salts per thousand parts of water (ppt). Seawater is about 35 ppt or 3.5% salts.

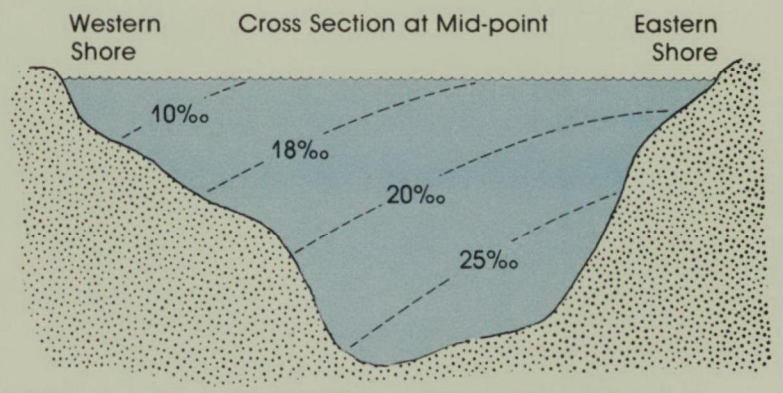

Figure 4. Cross section of an estuary showing effect of Coriolis force on isohalines (locations in the water where the salinity is equal).

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1. Impact of Tropical Storm Agnes on Chesapeake Bay. Baltimore District, Corps of Engineers, Dept. Army, March 1975. p. 9.

2. Impact of Tropical Storm Agnes on Chesapeake Bay. Baltimore District, Corps of Engineers, Dept. Army, March 1975. p. 11.

Wind

The greatest effect of wind on estuarine circulation is seen in day-to-day wind patterns. Wind pushes water, thereby imposing mixing patterns of the water, especially in shallow estuaries such as the Chesapeake Bay. On the Bay, prevailing winds are westerly. Since the Coriolis effect will deflect moving water to the right going up the Bay, these two forces together push water generally eastward. The wind shows its greatest power where the estuary is less sheltered and wider.

Wind also works together with barometric pressure which depresses or raises the level of surface water on the Bay. These two forces influence the nature of the classic two-layered circulation by occasionally causing a flow reversal. The forces of wind and barometric pressure changes may produce complex internal waves. These waves or oscillations may be important in contributing to vertical mixing, churning up nutrients from rich bottom waters.

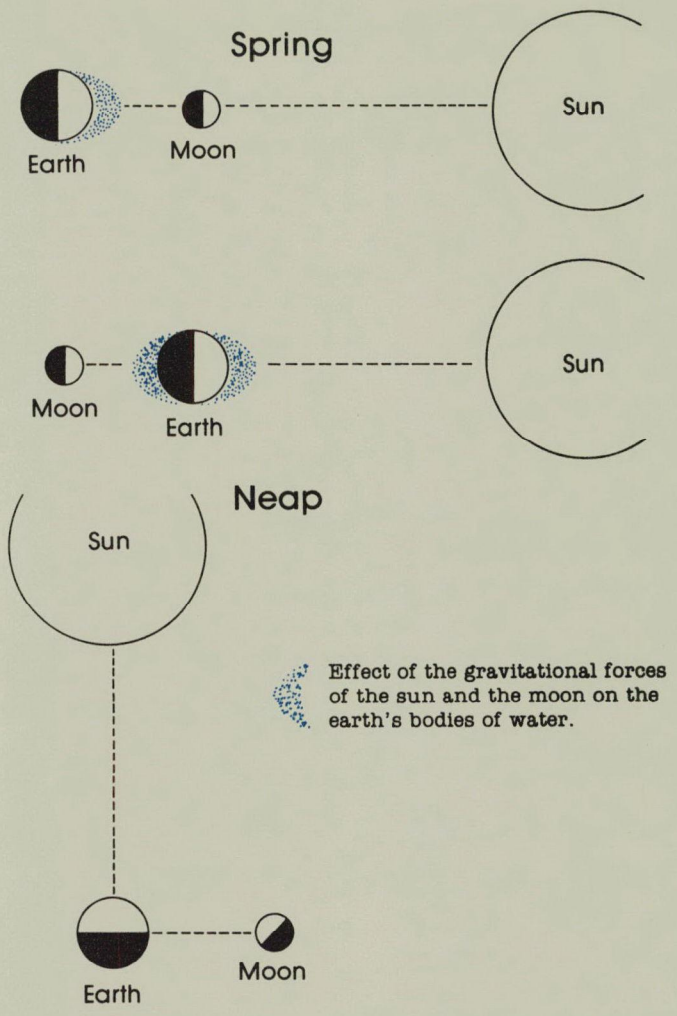


Figure 5. Location of the sun and moon relative to the earth during spring and neap tides. Dark area represents shadowed parts of the moon and earth.

Tides

Tides are waves with a length of about half the circumference of the earth (23,300 km, 12,600 miles) and are caused by the gravitational attraction of the sun and moon on the earth. The attraction is strongest on the side of the earth facing the moon, causing the water on that side to bulge out and be pulled toward the moon. The sun also exerts tidal influence on the seas, although the bulge is smaller, because the sun is so much farther away.

The effect of the sun becomes especially important when the sun and moon are lined up with the earth (See Figure 5). The combined gravitational attraction produces a very strong tide, called the spring tide. It occurs about every 14 days at new and full moon. Neap tides, or tides with ranges lower than normal, occur when the sun and moon are at right angles to each other, also about every 14 days.

In an estuary such as the Bay, daily tides could affect stratification, slightly altering circulation patterns. A flood tide will push the salt water intrusion further upstream in the upper Bay and tributaries than an ebb tide . Spring and neap tides emphasize these fluctuations; while a spring tide decreases stratification, a neap tide increases stratification.

Seasonal Circulation in the Chesapeake Bay

Seasons in the Chesapeake Bay are noted by important changes in circulation. Freshwater inflow, one of the four forces driving circulation, almost entirely on its own causes these variations. Changes are reflected primarily in salinity and are revealed at zones of maximum turbidity and in the two-layered flow.

Figure 6 is a map of the Bay showing zones of maximum turbidity and areas where the two-layered flow would most likely be susceptible to seasonal changes. The rivers on the Western Shore contribute most of the freshwater to the Bay. During the month of March, these rivers together contributed an average of 160 thousand cubic feet per second over a 16 year period according to a 1968 U.S.G.S. report (See Figure 7). This number is about 80 times greater than the same contribution during September.

How does this massive difference in freshwater inflow during the spring affect circulation? In the major rivers on the western side of the Bay stratification increases, and the water will exhibit a more obvious two-layered flow with a distinct halocline. The zone of maximum turbidity will shift downstream, widening spawning grounds in those rivers. However, at the same time, vertical mixing decreases, limiting the availability of nutrients and oxygen to the water column. Productivity will begin to decrease and continue throughout the summer.

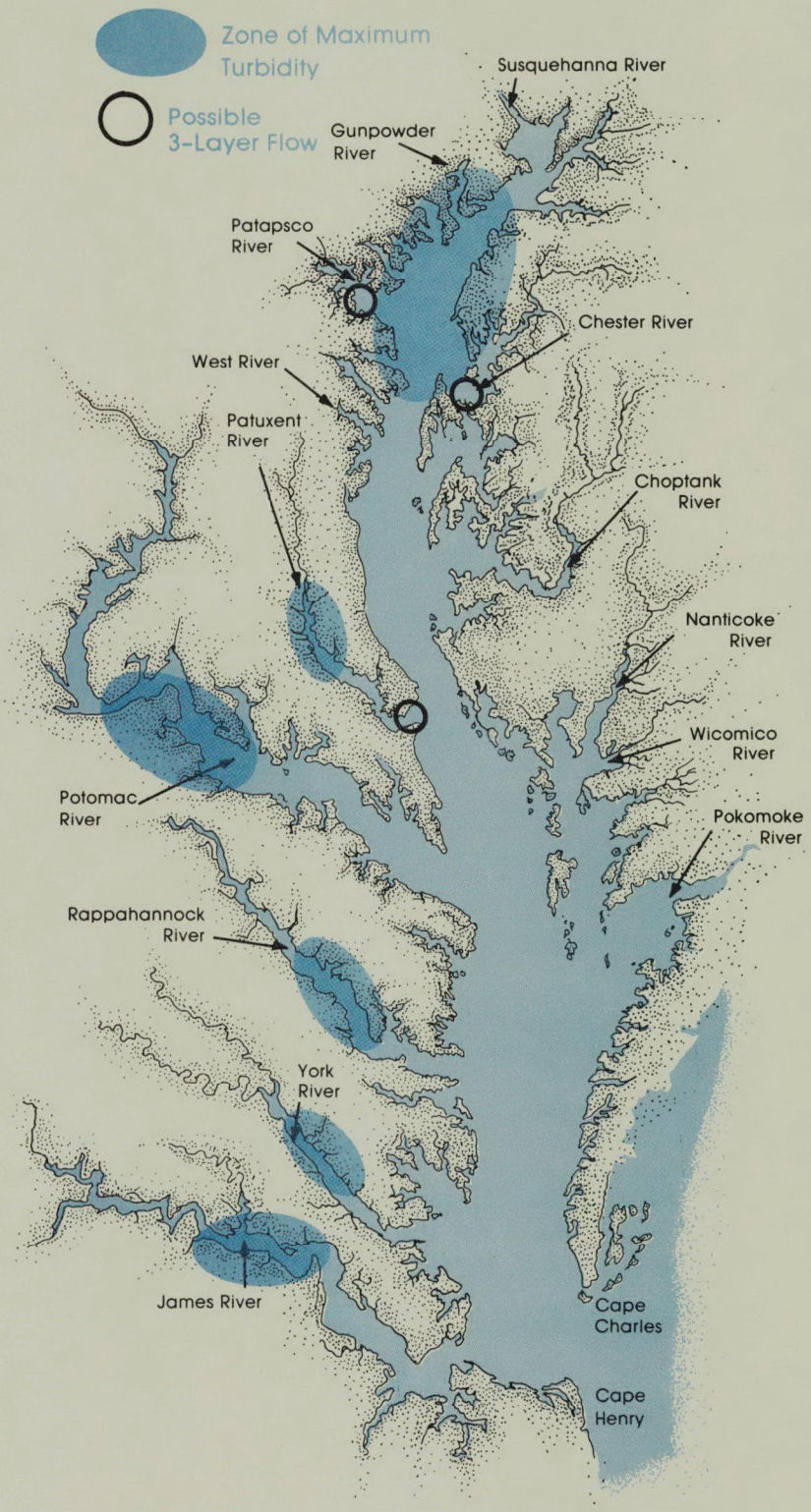
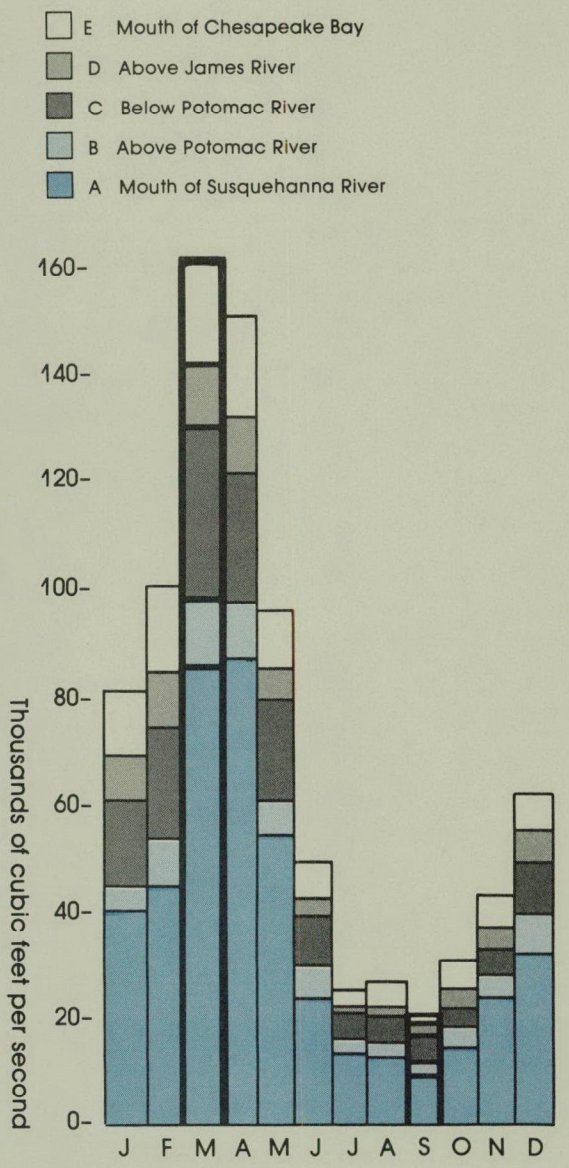


Figure 6. Areas of maximum turbidity and where three-layered flow in the Bay is possible.

Certain parts of the northern tributaries closest to the Bay may exhibit a three-layered circulation pattern at their mouths if the freshwater inflow is great enough. Water from the Susquehanna River, for example, can cause this type of flow pattern in Baltimore Harbor (See Figure 8). In this situation, freshwater from the river flows into



Source: Monthly Surface Water Inflow to the Chesapeake Bay, USDOI, Geological Survey, Water Resources Division, Arlington, VA, October 1968, by Conrad D. Bue

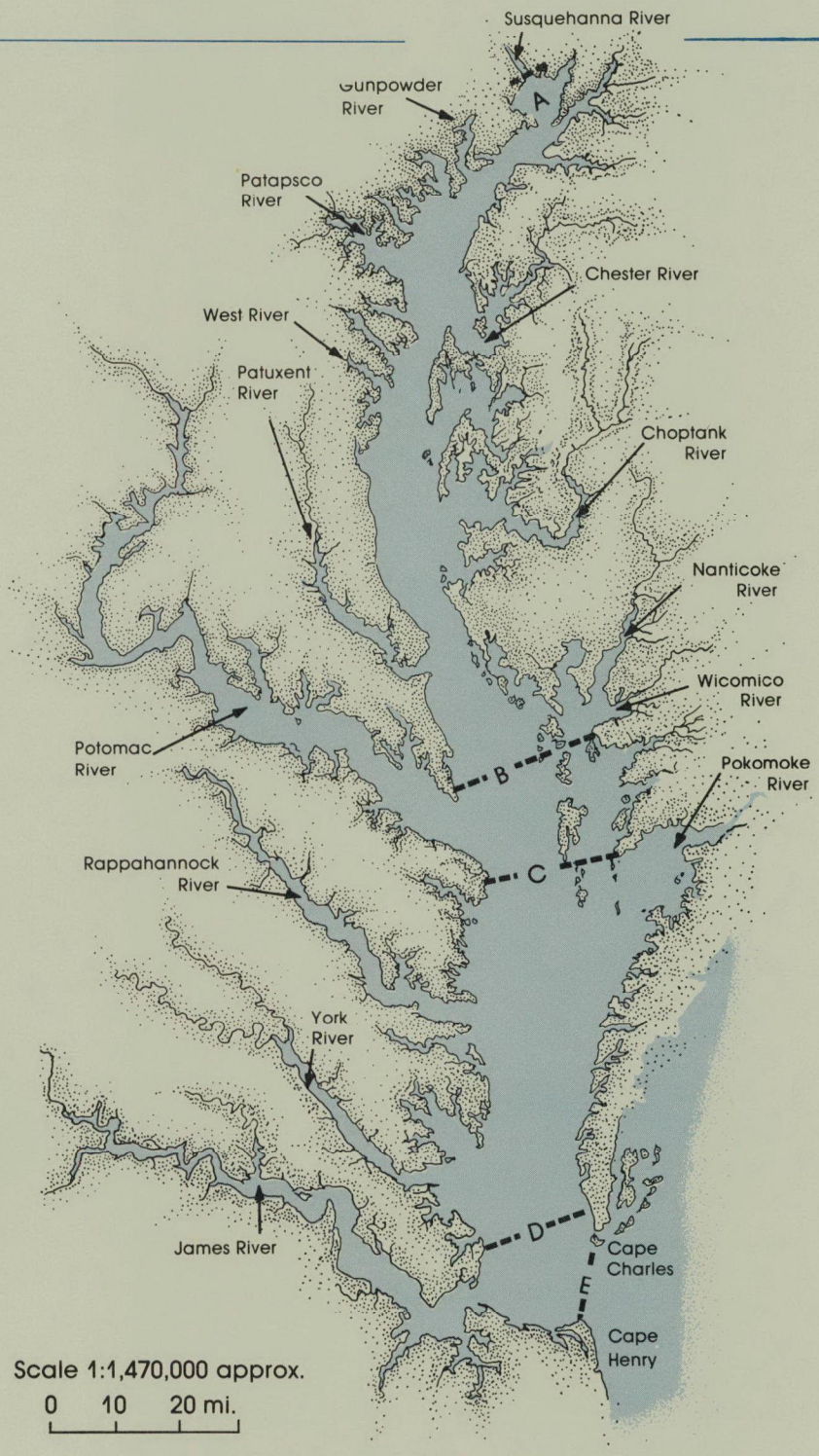


Figure 7. Typical seasonal freshwater inflow showing relative input at various locations in the Bay.

the Harbor in an upper layer, looping outward via a middle section. Because flushing action from this pattern is very slow, Baltimore Harbor can act as a sink, trapping material within it.

During the autumn, freshwater inflow, barring storms, is drastically lower. Zones of maximum turbidity shift upstream, narrowing spawning grounds as well as reducing the amount of water over spawning beds.

Partly for this reason, most of the Bay's anadramous fish travel upstream to spawn during late winter and early spring. Vertical mixing also increases during the fall, and more nutrients and oxygen become available to enrich the water column.

The seasonal circulation patterns described here, and the resulting effects on nutrients are natural fluctuations. Accelerated enrichment from human activity has unknown effects on these intricate interactions. Studying circulation will help us understand the pathways and effects of pollutants, and thus, what limits we may have to impose on sources contributing pollutants to the Bay.

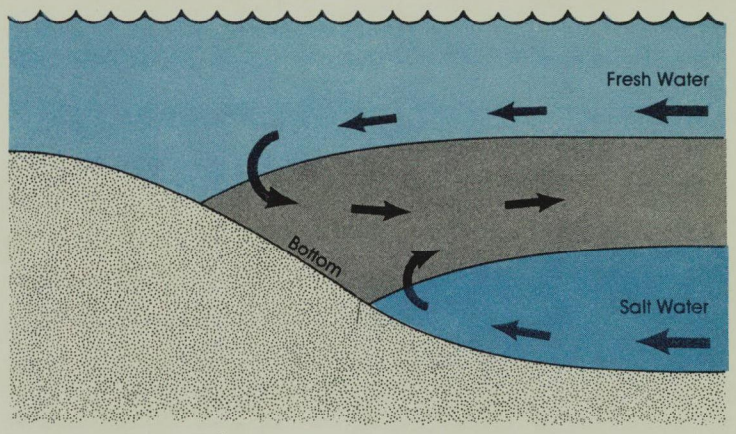


Figure 8. Three-layered flow pattern showing a freshwater upper layer and salty lower layer flowing inward and flushing outward through a middle, brackish layer.

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summary 2

EPA Chesapeake Bay Program Information Series

Toxics
Sediment-Animal Relationships

August 1980

Importance

The sediments of the Bay contain a variety of nutrients, minerals, decaying organic matter, and, possibly, toxic chemicals. The benthic, or bottom-dwelling, organisms mix these sediments, much as earthworms mix the earth of a flower garden. Such organisms play a vital role in the exchange of materials, including toxic compounds, within the sediments and between the sediments and Bay waters. To better understand the complex relationships between sediments and the organisms that inhabit them, two of the organizations sponsored by the Chesapeake Bay Program are conducting companion studies in Maryland and Virginia. This research summary, which is one of a series of publications describing Chesapeake Bay Program research, presents the preliminary findings of these sediment-animal studies.

Research

The main objectives of the research are to:

--Investigate the diversity and abundance of benthic organisms and the types of sedimentary structures, such as burrow tubes, that they create.

--Determine the relationships among species of organisms found, sediment types, and pollutant concentrations.

--Diagram in three-dimensional fashion the benthic environment, to illustrate the distribution of benthic organisms and their mixing operations.

--Assess the impact of the benthic animals on the exchange of materials, in particular toxic materials, between the sediment and the water.

Box-core samples, which provide a glimpse of the vertical profile of the benthic environment, were collected at 65 Bay-wide sampling sites, 25 in Virginia and 40 in Maryland. Once these samples were taken, the box cores were dissected, and radiographic (x-ray), biological, grain-size, and carbon analyses were done. From these analyses, several observations have been made.

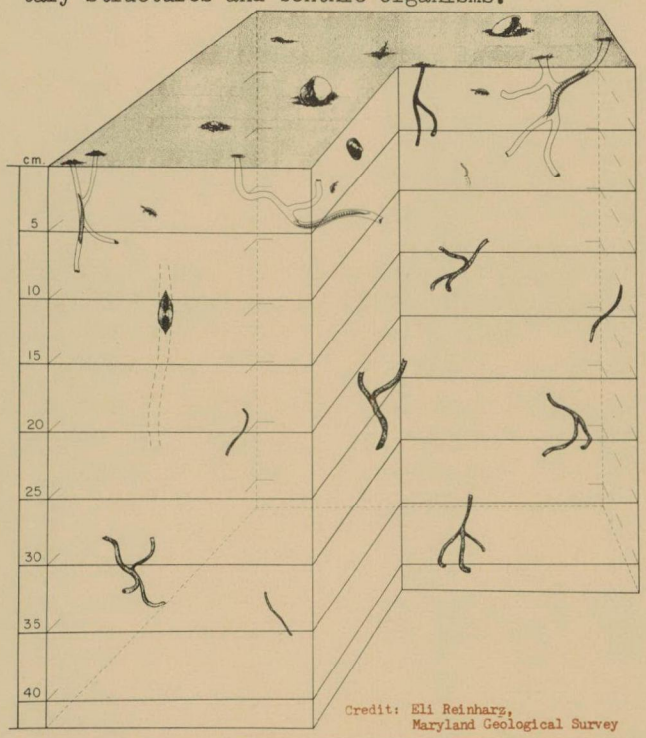
The Virginia researchers found benthic organisms in sediment as deep as the longest box cores collected (24 inches or 60 centimeters). However, animals are seldom found deeper than 12 inches (30 cm.). This finding suggests that benthic organisms mix surface sediments into deeper layers that were deposited up to 100 years earlier, depending on local sedimentation rates and depth of burrowing. Most organisms are concentrated in the upper few centimeters of sediment. Differences in densities and vertical distributions

of organisms were found between sampling periods, reflecting characteristic seasonal fluctuations. A microscopic examination of sediment particles was also undertaken to describe and quantify their form and size, and to determine the presence of organic carbon and sulfur.

The radiographic analysis identified the organisms responsible for the structures observed. Examples of the organisms identified include bloodworms and other polychaetes, molluscs, and certain crustaceans.

Information collected is used to construct three-dimensional drawings to represent the sediment community. Specific organisms and their burrow systems will be illustrated to show the diversity of sedimentary structures. An example of a three-dimensional drawing is presented in Figure 1.

Figure 1. Three-dimensional diagram of sedimentary structures and benthic organisms.



Credit: Eli Reinharz, Maryland Geological Survey

Data on depth distribution, feeding types, and habitat preference of common organisms found in the box cores are presented in Table 1. The wide range of species' characteristics indicates the variety of niches in the sediment community.

Preliminary results of the projects show that:

--Biologic activity in the bottom sediments is much reduced in high-energy environments, such as the near-shore, because of wave and current action.

--From the Susquehanna Flats to the mouth of the Bay, a gradual increase in numbers of biogenic structures is observed. As salinity increases, there is a corresponding increase in the number of types of organisms in the sediment.

--In deeper areas of the Bay, few burrows and tubes were found, because deeper areas of the Bay lack oxygen at certain times of the year.

--The density of organisms and the diversity of sedimentary structures are reliable indicators of chemical exchange rates between the sediment and the water.

--Benthic animals inhabit Chesapeake Bay sediments to at least 24 inches (60 cm); however, most organisms are located in the top 4/5 inch (2 cm).

--The density of organisms and their vertical distribution change seasonally. These fluctuations significantly affect the distribution of chemicals in the sediments.

TABLE 1. Characteristics of Some Benthic Organisms Found in the Chesapeake Bay

	Depth Distribution	Feeding Type	Sedimentary Structures	Habitat Preference
Mollusks				
Busycon carica (Whelks)	surface to 1.2 in. 3 cm	carnivore	furrows left from plowing action	sand-higher salinities
Anadara transversa (small non commercial salt water clam)	surface	feeds on suspended plants and animals in the water	obvious fecal pellets, sometimes left in piles	euryhaline (a wide range of salinities) silty clay to medium sand
Macoma balthica (Baltic macoma) small non commercial salt water clam)	0-8 in. 0-20 cm	selective bottom feeder, or suspension feeder	fecal pellets - 5.84 kg sed/m^2	all sediment types but prefers finer types
Annelids (segmented worms)				
Clymenella torquata	0-10 in. 0-25 cm	sub-surface selective bottom feeder	vertical sand tubes for transport of O_2 and food - 168.5 liters/m^2/yr	silty fine sand to medium sand
Loimia medusa	0-16 in. 0-40 cm	selective bottom sediment feeder using tentacles on surface	U-shaped sand tube	fine sediments
Nereis succinea (bloodworm)	0-6 in. 0-15 cm	omnivorous forager, non-selective bottom sediment feeder	burrower, producing fecal mounds	wide range
Pectinaria gouldii	0-2.4 in. 0-6 cm	selective sub-surface feeder using tentacles to sort food	mobile tube dweller, carrying tube along with it - reworks 6 g sed./worm/day	silt-fine sand
Crustaceans				
Ampelisca abdita (amphipod)	0-1.2 in. 0-3 cm	selective surface feeder using antennae to scrape along surface	tube dweller whose numbers can become so great as to stabilize sediment, increasing the sedimentation rate	fine sediments
Upogebia affinis (mud shrimp)	0-8 in. 0-20 cm	suspension feeder	burrower	muddy sand

Adapted from: Borsch, D.F. and Karl J. Nilsen, "The Biogenic Structure of Chesapeake Bay Sediments" EPA Chesapeake Bay Program, Trimester Report - 15 September 1979

--The greater the abundance and diversity of biogenic structures, the greater the exchange rates between bottom sediments and water will be.

In summary, the information gathered to date from these projects has resulted in knowledge concerning:

--benthic community structure.

--seasonal variations.

--variability of sedimentary structures down the Bay, down the sediment column, and between sediment types.

--sedimentary structures produced by each species.

Management Implications

This project will provide information on the relationship between benthic organisms and toxic materials in sediments, in addition to particle size, sediment type, organic and total carbon, sulfur, and water-content correlations.

The information gathered may identify sites where toxic materials are being mixed throughout the sediments. Since benthic organisms cause vertical mixing, they can distribute toxic substances that have settled on the bottom throughout the sediments and back into the water column.

In general, the animal-sediment studies will provide basic information that may aid in the development of toxic-substances policies. For instance, the identification of areas with potentially high toxic-chemical content would be useful in designating areas for commercial shellfish operations. Knowledge of the estuarine environment of the Bay bottom would also help assess the impact of dredge material disposal on benthic communities. Care samples with no benthic animals or sedimentary structures, for example, might point to a dead area, which may have been harmed by dredge material, or a core full of benthic animals and structures from a once dead area would indicate where communities have recolonized.

These kinds of data provide a basis for future comparisons of the distribution and abundance of benthic organisms. Such population trends may serve as an important indicator of the Bay's health.

This summary highlights the research findings from two ongoing projects sponsored by the Chesapeake Bay Program: Chesapeake Bay Earth Science Study - Animal-Sediment Relationship (Maryland) - (Principal Investigator, Dr. Owen P. Bricker, Maryland Geological Survey) and The Biogenic Structure of Chesapeake Bay Sediments (Virginia) - (Principal Investigator, Dr. Donald F. Boesch, Virginia Institute of Marine Science).

This is one of a series of briefs, reports, research summaries, and final project reports designed to make available the findings, observations, and management implications of the Chesapeake Bay Program, a project of the U. S. Environmental Protection Agency. It is based on conversations with the principal investigators and on the final reports covering these projects.

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SAV

Light and Decline
of Bay Grasses
August 1981

Importance

Survival of submerged aquatic vegatation (SAV) in the Bay relies largely on the availability of light. Unlike their terrestrial neighbors, these aquatic plants are submerged in a watery medium which dissolves, suspends, transports, and deposits a wide assortment of substances. The dissolved and suspended materials reflect and absorb light as it passes through the water prior to reaching the plant. In comparison to land plants, then, SAV receives limited amounts of light, making light a major factor in controlling its growth and distribution. This requirement is why SAV lives primarily in the shallow waters of the Bay.

Ordinarily, sunlight is the source of energy for photosynthesis, the process in plants during which carbon dioxide and water combine to form glucose, releasing oxygen as a product. Light from nearly all of the radiant energy spectrum (x-ray to infrared) is effective in photosynthesis. Leaves commonly absorb about one half of the total radiant energy to which they are exposed (including about 80% of the visible light), but only a small fraction of the absorbed light energy is changed by photosynthesis into potential chemical energy for the production of food. Thus, the efficiency with which SAV utilizes the quantities of light is very important to its survival.

Fluctuations in populations of Bay grasses have always existed; but radical declines of all species in the early 1970's brought attention to these valuable grasses and led to intensive studies by researchers in both Maryland and Virginia under the U.S. Enivronmental Protection Agency's Chesapeake Bay Program. Part of the Program's research has focused on causes of the decline including climatic changes, light reductions, and increased herbicide usage. Because of the important role light plays in the growth of Bay grasses, several studies on light are being conducted. By understanding how light and other environmental factors control the growth and survival of SAV, scientists can understand the underlying factors causing populations to fluctuate. Effective management programs to improve detrimental conditions, such as reduced light availability, can then be implemented.

This research summary is one in a series of publications describing Chesapeake Bay Program research. It highlights research projects to date by W. Michael Kemp, et al., at University of Maryland's Horn Point Laboratory and Chesapeake Biological Laboratory, Robert L. Wetzel, et

al., and Robert J. Orth, et al., at the Virginia Institute of Marine Science in Gloucester Point, Virginia.

Research

Scientists in the Bay area have suggested that reduced light conditions could be partly responsible for the recent decline in SAV. These researchers are conducting several studies on how the quantity of light affects growth of SAV. Three reasons for reduced growth of SAV are:

1. SAV is very sensitive to light.

2. Suspended solids (turbidity) reflect light.

3. Colonies of epibiota (filter-feeding plants and animals) on leaves reflect light.

1. Sensitivity Experiments

To test the first hypothesis, researchers at the University of Maryland's Horn Point Laboratory conducted experiments on two dominant species of SAV, Potamogeton perfoliatus (redhead grass) and Myriophyllum spicatum (Eurasian watermilfoil). The plants were rooted in styrofoam cups containing estuarine sediments and grown in chambers. See Figure 1. Each chamber was covered with a shroud of different combinations of screens, allowing the researchers to simulate a wide range of light conditions--from 8.8 to 100 percent of incident light (light that falls on something). Outdoor measurements were made using a similar setup. Hourly rates of photosynthesis were estimated by measuring changes in concentration of dissolved oxygen, a product of photosynthesis, in the tanks.

Responses to varying quantities of light by the two SAV species followed a hyperbolic curve (shown in Figure 2) where with increasing light, photosynthesis rapidly increases, then levels off. The saturation level, the quantity of light at which the plants approach their maximum photosynthetic capabilities, begins for both species at about 600 microeinsteins (a unit measuring light quantities). But at this point, watermilfoil produced more oxygen, at nearly four milligrams of oxygen per gram of plant per hour (4 mg O_2(g plant)$^{-1}h^{-1}$), compared with three mgO_2(g plant)$^{-1}h^{-1}$ for redhead grass. Thus, watermilfoil shows greater photosynthetic capabilities and would probably survive better in low light conditions. The steep, initial slope of both curves shows that a slight change in quantity of light causes a large change in photosynthetic rate, indicating that

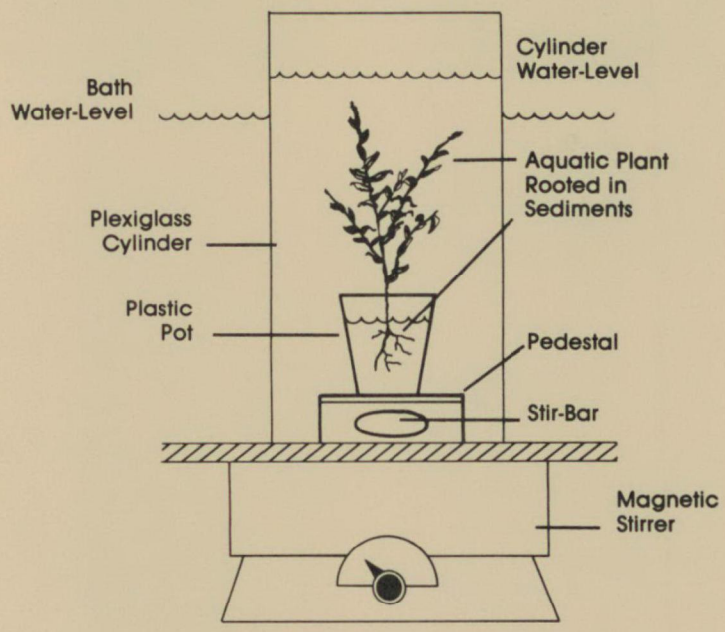

Figure 1. Diagram of experimental chamber for measuring light-manipulated rates of photosynthesis. Several of those cylinders sit in a water bath.

Source: Kemp, W. M., J. C. Stevenson, W. R. Boynton, and J. C. Means, Submerged Aquatic Vegetation in Chesapeake Bay: Its Role in Bay Systems and Factors Leading to its Decline. U. S. Environmental Protection Agency, Chesapeake Bay Program. Cooperative Agreement No. R805932, February 1981.

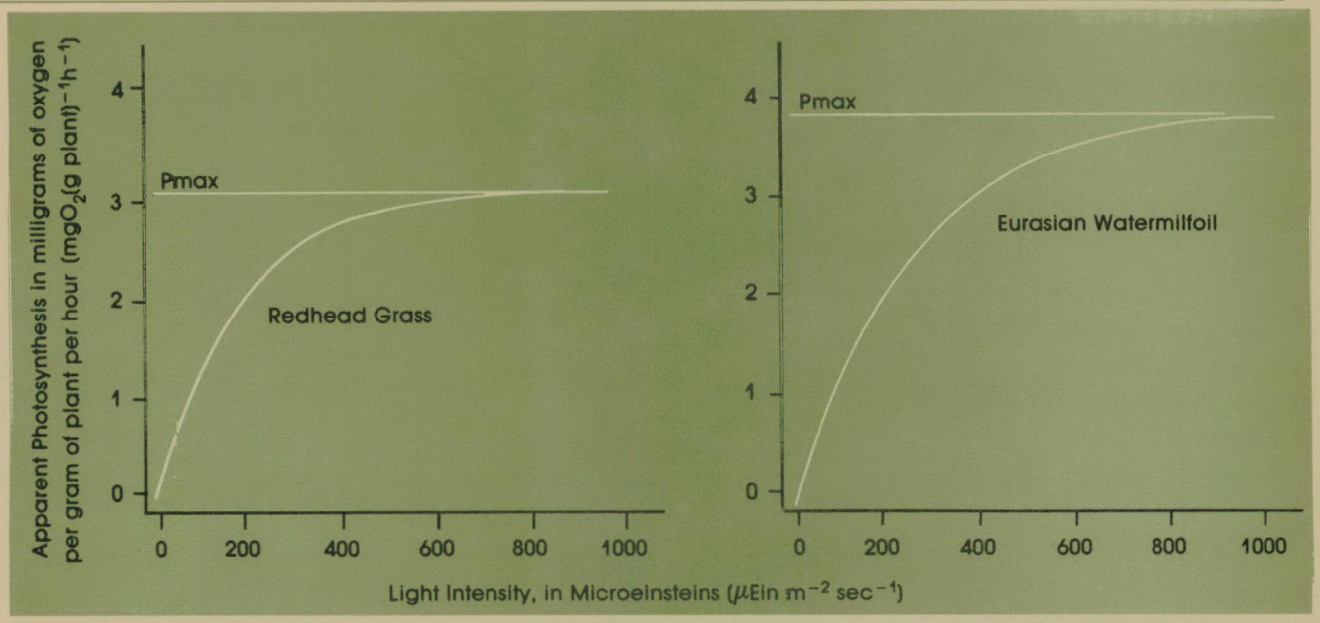

Figure 2. Photosynthetic responses of two submerged grasses to changing light conditions.

Source: Kemp, W. M., J. C. Stevenson, W. R. Boynton, and J. C. Means, Submerged Aquatic Vegetation in Chesapeake Bay: Its Role in Bay Systems and Factors Leading to its Decline. U. S. Environmental Protection Agency, Chesapeake Bay Program. Vol. 1 Cooperative Agreement No. R805932, February 1981.

these two species are very sensitive to decreases in light levels.

At the Virginia Institute of Marine Science (VIMS), similar baseline experiments on light levels are being conducted in the field using plexiglass dome enclosures. (See Figure 3). By monitoring the dissolved oxygen concentrations in each dome scientists can calculate the oxygen production and thus, the photosynthetic rate of an entire SAV community. Researchers have begun

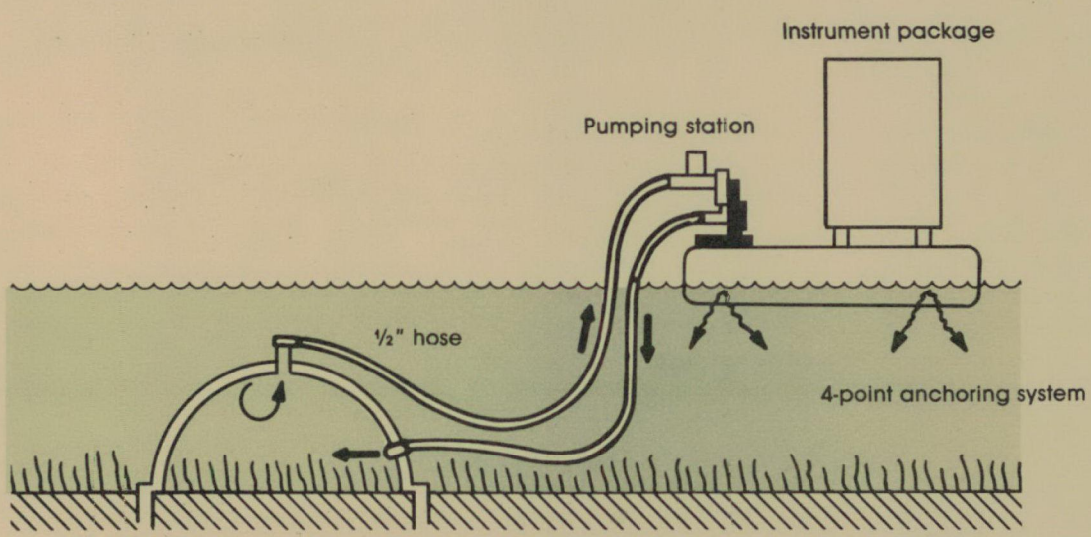

Figure 3. Dome enclosure used to measure photosynthetic rate in SAV communities.

Source: Robert J. Wetzel, Virginia Institute of Marine Science

shading experiments with these domes, aiming to determine how sensitive whole communities are to light levels. Their results will appear as curves, similar to those done by the researchers at Horn Point, but will show photosynthetic capability for communities composed of more than one species.

2. Turbidity Experiments

The direct effects of turbidity on plant productivity were examined by Horn Point researchers. Eelgrass populations were grown in aquaria using natural estuarine water and sediments under fluorescent lights. The researchers added high and low doses of sieved sediments to the colonies of eelgrass. Each day dissolved oxygen was measured at dawn and dusk, and before and after sediment treatments.

Figures 4 and 5 show the results of this experiment. Figure 4 shows the effects of sediment addition on light availability, with nearly twice as much light available in the untreated systems. The control systems (with just circulating water), as the upper line in Figure 5 shows, were also much more productive than either the low or high dosed colonies. The similar responses (lower lines in Figure 5) of the plants to both low and high doses of sediment show a nonlinear response, suggesting that plants are very sensitive to a little turbidity, and that after a certain concentration continued introduction of sediments does not further reduce plant production. Using mathematical equations, the scientists project that an increase in turbidity from 20 to 100 milligrams per liter could cause a 50 percent reduction in available light at 0.5 meter depth. Such drastic increases in turbidity are known to occur within hours following a widespread storm.

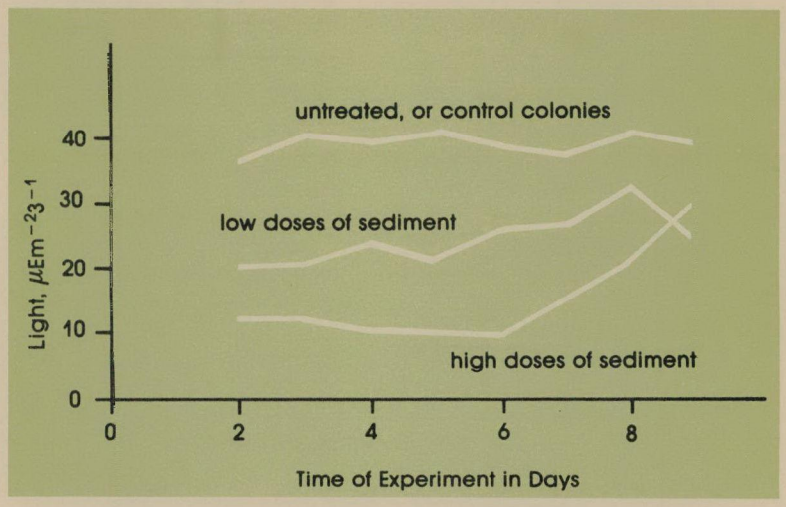

Figure 4. Effects of sediment on availability of light to SAV.

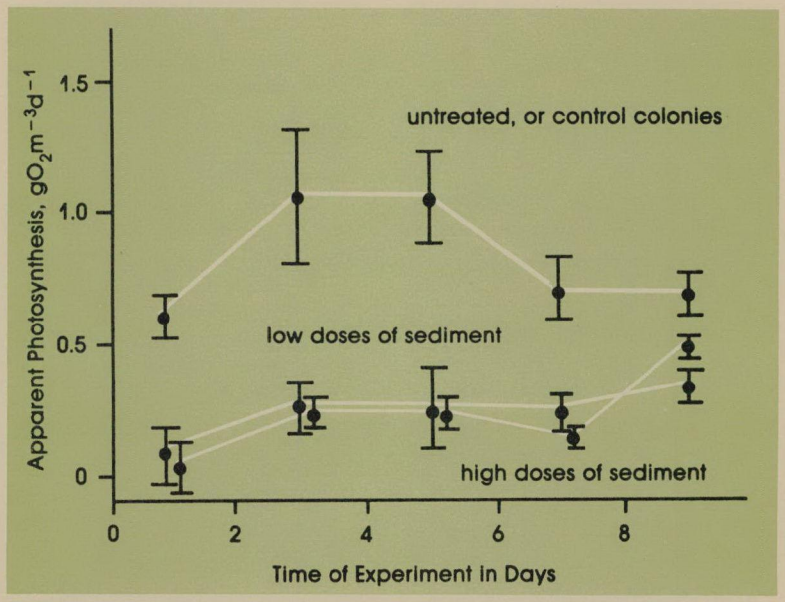

Figure 5. Photosynthetic response to sediment loading.

Source: Kemp, W. M., J. C. Stevenson, W. R. Boynton, and J. C. Means, Submerged Aquatic Vegetation in Chesapeake Bay: Its Role in Bay Systems and Factors Leading to its Decline. U. S. Environmental Protection Agency, Chesapeake Bay Program. Vol. 1. Cooperative Agreement No. R805932, February 1981.

3. Epibiota Experiments

Scientists at both Horn Point and VIMS are investigating the effect of fouling by plants and animals (epibota) on light availability to SAV

leaves. Researchers at Horn Point hypothesize that nutrient enrichment in the Bay causes increases in phytoplankton and bacteria which serve as food to fouling animals such as barnacles, hydroids and worms. These organisms, in turn, are able to proliferate on SAV leaves. Added to the colonies of fouling animals are floral components, such as diatoms and bacteria; the total encrustation reduces light available to the SAV.

From field studies, scientists found differences in observed fouling rates in different areas. Special plates (used to collect fouling organisms) in open areas or on the fringe of a grass bed, had fouling rates 18 times greater than those inside the bed. The researchers believe that inside the bed, currents are baffled, or slowed, so that less food reaches the epibiota compared with other areas subject to more active currents. Recruitment of epibiota could also be greater in the latter areas, where the currents would carry more animals.

The Horn Point scientists are continuing these investigations with more field and laboratory studies. They plan to assess fouling rates of epibiota in water at varying current rates and at different nutrient levels.

At VIMS, researchers are studying the role of grazers on the epibiota populations inhabiting blades of eelgrass. Specifically, they have been investigating the activities of one grazer, a snail called Bittium varium which feeds on epiflora (plant component of epibiota) growing on eelgrass.

The VIMS scientists have used a scanning electron microscope (SEM) to study the effects of Bittium grazing on eelgrass epibiota. Preliminary studies from SEM photographs have shown that the grazing of a single Bittium can be a significant factor in reducing the plant growth along its grazing trail (See Figure 6). In laboratory experiments, the researchers found that blades with Bittium had 2-1/2 times less epiphytic material (by weight) than control blades (without Bittium). It appears that Bittium eats or bulldozes material off, or to one side of the blade.

In the years preceding Hurricane Agnes, which struck the Bay in June 1972, Bittium was the most abundant animal found on eelgrass. It has a

Figure 6. Trail left by Bittium grazing on blade of eelgrass. The crust contains fragments of diatoms, bacteria, blue-green algae and organic debris.

Photo by: Jacques van Montfrans, Virginia Institute of Marine Science.

life cycle of 1.5 years with the release of young from eggs in June. Hurricane Agnes caused a drastic and sudden decrease of salinities in eelgrass beds at that time and may have killed the entire one-year class of Bittum that had just hatched. Thus, the decline of the grass in 1973 was possibly due to absence of a dense grazing population which under normal conditions would have kept eelgrass relatively clear of epibiotic growth. Combined with the usual summertime depression of available light from increased turbidity, the VIMS scientists hypothe size that the plants were unable to photosynthesize efficiently. The absence, or reduced abundance of Bittum in lower western shore eelgrass beds, to this day, may be the reason why eelgrass beds have not expanded as rapidly as they could.

The VIMS researchers will center future experiments on Bittium's tolerance to salinity; the effects of different Bittium densities on eelgrass; and the grazing effect by a single concentration of Bittium on eelgrass exposed to varying reductions of sunlight.

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summary 3

EPA Chesapeake Bay Program Information Series

Toxics Investigation of Organic Pollutants

September 1980

Importance

Production of synthetic organic chemicals has increased considerably since the Second World War. More than 1,000 new chemicals are introduced into the environment each year. Many, including some pesticides, plastics, and synthetic fibers, offer enormous public benefits. Others, such as PCB's, are extremely harmful, and the toxicity of many more synthetic chemicals remains unknown. Despite the lack of understanding of these chemicals' effects, many toxic synthetic organics enter the environment through misuse, ignorance, willful discharge or spills.

Once they enter the natural environment, toxic chemicals can directly harm plants and animals by damaging certain body organs and interfering with metabolic pathways. Or, they can accumulate in food chains. Within the food chain, specific animals, especially clams and oysters, can store up toxic chemicals in their bodies to a level where the animals become unfit for human consumption.

The accumulation of toxic organics in food chains, and their potentially adverse ecological and human health impacts are a primary concern of the Chesapeake Bay Program. In response to this concern, scientists are collecting data on levels of organic compounds in the Chesapeake Bay. The data will include compounds which have been designated as toxic, as well as those which have not yet been categorized as toxic or non-toxic.

This summary, one of a series of publications describing Chesapeake Bay Program research, will summarize findings to date of a two-year toxics research project headed by Dr. Robert J. Huggett at the Virginia Institute of Marine Science (VIMS) at Gloucester Point, Virginia. The major goal of this project is to design and demonstrate a scheme for detecting, identifying and locating man-made organic compounds in the Chesapeake Bay. Management agencies will be able to use this system to monitor the health of the Bay and control discharges of toxic substances.

Research

Toxic organic chemicals can accumulate in sediments, in the tissues of aquatic organisms, and sometimes in trace amounts in water. Scientists at VIMS are collecting samples of sediment, water and organisms at sites throughout the Bay, and each sample is being analyzed to determine what organic compounds are present.

To collect sediment samples, the VIMS scientists used a Smith-McIntyre grab (Figure 1) and sampled at 54 sites located at mouths of major tributaries and at deeper sites in the Bay (Figure 2).

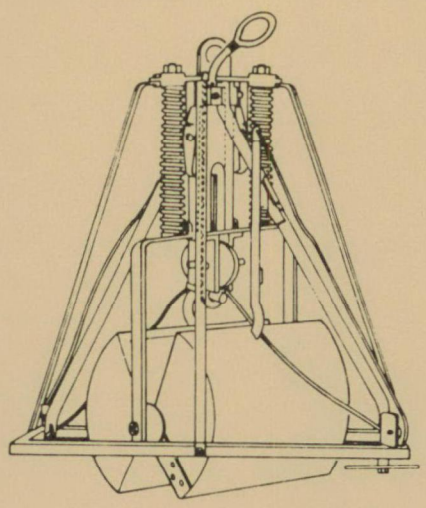

Figure 1. Smith-McIntyre Grab

The two molluscs chosen for sampling were Crassostrea virginica, the American oyster, and Rangia cuneata, a brackish water clam. The VIMS scientists collected these molluscs at 23 sites using either tongs or dredging methods. They chose to sample molluscs over other animals, since individual bivalves move very little, and thus, the pollutant concentrations they exhibit reflect specific areas.

Water samples were collected with Kemmerer bottles (brass tubes which open and close at both ends) at 36 sampling stations. The sites were located at major tributary mouths draining into the Bay, along the James River, and near suspected sources of toxic compounds (power plants, sewage treatment plants and industries). (Figure 2)

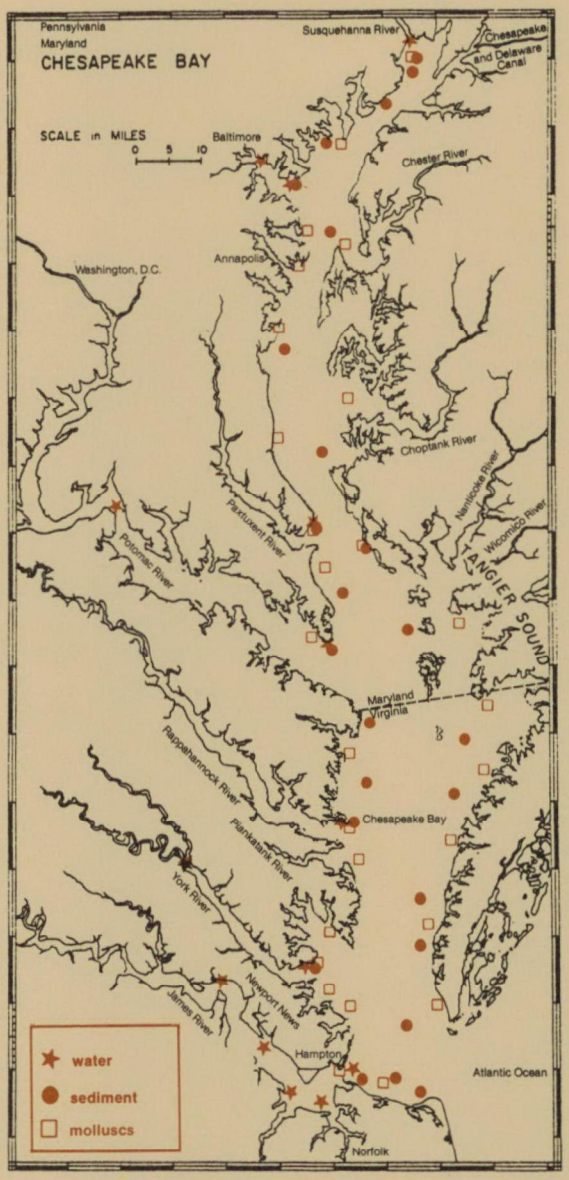

Figure 2. Sediment, Mollusc and Water Sampling Sites

Analytical Approach

Scientists at VIMS are using a variety of analytical tools to determine what organic compounds are present in the samples. Among these tools are high resolution Glass Capillary Gas Chromatography, Gas Chromatography-Mass Spectrometry, High Performance Liquid Chromatography and Gel Permeation Chromatography. All of these instruments are specifically designed or modified to work with complex organic mixtures. Each has a specific function in the analytical scheme.

So far, the scientists have analyzed 60 to 70 samples and will complete at least another 100 by the end of the project. At $500 to $5,000 per sample, analysis is expensive. However, monetary costs become negligible in the face of the potential environmental losses created by the presence of synthetic organics in the Chesapeake Bay.

Sediment and Mollusc Samples

Literally thousands of organic compounds exist in almost every sample; identifying individual substances would be nearly impossible without running the samples through many separations. Figure 3 shows the basic scheme involved in identifying organic compounds. The VIMS team begins separating the samples by removing as many organic compounds as possible. Since living things are composed of organic molecules, many naturally-occurring organics are also removed in the process. Separating the natural from the man-made ones is partially achieved by using one of the instruments, the Gel Permeation Chromatograph. The Liquid Chromatograph then separates the samples into three parts, each containing organics with similar characteristics.

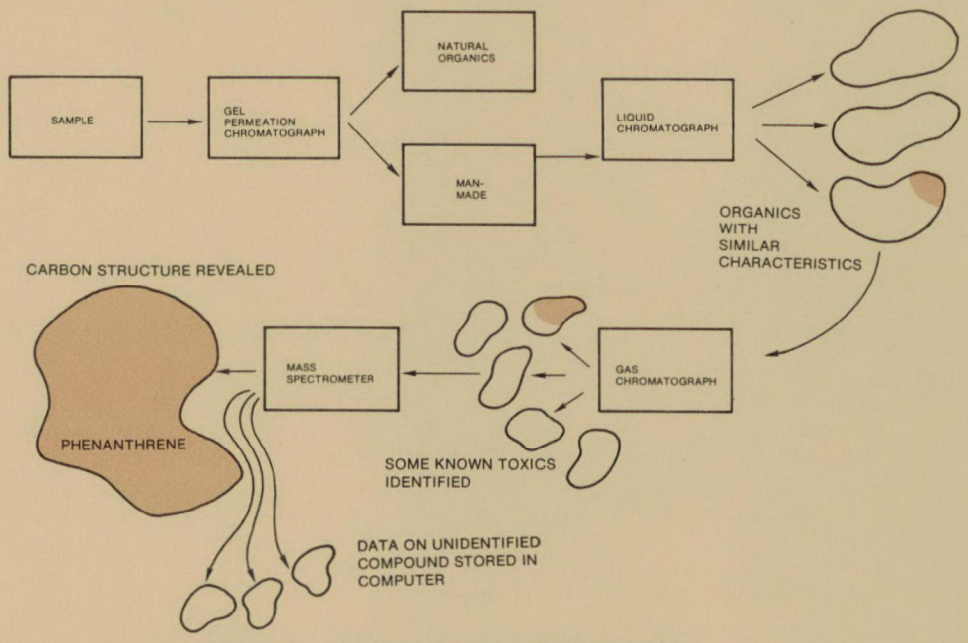

Figure 3. Identifying Organic Compounds

In the next step, the scientists begin identifying the compounds in each of these parts. The Gas Chromatograph separates many of the compounds from one another and estimates amounts of each present. Designated toxic synthetic organics are tentatively identified in this step. Figure 4A is an example of the output from a Gas Chromatograph. Each peak, or signal, such as Peak A, corresponds to at least one organic compound found in this sediment sample.

Scientists complete the identification of the samples by using the Mass Spectrometer. This instrument breaks down the compounds in each sample so that their carbon structure is revealed. Figure 4B shows a mass spectrograph of phenanthrene, the compound labeled Peak A in the Gas Chromatograph.

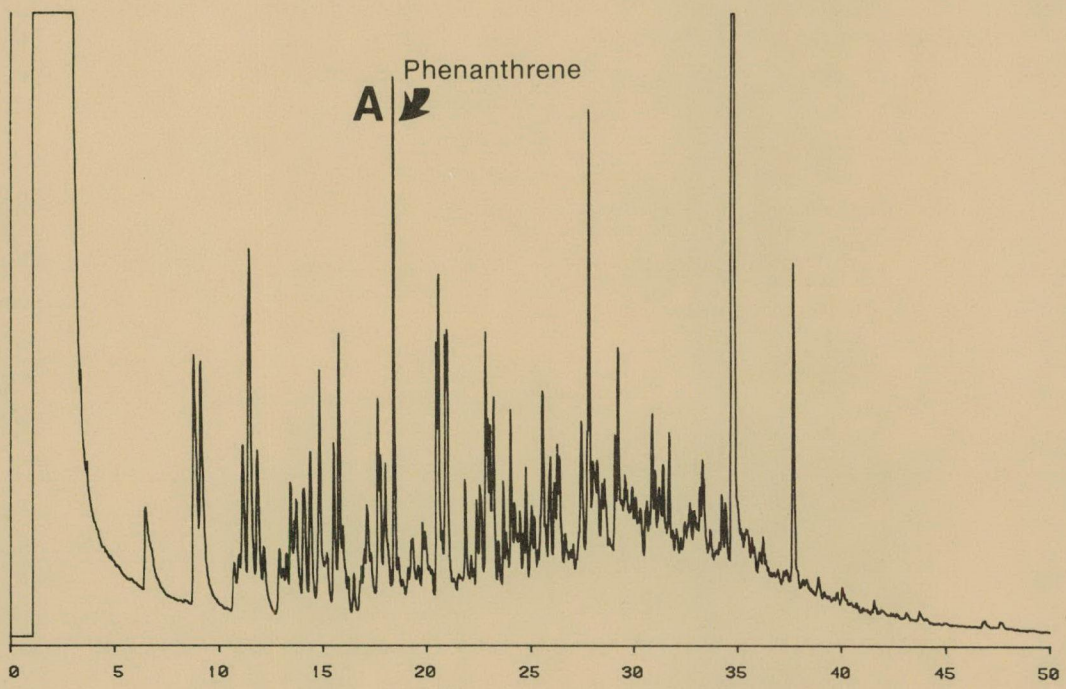

Figure 4A. Gas Chromatograph Showing Phenanthrene

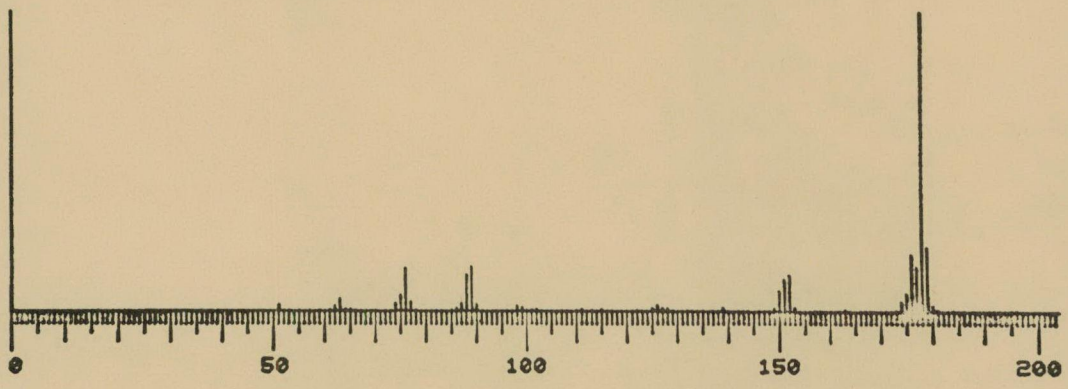

Figure 4B. Mass Spectrograph of Phenanthrene

At this point, only some of the organics are identified. Other signals corresponding to compounds not identified are stored in a computer for later examination.

Since thousands of unidentified compounds exist in a sample, the researchers have developed a ranking method to select those most important for further identification. The method utilizes a special computer program which searches the stored data and addresses questions such as:

--Do sampling locations exist where particular compound or compound type is present or absent?

--Do sampling locations exist where a particular compound stands out?

--Do significant trends exist in the composition or concentration of these compounds over time?

A compound thus selected would then undergo further analytical scrutiny following a process similar to that used for the separation of organic compounds within the samples. This selection method forms a crucial component of the system for monitoring the Bay's water quality. When the Chesapeake Bay Program is concluded, Maryland and Virginia will receive the Gas Chromatograph--Mass Spectrometer so that analysis and monitoring of toxic substantes can continue.

Water Samples

The water samples are analyzed utilizing a technique known as "purge and trap." Briefly, the water sample is placed in a tube through which a gas bubbles. If the sample contains any highly volatile compounds, such as bromoform or chloroform, they are stripped from the sample by the bubbles and collected in another tube containing an absorbent. Finally, the compounds are stripped from the absorbent by heat and run through a special gas chromatography procedure which can detect halogenated compounds.

Results to Date

The VIMS scientists have finished the first part of their project, the extraction, separation and identification scheme. As new and better analytical techniques come along, they will be incorporated to constantly update the system.

The researchers have also analyzed two separate samplings of sediments and molluscs. Computer programs to store and compare these data are nearly completed, and comparisons of samples have begun.

Separate water samplings have been completed, and the scientists have analyzed them for volatile halogenated organics. These organics are formed by the chlorination of waste water containing naturally-occurring organic matter. Some of those identified include chloroform, 1,1,1,-trichloromethane, carbon tetrachloride, trichloroethylene and bromoform. In general, the concentrations found thus far are less than 0.1 mg/L, the level which the U.S. Environmental Protection Agency set in 1978 as the maximum allowable amount for trihalomethanes in drinking water. In a few locations, for example in the Potomac River near the Blue Plains Power Plant, concentrations of some organics were greater than 10 mg/L.

Management Implications

Toxic organic pollutants are in the Chesapeake Bay--in the sediment, in the water and in the animals. Scientists have designated a few as hazardous, while the toxicity of most remains unknown.

Investigating organic pollutants in the Bay will help scientists identify what chemicals exist and how much. The research will allow scientists to select substances of known toxicity for long term monitoring. With further modification of the techniques developed by the VIMS scientists, resource management agencies will be able to conduct the monitoring themselves.

At the end of their project, the VIMS team will produce a map showing where toxic compounds are found in the Chesapeake Bay and where natural sinks for these pollutants exist. With the information gathered from monitoring the compounds and from these maps, managers can effectively impose limits on certain substances coming into the Bay, and thus, ensure this great estuary's integrity.

This is one of a series of briefs, reports, research summaries, and final project reports designed to make available the findings, observations, and management implications of the Chesapeake Bay Program, a project of the U.S. Environmental Protection Agency. It is based on conversations with the principal investigators and on the final reports covering these projects.

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EPA Chesapeake Bay Program Information Series

SAV Waterfowl and the Decline of SAV October 1981

Importance

The Chesapeake Bay is the most important wintering area in the Atlantic Flyway for more than a million and a half waterfowl. Since settlers first reached the Bay's shores, these birds have been known across the country to both hunters and birdwatchers. Of 45 species of ducks, geese and swans native to North America, about 30 migrate through, or winter in the Bay area, including Canada geese, whistling swans, canvasback ducks, ruddy ducks, common goldeneyes, redheads, black ducks and mallards. The Bay is attractive to waterfowl as a wintering habitat, because it provides birds with broad shoal waters in which to feed, protected rivers and bays in which to rest, a mild winter climate usually ice-free and abundant natural food resources. In addition to being a winter haven, the Bay also forms an important link in a chain of resting areas for birds migrating farther south.

Large beds of Bay grasses have been traditionally important to wintering waterfowl as food. Among the important species are widgeongrass, (Ruppia maritima), wildcelery (Vallisneria americana) and sago pondweed (Potamogeton pectinatus). But these food resources declined radically during the 1970's, possibly affecting the distribution and abundance of waterfowl in the region.

Widgeongrass Ruppia maritima — **Wildcelery** Vallisneria americana — **Sago Pondweed** Potamogeton pectinatus

Widgeongrass, wild celery and pondweed are some of the Bay grasses eaten by waterfowl wintering in the Bay.

To determine any relationships between submerged aquatic vegetation (SAV) and waterfowl, scientists at the U.S. Fish and Wildlife Service's Migratory Bird and Habitat Research Laboratory in Laurel, Maryland, examined historic and current levels of waterfowl and SAV populations, primarily in Maryland. Their project is part of the U.S. Environmental Protection Agency's Chesapeake Bay Program SAV studies which address, among other issues, the ecological role and value of SAV in the Bay. Learning more about waterfowl population trends and how they relate to the distribution and abundance of SAV will help scientists

understand what ecological changes can occur in the Bay when numbers and kinds of SAV are altered. Through these investigations, the value of SAV, and thus the need to control factors underlying its decline will be better understood.

Research

Part of the waterfowl study involved looking at feeding habits of ducks, which can be divided into two kinds of feeders--dabblers and divers. Dabblers feed by dabbling at the water's surface or tipping up in shallow water. Historically, they have been largely vegetation eaters and include mallards, black ducks, pintails and wigeons. Diving ducks, such as redheads, canvasbacks, ruddy ducks and common goldeneyes, have small wings with legs set back on their bodies, making walking difficult. Typically, they need open water across which to run prior to flight and cannot, therefore, feed in dense marshes or agricultural fields. These birds feed on a combination of plant and animal food.

To examine relationships between both kinds of feeders and populations of SAV, the U.S. Fish and Wildlife Service scientists first looked at data from annual waterfowl population surveys. Survey results prior to 1972 gave measures of long-term distributions and abundance of waterfowl, while results from 1972 to 1980 described current Bay waterfowl resources. The surveys were conducted from planes which fly over waterfowl concentrations during December or January every year. Observers in the plane estimated number, species and location of birds within established survey areas. Because SAV stock is often depleted during winter months, the researchers performed additional surveys in the autumns of 1978 and 1979 when more SAV was available.

Surveying Grasses:

The scientists also collected data from SAV surveys. Over 600 sampling stations of shoal water habitats were established in 1971 to monitor annual trends in Bay grass populations. Table 1 shows the percentage of SAV within each waterfowl survey area during the 1970's. By 1979 all of the 21 areas had drastically depleted stocks of important waterfowl foods, such as widgeongrass, sago pondweed and wild celery. For example, 25.5 percent of the Lower Choptank River sampling stations were vegetated in 1971, but this number fell to 12.8 percent in 1979. In the Susquehanna Flats area, percentage of stations with SAV fell from 36.4 percent in 1971 to only 6.9 percent in 1979.

Using information from both surveys, the scientists then compared and statistically analyzed the distribution and abundance of birds relative to SAV beds. They found some significant relationships between waterfowl and the decline of the Bay grasses.

Results

Reductions in SAV had varying effects on the distribution and abundance of waterfowl throughout the study period, depending on whether or not the species changed food preference during that time. Of the dabbling ducks, the mallards and blacks stayed and are found in areas where SAV persists. Pintails and wigeons wintered elsewhere during this period. Among diving ducks, those which did not adapt their diet to an environment with reduced SAV populations, tended to leave the area. Most notable among

Survey area[b]	Percent with vegetation, and sample size ( )								
	1971	1972	1973	1974	1975	1976	1977	1978	1979
Lower Choptank River	25.5 (51)	20.8 (48)	14.9 (47)	14.3 (49)	0.0 (47)	21.7 (46)	8.2 (49)	6.1 (49)	12.8 (47)
Manokin, Annemessex R.	33.3 (57)	12.7 (55)	10.7 (56)	17.6 (34)	5.8 (52)	14.0 (57)	12.5 (56)	0.0 (55)	0.0 (56)
Chester River	41.7 (36)	13.9 (36)	14.7 (34)	11.8 (34)	11.1 (36)	8.6 (35)	16.7 (36)	30.6 (36)	22.2 (36)
Eastern Bay	21.4 (28)	20.8 (24)	14.3 (28)	10.7 (28)	14.8 (27)	18.5 (27)	14.8 (27)	11.1 (27)	11.1 (27)
Smith Island (Maryland)	47.1 (17)	27.3 (11)	25.0 (12)	23.5 (17)	11.8 (17)	17.6 (17)	0.0 (17)	5.9 (17)	5.9 (17)
Bloodsworth, South Marsh I.	27.5 (40)	13.6 (44)	8.7 (46)	7.0 (43)	0.0 (43)	0.0 (45)	0.0 (46)	0.0 (46)	0.0 (45)
Patapsco R., Aberdeen P.G.	1.9 (52)	0.0 (50)	2.0 (50)	3.8 (52)	4.5 (22)	1.9 (52)	7.7 (52)	3.8 (52)	5.8 (52)
Honga River	30.0 (30)	23.3 (30)	3.3 (30)	3.3 (30)	3.4 (29)	3.4 (29)	0.0 (30)	3.3 (30)	0.0 (30)
Bayshore, Hooper Island	39.1 (23)	17.4 (23)	4.3 (23)	8.7 (23)	4.3 (23)	4.3 (23)	4.3 (23)	0.0 (23)	0.0 (23)
Magothy - Severn Rivers	33.3 (27)	7.4 (27)	14.8 (27)	14.8 (27)	. (0)	0.0 (25)	7.4 (27)	11.1 (27)	14.8 (27)
Susquehanna Flats	36.4 (22)	0.0 (30)	0.0 (30)	6.7 (30)	6.7 (30)	0.0 (29)	0.0 (30)	0.0 (29)	6.9 (29)
Miles River	12.5 (8)	37.5 (8)	12.5 (8)	12.5 (8)	25.0 (8)	28.6 (7)	25.0 (8)	12.5 (8)	0.0 (8)
Wye River	9.1 (11)	36.4 (11)	18.2 (11)	36.4 (11)	9.1 (11)	18.2 (11)	9.1 (11)	9.1 (11)	9.1 (11)
Little Choptank River	10.0 (30)	3.3 (30)	0.0 (30)	0.0 (30)	0.0 (30)	0.0 (30)	3.3 (30)	3.3 (30)	0.0 (30)
Upper Choptank River	11.1 (9)	20.0 (10)	0.0 (10)	0.0 (9)	0.0 (10)	0.0 (10)	0.0 (10)	0.0 (10)	0.0 (10)
Fishing Bay	8.0 (25)	0.0 (25)	0.0 (25)	0.0 (25)	0.0 (24)	0.0 (25)	0.0 (25)	0.0 (25)	0.0 (24)
Sassafras River	20.0 (10)	0.0 (10)	0.0 (10)	0.0 (10)	0.0 (10)	0.0 (10)	0.0 (10)	0.0 (10)	0.0 (10)
Northeast, Elk, Bohemia R.	5.0 (20)	0.0 (23)	0.0 (23)	0.0 (23)	0.0 (22)	0.0 (22)	0.0 (23)	0.0 (22)	0.0 (23)
Bayshore, Kent County	8.3 (12)	0.0 (6)	0.0 (12)	0.0 (12)	0.0 (12)	0.0 (12)	0.0 (12)	0.0 (12)	0.0 (12)
Patuxent River	0.0 (50)	0.0 (45)	0.0 (50)	2.0 (50)	0.0 (47)	0.0 (49)	0.0 (49)	0.0 (50)	0.0 (48)
Total	19.2 (624)	9.6 (613)	6.2 (629)	7.2 (610)	3.8 (552)	5.7 (628)	5.0 (638)	4.2 (636)	4.4 (631

[a]Data from the files of MBHRL, Laurel, Maryland.

[b]Frequency occurrence of SAV averaged over years, when multiplied by the extent of shoal habitat (<2.44 m at mlw) in an area, determined the sequence of survey areas used above.

Table 1. Percent of survey sites covered with SAV during the years 1971 to 1979.

these ducks are the redheads. Scientists suggest that one reason for not being able to switch to a new food type is the inability of these birds and others to consume animal matter because of their gullet and bill shape. In contrast, the canvasback can feed on animals and has adapted to the situation by changing its food preference to clams. This species stayed and is still found in relatively high numbers around the Bay.

Other waterfowl species developed different feeding patterns and even expanded their populations during the study time. Canada geese and whistling swans, for example, can

Whistling swans are common Bay waterfowl that have adapted to decreasing abundance of SAV by foraging on land. (Photo by R.E. Munro)

forage on land and now take advantage of the rich agricultural fields around the Bay.

Although fewer waterfowl species currently winter in Maryland, researchers believe their numbers can improve. Since formerly abundant species still migrate annually through the area, recovery of SAV resources will help bring these birds back.

This summary is one in a series of publications describing Chesapeake Bay Program research. It highlights the research to date of Robert E. Munro and Matthew C. Perry of the U.S. Fish and Wildlife Service, Migratory Bird and Habitat Research Laboratory in Laurel, Maryland.

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