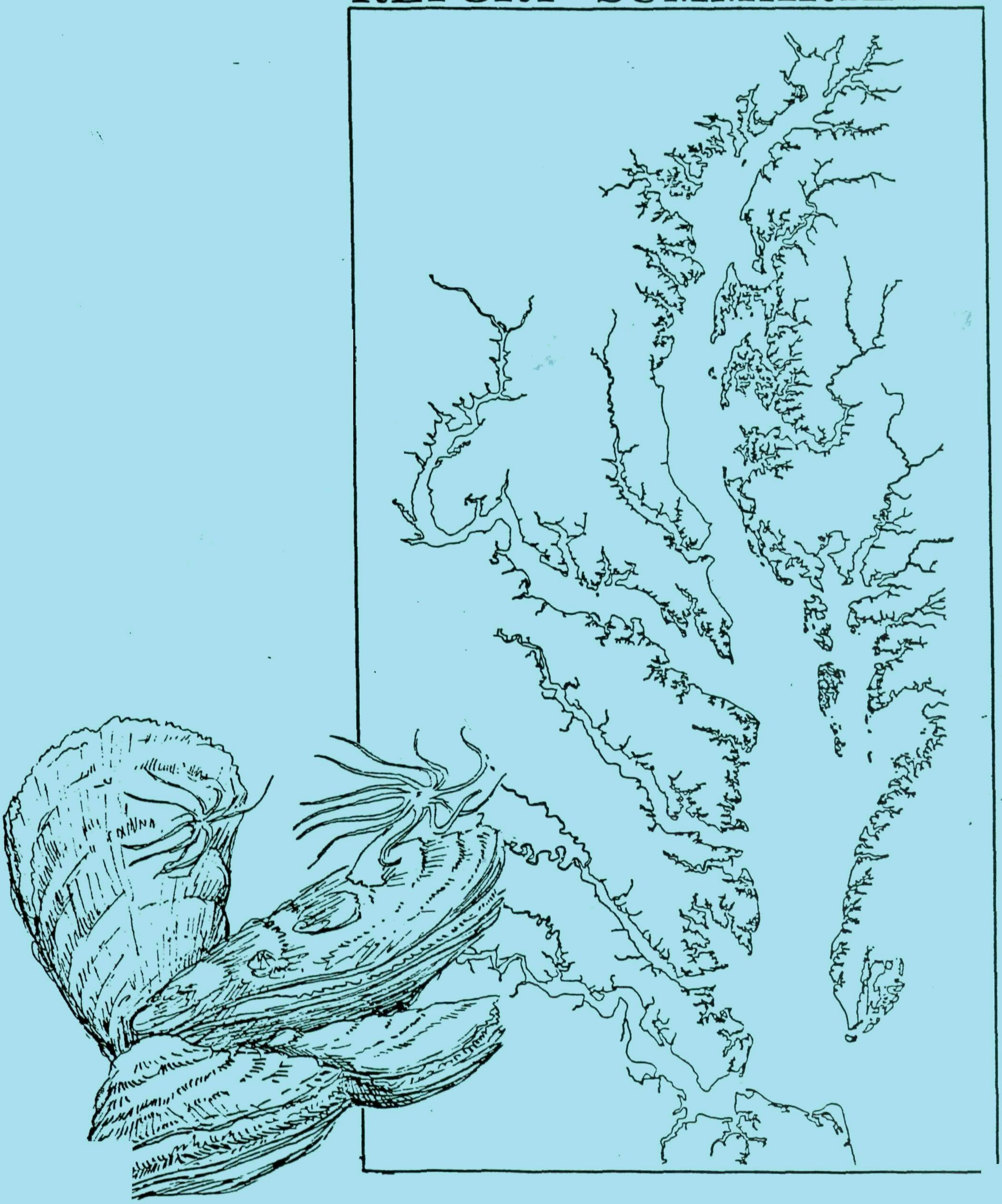
United States
Environmental Protection
Agency

Washington, D.C. 20460
September 1982

EPA

CHESAPEAKE BAY PROGRAM: TECHNICAL REPORT SUMMARIES



Foreword

For hundreds of years Chesapeake Bay has provided the natural resources for commercial and recreational pursuits. The productive waters of the Bay support oysters, clams, crabs, and commercial and sports fish. Migratory birds and waterfowl find food in its waters and beds of submerged aquatic vegetation. The estuary is also used for assimilation of wastes from numerous industrial and municipal dischargers. Rising pressure on these resources, however, has put increasing demand on the Bay's capability to maintain them. This pressure will no doubt continue as the Bay area population increases in the future.

Congress, in 1976, recognized these problems and directed the U.S. Environmental Protection Agency (EPA) to begin an in-depth study of the Bay. In this study, known as the Chesapeake Bay Program (CBP), research projects were conducted on nutrient enrichment, toxic chemicals, and the decline of submerged aquatic vegetation in Chesapeake Bay. All of the research was directed toward helping decision-makers understand some of the Bay's problems and know better how to regulate land activities that could affect the Bay and its resources. These investigations took place at many research institutes and universities, and involved a cooperative effort among State, Federal, and private organizations.

The research projects summarized in these compendiums present an overview of our investigations into water quality problems of the Bay. In addition, the projects form the foundation for our second final report, Chesapeake Bay Program Technical Studies: A Synthesis, and, as such, represent the heart of the scientific knowledge gained during our program.

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U.S. Environmental Protection Agency
Chesapeake Bay Program

Technical Report Summaries

September 1982

This document provides summaries of 13 technical studies initiated by the Chesapeake Bay Program.

A separate, more complete document, to be published sometime this winter, will include approximately 25 additional summaries.

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Introduction

In the fall of 1977, State (Maryland and Virginia) managers, EPA officials, and citizen groups cooperated to identify ten major problem areas to be addressed by the Program. Three of those areas received extensive attention: nutrient enrichment, toxic chemicals, and the decline of submerged aquatic vegetation. Forty principal investigators, from more than 30 institutions and organizations, evaluated ongoing research in the three problem areas and provided new research efforts to help fill in the missing pieces. This volume summarizes some of those projects.

The projects summarized in this report (and in the winter edition) form the basis for the CBP's three primary phases. From the research projects, as well as from other sources, a synthesis of the most up-to-date knowledge of the three problem areas was done. This is presented in the CBP's second final report, Chesapeake Bay Program Technical Studies: A Synthesis, which will be available this fall. Information from the synthesis papers, together with other historical data, were used in the second major phase of the program, a characterization of the water quality and resources in Chesapeake Bay. A report on this analysis will be completed in 1983. The final phase of the CBP, the management study, pulls together knowledge gained from the synthesis of the CBP's technical studies and characterization analysis, as well as from the program's modeling studies. Pollution control options determined from the management study are presented in the CBP's last report which will be finished in 1983.

This report contains summaries of 13 research projects that were initiated by the U.S. EPA's Chesapeake Bay Program, all of which are available from the National Technical Information Service. Our final edition, to be published sometime this winter, will include approximately 25 additional summaries. The individual project reports summarized in this volume can be obtained from the National Technical Information Service at 5285 Port Royal Road, Springfield, Virginia, 22161 (703-487-4650).

NUTRIENT ENRICHMENT

The CBP studied nutrients because the natural process of nutrient enrichment, or eutrophication, is being hastened by anthropogenic contributions of primarily nitrogen and phosphorus compounds. Though needed by Bay organisms to grow, excesses of these nutrients can deteriorate water quality.

When nutrients are introduced into an estuary in excessive amounts, detrimental effects may result. Growth of phytoplankton may be stimulated, causing dense and unsightly blooms. Or a few species may dominate, resulting in declines of other types and loss of species diversity. Although phytoplankton blooms produce photosynthetic oxygen as they develop, respiration may exceed photosynthesis as they die. As a result, oxygen will be depleted from the water. In addition, grazers and decomposers deplete oxygen by respiration as they consume the phytoplankton. Consequently, oxygen depletion from the water is a common corollary to nutrient enrichment.

To consider implementation of eutrophication control measures in a manner beneficial to Bay resources, the relationship of nutrients to water quality must be thoroughly understood. Researchers have identified the fundamental processes involved in the entire Bay system and historic trends in nutrient enrichment as compared to current levels. This effort has identified eutrophication trends and provided a better understanding of nutrient enrichment in the Bay.

TOXIC CHEMICALS

Before the initiation of the CBP in 1976, no systematic study of toxic materials in the Bay had ever been attempted. Toxic substances are usually defined as chemicals or chemical compounds that can poison living plants and animals, including humans. Two classes of toxic substances are potentially damaging to the Bay environment: inorganic and organic compounds. The inorganic materials are primarily metals. They can be produced and delivered to the Bay by natural processes as well as by human activities. Potentially toxic metals include arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu), mercury (Hg), lead (Pb), nickel (Ni), tin (Sn), and zinc (Zn). Many of the organic compounds are products of human activities. However, a few polynuclear aromatic compounds (PNA's) can occur naturally, and thus augment production of synthetic compounds. Some of the classes of synthetic organic compounds found in the Bay include: pesticides; phthalate esters; alkyl-benzines; plasticisers; polychlorinated biphenyls (PCB's); and other halogenated hydrocarbon compounds.

To establish the role of toxic substances in the Bay ecosystem, a thorough understanding of the Bay's chemical, physical, and biological dynamics was necessary. It was important to develop reliable information on the current level of toxins in the Bay, as well as information on the sources, pathways, and fate of these substances in the estuarine environment. This was the first time a Bay-wide assessment of baseline concentrations of toxic substances had been done. Research efforts in the toxic substances program centered on obtaining this information by studying the behavior of toxic materials coming from industrial, agricultural, and atmospheric sources. From such studies, resource management and regulatory strategies can be designed to reduce or eliminate environmental hazards, and protect and improve the quality of the Bay.

SUBMERGED AQUATIC VEGETATION

SAV has dramatically declined in the Bay since 1970. Such a decline is a major indication of ecological change. Because of its value to the Bay as a food source, habitat, nutrient buffer, and sediment trap, the CBP included it as a critical research area. SAV is eaten by ducks, geese, fish, and other species that benefit from its contribution to the detritus-based food web (dead organic matter). SAV also provides habitat for many organisms -- nurseries for juvenile stages of some fish species; refuge for molting blue crabs, and other invertebrates. A stable habitat for infauna and a substrate for epiphytic plants and animals is also provided. Additionally, SAV buffers nutrients in the Bay by absorbing nutrients from the water column during spring runoff and releasing them in autumn as detritus. SAV is considered to be a nutrient "pump," taking up nutrients from the sediment through its roots and releasing them as detritus. SAV also slows water movement, and its filtering action causes sediment to settle to the bottom, allowing the binding of sediment which helps to mitigate shoreline erosion and improves water clarity.

Correlating research results with information related to the effects of human activities on SAV has enabled scientists to determine the likely causes of the decline of these valuable plants. This will lead to the delineation of environmental conditions necessary for improved growth of SAV which, in turn, will provide Bay resource managers with the information they need to evaluate management options.

NUTRIENTS

Governing Chesapeake Waters: A History of Water Quality Controls on Chesapeake Bay, 1607-1972

John Capper, Garrett Power, and Frank R. Shivers

Chesapeake Bay has been called the most-studied and best understood estuary in the United States. Yet it is practically unexamined in the areas of the social sciences and the humanities. The many planning documents, of which the Corps of Engineers' Chesapeake Bay Study is the largest, are general compilations of information and issues rather than original pieces of research.

As a result, the present study has had the benefit of little scholarship to point the way. For example, nowhere is there even a simple compilation or listing of the State agencies that have been involved with the Bay over time. Records of what the government has been doing with the Bay, written as they are in varying documents, and scattered in various libraries in both Virginia and Maryland, have not found their way into the numerous bibliographies that have been assembled for the Bay. And the relationship of the governments of both states to the Bay is imperfectly documented. In Virginia, the State Water Control Board did not produce annual reports until 1972, the cutoff date for this study. In Maryland, the reports of water quality agencies tend to be perfunctory and repetitive, and give little indication of the real issues facing the agencies over the years. The researcher is forced to approach his material as though he were an archeologist, finding a few shards here, a few bone fragments there. Piecing together a coherent story out of the fragments requires a certain amount of logic, a workable hypothesis about the overall nature of the creature to be described, and some theories about how the evidence fits together.

This report has relied primarily on written sources. Those proving most fruitful have been the annual reports of various state agencies; the occassional reports of study commissions and blue ribbon panels; and the codes, statutes, and case law of the two states. Agency files proved difficult to use because they are boxed and stored, full of irrelevant material, disorganized, and uncataloged.

Use has also been made of the abundant collections of newspaper files in libraries. While newspaper articles may have questionable accuracy, they identify key issues and place them definitively in time. Without them, numerous controversies, left only to the official archivists, would go unrecorded. In this study, information from newspapers gives a sample of issues, and shows the broad trends in water quality awareness.

Another useful source has been feature articles in magazines. These are particularly useful, because they both reflect, and partially shape, the public attitudes toward the Bay. Changes in these attitudes provide data used throughout the report.

Introduction

Although tens of millions of dollars have been spent during the twentieth century for studies of the environmental quality of the Chesapeake Bay estuarine system, little attention has been paid to examination of the political, cultural, and economic character of Bay governance.

As part of the Congressional mandate establishing the Chesapeake Bay Program (CBP), the Environmental Protection Agency (EPA) was directed to review regional agencies responsible for Chesapeake Bay management, issues of concern in the region, and factors that must be considered in future programs developed for management of Chesapeake Bay enviromental quality.

This report discusses the physical, chemical, biological, and engineering aspects of the Bay in the context of political, cultural, and economic events which occurred nationally and in the region between 1607 and 1972. The objective is to present the debate concerning Chesapeake Bay quality as expressed through changes in public opinion within the region and how public attitude influenced the political process.

Procedure/Methodology

The authors drew on their expertise in the areas of resource planning, legislation, and Chesapeake Bay history to construct a temporal characterization of how the concept of water quality has been defined and managed in the Chesapeake Bay basin. In many respects the authors describe the history of Chesapeake Bay uses, and how priority for specific uses was established through the legislative process.

The authors, for the most part, relied on written sources such as reports from study commissions, legislation, case law, and, in some instances, regulatory agency files to describe important issues which surfaced in the region during the 400 year recorded history of the Bay. The evolution of Bay management is presented within the context of four eras: Colonial times to the turn of the century; 1900 to World War II; World War II to 1960; and 1960 to 1972.

Results/Conclusions

It is concluded that prior to the twentieth century the Chesapeake Bay management focus was primarily concerned with protection of public health and fisheries marketability. Only recently has the public initiated efforts to establish regulatory authorities directed toward enhancing or protecting

Chesapeake Bay water quality. The authors maintain, however, that Bay government agencies are often acting merely in response to public opinion and political pressure rather than following a course based on thoughtful analysis of environmental and economic conditions.

- By Stephen Katsanos

Historical Review of Water Quality and Climatic Data from Chesapeake Bay with Emphasis on Effect of Enrichment

Donald Heinle, Christopher D'Elia, Jay Taft, John S. Wilson, Marthe Cole-Jones, Alice B. Caplins, and L. Eugene Cronin

Review of available data on water quality in Chesapeake Bay has revealed changes over recent decades caused by enrichment with nutrients. In the upper and middle Bay, and several tributaries, concentrations of algae during the summer months have increased since the mid-1960's. There have been decreases in the clarity of the water. This is associated with increased algal stocks. Nutrient concentrations have also increased, phosphorus more notably so than nitrogen. In some of the tributaries, such as the Patuxent for which we have the most historically complete data, increased algal production has led to reduced concentrations of oxygen below the halocline in the middle part of the sub-estuary. The variations in concentrations of oxygen are now more extreme in surface waters than in the early 1960's in the Patuxent. Oxygen concentrations in the open Bay have not changed greatly, except possibly under extreme conditions, such as during periods of extensive ice cover. There have been historical variations in the abundance of commercial fishery stocks that may be closely related to climatic variations. Since 1969 or 1980, however, stocks of many anadromous species and marine spawners that represent higher trophic levels, have declined to new long-time lows. The principal exceptions are menhaden (marine-spawning planktivorous fish) and bluefish (marine-spawning top predators). That same time interval has, however, been a period of above average rainfall and corresponding reduced salinities in the Bay, making conclusions concerning effects of enrichment difficult to achieve.

Introduction

Enrichment of Chesapeake Bay waters by nutrients from sewage treatment plants, and agricultural and urban runoff emerged as a major water quality issue during the 1950's. Population growth and the related changes in land-use, the increasing reliance on secondary treatment of municipal wastes, and the centralization of sewage treatment services in the region's growing urban centers all contributed to increased nutrient loadings in some segments of Chesapeake Bay, particularly the upper Potomac River and Baltimore Harbor. By 1960 blue-green algae were creating nuisance conditions in the upper Potomac, and detrimental quantities were common in northern sections of the Bay ten years later.

The relationship between nutrient loadings from various sources and algae production has been reviewed by a number of Bay-area scientists, but trends and the extent of water quality changes have not been thoroughly documented. This report, sponsored by the Environmental Protection Agency's Chesapeake Bay Program, includes an historical review of Chesapeake Bay water quality and climatic data and documents nutrient-related changes that have occurred. The emphasis is on the effects of enrichment by the major nutrients, nitrogen and phosphorus. Climatic cycles are examined as well as the effects of one unusual climatic event, Tropical Storm Agnes.

Procedure/Methodology

Temperature and rainfall data applicable to the Chesapeake Bay region were compiled and examined for long term trends and possible relationships to the 20 year solar cycle. Fluctuations in annual mean water temperature were analyzed to determine the general trends and the frequency of extremely cold winters. Rainfall and freshwater flow data for the Bay proper and major tributaries were examined to determine cyclic trends and nutrient input factors. The frequency and intensity of major storm events were also examined and compared to detailed data describing the effects of Tropical Storm Agnes. All precipitation data were used in the analysis of short-term variations in freshwater flow. Long-term flow trends were determined by analysis of fixed-point salinity data.

The scientists developed estimated nutrient input values for municipal wastewater treatment facilities currently on-line and rated as capable of providing secondary treatment. The loading figures for each major tributary in the Chesapeake Bay basin (shown below) are based on the assumption that every one million gallons of secondary effluent contains 73.8 pounds of phosphorus and 182.6 pounds of nitrogen. The estimated total point source loadings, based on permitted flow, for the entire basin are:

	Nitrogen		Phosphorus	
River	Kg day^{-1}	$10^6 g\ yr^{-1}$	Kg day^{-1}	$10^6 g\ yr^{-1}$
Susquehanna	28,841	10,527	12,061	4,402
Patuxent	2,203	804	890	325
Potomac	38,864	14,185	14,495	5,290
Rappahannock	795	290	321	117
York	323	118	131	48
James	16,151	5,895	6,528	2,383
Chesapeake Bay (including tributaries)	108,916	39,754	44,020	16,067

Flow data and an inventory of known point sources were used to produce the following baseline estimates for flow in the drainage basin and percentage of flow that is treated sewage effluent:

River	27-yr average flow (cfs)	Point Sources of sewage (cfs)	Percent of freshwater that is sewage
Susquehanna	38,800	557	1.4
Patuxent	1,085	41.15	3.8
Potomac	13,900	670	4.8
James	10,100	302	3.0
Chesapeake Bay	75,200	2.034	2.7

Trend analysis was based on a review of demographic statistics, land-use changes, and water quality data; the last indicator gathered by a number of organizations involved in sampling Chesapeake Bay waters as far back as 1940. All data, unless clearly erroneous or suspect, were used. The investigators attempted to document all analytical techniques, identify data sources, and discuss the validity and comparability of various analytical techniques.

Results/Conclusions

Many of the Chesapeake Bay water quality changes, particularly in the tributaries, occurred prior to implementation of pollutant discharge permit and monitoring programs called for by the 1972 Federal Water Pollution Control Act. Trends for historic problem areas are difficult to identify, but data clearly indicate that nutrient loadings are increasing in historically-enriched areas and throughout the Bay. Phosphorus loadings are increasing more rapidly than nitrogen, possibly because of the use of phosphorus compounds in detergents.

Carbon loadings are also continuing to increase despite efforts to upgrade solids removal capabilities at municipal wastewater treatment facilities. Removal capabilities were improved between 1960 and 1969 through construction of secondary treatment modes at public wastewater treatment systems. Total carbon loadings have, however, consistently increased throughout the 1970's. Improved removal capabilities at sewage treatment systems have been outpaced by increases in regional population and increases in the percentage of population serviced by centralized treatment.

The population increases and related land-use changes have not been uniform throughout the region. The lower Susquehanna River Basin, for example, experienced a 10 percent growth rate between 1960 and 1970. The population in the Patuxent River basin nearly doubled during this same period. Effluent discharged to the Patuxent rose at a more rapid rate than the population, increasing from 2.6 million gallons a day (mgd) in 1963 to 26.6 mgd by 1973.

Changes in Chesapeake Bay water quality attributable to land-use and demographic changes are not uniformly distributed throughout the Bay. Upper Bay phosphorus concentrations, variable and seasonal in the past, have increased and are now relatively uniform all year. Nitrogen concentrations have also increased, but some of the increased loadings appear to be passing through the nutrient pool or are lost through denitrification. Nitrogen appears to be the limiting nutrient in the upper Bay, but low light intensity in this turbid region could be restricting algae production. Overall, algae production has increased.

The effects of nutrient enrichment in the middle Bay are modest, but early signs of change are present. Current phosphorus and chlorophyll a concentrations are slightly higher than historic measurements and primary algae stocks show signs of increased production. Dinoflagellate blooms are now common, and some data suggest that the deep-water dissolved oxygen minimum is changing. The effects of the altered dissolved oxygen regime on remineralization from sediments are significant and may be driven by particulate organic matter deposition rates.

The lower Bay is relatively unaffected by nutrient inputs although phosphorus concentrations have increased slightly. The negligible increase in nutrient levels may be attributable to dilution, which is significant in this region due to the massive exchange of water at the Bay's mouth. Another possible explanation is that nutrients are being trapped and utilized in upper sections of the Bay. If light restricts algae production in these upper regions, the nutrients might begin to progress further down the Bay and stimulate algae production there. Increases in algae productivity are now being observed below the Potomac River.

Concentrations of both major nutrients and chlorophyll a have increased in all parts of the Patuxent River and demonstrate a distinct downstream progression. Ambient concentrations of nutrients in the upper, turbid portion are relatively high all year. Although chlorophyll a has increased somewhat, light may be limiting primary production. Low dissolved oxygen concentrations in the upper Patuxent appear related to high concentrations of particulate carbon, not chlorophyll. Both nutrient and chlorophyll concentrations have increased in the lower river segments. Dissolved oxygen levels in the surface waters are increasingly variable, and extended periods of near anoxia in bottom waters are now being observed. Plankton in the Patuxent demonstrate a high dependence on recycled nitrogen during summer months, which suggests that restricting total annual input may limit primary production. The changes now being observed in the river will probably progress further as loading rates increase with population growth in the basin.

Changes in the upper Potomac cannot be documented, because dissolved oxygen and algae problems were present before systematic sampling programs were put in place. Algae production is increasing in the lower reaches, however, and major changes might occur next near the upper limits of salt intrusion.

The Rappahannock and York Rivers have both experienced increases in phosphorus and chlorophyll *a* concentrations. Trends for nitrogen cannot be determined. Minimum dissolved oxygen concentrations in the lower York bottom waters have decreased, but secondary effects have not been thoroughly studied. Periodic anoxia in the lower York has resulted in cyclic changes in rates of remineralization from sediments.

Conditions in the upper James are similar to those in the Potomac. Historic conditions and changes are not well documented, so trends could not be determined. Concentrations of both major nutrients have increased in the lower James, but there has not been a concurrent increase in chlorophyll *a*. Low dissolved oxygen levels in bottom waters have been observed recently, but trends cannot be established.

Recommendations

Natural dissolved oxygen regimes have been altered by nutrient inputs to some segments of Chesapeake Bay. Enrichment problems are occurring in some areas of the Bay but are not apparent throughout most of the estuary. Prudent, conservative management can prevent continued degradation.

Sensible efforts to reduce nutrient inputs should continue. Population projections for the watershed and present evidence suggest that changes in the ecology of the Bay can continue unless strategies for reducing nutrient inputs, such as land application of municipal sewage, are sought and pursued.

- By Stephen Katsanos

Water Quality Monitoring of the Three Major Tributaries to the Chesapeake Bay

David J. Lang and David Grason

This project characterizes the inputs from the Susquehanna, Potomac, and James Rivers -- the major sources of freshwater to Chesapeake Bay. The rivers were monitored for chemical, physical, and organic components.

The Susquehanna was monitored at Conowingo, Maryland; the Potomac at the Chain Bridge in Washington, D.C.; and the James at Cartersville, Virginia. Measurements were made for suspended sediment, nutrients, carbon, trace metals, key metals, pesticides, major ions, chlorophyll a, total solids, and discharge. Scheduled frequencies of measurement varied from daily to monthly sampling, depending on the type of measurement. Supplemental sampling was used to assess the impact of extreme events such as storms.

Study results provide estimates of pollutant loadings for use in evaluating the effects of existing and future land-use, water-use, and regional, economic developments in the freshwater portions of the Susquehanna, Potomac, and James River Basins.

Introduction

The objectives of this project were to provide:

1) Estimated loadings of major ions, suspended sediment, selected nutrient species, and major trace metals for the two-year data collection period.
2) An assessment of accuracy and limitations inherent in these estimates.
3) Seasonal characteristics of nutrients, pesticides, and chlorophyll a collected during the study.
4) Relationships, comparisons, correlations, and trends detected in selected water-quality constituents.

Procedure/Methodology

Water-quality data were collected from the three sites at regular intervals during base flow, and much more intensively during high flow. Daily or continuous data were collected on discharge, suspended sediment, specific conductance, and water temperature. Samples were collected, preserved, and analyzed according to scientifically-accepted procedures.

Bivariate linear regression equations were used to estimate all loads in this study. Logarithmic transformations of constituent loads (computed from instantaneous concentrations, discharges, and a factor to yield loads in pounds per day) were regressed against logarithmic transformations of concurrent measurements of discharge, suspended sediment, and specific conductance. The regression lines were fitted analytically by the method of least squares.

Results/Conclusions

Month by month comparisons of loads do not compare as well as annual total loads. This is because the regression technique does not allow for seasonal and antecedent-flow variations. The regression-load-estimations technique is most accurate in wetter years having a wide range of flow.

Two pesticides were consistently detected at the Conowingo and Chain Bridge stations -- 2,4-dichlorophenoxyacetic acid (2,4D) and atrazine, primarily in late spring and summer.

Maximum chlorophyll a concentrations at all three sites occurred during the high spring runoff, and are possibly related to high velocity runoff in the spring. Concentration peaks of lesser magnitude occurred during the late spring and summer, and are possibly related to temperatures and nutrient recycling.

Samples at selected Bay tributaries had total residual chlorine concentrations of less than, or equal to 0.01 mg L^{-1}, the lower limit of detection for the technique.

Aluminum, iron, and manganese concentrations correlated more closely with suspended-sediment totals than with discharge totals at the Potomac and Susquehanna Rivers. Correlations for the James River station were not as high.

According to discharge-weighted concentrations of sulfate, the Susquehanna and Potomac Rivers carry greater sulfate loadings than the James River, possibly due to coal mining activities within the former two rivers' drainage basins. The Potomac River at Chain Bridge has the highest discharge-weighted average concentration of total nitrogen (2.20 mg L^{-1}), primarily in the form of nitrite-nitrate. The James River at Cartersville has the highest discharge-weighted concentration of both total phosphorus (0.42 mg L^{-1}) and orthophosphate (0.13 mg L^{-1}).

In general, nutrient parameters associated with suspended material relate better to suspended sediment, while constituents with large solubilities relate better to discharge. All of the nutrient parameters at the Susquehanna River station correlate closely with discharge. For the Potomac River site, however, some parameters correlate better with suspended sediment, while others correlate better with discharge.

Comparisons of data for the Susquehanna River at Harrisburg and Conowingo indicate that loads of nutrients associate closely with the water phase (dissolved). Orthophosphate and nitrite plus nitrate, for example, increase in the downstream direction. However, for total phosphorous, organic and Kjeldahl nitrogen, organic carbon, aluminum, iron, and manganese (those parameters more closely associated with the suspended sediments), loads near the mouth of the Susquehanna River are less than those at Harrisburg, presumably because of the effects of the intervening hydroelectric dams during years of average streamflow.

High-flow sediment transport for the Potomac River at Chain Bridge is heavily influenced by seasonal variations, form and intensity of precipitation, and antecedent conditions.

Results/Conclusions

Water-quality loadings can be reasonably estimated by regression techniques, especially for wetter periods of one year or more.

Net transport of nutrient species and adsorbed constituents is dominated by relatively few spring and storm-related high flow events.

Atrazine and 2,4D are the two most consistently detected pesticides at the Susquehanna and Potomac sites.

The sparsity of coal-mining activity in the James River may be reponsible for the river's lower sulfate concentrations. Phosphorus loads are increasing in the James, and concentrations for both total phosphorus and orthophosphate are higher than in the other two tributaries.

Peak discharges above 400,000 ft^3sec^{-1} at the Susquehanna River at Conowingo resuspend sediments and their related water quality constituents which had previously been deposited behind the three hydroelectric dams. These discharges also transport constituents to the Bay in excess of those transported 40 miles upstream at Harrisburg.

Sediment transport at the Potomac River site is heavily influenced by antecedent and seasonal conditions in addition to precipitation quality and quantity.

Ware River Intensive Watershed Study

Gary F. Anderson, Cindy Bosco, and Bruce Neilson

The Ware River intensive watershed study includes examinations of runoff from four small catchments, instream transport of runoff, and their impacts on estuarine water quality.

Runoff quantity and quality were monitored for row crop, residential, and forested lands in the Ware basin for the period of October 1979 to July 1981. Loading rates have been calculated for both baseflow and stormflow contributions at each study site.

Concentrations increased during stormflow periods for all water quality constituents except dissolved silica. On the average, levels increased by an order of magnitude above the baseflow concentrations for particulate materials, and by a factor of two for dissolved constituents. Concentrations of total phosphorus, nitrogen, and dissolved ammonia were substantially higher in the runoff at the two agricultural sites than at the residential and forested catchments. The residential catchment had high concentrations of dissolved nutrients and BOD5 in both baseflow and storm runoff. Areal loading rates were controlled by runoff quantity rather than concentration. The residential site, which produced the greatest amount of storm runoff, also had the highest loading rates for all constituents except phosphorous and suspended solids. The well-drained upland farm produced the least amount of runoff of the four catchments monitored.

Baseflow accounted for a significant portion of the total flow at the forested and residential catchments, especially during winter months when the groundwater table was high. Nearly half of the total flow measured during the study period came from the ground. However, storm runoff produced 83 and 70 percent of the total phosphorus and nitrogen loads, and 62 and 91 percent of the BOD5 and suspended solids loads, respectively. Although only 13 of 114 site-events had rainfall greater than 5 cm, these accounted for more than 50 percent of the total storm runoff measured.

Results from the study of estuarine waters indicate that the Ware River contains a moderate amount of nutrients. However, during summer months, some of the nutrients, particularly inorganic phosphorus and organic nitrogen, reach levels associated with excessive enrichment. The Ware is typical of other small tributaries of Chesapeake Bay: nutrient levels are higher at low tide, the estuary is more homogenous laterally than longitudinally (with respect to nutrients), and vertical gradients exist for dissolved oxygen, total phosphorus, and suspended solids.

The phytoplankton are generally phosphorus limited, except during the annual spring phytoplankton blooms (April 1979 and March 1980) when uptake of inorganic nitrogen by plankton causes the system to be nitrogen limited. Impacts of nonpoint source pollution are slight and short-lived in the estuary. This appears to be due to dilution by Bay waters and sedimentation in the upstream marshes. Thus, impacts are typically observed only in the shallow upstream portions of the estuary.

Introduction

The objective of the Ware River Intensive Watershed Study was to characterize the contribution of various land-uses to the nonpoint source loadings into the Ware River, a tributary of Chesapeake Bay. The quality and quantity of runoff for the major land-uses and physiographic features of the watershed were measured over a two-year period. During that period, the nature, extent, and duration of storm-water impacts on the water quality of the Ware River estuary were also measured.

Procedure/Methodology

The sites selected for the study were occupied by land-uses typical of the Chesapeake Bay region: a forested site, a residential site, and two row-crop agriculture sites. These types of uses occupy about 87 percent of the land area in the Ware basin.

The undisturbed, mixed forest site was selected primarily because the catchment was exclusively forested, yet easily accessible for study. It has moderate slopes but poorly-drained soils underlying the debris on the forest floor.

The low density residential site is a small subdivision located adjacent to the shoreline of the estuary. It was selected in part because the homes have septic tanks and stormwater runoff is channeled through a series of roadside ditches.

The two row-crop agricultural sites are in typical corn and soybean annual rotation. Fertilizer application and herbicides are used to control weeds. The lowland soils are poorly-drained, while the upland soils are light, erosive, and well-drained. Relief is more pronounced at the upland site.

Of the four sites, three have continuous baseflow during winter due to high water table conditions. The upland agriculture site exhibits no baseflow. Flows at all sites were monitored by installing H-flumes in the drainage-ways.

Flow meters were installed at each flume to continuously monitor baseflow and stormflow conditions. Automatic water samplers were used to collect flow-proportioned-compositesamples during storms. In addition to runoff monitoring instruments, a recording rain gauge sensitive to 0.01 inch was installed at each site.

Samples were routinely collected during dry periods when baseflow occurred in order to characterize loadings during non-storm conditions. Baseflow and runoff samples were analyzed for total and dissolved phosphorus, total and dissolved Kjeldahl nitrogen, BOD5, suspended solids, total and dissolved ammonia, nitrite-nitrate nitrogen, and dissolved silica.

Estuarine water quality was studied to determine how it is affected by runoff. Sampling stations were established throughout the Ware River estuary and were sampled semi-monthly throughout the 27-month study with runabouts. Submersible pumps brought samples of water on board. In addition, several intensive surveys were conducted on the river to provide a comprehensive picture of how water quality varies temporally and spacially in response to tidal and diel effects. Monitoring was also conducted to study the nutrient dynamics surrounding the spring chlorophyll a maximum and the response of the estuary to nutrient pulse loads caused by runoff.

Results/Conclusions

Although nutrient concentrations in runoff from both agriculture sites were significantly higher than at the other two sites, so little runoff occurred that the total loadings are lower than at either the forest or residential catchment. The reduced flow (an order of magnitude below the other sites, probably due to the fact that much of the rainwater is lost to percolation into the rapidly permeable soils) more than compensated for the higher pollutant concentrations in the runoff. An exception is phosphorus, however, that had very high concentrations in runoff from the cultivated fields. Suspended solids coming from the denuded land were also very high.

The forest and the lowland residential sites have significant per area baseflow which was comparable in quality. The baseflow loading at these two sites was a significant portion of the total. Stormflow from the residential site, however, was greater than that from the forest on an areal basis. The manmade ditches and impervious surfaces (about 10 percent of the surface area at the residential site) were expected to accelerate surface runoff there. Because nutrient concentrations were generally higher in stormflow, the stormflow loading rates and combined loading rates were higher for the residential catchment. Another notable feature of the residential catchment was the high loading of dissolved nutrients in baseflow, particularly orthophosphorus and nitrite-nitrate. This striking difference between the baseflow quality of residential and forested catchments may be due to leaching from nearby septic tank drainfields or application of fertilizers within the residential area.

Baseflow accounted for 35 to 60 percent of the total flow from the forested and residential sites. However, because nutrient levels were higher in runoff, roughly 70 percent of the phosphorus, nitrogen, and BOD5, and over 90 percent of the suspended solids loadings occurred during stormflow.

Loading rates have been calculated for individual storms which account not only for the catchment size but also for the amount of rainfall. From these statistics, valid comparisons among sites having different catchment areas and different storm conditions can be made. Although the two agriculture sites did have the highest individual storm loading rate, the mean and median rates were greatest for the storms at the residential catchment. That is, most of the time the loading rate is highest at the residential catchment but, occasionally, a very high rate occurs at the other sites. Occasional high rates are important and were responsible for most of the total load at the two agriculture sites. Analysis of individual storms did not show any statistically significant relationship between amount of rainfall, and runoff or loading.

Nutrient concentrations are generally low in the Ware River estuary, especially when compared to freshwater tributaries or to larger, more urbanized systems. Even following significant rain events, extremely low nutrient concentrations for silicates, total phosphorus, orthophosphates, suspended solids, organic nitrogen, and nitrate-nitrite nitrogen were found in the estuarine waters. Moderate nutrient levels were generally found in upstream reaches where low TN:TP values are attributable to the discharge of phosphorus-rich wastewaters.

Nutrient water quality at the mouth fluctuated little with the tides; however, temporal variations in nutrient concentration were seen elsewhere in the estuary within a tidal period, especially in the brackish region. Maximum values for total Kjeldahl nitrogen, ammonia-nitrogen, total organic carbon, and total phosphorus occurred at times of low water slack; minimum values were present at high water slack. Nitrate-nitrite nitrogen concentrations were generally below detection limit throughout the estuary during the survey.

Spatially, there was a distinct longitudinal gradient present in the estuary. Although at no station or season were anoxic conditions encountered in the estuary, the percent saturation of dissolved oxygen was significantly higher at the mouth than in the upstream reaches. The study average showed 90 percent oxygen saturation present at the mouth; the upstream station had only 70 percent.

Similarly, a longitudinal gradient was evident during periods of runoff: freshwater storm influence was minimal near the mouth of the estuary, whereas the upper reaches of the estuary showed significant responses with respect to nutrient concentrations and salinity gradients. During periods of increased freshwater flow, a two-layer circulation system may exist. Results indicate that the broad portion of the estuary is essentially well mixed, predominately by tidal processes.

Recommendations

The overall impact of runoff on the Ware River estuary appears to be slight and relatively short-lived. Impacts are greatest in the marshes upstream. Nutrient loading rates vary within and among each land-use site and appear to fluctuate seasonally. The rates are a function of runoff quantity and increase accordingly with the amount of baseflow. Further study is needed to determine the relationship between loading rates and rainfall amount. The data presented can be used in conjunction with those from other watershed studies to calibrate mathematical models of land runoff for the Bay. However, the comparison of two very similar row-crop practices showed large differences in pollutant loadings, illustrating that soil, topography, and drainage properties must be considered in addition to land-use when making such loading projections. It is suggested that further watershed studies monitor subsurface flow to adequately characterize low-lying coastal watersheds.

Evaluation of Management Tools in the Occoquan Watershed

Barron Weand and Tom Grizzard

During the period May 1979 to May 1981, nine water-quality monitoring stations were operated in small catchments in the Occoquan Watershed of Northern Virginia. The study sites incorporated different land-uses (pasture-land, corn croplands, suburban development, and forest) as well as contrasting management approaches (heavy versus light grazing, no-till versus minimum-till cropping, and detention ponds). Water samples were routinely analyzed for total suspended solids, ammonia nitrogen, total Kjeldahl nitrogen, oxidized nitrogen, ortho-phosphorus, total soluble phosphorus and total phosphorus. Meterological records were also kept during the study period, and collections of dryfall and precipitation were routinely analyzed.

Loading rates, calculated as kilograms per hectare per centimeter precipitation, indicated that the heavily-grazed pasture site generally exhibited the highest pollutant concentrations. The forested site and lightly-grazed pasture typically generated the least pollutant export. Significant differences were observed between the no-till and minimum-till croplands. The greatest differences were in the transport of soluble nutrient forms. Results of measurements at the stormwater pond were sometimes ambiguous, but some evidence indicated that proper maintenance of such a structure greatly improves its efficiency.

Measurements of atmospheric pollutant loadings indicated that the greater proportion generally came from wetfall. Annual loadings for various constitutents were calculated. The existence of acid rain in the study area was confirmed repeatedly, and the source was hypothesized to be sulfur oxides.

Introduction

This study was designed to characterize nonpoint source pollution from various land-use areas within the Occoquan Watershed and to provide a basis for the comparison of selected management practices. The data base was also intended to be used in the calibration of a mathematical pollutant transport model. Actual data collection began May 15, 1979 and continued through May 31, 1981.

Procedures/Methodology

Nine monitoring stations were established in small watersheds, primarily in agricultural areas. Drainage areas appropriate to the established criteria were selected with the assistance of the U.S. Cooperative Extension Service (CES), the

U.S. Soil Conservation Service (SCS), and the Virginia Division of Forestry (VDF).

Site one was a heavily-grazed pasture, as evidenced by visible erosion and loss of vegetative cover. The soils in this 12.7 hectare (ha) drainage area are moderately well-drained and relatively inefficient in producing runoff. While the upper reaches of the drainage showed a 4 percent average slope and better cover vegetation, the lower drainage was characterized by a 6 percent average slope and thin, poorly-established vegetation.

Site two was a no-till corn field of 10.8 ha, which was located on the same farm as sites one, three, and four. Soils similar to site one were predominant, and a relatively uniform slope of 8.5 percent was evidenced over the drainage area. Drainage from this area entered the pond. After the first season of monitoring, the management practice at this location was changed to minimum-till.

Site three was a small area of heavily-grazed pasture adjacent to site two and upstream of a farm pond. The drainage area was 4.5 ha, with a uniform slope of about 10 percent. The primary function of this station was to provide data on input to the farm pond (see site four).

Site four was located immediately below a farm pond and received runoff from sites two and three. Water flowed from the 5-ha pond by means of a 10-cm diameter riser pipe. Pool height in the pond varied seasonally according to precipitation, and at times even the emergency spillway was overtopped. Total drainage area to this lower station was 20.8 ha.

Site five was a very lightly-grazed pasture of 7.6 ha. The average slope here was 3.5 percent, and canopy heights of over 60 cm were observed late in the growing season. This site was paired with site one in an attempt to evaluate the effects of different management practices on pollutant loadings.

Site six was originally set up at a no-till corn cropland, but had to be abandoned shortly thereafter because of a change in management practices and problems with landowner cooperation. No data at this site were recorded.

Site seven drained 27.6-ha and collected runoff from a suburban townhouse development via a 183-cm corrugated metal pipe. The area was approximately 90 percent townhouse development, and 10 percent open land. Flow from this drainage proceeded to a dry, stormwater management pond, and was paired with site eight.

Site eight measured outflow from the stormwater management pond. Drainage to the pond included an area not measured at site seven, for a total drainage area of 35.7 ha. A perforated riser pipe provided detention in the pond, with the effluent passing through a concrete conduit. Together, sites seven and eight provided the potential for compiling a pollutant transport mass balance for the stormwater pond, and thus formed a management pair.

Site nine contained 30.6 ha of hardwood forest. Because the area was relatively undisturbed, this site represented pre-development conditions. The average slope in the watershed was 9.4 percent. Good under-canopy vegetation, and a thick layer of litter reduced runoff potential at this site.

Site ten contained 10.4 ha of corn, representing minimum-till management. The average slope was about 3.4 percent. This site was paired with site two in order to compare effects of management practices on pollutant loadings.

Each monitoring station was equipped with instruments which provded data on precipitation and runoff, and collected runoff samples during storm events. At one station, samples of atmospheric fallout were collected. Meterological parameters -- including solar insolation, mean wind speed, net evaporation, temperature, and relative humidity -- were also measured at this station.

Most of the monitoring sites were fitted with a type-H flume for primary flow control. Continuous stage measurements were recorded using pressure, transducer-type flowmeters. Each site also contained an automated sampler for the collection of discrete samples and a tipping bucket raingage which recorded rainfall in increments of 0.25 mm of precipitation.

The focus of the analytical efforts was on nutrient forms. The following determinations were routinely made: total Kjeldahl nitrogen (TKN); soluble Kjeldahl nitrogen (SKN); ammonia nitrogen (NH_3-N); oxidized nitrogen (ox-N), or combined nitrate and nitrite nitrogen; total phosphorus (TP); total soluble phosphorus (TSP); and total suspended solids (TSS).

Other analyses were also carried out with less frequency than those identified above. These included biochemical oxygen demand (BOD), chemical oxygen demand (COD), lead, zinc, pesticides, herbicides, and various soil parameters.

Results/Conclusions

During the study period (May 1979 through May 1981) a total of 245 storm events were monitored. The distribution of monitored events was uneven, due to varying precipitation patterns and different hydraulic efficiencies at each site.

Both median values for pollutant concentrations and loadings measured at the various sites were used for comparison. Whisker and box plots were also incorporated to provide a better interpretation of the data distribution.

The cropland sites (sites two and ten) produced relatively high nutrient concentrations in stormwater runoff. Pollutant loads were also found to be higher at site ten. The use of commercial fertilizers and animal manure on such lands obviously contributed to the nutrient levels observed.

As expected, the hardwood forest (site nine) and the lightly-grazed site (site five) produced both the lowest pollutant concentrations and loads. The lower levels of the forest are attributed to its abundant ground cover and forest canopy. The general lack of soil disturbance within the catchments is probably the basic factor in the low production of pollutants.

The concentrations of TSS, TKN, and TP were generally higher at the heavily-grazed pastureland (site one), reflecting the erodable nature of the soils in this catchment. As in the case of the cropland site (site ten), site one had high median loadings. The lowest concentrations were at the lightly-grazed pasture site (site five) and forrested site (site nine).

Site seven, the suburban site, produced high levels of pollutant concentrations and loadings. It is interesting to note that the median loading of total nitrogen at this site was as high, or higher, than those levels at the cropland sites. This may reflect the use of fertilizers in the suburban environment. The loading rates for total phosphorus and total suspended solids showed a similar pattern.

Data variability was evident among the parameters analyzed, and from site to site. For example, site seven was sampled more than any others and showed relatively small variabilities, and may reflect the unchanging nature of the site. The cropland sites (two and ten), however, undergo more intermittent disturbances, resulting in greater variabilities.

In addition, some water quality data were collected on an irregular basis. These data included concentrations of zinc and lead, measurements of biochemical and chemical oxygen demands, and analyses of pesticides.

Lead was detected only in the suburban catchment, and even then infrequently. Zinc appeared to be much more prevalent. The largest concentrations of total zinc were found at sites one and two, which were located on the same farm. Zinc was most consistently detected at the suburban site, but also found in all samples analyzed.

Median values of COD at all sites were nearly the same, except for the heavily-grazed pasture (site one), which was much higher. The forest site exhibited the lowest COD concentrations. In general, the BOD values measured were rather low. This may be due, in part, to constituents in the runoff (such as heavy metals or pesticides) which could inhibit bacterial growth. Analysis of filtered and unfiltered samples indicated that more than half of the BOD measured was soluble. Analysis of inhibited and uninhibited samples indicated that carbonaceous BOD represented 70 to 90 percent of the total.

During the course of this study, two sets of samples were collected specifically for analysis of pesticides and herbicides. The initial results were of some concern at that time because of relatively high concentrations of polychlorinated biphenyls (PCB's).

A broader scan for pesticides and herbicides was carried out seven months later. Levels of PCB's in these samples were noticeably lower. None of these samples was filtered, so that the variations observed in duplicate analyses might be due to differences in the suspended matter included in each individual sample.

Comparison of management practices indicated that the heavily-grazed pasture consistently produced greater pollutant concentrations than the lightly-grazed pasture. Statistical differences in pollutant concentrations were found for TN, TSN, TKN, ox-N, TP, and TSS. The similarity of these two sites, in terms of soils and hydraulic efficiencies, underscored the effect of management practices on pollutant export.

In comparing the no-till and minimum-till cropland site, statistically significant differences in observed concentrations were found for TN, TSN, ox-N, OP, and TSP. These differences were related primarily to soluble nutrient forms. During the study, site two was converted from no-till management to a minimum-till approach. The data suggest that both pollutant concentrations and hydraulic efficiencies increased under the minimum-till management.

Initial study of the farm pond indicated that removal efficiencies for suspended solids and nutrients were over 85 percent. However, allowance was not made for pond storage capacity in these estimates. After a survey was conducted to establish that capacity, an ensuing drought precluded additional estimates from being made. Concentration data alone, however, indicated high removal efficiencies for TSS and TP (85 percent and 86 percent, respectively), and a relatively low removal efficiency of 34 percent for TN.

Although 27 paired storms were monitored at the suburban detention pond site, the results were often contradictory. Because a satisfactory water balance could not be routinely made between the monitoring stations used, it was impossible to compare pollutant loadings with adequate confidence.

The cleaning (maintenance) of the stormwater pond during this study provided an interesting contrast. Evidence suggests that removal of most pollutants was increased after the maintenance activity was completed.

Atmospheric loadings were measured using a wetfall/dryfall collector located in an agricultural setting. Annual pollutant loadings from wetfall commonly exceeded those from dryfall. More solids deposition resulted from dryfall, however: over 60 percent of the total load (96.1 kg/ha/yr). Nutrient loadings were 16.8 kg/ha/yr for TN, and 0.65 kg/ha/yr for TP.

The pH of precipitation measured during this study was ordinarily in the range to warrant the term "acid" rain. The range of pH values observed was from 3.2 to 6.1, with a median value of 3.8. Indirect evidence suggested that sulfates were the causative factor.

The small catchments studied were all within the Occoquan Watershed. Similar studies of larger basins within the watershed were simultaneously carried out under the Occoquan Watershed Monitoring Program. Comparison of these results indicated that generally higher pollutant concentrations occurred at the small catchment sites. Unit area loads, however, were generally higher at the stream sites, due to the greater hydraulic efficiencies of the larger basins.

TOXIC SUBSTANCES

The Characterization of the Chesapeake Bay: A Systematic Analysis of Toxic Trace Elements

H.M. Kingston, R.R. Greenberg, E.S. Beary, B.R. Hardas, J.R. Moody, T.C. Rains, and W.S. Liggett

As part of a multidisciplinary study of Chesapeake Bay, the National Bureau of Standards (NBS) was asked to develop the techniques and procedures necessary to measure concentrations of trace and toxic elements within the water column throughout the length of Chesapeake Bay. The Inorganic Analytical Research Division of the Center for Analytical Chemistry at NBS has completed the analysis for selected elements [cadmium (Cd), cesium (Ce), chromium (Cr), cobalt (Co), copper (Cu), iron, (Fe), manganese (Mn), molybdenum (Mo), nickel (Ni), lead (Pb), scandium (Sc), tin (Sn), thorium (Th), uranium (U), and zinc (Zn)], including some elements at concentrations consistently below one picogram per milliliter.

The characterization of Chesapeake Bay was divided into five major phases. The first included the development and construction of a sampling system for the trace metallic elements dissolved in water and a filtration system for collecting the particulate elemental component.

The second phase consisted of sampling chemical stabilization by acidification and storage of the samples in the field. The total complement of 102 samples was obtained, filtered, acidified, and stabilized. There were also 51 replicate bottom samples obtained and frozen for archival use. A series of over 30 blanks was also prepared and integrated with the 102 water samples to be analyzed.

The third major phase of activity consisted of the chemical separation and preparation of samples for the analytical instrumental methods. The chemical separation/sample preparation stage of this work has been described in the literature for both instrumental techniques.

The fourth major phase consisted of instrumental analysis of the samples for the trace elements. The total number of elemental concentrations resulting from the analyses of the contracted elements exceeded 3000 and involved several thousand more unreported analyses totaling over 5000 separate determinations.

The fifth major phase involved data reduction and evaluation of the statistical significance of the blank. The blanks were statistically modeled for each element, and the blank and uncertainty of the blanks were applied to the data. The concentrations were adjusted uniformly to at least the 95 percent confidence limit.

Introduction

This report describes the National Bureau of Standards' (NBS) efforts in a multidisciplinary study of Chesapeake Bay coordinated by the U.S. EPA's Chesapeake Bay Program. The NBS used the best available technology to determine the trace and toxic element concentrations in the water column. As part of this program, the NBS collected and analyzed both the dissolved and suspended particulate fractions of 102 water samples covering the entire length of Chesapeake Bay. The elements of interest include Cd, Ce, Co, Cr, Cu, Fe, Mn, Mo, Ni, Pb, Sc, Sn, Th, U, and Zn. Specific chemical pre-concentration, separations, and manipulations were used to prepare the samples for analysis by Neutron Activation Analysis (NAA) and Graphite Furnace Atomic Absorption Spectrometry (GFAAS).

Except for neutron activation analysis and anodic stripping voltammetry, no analytical techniques are currently available for the untreated sample determination of trace elements in seawater at concentrations below 5 ug L^{-1}. Usually, it is necessary to preconcentrate the trace elements from a large volume and separate the transition elements from the alkali and alkaline earth elements. In such sample preparations, the efficiency of concentration, completeness of separation, and total analytical blank become critical to the final instrumental method.

A more recent separation procedure utilizing Chelex resin produced a sample devoid of alkali, alkaline earth, and halogen elements, and left a dilute nitric acid/ammonium nitrate matrix containing only the trace elements of the seawater sample. This procedure was used in conjunction with GFAA to analyze Chesapeake Bay estuarine samples.

Procedure/Methodology

A method of preparation for solid samples from 100 mL of estuarine or seawater, using Chelex 100 resin, followed by the determination of 12 trace elements by NAA was used in this study. This procedure has been used to analyze NBS SRM 1643a, as well as high salinity water samples collected near the mouth of Chesapeake Bay.

The extremely low trace concentrations in these estuarine waters made the procedural blank critically important. The integrity of the sample can be compromised by just brief exposure to normal laboratory air, or less-than-exhaustively-cleaned containers. In addition, the extremely high concentrations of alkali, alkaline earth, and halogen elements in the marine water matrix make direct analysis difficult, or impossible for most analytical techniques.

To circumvent these problems, special chemical and instrumental procedures were developed. Chemical separation/preconcentration procedures based on the chelating resin Chelex-100 were applied prior to NAA and GFAAS analysis.

The elimination of the matrix elements allowed the determination of many elements that could not otherwise be analyzed, and enhanced the sensitivity of other elements of interest. The control of the blank in this procedure has enabled its contribution to be sufficiently low that it did not limit the measurement of most elements in pristine samples.

To ensure sample integrity and accurate analytical blank determinations, 30 dissolved and particulate blanks were prepared during the sample collection. The blanks were then carried through all manipulations and analyses as additional samples.

Evaluations were made using statistical comparisons with data of known statistical reliability. The analysis, blank contribution, corrections, and mathematical manipulation of the data in this report have resulted in 58 data sets which are of known statistical reliability. These data sets contain the sample numbers arranged in a numerical sequence approximating the geological arrangement of Chesapeake Bay, from Susquehanna River to, and including, the Atlantic Ocean. The concentrations are given as a best value, and as a maximum and minimum value which represents at least the 95 percent confidence limit of the concentration. The significant figures of each concentration are determined by the range of the maximum and minimum value.

Although initially it may appear of uncertain interpretive value, a technique using mathematical ratios was used to look at relative amounts of elements. Scandium was chosen for this purpose, because it has relatively few anthropogenic uses. Because it is not used in a refined form in industry, and is refractory in nature, it is not expected to be introduced into the environment in an enriched state or in significant quantities. When these ratios are divided by ratios of average crustal material, a crustal enrichment factor (EF) results. This is done for convenience and also to allow a crude comparison with naturally-occurring material.

In these data the concentrations from Wedepohls' compilation for crustal elements has been used. Similar, though not identical, results could be obtained using other compilations. Additionally, the computation of EF's relative to average soils and average sedimentary rocks would be of value to see how the suspended sediments of Chesapeake Bay differ from those natural materials.

Ideally, the EF's for each element will remain constant if the sources contributing to the suspended sediment remain the same. Although the concentration of the various elements may fluctuate several orders of magnitude from sampling to sampling, the EF's should be constant if the sources are constant as they are not affected by mass loading.

Results/Conclusions

Uses of these EF's to produce an interpretive model for evaluating and concluding elemental relationship and origins can be postulated. However, actual conclusions cannot be drawn until a rigorous scrutiny of the statistical significance of the individual sets of enrichment factors has been completed. Because this technique has not been used previously for water particulates, many cross references between elements and geological positioning, as well as within set limits, must be evaluated.

In this report, the enrichment factors normalized to the Wedepohl crustal numbers have been given without interpretation to at least the 90 percent confidence limit.

These data are of sufficiently well-known reliability that statistical comparisons result in significant trends of known reliability. This work has not been included in this report and is sufficiently complex to comprise a separate recently-begun effort.

-By Ian Gillelan

Fate, Transport, and Transformation of Toxics Substances: Significance of Suspended Sediment and Fluid Mud

Maynard Nichols, Richard Harris, Galen Thompson, and Bruce Neilson

This research aimed to determine the distribution of selected metals in suspended material and fluid mud, to identify potential zones of toxic accumulation, and to trace their transport routes.

Observations of flow, salinity, suspended material, pH, and dissolved oxygen were accomplished in Bay-wide longitudinal sections and at four anchor stations in the northern Bay between March 1979 and April 1980. The observations cover a range of conditions, including seasonal high-low river discharge, sediment influx, neap-spring tide range, and oxygenated-anoxic water. Samples of suspended material, fluid mud, and bed sediment were analyzed for their particle size, organic matter, and metal content.

Metal concentrations of arsenic (As), copper (Cu), manganese (Mn), nickel (Ni), lead (Pb), tin (Sn), and zinc (Zn) in fluid mud and bed sediment per gram of material decrease seaward from a maximum in the Baltimore-Susquehanna River area. The metals Mn, Pb, and Zn are four to six times greater than Fe-corrected average shale, indicating major human input and significant accumulation in this zone.

Metal concentrations of cadmium (Cd), Cu, Pb, Ni, and Zn are maximal in surface suspended material from the central Bay. They are higher than landward, near potential sources, and they exceed concentrations in bed sediment two to 80 times. The enrichment is not natural compared to average shale or plankton; it is most likely created by bio-accumulation.

Transport of particle-associated metals from major sources follows either hydrodynamic pathways leading to particle accumulation by the estuarine circulation, or bio-ecological routes leading to bio-accumulation.

Management and monitoring strategies can reduce potentially toxic metals to acceptable levels and warn management agencies of toxic hazards.

This report is submitted by the Virginia Institute of Marine Science, School of Marine Science, College of William and Mary under sponsorship of the U.S. Environmental Protection Agency. This report covers the period July 1, 1978 to August 30, 1982.

Introduction

Each year, a substantial load of trace metals enters Chesapeake Bay from both natural and human sources. Regional production of toxic metals is increasing with increasing industrial activity and sewage discharge. At least half of all

Cd, Pb, Cu, and Cr reaching the Bay results from sewage and industrial waste. Low concentrations of metals are essential to Bay environment; however, if they are excessive, detrimental consequences may result. Toxic effects have not been demonstrated, but disturbing changes in the Bay environment have been observed: a decrease in oyster and striped bass populations, a lack of shad runs in the upper Bay, and declining clam catches. Knowledge of contamination levels, transport routes, and reservoirs of potential contaminants is necessary because toxicants may alter the quality of the Bay over periods of time.

This study investigates the role of suspended sediment and fluid mud in the fate of toxic metals in the Chesapeake Bay system. Fluid mud, an intermediate stage between mobile suspended material and mud, is chemically important because it is a reservoir for potentially toxic metals and a medium for chemical transfer.

Procedure/Methodology

A series of field observations defined the Bay-wide distribution of metal contaminants in the following way: suspended material was collected for analysis of toxic metals; water in which they occur was characterized; and sediments with which metals associate were analyzed for particle size and physical properties. Temporal variations of sediment and metal loading were established and potential zones of metal accumulation and their transport routes identified. Field observations included contrasting conditions such as seasonal high-low river discharge and sediment influx, neap-spring tide range, and oxygenated-anoxic water differences. The survey of 122 stations, with regard to these variables, along with the parameters of temperature, salinity, dissolved oxygen, pH, and total amounts of suspended material, resulted in 5576 measurements, including analyses of six to 11 metals.

Bed sediment and fluid mud were obtained with a stainless steel Smith-MacIntyre grab or Bouma box core. Suspended material collected on Nucleopore filters was analyzed by flame atomic absorption for Fe, Mn, and Zn. Flameless atomic absorption was used to obtain concentrations of As, Cd, Cu, mercury (Hg), Ni, Pb, and Sn.

Results/Conclusions

The Bay was characterized from the hydrographic and sedimentologic measurements and observations gathered from eight cruises. The turbidity maximum zone (stations 12 to 18) contains high suspended loads, fine particle size, and low organic carbon percentages. Low suspended loads, coarse particle size, and high organic percentages are common to the central Bay zone (stations 8 to 11); while stations one to seven, representing the near entrance reaches, have intermediate suspended loads, moderate particle size, and moderate organic percentages. Conditions in the deeper portions of the central Bay region favor accumulation of metals and fluid mud because of fine-grained, moderately-organic sediments which deposit rapidly.

Metal distributions in suspended material are vertically stratified, with mean surface and mid-depth concentrations greater than near-bottom depths. Cadmium, Cu, and Pb of surface and mid-depth waters are three to 12 times higher in summer than in spring. Concentrations of Cd, Cu, Pb, Ni, and Zn are maximal in surface suspended matter from the central Bay, suggesting bio-accumulation of metals from distant sources.

Bay water is well-buffered against pH change and is oxygenated, except in summer when near bottom water of the central Bay (below 10 m depth) is anoxic. Also, time, depth, and distance seaward are conditions which affect physical, chemical, and sedimentologic rates of transport and accumulation of toxic materials.

Recommendations

By dealing with Chesapeake Bay as an entity, the state of the Bay can be improved by reducing input of such potentially toxic metals as Cd, Cu, Ni, Pb, and Zn from wastewater and industrial discharges. Nutrients which stimulate organic production should be reduced in an attempt to alleviate the suspended solids load, of which some 40 to 60 percent is composed of organic material. Entrapment of river-borne sediment can be deterred by regulating inflows during periods of high sediment influx.

Potentially toxic metals should be managed by controlling them at their sources, by learning the long term changes and "far field" effects in zones of accumulation, and by recognizing amounts of toxicants in the system which are above natural levels, as well as the associations between metals and sediment. A monitoring system of the Bay and its tributaries, with a scientific data base, should be established to warn Bay managers of toxic hazards. Research should consider such factors as bio-accumulation of toxicants in plankton, the significance of repetitive sediment resuspensions, and the tributaries as sinks or sources of metals and sediments.

-By Debra A. Barker

Dredging: Implementation of Innovative Dredging Techniques in the Chesapeake Bay

Don V. Aurand and Alexandra Mamantov

The environmental effect of dredging and dredged material disposal has been an issue in the Chesapeake Bay region for some time. This report reviews eleven years of dredging records for Federal projects, six years of dredging records for private projects, current management programs, and scientific literature to define current programs and their effectiveness. Potential technological improvements are also described. A series of recommendations for improving dredging practices in Chesapeake Bay is provided.

It appears that current operations do not produce major consequences on the ecology of the Bay. However, attention should be given to future programs in order to ensure that the quality of the Bay does not deteriorate. Specific suggestions for possible improvements are: implementation of study programs to more clearly define the chemical nature of the sediments; better long-range planning with respect to disposal options; comprehensive monitoring programs to clarify long-term impacts; use of incentive payments to encourage innovative technologies; replacement of seasonal dredging restrictions by turbidity standards; possible Federal ownership of a small, pneumatic dredge for use in highly polluted areas; and repeal or modification of those portions of the Jones Act affecting importation of dredging equipment.

Introduction

Maryland, Virginia, and two Corps of Engineer's district offices set performance standards and issue permits for both new starts and maintenance dredging projects in Chesapeake Bay. Individually, and in some cases through joint review sessions, officials within the appropriate state and Corps district offices evaluate private and Federal dredging proposals for compliance with environmental guidelines and procedural requirements established by State and Federal legislation. Federal laws, including the Clean Water Act, National Environmental Policy Act, and Resource Conservation and Recovery Act, set minimum standards for evaluating dredging proposals. States can establish requirements more stringent than those authorized by Federal statute. Standards, permit processing procedures, and project operational requirements mandated by Maryland and Virginia differ. The two Corps district offices also employ different procedures to review dredging permit applications.

The environmental and economic effects of both private and public dredging projects are major issues within the Chesapeake

Bay region. The Bay is an important commercial fishery and recreational area. It also contains two major commercial ports, Baltimore and Norfolk, which together load approximately 90 percent of domestic coal exports, excluding the Great Lakes.

Coal exports in 1980 reached 92 million tons, a 39 percent increase over 1979 shipments. The two Chesapeake Bay ports were unable to expeditiously process shipments, and colliers were forced to drop anchor and wait until dockage and loading facilities were available. The coal industry projects that export demand could rise to 280 million tons by the year 2000. The industry maintains, however, that increased coal shipments cannot be moved through Baltimore and Norfolk unless channels and harborage facilities are expanded.

Harbor expansion, maintenance dredging, and private dredging are viewed cautiously by Bay fishermen and environmentalists for several reasons. Dredging itself results in increased turbidity, which some view as detrimental to fisheries. Dredged sediment disposal is also a major problem, particularly in the northern portions of the Bay. Although open water disposal was practiced in the past, concern over turbidity and the disposal of sediments contaminated by toxic pollutants has resulted in increased use of costly upland or confined disposal.

This report, prepared for the Environmental Protection Agency's Chesapeake Bay Program examines environmental, economic, and procedural issues related to dredging that have been raised in the Chesapeake Bay region. Dredging methods, effects, specific program requirements, and permit processing procedures are reviewed. The volume of dredging activity (both private and public), types of equipment used domestically and abroad, costs, and approaches for streamlining the permitting process are also examined.

Procedure/Methodology

Dredging records for the eleven years from 1970 to 1980 for Federal projects, and for the six years from 1975 to 1980 for private permits were examined at the Corps of Engineers Baltimore and Norfolk district offices. Historic dredging practices (equipment used), volume of material removed, disposal method (open water, upland, or confined disposal), project location, and project costs were determined. Federal statutory requirements, state standards, and permitting procedures were reviewed, and differences in processing techniques used by the two Corps district offices and the two states were described.

Domestic and foreign dredging equipment (importation of foreign equipment is restricted by the Jones Act) were examined. Equipment capabilities, design features, and turbidity factors were evaluated.

Results/Conclusions

The invesigators conclude that the overall environment of Chesapeake Bay has not been adversely affected by past dredging and disposal operations. They state, however, that concerns over dredging and disposal of contaminated sediments are legitimate and deserve special consideration.

Several options are presented, both technological and managerial, that the investigators feel could help minimize dredging costs -- attributable to compliance with environmental standards -- and ease permit processing procedures without increasing the risk of environmental degradation.

Other options include: repeal or modification of the Jones Act to ease restrictions on importation of equipment manufactured abroad; use of positioning equipment and silt curtains to minimize turbidity; and increased use of pneumatic dredges on small projects and on projects involving the removal of contaminated sediments.

Options for improving management of dredging programs, including measures that might streamline the permit review process are: use of turbidity performance standards instead of imposing seasonal moratoriums on dredging activity; chemical and bioassay testing of sediments for toxic contaminants; use of advanced treatment methods in confined disposal areas; and revision of effluent standards for upland disposal areas.

Recommendations

The investigators recommend that state regulatory agencies evaluate several of the above options and possibly modify their dredging programs accordingly. Specifically, they suggest that states attempt to eliminate uncertainty concerning the extent of sediment contamination within their jurisdictions by sampling and then developing advance plans for dredging and disposing of contaminated sediments. They also recommend existing policies requiring confined disposal be reevaluated and justified. States should encourage dredging contractors to use new, innovative equipment, but incentives instead of requirements should be the basis of such encouragement. Also, seasonal restrictions on dredging should be repealed and replaced by turbidity standards.

Two recomendations are advanced for consideration by Congress and the Corps of Engineers. Repeal of appropriate portions of the Jones Act is advocated, and the investigators suggest that the Corps of Engineers investigate the purchase of advanced pneumatic dredging equipment for use on the east coast.

-By Stephen Katsanos

SUBMERGED AQUATIC VEGETATION

Distribution and Abundance of Submerged Aquatic Vegetation in the Lower Chesapeake Bay, Virginia

Robert J. Orth, Kenneth A. Moore, and Hayden H. Gordon

Aerial photography and surface information were employed to delineate the distribution and abundance of submerged aquatic vegetation (SAV) in the lower Chesapeake Bay and its tributaries. Imagery of SAV determined from the aerial photographs was transferred onto 31 topographic quadrangles which represented over 8500 hectares of SAV. All information from this 1978 mapping effort was entered into a computerized data base.

The areas with the greatest concentration of SAV were located along the western shore of the Bay between Back River and York River; along the shoreline of Mobjack Bay; the shoal area between Tangier and Smith Islands and east of Great Fox Island; and behind the sand bars near Hungars and Cherrystone Creeks. The oligohaline and freshwater regions were essentially lacking SAV.

Analysis of 40 years of SAV historical data of six selected sites in the lower Bay revealed reduced coverage and density in the late 1930's (compared to coverage in 1970), an increase from 1937 to 1970, and then a large loss between 1971 and 1974 at five of the six sites. The decline continued through 1978 when the lowest levels of SAV in 40 years were witnessed.

Introduction

Submerged aquatic vegetation (SAV) systems serve many functional roles in the Chesapeake Bay ecosystem. Among these are habitat for macroinvertebrates, protection from predators for many species of juvenile fishes and crabs, and food for herbivores which feed off the diverse epiphytic growth on SAV blades. Submerged aquatic vegetation converts an otherwise bare sand or mud bottom into a complicated vegetated community that not only supports a varied animal population but also serves as a very efficient "nutrient pump" that moves nutrients from the sediment to the water column and vice versa. In addition, these grass beds aid in the reduction of shoreline erosion by absorbing wave energy due to the binding of the sediment by the roots and leaves of the plants.

Chesapeake Bay supports extensive shoal areas that are heavily vegetated with SAV. Historically, emphasis has been placed on these areas due to their importance as food for waterfowl. However, with the recent decline of SAV in the 1970's, their other important roles are now apparent. It is clear that these areas are important to the well-being of the Bay and must be properly managed. Proper management of SAV must begin not only with recognition of the importance of the resource but also with knowledge of where the resource is located and its abundance as well as the dynamics of the system. Thus, the objective of this study was to define the current distribution of SAV in the lower Chesapeake Bay and to focus on any trends related to the dynamics of the system that might exist in the historical records.

Procedure/Methodology

Aerial photography and field investigations were employed to delineate the distribution and abundance of SAV in the lower Chesapeake Bay. Aerial photographs were transferred onto topographic quadrangles (1:24,000). Individual SAV beds were measured and computed with an electronic planimeter and stored in a computer data base. Four density categories were applied to each bed: less than 10 percent cover, 10 to 40 percent cover, 40 to 70 percent cover, and 70 to 100 percent cover. Field investigations were done at numerous sites for species composition, percent cover, and bottom sediment types.

Results/Conclusions

Thirty-one mylar USGS topographic quadrangles were produced showing significant areas of SAV. Twenty-seven of these were of mesohaline and polyhaline areas which were dominated by a species mixture of Zostera marina and Ruppia maritima. The remaining four depicted significant areas of SAV in oligohaline and freshwater regions of the Potomac, Chickahominy, and James Rivers.

The oligohaline and freshwater regions essentially lacked SAV. Field investigations revealed mostly small areas of SAV usually adjacent to tidal marshes. The mesohaline and polyhaline regions of the largest rivers and creeks along the Chesapeake Bay shoreline contained the greatest concentrations of SAV. The most significant areas were: along the western shore of the Bay between Back River and the York River; along the shoreline of Mobjack Bay; throughout the shoal areas between Tangier and Smith Islands and east of the Great Fox Islands; and behind large protective sand bars near Hungars Creek and Cherrystone Creek that are located along the Bay's eastern shoreline.

The distribution of SAV species in tidal waters were classified into three associations based on their co-occurence: (1) eelgrass (Zostera marina) and widgeongrass (Ruppia maritima) dominating mesohaline and polyhaline waters; (2) pondweeds (Potamogeton spp) and pondweeds (Zannichellia palustris) dominating oligohaline waters; and (3) the freshwater species coontail (Ceratophyllum demersum). Species diversity increased in an upstream direction.

Analysis of 40 years of historical SAV data for six selected areas revealed changes in grass bed coverage. Five of the six sites, Mumfort Island and Jenkins Neck in the York, the East River in Mobjack Bay, Parrott Island in the Rappahannock River, and Fleets Bay, located between the Rappahannock and Potomac Rivers, showed reduced coverage and density in the late 1930's, an increase from 1937 to 1970, and then the largest loss between 1971 and 1974. Abundance of SAV at the sixth site, Vaucluse Shores (at the mouth of Hungars Creek on the eastern shore), has not changed so dramatically as the other sites. Differences have been attributed to changes in the physical features (sand bars and sand spits) in this area. Decreases in SAV at the first five sites continued through 1978 when the distribution and abundance was the smallest observed over the last 40 years.

Recommendations

Submerged aquatic vegetation communities are dynamic systems that change annually and seasonally in abundance. At present, much attention is directed to these systems because they are in a reduced state of abundance.

Aerial photography should be taken under the constraints of tidal height, sun angle, wind conditions, and other factors; at altitudes of 3740 meters which allows direct comparison to the standard topographic quadrangle (1:24,000); and during the early summer to record maximum standing crop of the vegetation. It is recommended that aerial photographs be taken, at the minimum, on an annual basis. In addition, because the oligohaline and freshwater regions have been shown to have scattered small beds of SAV that are not evident from the aerial photographs, it is recommended that further field studies be done in these areas to provide an understanding of the distribution, abundance, and resource value of the vegetation.

-By Linda C. Davidson

Distribution of Submersed Vascular Plants, Chesapeake Bay, Maryland

Richard R. Anderson

This research was initiated with the overall objectives of determining past and current (1978) distribution of submersed aquatic vegetation (SAV) in Chesapeake Bay, Maryland, and to formulate recommendations for future surveys with regard to frequency and methodology.

Current distribution of SAV was determined through interpretation of 1:24,000 scale black-and-white photographs were obtained during the growing season. Field work was conducted in all areas with the use of a seaplane. Distribution of SAV was mapped on 1:24,000 U.S. Geological Survey (USGS) topographic map mylars. Seventy seven maps were produced. Of the 40 sheets with less than 10 hectares of vegetation, 11 were north of the Chester/Magothy Rivers and 21 were south of the Choptank/Upper Patuxent Rivers to Smith Island on the Eastern Shore. This indicates that the mid-portions of Chesapeake Bay were relatively healthy with regard to distribution of submersed vegetation. This area of the Bay also contained the highest diversity of submersed vegetation.

Current diversity declined rapidly from eight types in the mid-Bay to two to three species in the southern portion of the Eastern Shore were Zannichellia palustris and Ruppia maritima predominated. There were only a few small areas of Zostera marina found in the lower Bay, those being in the South Marsh Island area.

Past distribution of SAV was determined through interpretation of archival photographs of varying scale and type. Distribution from 1952 to 1978 at various times within those years was plotted for three areas in the upper Bay. These sites encompassed the Chester River area, the Eastern Bay area, and one site on the western shore to include Salt Peter and Seneca Creeks.

Of the three areas, the Chester River site had the most usable photography. Trends in the Chester River area indicate fluctuation in distribution of SAV with time. The "bloom" and consequent decline of Myriophyllum spicatum over the whole Bay may have accounted for some of this fluctuation. The 1972 data show a decline in SAV, possibly from effects of a tropical storm during June of that year. There was an encouraging increase in distribution shown in the 1978 survey.

The Eastern Bay area site had very little data available for ascertaining distribution, but there does appear to be a downward trend from 1970 to 1978. The Salt Peter/Seneca Creek area site was selected due to the presence of a thermal power generating station which discharges heated water into Salt

Peter Creek. Operation of this plant began in 1962. SAV distribution data prior to 1960 and after beginning of operations (1964) indicate a relatively stable situation. This was, however, the time of Myriophyllum "blooms" and may mask the absence of other more thermally sensitive species. There also appears to be a slight downward trend in distribution from 1970 to 1978.

Recommendations for future SAV surveys include larger-scale, color photography that would better define species association in areas defined as "critical," at a frequency of at least once every three years.

This report was submitted by The American University under sponsorship of the U.S. Environmental Protection Agency, and covers the period June 1, 1978 to January 31, 1980. Work was completed as of September 30, 1979.

Introduction

Over the last ten years the Bay grass population of the Chesapeake has declined dramatically. In an attempt to better understand the trends in distribution and abundance of submersed aquatic vegetation, aerial photography was used to establish an SAV inventory of the Maryland portion of the Bay. By interpreting these black and white photos, investigators hoped to focus on species concentrations and to assess the usefulness of photography for estimating past and future trends.

While SAV beds may seem bothersome to some boaters, their importance to the Bay's ecosystem is seemingly limitless. Grasses are a principal source of food for waterfowl and some herbivorous fish species. SAV serves as a habitat for species of copepods and molluscs and as a nursery or shelter area for fishes and crabs. Grasses are the primary producers of vegetative biomass: almost all of the above ground crop is contributed to the detrital food chain. SAV has a wave-dampening function that reduces shoreline erosion and allows sediments to settle. Bay grasses also act as nutrient buffers and seasonally-important sources of dissolved oxygen.

For these many reasons, this study was conducted to determine past and current distributions of SAV, and to formulate recommendations for future surveys.

Procedure/Methodology

During the summer of 1978, aerial photographs were taken of the Bay shoreline where grasses are found. Fourteen percent of the area could not be photographed due to military restrictions, but field work was substituted. Field studies were also conducted in other areas to verify photographic information and to identify dominant species.

Information from the photographs was then transferred to 77 USGS Maps; 17 of the maps covered areas with no mappable vegetation and 24 contained less than 10 hectares of grasses.

To determine how distribution and abundance has changed over time, archival photos dating from 1952 to 1978 were analyzed. The Chester River area, the Eastern Bay area, and Salt Peter and Seneca Creeks were chosen to indicate historical trends.

Results/Conclusions

In interpreting the photographic coverage of the Maryland portion of the Bay, scientists determined that the mid-Chesapeake is relatively healthy in both diversity and abundance. Archival photographs indicate that grasses in the Chester River area increased until the 1960's, declined, and increased again until a decline after a tropical storm in 1972. There seems to be a trend of increased distribution in 1978.

Archival data for the Eastern Bay were too insignificant to draw any meaningful conclusions. Salt Peter and Seneca Creeks had a greater distribution of SAV than in the early 1970's but there seems to be some stabilization in the 1978 survey.

Recommendations

The study suggests that broad SAV surveys should be initiated every three years to record and predict trends. Yearly monitoring of regionally-representative areas should be more complete, including species composition, percentage cover, and seasonal growth characteristics. Color photography should be used as it enhances species distinctions. Lab and field studies should continue so that light, temperature, and other factors which control the survival of SAV can be determined.

-By Debra A. Barker

Distribution and Abundance of Waterfowl and Submerged Aquatic Vegetation in Chesapeake Bay

Robert E. Munro and Matthew C. Perry

Waterfowl populations in Maryland and Virginia portions of Chesapeake Bay were examined during long-term (1890-1970) and current (1972-1980) periods to identify trends in their distribution and abundance. Comparisons were also made between State and Atlantic Flyway populations and waterfowl species distributions among survey areas. Distribution and abundance of submerged aquatic vegetation (SAV) among waterfowl survey areas in Maryland were summarized for seven plant species during nine years (1971-1979). These data (SAV species combined) were used to test the hypothesis that annual variation in area populations of waterfowl was related to variation in the abundance of SAV, following an adjustment for annual variation in the general abundance of waterfowl. The distribution and abundance of SAV species declined in Maryland waters during the 1970's. There were few statistically significant relationships between distribution and abundance of waterfowl and SAV. But there was an implied biological relationship, because the most important waterfowl wintering areas were also among the most abundantly vegetated areas. This report was submitted by the U.S. Fish and Wildlife Service, Migratory Bird and Habitat Research Laboratory under the sponsorship of the Chesapeake Bay Program, U.S. Environmental Protection Agency.

Introduction

The Chesapeake Bay is the most important wintering area in the Atlantic Flyway for more than 1.5 million waterfowl, including Canada geese (*Branta canadensis*), whistling swans (*Cygnus columbianus columbianus*), canvasbacks (*Aythya valisineria*), ruddy ducks (*Oxyura jamaicensis*), common goldeneyes (*Bucephala clangula americana*), redheads (*Aythya americana*), black ducks (*Anas rubripes*), and mallards (*Anas platyrhynchos*). The estuary also serves as a resting area for birds that migrate farther south. Of the 45 species native to North America, 30 migrate through or winter in Chesapeake Bay.

Large beds of submerged aquatic vegetation, especially widgeongrass (*Ruppia maritima*), wild celery (*Vallisneria americana*), and sago pondweed (*Potamogeton pectinatus*), have traditionally been important to the Bay's population of waterfowl. The decline of the grasses, a major source of food for the birds, prompted this examination of historic and current relationships between waterfowl and SAV.

Procedure/Methodology

The U.S. Fish and Wildlife Service (USFWS) conducts annual population surveys of Chesapeake Bay waterfowl. Although information may be affected by weather conditions, and by birds not found, and those found but not counted, these surveys constitute the only long-term source of information on waterfowl distribution and abundance. These surveys were analyzed so that population comparisons between pre-1970 (long-term) and 1972-1980 (current) periods could be made. United States populations were used as baseline measures to indicate species trends. Species had to compose at least five percent of the Atlantic Flyway population to be considered in this study.

Waterfowl feeding habits were tabulated according to species, time period (pre-1960, 1960's, and 1970's), and organ source (gizzard, gullet, or unknown). This information, collected by Stewart during the 1950's, Rawls during the 1960's, and supplemented with current data, provided the information necessary to examine relationships between waterfowl and SAV as a food source.

Distribution and abundance records of SAV, taken from results of summer surveys conducted by the USFWS and Maryland Wildlife Administration during 1971-1979, were studied to determine the trends of SAV populations. Linear regression and analysis of variance techniques were used to examine relationships between waterfowl and SAV.

Results/Conclusions

Reductions in SAV populations affected the distribution and abundance of waterfowl species that were historically dependent on SAV and could not adapt to the changes. Some species left the area while others changed their feeding habits.

The SAV population as a whole declined dramatically in the 1970's. Vegetated sample stations in Maryland waters declined from approximately 29 percent during 1971 to 8 to 15 percent since 1973. Important waterfowl food plants, which were abundant during the late 1960's, became less prevalent in the Bay by 1973. Examples include widgeongrass, sago pondweed, horned pondweed, and wild celery.

Over 600 sampling stations of shoal water habitats were established to monitor these trends in Bay grass populations among waterfowl survey areas for nine years. By 1979 each of the 20 areas had depleted supplies of SAV. The lower Choptank River, for example, had 25.5 percent of its stations vegetated in 1971. By 1979, however, this total fell to 12.8 percent. Eastern Bay, another important wintering area for waterfowl, fell from 21.4 percent in 1971 to 11.1 percent in 1979.

Widgeongrass, the most important food item of wigeon and black ducks, was the most abundant and widely distributed species in each of nine annual surveys. Low populations of wigeon, pintails, and redheads, predominantly vegetarian in nature, were correlated with the overall decline of SAV.

Diving ducks, including canvasbacks and redheads, were most affected by the SAV decline. Diving ducks have small wings and legs set back on their bodies, making walking difficult. They need water to run across prior to flight and are thus unable to feed in dense marshes or agricultural fields. Redhead populations, which subsist on SAV, declined in numbers. Apparently they could not change their diets and exist in an area with reduced SAV populations. Canvasbacks, on the other hand, incorporated Baltic clams (Macoma spp) and other invertebrates into their diets, and therefore remain as important members of the Bay's wintering waterfowl population.

Puddle ducks, which feed by dabbling at the water's surface, were historically more dependent on vegetation. Puddle duck populations, as a group, are presently at one third their former level. Pintail and wigeon populations are now nearly absent from Maryland wintering areas. Other puddle ducks, such as black ducks and mallards, have also decreased.

Whistling swans survived the decline of SAV by foraging on the land. This species now depends more on the availability of unharvested cereal grains from agricultural fields than on SAV. The population of Canada geese continued a long-term increase in numbers during the 1970's. Like swans, Canada geese rely on cereal grains from fields around the Bay.

Recommendations

The declining numbers of waterfowl that winter in Chesapeake Bay are cause for concern. Biological links exist between abundance of grasses and certain waterfowl populations in the Bay, so that decreases in distribution and abundance of SAV can directly affect certain species of waterfowl. Recovery of SAV resources will encourage the return of SAV-dependent waterfowl that annually migrate through the area. Scientists should continue to study factors leading to the declension of SAV and how such changes affect other aspects of the Bay ecosystem.

-By Debra A. Barker

The Biology and Propagation of Eelgrass, *Zostera Marina*, in Chesapeake Bay

Robert J. Orth and Kenneth A. Moore

Basic biological aspects related to the growth and propagation of eelgrass in the lower Chesapeake Bay were studied in a series of six experiments designed to reveal information on seasonal aspects of standing crops, reproduction, transplanting and spontaneous revegetation in denuded areas, and growth of eelgrass seedlings under laboratory conditions of increased nutrient enrichment.

Data analysis revealed distinct seasonal trends in the growth cycle of eelgrass. Transplantation of eelgrass plugs in the fall insures greater survivability than doing so in other seasons. The primary method of revegetation by *Ruppia* sp. and *Zostera* sp. seems to be by lateral growth from adjacent unimpacted areas, although seed germination and subsequent seedling growth may be significant in certain areas. The addition of a balanced formulation of fertilizer stimulates the growth of eelgrass under laboratory conditions.

Introduction

Chesapeake Bay eelgrass beds are a valuable natural resource which provide a habitat for large numbers of macroinvertebrates, food for migrating waterfowl, and shelter for juvenile fishes and blue crabs. In addition, grass beds aid in the reduction of shoreline erosion by absorbing wave energy and serving as a sediment trap. Its contribution to the detrital food chain is also significant.

The recent (1970's) disappearance of eelgrass beds in the lower Bay has prompted an interest in replanting. Studies have shown that revegetation under favorable conditions is feasible but some problems still exist due to a lack of knowledge related to eelgrass biology. With this in mind, the six experiments in this study were designed.

I. Seasonal Aspects in the Standing Crop of Eelgrass Beds

Procedure/Methodology

Seasonal changes were observed in three study sites in the lower main Bay for changes in standing crop and to aid in the description of the reproductive biology of eelgrass:

a) near the mouth of Browns Bay in Mobjack Bay;
b) adjacent to the Guinea Marshes at the mouth of the York River; and at
c) Vaucluse Shore at the mouth of Hungars Creek on the Eastern Shore.

From June 1978 through June 1979, monthly ring samples were taken at each site. A 0.1 m^2 ring was placed on the bottom and all vegetation, including the roots and rhizomes, to a depth of about 10 cm was removed. Beginning in June 1979, core samples were taken as well. A comparison of the two procedures revealed little differences. Six core samples were taken at each site until January 1980 when sampling was reduced to three cores. Sample analysis yielded information on the number of vegetative and reproductive shoots per meter squared (m^2), mean length of shoots, biomass of the leaf, and root and rhizome fractions per m^2. Temperature and salinity measurements, as well as sediment samples, were taken at each site.

From November 1979 to May 1980 monthly seedling samples were taken at the Guinea Marsh in-shore area. These were analyzed for maximum length of the primary leaf, and the number of shoots and leaves per seedling.

Results/Conclusions

Each of the three sites showed similar trends for maximum and minimum values of parameters such as shoot biomass, shoot density, and number of reproductive shoots. The period of maximum biomass for vegetative shoots was in summer with the minimum occurring in the fall or winter months. However, there was a difference in the maximum biomass of the two years with 1980 showing a higher volume than 1979. This fact seems to indicate the presence of some enviromental control (e.g., temperature) or biological control (waterfowl interactions) that affects all grass beds and can vary from year to year.

Appearance and growth of new shoots occurred after mid-August and continued to be produced throughout the winter and spring. Measurements of mean length of shoots showed a distinct trend for all sites. Peak length occured in June-July for all sites except Vaucluse Shore which had peak length in May, possibly as a result of temperatures rising faster in this more shallow area.

Some differences existed as to the number of seedlings observed at each site. This is probably due not only to seed production differences within a particular area but also to possible seed dispersal from other areas.

II. Anthesis and Seed Production in *Zostera marina* L

Procedure/Methodology

Random samples were taken at seven to 10 day intervals from March 11, 1980 to May 28, 1980 at three sites to describe the timing involved in the flowering process of eelgrass. A subset of samples was taken beginning in January, 1980 in order to ascertain the beginning of the flowering period. Samples were analyzed for the number of vegetative and reproductive shoots, length, number and position of spadices per shoot; and number and size ranges of anthers and pistils within each spadix.

Results/Conclusions

Reproductive shoots were first observed in February 1980. Pollen release was first observed April 10, 1980 when the average water temperature was 14.3°C, and was completed at all stations by May 19, 1980. By May 28 the fruiting process was at full maturity. The period from pollen release to initial seed development and release was 28 days. This process begins and ends one month earlier in lower Chesapeake Bay than in areas further north.

III. Seed Germination of Eelgrass in the Lower Chesapeake Bay

Procedure/Methodology

Reproductive shoots of eelgrass were examined at nine stations weekly beginning in late April 1979 to identify the timing of eelgrass seed germination.

Results/Conclusions

Seed germination occurred every month except July and August when temperatures were too high for germination. The major period of seed germination occurred between November 1 and March 31 when water temperatures did not exceed 10°C. Storage of seeds at temperatures above 15 °C will prevent germination but may result in rotting. The data collected implies that low temperature, rather than salinity, may be the primary cause for seed germination. There does not seem to be a dormant period between seed release and germination.

The rate of seed germination varied from site to site. It was implied that these differences may be the result of subtle environmental differences such as runoff, temperature differences, or depth at which seeds are buried in the sediments.

IV. Tranplantation of Eelgrass into Recently Denuded Areas

Procedure/Methodology

Plants were removed from an established bed at the Guinea Marsh area and transplanted at a site near Mumfort Island in the York River. The Mumfort Island area was selected because it had been the site of extensive eelgrass beds but was now devoid of Zostera. In addition, it was fairly isolated and would probably not be disturbed by people.

Transplanting done by two different methods (plugs and mats) began in March 1979. A second transplanting effort was done in early June, a third in September and October, and a fourth in April 1980. Four additional sites were used in the transplanting effort during the last three experiments: Gloucester Point, Allens Island, Guinea Marsh in the York River, and Parrott Island in the Rapphannock River. Fertilizer was used in some transplants to assess the effect on success rate.

Results/Conclusions

A comparison of the two methods of transplanting indicates that the use of plugs is the better management option for mitigation mainly because it works better than the mat method, especially in more wave exposed areas where it costs far less and some anchoring mechanism is necessary.

Success of the transplants depended on the season of planting (fall was best and summer had the least success) and location. Downriver sites (Guinea Marsh, Allens Island, and Gloucester Point) had highest success compared to the upriver site (Mumfort Island). High temperatures and high reduction in available light (especially at the Mumfort Island site) make summer the least desirable time for transplanting. Sites chosen for transplants should have previously supported *Zostera*. Better growth results were obtained when Osmocote fertilizers (14-14-14) were used in spring 1980 transplants at Allens Island.

V. Regrowth of Submerged Vegetation into a Recently Denuded Boat Track

Procedure/Methodology

Monthly observations were made on a denuded one-meter square plot, within a boat track, to determine the percent of revegetation, regrowth patterns, and seedling recolonization. Sediment samples analyzed for particle grain size and interstitial nutrients were taken from this plot and an unimpacted vegetated area.

The entire length of the boat track was also observed monthly to determine revegetation patterns, effects of scouring or bioturbation, and any changes in orientation of cut. In addition, temperature, salinity, and PAR light readings were taken.

Results/Conclusions

Revegetation by *Ruppia* and *Zostera* occurred primarily as lateral growth from adjacent unimpacted areas. *Ruppia* seems to recolonize more rapidly than *Zostera*. After seven months *Ruppia* had spread over less than half of the denuded area. It appears that at least two seasons of growth are required for *Ruppia* recolonization, and possibly three for *Zostera*. Analysis of the sediments reveals them to be fairly homogeneous to depths of about 20 cm, probably due to active bioturbation.

No significant difference existed for interstitial nutrients inside or outside the denuded area.

VI. Growth of Eelgrass Seedlings Under Laboratory Conditions of Increased Nutrient Enrichment

Procedure/Methodology

Seedlings were collected from a grass bed at the Guinea Marsh site on the York River and placed in peat pots containing soil from the same site. Peat pots were placed in greenhouse holding tanks receiving flowing estuarine water from the York River and about fifty percent incident light at the water surface. Two formulations of Osmocote fertilizer were applied at three different dosages. Number of shoots, leaf blades per shoot, and length of the longest blade on the oldest shoot were recorded at two week intervals from March 20, 1980 to June 13, 1980.

Results/Conclusions

Growth by way of increased leaf length and vegetative production of increased number of shoots is stimulated by addition of fertilizer. The balanced formulation (14:14:14) produced better results in increased leaf length than the nitrogen rich formulation (18:6:12). Sixty percent of the fertilized plants exhibited three or more shoots per plant as compared to only four percent of the controls.

Recommendations

Prior to 1978 little was know about the basic biology of eelgrass. This study, while answering some questions about eelgrass biology, discovered many others which could not be answered. Several questions that should be addressed in future studies are: (1) what controls maximum production of eelgrass in a particular area; (2) what are the reasons for annual difference in shoot production and biomass; (3) what are the temperature and salinity effects on seed germination; and (4) what are the effects of fluctuating temperatures on seed storage.

-By Linda C. Davidson

Sediment Suspension and Resuspension from Small Craft Induced Turbulence

Hermann Gucinski

The objective of this study was to determine if small vessels operating in shallow waters have any measurable effects in producing increased turbidities by the resuspension of fine sediments that may affect submerged aquatic vegetation (SAV).

A two-phase approach was used, consisting of field tests in a suitable sub-estuary of Chesapeake Bay and laboratory measurements of propeller effects. During field trials, two different vessel types were used to make passes at set speeds over known water depths. Measurements of light extinction, transmission, and suspended sediment were made before and after boat wake and propeller disturbance. Laboratory experiments were conducted to delineate propeller contribution to possible resuspension; this was done using laser-doppler anemometry to map the turbulence field produced by propeller action.

This report was submitted by Anne Arundel Community College and the U.S. Naval Academy under the sponsorship of the U.S. Environmental Protection Agency's Chesapeake Bay Program.

Introduction

Causative factors for the widespread disappearance of SAV in the Chesapeake Bay, beginning in the early seventies, have been the subject of intense study. Many mechanisms have been hypothesized to explain this disappearance, including increased sediment loads caused by hurricane-produced runoff, the increasing reliance placed on herbicides in farm operations, nonpoint source pollution resulting from heavy development pressures in the coastal zone, and increased turbidities from increased use of Bay waters and tributaries by recreational watercraft. No one single factor appears to be responsible for the stresses causing reduction in SAV growth, but each mechanism needs investigation to find the most significant, or any synergistic effects of several interacting processes.

Small vessels operating in shallow waters, or with their wakes reaching shallow waters, may have measurable effects in producing increased turbidities by the resuspension of sediments. The time required for the sediment to settle out of the water column depends on particle size, the presence of background turbulence, and motion that may retard the settling rate and produce significant lateral transport of the resuspended sediment.

The disturbance may affect rooted SAV if the erosive forces are great enough to displace organic detritus and inorganic silts and muds normally stabilized by the rooted plants. Direct damage to the root may result. If the resuspended particles are small and have long settling times, then they can contribute to increased light extinction in the water column, possibly reducing the photosynthetic rate of SAV. Sediments may also settle onto the leaf structures of the plants and further reduce photosynthesis and respiration, thereby limiting productivity and stressing the bed further.

Laboratory studies and empirical field studies were used to assess variables such as depth to which effects can be felt, the relative magnitude of the suspension, and possible impact (of a biological nature) of propeller-generated sediment resuspension.

Procedure/Methodology

Field trials were made at three sites having reasonably uniform water depths, minimum variation of bottom sediments with a high percentage of small-sediment particles (<60 u), and availability of prior data on natural changes in suspended sediments.

Using two vessels, a 6.7-meter speedboat, and a nine-meter tugboat, passes at set speeds, chosen for maximum wave-making, were made along a series of buoys at each site. Before and after light extinction, transmission measurements, and water samples were obtained for gravimetric determination of suspended sediments.

Laboratory experiments, which measured water particle motion from the effect of a boat propeller, were conducted to predict the distribution of stresses sufficient for sediment resuspension.

Results/Conclusions

The resuspension of fine sediments in the path of a small craft is influenced by water depth, depth of immersion, size of the propeller, the advance ratio, and the wave-making tendency of the vessel. The depth to which stirring is sufficient appears to be quite limited. In this study, at depths of greater than 2 meters, reduction in SAV productivity was calculated at about 1 percent for small displacement craft of less than 9000 kg and 130 hp.

Light extinction measurements give the most statistically reliable and consistent results. They also show a correspondence to the laboratory results, thereby allowing formulation of a tentative hypothesis concerning the most significant variables that affect sediment resuspension.

Transmissionmeter readings, taken concurrently with photometer measurements, corroborate measurements of light extinction coefficients. The relatively lesser effects of the boat having the least propeller immersion is apparent, and is borne out by statistical comparison.

The gravimetric determination of suspended sediments was less statistically significant but does follow the pattern established by the photometer results.

However, the depths to which boating effects allow sediment resuspension coincide with depths where SAV growth is limited in Bay waters. Comparison of SAV maps suggests that areas of least SAV distribution and slowest recovery are also areas of greatest boating congestion. No conclusive studies have been done on this correlation. Sandy sediments predominate close to shore in waters less than 2.5 meters deep, and fine clay-like silts and muds are ubiquitous in deeper waters. Such distribution may have a protective effect for SAV beds in high wave/wake energy environments.

Recommendations

It is tentatively recommended that ecologically sensitive areas be investigated for the presence of fine sediments (< 60 u). Such areas should be protected from excessive traffic, particularly deep-draft, high-powered displacement craft.

-By Judy Broersma

TABLES OF WEIGHTS AND MEASURES

LENGTH

English	Metric
1 inch (in) = 2.540 centimeters	1 centimeter (cm) = .394 inch
1 inch (in) = 25.40 millimeters	1 millimeter (mm) = .0394 inch
1 foot (ft) = .305 meter	1 meter (m) = 3.281 feet

AREA

1 square foot (ft^2) = 0.093 square meter	1 sq. meter (m^2) = 10.764 square feet
1 square mile (mi^2) = 2.590 sq. kilometers	1 sq. kilometer (km^2) = 0.386 sq. miles
1 acre (a) = 0.404 hectare	1 hectare (ha) = 2.471 acres

VOLUME

1 gallon (gal) = 3.785 liters	1 liter (l) = 0.264 gallon (U.S.)

VELOCITY

1 cubic foot/sec (ft^3/sec) = .0283 m^3/sec	1 cu. meter/sec (m^3/sec) = 35.315 ft^3/sec

TEMPERATURE

degrees Farenheit (°F) = 9/5 (°C) + 32	degrees Celsius (°C) = 5/9(°F - 32)

MASS

1 ounce (oz) = 28,350 milligrams	1 milligram (mg) = 0.0000353 ounces
1 ounce = 28.350 grams	1 gram (g) = 0.0353 ounces
1 pound = 0.454 kilograms	1 kilogram (kg) = 2.205 pounds

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