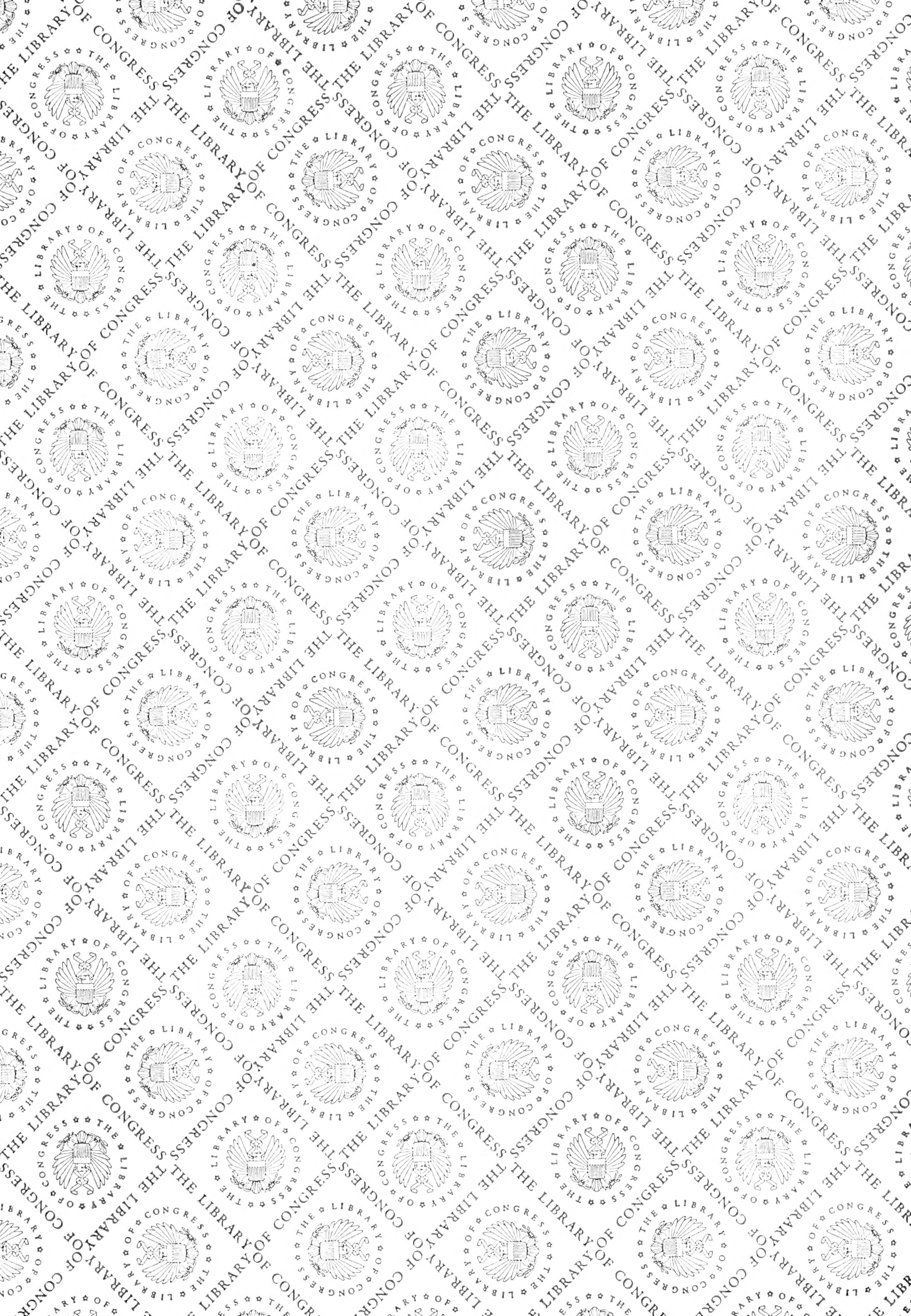

NOAA Estuary-of-the-Month
Seminar Series No. 5

Chesapeake Bay: Issues, Resources, Status, and Management

July 1988

U.S. DEPARTMENT OF COMMERCE
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Chesapeake Bay: Issues, Resources, Status, and Management

Edited by Samuel E. McCoy

Proceedings of a Seminar
Held September 23, 1985
Washington, D.C.

U.S. DEPARTMENT OF COMMERCE
C. William Verity, Secretary

National Oceanic and Atmospheric Administration
William E. Evans, Under Secretary

NOAA Estuarine Programs Office
Virginia K. Tippie, Director

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

AND

U.S. ENVIRONMENTAL PROTECTION AGENCY

PRESENT AN

ESTUARY-OF-THE-MONTH SEMINAR

ON

CHESAPEAKE BAY

ISSUES, RESOURCES, STATUS, AND MANAGEMENT

MONDAY, SEPTEMBER 23, 1985

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EDITOR'S PREFACE

The following are the proceedings of a seminar on Chesapeake Bay held on September 23, 1985, at the Herbert C. Hoover Building of the U.S. Department of Commerce in Washington, D.C. It was one of a continuing series of "Estuary-of-the-Month" seminars sponsored by the NOAA Estuarine Programs Office (EPO), held with the objective of bringing to public attention the important research and management issues of our Nation's estuaries. To this end, the seminar first presented a historical, scientific overview of the Bay by senior investigators, followed by an examination of management issues by scientists-managers of research institutions and science agencies involved in the Bay.

We acknowledge the assistance of Dr. Christopher F. D'Elia of the Chesapeake Biological Laboratory who had principal responsibility for assembling the speakers and whose long involvement with the Bay and its people was invaluable. The seminar was coordinated by Dr. James P. Thomas, EPO Senior Scientist, with the assistance of other members of the EPO staff. Seminar transcription was done by Ms. Margaret M. Powell, word processing by Ms. Janet A. Davis, and manuscript preparation by Ms. Alice L. Roberson.

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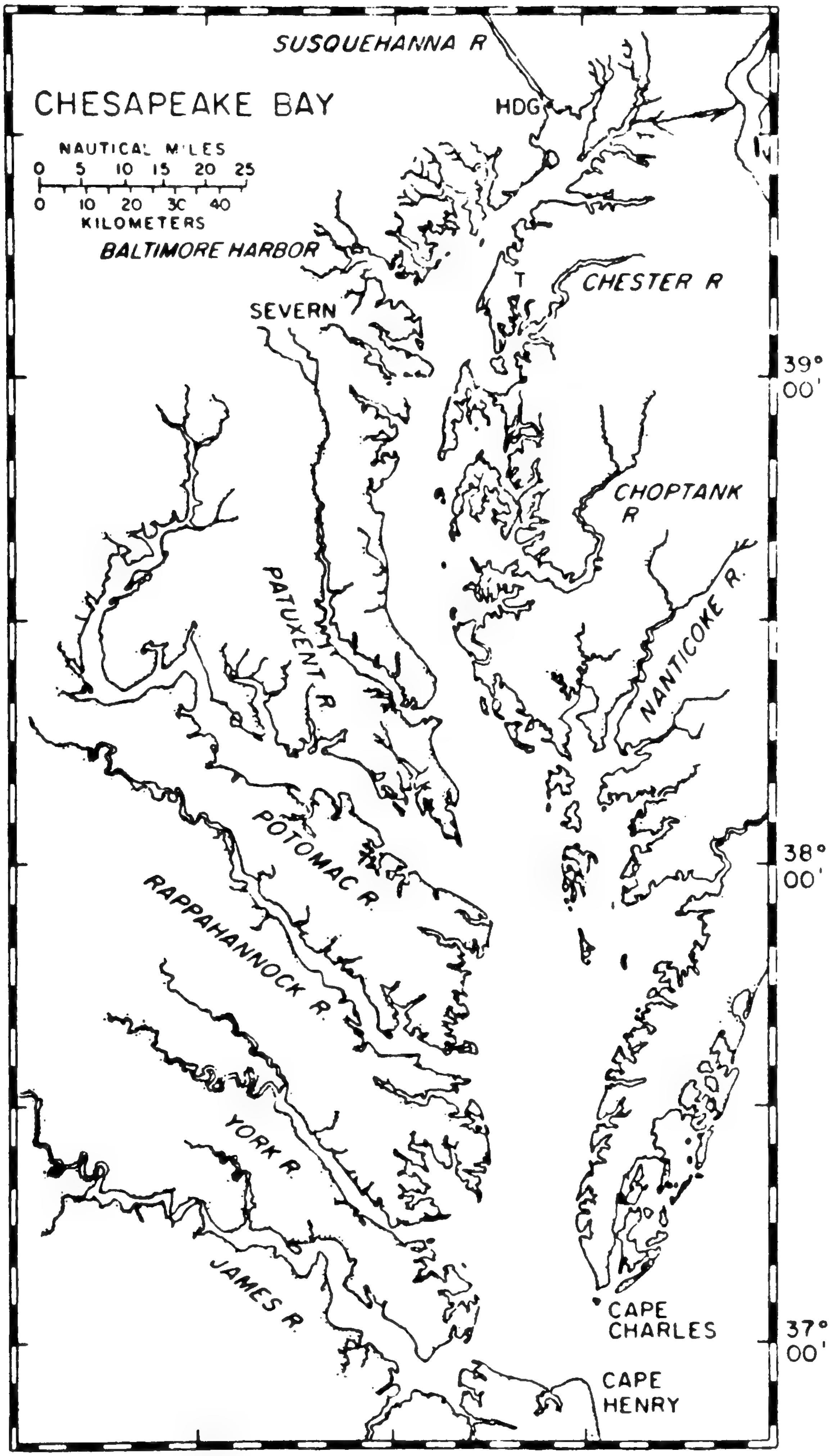


CHESAPEAKE BAY AND MAJOR TRIBUTARIES

PROCEEDINGS

Welcome: Dr. James P. Thomas

Dr. Thomas: Good morning. My name is Jim Thomas, I'm Senior Scientist of the NOAA Estuarine Programs Office.

On behalf of the NOAA Estuarine Programs Office and the U.S. Environmental Protection Agency, welcome to the fifth in a series of Estuary-of-the-Month Seminars. Previous seminars have covered Narragansett Bay, Delaware Bay, Long Island Sound, Boston Harbor and Massachusetts Bay, and today Chesapeake Bay. These seminars are to provide a forum in which we, who are concerned, can devise means in which to better manage our Nation's estuaries in the future.

Now I have the distinct pleasure to introduce to you today Bill Gordon, the Assistant Administrator for Fisheries, NOAA. Bill has been the Assistant Administrator since 1981 and has a long and distinguished history in all aspects of environmental concern, fishery science, and management. He came up through the field as a fishery biologist in the Great Lakes Region where he learned firsthand that cumulative degradation of the environment can take place.

He has witnessed the decline and now the rebirth of Lake Erie. Prior to coming to Washington, he was the Regional Director for the Northeast Region of the National Marine Fisheries Service where he became well-versed in complicated and often controversial natural resource issues.

Bill is an administrator who can see the big picture. He understands the relation of a healthy ecosystem to healthy, productive, natural resources. Because of this understanding, he has supported habitat initiatives and was instrumental in developing the National Habitat Conservation Policy.

Recognizing the importance of estuaries as fishery habitats and as actual resources in themselves, he has supported the establishment of the Estuarine Programs Office which coordinates estuarine research and policies within NOAA. It is my pleasure to introduce Bill Gordon, the Assistant Administrator for Fisheries.

INTRODUCTION TO SENATOR MATHIAS

Mr. Gordon: Thank you very much, ladies and gentlemen. I do want to thank you for coming because I hope you all share my enthusiasm for estuaries and, particularly, the Chesapeake Bay.

I'm here today to introduce a man who is so committed to the restoration of the Chesapeake Bay that he really needs no introduction. He comes from the State of Maryland and has represented that State in the House and in the Senate since 1960.

Senator Mathias's list of accomplishments on the Bay is impressive spanning over 15 years. As far back as 1969 the Senator sponsored bills to create interstate commissions for the Potomac and Susquehanna Rivers. In that year he sponsored an amendment to increase the authorization for a comprehensive Bay study involved with the formation of a Bi-State Chesapeake Bay Commission to insure better management.

Between 1976 and 1979, the Senator sponsored numerous Chesapeake Bay initiatives, including establishing a U.S. Environmental Protection Agency Program authorizing a 5-year study and the Chesapeake Bay Research Coordination Bill.

He has spearheaded efforts to authorize and appropriate money to EPA, NOAA, U.S. Department of Agriculture, U.S. Department of the Interior, and the Army Corps of Engineers and the states to study the various problems and develop a blueprint for restoring the Bay's resources.

So arduous in support of the Bay was he that Senator Mathias received the award from the Federal-State Chesapeake Bay Conference for the greatest contribution to the Bay's cleanup programs in 1983. The Senator has elevated the issues and problems confronting the Bay to the level of the White House. These accomplishments represent only a small portion of the Senator's contributions.

Perhaps there's no greater supporter of the Chesapeake Bay alive today than Senator Mathias. So it is my great honor to welcome Senator Mathias as the Keynote Speaker for the Chesapeake Bay Estuary-Of-The-Month Seminar. Senator, thank you very much for coming. We appreciate it very much.

CONGRESSIONAL VIEWS

Senator Mathias: Thank you very much, Mr. Gordon. First of all, let me say what a wonderful idea I think it is to have an Estuary-of-the-Month. As you were ticking off the estuaries that you've already looked at and ones that you're going to visit, I was overwhelmed by a sense of wanting to get out and get on the road and see all those places.

It's one thing to look at a map or to look at a study or a list of statistics about an estuary and in sort of a general way absorb what it's all about. But to look at it specifically and directly and to study it is worth a great deal because I think that will give you not only a sense of what each estuary -- the characteristics of each estuary -- but will give you a sense of how they relate to each other. And I think doing it once a month, an Estuary-of-the-Month, is a great idea. And I'm very happy to be able to visit with you as you take a hard look and a careful look at the Chesapeake Bay.

Now I think we have to settle one thing at the outset. That is, there is no doubt in my mind, as I think there is probably very little doubt in your mind, that you know more about the subject than I do. Certainly you know a good deal more about many aspects of the subject than I know. That makes me approach this job of talking about the Chesapeake with you with a great deal of humility because many of you have been highly trained, and have spent years in professional practice in various aspects of environmental science that deals with estuaries such as the Chesapeake Bay.

My real qualification, as Mr. Gordon has suggested, is that I've known the Bay a long time and have been fascinated with the Bay. When I was a boy my family would occasionally make forays into the Eastern Shore. In those days, the way you got to the Eastern Shore was by driving into the center of the City of Annapolis. Where the Field House at the Naval Academy now stands on filled land was a ferry slip. Then you drove a few miles across Kent Island and took a second ferry over to the mainland of the Eastern Shore. Having done that a number of times, I felt a very close association with the Bay and everything about it. So it has been a lifetime love affair. In talking to you today I have a practical difficulty sensing that you're the experts, to try to lay out something for you that may be of interest and value. They tell a story about a little girl who was late for Sunday School and her mother was looking for her and found her rummaging around in her bureau drawers and closets. And her mother asked her what she was doing, she ought to be on her way to Sunday School. She said, "Yes, but what can I wear that Jesus hasn't seen?" So I'm a little in that situation this morning. What can I tell you that you don't know?

Well, the first thing it seems to me in dealing with an estuary is to comprehend what an enormous, complex system it really is. In the case of the Chesapeake, it is, of course, a very large estuary which draws from an enormous territory. That creates political and economic consequences that have to be taken into account in practical terms. You're looking at a drainage basin that begins in the North in Southern New York; includes most of Central Pennsylvania; and all of Maryland except for just a very small portion of the northwest corner of Maryland which drains into the Ohio and Mississippi system. It includes great territories in West Virginia and Virginia, all of the District of Columbia, and parts of drainage from Delaware.

So it's a very big system that we're talking about and that has consequences that go beyond the political and the economic issues. It has consequences that deal with citizen behavior.

If some teenage kid is draining his crankcase in Harper's Ferry, West Virginia, just pulls the plug and lets the crankcase oil drain off the street, that oil is going to end up in the Chesapeake Bay sooner or later. So what happens in remote places can have a direct and consequential impact on the Chesapeake Bay.

A real estate developer in Harrisburg, Pennsylvania, can have an impact on the silting of the Bay, because the Susquehanna, which flows through Harrisburg, provides more than half of the freshwater to the Chesapeake Bay. It carries enormous amounts of freight other than water into the Bay, including silt and some polluting elements. So if that contractor in Harrisburg isn't conscious of the impact of his actions, he becomes a problem for Chesapeake Bay even though he's miles and miles removed from it.

Well, one of the places to start with the Bay, of course, is at the very beginning. One of the most fascinating descriptions of the Bay ever written was one of the first. An intrepid British explorer, Captain Gabriel Archer, explored the reaches of the Bay in June of the year 1607. Of course that was the time of extensive exploration and adventure on the coasts of America. Captain Archer wrote down what he saw. I would recommend his journal to you. I will just quote very briefly from it. It provides a kind of catalogue for us of the marine life that was then visible in the Chesapeake Bay. Captain Archer wrote, "The main river abounds with sturgeon." Imagine! Not the Caspian Sea, the Chesapeake Bay abounds with sturgeon, "...large and excellent good." I wonder if they got any caviar from that sturgeon? Think of what we're missing as a product.

He goes on to say, "....having also at the mouth of every brook and every creek exceedingly good fish of diverse kind... and in the large sounds near the sea are most fish, banks of oysters and many giant crabs better in taste than ours, one able to suffice four men." Think of it. Frightening thought, isn't it?

Well, unhappily, it's been a long time since we in the Chesapeake have been able to see one crab able to suffice four men. And I suppose that brings us to the next chapter in the story. We ought to consider the economic cost of the degradation of the Bay. Not just being deprived of huge crabs, but very practical costs in terms of the harvest that could be reached in the Bay.

Look at the statistics for 1880, a hundred years ago. You might think that life has progressed on this planet in some beneficial way the last hundred years and the harvest in the Chesapeake Bay must be better now than it was then. Well, in 1880 the oyster take was 123 million pounds of meat. But the National Marine Fisheries Service survey of 1968 reports that in 1968 that there were only 25 million pounds, just a fifth or twenty percent of what the take had been in 1880. By 1968, we were beginning to worry. In 1968 we were beginning to recognize that something was wrong, so you would hope that 20 years later things would have gotten better. But by 1984 it had dropped fifty percent from the 1968 level to only twelve million pounds, that is ten percent of what it had been a hundred years ago.

It doesn't take much imagination to translate that drop in the oyster take into jobs; into nutritional values that would have been available; into wealth as far as the State is concerned; and into all the different factors which can be derived from that decrease, considering what had once been a bountiful harvest.

You can take similar figures for shad, for rockfish, striped bass, for almost any species that you want to look at. And they are all the same dismal, downward trend.

There are a lot of competing interests, each one seeking to extract the maximum for its own good, that have caused these severe changes in really all aspects of the Bay's ecosystem.

When we started out intensively looking at the Bay's problems we thought we would find a goat or maybe one or two goats. But it now appears that there are a number of problems. The whole system has problems, and it needs to be repaired and reinforced.

At the rate things were going less than a decade ago, if that downward trend which was illustrated by the oyster take continued, then the largest and richest estuary in North America could have become a "Dead Sea." Not at some future time, but in our lifetime.

We had an interesting author in Maryland named Earl Swepson a generation ago who wrote a number of very readable books about the Chesapeake Bay country. He published one in 1923 in which he accurately predicted what has since come to pass. In talking about oystering and oystermen and the oyster fishery in general he said, "Maryland has established no really constructive policy to maintain this great natural wealth. The State of Virginia through oyster culture and planting on a large scale has been able within the past decade to stem the pollution within its waters. The citizens of Maryland, if they propose to maintain this great natural resource, must get together on broad and constructive planning or it will be only a matter of years before the watermen with their picturesque craft will be forced to find other means of livelihood, while the State's loss will be many millions of dollars."

Well, that proved to be all too prophetic. And even the fact that there were prophets at that time, 50 years ago, we let that prophecy fulfill itself.

Finally, we were able to undertake the Environmental Protection Agency's study, and that was a major change. I recall with enormous pleasure the real beginning of that study. My wife and my two sons, who were at that time just boys, undertook to tour the Bay. And we started in Baltimore, went up to Havre De Grace and down the Eastern Shore to Crisfield and across the Bay to the Patuxent and back to Annapolis. It was a wonderful experience as a family. The outgrowth of that experience, because we stopped at points along the Bay and talked to the experts at each locality, was the concept for this Chesapeake Bay study. And we ultimately were able to get the Congress to appropriate 27 million dollars for the purpose of the study. It cost roughly 5 million a year with some additional money to clean it up and complete it at the end.

The picture that that study provided us for the Chesapeake Bay was not a very romantic or pretty picture because the problems were getting ahead of the Bay's natural capability to deal with those problems on its own. But while painting this somewhat gloomy picture, the EPA-Chesapeake Bay study gave us every reason to hope that with the proper steps, taken as quickly, as possible we could restore the Bay's health.

Of course, one of the things that the study emphasized is that if the Bay is to survive it has to be addressed as a total entity. The waters of the Bay can't be treated as the Maryland waters north of the state line and the Virginia waters south of the state line. The crabs that spawn in Hampton Roads and then move up the Bay don't know where that line is. The oyster which is produced north of that line and flows south doesn't know where that line is. You have to ignore those political boundaries and treat the Bay as an entity. Not only the Bay itself, but this enormous basin with its multi-state complex problems.

Another thing that the study has done is to indicate what tools we need to do the job; this is enormously important. The fact that we have already begun to apply those tools and have gotten some results, is grounds for some encouragement. We've gotten the States working together -- you know, for years Maryland and Virginia have contested the waters of the Chesapeake Bay. In fact, when Lord Baltimore first sailed into Maryland -- settling the first Maryland State Colony -- he was occupying land that heretofore had belonged to the Colony of Virginia, the Old Dominion. And a Virginian named Captain Clayburne contested that Maryland claim, and they actually fought a naval battle that the Virginians and the Marylanders fought in about 1630 off Kent Island. And there's been bad feelings between Maryland and Virginia all of those years.

It has been impossible to get Marylanders and Virginians to cooperate on Bay problems. In fact, within a relatively short time ago, oystermen in Maryland were shooting at oystermen from Virginia who they thought were poaching in Maryland waters and vice versa. There were a couple of people killed every year in the oyster wars. So there were very bad feelings. It went beyond bad feelings; it was bad blood.

But an extraordinary change took place with which I have to give John Warner considerable credit. Because after talking with John we got him interested. And he in turn enlisted the interest of Governor Dalton of Virginia, and the three of us went down to Tangier Island. I believe that visit to Tangier Island was the first overt expression of joint official Maryland-Virginia interest in the problems of the Bay. And with that move, things began to move politically.

Well, Pennsylvania had also been silent on the subject of the Bay. We hadn't shot at Pennsylvanians over the Bay; we had other territorial problems with them. But they had not taken any interest in the Bay until Governor Thornburg joined in this crusade. Because the State of Pennsylvania contributes more than half of the freshwater intake to the Bay, that was enormously important to enlist Pennsylvania in the cause of saving the Bay.

In 1983, right after the EPA study was released, we were able to get the Governor of Maryland, the Governor of Virginia, the Governor of Pennsylvania, and the Mayor of the District of Columbia, an absolutely unprecedented line-up, to respond to the challenge that the study presented by making commitments on behalf of their States to address the problems outlined in the study.

Capping this, President Reagan in his 1984 State-of-the-Union message made a major Federal commitment, which was not as large in dollars as we hoped it might be, but which was enormously important in terms of the stimulus that it gave to the whole Chesapeake Bay problem. He praised the administration of the Bay's cleanup program for a 4 year period.

And then following the President's pledge, and I'm sure assisted by it, five Federal agencies have joined the undertaking, NOAA, very importantly; the Fish and Wildlife Service; the Army Corps of Engineers; and the Soil Conservation Service; and the Geological Survey. All came to Capitol Hill and in a rather formal and ceremonial way signed a Memorandum of Understanding with EPA spelling out the role of each in the Chesapeake Bay Program.

Congress responded, notwithstanding the very stringent budget restraints of these days, the Congress has responded by appropriating funds for these agencies to perform their Bay missions.

The latest chapter, in July we undertook a tour of the Bay in which we looked at what's happening on the spot. Paul Sarbanes, a Senator from Maryland; Lee Thomas, the EPA Administrator; Secretary of the Interior, Secretary Odell; Governor Hughes, Governor Robb, and a number of other people, all joined together in making this tour of the Bay to see firsthand what each of the Federal agencies are contributing to the effort. For example, the Corps of Engineers took us to an area of shoreline erosion and showed us exactly what that danger is, how nature operates and what it can do to combat the problem. The Soil Conservation Service demonstrated how it's addressing the agricultural non-point source pollution problem, which incidentally is now recognized as one of the very major villains in this whole system. The Fish and Wildlife Service and NOAA showed us the restoration of the fisheries, and EPA demonstrated what it's doing to improve the water quality. So there is a role, an important role, for each of the stars in this drama.

The States have come forward with very impressive roles. Maryland is starting a 5 year, 40 million dollar program to control agriculturally related non-point source pollution. Last Friday a number of the members of Congress and the Governors of Maryland, Virginia, and Pennsylvania, and the Mayor of the District of Columbia, met with Lee Thomas in a ceremony when EPA released the Chesapeake Bay Restoration and Protection Plan. I think it's the first and only comprehensive plan which shows what the States and what the District of Columbia and what the Federal agencies need to do and are doing to correct the problems and outline a course for the future.

The Bay Restoration Plan is, of course, one more step along a very torturous path of renewal that will take many years to complete. And there are a lot of pitfalls on this path. Last week we got around one by steering a devious course in the Senate. The budget had not provided for the Soil Conservation Service personnel to deal with the very important role that they can play on the overall plan. And we were able to prevail in the adoption of an amendent, which doesn't cost a great deal of money, but which does give us those all important spots in soil conservation to continue the work of that agency.

We have to be very precise from this point on. We started out in the dark. We started out, in fact, worse than in the dark because we had some misconceptions. We were on the wrong track in some respects. But now we know a great deal more than we have ever known about the Chesapeake Bay, probably more than anyone has ever known about the Chesapeake Bay, probably more than anyone has ever known about any estuary. So we have to begin to be very precise. I think if we are precise and persistent we can look forward to the day when the major resources are back, perhaps not to that bountiful stage which Captain Gabriel Archer found in 1607, but maybe at least back to where they were at the beginning of the century.

The Bay is, of course, a tremendous legacy from the past of this country and this continent. And it is such a remarkable system, the more you study it, the more you learn what its denizens are -- the waterfowl, the fish, everything that lives on it and in it and around it -- the more you understand how remarkable this system is and how it interrelates.

It is amazing, but considering the abuse that the Bay has taken, particularly in the last century, it's as beautiful and as healthy as we see it to be when we visit it on some crisp, clear morning and watch all the myriad wonders of the Bay coming to life, waking up and beginning a new day. And that beauty and that vitality have to be preserved. That life has to be protected. And that life is in our hands. And the interests of groups like yours can be enormously effective and powerful in preserving it for all time.

Thank you very much.

Dr. Thomas: Senator Mathias, thank you very much for coming here today and presenting us with such a truly fine overview of the Bay. I think many of us can relate rather directly to your great love for Chesapeake Bay and the message you carry. Thank you.

It is a pleasure for me to introduce Dr. Chris D'Elia and thank him for organizing today's seminar. Dr. D'Elia is an Associate Professor at the University of Maryland Center for Environmental and Estuarine Studies, Chesapeake Biological Laboratory, located at Solomons Island, Maryland. He has been with the Chesapeake Biological Laboratory since 1977 and has had major research interests in nutrient enrichment and the degradation of Chesapeake Bay. Additionally, he has served on a number of environmental groups and panels at the State and the national level dealing with the Chesapeake Bay in the field of biological oceanography. Dr. D'Elia will be taking charge of today's program, including the Panel Discussion at the end of the day.

I encourage everyone to stay through the Panel Discussion in order that we might learn what data and information gaps exist and what we might do to help improve the management of our Nation's estuaries.

Chris, we're pleased to have you and your speakers today. I'm pleased to introduce Dr. Chris D'Elia.

SEMINAR INTRODUCTION

Dr. D'Elia: Thank you very much, Jim. It's great to be here and great to have such a super turnout, and we very much appreciate Senator Mathias's interest and attention to this seminar series today.

It's been a busy week in the Chesapeake Bay area, starting with the EPA's Chesapeake Bay Restoration and Protection Plan, this seminar, various committee meetings, and leading up to the Chesapeake Bay Commission's program at the end of the week in Baltimore.

This particular presentation is really designed to be a scientific, technical, and understandable program. If you'll notice, on the program I put primarily active research scientists in the beginning in making presentations. And we're starting with a morning session which is going to have sort of a background and informational aspect to it. And then we're going to move on to an afternoon session, which is going to discuss some of the controversies and things that we don't understand so well about Chesapeake Bay. And then it's going to move into management issues, some of the things that we really need to do in terms of managing it better. And then finally ending up with a panel discussion, which includes a mix of scientists and managers.

This is the Chesapeake Bay. I would like to point out several things that I think are very important as we go along today.

The first thing is there are numerous tributaries and subtributaries, et cetera, on this Bay. It's a long Bay, there's a lot of shoreline on the Chesapeake Bay. And I point this out to you because it's in contrast to other estuaries that have been discussed in these NOAA Estuary-of-the-Month seminars.

For example, compare Chesapeake Bay with Long Island Sound. Long Island Sound has a relatively straight shoreline and relatively few tributaries and relatively great flushing by the sea.

So what we're dealing with in Chesapeake Bay is quite a different situation than what we might talk about in other estuaries. And I encourage people to think about the comparison of this estuary to those estuaries. There's a lot of shoreline, lots of places for people to impact these days.

And of course the non-point issue that Senator Mathias alluded to is particularly critical in such a configuration.

Another thing I want everybody to keep in mind is the fact that the Chesapeake Bay area is really burgeoning in population. While other areas of the country may not be growing at a great clip, this particular area really is. So with all that shoreline and all the potential for people to live on it and use the resources, there is potential for problems.

As we move on to the resources issue, I want to make several points. We often talk about pollution and loss of habitat. We often talk about the depth of the Bay, and we paint very stark pictures. I want to divide the issue, if I can, into two things. It's not just a pollution issue. It's a resources management issue. It's fisheries statistics. It's fishery management. I think that these things don't often get enough attention.

We're too willing to blame the other guy for his pollution, what he's added to the Bay, and not willing enough sometimes to look carefully at the stewardship of our fisheries resources. And I think you'll see in an excellent presentation later, a little bit more about that.

I hope to see us address somewhat the role of science in management. This, I have a particular love and affection for. I think it's a very critical thing to be able to present science as well as possible to a wide variety of people and have scientists and management interact to produce the best possible plans.

I must tell you quite frankly that many scientists in the Bay area feel somewhat disenfranchised by the present schedule of primarily management and political activities. And I hope that we can try in the future to have better involvement of the local scientists in the plans.

So much for my propaganda. I'll get into some procedural things now. I'll ask the speakers to try to keep to twenty minutes if they can. That way we'll try to be on schedule.

There are a few alterations to the program that I'll point out. Dr. Rothschild will be represented by Mr. Cluney Stagg. There will also be a movie added at noontime by the Maryland Sea Grant Program, the movie is "The Chesapeake, a Twilight Estuary."

With that, I think it's time to move on and get into the program. I would like to introduce the first talk, which will be about the "History, Geology and Demographics of Chesapeake Bay." Our presenters are generally organized in pairs. We did this to try to get as wide a perspective as possible. People have been told not to just look at their own bailiwick.

We have two excellent "authors," if you will, of the first presentation, someone who knows a great deal about the history of Chesapeake Bay and who has been here for 25 years doing research on the Chesapeake Bay. So I want to introduce, without further ado, Dr. Robert Biggs from the University of Delaware.

CHESAPEAKE BAY, HISTORY, RESOURCES, AND POLLUTION

HISTORY, GEOLOGY, AND DEMOGRAPHICS

by

Dr. Robert B. Biggs, University of Delaware

and

Dr. Grace S. Brush, Johns Hopkins University

Dr. Biggs: I would like to start with a simple declarative sentence to try to get your attention, that is, "The Chesapeake Bay is very small."

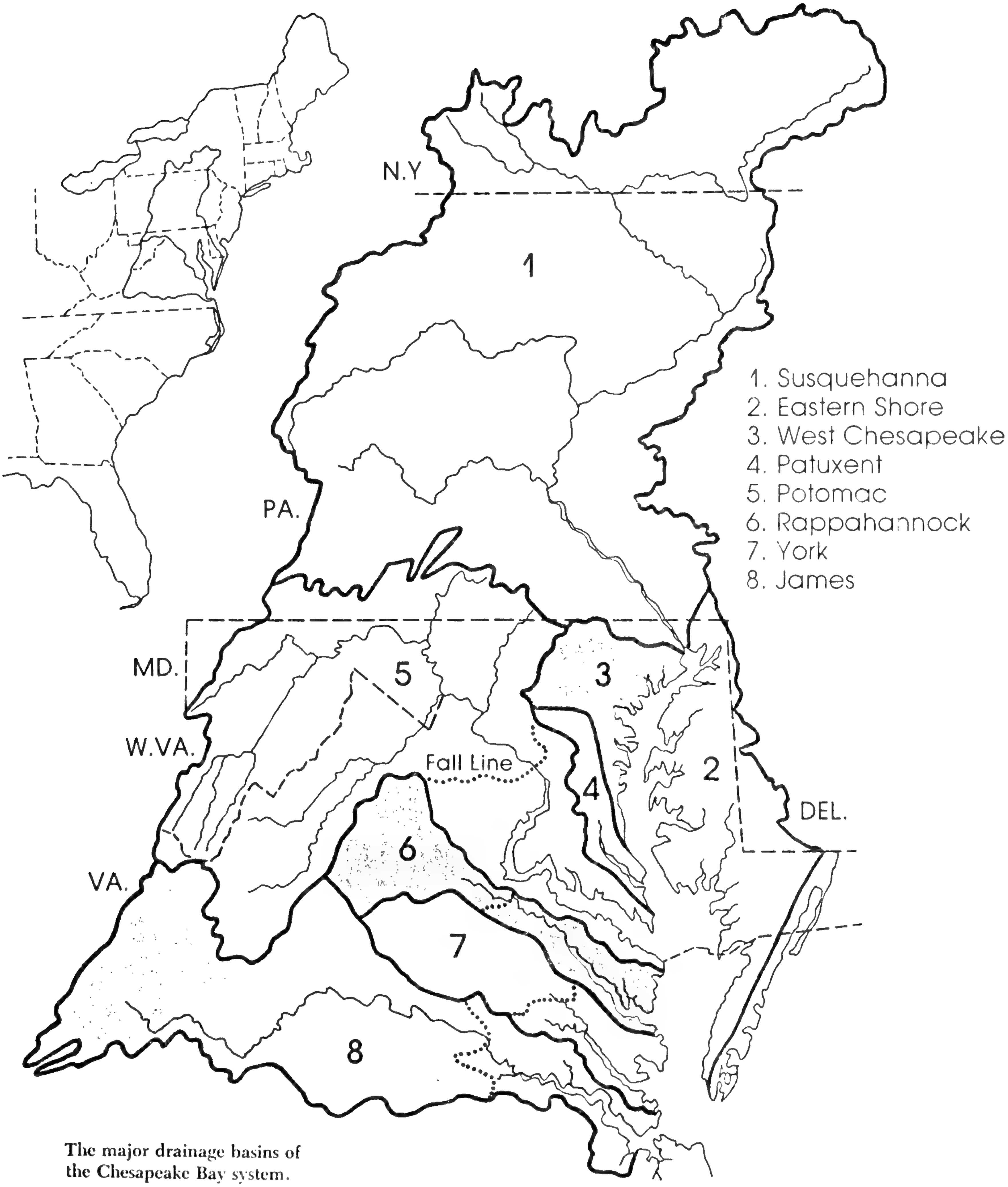
The Chesapeake and its tributaries represent only 7 percent of the 64,000 square mile watershed that's illustrated in Figure 1. The principal watersheds are the Susquehanna Basin and the Potomac Basin. Smaller basins include the Rappahannock, York, and the James River Basins.

The Chesapeake is small. Its average depth is only 8 meters. The volume of water contained in the Chesapeake and its tributaries is fifteen cubic miles. That volume is so small that most of the physical processes that occur in the Chesapeake Bay, although not necessarily the most important ones, are a function of what happens on the continental shelf off the Mouth of the Bay. Except for a small area at river mouths where they discharge into the open waters of the Bay, the Chesapeake's elevations and major current structures are controlled by what happens on the continental shelf.

From a regional geologic perspective the Chesapeake Bay lies in the Atlantic Coastal Plain and is bordered in the inland by a fall line where the Coastal Plain laps up against the peidmont.

The Chesapeake is small. It's so small that if you look at a cross-section of the Chesapeake representing only the unconsolidated sediments, you can't see the Chesapeake Bay in the cross-section. Its maximum depth of 175 feet doesn't even show in the thickness of a line.

The Chesapeake is large. It has 18 trillion gallons of water in it. If you were to build a process plant to try to extract something from the water of the Chesapeake Bay and you shut off all the river systems so that all you had to do was pump out that 18 trillion gallons, you could pump a million gallons a day and it would take 15 years to empty the Chesapeake. It's a very large body of water.



The major drainage basins of the Chesapeake Bay system.

Figure 1

The Chesapeake is large. It's 8,000 miles of shorelines would extend from the U.S.-Canadian border to the U.S.-Mexican border, along the Atlantic and Gulf coastline of the United States.

Its 4,400 square miles of surface area makes it the largest estuary in the continental United States.

The 450 miles long Susquehanna River is the largest freshwater system to discharge on the east coast of the United States and the largest to discharge from Eastern North America into the Atlantic Ocean Basin except for the St. Lawrence. The Chesapeake is a very large system.

So whether it's large or small depends in part on the perspective from which you view the system. I hope that you keep the perspective that in some cases it's a very large system and in other it's a very small system, but in all cases it's a very important system.

The modern Chesapeake originated during the last rise in sea level, which probably began on the order of 12,000 or 13,000 years ago. In Figure 2, we present a sea level rise curve for the Delmarva Peninsula. The data from which it was constructed are coastal areas on the Delmarva Peninsula are verified in the Chesapeake System by dates on peats which are found buried over wide geographic areas in the Chesapeake. Sea level was on the order of 20 meters below its present elevation approximately 8,000 years ago, about the time that the proto Chesapeake Bay in its present geographic configuration was flooded by this rise in sea level.

The Chesapeake has a remnant Pleistocene channel in it. This remnant Pleistocene channel, created when sea level was standing at some lower elevation than at the present time, generally follows the present deep channel of the Bay. At Annapolis the maximum depth of the Pleistocene channel is on the order of 200 feet below the present sea level while the mouth of the Rappahannock River is 140 feet.

The present configuration of the Chesapeake represents only the latest design of the Bay. During as many as seven other sea level excursions during the last million years, other novel configurations of the Chesapeake Bay may have existed. For example, some evidence suggests that the Chesapeake used to exit from across Delmarva Peninsula in the vicinity of Chincoteague, Virginia.

For our purposes today we're interested in part in people interactions with the Chesapeake. Rather than present a demographic map which shows you where the people live in Chesapeake

Bay, we've chosen to illustrate where the people live in Chesapeake Bay by showing the locations of the principal point sources which occur around the Bay (Figure 3). They occur as one would expect, in the vicinity of Baltimore, in the vicinity of Washington, in the vicinity of Richmond, and in the vicinity of Norfolk.

The population of 12.7 million people who live in the Chesapeake drainage basin are concentrated in three or four major metropolitan areas. This suggests that if one is interested in controlling pollution from point sources, one has a reasonable ability to identify and control those point sources in the main because they represent a few relatively small areas.

That's not to say the smaller sewage treatment plants on the Eastern Shore at other locations on the Bay, are not important in their local areas, but we can capture 70 percent of all point sources by controlling four major metropolitan areas in the Chesapeake.

It's projected that the 12.7 million population in 1980 will reach 14.6 million population in the year 2000. It's also projected that the population distribution will not be uniform across this area. In fact, most of the population increase will occur in the vicinity of the York River, which has no sewage treatment plants, relatively low population at the present time, and which is expected to grow 43 percent by the year 2000.

The Rappahannock River Peninsula and its drainage basin is expected to grow 40 percent in the next 15 years, and the Patuxent River Basin is expected to grow 27 percent in the next 15 years.

Land uses are illustrated in the pie diagrams (Figure 4). In 1950, approximately half of the total drainage basin of the Chesapeake was in forest and hasn't changed dramatically in the 30 years from 1950 to 1980.

However, the amount of urban area has increased from 5 to 14 percent in 30 years in the drainage basin, mostly at the expense of pasture land. Intensive urbanization, localized in specific areas, may be susceptible to controls and regulations because it is focused in relatively definable geographies.

When John Smith sailed into the Mouth of the Chesapeake his logs indicate that the area, as one would expect, was essentially fully forested. It was forested with a full-growth climax forest. His crews described a layer of waist deep humus on the forest floor that overlaid the mineral soils. Half of it had been destroyed by 1850 in the watershed of the Chesapeake. Destruction of this forest and its conversion to agricultural lands principally resulted in a dramatic increase in the rate of sedimentation in the Chesapeake (Table 1).

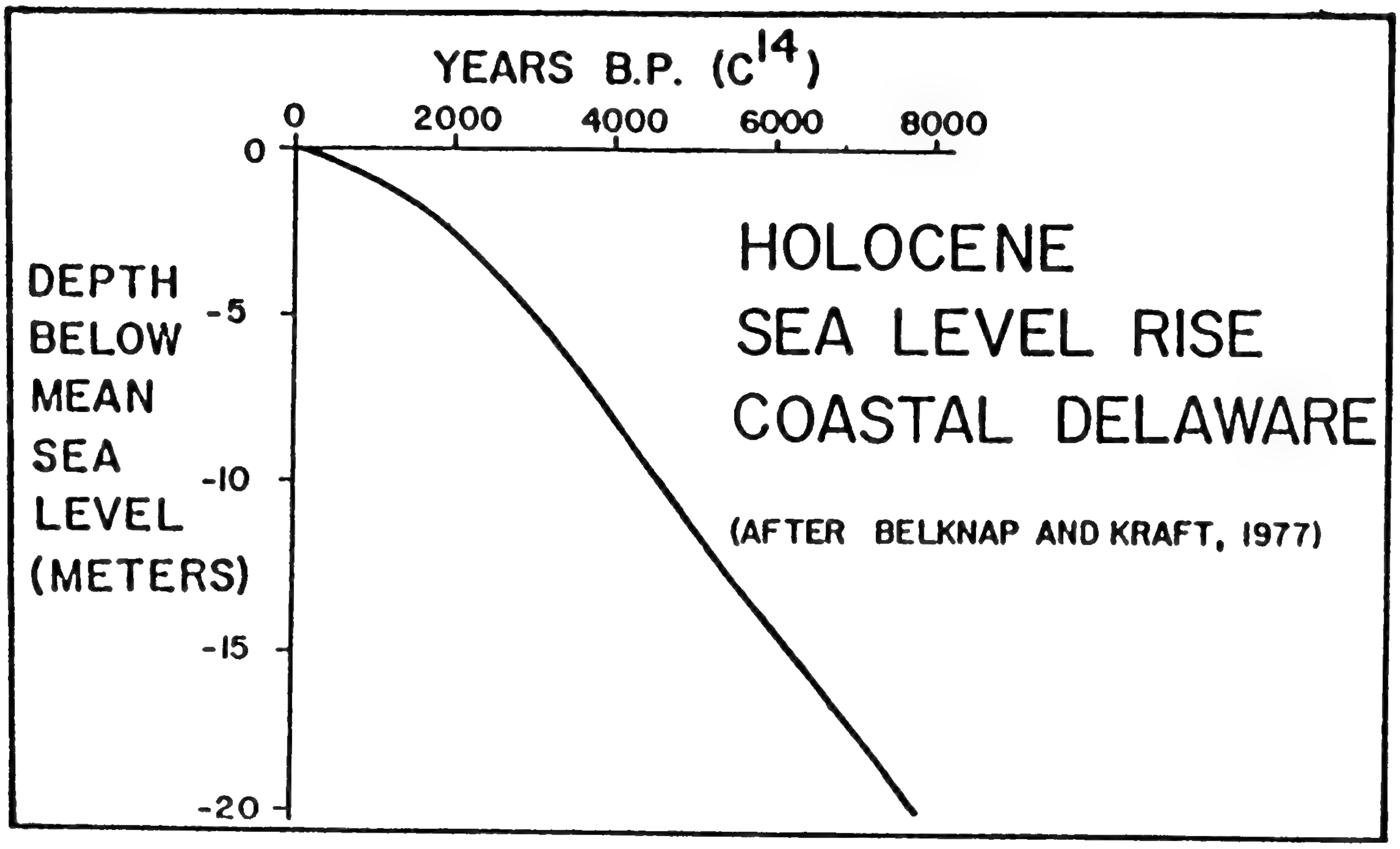


Figure 2. Sea level history on Delmarva

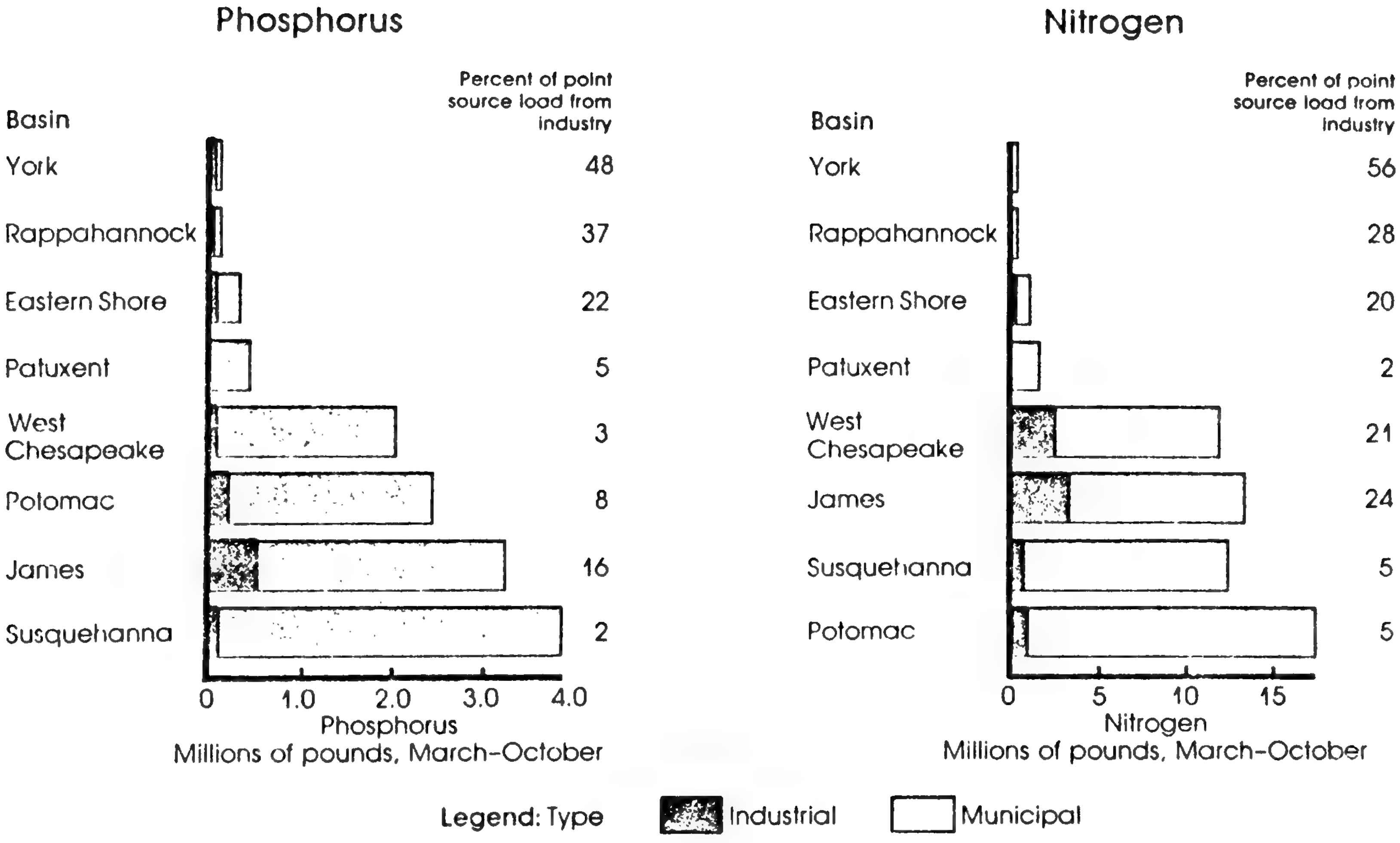


Figure 3. Discharge of phosphorus and nitrogen from point sources under existing (1980) conditions and percentage of point source discharge from industrial point sources (from EPA, 1983).

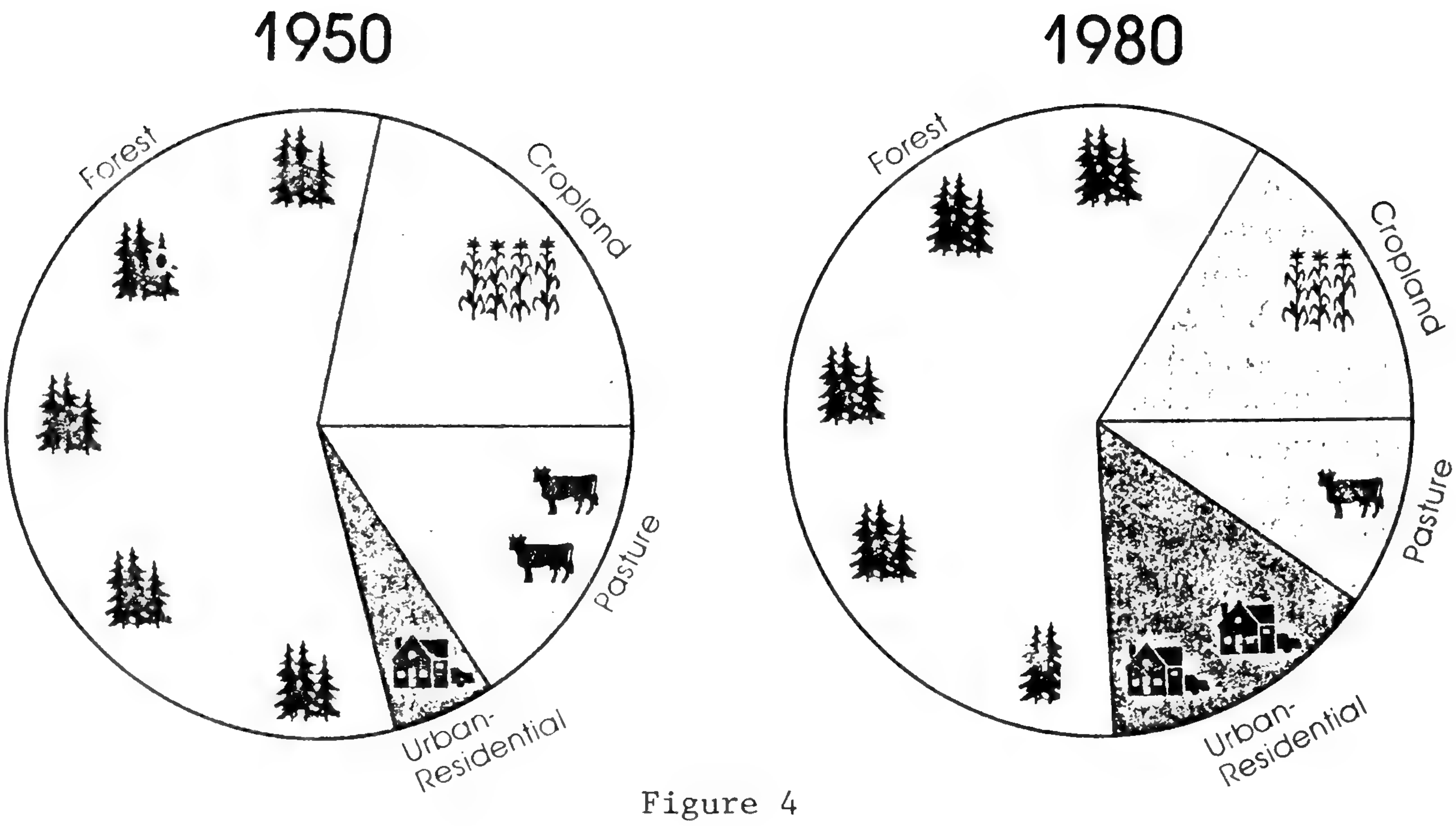


Figure 4

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

Table 1

Summary of Sedimentation Rates

Pre-settlement rates are based on carbon-14 dated sediment. Post-settlement rates are average rates calculated between a maximum of five pollen horizons. The pollen horizons represent historically documented changes in the regional vegetation and include initial land clearance, shift to intensive agriculture, beginning of the chestnut blight, demise of chestnut, and the beginning of large-scale urbanization. (Brush, unpublished).

	$\bar{x}$	n	$s_{\bar{x}}$
Pre-European	0.14	9	0.05
Post-European	0.30	53	0.19
<20% Land Cleared			
Upstream	0.15	6	0.20
Midstream	0.24	5	0.20
Downstream	1.17	3	0.06
40-50% Land Cleared			
Upstream	0.39	15	0.22
Midstream	0.37	16	0.19
Downstream	0.17	8	0.13

Pre-settlement sedimentation rates for the Chesapeake Bay, in the basin and its tributaries, were on the order of .14 centimeters per year.

By the time 20 percent of the land had been cleared by agricultural activity, the rate of sedimentation had increased to as much as .24 centimeters (cm) per year. By the time half the land had been cleared, essentially by the time it reached its present status on the Chesapeake Bay, sedimentation rates increased to as much as .39 cm per year. These data are based on a relatively large number of samples in several of the major tributaries in the Chesapeake Bay.

We know something of the historic attributes of the Chesapeake. Part of the research that has been conducted over the last 5 or 6 years with special intensity in the Chesapeake has been related to an attempt to discern and decipher the history of what's happening in the Chesapeake Bay. We have no quantitative historical record of activities that have occurred and may have impacted a change in ecology of the Chesapeake. One example of the kind of information that can be derived from a sediment core is illustrated in Figures 5, 6, and 7.

The City of Baltimore has discharged most of its treated sewage into a small sub-estuary of the Bay called Back River. An area immediately adjacent to Back River has essentially the same circulation and receives nothing but recreational or a very moderate level of sewage input. That area is called Middle River. An analysis of a sediment core (Figure 5) for the Middle River and the Back River as a function of time from 1780 to 1980 showed the clear change in sediment degradation products, perhaps associated with eutrophication, associated with the input of nutrient-laden waters into Back River.

Sediments can provide us with evidence of what changes have occurred in systems. In Figure 6, we show two cores located in Chesapeake Bay, one north of Annapolis and one in the vicinity of the mouth of the Patuxent River, illustrating the concentration of zinc in the core sediments as a function of time. This example is merely to show that from 1780 to 1980 concentrations of zinc reached some sort of a maximum at about 1940. The rise of zinc and other metals begins around 1880, which may be an indication of the initiation of industrial activities and other workings affecting the Bay.

The fact that this pattern is observed in areas far removed down the Bay suggests that the transport of potentially toxic materials may in fact be relatively widespread in the Chesapeake.

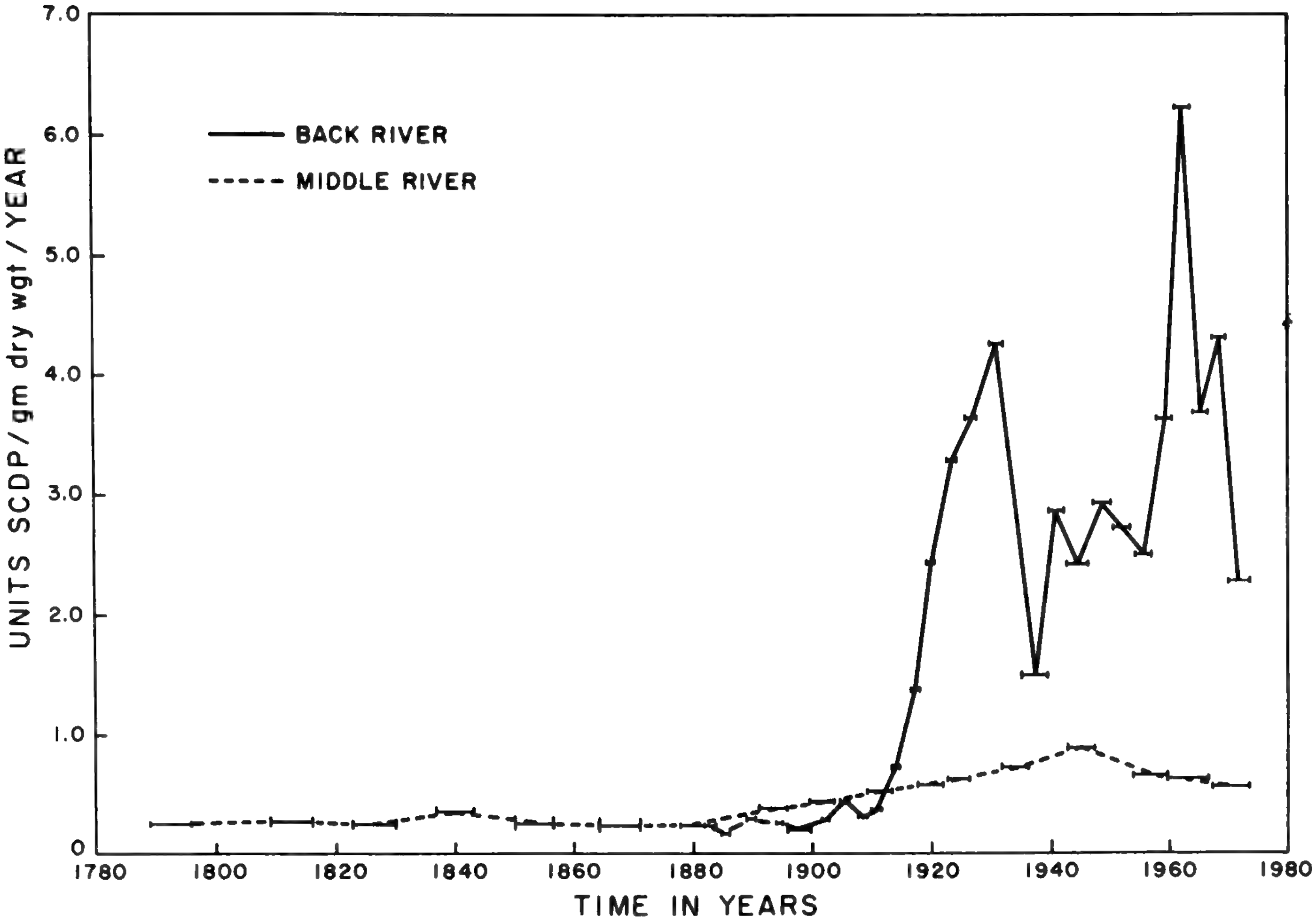


Figure 5. Comparison of sedimentary chlorophyll degradation products in Back and Middle Rivers (from Brush unpublished).

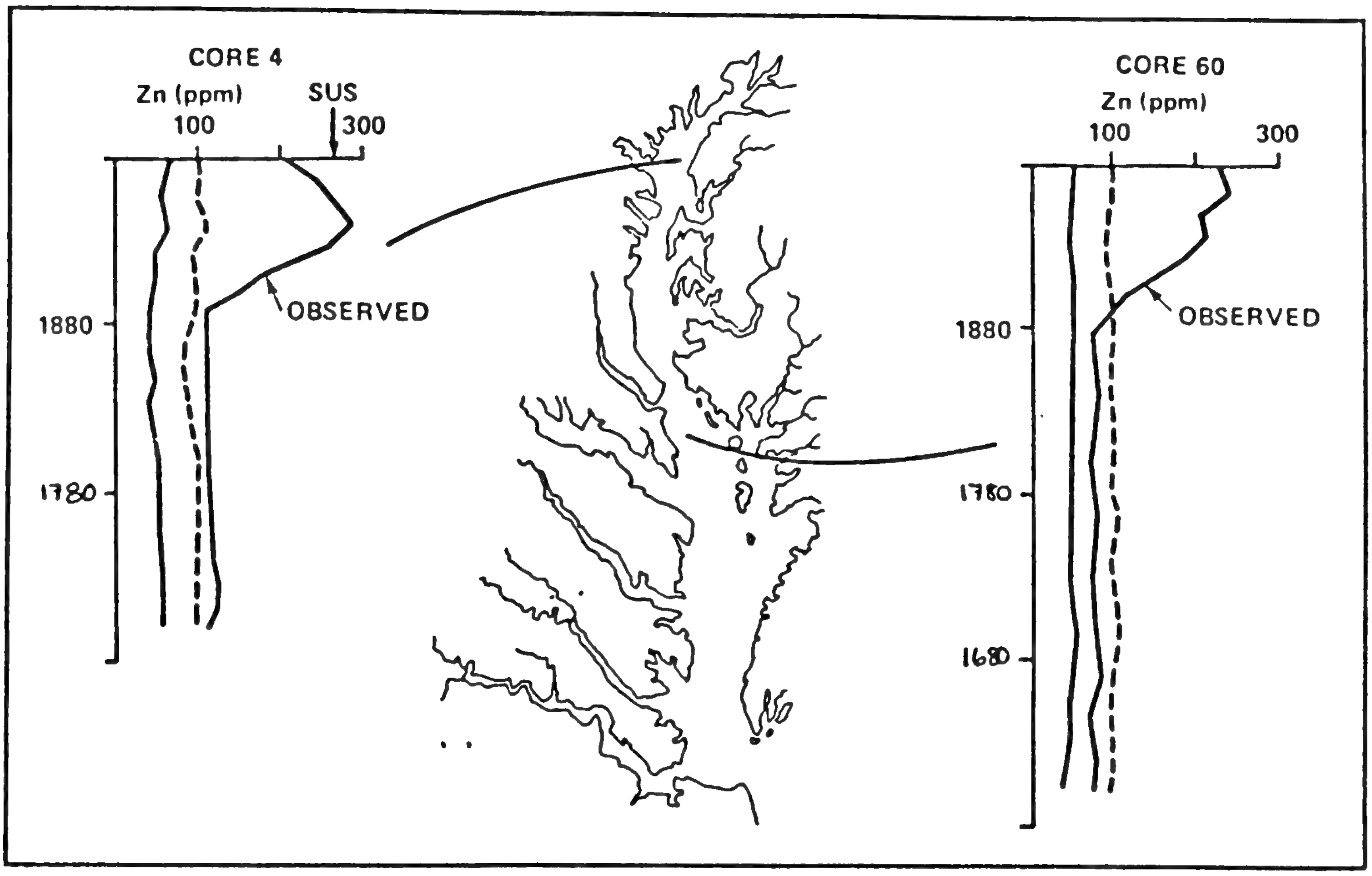


Figure 6. Zinc concentrations in dated cores from Chesapeake Bay (from EPA, 1983).

We offer the following history of the Chesapeake (Figure 7). The Chesapeake was discovered in 1607. Across the bottom of the illustration are depicted historic events or times to provide a reference point.

The population of the northern Chesapeake Bay area at the time of the colonists arrival was on the order of 100,000 in the entire watershed.

Just prior to the Revolutionary War, there was a significant population upheaval in the Chesapeake watershed. That population grew rapidly until about 1880 or 1890 when it became stable. After World War II, the population increased dramatically again. The projection is that it will continue to increase rather dramatically.

Subsistance agriculture, lumbering, tobacco farming, and eventually agribusiness resulted in the improvement of fully 50 percent of the Chesapeake watershed by 1850. Since that time, fields have been going back to forests or have been converted to urban or residential areas. Sedimentation rates and metal loads are also depicted and have been described earlier.

When was the first Bay-wide synoptic nutrient cruise ever conducted? The first Bay-wide historical nutrient cruise that attempted to cover the entire Chesapeake Bay and the major tributaries was conducted by the Chesapeake Bay Institute, Johns Hopkins University, in 1963. Note that by 1963, the metal loads appear to have already been declining.

Agricultural activity had peaked a hundred years prior to that; the population was almost what it is today; and metal loads had already started to decline. From a direct historical perspective from a day on Chesapeake perspective, it's difficult to look back at existing data and try to understand what changes have occurred to date.

Whether by geochemical or paleontological methods, we think that the stratigraphy of selected cores from the Chesapeake Bay can be used to determine what's happened to the system as the population of diatoms versus dinoflagellates changes dramatically; as the contribution of organic matter to the system changes dramatically; as periods of persistent anoxia seem to occur; do any of these have precedence in the past or are they unprecedented?

Perhaps by understanding the stratigraphy of some of these cores, whether geochemically or paleontologically, we can get a feeling for how the Chesapeake has changed in response to natural and anthropogenic influences that have occurred there.

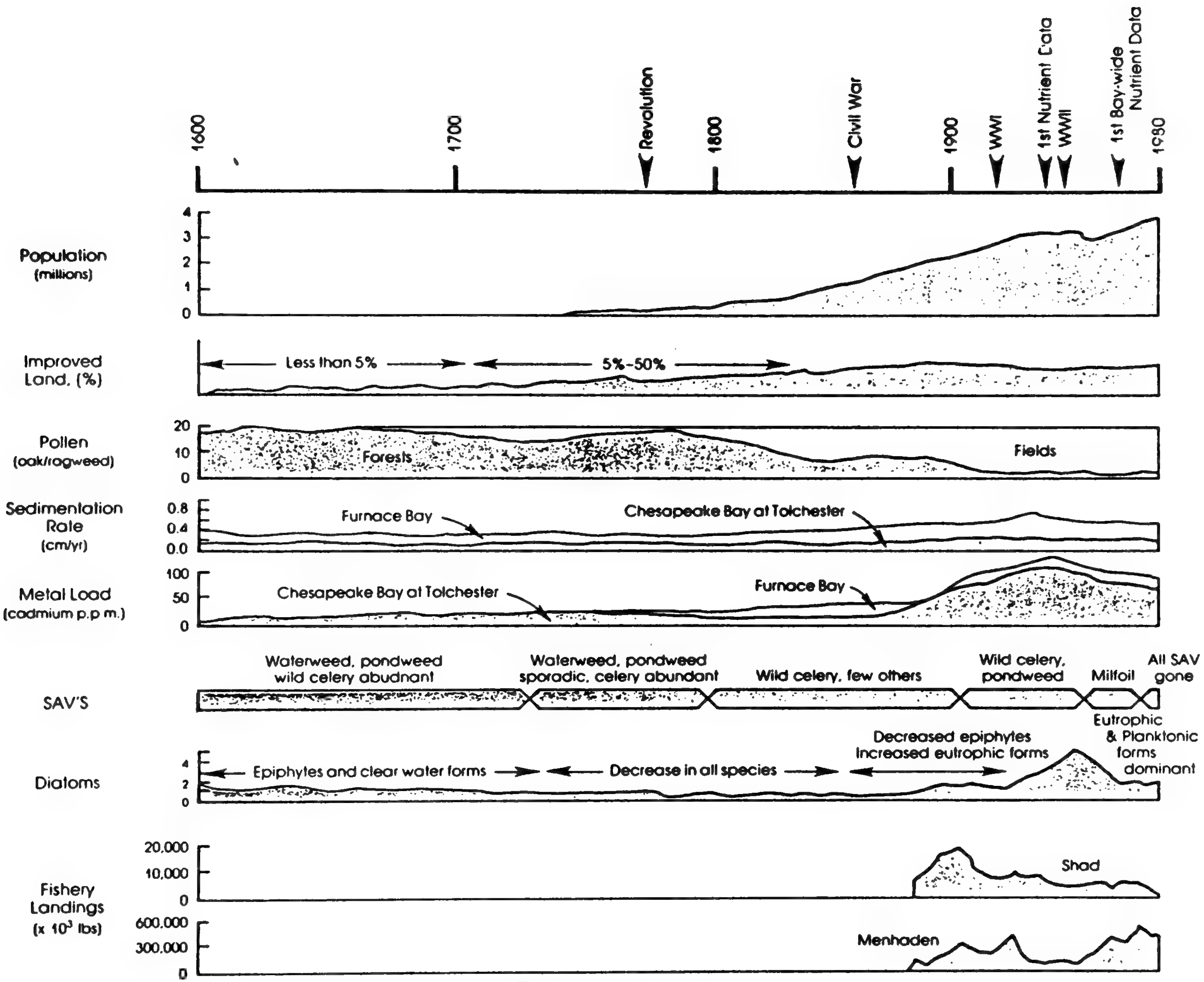


Figure 7, EPA, 1983

TIME HISTORY OF NORTHERN CHESAPEAKE BAY, 1600 TO 1980. An important aspect of understanding how Chesapeake Bay will respond to pollution is to examine the Bay's past. In the northern Bay, human activity, beginning at the top of the chart with population growth, has been changing water quality since the time line began (see Appendix A for further discussion).

Another major area that I think needs work from the geological, sedimentological, and toxicological perspective is that we must develop a series of models of suspended sediment movement linked to a two-dimensional or three-dimensional model of the Chesapeake. We must put suspended sediments in those models because toxic materials that enter the Chesapeake Bay seem to cling to and have an affinity for suspended sediments. Where the sediments go, so go most of the toxic materials.

Perhaps, we're going to go to no-till agriculture in the Basin because it's an economic imperative. When we go to no-till agriculture, if we reduce the suspended sediment input to the Chesapeake Bay, we'll increase the light that's available to the Bay. Some would say that given the nutrient concentrations that we have at the present time, light is the limiting factor that controls primary production in the Bay. How long will it take the effects of no-till agriculture to increase water clarity? Where will it be achieved first? How will these interact with the nutrients of the Bay?

These are some problems that we think are of critical importance from the perspective of geology and sedimentology that need to be addressed in the Chesapeake.

Thank you.

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CLIMATE AND CIRCULATION

by

Dr. William C. Boicourt
Horn Point Environmental Laboratories

Dr. Boicourt: I'm to address the climate and circulation of the Chesapeake Bay. Given the brief time, I'd like to consider climate in a narrow sense -- the interannual variability. In order to cover the other aspects of climate, I am going to take a certain amount of professorial license and assign reading in the 1941 Yearbook of Agriculture entitled "Climate and Man."

I want to quickly convey how the Chesapeake Bay moves, how we're doing as scientists in providing a description of the Chesapeake Bay circulation, and how we can use this understanding to try to reduce the uncertainty in assessing the long-term trends in the health of Chesapeake Bay.

The Chesapeake Bay is the archetypical estuary for physical oceanographers. It dominates the physical oceanographic literature to the point where my colleagues in Europe bridle at the fact that they have to either come here and work on the Bay or at least compare their small, unimportant estuaries to the circulation of Chesapeake Bay. To be fair, some of my colleagues from across the water have come to the Bay and have done rather well in providing new insight into estuarine circulation.

For a description of the circulation (which most of you know well), we describe a simple experiment:

Here we have a basin. On the left-hand side is freshwater, on the right-side is saltwater, and there is a partition separating the two. To put this experiment in perspective, I should explain that even physical oceanographers perform it. I used to consort with a bunch of decidely elitist oceanographers who described themselves as geophysical fluid dynamicists at an institution up in Massachusetts that goes down to the bottom of the ocean to find Titanics. They conducted this experiment in a rather different manner -- the basin was a gin bottle and the two fluids were ethanol and paint thinner. The results are basically the same, and provide more insight than you might expect at first. Your intuition says that saltwater is heavier than freshwater.

What happens when you pull the partition between the two fluids? I'll ask you this on the same exam after the reading assignment, but I'll give you a hint. The heavier saltwater flows under the freshwater, and the freshwater flows over the saltwater. This process continues to the point where there is an equilibrium. Thereafter, this picture stands until molecular diffusion removes the salinity difference between the two. That is a very, very slow process. This picture here resembles what we describe as a salt-wedge estuary, which the Chesapeake is not. The amount of freshwater flowing towards the sea over the saltwater flowing towards the head of the estuary is not much greater than the total freshwater moving in.

The Chesapeake Bay, if you took a typical cross-sectional area in the mid-section of the Bay, maybe a 100,000 square meters, and tried to move the Susquehanna through that you get 1 centimeter per second average velocity across the crosssection. And that is about a kilometer a day, seemingly not very strong.

Then we go out to our current meters in the estuary and find indeed that the estuary has mean velocities 10 times the amount or even 25 times that amount. What drives this robust circulation?

This is a picture of what's called a partially mixed estuary by Pritchard's definition. We see freshwater moving toward the mouth of the estuary and saltwater penetrating in along the bottom. The Chesapeake Bay is the foremost example of this type of estuary. During the process of moving toward the mouth of the estuary, the freshwater mixes with the lower water reducing its freshwater component, and getting saltier and saltier as it moves to the sea. Likewise, the ocean water moving toward the head of the estuary gets fresher and fresher to the point where it reduces its saltwater component.

The critical driving element in the Chesapeake Bay circulation is this mixing process, which we traditionally think of as the turbulence generated by the sloshing back and forth of the tidal currents over the bottom of the Bay. This picture has been modified somewhat lately, but mixing remains the crucial determinant of Bay circulation.

Well, we've known this circulatory picture for 30 years. What's new? And how did we get there?

We got there in the last 20 years by an increasing use of moored instrumentation. If you picked up the description of NOAA's circulatory survey, you will see described that they've conducted a large set of mooring operations over the Bay. For example, 61 current meters were placed on 23 moorings in June 1980 under EPA sponsorship.

The ability to cover the shorter term variability over a longer time with the instrumentation has provided a lot of insight. Large scale arrays are possible when groups get together, such as the cooperation between NOAA and ourselves at the Chesapeake Bay Institute. At that time, NOAA maintained four long-term moorings at the southern end of the Bay while we maintained three in the upper end of the Bay. There was an overlap of about a year-and-a-half and we learned quite a bit from that long-term measurement series.

What have we learned?

I'll be rather short and broad in view as some of these circulation studies encompass very many researchers even those from across the water. They are listed here in a crude chronological order. Clearly there's been numerical modeling forever, but recently this has come to fruition in some very interesting models that a lot of researchers are finding very helpful.

Meteorologically Forced Circulation: Just to remind ourselves as physical oceanographers that we discovered that the wind can move the water. We've always said, those of us who are old, that we clearly understood this from first principles, but we've been reminded by the new wave that the "wind driving has been neglected." There is some support for both positions, but the work done by Alan Elliot, Dong-Ping Wang, and the work done by Professor Pritchard and his students, specifically Grano, Vieira, and Goodrich has revealed fascinating details of the process.

There's some truth on either side. But the work done by Alan Elliot and Dong-Ping Wang on the Potomac River and the work done by Don Pritchard and his students Grano, Vieira, and Dave Goodrich has shown what some of these circulations can do. A quick qualitative picture of what happens in the estuary: We have a simple Chesapeake Bay here. We took away the Potomac River and all the tributaries and the Susquehanna and treated it as simply a basin. I guess I can't assume that people are so uncouth as to blow on their soup. But I have in the interest of this experiment. When you blow on the soup, the water (soup) in the far end of the bowl sets up a little higher than the soup in the near end of the bowl. And if you blow too hard?

But the primary consequence of the winds is a drop in the water level in the north end of the Bay. That's a common experience. When there's a strong northwesterly, we get extremely low tides. Water is forced out of the Bay, and a classical two-layer circulation is set up, with strong flow to the south in the surface layers and a delayed up-estuary flow in the lower layers.

We have learned that the cross-estuary tilt of the pycnocline resulting from the rotation of the earth can be upset by the wind. A cross-sectional view looking up the Chesapeake Bay at Mid-Bay shows a higher salinity water along the eastern shore. A cross estuary wind can not only reverse this slope, but also drive upwelling along the side.

Mixing: The crux of the ocean circulation problem has for a long time been with the small-scale motions of the ocean we call turbulence and which causes mixing. We don't understand it very well, but we try hard, for the rewards are a more accurate description of the larger scale circulation processes. Mixing processes in the estuary were traditionally thought to be moving back and forth over the bottom with the tidal currents. We see it as a balance between the horizontal motions tending to produce what's called buoyancy flux versus the act of vertical motions to destroy that stratification.

If we apply bottom-generated turbulence and turbulence generated by the wind at the surface to the salinity versus the depth profile, then this smooth increase in salt with depth would change. Classical entrainment theory would predict that this smooth change would become abrupt. It turns out that the Bay looks more like the smooth profile, even with winds stirring the upper layers. We are forced therefore to examine the mixing processes in more detail. Internal waves and shear instability mechanisms are throught to be important here, but the precise mechanisms are still unknown.

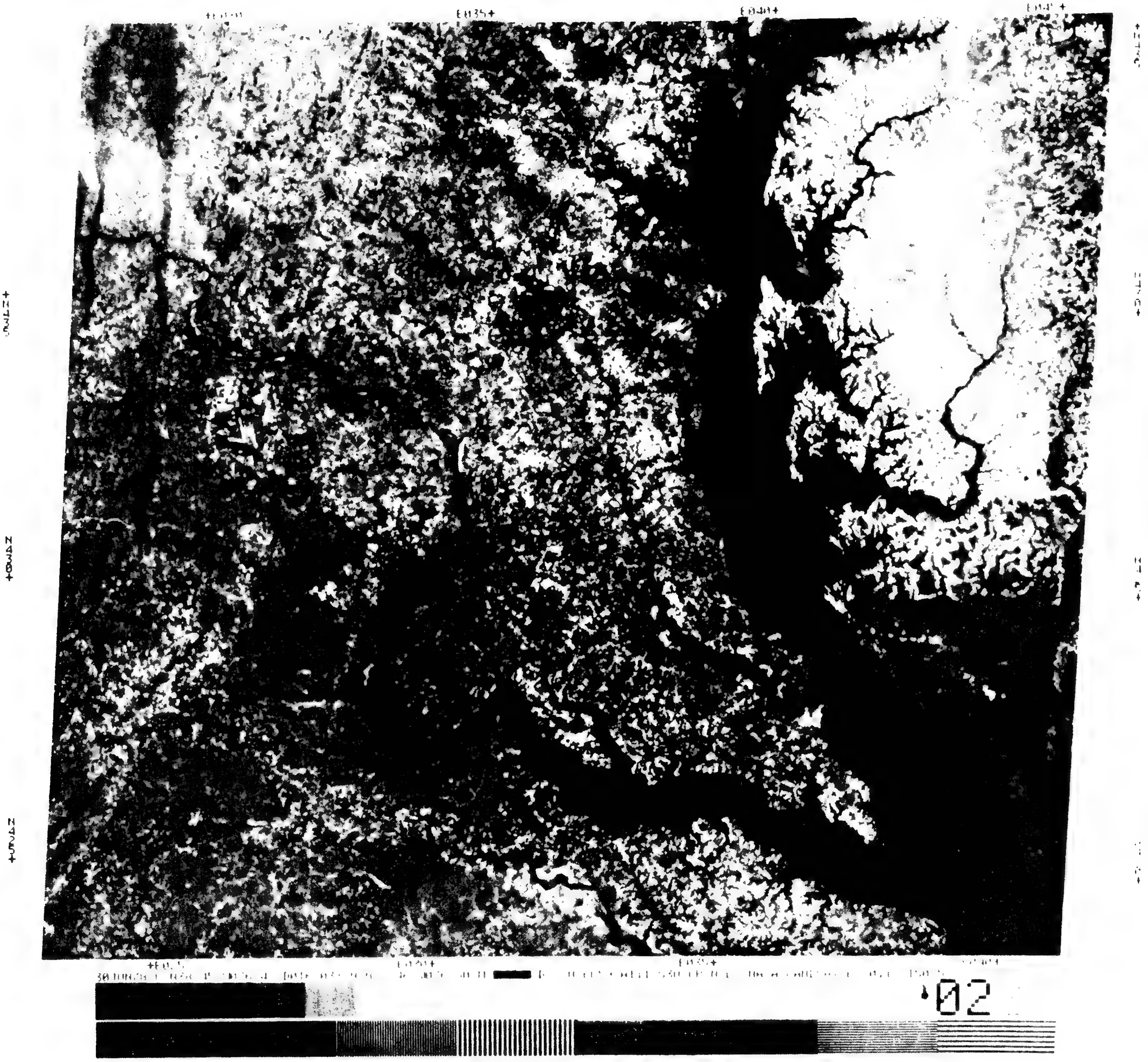
I list in Table 1 a category called "topographically induced circulation" that comprises many flow processes. If you are a kayaker or canoeist or a stream fisherman, you would laugh at what we consider discoveries in this area -- superimposed on the steady flow of the estuary are many eddies and jets and regions of high and low currents. This LANDSAT satellite image shows the dendritic nature of the Chesapeake Bay's geometry. The channel curvature and the complex side boundaries generate many local flow features that influence the transport of water and waterborne materials in the estuary. An intense array of instruments such as this one deployed in the Potomac River is necessary to examine such flow features. With this array we revealed small-scale jets, eddies, and both coupled and independent flows in the upper and lower layers.

Tributary -- main stem interaction: This area of research is of particular interest at the moment. We are finding that

Table 1
ACTIVE RESEARCH

Estuarine Circulation

- Meteorological Circulation
- Tributary - Main Stem Interactions
- Topographically Induced Circulation
- Mixing
  - Wind
  - Boundary
  - Internal



LANDSAT SCENE COURTESY OF NASA

each tributary has something to reveal concerning the transport of water and salt in an estuary. An especially interesting tributary is the Patapsco River -- Baltimore Harbor System, where a remarkable three-layer circulation was discovered. The Patapsco River cannot provide sufficient flow to drive a classical two-layer circulation. The fresher upper layers of the main stem of the Chesapeake Bay therefore move into the Harbor, mixing as they go with the saltier waters below. The salty lower layers of the Bay also move into the Harbor along the dredged shipping channel. What happens when these two currents move in? There has to be an outflow and it occurs at mid-depth. This has been inferred by Pritchard and Carpenter many years ago and until recently hasn't had a direct measurement.

Here are flow measurements revealing the three-layer structure. Six current meters are employed to resolve the remarkably small scales of this profile.

Bob Biggs mentioned the importance of the continental shelf. Until told that we ought to pay attention to the sea level at the continental shelf, we were always ignoring that and treating the continental shelf as a large reservoir and source of high salinity water. But now we've become very interested in the source waters on the continental shelf realizing that the continental shelf sea level can drive motions in the estuary, especially very low frequency.

We've also studied where the Chesapeake Bay water goes when it exits the continental shelf. At times it moves all the way to Cape Hatteras during high outflow and to the Gulf Stream.

I mentioned numerical modeling. Dr. Shenn-Yu Chao at the University of Maryland is developing a computer model, a mathematical description, of the circulation of the Bay and the inner continental shelf. Of interest is the outflow from the Bay, which can move rapidly down the coast toward Cape Hatteras, and ultimately, become entrained in the Gulf Stream. This is the upper layer model predictions. In spite of the simplistic geometry, the picture is a remarkably accurate description of the Chesapeake Bay outflow plume, as observed recently in our microbial exchanges coupling in coastal Atlantic systems experiments. The flow of water into the Chesapeake Bay in the lower layer intensifies along the coast off Virginia Beach.

Modeling is especially helpful in the attempt to assess long-term trends. Bob Biggs referred to the lack of long-term data sets on the Chesapeake Bay. The EPA Chesapeake Bay Program could only develop a 30-year record on dissolved oxygen of the Bay. Such a record length is uncomfortably short to assess trends or help guide costly management decisions. One role the numerical model can play is to reduce the complexity and uncertainty resulting from the lack of long-term data sets. If we can develop an accurate model of the Bay's behavior during intervals when we have an adequate set of observations, then we can use this model to predict the Bay's response to the driving forces for intervals which are not well covered by observations.

Long-term records and modeling are the only avenues toward understanding of the interannual variability of a natural system. This interannual variability must be addressed in order to be able to normalize the records from the estuary to detect changes that are the result of man's influences. In the case of dissolved oxygen, for instance, we must be able to separate the fluctuations due to variations in river flow (and hence, stratification) and increases in nutrient loadings on the Chesapeake Bay.

I would like to endorse what has been a traditional role played by government agencies in the realm of long-term measurements. The National Oceanic and Atmospheric Administration and the U.S. Geological Survey have historically provided long-term observations of such variables as river flow, sea level, and meteorological forcing, upon which we depend greatly for insight into the processes of the Chesapeake Bay. Given the precedent and the tradition, I would like to encourage these agencies to initiate new long-term observations in estuaries. Moreover, the recent move to provide real-time or near real-time sea level and flow information should be commended. The Federal agencies have the experience and the means to provide the oversight and continuity that long-term data sets require.

Thank you.

RESOURCES AND ECONOMICS

by

Dr. Herbert M. Austin
Virginia Institute of Marine Sciences

Dr. Austin: This is one of those papers that has a single author from one Chesapeake Bay state, the State of Virginia, but I want to reassure my friends from the north that I have talked to people in the Maryland Department of Natural Resources (DNR) in preparing my talk.

Inevitably, when we speak of the Chesapeake Bay the conversation turns to the resources, their issues, status, and management. More than we, they're the inhabitants of the Bay and we're the stewards. We must consider their needs above our own.

The Issues

Despite our earlier State, Federal, and Congressional efforts, it wasn't until the EPA Bay Report was released in 1983 that there was a focused concern, and a public awareness of the Bay and its problems. These efforts in the winter of 1983, culminated with the Governors' Conference. The 1984 General Assemblies of the Bay States had a clear mandate of the need for political and legislative reforms and the resources needed to fulfill them.

Fisheries resource management has probably made more progress in the last 2 years than we have in the last 2 decades. In spite of the mandates, reforms, initiatives, and policy statements, biological cycles in the Bay occur more slowly than political cycles, and the public is impatient. We're trying to rectify more than 50 to a 100 years of neglect, and activities in the area of resource management are under scrutiny, and unresolved issues still await asking.

What are the resources? I shall address several; each as a fishery. By definition, a fishery is the resource and the harvester. We can't separate them.

The recreational component ranges from the child on the dock to the more sophisticated, high-speed boats capable of blue water fishing. Both the child on the dock and the sophisticated fisherman are interested in striped bass, bluefish, weakfish, spot, croaker, and flounder.

The commercial fishery ranges from a single man in a small boat on a tributary or creek to the pound net on major tributaries of the Bay to the multi-million dollar menhaden fishery.

Conflicts among users remains an issue -- not one that impacts stock size so much, but one that pits otherwise allies, one against the other. These include the recreational versus the commercial fisheries for a given species, with the striped bass as probably the best example. There is the new versus traditional technology, for example: the "high roller" gill netters that appeared in Virginia 4 years ago pitted against the more traditional gill nets used; or the hydraulic escalator dredge, which operates seven times more efficiently in the removal of hard clams, than the more traditional patent tongs.

Competition for space between the menhaden purse seine, crab pot, and the recreational fisherman's hook is a problem when each may try to occupy the same place at the same time.

These user conflicts, however, are socioeconomic problems more than they are biological issues. It is not my intent today to carry out a scientific discourse dealing with the spawning habits, the feeding habits, the growth rates, or the population dynamics of the various species.

I find that as I talk to the public, those interested in the Bay, their understanding of the resource population dynamics has improved dramatically in recent years, and that the informed public often ask very informed questions, and as a scientist they're sometimes difficult questions to answer.

However, part of this deals with the status of the stocks, so I feel I have to make a few comments. A fishery stock is kind of like a money market account. If you have 10,000 dollars in principal, you should not spend it. You should only spend what you make in interest.

A fishery stock works this way. Unfortunately, recruitment fluctuates from year-to-year just as the interest rate does. Fishermen get used to harvesting at a certain level. Then, when the recruitment rate drops below the harvest rate, we begin spending our "principal." In many cases this has happened to stocks in the Chesapeake Bay. Regardless of why the "interest rate" dropped, whether it was a change in climate, or a change in water quality, or overharvesting, that is, "overspending the principal."

Status of the Stocks

The striped bass seems to be a cause celebre in the Chesapeake Bay these days. Somehow its problems seem to be the epitome of the status of the Bay itself. The stock does seem to have bottomed out, and I think that there are indications that it has begun to recover. We are seeing a larger, average-size striped bass, rockfish, in the Bay, which suggests that the minimum size limits are being effective.

In Virginia, we've seen a rather significant increase in our recruitment index over the last five years. If you look at Maryland waters, however, you find that their riverine systems of the Chesapeake Bay show average or below average recruitment.

Moreover, when we move to the Upper Bay, the Susquehanna Flats, which traditionally carry the entire Chesapeake Bay stock, we find there is an almost total recruitment failure. I think we should change our focus and take a closer look at what's happening at the Head of the Bay on the Susquehanna Flats, and perhaps, ask our Pennsylvania neighbors to assist us in this closer examination.

We see limited recovery of shad and river herring stocks in Virginia. The situation remains static in Maryland. I could tell you that we've seen a 100 percent increase in the shad run this year, which wouldn't mean a whole lot when you know that landings actually rose from 200 to 500 metric tons.

Generally, the other stocks such as weakfish, spot, croaker, and flounder tend to fluctuate primarily due to the impacts of climatic events. We have not documented the impacts on these stocks that we can relate to pollution. Overharvesting is probably the greatest cause of a stock decline once the fish pass a normal cyclic peak. On the other hand, some stocks of these if they weren't fished at all, would decline, naturally.

While the Bay blue crab stock "appears" to be stable, there has been such an increase in fishing effort over the last few years that in all likelihood the catch-per-unit effort throughout the Chesapeake Bay has been reduced. Commercial catch data (our index of stock size) show an increase, but reduced catch-per-unit of effort suggest an actual stock decline.

The oyster harvest is down in both States. Recruitment is down. Efforts are being made, significant in Virginia, to examine why there has been a decline in recruitment and see whether corrective measures can be followed.

I want to close with a few comments on a new effort that has been initiated. This is the Federal/State/Chesapeake Bay Stock Assessment Committee. Thanks to Senator Mathias and support from other Senators from Maryland, Virginia, and Pennsylvania, NOAA has received a million-and-a half dollars for Bay-wide stock assessment activities.

This cooperative Committee includes membership from the NOAA Estuarine Programs Office, Northeast Fisheries Center of the National Marine Fisheries Service, the Maryland DNR, Virginia Marine Resources Commission, Virginia Institute of Marine Sciences, and representatives from academia in Pennsylvania, Maryland, and Virginia.

The EPA Bay study made a policy decision when it started its five-year study, that was not to examine fisheries, but to look at problems of water quality, submerged aquatic vegetation, and toxics in the water. This was okay, except that toward the end of the study it seemed that every time the telephone rang it was somebody from the EPA study wanting some fishery data so that they could relate fisheries to trends in water quality. These types of data were simply not available at that time in the right format to provide to people in other disciplines.

The data that we did have has been collected sporadically over the years, and even for those studies that have 25 or 30 years worth of data, nobody had ever attempted to look at these data in entirety. The major effort of the Chesapeake Bay Stock Assessment Committee this year will be to get these data sets into a format that water quality scientists and other fishery scientists can look at and use when trying to determine the trends and also to see how they relate to each other.

In addition, after the initial efforts where the long-term data bases are examined, the Committee plans to move into assuming continued funding of an area looking at biological effects where the problems that are addressed in the EPA report and the problems that are being observed today in the fisheries and stocks are actually examined for cause and effect.

Significant progress has been made but knowledge is kind of like fish, it doesn't keep very well. We need to continue our efforts. Thank you.

Dr. D'Elia: We have time for one quick question.

[No response].

Dr. D'Elia: Thank you very much.

Next we're going to have a joint presentation. I've been promised by each of the speakers that they will each hold to 10 minutes. They are going to talk about toxic pollution. Dr. Robert J. Huggett from VIMS and Dr. James G. Sanders from the Academy of Natural Sciences. Dr. Huggett will lead off.

TOXIC POLLUTION: ORGANIC POLLUTANTS

by

Dr. Robert J. Huggett
Virginia Institute of Marine Sciences

Dr. Huggett: Thank you, Chris.

The presentation on toxic pollution will be divided. I will talk about the organic pollutants in the Chesapeake Bay, and my colleague will talk about inorganics. I will, as will he, mention some of the biological impacts resulting from toxics that we do know about at this point in time.

By far, the most abundant organic pollutants in the Chesapeake Bay are members of a group of compounds called polynuclear aromatic hydrocarbons (PAHs). They are produced by automobiles, our home furnaces, and almost any combustion process which uses carbonaceous fuels. Some of them are known to be mammalian carcinogens, teratogens, and mutagens. And some of them have the same effect on fish.

The concentration of the PAHs in the Bay's bottom sediments are greatest near the river mouths in the Southern Bay. In the Upper Bay the concentrations tend to increase from the Potomac River mouth north to Baltimore Harbor. There is then a decrease with another relatively high concentration near the Chesapeake and Delaware Canal. At the time of our first sampling (spring of 1979), the mouth of the Susquehanna contained low levels of PAHs. In the fall of 1979, the Susquehanna had much higher concentrations. The first set of samples was taken when the river flow was very high. Apparently, everything coming down was being flushed out of this area and down into the Bay. Prior to and during the fall sampling, there was almost no flow, and what was coming over the Connowingo Dam was deposited near the mouth.

One can pick an individual compound, benzopyrene, perhaps the most famous of the PAHs suite, and get the same distribution. Basically higher concentrations are near the mouths of our rivers and concentrations build up in the Upper Bay. The reason for this buildup is likely due to the fact that the sediments in the Upper Bay are more fine grained than they are in the Southern Bay. In the Upper Bay, there are more silts and clays. Also, there's a higher human population in this area. As I mentioned earlier, major sources for these PAHs are smokestacks and automobiles. The materials enter the atmosphere and are subject to windborne transport. We believe a reason for the higher concentration in the Upper Bay is that the contaminated clouds, if you will, come over the Bay and the PAHs are rained down.

We have detected hundreds of individual PAH in the Bay's sediments. If they are having an impact on the biota, it is likely not to be from just one, but from some combination of them. I think that it is a real challenge for scientists to try to figure out what's going on.

One can pick any of the hundreds of PAHs that we have detected in Baltimore Harbor and it will show trends in concentration. It looks as if there may be point sources. We went to some of the industrial outfalls in the area, collected, and analyzed sediment samples. The concentrations found obviously indicate that there are point sources. There is windborne transport, but in the highly urbanized, industrialized areas there are, as well, industrial and municipal inputs.

If we were to examine the same compound in Elizabeth River, Virginia, we would likely see even higher concentrations. Perhaps, the Elizabeth River contains the highest concentration of PAHs of any estuary in the world -- 200 parts per million of benzo(a)pyrene at approximately 1 foot of depth. The reason is creosote. Since the turn of the century there were four or five industries on the river that treated telephone poles, railroad ties and pilings with creosote, which is a mixture of these PAHs. It was used as a pesticide to keep out worms and fungi. They spilled it and it seeped into the river. Today, the sediments have the historical record. In cores of bottom sediments one can see the black inclusions that are basically pure creosote.

If you take these sediments and put them in a tank of flowing water and put fish in the tank, after a week you start to see fin erosion. In controls with clean sediment, none of these effects are seen. Other effects include skin lesions after about 2-1/2 to 3 weeks. In some cases the lesions penetrate the stomach cavity. Fish collected in the field (i.e, Elizabeth River) showed many of the same effects as those investigated in the tank laboratory experiments. Perhaps most strikingly of all in a highly contaminated area of this one river, the Elizabeth, almost 100 percent of the trout and croaker over 8 inches in length are blind with cataracts. Some of these compounds (PAHs), by the way, cause cataracts in mammals as well.

Some animals have the ability to metabolize compounds such as the PAHs. They are trying to get rid of them by making them more polar so they exit the body more easily. But in the process, they may make them more toxic. It's not the parent compound that does the damage in many cases but the metabolite.

This is a very exciting field of research. I personally believe that by going out as chemists and just analyzing a few samples of sediment or water, we are not going to learn very much. And by the same token, I feel that if biologists just perform classical bioassays and the like, while important, they are not going to get the total picture either. I believe we have to combine our efforts and start to utilize some of the technologies that researchers in medical schools have used for years, e.g., immunology, embryology, enzyme kinetics, and everything else to try to get a better understanding.

In closing, I'd like to say that I think the resources in the Chesapeake Bay are in pretty good shape. It looks like, or the signs are, that some of the levels of some of the PAHs may be increasing in the Bay. We know they can be harmful. We have problem areas in the Elizabeth River and Baltimore Harbor; some of the other smaller tributaries are highly impacted with waste. In general, we're in pretty good shape. I hope that we have caught this problem of chemical pollutants in time. With that I would like to turn the program over to my colleague.

TOXIC POLLUTANTS

by

Dr. James G. Sanders
Academy of Natural Sciences

Dr. Sanders: Thank you, Bob. I, too, will be brief. Because of time limitations, I can only begin to identify the problems that we have with inorganic compounds. Therefore, I will focus only on metals and metal loadings. In the next 10 minutes I'd like to present three different points:

1. Anthropogenic inputs of toxic trace metals to the Chesapeake Bay equal, and in some cases exceed, natural inputs.

2. A substantial fraction of many of these metals become associated with the Bay's sediments, thereby remaining and accumulating within the main stem of the Chesapeake Bay.

3. The cause-and-effect relationships between elevated metal levels and organism toxicity have not been well established. However, there are strong indications that sub-lethal impacts currently occur.

Anthropogenic and Natural Inputs

Trace metal loadings to rivers are a mixture of both natural weathering of rocks and soils plus some man-derived inputs. An examination of the major tributaries in the Chesapeake Bay made during the Chesapeake Bay Program and comparison with studies from the early 1960s have shown that loadings have not changed significantly between the mid-1960s and today.

Indeed, if we compare the metal loadings that we see in the major tributaries to what we might call worldwide, "average" uncontaminated river water, we see that they compare rather well (Table 1). However, the rivers themselves are not the only source of toxic metals in the Bay. There are several other significant sources. Table 2, which was taken directly from the Chesapeake Bay Program's technical synthesis, indicates that large quantities of cadmium, copper, chromium, lead, and zinc are entering in industrial and waste water effluents and in atmospheric emissions. These inputs are approximately equal to inputs from rivers (Table 2).

TABLE 1

METAL	CHESAPEAKE BAY TRIBUTARIES	"AVERAGE" RIVER WATER
IRON	3,250	3,000
COPPER	517	410
ZINC	1,444	3,000
CHROMIUM	551	380
LEAD	307	310

ESTIMATED ANNUAL LOADINGS OF FIVE TRACE METALS TO CHESAPEAKE BAY FROM ITS MAJOR TRIBUTARIES (IN M TONS) IN COMPARISON WITH PREDICTED LOADINGS IN THE SAME QUANTITY OF WORLD-WIDE, "AVERAGE" RIVER WATER.

TABLE 2

SOURCE	CD	CR	CU	PB	ZN
INDUSTRY	178	200	190	155	167
MUNICIPAL WASTEWATER	6	200	99	68	284
ATMOSPHERIC	3	-	28	34	825
URBAN RUNOFF	7	10	9	111	63
RIVERS	75	551	517	307	1,444
SHORE EROSION	1	83	29	28	96

LOADINGS OF METALS FROM THE MAJOR SOURCES AND PATHWAYS TO CHESAPEAKE BAY (VALUES IN M TONS/YEAR; TAKEN FROM THE CHESAPEAKE BAY PROGRAM'S TECHNICAL SYNTHESIS).

For example, 19 percent of chromium loadings to the Bay comes from industrial sources; an additional 19 percent is entering the Bay in waste water, a loading approximately equal to the loading from rivers. For some metals, in particular cadmium, the amount of anthropogenic input greatly exceeds natural river loadings.

In addition to these averaged loadings for the entire Chesapeake Bay, single estuaries may be heavily impacted. As an example, copper enters the Patuxent River estuary primarily from four different sources; all four sources are approximately equal in magnitude (Table 3). The first source is natural weathering of rocks and soils; the second source is copper contained in sewage effluents; the third source is copper contained in cooling water effluent from a conventional power plant; the fourth source is copper leaching from bottom paints on recreational vessels. For this one sub-estuary, therefore, the inputs of copper from anthropogenic sources far exceed natural loadings.

Association with Sediments

Most of the metals that enter the Chesapeake Bay are associated with sediments. Many toxic metals have a high affinity for particles, as has been discussed earlier. Therefore, metals entering the Chesapeake Bay can end up in sediments, and not be transported to the ocean.

Several metals are now found in sediments in concentrations that greatly exceed natural levels, in particular, cadmium, cobalt, lead, and zinc. If we determine the amount of metal in excess of natural levels, metal enrichment in the Chesapeake Bay is not significantly different from many other east coast estuaries that have been subjected to man's influence, such as the Delaware Bay, the Hudson River estuary, and Narragansett Bay (Table 4).

Metal levels in sediments are in general higher in the Northern Bay and decrease seaward (Figure 1). This general decline is caused primarily by physical processes discussed earlier and the predominance of fine materials (clays and silts) in the Northern Bay. The metals are primarily associated with the fine fraction, and therefore are found in the Northern Bay.

Metal distributions also follow general water circulation patterns, with higher concentrations along the western shore. In addition, some of the largest source of metals are in the Northern Bay.

TABLE 3

SOURCE	ANNUAL LOADING
NATIONAL WEATHERING	650
MUNICIPAL WASTEWATER	2,000
POWER PLANT COOLING WATER DISCHARGE	1,150
ANTI-FOULING PAINTS	1,700

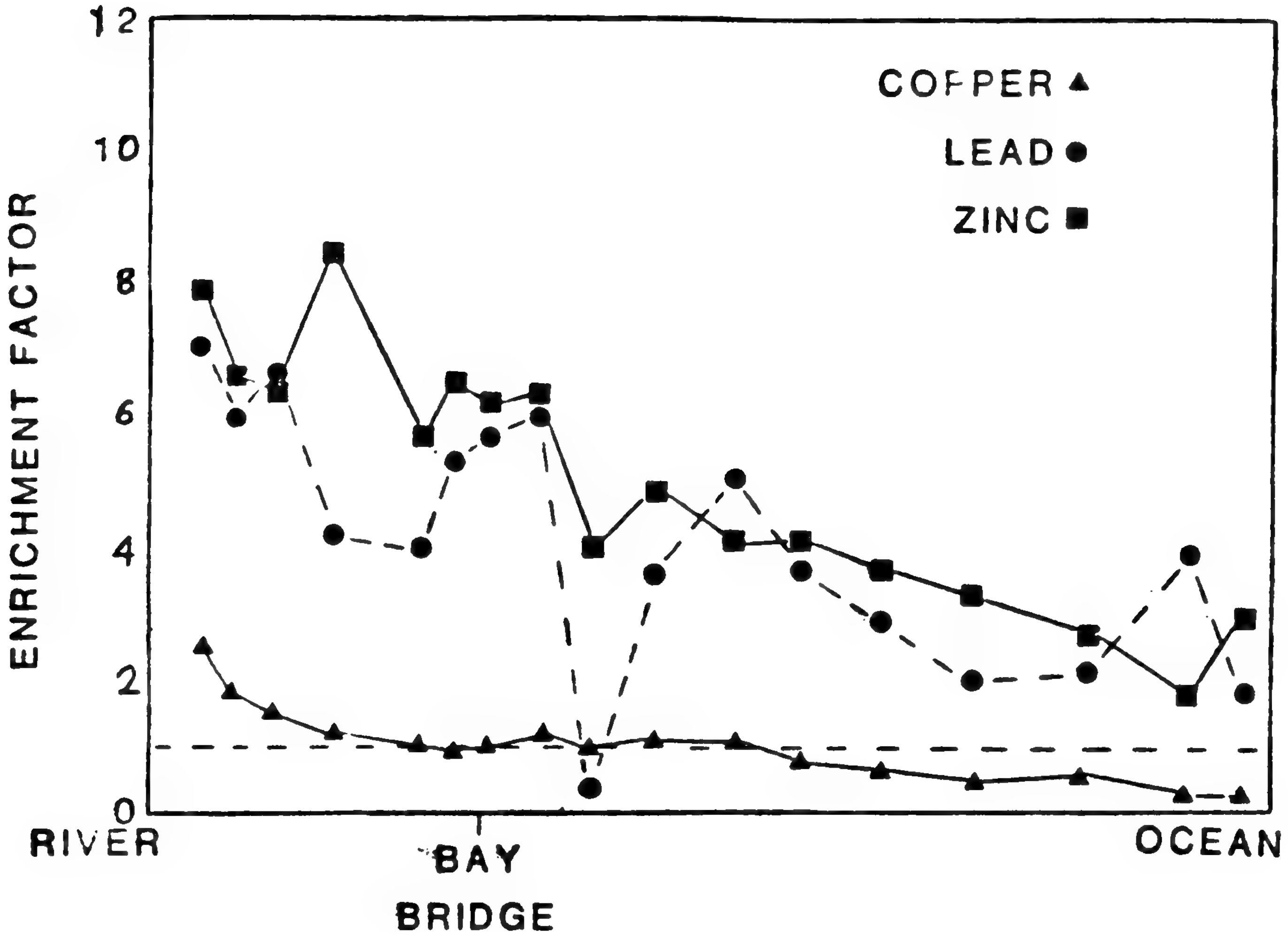
LOADINGS OF COPPER TO THE PATUXENT RIVER ESTUARY (IN KG/YEAR).

TABLE 4

LOCATION	COPPER	ZINC	LEAD
NARRAGANSETT BAY	6	6	17
HUDSON ESTUARY	2	4	9
DELAWARE BAY	2	10	16
CHESAPEAKE BAY	1	5	5
SAVANNAH RIVER	1	1	3
MISSISSIPPI DELTA	1	3	3
SAN ANTONIO BAY	1	3	4

AVERAGE ENRICHMENT FACTORS FOR THE CONCENTRATIONS OF SEVERAL TRACE METALS IN A VARIETY OF COASTAL SEDIMENTS.

FIGURE 1



AVERAGE ENRICHMENT FACTORS FOR THE CONCENTRATIONS OF SEVERAL TRACE METALS IN SEDIMENTS IN CHESAPEAKE BAY, ALONG A TRANSECT FROM THE SUSQUEHANNA RIVER FLATS TO THE BAY MOUTH.

There are localized "hotspots" of elevated metal levels, just as there are for organic compounds, particularly around industrial areas like the Baltimore Harbor area and the Elizabeth River-Hampton Roads area.

Potential Impact

I would like to address the potential for toxic effects. Do we have a problem in the Chesapeake Bay? This is a very difficult question to answer definitively. There are many physical, chemical, and biological factors that must be considered before this question can be answered.

We cannot predict impacts of toxic compounds to an estuary by running one or even a series of single-species bioassays under laboratory conditions; the natural ecosystem is far too complex to be so simply described. Organisms interact with one another and with the fluid in which they live. These interactions are not simplistic ones, nor can they be ignored. I heartily endorse Bob Huggett's suggestion that biologists and geochemists work more closely together in coming years to discover important cause-and-effect relationships.

Toxic metals have complex geochemistries and are present in a variety of different chemical forms, only some of which are biologically available and therefore toxic. In addition, inorganic compounds, like organic compounds, can be taken up by biota and can be further transformed. These transformations often yield compounds that have widely differing toxicity than the parent compound.

There are indications that elevated metal levels within the Chesapeake Bay are exerting sub-lethal influences on the ecosystem. We find high levels of metals in the organisms themselves, and we also see altered species composition and reduced species diversity in some areas.

As an example, many species of phytoplankton are sensitive to low concentrations of arsenate, concentrations found in some areas of the Bay, while other species tolerate concentrations two orders of magnitude higher (Table 5). In the event of arsenate loading, for example, the sensitive species drop out of a community, leaving only the resistant species behind. Although difficult to detect, this type of impact may be extremely significant to the ecosystem as a whole, because phytoplankton form the base of the food chain and such alterations can affect the feeding of higher trophic levels.

These are very complex problems; problems that will take some time to answer.

TABLE 5

SPECIES	ARSENATE uG·L-1
ISOCHRYSIS GALBANA	2
RHIZOSOLENIA FRAGILISSIMA	2.5
SKELETONEMA COSTATUM	5
AMPHIDINIUM CARTERAE	10
CHAETOCHEROS PSEUDOCRINITUM	20
THALASSIOSIRA PSEUDONANA	>100
TETRASELMIS CONTRACTA	>100

SENSITIVITY OF DIFFERENT SPECIES OF PHYTOPLANKTON TO ARSENATE. ARSENATE CONCENTRATIONS SHOWN ARE THOSE NECESSARY TO CAUSE A 50% REDUCTION IN GROWTH RATE.

In conclusion, I've presented only a small amount of information today because we have so very little time. I hope, however, that I've conveyed to you some sense of the degree of toxic metal pollution within the Chesapeake Bay and the complexity of the problem that confronts us, particularly with regard to the determination of toxicity, cause-and-effect relationships, and where the toxicity may occur.

I hope that future meetings will find us further along in our efforts to determine the extent of trace metal stress in the Chesapeake Bay.

SUBMERGED AQUATIC VEGETATION

by

Drs. Robert J. Orth and Polly J. Penhale
Virginia Institute of Marine Sciences

Abstract

Submerged aquatic vegetation (SAV) systems in the Chesapeake Bay are an important natural resource, providing a habitat to numerous species, a food source for wintering waterfowl, a buffer for shoreline erosion, and a contribution to the primary productivity of these shoal areas. These systems have undergone natual oscillations in the past but the most recent decline, which has affected all species in all areas of the Bay, appears to be related to the increasing amounts of nutrients and sediments being washed into the Bay. Issues facing researchers and managers today are related to conserving existing stands and restoring SAV beds to areas that are now devoid of any vegetation. Research should be geared to monitoring the status of the Bay SAV communities and to refine our understanding of those factors that control the distribution and abundance of SAV. Managers should view transplanting programs with caution and give priority to conservation of existing beds as opposed to mitigation plans to offset potential SAV losses.

Dr. Orth: Until recently, SAV systems in the Chesapeake Bay has been one of the least studied of the Bay's natural resources. Often considered a nuisance because it interferes with human activities such as boating or fishing or washes up on the beaches of expensive waterfront homes, SAV communities are now being shown to be an important part of the Bay's ecosystem.

SAV systems are appreciated when understood in the context of the many roles that SAVs perform in shallower water areas where they occur. They are a source of food for wintering waterfowl and a habitat and nursery for a diverse array of animals. They stabalize bottom sediments and, in same areas, can be a barrier to shoreline erosion. They are an important source of primary production and are an important element in the nutrient cycling at these shoal environments.

The Bay, with its extensive littoral area and broad salinity range supports many different species of SAV. These species are distributed along the Bay's salinity gradient depending on their different salinity tolerences. Eelgrass which is tolerant of high salinities is found in the lower reaches. Watermilfoil, sago pondweed, redhead grass, wild celery, coontail, and naiads are less tolerant of high salinities and are found in the middle and upper reaches of the Bay.

Widgeon grass, which is tolerant of a wider range of salinities is usually found from the Bay mouth to the Susquehanna flats.

SAV systems in the Bay have been marked by a series of distinct oscillations with both desirable and undesirable species changing over time. Fragmentory evidence indicate that until recently, SAV has been a widespread feature of the Bay's shallow water bottom, although its past has been marked with some specific fluctuations in abundance.

The decline of eelgrass in the lower and middle sections of the Bay during the 1930s coincided with its worldwide decline. Eelgrass gradually returned over the next 30 years until the more recent period of decline in the 1970s.

Several other species considered to be nuisance forms also have fluctuated. Water chestnut created problems in the Potomac River in the 1920s and the 1950s with declines being attributed to local eradication programs.

Watermilfoil expanded very rapidly in the Potomac River and in the Upper Bay in the late 1950s and 1960s, but was reduced in abundance by the 1960s.

The recent decline of SAV, which affected all major species in all sections of the Bay, is a local phenomena as there are no widespread reports of SAV declines in other areas of the east coast. Loss of these important communities occurred in the 1960s in the upper and middle Bay areas.

Bay-wide decline of SAV accelerated in the 1970s and continued through 1980 with the most rapid declines occurring in 1972 through 1974, especially after the occurrence of tropical storm Agnes. Sections of the Bay that once contained lush stands of SAV had either no SAV (e.g., Patuxent, Piankatank, and Rappahannock Rivers) or only remnant stands (e.g., Potomac and Upper York Rivers and Susquehanna flats). Many of these areas still contain little SAV through 1984, although there has been some encouraging signs or regrowth in several locations. There are still substantial beds of SAV, but these are primarily located in the Lower Bay area. Areas in the Lower Bay, in close proximity to SAV stands that persisted through the 1970s, are apparently being revegetated by natural processes, primarily by seeds that are transported from adjacent vegetated areas.

Another encouraging sign has been the resurgence of many native SAV species, as well as the exotic species hydrilla, in the tidal fresh water portions of the Potomac River, where lush stands were reported to occur in the early 1900s. Whether or not this vegetation persists today and is indicative of a renewal of favorable growing conditions, remains for future surveys to document.

Hydrilla is a species with an extremely rapid growth rate and can rapidly colonize new areas as well as out-compete other species. While hydrilla is generally considered a nuisance species in many areas of the United States, its role in the ecology of the Potomac River is largely unknown and remains to be demonstrated.

The causes for the most recent SAV decline are several. Although herbicides were initially indicated because of the large quantities being used by farmers, research showed that levels of herbicide found in the water were significantly below the levels needed to suppress the SAV growth.

Both field observations and controlled experiments have suggested that the major factors are nutrient enrichment and increased turbidity. Areas of the greatest SAV decline occurred in those areas where nutrient enrichment has been the greatest.

Nutrients stimulate phytoplankton growth and epiphyte growth on the plant surface; this along with the increased turbidity have reduced the light available for plant photosynthesis.

The biological factors such as the reduction of periphyton grazing community, or swan and ray activity may be locally important, but probably play a secondary role in the overall SAV decline of the Bay.

Although there has been no accurate documentation of the decline's impact, some direct and indirect evidence indicates that the effects on water quality and secondary production may be considerable. Several waterfowl species that eat SAV have declined. Some shoreline areas once protected by the baffling effects of the plants are now having increased problems with erosion. Because SAV supports very dense populations of invertebrates, the decline has virtually eliminated the habitats for many species and has had an effect on the overall production in these areas.

The two major issues presently facing SAV communities today are, one, how best can we conserve and manage the remaining beds of SAV in the Bay? And two, what can be done to restore SAV communities to areas that once contained these lush stands that are now devoid of vegetation?

One key element tying these two issues together is that any plan to manage or restore SAV in the Bay must fully comprehend those factors that control SAV growth and survival. There is evidence suggesting that in addition to direct losses by dredge-and-fill operations, SAV in the Bay, as well as in many other parts of the world, are affected by nutrient inputs and suspended sediments. Areas of the greatest SAV decline are in close proximity to urban or industrial areas suggesting that man's activities are directly responsible for much of the decline. Natural perturbations, such as hurricanes and ice scour also occur, but these events are beyond human control. If SAV is to be a part of the Bay's future, we must concentrate our efforts on controlling sediment and nutrient input into the Bay and its estuaries.

Since sediment and nutrient inputs are often cited as factors in the overall decline of the Bay, Federal and State Bay cleanup efforts will certainly have positive benefits for these systems. These cleanup activities are aimed at reducing sediment and nutrient input by controlling runoff with Federal land use practices, such as buffer strips along shorelines and farmlands and improved wastewater treatment facilities. Although some actions are currently being implemented, stricter enforcement and better controls will be necessary in the future as the population in the Bay's watershed increases and the demands placed on the Bay's resources increase.

The long-term solution to the Bay's problems and SAV health will be difficult and expensive to implement but are absolutely necessary if we are to maintain current conditions. It is also important to examine those activities having an adverse impact on SAV beds in the short-term and determine viable solutions.

The most immediate problems are dredge-and-fill operations that permanently remove SAV habitats. Because SAV beds are so reduced in abundance, those areas still containing viable beds are now even more important. As water conditions improve, these beds may serve as a source of propagules for natural revegetation of nearby denuded areas or for future transplanting projects. Thus, resource managers should give serious consideration to any proposed project that would have an adverse impact on SAV. It's obvious, however, that in some situations, economic benefits of these projects may be substantial and need to be weighed in light of the importance of SAV.

Transplant programs for SAV in the Bay have their place,but should be viewed today with caution. Transplanting may be the only mechanism for revegetating areas that are totally devoid of any SAV. These areas may be so far removed from any existing bed that natural revegetation may not occur. Transplanting, however, may not succeed if conditions are not suitable for regrowth. State agencies should not blindly proceed with transplant programs without attempting to understand the critical factors affecting plant survival and improved water quality conditions. Well-designed transplant programs do have a place in the Bay. They should be viewed as tools to better understand those factors affecting SAV growth and to monitor water quality conditions of selected Bay sites. Thus, any transplant effort should have a concomitant monitoring program to gauge success or failure of the plants. Transplanting has been conducted successfully in the lower Bay and the Potomac River. Nevertheless, we do have sites that have continually failed in our transplant efforts. The environmental information gained from these sites where transplants die when compared to successful sites, could have important implications when implementing plans for improved water quality through better land use practices and point source pollutant reductions.

At present, mitigation plans to offset potential SAV losses caused by dredging operations should not be viewed as a viable option for the Chesapeake Bay. If conditions for suitable SAV growth do not improve, replanted SAV will certainly not survive. Because mitigation of SAV is still in the early research phases, conservation of existing SAV beds should be a priority consideration of any management agency.

SAV communities in the Bay today are experiencing problems and will continue to do so unless management strategies are developed to protect them. Reversing the recent decline and attempting to restore the valuable communities will require a Bay-wide plan to both reduce nutrient inputs and continue to improve soil erosion control practices.

Existing stands must be preserved, and SAV regrowth monitored to determine their persistence in particular areas. Although hydrilla is considered a nuisance species in other regions, it may play an important role in the Potomac River, which has had no extensive beds in the last 60 years. Control of this species should be carefully considered and initially directed locally where hydrilla impedes navigation or marina operations.

SAV systems have historically been a very important part for the Bay's ecosystem. Their preservation will require an ecosystem approach to understanding and controlling sources of stress. Anything less will result in continued deterioration of SAV in areas where they are in very low abundance and ultimately in those areas where healthy beds still persist. The future of the Bay's SAV will depend on our approach to solving the problems of today and our commitment to a healthier Bay in the future.

Thank you.

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SCIENTIFIC CONTROVERSIES

NITROGEN VS. PHOSPHORUS

by

Dr. Christopher D'Elia
Chesapeake Biological Laboratory

Dr. D'Elia: Before I begin, I have two comments. Dr. Eric Schneider, being concerned about the limited time available, put this big alarm clock in front of me figuring I could look at it and keep on schedule.

Secondly, I hope everyone who is not a scientist understands that scientific controversies play an important role in science. We scientists are often perceived as being a contentious, disagreeable lot who can't really agree with each other, much less anybody who has any decisions to make.

When I put today's program together and planned a session on scientific controversies, I wasn't doing so with a mind to showing people the disagreeable side of us scientists, but to show people that there are many things that we scientists don't know much about and that we need to understand more fully to be able to make informed decisions. So if we have arguments at all today, consider them friendly and constructive discussions among ourselves toward the goal of understanding things better.

With that, I'll launch into my talk on the nitrogen-versus-phosphorus controversy, a very important one, I feel.

I want to talk about the Patuxent River, which is merely a little tributary on the Western Shore of the Chesapeake. It is very far down on the list of tributaries in terms of its volume of flow. However, it has one very important characteristic; it is between two pretty big and important cities, Washington and Baltimore, and these cities represent the boundaries of a very expanding population center. As a result, there are all kinds of things happening in the Patuxent Basin that are indications of what might be happening to the rest of the Chesapeake. In fact, on a flow-weighted basis we're seeing an impact with sewage effluent that approximates what we've seen on the Potomac River.

Figure 1 shows a trend that is not a very encouraging one. It depicts the daily rate of discharge of sewage effluent being discharged into the Patuxent River. Presently, it's a trickle relative to the Blue Plains effluent being discharged into the

PATUXENT RIVER

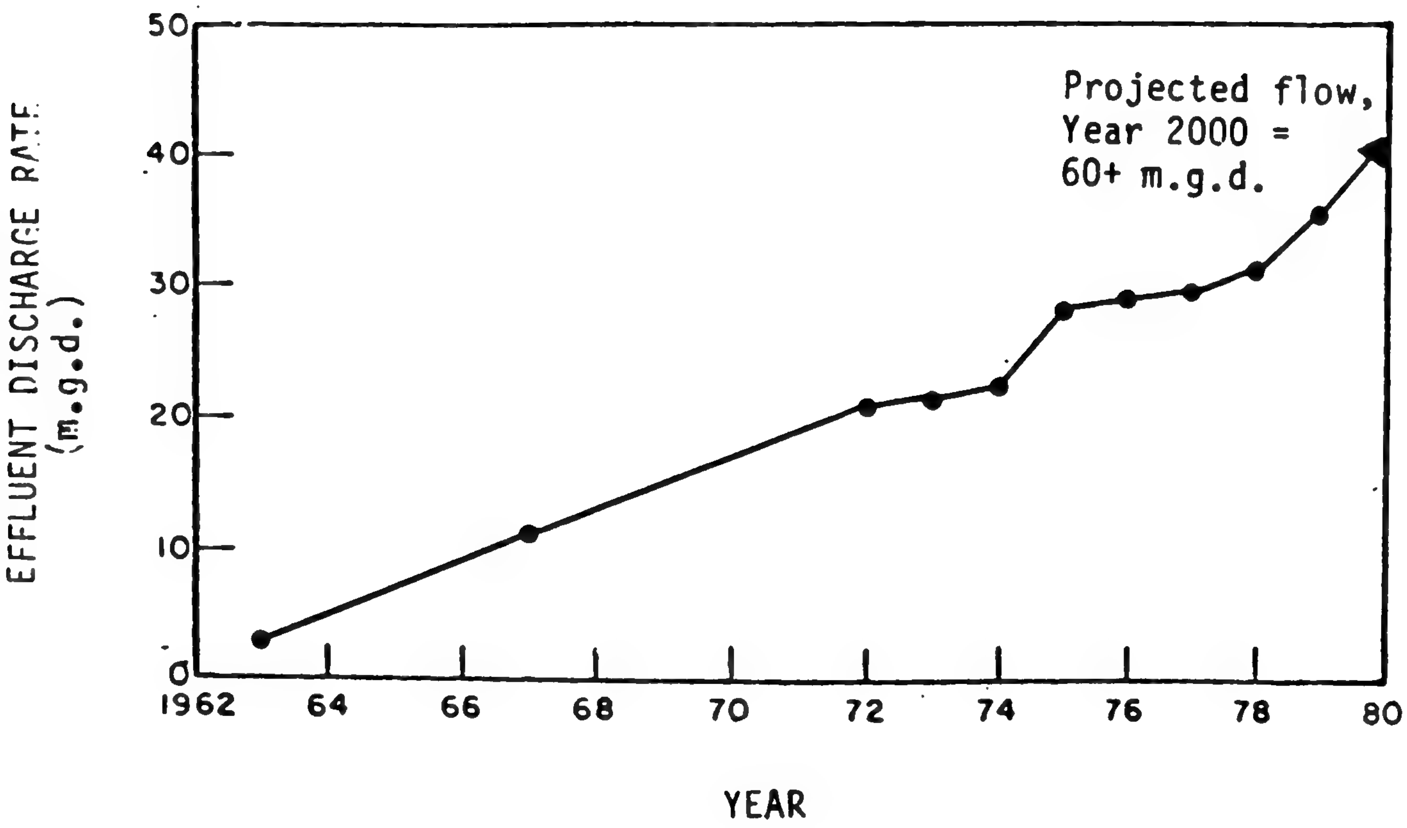


Figure 1. Trend of Sewage Effluent Discharged

Potomac River. But then again, the Patuxent River is a trickle relative to the Potomac. We're up to about 38 million gallons of discharge per day right now. We anticipate by the year 2000 as much as 60 million gallons a day.

Now, one thing that needs to be mentioned about the Chesapeake Bay, and the Patuxent is no exception as this applies equally as well, is that things vary tremedously depending on the climate, wet years, dry years, et cetera.

On an annual basis, a greater percentage of phosphorus is derived from terrigeneous point sources (e.g., sewage effluent) and nitrogen from non-point sources (e.g. runoff). However, there's an important caveat: that the sediments in the estuarine saline portions of the Chesapeake Bay and Patuxent River, of course, are in essence, seasonally very significant non-point sources of phosphorus that are often unaccounted for as non-point sources. They represent a source of phosphorus to the water column that can be very, very difficult to control.

The sequence of nutrient enrichment is as shown in Figure 2. When we add nutrients to a system, like the river, nutrient concentrations in the water column increase. This, in turn, stimulates the growth of algae. The algae block light out in the water column and the accumulated algae constitute increased particulate loads. This particulate organic matter settles to deep water and subsequently decays and consumes the oxygen. The anoxia that we presently see in the mainstem of the Chesapeake Bay is believed to be largely the result of decay of biomass from the local productivity of phytoplankton stimulated by the input of nutrients to the Bay and not by the decay of organic matter from terrigenous sources. We think it's getting worse because the nutrients are being added at a greater rate and the phytoplankton are growing faster in response.

Now comes a very important point: The Chesapeake estuary is stratified. There is a lighter, freshwater layer on top. Most of the pollutants come in via a surface flow. The heavier, saltier water on the bottom, whose salt is derived from relatively "clean" ocean water, mixes in. Especially important is what I refer to extremely loosely as a "salinity transition zone," shown in Figure 3. I know my scientific colleagues might take me to task for that usage, which I use as a broad generalization.

This is the zone, in particular, I think that we need to be worrying about right now. I would argue very strongly that while it's certainly important to be concerned with the main

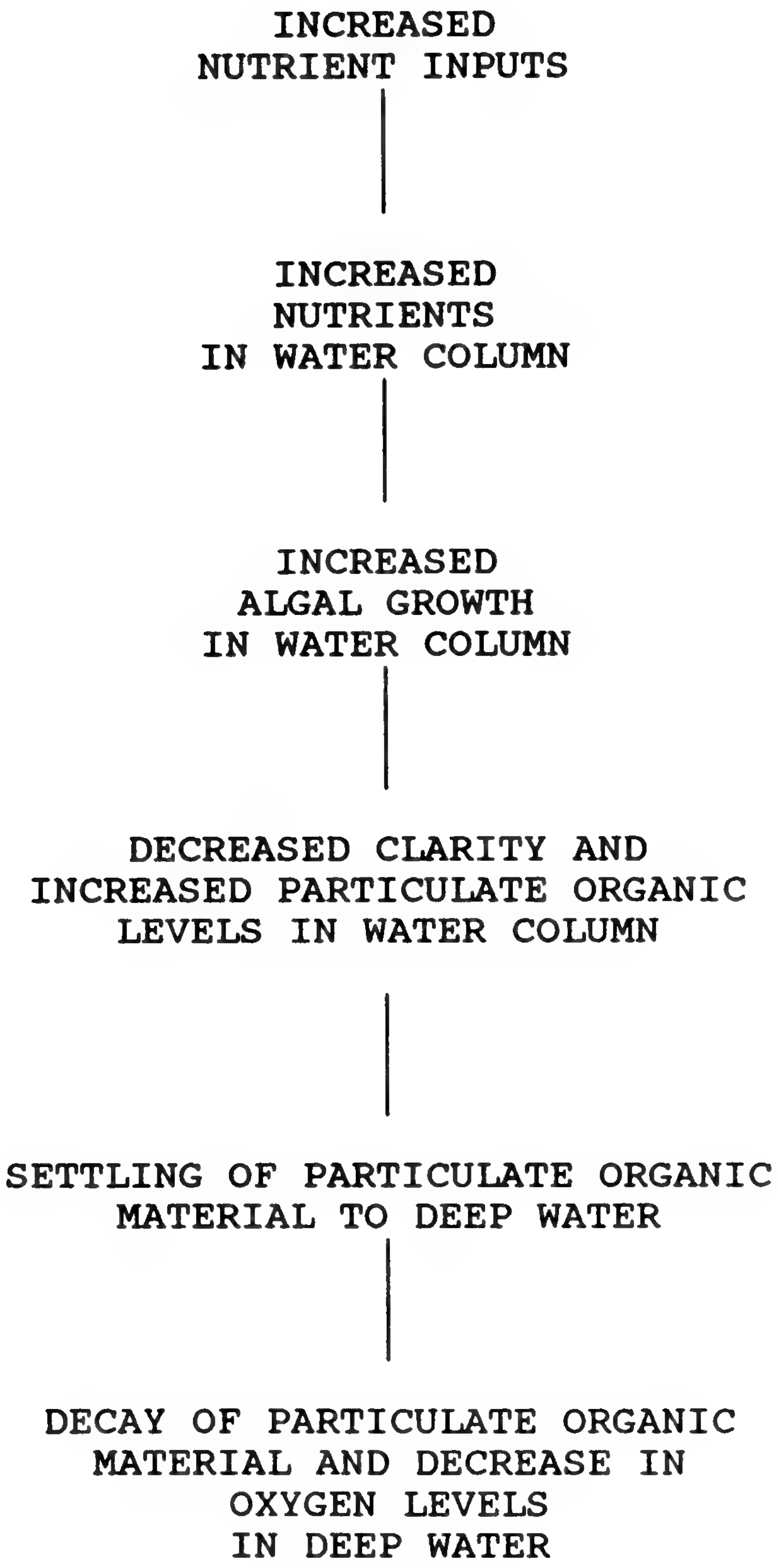
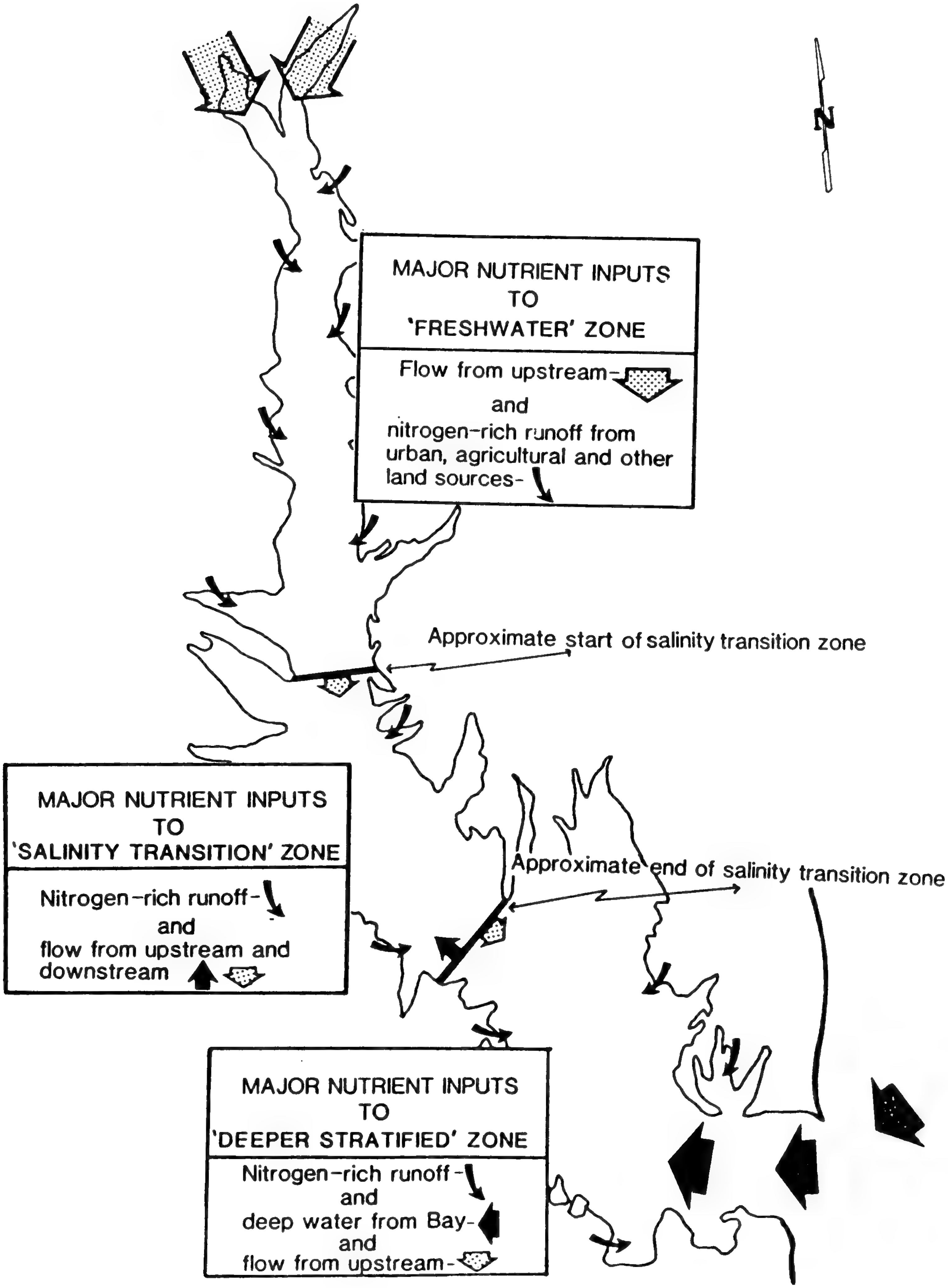


Figure 2. Scheme of possible effects of enrichment in a stratified water column.

Patuxent River High Flow Season



MAJOR NUTRIENT INPUTS
TO
'FRESHWATER' ZONE

Flow from upstream- ⇩
and
nitrogen-rich runoff from urban, agricultural and other land sources- ↘

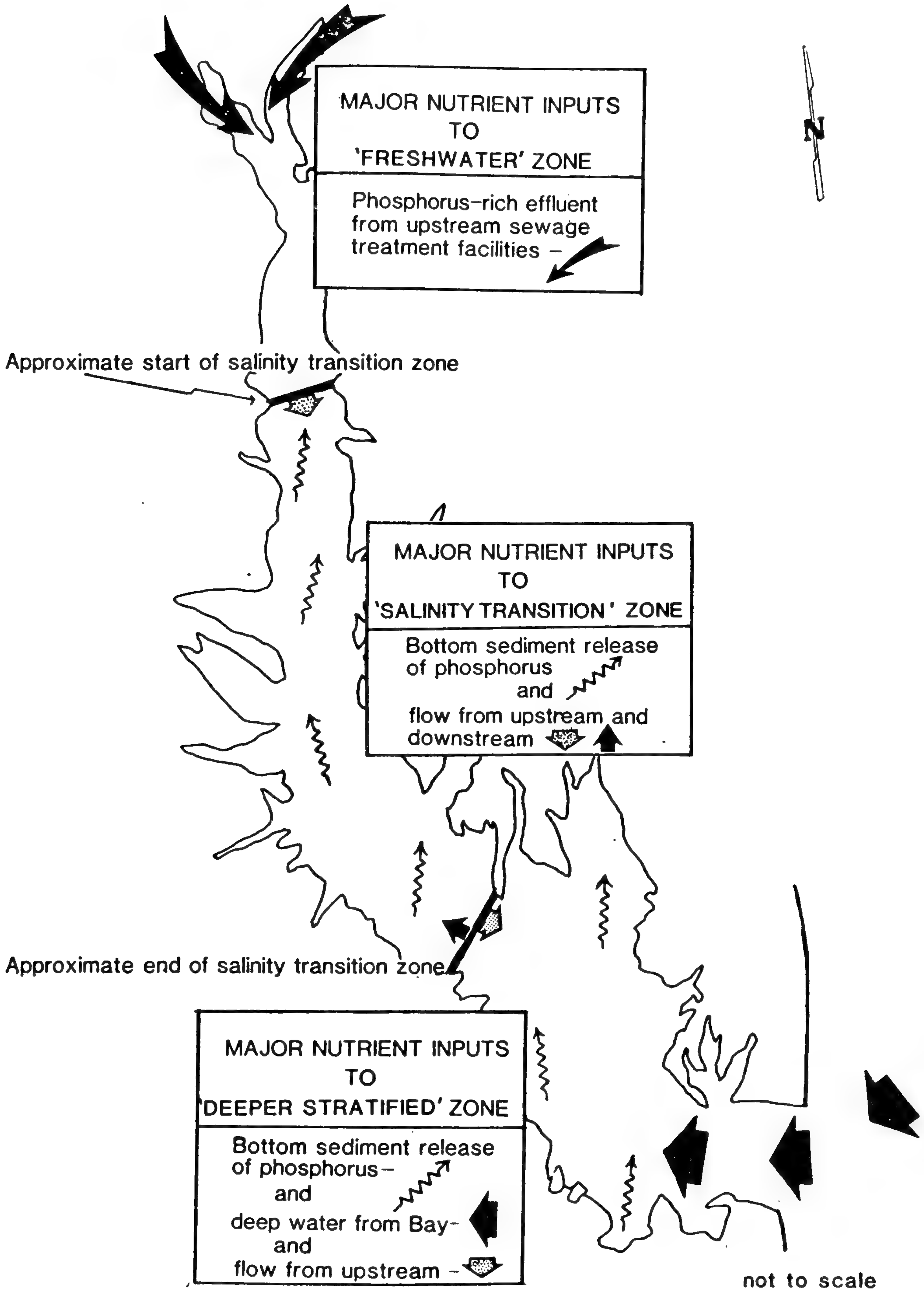
MAJOR NUTRIENT INPUTS
TO
'SALINITY TRANSITION' ZONE

Nitrogen-rich runoff- ↘
and
flow from upstream and downstream ⬆ ⇩

MAJOR NUTRIENT INPUTS
TO
'DEEPER STRATIFIED' ZONE

Nitrogen-rich runoff- ↘
and
deep water from Bay- ◀
and
flow from upstream- ⇩

Figure 3A



Patuxent River Low Flow Season

Figure 3B

stem of the Bay, we're looking at the largest problem in terms of volume of water to clean up first. We really need to be focusing more on the tributaries, the areas that are smaller in water volume but where I think we have the best chance of doing something in the near-term. The salinity transition zones of tributaries are important in the tributaries.

Figure 4, derived from the "Heinle Report" to EPA, illustrates that the nutrient enrichment sequence as shown has occurred on the Patuxent. There are two points to note. First, downstream of the Benedict Bridge is where you start to see the higher salinities in the river. Even in the old data, 1936 to 1939, in the estuarine portion (downstream of Benedict Bridge), we had historically high concentrations of phosphorus in the water column in the summertime. In more recent data, 1968 and after, we see again the same kind of a pattern, very high concentrations of phosphorus in the summertime. Although in general, phosphorus levels are quite high the year-round. Second, there have been drastic increases in phosphorus upstream of the bridge, in fresher waters.

How might those concentrations affect algal growth? In the business of nutrients, the rule of thumb is, if it's there, it's probably not as important as it is if it's not there. A limiting nutrient is one that controls the growth of plants by its scarcity. By virtue of the fact that it's not present in abundance, it controls plant growth. Plants need nutrients to grow. We put fertilizers on our gardens to supply more of a growth-limiting nutrient to increase the concentrations.

The high summertime phosphorus levels downstream suggest that there is something going on in that area of the estuary that is putting phosphorus into the water column in excess of algae demand and from a source that we might not be able to control very effectively with a traditional management strategy.

Next in the sequence of enrichment effects that I illustrated, turbidity increases as phytoplankton grows in response to nutrients. The increase in turbidity is indicated by Secchi depth which shows how far you can lower a small white disk before it disappears. Obviously, the deeper you can lower it, the clearer the water.

Well, in the "good old days," you could lower the Secchi disk deeper in the southern part of the river, of the Patuxent River, before it would disappear. In more recent data, we see that the Secchi depths are considerably less than they used to be as illustrated in Figure 5. This is some of the most important evidence that was adduced in the EPA Chesapeake Bay study that has led to a lot of the further refinements in our knowledge.

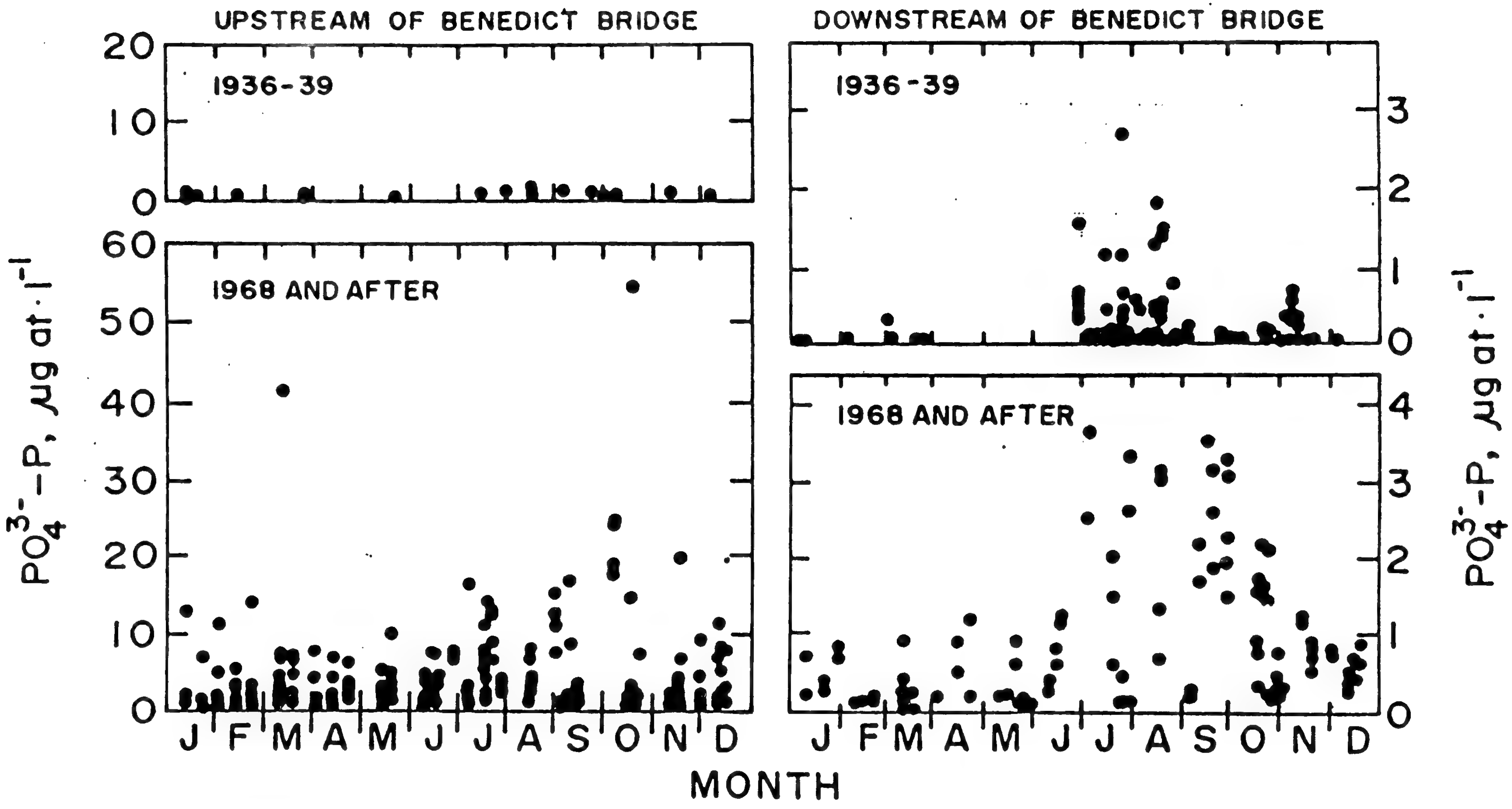


Figure 4. Concentrations of orthophosphate-P in surface waters of the Patuxent River upstream and downstream of Benedict Bridge versus time of year.

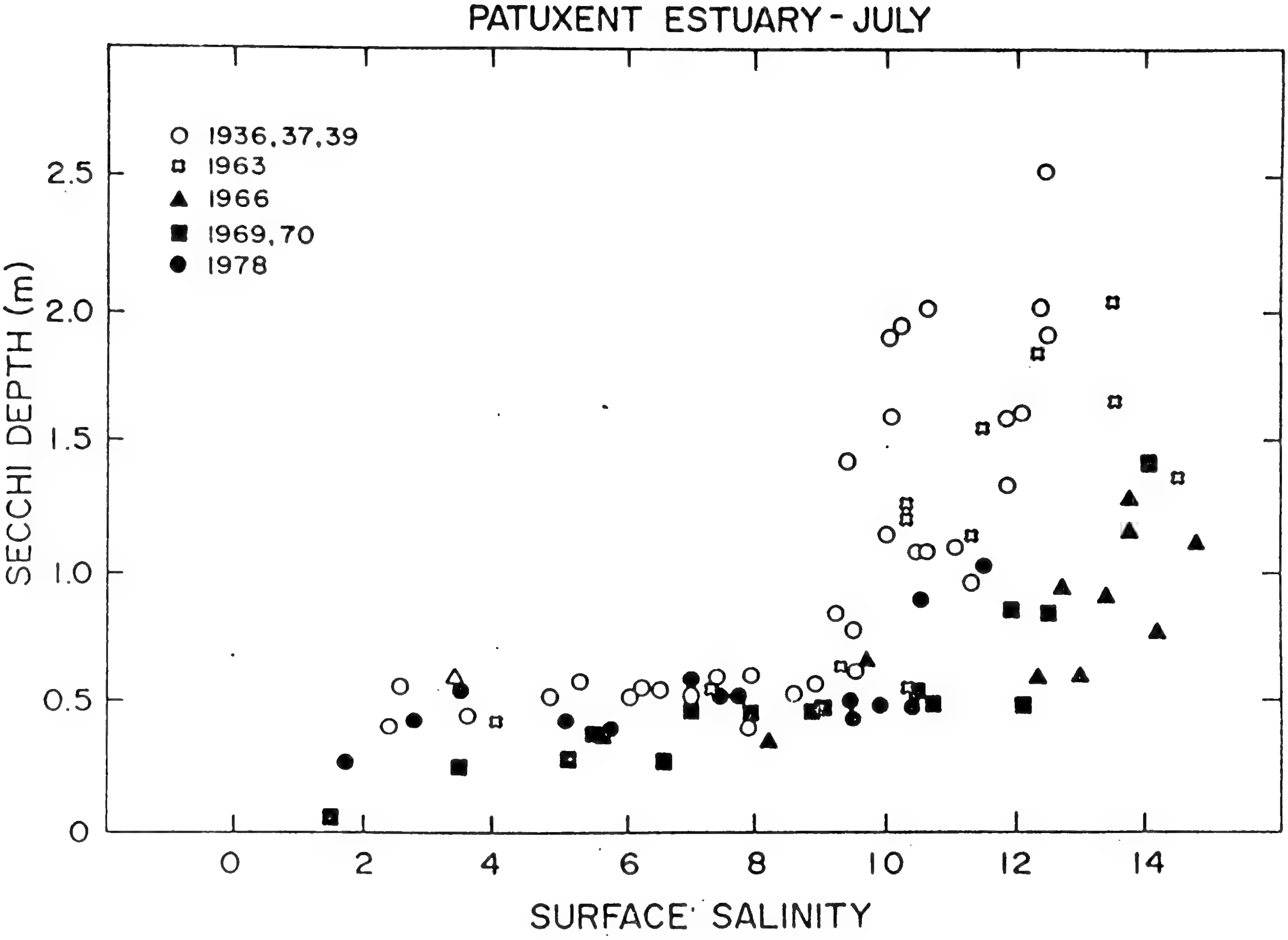


Figure 5 Secchi depth during July in the Patuxent estuary versus salinity (Heinle et al. 1980).

We've seen some striking changes in the Patuxent River over time in other regards. Nutrient-stimulated increase in turbidity alone is not the sole manifestation. Turbidity could also be due to increased sediment loads, for example. However, present evidence suggests that there was an increase in phytoplankton growth and that an accumulation of algae biomass decreased water clarity.

If we compare older data with newer data on the Patuxent River, we have seen a year-round increase in phytoplankton counts at the Benedict area, the "salinity transition" zone of the river. Concomitant with that, if we compare minimum dissolved oxygen concentrations in 1938 with 1978 June and August data, we see a strikingly lower dissolved oxygen content in deep water in recent years as depicted in Figure 6.

To be sure, the main stem of the Bay also influences downstream oxygen concentrations. However, in the Benedict-Sheridan Point area, there's a particularly pronounced oxygen sag. This has been identified by the State of Maryland as a critical zone, an area that we see as being a particularly impacted area, and one that I am optimistic that we can improve.

Conventional dogma states that fresh waters are phosphorus-limited and marine waters are nitrogen-limited. If one wants to make any inroads to controlling the oxygen depletion/nutrient problems in the Bay, ideally one wants to make the nutrient that's in shortest supply in even shorter supply.

So in freshwater, where phosphorus is usually in shorter supply than nitrogen what one generally does is remove phosphorus. In marine waters we haven't had very much experience in terms of nutrient-control strategies; but we do know that generally speaking nitrogen is in least availability and that nitrogen (N) is the element of major concern for management.

Because estuaries lie in between freshwater and sea water areas, the question arises, naturally, what limits the growth of algae in estuaries, and what would we want to control?

How can one determine which nutrient is a limiting nutrient? Studies to do so have fallen into four general categories as described in Figure 7.

Enrichment studies are probably the most direct way of finding out which nutrient element limits plant growth, because one merely takes a parcel of water and adds nutrients to see what grows in response to nutrient enrichment.

Elemental ratios of nutrients dissolved in the water are extremely important in giving a general idea of what's available in excess. But there are also some problems associated with that approach.

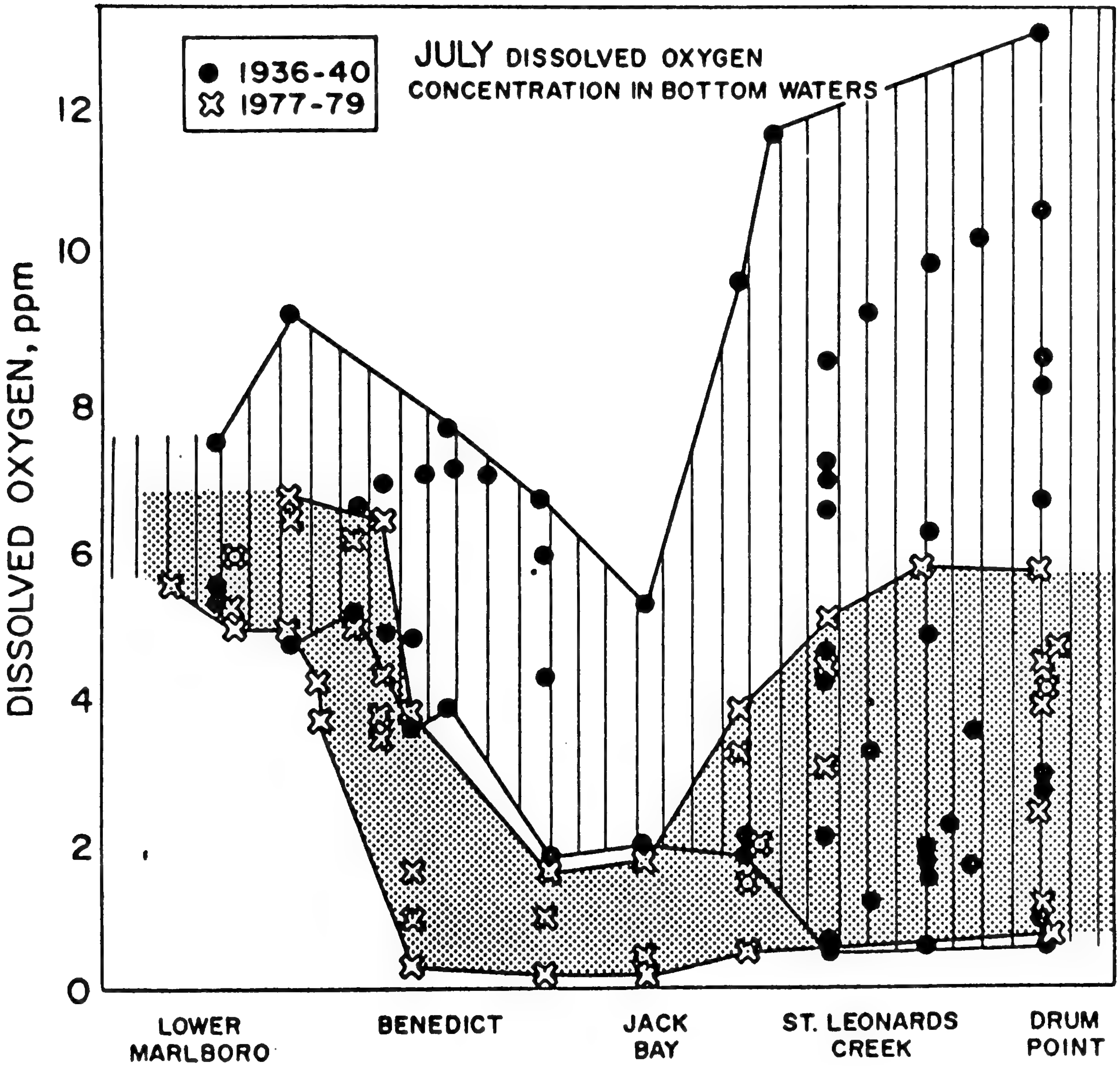


Figure 6. Concentrations of dissolved oxygen in bottom waters of the Patuxent River estuary during July 1936-1940 and July 1977-1979.

HOW DO WE PREDICT ENRICHMENT EFFECTS?

1. Enrichment studies
2. Mathematical models
3. Elemental ratios
4. Physiological measurements

Figure 7.

The State of Maryland has quite a good mathematical water quality model for the Patuxent River. The model includes one very important feature, which is sediment-nutrient release. I would agree -- and I don't have time to develop the argument very much here -- that while mathematical models are pretty good in telling us approximately how much of a pollutant is delivered to a given area of an estuary, they're not very helpful for distinguishing whether nitrogen or phosphorus is the critical element to control. Much of the controversy regarding N and P in the Chesapeake centers on what I think is an over-reliance on such models by managers.

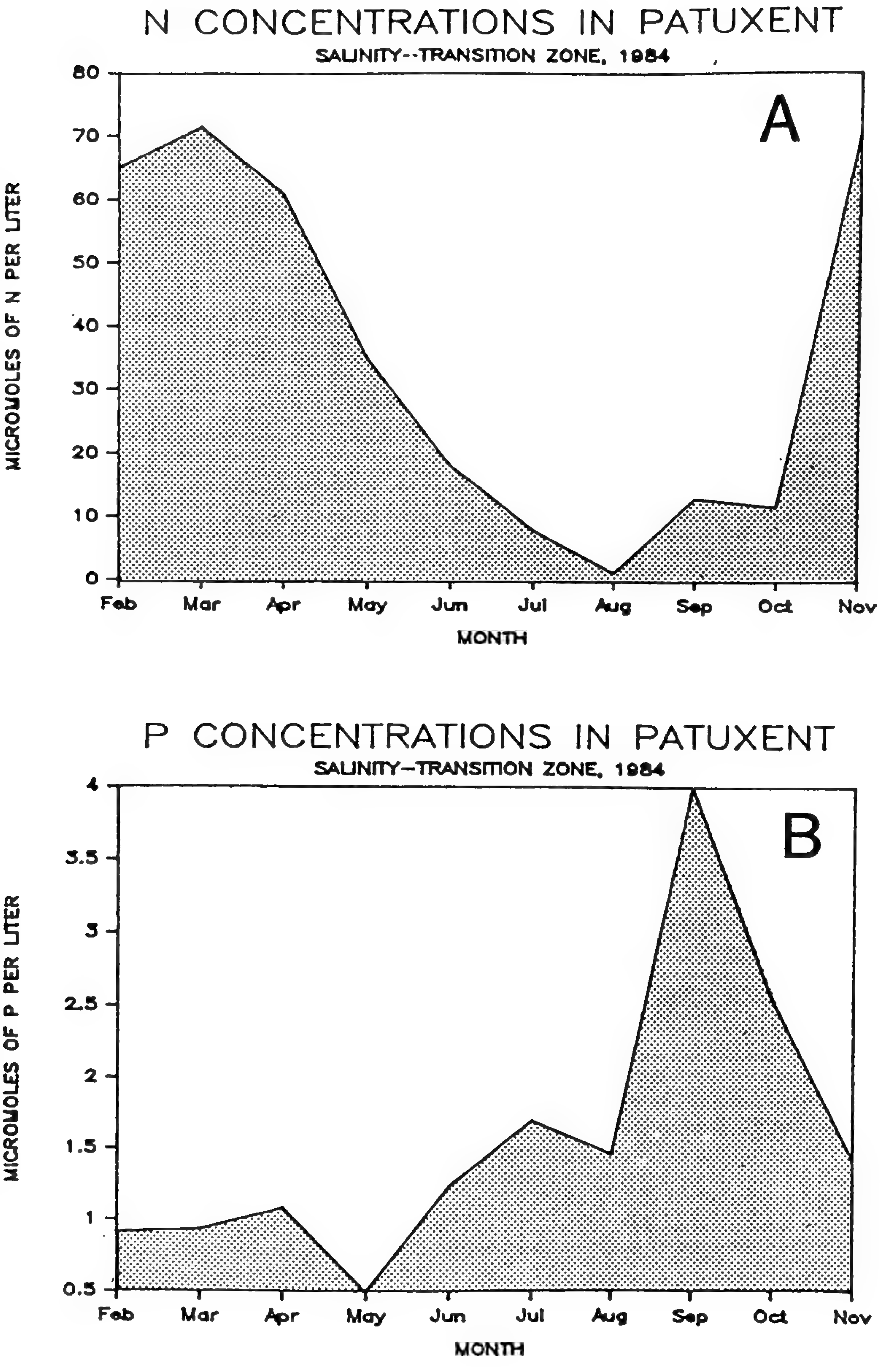
Monitoring studies have given us excellent information on dissolved inorganic nitrogen (DIN) elemental ratios. If one looks at the nutrient concentrations at Benedict, again remembering that what's there in least supply is likely to be the limiting nutrient. Figure 8 illustrates an excess of dissolved inorganic phosphous (DIP) in the summer and very little DIN, and vice versa in the winter. Nitrate, nitrite, and ammonium are forms of nitrogen. And phosphate is a form of phosphorus. In Figure 8, you see that there is a very high peak of nitrogen in the wintertime and a very high peak of phosphorus in the late summer. When you take the ratio of dissolved inorganic nitrogen to phosphorus, we get something analogous to a fertilizer ratio used by farmers and gardeners. We see that the river is extremely nitrogen-rich in the winter (DIN:DIP > 90:1) and very nitrogen-poor in the summer (DIN:DIP < 5:1). What does that mean?

It means that the relative abundance of nitrogen in the wintertime is much greater than it is in the summertime and that the relative availability of phosphate in the summertime is much greater than it is in the wintertime.

As I said, commercial fertilizer constitutes a good analogy. Plants need nutrients in certain ratio. The 10-10-10 or other ratio you see on a fertilizer bag tells whether it is ideal for vegetables, lawns, et cetera. Since algae are plants also, they as well need an ideal supply ratio of nitrogen to phosphorus.

It turns out that the ratio of nitrogen atoms to phosphorus that the average planktonic alga needs is somewhere between 10 and 20 to 1. So as we can infer from Figure 8, in the summertime phosphorus is relatively abundant and nitrogen is relatively scarce, and vice versa in the wintertime.

Secondarily treated sewage effluent is extremely P-rich. The ratio of nitrogen to phosphate in sewage is very, very low, typically 5 or 6 to 1. So sewage is very phosphorus-rich relative to plants' needs.



N CONCENTRATIONS IN PATUXENT

SALINITY--TRANSITION ZONE, 1984

P CONCENTRATIONS IN PATUXENT

SALINITY–TRANSITION ZONE, 1984

Figure 8.

Runoff tends to be N-rich. For purposes of this talk, I divide the Patuxent into three different zones as shown in Figure 3. One's the "upstream" area. One's what I have called loosely the "salinity transition" zone, and the other is the "deep stratified" zone. During the high-flow season, terrestrial runoff probably accounts for the very high availability of nitrogen and relative unavailability of phosphorus. During that period, there is nitrogen-rich runoff from urban sources, agriculture, and other land sources and there is relatively low demand in the water for these compounds. The result is a very nitrogen-rich system.

We also have the input of water from the Susquehanna. Oddly enough, it's very important in delivering nitrogen to the Patuxent River. The deep water actually "turns the corner" into the Patuxent because of the circulation of flow of an estuary, and carries lots of nitrogen into the estuary during the wintertime.

But the winter is not the major growing season. We're interested in controlling the growth of plants during the major growing season which is the summer and the low-flow season, when the situation is different.

The major external source during this period is phosphorus-rich effluent from upstream sewage treatment plants. The non-point sources are relatively low during low-flow, and point sources predominate. However, there is a "non-point source," if you will, of phosphorus coming from bottom sediments that in essence "buffers" the concentration of phosphorus at very, very high levels in the lower part of the estuary. This, in essence, make phosphorus very abundant relative to nitrogen in the estuary during the low-flow period.

Given the knowledge of ratios and their seasonal variation, we did some enrichment studies at Benedict, Maryland. When I say "we," I'm talking mainly about Jim Sanders, Walt Boynton and Steve Cibik and myself, in which we were looking at the nutrient enrichment of outdoor, continuous culture, phytoplankton tanks. I will not dwell on the details; but basically, you add nitrogen or phosphorus and see what grows. What stimulates growth the most is the limiting nutrient. That is, if you add nitrogen and you get a big growth response, nitrogen is the limiting nutrient.

Figure 9 indicates what we found: In the summertime if we added dissolved inorganic nitrogen compounds, we got a tremedous stimulation of growth in the tanks very soon after an experiment started. Natural phytoplankton communities were used that were isolated directly from the river. So one would expect that their nutritional condition when they were put into that tank is

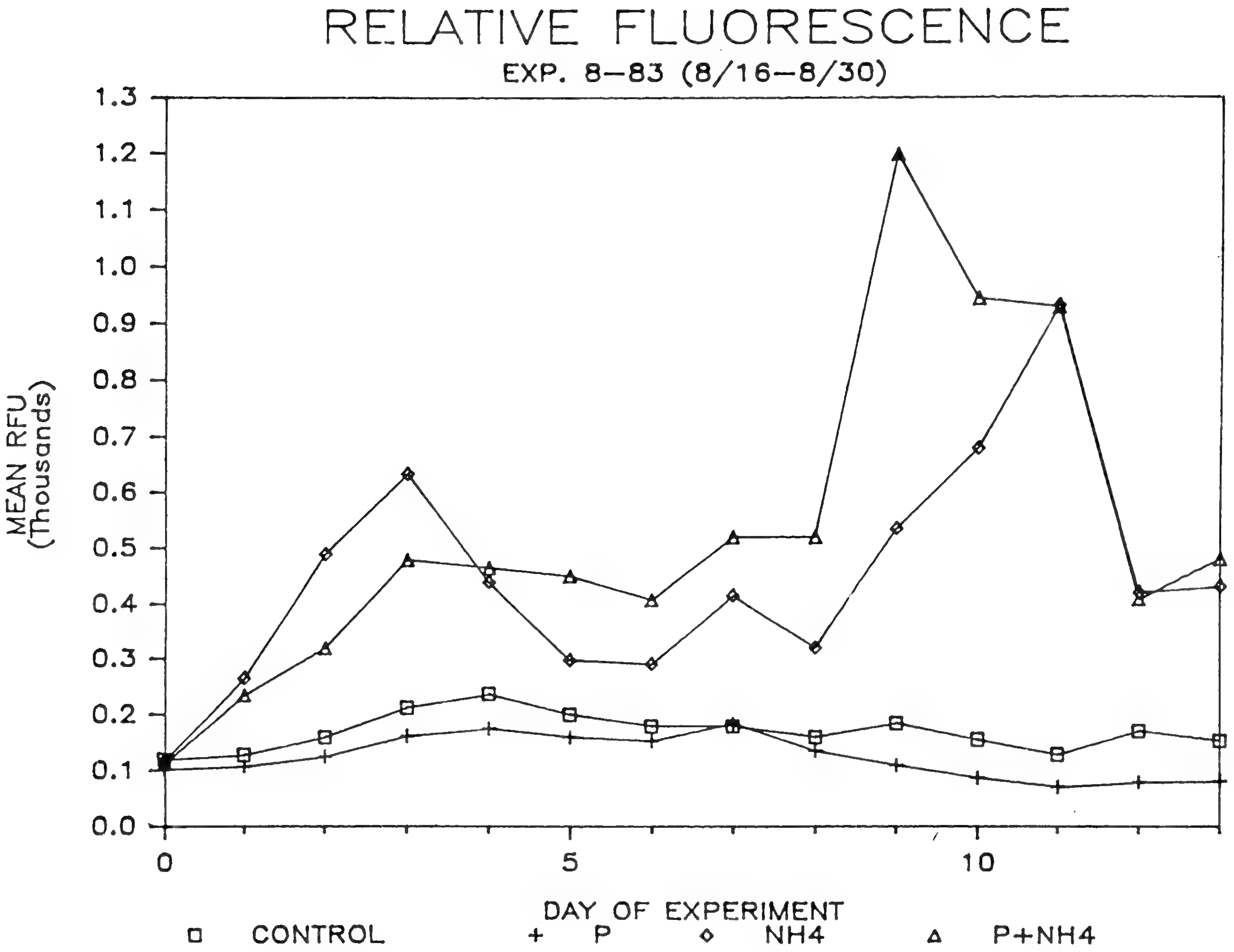

RELATIVE FLUORESCENCE
EXP. 8-83 (8/16-8/30)
MEAN RFU (Thousands)
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
5
10
DAY OF EXPERIMENT
□ CONTROL
+ P
◇ NH4
△ P+NH4

Figure 9.

a good indicator of what their actual nutritional condition is in the river. And here, nitrogen was deficient. The control tank to which we added nothing whatsoever gave no response, nor did the P-tank. So we can add phosphorus in the summer period and not get a response whatsoever.

In wintertime we see a weak response to phosphorus rather late in an experiment. For nitrogen, there is no response whatsoever.

This is completely in keeping with the availability of nitrogen or phosphorus that I showed above. In the spring and fall, we find that neither N or P stimulates growth. Neither phosphorus nor nitrogen addition is very important, as one would also expect from monitoring data.

I can summarize for you what we have seen in terms of nutrient limitation over the annual cycle in the Patuxent River. In Figure 9, the ordinal scale represents a relative indication of nutrient limitation in the Patuxent. The higher the index value, the more likely that nutrient is limiting by our enrichment studies. The first summer we saw a strong response to nitrogen addition and very little to phosphorus.

Late fall saw no response to nutrient enrichment. In the winter season of 1983-1984, we saw some response to phosphorus, but on a relative level, that response was less than nitrogen the previous summer. In the springtime, there was no response to the addition of either nutrient. The following year, we got a large response to nitrogen and very, very little response to phosphorus.

Figure 10 clearly shows that we get a much greater response to addition of nitrogen to our system than we do to phosphorus. The system, therefore, is likely to be a nitrogen-limited system.

What does this mean in terms of its management implications? Well, I think there is a very simple take-home lesson there. If we are really going to try to control the anoxia problem, at least in the tributaries, we must control the growth of algae. To control the growth of algae, we have to remove what's available in least supply -- the "limiting nutrient". That is nitrogen, I think, for most of the saline regions of the Patuxent River and probably for elsewhere in the saline regions of the Chesapeake Bay during the low-flow season.

So we're going to need to develop some strategy to control N inputs. I have not included in the program and discussions of how one might go about doing this. Generally speaking, N removal has been regarded as a very, very expensive and difficult process to do both for point and non-point sources. I think there is some

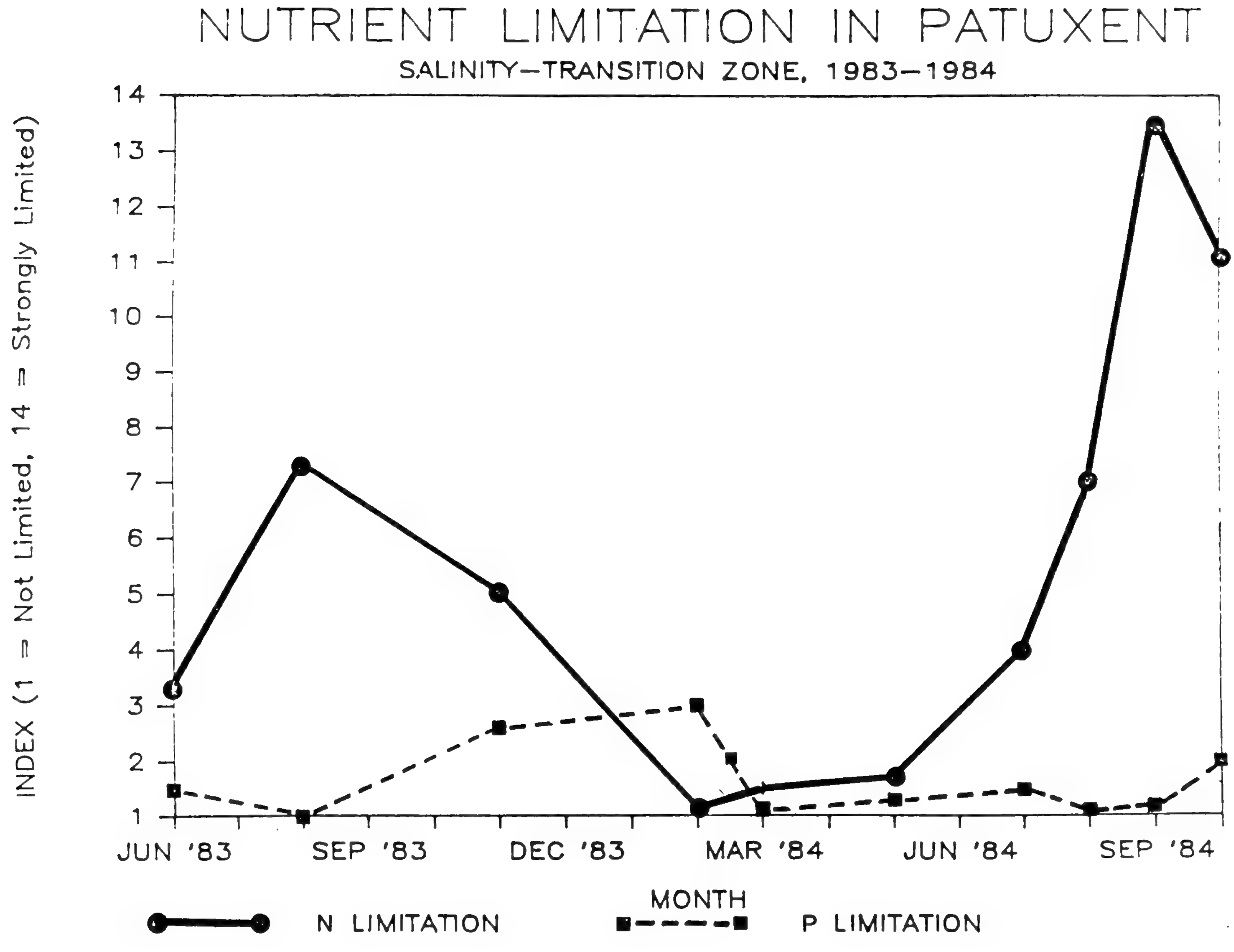

NUTRIENT LIMITATION IN PATUXENT
SALINITY–TRANSITION ZONE, 1983–1984
INDEX (1 = Not Limited, 14 = Strongly Limited)
14
13
12
11
10
9
8
7
6
5
4
3
2
1
JUN '83
SEP '83
DEC '83
MAR '84
JUN '84
SEP '84
MONTH
N LIMITATION
P LIMITATION

Figure 10.

evidence now that there are sewage treatment processes available that are both cost-effective and technologically reliable. So, for at least the point sources, it looks like we do have a chance of limiting the amount of nitrogen entering the system. I open that to debate in the management community, and I hope that serious consideration is given to it there.

With regard to non-point sources of nitrogen, it is possible that we can do something to reduce nitrogen inputs. I'm a very strong proponent of the concept of the critical areas zoning that has been legislated in Maryland; this legislation and resulting regulation call for set-backs and other things that might be done to help reduce the non-point source inputs.

So I think that with set-backs, best-management practices of farms, judicious application of fertilizers by homeowners, proper construction practices, etc., we can make some inroads in the nitrogen control situation.

I think with that I will stop my talk and take one or two questions before we have to move on to the next speaker.

Thank you.

Dr. D'Elia: The next speaker is Jay Taft of Harvard University, who with Tom Malone, is going to discuss the anoxia problem in the Chesapeake Bay, what we know about it and what we can conceivably do about it. So, Jay Taft?

ANOXIA

by

Dr. Jay L. Taft
Howard University

and

Dr. Thomas C. Malone
Horn Point Environmental Laboratory

Dr. Taft: I'm very pleased to be back in this area for a conference on Chesapeake Bay. I am also pleased to acknowledge Tom Malone as the co-presenter; but he is not responsible for any statements that I might make.

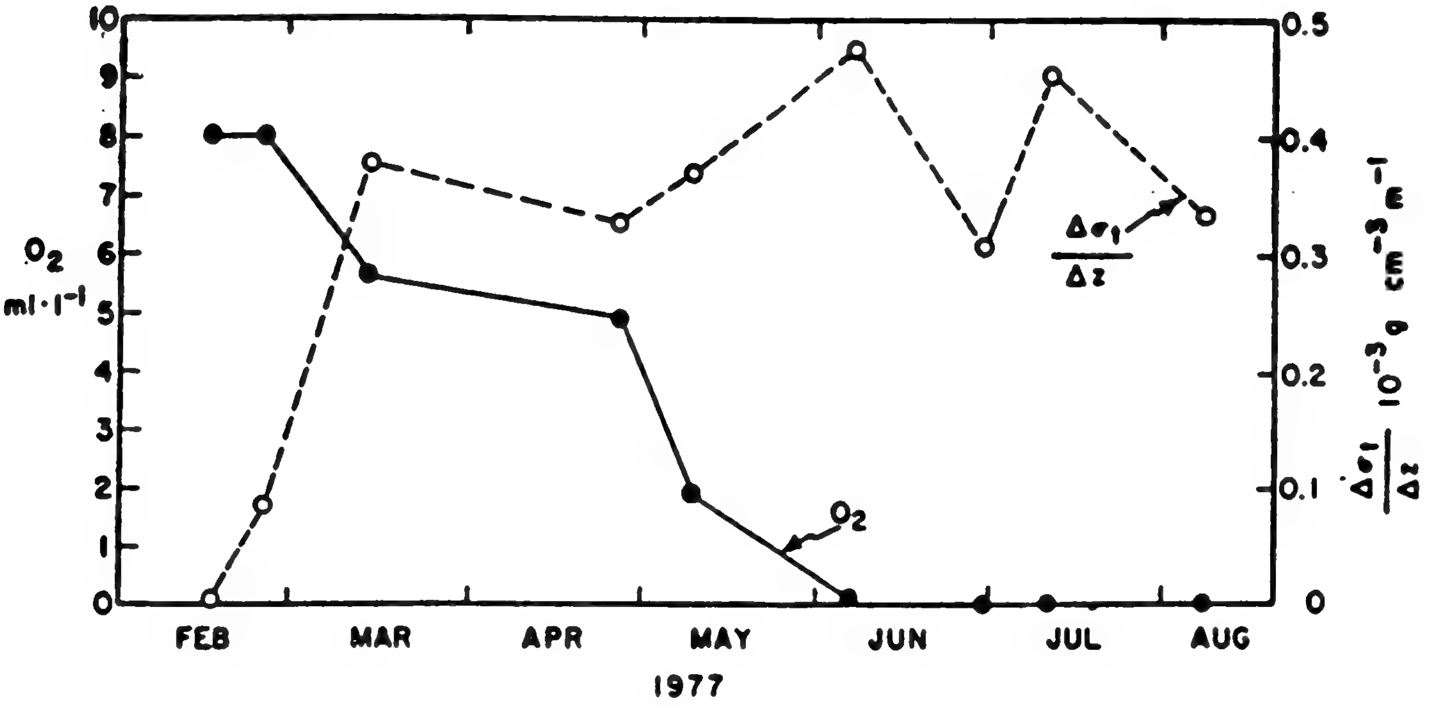
Chris D'Elia has asked us to discuss anoxia in the Chesapeake Bay. Anoxia, in a broader context, is part of an oxygen gradient. Oxygen gradients are normal features of systems that have density gradients in the vertical. In the Chesapeake, the first account of possible oxygen stress was published in 1629 in the notes of John Smith. His party was travelling up one of the tributaries and observed fish swimming near the surface with their heads out of the water. They also observed dead fish along the shore. This behavior has been associated with oxygen stress or with advective processes carrying organisms into the shallows. In modern accounts, both fish and crabs have been observed to behave in the same fashion producing "jubilees" along the shore, presumably an escape response to low oxygen water being advected into the shallows.

The first account I have found explaining the mechanism for forming oxygen gradients in estuaries was written by Sales and Skinner, in the Journal of the Franklin Institute in 1917, from data collected in the Potomac River Estuary and in the Upper Chesapeake Bay in 1912. They write, "...this phenomenon is caused by the stratification of the water due to the specific gravity of the under-run of sea-water, which cuts off vertical circulation, and to the subsequent depletion of the oxygen in the lower layers by natural agencies." The "natural agencies" involved were respiration of plants and animals, direct oxidation of dead organic matter, and the decomposition which results from the action of bacteria. Newcombe, working out of the Chesapeake Biological Laboratory in the late 1930's and early 1940's, further documented the observations made by Sales and Skinner. In an article in Science, July 22, 1938, Newcombe and Horne write, "Studies on the physical and chemical properties of Chesapeake Bay waters during the summer of 1936 gave evidence of a definite oxygen-poor layer at the bottom in deeper regions, and data from subsequent series of water samples have proved the existence of that layer and have furnished interesting information concerning its vertical and horzontal extent".

This role of density stratification is illustrated by the data from the Bay in 1977 shown in Slide 1. As the water-column density gradient, expressed as change in sigma-t over change in depth, increases from February to June to oxygen concentration in the lower layer decreases from near saturation to anoxia. Even in February, when temperatures are still rather low, if stratification increases there are enough "natural agencies" consuming oxygen in the deep water that oxygen concentration declines. Slide 2 shows the relationships among the annual cycles of deep water tmperature, oxygen concentration and salinity, and change in density over change in depth during 1964 to 1966 and 1969 to 1971 in the middle portion of Chesapeake Bay. Again, we see that through the annual cycle, the oxygen concentration in the deep water is generally low or zero in summer and early fall and increases at otheer times of the year. The oxygen plot in Slide 2a shows reoxygenation events in August of both 1964 and 1965, after which the deep layer again lost oxygen before the surface water temperature decreased to produced seasonal reoxygenation. Short-term reoxygenation during summer was not observed in the data set for 1969 to 1971.

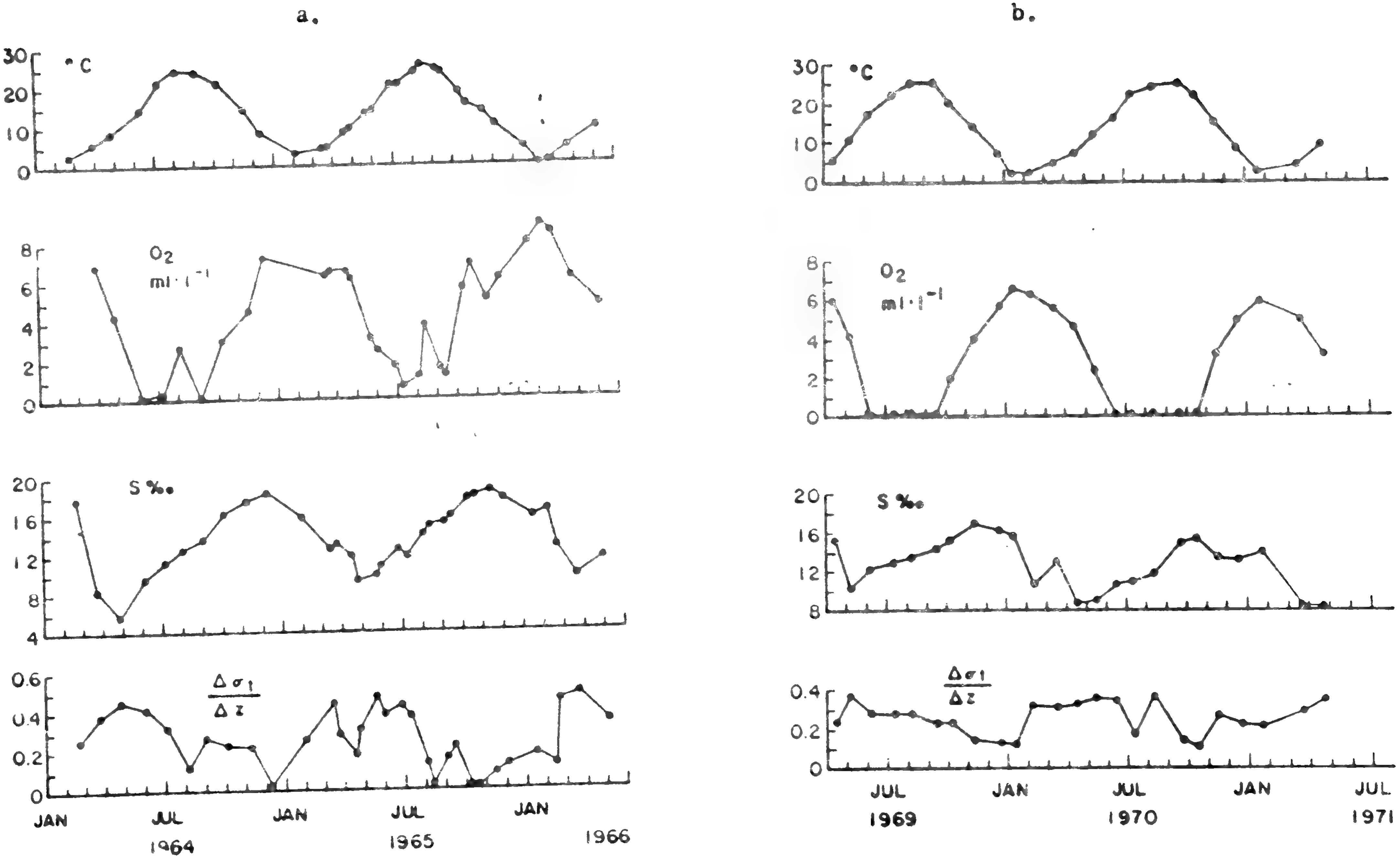
The emerging picture is that anoxia has been a recurrent feature with varying intensity. There are other observations, particularly about fisheries and submerged aquatic vegetation, in the Chesapeake Bay which lead us to believe that the system is under stress. However, we are faced with a difficult interpretational problem because the data are spotty in time and space. We must make some judgements about the quality of the data and how to use them. Also, the mechanism is more complex than presented by Sales and Skinner. Slide 3 shows two graphs of change in dissolved oxygen concentration vs. change in salinity over the same depth from the upper to the lower layer. Each datum point in Slide 3a represents a vertical profile in the mid-bay during the month of July in ten different years between 1949 and 1980. Linear regression analysis yields an equation for the line through the points which has a regression coefficient of 0.87. If we assume that the vertical structure of the water column and its processes can reach a steady-state in the summer, then the line in Slide 3a represents the steady-state relationship between the salinity gradient and the dissolved oxygen gradient. This further implies steady-state between oxygen utilization in the deeper layer and its resupply via the surface. If we apply this model to other seasons, we might be able to test for a steady-state in the utilization and resupply processes.

Slide 1



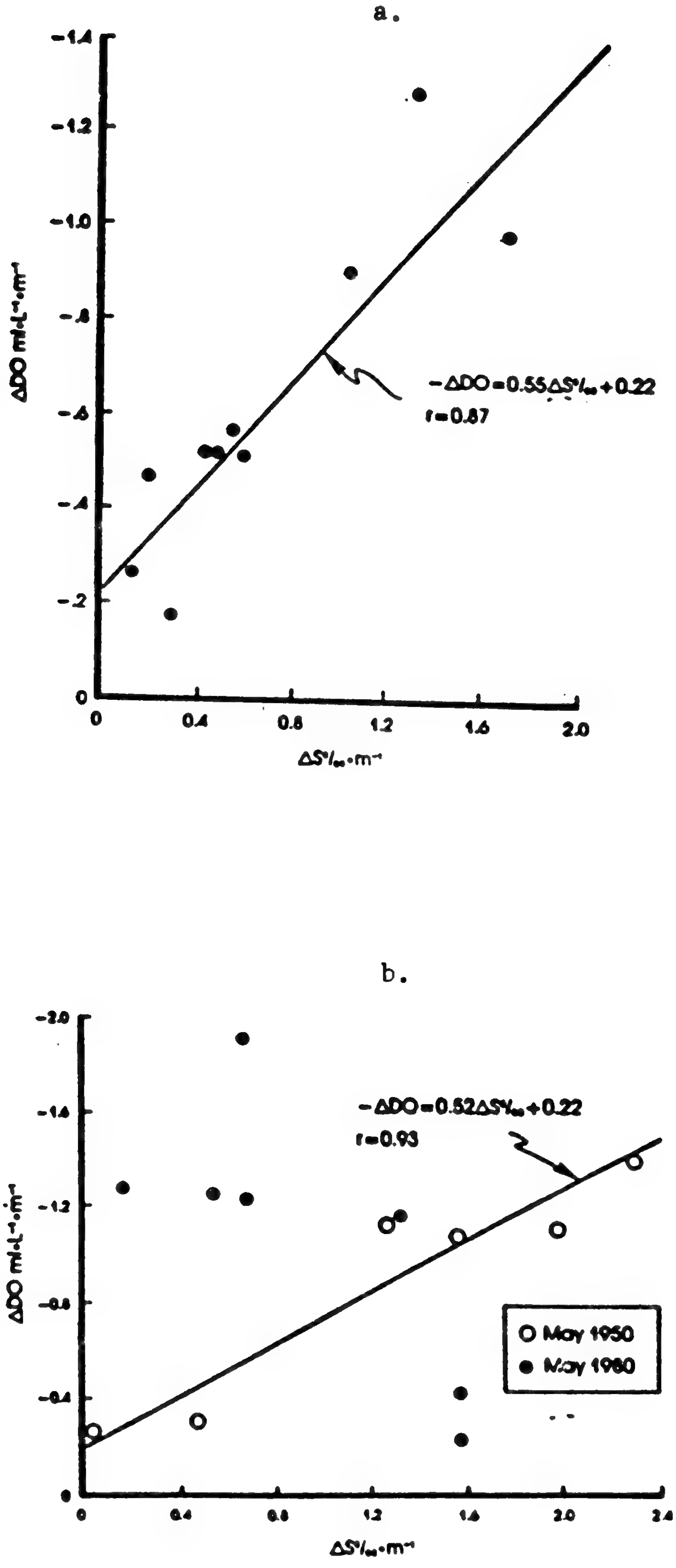
The dashed line shows change in density over water column depth for a station in the mid-portion of Chesapeake Bay. The solid line shows corresponding oxygen concentration in the deep water.

Slide 2



Annual cycles of deep water temperature, oxygen concentration, and salinity, and the deep layer to surface layer density change in the mid-portion of Chesapeake Bay.

Slide 3



Change in oxygen concentration over depth plotted against the salinity change over the same depth. Panel (a) for summer samples taken in 10 different years between 1949 and 1980. Panel (b) for the upper to middle portion of Chesapeake Bay during May 1950 and 1980.

Slide 3b shows a similar plot for data in the month of May 1950 and 1980. The 1950 data give a regression which is virtually identical to the steady-state model constructed with the 10 years of summer data. The May 1980 data, however, diverge significantly from the model. Data points in the upper left of the plot represent sharp reductions in oxygen concentration over relatively small salinity increases. This might be explained by large differences in the spring freshet which typically peaks during April. The average Susquehanna River flows in April were 85,000 cubic feet per second (cfs) in 1950 and 94,000 cfs in 1980. During May of both years, the flow averaged about 39,000 cfs. It is not clear that the circulation effects of an 11% increase in April flow rates would have resulted in the sharp difference between the two plots in Slide 3b. However, it would be reasonable to expect greater oxygen demand in the deeper waters to give such a result. The organic matter stimulating greater oxygen consumption in May 1980 could have been delivered with the spring freshet, or it could have autocthonous material from recent or previous production. From this minimal amount of data, we might suspect that there was significantly more organic material in the deep layers of the Bay in May 1980 than in 1950, under similar river flow regimes.

Returning to the annual cycle of events in the Bay, let us consider the time scale of some of the major processes. The spring freshet maks the onset of oxygen decline in the main portion of the Bay. The freshet delivers fresh water to the system which influences the stratification through the processes discussed by Bill Boicourt. The water also delivers organic material which can be decomposed in the Upper Bay, thereby reducing oxygen concentration. The freshet also delivers nutrients to the Main Bay which are utilized by phytoplankton, through the processes described by Chris D'Elia, which increases the organic matter in the system and the ultimate oxygen demand. Thus, the spring freshet can be a pulse source of both organic material and the nutrients required to produce new organic matter within the Bay. Decomposition then feeds nutrients back into the system so that cycles are established and keep functioning through the year in the absence of additional strong inputs from the watershed.

The vertical stratification portion of the annual cycle has the general form depicted in Slide 2, but it is subject to local modifications and to far-field forces affecting advection on intermediate time-scales. Bill Boicourt gave examples of local mixing, such as wind mixing and mixing due to turbulence over the tidal cycle. There is some potential each time the tide changes for mixing to occur near the picnocline. Comprehensive vertical mixing occurs in the York River Estuary on a spring-tide, neap-tide cycle. Therefore, time scales influencing stratification range from 1 year for major fresh water inflows, to monthly for places like the York River, to 5 to 10 days for mixing driven by meteorological events.

Advective processes, those which move water without necessarily mixing it, also occur on various time-scales. Internal waves can move water vertically on scales of minutes to hours. These were first suggested and possibly observed by Biggs and Flemer during close time-series oxygen measurements made in Chesapeake Bay. Local wind forcing can advect surface waters across the Bay. The lower layer flows upwind to maintain hydrostatic equilibrium shifting the tilt of the picnocline on time-scales of a few days. Data collected by Tom Malone and his group illustrate this phenomenon in Slide 4. The upper panels show both the picnocline and the oxycline tilting downward to the west on 20 August 1984.

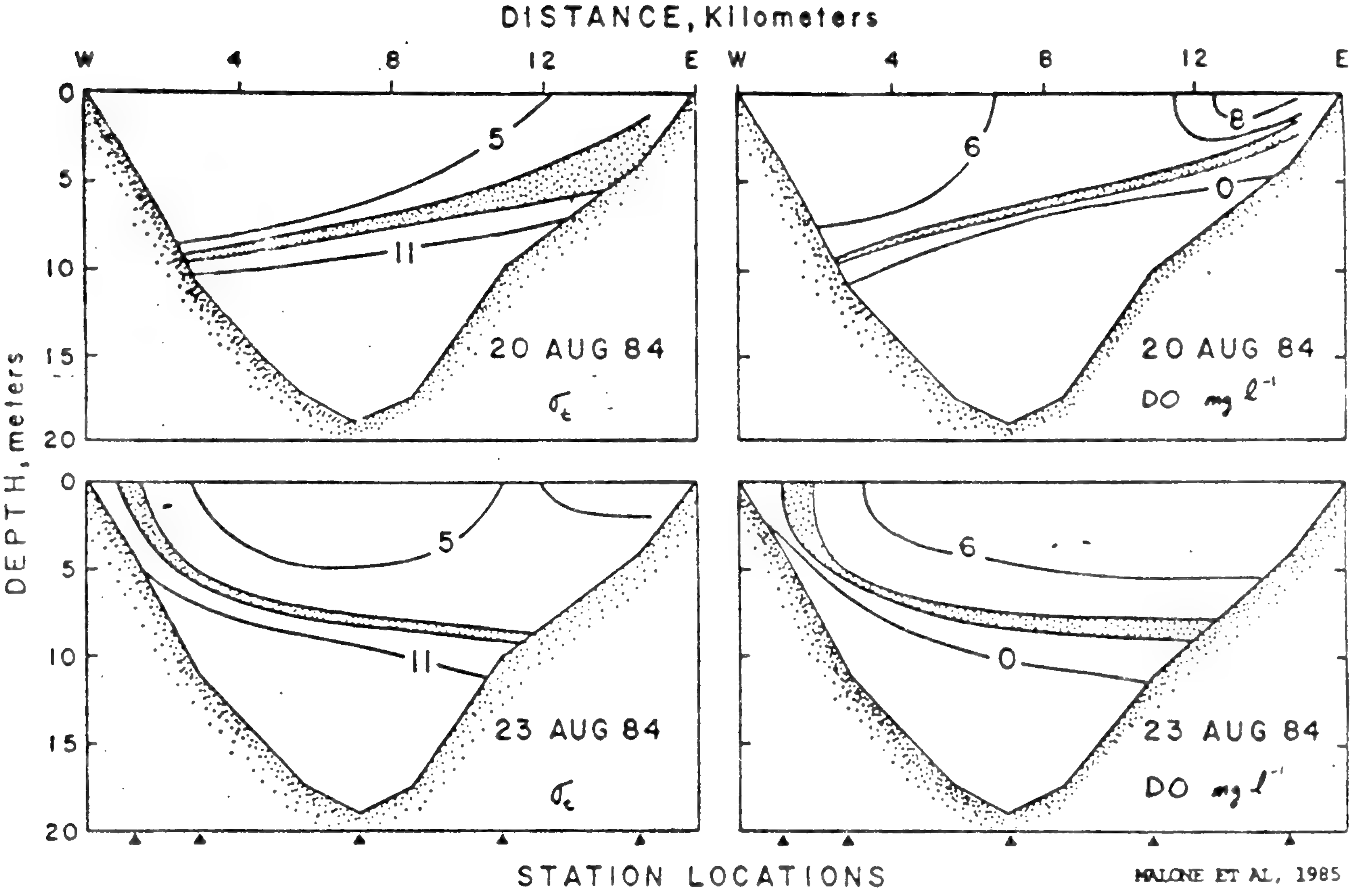
By 23 August, as shown in the lower panels, local winds have shifted the tilt downward to the east. This process has been implicated in "jubilees" during which crabs and fish come inshore to escape low-oxygen water moving into the shallows.

To summarize, there are some historical data with which we can compare recent information and suggest that changes have occurred adversely effecting biological resources in Chesapeake Bay. Although we belive low-oxygen concentrations in deep water is a normal feature of summer in Chesapeake Bay, indications are it has increased in spatial and temporal extent. Deterioration with respect to oxygen is most likely caused by increased material both entering the Bay and being produced in it in response to inorganic nutrient inputs. Recent careful studies have shown that summer anoxia can be interrupted by local mixing events, and that, once formed, anoxic water may be advected from place to place by local and far-field meteorological events. Such variability must be accounted for as we assess the long-term trend. It will also hamper our ability to detect improvements in conditions in response to management actions implemented for both point and non-point source nutrient inputs.

I would like to stop there; and if there are any questions, I'd be happy to try to answer them. Yes?

Question: Would you care to venture an opinion as to whether or not the trend that you've seen is related to our use of the Bay as opposed to being what might naturally happen in a body of water under relatively pristine conditions, nevertheless, natural history for a body of this type?

Slide 4



West-east transect from the Patuxent River to the Choptank River showing the response of the picnocline and oxycline to wind forcing.

Dr Taft: The question is: If the trend is real, is it due to a natural progression of things in the system or can it be attributed to anthropogenic effects or man's effects on the system.

I think certainly that there's a small component of natural degradation in the system. However, I think that the major changes that we have seen parallel not only the growth in the watershed, but the changes in agriculture in the watershed. Specifically, with respect to nutrients, the amount of land and crops has not changed very much, as Bob showed earlier this morning. But the intensity of that land use such as getting three crops in two years instead of one crop per year, the sharp trend in the increase of soluble nitrogen fertilizers which has increased while the total nitrogen suspension since 1955 has doubled, and the use of soluble ammonia fertilizers has gone up ten or fifteen times. So the growth, the way we're using the land, all parallel the changes that we see and can be associated, correlated, with the changes that we see in the system. But we don't have as good a historical data set to make all of the exact connections that we would like to.

Dr. D'Elia: Thank you very much.

(Tools for assessing changes in the system are being developed in the form of monitoring programs to collect appropriate data sets and mathematical models to help evaluate and fill gaps in the data sets. Since this talk was delivered, better data have been collected, a steady-state model for the Chesapeake Bay has been developed and used, and a real time three-dimensional model has been commissioned for development. With these tools in hand, managers should make more informed decisions and have the ability to both project and actually assess the results of those decisions.)

THE ROLES OF BLUE-GREEN ALGAE

by

Dr. Lawrence W. Haas
Virginia Institute of Marine Sciences

and

Dr. Hans W. Paerl
University of North Carolina

When you mentioned the word cyanobacteria to a plankton ecologist or water quality manager in the Chesapeake Bay Region, more likely than not, their thoughts turn to a surface scum of cyanobacteria in the tidal freshwater section of the Potomac River. For many, these blooms have come to epitomize the undesirable effects of eutrophication in the Chesapeake Bay Region.

What are cyanobacteria? Why do they appear in such high concentrations in the certain parts of the estuary at certain times of the year? Can we expect similar occurrences in the future in saline portions of the Chesapeake Bay? Are there cyanobacteria in the more saline portions of the Bay and, if so, what role do they play in the plankton community? These are some of the questions I hope to answer.

Cyanobacteria are photosynthetic organisms which occur in a variety of morphological types including single cells measuring only a micrometer in diameter, chains of single cells, colonies of single cells held together by a mucoid-like substance, filaments composed of many cells, and aggregates of filaments ranging in size from loosely aggregated tufts barely visible to the naked eye, to "mats" of filaments measuring several centimeters thick. Cyanobacteria are widely distributed in both marine and freshwater habitats. My comments today will address only planktonic cyanobacteria, those forms which spend all of most of their life cycle suspended in the water column. I will ignore the variety of cyanobacteria found, often in abundance, on estuarine and salt pond sediments, and attached to salt marsh plants, submerged aquatic vegetation, shells, pilings, or almost any solid substrate in the marine environment.

Some of the pertinent physiological, morphological characteristics of cyanobacteria are listed in Table I and include:

1. A cellular structure fundamentally similar to that of bacteria which places them with bacteria in the group of organisms known as prokaryotes. It is this characteristic which accounts for the commonly used term cyanobacteria.

Physiological and Morphological Characteristics of Cyanobacteria

1. Prokaryotic Cellular Structure.

2. Photosynthesis:

$$\begin{array}{l} CO_2 + \text{Light} \\ \text{Chlorophyll} \end{array} \dashrightarrow CH_2 + 02$$

3. Vertical Motility and Depth Regulation Via Internal Gas Vacuoles.

4. Nitrogen Fixation:

N2 ---------> Biomass and Metabolism

Table I

2. Cyanobacteria are photosynthetic. They use light energy and chlorophyll-a to convert carbon dioxide into cellular biomass and in the process produce oxygen. This process is essentially identical to photosynthesis in terrestrial plants and all other marine and freshwater algae. It is this characteristic which accounts for the other commonly used name for this group: blue-green algae.

3. Although lacking external means of motility such as flagella or cilia, some cyanobacteria contain intracellular gas vacuoles. By regulating the number of these internal, gas-filled vesicles, cyanobacteria are capable of vertical rates of migration that rank among the highest observed for algae, up to 2-3 m hr^1.

4. Unlike other algae, certain species of cyanobacteria are capable of utilizing nitrogen gas from the atmosphere for biomass and metabolic processes. Species which are capable of nitrogen fixation are not dependent on inorganic forms of nitrogen found in their environment such as nitrate, nitrite, or ammonium, which are required by other algae.

Although an abundant supply of nitrogen and phosphorus is necessary to support the high algal biomass which occurs in summer, cyanobacteria blooms, it appears that certain adaptive responses of the principal bloom-forming cyanobacteria, *Microcystis aeruginosa*, are a more immediate cause of surface scum formation. As temperature and light availability increase in the spring and early summer, algal growth rates increase and algal biomass accumulates in the water column. Fueled by an abundance of nutrients, algae may become so dense that light in the water column is decreased by self-shading, and/or carbon dioxide availability is decreased by an excess of demand over supply. *Microcystis aeruginosa* has been shown to respond to both of these conditions by increasing its bouyancy and floating to the surface where the availability of both light and carbon dioxide are maximal (Paerl and Ustach, 1982). Unlike other algae which are actually inhibited by summer surface light intensities, *M. aeruginosa* responds to high light intensities by producing a pigment which protects its photosynthetic apparatus from the deleterious effects of too much light (Paerl et al., 1983). It is this unusual capability of *M. aeruginosa* to resist and thereby exploit high surface light intensities which is responsible for their dense accumulation at the surface. Coincident with this migration to the air-water interface, *M. aeruginosa* changes its morphology from individual small cells to a colonial form comprised of thousands of cells in a mucous envelope. A secondary but significant effect of surface scum formation is that light availability to more desirable algae species distributed throughout the water column is decreased with a consequent reduction in their growth and abundance.

In studies of North Carolina estuaries, Paerl (1982, 1983) has demonstrated that cyanobacteria require quiescent or stable water conditions in order to form surface scums or blooms. In the tidal fresh water region of rivers, water column stability is enhanced by a reduction in river flow, by high solar radiation which leads to thermal stratification, and by decreased winds. The effect of these factors on bloom formation in the tidal Potomac is emphasized in a study by M.P. Sullivan (1985) at the Metropolitan Washington Council of Governments. He reviewed 36 years of hydrometeorological data for the Potomac River and developed an environmental index which included all of the aforementioned factors. As shown in Figure 1, the index, which ranges from a highly unfavorable -6 (high flow, high wind, low solar radiation and temperature) to a highly favorable +6 (low flow, low wind, high temperature and solar radiation), correlates well with average summer algal biomass determined from twelve summer blooms since 1965. Bloom severity is quantified as average surface water chlorophyll-a values from the upper 70 kilometers (km) of the tidal Potomac River. These data illustrate that hydrometeorological processes play a significant role in regulating bloom phenomenon and must be considered along with nutrient loading data in evaluating historical trends of blooms. Sullivan further suggests that the particularly severe and unexpected cyanobacterial bloom of 1983 may have resulted primarily from a highly unusual combination of low wind, high solar radiation and temperature, and low river flow which occurred during that summer. According to his probability analysis from 36 years of data, the 1983 index value of ca. 5.5 will occur only about 3 times in a hundred years.

The magnitude of the 1983 Potomac River bloom illustrates that the system still harbors sufficient nutrients to support an abundant algal biomass. The most likely source of nutrients for the 1983 bloom appears to have been the sediments and not direct point source additions. The Expert Panel, convened to study the 1983 bloom, hypothesized that a high pH, resulting from the depletion of carbon dioxide from the water column following high daily rates of photosynthesis, increased the flux of phosphorus from the sediments to the water column where it was available for phytoplankton growth (Expert Panel, 1985). Research this past year by Sybil Seitzinger at the Philadelphia Academy of Natural Sciences, who measured the rate of phosphorus release from isolated, intact sediment cores from the Potomac River subjected to various levels of pH, supports this hypothesis.

Can we expect surface scums of cyanobacteria to occur downstream in high salinity regions of the estuary if nutrient and other environmental conditions in those regions become favorable for bloom formation? Recent research by Paerl et al. (1984) in North Carolina and Kevin Sellner working in the Potomac River

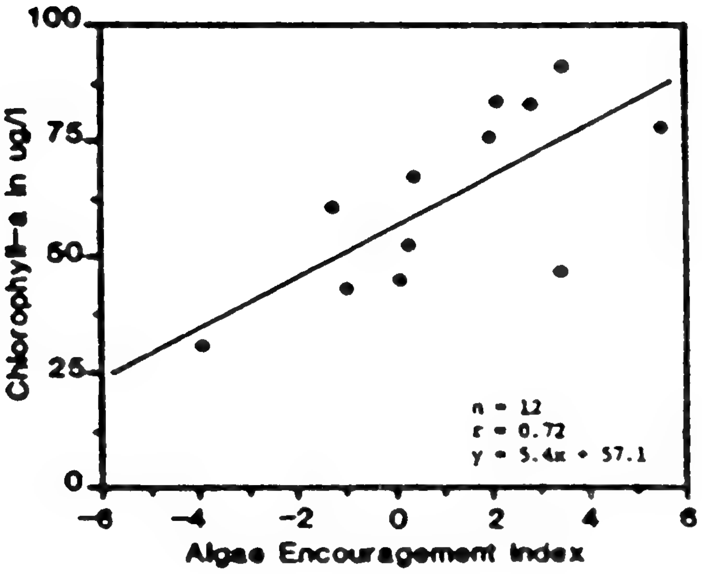


Figure 1

Relationship between Index and the summer average chlorophyll a values for the upper 70 km of the tidal Potomac for 12 years.

suggest that this is not likely to occur. In both laboratories, natural populations of freshwater bloom-forming cyanobacteria exposed to salinities as low as 5 o/oo were severely inhibited in terms of photosynthesis.

If bloom-forming cyanobacteria from freshwater regions won't survive in moderate and high salinities, can we expect to find significant populations of cyanobacteria in the Chesapeake Bay? Until a few years ago, most phytoplankton ecologists thought that cyanobacteria were not an important component of marine phytoplankton communities. However, with the advent of epifluorescent microscopy, it quickly became apparent that there was an abundant and ubiquitous population of small (ca. 1 um diameter) coccoid cyanobacteria in the world's oceans (Johnson and Sieburth, 1979; Waterbury et al., 1979), and that these small cyanobacteria were significant contributors to oceanic primary production (Li et al., 1983; Platt et al., 1983). Using epifluorescent microscopy, coccoid cyanobacteria fluoresce a bright crimson-red color under green light excitation while some forms fluoresce a gold-orange color under bluelight excitation (Haas, 1982). Both forms are easily and accurately quantified by this technique.

Coccoid cyanobacteria in the lower Chesapeake Bay plankton community are most abundant during the summer months when water temperatures are highest, as shown in Figure 2, which depicts phytoplankton abundance data collected by Harold Marshall of Old Dominion University at stations in the lower Bay and in the lower James River during 1982-83. The cell counts were made using inverted microscopy. The data show that picoplankton (phytoplankton less than 2 um in diameter and in this case dominated by cyanobacteria) reached peak abundances of ca. $15x10^3$ ml^{-1} during July, August, and September at both stations. The lower James River station also illustrates the sequence of a spring bloom of relatively large diatoms preceeding the summer maximum of picoplankton.

Figure 3 shows cyanobacterial abundance along the salinity gradient of the lower Bay and James River for August 1983. The data are from a transect starting in the lower Bay near Cape Charles (salinity 23 o/oo), progressing into Hampton Roads (0 km and 22 o/oo) and continuing about 75 km upriver past Jamestown Island (2 o/oo). Samples were collected from ca. 1 meter depth at each station for 14 consecutive days, except for the Cape Charles station which was sampled only four times. Cell counts were made with epifluorescent microscopy and for the purposes of this presentation, the counts for all days were averaged and a standard error depicted. In the lower Bay near the Eastern Shore, total cyanobacterial counts were nearly 10^6 ml^{-1} with total abundances not changing appreciably upriver. The proportion of orange fluorescing cells, which are the only type found

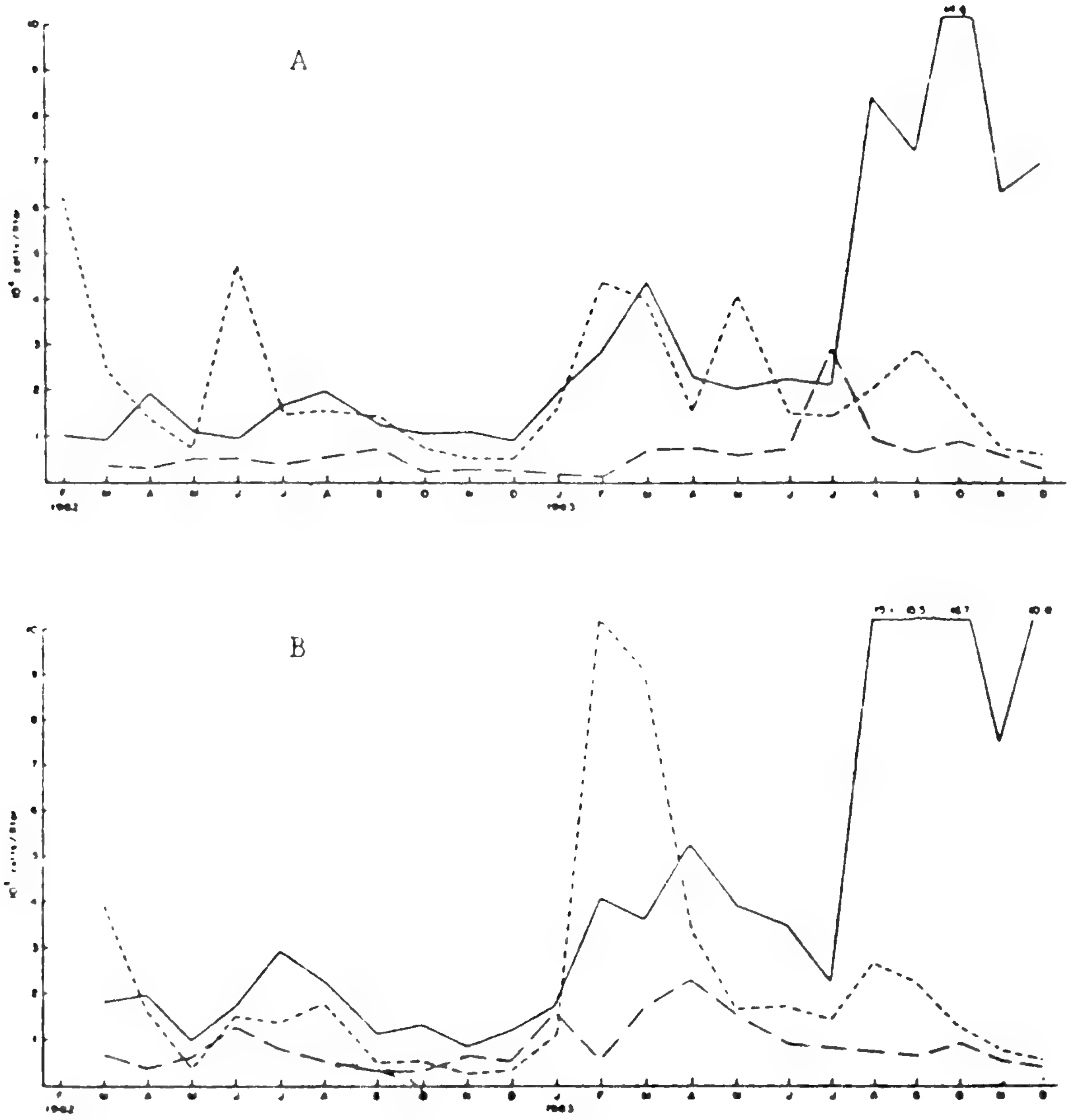


Figure 2

Combined surface and bottom averages for total cell concentrations of picoplankton (———), diatoms (-----), and cryptomonads (·········) at lower Bay stations (A), and Hampton Roads stations (B).

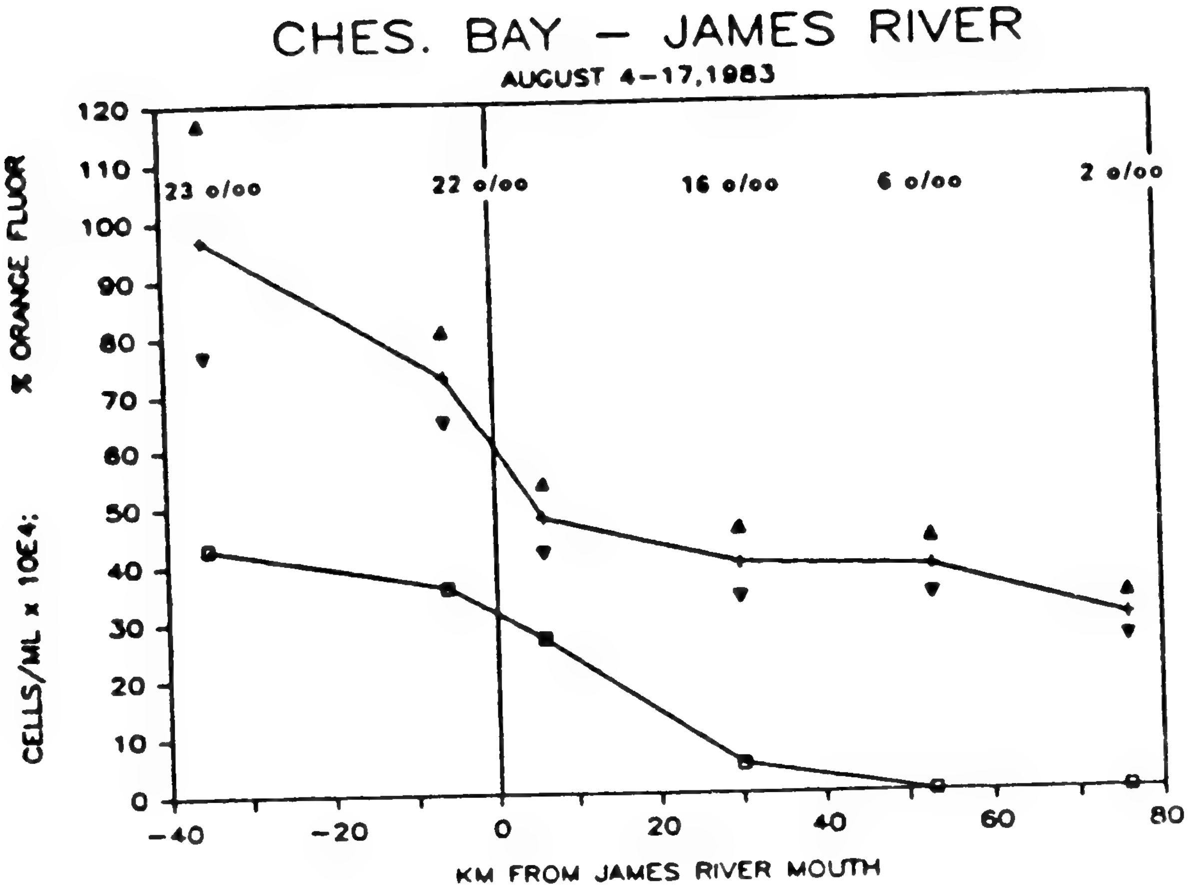


Figure 3

Coccoid cyanobacteria concentrations (+---+) and percent orange fluorescing cyanobacteria (□---□) in the lower Chesapeake Bay and James River. Triangles denote standard of the mean.

in oceanic waters, is highest (ca. 45%) at the highest salinity and decreases rapidly to zero percent at about 10 o/oo. These are extremely high cell numbers for phytoplankton and considering the moderate levels of chlorophyll observed in the James River during this period (ca. 10-13 ug 1^{1}), cyanobacteria probably accounted for most of the primary production. The differences in cyanobacterial abundances in the Lower Bay for August 1983 depicted in Figures 2 and 3 probably reflects the reduced efficiency of inverted microscopy to accurately count these small cells. Since there is no historical record for cyanobacterial abundances in the Chesapeake Bay plankton, it is difficult to speculate if these high concentrations of cyanobacteria observed with epifluorescent microscopy represent a "normal" condition or long-term response to nutrient enrichment.

The presence of high numbers of coccoid cyanobacteria has implications for other aspects of the plankton ecosystem. Phytoplankton constitute the base of the food web in the Chesapeake Bay; they are the primary source of fixed carbon which supports all the higher trophic levels. This process is illustrated in Figure 4 which depicts the quintessential marine food chain starting with a large diatom consumed by a copepod which in turn is consumed by a planktivorous fish consumed by a top carnivore. With a large phytoplankton at the base, only one intermediate level is needed before a fish gets its food. However, in a plankton ecosystem where coccoid cyanobacteria dominate, this is not the case. Figure 5 depicts the trophic relationships thought to dominate in the North Pacific Gyre where coccoid cyanobacteria dominate the phytoplankton, and I believe it is a realistic representation of trophic processes in the Lower Chesapeake Bay during the summer months. Here we see cyanobacteria being consumed by protozoan flagellates which, in turn, are consumed by a ciliate. This ciliate may then be consumed by a copepod. Compared to the Figure 4, where there was only one step between a phytoplankter and a copepod, there are now potentially two levels. Since each added level in a food chain or web necessarily reduces the amount of energy reaching the higher trophic levels, the presence of substantial numbers of picophytoplankton at the base of the food web may reduce production or alter the species composition at the higher levels.

Protozoan grazing of cyanobacteria in the Chesapeake Bay has been demonstrated (Haas, 1982) and Hans Paerl has described protozoans grazing the interior of a _M_. _aeruginosa_ colony in a tidal freshwater habitat.

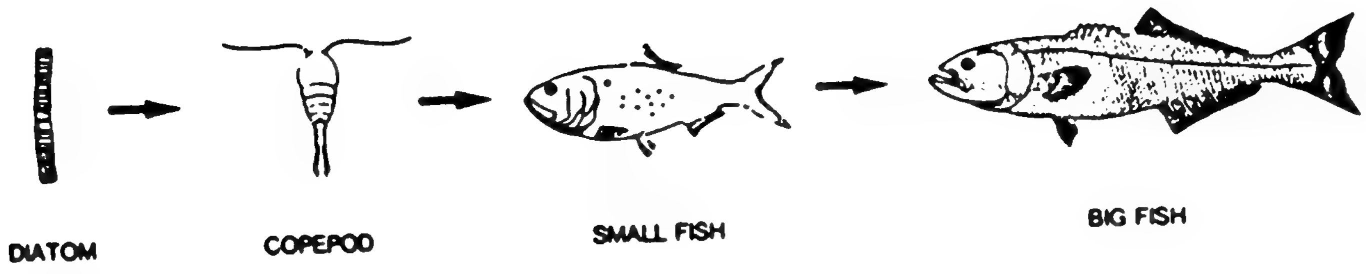


Figure 4

A typical microplankton food chain for the Chesapeake Bay.

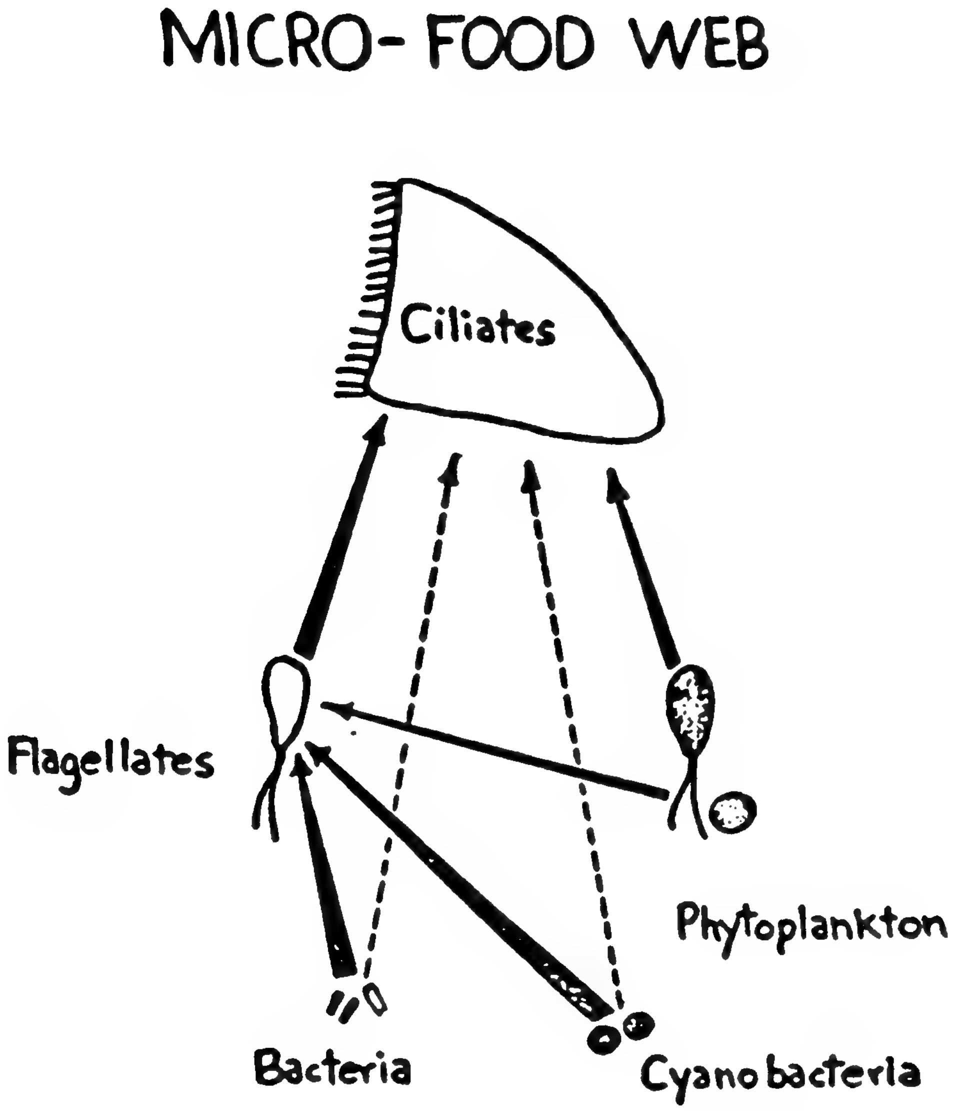


Figure 5

Diagram of probable food web linkages among plankton organisms in the North Pacific.

A cyanobacterial-based food web may have significant implications for nutrient cycles in estuaries. For example, diatoms are generally large cells which may sink rapidly out of the euphotic zone to the sediments. Furthermore, diatoms are grazed primarily by copepods which produce fecal pellets containing significant amounts of carbon, nitrogen, and phosphorus. These pellets sink rapidly to the sediments where they are likely to be remineralized to forms of nitrogen and phosphorus which, under suitable conditions, leave the sediments and are once again available to the phytoplankton. This may be a long-term cycle and because of the net up-estuary flow of bottom water in estuaries, the nutrients tend to be retained in the estuary rather than being flushed out. In contrast, cyanobacteria are small and do not sink out of the euphotic zone. Furthermore, they are grazed primarily by protozoans which excrete soluble nitrogenous waste products which are immediately available for phytoplankton use. This rapid recycling of nutrients may, in fact, help to maintain cyanobacterial blooms. However, by being retained in the surface waters, nutrients are more likely to be flushed out of the system by down-estuary surface flows. Thus, nutrient cycles may differ with respect to the principal agents of recycling, and the sites and rates of recycling between phytoplankton communities dominated by coccoid cyanobacteria and those dominated by larger phytoplankton.

In conclusion, it appears that the tidal freshwater Potomac River still contains sufficient nutrients to support a major bloom. It is apparent that in future work in this region, more attention must be accorded to geochemical and biological processes which regulate the flux of nutrients between the sediment and water column. The recent emphasis in sediment processes related to nutrient cycling illustrates the need to consider the total ecosystem when considering plankton processes. Experiments on phytoplankton-nutrient interactions may be performed in bottles, but it is important to remember that phytoplankton don't live in bottles; they exist as part of a complex ecosystem with air-water and sediment-water interfaces and are subject to meteorological as well as hydrologic influences.

In the more saline portions of the Chesapeake Bay, I think we are only beginning to realize the potentially important role played by cyanobacteria in planktonic processes. Their contribution to primary production during the warmer months and their impact on food chain and nutrient recycling processes are likely to be substantial. It is unfortunate that the recently instituted Chesapeake Bay phytoplankton monitoring programs in both Maryland and Virginia, which are designed to provide baseline data on phytoplankton abundance and composition into the 21st century, are not using enumeration techniques which are capable of accurately counting cyanobacteria.

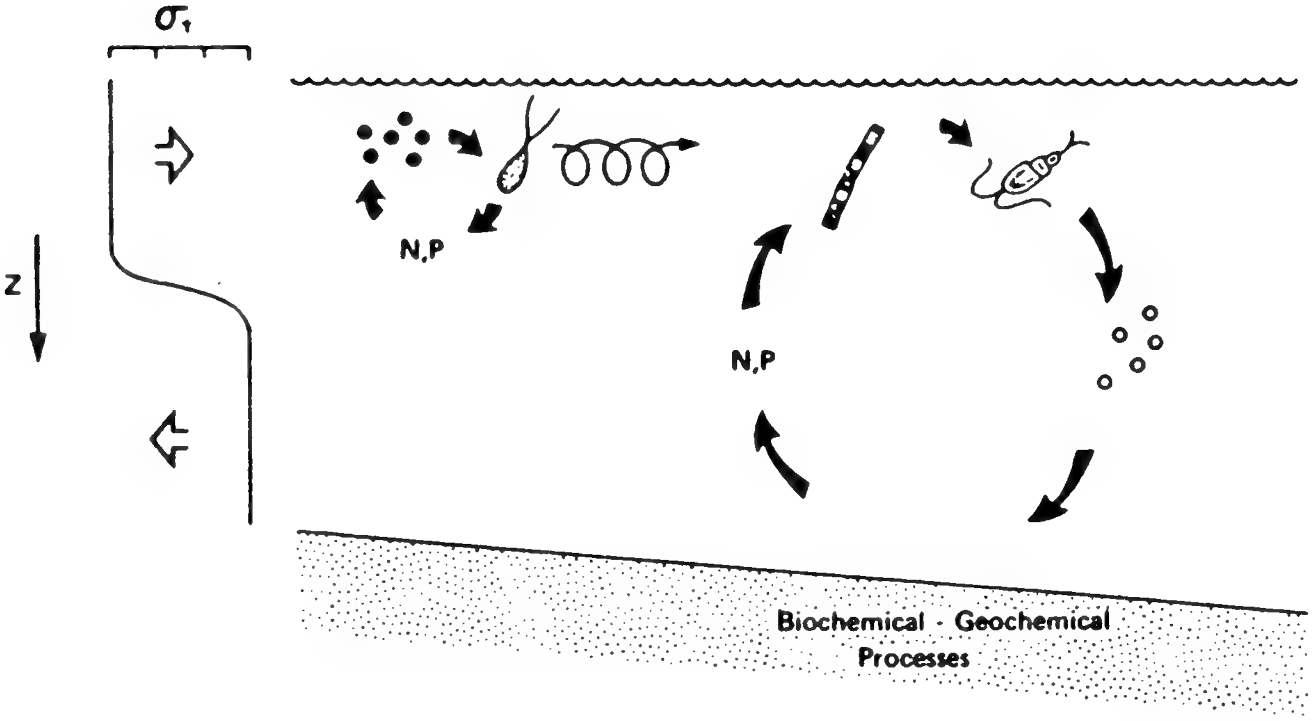


Figure 6

Possible routes of phosphorus (P) and nitrogen (N) recycling in a hypothetical two-layer estuarine system.

Acknowledgements

We would like to thank Drs. S. Seitzinger, H. Marshall, and K. Sellner for allowing us to use their unpublished data.

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MANAGEMENT ISSUES

CASE STUDY: POTOMAC RIVER - BETTER OR WORSE?

by

Drs. James P. Bennett and Edward Callender
United States Geological Survey

Abstract

In the 30 years preceding 1985, approximately $1 billion was spent on upgrading sewage treatment plant performance in an effort to improve water quality conditions in the tidally influenced Potomac River near Washington, D.C. Although algae blooms can still occur when hydrologic and weather conditions are favorable, dissolved oxygen conditions in the tidal-fresh portion of the river are greatly improved. The greater than natural present-day supply of nutrients to the estuary has aggravated the naturally-occurring phenomenon of summertime bottom water anoxia. It is not clear that recent cleanup efforts have had any effects on the phenonmenon, and in fact the large reservoir of nutrients in the bottom sediments should prevent the effects of cleanup from becoming evident for some time. The recent resurgence of submersed vegetation in the tidal-fresh portion of the river has a potential to alter nutrient budgets throughout the influenced portion and appears to have had a positive effect on the tidally water quality.

Dr. Bennett: A number of the very difficult technical issues that I was concerned about being able to present in 20 minutes have been brilliantly covered earlier; therefore, I will proceed right to the heart of the issues.

I will address three different topics in this presentation. First, better or worse in the tidal river; second, better or worse in the estuary; and third, some recent developments that may well invalidate extrapolating these conditions into the future. In the USGS study, the tidal river extends from Chain Bridge near D.C. to Quantico; and the estuarine zone extends from Morgantown, Maryland, to the mouth on the Chesapeake Bay.

In the past 20 years, approximately one billion dollars have been spent on construction and improvement of the sewage treatment plant capabilities in the District of Columbia. As you saw in one of the earlier presentations this morning, probably the most advanced waste treatment facility, certainly the largest advanced waste treatment plant in the Chesapeake Bay watershed, is in the District of Columbia. Although Figure 1 shows an approximate 2.5 fold increase in waste-water flow in the last 30 years, 5 day B.O.D. and total phosphorous, both, have decreased markedly over that time span. At the same time, total nitrogen loading has been essentially constant since 1970. Now looking at the River, what has that billion dollars bought us?

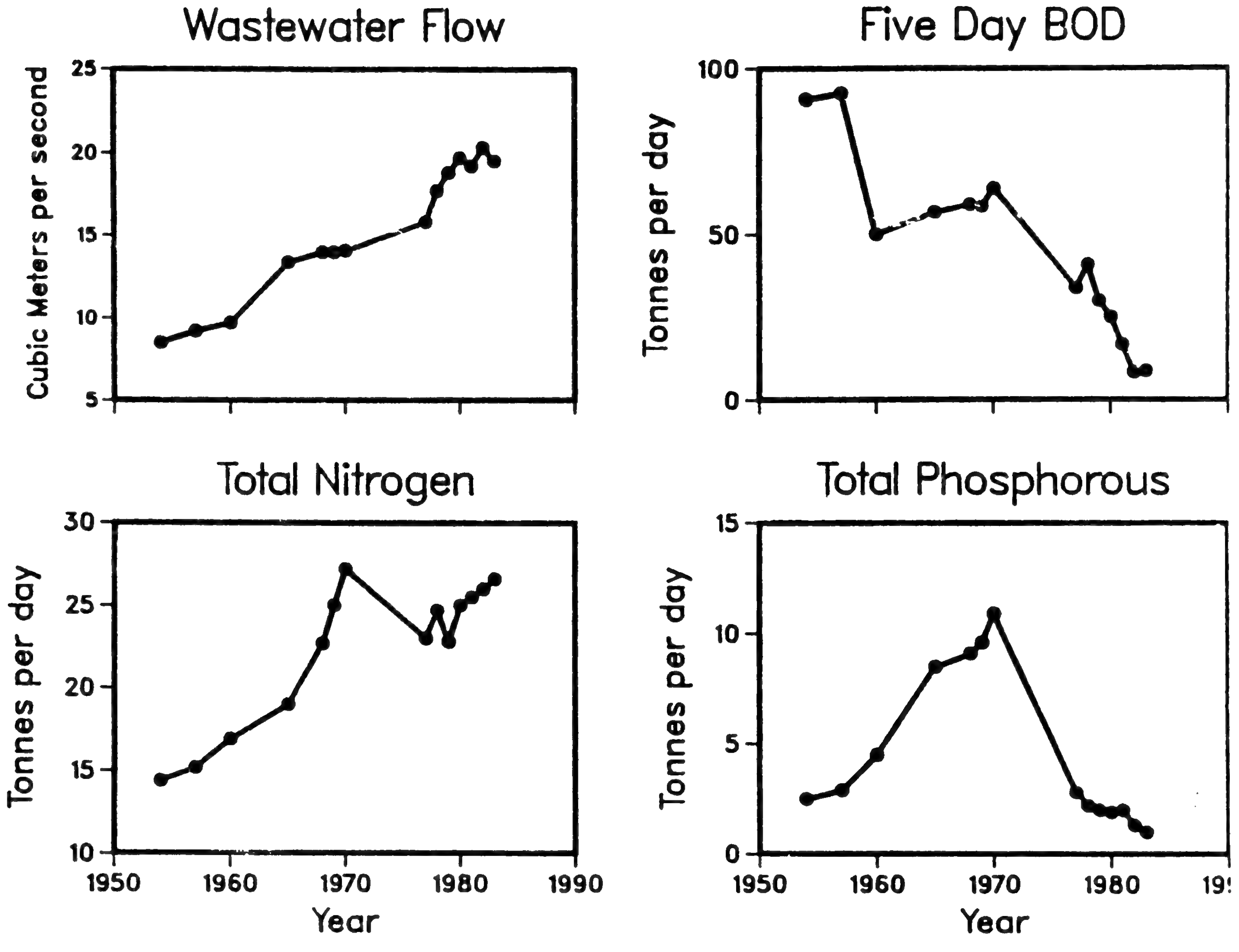


Figure 1 History of Sewage Treatments Plant Loads to Tidal Potomac River.

The next four figures present longitudinal profiles showing the evolution over time of critical water quality parameters in the segment of the River between Chain Bridge and the U.S. Highway 301 Bridge (Morgantown). All data were collected during August and as nearly as possible at comparable discharges. In Figure 2, the earlier profiles show very low dissolved oxygen immediately downstream from the Washington, D.C. area. More recent profiles all show improved conditions. That is the primary result of the work that's gone on in the D.C. area sewage treatment plants in the last 20 years. The dissolved ammonia profiles in Figure 3 show a great improvement in the ammonia picture following bringing on line the nitrification facility at the Blue Plains sewage treatment plant between 1980 and 1981. Figure 4 shows total phosphorous as "P." The 1968 profile shows P values much greater than any of the others and the gradual improvement has continued since 1977.

Figure 5, the final longitudinal profile shows chlorophyll-a. The observation was made earlier that it is much more difficult to illustrate the cause-and-effect relationships governing these longitudinal profiles. The reason being, that there is no significant nutrient limitation on chlorophyll-a in the tidal river, at any rate, until chlorophyll-a concentrations of bloom proportions are reached.

We have developed a phytoplankton growth index, which incorporates all of the independent variables that were discussed in the previous presentation. In addition, we included a measure of spring-time inflow which improves the predictive capability of the index. Figure 6 gives a plot of index values and descriptions of the independent variables.

In the tidal river the answer to the question of better or worse is, with respect to dissolved oxygen, much better. With regard to the occurrence of alga blooms, it depends on hydrologic factors, on sunlight, on temperature, and on spring-time inflow rather than what we've been able to do with regard to reducing nutrients. We haven't reached a point where there is any significant nutrient limitation at least until after bloom conditions are well established. Here also, the answer to the question better or worse is better because modern-day blooms haven't been accompanied by the periods of anoxic degradation that were common in the 1960s.

There has been considerable discussion of nutrients here. Before I proceed to the estuary, I would like to briefly address nutrient budgets, where the nutrients come from, and where they go in the Potomac River. The first column in Figure 7 shows the

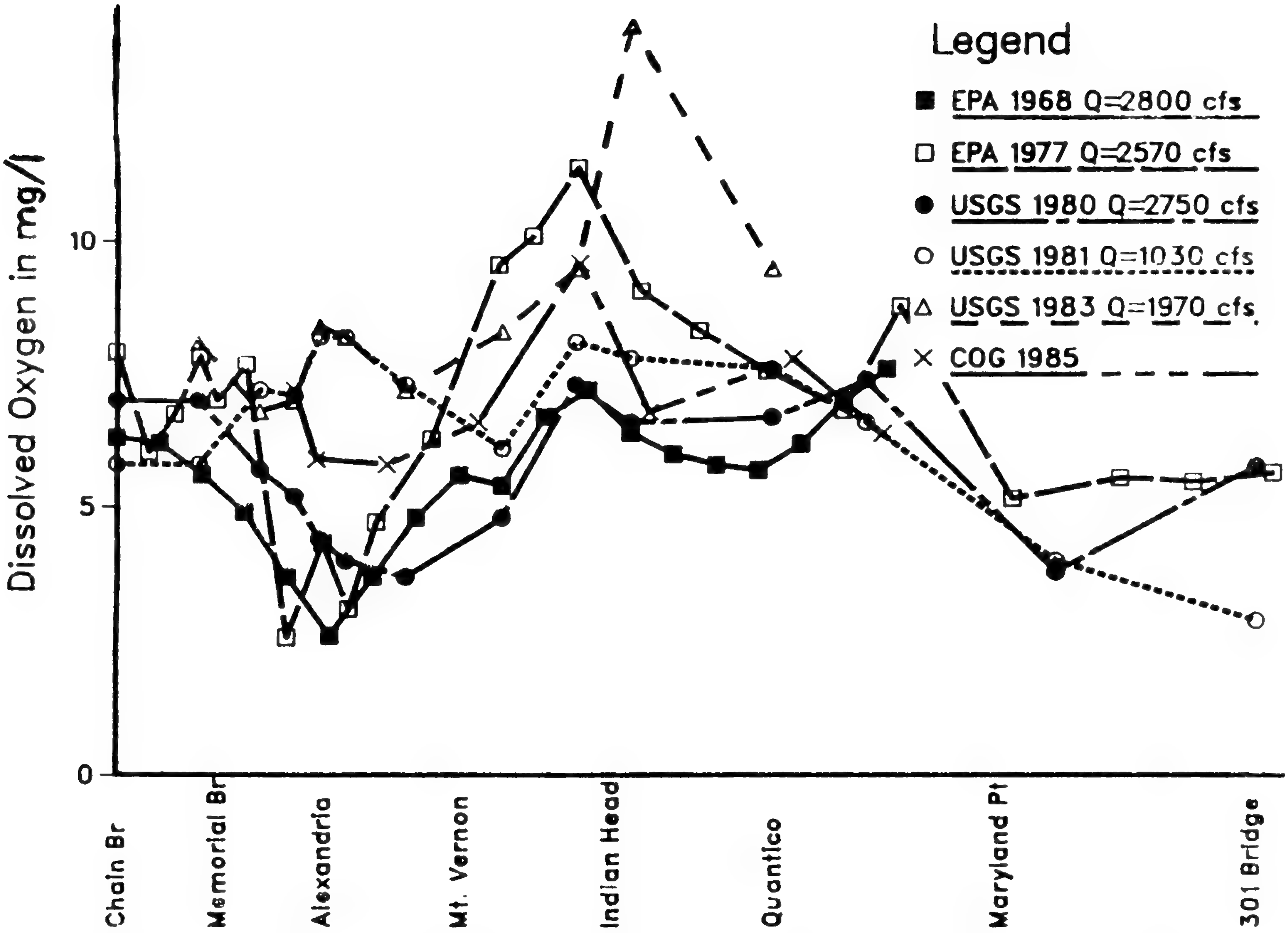


Figure 2 Longitudinal Profiles of Dissolved Oxygen, 1968-1985.

Figure 3 Longitudinal Profiles of Dissolved Ammonia, 1968-1983.

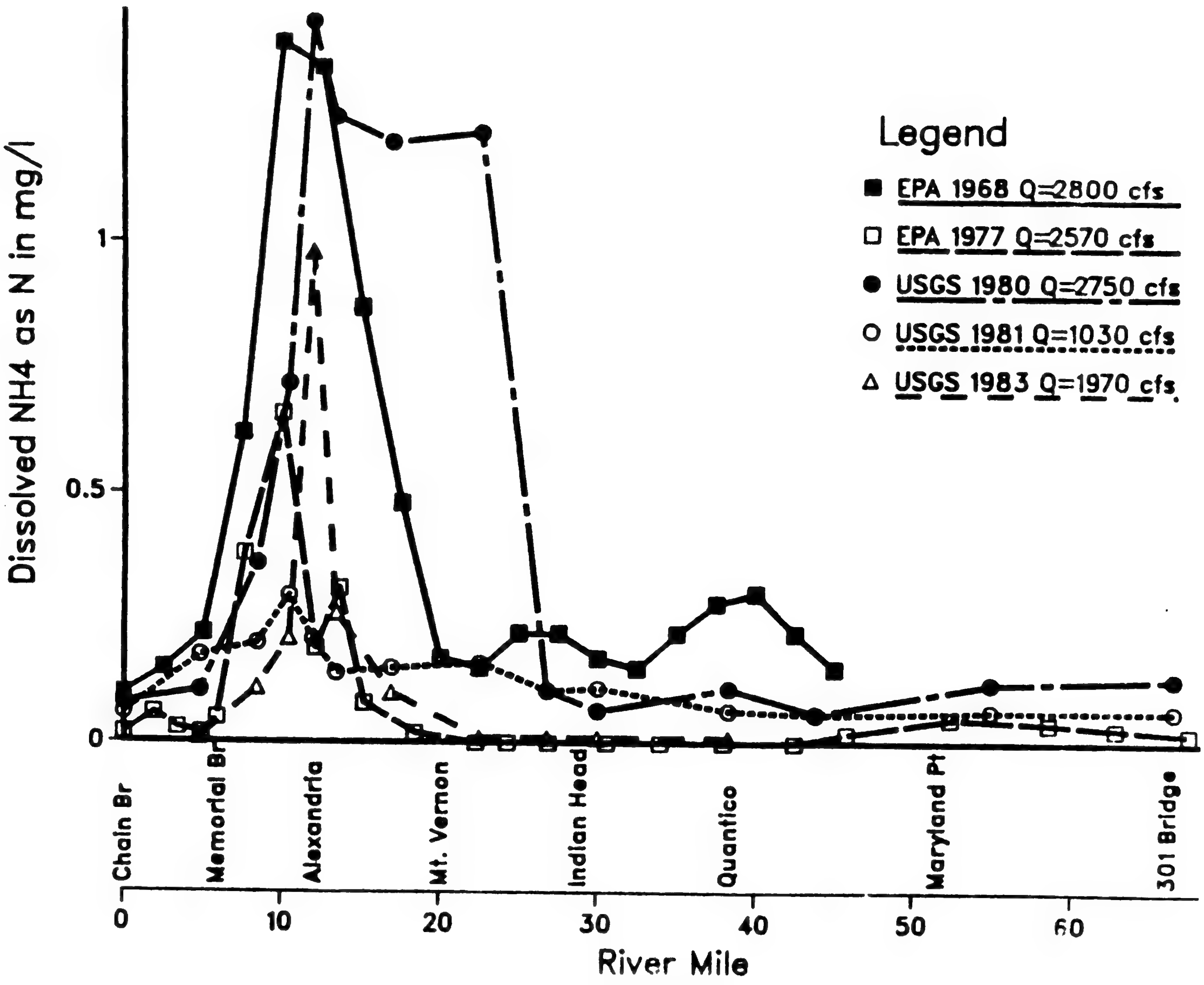
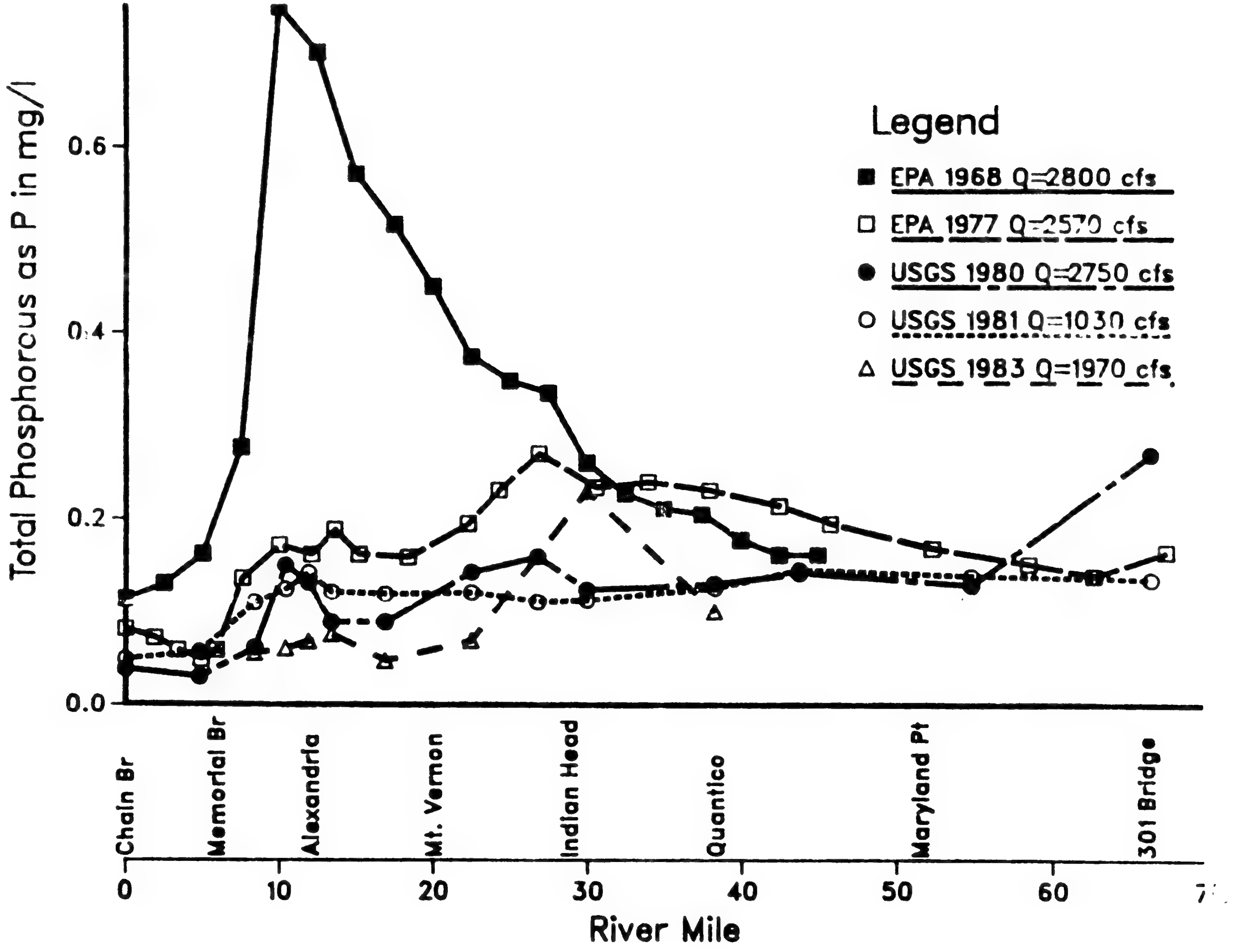


Figure 4 Longitudinal Profiles of Total Phosphorous, 1968-1983.



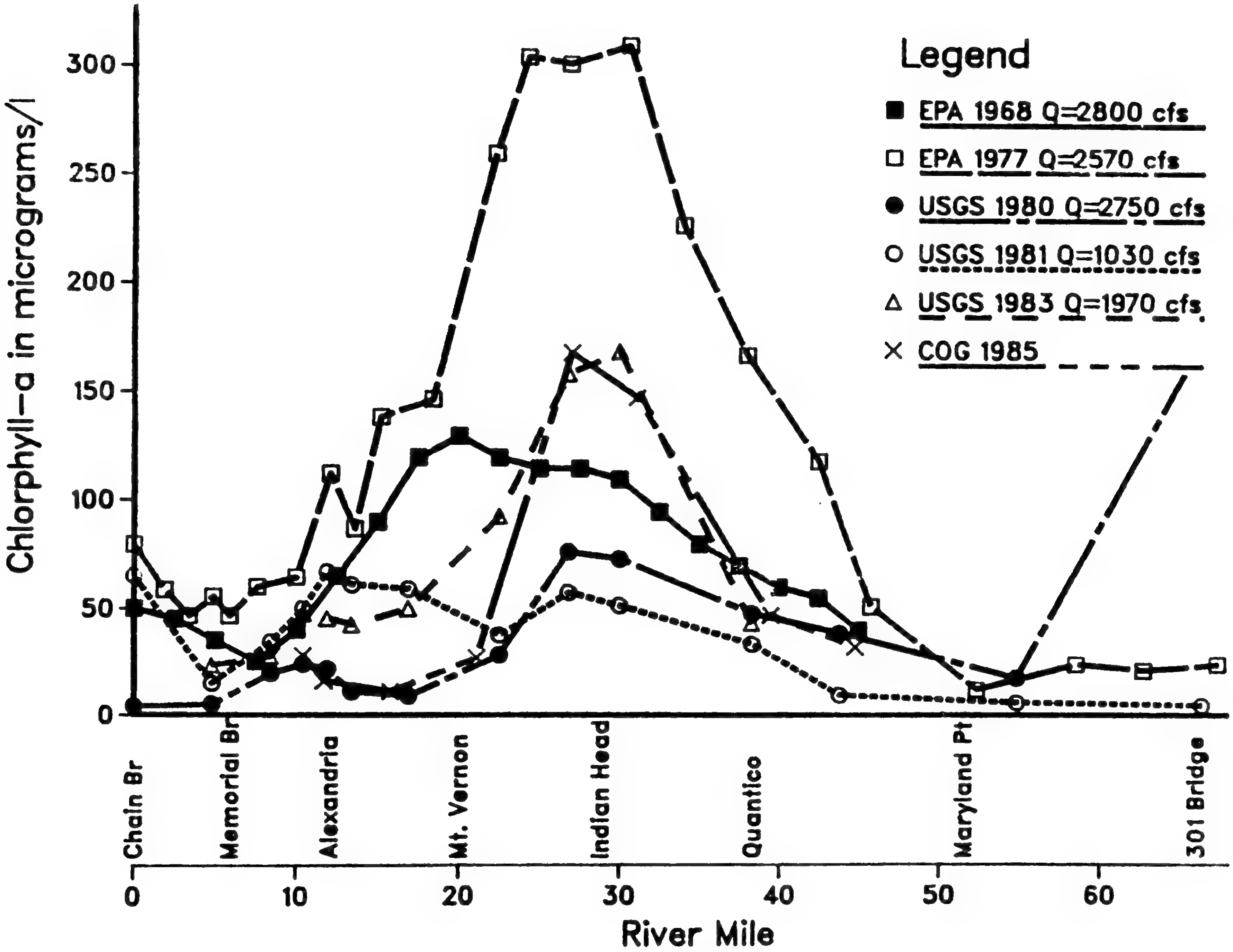
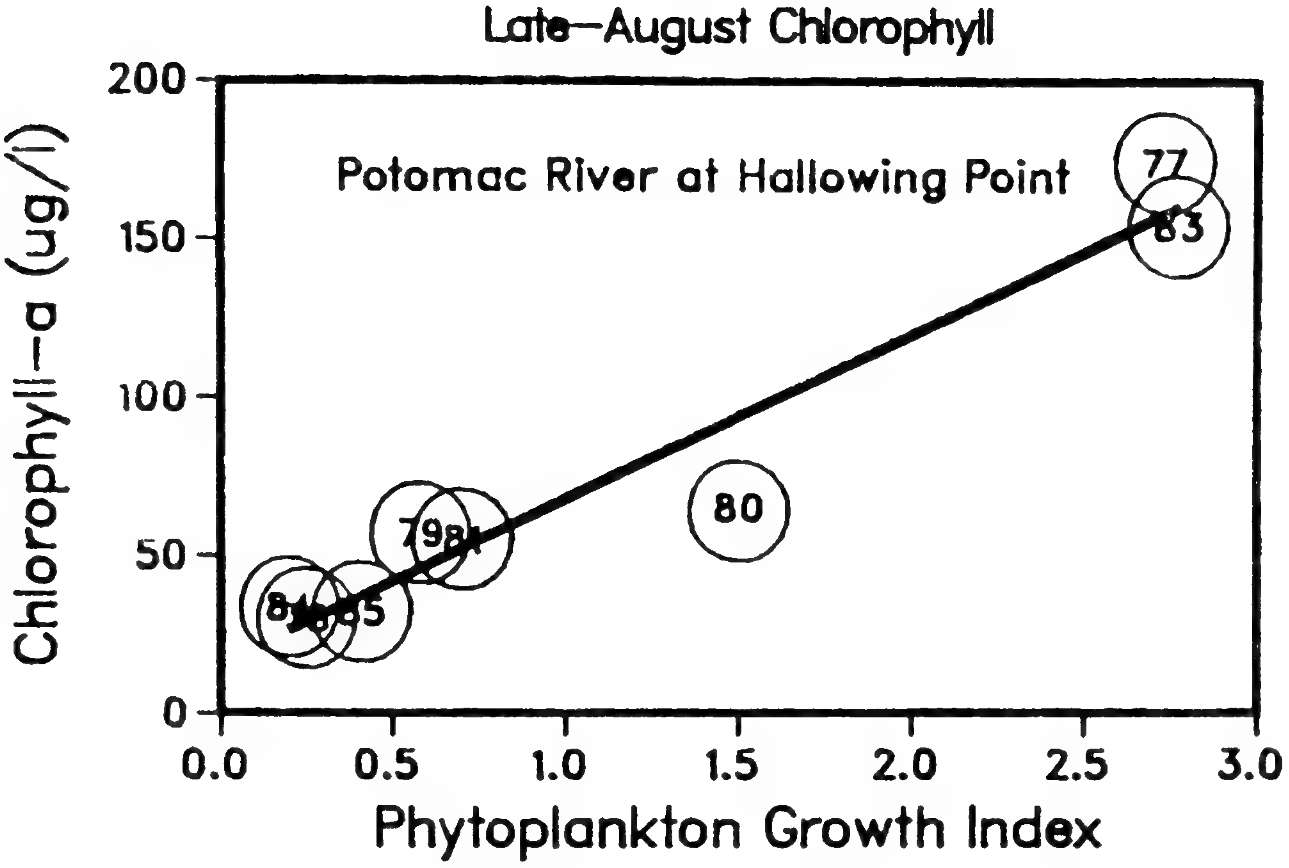


Figure 5 Longitudinal Profiles of Chlorophyll-a, 1968-1983.



$$GI = [RI*SI*TI]_{July}\ [RI*SI*TI]_{Aug}\ II$$

RI = Retention Index = (Ret time)/(Ave ret time)

SI = Sunlight Index = Min sun/Ave min sun

TI = Temperature index = Water temp/Ave water temp

II = Inflow Index = Spring inflow--January through May

Figure 6 Late-August Phytoplankton Chlorophyll-a Growth Index for the Lower Tidal-fresh Potomac River.

Annual Loading and Percentages by Source and Sink

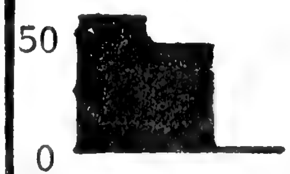
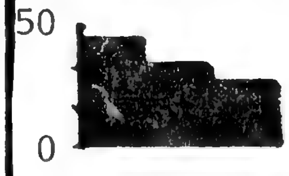
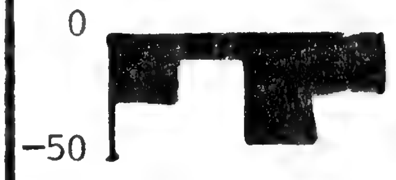
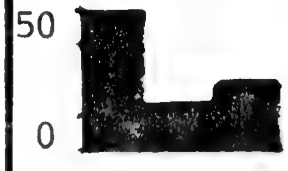
	NUTRIENT IN TONNAGES	SOURCES RIVER NON POINT POINT	SINKS TIDAL RIVER TRANSITION ZONE ESTUARY CHESAPEAKE BAY
Sediment	2,000,000		
Dissolved Silica	112,000		
Total Phosphorous	4,100		
Total Nitrogen	44,000		

Figure 7 Summary of Nutrient and Sediment Sources and Sinks by Percentage.

amounts of various nutrients entering the tidally influenced Potomac River, during the water years 1979 to 1981 (i.e., October 1978 through September 1981). In this figure, the "River" source refers to the watershed upstream of Washington, D.C.; the "Non-Point" source refers to all direct runoff and tributary inflow below Washington; and "Point" refers to sewage treatment plants.

Restricting this discussion to total phosphorus and total nitrogen, approximately one quarter of each comes from non-point sources; that is, from the sewage treatment plants. Approximately half of the supply of each nutrient comes from the "River" source and the remaining quarter from local runoff. It is important to remember that only 25 percent of total nitrogen and total phosphorus come from sewage treatment plants; the remainder comes from sources that are much more difficult to control.

Where do nutrients go? Roughly 75 percent of both of these nutrients are retained within the system or, in the case of nitrogen, denitrified out of the water column. Therefore, between the head of tide at Chain Bridge and the Chesapeake Bay, the Potomac Tidal River and Estuary remove about 75 percent of those two nutrients. Most of that removal occurs in the estuary.

Consider the estuary and recall earlier presentations that showed that these nutrients have been collecting in the estuarine bottom sediments for quite a number of years. These bottom sediment nutrients are available for recycling during summertime and produce food for the algae. USGS observations have shown that the organic carbon in the bottom sediments changes in composition between U.S. Highway 301 Bridge and the mouth of the estuary from essentially terrestrial in origin to mostly marine in origin. This lends support to the statement made earlier that an appreciable fraction of the carbon that produces the bottom-water anoxia is grown in place.

Figure 8 summarizes the results of an in-depth reconnaissance conducted by the USGS during the summer of 1984. The panel in the lower left shows the proportion of the volume of the estuary that was anoxic during the time period from April through October. Approximately, 20 percent was anoxic at the peak, and this volume covered 30 percent of the bottom area. This is obviously an extensive problem.

Because nutrient removal efforts in the upper part of the river have essentially not influenced the nitrogen supply, what we've done so far has done nothing and will not do anything to significantly alter this situation. I can say this because USGS observations from the 1984 summer indicate that if there is a limiting nutrient, it is nitrogen. In so far as the estuary

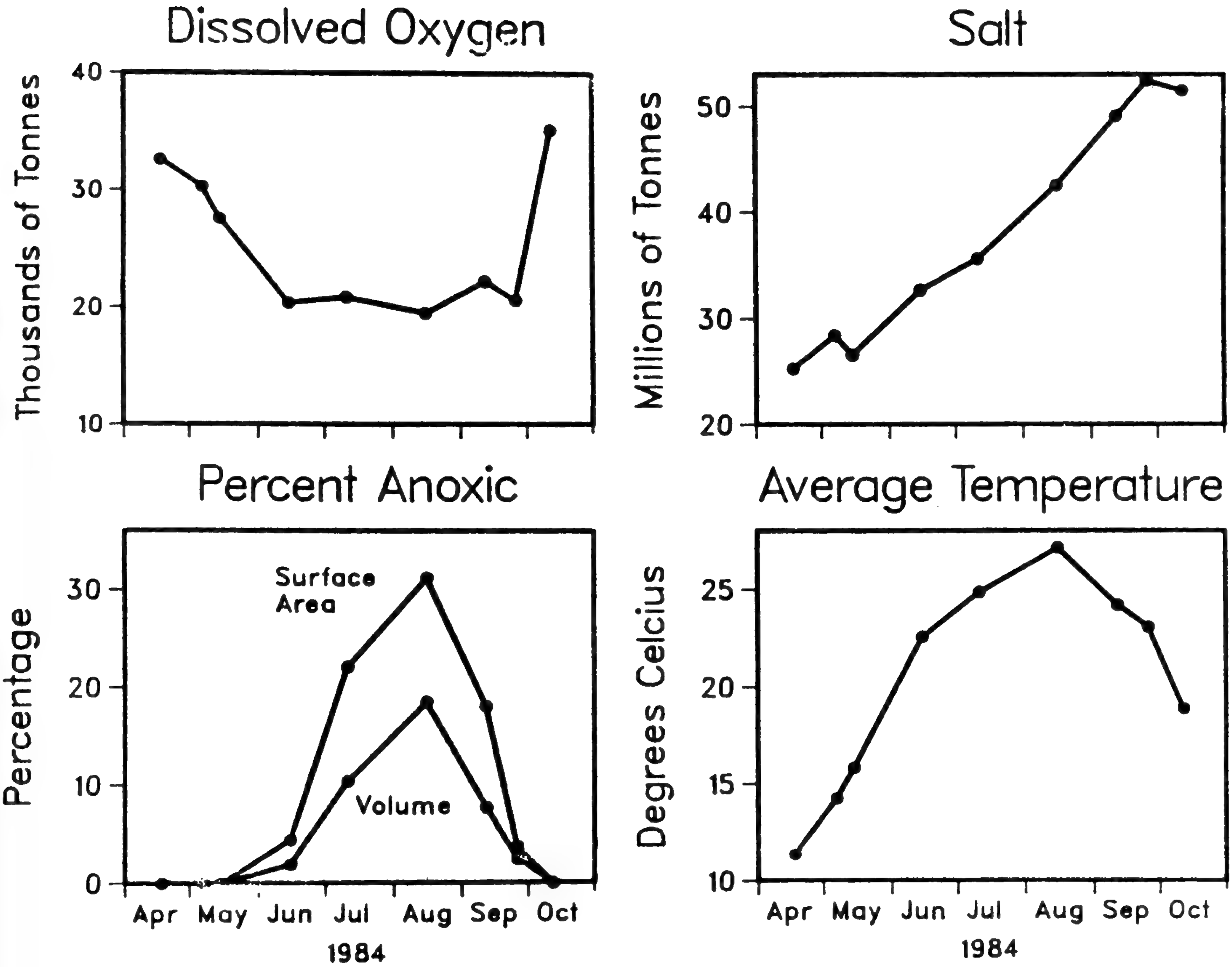


Figure 8 Summertime 1984 Time Histories of Amounts of Oxygen and Salt, and Average Temperature in the Potomac Estuary, Cobb Island to Chesapeake Bay.

receives more than its "natural" supply of nitrogen then, as was mentioned earlier, it was worse than "the natural situation." I say this because of the tremedous reserve of nitrogen in the bottom sediments, improvements due to reduction of the nitrogen supply will take an appreciable length of time to become apparent.

I'd also like to reinforce the point made earlier concerning the variability of the extent of anoxia. Stratification, a physical phenomenon, is very important in determining how early it develops and how long it lasts. During the high inflow summer of 1984, stratification developed early and was strong throughout the season. USGS observations have been that anoxia was much more extensive during 1984 than in the summer of 1985, which was a low-flow summer.

The remainder of this presentation deals with conditions developing now in the tidal river which have a potential to radically alter the nutrient budget picture just presented. Since 1983, there has been a major resurgence of the amount of submersed aquatic vegetation in the tidal river. Between each of the summers 1983 to 1984 and 1984 to 1985, there has been an approximate ten-fold increase in the amounts of submersed aquatic vegetation growing in the tidal river.

The U.S. Army Corps of Engineers, calculated that the plants have the potential to cover 33,000 acres in the tidal fresh part of the Potomac River. This is about two-thirds of the river bottom between Quantico and, say, Haines Point. The plants may be present from as early as late May through mid-November. Considering the 33,000 acre figure and using preliminary estimates of the density of the biomass cover from 1985 USGS submersed vegetation surveys, one can conclude that the biomass that could be produced is on the order of ten times what was contained in the algae bloom of 1983. This is a significant amount of biomass and it could have quite a major effect on the water quality conditions in the river. This biomass would tie up a 12 to 40 day (depending on which author's figures on how much phosphorous is contained on the average in these plants) supply of the sewage treatment plant supplied nitrogen and a 30 to 150 day supply of the sewage treatment plant supplied phosphorous. Again the potential to significantly impact the water quality conditions is obvious.

The plants also significantly alter the water s clarity. In areas where there are large patches of vegetation, the bottom is clearly visible in 5 feet of water. Whereas, in earlier years, visibility was limited to a few inches. There has also been a major change in wildlife in this area; large numbers of sprey, Canadian geese, and ducks are present. Although marina operators are not too happy about this development, in general, water quality conditions seem to have improved with the appearance of the SAV.

In summary then, the billion or so dollars that were spent on improving the STP treatment capabilities in the D.C. area have produced a better effect, a positive effect, with respect to dissolved oxygen conditions. However, there still doesn't appear to be enough nutrient removal to significantly limit algae blooms. In the estuary the nutrient cycling and the anoxia have not been significantly affected by recent cleanup efforts. And I think we're still waiting on the verdict on the reappearance of the submersed vegetation.

Thank you.

ASSESSING ENVIRONMENTAL QUALITY: NEW TECHNIQUES

by

Dr. Walter R. Boynton
Chesapeake Biological Laboratory

Dr. Boynton: As my presentation will demonstrate today, it's going to be apparent that most researchers and other people interested in Chesapeake Bay deal with the same estuary and interpret it in different ways. And that can be both instructive as well as amusing.

Let me make a few quick introductory points here. One is that throughout the world and throughout the United States estuaries are common. It's something that we see all over our landscape. They are, in addition, close to metropolitan areas, close to people, and they're very productive. And because they're close to us and because they're productive and valuable, we have major interests in watching the patterns that emerge over periods of time.

This is sort of the union card around here I think. In any case, I would like to make the additional point that problems either real or perceived that have appeared in the Chesapeake and its tributaries are problems similar to those seen in estuaries around the world. So in some ways it's gratifying that we're not dealing with some sort of unique environmental problem; it's one that's shared by many around the world.

So with that little bit of introduction, I have to talk about monitoring and some approaches to monitoring. In particular, I'm going to talk about some of the things that we've considered in developing one of the newer monitoring programs that's currently operating in Chesapeake Bay, and this is one that's supported by the Office of Environmental Programs (OEP), State of Maryland.

In the view of many people associated with that program, some of the key goals have to do with the description of trends of important variables -- meaning variables that we can, through mental or more formal models, relate to the status of the environment and relate also to possible management strategies. Secondly, also of real importance, is the detection of significant differences in both time and space and how they relate to these important descriptors of the environment. I might add here that this is something in the past we may have fallen down on a little bit or, perhaps, simply have not done as well as we could have done. And the last is synthesis of monitoring data into forms that are useful to resource managers -- and I mean -- in terms of water quality models, statistical relationships, input/output models, one could throw in various types of budgets, and so forth.

This is probably one of the more difficult tasks to actually accomplish. Throughout the Bay Region and various buildings here and there I'm told that there are these large data bases that are either being developed or are developed and so forth. And while that's good and perhaps it's absolutely necessary, the reason for doing all of this storage and so forth is so that we can try to put some of these pieces of information together in coherent pictures that are useful in addressing the management issues of the Bay.

Let me try to provide a little bit more background on the notions of monitoring in estuaries, in particular Chesapeake Bay. And I have three points to make.

Estuaries are complex. There are lots of components. There are the conflicts in the resource uses that are impacting the environment and the environmental impact on these resource issues. Take for example, the Patuxent River Basin where there's a power plant, electricity being generated, recreation, and commercial fishing's going on. There are timberlands, which have different runoff characteristics than agricultural activities. Sewage discharges, treatment and so on is another feature of the landscape. And one of the things I've always found interesting about some of these basins is that, for example, the Patuxent River is also an important source for drinking water. So we go from drinking water to sewage treatment to fisheries, recreation and so forth. So we're dealing with fairly complex systems and many of these activities have important inputs modifying the water quality and habitat conditions.

The second point is that these systems are variable. The connection between the land and the water, I think, to a large extent is responsible for this. And the variability takes place over many different time scales, which need to, of course, be recognized for monitoring programs. The Patuxent River Basin time scales show gross characteristics of change.

Another important indicator of change in the Chesapeake Bay variability is in the long-term record of freshwater flow to the Bay. And if you're an ecologist, you can visualize patterns where there seems to be periods of low freshwater flow and high freshwater flow. Variability is an important consideration.

There are some things that the SAV group at the University of Maryland put together; change in terms of atrazine, a herbicide, being used in the basin; variability in the Susquehanna River flow; some notions of sediment yield in the Patuxent River Basin being very possibly influenced by both construction activities and practices through several decades; Hurricane Agnes, a natural event; fertilizer sales from Maryland; again, change in general practices; and sewage discharge from Washington.

So what I'm saying here is that within the context of monitoring characteristics of the Bay, there are important forcing functions, some of them natural, some of them man-influenced that are also changing.

Monitoring programs, in our view, need to be able to sort out the natural variability, and I've given you some examples of that, from the types of change that is induced by human activities. If we can't do that, then we have a real problem in continuing to monitor.

We also need to be able to detect and reasonably assign changes in habitat quality or water quality conditions to management activities. Again, we're interested in being able to -- it seems necessary, rather -- to be able to detect changes in inputs and then from soup to nuts, if you will, in the biological food web situation.

And lastly, we need to be able to take some of these nice little patterns for monitoring, and as I said before and as I say again, be able to synthesize these various and sundry factors influencing the things we're concerned about in a way that's useful for the management community.

Various people have showed some examples of monitoring; I wanted to show you a few more that have been going on in the Bay Region for a number of years. One of them, for example, is an anadromous fish survey that's been conducted since the early 1950s. So there's some sense of continuity there.

Another program of monitoring which has changed its form a bit over the years is that of submerged aquatic vegetation sampling. And it shows the pattern in sea grass abundance in the Upper Chesapeake Bay.

As you know, and I'll show you explicitly in a few minutes, there's lots of different kinds of monitoring going on here. Some of it is of relevance to the Chesapeake Bay, but the monitoring takes place in the Canadian Artic, as well as through the flyways. For example, a bit of synthesis in terms of monitoring wherein the relative abundance of vascular plants can be correlated with two species of dabbling duck abundance as percentages of the North American population for a number of years. Again, some continuity, a little bit of synthesis and the suggestion that perhaps the relative abundance of ducks in the Chesapeake, those that have some relationship to sea grass, is in fact related to sea grass abundance. You can see, in the recent years, when the decline was very intense, redhead abundance was really quite low.

There's considerable room for improvement in our monitoring, to say the least. There are data gaps. I might ask where are the data from 1939, 1940, 1941, 1965, 1968 and so forth? And the fact of the matter is, for many of these variables, dissolved oxygen being an obvious important one, they simply don't exist. So one area I think that the monitoring community, scientific community as well, ought to be very keyed on is this notion of continuity in measurements. That's one place I think we can really improve. And I'll say a few more things about that in a moment.

Throughout the day we've seen all kinds of activities that are occurring in the Chesapeake Bay. And I took some time and made a number of phone calls and listed what I call examples of Chesapeake Bay monitoring programs. Early on in my search, it became very clear to me, without a very large effort, I wasn't going to be able to list them all. I have a few points to make here. One is that there is an awful lot of activity going on that can be construed to be monitoring or is in fact called monitoring.

The second point is that, and this is good in our view, we're worried about things like freshwater inflow, a forcing function on the Bay. People are interested in trying to assess migratory waterfowl, one of the end products of the Bay, which has substantial economic interest.

And one could go on with examples of where people are measuring rate of input, where they are measuring the relative abundance of characters that are deemed important in an estuarine system.

Lastly, there are all types of measurement schedules. Some of them by and large seem to be quite appropriate; others might need a little more fine tuning, but they range from the decades to the hours. And I'll say a bit more about that in a second.

In developing the OEP Monitoring Program, we considered several generic issues at some length that I thought might be of interest to this audience when they're considering, perhaps, putting monitoring programs together.

One of the characteristics of monitoring programs, I don't mean to embarrass anybody, particularly myself, is that it seems that measurements have to be reasonably simple. Monitoring programs need to go on and on and on in order to develop the type of trends that are interpretable and in which we can have some confidence.

These measurements need to be replicated so we can see and detect differences. It would be outrageously expensive, possibly not even technically feasible, to on a very routine basis do some very "Jet Jackson" like things. It is probably important that some of these sophisticated measurements are made to resolve and help us interpret monitoring; but it seems to us that basically monitoring measurements made in the Bay need to be reasonably simple because they're the ones that we can reasonably afford and that can be made on a routine basis.

Consideration of time and space scales has gotten a lot of press lately. And it seems to me from my view of these monitoring programs that the idea is sinking in that one cannot go out and measure all variables with the same spatial and time intensity. Different things are happening on different time and space scales, and in order to understand them they need to be measured appropriately.

For example, if one were to take contours of oxygen from the east to the west side of the Bay, drop an oxygen probe and measure at about 8 meters or so, there's 4 parts per million oxygen, one would come to quite a different conclusion on the first day if 3 days later we went down and measured oxygen at about 6 or 7 or 8 meters and found out that it was anoxic.

So the point here is that we can reach misleading, perhaps confusing conclusions if some of these things are not measured on an appropriate time and space scale. That's easy to say. It's considerably more difficult to do, and there is, of course, uncertainty.

One of the nice things that's been happening, I think, in the last decade in the Bay is structures. Real things like these that are part of the Bay, we're starting to know about. And the more we know, I think the more fine-tuned a monitoring program could possibly be.

A feature of these monitoring programs that I'd like to promote and the group would like to promote is the notion that some measurements be integrated. That is, take into consideration a number of variables and measure something that tends to not only be of management or scientific interest, but also integrates some other things that may in and of themselves be hard to interpret. Phytoplankton, biomass, and photosynthesis are naturally linked. In regular monitoring terms what we're talking about is phytoplankton biomass, chlorophyll-a measurements, and primary productivity measured with carbon 14 or some other standard technique. But the notion of some kind of integration of lots of variables into something that's measurable and important is a useful consideration.

The third point, and I made these in other places, is long-term. I have some interesting primary productivity data from a place in the Mid-Chesapeake Bay over a 6-year period. Not a tremedously long period of time, but it's 6 years, and these sort of data bases are a bit rare. Made with the same technique once or twice a month for 6 years. And what we find here is some very substantial differences not so much in the pattern of productivity, but rather in the magnitude of the productivity.

Interestingly enough, we had a bit of a natural experiment occurring here. In June of 1982 tropical storm Agnes added a considerable amount of freshwater and nutrients and other materials to the Bay. And one story could go that the phytoplankton productivity and phytoplankton biomass also followed a similar pattern responded, and there was a bit of a memory there perhaps in 1973, and then productivity gradually decreased to around 400 grams per square meter per year thereafter.

In 1973 to 1977, nutrient loading from the Susquehanna River was reasonably comparable. So we have a bit of natural variability here that could have led us to some quite different conclusions about the response of the Bay to large influxes of nutrients had this data base not been around. So, long-term data are very important.

Lastly, we're very concerned with the infrastructure within these monitoring programs to try to synthesize the data that are being collected. Not just organize it, but rather synthesize it into forms that makes some scientific sense. In other words, we think we're getting a good reflection of what reality is, and into a form that's useful in making decisions.

This is from that program. It's a very early piece of information that was developed. And it has to do ultimately with trying to understanding what's regulating and modifying the degree of anoxia in some portions of the Bay.

One of the things that I think is interesting here is that even in our early attempt at some synthesis, we see some things starting to connect up within this ecosystem, which is causing an event that we're all concerned about, and that is, productivity generating the primary organic material there, sinking some portion beneath the pycnocline and getting a nice reflection in the subpycnocline chlorophyll with the amount of material that is on its way into the deep water vis-a-vis the sediment traps and with some lags. This seems to be a signal, perhaps a mixture of both physics of the system and biology describing the degree of anoxia.

So I would make a strong punch that collecting data is nice. Having well-designed programs is, of course, absolutely essential. But spending a good deal of time and recognition of the importance of synthesis, putting together the story, is also incredibly important.

My final point concerns something that's been getting a little more press nowadays than what it did in the past, although it's certainly not unique at this point, and that is trying to consider within the context of a monitoring program not just stocks, but also the rates. To say this another way that we all understand, it is awfully important for us to know how much money we have in our wallet or bank account. That is very, very important and we're all concerned with it.

Hence, it's also important in ecosystems to know how many characteristics are there and what sort they are and so forth. And we're doing a reasonable job at that to some extent.

It's also important in economics or in our own personal life, and it helps us to understand how much money there is in our wallet or bank account if we know who is writing the checks and how much they're for and when they're being written.

So what I'm suggesting is a mechanism that is available, lots of different examples of it, wherein within the context of simple, routine, mundane, boring, at times, monitoring programs one ought to be measuring some rates or fluxes. That is, the major things that are connecting these stocks and the reason for that is it gives us better understanding and some anticipation of whether the stocks are going to get bigger or smaller.

I suggest continued monitoring of these fluxes that are being either directly or indirectly measured within some of the monitoring programs, i.e., inputs from the land of various and sundry sources; that's the rate, those are being measured; the concentrations of nutrients, of plankton, and to some extent the abundance of members of the food web are being measured; and of course stock measurements.

We're also starting to measure, either directly or indirectly, some kinds of recycling from the bottom back into the water. A number of people have suggested that bottoms may be real important influences on overall water quality.

The deposition of organic matter from the plankton, the composition of it from the shallow euphotic waters to the deep waters of the Bay, is certainly another potentially important descriptor of water quality conditions and the possible trajectory that they might take.

I think I've made my points enough. There were a few of them. And I'm not going to reiterate, but I will answer any questions if you have them.

Thank you.

THE STEWARDSHIP OF THE CHESAPEAKE BAY FISHERY RESOURCES

by

Drs. Cluney M. Stagg and Brian J. Rothschild
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Stewardship means exercising responsible care of entrusted possessions. In the case that we are considering this afternoon, the fishery resources of the Chesapeake Bay are the entrusted possessions. The central questions that we will address are these: Who is taking care of Chesapeake Bay's fishery resources, and how can this task best be accomplished?

This doesn't necessarily have anything to do with how much money we spend on study or cleaning up the Bay. It has nothing to do with the number of conferences we have or media events. What it really has to do with is how we think about the resource, how we think about taking care of the resource, and the degree to which existing institutions lend themselves to the task of protecting the resource in a cost-effective manner.

Often the way we think about Chesapeake Bay and its resources is wrong-headed and frequently the cost-effectiveness of the way that we develop information on the resources is not efficient. With this as a point of departure, how can we hope to modify old institutions or create new institutions with new capabilities to do a better job of stewardship?

Let us look at the way we think about the problem, particularly from the perspective of how the process is portrayed to the public. It is amazing how the ordinarily clear thinking of public officials and scientists appears at times to be so facilely translated by the media. A recent newspaper article made the following assertions:

> "But a year after initiating a massive restoration effort, the governors, senators and cabinet officials were more optimistic about the health of the estuary."
>
> "We're getting on top of the problem; we're beginning to identify what's wrong with the Bay."
>
> "We're really at a point where we hope to see positive progress."

> "The public officials observed some of the toughest challenges now before Chesapeake Bay scientists."

Let's look in some detail at these four points:

1. What is the massive restoration effort and how do we measure the health of the estuary relative to fishery resources?
2. What are the problems? What's wrong with the Bay?
3. What progress has been made?
4. What are the tough challenges?

First, we consider:

<u>What is the massive restoration effort</u>?

When we talk about restoring the Bay, we are actually talking about restoring the living resources of the Bay. It was the decline in harvest of commercially and recreationally valuable fish that focused the public's attention on the Bay. The success of all the restoration efforts will be measured largely on the degree to which these resources become once again available -- particularly in the public's perception.

What has been referred to as the massive restoration effort involves at least $150 million dollars during this and next year, of which roughly 5 percent is being spent on fisheries management and enhancement *per se*. A considerable amount is being spent on protecting or enhancing water quality. This is good and there are valid reasons for wanting to restore water quality. But what are we doing about the stewardship of fishes? As the draft report of the Chesapeake Bay Commission Fisheries Work Group states, referring to water quality expenditures:

> "Unfortunately, we do not know when we can expect a response from these efforts in terms of the abundance of living resources, but it may be many years, even decades."

<u>What are the real problems</u>?

Often the *perceived problems* in fisheries are taken to be: eutrophication, oxygen depletion, loss of submerged aquatic vegetation, pollutants, acid rain, and so forth. In sum, fisheries problems are stated in terms of poor water quality and loss of habitat, and indeed these may be factors in determining fish abundance. From a fisheries management perspective, while not decrying what others are working on, these are not the really relevant issues.

Then what are the real stewardship issues relative to the fishery resources of Chesapeake Bay? First, let us discuss some of the more obvious manifestations of the fundamental problems.

1. The declining abundances of important species. Are these conditions due to too much fishing or to environmental factors or both. Consider the following specifics:

* American Shad - The abundance of American shad is at a historical low. Are there additional ways to assist in the recovery of this species, in addition to the current moratorium in Maryland?

* River Herrings - Commercial landings of the river herring have declined sharply in recent years. What is the current status of each of these species?

* Striped Bass - Despite a great deal of research, there's still many questions centering on the factors that determine year-class success in this species. Are we asking the right questions?

* Atlantic Menhaden - Catches appear to be stable. Are sufficient statistics being reported to be able to know with reasonable certainty?

* Atlantic Croaker - Can any management steps be taken to assist in the recovery of this species? Or are we dependent on climate-scale factors for any future recovery?

* Weakfish - This is one of the most important recreational species in the Chesapeake Bay. Do we need additional regulations to protect sea trout?

* Spot - Although year-to-year variability appears to be high, spot landings have generally declined since the late 1940s or early 1950s. What do we know from existing information about the causes for this decline?

* Oysters - This is the most valuable commercial fishery in the Chesapeake Bay and landings have declined almost continuously since the late 1950s. What do we know about the reasons for decline?

* Blue Crabs - This species is the key component of the seafood industry in Chesapeake Bay during the summer months. Does the existing information on the biology and population dynamics of the species support the current laws and regulations for blue crabs?

* Soft-Shell Clams - The soft shell clam harvest has declined dramatically since it peaked in the mid-1960s. Can we significantly increase the yield-per-recruit by reducing the minimum legal size, as recent preliminary studies have suggested?

Other examples of declining stocks could be given.

2. Allocation conflicts. Conflicts arise between recreational and commercial interests, users of traditional and modern fishing gears, and among states.

3. Determining the timing, location, and probability of success of oyster shell and spat landings. The oyster repletion program is the cornerstone of oyster management in the Chesapeake Bay. How effective is this program with respect to maintaining or rehabilitating oyster stocks?

4. Predicting the effects of hatchery construction for striped bass and oysters. For example, what is the likelihood of hatchery fry adding a significant enhancement effect to the striped bass population(s) or reducing heterogeneity of the wild stock.

5. Measuring the effectiveness of management activities. At present, we cannot because we do not have, among other things, good catch and effort statistics.

The points raised above represent some of the day-to-day problems faced by fishery management agencies and researchers.

The Fundamental Issues

We need to see serious consideration of the underlying, fundamental problems, which are essentially institutional issues. There is no system in place to provide overall strategic direction and focus to:

1. Fisheries Statistics - Catch and fishing effort for all species in the Bay are vaguely known. For most fisheries, there are no effort statistics and without these it is difficult to tell whether fluctuations in catch relate merely to changes in fishing effort or whether, in fact, they relate to actual changes in abundance of the populations. Without some appraisal of the catch and changes in catch per unit of effort, it is extremely difficult to determine changes in fish populations -- except those that are catastrophic -- and hence the quality of management decisions cannot be known.

2. Multi-Jurisdictional Management - Many of the Chesapeake Bay's resources, including striped bass, blue crabs, and American eels, are composed of single migratory stocks, however, they are managed independently by at least Maryland, Virginia, the Potomac River Fisheries Commission, and the District of Columbia. There are various degrees of interstate cooperation. At the present time, there is no mechanism which ensures the formal exchange of technical information on the resources of the Bay, nor is there an organization with the authority and expertise to enforce interstate fisheries regulations.

3. Institutional Building - We believe that there needs to be a means of coordinating in a formal setting the activities of the many research institutions and management agencies in the whole Chesapeake Bay Region, so that the quality of over-all fisheries research can be enhanced.

Progress

However, this is not to say that progress in some of these areas is not being made. For example, consider the following activities:

1. The NOAA appropriation of $1.5 million dollars for FY 1985, with $720,000 budgeted for conducting observations on living marine resources and $135,000 budgeted for improving fishery statistics.

A group that includes many of the scientists and managers involved with the Chesapeake Bay fisheries, called the Chesapeake Bay Stock Assessment Committee (CBSAC) has been formed to oversee this work. This group includes managers from Pennsylvania, Maryland, Virginia, the District of Columbia, the Federal Government, and representatives from the scientific community. The Committee was formed to develop a cooperative Chesapeake Bay Stock Assessment Program. However, this group does not have the authority to manage fisheries; and Federal funding is on a year-to-year basis.

2. Fishery management plans are being developed for a number of major fisheries by both Maryland and Virginia and informal cooperation is envisioned as these plans are prepared.

What are the scientific challenges?

We looked at some of the scientific challenges in a very brief way when we considered some of the day-to-day problems of fisheries management, and many are tough challenges. However, it seems to us that the greatest challenge isn't scientific. Rather, it is to get people to think about the right thing.

The challenge is not the development of many fishery management plans or stock assessments (and we are not minimizing the importance of rational day-to-day fishery management). Rather, it _is_ to create an institution that can marshall scientific expertise on fishes and the environment of fish, an institution to "formalize cooperative fisheries management, research and statistical collection efforts." An institution that would do this was proposed in the _Report of Workshop on Chesapeake Bay Fisheries Statistics_, held in Fredricksburg, Virginia, in July of 1982. A Chesapeake Bay Cooperative Fisheries Investigation Unit to coordinate the activities of state and Federal agencies and academic institutions should be formed without further delay. Possibly, CBSAC will adopt and effect this role.

First, this would provide for coordination of information on stocks and environmental information relevant to stocks. Secondly, it would provide a mechanism for publishing reports and scientific papers. Third, it would provide a mechanism for annual coordinated sampling cruises for the entire Bay. Fourth, it would provide an annual meeting to discuss in detail scientific topics of concern. And lastly, it would provide a sounding board to address scientific questions that might involve fishes that live in the waters of both states and the District of Columbia as well.

To conclude, from a fisheries management viewpoint, the greatest challenge is to create an institution to formalize cooperative fisheries management, research, and statistical collection efforts. While institutions exist which _could_ develop, facilitate, and coordinate the approaches we have specified, the simple fact is that these necessary actions are _not_ now being done.

Thank you.

MANAGEMENT OF THE CHESAPEAKE BAY'S WATERFOWL RESOURCES

LONG-TERM TRENDS (1948-86) OF WINTERING WATERFOWL IN CHESAPEAKE BAY

by

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Few areas in the world have been as historically famous as Chesapeake Bay for wintering waterfowl. This 180 mile long bay, with 4,000 miles of shoreline and extensive shoal water areas for feeding, provided optimum habitats for millions of waterfowl during winter. Accounts by sportsmen and naturalists relate how the water areas were covered with ducks. From approximately 1880 to 1910, waterfowl wintering on the Chesapeake Bay sustained the largest market hunting business known to man. Waterfowl were killed by the thousands and stuffed into barrels for transport by train to the major cities in the east.

A decreasing number of waterfowl in the Chesapeake Bay early in the 20th century aroused concern among Americans, and in 1918 market hunting was outlawed with the historically important treaty between the United States of America (USA) and Great Britain (for Canada). Waterfowl populations began to slowly increase in North America until the drought of the 1930s, coupled with excessive drainage of northern breeding areas, resulted in population declines and again aroused the public to the plight of our waterfowl. New hunting regulations in 1935 outlawed the use of live decoys and bait while hunting. The now well-known "duck stamp" program was initiated in 1935 to provide funds to establish more waterfowl refuges in the USA.

During the 1960-80s, the public became increasingly concerned about environmental pollution impacts on waterfowl habitats. The Chesapeake Bay, with hugh metropolitan areas on the western shore, received the brunt of this abuse, resulting in continued degradation of habitat. It was during this period that biologists became poignantly aware that SAV was disappearing in many areas of the Bay (Bayley, et al. 1978). Parts of some rivers, especially in the Upper Bay region, became totally devoid of plants.

The objective of this report is to discuss the present status of the major waterfowl species in the Chesapeake Bay based on analysis of 39 years (1948-86) of winter survey data. Each waterfowl species was compared to the status of populations in the Atlantic Flyway and North America to determine if changes detected in the Chesapeake Bay were due to conditions in the Bay, or to Flyway or Continental population levels.

The assistance of Edward Burton with the preparation of graphs and of Valerie Lumsden in word processing is appreciated. Robert Munro assisted with analysis and interpretation of data. Drafts of this manuscript were reviewed by Ronald Eisler, James Fleming, Robert Munro, and Vermon Stotts.

METHODS

All survey data used in this report were obtained from unpublished data in files of the Office of Migratory Bird Management, U.S. Fish and Wildlife Service (USFWS), Laurel, Maryland. The Chesapeake Bay counts represent counts in Maryland and Virginia combined. Aerial surveys were flown at low levels (25-100 m) with single engine aircraft of the USFWS and various State wildlife agencies. Surveys in the Chesapeake Bay have been conducted since 1948 in early January when waterfowl populations are more stable and concentrated than at other times during the winter. The average number of waterfowl during the 1980s was compared with the average number during years before 1980 to determine present status of waterfowl. Survey data in graphs are presented as 5-year averages (except for the 4-year period, 1983-86) to minimize annual fluctuations and to emphasize long-term trends. Further discussion on survey techniques and data analysis are given in Perry et al. (1981).

RESULTS AND DISCUSSION

Tundra Swan

Tundra swan (Cygnus columbianus) populations in the Chesapeake Bay have been variable during the 39-year period of aerial surveys (Table 1; Fig. 1). Lowest numbers occurred at the beginning of the surveys in 1948 (18,216) and then peaked in 1955 (75,854). Populations were also high in the mid-1960s. The long-term average population was 36,710. The average recorded during the 1980s was 35,065 which was only 5% less than the pre-1980 average of 37,070.

In the early years of the surveys, swans in the Chesapeake Bay were found mostly in the lush aquatic vegetation beds in the central portions of the Eastern Shore. In the late 1960s and early 1970s, however, tundra swans began to feed in agricultural fields on waste corn and winter cover crops. Although most of this feeding occurred on the Eastern Shore one large flock of approximately 1,000 was seen regularly in farm fields near Benedict, Maryland, not far from the Patuxent River. The use of fields for feeding areas occurred in the Bay area (Munro 1980) at the same time that SAV beds in the Bay were disappearing. Stewart (1962) did not mention field feeding by swans. The swans adapted to an alternate feeding pattern which appears to be to their advantage.

The Chesapeake Bay historically has been the most important wintering area for tundra swans in North America, and in the early years of the survey population trends in the Chesapeake Bay, Atlantic Flyway, and North America were similar. During the 1970s and 1980s, however, an increasing number of tundra swans have been recorded in North Carolina. During this period more than half of the Atlantic Flyway population was recorded in North Carolina. This change in distribution was most likely due to increased number of agricultural areas in North Carolina and overall less human disturbances in these feeding areas. Agricultural fields in North Carolina tend to be larger than in other areas, which also may favor the large swans during take off. The increased population and purported damage to agricultural areas by the swans were two reasons for establishing special hunting regulations for tundra swans in North Carolina during the 1984-85 and 1985-86 hunting seasons.

Canada Geese

Canada geese (Branta canadensis) populations in the Chesapeake Bay area have undergone phenomenal changes during the 39 years of winter surveys (Table 1; Fig. 2). As was the case with tundra swans, lowest numbers occurred at the beginning of the survey in 1948 (62,130). This population steadily increased and peaked in 1981 (701,470). The long-term average was 382,760. The average during the 1980s was 590,335 geese which was 75% higher than the pre-1980s average (337,352). Overall, population trends in the Chesapeake Bay during the 39 year-period were not similar to trends in the Atlantic Flyway and North America. Populations south of the Chesapeake Bay (mainly North Carolina) declined during this period, whereas continental trends have been variable.

This dramatic increase in Canada goose populations appears to be directly related to their ability to capitalize on abundant food in the agricultural areas of the Eastern Shore. Waste corn available to geese after harvesting provided the necessary high energy food for geese at the same time their traditional foods of emergent and submergent plants were declining throughout the Bay. Goose populations continued to increase during the 1970s-80s despite liberal hunting regulations for this species. By feeding on high energy food, geese were able to feed less frequently and were therefore exposed to less hunting pressure than species constantly searching for food. By maintaining excellent body condition throughout the winter, geese were in good breeding condition on reaching nesting areas in northern Canada. Geese usually improve their breeding condition by feeding at James Bay, Canada before the final flight north.

Some people are now concerned that increased hunting pressure on the Eastern Shore and abundant food resources in Pennsylvania and New York may result in fewer geese migrating to the DELMARVA peninsula. This "shortstopping" phenomenon began during the 1960s and resulted in reductions to the historically large goose populations in the Southeast, especially North Carolina. As long as there are abundant snow-free corn fields and ice-free water areas, Canada geese will minimize their southward migration, especially to areas that are heavily hunted.

American Black Duck

The black duck (Anas rubripes) has traditionally frequented the eastern coast, and large numbers have been recorded in the Chesapeake Bay (Table 1; Fig. 3). The highest number of black ducks in the Bay were recorded in 1955 (281,485) and the lowest in 1979 (28,820). The long-term average population was 84,197 ducks. During the 1980s, the population averaged only 51,365 ducks, which was 44% lower than the pre-1980s average of 91,379.

During the 1950s, approximately half of the Atlantic Flyway black ducks were recorded in the Chesapeake Bay. During the 1960s and 1970s only one third were recorded in the Bay, and during the 1980s less than one fourth of the Atlantic Flyway black ducks wintered in the Chesapeake Bay. Although black duck populations have declined most dramatically in the Chesapeake Bay, declines have been noted in all wintering areas of the Flyway. Surveys now record black ducks most frequently in coastal areas of New Jersey.

During the 1950s, approximately 85% of the Maryland black ducks were recorded in sections of the Eastern Shore of the Bay, especially the Chester River (Stewart 1962). With the demise of the SAV, black ducks did not have an alternate food source readily available. Most black ducks in the Chesapeake Bay during recent years were found on fresh water areas of the Patuxent River and tributaries of the York and James Rivers. In these areas, black ducks fed on seeds of smartweeds (Polygonum spp.), rice cutgrass (Leersia oryzoides), and other marsh plants (Perry and Uhler 1981). Small flocks of black ducks are also recorded throughout the cordgrass (Spartina alterniflora) marshes in the brackish areas of the Bay. The salt marsh snail (Melampus bidentatus) is their predominant food. Black ducks have also been observed feeding on corn in agricultural areas near the Chester River (pers. comm. V.D. Stotts).

Mallard

The mallard (Anas platyrhynchos) has traditionally been mainly a Mississippi Flyway duck, but populations tend to spill over to other Flyways. Mallard population trends in the Bay are similar to those of the black duck (Table 1; Fig. 3). Mallard populations in the Chesapeake Bay were lowest in the late 1940s and early 1950s, with a low count in 1949 (8,235). Excellent breeding conditions in the prairie provinces of Canada in the mid-1950s caused populations to rise, and a peak wintering population in the Chesapeake Bay occurred in 1956 (182,195). Drought conditions in the late 1950s and early 1960s caused populations to decrease and to remain relatively low and stable throughout the 1970s.

In the mid-1970s large numbers of game-farm mallards were released in the Chesapeake Bay with releases continuing throughout the 1980s. The release program is probably a major reason that mallard numbers in the Chesapeake Bay were 16% higher during the 1980s (57,553) than the pre-1980 average (49,826). Many of these game-farm mallards are found in close association with man, and appear to adapt to changing environmental conditions more readily than the closely related black duck. Mallards were more numerous than black ducks in the Chesapeake Bay during eight of the last ten years (1977-86). The long-term average population of mallards in the Chesapeake Bay was 51,212.

Stewart (1962) found that seeds of smartweeds, bulrushes (Scirpus spp.), and burreed (Sparganium americana) predominated in the mallard diet in fresh water areas. In brackish areas, seeds, leaves, and stems of SAV were more important as food sources. Rawls (1978) found SAV as the predominant food during the 1960s, whereas, Munro and Perry (1981) found only 5% of the food eaten by mallards was SAV during the 1970s. Seeds of a variety of marsh plants (over 100) were the predominant foods.

Wigeon

Wigeon (Anas americana) populations in the Chesapeake Bay declined during the years of aerial surveys (Table 1; Fig. 4). Peak populations occurred in 1955 (144,350), most likely due to excellent production in the breeding provinces of Canada. Wigeon numbers declined to a low of only 900 ducks in 1984. The long-term average winter population was 29,246. During the 1980s the winter population has averaged only 5,226 ducks, which was 85% lower than the pre-1980s average of 34,500. Population declines of wigeon in the Chesapeake Bay have occurred at a faster rate than those in the Atlantic Flyway and in North America.

Wigeon in the Chesapeake Bay have traditionally been associated with the canvasback and tundra swan, and usually fed in vegetated areas. During the 1950s, over 80% were recorded along the Eastern Shore of the Bay (Stewart 1962). Wigeon typically ate the upper vegetated parts of plants that were discarded or dislodged by canvasback or other waterfowl, although they also fed on winter buds of wild celery (Vallisneria americana) (Stewart 1962). During the 1960s, wigeon fed on the exotic plant eurasian watermilfoil (Myriophyllum spicatum) more than any other duck species (Rawls 1978). Because the wigeon was unable to change to alternate food sources as some other species did, wigeon numbers in the Bay declined as the amount of vegetation decreased.

Northern Pintail

The pintail (Ana acuta) is mainly a Pacific Flyway duck although large numbers have occurred in the Chesapeake Bay (Table 1; Fig. 4). Peak populations occurred in 1956 (78,211) but numbers declined to a low of only 400 in 1970. The long-term average number of pintail in the Chesapeake Bay is 16,282. During the 1980s, an average of only 3,935 ducks were recorded which was 79% lower than the pre-1980s average of 18,982. The average number of pintail in the Atlantic Flyway during the 1980s was 52,657, and most were recorded in the Carolinas. Continental pintail populations reached an all-time low in 1986.

The pintail, like the wigeon, was most common in the Chesapeake Bay during periods of good breeding conditions in Canada and excellent winter habitat in the Chesapeake Bay. With the loss of SAV in the Bay, pintail populations have decreased, and it seems that this species was unable to take advantage of alternate food sources, with one notable exception. Perry and Uhler (1981) found that pintail from the James River had fed on the Asiatic fresh-water clam (Corbicula manilensis) more than any of the other duck species examined. However, umbrella sedges (Cyperus spp.), rice cutgrass, and smartweeds were predominant foods.

Canvasback

The canvasback (Aythya valisineria) has traditionally been synonymous with the Chesapeake Bay, and large numbers have wintered in the Bay (Table 1; Fig. 5), especially in the Susquehanna Flats area. During the heyday of market hunting the canvasback continually commanded top price among ducks in the market. It is not known how many canvasbacks once frequented the Bay, but aerial surveys since 1948 showed that peak numbers were recorded in 1954 (399,320). Canvasback populations plummeted shortly afterwards to a low of 48,120 in 1958.

Populations increased in the mid-1960s as a result of better conditions on the breeding grounds and to restrictive hunting regulations. Canvasback numbers, however, decreased again in the late 1960s, and in 1972 the hunting season on canvasbacks was closed. The long-term average population of canvasbacks in the Chesapeake Bay was 104,012 in the 1980s the population averaged 52,931, which was 54% lower than the pre-1980s average of 115,811. In 1986 canvasback in the Bay were at an all-time low of 34,300. Canvasback populations in the Chesapeake Bay during the 1970-80s have been relatively stable despite increasing number of canvasbacks in the Atlantic Flyway and North America. The phenomenon led Perry et al. (1981) to speculate that habitat degradation in the Bay was adversely affecting numbers of wintering ducks.

When SAV beds in the Bay declined the canvasback was forced to seek alternate food sources. It did this much more effectively than other duck species, and now the Chesapeake Bay canvasbacks feed predominantly on molluscs (Perry et al. 1981). This food source, however, is not considered to be as nutritionally sound as the high energy plant tubers upon which it formerly fed (Perry et al. 1986).

Redhead

Redhead (Aythya americana) population numbers in the Chesapeake Bay are on a long-term downward trend (Table 1; Fig. 5). Although there was a peak number of redheads in 1956 (118,800), this population has steadily declined to a low of only 800 ducks in 1983. The long-term average was 35,288 redheads. During the 1980s the average winter population recorded in the Bay was only 3,506 which was 92% less than the pre-1980s average of 42,240. Most of these ducks are seen in the Tangier Island area. An average of 97,914 redheads were recorded in the Atlantic Flyway during the 1980s, indicating that population declines in the Chesapeake Bay have been more drastic than in other areas.

Unlike the canvasback, the redhead did not change its food habits as habitat conditions changed. It still feeds on the upper vegetative parts of submerged aquatics. With the loss of SAV in the Bay, redhead populations in the Bay declined, and now redheads are most abundant in North Carolina, Florida, and Texas where SAV is abundant. Because the redhead is now wintering in different areas than the canvasback, hunting regulations are no longer the same as they were historically.

Scaup

Scaup populations in the Chesapeake Bay consist of two species, the greater (Aythya marila) and lesser (Aythya affinis) scaup. Scaup (Table 1; Fig. 6) in the Chesapeake Bay peaked in 1954 at 403,658 and then declined in the late 1950s.

Populations increased in the 1960s and then declined steadily to a low of 10,700 in 1982. The long-term average population size was 65,909. In the 1980s, the population was 28,973 which was 61% lower than the pre-1980s average of 73,988. Trends of scaup populations in the Chesapeake Bay have not been similar to those in North America and the Atlantic Flyway. For unknown reasons scaup populations in the Chesapeake Bay in the early 1960s did not reflect the record 2.6 million recorded throughout North America.

Historically, scaup have fed on molluscs and crustaceans (Stewart 1962, Munro and Perry 1981), and current food habits indicate similar food preferences. It is doubtful whether the loss of SAV in the Bay has significantly affected the distribution or abundance of scaup, although the diversity of invertebrate food organisms has probably declined due to the loss of SAV (Perry et al. 1981).

Common Goldeneye

The goldeneye (Bucephala clangula) is a hole-nesting duck that breeds in the forested wetlands of southern Canada. Wintering populations in the Chesapeake Bay peaked in 1956 at 40,518 and reached a low in 1976 at 2,445 (Table 1; Fig. 7). The long-term average population in the Bay is 19,659. In the 1980s the average population in the Bay has been 17,513 which is 13% lower than the pre-1980s average of 20,128. Trends of goldeneye populations in North America and Atlantic Flyway have been similar during survey years.

Goldeneye feed mainly on invertebrates (Stewart 1962, Munro and Perry 1981), and changes in the distribution and abundance of SAV have probably not affected goldeneye populations. The amount of vegetation eaten by goldeneye has declined, however, during the hundred years in which food habits analyses have been conducted.

Bufflehead

Although the bufflehead (Bucephala albeola) and goldeneye both breed and winter in similar habitat, their wintering population trends are different (Table 1; Fig. 7). Bufflehead numbers have been steadily increasing from a low of 2,502 in 1959 to a peak of 36,023 in 1977. The long-term average population was 14,813. During the 1980s the average population was 16,840 ducks which was 17% higher than the pre-1980s average of 14,444. Population trends in the Chesapeake Bay have been similar to those in the Atlantic Flyway and in North America for the bufflehead.

The bufflehead has traditionally been an invertebrate feeder although vegetation has formed a more important part of its diet in the past than it does now. During the 1970s the predominant food eaten by buffleheads was the duck clam (Mulinia lateralis) (Munro and Perry 1981).

Ruddy Duck

The ruddy duck (Oxyura jamaicensis) has shown a significant decline in numbers in the Chesapeake Bay during years of aerial surveys (Table 1; Fig. 8). Peak numbers occurred in 1953 (124,740) and declined to a low in 1976 (4,703). The long-term population average for the Chesapeake Bay was 33,642. In the 1980s the average population was 15,729 which was 58% less than the pre-1980s average of 37,560. Trends of the Chesapeake Bay ruddy duck populations have been different than those in the Atlantic Flyway and North America. Highest numbers of ruddy ducks in the Atlantic Flyway are recorded in North Carolina.

Ruddy duck population trends in the Chesapeake Bay have paralleled trends in the Atlantic Flyway and in North America indicating that these changes are a continental phenomenon.

Although the ruddy duck was traditionally a vegetative feeder (Cottam 1939), it now is feeding to a greater extent on invertebrates (Perry et al. 1981). Increasing numbers of ruddy ducks are recorded around cities like Baltimore and Washington, D.C. (Wilds 1979), where they are probably feeding on tubificid worms (Tubificidae) (Stark 1978).

Scoter

Scoter (Melanitta spp.) populations in the Chesapeake Bay have been variable (Table 1; Fig. 8). Peak population occurred in 1971 (130,900), and then reached a low of 1,551 in 1981. The long-term average was 16,760. The average in the 1980s was 6,565 which is 65% lower than the pre-1980s average of 18,990. The average Atlantic Flyway scoter population during the 1980s was 57,386.

Scoters are traditionally invertebrate feeders (Cottam 1939, Martin, Zim, and Nelson 1951) although no record of their food habits was made by Stewart (1962), Rawls (1978), or Munro (1981) for the Chesapeake Bay. Changes in their distribution within the Chesapeake Bay may be due to changing food resources and should be investigated.

Summary

Overall the long-term average of the Chesapeake Bay waterfowl during January has been 1 million birds. During the 1980s the average was still 1 million birds, although there were major changes in species composition. For example, Canada goose populations during the 1980s were 75 percent higher than the average population prior to 1980. This is directly related to their ability to utilize the abundant field crop resources (mainly corn) on the Eastern Shore.

Only the mallard and bufflehead populations during the 1980s are higher than their average populations during the 32-year period of 1948-79. All other species of ducks have shown significant declines, which seems to be directed related to the degradation of waterfowl habitat in the Chesapeake Bay. Duck populations in the Chesapeake Bay can be expected to remain at low levels until SAV beds recover in the Bay and production improves on the breeding areas.

Table 1. Range and Average Populations of 13 Waterfowl Species in Chesapeake Bay 1948-1986 as Determined by Aerial Winter Surveys.

Species	High Count (Year)	Low Count (Year)	39-Year Mean	1980s Mean
Tundra Swan	75,854 (1955)	18,216 (1948)	36,710	35,065
Canada goose	701,470 (1981)	62,130 (1948)	382,760	590,335
Black duck	281,485 (1955)	28,820 (1979)	84,197	51,365
Mallard	182,195 (1956)	8,235 (1949)	51,212	57,553
Wigeon	144,350 (1955)	900 (1984)	29,246	5,226
Pintail	78,211 (1956)	400 (1970)	16,282	3,935
Canvasback	399,320 (1954)	34,300 (1986)	104,012	52,931
Redhead	118,800 (1956)	800 (1983)	35,288	3,506
Scaup	403,658 (1954)	10,700 (1982)	65,909	29,973
Goldeneye	40,518 (1956)	2,445 (1976)	19,659	17,513
Bufflehead	36,023 (1977)	2,502 (1959)	14,813	16,840
Ruddy duck	124,740 (1953)	4,703 (1976)	33,642	15,729
Scoter	130,900 (1971)	1,5511 (1981)	16,760	6,565

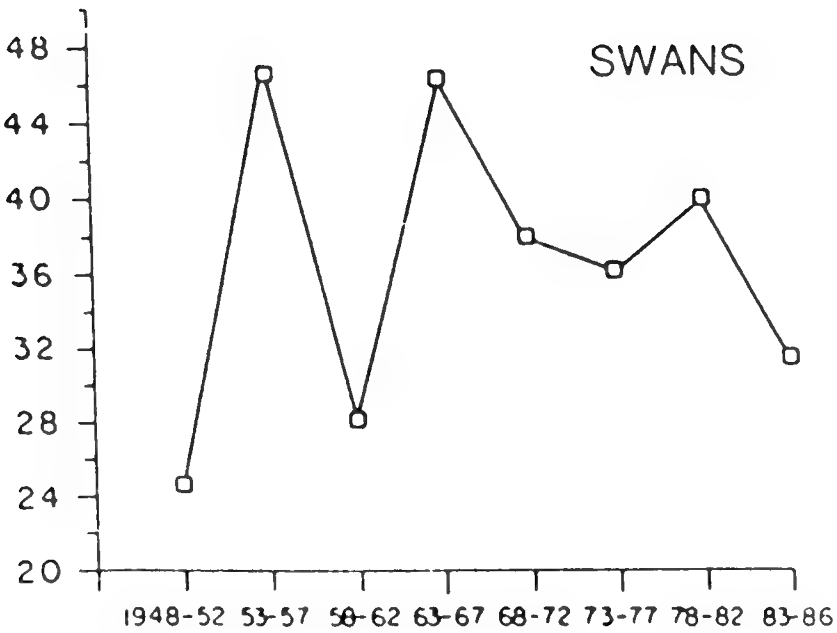

Figure 1. Long-term trends in populations (x1000) of tundra swans in the Chesapeake Bay during eight periods from 1948 through 1986.

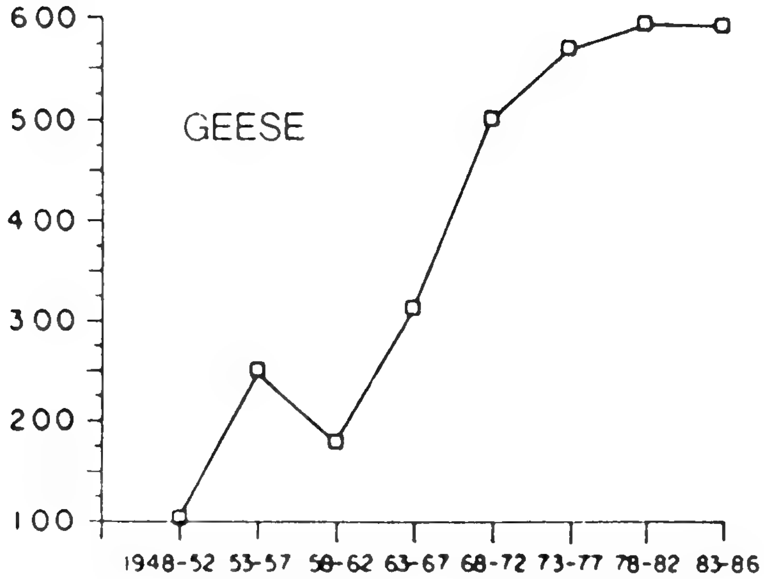

Figure 2. Long-term trends in populations (x1000) of Canada geese in the Chesapeake Bay during eight periods from 1948 through 1986.

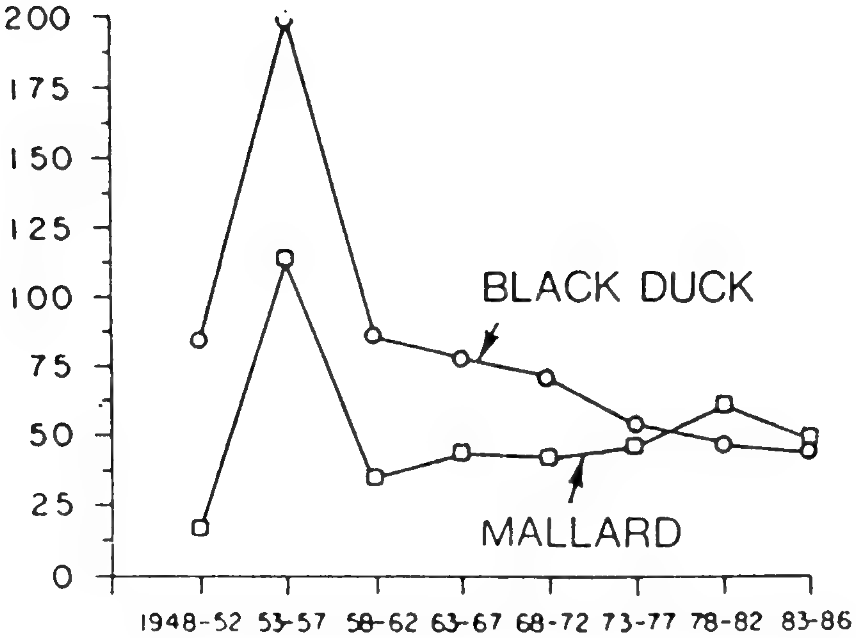

Figure 3. Long-term trends in populations (x1000) of black ducks and mallards in the Chesapeake Bay during eight periods from 1948 through 1986.

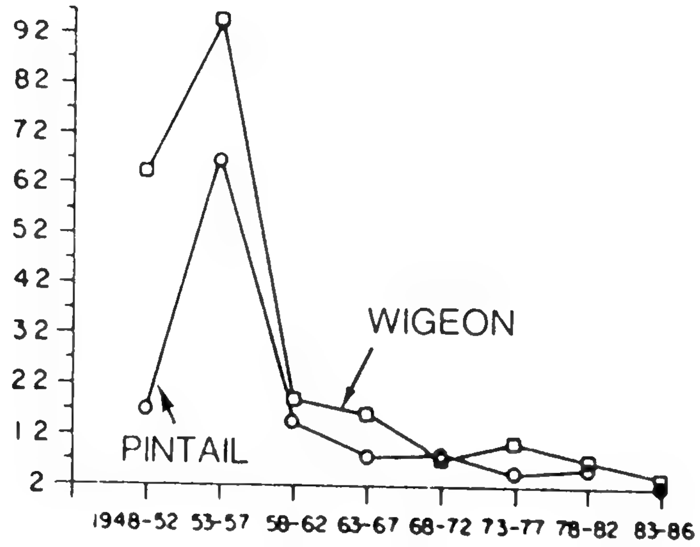

Figure 4. Long-term trends in populations (x1000) of wigeon and pintail in the Chesapeake Bay during eight periods from 1948 through 1986.

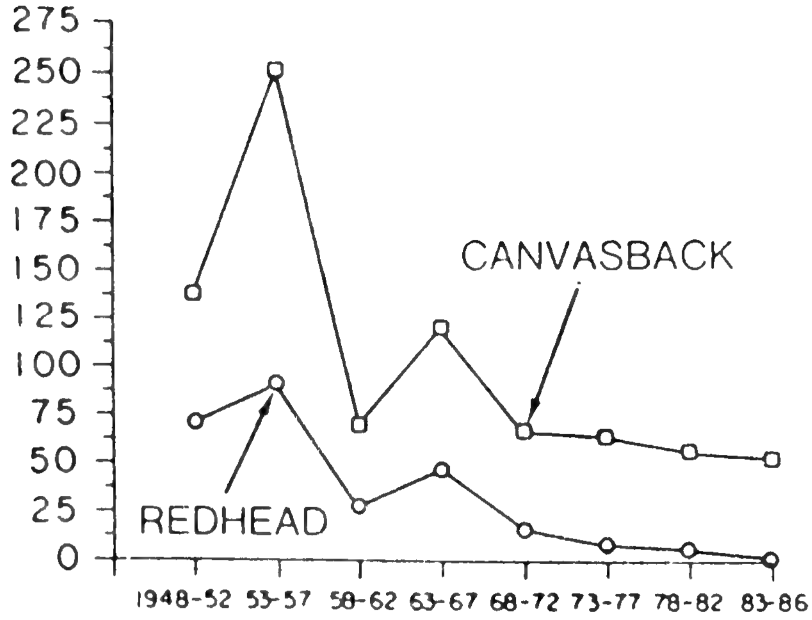

Figure 5. Long-term trends in populations (x1000) of canvasback and redhead in the Chesapeake Bay during eight periods from 1948 through 1986.

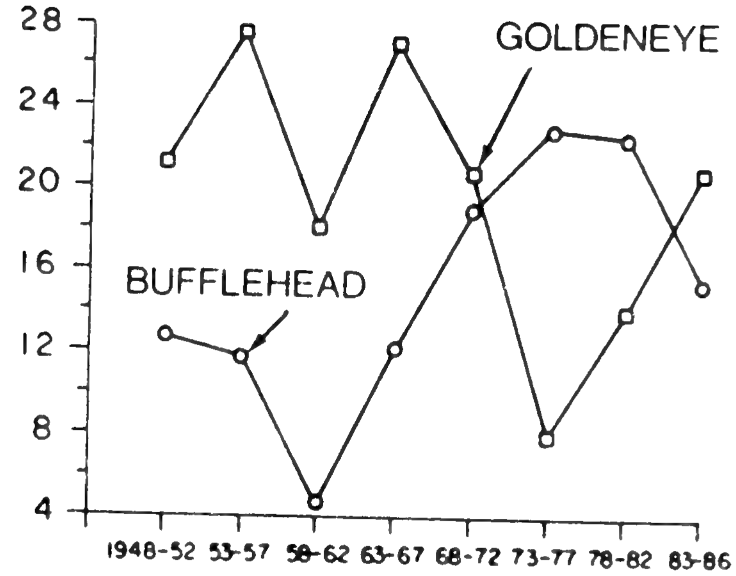

Figure 7. Long-term trends in populations (x1000) of goldeneye and bufflehead in the Chesapeake Bay during eight periods from 1948 through 1986.

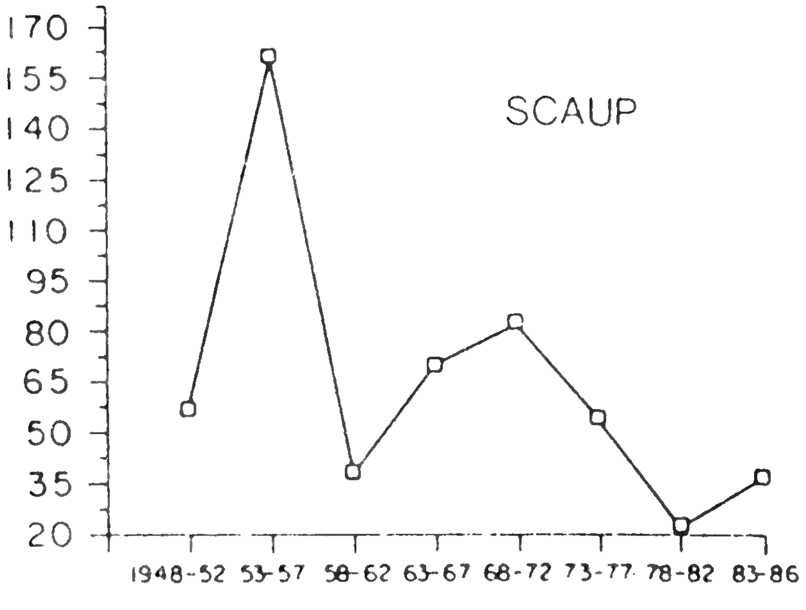

Figure 6. Long-term trends in populations (x1000) of scaup in the Chesapeake Bay during eight periods from 1948 through 1986.

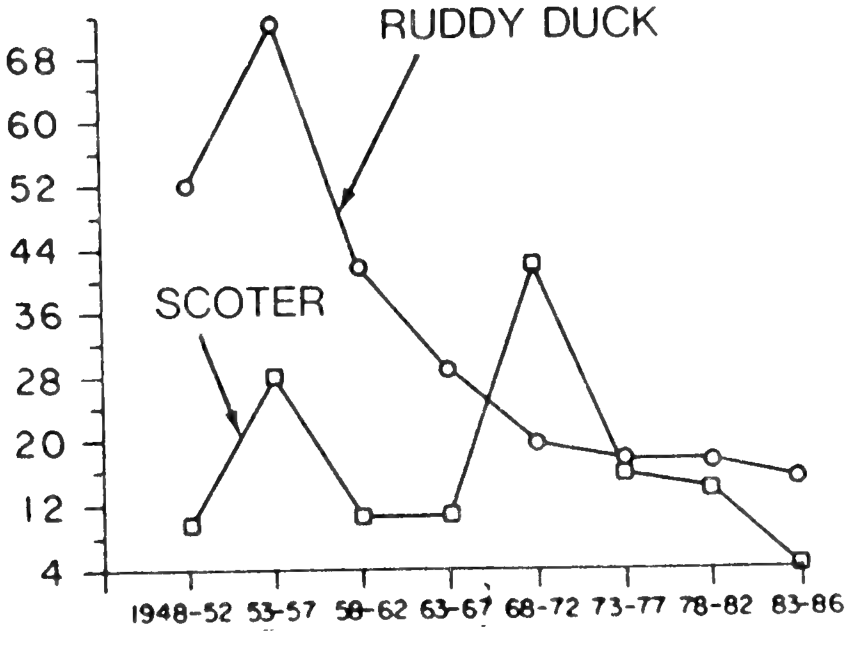

Figure 8. Long-term trends in population (x1000) of ruddy duck and scoter in the Chesapeake Bay during eight periods from 1948 through 1986.

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PANEL DISCUSSION

PANELISTS

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PANEL DISCUSSION

Dr. D'Elia: I'll start from the far end introducing the people on the Panel.

Dr. Tom Malone, from the University of Maryland Center for Environmental and Estuarine Studies; Dr. Jim Sanders, whom we have heard from before; Dr. Ed Houde, who is finishing up his term with the National Science Foundation Biological Oceanography Program and has been on leave from the Chesapeake Biological Laboratory; Dr. Howard Seliger, who is with Johns Hopkins University; Dr. Grace Brush of the same; Dr. Glen Kinser with the U.S. Fish and Wildlife Service; Dr. Al Morris, who is with the U.S. EPA Region III; Mr. Bill Eichbaum, who is Assistant Secretary for Environmental Programs, State of Maryland; and of course you know Jim Thomas and me.

So with that, I'll ask a question, and anybody can feel free to jump in. I've always been interested in knowing, with all the focus on anoxia, what can we do about it in the Bay? Anybody got an answer? Why don't I pick Tom Malone?

Dr. Malone: What can we do about anoxia in the main stem of the Bay? I think the question remains open right now, whether or not, and I don't say that this isn't the case, but whether or not the increase in anthropogenic nutrient inputs into the Bay has in fact aggravated the situation. Unfortunately, I think that, as some of the people today have pointed out, the data sets that exist do not allow us to establish a cause-and-effect relationship between inputs of nutrients, but they diffuse inputs or point source inputs, and the actual magnitude in terms of the volume of and areal extent of anoxia in the Bay. I think that's one of the most important things that we need to establish not only from the point of view of understanding the mechanisms that couple these inputs and outputs, but also from the point of view of management.

For example, understanding how relationships among nutrient inputs, phytoplankton production, and anoxia are related in space and time is critical to determine how to manage inputs of nutrients, be they nitrogen or phosphorous.

I guess the basic point I want to make is that we don't have the data base to establish the link between nutrient input and oxygen depletion. The analogy that was made would be one that would, say, compare to nuclear arms. We know that the U.S. and Russia have enough weaponry to totally destroy the earth ten times over, and we have no idea right now for the Chesapeake Bay whether or not we're up in that ozone layer in terms of nutrient inputs or whether our input is basically, you know, just noise in the system that's being mainly controlled by variations in climate.

Dr. D'Elia: Bill Eichbaum seems to be reacting differently there.

Mr. Eichbaum: I'd put a slightly different spin on that ball maybe. And for those of you, I'm not a scientist, I'm a lawyer, so it's easy to put a different spin on a scientific ball and not to worry too much about it.

But it does seem to me that there are two things in terms of the answer to the question to keep in mind. One is, and I haven't been here all day, but I caught most of Walt Boynton's talk and your point of the data base. I mean, the monitoring program is in place in part to try and develop that data base so that if we don't know those relationships or enough data to know those relationships now, we will at some point in the future.

And secondly, at least to the extent that you can have a reasonable program for reduction of nutrients, we are doing that, both from point sources and non-point sources, and both in terms of I guess what I call near-field effects on dissolved oxygen and the main stem of the Bay. We will begin to pick up those relationships and trends, if they can be picked out from the background, over time.

So I think I would, as I say, have a slightly different perspective, but not disagreeing.

Dr. Malone: I couldn't agree with Bill more. I think initiation of monitoring programs has been one of the most important things that's happened in the last couple of years.

Dr. D'Elia: Howard, could we hear from you on that?

Dr. Seliger: Well, I really came here to learn something about the Chesapeake Bay that other people were willing to talk about. I have been depressed ever since I heard the Governor say that we knew what to do and we were going to do it.

I have no idea on what precisely to do. I don't know what the relationship is between nutrients and anoxia or between the Connowingo Dam, the increase in anoxia and the subsequent loss of fish species.

I think I would take the side of Larry Haas and say that perhaps the data we've been collecting is not really related to food chains. If we want to know about anoxia, we have to ask about the effect of anoxia in the various tributaries. The central channel of the Bay is a transport train and it's also a ship train.

We really don't know anything about the way in which the processes in the Bay affect the food chains. Since we're interested in fish and phytoplankton, I don't see that the research in any way is at a level that would allow us to make management decisions.

Dr. D'Elia: I wonder if anyone in the audience has any particular question about anoxia they want to address to anybody. All right?

Dr. Harriette Phelps, University of the District of Columbia: I'm surprised a little at the confusion on monitoring and research. Monitoring is an engineering concept with a definite goal or with definite effort levels. Research, on the other hand, is not a known endpoint. It's distinguished by the ability to ask the right questions, which is after all, what we were trained as scientists for. And I assume that we are not asking the right questions.

For example, we're confusing correlation with effect. We're monitoring like heck, but what you measure might have nothing to do with a parallel for measurement, especially for biological systems, which are far more complex.

Secondly, we aren't even asking ... well, we can't even answer basic questions like what is the cause of decline of the fish, I'll say herring? Another one that I see every day, practically, which is the incredible resurgence of submerged aquatic vegetation in the Potomac? Nothing that the Corps of Engineers has done has put that in place. They should be out there measuring that every minute to find out why it is occurring. Because I don't think we've even come close to a handle of what is going on. I think we are losing our focus on biological inputs. So you've got to be able to ask intelligent questions and focus our research.

Dr. D'Elia: With that, I think the best person to deal with this is Al Morris, who frequently gets accused of monitoring and not doing enough research if that's the central issue. Do you have any comment on that?

Dr. Morris: I don't think the best person to ask for that question is Al Morris at all.

My approach would be a little bit different, I think. And I think my perspective is one which hasn't been brought out today, which I will endeavor at Jim's invitation, to bring out now. I think Jim asked me to comment on a couple of things. One is the Restoration and Protection Plan and the other one is sort of my perspective of what some other items that should have been discussed or that at least bear on the discussion today in terms of what I think the speakers were getting at, which is basically a restoration of the Bay.

The Restoration and Protection Plan that was issued last Friday with a lot of hoopla and excitement has been criticized both internally and externally and has also been applauded and probably for very different reasons.

It's been criticized because it didn't go far enough and because some of the statements in there were a little bit tenuous in terms of science. I agree that they were and are.

It's been applauded, and I think rightfully so, because it makes a major milestone in institutional cooperation, a regional cooperation that has for the first time, I think, looked at the Bay as a whole from the standpoint of the agencies who impact it and can institutionally have an impact on changing the way things happen in the Bay if there is a will to do that.

So we have in one book for the next year the activities which will be undertaken by three states, the District of Columbia, and six Federal agencies to work on the Bay. It doesn't mean that they're all coordinated necessarily or neatly packaged. But they are there, and there is a will to do it and a will to work.

The other component in terms of today's discussion, which I think would be helpful for you to help us with as scientists, is two other major areas that we didn't spend much time on. And let me go back to the first discussion that we had this morning from Senator Mathias where he spoke a lot about the political side of what we're doing and how he had managed to pull together a number of agencies and get money for the study and also the recognition up to the national level to the Office of the President of the United States.

So I think that is one area that needs to be recognized. That unless we get that kind of recognition and that kind of support, then we can do all the talking we want in forums like this and we will be talking to ourselves in terms of implementing a solution.

So first is the institutional mechanism and institutional will. And that has been put together into the Executive Council of the Chesapeake Bay Program. The second component of it is public information, public participation, because that in essence takes the concern which you have expressed today, translates that into a political support which has been recognized by the Congress and also recognized by the President.

All three of those pieces such as institutional mechanism and will, public participation and information, and the scientific community, and the definition of what is wrong and what we can do about it, are all integral to solving the problem which we're here discussing today.

So with that, I throw that out basically as an overview from my perspective in terms of management. Management doesn't mean what we discussed in the last portion of today's topic from the standpoint of at least Bill and I and our major roles here and William and Jim. In fact, this end of the table seems to be involved in an inter-tidal zone. Not the kind we talked about today. But the inter-tidal zone between policy-makers and scientists.

We are day-to-day having to interpret for the policy-makers what you folks are telling us and taking abuse from them as to why we don t known more precisely to the tune of a 100 percent certainty what we're advising them to do. And from their side of it or from your side of it we're taking the shots sometimes that you are disenfranchised from the process. And from that standpoint trying to explain on the other side how far we can go and what we need to do to market your ideas and your science in order to turn it into public policy and financial support.

So basically I think those are some components, Chris, of what would be helpful and why we need your help. The monitoring aspects that were just mentioned are a piece of that, and we certainly need to be able to answer it. But we can raise some of the questions to you in terms of the answers we need in order to get support for what you want to do and why you want to do it better.

Dr. D'Elia: Since I made the statement about disenfranchisement, I suppose it's reasonable for me to jump in here.

I think sometimes we have to remember some of the lessons ... I'm not trying to be too harsh with this. But there have been other attempts in developing science-management relationships in other countries that have not been very successful because people have wished things to be true that aren't necessarily true.

Dr. Morris: Right.

Dr. D'Elia: And I refer specifically to the Lyseinko case in Russia. I'm not doing exactly the same thing. But there is danger in management that people wish things to be true and expect the science to fall in line. And in defense of the scientific community, sometimes I feel that we are not given an adequate chance to help develop the questions and say how we might go about answering them.

Dr. Morris: That is an issue that will come up periodically and you need to keep raising it because we need your input, and there should be a mechanism in order to get it. And it should be listened to and evaluated.

I had a boss once who was somewhat like that and said that he wanted things to come out a certain way in terms of science. And I suggested to him the next day that maybe he should have a law passed that the sun wouldn't come up the next day and see if the political system could do that in terms of science.

It's the same sort of thing. We need to have you in. And I think there's a two-way street in terms of the needs of the policy-makers for the certainty that you can or can't provide in your recognition of how you get into the process and market and sell in terms of what you know, how certain you are, and what we can do about it.

Dr. D'Elia: How can we help? I think that's the next logical question.

Dr. Morris: Well, in terms of the Chesapeake Bay Program, we have a scientific thing called an advisory committee, which is set up to do that. Also, there are other mechanisms in which you can get in through the university or through your state or just by giving a call. But there is an institutional mechanism to get the scientific world in, and I think you need to make sure that, one, that piece of the institution is there. And secondly, when you're invited, that you participate.

Dr. Thomas: If I might just comment on that ... one of the conferences of the Estuary-of-the-Month series is exactly this sort of thing. We've made a real attempt to involve the Sea Grant Program from the States of Maryland and Virginia. So I hope that we'll at least respond. The heart is in the right place.

Dr. D'Elia: The Rothschild-Stagg paper at the end suggested that we needed to reconsider our institutional arrangement for fisheries in a more serious fashion. Does anybody on the panel have a comment on that? Ed?

Dr. Houde: I think that I generally would agree with Stagg and Rothschild. Fishery management is a complex business anywhere, and here in the Chesapeake Region where you've got three or four states that are involved, allocation problems are especially difficult among users. A good institution that gets both administrators and scientists together on a commission or board, I think that Stagg called it a "Chesapeake Bay Fishery

Cooperative Investigation," would be very good. What he's suggested sounds much like what has been done in the California area with the California Cooperative Fishery Investigation over the years. This organization is recognized worldwide and is one of the foremost agencies both in recommending and carrying out resource-oriented research. From a management point of view, I guess you could question just how effective that organization has been. But nonetheless, to organize our research, to make recommendations for management and get the states cooperating, I'd endorse the idea of that kind of institution.

Dr. D'Elia: Any comments on that?

Dr. Kinser: I guess one thing that I saw, particularly in the Stagg paper, it made me realize that with the research and the monitoring that we're doing we're still a long way from answering a lot of the questions. And there's a need for action at this time.

That's not to say that we should do away with either research or monitoring, but I think we should make action an equal partner in this. We may not know for years to come what the exact impact will be of a particular nutrient for any other situation; and let's go ahead and take some forward action to change this trend that we've seen in many species around.

That may be by reducing nutrients. It may be by reducing sediment. It may be by dealing with point source impact, nonpoint source impact, et cetera. I think we need to make a progressive effort in each one of those fronts. We can't kid ourselves. Thirteen million people have an impact on the Chesapeake Bay ecosystem, and we seem to be avoiding that if we wait for these decisions.

Dr. D'Elia: I can't agree more. I guess waiting is not the thing to do now. But in addressing the setting up of an institution for the stewardship of fishery resources, I wonder is that practical? Would it be easy to do? How would one go about it? Any comments on that?

Dr. Kinser: I think it would be very difficult in fisheries or in wildlife. In the waterfowl issue you're talking about multiple states. You're talking about international situations. Each one of them is going to be very difficult. The striped bass issue might be an example of that. Some states are reducing the take; some are not doing anything at all.

Question: I'm afraid that you can't say that some are not doing anything at all. That's just one example. I just wonder why the Atlantic States Marine Fisheries Commission isn't represented or why it wasn't mentioned. You do have a body there that does do some or has some management curfew and who could certainly have made some contribution here today. I don't represent them, by the way, but I certainly agree with our last speaker that we do need this stewardship responsibility. But there is one area where we do have a "little say" on the Chesapeake Bay..and most of the states have done something on striped bass.

Dr. Kinser: I'll agree with that. That's one I think you're involved with through multi-governmental bodies. And in the case of the waterfowl, you're dealing with Canada as well.

Dr. D'Elia: To be sure, the entry of Pennsylvania as a full partner last week is an important thing. You can't deny that. But that's more, I think, from the point of view of the water quality issue than stewardship of the fishery resources.

Dr. Morris: Aren't they all linked? I mean, to have Pennsylvania in finally, even though a reluctant bride, is important in terms of solving the problems of the Bay. Unless Pennsylvania is willing to put regulation on the industries, municipalities, and farmlands that flow into the Susquehanna, I doubt that we're going to clean up the Bay. So to have them involved in the process is certainly important to the overall health of the Bay, I would think.

Dr. D'Elia: I would agree. What I'm addressing particularly is the fisheries efforts in the regulation of catches and things like that. Too often we tend to couch the Chesapeake Bay as a water quality issue alone and fail to consider the impact of overfishing. I think that was made by several speakers today. And I think this is the particular effort of Mr. Stagg, the preservation of an institution.

Mr. Eichbaum: I don't think one of the approaches we've tried to take in Maryland, and you can quarrel as to whether we've been successful or not, is to not have this be a water quality issue. The point is that the water quality and habitat ought to be there for the fishery resource in its total biological sense.

As I say, you might quarrel with specific elements. And I have trouble if we begin to go, kind of break it apart into new institutions. We certainly have a fishery issue here, a water quality issue here.

We think that at least some sort of marriage in that area between the two is important. And I guess I noticed a last bit of that slide so that the fishery subcommittee of the Chesapeake Bay Commission was going to be reconstituted. But the speaker didn't say anything about that. That might be a good starting place to begin to do this. But, again, in the overall context of looking at both issues. Okay?

Dr. Houde: Just to respond a bit, I don't have a big argument with Bill, but I think there is a perception among a lot of the people, people involved in the fishing industry of the Chesapeake, that those people who are exploiting the resource would strongly like to believe that it's only a water quality issue or at least that the water quality dominates the problem.

It clearly is a big problem and the multiple changes that we've heard about today in the Bay quite likely have caused a lowering of the potential of productivity in the Bay. People involved in exploiting the resource are very reluctant to accept that the yields are no longer going to be as high as they were. So it's a people problem.

Mr. Eichbaum: I agree with you, and that's why I want to talk about both issues at the same time. Sort of secretly at home at night the people that work at OEP would say, "If they just managed the fish right, we wouldn't have any problem." And the people at DNR sit there at night and say, "If you give me clean water, the fish will be fine."

And that's what we've got to cut through, it seems to me. I think we've made some progress in the last couple of years in that regard. And I agree with you that the constituency groups have all different kinds of perspectives. But I want to go out ... in fact, we're going to do this with one of the fishing associations in Maryland next month. Verna Harris from DNR and I are going to go out and talk about living resources and water quality and try and make them understand the relationship.

Dr. D'Elia: One comment I have, it's sort of one of the institutional-political quirks we have with the way the system works. EPA is really charged mainly with the responsibility of taking care of the Chesapeake Bay, and EPA's orientation has typically been a water quality orientation, and nobody is faulting them on it.

NOAA, on the other hand, and I'm not trying to be solicitous of them for putting the seminar on, is interested more in the resources aspects of things. But NOAA hasn't been terribly involved. So for that reason we haven't seen the kind of involvement with stock assessment and things that are so badly needed. Can EPA cover the role adequately of fisheries stewardship?

Dr. Morris: Not really. I don't think so. It's not our charge, and we're going to be funded for it. But I think the fact that NOAA and Fish and Wildlife Service are all now involved, that should help in getting these programs together so in fact they work cooperatively, don't duplicate, and also that we then start looking at holes so if there are holes where we need information, in order to fill some of the gaps that were mentioned, then we can start going back and plugging them in the budget process, which we haven't done yet.

So my sense would be that while you may need a new institution to work on the management problems, certainly don't separate it from the water quality so that all of a sudden we've got the possibility of going two separate ways again when we're just starting to pack the people together. Because if there's one thing we've heard today, it's that we don't have the linkages between water quality and resource productivity. And those two are linked somehow even though we can't define them today.

Dr. Thomas: I think, if I'm not speaking out of turn here, I think that NOAA really is interested in working with the EPA, the Fish and Wildlife Service, the states and so on to provide that linkage, that linkage between habitat and quality and effects on the stocks, the living stocks, so that ultimately the point and non-point source loadings can be regulated in such a way that we know what the impacts are on the living marine resources.

I don't think the general public is as interested in the habitat quality as they are in the living marine resources. So we would like to work with the other agencies and institutions involved in order to further that relationship for more suitable management.

Dr. D'Elia: Some questions? Yes, Joe?

Dr. Joseph Mihursky, Chesapeake Biological Laboratory: I want to address this question to Bill. And I'd like to ask this question of certain members of the panel.

Senator Mathias in his efforts pointed out the need to not only have EPA involved in the Bay, but also have NOAA involved, so you have the legislature forcing, you know, a water quality oriented organization and a living resource agency to come together on the Bay.

Similarly, at the State level, Senator Fowler had a bill passed that Health and Hygiene and DNR must get together and provide the Legislature with a report on the monitoring efforts for the Bay.

What I'd like to ask is would the agencies have done that on their own, or was it necessary for the political process to force it?

Mr. Eichbaum: Well, in the case of Maryland, I think the answer to the question is, yeah, we would have done it on our own. We had been. That bill specifically deals with the monitoring issue, and both agencies had in fact been working and doing it in a cooperative way in monitoring and other issues, the whole Maryland program.

In fact, we supported Senator Fowler's legislation because we saw that as important to providing a framework for long-term commitment by the Legislature that in fact they be a part of that process of keeping those two agencies together over the long haul of a 5- or 30-year monitoring program. So we think it's valuable. Sometimes it's essential. It didn't happen to be in that particular case.

Dr. Morris: On the Federal side, my sense is that we would have gotten together. At least I would like to think we would have. But certainly from a pragmatic standpoint what the Senator did was extremely important in making it come about quicker.

Dr. Thomas: I certainly would agree with Al on that. I think from a pragmatic sense, certainly NOAA would want to be involved in that. I might add that contained in the functional statement for the NOAA Estuarine Programs Office in terms of its formation it really includes just this sort of thing we're talking about in terms of coordinating and in helping to improve the management of our Nation's estuaries with regard to living marine resources within NOAA as well as coordinating with other Federal and state academic agencies and institutions.

So I submit that Senator Mathias has probably hastened the process, but I think in a most desirable way.

Dr. Morris: For a very pragmatic reason too, because in the budget battles the agencies are fighting over the same pot of money. So bureaucratically it gets very easy to develop bureaucratic enemies. Whereas now that we're sitting around the same table and find out that there's a human being on the other side of the face it's much easier to call up on the phone and say, "Hey, how about we getting together on this; I think we can work it out?" So from that standpoint the Senator did a very valuable thing putting us all together quicker rather than waiting.

Question: I'd just like to ask one question to the panel at large. We've heard a lot of information on monitoring data and the need for more monitoring data for various parameters, and there has been some emphasis on cause-and-effect relationships and the need for that kind of data. I'd like to find out, though, what is the role of the Federal and state agencies in terms of more practical solutions to various problems? I might use the example of the use of emergent vegetation in small settling ponds to control non-point source base water runoff from large housing developments. Those type of solutions, which do require scientific research, but are not what you would call more along the lines of pure science.

Mr. Eichbaum: That's a good question. It's kind of that interface between research and application, and it is an issue which frequently we tend to rely on the private sector and entrepreneurship to try and begin to fill gaps, or engineering firms.

We do have some efforts, particularly in the sewage area and in the storm water management area where we've actually put money into the State budget to fund the development of technology to actually apply in the field. The State of Maryland reports annually on what we're doing in the Bay. And, you know, thumbnail sketches of those programs would be in that Annual Report. And anybody could follow up with in more detail with a particular agency.

Dr. D'Elia: More questions?

Question: I have one question with regards to the institutional framework necessary for coordination of fisheries management within the Chesapeake Bay or between any two jurisdictions.

I think it's in place right now if it were fully exploited. That is, the Atlantic States Marine Fisheries Commission (ASMFC), which was referred to earlier by Mr. Martin. There is a section in that Commission called the Chesapeake Bay Section, which does include Maryland, Virginia, and Pennsylvania.

The interaction between the fishery biologists, the research community within the university systems of the individual states could very easily be worked into that Section to coordinate work and to bring together or merge the habitat quality, water quality and fishery management questions.

I don't disagree with the need for an institutional forum, but I think we already have a basis that can be built upon in the ASMFC. The bottom line, however, is that the proof of the pudding is bringing it home and enacting it in various provisions so far within the interstate fisheries management program. That is once the Commission has agreed to something away from home and you come back to your individual jurisdictions and bring it into play, such as striped bass regulations, which are not uniform at this point in time, and there has not been, after 1981, passage of a plan of uniform regulations put into effect within 2 months or 6 months when the opportunity, however, existed.

I think the onus has to come back to the states. And if the states are indeed willing to adopt regulations consistent with the findings of the scientific community, recommendations, and mount research programs along these guidelines, the framework exists. All we need to do is just add on a little more infrastructure beyond that which now exists within the ASMFC structure process. That is, a legislative appointee, a gubernatorial appointee, and a fisheries manager. Three representatives from each of those states, or commissioners. Build a scientific base underneath it and you've got basically the institutional framework I think you're requesting for fisheries management, unless I read it wrong.

Dr. Houde: I think you may be right, that there could be the base there, but the number of constraints that you listed in your last two or three minutes, to me, are significant and difficult ones.

Question: This is regardless of your institutional framework?

Dr. Kinser: I don't think we have the ethic that we need. I don't think we're taking individual responsibility as states or as individuals. And I think that's probably a key behind it. If we're not going to take that individual responsibility for our own actions ... I mean, we can go out on the Bay and look and daily there are many decisions that are being made that are having small, minor impacts on the Bay, but which are cumulative. And I think that's where we're failing to deal with this.

We're balancing things. And unfortunately, the environmental aspect always comes up negative in the cost-benefit in the individual decision basis. You're balancing things like do we put a building on the river ... out over the river because of the fact that these townhouses or apartments or condos will sell a lot better if you have a water view. That doesn't balance well against saying, "Well, we only have six acres that are going to be impacted here." And it just seems to be a snowballing thing. You can look at the decisions we're making, I think, on a whole variety of things ranging from EDS permits to discharge of spoil material, overboard spoil, and the increasing problem with sediment and toxics in the Bay downstream of that. You know, I think it's just a whole sequence of events.

And that applies to the fisheries decisions as well.

Dr. D'Elia: Question in the back?

Question: I would be curious to know what is the number of publicly owned sewer plants in the State of Maryland, and what the State of Maryland is doing for getting them into compliance?

Mr. Eichbaum: About three hundred and thirty treatment plants in the State, public and private. The last report which we did, which was about 1-1/2 years ago or 2 years ago actually, indicated that about half of those plants had some form of violation other than minor or paperwork.

Following that revelation we've done a couple of things. One is about doubled our inspection resources on those plants. Secondly, for the first time begun to file civil penalties against units of government for violations of the plant. And thirdly, is to develop a plant-by-plant strategy that states what they will be doing, when they will be doing it, when they will do it by. That strategy basically provides for every plant in the State to be in compliance with what we believe are the required water quality derived effluent limitation by 1988.

Probably the two exceptions to that are Oakland in Garret County, which does not discharge to the Chesapeake system, but which has never had a sewage treatment plant, they are starting construction now. They have a posted penalty, and they will be in compliance a lttle bit later than that.

And the final completed construction of the Back River Sewage Treatment Plant at Baltimore, which is about 108 million gallons per day plant, which will be totally reconstructured, is also the first sewage treatment plant in the country, which was built to protect oysters back in about 1915, I guess, will be totally reconstructed at a cost in excess of 400 million dollars. That's going to carry us into the early 1990s. Did I answer your questions?

Dr. D'Elia: A question way in the back?

Question: What is the relationship between the National Marine Fisheries Service and the Atlantic Marine Fisheries Commission? And is the Atlantic Commission the same thing as the regional fisheries management council? Do you think that the National Fisheries Service can input advice.

Dr. Thomas: All three outfits that you talked about are different. The National Marine Fisheries Service has input into the Atlantic States Marine Fisheries Council as well as the Fishery Management Council. And essentially, there are scientific and technical groups, and the National Marine Services Fisheries' personnel are on each of these groups. Additionally, NOAA has formed the Chesapeake Bay Stock Assessment Committee with members from the States of Maryland, Virginia, and Pennsylvania, and District of Columbia. So I think there certainly is a great deal of networking. And I hope that the informational flow will be coming to heel.

Dr. Barber: Mary Barber, from NOAA. The Chesapeake Bay efforts that have gone on are going to be used as a model across the Nation now for investigating other estuaries and dealing with the management problems there. On the panel we've got a wide range of perspectives and backgrounds, and I would like you all to give me some views about it from your perspectives and backgrounds. What are the successes and failures of the Chesapeake Bay efforts? What might you say to other areas across the country that are developing plans, et cetera? What might you say to them about using a model of the Chesapeake Bay?

Dr. D'Elia: Why don't we start down at that end and give these people a little relief here?

Dr. Malone: I feel one of the biggest successes, and I speak as a relative newcomer in this whole business of the Bay, one of the biggest successes of the Chesapeake Bay Program *per se* has been better definition and definition that's good enough to ask the perfect questions to study the environmental problems that are facing the Bay.

And I think they have forced the various states to face up to the fact that we've got to work together in order to solve some of the problems that exist. So a very brief answer to your question is that I think we are in a position to define some of the problems. We are in a position and some of the other people on the panel have stated this to begin to move towards at least some short-term solutions without putting into massive efforts.

For example, I believe, there have been statements as some of you know, to put a tremendous amount of money into eliminating all of the point and non-point pollutant inputs into the Bay, without understanding especially, the inputs in terms of the nutrients what the impact of that would be.

We are in a position, I think, now to go out and dovetail a meaningful program with research projects that deal with how to relate to various things or how to monitor them in a cause-and-effect fashion. And the groundwork has been laid for that.

Dr. Sanders: Again, as Tom said, I come into this fairly late too. But I think that one of the biggest successes that I see, both inside and outside the Bay area in the late seventies, and also as a scientist inside the Bay in 1980, one of the biggest successes is probably the cooperation between both regional managers and also regional scientists. I think that a program this large requires that these different groups coordinate with one another. And I think that this will continue to be a very valuable resource for this region for some time to come.

I guess one of the biggest disappointments that I had is that as we enter this new phase in Bay program management issues, that I don't believe that we're moving well enough to begin to put together the geochemical linkages with biological interactions that we see within both fluctuations of stock and also in basic productivity assessments.

I think that there are still a number of questions and a number of areas that need to filled in how these organisms are interacting with their environment. And I don't see that we're moving in that direction.

Dr. Houde: I've been impressed with the marshalling of political and public support that I've seen since I've come into the Chesapeake Region. I think that this could be held up as a model to other people. I suspect that within the next 5 years we will obtain the answers to some of the problems that we've talked about today. I think Jay Taft alluded to needing to do more modeling and to use some of the newer remote sensing techniques.

The nutrient problem I think is in everybody's mind. Some of Bennett's assertions relative to phosphorus removal not having much effect, I think, ought to impress us. We are beginning to get some insights into the problems here in the Chesapeake Bay.

As far as fisheries management, which I've been closer to, I wouldn't say that I'm completely disappointed. I think there is a lot of potential to do some very good management in the Bay that we have not accomplished at present. We've talked about the ways it might be done in the last minutes.

Dr. Seliger: Well, I'm not a newcomer to the Bay. I've been institutionalized for a long time in the Bay. I've been institutionalized ever since the Rhode River Consortium, the Chesapeake Bay Consortium, ad nauseam. I think, however, that we have the opportunity to do something since we have the public support and the financial support, and I agree completely with Tom Malone that we have a much better idea of what to do and how possibly to relate some of the cause-and-effect relationships to the monitoring program that we didn't have before.

And I think in a sense when one publishes every year in the professional journals observations about the Bay that one didn't know before and that one hasn't been able to predict, then one really is not in a position at the present time to advise the managers on exactly what management decisions to make.

I think it's analogous to this fellow coming in to see his doctor who says, "I'm covered with sores; I keep getting mugged on my way to work." And the doctor says, "Well, you better watch your diet (nutrients), it will help." But that may not be the causality that is influencing the open sores.

I think it's unfortunate that we talk about the Chesapeake Bay as "A Chesapeake Bay." It's really a very unusual estuary in that it is the sum of all its tributaries. The central channel during the winter and early spring serves as migration for larval life stages of fish that spawn outside the Bay and mainly as a shipping channel for the rest of the year.

But what we must consider is the sum of the tributaries to this Bay; and each of them has a different weighting factor. Some of them require more than a "hundred feet" of grass. Some of them might require a lot more. I think we may find, for example, that sedimentation into the Bay is much more significant than sewage plant effluents. It might be easier to put all of our money into upgrading sewage treatment because we can monitor sewage plant effluent very easily. But it may not save the Bay. And particularly it may not save the particular species which spawn and use food sources in the tributaries. I think this is a very important consideration that we haven't addressed at all.

Dr. Brush: I think one of the very important aspects of this program, and it was very unique, was to really look at the long-term history of some aspects of the Bay. We were able to document very clearly that SAV was not a cyclic life and death phenomena but that actually the demise of SAV was clearly related to human activity.

The thing that I find disappointing is that the monitoring program has not incorporated this technique which gives measurements of long-term variability into their program. We have been doing very detailed sedimentation rates which have allowed us to calculate annual rates of sedimentation in several tributaries of the Chesapeake Bay, particularly in the Upper Bay.

We have been able to show, for example, in those years when there was high peak flow there is also high sedimentation. If this fine sediment is carrying with it toxics, nutrients, and so on, it is extremely important to know how far it's going and how quickly it goes from one place to another.

The stratigraphic work is able to address those problems, and we have been able to compile some long-term trends.

Dr. Kinser: I've been impressed by the monitoring and research. I've been impressed by the cooperation. I've had a lot of second thoughts about some other things, however.

I'm apprehensive about much of the voluntary cooperation that is stressed as a keynote of the Bay program. I don't think it will work. That may be too negative a statement, but I don't think it will.

I'm also concerned that we're going on to continue making decisions that are adverse to the Bay on a daily basis. We're getting incomplete mitigation for projects that are going on and being permitted by the various agencies that are or are not at this table. So I have some concerns in that area.

Dr. Morris: Strengths I think are in the line of having the institutional mechanism in terms of the organizations that can control the inputs into the Bay or an organization whereby we can exert that control.

Secondly, I think the benefit has been in terms of public information, public participation, in terms of letting people know what's going on and getting feedback about what should be done.

Thirdly, from a scientific point of view, I think we have maybe determined some of the significant problems of the Bay and permitted us to at least put the band-aid on the sores if not to find what the cause of the sores are.

In terms of the deficiency, I think the deficiency has been that we have not been specific enough in defining the cause-and-effect relationships between the living resources and the water quality characteristics; and therefore, we cannot define quantitative loads which we want to use as targets for our control programs.

Mr. Eichbaum: I guess just three points I'd make for somebody else looking at this.

One is define the questions that you think you're trying to answer that identify what the problem in your estuary is.

Secondly, if you can do that and you are still thinking or studying or whatever the issue and have the money, I would start right away a monitoring program. We spent 27 million over 6 or 7 years and didn't even have a regularized monitoring program of the Bay. Anecdotal particular research project, yeah, but not a monitoring program.

Thirdly, I think, is to have some sort of an overall management institution put into place right away to manage the process that is made up of the relevant levels of government and appropriate private sector representation.

Dr. Thomas: I think we've been very encouraged from NOAA's standpoint to see the kind of networking and interaction occurring between the Federal agencies and the states and so on. I certainly feel that we feel that to clean up costs money, costs a great deal of money. And the cleanup needs to be directed or guided to clean up the right kinds of things in the right amounts at the right locations.

And while it's certainly easier theoretically to mount a massive cleanup, that is, to cut out all loadings from all sources and so on, with today's tight economic times it probably makes better sense, provided we can get the knowledge we need to, because I think it requires more skill, to, make a linkage between habitat and either the anthropogenic influence to habitat or take the climatically, naturally influenced habitat, but to make that linkage the habitat and the living marine resources so that the portion that man is having some impact on, the anthropogenic loadings that we control, that we can tell what these impacts are in regard to the living marine resources. And then regulate those things for desirable ends rather than strictly across the board cleanup on all issues.

It is quite difficult and it will cost money and it will take time.

Dr. D'Elia: I sort of agree and sort of disagree with Bill Eichbaum. I think that one of the things I've been most impressed with in the last 8 years I've been working in the system is that we are defining the questions much better than we ever have before in seeking the answers.

I'm not convinced that the monitoring program, for example, is always put in the context of answering questions. Very often monitoring seems to be the end and not just the means. I think it's very important that we always try to have a reason for doing anything. I'm not disputing the need to monitor; I think the need is there. But we always need to focus on why we do it.

So I would say that what we've done best is really started to define the questions and tried to develop some public sense of what we want out of the Chesapeake Bay, which is really the bottom line.

I think I'll stop my comments there. But I see Gene Cronin squirming in his seat. I knew that we couldn't have that kind of question asked and not include Gene. Do you have any comment?

Dr. L.E. Cronin: Well, I've very much enjoyed every bit of this seminar all day. I'd like to ask you one question. As I recall the purpose of the Chesapeake Bay Program, the statement and committed purpose of all of the participants at the present time is something like this, and maybe you can make it more precise:

"Restore the biological health, productivity and useful resources in the Chesapeake Bay system." Is that approximately right?

We've talked a lot about fishery resources, but I'm particularly interested in what this panel means by biological health of the Chesapeake Bay system, since that's our first target. We've said things related to it, but I'm not sure our definition is your definition. I'd appreciate a comment.

Dr. D'Elia: That could keep us going quite a while.

Dr. Morris: I think, Gene, in terms of the discussion it would have to be along the lines that we talked about the other day at the meeting you were at. But for the people who weren't there, basically it seems to me that the world that we're in now, the biological health has to be related to the uses of the Bay which we define as the ones we want to protect and are willing to put the resources ... energy, dollars, and political will ... behind to protect.

So the Bay is being used for a number of different things, all of which society agrees or many of which society agrees are appropriate and as many of the speakers mentioned today, they conflict.

So part of the problem is to define those uses of the Bay which society wants to protect, and it's primarily implied in the legal requirements that we have to protect the Bay, and meet the habitat, water quality, and other requirements necessary to meet those uses. I see it as a mixture with one not where society defines the priority, and then we can protect those things and the water quality that we design, the hydrology would be designed, and the uses would be designed to reflect what society wants the Bay to become.

Dr. Houde: I might be a little more specific. It's hard to say, Gene, just what we'd be satisfied with with regard to fishery resources. But no one today has said much about the specific technologies we now have at hand to possibly put a big bandage on the Bay. It is possible to raise millions of striped bass, for example. Costs are formidable and there are different opinions about using this method to restore fish to the Bay to jump over the recruitment bottleneck that seems to be in the way for the last 15 years.

Knowing what level of enhanced restoration would satisfy us is another question. All of us would like to have something like the early explorers saw that Senator Mathias told us about this morning, but of course we can't have that.

I think what fishery managers would like to have in lieu of that, though, is stability. Stable production at some lower level than we perhaps had in the 19th century would be, I think, a very acceptable alternative.

Mr. Eichbaum: Maybe I could say just a few words on that, Gene. It seems to me that the Chesapeake Bay is, perhaps, the only experiment that we have going on in this country and maybe in the world where we're, at least what I think the State of Maryland is trying to do, is to see if it's possible to limit the adverse impacts of human activity on a functioning biological system so that system can survive without being completely managed by mankind. It seems to me that's the real test of what we're about. And I happen to think that we have to meet that challenge, and I think we're going in the right direction to do it in the Bay.

One aspect that we haven't talked about that I just want to touch on because it's relevant to that is the mammouth effort to not just worry about what goes into the water, but also worry about what's going on on the land adjacent to the Bay. Because I'm convinced that we could clean up all the pipes and perhaps have perfect fisheries management plans, but if the development practices of the last 40 years continue, we will not have a Chesapeake Bay in the way we know or think of it, at least historically.

I flew with the governors last Friday in helicopters, and that was quite an experience to fly from Washington, D.C. to Lancaster County to Elkneck to the Rappahannock, go up the Western Shore and down the Eastern Shore at a thousand feet in about six-and-a-half hours. Because what you see is that we're occupying the land. And we are disturbing it, and we are shoving it about. And we are not only moving it and the stuff we dump on it into the Bay, but we are destroying habitat in the stream, adjacent to the stream, in the wetlands, adjacent to the wetlands at a rate and an intensity which is absolutely astounding. And unless we reverse that, I don't think any of the stuff we've talked about matters. And the critical area, as you know, is designed to start doing that where we will essentially, we hope, in the administration insure that somewhere around 85 percent of the shoreline of the Bay and its tributaries remains in forest land and hopefully in agriculture land with best management practices really in place, both to protect water quality, to protect in-the-water habitat and to protect land habitat for all of the species which depend on that.

So I view it really as a major ecological experiment in the use of that word from the early 1970s. And that's what those phrases mean.

Mr. Morris: Gene, now that you've asked the question and they've answered it, are you going to tell them whether they're right or not?

We sat down and talked about this for most of a year, as I recall, and we decided to do away with the term. Correct?

Dr. L.E. Cronin: We did for that purpose, but it's still conserving, our objective is chemical work and physical work and managing what happens on land and managing flows from rivers, quality and quantity and all of those. It's almost always the biological systems that are receiving in the Chesapeake Bay. That is not the only important value, obviously. But that is why we're at this. Yet we're not always linking what we do to the biological system, the whole biological system, not just the harvest of fish.

Mr. Eichbaum: Well, I think that's what we're trying to do, Gene, and, you know, that's why I talk the whole biological system; it's not just rockfish.

Dr. L.E. Cronin: I appreciate the fact that you said that, Bill, but I just haven't had much of a sense today that we're really talking about all of the important biological components and processes in the Chesapeake Bay. We didn't know how to put it. I think we must learn that to give us a decent, sort of honorary, target for all of what we're talking about, because we're doing a great many good things, but we're not.

Dr. Morris: Could I follow up on that because that brings up a point in terms of public policy, which I think is important and which the gentleman down the way raised before. What are we doing and do we know what we're doing?

Well, I think what we're at is an incrementalization toward improvement. We have some information now on what the problems are and we are trying to move toward correcting those problems. We will find others as we go, and those will have to be brought into it. But it's this constant pushing toward goals in the mist which is some of the excitement and some of the frustration of this program.

And the fact that some of those goals are mutually exclusive are going to continue to take our energies and others to try and help us define them. But from a scientific point of view, as you have, Gene, the ones who follow you need to do as you have done, I think, in terms of helping us define numerically what those issues are so that we can achieve them on the social scientists. And it's not something that we can stop and say, "Right now we're going to do it." We have the best information we'll have today and we're moving to try and mitigate the problem.

As we get more, we're going to have to make a couple of comments. One is that in terms of the use of the land, the land is very different from one part of the Bay to the other. When we look at the long cores from the upper Chesapeake Bay around Furnance Bay, the history of the diatoms, which are an indication of eutrophication, show a change in those species composition related with runoff from the land and with sewage input.

If you go down to the Ware River or where you have a very sand substrate, even though there is still a lot of agriculture, the impact there was more beneficial. Prior to any European settlement, diatom populations were extremely sparse indicating oligotrophic conditions. Runoff from the land in that case probably enriched the estuary.

I think that a management plan that does not consider the fact that the drainage areas are very different geologically is going to not be as effective as one that considers those differences.

Another thing that I think needs to be considered is that even though we know that the anthropogenic impact is very great, there is still a climatic impact, so that in dry years the impact might be quite different that when there is high runoff, for example.

Dr. D'Elia: I think with that we probably ought to call a halt to the day; it's been a long one, but I think an interesting one. I want to thank the members of the panel. I want to thank the speakers and the audience for participating. I hope it was a benefit to people. Before we adjourn, Dr. Thomas wants to speak a final word.

Dr. Thomas: Yes, I would, Chris. Thanks very much. On behalf of the NOAA and the U.S. Environmental Protection Agency, we'd like to thank you, Chris, for organizing today's activities. I think it's been very, very fine. I'd like to thank the speakers for their excellent presentations, the panelists for their comments, and certainly the audience for participating and lasting through the day.

Thank you very much.

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